INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

T.801

(08/2002)

SERIES T: TERMINALS FOR TELEMATIC SERVICES

Information technology – JPEG 2000 image coding system: Extensions

ITU-T Recommendation T.801

INTERNATIONAL STANDARD ISO/IEC 15444-2
ITU-T RECOMMENDATION T.801

Information technology – JPEG 2000 image coding system: Extensions

Summary

This Recommendation | International Standard defines a set of lossless (bit-preserving) and lossy compression methods for coding continuous-tone, bi-level, grey-scale, colour digital still images, or multi-component images.

This Recommendation | International Standard:

- specifies extended decoding processes for converting compressed image data to reconstructed image data;
- specifies an extended codestream syntax containing information for interpreting the compressed image data;
- specifies an extended file format;
- specifies a container to store image metadata;
- defines a standard set of image metadata;
- provides guidance on extended encoding processes for converting source image data to compressed image data;
- provides guidance on how to implement these processes in practice.

Source

ITU-T Recommendation T.801 was prepared by ITU-T Study Group 16 (2001-2004) and approved on 29 August 2002. An identical text is also published as ISO/IEC 15444-2.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Page

Page

INTERNATIONAL STANDARD
ITU-T RECOMMENDATION

Information technology – JPEG 2000 image coding system: Extensions

1 Scope

This Recommendation | International Standard defines a set of lossless (bit-preserving) and lossy compression methods for coding continuous-tone, bi-level, grey-scale, colour digital still images, or multi-component images.

This Recommendation | International Standard:

- specifies extended decoding processes for converting compressed image data to reconstructed image data;
- specifies an extended codestream syntax containing information for interpreting the compressed image data;
- specifies an extended file format;
- specifies a container to store image metadata;
- defines a standard set of image metadata;
- provides guidance on extended encoding processes for converting source image data to compressed image data;
- provides guidance on how to implement these processes in practice.

2 References

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

2.1 Identical Recommendations | International Standards

- ITU-T Recommendation T.81 (1992) | ISO/IEC 10918-1:1994, *Information technology – Digital compression and coding of continuous-tone still images: Requirements and guidelines.*
- ITU-T Recommendation T.82 (1993) | ISO/IEC 11544:1993, *Information technology – Coded representation of picture and audio information – Progressive bi-level image compression.*
- ITU-T Recommendation T.83 (1994) | ISO/IEC 10918-2:1995, *Information technology – Digital compression and coding of continuous-tone still images: Compliance testing.*
- ITU-T Recommendation T.84 (1996) | ISO/IEC 10918-3:1997, *Information technology – Digital compression and coding of continuous-tone still images: Extensions.*
- ITU-T Recommendation T.84 (1996)/Amd.1 (1999) | ISO/IEC 10918-3:1997/Amd.1:1999, *Information technology – Digital compression and coding of continuous-tone still images: Extensions – Amendment 1: Provisions to allow registration of new compression types and versions in the SPIFF header.*
- ITU-T Recommendation T.86 (1998) | ISO/IEC 10918-4:1999, *Information technology – Digital compression and coding of continuous-tone still images: Registration of JPEG Profiles, SPIFF Profiles, SPIFF Tags, SPIFF colour Spaces, APPn Markers, SPIFF Compression types and Registration Authorities (REGAUT).*
- ITU-T Recommendation T.87 (1998) | ISO/IEC 14495-1:2000, *Information technology – Lossless and near-lossless compression of continuous-tone still images – Baseline.*

- ITU-T Recommendation T.88 (2000) | ISO/IEC 14492:2001, *Information technology – Lossy/lossless coding of bi-level images.*
- ITU-T Recommendation T.800 (2002) | ISO/IEC 15444-1:2003, *Information technology – JPEG 2000 image coding system: Core coding system.*

2.2 Additional references

- ITU-T Recommendation T.42 (1996), *Continuous-tone colour representation method for facsimile.*
- ISO/IEC 8859-1:1998, *Information technology – 8-bit single-byte coded graphic character sets – Part 1: Latin alphabet No. 1.*
- ISO 8601:2000, *Data elements and interchange formats – Information interchange – Representation of dates and times.*
- ISO 3166-1:1997, *Codes for the representation of names of countries and their subdivisions – Part 1: Country codes.*
- ISO 3166-2:1998, *Codes for the representation of names of countries and their subdivisions – Part 2: Country subdivision code.*
- ISO/IEC 11578:1996, *Information technology – Open Systems Interconnection – Remote Procedure Call (RPC).*
- ISO/IEC 646:1991, *Information technology – ISO 7-bit coded character set for information interchange.*
- ISO 5807:1985, *Information processing – Documentation symbols and conventions for data, program and system flowcharts, program network charts and system resources charts.*
- ISO/IEC 15938, *MPEG-7.*
- ISO 10126-2:1991, *Banking – Procedures for message encipherment (wholesale) – Part 2: DEA algorithm.*
- IEEE Standard 754-1985 R1990, *IEEE Standard for Binary Floating-Point Arithmetic.*
- IETF RFC 1321 (1992), *The MD5 Message-Digest Algorithm.*
- IETF RFC 1766 (1995), *Tags for the Identification of Languages.*
- IETF RFC 2279 (1998), *UTF-8, A transformation format of ISO 10646.*
- IETF RFC 2630 (1999), *Cryptographic Message Syntax.*
- IETF RFC 2313 (1998), *PKCS #1: RSA Encryption, Version 1.5.*
- International Color Consortium, ICC profile format specification. ICC.1.
- IEC 61966-2-1:1999, *Multimedia systems and equipment – Colour measurement and management: Part 2-1: Colour management – Default RGB colour space – sRGB, plus its Amendment 1: 2003.*
- Digital Imaging Group, Flashpix digital image file format. Version 1.0.1, 10 July 1997.
- PIMA 7666. *Photography-Electronics still picture imaging-Reference Output Medium Metric RGB Color encoding: ROMM-RGB*.
- PIMA 7667:2001. *Photography-Electronics still picture imaging-Extended sRGB color encoding e-sRGB*.
- Federal Information Processing Standard Publication (FIPS PUB) 186-2, Digital Signature Standard (DSS). <http://www.itl.nist.gov/fipspubs/fip186-2.pdf>
- ANSI X9.30.2-1997, *Public Key Cryptography for the Financial Services Industry – Part 2: The Secure Hash Algorithm (SHA-1)*. <http://www.itl.nist.gov/fipspubs/fip180-1.htm>
- W3C. Extensible Markup Language (XML 1.0), 2nd edition Rec-xml-2000106, <http://www.w3.org/TR/REC-xml>.
- W3C. Namespaces in XML, Rec-xml-names-19990114, <http://www.w3.org/TR/1999/REC-xml-names>.
- W3C. XML Schema Part 1: Structures, Rec-xmlschema-1-20010502, <http://www.w3.org/TR/xmlschema-1>.
- W3C. XML Schema Part 2: Datatypes, Rec-xmlschema-2-20010502, <http://www.w3.org/TR/xmlschema-2>.

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply. The definitions defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 clause 3 also apply to this Recommendation | International Standard except for the terms decomposition level, sub-band and resolution which are redefined in this clause.

3.1 **attribute**: An XML construct that is a name-value pair extending or qualifying the meaning of an element.

3.2 **cell**: An optional subdivision of a tile used for low-memory encoding and decoding.

3.3 **component**: Compressed data from the codestream representing a single set of two-dimensional data.

3.4 **component collection**: A subset of intermediate components used as inputs to a multiple component transformation stage, and a subset of intermediate components obtained as outputs from a multiple component transformation stage. The subset's constituent components may occur in an arbitrary order, i.e., permuted with respect to their order of appearance in the set of input or output intermediate components.

3.5 **component reconstruction arrays**: A general term that refers to any of the following; decorrelation transformation array, dependency transformation array or offset array.

3.6 **compositing**: The act of combining two compositing layers into a single, non-redundant set of image channels.

3.7 **compositing layer**: A set of non-redundant channels drawn from one or more codestreams that shall be treated as a group. The set of compositing layers within the JPX file may then be combined by compositing or animation instructions to form a rendered result. For example, one layer may be a simple RGBA codestream. Another layer may consist of R, G and B channels generated by the application of a palette to one component from codestream 1, and an opacity channel directly extracted from codestream 2.

3.8 **deadzone**: The interval within which all sub-band coefficients are quantized to 0.

3.9 **decomposition level**: A collection of sub-bands where each coefficient has the same spatial impact or span with respect to the original samples. These include the LL, LH, HL, HH, LX, HX, XL, and XH sub-band splits out of decomposition sublevels.

3.10 **decomposition sub-level**: A collection of sub-bands that result from splits of a sub-band from a lower decomposition sub-level or splits of either LL, LX or XL sub-bands from a higher decomposition level.

3.11 **decorrelation transformation array**: An array of coefficients that maps the input components of a component collection to the output components of the collection via a multiple component decorrelation transformation.

3.12 **dependency transformation array**: An array of coefficients that maps the input components of a component collection to the output components of the collection via a multiple component dependency transformation.

3.13 **element**: An XML construct that consists of a start tag and an end tag with data enclosed within.

3.14 **HX sub-band**: The sub-band obtained by forward horizontal high-pass analysis filtering and no vertical analysis filtering. This sub-band contributes to reconstruction with inverse horizontal high-pass synthesis filtering and no vertical synthesis filtering.

3.15 **intermediate component**: A single two-dimensional array of data involved in a stage of a multiple component transformation.

3.16 **JPX baseline**: A specific subset of the features of the JPX file format.

3.17 **JPX baseline reader**: An application that correctly interprets all files that conform to the definition of a JPX baseline file.

3.18 **JPX file**: The name of file in the file format described in this Recommendation | International Standard. Structurally, a JPX file is a contiguous sequence of boxes.

3.19 **LX sub-band**: The sub-band obtained by forward horizontal low-pass analysis filtering and no vertical analysis filtering. This sub-band contributes to reconstruction with inverse horizontal low-pass synthesis filtering and no vertical synthesis filtering.

3.20 **metadata**: Additional data associated with the image data beyond the image data.

3.21 **namespace**: A collection of names, identified by a URI, that allows XML documents of different sources to use the same element names within a single document to avoid element name conflicts.

3.22 **offset array**: An array of coefficients containing offsets which are added to intermediate components during multiple component transformation of a component collection.

3.23 reconstructed image component: The set of output intermediate components from the final transformation stage in the inverse multiple component transformation process.

3.24 rendered result: The result generated by combining the compositing layers in the JPX file, either by composition or animation.

3.25 resolution: The spatial relation of samples to a physical space. In this Recommendation | International Standard, the decomposition levels of the wavelet transformation create resolutions that differ by powers of two in either just horizontal, just vertical or both horizontal and vertical directions. The last (highest) decomposition level includes either an LL, LX or XL sub-band which is considered to be a lower resolution. Therefore, there is one more resolution level than decomposition levels.

3.26 sub-band: A group of transformation coefficients resulting from the sequence of low-pass and high-pass filtering operations, either just horizontally, just vertically or both horizontally and vertically.

3.27 spatially reconstructed component: A component which has been extracted from the codestream and passed through the decoding and inverse wavelet transformation process as specified by this Recommendation | International Standard. The set of spatially reconstructed components is the set of input components to the first transformation stage in the inverse multiple component transformation process.

3.28 transformation stage: A set of component collections and associated multiple component transformations.

3.29 visual masking: Visual masking is a mechanism where artefacts are masked by the image acting as a background signal.

3.30 XH sub-band: The sub-band obtained by no forward horizontal analysis filtering and vertical high-pass analysis filtering. This sub-band contributes to reconstruction with vertical high-pass synthesis filtering and no inverse horizontal synthesis filtering.

3.31 XL sub-band: The sub-band obtained by no forward horizontal analysis filtering and vertical low-pass analysis filtering. This sub-band contributes to reconstruction with vertical low-pass synthesis filtering and no inverse horizontal synthesis filtering.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply. The abbreviations defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 clause 4 also apply to this Recommendation | International Standard.

CCITT International Telegraph and Telephone Consultative Committee, now ITU-T

DPI Dots per inch

IPR Intellectual Property Rights

UUID Universal Unique Identifier

5 Symbols

For the purposes of this Recommendation | International Standard, the following symbols apply. The symbols defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 clause 4 also apply to this Recommendation | International Standard.

ADS Arbitrary decomposition styles marker

ATK Arbitrary transformation kernels marker

CBD Component bit depth definition marker

DCO Variable DC offset marker

DFS Downsample factor styles marker

MCC Multiple component collection transformation marker

MCO Multiple component transformation ordering marker

MCT Multiple component transformation definition marker

NLT Non-linearity point transformation marker

VMS Visual masking marker

6 General description

The purpose of this clause is to give an overview of this Recommendation | International Standard. Terms defined in previous clauses in this Recommendation | International Standard will also be introduced. (Terms defined in clauses 3 and 4 in ITU-T Rec. T.800 | ISO/IEC 15444-1 continue to apply in this Recommendation | International Standard.)

This Recommendation | International Standard defines a set of lossless (bit-preserving) and lossy compression methods for coding continuous-tone, bi-level, grey-scale, colour digital still images, or multi-component images. This set of methods extends the elements in the core coding system described in ITU-T Rec. T.800 | ISO/IEC 15444-1. Extensions which pertain to encoding and decoding are defined as procedures which may be used in combination with the encoding and decoding processes described in ITU-T Rec. T.800 | ISO/IEC 15444-1. Each encoding or decoding extension shall only be used in combination with particular coding processes and only in accordance with the requirements set forth herein. These extensions are backward compatible in the sense that decoders which implement theses extensions will also support configuration subsets that are currently defined by ITU-T Rec. T.800 | ISO/IEC 15444-1. This Recommendation | International Standard also defines extensions to the compressed data format, i.e., interchange format and the abbreviated formats.

6.1 Extensions specified by this Recommendation | International Standard

The following extensions are specified in this Recommendation | International Standard.

6.1.1 Syntax

An extension of the code stream syntax is described in Annex A. This extension provides all the codestream signalling in this Recommendation | International Standard. Further, it anticipates signalling needed for future specifications that include this Recommendation | International Standard as a normative reference. In addition to the codestream syntax defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, the following capabilities are supported: variable DC offset, variable scalar quantization, trellis coded quantization, visual masking, arbitrary decomposition, arbitrary transformation kernels, single sample overlap, multiple component transformations, non-linear transformation, arbitrary regions of interest. These extended markers conform to the same rules as the syntax in ITU-T Rec. T.800 | ISO/IEC 15444-1.

6.1.2 Variable DC offset

An extension which provides for variable DC offset is described in Annex B. Variable DC offset may be used to generate a better data distribution for input to the ICT or RCT multi component transformation, defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, and/or the wavelet transformation. Images with very skewed sample distributions may benefit from a non-default DC offset.

6.1.3 Variable scalar quantization

An extension that provides for variable scalar quantization is described in Annex C. This extension allows smaller or larger deadzones to be used with the scalar quantizer. This technique may improve visual appearance of low level texture.

6.1.4 Trellis coded quantization

An extension of the quantization is described in Annex D. This extension provides for trellis coded quantization (TCQ). The TCQ algorithm applies spatial-varying scalar quantization to its input sequence by choosing one of four scalar quantizers for each sample. Quantizer indices from supersets of these quantizers along with quantizer transitions in the form of a trellis provide all information necessary to reconstruct TCQ encoded wavelet coefficients.

6.1.5 Visual masking

An extension which provides for visual masking is described in Annex E. Visual masking is a mechanism where artefacts are masked by the image acting as a background signal. The main goal is to improve the image quality, especially for displays. The first effect of this technique is to improve the image quality, where the improvement becomes greater as the image becomes more complex. The second main effect of this technique is that for a given fixed bit-rate, the image quality is more robust against variations in image complexity. This is accomplished at the encoder via an extended non-linearity interposed between the transformation stage and the quantization stage.

6.1.6 Arbitrary decomposition

An extension providing for arbitrary decomposition of the tile component is described in Annex F. This extension can control the bandpass extent of wavelet sub-bands and thus provide control over the decorrelation process in order to tune compression performance. This extension also allows for transcoding of other wavelet based compression algorithms into codestreams of this Recommendation | International Standard.

6.1.7 Arbitrary wavelet transformation

Extensions that provide for transformation of image tile components using user defined wavelet filters are described in Annexes G and H. Annex G describes whole sample filters while Annex H describes arbitrary filters.

6.1.8 Single sample overlap discrete wavelet transformations

Extensions providing for block based wavelet transformations are described in Annex I. These extensions consist of one method for tile based wavelet transformation without tiling artefacts and one method for cell-based wavelet transformation.

6.1.9 Multiple component transformations

An extension which provides for multiple component transformations is described in Annex J. This extension specifies two types of multiple component transformations:

1) A specification of a multiple component transformation which uses linear transformations of bands to reduce the correlation of each band. This is similar to the most common colour transformations.
2) A specification of a wavelet transformation along the component direction.

6.1.10 Non-linear transformation

Annex K specifies two non-linear point transformations that are used after decoding processes and inverse multiple component transformations to map reconstructed values back to their proper range. These transformations, gamma and look-up table (LUT) style non-linearities, may be employed by encoders prior to multiple component transformation and encoding to increase compression efficiency. A common usage of these transformations might be to perceptually flatten a scanner or sensor with a linear response, from 12 bits to 8 bits precision prior to compression.

6.1.11 Region of interest

An extension which provides for Region of interest coding using the scaling based method is described in Annex L. The scaling based method provides for having different scaling values for different regions of interest. The extension also specifies how to generate the masks in the wavelet domain that describe the set of wavelet coefficient belonging to each Region of interest.

6.1.12 File format

An extension of the file format is described in Annex M. This extension provides for the exchange of compressed image files between application environments. This extension is an optional file format, called JPX, that applications may choose to use to contain JPEG 2000 compressed image data. JPX is an extension to the JP2 file format defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex I. The format:

1) specifies a binary container for both image and metadata;
2) specifies a mechanism to indicate image properties, such as the tone-scale or colour space of the image;
3) specifies a mechanism by which readers may recognize the existence of intellectual property rights information in the file;
4) specifies a mechanism by which metadata (including vendor specific information) can be included in files specified by this Recommendation | International Standard;
5) specifies a mechanism by which multiple codestreams can be combined into a single work, by methods such as compositing and animation.

6.1.13 Metadata definitions

Metadata definitions are described in N. Metadata is additional information that is associated with the primary data (the image). In the context of this Specification, it is "additional data linked with the image data beyond the pixels which define the image." Metadata, to be most valuable for the owner(s) and user(s) of an image, needs to be consistently maintained throughout the image lifecycle. In today's environment of image editing applications, rapid transmission via the Internet, and high quality photographic printers, the lifecycle of a digital image may be very long as well as complex.

6.2 Relation between extensions

The relations, at decoder side, between the extensions listed above are given in Figure 6-1. Technologies described in ITU-T Rec. T.800 | ISO/IEC 15444-1 are indicated in the boxes.

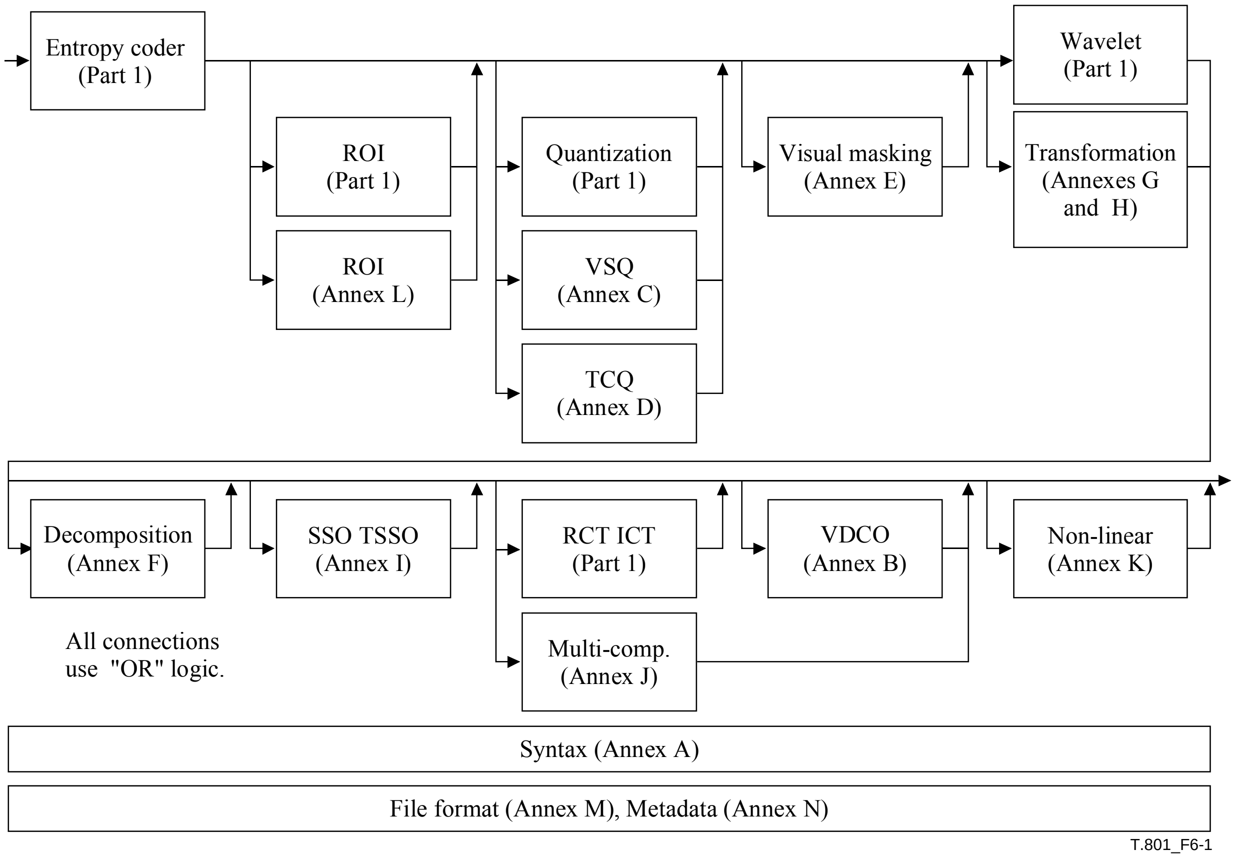


Figure 6-1 – Decoder block diagram

Annex A

Compressed data syntax, extension

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate.

This annex specifies the marker and marker syntax extensions to the ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A syntax. These markers provide all the codestream signalling in this Recommendation | International Standard. Further, it anticipates signalling needed for future specifications that include this Recommendation | International Standard as a normative reference.

All positive (unsigned) integer values of parameters are placed in the codestream as unsigned integers. All other (signed) integers are expressed in two's complement. Unless otherwise indicated, all values are in big endian order.

Some marker segment parameters have values defined with bits. In some cases there are bits, denoted by "x," that do not correspond to any parameter and are unused by all parameters. The codestream shall have zero value bits for those cases. The decoder shall ignore these bits.

A.1 Extended capabilities

The syntax in this annex supports the extensions in this Recommendation | International Standard. These marker segments conform to the same rules as the syntax in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A. The addition of parameter values to some marker segments in ITU-T Rec. T.800 | ISO/IEC 15444-1 and the addition of new marker segments signals the information specific to the extensions in this Recommendation | International Standard. In every marker segment the first two bytes after the marker shall be an unsigned value that denotes the length in bytes of the marker segment parameters (including the two bytes of this length parameter but not the two bytes of the marker itself). When a marker segment that is not specified in this Recommendation | International Standard or in ITU-T Rec. T.800 | ISO/IEC 15444-1 is encountered in a codestream, the decoder shall use the length parameter to discard the marker segment. Table A.1 shows the marker segments affected by this Recommendation | International Standard.

Table A.1 – Syntax support for extensions

Extension	Extended ITU-T Rec. T.800 | ISO/IEC 15444-1 marker segments	New marker segments
All extensions	SIZ	–
Variable DC offset	–	DCO
Variable scalar quantization	QCD, QCC, SOT	QPD, QPC
Trellis coded quantization	QCD, QCC, SOT	QPD, QPC
Visual masking	–	VMS
Single sample offset transform	SIZ, COD, COC	–
Arbitrary decomposition styles	COD, COC	DFS, ADS
Arbitrary transformation kernels	COD, COC	ATK
Multiple component transform	COD	CBD, MCT, MCC, MCO
Non-linearity point transformation	–	NLT
Arbitrary shaped region of interest	RGN	–

A.2 Extensions to ITU-T Rec. T.800 | ISO/IEC 15444-1 marker segment parameters

This clause describes the extensions to marker segments defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex A.

A.2.1 Image and tile size (SIZ), extended

The capability parameter Rsiz of ITU-T Rec. T.800 | ISO/IEC 15444-1 denotes the necessity or usefulness of extensions of this Recommendation | International Standard for decoding the codestream. Table A.2 is used to define this parameter.

Table A.2 – Capability Rsiz parameter, extended

Value (bits) MSB LSB	Capability
0000 0000 0000 0000	Capabilities specified in ITU-T Rec. T.800 | ISO/IEC 15444-1 only
1000 xxxx xxxx xxxx	At least one of the extended capabilities specified in this Recommendation | International Standard is present
1000 xxx0 xxxx xxx1	Variable DC offset capability is required to decode this codestream[a) b)]
1000 xxxx xxxx xx1x	Variable scalar quantization capability is required to decode this codestream[a)]
1000 xxxx xxxx x1xx	Trellis coded quantization capability is useful to decode this codestream[c)]
1000 xxxx xxxx 1xxx	Visual masking capability is useful to decode this codestream[c)]
1000 xxxx xxx1 xxxx	Single sample overlap capability is required to decode this codestream[a)]
1000 xxxx xx1x xxxx	Arbitrary decomposition style capability is required to decode this codestream[a)]
1000 xxxx x1xx xxxx	Arbitrary transformation kernel capability is required to decode this codestream[a)]
1000 xxxx 1xxx xxxx	Whole sample symmetric transformation kernel capability is required to decode this codestream[a)]
1000 xxx1 xxxx xxxx	Multiple component transformation capability is required to decode this codestream[a)]
1000 xx1x xxxx xxxx	Non-linear point transformation capability is useful to decode this codestream[c)]
1000 x1xx xxxx xxxx	Arbitrary shaped region of interest capability is required to decode this codestream[a)]
1000 1xxx xxxx xxxx	Precinct-dependent quantization is required to decode this codestream[a)]
	All other values reserved

a) "Required to decode" implies that no useful data or image can be reconstructed without the use of this capability.

b) Shall not be used with the multiple component transformation.

c) "Useful to decode" implies that use of this capability would improve the quality of the reconstructed data or image; however, the data or image may be decoded without its use.

A.2.2 Start of tile-part (SOT) extended

If Rsiz indicates that the precinct-dependent quantization capability is used, then the SOT marker segment from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex A, is extended to allow 1-65535 tile-parts. Table A.3 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.5 and Table A.4 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.6.

Table A.3 – Start of tile-part parameter values, extended

Parameter	Size (bits)	Values
SOT	16	0xFF90
Lsot	16	10
Isot	16	0-65 534
Psot	32	0, or 14-(2^{32}–1)
TPsot	16	0-65535
TNsot	16	Table A.4

Table A.4 – Number of tile-parts, TNsot, parameter value, extended

Value	Number of tile-parts
0	Number of tile-parts of this tile in the codestream is not defined in this header
1-65535	Number of tile-parts of this tile in the codestream

A.2.3 Coding style (COD, COC), extended

Geometric manipulation is enabled with two bits in the Scod parameter shown in Table A.5.

If the Rsiz field of the SIZ marker segment indicates that the multiple component transformations are used, then Table A.8 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.17.

If the Rsiz field of the SIZ marker segment indicates that the arbitrary transformation kernels are used, then Table A.10 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.20.

If the Rsiz field of the SIZ marker segment indicates that the single sample overlap transformation capability is necessary, then an extra 8 bit field is added to ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.13 after the transformation field as shown in Table A.7. The SSO values are found in Table A.11.

If the Rsiz field of the SIZ marker segment indicates that the arbitrary decomposition styles are used then the maximum number of decomposition levels field definitions are found in Table A.9 rather than in ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.13. This is shown in Table A.7.

Table A.5 – Coding style parameter values for the Scod parameter

Values (bits) MSB LSB	Coding style
`xxxx xxx0`	Entropy coder, precincts with PPx = 15 and PPy = 15
`xxxx xxx1`	Entropy coder with precincts defined below
`xxxx xx0x`	No SOP marker segments used
`xxxx xx1x`	SOP marker segments may be used
`xxxx x0xx`	No EPH marker used
`xxxx x1xx`	EPH marker shall be used
`xxxx 0xxx` `xxxx 1xxx`	Offset in the horizontal dimension, $z_x = 0$ (CBAP) Offset in the horizontal dimension, $z_x = 1$
`xxx0 xxxx` `xxx1 xxxx`	Offset in the vertical dimension, $z_y = 0$ (CBAP) Offset in the vertical dimension, $z_y = 1$
	All other values reserved

Table A.6 – Coding style parameter values of the SGcod parameter

Parameters (in order)	Size (bits)	Values	Meaning of SGcod values
Progression order	8	ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.16	Progression order
Number of layers	16	1-65535	Number of layers
Multiple component transformation	8	Table A.8	Multiple component transformation usage

Table A.7 – Coding style parameter values of the SPcod and SPcoc parameters, extended

Parameters (in order)	Size (bits)	Values (bits) MSB LSB	Meaning of SPcod values
Maximum number of decomposition levels	8	Table A.9	Decomposition mapping and levels
Code-block width	8	ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.18	Code-block width exponent offset value, *xcb*
Code-block height	8	ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.18	Code-block height exponent offset value, *ycb*
Code-block style	8	ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.19	Style of the code-block coding passes
Transform	8	Table A.10	Wavelet transformation used
SSO overlap	16	Table A.11	SSO overlap values
Precinct size	variable	ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.21	If Scod or Scoc = xxxx xxx0, this parameter is not present, otherwise this indicates precinct width and height. The first parameter (8 bits) corresponds to the N_LLL, N_LLX, or N_LXL sub-band. Each successive parameter corresponds to each successive resolution in order.

Table A.8 – Multiple component transformation for the SGcod parameters

Values (bits) MSB LSB	Multiple component transformation type
0000 0000	No multiple component transformation specified.
0000 0001	Component transformation used on components 0, 1, 2 for coding efficiency. Irreversible component transformation used with irreversible filters. Reversible component transformation used with reversible filters.
0000 0x10	Array-based multiple component transformation is used. May be combined with wavelet-based multiple component transform.
0000 01x0	Wavelet-based multiple component transformation is used. May be combined with array-based multiple component transform.
	All other values reserved.

Table A.9 – Decomposition for the SPcod and SPcoc parameters, extended

Values (bits) MSB LSB	Decomposition type
0000 0000 to 0010 0000	Number of levels of wavelet decomposition, dyadic decomposition, N_L (Zero implies no transform.).
1000 0001 to 1111 1111	If in the main header: Downsampling factor style index value (1 to 127). (See A.3.3.) If in tile-part header: Arbitrary decomposition style index value (1 to 127). (See A.3.4.)
	All other values reserved

Table A.10 – Transformation for the SPcod and SPcoc parameters, extended

Values (bits) MSB LSB	Transformation type
0000 0000	ITU-T Rec. T.800 | ISO/IEC 15444-1 9-7 irreversible wavelet transform.
0000 0001	ITU-T Rec. T.800 | ISO/IEC 15444-1 5-3 reversible wavelet transform.
0000 0010 to 1111 1111	Arbitrary transformation kernel definition index value (2-255). Definitions are found in the appropriate ATK marker segment (see A.3.5).

Table A.11 – SSO parameters, extended

Values (bits) MSB LSB	SSO size (see Annex I)
0xxx xxxx xxxx xxxx 1xxx xxxx xxxx xxxx	SSO not used SSO used
x0xx xxxx xxxx xxxx x1xx xxxx xxxx xxxx	TSSO not used for every tile in the image (shall be the same in every COD marker segment) TSSO used for every tile in the image (shall be the same in every COD marker segment)
xx0x xxxx xxxx xxxx xx1x xxxx xxxx xxxx	Vovlp = 0 (shall be the same in every COD marker segment) Vovlp = 1(shall be the same in every COD marker segment)
xxx0 xxxx xxxx xxxx xxx1 xxxx xxxx xxxx	Hovlp = 0 (shall be the same in every COD marker segment) Hovlp = 1(shall be the same in every COD marker segment)
xxxx 0xxx xxxx xxxx x1xx 1xxx xxxx xxxx	TBDWT is not used (shall be the same in every COD marker segment) TBDWT is used (shall be the same in every COD marker segment)
xxxx xxxx xxxx 0000 to xxxx xxxx xxxx 1111	Cell width exponent value, XC = 2^{value}
xxxx xxxx 0000 xxxx to xxxx xxxx 1111 xxxx	Cell height exponent value, YC = 2^{value}
	All other values reserved

A.2.4 Quantization (QCD, QCC), extended

If Rsiz indicates that the variable scalar quantization (see Annex C) capability is used, then the deadzone adjustment is signalled in modified QCD and QCC marker segments from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex A. If Rsiz indicates that trellis coded quantization is used, then these values are also signalled via the extended QCD and QCC marker segments from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex A. This shall only be used with irreversible transformations.

Table A.12 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.28, and Table A.13 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.30.

Table A.12 – Quantization default values for the Sqcd, Sqcc, Sqpd, and Sqpc parameters, extended

Values (bits) MSB LSB	Quantization style	SPqxx size (bits)	SPqxx usage
xxx0 0000	No quantization	8	ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A
xxx0 0001	Scalar derived (values signalled for N_LLL sub-band only). Use ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-5.	16	ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A
xxx0 0010	Scalar expounded (values signalled for each sub-band). There are as many step sizes signalled as there are sub-bands.	16	ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A
xxx0 0011	Variable deadzone and scalar derived (values signalled for N_LLL sub-band only). Use ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-5.	32	Table A.13
xxx0 0100	Variable deadzone derived and scalar expounded (values signalled for each sub-band). There are as many step sizes signalled as there are sub-bands.	16	Table A.14 then Table A.15
xxx0 0101	Variable deadzone and scalar expounded (values signalled for each sub-band). There are as many step sizes signalled as there are sub-bands.	32	Table A.13
xxx0 1001	Trellis coded quantization derived (values signalled for N_LLL sub-band only). Use ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-5.	16	ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A
xxx0 1010	Trellis coded quantization expounded (values signalled for each sub-band). There are as many step sizes signalled as there are sub-bands.	16	ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A
000x xxxx to 111x xxxx	Number of guard bits 0-7.		
	All other values reserved.		

Table A.13 – Quantization values (irreversible transformation only), extended

Values (bits) MSB LSB	Deadzone adjustment and quantization step size values
0000 0000 0000 0000 xxxx xxxx xxxx xxxx to 1111 1111 1111 1111 xxxx xxxx xxxx xxxx	Variable deadzone, num_nz$_b$, value –32 768-32 767 (see Equation C-1)
xxxx xxxx xxxx xxxx xxxx x000 0000 0000 to xxxx xxxx xxxx xxxx xxxx x111 1111 1111	Mantissa, μ_b, of the quantization step size value 0-2 047 (see ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-3)
xxxx xxxx xxxx xxxx 0000 0xxx xxxx xxxx to xxxx xxxx xxxx xxxx 1111 1xxx xxxx xxxx	Exponent, ε_b, of the quantization step size value 0-31 (see ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-3)

Table A.14 – SPqcd, SPqcc, SPqpd, and SPqpc parameters (irreversible transformation only), extended

Values (bits) MSB LSB	Deadzone adjustment values (one for each sub-band)
0000 0000 0000 0000 to 1111 1111 1111 1111	First two bytes of SPqcx are the deadzone adjustment, num_nz$_b$, value –32 768-32 767 (see Equation C-1)

Table A.15 – SPqcd, SPqcc, SPqpd, and SPqpc parameters (irreversible transformation only), extended

Values (bits) MSB LSB	Quantization step size values

`xxxx x000 0000 0000`
to
`xxxx x111 1111 1111`
	After first two bytes of SPqcx are the mantissa, μ_b, of the quantization step size value 0-2 047 (see ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-3)

`0000 0xxx xxxx xxxx`
to
`1111 1xxx xxxx xxxx`
	After first two bytes of SPqcx are the exponent, ε_b, of the quantization step size value 0-31 (see ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-3)

A.2.5 Region of interest marker (RGN), extended

If Rsiz indicates that an arbitrary region of interest is used (see Annex L), then the description of a coefficient shift and a mask are signalled in a modified RGN marker segment from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex A. Table A.16 replaces ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.25. If there is RGN marker segment in the main header with a Srgn = 0, there shall not be any RGN marker segment anywhere in the codestream with a non-zero Srgn value for the component given by the corresponding Crgn value. Likewise, if there is RGN marker segment in the main header with a non-zero Srgn value, there shall not be any RGN marker segment anywhere in the codestream with a Srgn = 0 for the component given by the corresponding Crgn value.

When used in both the main header and the first tile-part header, the RGN in the first tile part header overrides the main for that tile. Also, an RGN specifying a single component (Crgn ≠ 65 535) overrides on specifying all components (Crgn = 65 535). Thus the order of precedence is the following:

Tile-part RGN (Crgn ≠ 65 535) > Tile-part RGN (Crgn = 65 535) > Main RGN (Crgn ≠ 65 535) > Main RGN (Crgn = 65 535)

where the "greater than" sign, >, means that the greater overrides the lesser marker segment.

Table A.16 – Region-of-interest parameter values for the Srgn parameter

Values	ROI style (Srgn)	SPrgn usage
0	Implicit ROI (maximum shift)	ITU-T Rec. T.800 | ISO/IEC 15444-1 Table A.26
1	Arbitrary region of interest, rectangle	Table A.18
2	Arbitrary region of interest, ellipse	Table A.18
	All other values reserved	

Table A.17 – Component index parameter value for the Crgn parameter

Parameter	Size (bits)	Values	Components index parameter
Component	16	0-16 383 16 394-65 354 65 535	Specifies component to which these region of interest descriptions apply Reserved Region of interest descriptions apply to all components

Table A.18 – Region-of-interest values from SPrgn parameter (Srgn = 1 or Srgn = 2)

Parameter	Size (bits)	Values	Meaning of SPrgn parameter
Binary shift	8	0-255	Binary shifting of coefficients in the region of interest above the background.
XArgn (left)	32	$0\text{-}(2^{32}-1)$	Horizontal reference grid point from the origin of the first point. (In the case of the ellipse, Srgn = 2, this value shall not exceed the width of the image.)
YArgn (top)	32	$0\text{-}(2^{32}-1)$	Vertical reference grid point from the origin of the first point. (In the case of the ellipse, Srgn = 2, this value shall not exceed the height of the image.)
XBrgn (right)	32	$0\text{-}(2^{32}-1)$	Horizontal reference grid point from the origin of the second point.
YBrgn (bottom)	32	$0\text{-}(2^{32}-1)$	Vertical reference grid point from the origin of the second point.

A.3 Extended marker segments

Table A.19 lists the markers specified in this Recommendation | International Standard.

Table A.19 – List of markers and marker segments

	Symbol	Code	Main header[a)]	Tile-part header[a)]
Variable DC offset	DCO	0xFF70	optional	optional
Visual masking	VMS	0xFF71	optional	optional
Downsampling factor style	DFS	0xFF72	optional	optional
Arbitrary decomposition style	ADS	0xFF73	optional	optional
Arbitrary transformation kernels	ATK	0xFF79	optional	optional
Component bit depth	CBD	0xFF78	optional	optional
Multiple component transformation definition	MCT	0xFF74	optional	optional
Multiple component collection	MCC	0xFF75	optional	optional
Multiple component transformation ordering	MCO	0xFF77	optional	optional
Non-linearity point transformation	NLT	0xFF76	optional	optional
Quantization default, precinct	QPD	0xFF5A	optional	optional
Quantization component, precinct	QPC	0xFF5B	optional	optional

[a)] Required means the marker or marker segment shall be in this header if this extension is used. Optional means it may be used in the header if this extension is used.

A.3.1 Variable DC offset (DCO)

Function: Describes the variable DC offset for every component.

Usage: Present only if the variable DC offset capability bit in the Rsiz parameter (see A.2.1) is a one value. Main and first tile-part header of a given tile. Optional in both the main and tile-part headers. No more than one shall appear in any header. If present in the main header, it describes the variable DC offset for every component in every tile. If present in the first tile-part header of a given tile, it describes the variable DC offset for every component in that tile only. When used in both the main header and the first tile-part header, the DCO in the first tile part header overrides the main for that tile. Thus the order of precedence is the following:

Tile-part DCO > Main DCO

where the "greater than" sign, >, means that the greater overrides the lesser marker segment.

Shall not be used with the multiple component transform.

Length: Variable depending on the number of components.

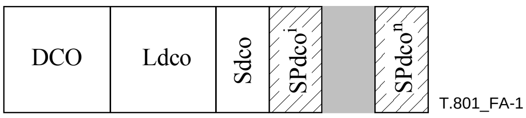


Figure A.1 – Variable DC offset syntax

DCO: Marker code. Table A.20 shows the size and parameter values for coding style component marker segment.

Ldco: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Ldco = \begin{cases} 3 + Csiz & Sdco = 0 \\ 3 + 2 \cdot Csiz & Sdco = 1 \\ 3 + 4 \cdot Csiz & Sdco = 2 \\ 3 + 8 + \cdot Csiz & Sdco = 3 \end{cases} \quad \text{(A-1)}$$

where Csiz is from ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A.

NOTE – If Ldco were to be larger than 65 535, then the DCO marker segment cannot be used. Instead multiple component transformation functionality could be used.

Sdco: Variable DC offset type definition.

$SPdco^i$: Variable DC offset for the ith component. There is one SPdco parameter for every component in the image.

Table A.20 – Variable DC offset parameter values

Parameter	Size (bits)	Values
DCO	16	0xFF70
Ldco	16	5-32 770
Sdco	8	Table A.21
$SPdco^i$	variable	Table A.21

Table A.21 – Variable DC offset parameter values for the Sdco parameter

Values (bits) MSB LSB	Offset type definition
0000 0000	Offsets are 8 bit unsigned integers
0000 0001	Offsets are 16 bit signed integers
0000 0010	Offsets are 32-bit floating point (IEEE Std. 754-1985 R1990)
0000 0011	Offsets are 64-bit floating point (IEEE Std. 754-1985 R1990)
	All other values reserved

A.3.2 Visual masking (VMS)

Function: Describes the visual masking for all tile-components in the image or tile.

Usage: Present only if the visual masking capability bit in the Rsiz parameter (see A.2.1) has the value one. Optionally used in the main and/or the first tile-part header of a given tile. No more than one VMS marker segment for a component shall appear in any header. When used in both the main header and the first tile-part header, the VMS marker segment in the first tile part header overrides the one in the main header for that tile. A VMS marker segment specifying a single component (Cvms ≠ 65 535) overrides on specifying all components (Cvms = 65 535). Thus the order of precedence is the following:

Tile-part VMS (Cvms ≠ 65 535) > Tile-part VMS (Cvms = 65 535) > Main VMS (Cvms ≠ 65 535) > Main VMS (Cvms = 65 535)

where the "greater than" sign, >, means that the greater overrides the lesser marker segment.

Length: Fixed.

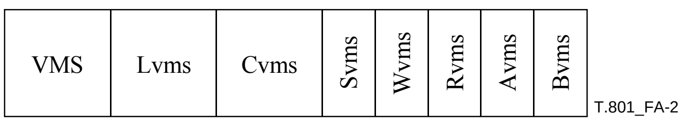


Figure A.2 – Visual masking syntax

VMS: Marker code. Table A.22 shows the size and parameter values for coding style, default marker segment.

Lvms: Length of marker segment in bytes (not including the marker). Fixed at 7 bytes.

Cvms: The index of the component to which this marker segment applies. Could be all components.

Svms: Minimal resolution level and respect block boundaries flag.

Wvms: Window width variable, *win_width* (see E.6).

Rvms: Bits retained variable, *bits_retained* (see E.6).

Avms: Value of the numerator of the α parameter, $\alpha = Avms/128$ (see E.6).

Bvms: Value of the numerator of the β parameter, $\beta = Bvms/128$ (see E.6).

Table A.22 – Visual masking parameter values

Parameter	Size (bits)	Values
VMS	16	0xFF71
Lvms	16	9
Cvms	16	Table A.23
Svms	8	Table A.24
Wvms	8	0-8
Rvms	8	0-255
Avms	8	0-255
Bvms	8	0-255

Table A.23 – Component parameter value for the Cvms parameter

Values	Component index parameter
0-16 383 16 394-65 354 65 535	Specifies component to which these region of interest descriptions apply Reserved Region of interest descriptions apply to all components

Table A.24 – Visual masking for the Svms parameters

Values (bits) MSB LSB	Visual masking parameters
x000 0000 to x001 0000	Minimum resolution level value, *minlevel* (0-32) (see E.6)
0xxx xxxx 1xxx xxxx	Variable *respect_block_boundaries* = 0 (see E.6) Variable *respect_block_boundaries* = 1 (see E.6)
	All other values reserved

A.3.3 Downsampling factor styles (DFS)

Function: Describes the arbitrary decomposition pattern for the lowest resolution sub-band for all tiles of a given component.

Usage: Present only if the custom decomposition style bit in the Rsiz parameter (see A.2.1) is a one value. Main header. Assigned to a component by an index in the main header COD or COC markers.

Length: Variable.

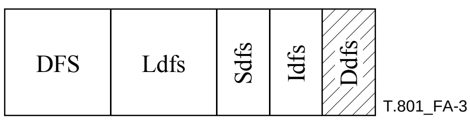


Figure A.3 – Downsampling factor styles syntax

DFS: Marker code. Table A.26 shows the size and values of the symbol and parameters for coding style, default marker segment.

Ldfs: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Ldfs = 4 + \left\lceil \frac{Idfs}{4} \right\rceil \tag{A-2}$$

Sdfs: The index of this DFS marker segment. This marker segment is associated with a component via the parameter in the COD or COC marker segments found in the main header.

Idfs: Number of elements in the string defining the number of decomposition sub-levels.

Ddfs: String defining the number of decomposition sub-levels. The two bit elements are packed into bytes in big endian order. The final byte is padded to a byte boundary.

Table A.25 – Downsampling factor styles parameter values

Parameter	Size (bits)	Values
DFS	16	0xFF72
Ldfs	16	5-65 535
Sdfs	16	0-15
Idfs	8	0-255
Ddfs	variable	String of elements

A.3.4 Arbitrary decomposition styles (ADS)

Function: Describes the arbitrary decomposition pattern for a tile-component or all tile-components within a single tile.

Usage: Present only if the custom decomposition style capability bit in the Rsiz parameter (see A.2.1) is a one value. Shall not be used to describe the decomposition described in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex F. Main and first tile-part header of a given tile. There may be up to 127 such marker segments with unique index values. If an index value is found in a tile-part header, then it is used instead of an ADS marker segment in the main header with the same index value. These are assigned to a particular tile-component via the parameter in the COD or COC marker segments found only in a specific tile-part header.

Length: Variable.

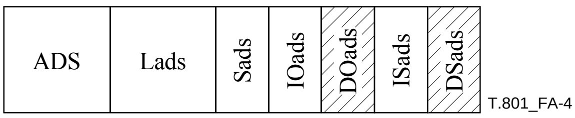


Figure A.4 – Arbitrary decomposition styles syntax

ADS: Marker code. Table A.26 shows the size and values of the symbol and parameters for coding style, default marker segment.

Lads: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Lads = 5 + \left\lceil \frac{IOads + ISads}{4} \right\rceil \tag{A-3}$$

Sads: The index of this ADS marker segment. This marker segment is associated with a component via the parameter in the COD or COC marker segments found in that tile-part header.

IOads: Number of elements in the string defining the number of decomposition sub-levels.

DOads: String defining the number of decomposition sub-levels. The two bit elements are packed into bytes in big endian order. The final byte is padded to a byte boundary.

ISads: Number of elements in the string defining the arbitrary decomposition structure.

DSads: String defining the arbitrary decomposition structure. The two bit elements are packed into bytes in big endian order. The final byte is padded to a byte boundary.

Table A.26 – Arbitrary decomposition styles parameter values

Parameter	Size (bits)	Values
ADS	16	0xFF73
Lads	16	3-65 535
Sads	8	1-127
IOads	8	0-255
DOads	variable	String of elements
ISads	8	0-255
DSads	variable	String of elements

A.3.5 Arbitrary transformation kernels (ATK)

Function: Describes a transformation kernel and an index that allows assignment to tile-components.

Usage: Present only if the arbitrary transformation kernel capability bit in the Rsiz parameter (see A.2.1) is a one value. Main and first tile-part header of a given tile. May be up to 254 marker segments in any header. A marker segment in the tile-part header with the same index as one in the main header overrides the main header marker segment.

Length: Variable.

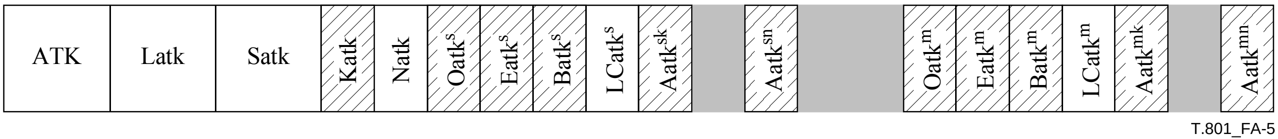


Figure A.5 – Arbitrary transformation default syntax

ATK: Marker code. Figure A.5 shows the size and values of the symbol and parameters for arbitrary transformation marker segment.

Latk: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Latk = \begin{cases} 5 + 2Natk + sizeof(Coeff\_Typ)\left(1 + \sum_{s=0}^{Natk-1} LCatk^{s}\right) & WT\_Typ = IRR, Filt\_Cat = ARB \\ 5 + Natk + sizeof(Coeff\_Typ)\left(1 + \sum_{s=0}^{Natk-1} LCatk^{s}\right) & WT\_Typ = IRR, Filt\_Cat = WS \\ 5 + 3Natk + sizeof(Coeff\_Typ)\left(Natk + \sum_{s=0}^{Natk-1} LCatk^{s}\right) & WT\_Typ = REV, Filt\_Cat = ARB \\ 5 + 2Natk + sizeof(Coeff\_Typ)\left(Natk + \sum_{s=0}^{Natk-1} LCatk^{s}\right) & WT\_Typ = REV, Filt\_Cat = WS \end{cases} \quad \text{(A-4)}$$

where *sizeof(Coeff_Typ)* is the size (in bytes) of the Satk parameter that takes values of the type *Coeff_Typ*.

Satk: Index of the ATK marker segment; the type, *Coeff_Typ*, of the scaling factor and lifting step parameters; the wavelet filter category, *Filt_Cat*; wavelet transformation type, *WT_Typ*, the initial odd or even subsequence, m_{init}. The values "0000 0000" and "0000 0001" are not available for this index having been assigned to the 9-7 irreversible wavelet filter and the 5-3 reversible wavelet filter respectively in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A.

Katk: The scaling factor, *K*. Present for irreversible transformation only, *WT_Typ* = *IRR*.

Natk: Number of lifting steps, N_{LS}.

Oatk^s: Offset for lifting step *s*, off_s. The index, *s*, ranges from *s* = 0 to Natk – 1. Present only if *Filt_Cat* = *ARB*.

Eatk^s: The base two scaling exponent for lifting step *s*, ε_s. Present only with reversible transformation, *WT_Typ* = *REV*. The index, *s*, ranges from *s* = 0 to Natk – 1.

Batk^s: Additive residue for lifting step, *s*. Present for reversible transformations (*WT_Typ* = *REV*) only. The index, *s*, ranges from *s* = 0 to Natk – 1.

LCatk^s: Number of lifting coefficients signalled for lifting step *s*. Provides the range, *k*, for Aatk^{sk}. The index, *s*, ranges from *s* = 0 to Natk – 1.

Aatk^sk: The *k*th lifting coefficient for the lifting step *s*, $\alpha_{s,k}$. The index, *s*, ranges from *s* = 0 to Natk – 1. The index, *k,* ranges from *k* = 0 to LCatk – 1.

Table A.27 – Arbitrary transformation parameter values

Parameter	Size (bits)	Values
ATK	16	0xFF79
Latk	16	9-65 535
Satk	16	Table A.28
Katk	0 8 16 32 64 128	*WT_Typ* = *REV* *WT_Typ* = *IRR*, *Coeff_Typ* = 0 *WT_Typ* = *IRR*, *Coeff_Typ* = 1 *WT_Typ* = *IRR*, *Coeff_Typ* = 2 *WT_Typ* = *IRR*, *Coeff_Typ* = 3 *WT_Typ* = *IRR*, *Coeff_Typ* = 4
Natk	8	0-255
Oatk^s	0 8	Filt_Cat = WS –128-127; *Filt_Cat* = *ARB*
Eatk^s	0 8	*WT_Typ* = *IRR* 0-255; *WT_Typ* = *REV*
Batk^s	0 8 16 32 64 128	*WT_Typ* = *IRR* *Coeff_Typ* = 0 *Coeff_Typ* = 1 *Coeff_Typ* = 2 *Coeff_Typ* = 3 *Coeff_Typ* = 4
LCatk^s	8	0-255
Aatk^{sk}	8 16 32 64 128	*Coeff_Typ* = 0 *Coeff_Typ* = 1 *Coeff_Typ* = 2 *Coeff_Typ* = 3 *Coeff_Typ* = 4

Table A.28 – Arbitrary transformation values for the Satk parameter

Values (bits) MSB LSB	Index

`xxxx xxxx 0000 0010`
to
`xxxx xxxx 1111 1111`
	Index of this marker segment (2-255)

`xxxx x000 xxxx xxxx`
`xxxx x001 xxxx xxxx`
`xxxx x010 xxxx xxxx`
`xxxx x011 xxxx xxxx`
`xxxx x100 xxxx xxxx`
	Parameters 8-bit signed integer, *Coeff_Typ* = 0
	Parameters 16-bit signed integer, *Coeff_Typ* = 1
	Parameters 32-bit floating point (IEEE Std. 754-1985 R1990), *Coeff_Typ* = 2
	Parameters 64-bit floating point (IEEE Std. 754-1985 R1990), *Coeff_Typ* = 3
	Parameters 128-bit floating point (IEEE Std. 754-1985 R1990), *Coeff_Typ* = 4

`xxxx 0xxx xxxx xxxx` `x1xx 1xxx xxxx xxxx`	Arbitrary filters, *Filt_Cat* = *ARB* WS filters, *Filt_Cat* = *WS*
`xxx0 xxxx xxxx xxxx` `xxx1 xxxx xxxx xxxx`	Irreversible filter, *WT_Typ* = *IRR* Reversible filter, *WT_Typ* = *REV*
`xx0x xxxx xxxx xxxx` `xx1x xxxx xxxx xxxx`	Modify even-indexed subsequence in first reconstruction step, $m_{init} = 0$ Modify odd-indexed subsequence in first reconstruction step, $m_{init} = 1$
`x0xx 0xxx xxxx xxxx` `x1xx xxxx xxxx xxxx`	Boundary extension method used in lifting steps is constant, *Exten* = *CON* Boundary extension method used in lifting steps is whole-sample symmetric, *Exten* = *WS*
	All other values reserved

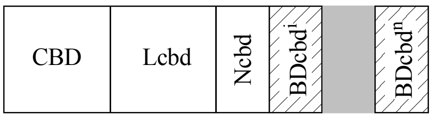
A.3.6 Component bit depth definition (CBD)

Function: Defines the bit depth of reconstructed image components coming out of any multiple component transformation process.

Usage: Present only if the multiple component transformation capability bit in the Rsiz parameter (see A.2.1) is a one value. Main header. The CBD marker segment is required if the multiple component transformation processes are used. At most there can be one CBD in the main header.

The presence of a CBD marker segment in a codestream alters the procedures used to determine the precision of output image components and the interpretation of the SIZ marker. See Annex J for further details.

Length: Variable depending on the number of reconstructed image component bit depths signalled.



T.801_FA-6

Figure A.6 – Component bit depth definition syntax

CBD: Marker code. Table A.29 shows the size and parameter values for component bit depth definition syntax.

Lcbd: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Lmct = \begin{cases} 5 & \text{Ncbd} = \texttt{1xxx xxxx xxxx xxxx} \\ 4 + \text{Ncbd} & \text{Ncbd} = \texttt{1xxx xxxx xxxx xxxx} \end{cases} \qquad \text{(A-5)}$$

Ncbd: Number of component bit depths included in marker segment. Table A.30 shows the value for the Ncbd parameter.

$BDcbd^i$: Bit depth and sign of the reconstructed image components in the order in which they are created as determined by the MCC and MCO marker segments. Either one value is signalled for all components (see Table A.30) or an individual bit depth is given for each component.

Table A.29 –Component bit depth definition parameter values

Parameter	Size (bits)	Values
CBD	16	0xFF78
Lcbd	16	5-16 388
Ncbd	16	Table A.30
$BDcbd^i$	8	Table A.31

Table A.30 – Component bit depth definition values for the Ncbd parameter

Values (bits) MSB LSB	Number of reconstructed image component bit depths in marker

`x000 0000 0000 0001`
to
`x100 0000 0000 0000`
	Number of reconstructed image components (1-16 384)

`0xxx xxxx xxxx xxxx` `1xxx xxxx xxxx xxxx`	Bit depths included, one per reconstructed image component One bit depth included, applies to *all* reconstructed image components
	All other values reserved

Table A.31 – Component bit depth definition values for the $BDcbd^i$ parameter

Values (bits) MSB LSB	Reconstructed image component bit depths

`x000 0000`
to
`x010 0101`
	Component sample bit depth = value + 1. From 1 bit deep through 38 bits deep respectively.

`0xxx xxxx`	Component sample values are unsigned values
`1xxx xxxx`	Component sample values are signed values
	All other values reserved

A.3.7 Multiple component transformation definition (MCT)

Function: Defines one multiple component transformation array per marker segment. The type and index of the array defined in this marker distinguishes it from other MCT marker segments in a given header. This array can be assigned to a collection of components within the MCC marker segment.

Usage: Present only if the multiple component transformation capability bit in the Rsiz parameter (see A.2.1) is a one value. Main and first tile-part header of a given tile. There may be up to 255 MCT marker segments, or series of marker segments, in the main header. There may be up to 255 MCT marker segments, or series of marker segments, in any tile-part header. An MCT marker segment in a tile-part header with the same index (Imct) as one in the main header overrides the main header MCT segment for that tile.

A series of MCT marker segments (defined as having the same Imct value in the same header and a Ymct > 0) shall all appear in the same header in order of (consecutive) Zmct parameter values.

To apply the transformation array included in an MCT marker segment, an MCC marker segment must exist that associates the MCT marker segment with a component collection. This association is made through the array definition index of the MCT marker segment and the $Tmcc^i$ fields of MCC marker segments. If no such MCC marker segment exists, then the transformation array included in the MCT marker segment shall not be used in the decoding process.

Length: Variable depending on the size of the array.

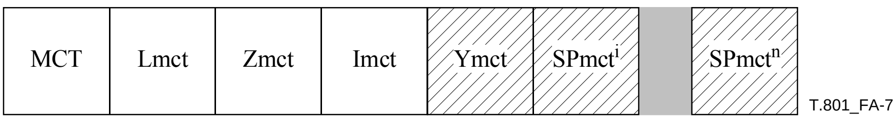


Figure A.7 – Multiple component transformation definition syntax

MCT: Marker code. Table A.32 shows the size and parameter values for multiple component transformation definition marker segment.

Lmct: Length of marker segment in bytes (not including the marker).

Zmct: Index of this marker segment in a series of MCT marker segments. All the marker segments in the series have the same Imct parameter value present in this header. The data in each subsequent MCT marker segment shall be appended, in order, to make on stream of $SPmct^i$ parameter values. The Ymct parameter values are present only in the first marker segment in the series (Zmct = 0).

Imct: Multiple component transformation index value, array type, and parameter size. An MCT marker segment, or series, with a given Imct value in the tile-part header overrides a main header MCT marker segment, or series, with the same Imct value.

Ymct: Index of the last number of MCT marker segment in the series. For every series of MCT marker segments (i.e., MCT marker segments in this header with the same Imct parameter value), there shall be MCT marker segment with Zmct parameter values of 0 to Ymct. The last MCT marker segment will have Zmct = Ymct. This value is present only in the first marker segment in the series (Zmct = 0).

$SPmct^i$: Parameters for the multiple component transformation definition. One parameter value for each element in the array. See J.2 to determine the number of array elements and their order in the marker segment. The number of elements in a row and the number of rows (elements in a column) are determined by the type of array and the number of the input and output components to which it is assigned.

Table A.32 – Multiple component transformation definition parameter values

Parameter	Size (bits)	Values
MCT	16	0xFF74
Lmct	16	6-65 535
Zmct	16	0-65 535
Imct	16	Table A.33
Ymct	0 16	If Zmct > 0 0-65 535
$SPmct^i$	variable	Table A.33

Table A.33 – Multiple component transformation definition values for the Imct parameter

Values (bits) MSB LSB	Index of the array definition, type and parameter type

`xxxx xxxx 0000 0001`
to
`xxxx xxxx 1111 1111`
	Index of the array definition, 1-255

`xxxx xx00 xxxx xxxx`	Dependency transformation array type
`xxxx xx01 xxxx xxxx`	Decorrelation transformation array type
`xxxx xx10 xxxx xxxx`	Offset array type
`xxxx 00xx xxxx xxxx`	Array elements are 16 bit signed integers
`xxxx 01xx xxxx xxxx`	Array elements are 32 bit signed integers
`xxxx 10xx xxxx xxxx`	Array elements are 32-bit floating point (IEEE Std. 754-1985 R1990)
`xxxx 11xx xxxx xxxx`	Array elements are 64-bit floating point (IEEE Std. 754-1985 R1990)
	All other values reserved

A.3.8 Multiple component transform collection (MCC)

Function: Describes the collection of input intermediate components, the collection of output intermediate components, and the associated wavelets or arrays for a multiple component transform. This marker segment can appear in the main header and can be referred to or overridden by an MCC marker in a tile-part header.

Usage: Present only if the multiple component transformation capability bit in the Rsiz parameter (see A.2.1) is a one value. Main and first tile-part header of a given tile. There may be up to 255 MCC marker segments, or series of marker segments, in the main header. There may be up to 255 MCC marker segments, or series of marker segments, in any tile-part header. An MCC marker segment in a tile-part header with the same index (Imcc) as one in the main header overrides the main header MCC segment for that tile.

A series of MCC marker segments (defined as having the same Imcc value in the same header and a Ymcc > 0) shall all appear in the same header in order of (consecutive) Zmcc parameter values.

Length: Variable depending on the number of component collections.

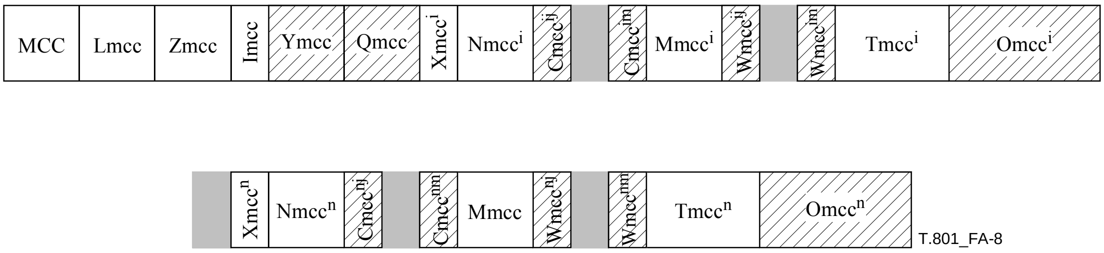


Figure A.8 – Multiple component collection syntax

MCC: Marker code. Table A.34 shows the size and parameter values for multiple component collection marker segment.

Lmcc: Length of marker segment in bytes (not including the marker).

Zmcc: Index of this marker segment in a series of MCC marker segments. All the marker segments in the series have the same Imcc parameter value present in this header. The data in each subsequent MCC marker segment shall be appended, in order, to make one stream of the other parameters. The Ymcc and Qmcc parameter appears only in the first marker segment (Zmcc = 0).

Imcc: Index of this marker segment. An MCC marker segment, or series, with a given Imcc value in the tile-part header overrides a main header MCC marker segment, or series, with the same Imcc value.

Ymcc: Index of the last number of MCC marker segment in the series. For every series of MCC marker segments (i.e., MCC marker segments in this header with the same Imcc parameter value), there shall be MCC marker segment with Zmcc parameter values of 0 to Ymcc. The last MCC marker segment will have Zmcc = Ymcc. This value is present only in the first marker segment in the series (Zmcc = 0).

Qmcc: The number of collections in the MCC marker segment. This value is present only in the first marker segment in the series (Zmcc = 0).

$Xmcc^i$: Indicates type of multiple component transform used for the ith component collection (wavelet or array-based decorrelation or array-based dependency). Defines the interpretation applied to Tmcc.

$Nmcc^i$: Indicates the number of input components for the ith component collection and defines the number of bits (8 or 16) used to represent the component indices in ith collection.

$Cmcc^{ij}$: Input intermediate component indices included the ith component collection. The number of indices in the ith component collection is $Nmcc^i$. Each index denotes an input intermediate component. The order of the indices defines the ordering applied to the input intermediate components prior to application of the inverse transform.

$Mmcc^i$: Indicates the number of output intermediate components for the ith component collection and defines the number of bits (8 or 16) used to represent the component indices in ith collection. If anything other than an array-based irreversible decorrelation transform is used, $Mmcc^i$ must equal $Nmcc^i$.

$Wmcc^{ij}$: Intermediate component indices included the ith output component collection. The number of indices in the ith component collection is $Mmcc^i$. All output intermediate component indices in a given MCC marker segment shall appear only once across all collections in that MCC marker.

$Tmcc^i$: For array-based component collection transforms, $Tmcc^i$ assigns arrays defined in an MCT marker segment to the ith component collection. An MCT marker segment with the right type and index in the first tile-part header of a tile is used before an MCT marker segment with the right type and index in the main header. $Tmcc^i$ also indicates the reversibility of array-based component transforms.

For wavelet-based component collection transforms, $Tmcc^i$ assigns a wavelet kernel defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A or an ATK marker segment and the number of wavelet decomposition levels for the ith component collection (only the dyadic decomposition of ITU-T Rec. T.800 | ISO/IEC 15444-1 is supported). An ATK marker segment with the proper index in the first tile-part header of a tile is used before an ATK marker segment with the proper index in the main header. $Tmcc^i$ also contains the index of an MCT marker segment that contains component additive offsets.

$Omcc^i$: Present in the MCC marker segment only for those component collections that use a wavelet-based transform. $Omcc^i$ indicates the reference grid offset to apply in the component dimension for the ith component collection (see J.2.2).

Table A.34 – Multiple component collection parameter values

Parameter	Size (bits)	Values
MCC	16	0xFF75
Lmcc	16	5-65 535
Zmcc	16	0-65 535
Imcc	8	1-255
Ymcc	0 16	If Zmcc > 0 0-65 535
Qmcc	0 16	If Zmcc > 0 0-16 383
$Xmcc^i$	8	Table A.35
$Nmcc^i$	16	Table A.36
$Cmcc^{ij}$	8 16	0-255 0-16 383
$Mmcc^i$	16	Table A.37
$Wmcc^{ij}$	8 16	0-255 0-16 383
$Tmcc^i$	24	Table A.35
$Omcc^i$	32	0-4 294 967 295

Table A.35 – Multiple component collection values for the $Xmcc^i$ parameter

Values (bits) MSB LSB	Coding style	$Tmcc^i$ parameter
xxxx xx00 xxxx xx01 xxxx xx11	Component collection transform is array-based dependency transform Component collection transform is array-based decorrelation transform Component collection transform is wavelet-based transform	Table A.38 Table A.38 Table A.39
	All other values reserved	

Table A.36 – Multiple component collection values for the $Nmcc^i$ parameter

Values (bits) MSB LSB	Coding style
0xxx xxxx xxxx xxxx to 1xxx xxxx xxxx xxxx	Input component collection indices ($Cmcc^i$) are 8 bit integers Input component collection indices ($Cmcc^i$) are 16 bit integers
x000 0000 0000 0001 to x100 0000 0000 0000	Number of input components in ith component collection (1-16 384)

Table A.37 – Multiple component collection values for the $Mmcc^i$ parameter

Values (bits) MSB LSB	Coding style
0xxx xxxx xxxx xxxx to 1xxx xxxx xxxx xxxx	Output component collection indices ($Wmcc^i$) are 8 bit integers Output component collection indices ($Wmcc^i$) are 16 bit integers
x000 0000 0000 0001 to x100 0000 0000 0000	Number of output components in ith component collection (1-16 384)

Table A.38 – Multiple component collection values for the $Tmcc^i$ parameter (array-based)

Values (bits) MSB LSB	Coding style
xxxx xxxx xxxx xxxx 0000 0000 xxxx xxxx xxxx xxxx 0000 0001 to xxxx xxxx xxxx xxxx 1111 1111	No assigned transform array (NULL array) Decorrelation or dependency transform array index
xxxx xxxx 0000 0000 xxxx xxxx xxxx xxxx 0000 0001 xxxx xxxx to xxxx xxxx 1111 1111 xxxx xxxx	No assigned offset array (NULL array) Offset array index
xxxx xxx0 xxxx xxxx xxxx xxxx xxxx xxx1 xxxx xxxx xxxx xxxx	Decorrelation or dependency transform is irreversible Decorrelation or dependency transform is reversible
	All other values reserved

Table A.39 – Multiple component collection values for the $Tmcc^i$ parameter (wavelet-based)

Values (bits) MSB LSB	Coding style
xxxx xxxx xxxx xxxx 0000 0000 xxxx xxxx xxxx xxxx 0000 0001 xxxx xxxx xxxx xxxx 0000 0010 to xxxx xxxx xxxx xxxx 1111 1111	ITU-T Rec. T.800 | ISO/IEC 15444-1 9-7 irreversible filter ITU-T Rec. T.800 | ISO/IEC 15444-1 5-3 reversible filter Index of the ATK marker segment containing the wavelet kernel for component collection
xxxx xxxx 0000 0000 xxxx xxxx xxxx xxxx 1111 1111 xxxx xxxx	Index of MCT marker segment containing additive offsets for component collection
xx00 0000 xxxx xxxx xxxx xxxx xx10 0000 xxxx xxxx xxxx xxxx	Number of dyadic wavelet decomposition levels used in the component collection (0-32)
	All other values reserved

A.3.9 Multiple component transform ordering (MCO)

Function: Describes the order in which multiple component transforms are applied during inverse multiple component transform processing.

Usage: Present only if the multiple component transformation capability bit in the Rsiz parameter (see A.2.1) is a one value. At most one MCO marker segment in main and first tile-part header of a given tile. If used in the main header, this marker segment defines the default ordering of multiple component transform stages for all tiles. If used in the first tile-part header, then the component transform order established by the MCO marker segment overrides any default ordering defined by a main header MCO marker segment.

Length: Variable depending on the number of multiple component transform stages used.

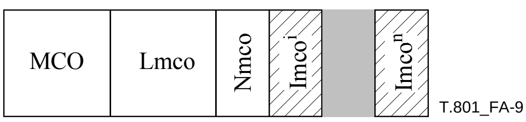


Figure A.9 – Multiple component transform ordering syntax

MCO: Marker code. Table A.40 shows the size and parameter values for the multiple component transform ordering marker segment.

Lmco: Length of marker segment in bytes (not including the marker). The length is given by the following expression:

$$\text{Lmco} = 3 + \text{Nmco} \tag{A-6}$$

Nmco: Number of multiple component transform stages specified for inverse transform processing. If Nmco = 0, then no multiple component transform processing is used for the current tile and no Imco^i parameters shall appear. Otherwise, Nmco specifies the number of MCC marker segment identifiers that will follow.

Imco^i: Index of the MCC marker segment containing the component collection information for the ith inverse multiple component transform stage (see A.3.8).

Table A.40 – Multiple component intermediate collection parameter values

Parameter	Size (bits)	Values
MCO	16	0xFF77
Lmco	16	3-258
Nmco	8	0-255
Imco^i	8	0-255

A.3.10 Non-linearity point transformation (NLT)

Function: Describes either a gamma or LUT non-linearity to be applied to a single component or all components.

Usage: Present only if the non-linearity point transformation capability bit in the Rsiz parameter (see A.2.1) is a one value. Main and first tile-part header of a given tile. There may be no more than one marker segment per component plus one default in any header.

When used in the main header, the defined non-linearity can be established as a default for all components or established as a default for a single component. When used in a tile-part header, it can be used to establish a default for all components in the tile or to set the non-linearity transformation for a single component in that tile. Thus, the order of precedence is the following:

Tile-part NLT > Tile-part NLT default > Main NLT > Main NLT default

where the "greater than" sign, >, means that the greater overrides the lesser marker segment.

Length: Variable depending on the value of Tnlt.

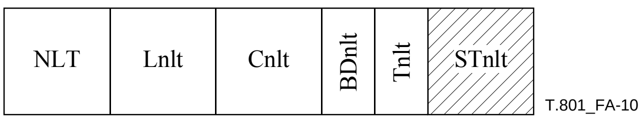


Figure A.10 – Non-linearity point transformation syntax

NLT: Marker code. Table A.41 shows the size and values of the symbol and parameters for non-linearity point transformation marker segment.

Lnlt: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Lnlt = 6 + \begin{cases} 15 & Tnlt = 1 \\ 11 + (N_{points} \cdot \Psi_{Tval}) & Tnlt = 2 \end{cases}$$
$$\Psi_{Tval} = \begin{cases} 1 & PTval \in [1, 8] \\ 2 & PTval \in [9, 16] \\ 4 & PTval \in [17, 32] \end{cases} \tag{A-7}$$

Cnlt: The index of the component to which this marker segment relates. The components are indexed 0, 1, 2, etc. If this value is 65 535, then this marker segment applies to all components. Table A.42 shows the value for the Cnlt parameter.

BDnlt: Bit depth and sign of the decoded image component, Z_i, after processing of the *i*th reconstructed image component by the non-linearity. If Cnlt = 65 535, then this value applies to all components. Table A.43 shows the values for the BDnlt parameter.

Tnlt: Non-linearity type. Table A.44 shows the value for the Scod parameter.

STnlt: Parameter values associated with the non-linearity as controlled by the Tnlt field.

Table A.41 – Non-linearity transformation parameter values

Parameter	Size (bits)	Values
NLT	16	0xFF76
Lnlt	16	12-65 535
Cnlt	16	Table A.42
BDnlt	8	Table A.43
Tnlt	8	Table A.44
STnlt	variable	Table A.44

Table A.42 – Non-linearity transformation parameter values for the Cnlt parameter

Values	Components index parameter
0-16 383	Defines component to which these non-linearity transformation descriptions in this marker segment apply
65 535	Non-linearity transformation descriptions in this marker segment apply to all components
	All other values reserved

Table A.43 – Decoded image component bit depth parameter values for the BDnlt parameter

Values (bits) MSB LSB	Decoded image component bit depth

`x000 0000`
to
`x010 0101`
	Component sample bit depth = value + 1. From 1 bit deep through 38 bits deep respectively.

`0xxx xxxx`	Component sample values are unsigned values
`1xxx xxxx`	Component sample values are signed values
	All other values reserved

Table A.44 – Non-linearity transformation parameter values of the Tnlt parameter

Values (bits) MSB LSB	Meaning of Tnlt values	STnlt usage
`0000 0000`	No non-linearity transformation applied	–
`0000 0001`	Gamma-style non-linearity transformation	Table A.45
`0000 0010`	LUT-style non-linearity transformation	Table A.46
	All other values reserved	–

Table A.45 – Non-linearity transformation parameter values of the STnlt parameter (Tnlt = 1)

Parameter (in order)	Size (bits)	Values	Meaning of STnlt values
E	24	$\{0,\ldots,255\}+\frac{\{0,\ldots,65\,535\}}{65\,535}$	Non-linearity exponent (8-bit integer + 16-bit fraction)
S	24	$\{0,\ldots,255\}+\frac{\{0,\ldots,65\,535\}}{65\,535}$	Non-linearity toe slope (8-bit integer + 16-bit fraction)
T	24	$\{0,\ldots,255\}+\frac{\{0,\ldots,65\,535\}}{65\,535}$	Non-linearity threshold (8-bit integer + 16-bit fraction)
A	24	$\{0,\ldots,255\}+\frac{\{0,\ldots,65\,535\}}{65\,535}$	Non-linearity continuity parameter A (8-bit integer + 16-bit fraction)
B	24	$\{0,\ldots,255\}+\frac{\{0,\ldots,65\,535\}}{65\,535}$	Non-linearity continuity parameter B (8-bit integer + 16-bit fraction)

Table A.46 – Non-linearity transformation parameter values of the STnlt parameter (Tnlt = 2)

Parameters (in order)	Size (bits)	Values	Meaning of STnlt values
Npoints	16	1-8 191	(Number of points – 1) in the LUT-style non-linearity definition (all other values reserved)
Dmin	32	0-(2^{32}–1)	Dmin = parameter value / (2^{32}–1)
Dmax	32	1-(2^{32}–1)	Dmax = parameter value / (2^{32}–1)
PTval	8	0000 0001 to 0010 0000	Precision of Tvalue parameter in bits (1-32). This also implies how many bytes are used to express the Tvalue (all other values reserved)
Tvalue	8, PTval ≤ 8; 16, 9 ≤ PTval ≤ 16 32, PTval > 16	variable	Run of table values for the LUT-style non-linearity. The (Npoints + 1) parameters are unsigned integers. The actual value of Tvalue is Tvalue = parameter value / (2^{PTval} – 1)

A.3.11 Quantization default, precinct (QPD)

Function: Describes the quantization default used for compressing all components of a particular resolution level and precinct. The parameter values can be overridden for an individual component, resolution level, and precinct by a QPC marker segment which, if present, must appear in a tile-part header prior to any packets for that component, resolution level, and precinct.

Usage: Main and any tile-part header. Several QPD marker segments may appear in any tile-part header, but only one for each resolution level and precinct. If a QPD is used in a tile-part header it overrides the quantization characteristics defined by either QCD or QCC marker segments for all components of the resolution level and precinct indexed by the QPD within the scope of the particular tile. Thus, the quantization characteristics of a particular resolution level, precinct pair is determined by the presence of QCD, QCC, QPD or QPC markers in the following order of precedence:

Any tile-part QPC > Any tile-part QPD > First tile-part QCC > First tile-part QCD >
Main QPC > Main QPD > Main QCC > Main QCD

When QPD marker segments are used, they must appear in tile-part headers before any packets are found for the indexed resolution level and precinct.

Length: Variable depending on the number of quantized sub-bands within the resolution level indexed.

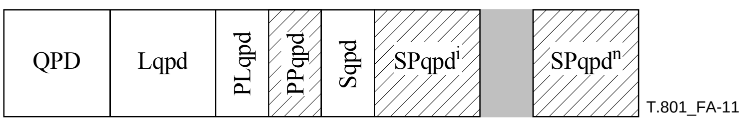


Figure A.11 – Quantization default, precinct syntax

QPD: Marker code. Table A.47 shows the size and values of the symbol and parameters for quantization default, precinct marker segment.

Lqpd: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Lqpd = \begin{cases} 5 + \text{num\_subbands\_lev} & \text{no\_quant AND PLqpd} < 128 \\ 7 & \text{quant\_derived AND PLqpd} < 128 \\ 5 + 2 \cdot \text{num\_subbands\_lev} & \text{quant\_expounded AND PLqpd} < 128 \\ 6 + \text{num\_subbands\_lev} & \text{no\_quant AND PLqpd} \geq 128 \\ 8 & \text{quant\_derived AND PLqpd} \geq 128 \\ 6 + 2 \cdot \text{num\_subbands\_lev} & \text{quant\_expounded AND PLqpd} \geq 128 \end{cases} \quad \text{(A-8)}$$

where *num_sub-bands_lev* can be derived from F.2.4 for each resolution level and whether this marker segment has *no_quant*, *quant_derived*, and *quant_expounded* is signalled in the Sqpd parameter.

NOTE – The Lqcd can be used to determine how many quantization step sizes are present in the marker segment. However, there is not necessarily a correspondence with the number of sub-bands present because the sub-bands can be truncated with no requirement to correct this marker segment.

PLqpd: The resolution level index for the quantization values signalled. Equation A-9 shows how this marker segment is constructed based on the resolution level index, *lev,* as well as the precinct index, *prec.*

$$PLqpd = \begin{cases} lev & prec < 256 \\ 128 + lev & prec \geq 256 \end{cases} \quad \text{(A-9)}$$

The resolution level index, *lev,* can range from 0 to N_L, where N_L is the number of decomposition levels defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, A.6.1.

PPqpd: The precinct index for the quantization values signalled. The size of this marker segment parameter will be one byte when the PLqpd parameter is less than 128, but two bytes when PLqpd is greater than or equal to 128. This parameter will then just hold the precinct index, *prec*. The precinct index, *prec,* can range from 0 to *numprecincts* –1, where *numprecincts* is the number of precincts at resolution level *lev* and is also defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, B.6.

Sqpd: Quantization style for all components at the resolution level, *lev*, and precinct, *prec*.

SPqpd^i: Quantization step size value for the ith sub-band at the resolution level, *lev*, in the order defined for lev in F.2.4. The number of parameters is at least as large as the number of sub-bands in the tile-component with the greatest number of sub-bands at resolution level, *lev*.

Table A.47 – Quantization default, precinct parameter values

Parameter	Size (bits)	Values
QPD	16	0xFF5A
Lqpd	16	6-101
PLqpd	16	0-32 or 128-160
PPqpd	8 16	0-255, PLqpd < 128 0-65 535, PLqpd ≥ 128
Sqpd	8	Table A.12
SPqpd^i	variable	Table A.12

A.3.12 Quantization precinct component (QPC)

Function: Describes the quantization used for compressing a particular component, resolution level, and precinct.

Usage: Main and any tile-part header. Several QPC marker segments may appear in any tile-part header, but only one for each component, resolution level, and precinct. If a QPC is used in a tile-part header it overrides the quantization characteristics defined by QCD, QCC, or QPD marker segments for the triplet indexed by the QPC within the scope of the particular tile. Thus, the quantization characteristics of a particular component, resolution level, and precinct is determined by the presence of QCD, QCC, QPD or QPC markers in the following order of precedence:

Any tile-part QPC > Any tile-part QPD > First tile-part QCC > First tile-part QCD >
Main QPC > Main QPD > Main QCC > Main QCD

When QPC marker segments are used, they must appear in tile-part headers before any packets are found for the indexed component, resolution level, and precinct.

Length: Variable depending on the number of quantized sub-bands within the resolution level indexed.

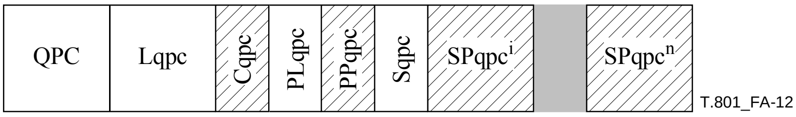


Figure A.12 – Quantization precinct component syntax

QPC: Marker code. Table A.48 shows the size and values of the symbol and parameters for quantization component marker segment.

Lqpc: Length of marker segment in bytes (not including the marker). The value of this parameter is determined by the following equation:

$$Lqpc = \begin{cases} 6 + \text{num\_subbdands\_lev} & \text{no\_quant } \mathit{AND} \text{ Csiz} < 257 \mathit{AND} \text{ Plqpc} < 128 \\ 8 & \text{quant\_derived } \mathit{AND} \text{ Csiz} < 257 \mathit{AND} \text{ Plqpc} < 128 \\ 6 + 2 \cdot \text{num\_subbdands\_lev} & \text{quant\_expounded } \mathit{AND} \text{ Csiz} < 257 \mathit{AND} \text{ Plqpc} < 128 \\ 7 + \text{num\_subbdands\_lev} & \text{no\_quant } \mathit{AND} \text{ Csiz} \geq 257 \mathit{AND} \text{ Plqpc} < 128 \\ 9 & \text{quant\_derived } \mathit{AND} \text{ Csiz} \geq 257 \mathit{AND} \text{ Plqpc} < 128 \\ 7 + 2 \cdot \text{num\_subbdands\_lev} & \text{quant\_expounded } \mathit{AND} \text{ Csiz} \geq 257 \mathit{AND} \text{ Plqpc} < 128 \\ 7 + \text{num\_subbdands\_lev} & \text{no\_quant } \mathit{AND} \text{ Csiz} < 257 \mathit{AND} \text{ Plqpc} \geq 128 \\ 9 & \text{quant\_derived } \mathit{AND} \text{ Csiz} < 257 \mathit{AND} \text{ Plqpc} \geq 128 \\ 7 + 2 \cdot \text{num\_subbdands\_lev} & \text{quant\_expounded } \mathit{AND} \text{ Csiz} < 257 \mathit{AND} \text{ Plqpc} \geq 128 \\ 8 + \text{num\_subbdands\_lev} & \text{no\_quant } \mathit{AND} \text{ Csiz} \geq 257 \mathit{AND} \text{ Plqpc} \geq 128 \\ 10 & \text{quant\_derived } \mathit{AND} \text{ Csiz} \geq 257 \mathit{AND} \text{ Plqpc} \geq 128 \\ 8 + 2 \cdot \text{num\_subbdands\_lev} & \text{quant\_expounded } \mathit{AND} \text{ Csiz} \geq 257 \mathit{AND} \text{ Plqpc} \geq 128 \end{cases} \quad \text{(A-10)}$$

where *num_sub-bands_lev* can be derived from F.2.4 for each resolution level and whether this marker segment has *no_quant*, *quant_derived*, and *quant_expounded* is signalled in the Sqpc parameter.

NOTE – The Lqpc can be used to determine how many step sizes are present in the marker segment. However, there is not necessarily a correspondence with the number of sub-bands present because the sub-bands can be truncated with no requirement to correct this marker segment.

Cqpc: The index of the component to which this marker segment relates. The components are indexed 0, 1, 2, etc. (Either 8 or 16 bits depending on Csiz value.)

PLqpc: The resolution level index for the quantization values signalled. Equation A-11 shows how this marker segment is constructed based on the resolution level index, *lev,* as well as the precinct index, *prec.*

$$PLqpd = \begin{cases} lev & prec < 256 \\ 128 + lev & prec \geq 256 \end{cases} \quad \text{(A-11)}$$

The resolution level index, *lev,* can range from 0 to N_L, where N_L is the number of decomposition levels defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, A.6.1.

PPqpc: The precinct index for the quantization values signalled. The size of this marker segment parameter will be one byte when the PLqpc parameter is less than 128, but two bytes when PLqpc is greater than or equal to 128. This parameter will then just hold the precinct index, *prec*. The precinct index, *prec,* can range from 0 to *numprecincts* –1, where *numprecincts* is the number of precincts at resolution level *lev* and is also defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, B.6.

Sqpc: Quantization style for this component, resolution level, *lev*, and precinct, *prec*.

$SPqpc^i$: Quantization value for the ith sub-band at resolution level, *lev*, in the defined order for *lev* in F.2.4. The number of parameters is at least as large as the number of sub-bands in the relevant tile-component with the greatest number of sub-bands at resolution level, *lev*.

Table A.48 – Quantization precinct component parameter values

Parameter	Size (bits)	Values
QPC	16	0xFF5B
Lqpc	16	5-199
Cqpc	8 16	0-255; if Csiz < 257 0-16 383; Csiz ≥ 257
PLqpc	16	0-32 or 128-160
PPqpc	8 16	0-255, PLqpd < 128 0-65 535, PLqpd ≥ 128
Sqpc	8	Table A.12
$SPqpc^i$	variable	Table A.12

Annex B

Variable DC offset, extension

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard, except the Multiple Component Transformation in Annex J. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

This annex specifies variable DC offset that converts the signed values resulting from the decoding process to the proper reconstructed samples. It can be applied to with both signed and unsigned component data.

B.1 Variable DC offset flow

DC offset occurs external to any component transformations, i.e., prior to component transformations during encoding and after component transformations during decoding. Figure B.1 shows the flow of DC offset in the system with a multiple component transformation from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex G.

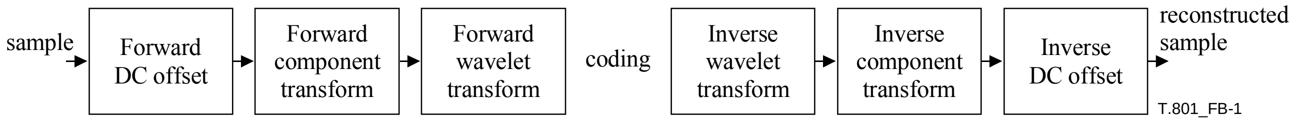


Figure B.1 – Placement of the DC offset with multiple component transformation

Figure B.2 shows the flow of DC offset in the system without a multiple component transformation from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex G.

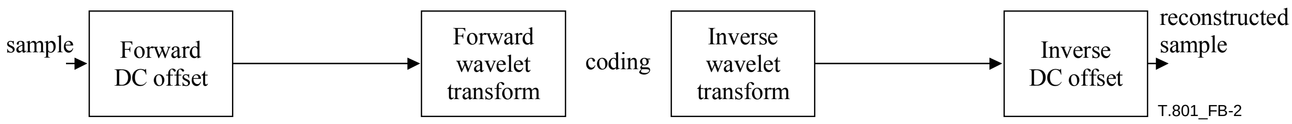


Figure B.2 – Placement of the DC offset without multiple component transformation

B.2 Inverse DC offset

If the DCO marker segment is present in the main or tile-part header (see A.3.1), then the DC offset, O_i, is specified by that marker. All samples of a given component are offset by adding the same quantity to each sample as follows:

$$I'(x, y) = I(x, y) + O_i \quad \text{(B-1)}$$

If no DCO marker segment is present, then the DC offset is performed as described in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex G.

NOTE – If I' is not of the same precision or dynamic range as the output data it may be rounded to the closest precision and clipped in bounds.

B.3 Forward DC offset (informative)

The variable DC offset allows user control of the actual offset value. The offset, O_i, may be chosen as any value, but it is suggested that it be within the dynamic range and precision of the original data. The default value for unsigned data is:

$$O_i = 2^{Ssiz^i} \quad \text{(B-2)}$$

where $Ssiz^i$ comes from ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex A. For signed data the default in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex G, is to have no offset ($O_i = 0$). Any other value must be signalled in a DCO marker segment in either the main or tile-part header. All input data is then offset by subtracting the fixed offset from all samples in the tile component. When using a variable DC offset in conjunction with a reversible transformation, the offset should be an integer value.

$$I(x, y) = I'(x, y) - O_i \quad \text{(B-3)}$$

When a non-default offset is used, care must be taken to adjust the number of guard bits to account for any potential increase in bit depth of the offset data. If the offset, O_i, is chosen within the dynamic range of the original data, then increasing the number of guard bits, G, by one will be sufficient to handle any potential increase.

For most images the default offset setting gives good compression performance. However for some images that have sharply peaked histograms, with a small amount of highly contrasting data, significantly improved performance can be obtained if the offset is set nearer the mode of the histogram.

Annex C

Variable scalar quantization, extension

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

Variable scalar quantization extends the default scalar quantization described in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex E, to allow deadzones of variable width (up to four times the step size). Variable scalar quantization shall only be used with irreversible filters.

C.1 Variable scalar quantization

All terminology and variables described in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex E, remain the same for variable scalar quantization. An additional parameter nz_b is used to convey the adjusted deadzone size. The adjusted deadzone size is $2(1-nz_b)\Delta_b$. When $nz = 0$ this is equivalent to the scalar quantizer in ITU-T Rec. T.800 | ISO/IEC 15444-1, Annex E, with a deadzone of twice the stated step size. When $nz_b > 0$ then the deadzone is smaller, and when $nz_b < 0$ then the deadzone is larger. The value of nz_b must lie in the range [–1, 1)[1].

When $nz = 0$ for all sub-bands, there is no need to transmit adjusted deadzone factors. However, if $nz_b \neq 0$ for at least one sub-band, then extended QCD, QCC, QPD, and/or QPC marker segments shall appear in either the main header or the first tile-part header of a given tile (see A.2.4). The value nz_b is represented as:

$$nz_b = \frac{\mathrm{num\_nz}_b}{2^{15}} \tag{C-1}$$

When an extended QCD, QCC, QPD, QPC marker segment appears, the adjustment factors are either signalled for each sub-band explicitly, or else signalled only for the LL sub-band. The former is known as expounded deadzone adjustment and the latter is known as derived deadzone adjustment. In the latter case, all the deadzone adjustment factors nz_b are derived implicitly from the single deadzone adjustment factor nz_0 corresponding to the LL band, according to:

$$nz_b = nz_0 \tag{C-2}$$

C.2 Variable scalar dequantization for irreversible filters

For generalized scalar dequantization with irreversible filters the reconstructed values are computed as:

$$Rq_b(u,v) = \begin{cases} (\overline{q}_b(u,v) + r2^{M_b-N(u,v)} - nz_b)\Delta_b & \overline{q}_b(u,v) > 0 \\ (\overline{q}_b(u,v) - r2^{M_b-N(u,v)} - nz_b)\Delta_b & \overline{q}_b(u,v) < 0 \\ 0 & \overline{q}_b(u,v) = 0 \end{cases} \tag{C-3}$$

where nz_b is the transmitted deadzone adjustment factor from the extended QCD, QCC, QPD, QPC marker segments and all other parameters are as described in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex E. If there is no extended QCD, QCC, QPD, QPD marker segment applicable to a component in the codestream, then $nz_b = 0$ for all sub-bands. When $nz_b = 0$ this formula is identical to the scalar dequantization used with irreversible filters in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex E.

The variable scalar quantizer shall only be used with irreversible transforms.

---

[1] The "[" means the first value is included and the ")" means the last value is excluded.

C.3 Variable scalar quantization for irreversible filters (informative)

The quantized coefficients, $q_b(u, v)$, are computed from the unquantized coefficients, $a_b(u, v)$, by:

$$q_b(u,v) = \begin{cases} sign(a_b(u,v)) \left\lfloor \dfrac{|a_b(u,v)| + nz_b \Delta_b}{\Delta_b} \right\rfloor & |a_b(u,v)| \geq -nz_b \Delta_b \\ 0 & |a_b(u,v)| < -nz_b \Delta_b \end{cases} \quad \text{(C-4)}$$

where Δ_b is the quantization step size included in the QCD, QCC, QPD, QPC marker segments of ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex A, and nz_b is a deadzone adjustment parameter included in the extended QCD, QCC, QPD, QPC marker segments. If $nz_b = 0$ for all sub-bands, then it need not be signalled. If nz_b is identical for all sub-bands, then the derived signalling may be used in the extended QCD, QCC, QPD, QPC marker segments.

Annex D

Trellis coded quantization extensions

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

This annex specifies the trellis coded quantization (TCQ) option for encoding and reconstructing a sequence of wavelet coefficients. TCQ shall only be used with irreversible transformations.

D.1 Introduction to TCQ

The TCQ algorithm applies spatial-varying scalar quantization to its input sequence by choosing one of four scalar quantizers for each sample. Quantizer indices from supersets of these quantizers along with quantizer transitions in the form of a trellis provide all information necessary to reconstruct TCQ encoded wavelet coefficients.

Figure D.1 depicts the four separate scalar quantizers (D_0, D_1, D_2, and D_3) used for this Recommendation | International Standard. Included with this figure is information regarding scalar quantized indices (m_{D_i}), reconstruction levels $(R_{D_i}(m_{D_i}))$, and eventual union quantizer indices $(Q_{D_i}(m_{D_i}))$ for each scalar quantizer.

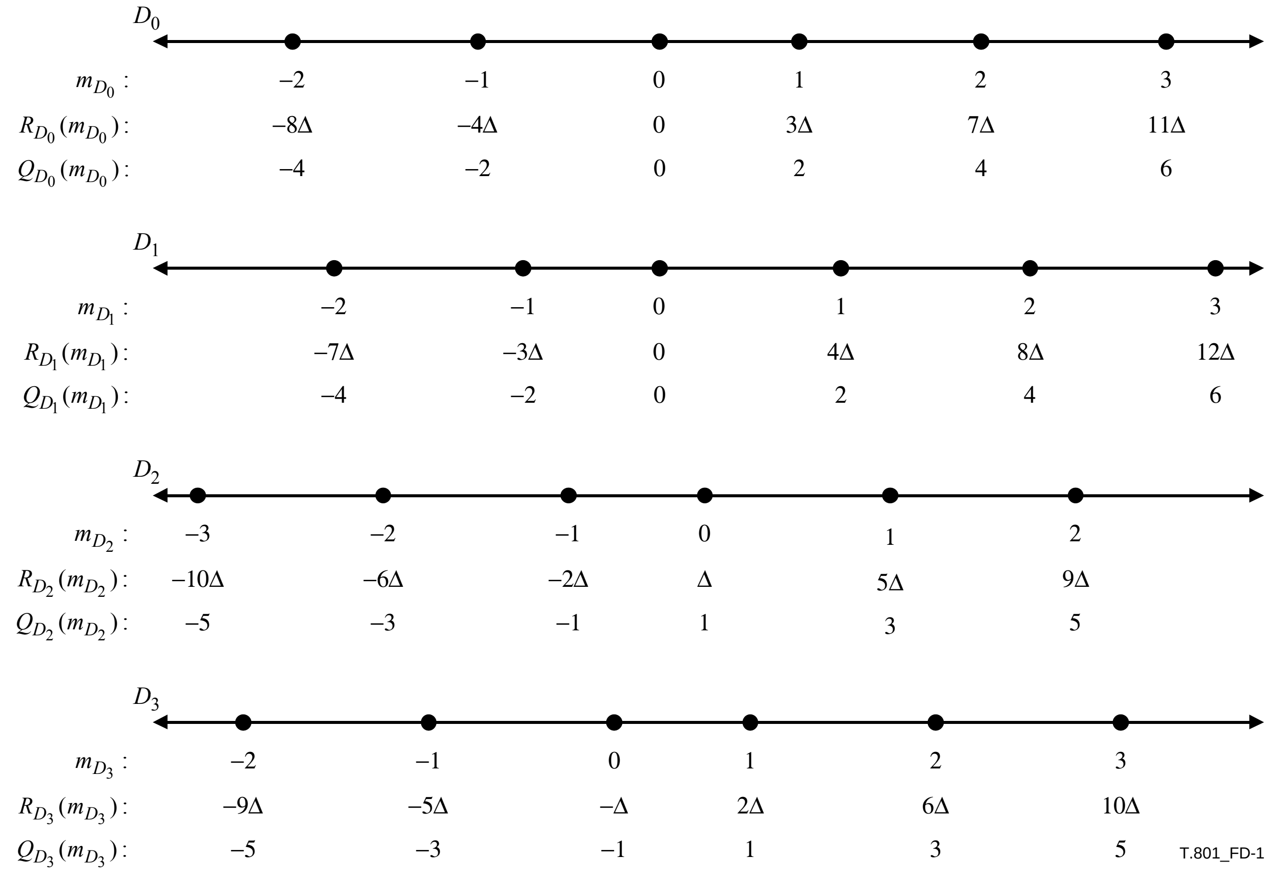


Figure D.1 – Scalar quantizers used for TCQ

Figure D.2 shows the combination of these scalar quantizers into union quantizers, A_0 and A_1, along with the indices available with each quantizer and the corresponding reconstruction levels $(R_{A_i}(m_{A_i}))$.

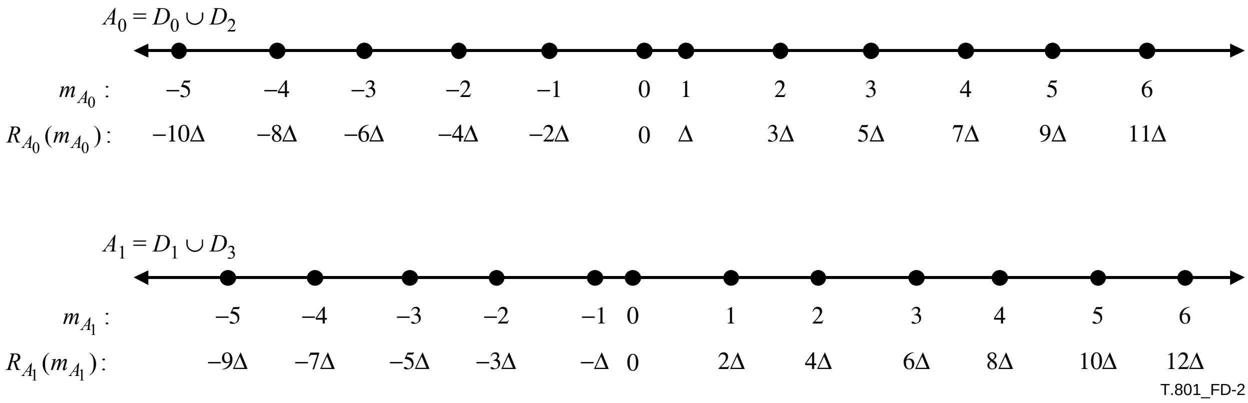


Figure D.2 – Union quantizers for TCQ

The eight state trellis directed graph with possible quantizer transitions is shown in Figure D.3, flowing left to right, where each node represents a possible trellis state. Columns of nodes represent stages which are ordered from left to right. There are exactly K+1 stages if K data points are quantized. Each node in Figure D.3 is labelled as $N_{k,s}$, where k corresponds to the stage index for the node and s is the trellis state of the node.

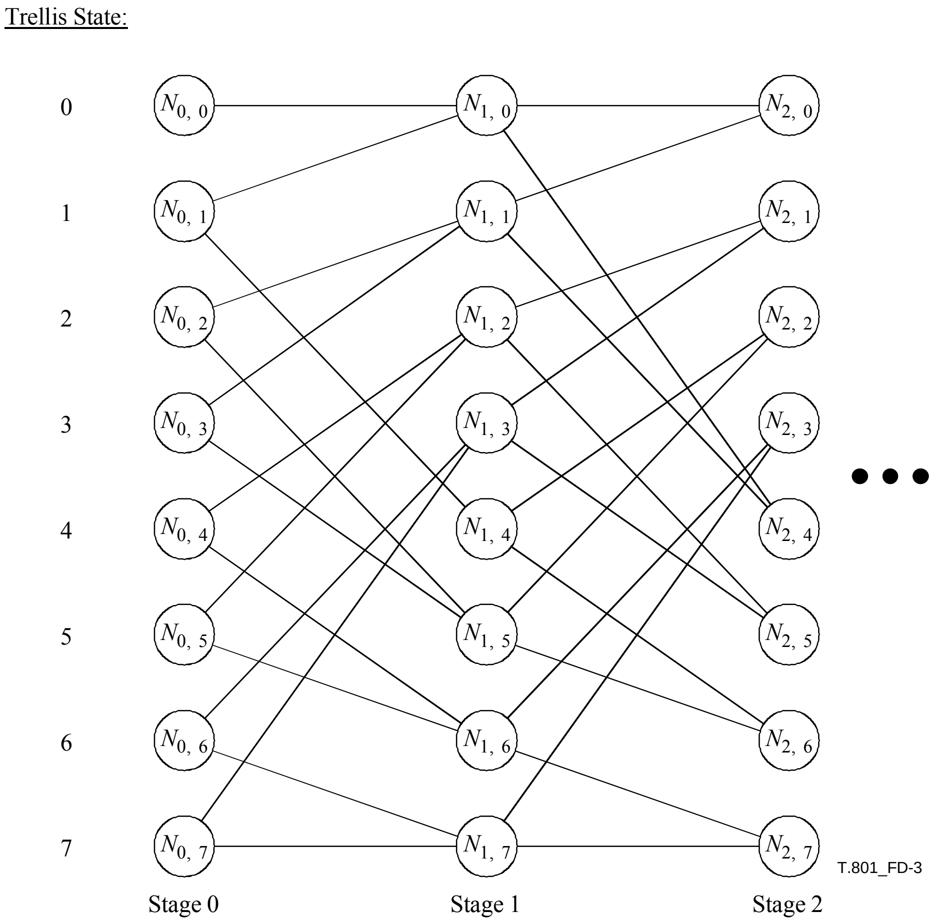


Figure D.3 – Trellis showing node indices

D.2 Sequence definition

TCQ processing is performed independently on each codeblock. The coefficients of a given codeblock are scanned following the order described in ITU-T Rec. T.800 | ISO/IEC 15444-1, D.1, to form a sequence of coefficients processed by TCQ.

D.3 Forward TCQ quantization (informative)

All TCQ code-block sequences within a particular sub-band b use the same quantization step-size Δ_b. As with the scalar quantization option described in ITU-T Rec. T.800 | ISO/IEC 15444-1, E.2, no particular selection of step sizes is required for TCQ. In fact, the ε_b and μ_b values which parameterize Δ_b can be derived according to ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation E-5. A recommended algorithm for choosing the set of Δ_b is that of Lagrangian Rate Allocation (LRA) defined in D.5.

Regardless of the algorithm for choosing the Δ_b, parameters ε_b and μ_b are determined to most closely represent the desired Δ_b by the following:

$$\Delta_b = 2^{R_b - \varepsilon_b - 1}\left(1 + \frac{\mu_b}{2^{11}}\right) \qquad \text{(D-1)}$$

where, as described in ITU-T Rec. T.800 | ISO/IEC 15444-1, E.1, R_b is the dynamic range of sub-band b. The ε_b and μ_b values are then used to set the $SPqcd^i$, $SPqcc^i$, $SPqpd^i$, $SPqpc^i$ parameters in the QCD, QCC, QPD, QPC marker segments (see ITU-T Rec. T.800 | ISO/IEC 15444-1, A.6.4 and A.6.5).

Several look-up-tables (LUTs) are used for purposes of forward quantization. Table D.1 specifies four pre-defined LUTs: $N_0^P\left(N_{k,s}\right)$ and $N_1^P\left(N_{k,s}\right)$ define the parent nodes for $N_{k,s}$ in the trellis; $D_0^P\left(N_{k,s}\right)$ and $D_1^P\left(N_{k,s}\right)$ define the scalar quantizers that lead to $N_{k,s}$ from its parent nodes. Five other LUTs are maintained during forward quantization.

– $q_D(D_i)$ holds the best quantizer index for each scalar quantizer;
– $d_D(D_i)$ holds the resulting distortion due to each scalar quantizer;
– $d_N(N_{k,s})$ holds the cumulative distortion at node $N_{k,s}$, (survivor distortion);
– $B(N_{k,s})$ holds the parent node which yields lowest survivor distortion at node $N_{k,s}$;
– $q_N(N_{k,s})$ holds the index for the quantizer which leads from parent node $B(N_{k,s})$ to $N_{k,s}$.

The complete TCQ encoding algorithm which determines the sequence q_k of quantized indices for a particular code-block sequence is outlined in Figure D.4 and Table D.2. Additionally, optimum progressive TCQ performance is achieved when the three entropy coder passes (see ITU-T Rec. T.800 | ISO/IEC 15444-1, D.3) for the last bit-plane of a given code-block are concentrated into a single packet.

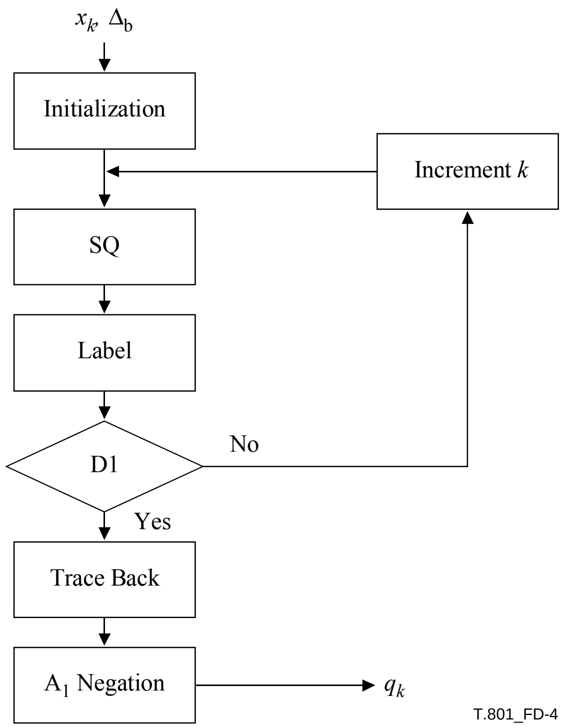


Figure D.4 – Forward TCQ processing

Table D.1 – Parent LUTs for $k > 0$ in the trellis of Figure D.3

Node	**Parent nodes**		**Parent scalar quantizers**	
	$N_0^P(N_{k,s})$	$N_1^P(N_{k,s})$	$D_0^P(N_{k,s})$	$D_1^P(N_{k,s})$
$N_{k,0}$	$N_{k-1,0}$	$N_{k-1,1}$	D_0	D_2
$N_{k,1}$	$N_{k-1,2}$	$N_{k-1,3}$	D_1	D_3
$N_{k,2}$	$N_{k-1,4}$	$N_{k-1,5}$	D_2	D_0
$N_{k,3}$	$N_{k-1,6}$	$N_{k-1,7}$	D_3	D_1
$N_{k,4}$	$N_{k-1,0}$	$N_{k-1,1}$	D_2	D_0
$N_{k,5}$	$N_{k-1,2}$	$N_{k-1,3}$	D_3	D_1
$N_{k,6}$	$N_{k-1,4}$	$N_{k-1,5}$	D_0	D_2
$N_{k,7}$	$N_{k-1,6}$	$N_{k-1,7}$	D_1	D_3

Table D.2 – Description of functional blocks in Figure D.4

Block	Description
Initialization	Set $d_N(N_{0,0}) = 0$ and $d_N(N_{0,s}) = \infty$ for $s = 1, ... , 7$. Set $k = 0$.
SQ	For each quantizer D_i ($i = 0, 1, 2, 3$), find the best quantizer index and compute its squared error., i.e., $$d_D(D_i) = \min_m \left\{ (x_k - R_{D_i}(m))^2 \right\}$$ and set $q_D(D_i)$ equal to the minimizing index value m.
Label	For each stage $s = 0, ... , 7$: $$\text{if } (d_N(N_0^P(N_{k+1,s})) + d_D(D_0^P(N_{k+1,s})) \le d_N(N_1^P(N_{k+1,s})) + d_D(D_1^P(N_{k+1,s}))):$$ $$d_N(N_{k+1,s}) = d_N(N_0^P(N_{k+1,s})) + d_D(D_0^P(N_{k+1,s}))$$ $$q_N(N_{k+1,s}) = q_D(D_0^P(N_{k+1,s}))$$ $$B(N_{k+1,s}) = N_0^P(N_{k+1,s})$$ else: $$d_N(N_{k+1,s}) = d_N(N_1^P(N_{k+1,s})) + d_D(D_1^P(N_{k+1,s}))$$ $$q_N(N_{k+1,s}) = q_D(D_1^P(N_{k+1,s}))$$ $$B(N_{k+1,s}) = N_1^P(N_{k+1,s})$$
D1	At end of data sequence?
Inc k	Increment the sequence index k.
Trace Back	Set $k = K$. Find $s_{\min}$ (out of $s_{\min}$= 0, ... , 7) such that $d_N(N_{k,s_{\min}})$ is minimum. Set $N = N_{k,s_{\min}}$. While ($k > 0$): $$q_{k-1} = q_N(N)$$ $$N = B(N)$$ $$k = k - 1$$
A_1 Negation	If using A_1 union quantizer and if $q_k = 1$ then set $q_k = -1$. If using A_1 union quantizer and if $q_k = -1$ then set $q_k = 1$.

D.4 Inverse quantization (normative)

Decoded TCQ quantized indices may be reconstructed to wavelet coefficients using either the recommended full TCQ dequantization process or an approximate scalar dequantization. The full TCQ dequantization process should not be used, however, when the cleanup pass of the last bit-plane for the current code-block sequence is not fully decoded. This can occur when only part of the codestream has been transmitted or decoded.

D.4.1 Full TCQ dequantization

This approach for reconstructing wavelet coefficients uses the same quantization step size as defined in Equation D-1, where ε_b and μ_b are derived from the SPqcd^i, SPqcc^i, SPqpd^i, SPqpc^i parameters in the QCD, QCC, QPD, QPC marker segments (see ITU-T Rec. T.800 | ISO/IEC 15444-1, A.6.4 and A.6.5.

The full dequantization process is outlined below in Figure D.5 and Tables D.3, D.4 and D.5. Input to this process is the code-block sequence of TCQ indices q_k (equivalent to $\overline{q}_b$ as defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, Equation E-1) and its output is the sequence x_k of reconstructed wavelet coefficients for the current code-block.

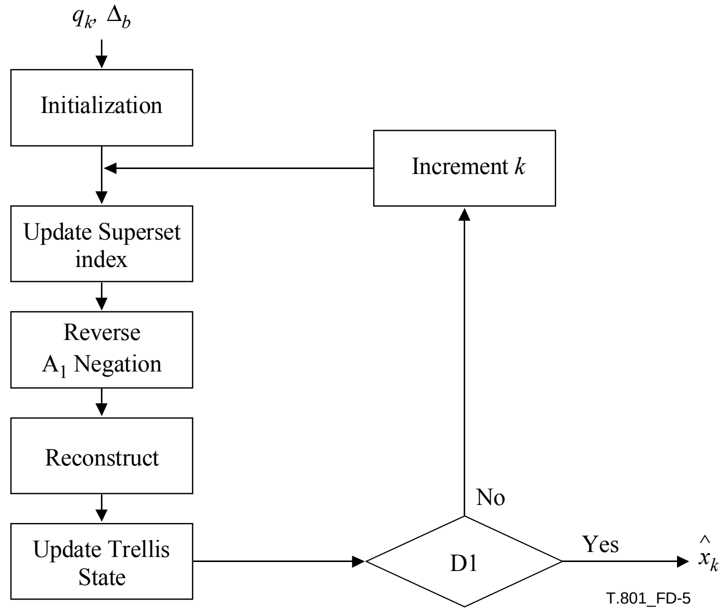


Figure D.5 – Full inverse processing for TCQ indices

Table D.3 – Description of functional blocks in Figure D.5

Block	Description
Initialization	Initialize the trellis state index s and the sequence index k: $s = 0$; $k = 1$.
Update Superset Index	Set the current union quantizer index using Table D.4: $a = A(s)$.
Reverse A_1 Negation	If a = A_1 and if $q_k = 1$ then set $q_k = -1$. If a = A_1 and if $q_k = -1$ then set $q_k = 1$.
Reconstruct	Form reconstructed coefficient x_k: $$\hat{x}_k = R_a(q_k) + \begin{cases} -r\Delta_b & R_a(q_k) > 0 \\ 0 & R_a(q_k) = 0 \\ r\Delta_b & R_a(q_k) < 0 \end{cases}$$ where $R_{A_i}(m)$ is defined in Figure D.2, and r is a reconstruction parameter. A reasonable setting is r = 01,25 when $\lvert q_k \rvert \le 2$ and r = 0 otherwise.
Update Trellis State	Update the current trellis state using Table D.5: $s = S(s,q_k)$.
D1	At end of code-block data sequence?
Inc k	Increment the sequence index k.

Table D.4 – Look-up table for *A*(*s*)

Current state *s*	*A*(*s*)
0	A_0
1	A_0
2	A_1
3	A_1
4	A_0
5	A_0
6	A_1
7	A_1

Table D.5 – Look-up table for $S(s,q_k)$

Current state s	q_k Odd/Even	$S(s,q_k)$
0	Even	0
	Odd	4
1	Even	4
	Odd	0
2	Even	1
	Odd	5
3	Even	5
	Odd	1
4	Even	6
	Odd	2
5	Even	2
	Odd	6
6	Even	7
	Odd	3
7	Even	3
	Odd	7

D.4.2 Approximate dequantization

Unlike the full dequantization, this approach uses twice the step sizes defined in Equation D-1. Specifically,

$$\Delta_b = 2^{R_b - \varepsilon_b}\left(1 + \frac{\mu_b}{2^{11}}\right) \qquad \text{(D-2)}$$

The approximate dequantization process is outlined in both Table D.6 and Figure D.6. Input to this process is the code-block sequence of partially or fully decoded TCQ indices q_k and its output is the sequence of reconstructed wavelet coefficients for the current code-block. This dequantization technique corresponds to the basic scalar dequantization described in ITU-T Rec. T.800 | ISO/IEC 15444-1, and as such, does not require special processing to reasonably decode TCQ indices.

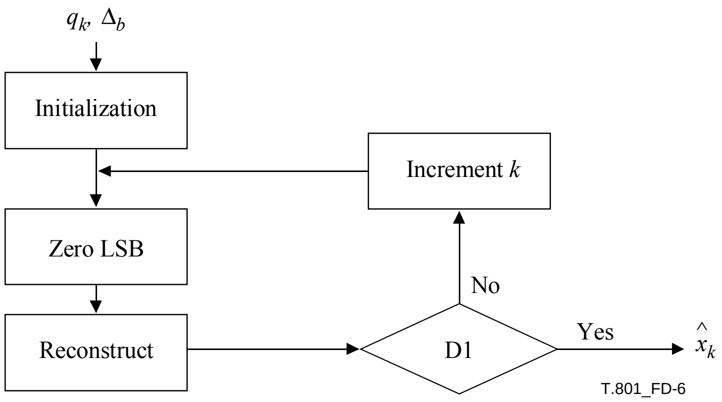


Figure D.6 – Approximate dequantization of TCQ indices

Table D.6 – Description of functional blocks for Figure D.6

Block	Description
Initialization	Initialize the sequence index k: $k = 1$.
Zero LSB	Zero out LSB of q_k.
Reconstruct	Form reconstructed coefficient x_k: $$\hat{x}_k = \begin{cases} \left(q_k + r2^{M_b - N_b(k)}\right) \cdot \Delta_b, & q_k > 0 \\ \left(q_k + r2^{M_b - N_b(k)}\right) \cdot \Delta_b, & q_k < 0 \\ 0, & q_k = 0 \end{cases}$$ where M_b, $N_b(k)$, and r are as defined for ITU-T Rec. T.800 | ISO/IEC 15444-1, Equation E-8.
D1	At end of code-block data sequence?
Inc k	Increment the sequence index k.

D.5 Lagrangian rate allocation (informative)

This algorithm uses three sets of parameters to determine all sub-band step sizes. The first set is listed in Table D.7 and provides statistics for each sub-band, including standard deviation (σ_b), size weight (β_b), energy weight (Υ_b), and generalized Gaussian density (GGD) parameter (α_b). The second set of parameters include α_b and quantizer-dependent parameters which are listed in Tables D.8, D.9, D.10 and D.11. The parameters listed in these tables are based on experimentally obtained rate-distortion data for both TCQ and scalar quantization in conjunction with the entropy coder described in ITU-T Rec. T.800 | ISO/IEC 15444-1. Finally, the last parameter set simply provides the free parameter λ which is used during constrained minimization of overall image domain mean-squared error.

Table D.7 – Sub-band statistics required for LRA

Statistic	Description
σ_b	Standard deviation for sub-band *b*.
β_b	Size weight for sub-band *b* (the proportion of the number of coefficients in sub-band *b* to the total number of image pixels).
Υ_b	Energy weight for sub-band *b* (the amount of image domain squared error introduced by a unit error in a single wavelet coefficient for sub-band *b*).
α_b	GGD parameter for sub-band *b*. Found by solving, $$\frac{\sum_k (x_k - \bar{x}_b)^4}{(\sigma_b^2)^2} = \frac{\Gamma\left(\frac{5}{\alpha_b}\right)\Gamma\left(\frac{1}{\alpha_b}\right)}{\Gamma\left(\frac{3}{\alpha_b}\right)^2}$$ where x_k is the sequence of data for sub-band *b* and $\bar{x}_b$ is its mean.

Table D.8 – ρ_b parameters for TCQ

	$\alpha_b = 0,5$	$\alpha_b = 0,75$	$\alpha_b = 1,0$	$\alpha_b = 1,5$	$\alpha_b = 2,0$
m_h	–1,661 0	–1,661 0	–1,661 0	–1,661 0	–1,661 0
a_h	–0,298 5	0,076 5	0,214 4	0,302 3	0,318 6
y_1	–2,300 0	3,000 0	–0,823 9	–0,522 9	0,221 8
m_l	0,056 3	0,000 0	–0,195 0	–0,334 4	–1,491 7
a_l	0,148 0	0,000 0	–0,124 0	–0,152 6	–0,331 1
y_2	–2,300 0	–2,208 0	–0,823 7	–0,522 9	–0,221 8
a	72,078 1	2,254 3	70,188 5	1,215 3	1,326 7
ζ	–0,093 8	0,046 0	0,048 7	0,075 0	–0,004 0
p	283,241 4	14,772 3	598,091 3	32,754 8	70,803 2
m_c	1,661 0	1,661 0	1,661 0	1,661 0	1,661 0

Table D.9 – Δ_b parameters for TCQ

	$\alpha_b = 0,5$	$\alpha_b = 0,75$	$\alpha_b = 1,0$	$\alpha_b = 1,5$	$\alpha_b = 2,0$
m_h'	0,500 0	0,500 0	0,500 0	0,500 0	0,500 0
a_h'	0,225 0	0,225 0	0,225 0	0,225 0	0,225 0
y_1'	–4,000 0	–3,398 0	–3,000 0	–3,000 0	–2,398 0
m_l'	0,027 6	0,023 7	0,031 1	0,021 3	0,047 3
a_l'	0,109 6	0,082 8	0,092 5	0,062 7	0,108 1
y_2'	–4,000 0	–3,398 0	–3,000 0	–3,000 0	–2,398 0
a'	293,330 0	32 606 000,000 0	399,630 0	81 289 000,000 0	1 806,700 0
ζ'	–1,506 7	–1,132 9	–0,875 9	–0,592 2	0,581 8
p'	855,370 0	102 500 000,000 0	1 523,900 0	321 130 000,000 0	6 809,000 0
m_c'	0,211 7	0,302 8	0,390 3	0,651 8	15,378 3

Table D.10 – ρ_b parameters for SQ

	α_b = 0,5	α_b = 0,75	α_b = 1,0	α_b = 1,5	α_b = 2,0
m_h	–1,661 0	–1,661 0	–1,661 0	–1,661 0	–1,661 0
a_h	–0,102 6	0,274 4	0,424 9	0,509 5	0,528 5
y_1	–0,784 7	–1,386 3	–0,779 1	–0,648 2	–0,396 8
m_l	0,406 0	–0,094 2	–0,431 5	–0,703 4	–1,532 2
a_l	0,318 6	–0,130 6	–0,336 2	–0,455 9	–0,607 9
y_2	–0,419 1	–0,411 5	–0,343 5	–0,128 2	–0,059 9
a	0,591 2	0,493 4	0,385 9	0,150 1	0,035 0
ζ	0,172 1	0,081 9	0,042 4	0,022 7	–0,024 9
p	3,222 5	4,091 5	3,867 3	2,588 9	1,416 3
m_c	1,661 0	1,661 0	1,661 0	1,661 0	1,661 0

Table D.11 – Δ_b parameters for SQ

	α_b = 0,5	α_b = 0,75	α_b = 1,0	α_b = 1,5	α_b = 2,0
m_h'	0,500 0	0,500 0	0,500 0	0,500 0	0,500 0
a_h'	0,468 7	0,468 7	0,468 7	0,468 7	0,468 7
y_1'	–2,400 0	–1,937 6	–1,477 1	–1,456 9	–1,502 5
m_l'	0,049 8	0,083 7	0,064 3	0,043 9	0,036 4
a_l'	0,119 6	0,162 2	0,094 9	0,064 0	0,054 7
y_2'	–2,400 0	–1,937 6	–1,477 1	–1,456 9	–1,502 5
a'	3,474 6	10,733 5	4,890 8	3,805 1	5,363 5
ζ'	–0,635 8	–0,526 6	–0,600 1	–0,513 1	–0,028 0
p'	16,961 5	85,298 6	82,061 2	32,483 8	29,983 9
m_c'	0,185 1	0,146 9	0,283 7	0,405 1	2,085 1

The LRA process is defined in Figure D.7 and Table D.12.

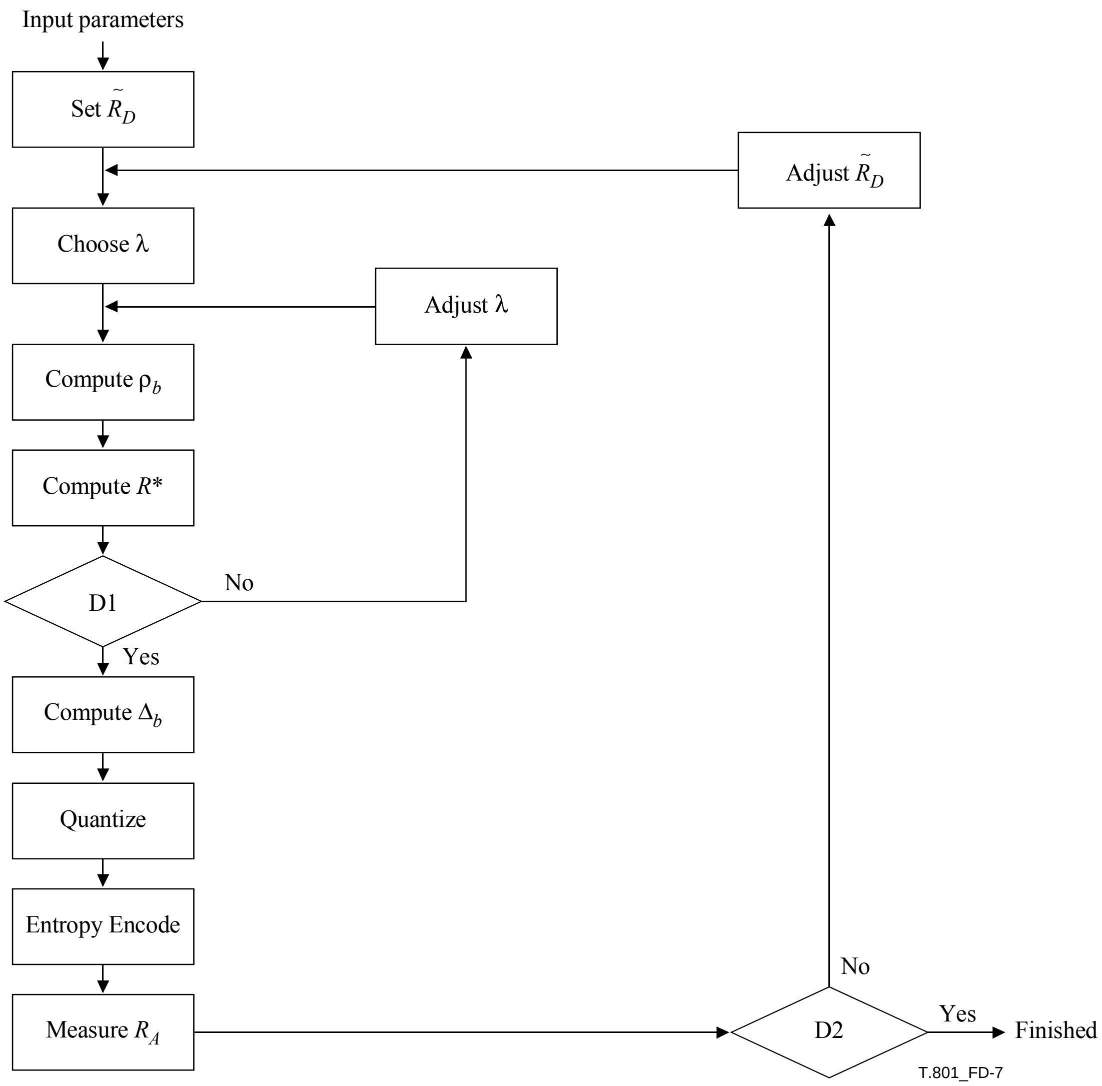


Figure D.7 – Lagrangian rate allocation

Table D.12 – Description of functional blocks in Figure D.7

Block	Description
Set $\tilde{R}_D$	Set $\tilde{R}_D$ equal to desired bit-rate R_D.
Choose λ	Provide initial estimate for Lagrangian multiplier.
Compute ρ*b*	$\rho_b = R_h + R_c + R_l$ for each sub-band *b*, where $R_h = m_h v + a_h$, $$R_c = \begin{cases} m_c a \left\{ \left[1 + \left(\frac{v + a - \xi}{a} \right)^p \right]^{\frac{1}{p}} - 1 \right\}, & for\ v > y_2 \\ 0, & \text{otherwise} \end{cases}$$ $$R_l = \begin{cases} m_l v + a_l, v > y_1 \\ 0, \quad \text{otherwise} \end{cases} \quad \text{where } v = \log\left(\frac{\lambda}{\gamma_b \sigma_b^2} \right)$$
Compute R^*	$$R^* = \sum_b \beta_b \rho_b$$
D1	R^* within tolerance of $\tilde{R}_D$?
Adjust λ	Properly tune λ so $\tilde{R}_D$ and R^* converge within tolerance.
Compute Δ_b	$\Delta_b = 10^{\Delta_h + \Delta_l + \Delta_c}$ for each sub-band *b* where $\Delta_h = m'_n v + a'_h$ $$\Delta_c = \begin{cases} m'_c a' \left\{ \left[1 + \left(\frac{v + a' - \xi'}{a'} \right)^{p'} \right]^{\frac{1}{p'}} - 1 \right\}, & for\ v > y'_2 \\ 0, & \text{otherwise} \end{cases}$$ $$\Delta_l = \begin{cases} m'_l v + a'_l, v > y'_1 \\ 0, \quad \text{otherwise} \end{cases} \quad \text{where } v = \log\left(\frac{\lambda}{\gamma_b \sigma_b^2} \right)$$
Quantize	Use Δ_b to quantize wavelet coefficients.
Entropy encode	Run quantized indices through variable length encoding.
Measure R_A	Measure achieved rate resulting from step sizes.
D2	R_A within tolerance of R_D?
Adjust $\tilde{R}_D$	Properly tune $\tilde{R}_D$ so R_A and R_D converge within tolerance.

Annex E

Visual masking, extensions

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

This annex describes an option that allows the coder to exploit the masking properties of the human visual system.

E.1 Introduction to visual masking (informative)

Visual masking is a mechanism where artefacts are masked by the image acting as a background signal. The main goal is to improve the image quality, especially for low resolution (often measured in dots per inch, or DPI) displays. The first effect of this technique is to improve the image quality, where the improvement becomes greater as the image becomes more complex. The key area of improvement is in low amplitude textures, such as skin. Another area of improvement is in knife-edges (i.e., those with zero transition width) in graphical images created digitally. The second main effect of this technique is that for a given fixed bit-rate, the image quality is more robust against variations in image complexity. This is accomplished at the encoder via an extended non-linearity interposed between the transformation stage and the quantization stage. At the decoder, the inverse non-linearity is applied after dequantization, prior to the inverse wavelet transformation (see Figure E.1).

E.2 Point-wise extended non-linearity (informative)

The extended masking option treats visual masking as a combination of two separate processes, i.e., self-contrast masking and neighbourhood masking. The visual masking effect is therefore exploited in two steps. The first step exploits the self-contrast masking effect by applying a point-wise power function (referred to here as the transducer function) to the original coefficient x_i obtained using an analysis filter with $gain_b$ (see ITU-T Rec. T.800 | ISO/IEC 15444-1, Table E.1), i.e.,

$$x_i \rightarrow y_i = sign(x_i)\left|\frac{x_i}{gain_b}\right|^{\alpha} \cdot gain_b \qquad \text{(E-1)}$$

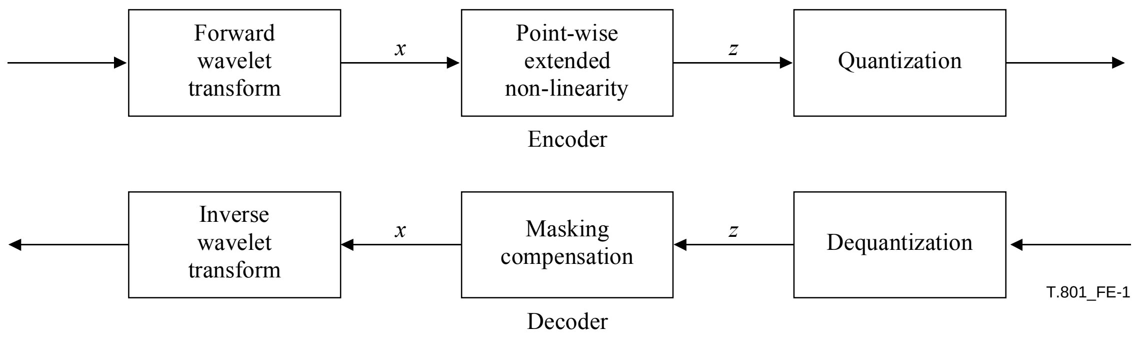


Figure E.1 – System diagram for point-wise extended masking extension

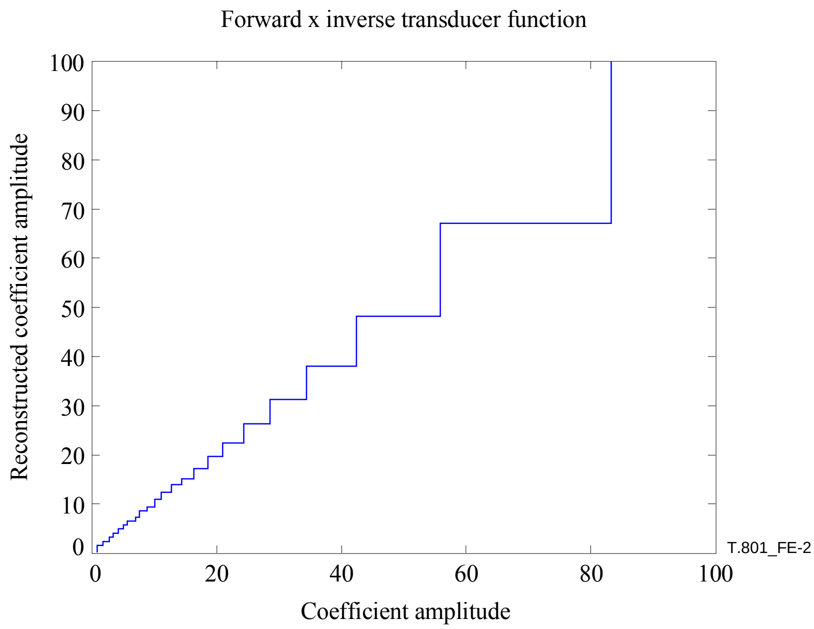


Figure E.2 – Non-uniform quantization for self-contrast masking

Equation E-1 is applied to all sub-bands above some specified resolution using the same value for α. The parameter α assumes a value between 0 and 1. A typical value of α is 0,7. Typically a point-wise extended non-linearity is not applied to the LL sub-band.

If uniform quantization is to be applied to y_i, the resultant quantization step sizes as a function of the coefficient value x_i is shown in Figure E.2. The quantization bins increase as the coefficient amplitude increases. This step assumes that each signal with which a coefficient is associated is lying on a common flat background. Under this assumption, $\{y_i\}$ are perceptually uniform. In a real image, however, this is usually not the case. Each signal is superimposed on other spatially neighbouring signals. There is some masking effect contributed from spatially neighbouring signals due to the phase uncertainty, receptive field sizes, as well as possible longer range effects. To further exploit this neighbourhood masking effect, the second step normalizes y_i by a neighbourhood masking weighting factor w_i which is a function of the amplitudes of the neighbouring signals, i.e.,

$$y_i \to z_i = \frac{y_i}{w_i} = \frac{sign(x_i)\left|\frac{x_i}{gain_b}\right|^{\alpha} \cdot gain_b}{g(N_i(\{\hat{x}_k\}))} \quad \text{(E-2)}$$

where w_i is a function *g(.)* of the causal neighbouring signals as perceived by the decoder $\hat{x}_k$, denoted in a vector form as $N_i(\{\hat{x}_k\})$, i.e., $w_i = g(N_i(\{\hat{x}_k\}))$. The resultant z_i is then subject to quantization. An advantage of this strategy is its ability to distinguish between large amplitude coefficients that lie in a region of simple edge structure from those in a complex region. This feature will assure the good visual quality of simple edges on a smooth background, which is often critical to the overall perceived visual quality.

Since the neighbourhood weighting factor w_i must be computed by the decoder as well as the encoder, the decoder perceived signals $\hat{x}_i$ must be computed to include the effects of quantization and reconstruction. That is:

$$\frac{|\hat{x}_i|}{gain_b} = \left(\frac{Q^{-1}(Q(|z_i|))}{gain_b} g(N_i(\{\hat{x}_k\}))\right)^{1/\alpha} \quad \text{(E-3)}$$

where $Q()$ denotes a quantization operation. The $\hat{x}_i$ depends on previously computed values in the causal neighbourhood, so $\hat{x}_i$ is always well defined.

This simulation of the quantization process is used by the encoder to ensure that both the encoder and the decoder perform exactly the same operation to calculate w_i. For non-scalable coding, this is a relatively simple problem. The encoder will use the final quantized neighbouring coefficients to calculate the neighbourhood masking factor.

For embedded coding the encoder cannot do the non-linear transformation based on the exact final compressed and quantized version of the coefficient x_k because the "extended non-linearity" is applied prior to scalable compression and the decoder might receive a truncated bit stream. Nevertheless, this discrepancy in w_i can be completely eliminated or reduced by using the same course quantization value from bit truncation of the neighbouring coefficients to calculate the masking weighting factor w_i at the encoder and the decoder. This is accomplished by maintaining only the *bits_retained* most significant bits of $Q(|z_i|)$ in the above formula (the rest of the bits are replaced with 0). As long as *bits_retained* is small enough (with respect to the lowest interesting bit rate at the decoder), the decoder will be able to obtain exactly the same quantized (bit truncated) version of the neighbouring coefficients. The compromise is a coarser granularity for w_i which may slightly affect the accuracy of the masking model. But experiments have suggested that the performance usually is not very sensitive to which quantized version of the neighbouring coefficients is used.

Visual masking may be applied to all resolution levels that have an index value not less than a particular level *minlevel* which can be specified in the bit stream. For example, if *minlevel* is set to 1, then the extended non-linearity is applied to all sub-bands except the lowest LL band.

E.3 Decoding with visual masking

When the VMS marker (see A.3.2) is present for component *c*, then the following shall occur between inverse quantization and inverse DWT. In component *c*, for each sub-band *b* with resolution level *r* not less than *minlevel*, execute the following formula in raster order over sub-band *b*:

$$x_i = sign(z_i)\left[\left|\frac{z_i}{gain_b}\right|\left(1+\left(a\sum_{k\in neighbourhood}\left|\frac{\hat{x}_k}{gain_b}\right|^{\beta}\right)/|\phi_i|\right)\right]^{1/\alpha}\cdot gain_b \tag{E-4}$$

where z_i is the coefficient under consideration, and $gain_b$ is the analysis filter gain (see ITU-T Rec. T.800 | ISO/IEC 15444-1, Table E.1). The normalization constant *a* is defined as $(1000\ /\ 2^{(R_I-1)})^{\beta}$ where R_I is the bit-depth of the spatially reconstructed component samples as specified in the SIZ marker segment (see ITU-T Rec. T.800 | ISO/IEC 15444-1, A.5.1). The neighbourhood is a causal neighbourhood of the current coefficient, z_i, having a nominal height of (*win_width*+1) and width of (2*win_width*+1) (see Figure E.3). The neighbourhood excludes the current coefficient, z_i, and shrinks to respect sub-band boundaries. The neighbourhood also shrinks to respect code block boundaries if *respect_block_boundaries* = 1. $|\phi_i|$ is the number of pixels in the neighbourhood of z_i.

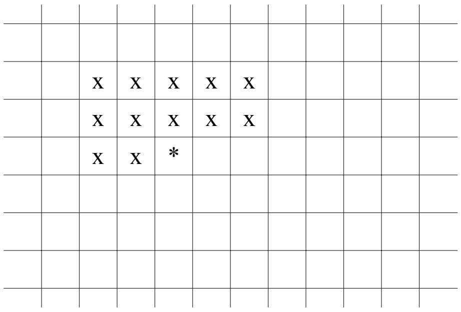
The value $\hat{x}_i$ is computed from a *bits_retained* quantized version of z_i denoted $\hat{q}_i$ as shown in Equations E-5 and E-6.

$$\hat{q}_i = \lfloor |z_i| / \Delta_b \rfloor \text{ with all but the } bits\_retained \text{ MSBs replaced by zero} \tag{E-5}$$

where Δ_b is the quantization step size and $\lfloor |z_i| / \Delta b \rfloor$ is an integer containing M_b unsigned bits. See ITU-T Rec. T.800 | ISO/IEC 15444-1, E.1, for definitions of Δ_b and M_b.

NOTE – For example, if $z_i = -36$, $\Delta_b = 5$, and $M_b = 10$, then $\lfloor |z_i| / \Delta b \rfloor$ = 00 0000 0111 (in binary). If *bits_retained* < 8 then, $\hat{q}_i = 0$. If *bits_retained* = 8, then $\hat{q}_i = 4$.

$N = 2win\_width + 1 = 5$, $|\phi_i| = 12$,"*" current coefficient, "x" are the causal surrounding coefficients.



T.801_FE-3

Figure E.3 – Causal neighbourhood

$$\frac{|\hat{x}_i|}{gain_b} = \left[\frac{\hat{q}_i \Delta_b}{gain_b}\left(1+\left(a \sum_{k\in neighbourhood}\left|\frac{\hat{x}_k}{gain_b}\right|^{\beta}\right)/|\phi_i|\right)\right]^{1/\alpha} \tag{E-6}$$

The values of *minlevel*, α, β, *win_width*, *respect_block_boundaries*, and *bits_retained*, all of which can differ for each component, are given in the VMS marker segment (see A.3.2).

NOTE – When *respect_block_boundaries* = 1, it allows parallel implementation and restricts error propagation, but may sacrifice some performance.

E.4 Encoding with visual masking (informative)

When employing visual masking on component *c*, the following should occur between the DWT and quantization. In component *c*, for each sub-band *b* with resolution *r* not less than *minlevel*, execute the following formula in raster order over sub-band *b*:

$$z_i = \frac{sign(x_i)\left|\frac{x_i}{gain_b}\right|^{\alpha} \cdot gain_b}{1+\left(a \sum_{k\in neighbourhood}\left|\frac{\hat{x}_k}{gain_b}\right|^{\beta}\right)/|\phi_i|} \tag{E-7}$$

where x_i is the wavelet coefficient under consideration, and the parameters $gain_b$, *a*, *neighbourhood*, and $|\phi_i|$ are defined as in E.3. The value $\hat{x}_i$ is defined as in Equations E-5 and E-6.

The values of *minlevel*, α, β, *win_width, respect_block_boundaries,* and *bits_retained*, all of which can differ for each component, are recorded in the VMS marker segment (see A.3.2).

E.5 Setting parameters (informative)

The parameter β assumes a value between 0 and 1, and, together with *win_width*, is used to control the degree of neighbourhood masking. The parameters β and *win_width* play important roles in differentiating coefficients around a simple edge from those in the complex area. The parameter *win_width* controls the degree of averaging; β controls the influence of the amplitude of each neighbouring coefficient. It is important that β assumes a value much smaller than 1. A good value of β is 0,2. This helps to protect coefficients around simple sharp edges, since the coefficients around sharp edges usually have high values. A small value of β suppresses the contribution of a few large coefficients around sharp edges to the masking factor, thus implicitly distinguishing coefficients around sharp edges from coefficients in a complex region.

A special case of the point-wise extended masking approach is the self-contrast masking approach achieved when β is set to 0. The self-contrast masking is referred to as the case where the mask signal is at exactly the same frequency, orientation and location as the distortion signal. This masking approach assumes that the wavelet band structure is used and filters are a good match to the visual system's underlying channels, which is usually not true. Therefore, it may have an over-masking problem at diagonal edges, especially at relatively lower bit rates.

Some parameters that are encoded into the VMS marker segment (see A.3.2) are α, β, *bits_retained* (the number of most significant bits to be retained for obtaining quantized neighbouring coefficients), *win_width* (half of the causal neighbourhood window width, i.e., $N = 2win\_width + 1$), and *minlevel* (the lowest frequency level at which masking will start). A good set of values for these parameters are 0,7, 0,2, 9, 6, and 1, respectively. The switch *respect_block_boundaries* is also included in the VMS marker segment.

E.6 Compatibility with other technologies (informative)

The visual masking extension works with both scalar quantization and TCQ (see Annex D) for irreversible filters. It can be combined with visual frequency weighting (see ITU-T Rec. T.800 | ISO/IEC 15444-1, J.12) to further improve the visual quality. Typically, the transform coefficients are multiplied by CSF weights before they are subjected to the "transducer" function. In some implementations, however, it is more convenient to interchange the operations because the CSF weighting can then be incorporated into the rate distortion optimization. To do this, the CSF weights, originally designed for the x domain, must be modified so that they can be applied in the z domain; they must be raised to the power α.

Annex F

Arbitrary decomposition of tile-components, extensions

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

The extension described in this annex specifies options available for forming wavelet sub-band decompositions. The notational conventions are first introduced followed by updates to various equations, text, decompositions and procedures from ITU-T Rec. T.800 | ISO/IEC 15444-1. Many of these new and updated procedures are defined recursively. Except for variables that are included in a recursive procedure's output parameter list, all variables for recursive procedures are maintained with internal copies that do not change outside of the procedure's scope.

F.1 Wavelet sub-bands

This Recommendation | International Standard provides four tiers of detail for specifying two-dimensional bandpass signals (called sub-bands) at various spatial resolutions. Each tier provides more information in defining finer detail in the sub-band decomposition structure. These tiers are defined below, starting with the tier with the lowest level of detail.

F.1.1 Tier 1: Number of decomposition levels

The first tier in defining sub-band decompositions is the number of wavelet decomposition levels, N_L. This value is signalled for each tile-component in the COD or COC markers as specified in Table A.15 of ITU-T Rec. T.800 | ISO/IEC 15444-1. As with that Recommendation | International Standard, decomposition level indices are 1 for highest resolution sub-bands and N_L for the lowest resolution sub-band. Resolution indices, on the other hand, are labelled with value zero for the lowest resolution and N_L for the highest resolution. A value of zero for N_L indicates no wavelet transformation for the tile-component.

F.1.2 Tier 2: Resolution formation

The various spatial resolutions are obtained through joint/disjoint horizontal and/or vertical downsampling of higher resolutions. As a result, spatial resolutions with subsampling factors from the original image that differ in the horizontal and vertical directions are allowed. As in ITU-T Rec. T.800 | ISO/IEC 15444-1, the orientation of each spatial resolution (or sub-band) is specified with a two-character code, where the first letter indicates horizontal filtering, the second letter indicates vertical filtering, and the letters L and H indicate lowpass or highpass filtering followed by decimation by a factor of two. This annex also provides for the third letter X to indicate no vertical/horizontal filtering and decimation. Since spatial resolutions are not produced with highpass processing and no two spatial resolutions can be the same, there are three possible orientations for each resolution: LL, LX, or HX. The signalling required to specify resolution formation is achieved via the COD, COC, and DFS marker segments (see A.2.3 and A.3.3) as described in F.2.5.

F.1.3 Tier 3: Sub-level decompositions

Wavelet sub-bands resulting from the first two tiers of wavelet processing may be further decomposed into new sub-bands of reduced bandpass extent. The concept of decomposition sub-levels is used to help convey this detail tier. An absolute maximum of three decomposition sub-levels may be produced at decomposition level *lev*, with the first sub-level resulting from decomposition of the next highest resolution level. Use of ADS marker segments (see A.3.4) for signalling the maximum number of sub-levels, $\theta(lev)$, for each decomposition level is described in F.2.

F.1.4 Tier 4: Horizontal and vertical splits to variable sub-level depths

Not all sub-bands must be decomposed to the maximum sub-level depth. As a result, sets of sub-bands with non-uniform size at the same decomposition level may be produced. The look-up-tables (LUTs) *S*() and *J*() defined in F.2 show how information in the ADS marker segments (see A.3.4) is used to signal the varying sub-level depth throughout complete wavelet decompositions.

Sub-bands can also be split disjointly in the horizontal and vertical directions, thus allowing sub-bands with subsampling factors from the original image that differ in the horizontal and vertical directions. As a result, sub-bands may be further decomposed into three separate sets of new sub-bands, as depicted in Figure F.1. The first set has decomposition sub-levels with LL, HL, LH and HH orientations that result from joint horizontal and vertical splits as in ITU-T Rec. T.800 | ISO/IEC 15444-1. The second set yields only LX and HX orientations that result from just horizontal splits of a sub-band. The final set provides XL and XH orientations that result from just vertical splits. In addition to indicating sub-level depth, the LUT *S*() provides details necessary to specify joint and disjoint horizontal/vertical processing. Figure F.1 also shows how the elements of *S*() would be assigned for such processing. As a result of disjoint horizontal and vertical processing, sub-bands may be produced during wavelet processing which have different horizontal and vertical downsampling factors from the original image. The LUT *R*(*lev*) is defined in F.2 for specifying the level and orientation of decomposition level *lev*.

Each of these three LUTs (*S*(), *J*() and *R*()) are used throughout most of the procedures defined in this annex. However, to avoid clutter, usage of these LUTs in a procedure is not explicitly specified unless these LUTs are modified by that procedure.

F.1.5 Complete sub-band notation

A colon separated notation is used to label the index *b* of sub-band a_b for the four tiered wavelet decomposition approach defined in this annex. This notation (which is a simple extension of that given in ITU-T Rec. T.800 | ISO/IEC 15444-1) begins with an index *lev* corresponding to the decomposition level of the sub-band, followed by the two-letter orientation for the first sub-level decomposition. For sub-bands with greater than one sub-level, a colon follows along with the second sub-level decomposition orientation. A final colon along with the third sub-level decomposition orientation ends the notation for sub-bands with greater than two sub-levels.

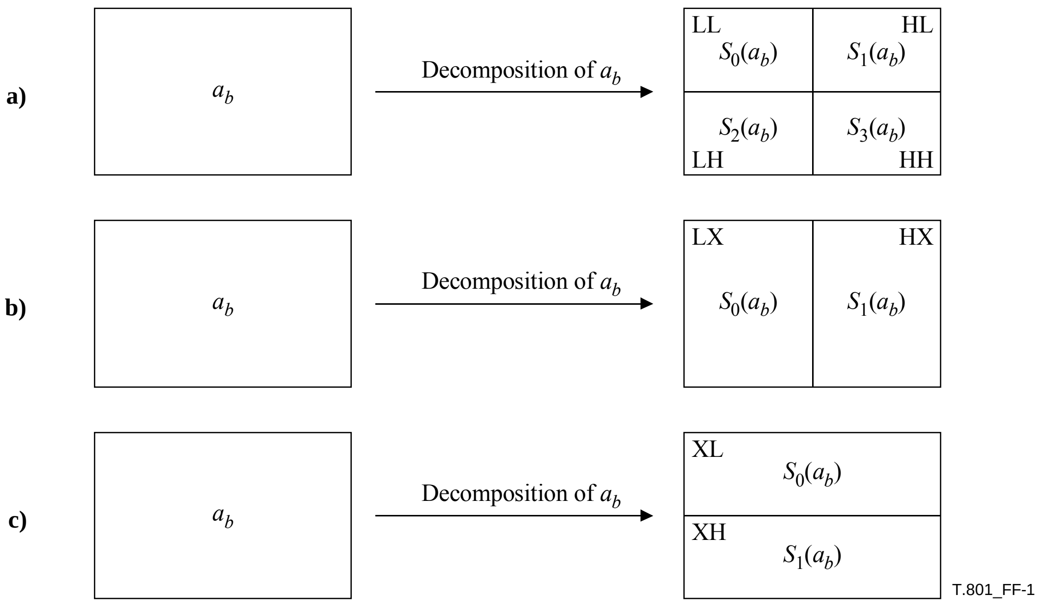


Figure F.1 – Possible splits of sub-bands

F.1.6 HorOrient, VerOrient and PrimeOrient sub-band operators

To aid definitions of procedures in this annex, the operator HorOrient(a_b) refers to the last filtering operation (H, L, or X) which has been applied in the horizontal direction to a given sub-band a_b, while the operator VerOrient(a_b) refers to the last filtering operation (H, L, or X) which has been applied in the vertical direction to a given sub-band a_b. The operator PrimeOrient(a_b) is used to refer to the orientation (LL, LX, XL, HL, LH, HX, XH or HH) of the highest sub-level sub-band which eventually spawns into sub-band a_b within the same decomposition level. For example, for sub-band $a_b = a_{2LH:HX}$, HorOrient(a_b) = H, VerOrient(a_b) = X, PrimeOrient(a_b) = LH.

F.2 Equation, text and decomposition updates

The arbitrary decomposition capability introduced in this annex impacts several clauses of ITU-T Rec. T.800 | ISO/IEC 15444-1 outside of the wavelet transform. These affected clauses are specified below along with updates to allow conformance with this annex.

F.2.1 Updates to N_LLL references

General references to sub-band N_LLL are made throughout ITU-T Rec. T.800 | ISO/IEC 15444-1. To conform to the extension specified in this annex, these references should be updated to any of the N_LLL, N_LLX or N_LXL sub-bands.

F.2.2 Context updates

The wavelet sub-level and horizontal/vertical disjoint processing introduced in this annex require updates to the context propagation shown in Table D.1 of ITU-T Rec. T.800 | ISO/IEC 15444-1. An update for this table is shown in Table F.1, with references made to Figure D.2 of ITU-T Rec. T.800 | ISO/IEC 15444-1.

Table F.1 – Updates to contexts for significance propagation and cleanup coding passes

Sub-bands with primary orientation of LL, LH, LX, XL, or XH			Sub-bands with primary orientation of HL and HX			Sub-bands with primary orientation of HH		Context Label[a)]
$\sum H_i$	$\sum V_i$	$\sum D_i$	$\sum H_i$	$\sum V_i$	$\sum D_i$	$\sum (H_i + V_i)$	$\sum D_i$	
2	x[b)]	x	x	2	x	x	≥ 3	8
1	≥ 1	x	≥ 1	1	x	≥ 1	2	7
1	0	≥ 1	0	1	≥ 1	0	2	6
1	0	0	0	1	0	≥ 2	1	5
0	2	x	2	0	x	1	1	4
0	1	x	1	0	x	0	1	3
0	0	≥ 2	0	0	≥ 2	≥ 2	0	2
0	0	1	0	0	1	1	0	1
0	0	0	0	0	0	0	0	0

a) The context labels are indexed only for identification convenience in this Specification. The actual identifiers used is a matter of implementation.

b) x = do not care.

F.2.3 Extension to ITU.T Rec. T.800 | ISO/IEC 15444-1 Equation B-14

This equation shows how tile-components divide into resolution levels, and should be updated for this annex according to:

$$
\begin{aligned}
trx_0 &= \left\lceil \frac{tcx_0}{2^{\mathrm{GET\_HOR\_DEPTH}(N_L - r)}} \right\rceil & trx_1 &= \left\lceil \frac{tcx_1}{2^{\mathrm{GET\_HOR\_DEPTH}(N_L - r)}} \right\rceil \\
try_0 &= \left\lceil \frac{tcy_0}{2^{\mathrm{GET\_VER\_DEPTH}(N_L - r)}} \right\rceil & try_1 &= \left\lceil \frac{tcy_1}{2^{\mathrm{GET\_VER\_DEPTH}(N_L - r)}} \right\rceil
\end{aligned}
\qquad \text{(F-1)}
$$

The usage for the procedures GET_HOR_DEPTH and GET_VER_DEPTH are defined in Figure F.2 whereas the definitions of these algorithms are depicted in Figure F.3.

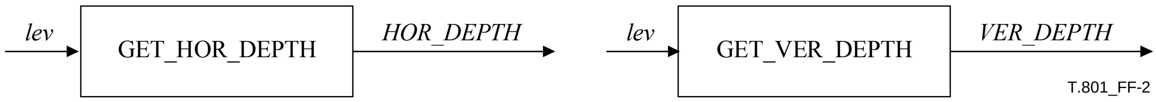


Figure F.2 – Parameters for the GET_HOR_DEPTH and GET_VER_DEPTH procedures

F.2.4 Remaining updates

From ITU-T Rec. T.800 | ISO/IEC 15444-1 Equation B-15 (defining sub-band dimensions tbx_i and tby_i), Equation E-4 (defining sub-band gains $gain_b$) and Equation E-5 (defining the number of sub-band decomposition levels, n_b) as well as the order, $O()$, of compressed sub-band data inside packet bitstreams and the dimensions *xpb* and *ypb* for precincts in each sub-band are defined for this annex by the front end procedure SET_SUBBAND_INFO shown in Figures F.4 and F.5 along with the recursive procedure RECUR_INFO defined by both Figures F.6 and F.7. The SET_SUBBAND_INFO procedure first calls the procedures INIT_θ and INIT_S_R (defined in F.2.5) to set up the LUTs $R()$, $S()$ and $J()$ using the N_L, $d_R()$, and I_R information retrieved via the COD, COC, and DFS marker segments and the $d_\theta()$, I_θ, $d_S()$, and I_S information retrieved via the DFS and ADS marker segments (see A.3.3, A.3.4 and F.2.5). The B-15 updates also refer to Table F.2 based on the orientations of various sub-bands. Although the order $O()$ is defined in reverse order by RECUR_INFO and the bulk of SET_SUBBAND_INFO, the last step in SET_SUBBAND_INFO reverses the order for proper output of sub-band information. Also, the front end procedure SET_SUBBAND_INFO calls the RECUR_INFO using parameters *rPPx* and *rPPy* which are the same *PPx* and *PPy* parameters signalled through COD and COC markers (see A.2.3) for each resolution *r* as described in B.6 in ITU-T Rec. T.800 | ISO/IEC 15444-1. To avoid *xpb* and *ypb* values less than one, both of these *rPPx* and *rPPy* values must also be greater than or equal to $\theta(N_L - r)$ for all resolution levels except resolution $r = 0$. Finally, as with most loops with the index *j* of length $J(S(a_b))$, the *j* index in RECUR_INFO is decremented to cause processing to recurse on the next lowest resolution level.

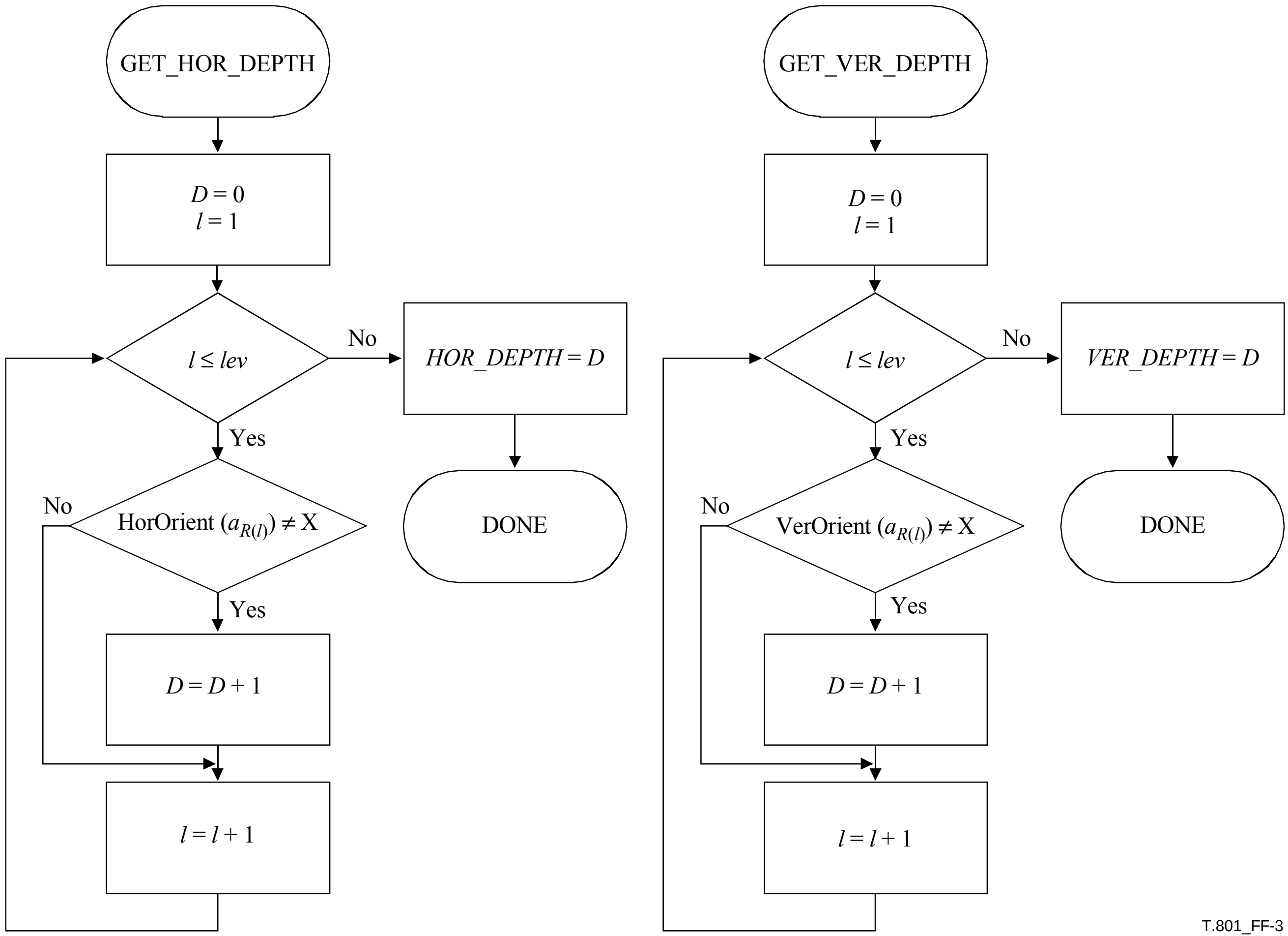


Figure F.3 – The GET_HOR_DEPTH and GET_VER_DEPTH procedures

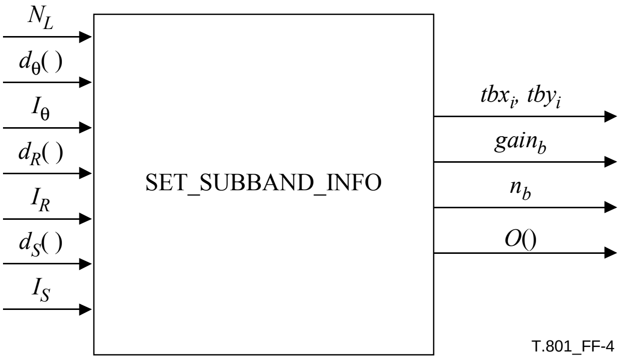


Figure F.4 – Parameters for the SET_SUBBAND_INFO procedure

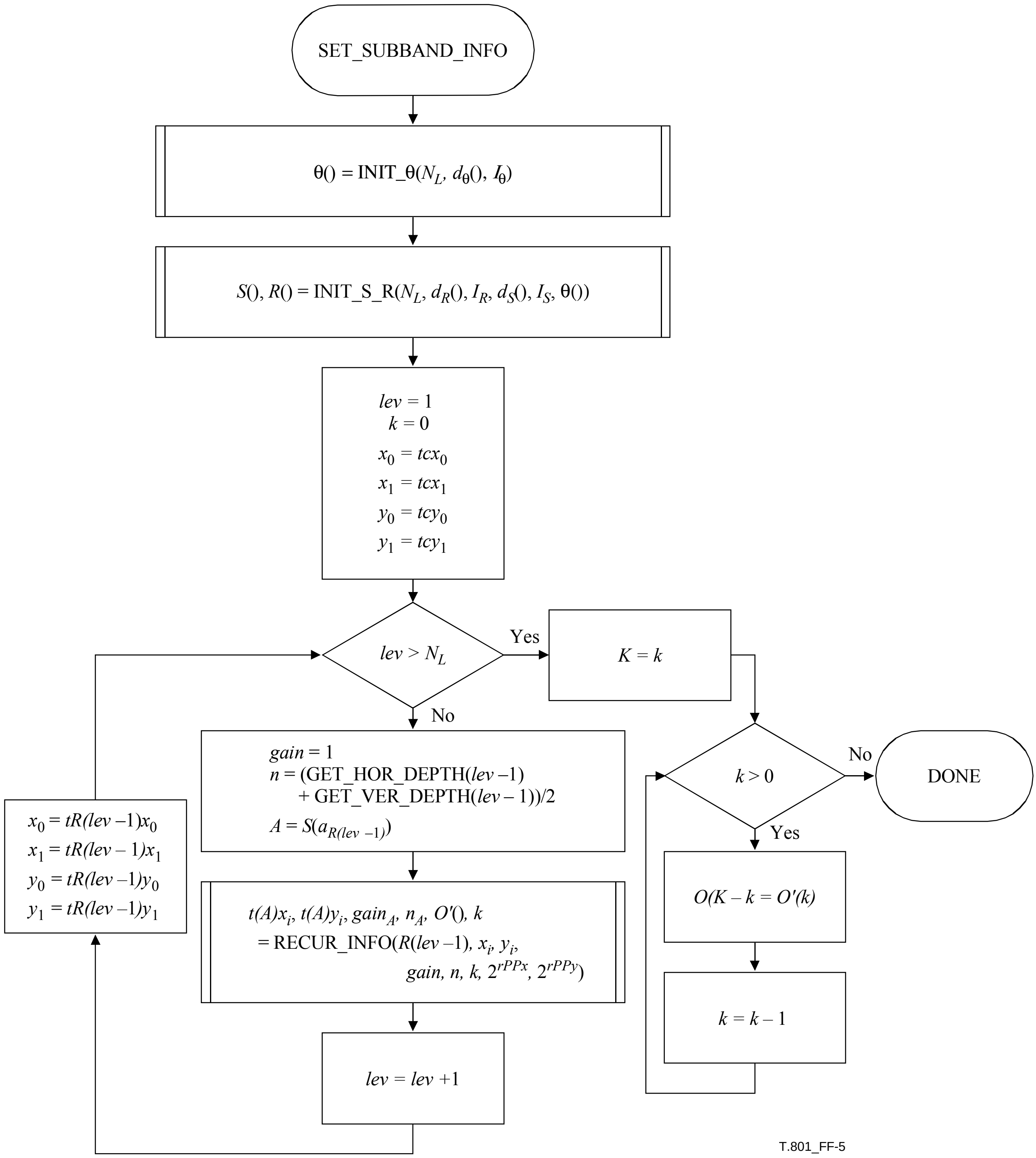


Figure F.5 – The SET_SUBBAND_INFO procedure

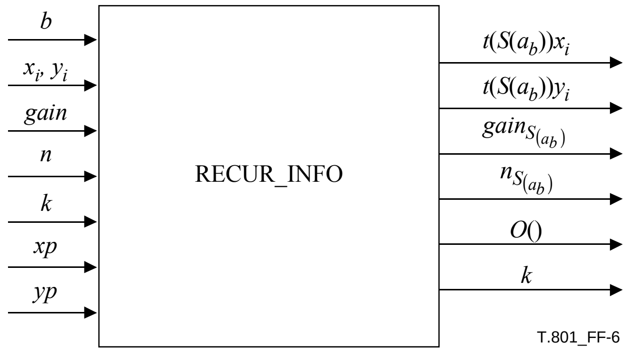


Figure F.6 – Parameters for the RECUR_INFO procedure

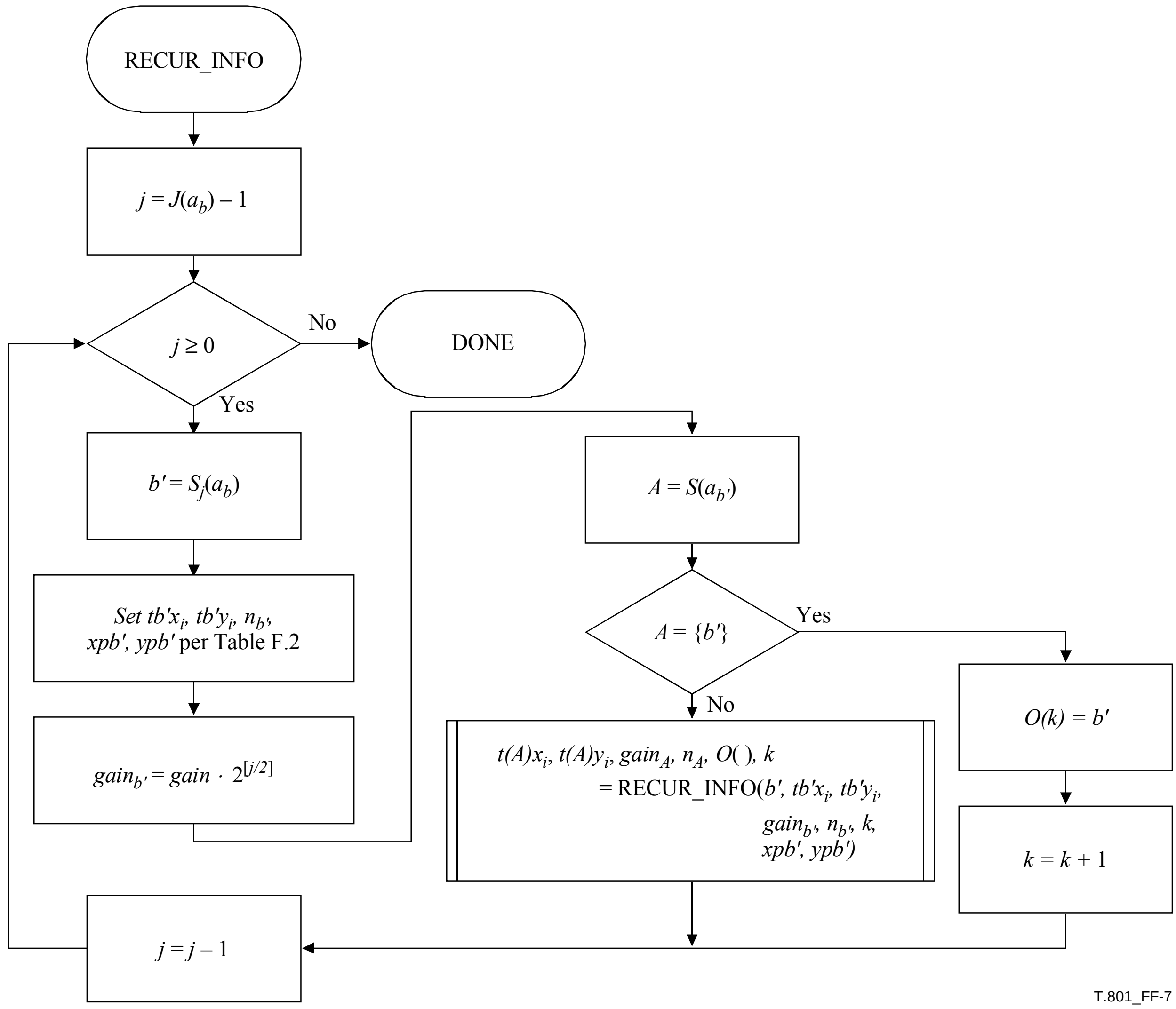


Figure F.7 – The RECUR_INFO procedure

Table F.2 – Quantities for sub-band info calculation

HorOrient($a_{b'}$)	VerOrient($a_{b'}$)	$tb'x_i$	$tb'y_i$	$n_{b'}$	xpb'	ypb'
L	L	$\lceil x_i/2 \rceil$	$\lceil y_i/2 \rceil$	$n+1$	$xp/2$	$yp/2$
H	L	$\lceil x_i/2 \rceil$	$\lceil y_i/2 \rceil$	$n+1$	$xp/2$	$yp/2$
L	H	$\lceil x_i/2 \rceil$	$\lceil y_i/2 \rceil$	$n+1$	$xp/2$	$yp/2$
H	H	$\lceil x_i/2 \rceil$	$\lceil y_i/2 \rceil$	$n+1$	$xp/2$	$yp/2$
L	X	$\lceil x_i/2 \rceil$	y_i	$n+1/2$	$xp/2$	yp
H	X	$\lceil x_i/2 \rceil$	y_i	$n+1/2$	$xp/2$	yp
X	L	x_i	$\lceil y_i/2 \rceil$	$n+1/2$	xp	$yp/2$
X	H	x_i	$\lceil y_i/2 \rceil$	$n+1/2$	xp	$yp/2$

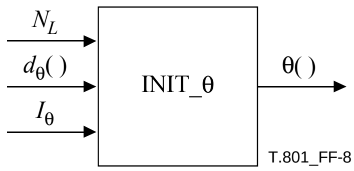


Figure F.8 – Parameters for the INIT_θ procedure

F.2.5 Updates to decomposition structure

Three arrays are used for specifying the decomposition structure for each tile-component. Each array is composed of two-bit values that are signalled in DFS and ADS markers (see A.3.3 and A.3.4). The first array, $d_\theta(i)$, $i = 0, \ldots, I_\theta-1$, is defined by the DOads and IOads ADS marker segment (see A.3.4) and is used by the INIT_θ procedure to determine the maximum number of sub-levels, θ(*lev*), in each decomposition level. Usage for this procedure is shown in Figure F.8 and the procedure itself is defined in Figure F.9. If the ADS marker segment is not defined for the current tile-component, the length I_θ is set to zero.

NOTE – The values of $d_\theta(i)$ used to set all θ(*lev*) in this procedure should be non-zero and thus equal to 1, 2 or 3. Remaining levels not set before encountering the end of $d_\theta(i)$ are set to the last $d_\theta(i)$ entry.

The second array, $d_R(i)$, $i = 0, \ldots, I_R-1$, is defined by Ddfs and Idfs DFS marker segments and specifies the dimensionality of each resolution level. The third array, $d_S(i)$, $i = 0, \ldots, I_S-1$, is defined by the DSads and ISads ADS marker segment (see A.3.4) and specifies the sub-level decomposition structure within each decomposition level. Both of these arrays are used along with other inputs by the INIT_S_R and LEV_S routines. The I/O structure for these procedures are depicted in Figures F.10 and F.12 and the corresponding algorithmic structures are defined in Figures F.11 and F.13, Tables F.3 and F.4. As with I_θ, if the DFS or ADS marker segments are not defined for the current tile-component, I_R or I_S respectively is set to zero. When either I_R or I_S equal zero, the INIT_S_R routine will modify the respective arrays to allow full sub-level depths with joint horizontal and vertical decomposition splits for all sub-bands in the wavelet decomposition. The first purpose of these procedures is to determine the LUT $S(a_b)$ which defines how a sub-band a_b decomposes into other sub-bands. This LUT is defined so that $S(a_b)$ equals the set of sub-band indices for decomposed sub-bands from sub-band a_b. The length LUT $J(a_b)$ is also defined by these routines to be the number of sub-bands which decompose from sub-band a_b. Therefore, $S(a_b) = \{S_0(a_b), \ldots, S_{J(a_b)-1}(a_b)\}$, where $S_j(a_b)$ is the sub-band index of the j-th sub-band decomposed from a_b. Also, $S(a_b) = \{b\}$ when a_b is not further decomposed. This occurs when terminating zeros are indexed in $d_S(i)$ or the sub-level depth of sub-band a_b equals the maximum, θ(*lev*), allowed for its level. Finally, the notation $a_{S(a_b)}$ is used to denote the set $\{a_{S_0(a_b)}, \ldots, a_{S_{J(a_b)-1}(a_b)}\}$.

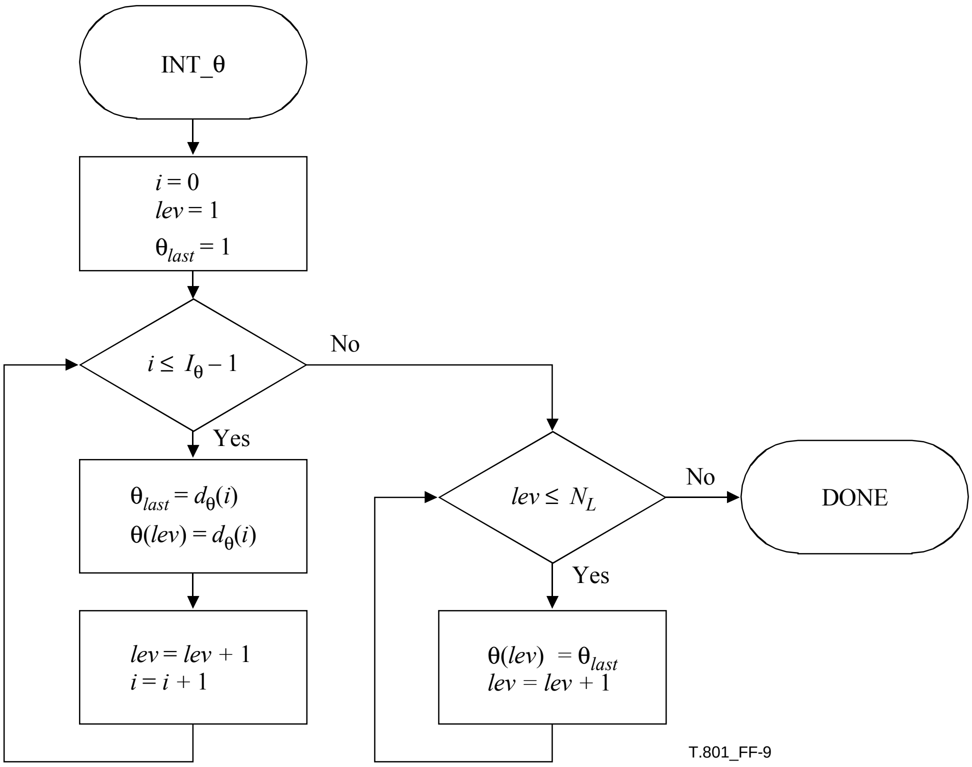


Figure F.9 – Procedure for setting maximum number of sub-levels, $\theta(lev)$

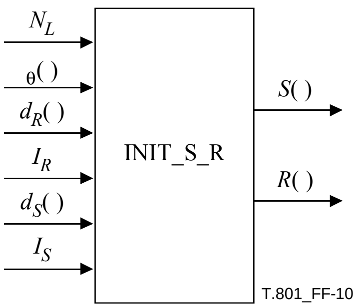


Figure F.10 – Parameters for the INIT_S_R procedure

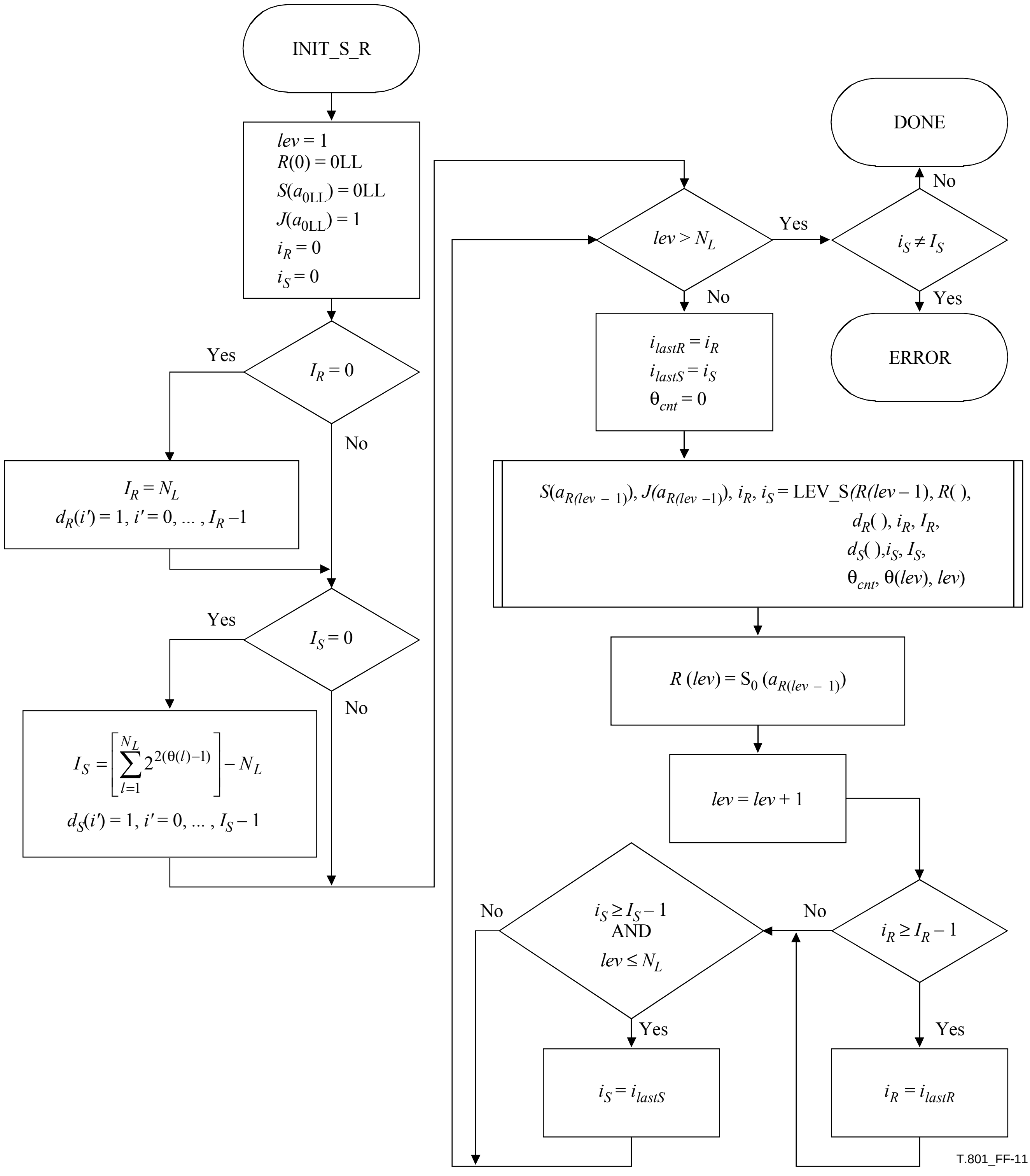


Figure F.11 – Upper level procedure for defining $S(a_b)$ and $R(lev)$

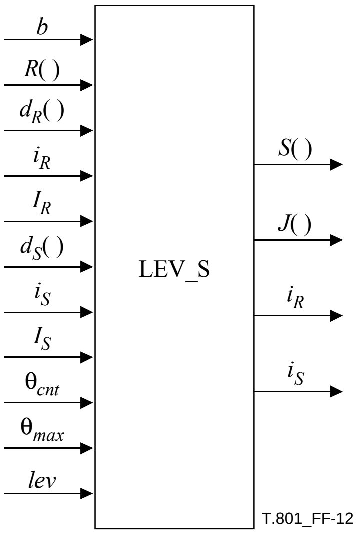


Figure F.12 – Parameters for the LEV_S procedure

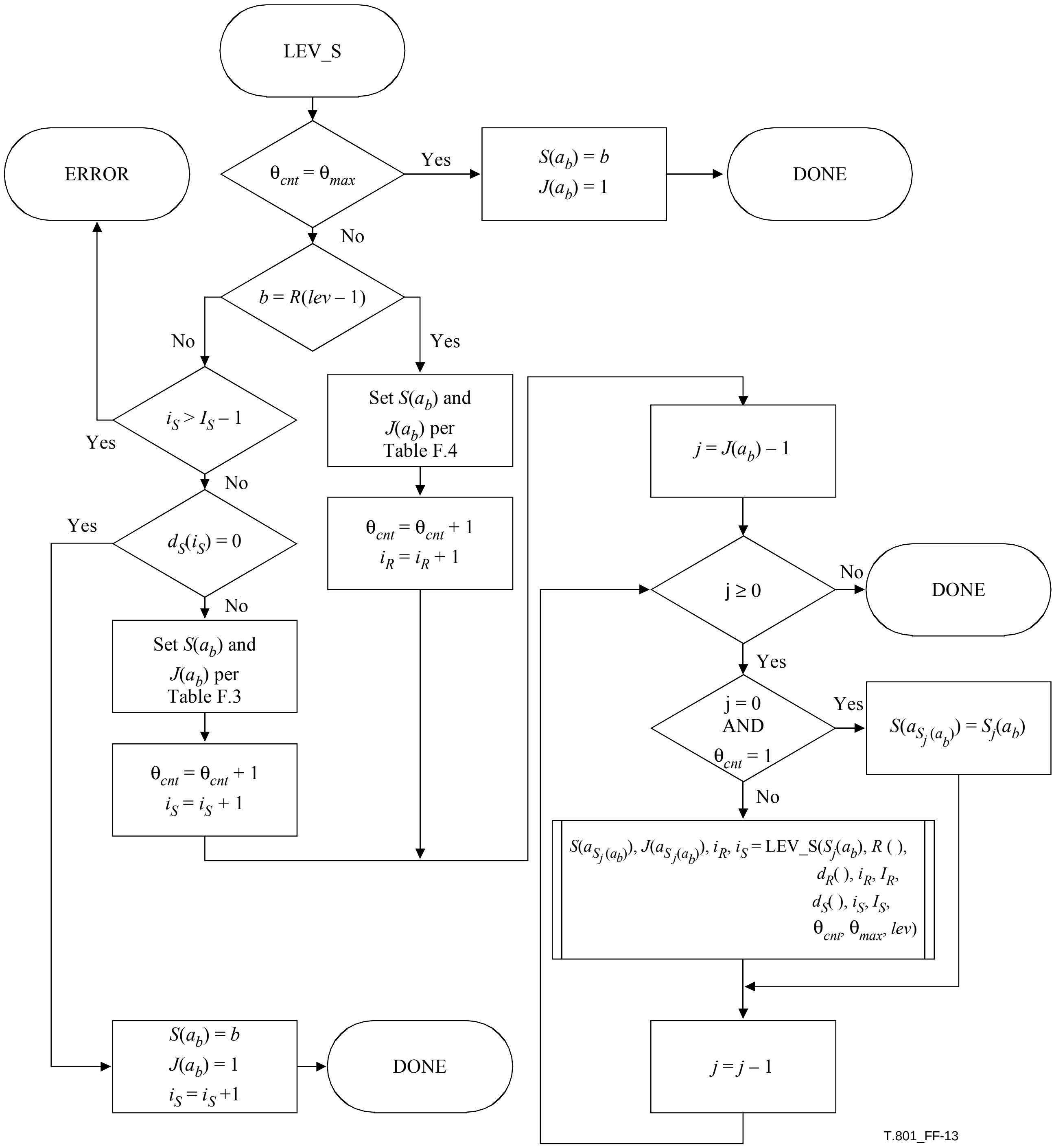


Figure F.13 – Procedure for defining $S(a_b)$

The final purpose of the INIT_S_R and LEV_S procedures is to define the $R(lev)$ LUT for each decomposition level. This LUT specifies the LL, LX, or XL sub-band orientation which results from the first sub-level of wavelet processing for a decomposition level. The corresponding sub-band is taken as the resolution at decomposition level *lev*. That is, resolution N_L-*lev* is given by $a_{R(lev)}$.

Table F.3 – $S(a_b)$ and $J(a_b)$ as a function of $d_S(i)$

$d_S(i_S)$	$S(a_b)$ = Set of indices for decomposed sub-bands from a_b	$J(a_b)$ = Length of set $S(a_b)$
1	{*b*:LL, *b*:HL, *b*:LH, *b*:HH}	4
2	{*b*:LX, *b*:HX}	2
3	{*b*:XL, *b*:XH}	2

Table F.4 – $S(a_b)$ and $J(a_b)$ as a function of $d_R(i)$

$d_R(i_R)$	$S(a_b)$ = Set of indices for decomposed sub-bands from a_b	$J(a_b)$ = Length of set $S(a_b)$
1	{*lev*LL, *lev*HL, *lev*LH, *lev*HH}	4
2	{*lev*LX, *lev*HX}	2
3	{*lev*XL, *lev*XH}	2

NOTE – The INIT_S_R routine uses $d_S(i)$ and $d_R(i)$ array elements in order to define $S()$, $J()$, and $R()$ for all decomposition levels.

Figure F.14 illustrates a sample wavelet decomposition. In this decomposition, $N_L = 3$, $d_\theta() = 31$, $I_\theta = 2$, $d_R() = 123$, $I_R = 3$, $d_S() = 320300203$, and $I_S = 9$. Table F.5 shows the various characteristics for this decomposition, including the $R()$ notation for each level, indicating that sub-band a_{0LL} represents resolution 3 (the original image), and that resolutions 2, 1 and 0 are represented by sub-bands a_{1LL}, a_{2LX} and a_{3XL} respectively. As in ITU-T Rec. T.800 | ISO/IEC 15444-1, precincts are specified with respect to these resolutions.

F.3 Inverse discrete wavelet transformation for general decompositions

The inverse transformation process is much like that described in Annex F.3 of ITU-T Rec. T.800 | ISO/IEC 15444-1. The only modifications necessary to provide arbitrary decomposition functionality are to the IDWT, 2D_SR, and 2D_INTERLEAVE procedures defined in that Annex.

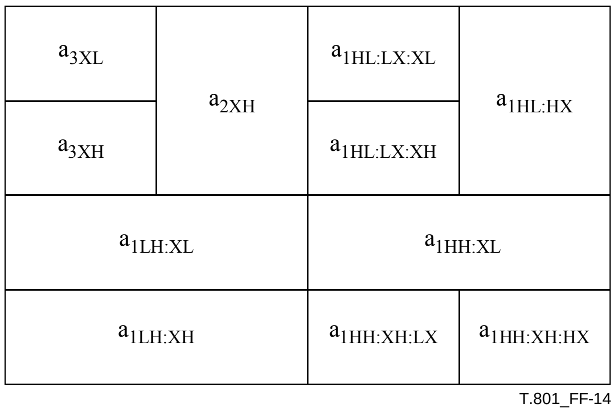


Figure F.14 – Sample wavelet decomposition with labelled sub-bands

Table F.5 – Characteristics for sample wavelet decomposition in Figure F.14

lev	θ(*lev*)	*S*()	Final Sub-bands (a_b)	HorOrient(a_b) / VerOrient(a_b)	PrimeOrient (a_b)	*R*(*lev*)
0	NA	NA	a_{0LL}	L/L	LL	0LL
		$S(a_{0LL})$ = {1LL, 1HL, 1LH, 1HH}				
		$S(a_{1LL})$ = {1LL}				
		S(a_{1HL}) = {1HL:LX, 1HL:HX}				
		$S(a_{1HL:LX})$ = {1HL:LX:XL, 1HL:LX:XH}				
		$S(a_{1HL:LX:XL})$ = {1HL:LX:XL}	$a_{1HL:LX:XL}$	X/L	HL	
		$S(a_{1HL:LX:XH})$ = {1HL:LX:XH}	$a_{1HL:LX:XH}$	X/H	HL	
		$S(a_{1HL:HX})$ = {1HL:HX}	$a_{1HL:HX}$	H/X	HL	
1	3	$S(a_{1LH})$ = {1LH:XL, 1LH:XH}				1LL
		$S(a_{1LH:XL})$ = {1LH:XL}	$a_{1LH:XL}$	X/L	LH	
		$S(a_{1LH:XH})$ = {1LH:XH}	$a_{1LH:XH}$	X/H	LH	
		$S(a_{1HH})$ = {1HH:XL, 1HH:XH}				
		$S(a_{1HH:XL})$ = {1HH:XL}	$a_{1HH:XL}$	X/L	HH	
		$S(a_{1HH:XH})$ = {1HH:XH:LX, 1HH:XH:HX}				
		$S(a_{1HH:XH:LX})$ = {1HH:XH:LX}	$a_{1HH:XH:LX}$	L/X	HH	
		S(*a*1HH:XH:HX) = {1HH:XH:HX}	$a_{1HH:XH:HX}$	H/X	HH	
		$S(a_{1LL})$ = {2LX, 2HX}				
2	1	$S(a_{2LX})$ = {2LX}				2LX
		$S(a_{2HX})$ = {2HX}	a_{2HX}	H/X	HX	
		$S(a_{2LX})$ = {3XL, 3XH}				
3	1	$S(a_{3XL})$ = {3XL}	a_{3XL}	X/L	XL	3XL
		$S(a_{3XH})$ = {3XH}	a_{3XH}	X/H	XH	

F.3.1 Modified IDWT procedure

The IDWT procedure is almost the same as that in ITU-T Rec. T.800 | ISO/IEC 15444-1. Differences deal with changes in the call to the modification of the 2D_SR procedure (MOD_2D_SR) as well as the extra calls to INIT_θ and INIT_S_R. Nevertheless, the modified usage is depicted in Figure F.15 and the actual procedure is shown in Figure F.16. Sub-bands stored in the codestream are provided to MOD_2D_SR in the same order as provided by the order LUT *O()* defined in F.2.4.

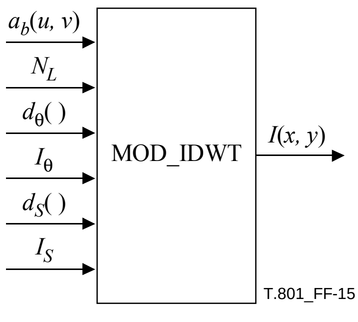


Figure F.15 – Parameters for the MOD_IDWT procedure

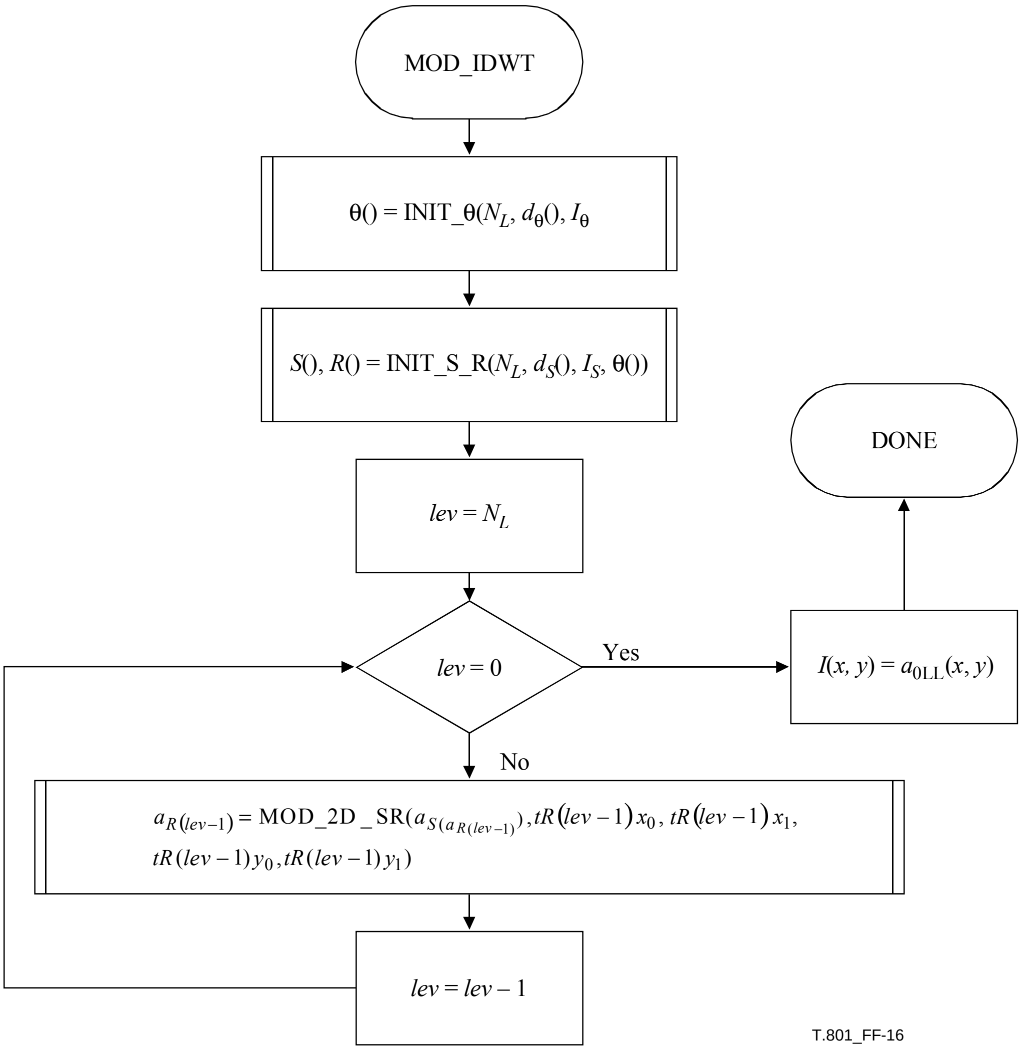


Figure F.16 – The MOD_IDWT procedure

F.3.2 Modified 2D_SR procedure

Major changes are required for 2D_SR from that in ITU-T Rec. T.800 | ISO/IEC 15444-1. This procedure is composed of operations which combine 2 or 4 sub-bands into a resulting sub-band. This procedure must also handle such processing throughout all sub-levels inside a decomposition level. To accommodate such processing, a recursive structure is used for this procedure. The parameters necessary for this procedure are shown in Figure F.17 and the new procedure itself is diagrammed in Figure F.18.

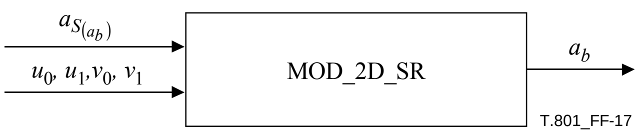


Figure F.17 – Parameters for the MOD_2D_SR procedure

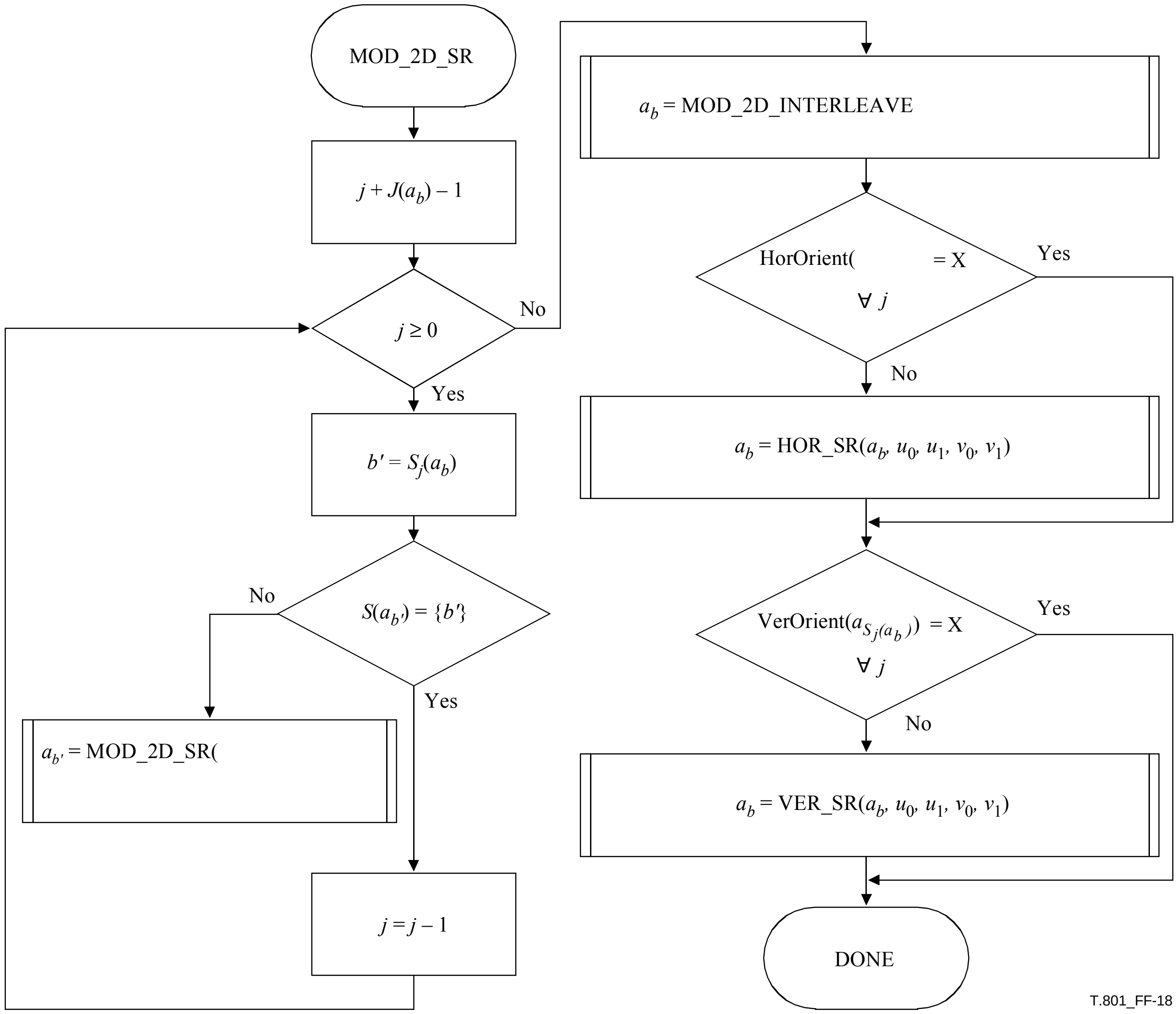


Figure F.18 – The MOD_2D_SR procedure

F.3.3 Modified 2D_INTERLEAVE procedure

Significant changes are also necessary for the 2D_INTERLEAVE procedure. These changes are due to both sub-level processing and disjoint horizontal/vertical sub-band splits. This procedure is shown in both Figures F.19 and F.20. As shown in the latter of these two figures, this routine now decides which of three lower level procedures must be used to interleave wavelet samples. The values of u_0, u_1, v_0 and v_1 in each of these three lower level procedures are those of tbx_0, tbx_1, tby_0 and tby_1 as redefined in F.2.4, where a_b is the sub-band to be interleaved and eventually reconstructed.

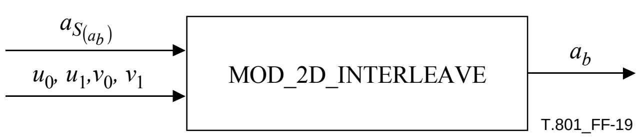


Figure F.19 – Parameters for the MOD_2D_INTERLEAVE procedure

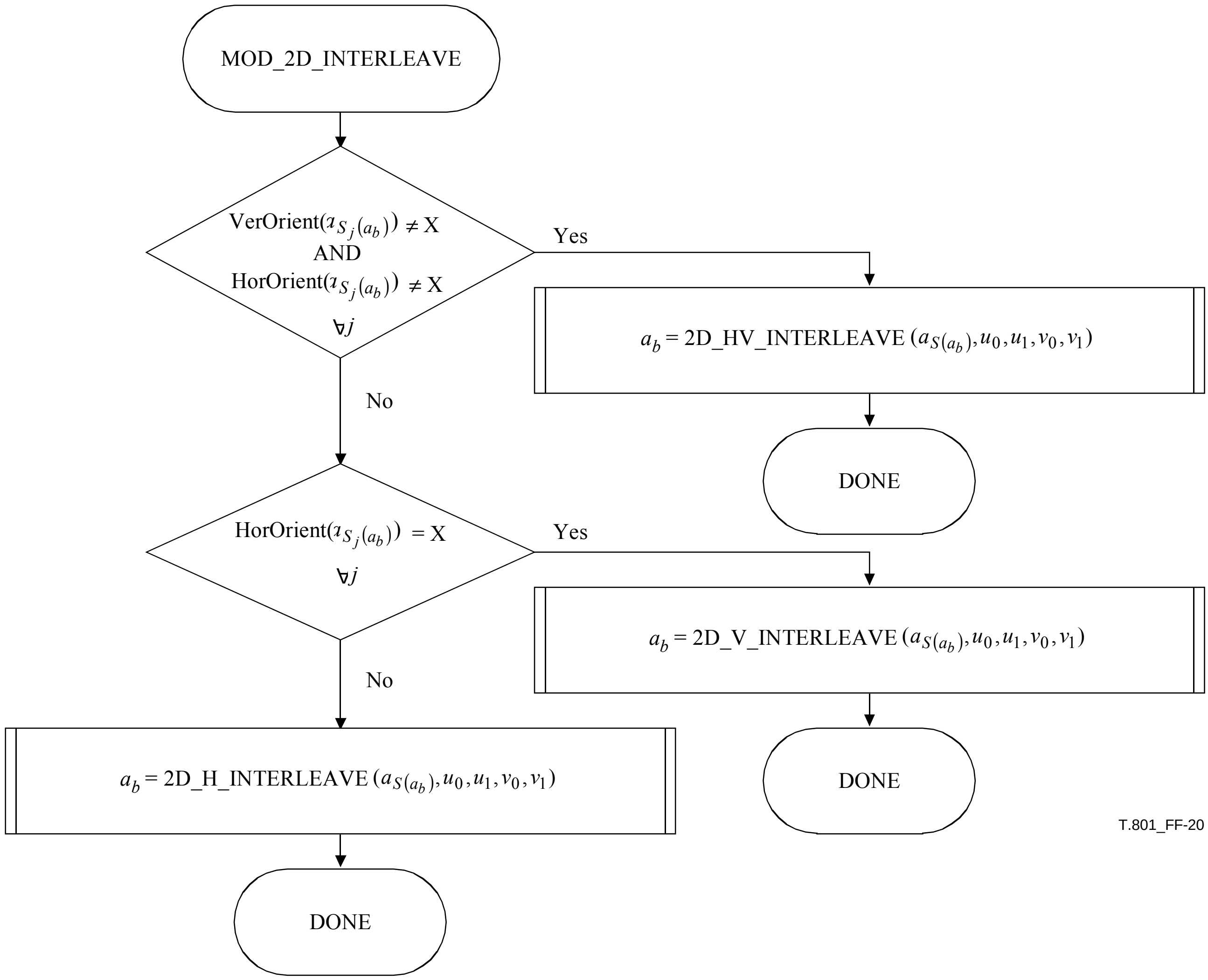


Figure F.20 – The MOD_2D_INTERLEAVE procedure

F.3.3.1 The 2D_HV_INTERLEAVE procedure

The 2D_HV_INTERLEAVE procedure is similar to the 2D_INTERLEAVE procedure from ITU-T Rec. T.800 | ISO/IEC 15444-1 . Usage for this procedure is shown in Figure F.21 and the actual procedure is shown in Figure F.22.

Figure F.21 – Parameters for the 2D_HV_INTERLEAVE procedure

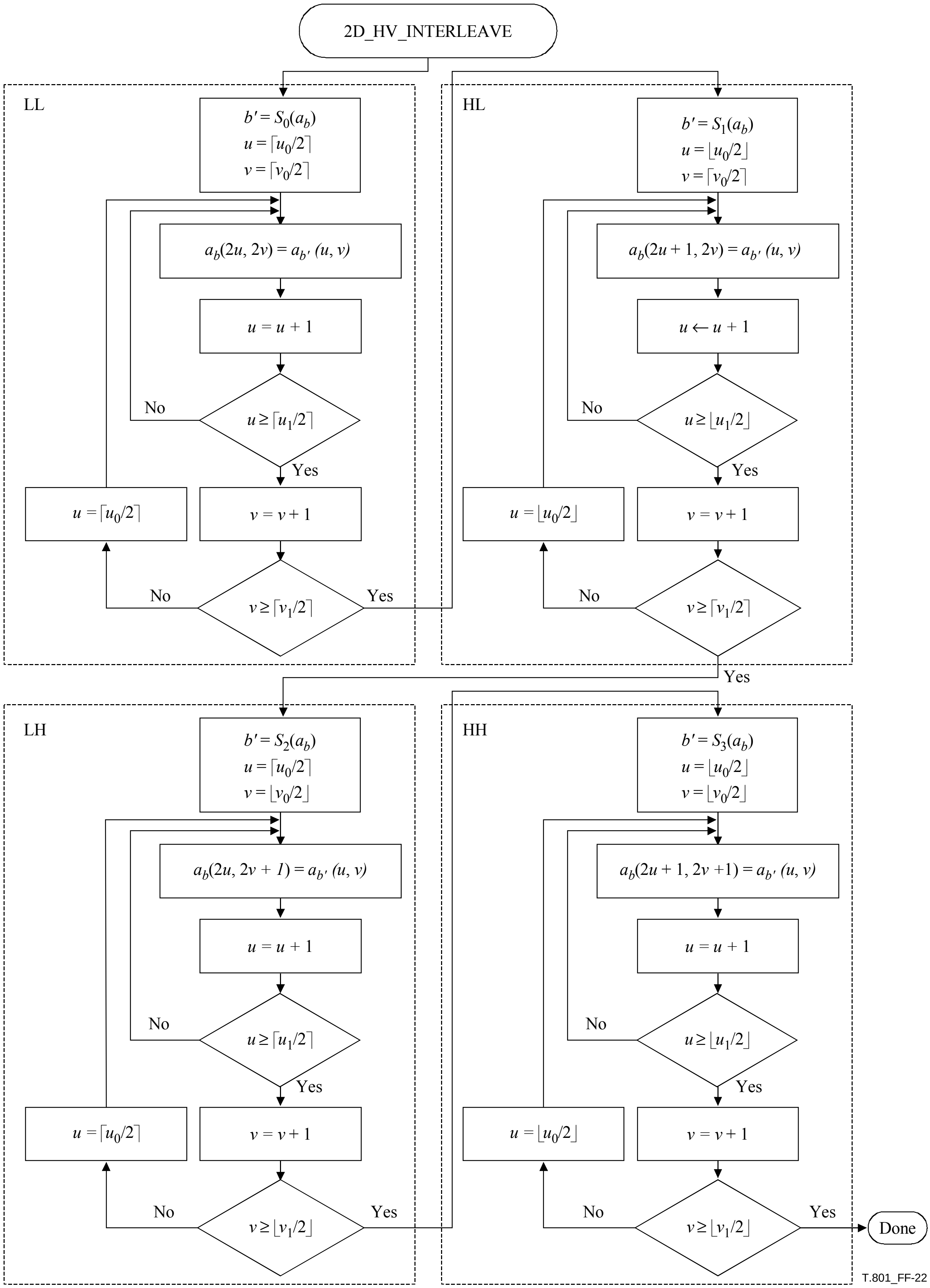


Figure F.22 – The 2D_HV_INTERLEAVE procedure

Figure F.23 – Parameters for the 2D_H_INTERLEAVE procedure

F.3.3.2 The 2D_H_INTERLEAVE procedure

The 2D_H_INTERLEAVE procedure defined in Figures F.23 and F.24 is used to accommodate disjoint processing along just the horizontal direction. As such, this procedure requires roughly half the 2D_HV_INTERLEAVE procedure logic to interleave samples in just the horizontal direction.

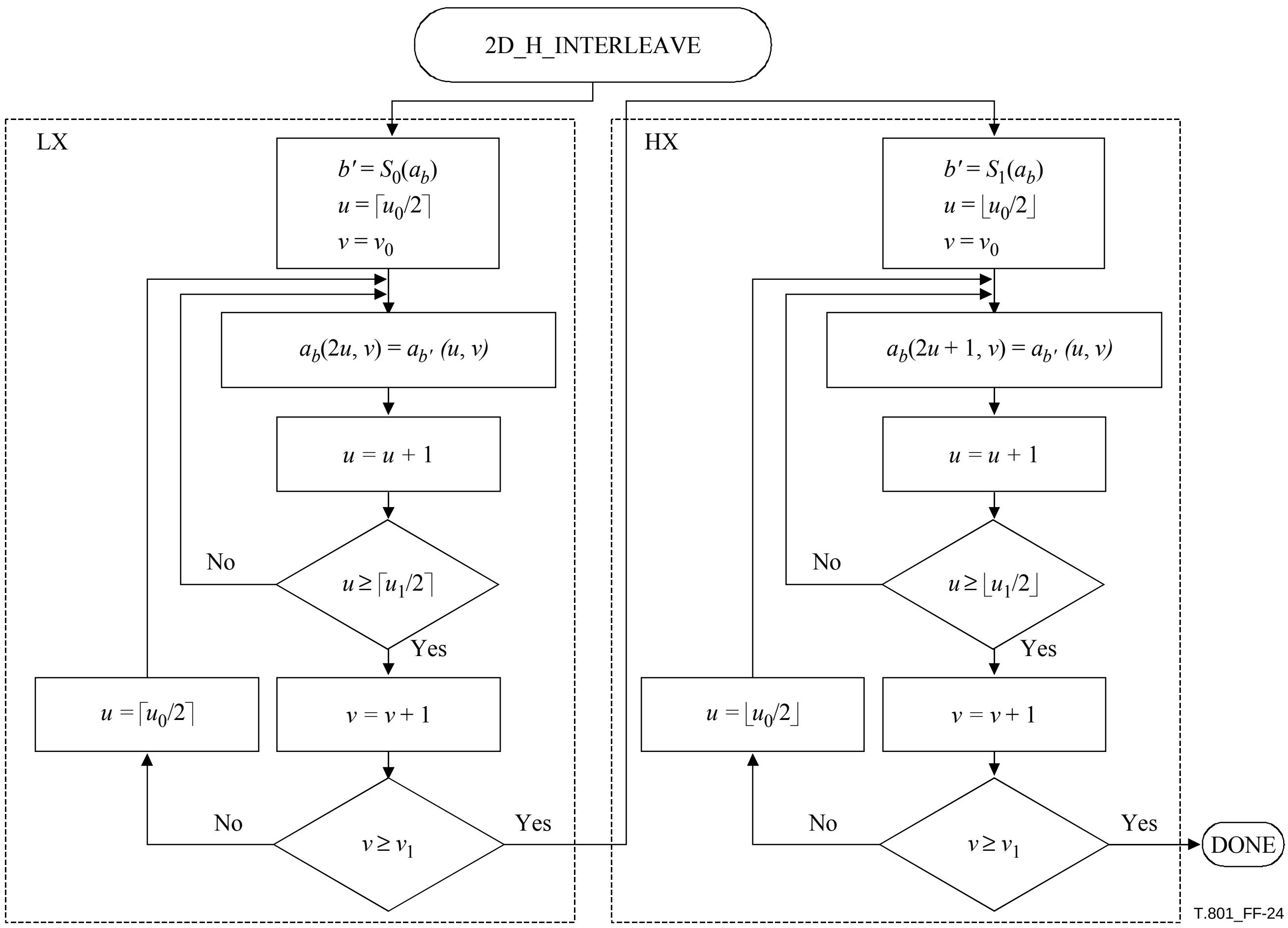


Figure F.24 – The 2D_H_INTERLEAVE procedure

F.3.3.3 The 2D_V_INTERLEAVE procedure

The procedure for interleaving samples due to disjoint wavelet processing in just the vertical direction is quite like that for the procedure defined above in F.3.3.2. The procedure for this case is depicted in Figures F.25 and F.26.

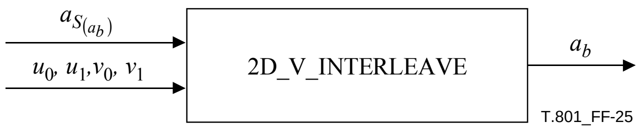


Figure F.25 – Parameters for the 2D_V_INTERLEAVE procedure

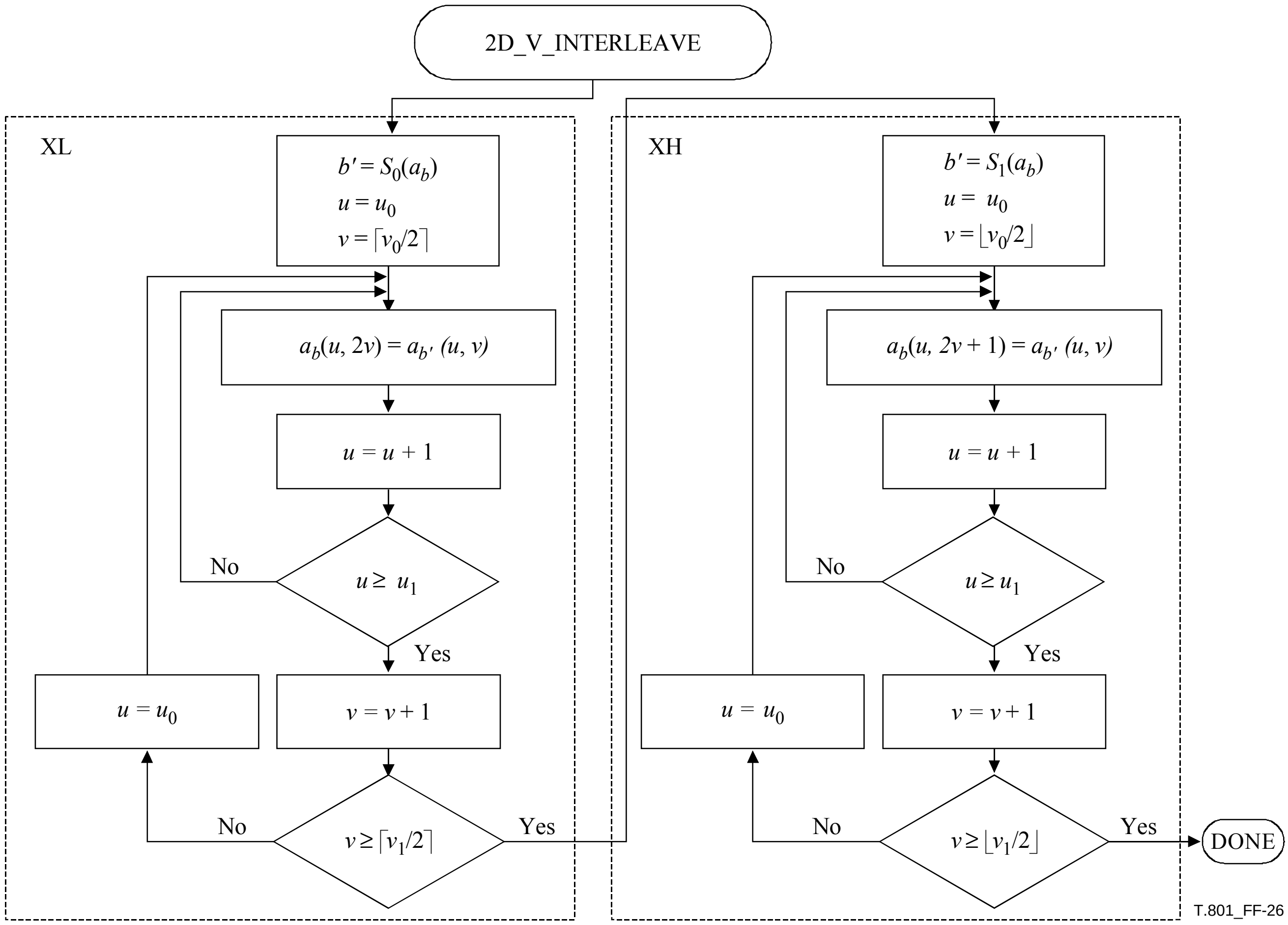


Figure F.26 – The 2D_V_INTERLEAVE procedure

F.4 Forward discrete wavelet transformation for general decompositions (informative)

Similar to the inverse transformation process, forward wavelet transformation requires changes to only the FDWT, 2D_SD, and 2D_DEINTERLEAVE ITU-T Rec. T.800 | ISO/IEC 15444-1 procedures.

F.4.1 Modified FDWT procedure

Like the MOD_IDWT procedure, the FDWT remains much like that in ITU-T Rec. T.800 | ISO/IEC 15444-1. The parameters for this procedure are shown in Figure F.27 and the structure of the procedure is shown in Figure F.28.

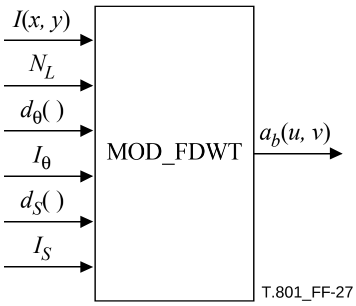


Figure F.27 – Parameters for the MOD_FDWT procedure

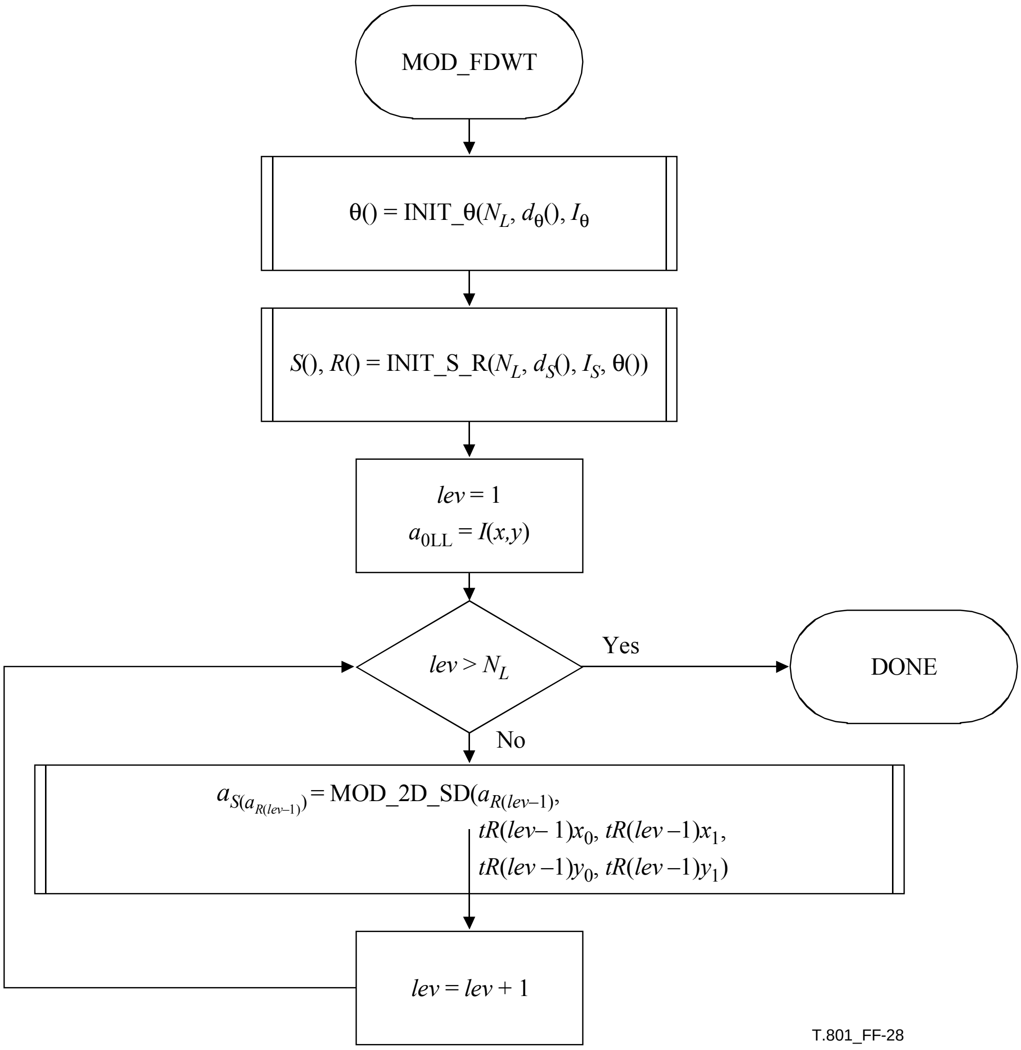


Figure F.28 – The MOD_FDWT procedure

F.4.2 Modified 2D_SD procedure

Major changes are required for 2D_SD from that in ITU-T Rec. T.800 | ISO/IEC 15444-1. This procedure is composed of operations which split one sub-band into 2 or 4 resulting sub-bands. This procedure must also handle such processing throughout all sub-levels inside a decomposition level. To accommodate such processing, a recursive structure is used for this procedure. The parameters necessary for this procedure are shown in Figure F.29 and the new procedure itself is diagrammed in Figure F.30.

Figure F.29 – Parameters for the MOD_2D_SD procedure

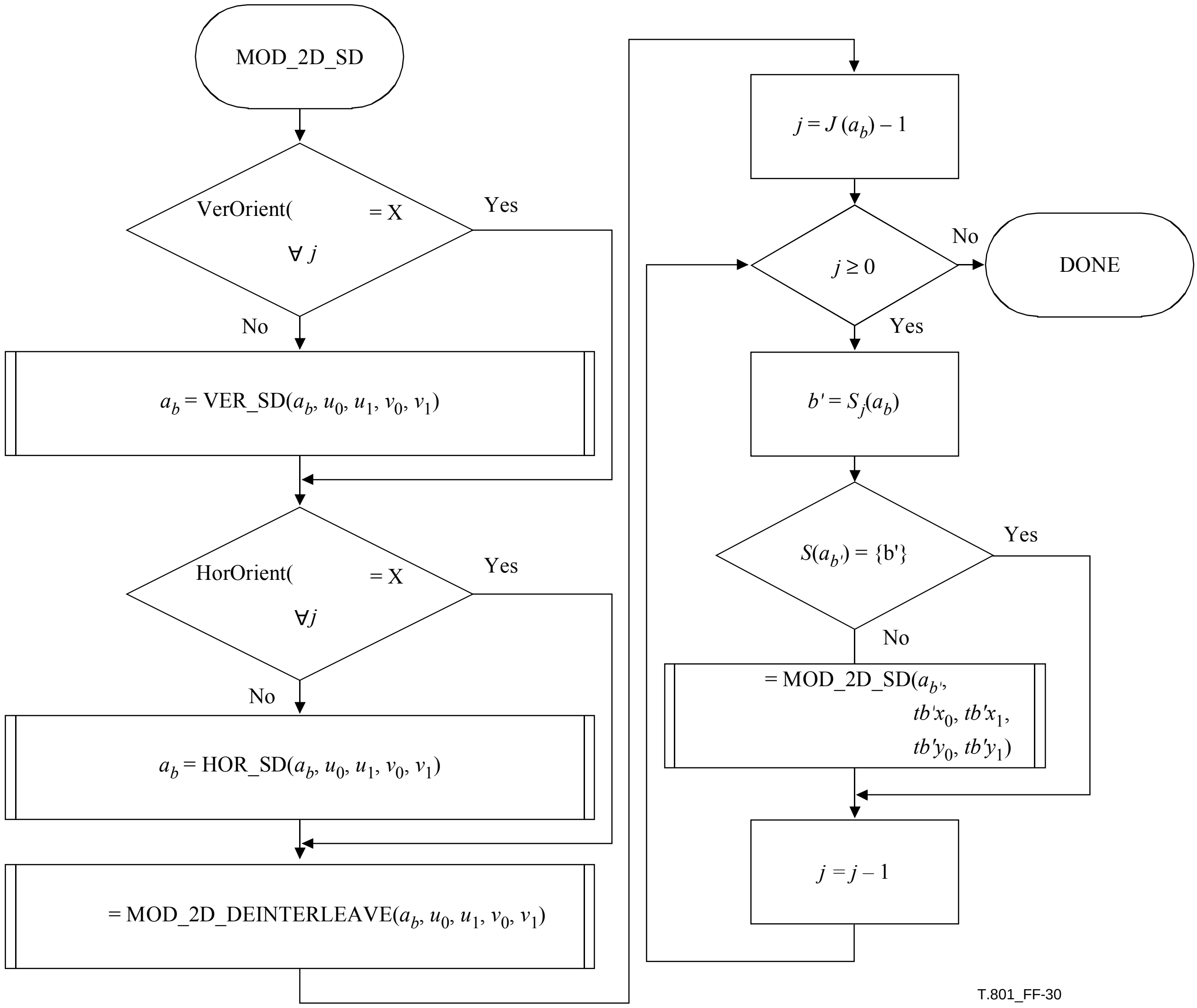


Figure F.30 – The MOD_2D_SD procedure

F.4.3 Modified 2D_DEINTERLEAVE procedure

Significant changes were also necessary for the 2D_DEINTERLEAVE procedure. These changes are due to both sub-level processing and disjoint horizontal/vertical sub-band splits. This procedure is shown in both Figures F.31 and F.32. As shown in the latter of these two figures, this routine now decides which of three lower level procedures must be used to deinterleave wavelet samples. As with the MOD_2D_INTERLEAVE procedure, the values of u_0, u_1, v_0 and v_1 in each of these three lower level procedures are those of tbx_0, tbx_1, tby_0 and tby_1 as defined in F.2.4 for the sub-band a_b which is being decomposed/deinterleaved.

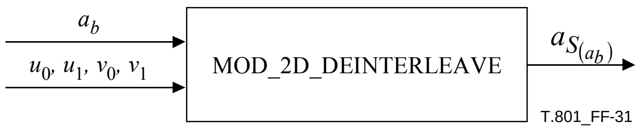


Figure F.31 – Parameters for the MOD_2D_DEINTERLEAVE procedure

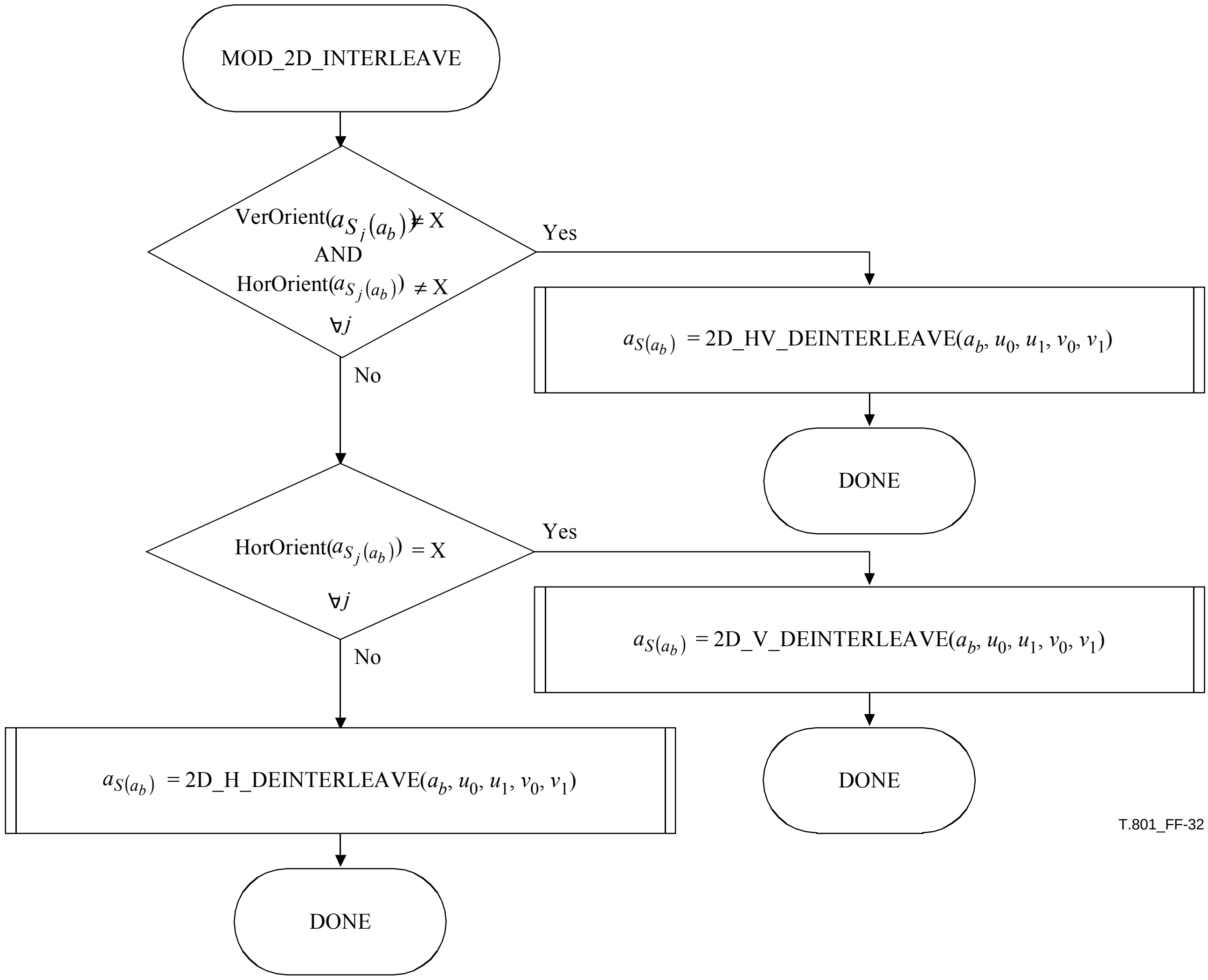


Figure F.32 – The MOD_2D_DEINTERLEAVE procedure

F.4.3.1 The 2D_HV_DEINTERLEAVE procedure

The 2D_HV_DEINTERLEAVE procedure is similar to the 2D_DEINTERLEAVE procedure from ITU-T Rec. T.800 | ISO/IEC 15444-1. Usage for this procedure is shown in Figure F.33 and the actual procedure is shown in Figure F.34.

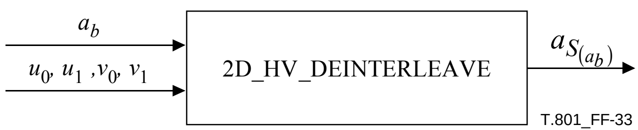


Figure F.33 – Parameters for the 2D_HV_DEINTERLEAVE procedure

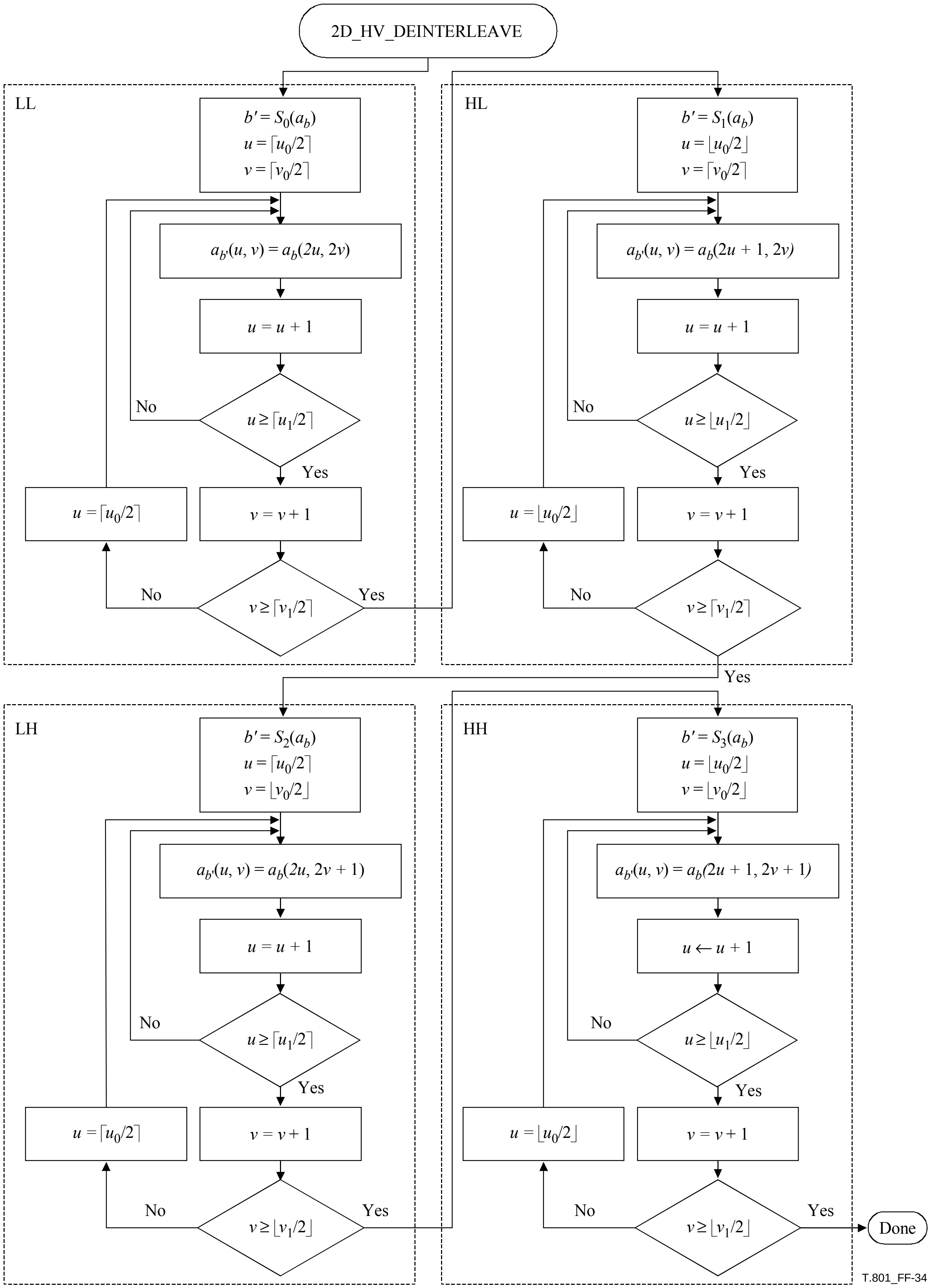


Figure F.34 – The 2D_HV_DEINTERLEAVE procedure

Figure F.35 – Parameters for the 2D_H_DEINTERLEAVE procedure

F.4.3.2 The 2D_H_DEINTERLEAVE procedure

The 2D_H_DEINTERLEAVE procedure is used to accommodate disjoint processing along just the horizontal direction. As such, this procedure requires roughly half the logic in the 2D_HV_DEINTERLEAVE procedure above. The diagram of this procedure is given in Figures F.35 and F.36.

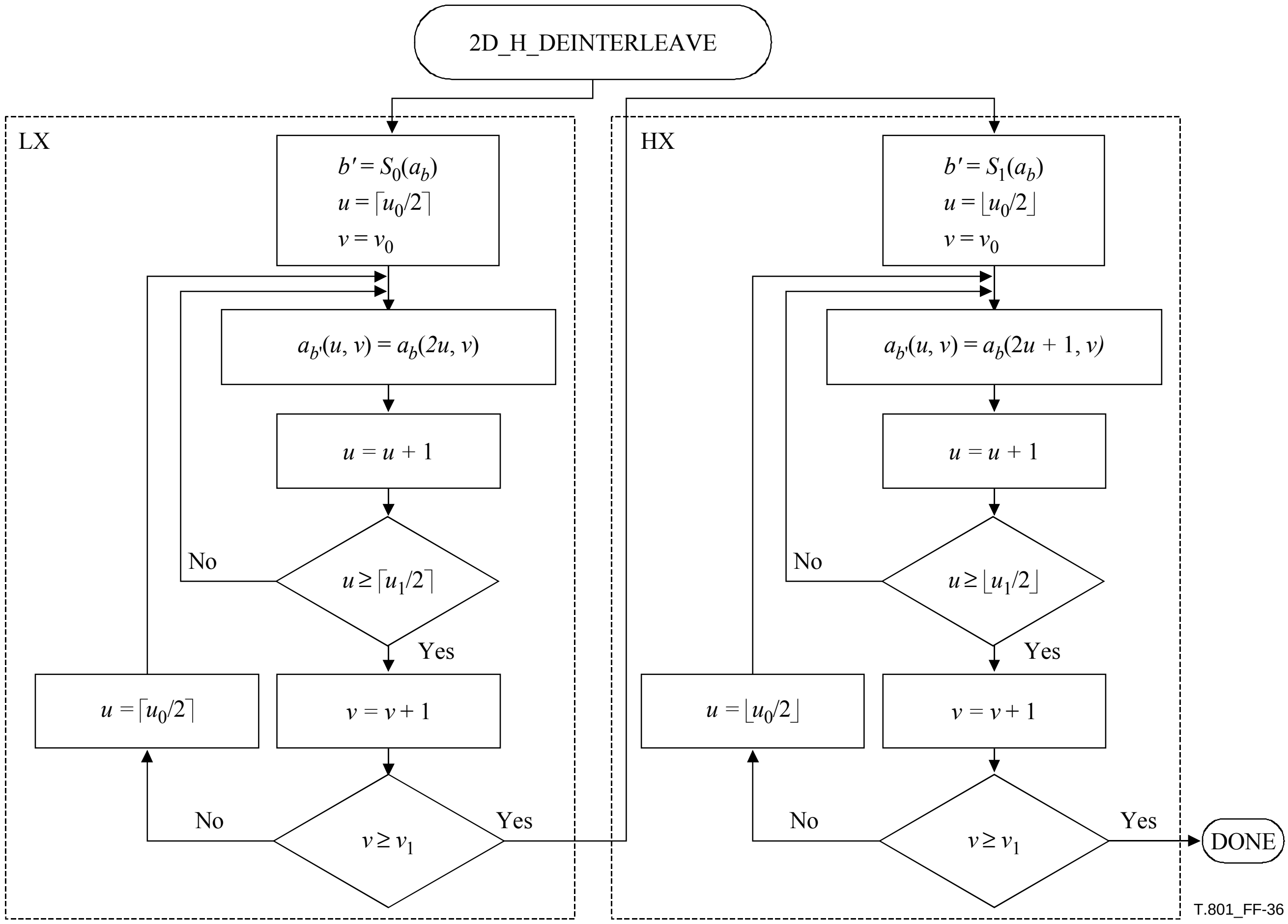


Figure F.36 – The 2D_H_DEINTERLEAVE procedure

F.4.3.3 The 2D_V_DEINTERLEAVE procedure

The procedure for deinterleaving samples due to disjoint wavelet processing in just the vertical direction is quite like that for the procedure defined in F.4.3.2. The procedure for this case is depicted in Figures F.37 and F.38.

Figure F.37 – Parameters for the 2D_V_DEINTERLEAVE procedure

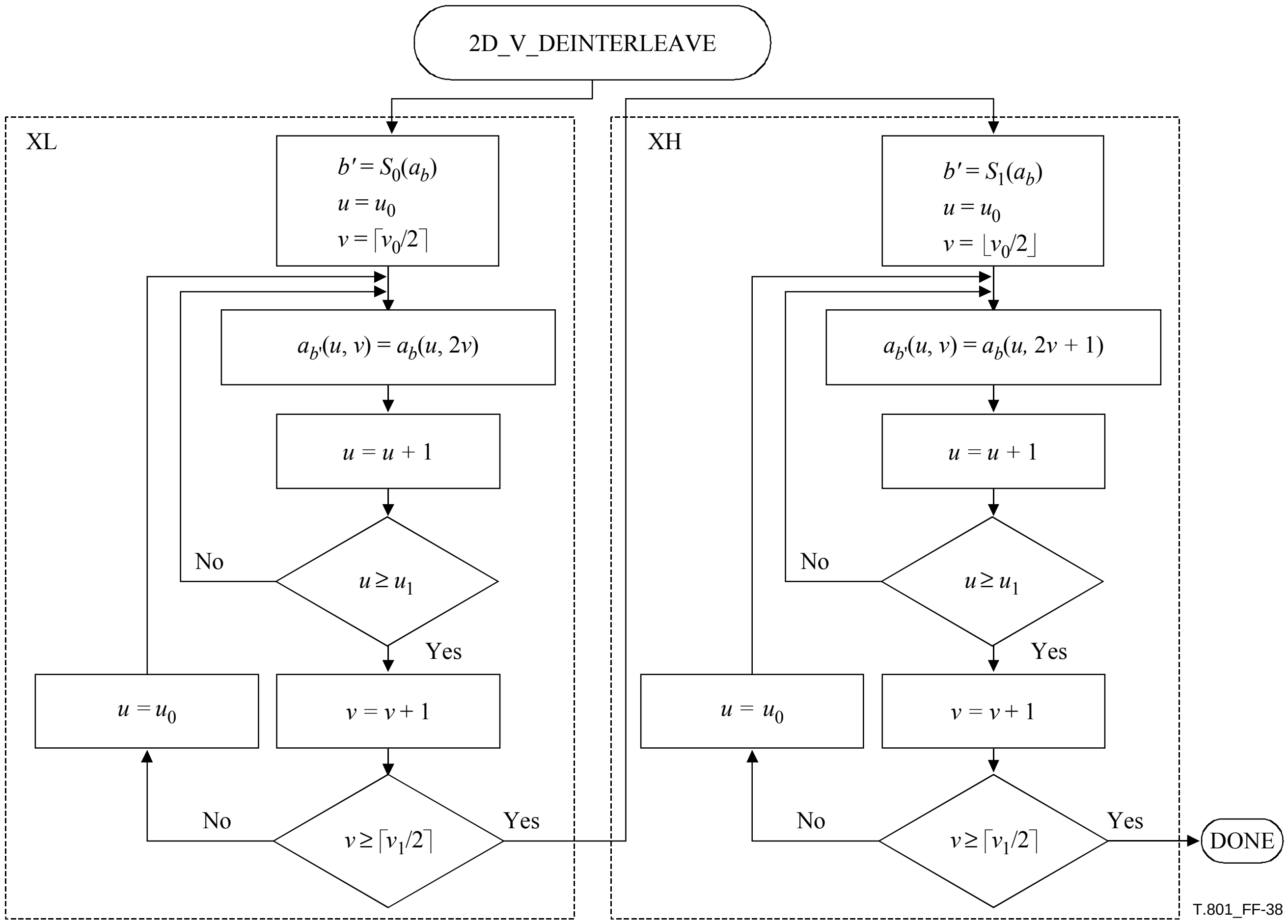


Figure F.38 – The 2D_V_DEINTERLEAVE procedure

Annex G

Whole-sample symmetric transformation of images, extensions

(This annex forms an integral part of this Recommendation | International Standard)

This Recommendation | International Standard uses a transformation of tile components.

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate.

This annex specifies two extensions of the one-dimensional sub-band reconstruction procedure 1D_SR (see ITU-T Rec. T.800 | ISO/IEC 15444-1): the 1D_SR_WS procedure and the 1D_SD_WS procedure for whole-sample symmetric (WS) wavelet transformations.

G.1 Wavelet transformation parameters, definitions and normalizations

Table G.1 lists the parameters used in the wavelet transformations that are signalled in the codestream. Signalling for these parameters is defined in the ATK marker segment (see A.3.5).

Table G.1 – Parameters for wavelet transformations

Parameter tag	Meaning	Value(s)
Coeff_Typ	Numerical type of lifting step coefficients	8-bit signed integer 16-bit signed integer 32-bit float 64-bit float 128-bit float
Filt_Cat	Wavelet transformation category	arbitrary (*ARB*) whole-sample symmetric (*WS*)
WT_Typ	Wavelet transformation type	irreversible (*IRR*) reversible (*REV*)
m_{init}	Update characteristic of first reconstruction lifting step	even-subsequence update (0) odd-subsequence update (1)
N_{LS}	Number of lifting steps	8-bit unsigned integer
ε_s	Base-2 scaling exponent for lifting step *s* (reversible transformations only)	8-bit unsigned integer: defined for $0 \le s < N_{LS}$
β_s	Additive residue for lifting step *s* (reversible transformations only)	*Coeff_Typ*: defined for $0 \le s < N_{LS}$
K	Scaling factor (irreversible transformations only)	Coeff_Typ
L_s	Number of lifting coefficients for lifting step *s*	8-bit unsigned integer: defined for $0 \le s < N_{LS}$
$\alpha_{s,k}$	*kth* lifting coefficient for lifting step *s*	*Coeff_Typ*: defined for $0 \le s < N_{LS}$ $0 \le k < L_S$

G.2 Whole-sample symmetric (WS) wavelet transformations reconstruction

The procedures specified in this subclause apply only in the case of ATK markers segments for which *Filt_Cat = WS*.

G.2.1 Normalization of WS wavelet transformations

This subclause specifies conditions on parameters that a compliant codestream must satisfy.

Define D_s to be the sum of the lifting coefficients $\alpha_{s,k}$ for lifting step s, $0 \le s < N_{LS}$ (normalized in the case of reversible transforms):

$$D_s = 2 \cdot \sum_{k=0}^{L_s-1} \alpha_{s,k} \quad \text{if} \quad WT\_Typ = IRR$$

$$D_s = \frac{2}{2^{\varepsilon_s}} \sum_{k=0}^{L_s-1} \alpha_{s,k} \quad \text{if} \quad WT\_Typ = REV$$

Define parameters B_s recursively:

$$B_s = D_s B_{s-1} + B_{s-2}, \text{ for } s = 0 \text{ to } N_{LS-1} \tag{G-1}$$

with the initial conditions being: $B_{-1} = 1$ and $B_{-2} = 1$.

G.2.1.1 Normalization of reversible wavelet transformation

For reversible wavelet transformations (*WT_Typ=REV*), the parameters B_s must satisfy one of the following conditions:

$$B_{N_{LS}-2} = 1 \text{ if } m_{init} = 1, \text{ or}$$

$$B_{N_{LS}-1} = 1 \text{ if } m_{init} = 0$$

G.2.1.2 Normalization of irreversible wavelet transformation

For irreversible wavelet transformations (*WT_Typ = IRR*), the parameters B_s and the scaling parameter, K, must satisfy one of the following conditions:

$$B_{N_{LS}-2} = K \text{ if } m_{init} = 1, \text{ or}$$

$$B_{N_{LS}-1} = K \text{ if } m_{init} = 0$$

G.2.2 One-dimensional sub-band reconstruction procedure for WS wavelet transformations

The one-dimensional sub-band reconstruction (1D_SR_WS) procedure is implemented as a sequence of primitive lifting steps, which alternately modify odd-indexed samples with a weighted sum of even-indexed samples and even-indexed samples with a weighted sum of odd-indexed samples.

G.2.2.1 The 1D_SR_WS procedure

As illustrated in Figure G.1, the 1D_SR_WS procedure takes as input a one-dimensional array, Y, of interleaved lowpass and highpass coefficients, the index i_0 of the first sample in array Y, the index i_1 of the sample following the last sample in array Y. It produces as output an array, X, with the same indices (i_0, i_1).

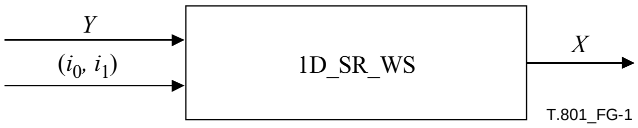


Figure G.1 – Parameters of the 1D_SR_WS procedures

For signals of length one (i.e., $i_0 = i_1 - 1$), the 1D_SR_WS procedure sets the value of $X(i_0)$ to $X(i_0) = Y(i_0)$ if i_0 is an even integer, and to $X(i_0) = Y(i_0)/2$ if i_0 is an odd integer.

For signals of length greater than or equal to two (i.e., $i_0 < i_1 - 1$), as illustrated in Figure G.2, the 1D_SR_WS procedure applies the 1D_FILTR_WS procedure to *Y* to produce the reconstructed signal, *X*.

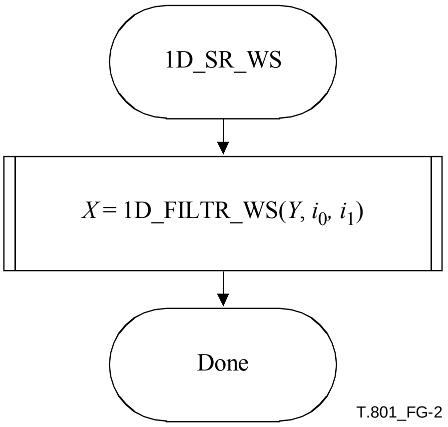


Figure G.2 – The 1D_SR_WS procedure

NOTE – Unlike in ITU-T Rec. T.800 | ISO/IEC 15444-1, the 1D_SR_WS procedure does not extend the signal prior to applying the 1D_FILTR_WS procedure. Instead, a procedure equivalent to the extension procedure is included in the 1D_FILTR_WS procedure.

G.2.2.2 The 1D_FILTR_WS procedures

Two versions of the reconstruction procedure (1D_FILTR_WS) are specified, depending on whether the transformation is reversible or not (*WT_Typ=REV* or *IRR*). In the following two subclauses, the function $PSE_O(i)$ equals the function $PSE_O(i, i_0, i_1)$ specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, Equation F-4.

G.2.2.2.1 The reversible one-dimensional reconstruction (1D_FILTR_WS) procedure

As shown in Figure G.3, the input parameters to procedure 1D_FILTR_WS are V, i_0, i_1, N_{LS}, and $\alpha_{s,k}$, β_s, ε_s, L_s for $s = 0, 1, 2, \ldots, N_{LS} - 1$ and $k = 0, 1, 2, \ldots, L_s - 1$.

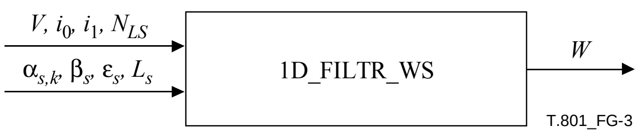


Figure G.3 – Parameters of the 1D_FILTR_WS procedure

The 1D_FILTR_WS procedure starts with the following N_{LS} lifting steps, where the variable s decreases from $N_{LS} - 1$ to zero (for $s = N_{LS} - 1, N_{LS} - 2, \ldots, 1, 0$):

$$V(2n+m_s) = V(2n+m_s) - \left\lfloor \frac{\left(\sum_{k=0}^{l_s-1} \alpha_{s,k} \cdot \left(V(PSE_O(2n+m_s-(2k+1))) + V(PSE_O(2n+m_s+(2k+1)))\right) \right) + \beta_s}{2^{\varepsilon_s}} \right\rfloor \quad \text{(G-2)}$$

where $m_{N_{LS-1}} = m_{init}$ and $m_s = 1 - m_{s+1}$ indicates whether the sth lifting step updates even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), where L_s is the number of lifting coefficients for lifting step s, and where the range of n is defined by $i_0 \le 2n + m_s < i_1$.

The values of $V(k)$ such that $i_0 \le k < i_1$ form the output $W(k)$ of the 1D_FILTR procedure:

$$W(k) = V(k) \quad \text{(G-3)}$$

G.2.2.2.2 The irreversible one-dimensional reconstruction (1D_FILTR_WS) procedure

As shown in Figure G.4, the input parameters to procedure 1D_FILTR_WS are V, i_0, i_1, K, N_{LS}, and $\alpha_{s,k}$, L_s for $s = 0, 1, 2, \ldots, N_{LS} - 1$ and $k = 0, 1, 2, \ldots, L_s - 1$.

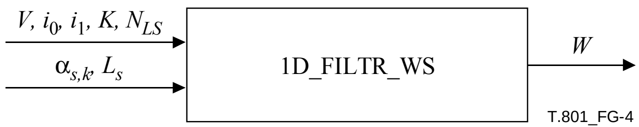


Figure G.4 – Parameters of the 1D_FILTR_WS procedure

The 1D_FILTR_WS procedure starts with two scaling steps:

$$V(2n) = K \cdot V(2n) \text{ for } i_0 \le 2n < i_i \quad \text{(G-4)}$$

$$\text{and } V(2n+1) = (1/K) \cdot V(2n+1) \text{ for } i_0 \le 2n+1 < i_i \quad \text{(G-5)}$$

The 1D_FILTR_WS procedure then performs the following N_{LS} lifting steps (for $s = N_{LS} - 1, N_S - 2, \ldots, 1, 0$):

$$V(2n+m_s) = V(2n+m_s) - \left(\sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot \left(V(PSE_O(2n+m_s-(2k+1))) + V(PSE_O(2n+m_s+(2k+1)))\right) \right) \quad \text{(G-6)}$$

where $m_{N_{LS-1}} = m_{init}$ and $m_s = 1 - m_{s+1}$ indicates whether the sth lifting step updates even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), where L_s is the number of lifting coefficients for lifting step s, and where the range of n is defined by $i_0 \le 2n + m_s < i_1$.

The values of $V(k)$ such that $i_0 \le \mathrm{k} < i_1$ form the output $W(k)$ of the 1D_FILTR_WS procedure:

$$W(k) = v(k) \quad \text{(G-7)}$$

G.3 Whole-sample symmetric (WS) wavelet transformation decomposition (informative)

The one-dimensional sub-band decomposition procedure 1D_SD_WS is implemented as a sequence of primitive lifting steps, which alternately modify odd-indexed samples with a weighted sum of even-indexed samples and even-indexed samples with a weighted sum of odd-indexed samples.

G.3.1 The 1D_SD_WS procedure (informative)

As illustrated in Figure G.5, the 1D_SD_WS procedure takes as input a one-dimensional array, X, the index i_0 of the first sample in array X, and the index i_1 of the sample following the last sample in array X. They produce as output an array, Y, of interleaved lowpass and highpass coefficients, with the same indices (i_0, i_1).

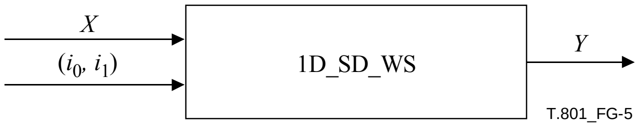


Figure G.5 – Parameters of the 1D_SD_WS procedure

For signals of length one (i.e., $i_0 = i_1 - 1$), the 1D_SD_WS procedure sets the value of $Y(i_0)$ to $Y(i_0) = X(i_0)$ if i_0 is an even integer, and to $Y(i_0) = 2X(i_0)$ if i_0 is an odd integer.

For signals of length greater than or equal to two (i.e., $i_0 < i_1 - 1$), as illustrated in Figure G.6, the 1D_SD_WS procedure applies the 1D_FILTD_WS procedure to X to produce the decomposed signal, Y.

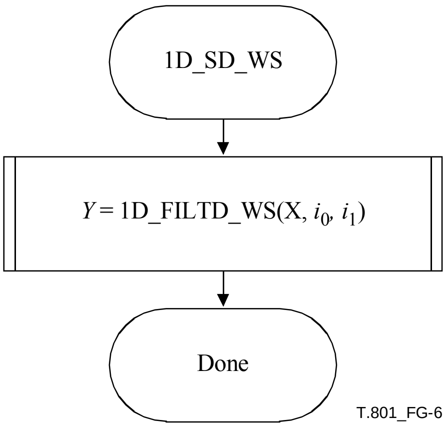


Figure G.6 – The 1D_SD_WS procedure

NOTE – Unlike in ITU-T Rec. T.800 | ISO/IEC 15444-1, the 1D_SD_WS procedure does not extend the signal prior to applying the 1D_FILTD_WS procedure. Instead, a procedure equivalent to the extension procedure is included in the 1D_FILTD_WS procedure.

G.3.2 The 1D_FILTD_WS one-dimensional decomposition procedure (informative)

Two versions of the decomposition procedures are specified, depending on whether the transformation is reversible or not (*WT_Typ* = *REV* or *IRR*). In the following two subclauses, the function $PSE_O(i)$ equals the function $PSE_O(i, i_0, i_1)$ specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, Equation F-4.

G.3.2.1 The 1D_FILTD_WS reversible one-dimensional decomposition procedure (informative)

As shown in Figure G.7, the input parameters to the reversible version of procedure 1D_FILTD_WS are V, i_0, i_1, N_{LS}, and $\alpha_{s,k}$, β_s, ε_s, L_s for for $s = 0, 1, 2, ..., N_{LS} - 1$ and $k = 0, 1, 2, ..., L_s - 1$.

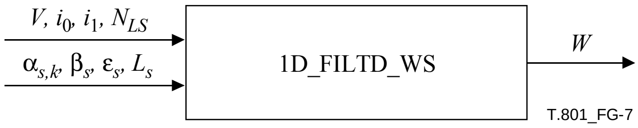


Figure G.7 – Parameters of the 1D_FILTD_WS procedure

The reversible 1D_FILTD_WS procedure consists in the following N_{LS} lifting steps (for $s = 0, 1, 2, \ldots, N_{LS} - 1$, starting with $s = 0$):

$$V(2n+m_s) = V(2n+m_s) + \left\lfloor \frac{\left(\sum_{k=0}^{l_s-1} \alpha_{s,k} \cdot (V(PSE_O(2n+m_s-(2k+1))) + V(PSE_O(2n+m_s+(2k+1))))\right) + \beta_s}{2^{\varepsilon_s}} \right\rfloor \quad \text{(G-8)}$$

where $m_{N_{LS-1}} = m_{init}$ and $m_s = 1 - m_{s-1}$ indicates whether the sth lifting step updates even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), where L_s is the number of lifting coefficients for lifting step s, and where the range of n is defined by $i_0 \le 2n + m_s < i_1$.

The values $W(k) = V(k)$ form the output $W(k)$ of the 1D_FILTD_WS procedure. The output values are the values in the range $i_0 \le k < i_1$.

G.3.2.2 The irreversible one-dimensional decomposition procedure (1D_FILTD_WS) (informative)

As shown in Figure G.8, the input parameters to the irreversible version of procedure 1D_FILTD_WS are V, i_0, i_1, K, N_{LS}, and $\alpha_{s,k}$, L_s for for $s = 0, 1, 2, \ldots, N_{LS} - 1$ and $k = 0, 1, 2, \ldots, L_s - 1$.

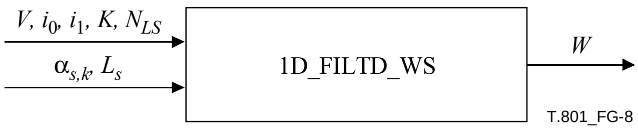


Figure G.8 – Parameters of the 1D_FILTD_WS procedure

The 1D_FILTD_WS procedure performs the following N_{LS} lifting steps (for $s = 0, 1, \ldots, N_{LS} - 1$, starting with $s = 0$):

$$V(2n+m_s) = V(2n+m_s) + \left(\sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot (V(PSE_O(2n+m_s-(2k+1))) + V(PSE_O(2n+m_s+(2k+1))))\right) \quad \text{(G-9)}$$

where $m_{N_{LS-1}} = m_{init}$ and $m_s = 1 - m_{s-1}$ indicates whether the sth lifting step updates even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), where L_s is the number of lifting coefficients for lifting step s, and where the range of n is defined by $i_0 \le 2n + m_s < i_1$.

The 1D_FILTD_WS procedure ends with two scaling steps:

$$V(2n) = (1/K) \cdot V(2n) \text{ for } i_0 \le 2n < i_i \quad \text{(G-10)}$$

$$\text{and } V(2n+1) = K \cdot V(2n+1) \text{ for } i_0 \le 2n+1 < i_1 \quad \text{(G-11)}$$

The values $W(k) = V(k)$ form the output $W(k)$ of the 1D_FILTD_WS procedure. The output values are the values in the range $i_0 \le k < i_1$.

G.4 Examples of WS wavelet transformations (informative)

Examples of wavelet transformations are specified in terms of their signalled values, as listed in Table G.1. Parameters that occur in sequences (e.g., L_S, $s = 0, \ldots, N_{LS} - 1$) are enumerated in order of increasing index. The suggested ATK marker segment index values are informative only, and decoders must verify whether codestreams containing ATK marker segments indexed with these values actually contain the example wavelet transformations specified below.

Both of the wavelet transformations from ITU-T Rec. T.800 | ISO/IEC 15444-1 are provided here for illustrative purposes. The wavelet transformations specified by the procedures in this annex in conjunction with the parameters listed in Tables G.2 and G.3 are mathematically equivalent to the transformations specified in ITU-T Rec. T.800 | ISO/IEC 15444-1 .

G.4.1 Reversible WS wavelet transformations (*WT_Typ* = *REV*) (informative)

Typical values for the β_s parameter are $2^{\varepsilon_s - 1}$.

G.4.1.1 Reversible 5-3 wavelet transformation (informative)

The transformation specified by the following parameter values is mathematically equivalent to the default reversible transformation specified in ITU-T Rec. T.800 | ISO/IEC 15444-1.

Table G.2 – Parameters of the 5-3 reversible wavelet transformation

Parameter	Value(s)
Normative ATK marker segment index	Binary: 0000 0001
m_{init}	0
N_{LS}	2
L_s	1, 1
$\alpha_{s,k}$	$\alpha_{0,0} = -1$ $\alpha_{1,0} = 1$
ε_s	1, 2
β_s	1, 2

The first decomposition step *($s = 0$)* is specified with negative lifting coefficients and an additive residue of 1. This apparent difference with the ITU-T Rec. T.800 | ISO/IEC 15444-1 definition is necessitated by the fact that decomposition updates are systematically *added* to the input vector by the procedures of this annex whereas the first reversible decomposition lifting step in the definition of ITU-T Rec. T.800 | ISO/IEC 15444-1, F.4.8.1, *subtracts* its update. The corresponding reconstruction lifting steps also differ in the sign of their updates. The transformation specified by the above parameter values is, however, mathematically equivalent to the ITU-T Rec. T.800 | ISO/IEC 15444-1 definition of the reversible 5-3 wavelet transformation.

G.4.1.2 Reversible 13-7 wavelet transformation (informative)

Table G.3 – Parameters of the 13-7 reversible wavelet transformation

Parameter	Value(s)
Normative ATK marker segment index	Binary: 0111 1111
m_{init}	0
N_{LS}	2
L_s	2, 2
$\alpha_{s,k}$	$\alpha_{0,k} = -9, 1$ $\alpha_{1,k} = 5, -1$
ε_s	4, 4
β_s	8, 8

G.4.2 Irreversible WS wavelet transformations (***WT_Typ* = *IRR***) (informative)

G.4.2.1 Irreversible 5-3 wavelet transformation (informative)

This is the irreversible version of the ITU-T Rec. T.800 | ISO/IEC 15444-1 reversible 5-3 wavelet transformation specified in G.4.1.1:

Table G.4 – Parameters of the 5-3 irreversible wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 0111 0110
m_{init}	0
N_{LS}	2
L_s	1, 1
$\alpha_{s,k}$	$\alpha_{0,0} = -\frac{1}{2}$ $\alpha_{1,0} = \frac{1}{4}$
K	1

G.4.2.2 Irreversible 7-5 wavelet transformation (informative)

Table G.5 – Parameters of the irreversible 7-5 wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 0111 0101
m_{init}	0
N_{LS}	3
L_s	1, 1, 1
$\alpha_{s,k}$	$\alpha_{0,0} = \frac{2}{25}$ $\alpha_{1,0} = -\frac{175}{406}$ $\alpha_{2,0} = \frac{609}{2500}$
K	$\frac{116}{100}$

G.4.2.3 Irreversible 9-7 wavelet transformation (informative)

This is the default irreversible wavelet transformation specified in ITU-T Rec. T.800 | ISO/IEC 15444-1; the transformation specified by the following parameter values is mathematically equivalent to the ITU-T Rec. T.800 | ISO/IEC 15444-1 transformation. Exact expressions for the values given by decimal approximations in Table G.6 can be found in Annex F of ITU-T Rec. T.800 | ISO/IEC 15444-1.

Table G.6 – Parameters of the irreversible 9-7 wavelet transformation

Parameter	Value(s)
Normative ATK marker segment index	Binary: 0000 0000
m_{init}	0
N_{LS}	4
L_s	1, 1, 1, 1
$\alpha_{s,k}$	$\alpha_{0,0} = -1.586\,134\,342\,059\,924$ $\alpha_{1,0} = -0.052\,980\,118\,572\,961$ $\alpha_{2,0} = 0.882\,911\,075\,530\,934$ $\alpha_{3,0} = 0.443\,506\,852\,043\,971$
K	1.230 174 104 914 001

Annex H

Transformation of images using arbitrary wavelet transformations

(This annex forms an integral part of this Recommendation | International Standard)

This Recommendation | International Standard defines a transformation of tile components. In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate.

This annex specifies an extension of the one-dimensional sub-band reconstruction procedure 1D_SR specified in ITU-T Rec. T.800 | ISO/IEC 15444-1. The internal structure of this extension differs from the internal structure of procedure 1D_SR in ITU-T Rec. T.800 | ISO/IEC 15444-1 because of the greater generality of this annex. The procedure in this annex, 1D_SR_ARB, is specified as a sequence of lifting steps, each of which involves a signal extension operation and an update operation. A scaling operation is performed in the case of irreversible wavelet transformations. Syntax is specified whereby an implementation may use wavelet transformations signalled in the codestream by the encoder.

H.1 Wavelet transformation parameters and normalizations

Table G.1 lists filter parameters for wavelet transformations that are signalled in the codestream. Signalling for these parameters is included in the ATK marker segment (see A.3.5). Table H.1 lists additional parameters contained in the ATK marker segment that are used exclusively in this annex.

Table H.1 – Additional parameters for arbitrary wavelet transformations

Parameter tag	Meaning	Value(s)
Exten	Boundary extension method used in lifting steps	constant (*CON*) whole-sample symmetric (*WS*)
off_s	Offset for lifting step *s*	8-bit signed integer: defined for $0 \le s < N_{LS}$

H.1.1 Normalization of ARB wavelet transformations

The procedures specified in this subclause apply only in the case of ATK marker segment for which *Filt_Cat* = *ARB*. The parameter D_s defined in G.2.1 represents the sum of the lifting coefficients for step *s,* $0 \le s < N_{LS}$ (normalized in the case of reversible transformations). This parameter is redefined in this annex as follows:

$$D_s = \sum_{k=0}^{L_s-1} \alpha_{s,k} \quad \text{if } WT\_Typ = IRR$$

$$D_s = \frac{1}{2^{\varepsilon_s}} \sum_{k=0}^{L_s-1} \quad \text{if } WT\_Typ = REV$$

The normalization requirements in G.2.1 remain as specified**,** using the above redefinition of D_s.

H.1.2 Compatibility of ARB and WS wavelet transformations

The transformations defined in this annex constitute an extension of the transformations defined in Annex G**.** The output produced by the procedures in Annex G using an ATK marker segment specifying *Filt_Cat* = *WS* is equal to the output produced by the procedures in this annex if the ATK marker segment is interpreted by setting the extension option to *Exten* = *WS* and modifying ("unfolding") the filter parameters for each lifting step as follows, in the order specified:

1) Duplicate the sequence of lifting coefficients: define $\alpha_{s,k+L_s} = \alpha_{s,k}$ for $k = 0, \dots, L_s - 1$.

2) Reverse the first half of the extended sequence of lifting coefficients: set $\alpha_{s,k} = \alpha_{s,2L_s-1-k}$ for $k = 0, \ldots, L_s - 1$.

3) Define the value of the offset parameter: $off_s = m_s - L_s$.

4) Redefine the value of the parameter indicating the number of lifting coefficients: $L_s = 2L_s$.

H.2 Arbitrary (ARB) wavelet transformation reconstruction procedures

The procedures specified in this subclause apply only in the case of ATK marker segment for which *Filt_Cat* = *ARB*. The extended one-dimensional sub-band reconstruction filtering (1D_SR_ARB) procedure defined in this annex is specified as a sequence of lifting steps, which alternately update the odd subsequence with a weighted sum of even-indexed samples and update the even subsequence with a weighted sum of odd-indexed samples. The option of reversible or irreversible transformation is signalled by the *WT_Typ* parameter.

H.2.1 The extended 1D_SR_ARB procedure

As illustrated in Figure H.1, the extended 1D_SR_ARB procedure takes as input a one-dimensional array, *Y*, of interleaved lowpass and highpass coefficients, the index i_0 of the first sample in array *Y*, and the index i_1 of the sample following the last sample in array *Y*. It produces as output a reconstructed array, *X*, with the same indices (i_0, i_1).

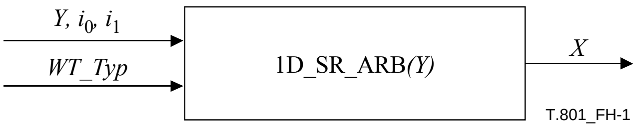


Figure H.1 – Parameters of the extended 1D_SR_ARB procedure

For signals of length one (i.e., $i_0 = i_1 - 1$), the 1D_SR_ARB procedure sets the value of $X(i_0)$ to $X(i_0) = Y(i_0)$ if i_0 is an even integer, and to $X(i_0) = Y(i_0)/2$ if i_0 is an odd integer.

For signals of length greater than or equal to two (i.e., $i_0 < i_1 - 1$), as illustrated in Figure H.2, the 1D_SR_ARB procedure applies a scaling step in the case of irreversible transformations (*WT_Typ* = *IRR*) and then applies a sequence of lifting steps, defined by the parameters from Tables G.1 and H.1, to produce the reconstructed signal, *X*. The variable *s*, which indexes the lifting steps, decreases from $N_{LS} - 1$ to zero in the reconstruction process.

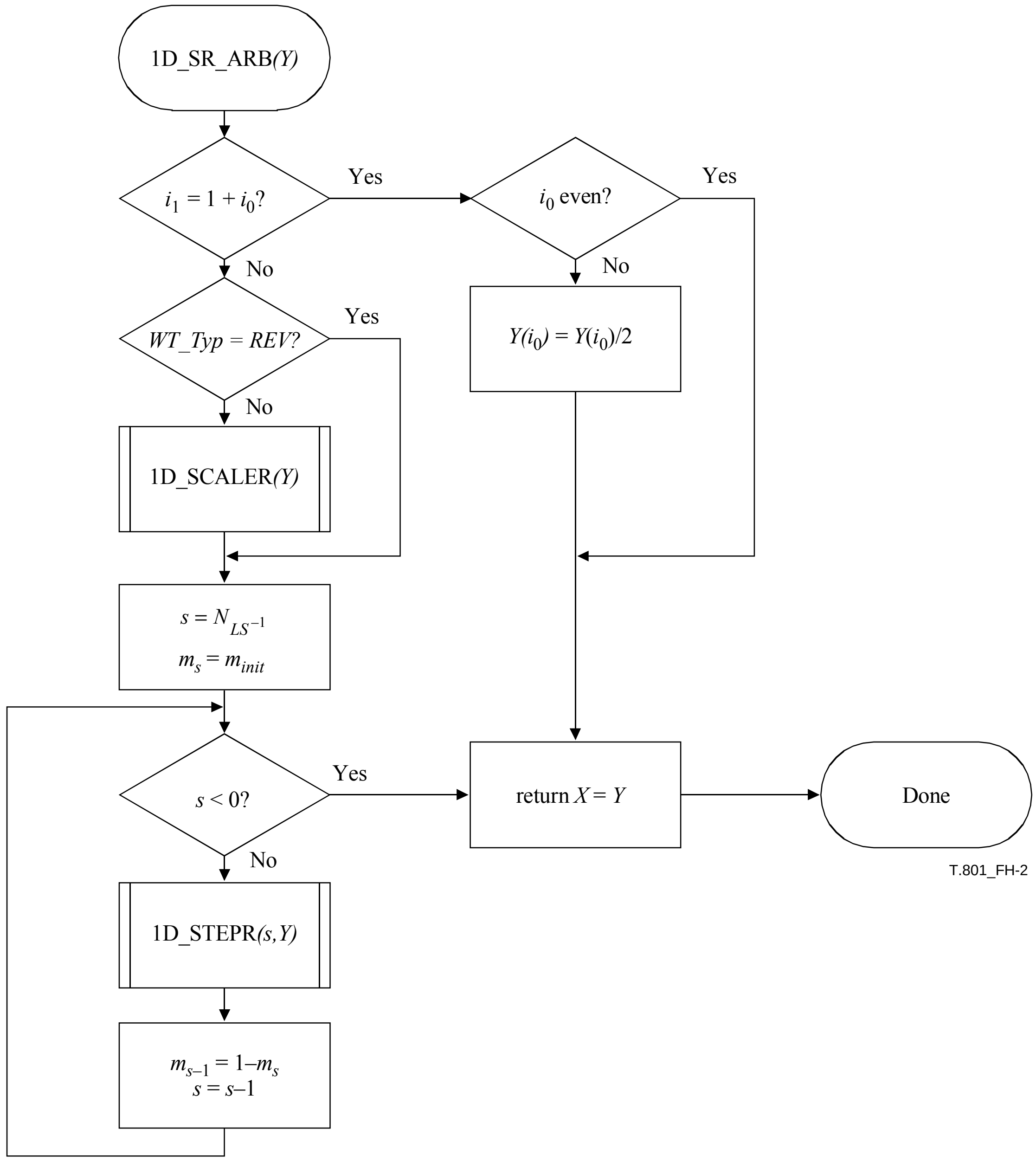


Figure H.2 – Extended procedure 1D_SR_ARB

H.2.2 The 1D_SCALER procedure

As shown in Figure H.3, procedure 1D_SCALER applies a scaling procedure to interleaved input vector V using signalled parameter K from Table G.1 and produces an updated version of vector V with the same indices (i_0, i_1). This procedure is used only in irreversible transformations.

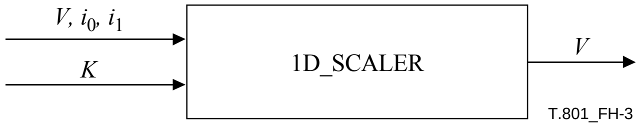


Figure H.3 – Parameters of the 1D_SCALER procedure

The 1D_SCALER procedure performs the following scaling operations:

$$V(2n) = K \cdot V(2n) \text{ for } i_0 \le 2n < i_1 \quad \text{(H-1)}$$

$$\text{and } V(2n+1) = (1/K) \cdot V(2n+1) \text{ for } i_0 \le 2n+1 < i_1 \quad \text{(H-2)}$$

H.2.3 The 1D_STEPR procedure

As shown in Figure H.4, procedure 1D_STEPR applies one reconstruction lifting step to interleaved input vector *V* and produces an updated version of vector *V* with the same indices (i_0, i_1).

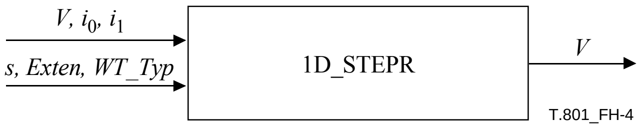


Figure H.4 – Parameters of the 1D_STEPR procedure

Procedure 1D_STEPR applies an extension procedure, determined by the *Exten* parameter, to the input, *V*. This is followed by a reconstruction update filtering procedure, determined by the *WT_Typ* parameter, as seen in Figure H.5. Only one of the two subsequences of *V* (the even- or the odd-indexed subsequence) is updated on each pass through 1D_STEPR.

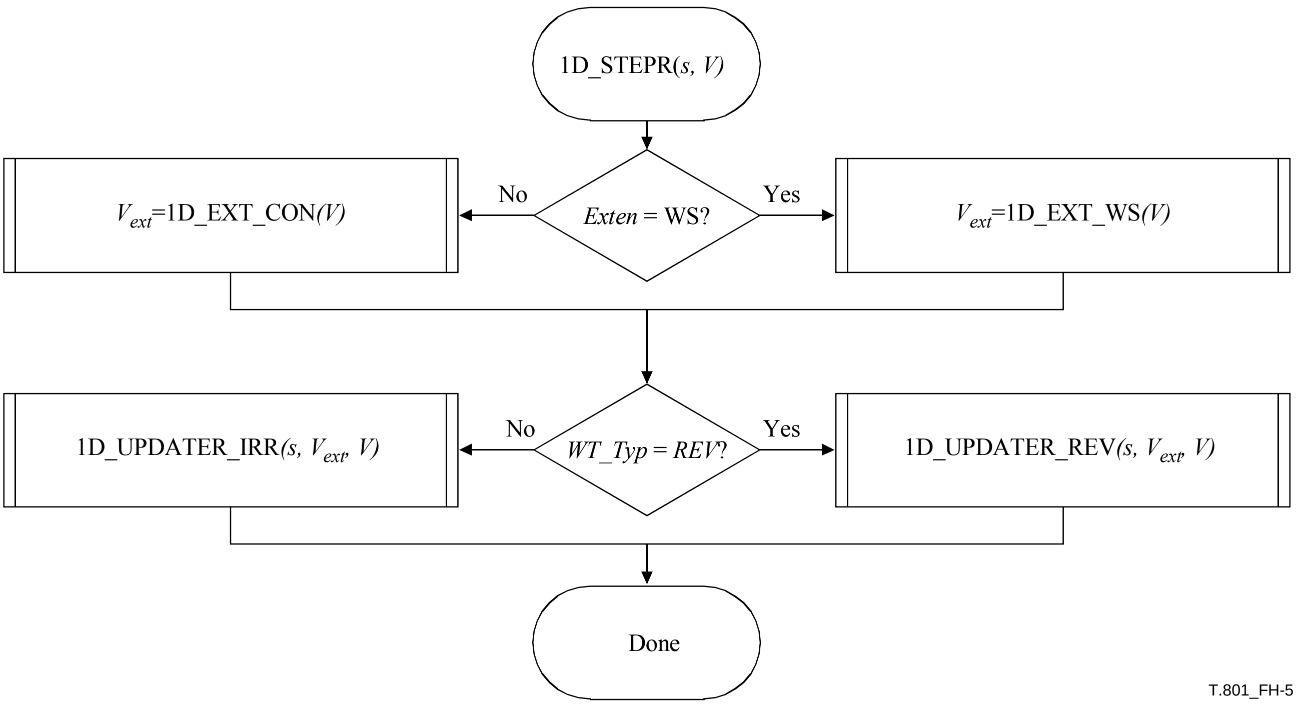


Figure H.5 –Procedure 1D_STEPR

H.2.4 Extension procedures

The exact manner in which extended samples are accessed in a realization of this Recommendation | International Standard (e.g., by copying extended arrays, by buffering, by indirect addressing, or by some other strategy) is implementation-dependent. This subclause is normative only insofar as it defines mathematical extensions of the input vector of sufficient length to enable the 1D_UPDATER_REV and 1D_UPDATER_IRR procedures to perform their update filtering operations as specified.

H.2.4.1 Minimum extension lengths

Although procedures 1D_EXT_WS and 1D_EXT_CON in principle define arbitrarily long extensions of the input vector, *V,* the minimum number of extended samples required to perform a given lifting step, *s*, can be calculated in terms of the wavelet transformation parameters for that step. The minimum extension lengths, i_{left} and i_{right}, for lifting step *s* are defined to be the smallest non-negative integers such that the interval $[i_0 - i_{left}, i_1 - 1 + i_{right}]$ contains all indexes addressed by the update filtering procedures 1D_UPDATER_REV*(s)* and 1D_UPDATER_IRR*(s)*. Minimum extension lengths for lifting step *s* are given in Tables H.2 and H.3 as functions of the parity of i_0 and i_1, the update characteristic, m_s, the number of lifting coefficients, L_s, and the offset, off_s. A minimum extension length is zero whenever an expression in either of these two tables evaluates to a negative number for some particular set of parameter values.

Table H.2 – Minimum left extension length

i_{left}:	$m_s = 0$	$m_s = 1$
i_0 even	$-1 - 2off_s$	$-2off_s$
i_0 odd	$-2 - 2off_s$	$1 - 2off_s$

Table H.3 – Minimum right extension length

i_{right}:	$m_s = 0$	$m_s = 1$
i_1 even	$2(L_s - 1 + off_s)$	$-1 + 2(L_s - 1 + off_s)$
i_1 odd	$1 + 2(L_s - 1 + off_s)$	$-2 + 2(L_s - 1 + off_s)$

H.2.4.2 1D_EXT_WS procedure

As shown in Figure H.6, the 1D_EXT_WS procedure accepts as input a vector *V* supported on an interval (i_0, i_1) and outputs a vector V_{ext} supported on a larger interval containing values of *i* beyond the range $i_0 \le i < i_1$. Except for the minimum extension lengths, i_{left} and i_{right} (specified above in H.2.4.1), this procedure is identical to the 1D_EXTR procedure defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.3.7. This procedure does not modify its input vector, *V.*

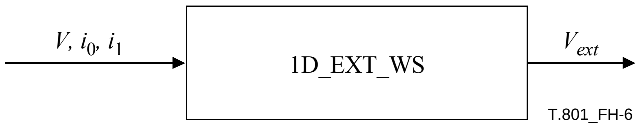


Figure H.6 – Parameters of the 1D_EXT_WS procedure

H.2.4.3 1D_EXT_CON procedure

As shown in Figure H.7, the 1D_EXT_CON procedure accepts as input a vector *V* supported on an interval (i_0, i_1) and outputs a vector V_{ext} supported on a larger interval containing values of *i* beyond the range $i_0 \le i < i_1$. The minimum extension lengths required for an extension created by procedure 1D_EXT_CON are specified above in H.2.4.1. This procedure does not modify its input vector, *V.*

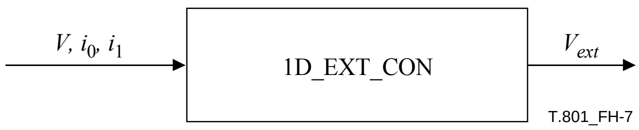


Figure H.7 – Parameters of the 1D_EXT_CON procedure

Procedure 1D_EXT_CON defines constant extensions of the even- and odd-indexed subsequences in *V* according to the following rules.

For $i_0 \le i < i_1$:

$$V_{ext}(i) = V(i)$$

For $k \ge 1$:

$$V_{ext}(i_0 - 2k) = V(i_0)$$

$$V_{ext}(i_0 + 1 - 2k) = V(i_0 + 1)$$

$$V_{ext}(i_1 - 1 + 2k) = V(i_1 - 1)$$

$$V_{ext}(i_1 - 2 + 2k) = V(i_1 - 2)$$

H.2.5 One-dimensional reconstruction update filtering procedures

Two reconstruction update filtering procedures are defined, one for reversible transformations (1D_UPDATER_REV) and one for irreversible transformations (1D_UPDATER_IRR). Reconstruction steps are defined recursively as even-subsequence updates *(m_s = 0)* or odd-subsequence updates *(m_s = 1)*, beginning with step number $N_{LS} - 1$, whose update characteristic is signalled in Table G.1 by the m_{init} parameter, and recursing downward: $m_{s-1} = 1 - m_s$. Both procedures take as input an interleaved input vector V and produce as output an updated version of vector V with the same indices (i_0, i_1).

H.2.5.1 Reversible one-dimensional reconstruction update (1D_UPDATER_REV) procedure

Procedure 1D_UPDATER_REV modifies either the even- or the odd-indexed subsequence in vector V by a weighted sum of samples from the extended sequence, V_{ext}, after applying a rounding operation to the weighted sum. Figure H.8 shows the input parameters to procedure 1D_UPDATER_REV.

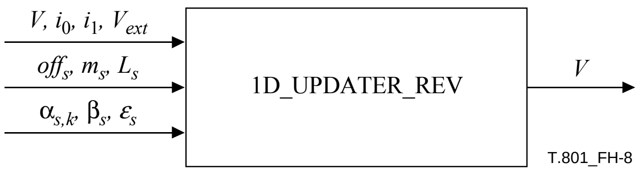


Figure H.8 – Parameters of the 1D_UPDATER_REV procedure

The 1D_UPDATER_REV procedure performs the following update filtering operation:

$$V(2n + m_s) = V(2n + m_s) - \left\lfloor \frac{\left(\sum_{k=0}^{L_s - 1} \alpha_{s,k} \cdot V_{ext}(2n + 1 - m_s + 2(k + \mathit{off}_s)) \right) + \beta_s}{2^{\varepsilon_s}} \right\rfloor \qquad \text{(H-3)}$$

for all n such that $i_0 \le 2n + m_s < i_1$.

H.2.5.2 Irreversible one-dimensional reconstruction update (1D_UPDATER_IRR) procedure

Procedure 1D_UPDATER_IRR modifies either the even- or the odd-indexed subsequence in vector V by a weighted sum of samples from the extended sequence, V_{ext}. Figure H.9 shows the input parameters to procedure 1D_UPDATER_IRR.

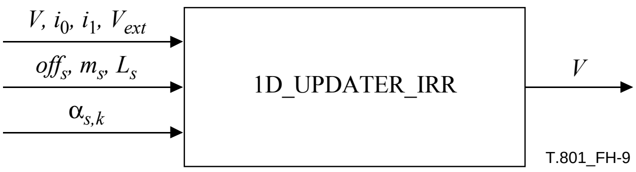


Figure H.9 – Parameters of the 1D_UPDATER_IRR procedure

The 1D_UPDATER_IRR procedure performs the following update filtering operation:

$$V(2n + m_s) = V(2n + m_s) - \sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot V_{ext}(2n + 1 - m_s + 2(k + off_s)) \quad \text{(H-4)}$$

for all n such that $i_0 \le 2n + m_s < i_1$.

H.3 Arbitrary (ARB) wavelet transformation decomposition procedures (informative)

The extended one-dimensional sub-band decomposition filtering (1D_SD_ARB) procedure is implemented as a sequence of lifting steps, which alternately update the odd subsequence with a weighted sum of even-indexed samples and update the even subsequence with a weighted sum of odd-indexed samples.

H.3.1 Extended 1D_SD_ARB procedure (informative)

As illustrated in Figure H.10, the extended 1D_SD_ARB procedure takes as input a one-dimensional array, X, of data, the index i_0 of the first sample in array X, and the index i_1 of the sample following the last sample in array X. It produces as output an array, Y, of interleaved sub-band samples, with the same indices (i_0, i_1).

Figure H.10 – Parameters of the extended 1D_SD_ARB procedure

For signals of length one (i.e., $i_0 = i_1 - 1$), the 1D_SD_ARB procedure sets the value of $Y(i_0)$ to $Y(i_0) = X(i_0)$ if i_0 is an even integer, and to $Y(i_0) = 2X(i_0)$ if i_0 is an odd integer.

For signals of length greater than or equal to two (i.e., $i_0 < i_1 - 1$), as illustrated in Figure H.11, the 1D_SD_ARB procedure applies a sequence of lifting steps, defined by the parameters from Table H.1, and then applies a scaling step in the case of irreversible transformations *(WT_Typ = IRR)* to produce the decomposed signal, Y. The variable s, which indexes the lifting steps, increases from zero to $N_{LS} - 1$ in the decomposition process.

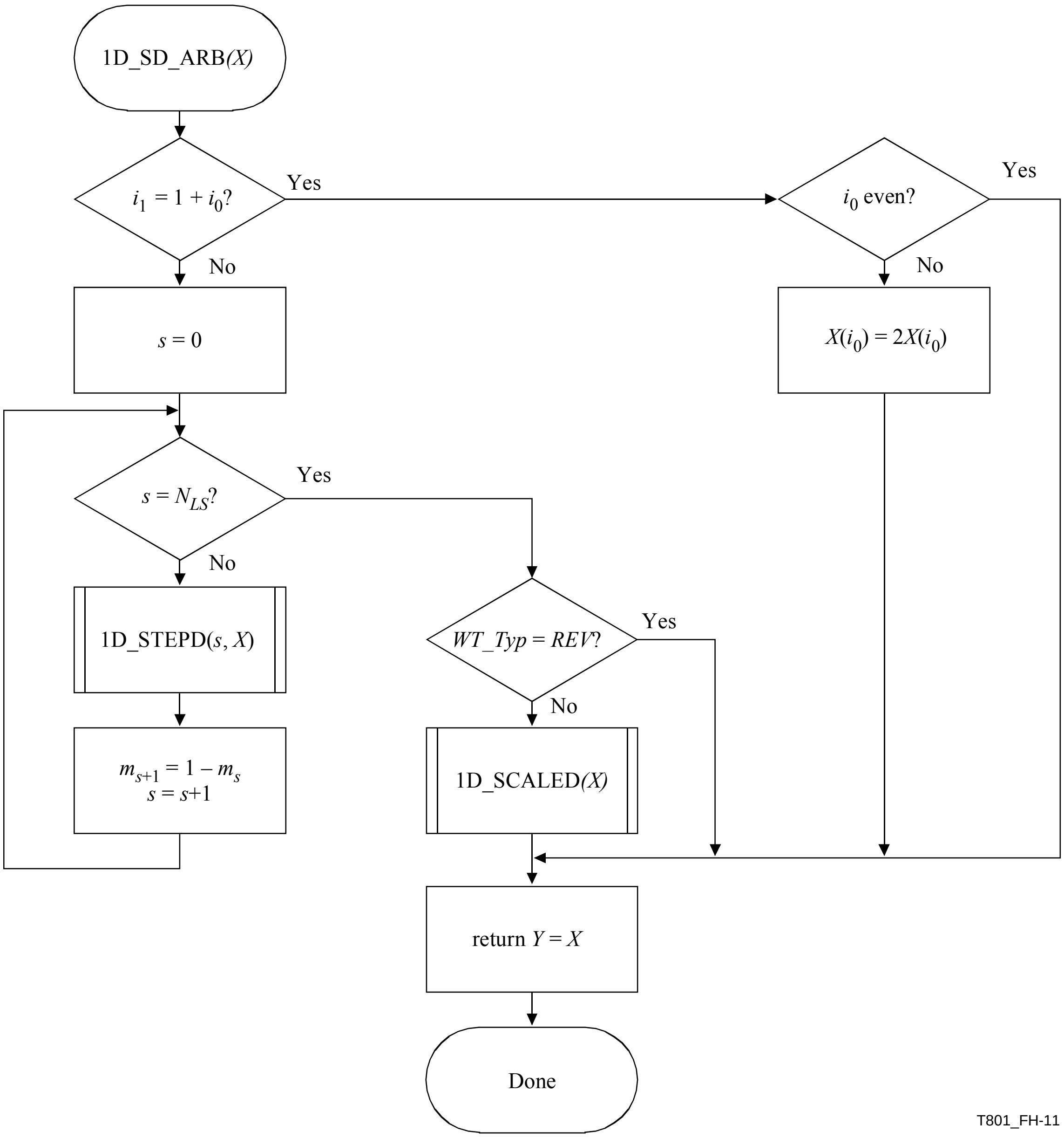


Figure H.11 – Extended procedure 1D_SD_ARB

H.3.2 The 1D_STEPD procedure (informative)

As shown in Figure H.12, procedure 1D_STEPD applies one decomposition lifting step to input vector V and produces an updated version of vector V with the same indices (i_0, i_1).

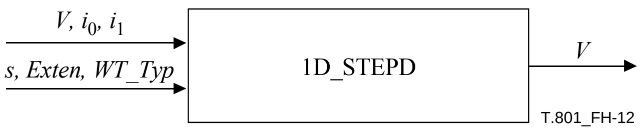


Figure H.12 – Parameters of the 1D_STEPD procedure

Procedure 1D_STEPD applies an extension procedure, determined by the *Exten* parameter, to the input, V. This is followed by a decomposition update filtering procedure, determined by the *WT_Typ* parameter, as seen in Figure H.13. Only one of the two subsequences of V (the even- or the odd-indexed subsequence) is updated on each pass through 1D_STEPD.

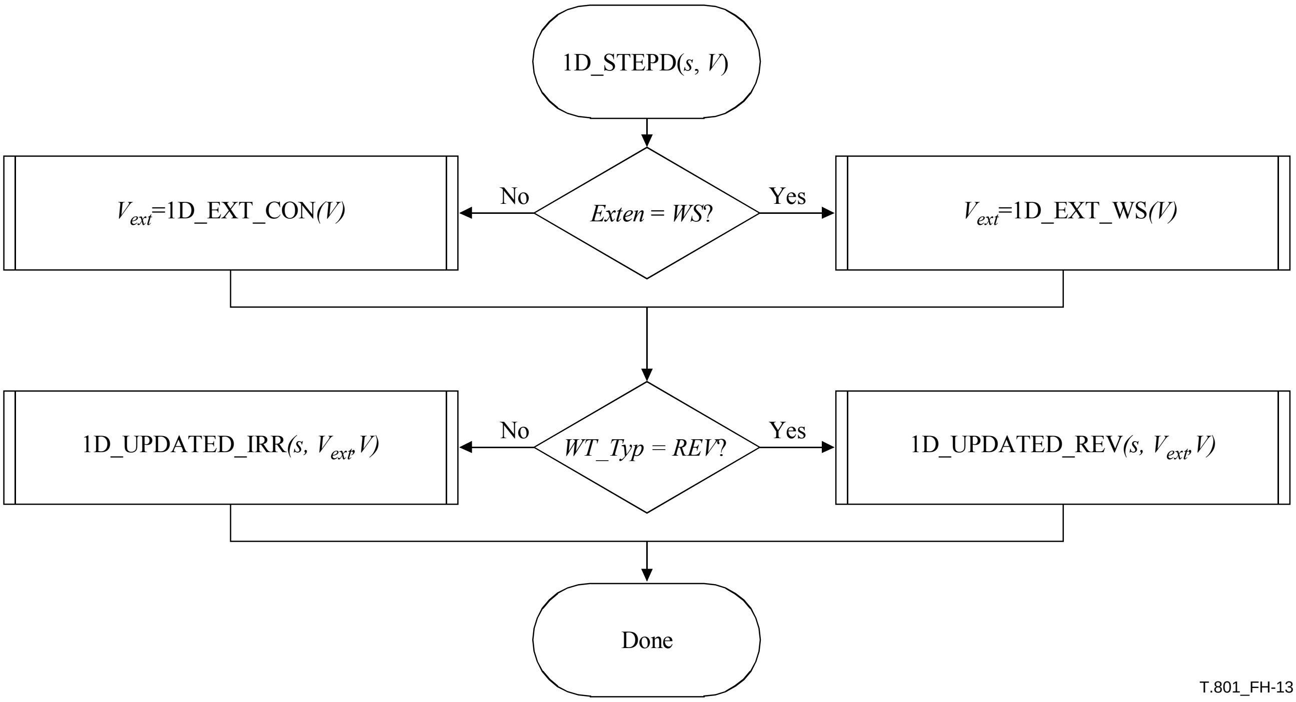


Figure H.13 – Procedure 1D_STEPD

H.3.3 Extension procedures (informative)

The extension procedures 1D_EXT_CON and 1D_EXT_WS shown in Figure H.13 are identical to the procedures specified in H.2.4, including the specifications of minimum extension lengths.

H.3.4 One-dimensional decomposition update procedures (informative)

Two decomposition update filtering procedures are defined, one for reversible transformations (1D_UPDATED_REV) and one for irreversible transformations (1D_UPDATED_IRR). Decomposition steps are defined recursively as even-subsequence updates $(m_s = 0)$ or odd-subsequence updates $(m_s = 1)$. Both procedures take as input a vector V and produce as output an updated version of vector V with the same indices (i_0, i_1).

H.3.4.1 Reversible one-dimensional decomposition update (1D_UPDATED_REV) procedure (informative)

Procedure 1D_UPDATED_REV modifies either the even- or the odd-indexed subsequence in vector V by a weighted sum of samples from the extended sequence, V_{ext}, after applying a rounding operation to the weighted sum. Figure H.14 shows the input parameters to procedure 1D_UPDATED_REV.

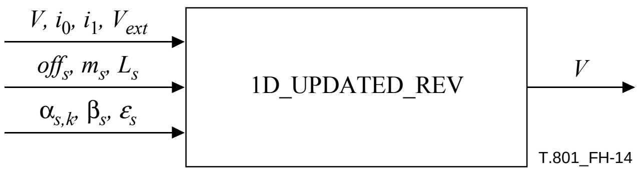


Figure H.14 – Parameters of the 1D_UPDATED_REV procedure

The 1D_UPDATED_REV procedure performs the following update filtering operation:

$$V(2n+m_s) = V(2n+m_s) + \left\lfloor \frac{\left(\sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot V_{ext}(2n+1-m_s+2(k+\mathit{off}_s)) \right) + \beta_s}{2^{\varepsilon_s}} \right\rfloor \qquad \text{(H-5)}$$

for all n such that $i_0 \le 2n + m_s < i_1$.

H.3.4.2 Irreversible one-dimensional decomposition update (1D_UPDATED_IRR) procedure (informative)

Procedure 1D_UPDATED_IRR modifies either the even- or the odd-indexed subsequence in vector V by a weighted sum of samples from the extended sequence, V_{ext}. Figure H.15 shows the input parameters to procedure 1D_UPDATED_IRR.

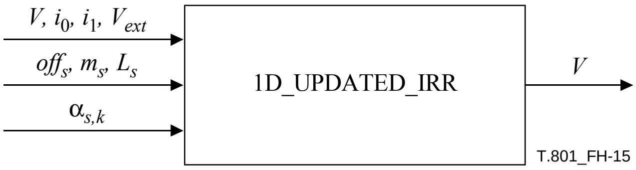


Figure H.15 – Parameters of the 1D_UPDATED_IRR procedure

The 1D_UPDATED_IRR procedure performs the following update filtering operation:

$$V(2n+m_s) = V(2n+m_s) + \sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot V_{ext}(2n+1-m_s+2(k+\mathit{off}_s)) \qquad \text{(H-6)}$$

for all n such that $i_0 \le 2n + m_s < i_1$.

H.3.5 1D_SCALED procedure (informative)

As shown in Figure H.16, procedure 1D_SCALED applies a scaling procedure to interleaved input vector V using signalled parameter K from Table H.1 and produces an updated version of vector V with the same indices (i_0, i_1). This procedure is used only in irreversible transformations.

Figure H.16 – Parameters of the 1D_SCALED procedure

The 1D_SCALED procedure performs the following scaling operations:

$$V(2n) = (1/K) \cdot V(2n) \qquad \text{for } i_0 \le 2n < i_1 \qquad \text{(H-7)}$$

$$\text{and} \qquad V(2n+1) = K \cdot V(2n+1) \qquad \text{for } i_0 \le 2n+1 < i_1 \qquad \text{(H-8)}$$

H.4 Examples of ARB wavelet transformations (informative)

Examples of optional wavelet transformations are specified in terms of their signalled parameters, as listed in Tables G.1 and H.1. Parameters that occur in sequences (e.g., L_s, $s = 0, \ldots, N_{LS} - 1$) are enumerated in order of increasing index. The suggested ATK marker segment index values are informative only, and decoders must verify whether codestreams containing ATK marker segments indexed with these values actually contain the example wavelet transformations specified below.

H.4.1 Examples of arbitrary wavelet transformations (Filt_Cat = ARB) (informative)

All of the example wavelet transformations presented in this subclause are based on linear phase wavelet transformations of the type known as "half-sample symmetric." The equivalent convolutional filters have even-length impulse responses, with symmetric lowpass impulse responses and antisymmetric highpass impulse responses.

H.4.1.1 Reversible ARB wavelet transformations (WT_Typ = REV) (informative)

H.4.1.1.1 The reversible Haar 2-2 wavelet transformation (informative)

Table H.4 – Parameters of the reversible Haar 2-2 wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 1111 1111
m_{init}	0
N_{LS}	2
L_s	1, 1
$\alpha_{s,k}$	$\alpha_{0,0} = -1$ $\alpha_{1,0} = 1$
ε_s	0, 1
β_s	0, 1
Exten	CON
off_s	0, 0

H.4.1.1.2 Reversible 2-6 wavelet transformation (informative)

Table H.5 – Parameters of the reversible 2-6 wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 1111 1110
m_{init}	1
N_{LS}	3
L_s	1, 1, 3
$\alpha_{s,k}$	$\alpha_{0,0} = -1$ $\alpha_{1,0} = 1$ $\alpha_{2,k} = 1, 0, -1$
ε_s	0, 1, 2
β_s	0, 1, 2
Exten	CON
off_s	0, 0, –1

H.4.1.1.3 Reversible 2-10 wavelet transformation (informative)

Table H.6 – Parameters of the reversible 2-10 wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 1111 1101
m_{init}	1
N_{LS}	3
L_s	1, 1, 5
$\alpha_{s,k}$	$\alpha_{0,0} = -1$ $\alpha_{1,0} = 1$ $\alpha_{2,k} = -3, 22, 0, -22, 3$
ε_s	0, 1, 6
β_s	0, 1, 32
Exten	CON
off_s	0, 0, –2

H.4.1.2 Irreversible ARB wavelet transformations (WT_Typ=IRR) (informative)

H.4.1.2.1 Irreversible 6-10 wavelet transformation (informative)

Table H.7 – Parameters of the irreversible 6-10 wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 1111 1011
m_{init}	1
N_{LS}	7
L_s	1, 1, 2, 1, 2, 1, 3
$\alpha_{s,k}$	$\alpha_{0,0} = -1$ $\alpha_{1,0} = 1{,}586\ 134\ 342\ 06$ $\alpha_{2,k} = -0{,}460\ 348\ 209\ 828, 0{,}460\ 348\ 209\ 828$ $\alpha_{3,0} = 0{,}25$ $\alpha_{4,k} = 0{,}374\ 213\ 867\ 768, -0{,}374\ 213\ 867\ 768$ $\alpha_{5,k} = -1{,}336\ 134\ 342\ 06$ $\alpha_{6,k} = 0{,}293\ 067\ 171\ 03, 0, -0{,}293\ 067\ 171\ 03$
K	1
Exten	WS
off_s	0, 0, 0, –1, 0, 0, –1

H.4.1.2.2 Irreversible 10-18 wavelet transformation (informative)

Table H.8 – Parameters of the irreversible 10-18 wavelet transformation

Parameter	Value(s)
Suggested ATK marker segment index	Binary: 1111 1010
m_{init}	1
N_{LS}	11
L_s	1, 1, 2, 1, 2, 1, 2, 1, 2, 1, 5
$\alpha_{s,k}$	$\alpha_{0,0}$ = –1 $\alpha_{1,0}$ = 0,997 150 691 05 $\alpha_{2,k}$ = –1,005 731 278 27, 1,005 731 278 27 $\alpha_{3,0}$ = –0,270 403 576 31 $\alpha_{4,k}$ = 2,205 099 723 43, –2,205 099 723 43 $\alpha_{5,0}$ = 0,080 599 957 36 $\alpha_{6,k}$ = –1,626 825 323 50, 1,626 825 323 50 $\alpha_{7,0}$ = 0,520 403 576 31 $\alpha_{8,k}$ = 0,604 046 642 50, –0,604 046 642 50 $\alpha_{9,0}$ = –0,827 750 648 41 $\alpha_{10,k}$ = –0,066 158 129 64, 0,294 021 377 20 0, –0,294 021 377 20 , 0,066 158 129 64
K	1
Exten	WS
off_s	0, 0, 0, –1, 0, 0, 0, –1, 0, 0, –2

H.4.2 Example of a structure for lifting implementation of half-sample symmetric wavelet transformations (informative)

The lifting steps given in Figure H.17 guarantee that the filters implemented are half-sample symmetric. The parameters $\alpha_{s,k}$ used in Figure H.17 are different from those used in all other sections. The function $R(x)$ is either the identity $R(x) = x$ (for irreversible transformations) or $R(x) = \left\lceil \frac{x+\beta_s}{2^{\varepsilon_s}} \right\rceil$ for reversible transformations.

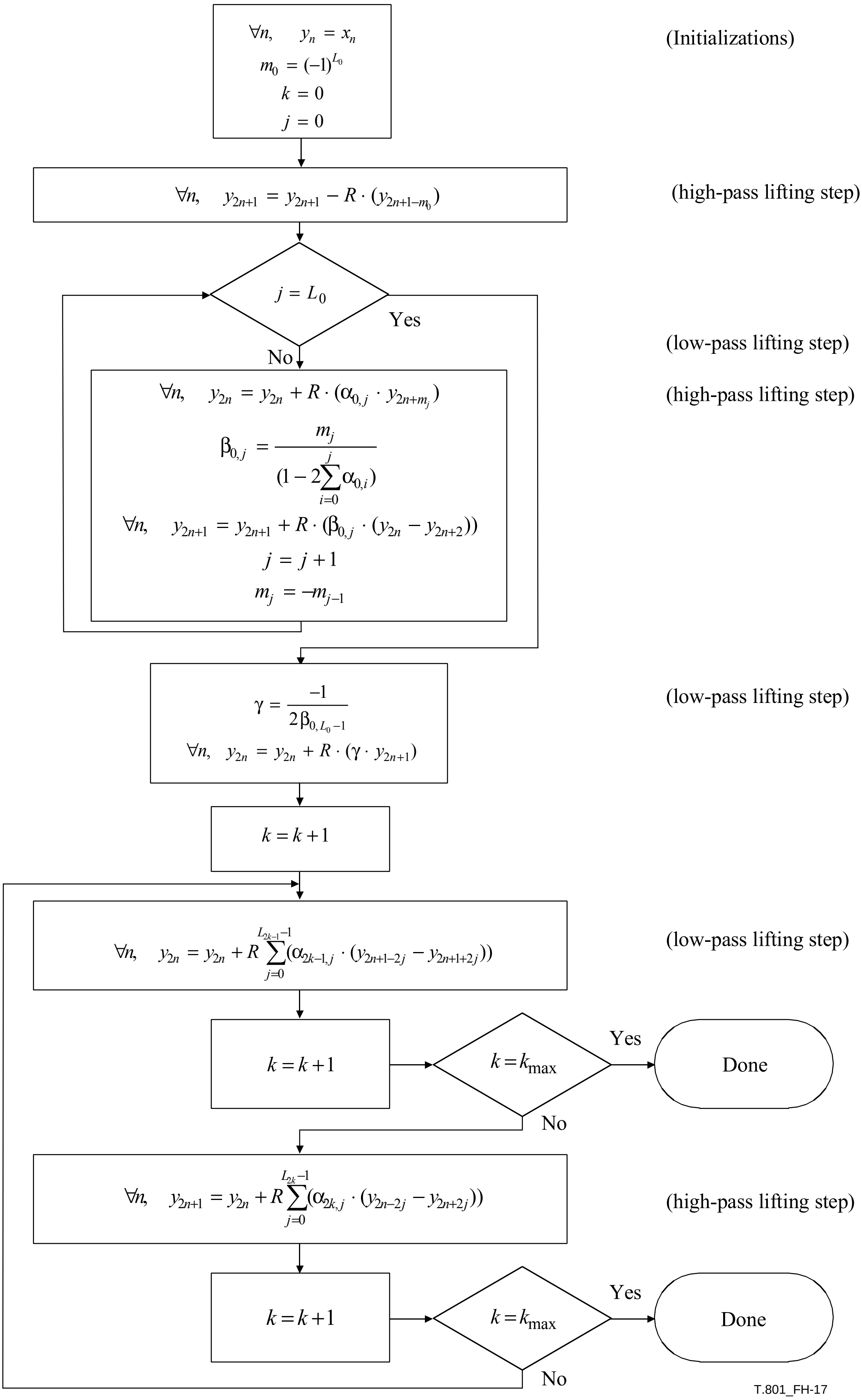


Figure H.17 – Lifting implementation for forward half-sample symmetric wavelet transformations

Annex I

Single sample overlap discrete wavelet transform, extensions

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 as well as an extension to Annex G that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

I.1 Introduction to single sample overlapping

This annex specifies three possible extensions.

The code-block anchor point (CBAP) extensions concern the partitioning of sub-bands into code-blocks, and enable memory-efficient implementations of the DWT, as well as memory-efficient geometric manipulations of compressed image data (90°, 180° and 270° rotations, and mirror operations).

The single sample overlap (SSO) extension (see I.3.1 and I.3.2) concerns the independent application of the discrete wavelet transformation to blocks of samples which overlap by one row and one column, which enables a low-memory block-based implementation of the discrete wavelet transformations, both forward and inverse.

The tile single sample overlap (TSSO) extension (see I.3.1 and I.3.2) concerns the partitioning of images into image tiles which overlap by one row and one column of samples.

I.2 The code-block anchor points (CBAP) extension

The parameters z_x and z_y are signalled in the Scod marker parameter (see A.2.3). If they are both equal to zero, then no modification need be made to ITU-T Rec. T.800 | ISO/IEC 15444-1. If either of z_x and z_y is equal to 1, then the following modifications to annexes of ITU-T Rec. T.800 | ISO/IEC 15444-1 need to be made.

I.2.1 Division of resolution levels in precincts

This subclause replaces ITU-T Rec. T.800 | ISO/IEC 15444-1, B.6.

Consider a particular tile-component and resolution level whose bounding sample coordinates in the reduced resolution image domain are (trx_0, try_0) and (trx_1–1, try_1–1), as already described. Figure I.1 shows the partitioning of this tile-component resolution level into precincts. The precinct is anchored at location (z_x, z_y), so that the upper left hand corner of any given precinct in the partition is located at ($z_x + m \cdot 2^{PPx}$, z_y + n $\cdot\ 2^{PPy}$) where *m* and *n* are integers, and *PPx* and *PPy* are signalled in the COD or COC marker segments (see ITU-T Rec. T.800 | ISO/IEC 15444-1, A.6.1 and A.6.2). *PPx* and *PPy* may be different for each tile-component and resolution level. *PPx* and *PPy* must be at least 1 for all resolution levels except *r* = 0 where they are allowed to be zero.

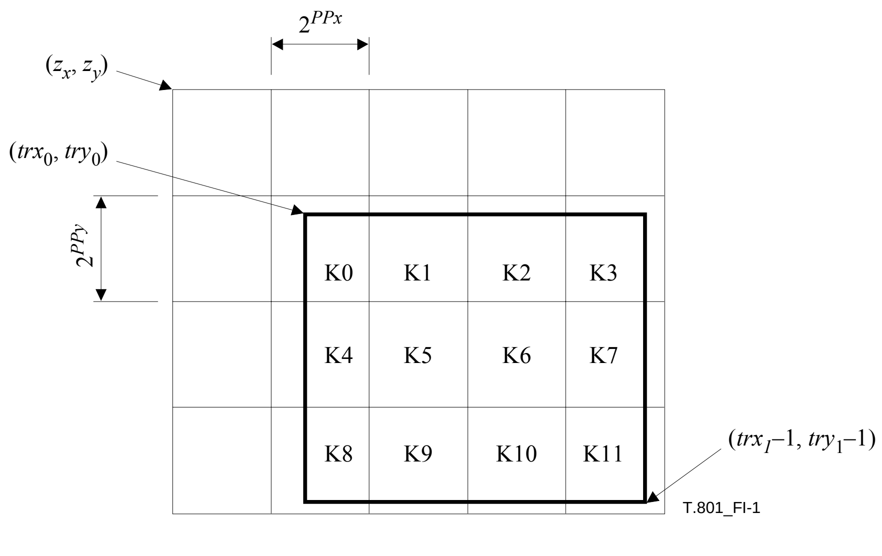


Figure I.1 – Precincts of one reduced resolution (modified Figure B.8 of ITU-T Rec. T.800 | ISO/IEC 15444-1)

The number of precincts which span the tile-component at resolution level, *r*, is given by

$$numprecinctswide = \begin{cases} \left\lceil \frac{trx_1 - z_x}{2^{PPx}} \right\rceil - \left\lfloor \frac{trx_0 - z_x}{2^{PPx}} \right\rfloor & trx_1 > trx_0 \\ 0, & \text{otherwise} \end{cases} \quad \text{(I-1)}$$

$$numprecinctshigh = \begin{cases} \left\lceil \frac{try_1 - z_y}{2^{PPy}} \right\rceil - \left\lfloor \frac{try_0 - z_y}{2^{PPy}} \right\rfloor & try_1 > try_0 \\ 0 & \text{otherwise} \end{cases} \quad \text{(I-2)}$$

Even if Equations I-1 and I-2 indicate that both *numprecinctswide* and *numprecinctshigh* are nonzero, some, or all, precincts may still be empty as explained below. The precinct index runs from 0 to *numprecincts* – 1 where *numprecincts* = *numprecinctswide* * *numprecinctshigh* in raster order (see Figure I.1). This index is used in determining the order of appearance, in the codestream, of packets corresponding to each precinct, as explained in ITU-T Rec. T.800 | ISO/IEC 15444-1, B.12.

Let (px_0, py_0) and ($px_1 - 1$, $py_1 - 1$) be the upper-left and lower-right corners of a precinct from resolution *r* as shown in Figure I.1. This precinct maps into the three sub-bands $(N_L - r + 1)HL$, $(N_L - r + 1)LH$ and $(N_L - r + 1)HH$ with upper-left and lower-right corners (px_0, py_0) and ($pbx_1 - 1$, $pby_1 - 1$) where:

$$pbx_0 = \left\lceil \frac{px_0 - xo_b}{2} \right\rceil + (1 - xo_b)z_x \quad \text{(I-3)}$$

$$pby_0 = \left\lceil \frac{py_0 - yo_b}{2} \right\rceil + (1 - yo_b)z_y \quad \text{(I-4)}$$

$$pbx_1 = \left\lceil \frac{px_1 - xo_b}{2} \right\rceil + (1 - xo_b)z_x \quad \text{(I-5)}$$

$$pby_1 = \left\lceil \frac{py1 - yo_b}{2} \right\rceil + (1 - yo_b)z_y \quad \text{(I-6)}$$

where xo_b and yo_b are given in ITU-T Rec. T.800 | ISO/IEC 15444-1, Table B.1.

It can happen that a precinct is empty, meaning that no sub-band coefficients from the relevant resolution level actually contribute to the precinct. This can occur, for example, at the lower right of a tile-component due to sampling with respect to the reference grid. When this happens, every packet corresponding to that precinct must still appear in the codestream (see ITU-T Rec. T.800 | ISO/IEC 15444-1, B.9).

I.2.2 Division of the sub-bands into codeblocks

This subclause modifies ITU-T Rec. T.800 | ISO/IEC 15444-1, B.7.

The following two sentences concerning the code-block partition should replace the ones present in ITU-T Rec. T.800 | ISO/IEC 15444-1, B.7, following Equation B-19.

Like the precinct, the code-block partition is anchored at (z_x, z_y), as illustrated in ITU-T Rec. T.800 | ISO/IEC 15444-1, Figure I.2. Thus, all first rows of code-blocks in the code-block partition are located at $y = z_y + m \cdot 2^{ycb'}$ and all first columns of code-blocks are located at $x = z_x + n \cdot 2^{xcb'}$, where *m* and *n* are integers.

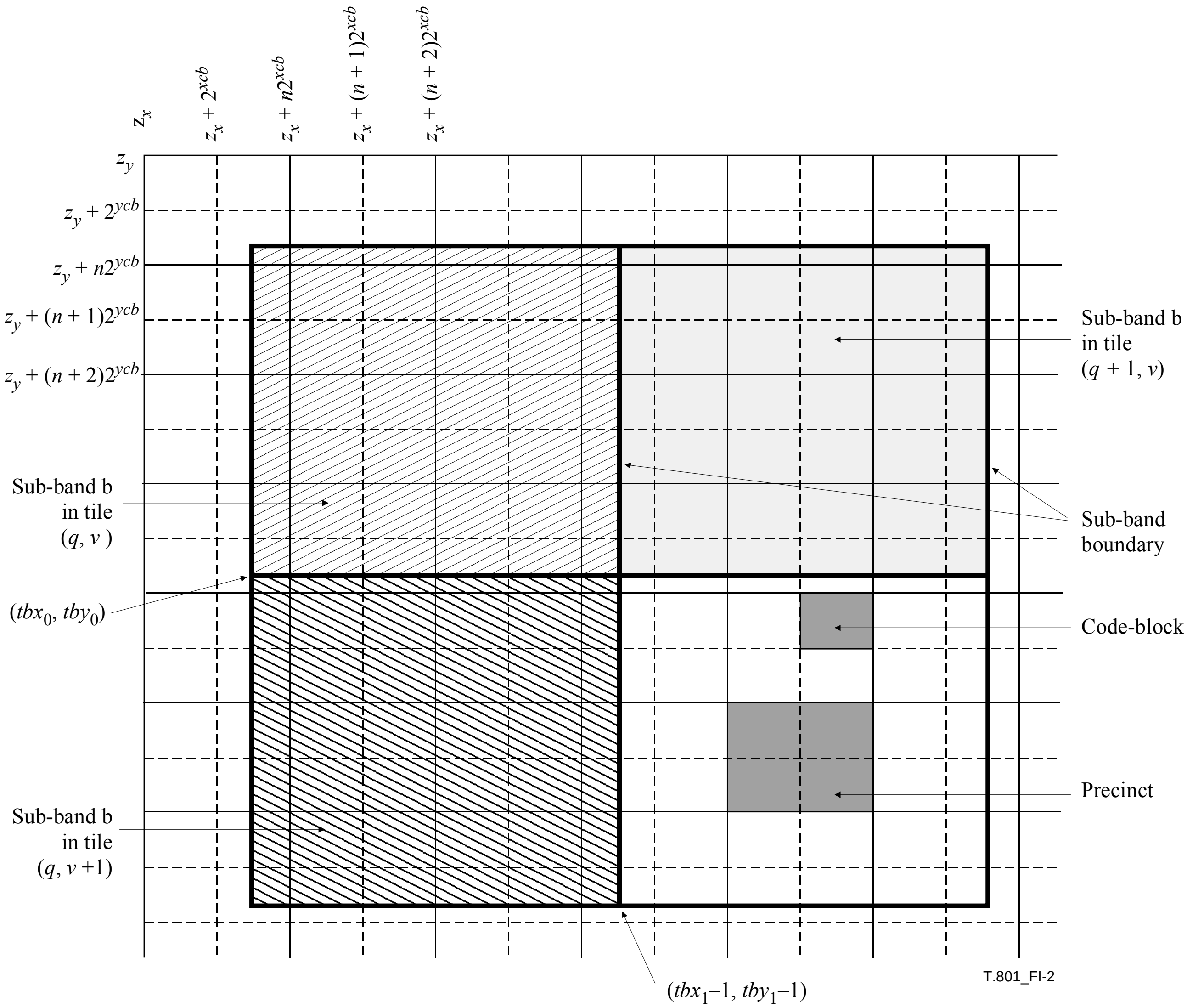


Figure I.2 – Codeblocks and precincts in sub-band *b* from four different tiles

I.2.3 Resolution level-position-component-layer progression

This subclause replaces ITU-T Rec. T.800 | ISO/IEC 15444-1, B.12.1.3.

Resolution level-position-component-layer progression is defined as the interleaving of the packets in the following order:

for each $r = 0, \ldots, N_{max}$

for each $y = ty_0, \ldots, ty_1-1$,

for each $x = tx_0, \ldots, tx_1-1$,

for each $i = 0, \ldots,$ Csiz–1

if $((y - z_y)$ divisible by $YRsiz(i) \cdot 2^{PPy(r,\, i) + N_L(i) - r})$ OR $((y = ty_0)$ AND $((try_0 - z_y) \cdot 2^{N_L(i) - r}$ NOT divisible by $2^{PPy(r,\, i) + N_L(i) - r}))$

if $((x - z_x)$ divisible by $XRsiz(i) \cdot 2^{PPx(r,\, i) + N_L(i) - r})$ OR $((x = tx_0)$ AND $((trx_0 - z_x) \cdot 2^{N_L(i) - r}$ NOT divisible by $2^{PPx(r,\, i) + N_L(i) - r}))$

for the next precinct, k, if one exists,

for each $l = 0, \ldots, L-1$

packet for component i, resolution level r, layer l, and precinct k.

In the above, k can be obtained from:

$$k = \left\lfloor \frac{\left\lceil \frac{x - z_x}{XRsiz(i) \cdot 2^{N_L - 1}} \right\rceil}{2^{PPx(r,\, i)}} \right\rfloor - \left\lfloor \frac{trx_0 - z_x}{2^{PPx(r,\, i)}} \right\rfloor + numprecinctswide(r,\, i) \cdot \left(\left\lfloor \frac{\left\lceil \frac{y - z_y}{YRsiz(i) \cdot 2^{N_L - 1}} \right\rceil}{2^{PPy(r,\, i)}} \right\rfloor - \left\lfloor \frac{try_0 - z_y}{2^{PPy(r,\, i)}} \right\rfloor \right) \qquad \text{(I-7)}$$

I.2.4 Position-component-resolution level-layer progression

This subclause replaces ITU-T Rec. T.800 | ISO/IEC 15444-1, B.12.1.4.

Position-component-resolution level-layer progression is defined as the interleaving of the packets in the following order:

for each $y = ty_0, \ldots, ty_1-1$,

for each $x = tx_0, \ldots, tx_1-1$,

for each $i = 0, \ldots,$ Csiz–1

for each $r = 0, \ldots, N_L$ where N_L is the number of decomposition levels for component i,

if (($y - z_y$) divisible by $YRsiz(i) \cdot 2^{PPy(r,\, i)+N_L(i)-r}$) OR (($y = ty_0$) AND ($(try_0 - z_y) \cdot 2^{N_L(i)-r}$ NOT divisible by $2^{PPy(r,\, i)+N_L(i)-r}$))

if (($x - z_x$) divisible by $XRsiz(i) \cdot 2^{PPx(r,\, i)+N_L(i)-r}$) OR (($x = tx_0$) AND ($(trx_0 - z_x) \cdot 2^{N_L(i)-r}$ NOT divisible by $2^{PPx(r,\, i)+N_L(i)-r}$))

for the next precinct, k, if one exists, in the sequence shown in Figure I.1

for each $l = 0, \ldots, L-1$

packet for component i, resolution level r, layer l, and precinct k.

In the above, k can be obtained from Equation I-7. To use this progression, *XRsiz* and *YRsiz* values shall be powers of two for each component. A progression of this type might be useful in providing high sample accuracy for a particular spatial location in all components.

I.2.5 Component-position-resolution level-layer progression

This subclause replaces ITU-T Rec. T.800 | ISO/IEC 15444-1, B.12.1.5.

Component-position-resolution level-layer progression is defined as the interleaving of the packets in the following order:

for each $i = 0, \ldots,$ Csiz–1

for each $y = ty_0, \ldots, ty_1-1$,

for each $x = tx_0, \ldots, tx_1-1$,

for each $r = 0, \ldots, N_L$ where N_L is the number of decomposition levels for component i,

if (($y - z_y$) divisible by $YRsiz(i) \cdot 2^{PPy(r,\, i)+N_L(i)-r}$) OR (($y = ty_0$) AND ($(try_0 - z_y) \cdot 2^{N_L(i)-r}$ NOT divisible by $2^{PPy(r,\, i)+N_L(i)-r}$))

if (($x - z_x$) divisible by $XRsiz(i) \cdot 2^{PPx(r,\, i)+N_L(i)-r}$) OR (($x = tx_0$) AND ($(trx_0 - z_x) \cdot 2^{N_L(i)-r}$ NOT divisible by $2^{PPx(r,\, i)+N_L(i)-r}$))

for the next precinct, k, if one exists, in the sequence shown in Figure I.1

for each $l = 0, \ldots, L-1$

packet for component i, resolution level r, layer l, and precinct k.

In the above, k can be obtained from Equation I-7. A progression of this type might be useful in providing high accuracy for a particular spatial location in a particular image component.

I.3 The SSO extension

This subclause applies only if the SSO extension is selected. The selection of the SSO extension is signalled in the extended COD and COC markers (see A.2.3) and is only applicable to WS wavelet transformations (i.e., *Filt_Cat* = *WS*). The parameters relevant to the SSO extension *XC*, *YC* are signalled in the COD and COC extended marker segment.

I.3.1 Single sample overlap inverse discrete wavelet transformation (SSO-IDWT)

The selection of the SSO extension requires a modification of the 1D_FILTR_WS filtering procedure described in G.2.2.2 (the 1D_FILTR_SSO procedure), as well as a modification of the IDWT, 2D_SR, HOR_SR, VER_SR and 1D_SR procedures described in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.3: the IDWT_SSO, 2D_SR_SSO, HOR_SR_SSO, VER_SR_SSO and 1D_SR_SSO procedures. These modifications are specified in this subclause.

I.3.1.1 The IDWT_SSO procedure

The IDWT_SSO procedure (illustrated in Figure I.3) starts with the initialization of the variable *lev* (the current decomposition level) to N_L, of the variable XC_{N_L} to $XC/2^{N_L}$ and of the variable YC_{N_L} to $YC/2^{N_L}$, where *XC* and *YC* are given in the COD/COC marker, in the SSO offset portion. The 2D_SR_SSO procedure (described in I.3.1.2) is performed at every level *lev*, where the level *lev* decreases at each iteration, until iterations are performed. The 2D_SR_SSO procedure is iterated over the *lev*LL, *lev*LX or *lev*XL sub-band produced at each iteration. Finally, the sub-band $a_{0LL}(u_{0LL}, v_{0LL})$ is the output array $I(x, y)$.

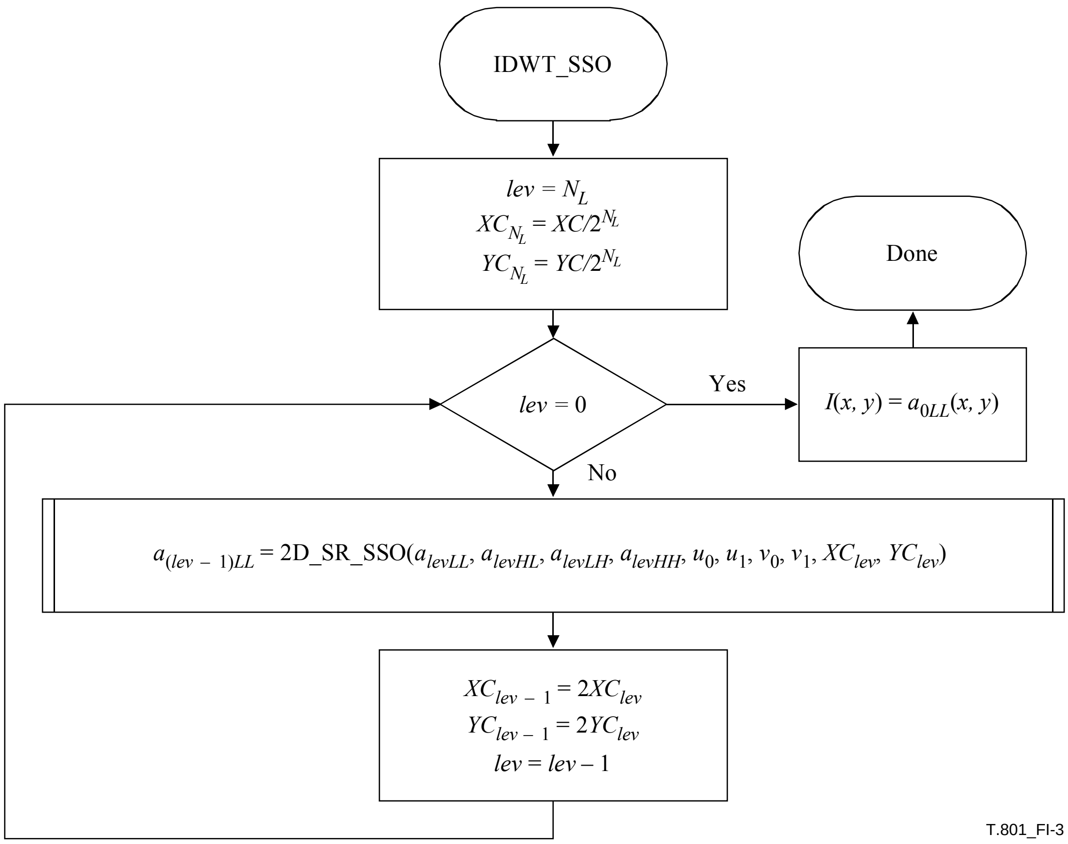


Figure I.3 – The IDWT_SSO Procedure

I.3.1.2 The 2D_SR_SSO Procedure

The 2D_SR_SSO procedure is identical to the 2D_SR procedure described in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.3.2, except for the addition of the parameters XC_{lev}, YC_{lev} (see Figure I.4), which are respectively used by the HOR_SR_SSO and VER_SR_SSO procedures (see I.3.1.3 and I.3.1.4). The 2D_SR_SSO procedure uses the 2D_INTERLEAVE procedure specified in ITU-T Rec. T.800 | ISO/IEC 15444-1.

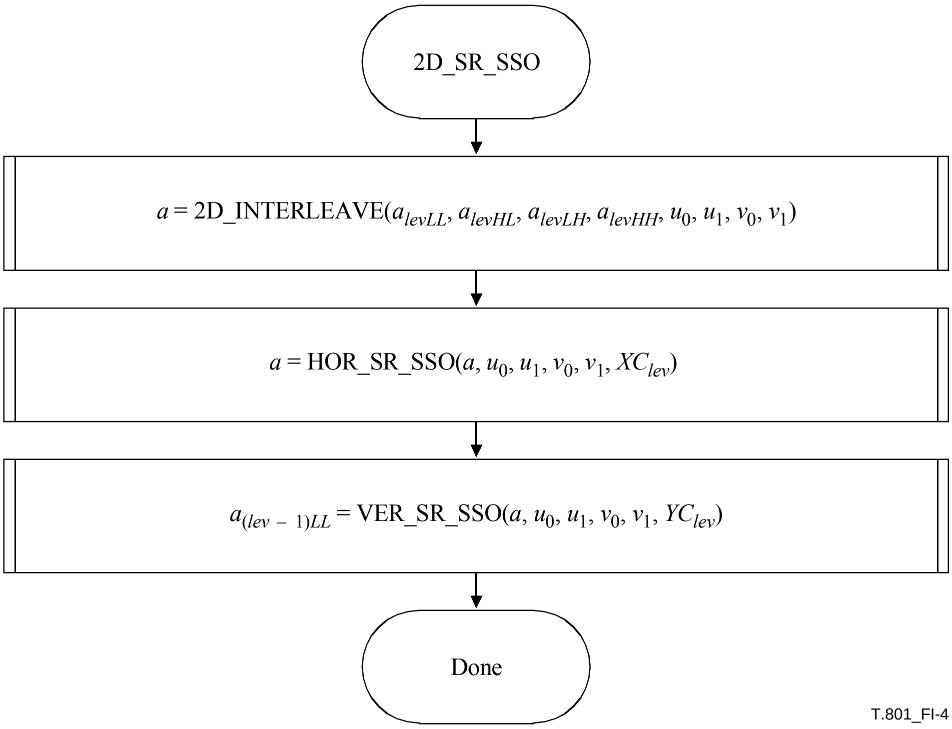


Figure I.4 – The 2D_SR_SSO procedure

I.3.1.3 The HOR_SR_SSO procedure

The HOR_SR_SSO procedure is identical to the HOR_SR procedure described in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.3.4, except for the addition of the parameter *xC*, which is used by the 1D_SR_SSO procedure (see I.3.1.5).

I.3.1.4 The VER_SR_SSO procedure

The VER_SR_SSO procedure is identical to the VER_SR procedure described in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.3.5, except for the addition of the parameter *yC*, which is used by the 1D_SR_SSO procedure (see I.3.1.5).

I.3.1.5 The 1D_SR_SSO procedure

The 1D_SR_SSO procedure is identical to the 1D_SR procedure described in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.3.6, except for the addition of the parameter *dC* (which is an input to the 1D_FILTR_SSO procedure) and the replacement of the 1D_FILTR procedure by the 1D_FILTR_SSO procedure (see I.3.1.6). The parameter *dC* is either the parameter *xC* (if called by the HOR_SR_SSO procedure) or the parameter *yC* (if called by the VER_SR_SSO procedure).

I.3.1.6 The 1D_FILTR_SSO procedure

The 1D_FILTR_SSO procedure is a modification of the 1D_FILTR_WS procedure described in G.2.2.2. The input and output parameters of the 1D_FILTR_SSO procedure are given in Figure I.5.

Figure I.5 – Parameters of the 1D_FILTR_SSO procedure

Let k_0 be defined by:

$$k_0 = \left\lfloor \frac{i_0}{dC} \right\rfloor \tag{I-8}$$

and N_I is defined by:

$$N_I = \left\lceil \frac{i_1 - 1}{dC} \right\rceil - \left\lfloor \frac{i_0}{dC} \right\rfloor \tag{I-9}$$

Subdivide the interval $[i_0, i_1 - 1]$ into the N_I intervals $I_p = [n_p, n_{p+1}]$ ($p = 0, 1, \ldots, N_I - 1$), where n_p is defined by:

$$n_0 = i_0,\ n_{N_I} = i_1 - 1 \text{ and } n_p = (k_0 + p)dC \text{ for } p = 1, \ldots, N_I - 1 \tag{I-10}$$

For an index $i \in I_p$, define the function $PSE_{O,p}(i)$ as:

$$PSE_{O,p}(i) = PSE_O(i, n_p, n_{p+1} + 1) \tag{I-11}$$

where the function $PSE_O(i, i_0, i_1)$ is defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, Equation F-4.

I.3.1.6.1 Reversible transformations

This subclause specifies for reversible transformations the modifications of each lifting step s as specified in Equation G-2. The modification of Equation G-2 ensures that each coefficient $V(2n + m_s)$ is calculated exclusively from coefficients the indices of which belong to the same interval I_p as $2n + m_s$. At each lifting step, all values $V(n_p)$ for $\{n_p | mod(n_p, dC) = 0;\ p = 0, 1, \ldots, N_I\}$ if any, remain unmodified, while all other values $V(2n + m_s)$ (i.e., for which $2n + m_s$ belongs to a single interval I_p) are modified according to Equation I-12:

$$V(2n + m_s) = V(2n + m_s) - \left\lfloor \frac{\left(\sum_{k=0}^{L_s - 1} \alpha_{s,k} \cdot \left(V(PSE_{O,p}(2n + m_s - (2k+1))) + V(PSE_{O,p}(2n + m_s + (2k+1))) \right) \right) + \beta_s}{2^{\varepsilon_s}} \right\rfloor \tag{I-12}$$

I.3.1.6.2 Irreversible transformations

This subclause specifies for irreversible transformations the modifications of each lifting step s as specified in Equation G-6. The scaling steps specified in Equations G-4 and G-5 are not modified. The modification of Equation G-6 ensures that each coefficient $V(2n + m_s)$ is calculated exclusively from coefficients the indices of which belong to the same interval I_p as $2n + m_s$. At each lifting step, all values $V(n_p)$ for $\{n_p | mod(n_p, dC) = 0; p = 0, 1, ... , N_I\}$, if any, are modified according to Equation I-13:

$$V(n_p) = (1/B_s)V(n_p) \tag{I-13}$$

where B_s is defined in Equation G-1, while all other values $V(2n + m_s)$ (i.e., for which $2n + m_s$ belongs to a single interval I_p) are modified according to Equation I-14:

$$V(2n+m_s) = V(2n+m_s) - \left(\sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot (V(PSE_{O,p}(2n+m_s-(2k+1))) + V(PSE_{O,p}(2n+m_s+(2k+1)))) \right) \tag{I-14}$$

I.3.2 Single sample overlap forward discrete wavelet transformation (informative)

The selection of the SSO extension requires a modification of the 1D_FILTD_WS filtering procedure described in G.3.2 (the 1D_FILTD_SSO procedure), as well as a modification of the FDWT, 2D_SD, HOR_SD, VER_SD and 1D_SD procedures specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.4 (the FDWT_SSO, 2D_SD_SSO, HOR_SD_SSO, VER_SD_SSO and 1D_SD_SSO). These modified procedures are specified in this subclause.

I.3.2.1 The FDWT_SSO procedure

The FDWT_SSO procedure (illustrated in Figure I.6) starts with the initialization of the variable *lev* (the current decomposition level) to 1, of the variable XC_1 to XC and of the variable YC_1 to YC, where XC and YC are given in the COD/COC marker (see Table A.9). The 2D_SD_SSO procedure (described in I.3.1) is performed at every level *lev*, where the level *lev* increases at each iteration, until N_L iterations are performed.

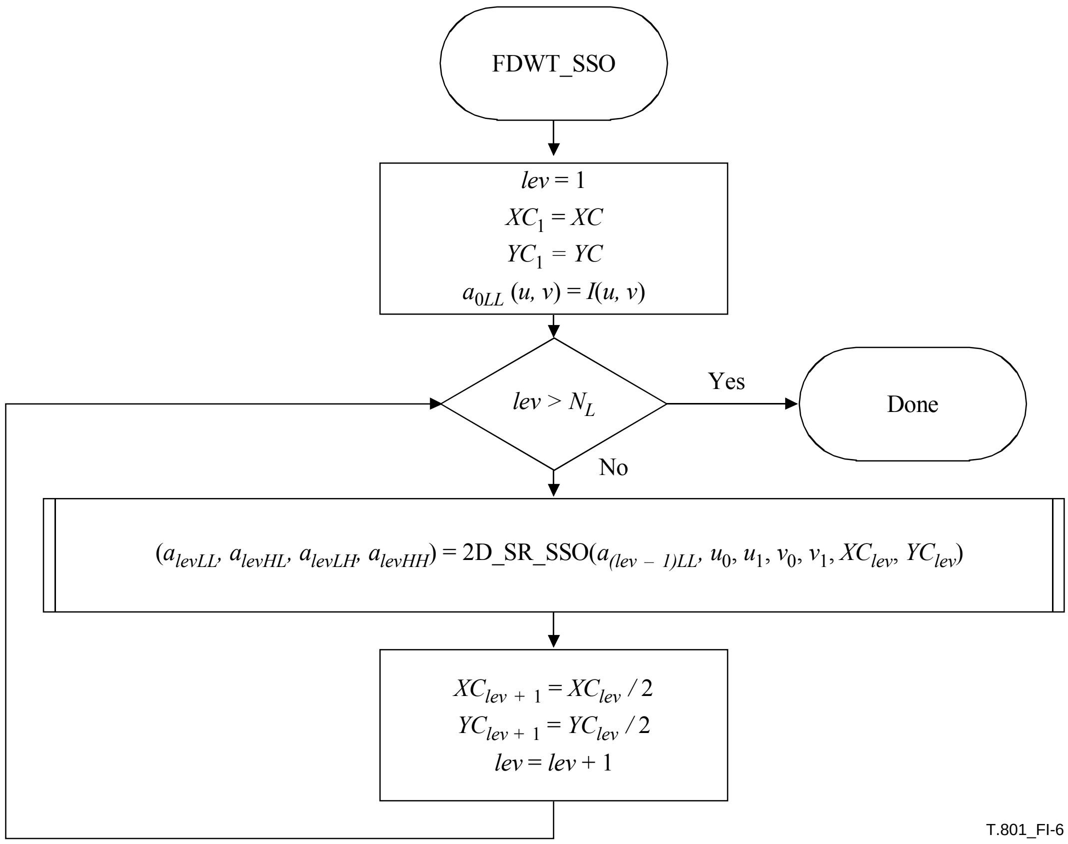


Figure I.6 – The FDWT_SSO procedure

I.3.2.2 The 2D_SD_SSO procedure

The 2D_SD_SSO procedure is identical to 2D_SD procedure specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.4.2, except for the addition of the parameters XC_{lev}, YC_{lev} (see Figure I.7), which are respectively used by the HOR_SD_SSO and VER_SD_SSO procedures (see I.3.2.3 and I.3.2.4).

I.3.2.3 The HOR_SD_SSO procedure

The HOR_SD_SSO procedure is identical to the HOR_SD procedure specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.4.4, except for the addition of the parameter *xC*, which is used by the 1D_SD_SSO procedure (see I.3.1).

I.3.2.4 The VER_SD_SSO procedure

The VER_SD_SSO procedure is identical to the VER_SD procedure specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.4.3, except for the addition of the parameter *yC*, which is used by the 1D_SD_SSO procedure (see I.3.1).

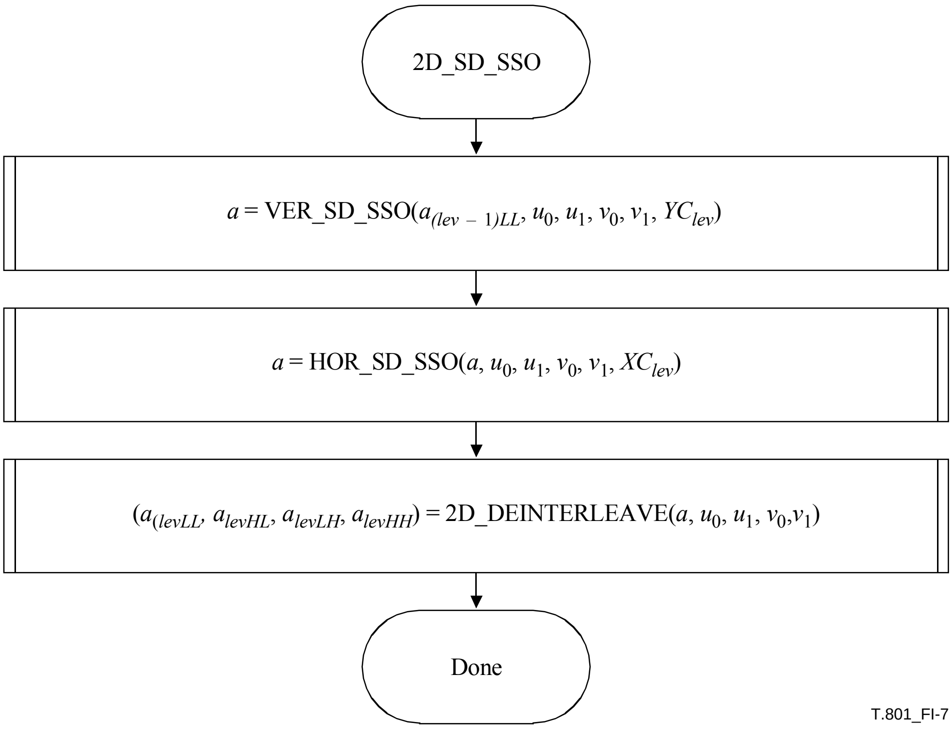


Figure I.7 – The 2D_SD_SSO procedure

I.3.2.5 The 1D_SD_SSO procedure

The 1D_SD_SSO procedure is identical to the 1D_SD procedure specified in ITU-T Rec. T.800 | ISO/IEC 15444-1, F.4.6, except for the addition of the parameter *dC* (which is an input to the 1D_FILTD_SSO procedure) and the replacement of the 1D_FILTD_WS procedure by the 1D_FILTD_SSO procedure (see I.3.2.6). The parameter *dC* is either the parameter *xC* (if called by the HOR_SD_SSO procedure) or the parameter *yC* (if called by the VER_SD_SSO procedure).

I.3.2.6 The 1D_FILTD_SSO procedure

The 1D_FILTD_SSO procedure is a modification of the 1D_FILTD_WS procedure described in G.2.2.2. The input and output parameters of the 1D_FILTD_SSO procedure are given in Figure I.8.

I.3.2.6.1 Reversible transformations

This subclause specifies for reversible transformations the modifications of each lifting step s as specified in Equation G-8. The modification of Equation G-8 ensures that each coefficient $V(2n + m_s)$ is calculated exclusively from coefficients the indices of which belong to the same interval I_p as $2n + m_s$. As a consequence, at each lifting step, all values $V(n_p)$ for $\{n_p|mod(n_p, dC) = 0; p = 0, 1, ... , N_I\}$, if any, remain unmodified, while all other values $V(2n + m_s)$ (i.e., for which $2n + m_s$ belongs to a unique interval I_p) are modified according to Equation I-15:

$$V(2n+m_s) = V(2n+m_s) + \left\lfloor \frac{\left(\sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot (V(PSE_{O,p}(2n+m_s-(2k+1))) + V(PSE_{O,p}(2n+m_s+(2k+1)))) \right) + \beta_s}{2^{\varepsilon_s}} \right\rfloor \quad \text{(I-15)}$$

I.3.2.6.2 Irreversible transformations

This subclause specifies for irreversible transformations the modifications of each lifting step s as specified in Equation G-9. The modification of Equation G-9 ensures that each coefficient $V(2n + m_s)$ is calculated exclusively from coefficients the indices of which belong to the same interval I_p as $2n + m_s$. At each lifting step, all values $V(n_p)$ for $\{n_p|mod(n_p, dC) = 0; p = 0, 1, ... , N_I\}$, if any, are modified according to Equation I-16:

$$V(n_p) = B_s V(n_p) \quad \text{(I-16)}$$

where B_s is defined in Equation G-1, while all other values $V(2n + m_s)$ (i.e., for which $2n + m_s$ belongs to a single interval I_p) are modified according to Equation I-17:

$$V(2n+m_s) = V(2n+m_s) + \left(\sum_{k=0}^{L_s-1} \alpha_{s,k} \cdot (V(PSE_{O,p}(2n+m_s-(2k+1))) + V(PSE_{O,p}(2n+m_s+(2k+1)))) \right) \quad \text{(I-17)}$$

The scaling steps specified in Equations G-10 and G-11 are not modified.

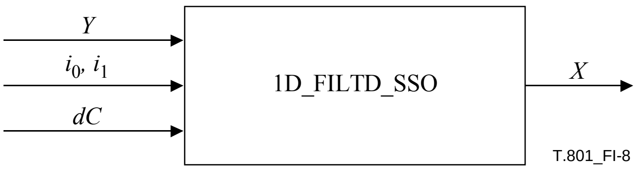


Figure I.8 – Parameters of the 1D_FILTD_SSO procedure

I.3.3 Selection of single sample overlap parameters (informative)

The selection of the SSO extension enables a low-memory block-based implementation of the wavelet transformations, both forward and inverse: for example, the forward transformation may be applied independently to SSO blocks of samples extracted from the image tile component. The parameters relevant to the selection of the SSO extension are: XC, YC, z_x and z_y (see I.2.2).

I.3.3.1 Division of image tile components into overlapping SSO blocks (informative)

SSO blocks are of width $XC + 1$ and height $YC + 1$ in the image tile component domain. The first and last row of a SSO block are always located at multiples of YC, while the first and last column of a SSO block are always located at multiples of XC (see Figure H.7). Two neighbouring SSO blocks overlap by either one row of samples (vertical neighbours), one column of samples (horizontal neighbours), or just one sample (diagonal neighbours).

I.3.3.2 Selection of tile parameters (informative)

To maximize coding efficiency, the following selection of tile parameters is recommended: mod($XTsiz$, XC) = 0 and mod($YTsiz$, YC) = 0.

To maximize memory efficiency, the following selection of encoding parameters is recommended: $XTOsiz = z_x$, $YTOsiz = z_y$.

I.3.4 SSO examples (informative)

I.3.4.1 Illustration in the case of the 5-3 forward reversible transformation (informative)

The first lifting step is:

$$V_{ext}(2n+1) = V_{ext}(2n+1) - \left\lfloor \frac{V_{ext}(2n) + V_{ext}(2n+2)}{2} \right\rfloor \text{ for } i_0 < 2n+1 < i_1 - 1 \qquad \text{(I-18)}$$

$$V_{ext}(2n+1) = V_{ext}(2n+1) - V_{ext}(2n+2) \text{ for } 2n+1 = i_0 \qquad \text{(I-19)}$$

$$\text{and } V_{ext}(2n+1) = V_{ext}(2n+1) - V_{ext}(2n) \text{ for } 2n+1 = i_1 - 1 \qquad \text{(I-20)}$$

The second lifting step is:

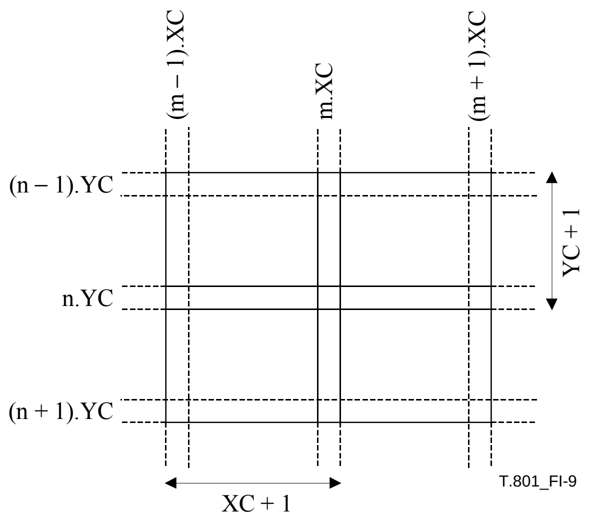


Figure I.9 – Position of SSO blocks

$$V_{ext}(2n) = V_{ext}(2n) + \left\lfloor \frac{V_{ext}(2n-1) + V_{ext}(2n+1) + 2}{4} \right\rfloor \text{ for } i_0 < 2n < i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \qquad \text{(I-21)}$$

$$V_{ext}(2n) = V_{ext}(2n) + \left\lfloor \frac{V_{ext}(2n+1) + 1}{2} \right\rfloor \text{ for } 2n = i_0 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \qquad \text{(I-22)}$$

$$V_{ext}(2n) = V_{ext}(2n) + \left\lfloor \frac{V_{ext}(2n-1) + 1}{2} \right\rfloor \text{ for } 2n = i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \qquad \text{(I-23)}$$

$$\text{and } V_{ext}(2n) = V_{ext}(2n) \text{ for } \mathrm{mod}(2n, dC) = 0 \qquad \text{(I-24)}$$

I.3.4.2 Illustration in the case of the 5-3 forward irreversible transformation (informative)

The first lifting step is:

$$V_{ext}(2n+1) = V_{ext}(2n+1) - \left(\frac{V_{ext}(2n) + V_{ext}(2n+2)}{2}\right) \text{ for } i_0 < 2n+1 < i_1 - 1 \quad \text{(I-25)}$$

$$V_{ext}(2n+1) = V_{ext}(2n+1) - V_{ext}(2n+2) \text{ for } 2n+1 = i_0 \quad \text{(I-26)}$$

$$\text{and } V_{ext}(2n+1) = V_{ext}(2n+1) - V_{ext}(2n) \text{ for } 2n+1 = i_1 - 1 \quad \text{(I-27)}$$

The second lifting step is:

$$V_{ext}(2n) = V_{ext}(2n) + \left(\frac{V_{ext}(2n-1) + V_{ext}(2n+1)}{4}\right) \text{ for } i_0 < 2n < i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-28)}$$

$$V_{ext}(2n) = V_{ext}(2n) + \frac{V_{ext}(2n+1)}{2} \text{ for } 2n = i_0 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-29)}$$

$$V_{ext}(2n) = V_{ext}(2n) + \frac{V_{ext}(2n-1)}{2} \text{ for } 2n = i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-30)}$$

$$\text{and } V_{ext}(2n) = V_{ext}(2n) \text{ for } \mathrm{mod}(2n, dC) = 0 \quad \text{(I-31)}$$

I.3.4.3 Illustration in the case of the 9-7 forward irreversible transformation (informative)

The first lifting step is:

$$V_{ext}(2n+1) = V_{ext}(2n+1) + \alpha(V_{ext}(2n) + V_{ext}(2n+2)) \text{ for } i_0 < 2n+1 < i_1 - 1 \quad \text{(I-32)}$$

$$V_{ext}(2n+1) = V_{ext}(2n+1) + 2\alpha V_{ext}(2n+2) \text{ for } 2n+1 = i_0 \quad \text{(I-33)}$$

$$\text{and } V_{ext}(2n+1) = V_{ext}(2n+1) + 2\alpha V_{ext}(2n) \text{ for } 2n+1 = i_1 - 1 \quad \text{(I-34)}$$

The second lifting step is:

$$V_{ext}(2n) = V_{ext}(2n) + \beta(V_{ext}(2n-1) + V_{ext}(2n+1)) \text{ for } i_0 < 2n < i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-35)}$$

$$V_{ext}(2n) = V_{ext}(2n) + 2\beta V_{ext}(2n+1) \text{ for } 2n = i_0 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-36)}$$

$$V_{ext}(2n) = V_{ext}(2n) + 2\beta V_{ext}(2n+1) \text{ for } 2n = i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-37)}$$

$$\text{and } V_{ext}(2n) = (1 + 2\beta) V_{ext}(2n) \text{ for } \mathrm{mod}(2n, dC) = 0 \quad \text{(I-38)}$$

The third lifting step is:

$$V_{ext}(2n+1) = V_{ext}(2n+1) + \gamma(V_{ext}(2n) + V_{ext}(2n+2)) \text{ for } i_0 < 2n+1 < i_1 - 1 \quad \text{(I-39)}$$

$$V_{ext}(2n+1) = V_{ext}(2n+1) + 2\gamma V_{ext}(2n+2) \text{ for } 2n+1 = i_0 \quad \text{(I-40)}$$

$$\text{and } V_{ext}(2n+1) = V_{ext}(2n+1) + 2\gamma V_{ext}(2n) \text{ for } 2n+1 = i_1 - 1 \quad \text{(I-41)}$$

The fourth lifting step is:

$$V_{ext}(2n) = V_{ext}(2n) + \delta(V_{ext}(2n-1) + (V_{ext}(2n+1)) \text{ for } i_0 < 2n < i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-42)}$$

$$V_{ext}(2n) = V_{ext}(2n) + 2\delta V_{ext}(2n+1) \text{ for } 2n = i_0 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-43)}$$

$$V_{ext}(2n) = V_{ext}(2n) + 2\delta V_{ext}(2n+1) \text{ for } 2n = i_1 - 1 \text{ and } \mathrm{mod}(2n, dC) \neq 0 \quad \text{(I-44)}$$

$$\text{and } V_{ext}(2n) = (1 + 2\beta(1+2\alpha) + 2\delta(1 + 2\gamma(1 + 2\beta(1+2\alpha))))V_{ext}(2n) \text{ for } \mathrm{mod}(2n, dC) = 0 \quad \text{(I-45)}$$

The scaling steps are the same for all coefficients.

I.4 The TSSO extension

This subclause applies only if the TSSO extension is selected. The selection of the TSSO extension enables the use of tiles without any visible artifact at the boundary of tiles. The tiles must overlap, but by one row and one column only.

I.4.1 Signalling for the TSSO

The selection of the TSSO extension is signalled in the extended COD and COC markers (see A.2.3). If the SSODWT is used with TSSO, then only wavelet transformations (reversible or irreversible) which use WS wavelet filters (i.e., *Filt_cat = WS*) may be used.

The parameters relevant to the selection of the TSSO extension *XTsiz*, *YTsiz* are signalled in the SIZ extended marker segments (see ITU-T Rec. T.800 | ISO/IEC 15444-1, A.5.1), while the parameters *Hovlp* and *Vovlp* are signalled in the SSO parameter of the COD maker (see Table A.11 of A.2.3).

I.4.2 Partitioning of the image into single-sample overlapping tiles

The tile partitioning specified in ITU-T Rec. T.800 | ISO/IEC 15444-1 is identical, except for these differences.

Equations B-7, B-8, B-9 and B-10 from ITU-T Rec. T.800 | ISO/IEC 15444-1 must be modified as follows:

$$tx_0(p, q) = max(XTOsiz + p \cdot XTsiz - (1 - Hovlp), XOsiz) \quad \text{(I-46)}$$

$$ty_0(p, q) = max(YTOsiz + q \cdot YTsiz - (1 - Vovlp), YOsiz) \quad \text{(I-47)}$$

$$tx_1(p, q) = min(XTOsiz + (p+1) \cdot XTsiz + Hovlp, Xsiz) \quad \text{(I-48)}$$

$$ty_1(p, q) = min(YTOsiz + (q+1) \cdot YTsiz + Vovlp, Ysiz) \quad \text{(I-49)}$$

Tiles are of width $tx_1(p, q) - tx_0(p, q) = XTsiz + 1$ and height $ty_1(p\ q) - ty_0(p, q) = YTsiz + 1$. They overlap by one column and one row as shown in Figure I.10 in the case of *Hovlp* = *Vovlp* = 0. The parameters *Hovlp* and *Vovlp* may have a value of zero or one.

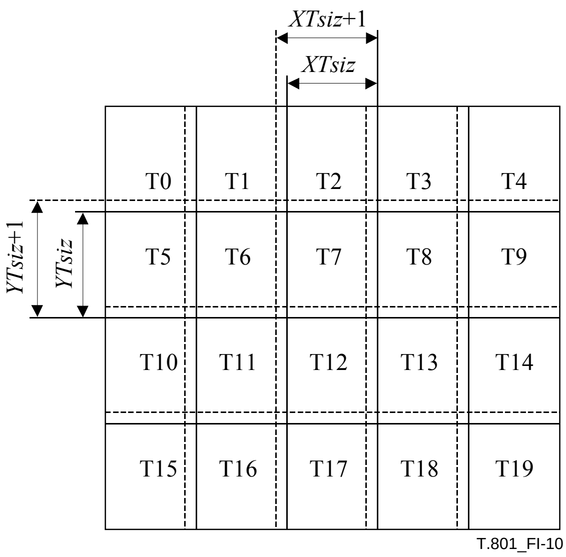


Figure I.10 – Tiling of the reference grid diagram

The tile parameters *XTsiz* and *YTsiz* must satisfy the following equations:

$$\mathrm{mod}(XTsiz,\ R_x \cdot 2^{N_L}) = 0 \text{ and } \mathrm{mod}(YTsiz,\ R_y \cdot 2^{N_L}) = 0 \qquad \text{(I-50)}$$

where R_x and R_y are the lowest common multiples of sub-sampling factor $XRsiz^i$ and $YRsiz^i$.

The tiling offsets *XTOsiz* and *YTOsiz* must satisfy the following equation:

$$\mathrm{mod}(XTOsiz,\ R_x \cdot 2^{N_L}) = 1 - Hovlp \text{ and } \mathrm{mod}(YTOsiz,\ R_y \cdot 2^{N_L}) = 1 - Volvp. \qquad \text{(I-51)}$$

Finally, the TSSO extension must be used for all tile components.

I.4.3 Reconstruction of images samples from reconstructed tiles

Since the reconstructed tiles overlap by one row and one column with neighbouring tiles, some image samples will be reconstructed separately in two or four different tiles. For any such sample, one must use the following rule.

If a sample is reconstructed from more than one tile, then the sample used for reconstruction is the sample value from the tile to the left if *Hovlp* = 0 and the sample value from the tile to the right if *Hovlp* = 1, the sample value from the tile to the top if *Vovlp* = 0 and the sample value from the tile to the bottom if *Hovlp* = 1.

I.5 Combining the SSO and TSSO extensions (informative)

It is possible to use the SSO extension in combination with the TSSO extension. When this occurs, the filtering procedures described in I.3 are applied to each overlapped tile separately. When *XTsiz* and *YTsiz* are multiples of *XC* and *YC* respectively, for example *XC* = *XTsiz* and *YC* = *YTsiz*, the values reconstructed at overlapping tile boundaries will not vary based upon the tile, so the rule described in I.4.3 is redundant. When *XTsiz* and *YTsiz* are not multiples of *XC* and *YC* respectively, then the rule for choosing reconstructed sample values in I.4.3 applies as described.

Furthermore, to improve memory efficiency, the following selection of encoding parameters is recommended: $XTOsiz = z_x$, $YTOsiz = z_y$.

Annex J

Multiple component transformations, extension

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard, except those found in Annex B. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1). The DC level shifting of tile-components described in Annex G of ITU-T Rec. T.800 | ISO/IEC 15444-1 is not performed when using any of the multiple component transformation procedures in this annex. Procedures exist in this annex that may be used in place of the DC level shifting described in ITU-T Rec. T.800 | ISO/IEC 15444-1 .

J.1 Introduction to multiple component transformation concepts

This annex specifies multiple component transformations. The most common multiple component transformation application is the compression of colour images. Standard colour images (RGB) are transformed into a colour space that is more conducive to spatial compression (i.e., YIQ). This technique can be extended for images that have more components; for example, LANDSAT images have seven components, six of which are highly correlated. It also can be used for the compression of CMYK images, multiple component medical images, and any other multiple component data.

There are two multiple component transformation techniques presented in this annex. The first is an array-based multiple component transformation which forms linear combinations of components to reduce the correlation of each component. This transformation structure permits component prediction transformations such as DPCM, and includes more complicated transformations such as the Karhunen-Loèvè Transformation (KLT). These array-based transformations can be implemented reversibly or irreversibly. The second multiple component transformation technique is a wavelet-based decorrelation transformation. The wavelet-based transformation may also be implemented reversibly or irreversibly. This annex provides a flexible mechanism to allow these techniques to be used in sequence if desired, e.g., an array-based transformation followed by a wavelet-based transformation. Furthermore, this annex provides mechanisms which allow components to be re-ordered and grouped into component collections.

Component collections may be formed to group together components with similar statistical properties to improve the compression efficiency of a multiple component transformation. Collections may also be used to reduce the computational complexity of component transformations by splitting a large component transformation involving many components into several transformations of smaller dimension. Frequently such splitting may be done with little loss in compression performance. Component collections also allow the application of array-based and wavelet-based transformations, on different collections, within the same compressed codestream.

It is possible using the techniques in this annex to generate more or fewer output (reconstructed image) components than the number of components encoded in the codestream. This allows encoders to transform original image components into a new domain and discard those transformed components containing little or no information prior to the creation of the compressed codestream. The encoder can nevertheless instruct a decoder on the proper way to regenerate an approximation to the original components given only the reduced set of codestream components. An encoder may also use the multiple component transformation processes to provide such functionality as generation of pseudo-color or grayscale renditions of a multiple component image.

The techniques described in this annex are powerful and can serve many different uses. This annex does not prescribe how to apply these techniques to a multiple component image to increase compression efficiency; neither does it describe the many possible applications of these techniques. A detailed example is included in O.3 which attempts to illustrate some of their flexibility. Procedures are defined in this annex which strictly control the usage of the multiple component transformation techniques. These procedures ensure that any decoder conforming to this annex will successfully decode properly formed codestreams that use these techniques. As with any set of powerful tools, it is quite easy to make unintended errors, and great care should be exercised in adhering to the procedures of this annex in application of multiple component transformations.

J.2 Overview of inverse processing

A powerful characteristic of this multiple component transformation annex lies in its ability to accommodate multiple decorrelation techniques within the same framework and allow reconstruction using a generalized decoder. Reconstruction in this case includes inverse decorrelation transformation (e.g. KLT, etc.), inverse dependency transformation (e.g., linear prediction, etc.) and inverse one-dimensional wavelet transformation. Figures J.1, J.3 and J.5

illustrate the inverse multiple component transformation processing steps needed to reconstruct image components from the codestream. The inverse multiple component transformation consists of a series of transformation stages. Within each stage, the set of available input components, called intermediate components, may be broken into component collections, each of which may be transformed with a different transformation method. The remainder of this subclause provides details regarding the order of decoder actions and the locations of required information within the codestream. This subclause does not address the equations governing application of a given transformation. Instead, individual multiple component transformations are referred to generically in this subclause and are detailed in J.3.

Various marker segments convey the multiple component transformation information. For two of these marker segments, the MCT and the MCC (see A.3.7 and A.3.8), it is possible that the amount of data required will be larger than the maximum amount of data allowed in a single marker segment. If multiple marker segments are needed to convey the data within an MCT or MCC marker segment, the data is split into a series of two or more marker segments. It is possible that a codestream may contain multiple series of marker segments in a main or first tile-part header. The marker segment index (Imct or Imcc) is repeated within each marker segment in the series. The data in a series of marker segments with the same marker segment index (Imct or Imcc) are grouped together. The entire series of marker segments shall be found in the same header, either the main header or the first tile-part header.

A field in each of the markers (Ymct or Ymcc) indicates the total number of marker segments that are used to convey the transformation information associated with that particular marker segment index (Imct or Imcc). A second field (Zmct or Zmcc) indicates the placement of a particular marker segment relative to all others in the same header sharing the marker index. When transformation information is distributed across more than one marker segment, the parameter lists from the marker segments are concatenated byte-wise in order of increasing Zmcc or Zmct. When such concatenation is completed, the resulting stream of parameters is then treated as if it had been transmitted in a single marker segment. The text that follows assumes that any such required concatenation of marker segment contents has been performed.

J.2.1 Inverse multiple component transformation (MCO_TRANSFORM)

As shown in Figure J.1, the inverse multiple component transformation is a transform that takes as its inputs the set of spatially reconstructed components from the codestream created by two-dimensional inverse wavelet transform and produces a set of reconstructed image components. Each multiple component sample is reconstructed by applying the processing steps as indicated in the codestream. The inverse transformation process is carried out in a series of steps known as transformation stages. The MCO marker segment (see Annex A.3.9) applicable to the given tile contains information regarding each of these stages. Specifically, the Nmco field of the MCO marker segment gives the number of transformation stages that will be applied during inverse processing.

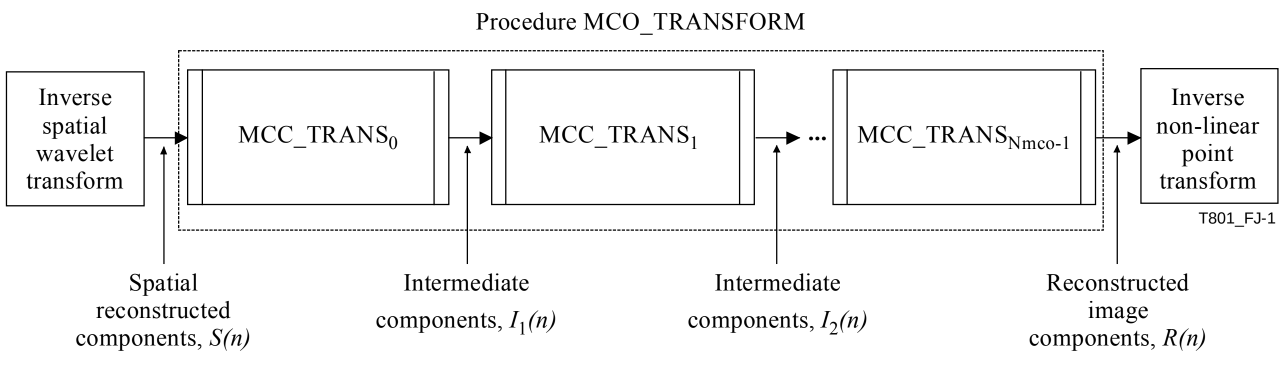


Figure J.1 – Inverse multiple component transformation processing

If Nmco = 0 for a tile, then no inverse multiple component transformation is performed on this tile and the *j*th reconstructed image component is given by the *j*th spatially reconstructed component. In this case, the tile is treated as if there were no multiple component transformations in use. The DC level shifting of tile-components described in Annex G of ITU-T Rec. T.800 | ISO/IEC 15444-1 is performed. The CBD marker segment, which is required with multiple component transformations, still applies to tiles where the multiple component transformation has been turned off. In fact the CBD marker segment applies to all tiles in an image that utilizes multiple component transformations. Since there may be different transformations in use in different tiles, the CBD marker segment must be constructed to accommodate the largest bit depths found in all tiles for a given component.

When a transformation is performed, the *k*th Imco field of the MCO marker segment contains the index of the MCC marker segment (see A.3.8) that applies for the *k*th stage of the inverse transformation. It is recommended, but not required, that decoders complete all processing within a given stage of the inverse transformation before beginning the next stage. (It is possible that an intelligent decoder might be able to determine only those processing steps required to produce a given set of reconstructed image components. However, completing all processing within a stage before proceeding to the next guarantees correct decoding of the codestream.) A flowchart corresponding to the operations that will result in the successful application of the inverse multiple component transformation is shown in Figure J.2. The processing consists of applying the MCC_TRANS procedure for each of the transformation stages indicated in the MCO marker segment.

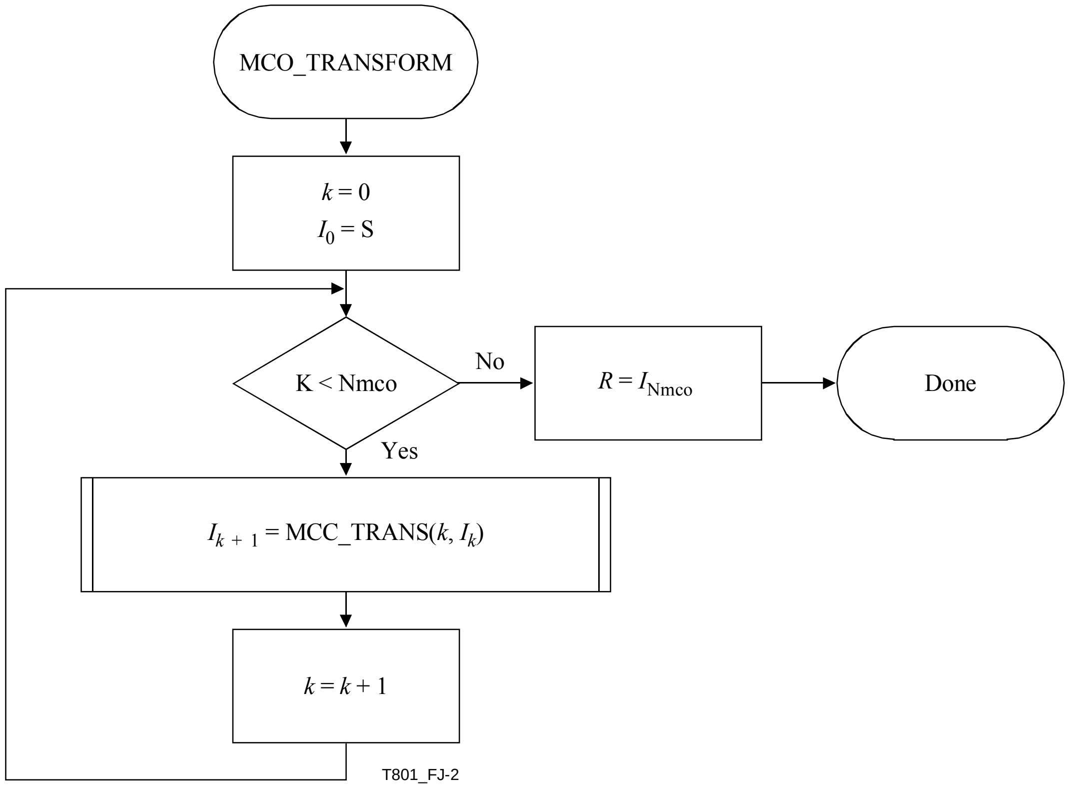


Figure J.2 – Procedure MCO_TRANSFORM

The multiple component transformation mechanism does not place restrictions on the bit depths of the reconstructed image components. Furthermore, it is possible for the number of spatially reconstructed components to differ from the number of reconstructed image components. Therefore, when using the multiple component transformation mechanism, a CBD marker segment (see A.3.6) shall be used. This marker segment indicates the total number of output image components and their respective bit depths after the inverse multiple component transformation is applied. Only one CBD marker segment may appear in the main header of the codestream. Thus all tiles in an image must contain the same number of components, and the component bit depths in the CBD marker segment must be of sufficient magnitude to cover the maximum bit depth of a component across all tiles.

When multiple component transformation processing is used, the SIZ marker segment (see A.2.1) shall indicate the number and bit depths of the components in the codestream after the inverse two-dimensional wavelet transform. In other words, the SIZ marker segment indicates the bit depths of codestream components after the forward multiple component transformation. This interpretation of the SIZ marker segment is subtly different from its interpretation under other decoding processes in this Recommendation | International Standard and ITU-T Rec. T.800 | ISO/IEC 15444-1, where it is used to indicate the number of output image components and their bit depths.

J.2.2 Multiple component transformation stage (MCC_TRANS)

Figure J.3 illustrates the processing involved in a single stage of the inverse multiple component transform. Within a given stage, a set of one or more CC_TRANS operations is performed. The order in which these operations are performed is unimportant; the syntax rules of the MCC marker segment guarantee that the CC_TRANS operations within a stage can be performed in parallel.

The set of input components available to the kth transformation stage, where $k \in [0, 1, \ldots, \text{Nmco}-1]$, is the set of intermediate components I_k. The set of components output from the kth transformation stage is the set of intermediate components I_{k+1}. The first set of intermediate components, I_0, is defined to be the set of spatially reconstructed components produced by the two-dimensional inverse wavelet transform. Intermediate component set I_0 contains Csiz components, where Csiz is indicated in the SIZ marker segment. If $S(n)$ is the nth spatially reconstructed component, then $I_0(n) = S(n)$, $n = 0, 1, \ldots$, Csiz–1. Similarly, the set of reconstructed image components is defined to be the final set of intermediate components. Intermediate component set I_{Nmco} contains Ncbd components, where Ncbd is indicated in the CBD marker segment. If $R(n)$ is the nth reconstructed image component, then $R(n) = I_{\text{Nmco}}(n)$, $n = 0, 1, \ldots$, Ncbd–1. The number of intermediate components, NI_k, in intermediate component set, I_k, for $0 \le k < \text{Nmco}$, is given by:

$$\text{NI}_k = 1 + \max_{i,j}[\text{Cmcc}^{ij}(k)] \qquad \text{(J-1)}$$

In this expression, the $\text{Cmcc}^{ij}(\text{k})$ are taken from the MCC marker segment corresponding to the kth transformation stage. The max function simply finds the largest Cmcc^{ij} value from the kth transformation stage across all component collections in that stage. The variable NI_0 = Csiz and NI_{Nmco} = Ncbd.

All of the information regarding the CC_TRANS operations is conveyed in the MCC marker segment. The index of the relevant MCC marker segment for the kth stage of the inverse multiple component transformation is obtained from the Imco^k field of the MCO marker segment. A flow diagram that results in correct decoding of the codestream is given in Figure J.4. (This flow diagram applies the CC_TRANS operations in the order that collections appear within the active MCC marker segment.)

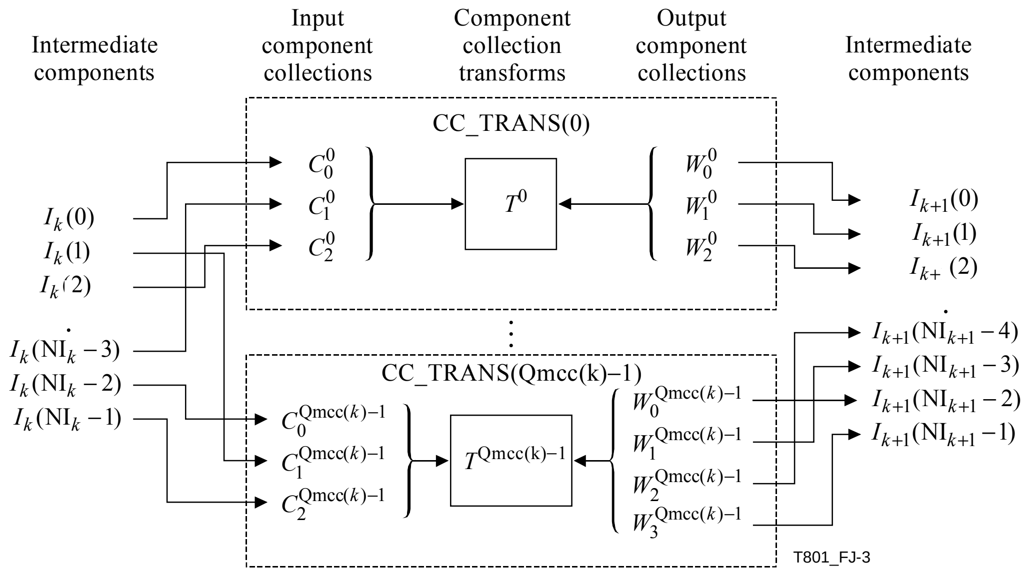


Figure J.3 – A single multiple component collection transformation (MCC_TRANS) stage

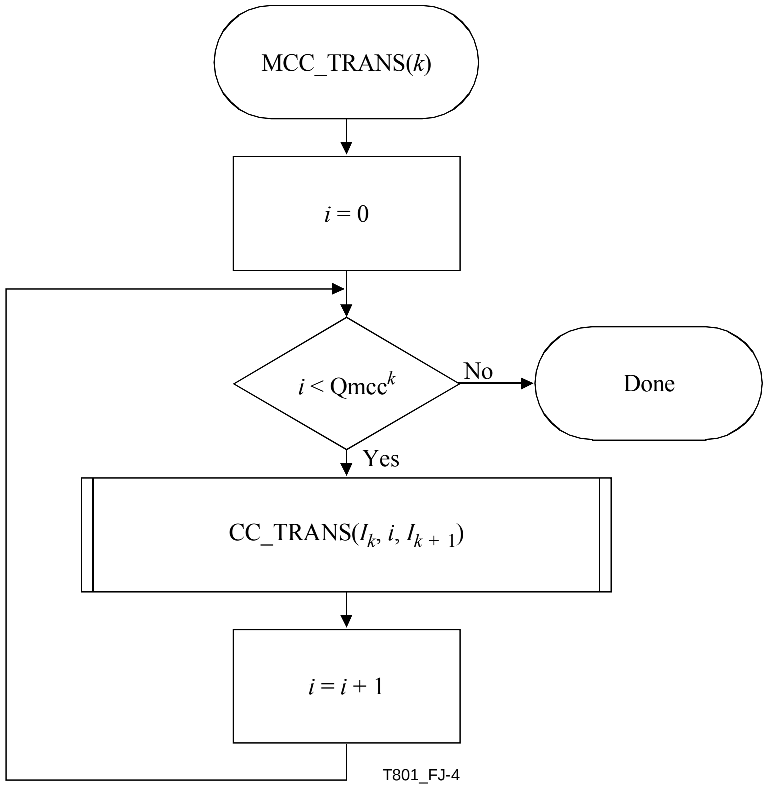


Figure J.4 – Procedure MCC_TRANS

J.2.3 Transformation component collection (CC_TRANS)

The processing flow to transform a given component collection is illustrated in Figure J.5. The figure shows the location of relevant MCC marker segment fields for the *i*th component collection within that marker segment. Each component collection within a transformation stage performs one of a number of different processing steps defined in subsequent clauses of this annex. The *i*th component collection operates on a subset, I_k^i, of the input intermediate components available at the current transformation stage, *k*, and it produces some subset, I_{k+1}^i, of the output intermediate components from the current transformation stage. In the figure, $\text{Cmcc}^i = \{\text{Cmcc}^{ij}\}$, $\forall\ j \in [0, 1, \ldots, \text{Nmcc}^i - 1]$, and $\text{Wmcc}^i = \{\text{Wmcc}^{ij}\}$, $\forall\ j \in [0, 1, \ldots, \text{Mmcc}^i - 1]$. For each of the component collections within the relevant MCC marker segment, the following subclauses, in order, describe the processing that occurs. (These subclauses parallel the functional blocks in Figure J.6.)

All of the transformation methods specified in this annex make use of component collections. A component collection consists of a list of input component indices along with a list of output component indices. Component collections are defined within the MCC marker segment (see A.3.8). The input component list of a collection specifies the order in which intermediate components input to the stage are accessed by the transform. In particular, for the *i*th component collection within the *k*th transformation stage, the *j*th input transformation component, C_j^i, is given by $I_k(\text{Cmcc}^{ij})$, where $0 \le j < \text{Nmcc}^i$. Similarly, the output component list of a collection specifies which intermediate components output by the stage are filled by an associated transform. Output component W_j^i (where $0 \le j < M\text{mcc}^i$) from the transformation is assigned to intermediate component $I_{k+1}(\text{Wmcc}^{ij})$. The indices Cmcc^{ij} and Wmcc^{ij}, and the numbers of input and output components, Nmcc^i and Mmcc^i, all appear in an MCC marker segment. The component collection mechanism allows for permutation of components at both input and output of the associated transformation.

The number of output components may be greater than, less than, or equal to the number of input components. Some restrictions are placed on the relationship between the number of input and output components depending on the type of transformation associated with a collection, as is described later. Also, all components appearing on the input list of a collection must have the same sample dimensions, as given in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex B, Equation B-13. This ensures that a sample from each component in the collection will be available at common locations on the reference grid by enforcing a registration of the input components in the collection.

The transformation that operates on the *i*th collection is identified in the Tmcc^i field of the active MCC marker segment. Additionally, the Tmcc^i field may reference arrays of transformation coefficients which are specified in MCT marker segments (see A.3.7) or may identify particular wavelet kernels for use (see A.3.5). The Omcc^i field may also be used to provide an offset in the component direction for a one-dimensional wavelet transform. In Figure J.6 and subsequent subclauses of this annex, T^i will refer to the transformation arrays or wavelet transform information corresponding to the ith component collection in the current transformation stage.

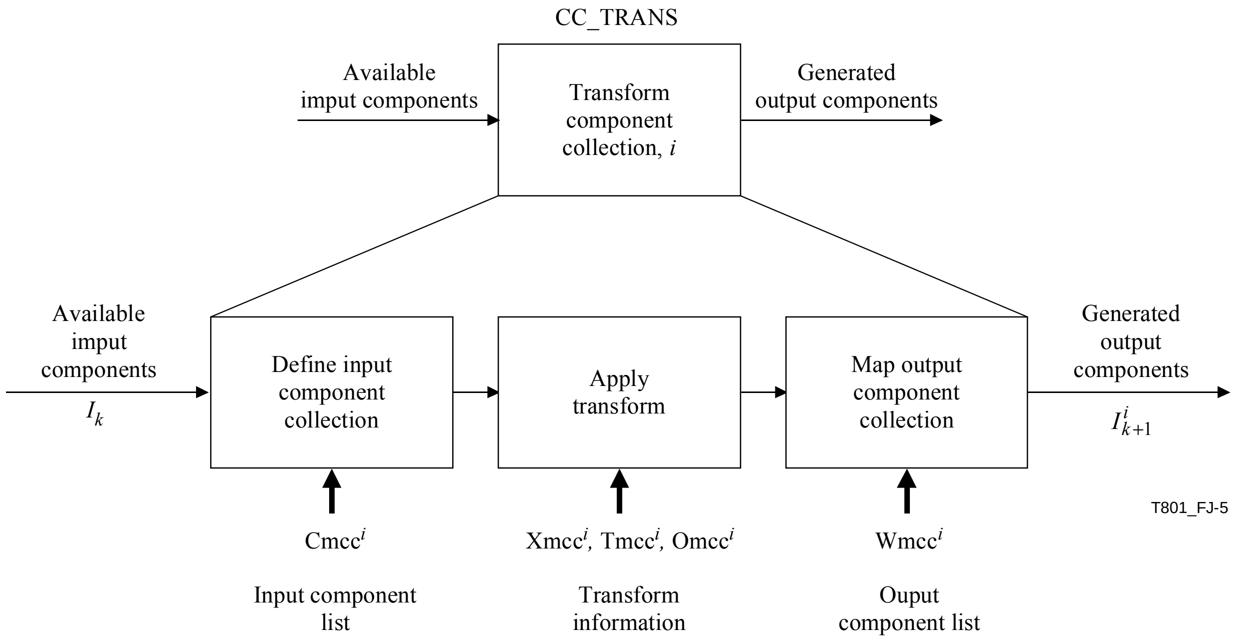


Figure J.5 – A single component collection transformation (CC_TRANS) stage

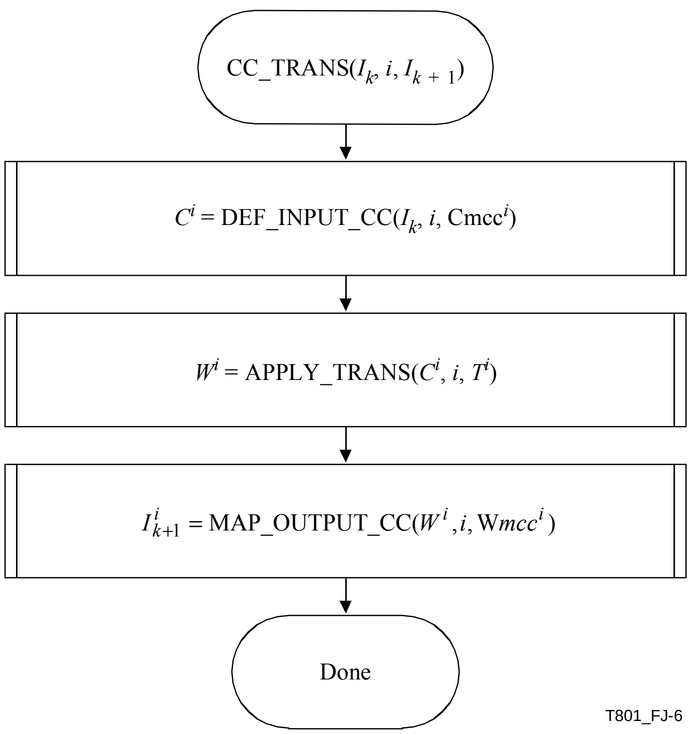


Figure J.6 – Procedure CC_TRANS

J.2.3.1 Define input component collection (DEF_INPUT_CC)

For the current collection, i, the set C^i of input components for the transformation is formed by selecting a subset of the available intermediate components, I_k. This set contains Nmcc^i components. The jth component, C^i_j, in the input set is given by intermediate component $I_k(\text{Cmcc}^{ij})$, where $0 \le j < N\text{mcc}^i$ and $\text{Cmcc}^{ij} \in [0, 1, ..., \text{NI}_k - 1]$. The index k is the transformation stage number, and the values of Nmcc^i and Cmcc^{ij} are defined in the ith collection of the MCC marker segment corresponding to transformation stage k. This MCC marker segment has the same index value, Imcc, as that given for the kth transformation stage, Imco^k, in the MCO marker segment.

It is required that the component collections comprising a transformation stage "touch" every available input intermediate component (i.e., the set of output intermediate components from the previous transformation stage). This means that every intermediate component index from 0 to $\text{NI}_k - 1$ must be present in the input component list of at least one component collection. If a given input intermediate component is not used in any transformation process in the current transformation stage, then it must appear in a null transformation (see J.3). As stated above, there is no general requirement that the number of output components from the transformation process equal the number of input components. It is therefore possible that additional components are inserted (or created) during the multiple component transformation process. This processing step does not necessarily occur explicitly during the transformation process. It may occur implicitly through the use of null intermediate components.

A null component is one whose output was left undefined by the previous transformation stage (i.e., the (k – 1)th stage) in the formation of the intermediate components, I_k. This can occur when the union of all output intermediate component lists from the previous transformation stage does not include every component number between 0 and the largest input component number, $\text{NI}_k - 1$, of the current transformation stage. In other words, there may be gaps in the set of output intermediate component numbers from the previous transformation stage. When a null component is accessed in a given input intermediate component collection, it is treated by the transformation process as a component with values that are identically zero. (The informative example in O.3 illustrates a potential use of null components.).

When forming a series of transformation stages that work together, care must be taken in the generation of the output and input component lists between successive transformation stages. It is not permitted for an output component number in stage k–1 to exceed the value $\text{NI}_k - 1$ for the current transformation stage k.

J.2.3.2 Apply transformation (APPLY_TRANS)

Given the input component set C^i, which contains Nmcc^i components, the selected inverse multiple component transformation is applied. The Xmcc^i field of the active MCC marker segment indicates the type of transformation used to transform the ith component collection. The allowed transformations and their application are discussed in J.3. The Tmcc^i field of the active MCC marker segment provides additional information that is required for the particular transformation, such as pointers to transformation array coefficients contained in an MCT marker segment (see A.3.7), wavelet transform kernels contained in an ATK marker segment (see A.3.5), number of wavelet transform levels, and indicators of the reversibility of the transform. In the case of the wavelet transform, the Omcc^i field also provides the equivalent of a tile offset for the one-dimensional wavelet transform. Application of the transformation results in a set of output components, W^i, which contains Mmcc^i components.

J.2.3.3 Assign output components (MAP_OUTPUT_CC)

The transformation for the ith component collection produces the set of Mmcc^i output components, W^i. The W^i are then assigned to a subset of the output intermediate components from the stage, I_{k+1}. Specifically, output component W_j^i (where $0 \le j < \text{Mmcc}^i$) from the transformation is assigned to intermediate component $I_{k+1}(\text{Wmcc}^{ij})$. This subset of the output intermediate component is also referred to as I_{k+1}^i. The Mmcc^i and Wmcc^{ij} values are found in the ith component collection of the active MCC marker segment for the kth transformation stage.

It is required that no output intermediate component appear more than once in the union of all output component collection lists within a particular MCC marker segment (i.e. $\text{Wmcc}^i \cap \text{Wmcc}^j = \varnothing, \forall\ i \ne j$). This rule implies that all component collections may be transformed in parallel without danger of overwriting previously computed results. As noted above, the output component list may be incomplete, thus allowing the transformation stage to create null components. The maximum output component number may not exceed $\text{NI}_{k+1} - 1$, the maximum input component number of the succeeding transformation stage. There is no requirement that the output component collection list be complete for the final transformation stage. However, the utility of such null image components is dubious and their use is not recommended.

J.3 Transformations

This subclause details the mathematics involved in the application of an inverse multiple component transformation. It also describes the location and interpretation of the remaining fields in the ith component collection of the active MCC marker segment that are required for application of the specific transformation.

For each of the transformations discussed in this subclause, it is assumed that the input component collection of the transformation, $C = C^i$, has already been formed. Individual components within the set are denoted as C_j, where $j = [0, 1, ..., N - 1]$, and $N = \text{Nmcc}^i$. All of the described transformations are assumed to produce a set of transformed components, $W = W^i$, with members denoted by W_j, where $j = [0, 1, \ldots, M-1]$, and M = Mmcc^i. This set of transformed components comprises the output component collection. These two sets of components will be referred to generically as input and output components of the transform. The equations presented in this subclause are normative only in the sense that they describe a result that the decoder must achieve; different implementations of these equations may exist for fully compliant decoders.

J.3.1 Array-based transforms

Array-based transformations are those that can be described by a set of equations that are linear in the input components. The transformation coefficients applied to the components in the following equations, as well as additive component offsets, are referred to as arrays. These arrays are stored within the codestream in MCT marker segments (see A.3.7). For array-based transformations, the Tmcc^i field of ith component collection in the active MCC marker segment contains the index of a transformation array and the index of an offset array. The Xmcc^i field for the ith component collection in the active MCC marker segment defines the type of array-based transformation to be applied (decorrelation or dependency, reversible or irreversible) to the component collection.

If the Tmcc^i array indices are non-zero, these indices, along with knowledge of the type of array-based transformation being applied, are used to select the appropriate MCT marker segments from which the coefficients are extracted. For the transformation array, the appropriate MCT marker segment is found by matching the MCT marker segment index found in the Imct parameter against the Tmcc^i transformation array index, and then matching the Xmcc^i transformation type against the array type found in the Imct parameter. For the offset array, the appropriate MCT marker segment is found by matching the MCT marker segment index found in the Imct parameter against the Tmcc^i offset array index, and then checking that the array type found in the Imct parameter indicates the array is an offset array. An index of zero in a Tmcc^i field indicates a null transformation or offset array, so that particular transformation steps may be skipped. For each of the array-based transformations discussed in this subclause, the number and storage order of the coefficients within the MCT marker segment is defined.

J.3.1.1 Decorrelation transformation

The decorrelation transformation type provides for an unconstrained linear combination of input components with additive offsets for each result. This transformation structure enables full matrix transformations such as the KLT.

J.3.1.1.1 Irreversible decorrelation transformation

The irreversible decorrelation transformation consists of a matrix multiplication of the input components followed by application of an additive offset. The transformation is applied by using Equation J-2.

$$
\begin{aligned}
W_0 &= t_{00}C_0 + t_{01}C_1 + t_{02}C_2 + t_{03}C_3 + \ldots + t_{0(N-1)}C_{N-1} + o_0 \\
W1 &= t_{10}C_0 + t_{11}C_1 + t_{12}C_2 + t_{13}C_3 + \ldots + t_{1(N-1)}C_{N-1} + o_1 \\
W2 &= t_{20}C_0 + t_{21}C_1 + t_{22}C_2 + t_{23}C_3 + \ldots + t_{2(N-1)}C_{N-1} + o_2 \\
W3 &= t_{30}C_0 + t_{31}C_1 + t_{32}C_2 + t_{33}C_3 + \ldots + t_{3(N-1)}C_{N-1} + o_3 \\
&\vdots
\end{aligned} \tag{J-2}
$$

If the decorrelation transformation array index provided by the Tmcc^i field for this component collection is zero, then the coefficients t_{ij} are given by $t_{ij} = 1$ for $i = j$ and $t_{ij} = 0$ for $i \neq j$. If the decorrelation transformation array index is not zero, then the referenced MCT marker segment contains $M \times N$ elements. The coefficients t_{ij} are stored in the marker segment in the following order: $t_{00}, t_{01}, \ldots, t_{0(N-1)}, t_{10}, t_{11}, \ldots, t_{1(N-1)}, \ldots t_{(M-1)(N-1)}$.

If the offset array index provided by the Tmcc^i field for this component collection is zero, then the coefficients o_i are given by $o_i = 0$. If the offset array index is not zero, then the referenced MCT marker segment contains M elements. The coefficients o_i are stored in the marker segment in the following order $o_0, o_1, \ldots, o_{M-1}$.

For an irreversible decorrelation transformation, the number of input components, N, is not required to equal the number of output components, M.

J.3.1.1.2 Forward irreversible decorrelation transformation (informative)

At a particular spatial location, (x, y), the M image components to be transformed are denoted by $W_0, W_1, \ldots, W_{M-1}$. The component dc offsets are given by $o_0, o_1, \ldots, o_{M-1}$, and the N components that result from the transformation are denoted by $C_0, C_1, \ldots, C_{N-1}$. The forward irreversible decorrelation transformation is applied by using Equation J-3.

$$
\begin{aligned}
C_0 &= t_{00}(W_0 - o_0) + t_{01}(W_1 - o_1) + t_{02}(W_2 - o_2) + \ldots + t_{0(M-1)}C_{M-1} \\
C_1 &= t_{10}(W_0 - o_0) + t_{11}(W_1 - o_1) + t_{12}(W_2 - o_2) + \ldots + t_{1(M-1)}C_{M-1} \\
C_2 &= t_{20}(W_0 - o_0) + t_{21}(W_1 - o_1) + t_{22}(W_2 - o_2) + \ldots + t_{2(M-1)}C_{M-1} \\
&\vdots
\end{aligned}
\tag{J-3}
$$

The offsets o_0, o_1, ... , o_{M-1} are included in an MCT marker segment. The offset array index provided by the Tmcc^i field for this component collection should match the MCT array index. If the offsets are all equal to zero, then the Tmcc^i field for this component collection can be set to zero and the offsets do not need to be included in an MCT marker segment.

The t_{ij} coefficients for the inverse transformation that are included in the MCT marker segment are in general not the same as those that appear in forward transformation equation. For example, if the transformation for this component collection is unitary, then the inverse transformation coefficients are the matrix transpose of the forward transformation coefficients. It is the responsibility of the encoder to form correctly the inverse transformation information required by the decoder.

J.3.1.1.3 Reversible decorrelation transform

The reversible decorrelation transformation consists of a set of single element linear transformations followed by application of an additive offset. For the reversible decorrelation transformation, the number of input components, N, is required to equal the number of output components, M. This is true even though the number of single element linear transformations applied in the processing is $N + 1$. The transformation is applied by the following set of equations:

Let temporary variable P be defined as:

$$
\begin{aligned}
P_0 &= C_0 \\
P_1 &= C_1 \\
P_2 &= C_2 \\
P_3 &= C_3 \\
&\vdots
\end{aligned}
$$

then form the following sequence of single element linear transformations using Equation J-4 and the given rounding rule.

$$
\left.
\begin{aligned}
S_l &= \sum_{i=0, i\neq(N-1-l)}^{N-1} t_{li}P_i + \frac{t_{l(N-1-l)}}{2} \\
PT_{N-1-l} &= -\left\lfloor \frac{S_1}{t_{1(N-1-l)}} \right\rfloor + P_{N-1-l} \\
P_{N-1-l} &= PT_{N-1-l}
\end{aligned}
\right\} \quad l = 0, 1, \ldots, N-1
\tag{J-4}
$$

Next compute the final single element transformation using Equation J-5 and apply the additive offset in Equation J-6 to form the output intermediate components. For the reversible decorrelation transformation, the sums S_l, $l = [0, 1, \ldots, N]$, must be generated in order and the single output term corresponding to that sum, P_{N-1-l}, must be adjusted before the next sum is computed.

$$
\begin{aligned}
S_N &= \sum_{i=0}^{N-1} t_{Ni}P_i + \frac{\left|t_{N(N-1)}\right|}{2} \\
PT_{N-1} &= \mathrm{sgn}(t_{N(N-1)}) \cdot \left[-\left\lfloor \frac{S_N}{\left|t_{N(N-1)}\right|} \right\rfloor + P_{N-1} \right] \\
P_{N-1} &= PT_{N-1}
\end{aligned}
\tag{J-5}
$$

$$
\begin{aligned}
W_0 &= P_0 + o_0 \\
W_1 &= P_1 + o_1 \\
W_2 &= P_2 + o_2 \\
W_3 &= P_3 + o_3 \\
&\vdots
\end{aligned}
\tag{J-6}
$$

Figure J.7 illustrates the computations described in Equations J-4 through J-6. Each stage of the transform adjusts exactly one output component. A linear combination of the unaltered components at each stage is first formed. This partial sum is rounded by a reversible rounding rule. The integer result is then added to the component that is adjusted at that stage (and the result is possibly negated at the last stage). These operations result in all-integer component values at each stage. Furthermore, since only a single component value is altered by an integer addition at each stage, the transform can be reversed simply by reversing the order of the single element transform steps. Also shown in the figure are two permutation matrices $P_R J$ and P_L which are incorporated into the structure of the reversible decorrelation transform. Here they explicitly indicate that the SERM factorization may not produce the transformed output components in the same order as the decorrelation matrix it is approximating. Given that the SERM factorization may not generate transformed components in the same order as the unitary transform it approximates, an encoder may choose to rectify this situation via the use of the output intermediate component collection index list.

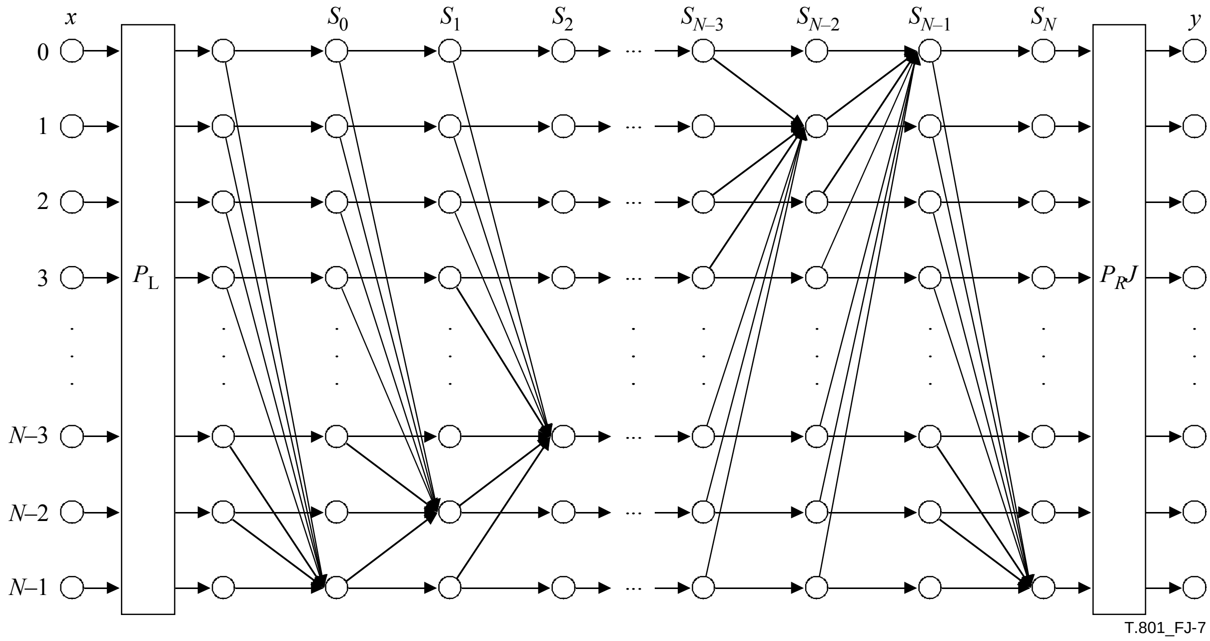


Figure J.7 – SERM implementation of reversible decorrelation transformation

NOTE – (informative): This reversible decorrelation transform structure accommodates a reversible factorization of a unitary $N \times N$ transform matrix that approximates its decorrelation properties. One such factorization technique, known as the single-row elementary reversible matrix (SERM) factorization is, described in [14]. Unitary transforms comprise a large class of multiple component transforms (examples include the KLT). An informative example is given in O.3 based upon the technique presented in [14].

If the decorrelation transformation array index provided by the Tmcc[i] field for this component collection is zero, then the coefficients t_{ij} are given by $t_{N(N-1)} = 1$, $t_{i(N-1-i)} = 1$ for $i \in [0, \ldots, N-1]$, and $t_{ij} = 0$ for all other i,j. If the decorrelation transformation array index is not zero, then the referenced MCT marker segment contains $(N+1) \times N$ elements. The coefficients t_{ij} are stored in the marker segment in the following order: t_{00}, t_{01}, ... , $t_{0(N-1)}$, t_{10}, t_{11}, ... , $t_{1(N-1)}$, ... $t_{N(N-1)}$. The coefficients are constrained to be integers for the reversible decorrelation transformation. Furthermore, the coefficients $t_{N(N-1)}$ and $t_{i(N-1-i)}$ for $\in [0, \ldots, N-1]$ are constrained to be exact positive integer powers of 2, while $t_{N(N-1)}$ is constrained to have an absolute value equal to an exact positive integer power of 2. This subset of the coefficients is interpreted as a set of scaling factors for each of the partial sums that are formed. This allows real-valued coefficients to be approximated to the nearest desired fractional bit. The restrictions on the coefficient values ensure that the sums can be carried out, if desired, with all-integer mathematical operations.

If the offset array index provided by the Tmcc^i field for this component collection is zero, then the coefficients o_i are given by $o_i = 0$. If the offset array index is not zero, then the reference MCT marker segment contains M elements. The coefficients o_i are stored in the marker segment in the following order: $o_0, o_1, \ldots, o_{M-1}$. For the reversible decorrelation transformation, the o_i are required to be integers.

J.3.1.1.4 Forward reversible decorrelation transformation (informative)

At a particular spatial location, (x, y) the N image components to be transformed are denoted by $W_0, W_1, \ldots, W_{N-1}$. The component dc offsets are given by $o_0, o_1, \ldots, o_{N-1}$, and the components that result from the transformation are denoted by $C_0, C_1, \ldots, C_{N-1}$. The forward irreversible decorrelation transformation is applied by using Equations J-7 through J-10. The SERM implementation of a forward reversible decorrelation transformation is shown in Figure J.8.

$$\begin{aligned} P_0 &= W_0 - o_0 \\ P_1 &= W_1 - o_1 \\ P_2 &= W_2 - o_2 \\ P_3 &= W_3 - o_3 \\ &\vdots \end{aligned} \tag{J-7}$$

$$\begin{aligned} S_0 &= \sum_{i=0}^{N-2} t_{0i} P_i + \frac{\left|t_{0(N-1)}\right|}{2} \\ PT_{N-1} &= \left\lfloor \frac{S_0}{\left|t_{0(N-1)}\right|} \right\rfloor + \operatorname{sgn}(t_{0(N-1)}) P_{N-1} \\ P_{N-1} &= PT_{N-1} \end{aligned} \tag{J-8}$$

$$\left.\begin{aligned} S_l &= \sum_{i=0,\ i \neq (l(-1))}^{N-1} t_{li} P_i + \frac{t_{l(l-1)}}{2} \\ PT_{l-1} &= -\left\lfloor \frac{S_l}{t_{l(l-1)}} \right\rfloor + P_{l-1} \\ P_{l-1} &= PT_{l-1} \end{aligned}\right\} \quad l = 1, 2, \ldots, N \tag{J-9}$$

$$\begin{aligned} C_0 &= P_0 \\ C_1 &= P_1 \\ C_2 &= P_2 \\ C_3 &= P_3 \\ &\vdots \end{aligned} \tag{J-10}$$

The input component values are first shifted by a dc offset. The results are assigned to temporary variables P_i. The N input components are then transformed in a series of $N + 1$ steps. In each step, exactly one of the input values is altered. The transformation steps must be carried out sequentially, and the temporary values, P_i, must be updated during each step and used in subsequent steps. In the first step, given in Equation J-8, the last temporary value is altered. Equation J-9 is then applied N times, with the value of l running from 1 to N. In the lth of these steps, temporary value P_l is altered. The final set of temporary values becomes the output of the transformation.

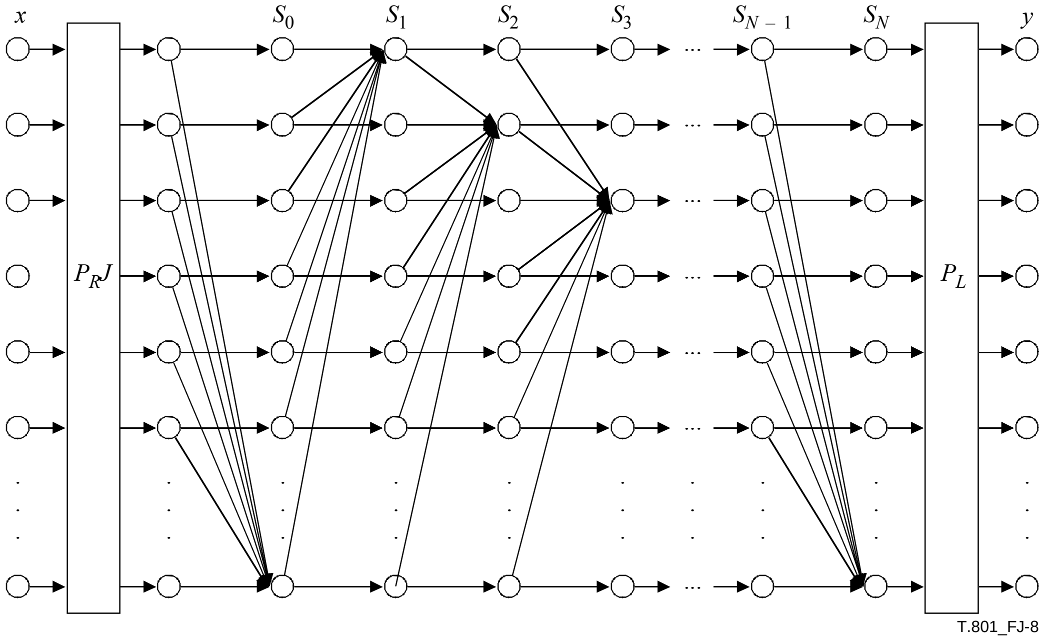


Figure J.8 – SERM implementation of forward reversible decorrelation transformation

The offsets o_0, o_1, ... , o_{M-1} must be integer valued and are included in an MCT marker segment. The offset array index provided by the Tmcc^i field for this component collection should match the MCT array index. If the offsets are all equal to zero, then the Tmcc^i field for this component collection can be set to zero and the offsets do not need to be included in an MCT marker segment.

The t_{li} coefficients for the inverse transformation that are included in the MCT marker segment are in general not the same as those that appear in forward transformation equation. In general, it will be true that t_{ij} in Equations J-4 and J-5 will be equal to $t_{(N-i)j}$ in Equations J-8 and J-9. There are some additional constraints on the coefficient values for the forward reversible decorrelation transformation. All of the t_{ij} must be integer valued, $t_{0(N-1)}$ must have an absolute value that is a power of 2, and $t_{i(i-1)}$ for $i = 1, 2, ... , N$ must be an exact power of 2. The coefficients that are powers of 2 can be interpreted in the equations as scale factors for each step in the transformation. Subclause O.3 provides an informative example illustrating a decorrelation transformation, its SERM factorization, and associated reversible implementation.

J.3.1.2 Dependency transformation

The dependency transformation type allows for predictive transformations. Inherent in the dependency transformation is the concept that the $(j + 1)^{\text{th}}$ output component can be computed only after the jth output component is decoded. The dependency transformation structure enables usage of prediction based DPCM-like transforms. An example of this transformation type is given in O.3.

J.3.1.2.1 Irreversible dependency transformation

The irreversible dependency transformation consists of an additive offset followed by a constrained linear combination of components. The dependency transformation is defined by the following set of equations:

$$\begin{aligned} Y_0 &= C_0 + o_0 \\ Y_1 &= C_1 + o_1 \\ Y_2 &= C_2 + o_2 \\ Y_3 &= C_3 + o_3 \\ &\vdots \end{aligned} \qquad \text{(J-11)}$$

$$
\begin{aligned}
W_0 &= Y_0 \\
W_1 &= t_{10}W_0 + Y_1 \\
W_2 &= t_{20}W_0 + t_{21}W_1 + Y_2 \\
W_3 &= t_{30}W_0 + t_{31}W_1 + t_{32}W_2 + Y_3 \\
&\vdots
\end{aligned} \qquad \text{(J-12)}
$$

Equation J-12 implies a particular structure in the irreversible dependency transformation array. Specifically, the irreversible dependency transformation array must be lower left triangular with zeros on and above the main diagonal. This particular structure guarantees that the array may be processed from top to bottom and causality will be preserved. This places a responsibility upon the encoder to form correctly the irreversible dependency transformation array in conjunction with the input and output intermediate component collection index lists. Figure J.9 illustrates the processing steps in the irreversible dependency transformation. The box labelled, $P(W_0, W_1, \ldots, W_{j-1})$, in the diagram is where the predictions for the current component being decoded is formed from previously decoded components.

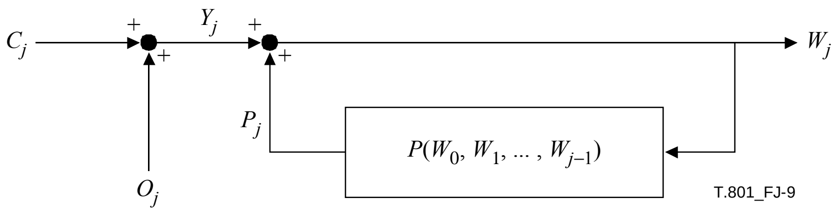


Figure J.9 – Irreversible dependency transformation

If the dependency transformation array index provided by the Tmcc^i field for the ith component collection is zero, then the coefficients t_{ij} are given by t_{ij} = 0 for all i, j. If the dependency transformation array index is not zero, then the referenced MCT marker segment contains $M \times (M - 1)/2$ elements. The coefficients t_{ij} are stored in the marker segment in the following order: $t_{10}, t_{20}, t_{21}, t_{30}, t_{31}, t_{32}, \ldots, t_{(M-1)0}, \ldots, t_{(M-1)(M-2)}$.

If the offset array index provided by the Tmcc^i field for the ith component collection is zero, then the coefficients o_i are given by $o_i = 1$. If the offset array index is not zero, then the referenced MCT marker segment contains M elements. The coefficients o_i are stored in the marker segment in the following order: $o_0, o_1, \ldots, o_{M-1}$.

For a dependency transformation, the number of input components, N, is required to equal the number of output components, M.

J.3.1.2.2 Forward irreversible dependency transformation (informative)

The forward irreversible dependency transformation consists of a constrained linear combination of components and an additive offset. At a particular spatial location, (x, y), the N image components to be transformed are denoted by $W_0, W_1, \ldots, W_{N-1}$. The component dc offsets are given by $o_0, o_1, \ldots, o_{N-1}$, and the components that result from the transformation are denoted by $C_0, C_1, \ldots, C_{N-1}$. The forward dependency transformation is defined by the following set of equations and illustrated in Figure J.10:

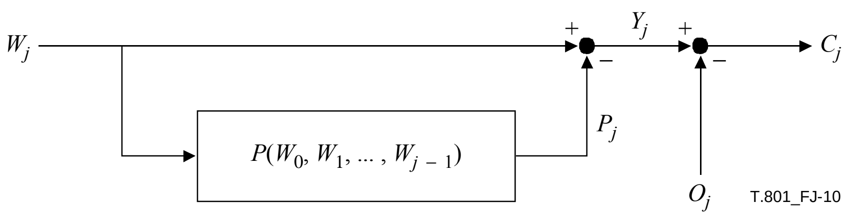


Figure J.10 – Forward irreversible dependency transformation

$$
\begin{aligned}
C_0 &= W_0 - o_0 \\
C_1 &= W_1 - o_1 - t_{10}W_0 \\
C_2 &= W_2 - o_2 - t_{20}W_0 - t_{21}W_1 \\
C_3 &= W_3 - o_3 - t_{30}W_0 - t_{31}W_1 - t_{32}W_2 \\
&\vdots
\end{aligned}
\tag{J-13}
$$

The offsets o_0, o_1, ... , o_{M-1} are included in an MCT marker segment. The offset array index provided by the Tmcc^i field for this component collection should match the MCT array index. If the offsets are all equal to zero, then the Tmcc^i field for this component collection can be set to zero and the offsets do not need to be included in an MCT marker segment.

The t_{ij} coefficients for the inverse transformation that are included in the MCT marker segment are in general the same as those that appear in forward transformation equation. In Equation J-12, all operations are additions, whereas in the forward transformation, all operations are subtractions.

J.3.1.2.3 Reversible dependency transformation

The reversible dependency transformation consists of an additive offset followed by a constrained linear combination of components. The reversible dependency transformation is defined by the following set of equations:

$$
\begin{aligned}
Y_0 &= C_0 + o_0 \\
Y_1 &= C_1 + o_1 \\
Y_2 &= C_2 + o_2 \\
Y_3 &= C_3 + o_3 \\
&\vdots
\end{aligned}
\tag{J-14}
$$

$$
\begin{aligned}
W_0 &= Y_0 \\
S_1 &= t_{10}W_0 + \left\lfloor \frac{t_{11}}{2} \right\rfloor \\
W_1 &= \left\lfloor \frac{S_1}{t_{11}} \right\rfloor + Y_1 \\
S_2 &= t_{20}W_0 + t_{21}W_1 + \left\lfloor \frac{t_{22}}{2} \right\rfloor \\
W_2 &= \left\lfloor \frac{S_2}{t_{22}} \right\rfloor + Y_2 \\
S_3 &= t_{30}W_0 + t_{31}W_1 + t_{32}W_2 + \left\lfloor \frac{t_{33}}{2} \right\rfloor \\
W_3 &= \left\lfloor \frac{S_3}{t_{33}} \right\rfloor + Y_3 \\
&\vdots
\end{aligned}
\tag{J-15}
$$

Equation J-15 implies a particular structure in the reversible dependency transformation array. Specifically, the reversible dependency transformation array must be lower left triangular with zeros above the main diagonal. The coefficients on the main diagonal of the array (except t_{00}) are scaling factors that may be used to scale real-valued dependency transformation arrays and represent them with a desired number of fractional bits. This particular structure guarantees that the array may be processed from top to bottom and causality will be preserved. This places a responsibility upon the encoder to properly form the reversible dependency transformation array in conjunction with the input and output intermediate component collection index lists. Figure J.11 illustrates the reversible dependency transformation processing. The box labelled "R" represents a rounding rule, which has been defined as the floor function in this Recommendation | Inernational Standard.

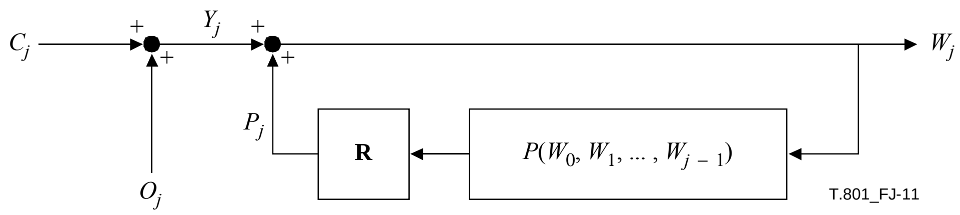


Figure J.11 – Reversible dependency transformation

If the dependency transformation array index provided by the Tmcc[i] field for this component collection is zero, then the coefficients t_{ij} are given by $t_{ij} = 0$ for all $i \neq j$, and $t_{ij} = 1$ for $i = j$. If the dependency transformation array index is not zero, then the referenced MCT marker segment contains $\frac{M(M+1)}{2} - 1$ elements. The coefficients t_{ij} are stored in the marker segment in the following order: t_{10}, t_{11}, t_{20}, t_{21}, t_{22}, t_{30}, t_{31}, t_{32}, t_{33}, ... , $t_{(M-1)0}$, ... , $t_{(M-1)(M-1)}$. For $i \neq j$, the t_{ij} coefficients have the same interpretation as in the irreversible dependency transformation. The additional $M - 1$ coefficients, t_{ij} where $i = j$ and $i > 0$, are interpreted as scaling factors for the partial sums S_l. The t_{ij} coefficients are constrained to be integers in the reversible dependency transformation. Furthermore, the t_{ij} coefficients for $i = j$ and $i > 0$ are constrained to be exact positive integer powers of 2. These restrictions ensure that the partial sums can be formed, if desired, with all-integer mathematical operations.

If the offset array index provided by the Tmcc[i] field for this component collection is zero, then the coefficients o_i are given by $o_i = 0$. If the offset array index is not zero, then the referenced MCT marker segment contains M elements. The coefficients o_i are stored in the marker segment in the following order: o_0, o_1, ... , o_{M-1}. These coefficients are constrained to be integers for the reversible dependency transformation.

For a reversible dependency transformation, the number of input components, N, is required to equal the number of output components, M.

J.3.1.2.4 Forward reversible dependency transformation (informative)

The forward reversible dependency transformation consists of a constrained linear combination of components and an additive offset. At a particular spatial location, (x, y), the N image components to be transformed are denoted by W_0, W_1, ... , W_{N-1}. The component dc offsets are given by o_0, o_1, ... , o_{N-1}, and the components that result from the transformation are denoted by C_0, C_1, ... , C_{N-1}. The forward dependency transformation is defined by the following set of equations. The forward dependency transformation is defined by the following set of equations and illustrated in Figure J.12:

$$
\begin{aligned}
C_0 &= W_0 - o_0 \\
S_1 &= t_{10}W_0 + \left\lfloor \frac{t_{11}}{2} \right\rfloor \\
C_1 &= \left\lfloor \frac{S_1}{t_{11}} \right\rfloor + W_1 - o_1 \\
S_2 &= t_{20}W_0 + t_{21}W_1 + \left\lfloor \frac{t_{22}}{2} \right\rfloor \\
C_2 &= -\left\lfloor \frac{S_2}{t_{22}} \right\rfloor + W_1 - o_2 \\
S_3 &= t_{30}W_0 + t_{31}W_1 + t_{32}W_2 + \left\lfloor \frac{t_{33}}{2} \right\rfloor \\
C_3 &= \left\lfloor \frac{S_3}{t_{33}} \right\rfloor + W_3 - o_3 \\
&\vdots
\end{aligned}
\tag{J-16}
$$

The offsets o_0, o_1, ... , o_{M-1} are integer valued and are included in an MCT marker segment. The offset array index provided by the Tmcc^i field for this component collection should match the MCT array index. If the offsets are all equal to zero, then the Tmcc^i field for this component collection can be set to zero and the offsets do not need to be included in an MCT marker segment.

The t_{ij} coefficients for the inverse transformation that are included in the MCT marker segment are in general the same as those that appear in forward transformation equation. There are constraints on these coefficient values, however. In particular, all t_{ij} must be integer valued, and t_{ii} for $i = 1, 2, \ldots, N-1$ must be exact powers of 2. (There is no t_{00} coefficient; the transformation equation implicitly assumes it to be equal to 1.) The t_{ii} can be interpreted as scale factor for the steps in the transformation.

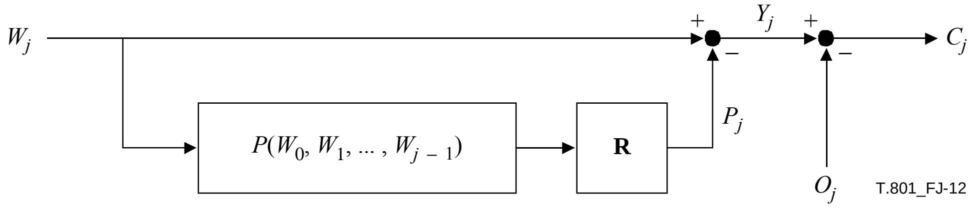


Figure J.12 – Forward reversible dependency transformation

J.3.2 Wavelet-based transformation

This subclause describes a wavelet-based decorrelation process. The MCC marker segment allows for the specification of a wavelet transformation to be applied to ith input component collection via the Xmcc^i marker parameter (see A.3.8). In fact, it is possible to use wavelet-based decorrelation on one component collection and array-based decorrelation on another within the same MCC marker segment. When wavelet-based decorrelation is used, an ATK marker segment (see A.3.5) specifies the wavelet transformation kernel used in processing the component collection. The Tmcc^i parameter in the MCC marker segment contains an index that specifies which ATK marker segment is to be used for the ith component collection. The Tmcc^i parameter also includes an index that points to an MCT marker segment containing additive offsets to apply to the input intermediate components after inverse wavelet transformation processing. The MCC marker segment signals the number of wavelet transformation levels in Tmcc^i, and a component offset Omcc^i to be employed during inverse wavelet transformation processing.

For a wavelet-based decorrelation transform, the number of input components, $N = \text{Nmcc}^i$, is required to equal the number of output components, $M = \text{Mmcc}^i$.

J.3.2.1 Inverse multi-dimensional wavelet transformation

The samples of component C_j are denoted by $C_j(x, y)$. At each spatial location, (x, y), $N_L + 1$ two-dimensional arrays are formed. Here, N_L is the number of wavelet transformation levels applied to the ith collection as determined from the Tmcc^i marker parameter. The arrays are denoted by $a_{N_L\text{LL}}(u,0)$, $a_{N_L\text{HL}}(u,0)$, $a_{(N_L-1)\text{HL}}(u,0)$, ... , $a_{1\text{HL}}(u,0)$. In each case, $tbx_0 \le u < tbx_1$, where tbx_0 and tbx_1 are determined appropriately for sub-band a_b as specified in Annex B of ITU-T Rec. T.800 | ISO/IEC 15444-1. For the purposes of this annex, it is assumed that the transformation is applicable to a tile-component with upper left corner at $(tcx_0, tcy_0) = (\text{Omcc}^i,0)$ and lower right corner at $(tcx_1 - 1, tcy_1 - 1) = (\text{Omcc}^i + M - 1, 0)$.

The (tbx_1, tbx_0) samples of each array, $a_b(u, 0)$, are taken from the $N = M$ samples $C_j(x, y)$, $j = [0, 1, \ldots, N-1]$. These are taken in order of the arrays as given above. Specifically, let $b = N_L\text{LL}$. Then the first $tbx_1 - tbx_0 = tN_L\text{LL}x_1 - tN_L\text{LL}x_0$ samples of $C_j(x, y)$, (i.e., $j = [0, 1, \ldots, tbx_1 - tbx_0 - 1]$) become the samples $a_b(u, 0)$, $u = [tbx_0, \ldots, tbx_1 - 1]$. Similarly, let $b = N_L\text{HL}$. Then the next $tbx_1 - tbx_0 = tN_L\text{HL}x_1 - tN_L\text{HL}x_0$ samples of $C_j(x, y)$ become the samples of $a_b(u, 0)$, $u = [tbx_0, \ldots, tbx_1 - 1]$, and so on.

The a_b arrays defined above are treated as sub-bands to be inverse wavelet transformed using the two-dimensional IDWT as described in Annex F of ITU-T Rec. T.800 | ISO/IEC 15444-1 (with extensions specified in Annexes G and H). The result of this inverse transform process is the two-dimensional array $I(z, 0)$, where $z = [\text{Omcc}^i, \text{Omcc}^i + 1, \ldots, \text{Omcc}^i + M - 1]$. This array represents the inverse wavelet transformation of the ith component collection in the kth transform stage. The values of $I(z, 0)$ are then the samples (at spatial location (x, y)) of the inverse transformed components W_j, where $j = [0, 1, \ldots, M-1]$. Specifically, $W_j(x, z) = I(j + \text{Omcc}^i, 0)$.

J.3.2.2 Forward multi-dimensional wavelet transformation (informative)

In what follows, we assume a specific component collection, i, to be transformed by the forward multiple component wavelet transform. The components in this collection are denoted by W_j, $j = [0, 1, \ldots, M-1]$. These components are transformed to obtain a collection of components, C_j, j = [0, 1, ... , N – 1]. For the wavelet decorrelation transform, it is required that $N = M$.

The components of this collection are transformed spatial location by spatial location. This transformation process is one-dimensional. However, it can be described using the two-dimensional wavelet transformation of Annex F of ITU-T Rec. T.800 | ISO/IEC 15444-1 with modifications and extensions as noted in Annex H of this Recommendation | International Standard.

The samples of component W_j are denoted as $W_j(x, y)$. At each spatial location (x, y), a two-dimensional array is formed. This array is constructed as $I(z + \mathrm{Omcc}^i, 0) = W_z(x, y)$, where z = [0, 1, ... , M – 1]. This array is one sample high, thus it is effectively a one-dimensional array. However, it may be treated as two-dimensional for purposes of a compact description of the multiple component wavelet transform.

The transform procedure FDWT (from Annex F of ITU-T Rec. T.800 | ISO/IEC 15444-1 with modifications and extensions specified in Annexes G and H) is applied to the array $I(z, 0)$. For this purpose, $I(z, 0)$ should be treated as a tile-component with upper left corner at $(tcx_0, tcy_0) = (\mathrm{Omcc}^i, 0)$ and lower right corner at $(tcx_1 - 1, tcy_1 - 1) = (\mathrm{Omcc}^i + M - 1, 0)$.

Using the notation of ITU-T Rec. T.800 | ISO/IEC 15444-1, the output of the FDWT procedure is the $N_L + 1$ sub-bands $a_{N_L\mathrm{LL}}$, $a_{N_L\mathrm{HL}}$, $a_{(N_L-1)\mathrm{HL}}$, ... , $a_{1\mathrm{HL}}$ (All sub-bands of the form a_{levHH} and a_{levLH} are empty.) Here, N_L is the number of decomposition levels to be applied. This value would be placed in the Tmcc^i field for the ith component collection in the current (i.e., kth) transformation stage.

Each such sub-band has samples $a_b(u, 0)$, $tbx_0 \le u < tbx_1$ with tbx_0 and tbx_1 determined as in Annex B of ITU-T Rec. T.800 | ISO/IEC 15444-1. These sub-band samples are then interpreted as samples of the transformed components, C_j, j = [0, 1, ... , N – 1], at spatial location (x,y). That is, $[C_0(x, y), C_1(x, y), \ldots, C_{N-1}(x, y)] = a_{N_L\mathrm{LL}}(tbx_0, 0), \ldots, a_{N_L\mathrm{LL}}(tbx_1 - 1, 0), a_{N_L\mathrm{HL}}(tbx_0, 0), \ldots, a_{N_L\mathrm{HL}}(tbx_1 - 1, 0), \ldots, a_{1\mathrm{HL}}(tbx_0, 0), \ldots, a_{1\mathrm{HL}}(tbx_1 - 1, 0)$. In each case, tbx_0 and tbx_1 are the values applicable to the sub-band indicated in the subscript of a_b.

Annex K

Non-linear transformation

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 5444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

This annex specifies two non-linear point transformations that are used after the decoding processes and inverse multiple component transformations to map reconstructed values back to their proper range. The forward non-linear transformation may be employed by encoders prior to the application of the forward multiple component transformation in order to increase compression efficiency of linear or near-linear original image data. For example, an application capturing original image data from a sensor with a linear response may apply the forward non-linear transformation to correct the data such that the bit allocation matches visual sensitivity.

K.1 Signalling the use of the non-linear transformations

The use of the non-linear transformation is signalled in the Rsiz parameter (see A.2.1).

K.1.1 Decoded component reconstruction

The non-linear transformations specified in this annex are "point" transformations. These transformations are applied to each sample ("point") in a given component. The transformations do not span components like the multiple component transformations described in Annex J. They may be used, however, in conjunction with the multiple component transformations. Figure K.1 shows where in the decoder's processing chain the non-linear transformation is applied. Conversely, on the encoder side, non-linear transformations would be applied prior to decorrelation and dependency transformations and wavelet processing.

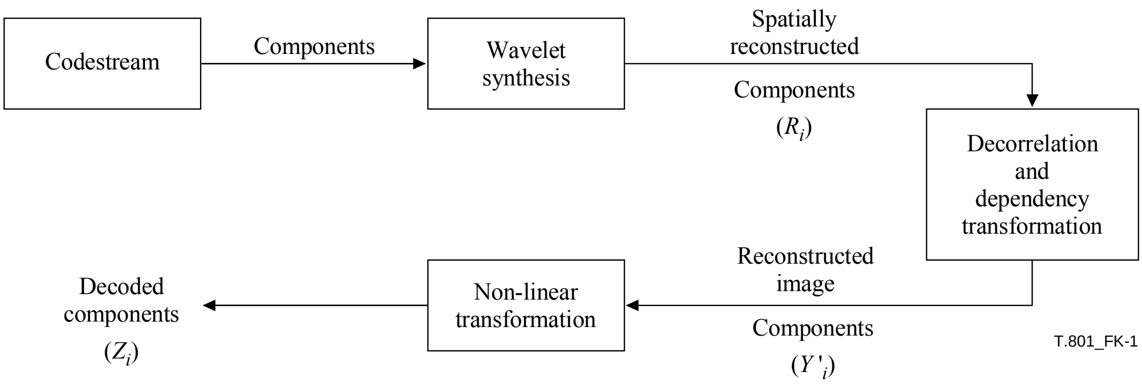


Figure K.1 – Non-linear transformation application during decoding

The forward transformation (on encoding) transforms the original image components (Z_i) into the inputs to the multiple component transformation (Y_i'). The reverse transformation (on decoding) transforms the reconstructed image components (Y_i') into the fully decoded components (Z_i).

K.1.2 Bit depth and interaction with the multiple component transformation

If a multiple component transformation is used in a codestream, the SIZ (see A.2.1) marker segment no longer carries the number of reconstructed image components and their bit depths. Instead, the SIZ marker segment contains the number of codestream components and their bit depths (R_i components in Figure K.1). Processing of the codestream components with the inverse decorrelation and dependency transformations may increase or decrease the number of reconstructed image components relative to the number of codestream components. Additionally, the bit depths of the reconstructed image components may be quite different from those of the codestream components. For these reasons, a CBD marker segment (see A.3.6) is always included in the codestream whenever a multiple component transformation is used. The CBD marker segment contains the number of reconstructed image components and their bit depths.

If a multiple component transformation is used in conjunction with non-linear point transformations, the CBD marker segment placed in the codestream shall specify the number of reconstructed image components and their bit depths prior to processing through the non-linear transformation. If no multiple component transformation is used, then the SIZ marker segment shall indicate the number of reconstructed image components and their bit depths.

K.1.3 Marker interpretation

Regardless of the use of the Multiple Component Transformation, an NLT marker segment (see A.3.10) is placed in the codestream whenever a non-linear transformation is used. The NLT marker segment indicates the bit depths of the decoded components that result from the application of a non-linear transformation to a reconstructed image component. Those reconstructed image components that do not undergo a non-linear transformation shall have no change in their bit depth.

K.2 Non-linear transformation specifications

This Recommendation | International Standard allows for the non-linear transformation to be stored in two different forms. The gamma-style non-linearity form specifies the transformation through parameters to an equation, and is specified in K.2.1. The LUT-style non-linearity form specifies the transformation by specifying a set of look-up table pairs and is specified in K.2.2.

K.2.1 Gamma-style non-linearity

The gamma-style transformation specifies the non-linear transformation using mathematical equations. That transformation is specified using two functional segments: a linear region for small component values, and a power-law exponential region for large component values. The actual transformation stored within the NLT marker segment is normalized such that the maximum value of the input and output components is +1.

K.2.1.1 Forward gamma-style non-linearity (encoding, informative)

The relationship between a normalized value z of original input component Z_i and normalized value y' of the gamma-adjusted component Y_i' is given by Equation K-1. An encoder using the non-linear transformation extension shall use the Y_i' component as input to the forward multiple component transformation, or directly to the forward wavelet transformation if the multiple component transformation is not used. Values z and y' are normalized such that the maximum value of the Z_i and Y_i' components, respectively, are +1.

$$y' = \begin{cases} -(A|z|^E - B) & z < -\frac{T}{S} \\ Sz & -\left(\frac{T}{S} \le z \le \frac{T}{S}\right) \\ Az^E - B & z > \frac{T}{S} \end{cases} \qquad \text{(K-1)}$$

In Equation K-1 S is the toe-slope, T is the toe-slope threshold, E is the gamma exponent, and A and B are continuity parameters. These parameters are stored in the NLT marker segment in normalized form such that the maximum value of the input and output components is +1.

Figure K.2 shows an example forward gamma non-linearity transformation that might be used by an encoder. This particular gamma-style transformation is from ITU-R Rec. BT.709 (HDTV).

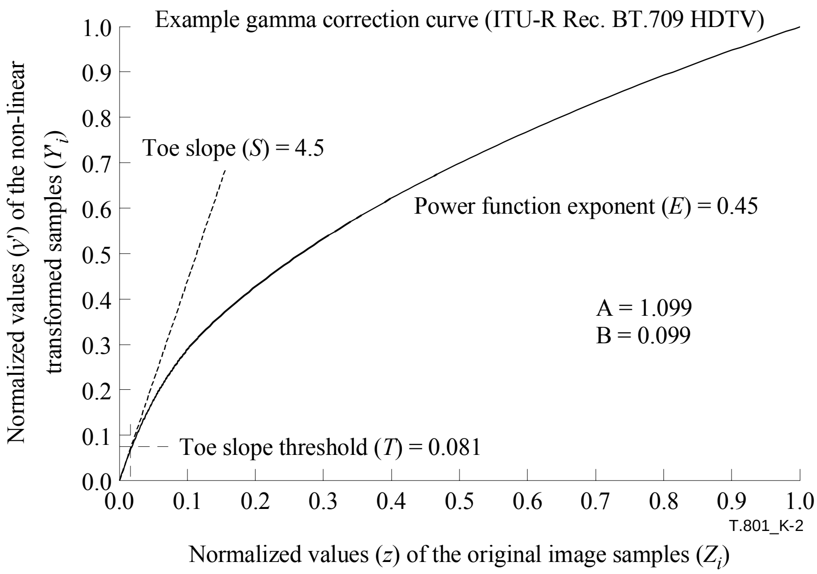


Figure K.2 – Example gamma-type forward non-linear transformation

K.2.1.2 Reverse gamma-style non-linearity (normative)

When decoding a codestream, a conforming reader shall apply the transformation specified by Equation K-2 to any component that indicates, through the NLT marker segment, that it should be processed using a gamma-style non-linearity. These equations take a normalized value y' value of component Y_i' as input and produce a normalized value z of the fully decoded Z_i component as output. The bit depth of the non-normalized Y_i' values is specified by the CBD marker segment, or by the SIZ marker segment if the multiple component extension is not used. The bit depth of the non-normalized Z_i values is specified by the BDnlt field in the NLT marker segment.

$$z = \begin{cases} -\left(\dfrac{|y'|+B}{A}\right)^{\frac{1}{E}} & y' < -T \\ \dfrac{y'}{S} & -T \le y' \le T \\ \dfrac{y'+B^{1/E}}{A} & y' > T \end{cases} \qquad \text{(K-2)}$$

The parameters T, S, E, A, and B are all communicated in the NLT marker segment. The transformation may be applied to the non-normalized component values by first scaling the coefficients of Equation K-2 to match the actual bit depths of the Z_i and Y_i' components. To scale the normalized coefficients to non-normalized form to convert an input component Y_i' of bit depth b_y directly to an output component Z_i of bit depth b_z without first normalizing the Y_i' component values and then denormalizing the Z_i values, the coefficients shall be transformed as follows in Equations K-3 and K-4.

$$f_y = \begin{cases} 2^{b_y} - 1 & Y_i' \text{ is unsigned} \\ 2^{b_y} - 1 & Y_i' \text{ is signed} \end{cases}$$
$$f_z = \begin{cases} 2^{b_z} - 1 & Z_i \text{ is unsigned} \\ 2^{b_z} - 1 & Z_i \text{ is signed} \end{cases} \qquad \text{(K-3)}$$

$$T_S = f_y \times T$$
$$S_S = \frac{f_y}{f_z} \times S$$
$$A_S = \frac{f_y}{f_z} \times A \quad \text{(K-4)}$$
$$B_S = f_y \times B$$

The value b_y is taken from the SIZ or CBD marker segment as appropriate. The value b_z is signalled in the BDnlt field of the NLT marker segment. Once the coefficients have been scaled appropriately, Equation K-5 can be applied directly to the integer image data for component Y_i' and produces the integer image data for component Z_i.

$$Z_i = \begin{cases} -\left(\frac{|Y_i'| + B_S}{A_S}\right)^{\frac{1}{E}} & Y_i' < -T_S \\ \frac{Y_i'}{S_S} & -T_S \le Y_i' \le T_S \\ \frac{Y_i' + B_S^{1/E}}{A_S} & Y_i' > T_S \end{cases} \quad \text{(K-5)}$$

K.2.2 LUT-style reverse non-linearity transformation

A non-linear transfer curve can often be approximated by a piece-wise linear function. The NLT marker segment provides a mechanism to specify such a non-linearity. This method is referred to as a "LUT-style non-linearity" for two reasons. First, from the specified information it is possible to build a look-up table to perform the transformation. Second, if the number of table values specified is equal to the number of possible decoded values, then a LUT is explicitly specified. While it is possible to approximate the gamma-style non-linearities specified in K.2.1, this mechanism allows for other transformations that cannot be specified using a simple gamma function.

The LUT-style non-linearity requires that a list of table values be supplied. The maximum possible number of LUT values for a table to produce component Z_i from component Y_i' is $N = 2^{b_y}$, where b_y is the number of bits used to represent the component Y_i' (as specified by the CBD marker if the multiple component transformation is used, or the SIZ marker segment (see A.2.3) if the multiple component transformation is not used). The minimum and maximum normalized LUT input values are D_{min} and D_{max}, respectively, where normalization includes shifting and linear scaling so that the range of the Y_i' component values is 0 to +1, regardless of whether component Y_i' is signed or unsigned.

The NLT marker specifies a total of N_{points} values, where $2 \le N_{points} \le N$. Those values are evenly distributed across the input range of D_{min} to D_{max}. Table value T_k (where $k = 0, 1, \ldots, N_{points} - 1$) represents the output of the reverse transformation for an input value of D_k. The D_k values are implicitly determined by D_{min}, D_{max}, and N_{points} through the following equation:

$$D_k = D_{min} + k\Delta$$
$$\text{where } \Delta = \frac{D_{max} - D_{min}}{N_{points} - 1} \quad \text{(K-6)}$$
$$\text{and } D_{max} > D_{min}$$

The actual LUT table values are specified in a normalized, shifted form, with the range of both the input and output components being 0 to +1, regardless of whether the components are signed or unsigned.

Values of the Y_i' input component (y') are normalized as follows before being processed through the LUT:

$$y'_{norm} = \begin{cases} \dfrac{y'}{2^{b_y} - 1} & Y_i' \text{ is unsigned} \\ \dfrac{y' + 2^{b_y - 1}}{2^{b_y} - 1} & Y_i' \text{ is signed} \end{cases} \tag{K-7}$$

If $y'_{norm} < D_{min}$, then y'_{norm} shall be clipped to D_{min}. If $y'_{norm} > D_{max}$, then y'_{norm} shall be clipped to D_{max}. The normalized values of the output component Z_i are then specified by the following equation:

$$\begin{gathered} z_{norm} = t_k + \left(\frac{y'_{norm} - D_k}{\Delta} \right)(t_{k+1} - t_k) \\ t_k = \frac{T_k}{2^{b_t} - 1} \end{gathered} \tag{K-8}$$

where k is the first integer such that $D_k \le y'_{norm} < D_{k+1}$. The final non-normalized value of the output component Z_i is specified by the following equation:

$$z = \begin{cases} z_{norm} \times (2^{b_z} - 1) & Z_i \text{ is unsigned} \\ z_{norm} \times (2^{b_z} - 1) - 2^{b_z - 1} & Z_i \text{ is signed} \end{cases} \tag{K-9}$$

where b_z is the bit depth of the output component Z_i and is signalled in the BDnlt parameter of the NLT marker segment. The parameters, N_{points}, D_{min}, D_{max}, the array of T_k values and b_t are signalled in the NLT marker segment. b_t is stored in the NLT marker segment in the PTval field. The array of T_k values is stored in the Tvalues field.

Annex L

Region of interest coding and extraction, extensions

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard. The capabilities of the codestream are defined by the SIZ marker segment parameter Rsiz (see A.2.1).

This annex describes the region of interest (ROI) technology. An ROI is a part of an image that is encoded with higher fidelity than the rest of the image (the background). The encoding is also done in such a way that the information associated with the ROI precedes the information associated with the background. The method used (and described in this annex) is the Scaling based method.

L.1 Decoding of ROI

The procedure specified in this subclause is applied only in the case of the presence of an RGN marker segment, see A.2.5 (indicating the presence of an ROI coded with the Scaling based method).

The procedure realigns the significant bits of ROI coefficients and background coefficients. It is defined using the following steps:

1) Get the corresponding shape information and the scaling value, *s*, from the RGN marker segment for each ROI. The following steps 2-6 are applied to each coefficient (u, v) of sub-band *b*.
2) Generate the ROI mask $\{M_i(u, v)\}$ for all ROI, see L.3 for details on how to generate the ROI mask.
3) For each coding block find the largest scaling value, S_{max} for any coefficient (u, v).
4) For each coefficient in each coding block find the highest scaling value and set $s(u, v)$ to:

$$s(u, v) = s_{Max} - max(s_i \cdot M_i(u, v)) \tag{L-1}$$

where i = *0... Number of ROI*–1

5) For each coefficient (u, v) discard the first $s(u, v)$ MSBs and shift up the remaining MSBs $s(u, v)$ places, as described in Equation L-2, for $i = 1, \ldots, M_b$

$$MSB_i(b, u, v) = \begin{cases} MSB_{i+s(u,v)}(b, u, v) & \text{if } i + s(u, v) \le N_b(u, v) \\ 0 & \text{if } i + s(u, v) > N_b(u, v) \end{cases} \tag{L-2}$$

6) Update the value of $N_b(u, v)$ as given in Equation L-3.

$$N_b(u, v) = \max(0, N_b(u, v) - s(u, v)) \tag{L-3}$$

L.2 Description of the Scaling based method

This subclause describes how to encode an image with one or more ROI. The encoding is given here as an informative section. However, failure to generate the correct ROI mask at the encoder side will greatly reduce the quality of the decoded image and will not allow lossless decoding.

L.2.1 Encoding with ROI (informative)

At the encoder side an ROI mask is created describing which quantized transformation coefficients must be encoded with better quality (up to lossless). The ROI mask is a bit map describing these coefficients for one ROI. See L.3 for details on how the mask is generated.

The quantized transformation coefficients are scaled in such a manner that the relative significance of each transformation coefficient is equal to the specified scaling value, s, of the ROI to which it applies. If a transformation coefficient belongs to several ROI the largest *s* value is chosen. If a transformation coefficient belongs to the

Background, the scaling value s equals 0. Before scaling the quantized transformation coefficients of one code-block, the highest, s_{Max}, and lowest, s_{Min}, scaling value for the coding block are found.

Consider a quantized transformation coefficient, $q_b(u,v)$, in the current coding block with corresponding scaling value, s (where $s_{Min} \le s \le s_{Max}$). After scaling, the individual bits of $q_b(u, v)$ end up $abs(s_{Max}–s)$ bit planes lower than the corresponding bits of a coefficient with $s = s_{Max}$. The number of magnitude bits for this coding block will hence increase by $(s_{Max}–s_{Min})$.

Since the coding blocks are treated independently, quantized transformation coefficients belonging to the same ROI might end up having different levels of significance in different coding blocks. This difference between coding blocks must be taken care of by the rate allocator. An example of this would be if an entire coding block belongs to the image background and another coding block has both ROI and background coefficients. In this case, the background coefficients in the second coding block would be downshifted by s–0 steps whereas in the first coding block no shifting would be done. In this case it is up to the rate allocation algorithm to make sure that the bit planes from the two coding blocks are put in the bit stream in the correct order.

When the entropy coder encodes the quantized transformation coefficients, the bit planes associated with the ROI are coded before or at the same time as the information associated with the background. The scaling value, s_i, for each ROI is specified by the user/application.

The method can be described using the following steps for a set of n ROI:

– For each coding block in each component:

1) Generate ROI mask for all ROI i, $\{M_i (u, v)\}$, see L.3.

2) Find s_{Min} and s_{Max}, where s_{Min} and s_{Max} are the smallest and largest scaling value in the current coding block, respectively.

3) Add $s_{Block} = s_{Max}–s_{Min}$ LSBs to each coefficient $|q_b(u, v)|$. The number M'_b of magnitude bit-planes for sub-band, b, will then be:

$$M'_b = M_b + s_{block} \tag{L-4}$$

where M_b is given by ITU-T Rec. T.800 | ISO/IEC 15444-1, Equation E-2, and the new value of each coefficient is given by:

$$|q_b(u, v)| = |q_b(u, v)| - 2^{s_{Block}} \tag{L-5}$$

4) For each coefficient in each coding block find the highest scaling value and set $s(u, v)$ to:

$$s(u, v) = s_{Max} - max(s_i - M_i(u, v)) \tag{L-6}$$

where i = $0...$ *Number of ROI*–1

5) Scale down all coefficients so that:

$$|q_b(u, v)| = \frac{|q_b(u, v)|}{2^{s(u, v)}} \tag{L-7}$$

6) For each ROI write the scaling value, s, shape, and reference points into the codestream using the RGN marker segment as described in A.2.5.

L.3 Region of interest mask generation

To achieve an ROI with better quality than the rest of the image while maintaining a fair amount of compression, bits need to be saved by sending less information for the background. To do this an ROI mask is calculated. The mask is a bit-plane indicating a set of quantized transformation coefficients whose coding is sufficient in order for the receiver to reconstruct the desired region with better quality than the background (up to lossless).

To illustrate the concept of ROI mask generation, let us restrict ourselves to a single ROI and a single image component, and identify the samples that belong to the ROI in the image domain by a binary mask, *M(x, y)*, where:

$$M(u,v)=\begin{cases}1 & \text{wavelet coefficient } (u,v) \text{ is needed}\\ 0 & \text{accuracy on } (u,v) \text{ can be sacrified without affecting ROI}\end{cases} \quad \text{(L-8)}$$

The mask is a map of the ROI in the wavelet domain so that it has a non-zero value inside the ROI and 0 outside. In each step, each sub-band of the mask is then updated line by line and then column by column. The mask will then indicate which coefficients are needed at this step so that the inverse transformation will reproduce the coefficients of the previous mask.

For example, the last step of the inverse transformation is a composition of two sub-bands into one. Then to trace this step backwards, the coefficients of both sub-bands that are needed are found. The step before that is a composition of four sub-bands into two. To trace this step backwards, the coefficients in the four sub-bands that are needed to give a perfect reconstruction of the coefficients included in the mask for two sub-bands are found.

All steps are then traced backwards to give the mask. If the coefficients corresponding to the mask are transmitted and received, and the inverse transformation calculated on them, the desired ROI will be reconstructed with better quality than the rest of the image (up to lossless if the ROI coefficients were coded losslessly).

Given below are descriptions of how the expansion of the mask is acquired in the rectangular and elliptic case and also how this is done for the various filters. Similar methods can be used for other filters.

L.3.1 Rectangular mask generation on the reference grid

The rectangular mask described in this subclause is generated on the reference grid. When generated on the reference grid the methods described in L.3.4 and L.3.5 are used for mask generation in the wavelet domain. A rectangle is described by four parameters, see Figure L.1, all signalled in the RGN marker, see A.2.5. The parameters are (*XArgn*, *YArgn*, *XBrgn*, *YBrgn*) where *XArgn* and *YArgn* are the *x* offset and *y* offset of the upper left corner of the rectangle from the reference grid origin, respectively; *YBrgn* is the height of the rectangle; *XBrgn* is the width of the rectangle.

The correct mask for the reference grid is given by Equation L-9.

$$\begin{aligned}XArgn &\le x < XArgn + XBrgn\\ YArgn &\le y < YArgn + YBrgn\end{aligned} \quad \text{(L-9)}$$

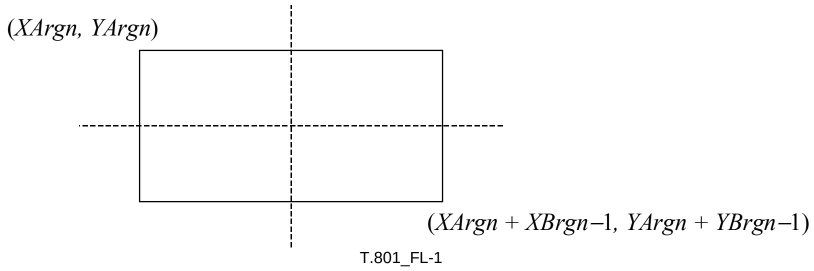


Figure L.1 – Rectangular mask on the reference grid

L.3.2 Elliptic mask generation on the reference grid

The elliptic mask described in this subclause is generated on the reference grid. When generated on the reference grid, the methods described in L.3.4 and L.3.5 are used for mask generation in the wavelet domain. An ellipse is described by four parameters, see Figure L.2, all signalled in the RGN marker, see A.2.5. The parameters are (*XArgn*, *YArgn*, *XBrgn*, *YBrgn*) where *XArgn* and *YArgn* are the *x* offset and *y* offset of the center of the ellipse from the reference grid origin, respectively; *YBrgn* is the height of the ellipse; *XBrgn* is the width of the ellipse.

The correct mask for the reference grid is given by Equation L-10.

$$YBrgn^2 \cdot (x - XArgn)^2 + XBrgn^2 \cdot (y - YArgn)^2 \le XBrgn^2 \cdot YBrgn^2 \quad \text{(L-10)}$$

Thus, a coordinate on the reference grid belongs to the ROI if and only if Equation L-10 is true.

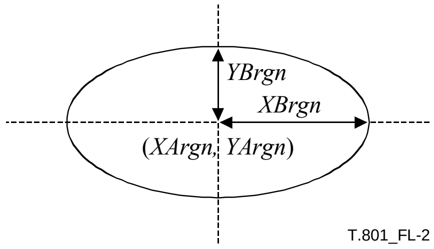


Figure L.2 – Elliptic mask on the reference grid

L.3.3 Region of Interest mask generation of whole-sample symmetric filter banks

The whole-sample symmetric filter banks are a subset of the arbitrary optional filter banks, the ROI mask generation can be described in the same way as for the arbitrary optional filter banks, see L.3.4. When using whole-sample symmetric, use the parameters defined in H.1.2.

L.3.4 Region of Interest mask generation of arbitrary optional filter banks

The generation of the ROI mask follows the arbitrary decomposition of tile-components as described in Annex F. However, instead of decomposing a tile-component, an ROI mask is decomposed. This ROI mask is defined on the reference grid, and is a two-dimensional binary mask with the same dimensions as the corresponding tile-component. The ROI mask has non-zero values where the samples of the tile-component belong to the ROI and zero values otherwise.

Instead of calculating the wavelet coefficients using the lifting steps, as described in Annex H, the lifting steps for the inverse discrete wavelet transformation are followed in reverse order and in each lifting step the wavelet coefficients that are used to reconstruct wavelet coefficients that correspond to non-zero samples in the ROI mask are found. For each lifting step, the ROI mask is updated so that all samples that correspond to wavelet coefficients that would have been used to reconstruct the wavelet coefficients that correspond to non-zero samples in the ROI mask are set to non-zero values. The mask generation must take into account what type of filter that has been used by the transformation and also whether or not the SSO transformation has been used. The different cases are described below.

This is done by replacing Equations H-4, H-5 and H-7 by:

Let the 1D mask, to be decomposed, be R_{ext}.

For each lifting step s where s ranges from 0 to $N_{LS} - 1$,

a)

$$\begin{aligned}&\text{if } (R_{ext}(2n+m_s)==1)\\&\text{then}\\&(R'_{ext}(2n+1-m_s+2(k+\mathit{off}_s)))=1, \text{ for all } k=0, \ldots, L_s-1\\&\text{and}\\&R'_{ext}(2n+m_s)=1\end{aligned} \quad \text{(L-11)}$$

where R_{ext} are the samples in the ROI mask, $M_i(u,v)$ corresponding to V_{ext} in Equations H-4, H-5 and H-7. R'_{ext} is R_{ext} after lifting step s. Moreover, $m_s = 1 - m_{s-1}$ indicates whether the sth lifting step applies to even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), and where L_s is the number of lifting coefficients for lifting step s.

b)

$$R_{ext} = R'_{ext} \quad \text{(L-12)}$$

L.3.4.1 Single sample overlap

This is done by replacing Equations I-12 and I-14 by:

For each lifting step s where s ranges from 0 to $N_{LS} - 1$,

a)

$$\begin{aligned}&\text{for all } n \text{ except } n_p,\ p = 0, 1, \ldots, N_I:\\&\text{if } (R(2n + m_s) == 1):\\&R'(PSE_{O,\,p}(2n + m_s - (2k+1))) = R'(PSE_{O,\,p}(2n + m_s + (2k+1))) = 1, \text{ for } k = 0, \ldots, L_s - 1\\&\text{for all } n_p,\ p = 0,1, \ldots, N_I:\\&\text{if } (R(n_p) == 1):\\&R'(n_p) = 1\end{aligned} \tag{L-13}$$

where R are the samples in the ROI mask, $M_i(u,v)$ corresponding to V in Equations I-12 and I-14. R' is R after lifting step s. Moreover, $m_s = 1 - m_{s-1}$ indicates whether the sth lifting step applies to even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), and where L_s is the number of lifting coefficients for lifting step s. N_I, p, n_p and $PSE_{O,\,p}()$ are defined as in Annex I.

b)

$$R = R' \tag{L-14}$$

After doing this for all the lifting steps, the ROI mask samples are separated into sub-bands the same way as the wavelet coefficients are separated in using the deinterleave procedure described in F.4.5 of ITU-T Rec. T.800 | ISO/IEC 15444-1.

This ensures that each coefficient that has affected a coefficient in the ROI during the inverse wavelet transformation will have a '1' in the corresponding place in the ROI mask

L.3.5 Fast generation of a rectangular mask (informative)

In the case of a rectangular ROI, the mask can be derived more quickly than for arbitrary shapes. In this case, instead of tracing how each coefficient and pixel value is reconstructed in the inverse transform, only two positions need to be studied, namely the upper left and the lower right corners of the mask. The top-left corner, (x_1, y_1) on the reference grid will be given in the RGN marker segment as XArgn, YArgn, and the bottom right corner (x_2, y_2), on the reference grid will be given by the parameters in the RGN marker segment as (XArgn + XBrgn–1), (YArgn + YBrgn–1), respectively (see A.3.8). The mask generation must take into account what type of filter that has been used by the transform. This can be combined with the single sample overlap transform.

In each level of decomposition, the steps described in the previous subclause are followed to see how the mask expands.

Let the 1D mask, to be decomposed, be R_{ext}, and let x_1 and x_2 and be the lowest and highest indices of non-zero samples in R_{ext}.

1) For each lifting step s where s ranges from 0 to $N_{LS} - 1$,
   a) Find the lowest sample index ($2n + m_s \geq x_1$) that is in the mask

$$x_1' = 2n + 1 - m_s + 2off_s \tag{L-15}$$

$$\begin{aligned}&\text{if } (x_1' > x_1):\\&x_1' = x_1\end{aligned} \tag{L-16}$$

b) Find the highest sample index $2n + m_s \le x_2$

$$x'_2 = 2n + 1 - m_s + 2(L_s - 1 + off_s) \quad \text{(L-17)}$$

$$\begin{array}{c} \text{if } (x'_2 > x_2): \\ x'_2 = x_2 \end{array} \quad \text{(L-18)}$$

c) Set

$$x_1 = x'_1,$$
$$x_2 = x'_2$$

where $m_s = 1 - m_{s-1}$ indicates whether the sth lifting step applies to even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), and where L_s is the number of lifting coefficients for lifting step s.

Let all samples between x_1 and x_2, inclusive, be non-zero and then separate the ROI mask samples into sub-bands the same way as the wavelet coefficients are separated in using the deinterleave procedure described in F.4.5 of ITU-T Rec. T.800 | ISO/IEC 15444-1.

L.3.5.1 Single Sample Overlap

In each level of decomposition, the steps described in L.3.4.1 are followed to see how the mask expands.

Let the 1D mask, to be decomposed, be R and let x_1 and x_2 be the lowest and highest indices of non-zero samples in R.

1) For each lifting step s where s ranges from 0 to $N_{LS} - 1$,

a) Find the lowest sample index ($2n + m_s \ge x_1$) that is in the mask

$$\begin{array}{c} \text{if } x_1 = n_p, p = 0, 1, \ldots, N_I: \\ x'_1 = x_1 \\ \text{else} \\ x'_1 = min(PSE_{O,\ p}(2n + m_s - (2k+1))),\ k = 0, \ldots, L_s - 1 \end{array} \quad \text{(L-19)}$$

$$\begin{array}{c} \text{if } (x'_1 > x_1): \\ x'_1 = x_1 \end{array} \quad \text{(L-20)}$$

b) Find the highest sample index $2n + m_s \le x_2$

$$\begin{array}{c} \text{if } x_2 = n_p, p = 0, 1, \ldots, N_I: \\ x'_2 = x_2 \\ \text{else} \\ x'_2 = max(PSE_{O,\ p}(2n + m_s + (2k+1))),\ k = 0, \ldots, L_s - 1 \end{array} \quad \text{(L-21)}$$

$$\begin{array}{c} \text{if } (x'_2 < x_2): \\ x'_2 = x_2 \end{array} \quad \text{(L-22)}$$

c) Set

$$x_1 = x'_1,$$
$$x_2 = x'_2$$

where $m_s = 1 - m_{s-1}$ indicates whether the sth lifting step applies to even-indexed coefficients ($m_s = 0$) or odd-indexed coefficients ($m_s = 1$), and where L_s is the number of lifting coefficients for lifting step s, and where off_s is the offset for lifting step s. N_I, p, n_p and $PSE_{O,\ p}()$ are defined as in Annex I.

Let all samples between x_1 and x_2, inclusive, be non-zero and then separate the ROI mask samples into sub-bands the same way as the wavelet coefficients are separated in using the deinterleave procedure described in F.4.5 of ITU-T Rec. T.800 | ISO/IEC 15444-1.

L.4 Remarks on region of interest coding

This subclause contains a remark for the case of multi-components and a remark on implementation precision.

L.4.1 Usage together with Maxshift method described in ITU-T T.800 | ISO/IEC 15444-1

The Maxshift method described in ITU-T T.800 | ISO/IEC 15444-1 must not be used together with the method described in this Recommendation | International Standard.

L.4.2 Multi-component remark (informative)

For the case of colour images, the method applies separately in each colour component. If some of the colour components are down-sampled, the mask for the down-sampled components is created in the same way as the mask of the non-down-sampled components.

L.4.3 Implementation Precision remark (informative)

This ROI coding method might in some cases create situations where the dynamic range is exceeded. This is however easily solved by simply discarding the least significant bit planes that exceed the limit due to the downscaling operation. The effect will be that the ROI will have better quality compared to the background, even though the entire bit stream is decoded. It might however create problems when the image is coded with ROI's in a lossless mode. Discarding least significant bit-planes for the background might have the result that the background is not coded losslessly; and in the worst case the background may not be reconstructed at all. This depends on the dynamic range available.

Annex M

JPX extended file format syntax

(This annex forms an integral part of this Recommendation | International Standard)

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate. This annex describes an extension to ITU-T Rec. T.800 | ISO/IEC 15444-1 that can be used alone or in conjunction with any of the other extensions in this Recommendation | International Standard.

M.1 File format scope

This annex defines an optional file format that applications may choose to use to contain JPEG 2000 compressed image data. This format is an extension to the JP2 file format defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex I. While not all applications will use this format, many applications will find that this format meets their needs. However, those applications that do implement this file format shall implement it as described in this entire annex.

This annex :

– specifies a binary container for both image and metadata;

– specifies a mechanism to indicate image properties, such as the tonescale or colourspace of the image;

– specifies a mechanism by which readers may recognize the existence of intellectual property rights information in the file;

– specifies a mechanism by which metadata (including vendor specific information) can be included in files specified by this Recommendation | International Standard;

– specifies a mechanism by which multiple codestreams can be combined into a single work, by methods such as compositing and animation.

M.2 Introduction to JPX

As defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex I, the JP2 file format provides a method by which applications can interchange images files in such a way that all conforming readers can properly interpret and display the image. However, some applications require extensions to the JP2 file format that would prevent the file from being properly interpreted by a conforming reader. For example, an image encoded in a CMYK colourspace will not be properly interpreted by a conforming JP2 reader.

Placing these non-compatible extensions into a JP2 file will introduce confusion in the marketplace, as a situation will exist where some readers can interpret some JP2 files but not others. While this confusion is inevitable when you consider the global set of all applications profiles, it must be avoided in some applications, such as on the consumer desktop.

Thus this annex defines a second file format to be used in applications that require functionality or data structures beyond those defined in the JP2 file format. This file format is called JPX.

M.2.1 File identification

JPX files can be identified using several mechanisms. When stored in traditional computer file systems, JPX files should be given the file extension ".jpf" (readers should allow mixed case). On Macintosh file systems, JPX files should be given the type code 'jpx\040'.

However, if a particular JPX file is compatible with the JP2 reader specification (as indicated by placing the code 'jp2\040' in the compatibility list in the File Type box), then the writer of that file may choose to use the extensions for the JP2 file format, as specified in I.2.1 of the JP2 file format, for that particular file. This will maximize the interoperability of that file without sacrificing file indication (as the BR field in the File Type box shall be 'jpx\040' for files completely defined by this Recommendation | International Standard).

In the JP2 file format, the File Type box provides information that a file reader can use to determine if it is capable of reading the file. This box is also present in other JPEG 2000 family file formats.

M.2.2 File organization

As in JP2 files, a JPX file represents a collection of boxes. The binary structure of a file is a contiguous sequence of boxes. The start of the first box shall be the first byte of the file, and the last byte of the last box shall be the last byte of the file. Many boxes are defined by this Recommendation | International Standard. In addition, other Recommendations | International Standards may define other boxes for use within JPX files. However, all information contained within a JPX file shall be in the box format; byte-streams not in the box format shall not be found in the file.

The binary structure of a box in a JPX file is identical to that defined in the JP2 file format (ITU-T Rec. T.800 | ISO/IEC 15444-1, I.4).

M.2.3 Greyscale/Colour/multi-component specification

The JP2 file format allowed the colourspace of the image to be specified in two ways (Enumerated or Restricted ICC methods). The JPX file format expands on this by:

– defining additional colourspaces for the Enumerated method (M.11.7.3.1);
– defining a method for vendors and other standards bodies to register additional Enumerated colourspaces (M.7.3.1);
– defining a new method to allow the use of any input ICC profile (the Any ICC method, M.11.7.3.2);
– defining a new method to allow vendors to define unique codes for colourspaces independently from a registration authority (the Vendor Colour method, M.11.7.3.3);
– allowing the use of extensions of the multiple component transformation and non-linearity transformation extensions within the codestream (see Annexes J and K).

M.2.4 Specification of opacity information

The JPX file format specifies two extensions for specifying opacity information. First, the file format allows for opacity channels to be stored in a separate codestream from the colour channels of the image. In many image editing applications, the colour data and the opacity data are edited separately, and thus it is useful to allow those channels to be stored in separate codestreams. This is described in the compositing layer architecture description in M.5.

Secondly, the JPX file format allows for the specification of fully transparent samples through a chroma-key. The file format specifies an array of sample values, one from each colour channel. Image locations that contain that combination of sample values shall be considered fully transparent. For example, the chroma-key may be specified as red = 134, green = 92 and blue = 47. Any location with this combination of red, green and blue sample values shall be considered fully transparent. This is defined in the specification of the Opacity box in M.11.7.6.

M.2.5 Metadata

In addition to specifying how the image data shall be stored, this Recommendation | International Standard defines, in Annex M, a number of metadata elements. These elements specify information such as how the image was created, captured or digitized, or how the image has been edited since it was originally created. This Recommendation | International Standard also includes the ability to specify intellectual property rights information, as well as the content of the image, such as the names of the people and places in the image.

In addition to the metadata defined within this Recommendation | International Standard, other forms of XML-based metadata and descriptions (for example those defined by Annex N), may be embedded in a JPX file within XML boxes.

Furthermore, the MPEG-7 binary box (as defined in M.11.19) may be used to store MPEG-7 binary (BiM) format metadata.

M.2.6 Storage of a codestream within JPX

In JP2, the entire codestream is required to be stored in a contiguous portion of the file. However, this restriction can be problematic for some applications. Image editing applications, for example, may desire to modify a single tile of the image and to write the modified tile to the end of the file without rewriting the file. Image servers or internet applications may desire to split the image up into multiple files on different disks or spread the codestream across the internet. The JPX file format allows these features by allowing the codestream to be divided into fragments. The fragmentation of codestreams is described in M.4.

M.2.7 Combining multiple codestreams

In addition to specifying the rendered result as a result of decompressing a single codestream and properly interpreting the colourspace of that codestream as specified in the JP2 file format, the JPX file format allows for multiple codestreams to be combined to produce the rendered result. These codestreams can be combined in a combination of two ways: compositing and animation. This is further described in M.5.

M.3 Greyscale/Colour/Palette/multi-component specification architecture

The JPX file format builds on the flexible colour architecture defined in the JP2 file format. Colourspace specifications are specified within Colour Specification boxes, as originally defined in JP2. However, JPX extends this box (within the binary structure limitations defined in JP2) to allow other methods to be used to specify the colourspace, and to allow a reader to select from the different colourspace specifications found in a single file when interpreting an image.

M.3.1 Extensions to the Colour Specification box header

In JP2, the APPROX and PREC fields were reserved for future use; JP2 writers are required to write default values into these fields. In JPX, these fields are defined and can be used by a JPX reader to make intelligent processing choices.

In both JP2 and JPX, a single file may contain multiple representations of the colourspace of the image. For example, a JPX image may contain an enumerated value, a complex ICC profile, and a Restricted ICC profile. These multiple methods are included to maximize interoperability as well as to provide optimized access. In this example, the enumerated value allows quick recognition, the complex ICC profile allows accurate interpretation using a full ICC engine, and the Restricted ICC profiles allows less complex readers to get a "good enough" result. Specifically, the Restricted ICC profile in this example is an approximation of the complex ICC profile. This approximation is specified within the Colour Specification box, and allows a reader to make trade-offs when interpreting the image.

The Colour Specification box also allows the writer to associate a precedence with each method. This information specifies a default priority in which the multiple colourspace specifications should be considered when selecting which specification will be used to interpret the decompressed code values.

However, the use of both the approximation and precedence information is beyond the scope of this Recommendation | International Standard. Applications are free to consider both pieces of information together and to define their own priorities for selecting which colourspace method to use when interpreting the image. For example, in a fast-preview mode, where speed is more important then quality, an application may desire to use the Restricted ICC profile even if it can use the more complex profile.

M.3.2 Extensions to the Enumerated method

The JPX format defines enumerated values for several additional colourspaces. In addition, this Recommendation | International Standard defines a mechanism by which vendors or other standards bodies can register additional values for the EnumCS field in the Enumerated Method. In general, there are no implementation requirements for these additional defined or registered colourspaces. Requirements for interpretation of specific spaces are defined within the file conformance definition.

In addition, the data structures for the enumerated method have been extended to allow for the specification of parameters that define exactly how that particular colourspace was encoded in the file. For example, the CIELab colourspace, as defined by ITU-T Rec. T.42 specifies six parameters that specify the exact encoding range and offsets of the stored data. To properly interpret a CIELab image, the decoder must know this information and apply those parameters to the decoded image data. Enumerated parameters are specified individually for each enumerated colourspace that requires parameters. However, many colourspaces do not require additional parameters, and thus additional parameters are not defined for those colourspaces. For colourspaces that do specify additional parameters, default values may be defined (as for example are done for the definitions of CIELab and CIEJab). If the entire block of additional parameters are not contained within the Colour Specification box, then the default values shall be used; however, if any additional parameter is specified for a particular Colour specification box, then all additional parameters must be specified for that Colour Specification box.

M.3.3 Any ICC method

In the JP2 file format, the Restricted ICC method was defined, allowing images to be encoded in a wide range of RGB and greyscale spaces. However, many colourspaces, such as CMYK and CIELab spaces, cannot be represented using the restricted set of ICC profiles allowed by the Restricted ICC method. JPX lifts this restriction by defining a separate method to allow any legal ICC input profile to be embedded in the file. This is a separate colour method than the Restricted ICC method, which is also legal in a JPX file. Applications shall not use the Restricted ICC METH value for embedding non-Restricted ICC profiles.

M.3.4 Vendor Colour method

While this Recommendation | International Standard defines a method by which new colourspaces can be registered, the registration method is not appropriate for use for defining codes for vendor-specific or private colourspaces. To allow the quick identification of these colourspaces, the JPX standard defines an additional colourspace specification method, called the Vendor Colour method. This method is very similar to the Enumerated method, except that instead of using 4-byte integer codes, the Vendor Colour method uses UUID's. These UUID values are generated by application developers when the definition of a particular colourspace is created.

It is legal to specify a Vendor Colour value in every JPX file. However, no reader is required to correctly interpret the image based solely on the Vendor Colour method. If an image writer desires to maximize interoperability outside the scope of the target application, it should use additional colour methods in the file (such as the Any ICC and Restricted ICC colour methods).

M.3.5 Palettized colour

Palettized colour is specified and works exactly as defined in the JP2 file format. A palettized image would contain a Palette box, which specifies the transformation from one to many components. The many components generated by the palette are then interpreted by the rest of the colour architecture as if they had been stored directly in the codestream.

M.3.6 Using multiple methods

The JPX file format allows for multiple methods to be embedded in a single file (as in the JP2 file format) and allows other standards to define extensions to the enumerated method and to define extended methods. This provides readers conforming to those extensions a choice as to what image processing path should be used to interpret the colourspace of the image.

If the file is to be JP2 compliant, the first method found in the file (in the first colourspace specification box in the JP2 Header box) shall be one of the methods as defined and restricted in the JP2 file format. However, a conforming JPX reader may use any method found in the file.

M.3.7 Interactions with the decorrelating multiple component transformation

The specification of colour within the JPX file format is independent of the use of a multiple component transformation or non-linearity correction within the codestream (the MCT, MCC, MCO and NLT markers specified in A.3.7, A.3.8, A.3.9 and A.3.10, respectively). The colourspace transformations specified through the sequence of Colour Specification boxes shall be applied to the image samples after the reverse multiple component transformation and reverse non-linearity correction has been applied to the decompressed samples. While the application of these decorrelating component transformations is separate, the application of an encoder-based multiple component transformation will often improve the compression of colour image data.

M.4 Fragmenting the codestream between one or more files

Another important feature of the JPX file format is the ability to fragment a single codestream within a single file or across multiple files. This allows applications to implement such features as:

- edit an image, resaving the changed tiles to the end of the file;
- distribute the image across several disks for faster access;
- distribute the image across the internet, allowing only certain customers access to the high quality or high resolution portions of the codestream;
- reuse of headers from within a codestream across multiple codestreams (to minimize file overhead when storing similar codestreams within the same JPX file).

Fragmentation in JPX works by specifying a table of pointers to the individual fragments. Each pointer specifies three things:

- The file in which the fragment is contained. Because multiple fragments across multiple codestreams may be stored in the same file, the format encapsulates all filename/URL data into a table (the Data Reference box). Each fragment specification then references an entry in the data reference table.
- The offset of the first byte of the fragment within the file specified. This offset is with respect to the first byte of the file (byte 0) and points directly to the first byte of codestream data for that fragment; it does not point to the start of a box containing that fragment.
- The length of the fragment, in bytes.

While the fragment offset does not point to the start of the box, any codestream data contained within a JPX file must be encapsulated in a box. If a codestream is contained within the JPX file in contiguous form, then it shall be encapsulated within a Contiguous codestream box as specified in the JP2 file format and M.11.8; the file shall not also contain a Fragment table representing that contiguous codestream. If the codestream is contained within the JPX file in multiple fragments, then the codestream shall be encapsulated within one or more Media Data boxes (defined in M.11.9).

Figure M.1 shows how a fragment table is used to specify a complete codestream in an example JPX file when all fragments are stored within the file itself. Because the data reference table was empty (no external references), it may not exist in the JPX file. Boxes other than the fragment related boxes are not explicitly shown.

In this example, the codestream is divided into four fragments. The dark lines on the bottom of the Media Data boxes show the portion of the contents of that Media Data box that represents the fragment. Two of those fragments are contained within the same Media Data box. For each fragment, the fragment list specifies the offset and the length of each fragment. The offset values point to the first byte of the codestream data, relative to the beginning of the file. For example, the first fragment is at the start of the contents of a Media Data box. The offset to that fragment is to the first byte of the contents of the box, not to the start of the box header. The length values specify the length only of the actual codestream data for that fragment.

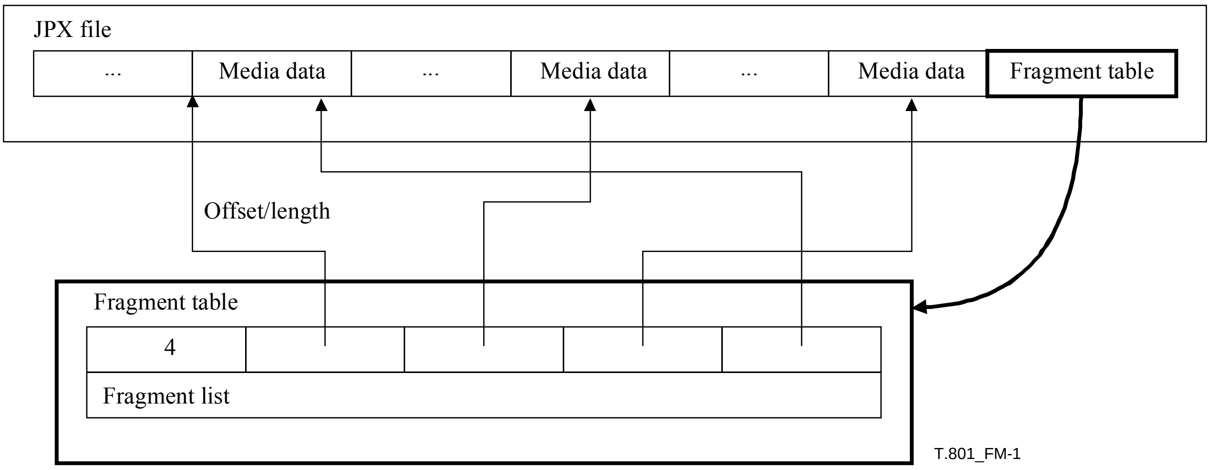


Figure M.1 – Example fragmented JPX file where all fragments are in the same file

To extract the complete codestream from the file, an application must locate the fragment table for that codestream in the file, and then parse the offsets and lengths from the fragment list. The application could then simply seek to the locations specified by the offsets and read the amount of data specified by the length.

Figure M.2 shows how a fragment table is used to specify a complete codestream in an example JPX file when some of the fragments are stored outside the file. In this case, the file shall contain a Data Reference box.

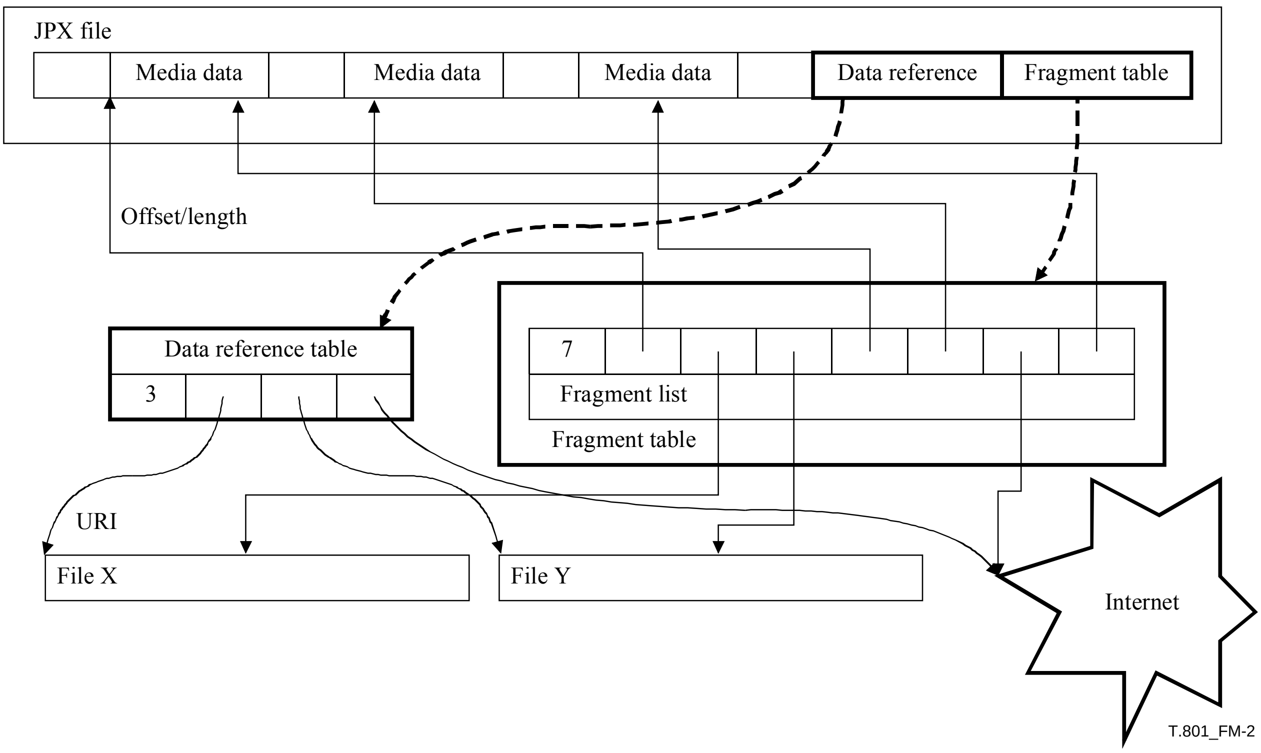


Figure M.2 – Example fragmented JPX file where some fragments are stored in other files or resources

In this example, two of the fragments are stored in separate but locally accessible files, and one of the fragments is stored across the internet.

M.5 Combining multiple codestreams

In the simplest JPX file, a rendered result is generated by decompressing a single codestream to one or more image channels and properly interpreting them in the context of the associated colourspace specification and optional opacity specification. This mode of operation is identical to that offered by JP2 except that JPX offers a wider range of colourspaces and specification methods. In addition to this, JPX offers a rich set of methods for combining multiple codestreams to form the rendered result.

In a JPX file it is possible to store multiple JP2 style "images." In the context of a single JPX file, these separate images are referred to as compositing layers. Each compositing layer comprises a set of channels that an application should treat as a unit for the purpose of rendering. The JPX file format includes syntax for specifying how the compositing layers in a file should be combined by the reader application to produce the rendered result. Both simple still image compositing and animation are supported.

In a JPX file, it is additionally possible to store a single image (or compositing layer) using multiple codestreams. This, for example, allows the separation of RGB components from an opacity channel component. This would permit a single opacity channel to be reused in other compositing layers in the JPX file. The file format also includes syntax for specifying how codestreams are combined to form compositing layers including how the codestreams should be spatially registered against each other.

In a JPX file, metadata can be associated with codestreams and compositing layers independently. Metadata may be shared between multiple codestreams.

M.5.1 Mapping codestreams to compositing layers

To facilitate the mapping of multiple codestreams to single compositing layers, the JPX format separates header fields defined for JP2 into two logical groups: those specific to a single codestream are grouped into a Codestream Header box (M.11.6) and those specific to a compositing layer are grouped into a Compositing Layer Header box (M.11.7). The process of mapping codestream components to channels is exemplified in Figure M.3. Multiple codestreams are combined via a Codestream Registration box (M.11.7.7) to provide the complete set of components for a compositing layer. A Component Mapping box (ITU-T Rec. T.800 | ISO/IEC 15444-1, I.5.3.5) in the Codestream Header box is used to specify how the components of any given codestream are mapped to channels. Interpretation of these channels is specified in the Compositing Layer Header box either using a Channel Definition box (M.11.7.5) or an Opacity box (M.11.7.6). The Opacity box is a new option in the JPX file format that provides an additional method for specifying compositing layers with simple compositing or that use chroma-key opacity.

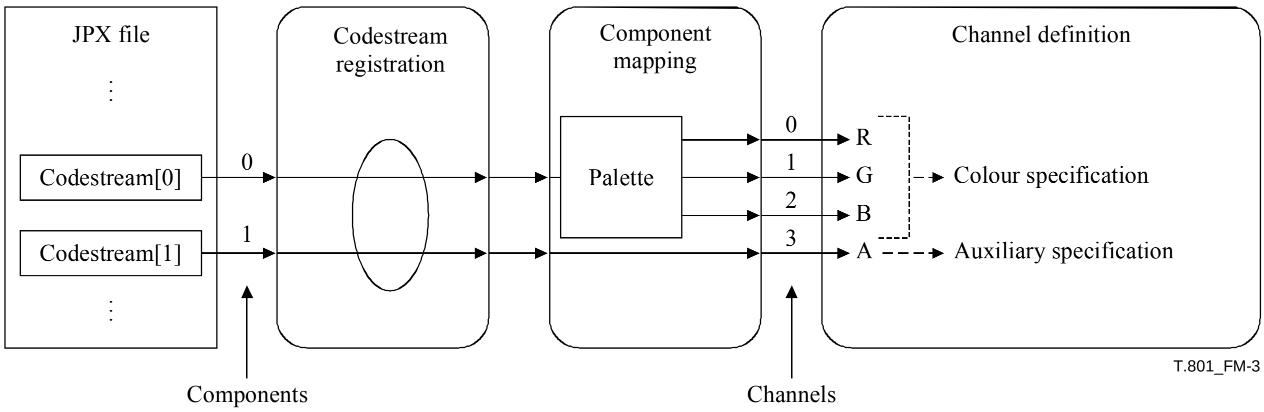


Figure M.3 – Example combination of two codestreams into a single compositing layer

M.5.1.1 Establishing a sequence order for compositing layers

A sequence order for compositing layers is required for any subsequent rendering or animation of the file. In the simplest case there are no Codestream Registration boxes in the file. In this case, which includes the case where all of the headers are present as global defaults, codestreams map directly to compositing layers and the compositing layer sequence order is given by the sequence order of the codestreams in the file.

If a Component Registration box is present in any Compositing Layer Header box, then there shall be one Component Registration box in every Compositing Layer Header box in the file. In this case, the order of compositing layers is given by the sequence order of compositing layer header boxes in the file.

M.5.1.2 Establishing an order for channels in a compositing layer

Where multiple codestreams are combined it is necessary to establish a sequence order over the combined set of channels generated from them. This sequence order is required so that specific channel numbers can be associated with channel definitions when using a Channel Definition box.

Channel ordering is zero based and performed independently for each compositing layer present in the file. The first n channels (numbered 0 through to $n - 1$) within the scope of a particular compositing layer are contributed by channels defined by the first Codestream Header box referenced in the layer's Component Registration box (where we assume this codestream generates n channels), the next m by the next codestream referenced in the layer's Component Registration box, and so on. Within each codestream, channel ordering is determined by the order of entries in the codestream's Component Mapping box, or by the order of components in the codestream if no Component Mapping box is present.

M.5.2 Sharing header and metadata information between codestreams and compositing layers

To minimize file overhead, it is useful to allow header and metadata information to be shared between codestreams and compositing layers where that information is identical. The JPX file format provides three mechanisms to share information: default headers, cross-references and label associations.

M.5.2.1 Default headers and metadata

When a JP2 Header box is found in a JPX file, the header information in that box shall be used as global default header information for all codestreams and compositing layers within the file. If a Codestream Header box includes boxes that also appear in the JP2 Header box, then these headers shall override the global headers for that specific codestream. If a Codestream Header box contains other boxes that do not appear in the global JP2 Header box, then these boxes shall augment the global header information for that specific codestream. Similarly, if a Compositing Layer Header box includes boxes that appear in the JP2 Header box, then these shall override the global headers for that specific compositing layer. If a Compositing Layer Header box contains other boxes that do not appear in the global JP2 Header box, then these boxes shall augment the global header information for that specific compositing layer.

Any metadata box, including IPR, XML and UUID boxes defined by the JP2 specification as well as additional metadata boxes defined by this specification, found at the file level (not contained within any other superbox) shall also be considered as containing global default information. As with header boxes, these global defaults may be overridden or augmented on a per codestream or per compositing layer basis by the inclusion of corresponding boxes in the codestream or layer header superboxes.

M.5.2.2 Cross-referencing headers and metadata

A Codestream Header box or Compositing Layer Header box may also contain a cross-reference to a box stored in another location. This cross-reference is very similar to the Fragment Table box used to specify the location of a fragmented codestream. In fact, a Cross-Reference box uses the same data structures as the Fragment Table box, with the addition of a field to specify the type of box being referenced. If a Codestream Header box or Compositing Layer Header box contains a Cross-Reference box, the reader shall consider the box pointed to by the reference as if it had been physically contained with the header. Cross-Reference boxes may be used equally for header and metadata.

M.5.2.3 Labelling and association

The Association box may be used to share a label (or other metadata) between codestreams and compositing layers by the inclusion of a Number List box within the Association box. A Number List box refers, by number, to a set of entities in the file. If the first box within an Association box is a Number List box, then any other boxes within the Association box will be associated with all of the entities referred to by the Number List box.

M.5.3 Composition

Composition data is divided into fixed options, contained in the Composition Options box (M.11.10.1), and a sequence of instructions contained in one or more Instruction Set boxes (M.11.10.2) boxes. Each instruction comprises a set of render parameters. Each instruction set has an associated repeat count which allows for the efficient representation of long sequences of repeating instructions such as occur in full motion sequences or in slide shows which use a repeated frame transition animation. A JPX file reader shall display a JPX file by reading and executing the instructions in sequence order, from each instruction set in sequence order and repeated according to its repeat value. The file is considered fully rendered either when there are no more instructions to execute, or no compositing layer is present for the current instruction.

M.5.3.1 Composition rendering

The composition data defines the width and height of a render area into which the compositing layers are to be rendered. The size of the render area is the size of the rendered result and can be thought of as the overall image size. Parameters in each render instruction may specify:

- a rectangular region to crop from the source compositing layer;
- the location to place the top left corner of the (possibly cropped) compositing layer with respect to the top left corner of the render area;
- the width and height of the region within the render area into which the (possibly cropped) compositing layer is to be rendered.

For example, in a composite image using an RGBA colour space for all compositing layers, the current compositing layer (R_t, G_t, B_t, A_t) is ideally rendered over the background (R_b, G_b, B_b, A_b) to form the composed image (R_c, G_c, B_c, A_c) according to the following equations:

$$\begin{aligned} A_c &= 1-(1-A_t)\times(1-A_b) \\ s &= \frac{A_t}{A_c} \\ t &= \frac{(1-A_t)\times A_b}{A_c} \\ R_c &= sR_t + tR_b \\ G_c &= sG_t + tG_b \\ B_c &= sB_t + tB_b \end{aligned} \tag{M-1}$$

In the case where the bottom sample is fully opaque, this simplifies to:

$$\begin{aligned} R_c &= A_t R_t + (1-A_t)R_b \\ G_c &= A_t G_t + (1-A_t)G_b \\ B_c &= A_t B_t + (1-A_t)B_b \end{aligned} \tag{M-2}$$

However, the above equations require access to the background pixel, and for a variety of reasons, individual applications may not be willing or able to support such a rendering process. It is possible to emulate continuous alpha blending even in these cases by thresholding or dithering the provided alpha channel in order to generate a set of completely transparent or completely opaque pixels which can be rendered using simple pixel replacement over an unknown background. Specification of such methods is however outside the scope of this Recommendation | International Standard.

M.5.3.2 Animation model

In addition to the basic cropping and positioning parameters, each render instruction may include LIFE, PERSIST and NEXT-USE parameters. The LIFE parameter assigns a temporal duration to the instruction. This is the period of time that the reader should aim to place between the appearance of any screen update resulting from execution of the current instruction and any screen update resulting from the execution of the next instruction. PERSIST is a binary field indicating whether or not the compositing layer rendered by the current instruction should be treated as part of the background for the next instruction. If an instruction specifies false for PERSIST, then the reader must save the background prior to execution and use this saved background when executing the next instruction.

M.5.3.2.1 Special cases of life and persistence

There are a number of special combinations of LIFE and PERSIST parameters that require specific treatment by the reader.

- When PERSIST is false and LIFE is zero, no action should be performed by the reader. This combination might be used for example to force a reader to step over a thumbnail or print frame that would be displayed by a reader not capable of displaying the file as an animation.
- When PERSIST is true and LIFE is zero then this instruction should be executed together with the next instruction. In practice this combination may occur for a sequence of more than two instructions and shall place the reader into a frame composition mode. This mode is exited when an instruction with non-

zero PERSIST is encountered or when the end of the animation is reached. The set of instructions executed whilst in frame composition mode is referred to as a frame composition sequence. In frame composition mode, a virtual compositing layer is created (off-screen) by executing the instructions in the frame definition sequence. The PERSIST and LIFE parameters for the closing instruction of a frame definition are applied to the virtual compositing layer. This mode permits multi-sprite animation.

– When LIFE is the maximum value that can be stored the reader shall interpret this as a request for indefinite life. If the driving application has the capacity, it shall progress to the next instruction upon completion of some predetermined user interaction such as a mouse click. In addition to its use in animations, this feature may be used in files that store multi-page documents in order to force the reader to pause after composition of each page.

In general, screen updates shall not be performed after an instruction which has zero LIFE unless it is the last instruction in a frame composition sequence.

M.5.3.2.2 Assigning compositing layers to instructions and layer reuse

Compression of animated sequences is considerably improved if compositing layers can be reused in multiple frames. At the same time it is desirable that instructions only reference compositing layers that have already been decoded or are sequentially next in the file. Further, decoders can better optimize their caching of compositing layers if they can tell which layers are to be reused ahead of time. These policies are enforced in JPX via the discipline used to associate compositing layers with instructions.

The first instruction is always associated with the first compositing layer in the file. This instruction may specify a value for NEXT-USE. This value is interpreted as the number of instructions, including the current instruction, until the current compositing layer is reused. A value of zero indicates to the reader that the current compositing layer shall not be used again and may be forgotten. A value of one implies that the current compositing layer is to be used with the next instruction and so on. The reader must maintain a record of which instructions have been assigned compositing layers in this fashion. Whenever an instruction is encountered that does not have a compositing layer assigned to it, the next unused compositing layer defined in the file in sequence order shall be used; the use of NEXT-USE does not specify a loop. A single compositing layer may be reused any number of times in any given animation.

M.5.3.2.3 Looping animations

It is possible to specify that an animation should be looped. That is, when the animation has been fully rendered, the reader resets the display to its initial state and displays the animation over again. A loop count is optionally specified as part of the composition options. As with life, the maximum value for the loop parameter is used to indicate indefinite looping. Looping impacts the caching strategy used by the reader as many readers will not wish to free any compositing layer once decoded.

M.6 Using reader requirements masks to determine how a file can be used

The JPX format defines a file architecture rather than a specific, fixed set of data structures that will be found in a file. This architecture is complex enough to permit quite distinct file structures. For example, a JPX file may include:

- animation;
- image collections;
- redundant image sets (e.g., print and display versions of the same scene); or
- single images in special colour spaces (e.g., Parameterized CIELab).

As a result, the JPX brand tells a reader little about what capabilities it will require in order to correctly read an arbitrary JPX file. Instead, JPX conveys this information using three expressions contained with in the header of the file. These expressions describe:

1) the full set of technologies/features present in the file;
2) the set of technologies/features required by a decoder in order to read the file in a form consistent with the intent of the files creator;
3) a fallback mode which can be used to display a minimally acceptable result (usually a thumbnail or preview).

The fallback mode is communicated using the File Type box and is primarily intended to indicate whether or not the file can be read by a reader with specifically standardized capabilities (such as a conforming JP2 or Baseline JPX reader). However, the combination of technologies required may be too complex for a simple listing of the functionalities in the file. For this reason, the technology/feature set information takes the form of encoded logic expressions and are contained in a Reader Requirements box.

In general, a reader need only identify that it satisfies the requirements outlined in point 2 in order to be assured of being able to read enough of the file to fulfil the creator's intent. On the other hand, an editor may want to inform a user if there is any aspect of the file that it does not know how to support. Because all JPEG 2000 family files are not necessarily interoperable with all JPX readers, these expressions describe each aspect of the file, and the combination of features that must be supported to interpret the file correctly.

M.6.1 Types of expressions

M.6.1.1 Fully understand aspects

An encoded expression is used to describe all of the items contained within the file, and the combinations of functionality required to read these items. This expression describes each major option a reader has for processing the features of the file, regardless of whether support for a particular feature is required to make use of that aspect of the file. For example, a file may contain metadata describing an original file from which it was created; however, a reader is not required to understand this metadata in order to correctly use the file.

M.6.1.2 Display contents

A second expression is used to describe the functionality required to display the contents of the file as desired. Files may contain several representations of a single image, so that the expression to display the contents correctly may include several options.

M.6.1.3 Fallback

In the event that a file cannot be displayed as desired by the writer, a fallback method for displaying the file is defined. The fallback methods are intended to be ultimately interoperable, as such, they may not generate the exact desired output.

A list of fallback methods is stored in the File Type box at the beginning of the JPEG 2000 family file: all files which start with a JPEG 2000 Signature box must contain a File Type box. The File Type box contains a list of known methods of reading the file. For example, the JP2 file format defines the JP2 fallback position. This specifies that a reader conforming to the JP2 file format specification, as defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, I.2.6, can read the file.

This Recommendation | International Standard defines one additional fallback position, JPX baseline, as defined in M.9. Also, other organizations may register other fallback positions by following the process defined in M.7. These define other minimal readers, and a set of file formats that are guaranteed to be readable by those readers.

Fallback methods are stored in the File Type box. The order within the box is of no significance. When a reader supports more than one of the fallback methods described in the file, it is up to the reader to determine which fallback methods to use.

M.6.2 Expression representation

The expressions of the requirements to fully understand all aspects, and to display the file as desired are stored in the Reader Requirements box, which is a mandatory feature of a JPX file format. If the Reader Requirements box is not present, the File Type box describes the full functionality of the file.

The Reader Requirements expressions are logical expressions involving functions which can be provided by the writer. These expressions may include vendor-specific options. The expression is factored into `AND`-separated sub-expressions, each containing only `OR` operations. These are then encoded into bitmasks which the reader can use to determine how to handle the file.

The Reader Requirements box includes two expressions, the Fully Understand Aspects expression, and the Display Contents expression. In general, these expressions will share several sub-expressions; shared sub-expressions are only stored once, and bitmasks are used to determine which sub-expressions belong to each expression.

M.6.2.1 Formulating requirements expressions

When formulating the requirements expressions describing a file, each expression is firstly factored into AND-separated sub-expressions, each sub-expression containing OR-separated options. Thus, an expression in the form:

$$(A \,\&\, B \,\&\, C \,\&\, E) \,|\, (D \,\&\, E) \qquad \text{(M-3)}$$

is factored into the expression:

$$(A | D) \& (B | D) \& (C | D) \& E \qquad \text{(M-4)}$$

Each sub-expression is expressed as a bit-array, with a flag set for each option appearing in that sub-expression. So, for example, the expression (A | D) becomes:

Table M.1 – Example expression

A	B	C	D	E
1	0	0	1	0

The full expression is written in table form:

Table M.2 – Expanded expression

A | D	B | D	C | D	E	
1	0	0	0	A
0	1	0	0	B
0	0	1	0	C
1	1	1	0	D
0	0	0	1	E

with each sub-expression in a column of the table. Thus, to satisfy the requirements of this expression, a reader has to support one of the functionalities in each column of the table.

However, there are two expressions to be encoded, and they will, in general, share common factors (because the functionality required to display a file is part of the functionality required to fully understand its contents). Thus, the two expressions are combined into one table, and a bitmask is provided to determine which columns in the table belong to each expression. So, if the expression in Equation M-3 is Display Contents and if the expression for Fully Understand Aspects is:

$$((A | D) \& (B | D) \& (C | D) \& E) \& (F | G) \qquad \text{(M-5)}$$

then, noting that the expression in Equation M-4 is a common factor, here, the resulting table is:

Table M.3 – Example factored expression

1	0	0	0	0	A
0	1	0	0	0	B
0	0	1	0	0	C
1	1	1	0	0	D
0	0	0	1	0	E
0	0	0	0	1	F
0	0	0	0	1	G
1	1	1	1	0	Display contents
1	1	1	1	1	Fully understand

where the first four columns are the Display Contents requirement, and all five sub-expressions are required to Fully Understand Aspects. Thus the bitmask for Display Contents is 11110, and the bitmask for Fully Understand Aspects is 11111.

This table can be read in columns, as a set of sub-expressions defining the functionality required of a reader, or in rows, as a set of compatibility bitmasks which a reader can use to determine whether it can read the file. By obtaining the bitwise OR of the rows which correspond to the functionalities present, and comparing the result with the bitmasks for the two expressions, a reader can determine whether it can satisfy the requirements of each.

Thus, a writer can construct the table in columns, setting flags corresponding to the options in each sub-expression, and generating the bitmasks describing which sub-expressions are ANDed together to form the full expressions for Fully Understand Aspects, and Display Contents. It can then obtain the compatibility bitmasks for each function which a reader may use in reading the file, by extracting the row corresponding to each functionality present.

M.6.2.2 Encoding requirements expressions

The requirements expressions are encoded in the Reader Requirements box, starting with a mask length, indicating the width of the compatibility bitmasks, to byte precision. This is followed by the bitmasks for the Fully Understand Aspects and Display Contents expressions, and in turn by a list of the features used and their compatibility masks, obtained from the rows of the expression table.

The list includes a set of standard features used (as specified in Table M.14) and their compatibility bitmasks, followed by a list of vendor-specific features (represented as UUIDs), together with the compatibility bitmasks associated with these. Apart from the separation into standard and vendor-specific features, the order of presentation is unimportant. This structure is fully specified in M.11.1.

M.6.2.3 Examples

For example, consider an image processing program that produces a JPX file containing a single image in the sRGB colour space, and a multiple codestream version containing the compositing layers, to allow an editor to work with the image, and includes metadata containing the history of the file, then the requirement to display the file is:

$$\text{sRGB} \,\&\, (\text{single codestream} \,|\, (\text{multiple codestream} \,\&\, \text{compositing})) \tag{M-6}$$

and to fully understand the file requires:

$$\text{sRGB} \,\&\, (\text{single codestream} \,|\, (\text{multiple codestream} \,\&\, \text{compositing})) \,\&\, \text{metadata} \tag{M-7}$$

Equation M-6 factors as:

$$\text{sRGB} \,\&\, (\text{single codestream} \,|\, \text{multiple codestream}) \,\&\, (\text{single codestream} \,|\, \text{compositing}) \tag{M-8}$$

Equation M-7 factors similarly, so the sub-expressions are:

a) sRGB;

b) single codestream | multiple codestream;

c) single codestream | compositing;

d) metadata.

The resulting expression table and bitmasks is shown in Table M.4.

The bitmasks indicate which sub-expressions are required for each degree of functionality. Thus the expression for Display Contents is:

$$(\text{Sub-expr a}) \,\&\, (\text{Sub-expr b}) \,\&\, (\text{Sub-expr d}) \tag{M-9}$$

Table M.4 – Example of a Reader Requirements expressions for Equations M-6 and M-7

	Sub-Exp a	Sub-Exp b	Sub-Exp c	Sub-Exp d
sRGB	1	0	0	0
single codestream	0	1	1	0
multiple codestream	0	1	0	0
compositing	0	0	1	0
metadata	0	0	0	1
Fully Understand Aspects bitmask	1	1	1	1
Display Contents bitmask	1	1	1	0

Thus, the above table is stored in the file as shown in Table M.5:

Table M.5 – Example of a Reader Requirements box for Equations M-6 and M-7

Mask Length (in bytes)	1[a)]				
Fully Understand Aspects bitmask	1	1	1	1	
Display Contents bitmask	1	1	1	0	
Number of Standard Features	5				
Standard Feature Compatibility list	sRGB				
	1	0	0	0	
	single codestream				
	0	1	1	0	
	multiple codestream				
	0	1	0	0	
	compositing				
	0	0	1	0	
	metadata				
	0	0	0	1	
Number of Vendor-Specific features	0				

a) 1 byte, because masks are 4 bits wide, which fits into 1 byte.

As a second example, suppose the ACME printer driver produces a JPX file which contains a single codestream sRGB image, for display, and a CMYK image which can be read by a printer driver using ACME's vendor-specific functions. For this file, the expression to Fully Display Contents is:

$$(\text{sRGB} \ \& \ \text{single codestream}) \mid (\text{CMYK} \ \& \ \text{single codestream} \ \& \ \text{ACME extensions}) \qquad \text{(M-10)}$$

while the expression to Understand All Aspects is:

$$((\text{sRGB} \ \& \ \text{single codestream}) \mid (\text{CMYK} \ \& \ \text{single codestream} \ \& \ \text{ACME extensions})) \ \& \ \text{metadata} \ \& \ \text{ACME print metadata} \qquad \text{(M-11)}$$

Factorizing these into sub-expressions gives:

$$\text{single codestream} \;\&\; (\text{sRGB} \,|\, \text{CMYK}) \;\&\; (\text{sRGB} \,|\, \text{ACME extensions}) \tag{M-12}$$

and:

$$\begin{gathered}\text{single codestream} \;\&\; (\text{sRGB} \,|\, \text{CMYK}) \;\&\; (\text{sRGB} \,|\, \text{ACME extensions}) \\ \&\; \text{metadata} \;\&\; \text{ACME print metadata}\end{gathered} \tag{M-13}$$

respectively.

The resulting file Reader Requirements table is shown in Table M.6:

Table M.6 – Reader Requirements table for Equations M-10 and M-11

sRGB	0	1	0	1	0
CMYK	0	1	0	0	0
single codestream	1	0	0	0	0
metadata	0	0	1	0	0
ACME extensions	0	0	0	1	0
ACME print metadata	0	0	0	0	1
Fully Understand Aspects bitmask	1	1	1	1	1
Display Contents bitmask	1	1	0	1	0

As always, each column represents a factor sub-expression, and each row provides a compatibility bitmask which a reader can use to determine whether it can read the file. This example includes vendor-specific features, and that sub-expressions can involve both standard and vendor-specific functionality.

These are stored in the file as shown in Table M.7:

Table M.7 – Reader Requirements box data for Equations M-10 and M-11

Mask Length	1					
Fully Understand Aspects bitmask	1	1	1	1	1	
Display Contents bitmask	1	1	0	1	0	
Number of Standard Features	4					
Standard Feature Compatibility list	sRGB					
	0	1	0	1	0	
	CMYK					
	0	1	0	0	0	
	single codestream					
	1	0	0	0	0	
	metadata					
	0	0	1	0	0	
Number of Vendor Features	2					
Vendor Feature Compatibility list	ACME extensions UUID					
	0	0	0	1	0	
	ACME print metadata UUID					
	0	0	0	0	1	

Also consider a JPX file that contains two compositing layers that are not combined by either animation or compositing; they are conceptually two separate rendered results. The first compositing layer contains a single codestream in the sRGB colourspace (specified using the Enumerated method). The second compositing layer contains a single codestream, for which the colourspace is specified using the Any ICC method. In addition, the second compositing layer contains vendor-specific metadata.

For this file, the expression to Fully Display Contents is:

(sRGB & single codestream) | (full ICC & single codestream & ACME extensions) (M-14)

while the expression to Understand All Aspects is:

((sRGB & single codestream) | (full ICC & sRGB & single codestream & ACME extensions)) (M-15)

Factorizing these into sub-expressions gives:

single codestream AND (sRGB | full ICC) AND (sRGB | ACME extensions) (M-16)

and:

single codestream AND sRGB AND full ICC AND ACME extensions (M-17)

respectively. The resulting file Reader Requirements table is shown in Table M.8:

Table M.8 – Reader Requirements box data for Equations M-16 and M-17

Mask Length	1						
Fully Understand Aspects bitmask	1	0	0	1	1	1	
Display Contents bitmask	1	1	1	0	0	0	
Number of Standard Features	3						
Standard Feature Compatibility list	sRGB						
	0	1	1	1	0	0	
	Any ICC						
	0	1	0	0	1	0	
	single codestream						
	1	0	0	0	0	0	
Number of Vendor Features	1						
Vendor Feature Compatibility list	ACME extensions UUID						
	0	0	0	1	0		

M.6.3 Testing an Implementation against requirements expressions

In order to determine whether it can read the file, the reader extracts the compatibility bitmask from the feature list entry corresponding to each functionality which it provides. If a flag is set in the bitmask, then this function is an option in the sub-expression corresponding to the flag.

Thus, if the reader performs a bitwise OR of the bitmasks for all of the functions which it provides, it can determine whether it can read the file by comparing the result with the Fully Understand Aspects and Display Contents bitmasks from the file. Also, by reconstructing the expression table and looking up the column (or columns) of the table where the file bitmask flag is set, and the reader's compatibility bitmask flag is not, the reader can determine which extra functionality is required to read the file.

If there is functionality provided by the reader, which is not in the feature list for the file, then the feature is not required to read the file (and the bitmask may be assumed to be all zeroes).

Consider the first example Reader Requirements box:

Table M.9 – Example Reader Requirements box to test

Mask Length (in bytes)	1				
Fully Understand Aspects bitmask	1	1	1	1	
Display Contents bitmask	1	1	1	0	
Number of Standard Features	5				
Standard Feature Compatibility list	sRGB				
	1	0	0	0	
	single codestream				
	0	1	1	0	
	multiple codestream				
	0	1	0	0	
	compositing				
	0	0	1	0	
	metadata				
	0	0	0	1	
Number of Vendor-Specific features	0				

In this example, if the reader supports the sRGB and single codestream functions, it looks up the bitmasks for these features (`1000` and `0110`, respectively). The bitwise OR gives the compatibility mask of this file for the reader, `1110`. Thus this reader can fully display the contents of the file; however, it will not understand all aspects of the file.

Noting that the compatibility mask for the reader (DCM) is 1110, and the Fully Understand Aspects Mask (FUAM) mask is 1111, the reader can perform (FUAM & !DCM) bitwise, to get 0001. This tells it that the missing functionality's bitmask has bit 4 set, so it can search the list for this, and determine that the missing functionality is metadata support.

M.7 Extensions to the JPX file format and the registration of extensions

Registration is the process of adding extensions to the capabilities to this Specification after the Specification has been published. In this Recommendation | International Standard, many capabilities may be extended through registration. Other items may be extended, but do not require the intervention of a third party to prevent extension conflict. This clause identifies those items which may be extended by registration and the process by which capabilities may be registered, as well as identifying those items which may be extended independent of registration and the process by which the Registration Authority will publish those extensions.

M.7.1 Registration elements

The registration process is composed of the following elements.

Table M.10 – Registration elements

Element	Identification
Registration Authority	WG1
Submitter	Entity creating the extension to this Recommendation | International Standard
Review Board	WG1 file format committee
Submission/Item	The proposed extension
Review Board chair	File Format editor
Test	Varies by item

Registration Authority: The organizational entity responsible for reviewing, maintaining, distributing, and acting as a point of contact for all activities related to the registration.

Submitter: The submitter is the organization or person who requests that the item be registered.

Review board: The review board is the organizational entity that approves the registration of a proposed item. It is composed of an ad hoc committee appointed by the Review Board Chair.

Review board chair: The review board chair is responsible for seeing that each candidate item is considered. He communicates with the submitter through the Registration Authority.

Test: Rationale that the Review Board should use to determine if submission/item should be registered.

Submission/Item: This is the proposal for registration. Each proposal shall include the name of the item to be extended, the proposed tag/identity for the extension, and a rationale/purpose for the extension.

M.7.2 Differentiation between publication and registration

In the JPX file format, several features of the file format may be extended independent of a registration process. For example, the format provides the Vendor Colour method to allow individual vendors to indicate custom colourspaces through a form of enumeration (using UUID's) without involving a third-party.

However, to promote interoperability, it is useful to gather the definitions indicated by these UUID's in one place. In this case, "registration" of the UUID is not needed to eliminate possible conflict with other vendors, and does not help a developer when considering which features should be implemented in a particular product.

As such, this proposal clearly differentiates between solutions that require the intervention of a registration committee from those solutions that can be created solely by the individual vendor. This proposal also allows the Registration Authority to label particular proposed element definitions as preferred solutions.

M.7.2.1 Published

Published items are those elements of a JPX file that can be safely extended, generally through the use of URL's or UUID's, without risk of conflict with other vendors. Values can be assigned for published items without the help of a third-party. However, it is useful to involve a third-party as a single "publisher" of the definitions of the extended elements from all vendors.

For example, a Vendor Colourspace value is a published item; the value is indicated through the use of a UUID. To promote interoperability, the Registration Authority shall publish a database of all known vendor colourspaces and the colourimetric definitions associated with each UUID.

M.7.2.2 Registered

Registered items are those elements of a JPX file that are restricted to a limited (albeit large in some cases) number of values. For these items, there exists the possibility that two vendors would use the same value for different meanings if there is not a third-party mediating the use of the element values. Also, in most cases, there are additional criteria for the allocation of values to registered items. Because the number of available values for most registered items is limited, and given that most problems can be solved using publishable items rather than registered items, the allocation of a registered value shall be considered as the specification of a preferred solution.

For example, an Enumerated Colourspace is a registered item; the value is indicated through the use of a 4-byte integer. The Review Board shall evaluate all proposed enumerated colourspaces in terms of preferred technologies. Proposed solutions that are considered preferred solutions shall be allocated a value by the Registration Authority. Proposers of solutions that are not preferred shall be referred to the Vendor Colourspace method as an alternate solution to the proposed problem.

M.7.2.3 Preferred published solutions

In some cases, such as the use of the UUID or XML boxes to embed metadata within a JPX file, there is not a corresponding registered item which can be used for preferred solutions. As such, the Registration Authority, upon recommendation from the Review Board, may choose to label a particular value of a published item as a preferred solution.

M.7.3 Items which can be extended by registration

The following items may be extended by registration. Only items that are listed here may be extended by registration.

Table M.11 – Items which can be extended by registration

Item	Purpose
Enumerated colourspaces	Define additional standard colourspaces
Desired reproduction boxes	Define additional reproduction scenarios and the data required to transform images for output in those scenarios
Compatibility modes	Define additional compatibility modes to promote interoperability in markets not explicitly addressed by the JPX baseline feature set
Standard feature list	Define additional standard feature codes for the Reader Requirements box

M.7.3.1 Enumerated colourspace

New values of the EnumCS field in the Colour Specification Box shall be registrable. A proposal to register a new enumerated colourspace must contain a complete colourimetric definition of that colourspace, instructions on how to use images in that colourspace, any required enumerated parameters (for the EP field in the Colour Specification box) and any default values of those parameters.

However, when evaluating proposed enumerated colourspaces, the Review Board shall limit the allocation of enumerated values to international and defacto standards, in addition to determining appropriateness of the proposed solution. Non-standard colourspaces shall be specified through the use of the Vendor Colourspace method.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

M.7.3.2 Desired reproduction boxes

New box types for Desired Reproduction information (like the Graphics Technology Standard Output box in the JPX format) shall be registrable. A proposal to register a new desired reproduction must contain a complete definition of the reproduction scenario, including the binary structure of the reproduction data as well as when an application should use the reproduction data.

The Review Board shall evaluate proposed reproductions based on the following criteria:

– Does it meet a need not already met by other defined reproductions?
– Is the binary format of the reproduction data sufficiently defined?
– Is it a general case or a vendor-specific case (i.e., output on a typical CRT vs output on a particular CRT model from a particular vendor)?

The Review Board shall restrict the allocation of Desired Reproduction boxes to general cases that meet needs not already met by other defined reproductions. Other proposed reproductions shall be specified by embedding the data in a UUID box and placing that UUID box within the Desired Reproduction superbox.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

M.7.3.3 Compatibility modes

New compatibility modes for the File Type box (values for the CLi fields) shall be registrable. A proposal to register a new compatibility mode must contain a complete definition of the JPX reader requirements for that compatibility mode, as well as the definition of the 4-byte CLi field for this mode.

The Review Board shall evaluate proposed compatibility modes based on the following criteria:

– Does it meet a need not already met by other compatibility modes?
– Is it expected that a wide range of applications will desire to implement support for the particular set of features required by this compatibility mode, or is this mode specific to a particular vendor or application?
– Are readers that support this compatibility mode required to support the entire JPX baseline feature set?
– Will the creation of this compatibility mode negatively affect interoperability in the target application area?

The Review Board shall restrict the allocation of compatibility modes to cases that meet the needs of a wide range of applications, that are not already met by other modes, and that do not negatively affect interoperability in the target application area. The allocation of modes to feature sets that do not require support for the baseline feature set will be denied in cases where the baseline features are appropriate for the target application.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

M.7.3.4 Standard feature codes

New values of the SFi field in the Reader Requirements box shall be registrable. A proposal to register a new standard feature code colourspace must be made along with the proposal to register that feature. As such, new standard feature codes shall only be allocated for new registered features.

M.7.4 Published items

The following items may be extended without the intervention of the Registration Authority, and the Registration Authority shall publish the specifications of those extensions. Only items that are listed here will be published. The text of extension to be published shall be evaluated by the Review Board before publication by the Registration Authority. In addition, the Review Board may choose to label particular published solutions as preferred, as described in Table M.12.

Table M.12 – Items which can be extended by registration

Item	Purpose
Vendor feature codes	Define additional vendor-specific features
Vendor colourspaces	Define additional vendor-specific colourspaces
Binary filter algorithms	Define additional algorithms for use in the Binary Filter box
UUID metadata	Define additional metadata for use within UUID boxes
XML metadata	Define additional metadata for use within XML boxes

M.7.4.1 Vendor feature codes

The Review Board shall publish the definition of submitted vendor feature codes (values of the VF^i field in the Application Profile box). All submissions must include a complete definition of the feature, including defined data structure, interactions with other data structures, and instructions on how to implement a decoder that supports that feature.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

M.7.4.2 Vendor colourspaces

The Review Board shall publish the definition of submitted vendor colourspace codes (values of the VCLR field in the METHDAT field for Colour Specification boxes that use the Vendor Colour method). All submissions must include a complete colourimetric definition of that colourspace, instructions on how to use images in that colourspace, any required vendor parameters (for the VP field in the Colour Specification box) and any default values of those parameters.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

In addition, the Review Board may choose to label a particular vendor colourspace as a preferred solution. The committee shall make this decision using the same criteria as would be used when evaluating a proposal for allocation of an enumerated colourspace value (as specified in M.7.3.1).

M.7.4.3 Binary filter algorithms

The Review Board shall publish the definition of submitted binary filter type values (values of the F field in the Binary Filter box). All submissions must include a complete definition of the algorithm and the format of the DATA field in the binary filter box.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

In addition, the Board may choose to label a particular binary filter as a preferred solution. The Board shall reserve this label for international or defacto standards, based on the desired use of the binary filter. For example, encryption technology can be used for both encrypting data and for creating digital signatures. While a particular binary filter may be a preferred solution for encrypting metadata, it may not be preferred for digital signatures.

M.7.4.4 UUID metadata

The Review Board shall publish the definition of submitted UUID's used in UUID boxes. All submissions must include a complete definition of the DATA field in the UUID box and instructions on using that data.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

In addition, the Board may choose to label a particular metadata specification as a preferred solution. The committee shall reserve this label for international or defacto standards, based on the target application for the metadata.

M.7.4.5 XML metadata

The Review Board shall publish the definition of submitted Document Type Definitions (DTD's) and XML Schema's used in XML boxes. All submissions must include a complete definition of the information contained in XML instance documents (found in XML boxes) that use that DTD or schema, as well as instructions on using that data.

The Review Board shall evaluate all submissions. If the text of the submission does not meet the requirements, then it shall be returned to the submitter for clarification.

In addition, the committee may choose to label a particular metadata specification as a preferred solution. The committee shall reserve this label for international or defacto standards, based on the target application for the metadata.

M.7.5 Registration process

The following is the registration process:

1) A submitter creates a candidate item for registration.
2) The candidate item is submitted to the Registration Authority.
3) The Registration Authority passes the candidate item to the Review Board Chair.
4) The Review Board Chair distributes the candidate item to the Review Board and schedules meetings, phone calls, etc. as appropriate for consideration of the item.
5a) If approved, the Chair passes the approval to the Registration Authority who notifies ISO and the submitter, and makes the registered or published item available.
5b) If declined, the Chair prepares a response document indicating why the item was declined and passes this to the Registration Authority who notifies the submitter.

M.7.6 Timeframes for the registration process

M.7.6.1 Requests for registration

The Review Board shall respond to all requests for registration within five months from the date of submission. Within that time period, the Review Board will meet at an official meeting of ISO/IEC JTC1/SC29/WG1 to evaluate the proposal, make a decision, and draft the response.

M.7.6.2 Requests for publication

The Review Board shall respond to all request for publication within two months from the date of submission. Within that time period, the Review Board will meet at an official meeting of ISO/IEC JTC1/SC29/WG1 or use e-mail discussions or conference calls to evaluate the proposal, make a decision, and draft the response.

M.7.6.3 Requests for preferred status for published solutions

The Review Board shall respond to all requests for preferred status for published solutions within five months from the date of submission. A request for preferred status may be made at the same time that the request for publication is made. Within that time period, the Review Board will meet at an official meeting of ISO/IEC JTC1/SC29/WG1 to evaluate the proposal, make a decision, and draft the response.

M.8 Differences from the JP2 binary definition

The box structure of a JPX file is identical to that of a JP2 file. A JPX file is a sequence of boxes, defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, I.6. However, many new boxes are defined, and the structures of several boxes are extended as follows:

– The BR field in the File Type box shall be "jpx\040" for files that are completely defined by this Recommendation | International Standard. In addition, a file that conforms to this Recommendation | International Standard shall have at least one CLi field in the File Type box, and shall contain the value 'jpx\040' in one of the CLi fields in the File Type box.

- Additional forms of the Colour Specification box are defined (M.11.7.2).
- The JPEG 2000 compressed codestream may contain extensions as defined in Annex A.
- Under some circumstances, the JP2 header box may be found in anywhere in the file, provided that it is not encapsulated within another box (it shall always be at the top level of the file). See M.11.5 for a description of the storage of the JP2 header box within a JPX file.
- Additional box types are defined within the scope of this Recommendation | International Standard.

M.9 Conformance

M.9.1 Interpretation of JPX data structures

All conforming files shall contain all boxes required by this Recommendation | International Standard as shown in Table M.13, and those boxes shall be as defined in this Recommendation | International Standard.

A JPX reader that supports a particular subset of JPX features is a conforming JPX reader if that reader properly supports all files that contain a Display Contents mask (in the Reader Requirements box) or a Fallback position (in the File Type box) indicating that the file can be read using only that particular subset of features; a conforming reader may fall back from any extended feature, as allowed by the Reader Requirements or File Type box, provided that the reader does not claim a higher level of conformance than it actually supports.

M.9.2 Support for JPX feature set

In general, a JPX reader is not required to support the entire set of features defined within this Recommendation | International Standard. However, to promote interoperability, the following baseline set of features is defined. Files that are written in such a way as to allow a reader that supports only this JPX baseline set of features to properly open the file shall contain a CLi field in the File Type box with the value 'jpxb' (0x6a70 7862); all JPX baseline readers are required to properly support all files with this code in the compatibility list in the File Type box. The definition of a JPX baseline file is as follows:

M.9.2.1 Compression types

Support for compression types other than JPEG 2000 (the C field in the Image Header box = 7) shall not be required to properly display the file.

M.9.2.2 Compositing layers

Support for multiple compositing layers is not required to properly display the file. However, the file may contain multiple compositing layers. If the file does contain compositing layers, the first compositing layer in the file (signalled by the first Compositing Layer Header box) shall be rendered. That compositing layer shall consist of one and only one codestream, which shall represent the rendered result as rendered into a single codestream. In addition, the codestream that shall be processed by a reader that only supports the JPX feature set shall be the first codestream in the file.

M.9.2.3 Codestreams

The codestream specified by the first compositing layer shall be compressed using the JPEG 2000 compression algorithm, as defined by ITU-T Rec. T.800 | ISO/IEC 15444-1 and shall not require support for extensions other than the irreversible decorrelation transformation (specified in J.3.1.1.1) and non-linearity transformation (specified in Annex K) extensions.

A conforming JPX baseline reader is not required to support other portions of the multiple component transformation extension. If support for the irreversible decorrelation transformation is required, then the first codestream shall be restricted as follows:

- The value of the Qmcc field in any MCC marker segment shall be 1.
- The $Xmcc^i$ field in any MCC marker segment shall indicate an array based decorrelation transformation.
- The $Tmcc^i$ field in any MCC marker segment shall indicate an irreversible transformation
- The Nmco field in any MCO marker segment shall be 1.

That codestream may contain other extensions provided that support for those extensions is not required to decode the codestream.

Other codestreams in the file may require support for other extensions in order to be decoded.

M.9.2.4 Colour specification

The first compositing layer shall contain at least one Colour Specification box from the following list:

- Enumerated method EnumCS values indicating either sRGB, sRGB-grey, ROMM-RGB, sYCC, e-sRGB, or e-sYCC.
- Enumerated method EnumCS value of CIELab using default values (EP fields are not specified).
- Enumerated method EnumCS value of CIELab using enumerated parameters (as specified in the EP fields in the Colour Specification box).
- Enumerated method EnumCS value of CIEJab using default values (EP fields are not specified).
- Enumerated method EnumCS value of CIEJab using enumerated parameters (as specified in the EP fields in the Colour Specification box).
- Restricted ICC method.
- Any ICC method.

A baseline JPX file may contain additional colourspace specifications, such as other enumerated values or vendor defined colourspace specifications. However, the file shall contain at least one colour specification method from the list above.

In addition, at least one Colour Specification box specified for the first compositing layer shall have an APPROX value of 3 or less (indicating a "reasonable" or better approximation of the true colourspace of the image).

M.9.2.5 Codestream fragmentation

The codestream used by the first compositing layer in a baseline JPX file may be fragmented. However, all fragments shall be in the JPX file itself and shall be found in the file in the order they are listed in the Fragment Table box, starting the search at byte 0 of the file and proceeding sequentially to the end of the file.

M.9.2.6 Cross-reference boxes

All Cross-Reference boxes that must be parsed in order to properly interpret or decode the first compositing layer in the file shall only point to fragments that are contained within the JPX file itself. Those fragments shall be in the same order in the file as they are listed in the Fragment List box, starting the search at byte 0 of the file and proceeding sequentially to the end of the file. In addition, all fragments shall be found in the file before the data representing the codestream used by the compositing layer. If that codestream is specified by a Contiguous Codestream box, then all fragments for the cross-reference shall be found before that Contiguous Codestream box. If the codestream is specified by a Fragment Table box, then all fragments for the cross-reference shall be found before the Media Data box containing the first fragment from the codestream.

M.9.2.7 JP2 Header box location

The JP2 Header box shall be found in the file before the first Contiguous Codestream box, Fragment Table box, Media Data box, Codestream Header box, and Compositing Layer Header box. Any information contained within the JP2 Header box shall be applied to the first codestream, as well as being used as default information for all other codestreams and compositing layers; the boxes within the JP2 Header box shall not be found within the Compositing Layer Header box or the Codestream Header box associated with the first compositing layer.

M.9.2.8 Opacity

A baseline JPX reader shall properly interpret opacity channels, through either direct mapping to a codestream component using either the Channel Definition box or the Opacity box, or by expansion from a palette. The use of opacity outside of the use of compositing layers within the JPX file indicates that the decoded image data shall be composited onto an application defined background.

M.9.2.9 Other data in the file

A baseline JPX file may contain other features or metadata, provided they do not modify the visual appearance of the still image as viewed using a reader that supports only the baseline JPX feature set. All baseline JPX readers should be aware of the existence of this data, as parsing or processing this data may be required in some extended applications. Applications that understand other data or features in the file are encouraged to support the behaviours and functions associated with that extended data.

M.10 Key to graphical descriptions (informative)

Each box is described in terms of its function usage and length. The function describes the information contained in the box. The usage describes the logical location and frequency of this box in the file. The length describes which parameters determine the length of the box.

These descriptions are followed by a figure that shows the order and relationship of the parameters in the box. Figure M.4 shows an example of this type of figure. A rectangle is used to indicate the parameters in the box. The width of the rectangle is proportional to the number of bytes in the parameter. A shaded rectangle (diagonal stripes) indicates that the parameter is of varying size. Two parameters with superscripts and a gray area between indicate a run of several of these parameters. A sequence of two groups of multiple parameters with superscripts separated by a gray area indicates a run of that group of parameters (one set of each parameter in the group, followed by the next set of each parameter in the group). Optional parameters or boxes will be shown with a dashed rectangle.

The figure is followed by a list that describes the meaning of each parameter in the box. If parameters are repeated, the length and nature of the run of parameters is defined. As an example, in Figure M.4, parameters C, D, E and F are 8, 16, 32 bit and variable length respectively. The notation G^0 and G^{N-1} implies that there are *n* different parameters, G^i, in a row. The group of parameters H^0 and H^{M-1}, and J^0 and J^{M-1} specify that the box will contain H^0, followed by J^0, followed by H^1 and J^1, continuing to H^{M-1} and J^{M-1} (M instances of each parameter in total). Also, the field E is optional and may not be found in this box.

After the list is a table that either describes the allowed parameter values or provides references to other tables that describe these values.

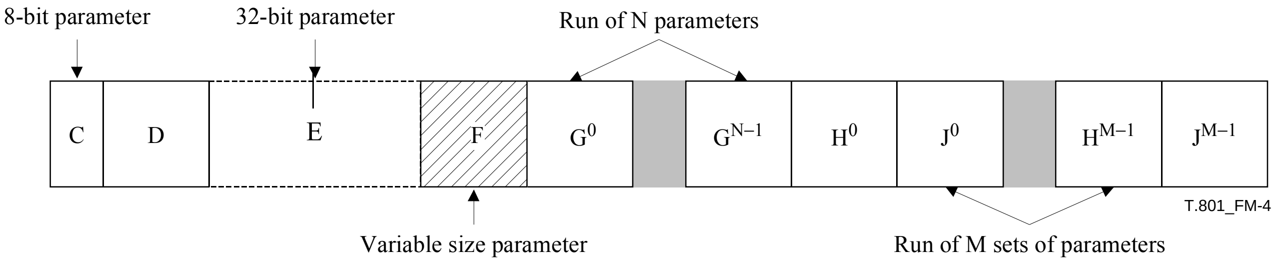


Figure M.4 – Example of the box description figures

In addition, in a figure describing the contents of a superbox, an ellipsis (…) will be used to indicate that contents of the file between two boxes is not specifically defined. Any box (or sequence of boxes), unless otherwise specified by the definition of that box, may be found in place of the ellipsis.

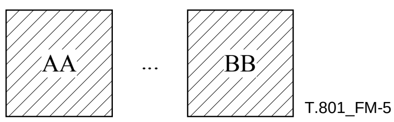


Figure M.5 – Example of the superbox description figures

For example, the superbox shown in Figure M.5 must contain an AA box and a BB box, and the BB box must follow the AA box. However, there may be other boxes found between boxes AA and BB. Dealing with unknown boxes is discussed in M.12.

M.11 Defined boxes

The following boxes are defined as part of JPX file format. In addition, any box defined as part of the JP2 file format that is not also listed here is also defined for use in a JPX file. However, this Recommendation | International Standard may redefine the binary structure of some boxes defined as part of the JP2 file format. For those boxes, the definition found in this Recommendation | International Standard shall be used for all JPX files.

Figure M.6 shows the hierarchical organization of the boxes in a JPX file. Several of these boxes are defined within the JP2 file format specification. This illustration does not specify nor imply a specific order to these boxes. In many cases, the file will contain several boxes of a particular box type. The meaning of each of those boxes is dependent on the placement and order of that particular box within the file.

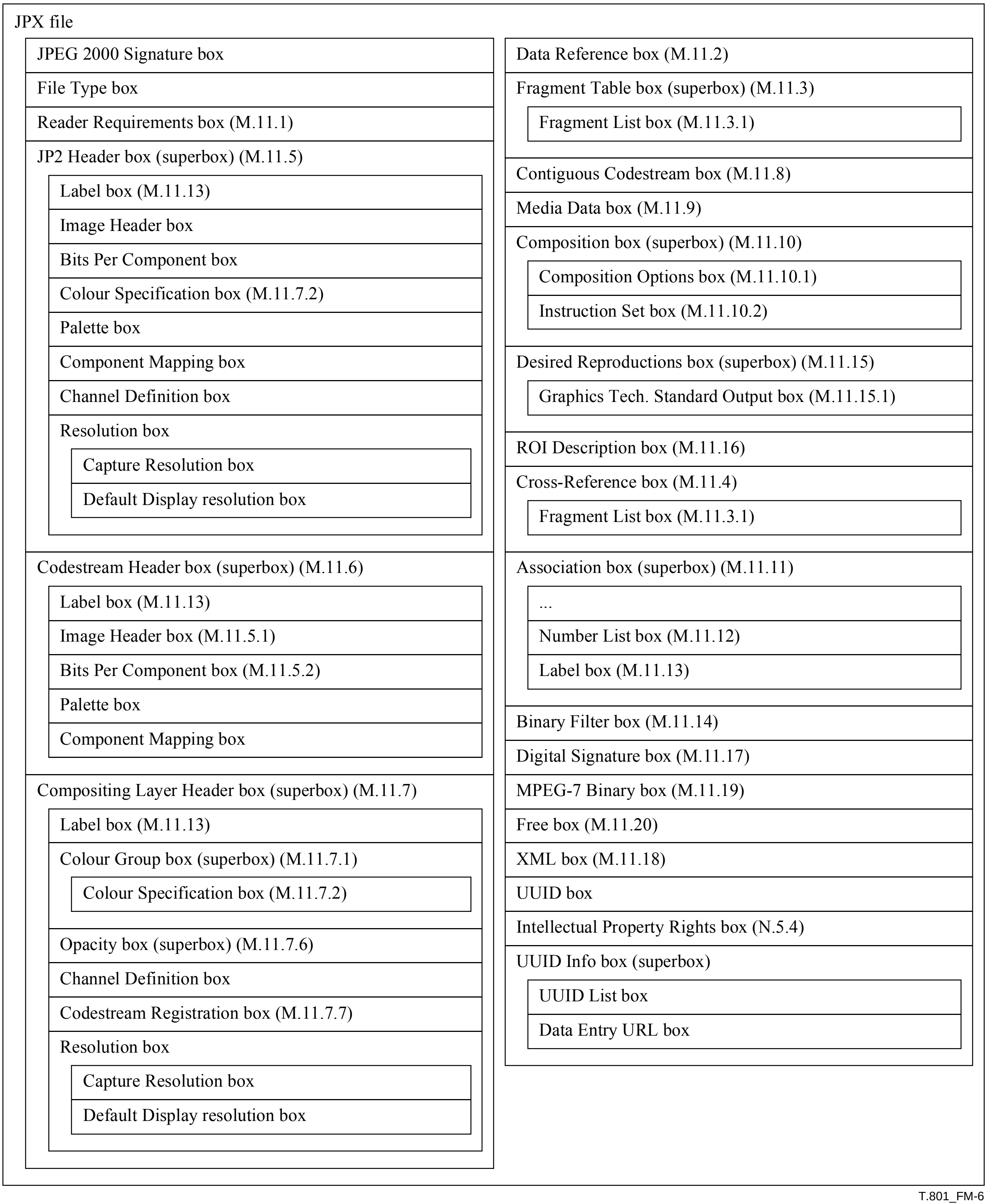


Figure M.6 – Boxes defined within a JPX file

Table M.13 lists all boxes defined as part of this Recommendation | International Standard. Boxes defined as part of the JP2 file format are not listed. A box that is listed in Table M.13 as "Required" shall exist within all conforming JPX files. For the placement of and restrictions on each box, see the relevant subclause defining that box.

Table M.13 – Boxes defined within this Recommendation | International Standard

Box name	Type	Required ?	Comments
Reader Requirements box (M.11.1)	'rreq' (0x7272 6571)	Yes	This box specifies the different modes in which this file may be processed.
JP2 Header box (superbox) (M.11.5)	'jp2h' (0x6A70 3268)	No	This box specifies JP2 compatibility and default header information for the codestreams and compositing layers.
Image Header box (M.11.5.1)	'ihdr' (0x6968 6472)	Yes	This box specifies the size of the image and other related fields.
Bits Per Component box (M.11.5.2)	'bpcc' (0x6270 6363)	No	This box specifies the bit depth of the components in the file in cases where the bit depth is not constant across all components.
Codestream Header box (superbox) (M.11.6)	'jpch' (0x6A70 6368)	No	This box specifies general information, such as bit depth, height and width about one specific codestream in the file.
Compositing Layer Header box (superbox) (M.11.7)	'jplh' (0x6A70 6C68)	No	This box specifies general information, such as colourspace and resolution, about one specific compositing layer in the file.
Colour Group box (superbox) (M.11.7.1)	'cgrp' (0x6367 7270)	No	This box groups a sequence of Colour Specification boxes that specify the different ways that the colourspace of a layer can be processed.
Colour Specification box (M.11.7.2)	'colr' (0x636F 6C72)	Yes	This box specifies one way in which the colourspace of an image can be processed. The definition of this box is extended from the definition in the JP2 file format.
Opacity box (M.11.7.6)	'opct' (0x6F70 6374)	No	This box specifies how opacity information is contained within a set of channels.
Codestream Registration box (M.11.7.7)	'creg' (0x6372 6567)	No	This box specifies the alignment between the set of codestreams that make up one compositing layer.
Data Reference box (M.11.2)	'dtbl' (0x6474 626C)	No	This box contains a set of pointers to other files or data streams not contained within the JPX file itself.
Fragment Table box (superbox) (M.11.3)	'ftbl' (0x6674 626C)	No	This box specifies how one particular codestream has been fragmented and stored within this JPX file or in other streams.
Fragment List box (M.11.3.1)	'flst' (0x666C 7374)	No	This box specifies a list of fragments that make up one particular codestream within this JPX file.
Cross-Reference box (M.11.4)	'cref' (0x6372 6566)	No	This box specifies that a box found in another location (either within the JPX file or within another file) should be considered as if it was directly contained at this location in the JPX file.
Contiguous Codestream box (M.11.8)	'jp2c' (0x6A70 3263)	No	This box contains one codestream from the JPX file, stored contiguously in a single box.
Media Data box (M.11.9)	'mdat' (0x6D64 6174)	No	This box contains generic media data, which is referenced through the Fragment Table box.
Composition box (superbox) (M.11.10)	'comp' (0x636F 6D70)	No	This box specifies how a set of compositing layers shall be combined to create the rendered result.
Composition Options box (M.11.10.1)	'copt' (0x636F 7074)	No	This box specifies generic options for the composition of multiple compositing layers.
Instruction Set box (M.11.10.2)	'inst' (0x696E 7374)	No	This box specifies the specific instructions for combining multiple compositing layers to create the rendered result.
Association box (superbox) (M.11.11)	'asoc' (0x6173 6F63)	No	This box allows several other boxes (i.e., boxes containing metadata) to be grouped together and referenced as a single entity.
Number List box (M.11.12)	'nlst' (0x6E6C 7374)	No	This box specifies what entities are associated with the data contained within an Association box.
Label box (M.11.13)	'lbl\040' (0x6C62 6C20)	No	This box specifies a textual label for either a Codestream Header, Compositing Layer Header, or Association box.
Binary Filter box (M.11.14)	'bfil' (0x6266 696C)	No	This box contains data that has been transformed as part of the storage process (such as compressed or encrypted).

Table M.13 – Boxes defined within this Recommendation | International Standard

Box name	Type	Required ?	Comments
Desired Reproductions box (superbox) (M.11.15)	'drep' (0x6472 6570)	No	This box specifies a set of transformations that must be applied to the image to guarantee a specific desired reproduction on a set of specific output devices.
Graphics Technology Standard Output box (M.11.15.1)	'gtso' (0x6774 736F)	No	This box specifies the desired reproduction of the rendered result for commercial printing and proofing systems.
ROI Description box (M.11.16)	'roid' (0x726F 6964)	No	This box specifies information about specific regions of interest in the image.
Digital Signature box (M.11.17)	'chck' (0x6368 636B)	No	This box contains a checksum or digital signature for a portion of the JPX file.
MPEG-7 Binary box (M.11.19)	'mp7b' (0x6D70 3762)	No	This box contains metadata in MPEG-7 binary format (BiM) as defined by ISO/IEC 15938.
Free box (M.11.20)	'free' (0x6672 6565)	No	This box contains data that is no longer used and may be overwritten when the file is updated.
Intellectual Property Rights (N.5.4)	'ipr' (0x6A70 3269)	No	This box contains intellectual rights information.

M.11.1 Reader Requirements box

The Reader Requirements box specifies what features or feature groups have been used in this JPX file, as well as what combination of features must be supported by a reader in order to fully use the file. The Reader Requirements box must immediately follow the File Type box, and there shall be one and only one Reader Requirements box in the file.

The type of a Reader Requirements box shall be 'rreq' (0x7272 6571'). The contents of the Reader Requirements box is as follows:

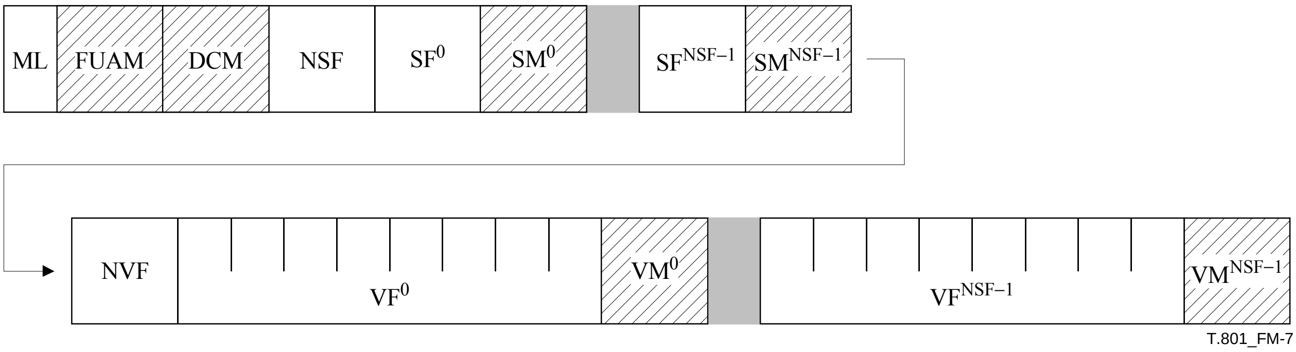


Figure M.7 – Organization of the contents of the Reader Requirements box

ML: Mask length. This field is a byte that specifies the number of bytes used for the compatibility masks. This field is encoded as a 1-byte unsigned integer.

FUAM: Fully Understand Aspects mask. This field is the mask describing the Fully Understand Aspects expression. This field is specified as a big endian integer of the size as specified by the ML field.

DCM: Decode Completely mask. This field is the mask describing the expression to display the image correctly. This field is specified as a big endian integer of the size as specified by the ML field.

NSF: Number of standard flags. This field specifies the number of standard feature flags contained within the Reader Requirements box. The value of this field shall be equal to the number of SF^i fields found within the Reader Requirements box. This field is encoded as a 2-byte big endian unsigned integer.

SF^i: Standard flag. This field specifies a standard feature flag. The number of SF^i fields shall be equal to the value of the NSF field. This field is encoded as a 2-byte big endian unsigned integer. Legal values of this field are shown in Table M.14.

SM^i: Standard mask. This field specifies the compatibility mask for the feature specified by SF^i. This field is specified as a big endian integer of the size as specified by the ML field.

NVF: Number of vendor features. This field specifies the number of vendor features specified in the Reader Requirements box. The value of this field shall be equal to the number of VF^i fields in the Reader Requirements box. This field is encoded as a 2-byte big endian unsigned integer.

VF^i: Vendor feature. This field specifies one vendor defined feature that is used in this JPX file. This field is encoded as a 128-bit UUID. Information about the feature specified by this UUID can be specified using the UUID Info box as defined in the JP2 file format.

VM^i: Vendor mask. This field specifies the compatibility mask for the feature specified by VF^i. This field is specified as a big endian integer of the size as specified by the ML field.

Table M.14 – Legal values of the SF^i field

Value	Meaning
1	Codestream contains no extensions
2	Contains multiple composition layers
3	Codestream is compressed using JPEG 2000 and requires at least a Profile 0 decoder as defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, A.10 Table A.45
4	Codestream is compressed using JPEG 2000 and requires at least a Profile 1 decoder as defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, A.10 Table A.45
5	Codestream is compressed using JPEG 2000 as defined by ITU-T Rec. T.800 | ISO/IEC 15444-1
6	Codestream is compressed using JPEG 2000 as defined in this Recommendation | International Standard
7	Codestream is compressed using DCT
8	Does not contain opacity
9	Compositing layer includes opacity channel (non-premultiplied)
10	Compositing layer includes premultiplied channel opacity
11	Compositing layer specifies opacity using a chroma-key value
12	Codestream is contiguous
13	Codestream is fragmented such that fragments are all in file and in order
14	Codestream is fragmented such that fragments are all in file but out of order
15	Codestream is fragmented such that fragments are in multiple local files
16	Codestream is fragmented such that fragments are across the internet
17	Rendered result created using compositing
18	Support for compositing layers is not required (reader can load a single, discrete compositing layer)
19	Contains multiple, discrete layers that should not be combined through either animation or compositing
20	Compositing layers each contain only a single codestream
21	Compositing layers contain multiple codestreams
22	All compositing layers are in the same colourspace
23	Compositing layers are in multiple colourspaces
24	Rendered result created without using animation
25	Animated, but first layer covers entire area and is opaque
26	Animated, but first layer does not cover the entire rendered result area
27	Animated, and no layer is reused
28	Animated, but layers are reused
29	Animated with persistent frames only
30	Animated with non-persistent frames
31	Rendered result created without using scaling
32	Rendered result involves scaling within a layer
33	Rendered result involves scaling between layers
34	Contains ROI metadata
35	Contains IPR metadata
36	Contains Content metadata

Table M.14 – Legal values of the SF^i field

Value	Meaning
37	Contains History metadata
38	Contains Creation metadata
39	Portion of file is digitally signed in a secure method
40	Portion of file is checksummed
41	Desired Graphic Arts reproduction specified
42	Compositing layer uses palettized colour
43	Compositing layer uses Restricted ICC profile
44	Compositing layer uses Any ICC profile
45	Compositing layer uses sRGB enumerated colourspace
46	Compositing layer uses sRGB-grey enumerated colourspace
47	Compositing layer uses BiLevel 1 enumerated colourspace
48	Compositing layer uses BiLevel 2 enumerated colourspace
49	Compositing layer uses YCbCr 1 enumerated colourspace
50	Compositing layer uses YCbCr 2 enumerated colourspace
51	Compositing layer uses YCbCr 3 enumerated colourspace
52	Compositing layer uses PhotoYCC enumerated colourspace
53	Compositing layer uses YCCK enumerated colourspace
54	Compositing layer uses CMY enumerated colourspace
55	Compositing layer uses CMYK enumerated colourspace
56	Compositing layer uses CIELab enumerated colourspace with default parameters
57	Compositing layer uses CIELab enumerated colourspace with parameters
58	Compositing layer uses CIEJab enumerated colourspace with default parameters
59	Compositing layer uses CIEJab enumerated colourspace with parameters
60	Compositing layer uses e-sRGB enumerated colourspace
61	Compositing layer uses ROMM–RGB enumerated colourspace
62	Compositing layers have non-square samples
63	Compositing layers have labels
64	Codestreams have labels
65	Compositing layers have different colour spaces
66	Compositing layers have different metadata

Table M.15 – Format of the contents of the Reader Requirements box

Field name	Size (bits)	Value
ML	8	1, 2, 4 or 8
EM	$8 \times ML$	Variable
DCM	$8 \times ML$	Variable
NSF	16	0-65 535
SF^i	16	0-65 535
SM^i	$8 \times ML$	Variable
NVF	16	0-65 535
VF^i	128	Variable
VM^i	$8 \times ML$	Variable

M.11.2 Data Reference box

The Data Reference box contains an array of URL's which are referenced by this file. Many of these references will be from Fragment Table boxes, specifying the location of the codestream fragments. Other references will be from Cross-Reference boxes. A JPX file shall contain zero or one Data Reference boxes, and that Data Reference box shall be at the top level of the file; it shall not be in any superboxes.

The Data Reference box is not a superbox because it does not contain only boxes.

The type of the Data Reference box shall be 'dtbl' (0x6474 626C), and its contents shall be as follows:

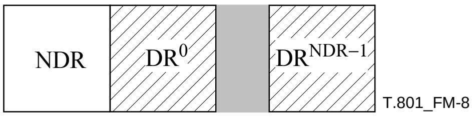


Figure M.8 – Organization of the contents of a Data Reference box

NDR: Number of data references. This field specifies the number of data references, and thus the number of URL boxes contained within this Data Reference Box.

DR^i: Data Reference URL. This field contains a Data Entry URL box, as defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, I.7.3.2. However, in this context, the Location field in the box is not specific to UUID Info Boxes. The meaning of the URL is specified in the context of the box that refers to the particular entry in the Data Reference box.

The indices of the elements in the array of DR^i fields is 1 based; a data reference of 1 in a DR^i field within a Fragment List box specifies the first Data Reference URL contained within the Data Reference Box. A data reference value of 0 is a special case that indicates that the reference is to data contained within this JPX file itself.

Table M.16 – Format of the contents of the Data Reference box

Field name	Size (bits)	Value
NDR	16	0-65 535
DR^i	Variable	Variable

M.11.3 Fragment Table box (superbox)

A Fragment Table box specifies the location of one of the codestreams in a JPX file. A file may contain zero or more Fragment Table boxes. For the purpose of numbering codestreams, the Fragment Table box shall be considered equivalent to a Contiguous Codestream box. Fragment Table boxes shall be found only at the top level of the file; they shall not be found within a superbox.

The type of the Fragment Table box shall be 'ftbl' (0x6674 626C), and its contents shall be as follows:

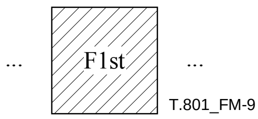


Figure M.9 – Organization of the contents of a Fragment Table box

Flst: Fragment List. This field contains a Fragment List box as specified in M.11.3.1.

M.11.3.1 Fragment List box

The Fragment List box specifies the location, length and order of each of the fragments that, once combined, form a valid and complete data stream. Depending on what box contains this particular Fragment List box, the data stream forms either a codestream (if the Fragment List box is contained in a Fragment Table box) or shared header or metadata (if the Fragment List box is contained in a Cross-Reference box).

If this Fragment List box is contained within a Fragment Table box (and thus specifies the location of a codestream), then the first offset in the fragment list shall point directly to the first byte codestream data; it shall not point to the header of the box containing the first codestream fragment.

If this Fragment List box is contained within a Cross-Reference box (and thus specifies the location of shared header or metadata), then the first offset in the fragment list shall point to the first byte of the contents of the referenced box; it shall not point to the header of the referenced box. However, if the referenced box is a superbox, then the offset of the first fragment does point to the box header of the first box contained within the superbox.

For all other offsets in the Fragment List box, the offsets shall point directly to the first byte of the fragment data and not to the header of the box that contains that fragment.

In addition, an offset within any Fragment List shall not point into a Binary Filter box. If the JPX file does contain one or more Binary Filter boxes, then all offsets in all Fragment list boxes shall be interpreted with respect to the length of the Binary Filter boxes, as stored in the file, not the length of the data after the application of the filter.

The type of the Fragment List box shall be 'flst' (0x666C 7374) and it shall have the following contents:

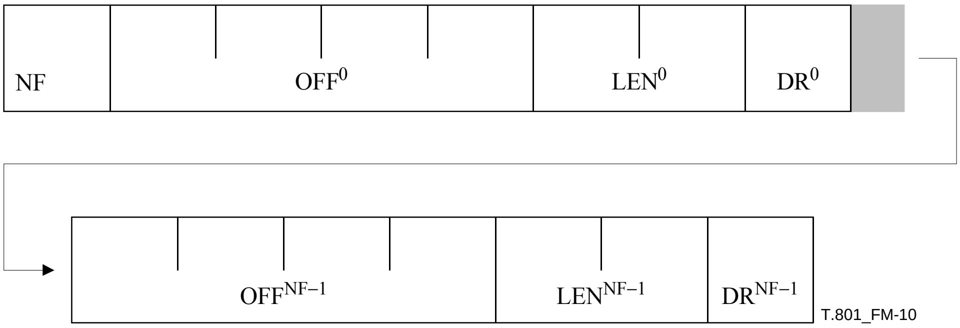


Figure M.10 – Organization of the contents of a Fragment List box

NF: Number of fragments. This field specifies the number of fragments used to contain the data stream. The number of {OFF, LEN, DR} tuples in the Fragment list box shall be the same number as the value of the NF field.

OFF^i: Offset. This field specifies the offset to the start of the fragment in the specified file. The offset is relative to the first byte of the file (for example, the first byte of the length field of the JPEG 2000 signature box header for a JPX file). This field is encoded as a 64-bit unsigned integer.

LEN^i: Length of fragment. This field specifies the length of the fragment. This value includes only the actual data and not any headers of an encapsulating box. This field is encoded as a 32-bit unsigned integer.

DR^i: Data reference. This field specifies the data file or resource that contains this fragment. If the value of this field is zero, then the fragment is contained within this file. If the value is not zero, then the fragment is contained within the file specified by this index into the array of DR^i fields in the Data Reference box, where an index value of 1 indicates the first element in the array. This field is encoded as a 16-bit unsigned integer.

Table M.17 – Format of the contents of the Fragment List box

Parameter	Size (bits)	Value
NF	16	0-65 535
OFF^i	64	$12\text{-}(2^{64}-1)$
LEN^i	32	$0\text{-}(2^{32}-1)$
DR^i	16	0-65 535

M.11.4 Cross-Reference box

If a JPX file contains multiple codestreams or compositing layers, it may be useful to share header and metadata information between those codestreams or compositing layers to minimize file size. One mechanism to share such data is to place a cross-reference to the actual metadata or header box into the Codestream Header or Compositing Layer Header box in place of the actual data. This is done using a Cross-Reference box. A JPX file may contain zero or more Cross-Reference boxes, and the Cross-Reference boxes shall be found only within Codestream Header boxes, Compositing Layer Header boxes, or Association boxes. Also, a Cross-Reference box shall not point to another Cross-Reference box. Also, because the Cross-Reference box contains a field followed by a box, the Cross-Reference box is not a superbox.

The type of the Cross-Reference box shall be 'cref' (0x6372 6566) and it shall have the following contents:

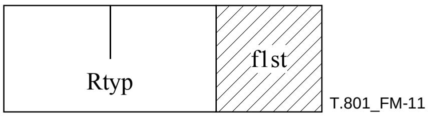


Figure M.11 – Organization of the contents of a Fragment table box

Rtyp: Referenced box type. This field specifies the actual type (as would be found in the TBox field in an actual box header) of the box referenced by this Cross-Reference box. However, a reader shall not attempt to locate a physically stored box header for the box represented by this cross-reference box, as it is legal to use a Cross-Reference box to create a new box that is not contiguously contained in other locations within this or other files, and thus the box header will not exist.

flst: Fragment List box. This box specifies the actual locations of the fragments of the referenced box. When those fragments are concatenated, in order, as specified by the Fragment List box definition, the resulting byte-stream shall be the contents of the referenced box and shall not include the box header fields. However, if the referenced box is a superbox, then the offset of the first fragment does point to the box header of the first box contained within the superbox. The format of the Fragment List box is specified in M.11.3.1.

Table M.18 – Format of the contents of the Cross-Reference box

Parameter	Size (bits)	Value
Rtyp	32	0-(2^{32}–1)
flst	Variable	Variable

M.11.5 JP2 Header box (superbox)

The JP2 Header box is syntactically unchanged from the structures defined in the JP2 file format. However, if the JPX file contains multiple codestreams or multiple compositing layers, then any boxes contained within the JP2 Header box shall be considered as defaults for all codestreams and compositing layers. For example, if a Compositing Layer Header box does not specify a Colourspace specification, then a reader shall apply the Colourspace Specification contained within the JP2 Header box to that particular compositing layer.

Also, if the codestream is specified by the JP2 Header box, then the semantic relationship of the Image Header box and Bits Per Component box contained within the JP2 Header box shall follow the rules defined in M.11.5.1 and M.11.5.2 respectively.

Also, the JPX file format allows the JP2 Header box to be located anywhere at the top-level of the file (but not within any superbox). However, certain fallback positions, such as the JPX baseline definition, may restrict the placement of this box. In addition, if this file does not require the JP2 Header box to meet the requirements of a fallback position, nor does it use the JP2 Header box to specify default information for multiple compositing layers or codestreams, then this box may be omitted from the file.

M.11.5.1 Image Header box

The format and structure of the Image Header box is identical to that defined in I.5.3.1 in ITU-T Rec. T.800 | ISO/IEC 15444-1 in the JP2 file format. However, the additional values of the fields within that box are defined for the JPX file format. In a JPX file, this box may be found either within the JP2 Header box or within a Codestream Header box.

The type of the Image Header box shall be 'ihdr' (0x6968 6472) and contents of the box shall have the following format:

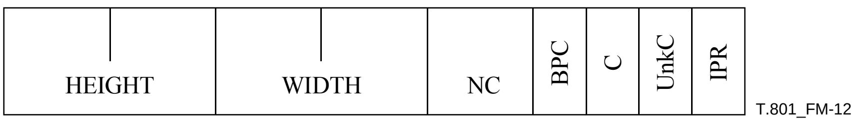


Figure M.12 – Organization of the contents of an Image Header box

HEIGHT: Image area height. The value of this field is identical to that defined for the JP2 file format.

WIDTH: Image area width. The value of this field is identical to that defined for the JP2 file format.

NC: Number of components. The value of this field is identical to that defined for the JP2 file format.

BPC: Bits per component. This parameter specifies the bit depth of the fully decompressed component, minus 1, and is stored as a 1-byte field. This shall represent the bit depth of the component after any inverse multiple component transformation or inverse non-linearity transformation extension has been applied. However, if the compression type of the codestream corresponding to this Image Header box is not JPEG 2000 or if neither the multiple component or non-linearity extension are used within the codestream, then the value of the field in this box shall match the respective bits per component data in the respective codestream format specification.

If the bit depth is the same for all components, then this parameter specifies that bit depth and shall be equivalent to the bit depth specified within the codestream using the data structures defined for that particular codestream format. If the components vary in bit depth, then the value of this field shall be 255, and the superbox that contains this Image Header box (either the JP2 Header box or a Codestream Header box) must contain a Bits Per Component box defining the bit depth of each component (as defined in I.5.3.2 in ITU-T Rec. T.800 | ISO/IEC 15444-1 in the JP2 file format). Components should be considered to have different bit depths if either the magnitude or sign of the bit depth of the components differ.

The low 7-bits of the value indicate the bit depth of the components. The high-bit indicates whether the components are signed or unsigned. If the high-bit is 1, then the components contain signed values. If the high-bit is 0, then the components contain unsigned values.

C: Compression type. This parameter specifies the compression algorithm used to compress the image data. Legal values of this field are as follows:

Table M.19 – Legal C values

Value	Meaning
0	**Uncompressed.** Picture data is stored in component interleaved format, encoded at the bit depth as specified by the BPC field. This value is only permitted for codestreams where all components are encoded at the same bit depth. When the bit depth of each component is not 8, sample values shall be packed into bytes so that no bits are unused between samples. However, each sample shall begin on a byte boundary and padding bits having value zero shall be inserted after the last sample of a scan line as necessary to fill out the last byte of the scan line. Simple values appear in component-interleaved order. When multiple sample values are packed into a byte, the first sample shall appear in the most significant bits of the byte. When a sample is larger than a byte, its most significant bit shall appear in earlier bytes.
1	**ITU-T Rec. T.4, the basic algorithm known as MH (Modified Huffman).** This value is only permitted for bi-level images.
2	**ITU-T Rec. T.4, commonly known as MR (Modified READ).** This value is only permitted for bi-level images.
3	**CCITT Rec. T.6, commonly known as MMR (Modified Modified READ).** This value is only permitted for bi-level images.
4	**ITU-T Rec. T.82 | ISO/IEC 11544.** Commonly known as JBIG. This value is only permitted for bi-level images.
5	**CCITT Rec. T.81 | ISO/IEC 10918-1 or ITU-T Rec.T.84 | ISO/IEC 10918-3**. Commonly known as JPEG. This compressed image stream shall conform to the syntax of interchange format for compressed image data as specified in the aforementioned standards. This value is only permitted for continuous tone, greyscale or colour images.
6	**JPEG-LS.**
7	JPEG 2000 compression (as defined by ISO/IEC 15444).
8	**JBIG2.**
9	**ITU-T Rec. T.82 | ISO/IEC 11544.** Commonly known as JBIG. This value is permitted for any image permitted by the JBIG standard.
	All other values reserved.

UnkC: Colourspace Unknown. The value of this field is identical to that defined for the JP2 file format.

IPR: Intellectual Property. The value of this field is identical to that defined for the JP2 file format.

Table M.20 – BPC values

Values (bits) MSB LSB	Component sample precision

`x000 0000`
`to`
`x010 0101`
	Component bit depth = value + 1. From 1 bit deep through 38 bits deep respectively (counting the sign bit, if appropriate)

`0xxx xxxx`	Components are unsigned values
`1xxx xxxx`	Components are signed values
`1111 1111`	Components vary in bit depth
	All other values reserved

M.11.5.2 Bits Per Component box

The Bits Per Component box specifies the bit depth of each fully decompressed component. This shall represent the bit depth of the component after any inverse multiple component transformation or reverse non-linearity transformation extension has been applied. components in the codestream. The structure of this box is identical to that defined in I.5.3.2 in ITU-T Rec. T.800 | ISO/IEC 15444-1 in the JP2 file format. However, if the compression type of the codestream corresponding to this Bits Per Component box is not JPEG 2000 or if neither the multiple component or non-linearity extension are used within the codestream, then the value of the field in this box shall match the respective bits per component data in the respective codestream format specification.

Table M.21 – Format of the contents of the Image Header box

Field name	Size (bits)	Value
HEIGHT	32	1-(2^{32}–1)
WIDTH	32	1-(2^{32}–1)
NC	16	1-16 384
BPC	8	See Table M.20
C	8	7
UnkC	8	0-1
IPR	8	0-1

M.11.6 Codestream Header box (superbox)

The Codestream Header box specifies header and metadata information specific to a particular codestream contained within the JPX file in order to create a set of channels. All Codestream Header boxes shall be located at the top-level of the file (not within any superbox).

Both codestreams and Codestream Header boxes are numbered separately, starting with 0, by their order in the file. Codestream Header box *i* shall be applied to codestream *i*. There shall either be one Codestream Header box in the file for each codestream, or there shall be zero Codestream Header boxes in the file. In the event that there are zero Codestream Header boxes, then the header information for all of the codestreams shall be taken to be the default header information contained within the JP2 Header box.

For the codestreams, the numbering shall consider both Contiguous Codestream boxes and Fragment Table boxes. For example, if a file contains 2 Contiguous Codestream boxes, followed by a Fragment Table box, followed by another Contiguous Codestream box, the JPX file contains 4 codestreams, where the codestreams contained directly in the first two Contiguous Codestream boxes are numbered 0 and 1, the codestream pointed to by the Fragment Table box is numbered 2, and the codestream contained within the last Contiguous Codestream box is numbered 3.

The type of a Codestream Header box shall be 'jpch' (0x6A70 6368). The contents of a Codestream Header box is as follows:

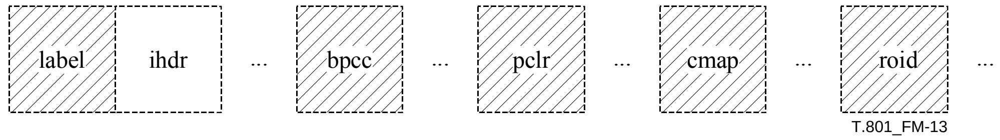


Figure M.13 – Organization of the contents of a Codestream Header box

label: Label box. This box specifies a label for this codestream. Its structure is specified in M.11.13.

ihdr: Image Header box. This box specifies information about this codestream, such as its height and width. Its structure is specified in M.11.5.1. If the JP2 Header box contains an Image Header box that accurately specifies this codetream, then it is not required that this Codestream Header box contain an Image Header box. Otherwise, this Codestream Header box shall contain an Image Header box. In addition, if the IPR flag in the Image Header box is set to 0, indicating no intellectual property rights information is specified for this codestream, then this Codestream Header box shall not contain an IPR box, and the reader shall not apply the contents of an IPR box at the top level of the file to this codestream.

bpcc: Bits Per Component box. This box specifies the bit depth of each component in the codestream after decompression. Its structure is specified in M.11.5.2.

pclr: Palette box. This box defines the palette to use to create multiple components from a single component. Its structure is specified in I.5.3.4 in ITU-T Rec. T.800 | ISO/IEC 15444-1 of the JP2 file format.

cmap: Component Mapping box. This box defines how image channels are identified from the actual components in the codestream. Its structure is specified in I.5.3.5 in ITU-T Rec. T.800 | ISO/IEC 15444-1 of the JP2 file format.

roid: ROI Description box. This box describes regions of interest within this codestream. These ROIs may or may not be directly associated with coded ROIs in the codestream. Its structure is defined in M.11.16.

The Codestream Header box may also contain other metadata boxes, including an IPR box, or cross-references to other boxes. If the Codestream Header contains a cross-reference, then the box pointed to by the cross-reference shall be considered as if it was physically stored in this Codestream Header box.

Also, if any of these boxes are contained within the JP2 header box and are not contained within this Codestream Header box, then those boxes should also be applied to this codestream.

M.11.7 Compositing Layer Header box (superbox)

The Compositing Layer Header box specifies header and metadata information specific to a particular compositing layer in the JPX file. Compositing layers are numbered, starting at 0, by the order in the file of the Compositing Layer Header boxes (box *i* specifies header information for compositing layer *i*). There shall be one Compositing Layer Header box in the file for each layer. All Compositing Layer Header boxes shall be located at the top-level of the file (not within any superbox).

The type of a Compositing Layer Header box shall be 'jplh' (0x6A70 6C68). The contents of a Compositing Layer Header box is as follows:

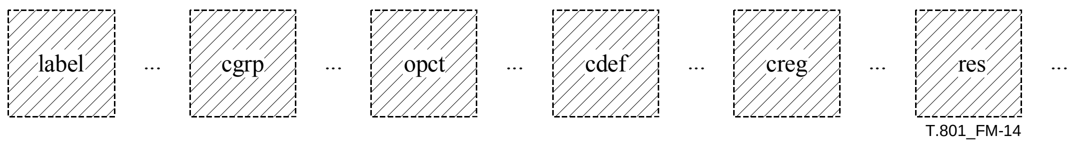


Figure M.14 – Organization of the contents of a Compositing Layer Header box

label: Label box. This box specifies a label for this compositing layer. Its structure is specified in M.11.13.

cgrp: Colour Group box. This box contains the complete colourspace specification (represented by a sequence of colour specification boxes) for this compositing layer. Its structure is specified in

M.11.7.1. If neither this box nor a cross-reference to another Colour Group box are found within the Compositing Layer Header box, then the default value of the colourspace specification for this compositing layer shall be the set of individual Colour Specification boxes found within the JP2 Header box. These Colour Specification boxes shall not be encapsulated within a Colour Group box.

opct: Opacity box. This box specifies that this compositing layer uses a simple opacity mode. Its structure is specified in M.11.7.6. If the Compositing Layer Header box contains an Opacity box, then it shall not contain a Channel Definition box, and any default Channel Definition box in the JP2 Header box shall be ignored for this compositing layer.

cdef: Channel Definition box. This box defines the channels in the image. Its structure is specified in I.5.3.6 in ITU-T Rec. T.800 | ISO/IEC 15444-1 of the JP2 file format. This box shall not be found if this Compositing Layer Header box contains an Opacity box.

creg: Codestream Registration box. This box specifies the spatial registration between the codestreams in this compositing layer. Its structure is specified in M.11.7.7. If any Compositing Layer Header box contains a Codestream Registration box, then every Compositing Layer Header box shall contain a Codestream Registration box.

res: Resolution box. This box specifies the capture and default display resolutions of the image. Its structure is specified in I.5.3.7 in ITU-T Rec. T.800 | ISO/IEC 15444-1 of the JP2 file format.

The Compositing Layer Header box may also contain other metadata boxes, including an IPR box, or cross-references to other boxes. If the Compositing Layer Header contains a cross-reference, then the box pointed to by the cross-reference shall be considered as if it was physically stored in this Compositing Layer Header box.

Also, if any of these boxes are contained within the JP2 header box and are not contained within this Compositing Layer Header box, then those boxes should also be applied to this compositing layer.

M.11.7.1 Colour Group box (superbox)

A Colour group box contains a set of related, equivalent, colour specification methods. When interpreting the colourspace of a codestream, any colour specification method contained within the specified Colour Group box may be used. This box shall be found only within a Compositing Layer Header box. This encapsulation reduces the storage overhead of sharing an entire set of colour specifications between layers.

A Colour Group box (or the JP2 Header box) shall not contain multiple Colour Specifications boxes with a METH value of 1 (Enumerated method), or multiple boxes with a METH value of 2 (Restricted ICC method). A single colour group may contain multiple Colour Specification boxes with a METH value of 3 (Any ICC method) or 4 (Vendor Colour method). Multiple ICC profiles (of the unrestricted variety) may be used to specify a particular colourspace with varying degrees of complexity (1D LUT's vs 3D LUT's), and multiple Vendor Colour methods may be used to specify multiple non-ICC based representations of the colourspace.

The JPX file may contain zero Colour Group boxes, which indicates that all compositing layers are in the colourspace specified within the JP2 Header Box (through a set of Colour Specification boxes stored directly within the JP2 Header boxes and not encapsulated within a Colour Group box).

However, if the file does not contain a colourspace specification within the JP2 Header Box (or does not contain the JP2 Header Box), then the JPX file shall contain at least one Colour Group box.

The type of a Colour Group box shall be 'cgrp' (0x6367 7270). The contents of a Colour Group box is as follows:

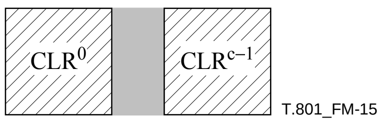


Figure M.15 – Organization of the contents of a Colour Group box

CLR^i: Colour Specification Box. This Colour Specification box specifies one method by which the colourspace of a particular codestream can be interpreted. The format of the Colour Specification box is specified in M.11.7.2

M.11.7.2 Colour Specification box

Each Colour Specification box defines one method by which an application can interpret the colourspace of the decompressed image data. This colour specification is to be applied to the image data after it has been decompressed and after any reverse multiple component transformation and reverse non-linearity transformation has been applied to the decompressed image data.

Colour Specification boxes may be found in either the JP2 Header box or in Colour Group boxes. In total, a JPX file may contain multiple Colour Specification boxes, and either the JP2 Header box or a particular Colour Group box may contain multiple Colour Specification boxes. However, all JPX files shall contain at least one Colour Specification box.

The box type and binary structure of a Colour Specification box is identical to that defined in the JP2 file format. However, to clarify the extensibility of the box with respect to defining new colour specification methods, the way in which it is described is changed within JPX. The contents of a Colour Specification box is as follows:

Figure M.16 – Organization of the contents of a Colour Specification box

METH: Specification method. This field specifies the method used by this Colour Specification box to define the colourspace of the decompressed image. This field is encoded as a 1-byte unsigned integer. The legal values of the METH field are as follows:

Table M.22 – Legal METH values

Value	Meaning
1	**Enumerated method.** This Colour Specification box indicates that the colourspace of the codestream is specified by an enumerated integer code. The definition of the format of this method is identical to the Enumerated Method in JP2. However, the JPX file format defines additional enumerated values as specified in M.11.7.3.1, as well as additional parameters for some enumerated colourspaces as specified in M.11.7.4.
2	**Restricted ICC method.** This Colour Specification box indicates that the colourspace of the codestream is specified by an embedded ICC profile of restricted type. The definition of and format of this method is identical to the Restricted ICC method defined in the JP2 file format, I.5.3.3 in ITU-T Rec. T.800 | ISO/IEC 15444-1.
3	**Any ICC method.** This Colour Specification box indicates that the colourspace of the codestream is specified by an embedded input ICC profile. Contrary to the Restricted ICC method defined in the JP2 file format, this method allows for any input ICC profile, defined by ICC-1. The binary format of the METHDAT field is specified in M.11.7.3.2.
4	**Vendor Colour method.** This Colour Specification box indicates that the colourspace of the codestream is specified by a unique vendor defined code. The binary format of the METHDAT field is specified in M.11.7.3.3.
	All other values reserved. For any value of the METH field, the length of the METHDAT field may not be 0, and applications shall not expect that the APPROX field be the last field in the box if the value of the METH field is not understood. In this case, a conforming reader shall ignore the entire Colour Specification box.

PREC: Precedence. This field specifies the precedence of this Colour Specification box, with respect to the other Colour Specification boxes within the same Colour Group box, or the JP2 Header box if this Colour Specification box is in the JP2 Header box. It is suggested, but not required, that conforming readers use the colour specification method that is supported with the highest precedence. This field is specified as a signed 1-byte integer.

APPROX: Colourspace approximation. This field specifies the extent to which this colour specification method approximates the "correct" definition of the colourspace. An example of approximation of a colourspace specification may be increased quantization in look-up tables or rounding in matrix coefficients. This field is specified as 1-byte unsigned integer. Legal values of this field are as follows:

Contrary to the APPROX field in a JP2 file (a file with "jp2\040" in the BR field in the File Type box), a value of 0 in the APPROX field is illegal in a JPX file (a file with "jpx\040" in the BR field in the File Type box). JPX writers are required to properly indicate the degree of approximation of the colour specification to the correct definition of the colourspace. This does not specify if the writer of the file knew the actual colourspace of the image data. If the actual colourspace is unknown, then the value of the UnkC field in the Image Header box shall be set to 1 and the APPROX field shall specify the degree to which this Colour Specification box matches the correct definition of the assumed or target colourspace.

In addition, high values of the APPROX field (indicating poor approximation) shall not be used to hide that the multiple Colour Specification boxes in either a Colour Group box or the JP2 Header box actually represent different colourspaces; the specification of multiple different colourspaces within a single Colour Group box is illegal.

Table M.23 – Legal APPROX values

Value	Meaning
1	This colour specification method accurately represents the correct definition of the colourspace
2	This colour specification method approximates the correct definition of the colourspace with exceptional quality
3	This colour specification method approximates the correct definition of the colourspace with reasonable quality
4	This colour specification method approximates the correct definition of the colourspace with poor quality
	All other values reserved

Table M.24 – Format of the contents of the Colour Specification box

Field name	Size (bits)	Value
METH	8	1-4
PREC	8	–128-127
APPROX	8	1-4
METHDAT	Variable	Variable

M.11.7.3 METHDAT field specifications in the Colour Specification box

The following subclauses define the fields and values that make up the METHDAT field for each defined colour specification method.

M.11.7.3.1 METHDAT values for the Enumerated method

The contents of the METHDAT field for Colour Specification boxes using the Enumerated method is defined as follows:

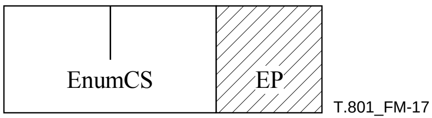


Figure M.17 – Organization of the contents of the METHDAT field for the Enumerated method

EnumCS: Enumerated colourspace. This field specifies the colourspace of the image using an integer code. To correctly interpret the colour of an image using an enumerated colourspace, the application must know the definition of that colourspace internally. This field contains a 4-byte big endian unsigned integer value indicating the colourspace of the image. Valid EnumCS values are those values defined for the Enumerated method in the JP2 file format and the values defined as follows (Table M.25).

Table M.25 – Additional legal EnumCS values

Value	Meaning
0	**Bi-level**: This value shall be used to indicate bi-level images. Each image sample is one bit: 0 = white, 1 = black.
1	**YC_bC_r(1)**: This is a format often used for data that originated from a video signal. The colourspace is based on ITU-R Rec. BT.709-4. The valid ranges of the YC_bC_r components in this space is limited to less than the full range that could be represented given an 8-bit representation. ITU-R Rec. BT.601-5 specifies these ranges as well as defines a 3 × 3 matrix transformation that can be used to convert these samples into RGB.

Table M.25 – Additional legal EnumCS values

Value	Meaning
3	**YC_bC_r(2)**: This is the most commonly used format for image data that was originally captured in RGB (uncalibrated format). The colourspace is based on ITU-R Rec. BT.601-5. The valid ranges of the YC_bC_r components in this space is [0, 255] for Y, and [–128, 127] for C_b and C_r (stored with an offset of 128 to convert the range to [0, 255]). These ranges are different from the ones defined in ITU-R Rec. BT.601-5. ITU-R Rec. BT.601-5 specifies a 3 × 3 matrix transformation that can be used to convert these samples into RGB.
4	**YC_bC_r(3)**: This is a format often used for data that originated from a video signal. The colourspace is based on ITU-R Rec. BT.601-5. The valid ranges of the YC_bC_r components in this space is limited to less than the full range that could be represented given an 8-bit representation. ITU-R Rec. BT.601-5 specifies these ranges as well as defines a 3 × 3 matrix transformation that can be used to convert these samples into RGB.
9	**PhotoYCC**: This is the colour encoding method used in the Photo CD™ system. The colourspace is based on ITU-R Rec. BT.709 reference primaries. ITU-R Rec. BT.709 linear RGB image signals are transformed to non-linear R'G'B' values to YCC corresponding to ITU-R Rec. BT.601-5. Details of this encoding method can be found in Kodak Photo CD products, *A Planning Guide for Developers*, Eastman Kodak Company, Part No. DC1200R and also in Kodak Photo CD Information Bulletin PCD045.
11	**CMY**: The encoded data consists of samples of Cyan, Magenta and Yellow samples, directly suitable for printing on typical CMY devices. A value of 0 shall indicate 0% ink coverages, whereas a value of $2^{BPS}–1$ shall indicate 100% ink coverage for a given component sample.
12	**CMYK**: As CMY above, except that there is also a black (K) ink component. Ink coverage is defined as above.
13	**YCCK**: This is the result of transforming original CMYK type data by computing R = $(2^{BPS}–1)–C$, G = $(2^{BPS}–1)–M$, and B = $(2^{BPS}–1)–Y$, applying the RGB to YCC transformation specified for YC_bC_r (2) above, and then recombining the result with the unmodified K-sample. This transformation is intended to be the same as that specified in Adobe Postscript.
14	**CIELab**: The CIE 1976 (L*a*b*) colourspace. A colourspace defined by the CIE (Commission Internationale de l'Eclairage), having approximately equal visually perceptible differences between equally spaced points throughout the space. The three components are L*, or Lightness, and a* and b* in chrominance. For this colourspace, additional Enumerated parameters are specified in the EP field as specified in M.11.7.4.1
15	**Bi-level(2)**: This value shall be used to indicate bi-level images. Each image sample is one bit: 1 = white, 0 = black.
18	**sYCC** as defined by IEC 61966-2-1, Amd.1. NOTE – It is not recommended to use ICT or RCT specified in ITU-T Rec. T.800 | ISO/IEC 15444-1 Annex G with sYCC image data. See ITU-T Rec. T.800 | ISO/IEC 15444-1, J.15, for guidelines on handling YCC codestreams.
19	**CIEJab**: As defined by CIE Colour Appearance Model 97s, CIE Publication 131. For this colourspace, additional Enumerated parameters are specified in the EP field as specified in M.11.7.4.2.
20	**e-sRGB**: As defined by PIMA 7667.
21	**ROMM-RGB**: As defined by PIMA 7666.
22	**YPbPr(1125/60)**: This is the well-known colour space and value definition for the HDTV (1125/60/2:1) system for production and international program exchange specified by ITU-R Rec. BT.709-3. The Recommendation specifies the colour space conversion matrix from RGB to YPbPr(1125/60) and the range of values of each component. The matrix is different from the 1250/50 system. In the 8-bit/component case, the range of values of each component is [1, 254], the black level of Y is 16, the achromatic level of Pb/Pr is 128, the nominal peak of Y is 235, and the nominal extremes of Pb/Pr are 16 and 240. In the 10-bit case, these values are defined in a similar manner.
23	**YPbPr(1250/50)**: This is the well-known colour space and value definition for the HDTV (1250/50/2:1) system for production and international program exchange specified by ITU-R Rec. BT.709-3. The Recommendation specifies the colour space conversion matrix from RGB to YPbPr(1250/50) and the range of values of each component. The matrix is different from the 1125/60 system. In the 8-bit/component case, the range of values of each component is [1, 254], the black level of Y is 16, the achromatic level of Pb/Pr is 128, the nominal peak of Y is 235, and the nominal extremes of Pb/Pr are 16 and 240. In the 10-bit case, these values are defined in a similar manner.
24	**e-sYCC**: e-sRGB based YCC colourspace as defined by PIMA 7667 Annex B.
	All other values reserved.

The generic RGB and grayscale spaces from the SPIFF file format are explicitly not included. Applications wishing to transcode SPIFF images using colourspaces 8 and 10 should specify, within the JPX file, the colourspace definition that a reader shall use to unambiguously interpret the image data. In many cases, this will be the sRGB or sRGB-greyscale spaces from JP2. In addition, the file writer should set the UnkC field in the Image Header box indicating that the actual colourspace is not known.

EP: Enumerated parameters. This field contains a series of parameters that augment the generic colourspace definition specified by EnumCS. Together, the EnumCS and EP fields describe the colourspace and how that colour data has been encoded in the JPX file. For example, the CIELab colourspace as described by ITU-T Rec. T.42 requires several parameters to describe the ITU encoding of the colour data. The format and value of the EP field is defined individually for each EnumCS as required. If a value of EP is not defined for a particular value of EnumCS, then the length of the EP field for that EnumCS value shall be zero, indicating that the EnumCS value alone describes the colourspace or default values are used as defined by the referenced colourspace definition. The format and values of the EP field are defined in M.11.7.4. However, the EP field shall be the last field in the Colour Specification box and shall be all bytes in the box following the EnumCS field to the end of the box.

Table M.26 – Format of the contents of the METHDAT field for the Enumerated method

Field name	Size (bits)	Value
EnumCS	32	0-(2^{32}–1)
EP	Variable	Variable

M.11.7.3.2 METHDAT values for the Any ICC method

The contents of the METHDAT field for Colour Specification boxes using the Any ICC method is defined as follows:

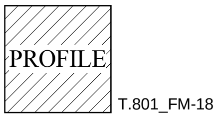


Figure M.18 – Organization of the contents of the METHDAT field for the Any ICC method

Profile: ICC Profile. This field contains an ICC input profile as defined by ICC-1, specifying the transformation between the decompressed code values and the PCS. Any input ICC profile, regardless of profile class, may be contained within this field.

Table M.27 – Format of the contents of the METHDAT field for the Any ICC method

Field name	Size (bits)	Value
PROFILE	Variable	Variable

M.11.7.3.3 METHDAT values for the Vendor Colour method

The contents of the METHDAT field for Colour Specification boxes using the Vendor Colour method is defined as follows:

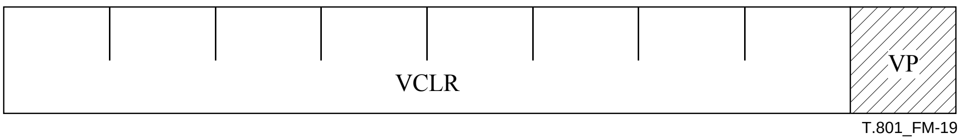


Figure M.19 – Organization of the contents of the METHDAT field for the Vendor Colour method

VCLR: Vendor Defined Code. This field specifies the colourspace of the image using a UUID. To correctly interpret the colour of an image using a Vendor defined colourspace, the application must know the definition of that colourspace internally. This field contains a 16-byte UUID indicating the colourspace of the image. These values are defined and shared by individual vendors and are outside the scope of this Recommendation | International Standard.

VP: Vendor parameters. This field specifies a series of parameters that augment the generic colourspace definition specified by VCLR. Together, the VCLR and VP fields unambiguously describe the colourspace. The format and value of the VP field is defined individually for each VCLR value as required. If a value of VP is not defined for a particular value of VCLR, then the length of the VP field for that VCLR value shall be zero, indicating that the VCLR value alone unambiguously describes the colourspace, or default values are used as defined by the referenced colourspace definition. The format and values of the VP field are defined by each individual vendor colourspace definition, and are outside of the scope of this Recommendation | International Standard. However, the VP field shall be the last field in the Colour Specification box and shall be all bytes in the box following the VCLR field to the end of the box.

Table M.28 – Format of the contents of the METHDAT field for the Vendor Colour method

Field name	Size (bits)	Value
VCLR	128	Variable
VP	Variable	Variable

M.11.7.4 EP field format and values

This field defines the format and values of the EP fields for Colour Specification boxes using the Enumerated method. If an EP field is not defined for a particular value of the EnumCS field, then the length of the EP field shall be zero.

M.11.7.4.1 EP field format for the CIELab colourspace

If the value of EnumCS is 14, specifying that the layer is encoded in the CIELab colourspace, then the format of the EP field shall be as follows:

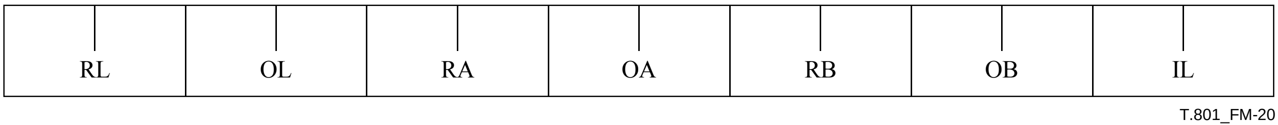


Figure M.20 – Organization of the contents of the EP field for the CIELab (EnumCS = 14)

The RL, OL, RA, OA, RB and OB fields describe how to convert between the unsigned values N_L, N_a, N_b, as defined by ITU-T Rec. T.42, that are sent to the compressor or received from the decompressor and the signed CIELab values L*, a*, b* as defined by the CIE. According to ITU-T Rec. T.42, the calculations from real values L*a*b* to $n_L n_a n_b$ bit integers, which are expressed by $N_L N_a N_b$, are made as follows:

$$N_L = \frac{2^{n_L} - 1}{RL} \times L^* + OL$$
$$N_a = \frac{2^{n_a} - 1}{RA} \times a^* + OA \qquad \text{(M-18)}$$
$$N_b = \frac{2^{n_b} - 1}{RB} \times b^* + OB$$

The IL field specifies the illuminant data used in calculating the CIELab values.

RL: Range for L*. This field specifies the *RL* value from Equation M-18. It is encoded as a 4-byte big endian unsigned integer.

OL: Offset for L*. This field specifies the *OL* value from Equation M-18. It is encoded as a 4-byte big endian unsigned integer.

RA: Range for a*. This field specifies the *RA* value from Equation M-18. It is encoded as a 4-byte big endian unsigned integer.

OA: Offset for a*. This field specifies the *OA* value from Equation M-18. It is encoded as a 4-byte big endian unsigned integer.

RB: Range for b*. This field specifies the *RB* value from Equation M-18. It is encoded as a 4-byte big endian unsigned integer.

OB: Offset for b*. This field specifies the *OB* value from Equation M-18. It is encoded as a 4-byte big endian unsigned integer

IL: Illuminant. This field specifies the illuminant data used in calculating the CIELab values. Rather than specify the XYZ values of the normalizing illuminant, which are used in calculating CIELab, the specification of the illuminant data follows ITU-T Rec. T.4 Annex E. The illuminant data consists of 4 bytes, identifying the illuminant. In the case of a standard illuminant, the 4 bytes are one of the following:

Table M.29 – Standard illuminant values for CIELab

Illuminant	Standard IL field value
CIE Illuminant D50	0x0044 3530
CIE Illuminant D65	0x0044 3635
CIE Illuminant D75	0x0044 3735
CIE Illuminant SA	0x0000 5341
CIE Illuminant SC	0x0000 5343
CIE Illuminant F2	0x0000 4632
CIE Illuminant F7	0x0000 4637
CIE Illuminant F11	0x0046 3131

When the illuminant is specified by a colour temperature, then the 4 bytes consist of the string 'CT', followed by two unsigned bytes representing the temperature of the illuminant in degrees Kelvin as a 2-byte big endian unsigned integer. For example, a 7500K illuminant is represented by the 4 bytes 0x4354 1D4C.

When the EP fields are omitted for the CIELab colourspace, then the following default values shall be used. The default L*, a* and b* range parameters are 100, 170 and 200. The default L*, a* and b* offset values are 0, 2^(N_a–1) and 2^(N_b–2) + 2^(N_b–3). These defaults correspond to the CIELab encoding in ITU-T Rec. T.42. The default value of the IL field is 0x0044 3530, specifying CIE Illuminant D50.

Other applications may use other range values by specifying EP field values. For example, the CIELab encoding in the ICC Profile Format Specification, ICC.1:2001-11 specifies ranges and offsets for the CIELab encoding that are different than the defaults given here. If the values specified in the CIELab encoding in the ICC Profile Format Specification, ICC.1:2001-11, are used, then they would have to be explicitly given in the EP fields.

Table M.30 – Format of the contents of the EP field for CIELab (EnumCS = 14)

Field name	Size (bits)	Value
RL	32	0-(2^{32}–1)
OL	32	0-(2^{32}–1)
RA	32	0-(2^{32}–1)
OA	32	0-(2^{32}–1)
RB	32	0-(2^{32}–1)
OB	32	0-(2^{32}–1)
IL	32	Variable

M.11.7.4.2 EP field format for the CIEJab colourspace

If the value of EnumCS is 19, specifying that the layer is encoded in the CIEJab colourspace, then the format of the EP field shall be as follows:

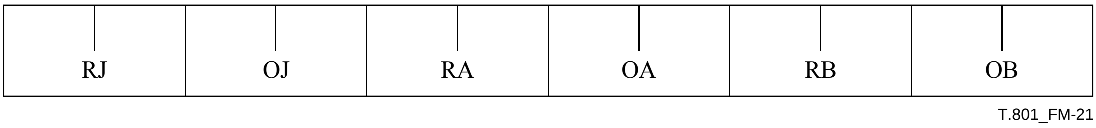


Figure M.21 – Organization of the contents of the EP field for the CIEJab (EnumCS = 19)

These fields describe how to convert between the unsigned values N_J, N_a, N_b, as defined by CIE Publication No. 131, that are sent to the compressor or received from the decompressor and the signed CIEJab values J, a, b as defined by the CIE. According to CIE Publication No. 131, the calculations from real values Jab to $N_J N_a N_b$ bit integers, which are expressed by $N_J N_a N_b$, are made as follows:

$$
\begin{aligned}
N_J &= \frac{2^{n_J} - 1}{RJ} \times J + OJ \\
N_a &= \frac{2^{n_a} - 1}{RA} \times a + OA \\
N_b &= \frac{2^{n_b} - 1}{RB} \times b + OB
\end{aligned}
\qquad \text{(M-19)}
$$

RJ: Range for J. This field specifies the *RJ* value from Equation M-19. It is encoded as a 4-byte big endian unsigned integer. If the EP field is not specified for this Colour Specification box, then the value of 100 for RJ shall be used.

OJ: Offset for J. This field specifies the *OJ* value from Equation M-19. It is encoded as a 4-byte big endian unsigned integer. If the EP field is not specified for this Colour Specification box, then the value 0 shall be used for OJ.

RA: Range for a. This field specifies the *RA* value from Equation M-19. It is encoded as a 4-byte big endian unsigned integer. If the EP field is not specified for this Colour Specification box, then the value of 255 for RA shall be used.

OA: Offset for a. This field specifies the *OA* value from Equation M-19. It is encoded as a 4-byte big endian unsigned integer. If the EP field is not specified for this Colour Specification box, then the value 2^{b-1} shall be used for OA, where *b* is the number of bits per sample for the 'a' channel.

RB: Range for b. This field specifies the *RB* value from Equation M-19. It is encoded as a 4-byte big endian unsigned integer. If the EP field is not specified for this Colour Specification box, then the value of 255 for RB shall be used.

OB: Offset for b. This field specifies the *OB* value from Equation M-19. It is encoded as a 4-byte big endian unsigned integer. If the EP field is not specified for this Colour Specification box, then the value 2^{b-1} shall be used for OB, where *b* is the number of bits per sample for the 'b' channel.

Table M.31 – Format of the contents of the EP field for CIEJab (EnumCS = 19)

Field name	Size (bits)	Value
RJ	32	0-(2^{32}–1)
OJ	32	0-(2^{32}–1)
RA	32	0-(2^{32}–1)
OA	32	0-(2^{32}–1)
RB	32	0-(2^{32}–1)
OB	32	0-(2^{32}–1)

M.11.7.5 Channel Definition box

The binary format of the Channel Definition box is identical to that defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, I.5.3.6. However, in a JPX file that is not readable by a JP2 reader, or in a codestream in a JPX file that will not be read by a JP2 reader, any channel may be associated with any colour or type. The following additional value of the $Asoc^i$ field are normatively defined:

Table M.32 – Colours indicated by the $Asoc^i$ field

Class of colourspace	Colour indicated by the following value of the $Asoc^i$ field			
	1	2	3	4
RGB	R	G	B	
Greyscale	Y			
XYZ	X	Y	Z	
Lab	L	a	b	
Luv	L	u	v	
YC_bC_r	Y	C_b	C_r	
Yxy	Y	x	y	
HSV	H	S	V	
HLS	H	L	S	
CMYK	C	M	Y	K
CMY	C	M	Y	
Jab	J	a	b	
n colour colourspaces	1	2	3	4

M.11.7.6 Opacity box

The Opacity box provides a minimal-overhead mechanism for specifying opacity through a chroma-key or specifying that a particular compositing layer contains only colour channels followed by a single opacity channel. If a Compositing Layer Header box contains an Opacity box, then it shall not contain a Channel Definition box. Compositing layers that require a channel definition more complex than can be defined using an Opacity box shall use a Channel Definition box. Each Compositing Layer Header box shall contain zero or one Opacity boxes, and Opacity boxes shall be found in no other locations in the file.

Chroma-keyed opacity is a form of paletization and as such images using chroma-keyed opacity must obey similar rules to full palettized images with respect to lossy compression. In either case, differences between the original image and the decompressed images reflect errors in a space that does not directly map to visual perception, and thus should not be coded or decompressed in a lossy mode. However, for chroma-key values, in contrast to a fully palettized component, only the samples of the image that are of the chroma-key value must be encoded and decoded losslessly. Joint lossless encoding of the chroma-keyed region and lossy coding of the remaining image region can be achieved using a ROI within the codestream.

The type of the Opacity box shall be 'opct' (0x6F70 6374). The contents of this box shall be as follows:

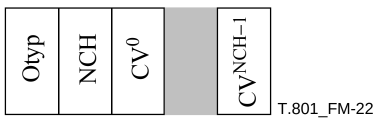


Figure M.22 – Organization of the contents of an Opacity box

Otyp: Opacity type. This field specifies the type of opacity used by this compositing layer. This field is encoded as a 1-byte unsigned integer. Legal values of the Otyp field are as follows:

Table M.33 – Otyp field values

Value	Meaning
0	The last channel in this compositing layer is an opacity channel and all other channels are colour channels where the channel association is equal to the channel number +1. For example, a four-channel compositing layer would contain 3 colour channels (with associations 1, 2 and 3 respectively) followed by an opacity channel. If the value of Otyp is 0, then the NCH, PR and CV^i fields shall not be found.
1	The last channel in this compositing layer is a premultiplied opacity channel and all other channels are colour channels where the channel association is equal to the channel number +1. For example, a four-channel compositing layer would contain 3 colour channels (with associations 1, 2 and 3 respectively) followed by a premultiplied opacity channel. If the value of Otyp is 0, then the NCH, PR and CV^i fields shall not be found.
2	This compositing layer specifies that samples of a particular colour shall be considered fully transparent (chroma-key). The chroma-key colour is specified by the NCH, PR and CV^i fields.
	All other values reserved.

NCH: Number of channels. This field specifies the number of channels used to specify the chroma-key colour. This value shall be equal to the number of channels in the compositing layer. This field is specified as a 1-byte unsigned integer.

CV^i: Chroma-key value. This field specifies the value of channel *i* for the chroma-key colour. Samples that match the chroma-key value for all channels shall be considered fully transparent. The size of this field is specified by the bit depth of the corresponding channel. If the value is not a multiple of 8, then each CV^i value shall be padded to a multiple of 8 bits with bits equal to the sign bit and the actual value shall be stored in the low-order bits of the padded value. For example, if the depth of a channel is a signed 10-bit value, then the CV^i value shall be stored in the low 10 bits of a 16-bit field and the high-order 6 bits shall be all equal to the sign bit of the value in this CV^i field.

Table M.34 – Format of the contents of the Opacity box

Field name	Size (bits)	Value
Otyp	8	0-2
NCH	8 0	0-255; if Otyp ≠ 2 Not applicable; if Otyp = 2
CV^i	Variable 0	Variable; if Otyp ≠ 2 Not applicable; if Otyp = 2

M.11.7.7 Codestream Registration box

When combining multiple codestreams to create a single compositing layer, it is important that the reference grids of those codestreams be properly registered to ensure the registration of the individual samples from the multiple components. This box specifies how those codestreams shall be registered when rendering the layer. A Compositing Layer Header box shall contain zero or one Codestream Registration boxes, and Codestream Registration boxes shall be found in no other locations in the file; a Codestream Registration box shall not be placed into the JP2 Header box to specify a default registration. If any Compositing Layer Header box contains a Codestream Registration box, then every Compositing Layer Header box shall contain a Codestream Registration box. If this Compositing Layer Header box does not contain a Codestream Registration box, then the compositing layer shall be represented by one and only one codestream.

If codestream registration is not specified for a particular compositing layer, then the codestreams in that compositing layer shall be aligned by directly aligning their reference grids at both (0,0) and (1,1).

If a Codestream Registration box exists, then the default display resolution (specified within a Resolution box with the same Compositing Layer Header box) applies to the compositing layer registration grid.

This registration is specified with respect to an independent compositing layer registration grid.

The type of the Codestream Registration box shall be 'creg' (0x6372 6567). The contents of this box shall be as follows:

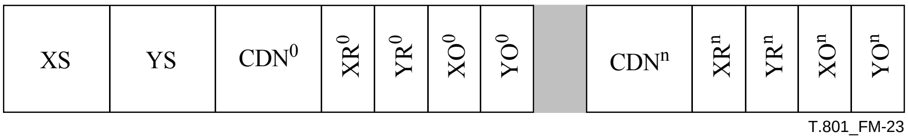


Figure M.23 – Organization of the contents of a Codestream Registration box

XS: Horizontal grid size. This field specifies the number of horizontal grid points on the compositing layer registration grid used to measure the distance between the reference grids of the individual codestreams. This field is encoded as a 2-byte unsigned integer.

YS: Vertical grid size. This field specifies the number of vertical grid points on the compositing layer registration grid used to measure the distance between the reference grids of the individual codestreams. This field is encoded as a 2-byte unsigned integer.

CDN^i: Codestream number. This field specifies the number of the codestream for this registration value.

XR^i: Horizontal resolution. This field specifies the horizontal distance between points on the reference grid of the codestream specified by the CDN^i parameter, measured in the number of points on the compositing layer registration grid. This field effectively specifies the horizontal scaling needed to match the codestream's reference grid with the compositing layer registration grid. This field is encoded as a 1-byte unsigned integer.

YR^i: Vertical resolution. This field specifies the vertical distance between points on the reference grid of the codestream specified by the CDN^i parameter, measured in the number of points on the compositing layer registration grid. This field effectively specifies the vertical scaling needed to match the codestream's reference grid with the compositing layer registration grid. This field is encoded as a 1-byte unsigned integer.

XO^i: Horizontal offset. This field specifies the horizontal distance from centre of the top left point on the reference grid of the codestream specified by the CDN^i parameter to the centre of the top left point on the compositing layer registration grid. This field is encoded as a 1-byte unsigned integer.

YO^i: Vertical offset. This field specifies the vertical distance from centre of the top left point on the reference grid of the codestream specified by the CDN^i parameter to the centre of the top left point on the compositing layer registration grid. This field is encoded as a 1-byte unsigned integer.

Table M.35 – Format of the contents of the Codestream Registration box

Field name	Size (bits)	Value
XS	16	0-65 535
YS	16	0-65 535
CDN^i	16	0-65 535
XR^i	8	0-255
YR^i	8	0-255
XO^i	8	0-255
YO^i	8	0-255

M.11.8 Contiguous Codestream box

In a JPX file, the Contiguous Codestream box contains an entire codestream as defined by the codestream syntax. However, unlike the JP2 file format, the codestreams contained within a JPX file are not restricted to codestreams defined by Annex A of ITU-T Rec. T.800 | ISO/IEC 15444-1. Codestreams contained within a JPX file may also use extensions to the codestream syntax defined in Annex A of this Recommendation | International Standard.

Contiguous Codestream boxes shall be found only at the top level of the file; they shall not be found within a superbox.

M.11.9 Media Data box

The Media Data box contains fragments of the JPEG 2000 codestream or other media data, such as MPEG-4 audio data. In any case, there shall be other boxes in the file that specify the meaning of the data within the Media Data box. Applications should not access Media Data boxes directly, but instead use the fragment table to determine what parts of which Media Data boxes represent a valid JPEG 2000 codestream or other media stream.

The type of a Media Data box shall be 'mdat' (0x6D64 6174). The contents of a Media Data box in general are not defined by this Recommendation | International Standard.

M.11.10 Composition box (superbox)

The Composition box specifies how the individual composition layers are combined to create the rendered result. It contains a set of global options, followed by a sequence of one or more sets of rendering instructions (each contained within an Instruction Set box). Each individual instruction is associated with a composition layer in the file and defines how that composition layer shall be rendered: its location, scaling, composite operation, etc. A reader that supports composition and animation shall display the file containing the Composition box by executing the sequence of instructions defined within the Composition box. Details on the composition and animation model are specified in M.5.3. A JPX file shall contain zero or one Composition boxes. If present, that box shall be found at the top level of the JPX file; it shall not be found within a superbox.

The type of the Composition box shall be 'comp' (0x636F 6D70) and it shall have the following contents:

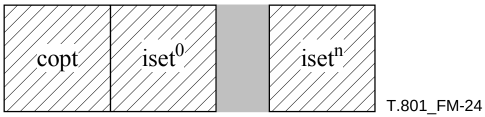


Figure M.24 – Organization of the contents of a Composition box

copt: Composition Options box. This box specifies parameters that apply to the composition or animation as a whole. It is defined in M.11.10.1.

$iset^i$: Instruction Set box. This box contains a set of instructions for how to combine the multiple composition layers in the file. The entire set of Instruction Set boxes specify the entire composition or animation, and are processed in the order they are found within the Composition box. The Composition Instruction box is defined in M.11.10.2

Table M.36 – Format of the contents of the Composition box

Parameter	Size (bits)	Value
copt	Variable	Variable
$iset^i$	Variable	Variable

M.11.10.1 Composition Options box

The Composition Options box specifies parameters that apply to the composition or animation as a whole. The Composition Options box shall be the first box in the Composition box and a Composition Options box shall not be found in any other location in the file.

The type of the Composition Options box shall be 'copt' (0x636F 7074) and contents of the box shall have the following format:

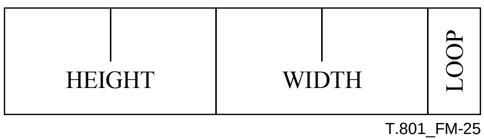


Figure M.25 – Organization of the contents of a Composition Options box

HEIGHT: Rendered result height. This field specifies the height, in samples, of the final rendered result. The resolution of this value is optionally defined in the Default Display Resolution box in the JP2 Header box. This field is encoded as a 4-byte unsigned integer.

WIDTH: Rendered result width. This field specifies the width, in samples, of the final rendered result. The resolution of this value is optionally defined in the Default Display Resolution box in the JP2 Header box. This field is encoded as a 4-byte unsigned integer.

LOOP: Looping count. This field specifies the number of times to fully execute the display instructions. A value of 255 indicates that the reader should repeat the entire set of instructions indefinitely. Prior to each execution of the instruction set, the display area shall be restored to its original state and all instructions' composition layer association reset. Each loop execution should be visually equivalent to redisplaying the composition from scratch. This field is encoded as a 1-byte unsigned integer.

Table M.37 – Format of the contents of the Composition Options box

Parameter	Size (bits)	Value
HEIGHT	32	$1\text{-}2^{32}–1$
WIDTH	32	$1\text{-}2^{32}–1$
LOOP	8	0-255

M.11.10.2 Instruction Set box

An Instruction Set box contains a set of rendering instructions, each represented through a series of composition parameters. In addition, the entire set of instructions contained within this box may be repeated according to a repeat count; this repeating occurs before the reader continues on with the instructions found within the next Instruction Set box in the Composition box. Instruction Set boxes shall be found only within a Composition box; they shall not be found in any other locations in the file.

The type of the Instruction Set box shall be 'inst' (0x696E 7374) and contents of the box shall have the following format:

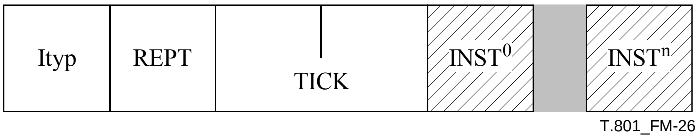


Figure M.26 – Organization of the contents of an Instruction Set box

Ityp: Instruction type. This field specifies the type of this instruction, and thus which instruction parameters shall be found within this Composition Instruction box. This field is encoded as a 16-bit flag. The meaning of each bit in the flag is as follows:

Table M.38 – Ityp field values

Value	Meaning
`0000 0000 0000 0000`	No instructions are present, and thus no instructions are defined for the compositing layers in the file.
`xxxx xxxx xxxx xxx1`	Each instruction contains XO and YO parameters.
`xxxx xxxx xxxx xx1x`	Each instruction contains the WIDTH and HEIGHT parameters.
`xxxx xxxx xxxx x1xx`	Each instruction contains the LIFE, N and PERSIST animation parameters.
`xxxx xxxx xxx1x xxxx`	Each instruction defines the crop parameters XC, YC, WC and HC.
	All other values reserved.

REPT: Repetition. This field specifies the number of times to repeat this particular set of instruction. This field is encoded as a 2-byte big endian unsigned integer. A value of 65 535 indicates to repeat the instruction indefinitely.

TICK: Duration of timer tick. This field specifies the duration of a timer tick (used by the LIFE instruction parameter) in milliseconds. This field is encoded as a 4-byte big endian unsigned integer. If the Ityp field specifies that the LIFE instruction parameter is not used, then this field shall be set to 0, and shall be ignored by readers.

$INST^i$: Instruction. This field specifies a series of instruction parameters for a single instruction. The format of this field is specified in M.11.10.2.1.

Table M.39 – Format of the contents of the Instruction Set box

Parameter	Size (bits)	Value
Ityp	16	0-65 535
REPT	16	0-65 535
TICK	32	0-(2^{32}–1)
$INST^i$	Variable	Variable

M.11.10.2.1 Instruction parameter

Figure M.27 shows the contents of each individual INST field (a single compositing instruction) within an Instruction Set box:

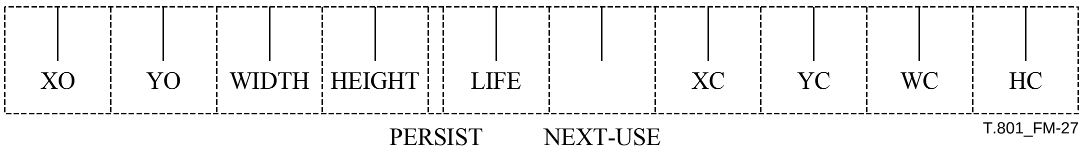


Figure M.27 – Organization of the contents of an INST field within an Instruction Set box

XO: Horizontal offset. This field specifies the horizontal location at which the top left corner of the compositing layer being acted on by this instruction shall be placed in the render area, in samples. This field is encoded as a 4-byte big endian unsigned integer. If this field is not present, a default value of zero shall be used.

YO: Vertical offset. This field specifies the vertical location at which the top left corner of the compositing layer being acted on by this instruction shall be placed in the render area, in samples. This field is encoded as a 4-byte big endian unsigned integer. If this field is not present, a default value of zero shall be used.

WIDTH: Width of the current compositing layer. This field specifies the width on the render area, in display samples, into which to scale and render the compositing layer being acted on by this instruction. This field is encoded as a 4-byte big endian unsigned integer. If this field is not present, the width of the compositing layer shall be used.

HEIGHT: Height of the current compositing layer. This field specifies the height on the render area, in display samples, into which to scale and render the compositing layer being acted on by this instruction. This field is encoded as a 4-byte big endian unsigned integer. If this field is not present, the height of the compositing layer shall be used.

PERSIST: Persistence. This field specifies whether the samples rendered to the display as a result of the execution of the current instruction shall persist on the display background or if the display background shall be reset to the its state before the execution of this instruction, before the execution of the next instruction. This field is encoded as a 1-bit boolean field. A value of 1 indicates true, that the current compositing layer shall persist. If this field is not present, the persistence shall be set to true.

LIFE: Duration of this instruction. This field specifies the number of timer ticks that should ideally occur between completing the execution of the current instruction and completing execution of the next instruction. A value of zero indicates that the current instruction and the next instruction shall be executed within the same display update; this allows a single frame from the animation to be composed of updates to multiple compositing layers. A value of 2^{31}–1 indicates an indefinite delay or pause for user interaction. This field is encoded as a 31-bit big endian unsigned integer. If this field is not present, the life of the instruction shall be set to 0.

NEXT-USE: Number of instructions before reuse. This field specifies the number of instructions that shall be executed before reusing the current compositing layer. This field allows readers to simply optimize their caching strategy. A value of zero implies that the current image shall not be reused for any ensuing instructions, notwithstanding the execution of a global loop as a result of a non-zero value of the LOOP parameter in the Composition Options box. The composition layer passed on for reuse in this manner must be the original compositing layer, prior to any cropping or scaling indicated by the current instruction. If this field is not present, the number of instructions shall be set to zero, indicating that the current compositing layer shall not be reused. This field is encoded as a 4-byte big endian unsigned integer.

XC: Horizontal crop offset. This field specifies the horizontal distance in samples to the left edge of the desired portion of the current compositing layer. The desired portion is cropped from the compositing layer and subsequently rendered by the current instruction. If this field is not present, the horizontal crop offset shall be set to 0. This field is encoded as a 4-byte big endian unsigned integer.

YC: Vertical crop offset. This field specifies the vertical distance in samples to the top edge of the desired portion of the current compositing layer. The desired portion is cropped from the compositing layer and subsequently rendered by the current instruction. If this field is not present, the vertical crop offset shall be set to 0. This field is encoded as a 4-byte big endian unsigned integer.

WC: Cropped width. This field specifies the horizontal size in samples of the desired portion of the current compositing layer. The desired portion is cropped from the compositing layer and subsequently rendered by the current instruction. If this field is not present, the cropped width shall be set to the width of the current compositing layer. This field is encoded as a 4-byte big endian unsigned integer.

HC: Cropped height. This field specifies the vertical size in samples of the desired portion of the current compositing layer. The desired portion is cropped from the compositing layer and subsequently rendered by the current instruction. If this field is not present, the cropped height shall be set to the height of the current compositing layer. This field is encoded as a 4-byte big endian unsigned integer.

References to Ityp within the individual instruction parameters in Table M.40 refers to the Ityp field within the Instruction Set box that contains this Instruction.

Table M.40 – Format of the contents of the $INST^i$ parameter in the Instruction Set box

Parameter	Size (bits)	Value
XO	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xxxx xxx1 Not applicable otherwise
YO	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xxxx xxx1 Not applicable otherwise
WIDTH	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xxxx xx1x Not applicable otherwise
HEIGHT	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xxxx xx1x Not applicable otherwise
PERSIST	1 0	0, 1; if Ityp contains xxxx xxxx xxxx 1xxx Not applicable otherwise
LIFE	31 0	0-(2^{31}–1); if Ityp contains xxxx xxxx xxxx 1xxx Not applicable otherwise
NEXT-USE	32	0-(2^{31}–1); if Ityp contains xxxx xxxx xxxx 1xxx Not applicable otherwise
XC	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xx1x xxxx Not applicable otherwise
YC	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xx1x xxxx Not applicable otherwise
WC	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xx1x xxxx Not applicable otherwise
HC	32 0	0-(2^{32}–1); if Ityp contains xxxx xxxx xx1x xxxx Not applicable otherwise

M.11.11 Association box (superbox)

The Association box allows data in the file to be associated with other data in the file. The Association box is a superbox, containing a sequence of two or more boxes. It creates independent semantic associations between the boxes it contains or the entities represented by those boxes. In particular, associations are created between the first box (or entities represented by it) (referred to as BF) and each of the other boxes (or represented entities) (referred to as B^i) in the sequence. In the case where there are more than one B^i boxes, it can be thought of as creating semantic clusters around the BF box. There is no explicit association between the B^i boxes.

For example, the association box may be used to associate a label with an entity (image, image set, metadata document, etc.) by placing a Label box in the Association box as BF and the other appropriate boxes as the B^i boxes. It may also be used to associate several items of metadata with the same image or image set by placing a Number List box as BF, followed by the metadata boxes as the B^i boxes. In addition, it may be used recursively to create different levels of association, for example to associate some metadata with a Region of Interest (ROI) and then to associate that ROI and its metadata with an image or image set. These examples are illustrated in Figures M.28 to M.31.

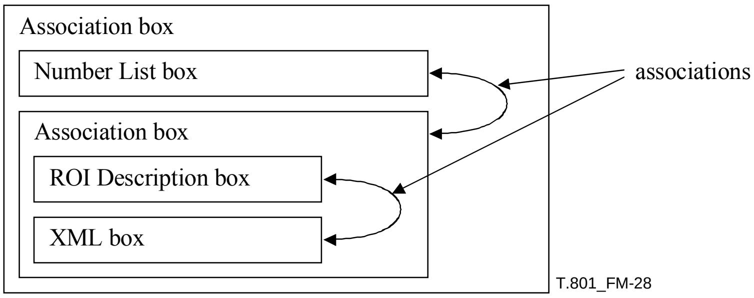


Figure M.28 – Example of ROI specific metadata associated with one or more images

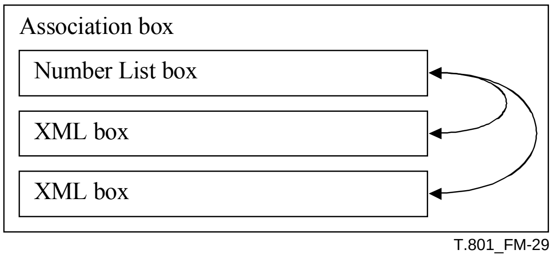


Figure M.29 – Example of Multiple XML documents associated with one or more images

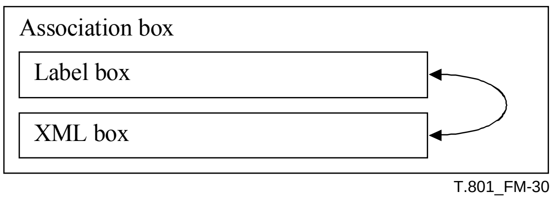


Figure M.30 – Example of a Labelled XML document

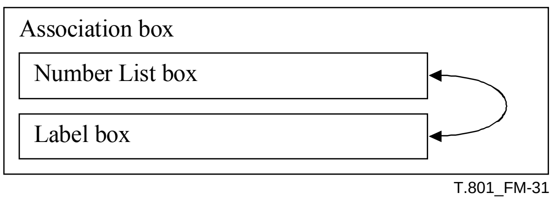


Figure M.31 – Example of a labelled image

The Association box is optional, and there may be multiple Association boxes in the file. An Association box may be found anywhere in the file except before the Reader Requirements box.

The type of an Association box shall be 'asoc' (0x6173 6F63). The contents of the Association box are defined as follows:

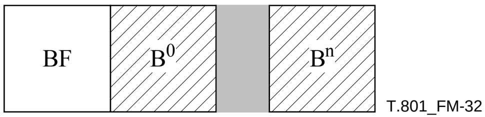


Figure M.32 – Organization of the contents of an Association box

BF: First box. This is the box to which all other boxes within this Association box are associated.

B^i: Box to be associated. This may be any box other than those that are restricted to occurring at particular locations within the file. This box shall be associated with the box BF.

Table M.41 – Format of the contents of the Association box

Parameter	Size (bits)	Value
BF	Variable	Variable
B^i	Variable	Variable

M.11.12 Number List box

The Number List box contains a list of numbers designating entities in the file. Within an Association box, a Number List box stands for the listed entities.

The type of a Number List box shall be 'nlst' (0x6E6C 7374). The contents of the Number List Box shall be as follows:

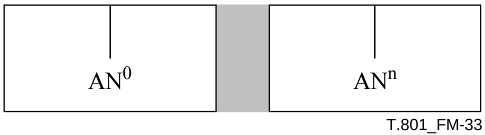


Figure M.33 – Organization of the contents of a Number List box

AN^i: Associate Number. This field specifies the number of an entity with which the data contained within the same Association box is associated. This value is stored as a 4-byte big endian unsigned integer, where the high order byte specifies the type of entity with which the data is associated, and the three low order bytes specify the number of that entity. Legal values of this field are as follows:

Table M.42 – AN^i field values

Value	Meaning
`0x0000 0000`	The rendered result.
`0x01XX XXXX`	The low three order bytes (of value *i*) specify Codestream *i* in the JPX file.
`0x02XX XXXX`	The lower three order bytes (of value *i*) specify Compositing Layer *i* in the JPX file.
	All other values reserved.

Table M.43 – Format of the contents of the Number List box

Parameter	Size (bits)	Value
AN^i	32	$0\text{-}(2^{32}–1)$

M.11.13 Label box

The Label box contains a textual label that may be associated with an entity or entities in the file by inclusion of the Label box within an Association box, a Codestream Header box, or a Compositing Layer Header box.

The type of a Label box shall be 'lbl\040' (0x6C62 6C20). The contents of the Label box are as follows:

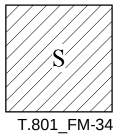


Figure M.34 – Organization of the contents of a Label box

S: Label string. A textual label associated with an entity. This value is stored as ISO/IEC 10646 characters in the UTF-8 encoding. Characters in the ranges U+0000 to U+001F inclusive and U+007F to U+009F inclusive, as well as the specific characters '/', ';', '?', ':' and '#', are not permitted in the label string. Label strings are not null-terminated or padded in any other way; every character that is present is significant.

M.11.14 Binary Filter box

The Binary Filter box allows portions of the file to be further compressed or encoded (i.e., encrypted). For example, if the file contains a significant amount of metadata in XML, it can be losslessly compressed to drastically reduce the file size. This box contains an indicator specifying how the data was transformed, as well as the transformed data. Once the data is transformed through the reverse operation (i.e., decrypted or decompressed), the resulting data shall be a sequence of boxes, where the first byte is the first byte of the first box header, and the last byte is the last byte of the last box. The Binary Filter box is optional, and there may be multiple Binary Filter boxes in the file. A Binary Filter box may be found anywhere in the file except before the Reader Requirements box.

A conforming decoder is not required to process the data within a Binary Filter box. Thus, a Binary Filter box shall not contain boxes for which interpretation is required for reader conformance.

The type of a Binary Filter box shall be 'bfil' (0x6266 696C). The contents of the Binary Filter box are defined as follows:

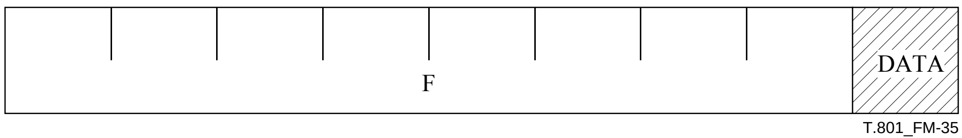


Figure M.35 – Organization of the contents of a Binary Filter box

F: Filter type. This field specifies how the data was transformed before storage. This value is encoded as a UUID. Standard defined values are:

Table M.44 – Legal Filter types

Value	Meaning
EC340B04-74C5-11D4-A729-879EA3548F0E	**Compressed with GZIP.** The contents of the DATA field have been compressed using the DEFLATE algorithm (as specified in RFC 1951). The compressed data is stored in the binary structure defined by the GZIP file format, as specified in RFC 1952.
EC340B04-74C5-11D4-A729-879EA3548F0F	**Encrypted using DES.** The contents of the DATA field has been encrypted using DES as defined in ISO 10126-2.
	All other values reserved.

If a conforming reader does not recognize the particular UUID, then the reader shall ignore this Binary Filter box.

DATA: Transformed data. This field contains previously transformed data. Once the reverse transformation has been applied (as specified by F), the result shall be a sequence of boxes. The contents of the data field may include information needed to perform the reverse filter, in addition to the filtered data. It is fully up to the definition of the F field to define the binary structure and format of the DATA field.

Table M.45 – Format of the contents of the Binary Filter box

Parameter	Size (bits)	Value
F	128	Variable
DATA	Variable	Variable

M.11.15 Desired Reproductions box (superbox)

The Desired Reproductions box specifies a set of transformations that must be applied to the image to guarantee a specific desired reproduction on a set of different output devices, respectively. For example, consider an image that contains real-world blue colours. This image is intended to be printed in a catalogue, and thus the printed image must match the actual colour of the original physical object when seen by a human viewer. However, the CMYK printing process does not reproduce the same range of blue colours as are viewable by the human visual system. In this instance, the catalog artist must determine how to best convert the blue colour in the image to a printed blue colour to minimize differences between the physical object from the printed reproduction.

A JPX reader is not required to process the image through the specified transformations.

This box contains a set of separate desired reproductions. There shall be only one Desired Reproductions box within the file, which may be found anywhere within the file.

The type of the Desired Reproductions box is 'drep' (0x6472 6570). This box is a superbox, and the contents of the box shall be as follows:

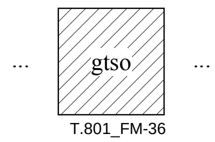


Figure M.36 – Organization of the contents of the Desired Reproductions box

gtso: Graphics Technology Standard Output box. This box specifies the desired output colour and tone reproduction for the rendered result when printed under commercial printing conditions. The format and definition of this box is specified in M.11.15.1

Other boxes may be found within the Desired Reproductions box. Readers shall ignore any boxes that they do not understand.

The Desired Reproduction box is optional for conforming files.

M.11.15.1 Graphics Technology Standard Output box

A Graphics Technology Standard Output box specifies the desired reproduction of the rendered result for commercial printing and proofing systems. The box contains an Output ICC profile specifying the desired conversion of the image from the Profile Connection Space (PCS) to the desired device specific output colourspace. There shall be only zero or one Graphics Technology Standard Output box within the file. If present, this box shall be found within the Desired Reproductions box.

The type of a Graphics Technology Standard Output box is 'gtso' (0x6774 736F). The contents of the box shall be as follows:

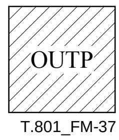


Figure M.37 – Organization of the contents of the Graphics Technology Standard Output box

OUTP: This field shall be a valid Output ICC profile as defined by the ICC Profile format specification ICC-1. Version information is embedded within the profile itself. Applications that only support specific versions of the ICC Profile Format Specifications can extract the version number from bytes 8-11 of the profile (bytes 8–11 of the contents of the Output ICC Profile box).

Table M.46 – Format of the contents of the Graphics Technology Standard Output box

Parameter	Size (bits)	Value
OUTP	Variable	Variable

M.11.16 ROI Description box

An ROI Description box contains information about parts of an image that might be useful in certain applications such as random access. The ROI description box can also be used together with the association box to associate metadata to parts of the image. The ROIs described in this box are not necessarily coded as ROIs within the codestream; it also allows an application or user to signal the importance of certain parts of an image even if theses parts are not emphasized by the RGN or ARN marker segment in the codestream. There can be multiple ROI Description boxes within the file. However, a ROI Description box shall be found only at the top level of the file, or within the JP2 Header box, a Codestream Header box or an Association box. If the ROI Description box is found within a Codestream Header box, then the ROIs described in that ROI Description box pertain to the particular codestream described by that Codestream Header box. If the ROI Description box is found within the JP2 Header box, then the ROI description box specifies default ROI information for all codestreams. If the ROI Description box is found at the top level of the file, then it specifies ROI information for the rendered result; the ROIs described at a top-level box are not directly associated with coded ROIs within any codestream.

The type of the ROI Description box shall be 'roid' (0x726F 6964). The contents of this box shall be as follows:

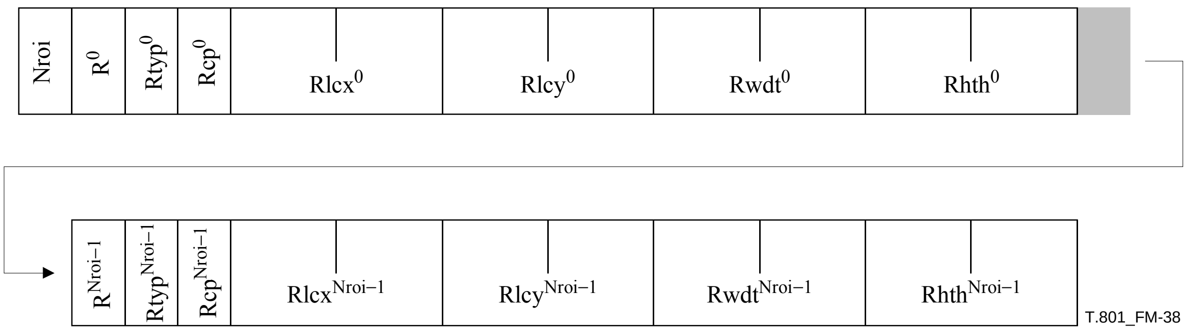


Figure M.38 – Organization of the contents of the ROI Description box

Nroi: Number of Regions of Interest. Encoded as an 8-bit integer.

R^i: Region of Interest present in codestream. Encoded as an 8-bit integer. Legal values of the R^i field are as follows:

Table M.47 – Legal R^i values

Value	Meaning
0	Codestream does not contain a static region of interest at this location.
1	Codestream contains a static region of interest at this location.
	All other values reserved.

$Rtyp^i$: Region of Interest type, can be either rectangular or ellipse. Encoded as an 8-bit integer. Legal values of the $Rtyp^i$ field are as follows:

Table M.48 – Legal $Rtyp^i$ values

Value	Meaning
0	Rectangular region of interest.
1	Elliptical region of interest.
	All other values reserved.

Rcp^i: Region of Interest coding priority. This value describes the coding priority of the Region of Interest. The value 0 means low coding priority and 255 means maximum coding priority. This value is encoded as a 1-byte unsigned integer. In transcoding applications, bits should be allocated with respect to the coding priority of each ROI.

$Rlcx^i$: Region of Interest horizontal location. In the case of rectangular area this is the location of the top left corner of the rectangle. In the case of an elliptic Region of Interest, this is the horizontal position of the centre point. This value is stored as a 4-byte big endian unsigned integer.

$Rlcy^i$: Region of Interest vertical location. In the case of rectangular area, this is the location of the top left corner of the rectangle. In the case of an elliptic Region of Interest, this is the vertical position of the centre point. This value is stored as a 4-byte big endian unsigned integer.

$Rwdt^i$: Region of Interest width. In the case of rectangular Region of Interest, this is the width of the rectangle. In the case of an elliptic Region of Interest, this is the horizontal axis. This value is stored as a 4-byte big endian unsigned integer.

$Rhth^i$: Region of Interest height. In the case of rectangular Region of Interest, this is the height of the rectangle. In the case of an elliptic Region of Interest, this is the vertical axis. This value is stored as a 4-byte big endian unsigned integer.

Table M.49 – Format of the contents of the ROI Description box

Parameter	Size (bits)	Value
Nroi	8	0-255
R^i	8	0-255
$Rtyp^i$	8	0-255
$Rlcx^i$	32	1-(2^{32}–1)
$Rlcy^i$	32	1-(2^{32}–1)
$Rwdt^i$	32	1-(2^{32}–1)
$Rhth^i$	32	1-(2^{32}–1)

M.11.17 Digital Signature box

This box contains a checksum or digital signature that may be used to verify data contained within the file. This digital signature is used to protect a very specific byte stream within the file. Any change to that byte stream will invalidate the digital signature. For example, if a compressed codestream is signed, and then later modified by adding error resilience markers, the digital signature will indicate that the byte stream has been modified.

The type of a Digital Signature box shall be 'chck' (0x6368 636B). The Digital Signature box is optional and may occur anywhere in the file except before the Reader Requirements box. There may be more than one Digital Signature box in the file. The contents of a Digital Signature box shall be as follows:

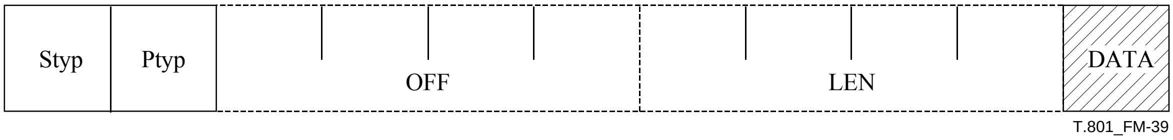


Figure M.39 – Organization of the contents of a Digital Signature box

Styp: Signature type. This field specifies the type of digital signature contained within this Digital Signature box. This field is encoded as a 1-byte unsigned integer. Legal values of the Styp field are as follows:.

Table M.50 – Legal Styp values

Value	Meaning
0	A checksum, generated by applying the MD5 algorithm to the source data, is stored in the DATA field of this Digital Signature box as a sequence of bytes in the order specified by RFC 1321.
1	The checksum is generated by applying the SHA-1 algorithm, as defined in ANSI X9.30.2, to the source data. The resulting signature is stored in the DATA field of this Digital Signature box as a 20-byte big endian unsigned integer.
2	The digital signature is generated by applying the DSA algorithm, as defined in FIPS 186-2, to the source data. The signature consists of two unsigned integers, r and s. The DATA field shall be 40 bytes long. The first 20 bytes shall be the value r, encoded as a 20-byte big endian unsigned integer. The second 20 bytes shall be the value s, encoded as a 20-byte big endian unsigned integer.
3	A digital signature, generated by applying the RSA signature algorithm with the MD5 message digest algorithm (according to PKCS #1 Version 1.5) to the source data, is stored in the DATA field of this Digital Signature box.
4	A digital signature, generated by applying the RSA signature algorithm with the SHA-1 message digest algorithm (according to PKCS #1 Version 1.5) to the source data, is stored in the DATA field of this Digital Signature box.
5	A ContentInfo value of the Cryptographic Message Syntax is stored in the DATA field of this Digital Signature box. Its 'content' field shall contain either a DigestedData value or a SignedData value, and in either case shall use the 'external signatures' mechanism described in section 5.2 of RFC 2630 to apply the chosen digest or signature algorithm to the source data.
	All other values reserved.

If key management is not an issue for a particular application (for example, if a checksum is being sent, or if the recipient already knows the public key with which to verify a signature), and if the CMS method (Styp = 5) is being used, it may help simple readers to include in the file an additional Digital Signature box using one of the other methods (Styp < 5) on the same source data. Readers without CMS support would still be able to process the additional box.

Determination of any required public key is outside the scope of this Recommendation | International Standard.

Ptyp: Source pointer type. This field indicates how the source data range that is signed by this Digital Signature box is specified. This field is encoded as a 1-byte unsigned integer. Legal values of the Ptyp field are as follows:

Table M.51 – Legal Ptyp values

Value	Meaning
0	The source data that is signed by this Digital Signature box shall be all bytes of the file, starting with the first byte, up to the byte immediately preceding the box header for this Digital Signature box. If the source data is specified using a Ptyp of 0, then this Digital Signature box shall not be in any superbox in the file; it must be at the top level of the file.
1	The source data that is signed by this Digital Signature box shall be a range bytes, starting with the byte at the location specified by the OFF field. The length of this range is specified by the LEN field. If the source data is specified using a Ptyp of 1, then OFF shall point to the start of a box header and the source range shall include only complete boxes; the Digital Signature box shall be at the same level in the box hierarchy as the box pointed to by the OFF field.
	All other values reserved.

OFF: Source data offset. This field specifies the offset in bytes to the start of the source data range that is signed by this Digital Signature box. This offset is relative to the first byte of the file. This field is encoded as an 8-byte big endian unsigned integer. If the value of Ptyp is 1, then this field shall not exist.

LEN: Source data length. If non-zero, this field specifies the length in bytes of the source data range that is signed by this Digital Signature box. A value of zero specifies that the end of the source data range is the last byte of the file. This field is encoded as an 8-byte big endian unsigned integer.

DATA: Signature data. This field contains the digital signature produced from the source data range. The format of this data is as specified by the Styp field.

Table M.52 – Format of the contents of the Digital Signature box

Parameter	Size (bits)	Value
Styp	1	0
Ptyp	1	0-1
OFF	64 0	0-(2^{64}–1); if Ptyp = 1 not applicable; if Ptyp = 0
LEN	64 0	0-(2^{64}–1); if Ptyp = 1 not applicable; if Ptyp = 0
DATA	variable	variable

M.11.18 XML box

The JP2 file format defines the XML box to contain a well-formed XML document as defined by XML 1.0. In a JPX file, this box is extended to allow JPX readers to better make use of the XML data. The format of the XML box is unchanged. However, a JPX reader should take the following actions to parse the XML document:

– If the reader finds the "xsi:schemaLocation" attribute in the root element, then the structure of this XML document or instance data is defined by a schema. This attribute specifies the physical location of the schema document.

– If the reader finds the "!DOCTYPE" line in the header of the XML document, then the structure of the XML document or instance data is defined by a Document Type Definition (DTD) document. This line specifies which DTD is used by this XML document or instance data, as well as the root element name and the location of the DTD.

– If the XML schema or DTD document referred to by the XML document contained within the XML box contains a comment field of the form "<!--HUMAN_SCHEMA_DTD_LOCATION: *LOC* -->", then a reader may retrieve a human readable document from the URL specified by *LOC*. This document shall contain a human readable description of the schema or DTD. This document will support application developers and users of the metadata.

M.11.19 MPEG-7 Binary box

This box contains metadata in MPEG-7 binary format (BiM) as defined by ISO/IEC 15938.

The type of an MPEG-7 Binary box shall be 'mp7b' (0x6D70 3762). It may be found anywhere in the file after the Reader Requirements Box. The contents of the MPEG-7 Binary box are as follows:

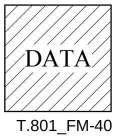


Figure M.40 – Organization of the contents of a MPEG-7 Binary box

DATA: MPEG-7 BiM Stream.

M.11.20 Free box

The Free box specifies a section of the file that is not currently used and may be overwritten when editing the file. Readers shall ignore all Free boxes. A Free box may be found anywhere in the file except before the Reader Requirements box.

The type of a Free box shall be 'free' (0x6672 6565). As a free box contains meaningless data, the contents of a Free box are undefined.

M.12 Dealing with unknown boxes

A conforming JPX file may contain boxes not known to applications based solely on this Recommendation | International Standard. If a conforming reader finds a box that it does not understand, it shall skip and ignore that box.

M.13 Using the JPX file format in conjunction with other multi-media standards (informative)

While the JPX file format provides a powerful architecture for storing still-images, there are many applications in which still-images are stored in conjunction with other multi-media types. For example, many digital still cameras allow the user to capture an audio annotation to describe a particular photograph.

This integration with other multimedia types is facilitated by the use of the Box structure for encapsulating data within the JP2 and JPX file format. The box structure itself has the same binary definition as a QuickTime atom or an MPEG-4 atom. As such, a file can be created using both JPX boxes and Quicktime or MPEG-4 atoms. Provided all offsets within the file are correct with respect to the data location from the beginning of the file (and take into account the presence of all boxes and atoms), a dual-mode file can be created.

For example, it is very easy to create a file that contains both a still photograph and an audio annotation. The boxes required to store the still photograph file can be combined with the atoms required to store a MPEG-4 audio file into a single file, as the MPEG-4, JPX and JP2 formats are flexible with respect to the location of many important boxes or atoms. A file writer would only need to be concerned that the offsets within the boxes and atoms are all determined such that they point to the location of the data in the combined file.

A reader that supports only the JPX file format would treat the file as a photograph. A reader that supports only the MPEG-4 audio standard would treat the file as an audio file. A new reader that supports both standards could then provide advanced features by combining photographic capabilities with audio capabilities.

Annex N

JPX file format extended metadata definition and syntax

(This annex forms an integral part of this Recommendation | International Standard.
This annex is optional to a JPX reader.)

This annex defines a comprehensive set of metadata elements that may be embedded in a JPX file within XML boxes. Use of this form of metadata is optional. Metadata encoded according to this annex shall be either correctly interpreted or ignored by a JPX reader.

N.1 Introduction to extended metadata

Metadata is additional information that is associated with the primary data (the image). In the context of this Recommendation | International Standard, it is additional data linked with the image data beyond the pixels which define the image. Metadata, to be most valuable for the owner(s) and user(s) of an image, needs to be consistently maintained throughout the image lifecycle. In today's environment of image editing applications, rapid transmission via the Internet, and high quality photographic printers, the lifecycle of a digital image may be very long as well as complex.

Image metadata is a building block for digital imaging that may be used within the wide spectrum of the imaging workflow. This annex defines a standard set of image metadata based on a generic concept that may be further divided into conceptual metadata groups. Each of these groups describes a unique aspect of the image. By partitioning metadata into discrete groups, users may extend a particular block without affecting the entire architecture thereby ensuring semantic interoperability while allowing others to add value to the metadata and image data itself.

N.2 Additional references for extended metadata

– ASTM E1708-95: *Standard Practice for Electronic Interchange of Color and Appearance Data*, 1995.
– DIG. DIG35 Specification: *Metadata for Digital Images. Version 1.0*, August 2000.
– DIG: *Flashpix digital image file format. Version 1.0.1*, 10 July 1997.
– IETF RFC 1766: *Tags for the Identification of Languages*, March 1995.
– IETF RFC 2396: *Uniform Resource Identifiers (URI): Generic syntax*, August 1998.
– IETF RFC 2426: *vCard MIME Directory Profile*, September 1998.
– ISO 12232:1998, *Photography – Electronic still-picture cameras – Determination of ISO speed.*
– ISO 12233:2000, *Photography – Electronic still-picture cameras – Resolution measurements.*
– ISO 12234-2:2001, *Electronic still-picture imaging – Removable memory – Part 2: TIFF/EP image data format.*
– ISO 14524:1999, *Photography – Electronic still-picture cameras – Methods for measuring opto-electronic conversion functions (OECFs).*
– JEIDA: *Digital Still Camera File Format Standard (Exif). Version 2.1*, June 1998.
– DENKER (JOHN S.): *See How It Files*, 1996.
– NMEA 0183: *Standard For Interfacing Marine Electronic Devices. Version 2.30*, March 1998.
– WIPO. Berne Convention for the Protection of Literary and Artistic Works. Paris Act of 24 July 1971, amended 28 September 1979.
– WIPO. World Intellectual Property Organization Copyright Treaty, 1996.
– W3C, XML Schema Part 1: Structures, Rec-xmlschema-1-20010502, <http://www.w3.org/TR/xmlschema-1>.
– W3C, XML Schema Part 2: Datatypes, Rec-xmlschema-2-20010502, <http://www.w3.org/TR/xmlschema-2>.

N.3 Scope of metadata definitions

This annex consists of four logical groups of metadata as well as common definitions of dataypes that are referred to by other metadata definitions. While each group is logically partitioned, they may be linked to each other to form additional semantics.

N.3.1 Image Creation metadata

The Image Creation metadata defines the "how" metadata that specifies the source of which the image was created. For example, the camera and lens information and capture condition are useful technical information for professional and serious amateur photographers as well as advanced imaging applications.

N.3.2 Content Description metadata

The Content Description metadata defines the descriptive information of "who," "what," "when," and "where" aspect of the image. Often this metadata takes the form of extensive words, phrases, or sentences to describe a particular event or location that the image illustrates. Typically, this metadata consists of text that the user enters, either when the images are taken or scanned or later in the process during manipulation or use of the images.

N.3.3 History metadata

The History is used to provide partial information about how the image got to the present state. For example, history may include certain processing steps that have been applied to an image. Another example of a history would be the image creation events including digital capture, exposure of negative or reversal films, creation of prints, transmissive scans of negatives or positive film, or reflective scans of prints. All of this metadata is important for some applications. To permit flexibility in construction of the image history metadata, two alternate representations of the history are permitted. In the first, the history metadata is embedded in the image metadata. In the second, the previous versions of the image, represented as a URL/URI, are included in the history metadata as pointers to the location of the actual history. The history metadata for a composite image (i.e., created from two or more previous images) may also be represented through a hierarchical metadata structure. While this Specification does not define the "how" or "how much" part of the processing aspect, it does enable logging of certain processing steps applied to an image as hints for future use.

N.3.4 Intellectual Property Rights metadata

The Intellectual Property Rights (IPR) metadata defines metadata to either protect the rights of the owner of the image or provide further information to request permission to use it. It is important for developers and users to understand the implications of intellectual property and copyright information on digital images to properly protect the rights of the owner of the image data.

N.3.5 Fundamental metadata types and elements

The Fundamental metadata types define common datatypes that may be used within each metadata groups. Those include an address type or a persona type which is a collection of other primitive datatypes. The Fundamental metadata elements define elements that are commonly referenced within other metadata groups. These include a definition for language specification and a timestamp.

N.4 Metadata syntax

As defined in ITU-T T.800 | ISO/IEC 15444-1 Annex I, the JP2 file format allows XML format metadata to be contained within the box structure. Metadata defined by this annex shall be well-formed XML as defined by XML 1.0. The XML shall conform to all the normative requirements of N.6, not just those expressed in the DTD and the XML Schema. The default character encoding shall be UTF-8 unless otherwise specified in the XML document.

N.4.1 Metadata schema definition language

This Recommendation | International Standard uses the XML Schema syntax as defined by XML Schema Part 1 and XML Schema Part 2 to describe the elements of the metadata.

N.4.2 Namespace

XML namespace is a collection of names, identified by a Universal Resource Identifier (URI), that allows XML documents of different sources to use elements with the same names, to be merged within a single document with no confusion. Considering JPX metadata, either incorporating other metadata for extensibility or being used in other applications, it is important to define a XML namespace for JPX elements and attributes. To specify the JPX XML namespace the following URI is defined.

```
xmlns:xsd=”http://www.jpeg.org/jpx”
```

The following namespace are used for XML and XML Schema defined elements, attributes and values:

```
xmlns:xml=”http://www.w3.org/XML/1998/namespace/”
xmlns:xsd=”http://www.w3.org/2001/XMLSchema”
```

N.4.3 Document type definition information

An XML Document type definition (DTD) for this Recommendation | International Standard is defined by the DTD specified in N.8.

The Formal Public Identifier (FPI) for this DTD shall be:

```
PUBLIC "-//SC29WG1/DTD JPXXML/XML//EN"
```

This FPI shall be used on the DOCTYPE declaration within a XML document referencing the DTD defined by this Recommendation | International Standard.

The following URL references the DTD for this Recommendation | International Standard:

```
"http://www.jpeg.org/metadata/15444-2.dtd"
```

In metadata defined by this annex, a DOCTYPE declaration shall be present prior to the root element of the XML document. The name in the DOCTYPE declaration shall be set to the root element name for the defined boxes in N.5. The system identifier may be modified appropriately to reference the DTD expressed in N.8.

N.4.4 XML Schema information

An XML Schema for this Recommendation | International Standard is defined by the XML Schema specified in N.9.

The following URL references the XML Schema for this Recommendation | International Standard:

```
"http://www.jpeg.org/metadata/15444-2.xsd"
```

Where an XML Schema location is used in metadata defined by this annex, the root element shall contain an xsi:schemaLocation attribute listing the jp namespace as specified in N.4.2 and the appropriate URL reference of the XML Schema file expressed in N.9.

N.5 Defined boxes

The following boxes are defined as part of JPX file format extended metadata. All boxes defined in this annex are optional unless otherwise stated. A JPX reader which supports the metadata defined in this annex shall understand all the elements within each box.

N.5.1 Image Creation metadata box

The Image Creation metadata box defines metadata that are related to the creation of a digital image. The scope of this box is applicable to metadata elements that are relevant to the creation of the digital image data, i.e., camera and scanner device information and its capture condition as well as the software or firmware to create such image. It defines the "how" metadata that specifies the origin of the image.

The type of the Image Creation box shall be 'xml\040' (0x786D 6C20) as defined in ITU-T T.800 | ISO/IEC 15444-1, I.7.1. The contents of this box shall be as follows:

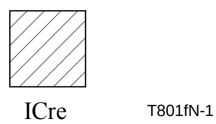


Figure N.1 – Organization of the contents of Image Creation box

ICre: Image Creation metadata field. This field shall be well-formed XML as defined by XML 1.0.

Table N.1 – Format of the contents of the Image Creation box

Field name	Size (bits)	Value
ICre	Variable	This field contains an XML document as defined in N.4, with the root element IMAGE_CREATION, containing metadata defined in N.6.1.

N.5.2 Content Description metadata box

This box comprises the content description of an image. The content description has two main purposes:

- Firstly: It can be used to classify the image. Images placed in a database need to be extracted from that database. For any image to be useful (happy snaps saved in the file system of a personal computer through to an extensive professional photo library), this is required. This classification may be used to search for images.
- Secondly: Once an image is retrieved, some data which describes the image but is not useful when searching may be included. For example – "Bob is the guy asleep on the lounge" is not all that useful when searching, but is useful when describing the content.

The metadata listed in this box contains data for both of the above cases.

The type of the Content Description box shall be 'xml\040' (0x786D 6C20) as defined in ITU-T T.800 | ISO/IEC 15444-1, I.7.1. The contents of this box shall be as follows:

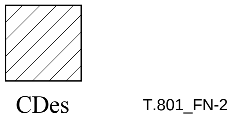


Figure N.2 – Organization of the contents of Content Description box

CDes: Content Description field. This field shall be well-formed XML as defined by XML 1.0.

Table N.2 – Format of the contents of the Content Description box

Field name	Size (bits)	Value
CDes	Variable	This field contains an XML document as defined in N.4, with the root element CONTENT_DESCRIPTION, containing metadata defined in N.6.2.

N.5.3 History box

This box contains the history of metadata of an image. The History metadata is used to provide partial information about how the picture got to the present state. This data is only approximate because:

- some of the data is collapsed, thus providing only a summary;
- some of the data may not have been properly entered because applications used were not able to update the history metadata.

The History box contains a summary of basic image editing operations that have already been applied to the image and previous version(s) of the image metadata. The History metadata is not designed to be used to reverse (undo) image editing operations.

The type of the History box shall be 'xml\040' (0x786D 6C20) as defined in ITU-T T.800 | ISO/IEC 15444-1, I.7.1. The contents of this box shall be as follows:

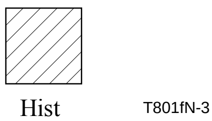


Figure N.3 – Organization of the contents of History box

Hist: History field. This field shall be well-formed XML as defined by XML 1.0.

Table N.3 – Format of the contents of the History box

Field name	Size (bits)	Value
MHist	Variable	This field contains an XML document as defined in N.4, with the root element HISTORY, containing metadata defined in N.6.3.

N.5.4 Intellectual Property Rights box

This box contains Intellectual property rights (IPR) related information associated with the image such as moral rights, copyrights as well as exploitation information.

The type of the Intellectual property rights box shall be 'jp2i' (0x6A70 3269) as defined in ITU-T T.800 | ISO/IEC 15444-1, I.6. The contents of this box shall be as follows:

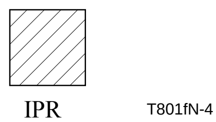


Figure N.4 – Organization of the contents of Intellectual Property Rights box

IPR: Intellectual Property Rights field. This field shall be well-formed XML as defined by XML 1.0.

Table N.4 – Format of the contents of the Intellectual Property Rights box

Field name	Size (bits)	Value
IPR	Variable	This field contains an XML document as defined in N.4, with the root element IPR, containing metadata defined in N.6.4.

N.5.5 Image Identifier box

This box contains the image identifier metadata of an image. The Image Identifier metadata is used to uniquely identify the image.

The type of the Image Identifier box shall be 'xml\040' (0x786D 6C20) as defined in ITU-T T.800 | ISO/IEC 15444-1, I.7.1. The contents of this box shall be as follows:

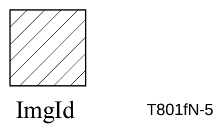


Figure N.5 – Organization of the contents of Image Identifier box

ImgId: Image Identifier field. This field shall be well-formed XML as defined by XML 1.0.

Table N.5 – Format of the contents of the Image Identifier box

Field name	Size (bits)	Value
ImgId	Variable	This field contains an XML document as defined in N.4, with the root element IMAGE_ID, containing metadata defined in N.6.5.

N.6 Metadata definitions

This clause specifies the metadata element syntax and semantics defined as part of JPX file format extended metadata. Each of the following metadata elements is based on the XML format as defined in XML 1.0. The metadata shall be either correctly interpreted or ignored by a JPX reader.

N.6.1 Image Creation metadata

This element specifies information that are relevant to the creation of the image file. This element may contain the sub-elements listed below.

```
<xsd:element name="IMAGE_CREATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:GENERAL_CREATION_INFO" minOccurs="0"/>
      <xsd:element ref="jp:CAMERA_CAPTURE" minOccurs="0"/>
      <xsd:element ref="jp:SCANNER_CAPTURE" minOccurs="0"/>
      <xsd:element ref="jp:SOFTWARE_CREATION" minOccurs="0"/>
      <xsd:element ref="jp:CAPTURED_ITEM" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
```

Figure N.6 – Schema of the Image Creation metadata

GENERAL_CREATION_INFO: General creation information. This element specifies generic information on how the image was created. The syntax of this element is specified in N.6.1.1.

CAMERA_CAPTURE: This element specifies a camera capture metadata of a scene. The syntax of this element is specified in N.6.1.2.

SCANNER_CAPTURE: This element specifies scanner capture metadata that may be used for various scanners such as flatbed and film scanners. The syntax of this element is specified in N.6.1.8.

SOFTWARE_CREATION: This element specifies software information that created the original digital image. The syntax of this element is specified in N.6.1.10.

CAPTURED_ITEM: This element contains description of the item that was digitally captured. The syntax of this element is specified in N.6.1.11.

N.6.1.1 General Creation Information metadata

This element specifies general information on how the image was created. Applications may choose to skip further parsing based on the values stored here. For example, if the application is only interested in digital camera metadata, it can skip additional parsing based on the Image source value. This element may contain the sub-elements listed below.

```
<xsd:element name="GENERAL_CREATION_INFO">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="CREATION_TIME" type="xsd:dateTime" minOccurs="0"/>
      <xsd:element name="IMAGE_SOURCE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="SCENE_TYPE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IMAGE_CREATOR" type="jp:tPerson" minOccurs="0"/>
      <xsd:element name="OPERATOR_ORG" type="jp:tOrganization" minOccurs="0"/>
      <xsd:element name="OPERATOR_ID" type="jp:tLangString" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.7 – Schema of the General Creation Information metadata

CREATION_TIME: This element specifies the date and time the image was created. This element should be stored when the creation process started. (E.g., it may be a 8 minute exposure.) This element should never be changed after it is written in the image creation device.

IMAGE_SOURCE: This element specifies the device source of the digital file, such as a film scanner, reflection print scanner, or digital camera. Table N.6 lists suggested values for this element.

Table N.6 – Image Source values

Value	Meaning
Digital Camera	Image create by a digital camera
Film Scanner	Image create by a film scanner
Reflection Print Scanner	Image create by a reflection print scanner (commonly referred to as flat bed)
Still From Video	Image create by from video
Computer Graphics	Image digitally created on computers

SCENE_TYPE: This element specifies the type of scene that was captured. It differentiates "original scenes" (direct capture of real-world scenes) from "second generation scenes" (images captured from pre-existing hardcopy images). It provides further differentiation for scenes that are digitally composed. Table N.7 lists suggested values for this element.

Table N.7 – Scene type values

Value	Meaning
Original Scene	Direct capture of real-world scenes
Second Generation Scene	Images captured from pre-existing hardcopy images such a photograph
Digital Scene Generation	Graphic arts or images digitally composed

IMAGE_CREATOR: This element specifies the name of the image creator. The image creator may be, for example, the photographer who captured the original picture on film, the illustrator, or graphic artist who conducted the image-creation process, etc. See Person type (N.7.1.13) for the format of this element.

OPERATOR_ORG: Operator organization. This element specifies the name of the service bureau, photofinisher, or organization where the image capture process (photographed, scanned or created by software) is conducted. See Organization type (N.7.1.14) for the format of this element.

OPERATOR_ID: This element specifies a name or ID for the person conducting the capture process.

N.6.1.2 Camera Capture metadata

This element specifies a camera capture of a scene. This element may contain camera and lens information, device characterization and camera capture settings.

```
<xsd:element name="CAMERA_CAPTURE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="CAMERA_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="SOFTWARE_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="LENS_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element ref="jp:DEVICE_CHARACTER" minOccurs="0"/>
      <xsd:element ref="jp:CAMERA_SETTINGS" minOccurs="0"/>
      <xsd:element name="ACCESSORY" type="jp:tProductDetails" minOccurs="0"

maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.8 – Schema of the Camera Capture metadata

CAMERA_INFO: Camera information. This element specifies information of the camera that captured the image. See Product Details type (N.7.1.21) for the format of this element.

SOFTWARE_INFO: Software information. This element specifies information about the software or firmware used to capture the image. See Product Details type (N.7.1.21) for the format of this element.

LENS_INFO: Lens information. This element specifies information about the lens that captured the image. See Product Details type (N.7.1.21) for the format of this element.

DEVICE_CHARACTER: Device characterization. This element specifies the technical characterization of the digital capture device. The syntax of this element is specified in N.6.1.3.

CAMERA_SETTINGS: Camera capture settings. This element specifies the camera settings used when the image was captured. The syntax of this element is specified in N.6.1.7.

ACCESSORY: This element specifies the information of the accessories used with the camera to capture the image. Professional and amateur photographers may want to keep track of a variety of miscellaneous technical information, such as the use of extension tubes, bellows, close-up lenses, and other specialized accessories. See Product Details type (N.7.1.21) for the format of this element.

N.6.1.3 Device Characterization metadata

This element specifies the technical characterization of the digital capture device. This element may contain the sub-elements listed below.

```
<xsd:element name="DEVICE_CHARACTER">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SENSOR_TECHNOLOGY" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="One-Chip Color Area"/>
            <xsd:enumeration value="Two-Chip Color Area"/>
            <xsd:enumeration value="Three-Chip Color Area"/>
            <xsd:enumeration value="Color Sequential Area"/>
            <xsd:enumeration value="Trilinear"/>
            <xsd:enumeration value="Color Sequential Linear Sensor"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="FOCAL_PLANE_RES" type="jp:tDoubleSize" minOccurs="0"/>
      <xsd:element name="SPECTRAL_SENSITIVITY" type="xsd:string" minOccurs="0"/>
      <xsd:element name="ISO_SATURATION" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="ISO_NOISE" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element ref="jp:SPATIAL_FREQ_RESPONSE" minOccurs="0"/>
      <xsd:element ref="jp:CFA_PATTERN" minOccurs="0"/>
      <xsd:element ref="jp:OECF" minOccurs="0"/>
      <xsd:element name="MIN_F_NUMBER" type="jp:tNonNegativeDouble" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.9 – Schema of the Device Characterization metadata

SENSOR_TECHNOLOGY: This element specifies either the type of image sensor or the sensing method used in the camera or image-capturing device. Table N.8 lists suggested values for this element.

Table N.8 – Sensor technology values

Value	Meaning
One-Chip Colour Area	An one-chip colour area sensor technology used.
Two-Chip Colour Area	A two-chip colour area sensor technology used.
Three-Chip Colour Area	A three-chip colour area sensor technology used.
Colour Sequential Area	A colour sequential area sensor technology used.
Trilinear	An trilinear sensor technology used.
Colour Sequential Linear Sensor	A colour sequential linear sensor technology used.

FOCAL_PLANE_RES: Focal plane resolution. This element specifies the number of pixels per meter in the X (width) and Y (height) directions for the main image. The resolution stored is the resolution of the image generated rather than the width and height of the image sensor.

SPECTRAL_SENSITIVITY: This element specifies the spectral sensitivity of each channel of the camera used to capture the image. It is useful for certain scientific applications. The contents of this element is compatible with ASMT E1708-95 and expected to be defined by another standard. If the Spectral Sensitivity data contains a "<" or "&" characters, then all of the occurrences of "<" shall be substituted with "<" and "&" shall be substituted with "&".

ISO_SATURATION: ISO saturation speed rating. This element specifies the ISO saturation speed rating classification as defined in ISO 12232.

ISO_NOISE: ISO noise speed rating. This element specifies the ISO noise-based speed rating classification as defined in ISO 12232.

SPATIAL_FREQ_RESPONSE: Spatial frequency response. This element specifies the Spatial Frequency Response (SFR) of the image capturing device. The syntax of this element is specified in N.6.1.4.

CFA_PATTERN: Colour filter array pattern. This element specifies the colour filter array (CFA) pattern of the image sensor used to capture a single-sensor colour image. The syntax of this element is specified in N.6.1.5.

OECF: Opto-electronic conversion function. This element specifies the Opto-Electronic Conversion Function (OECF). The OECF is the relationship between the optical input and the image file code value outputs of an electronic camera. The property allows OECF values defined in ISO 14524 to be stored as a table of values. The syntax of this element is specified in N.6.1.6.

MIN_F_NUMBER: Minimum F-number. This element specifies the minimum lens f-number of the camera or image capturing device.

N.6.1.4 Spatial Frequency Response metadata

This specifies the Spatial Frequency Response (SFR) of the image capturing device. The device measured SFR data, described in ISO 12233, can be stored as a table of spatial frequencies, horizontal SFR values, vertical SFR values, and diagonal SFR values.

```
<xsd:element name="SPATIAL_FREQ_RESPONSE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SPATIAL_FREQ_VAL" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="SPATIAL_FREQ" type="jp:tNonNegativeDouble"/>
            <xsd:element name="HORIZ_SFR" type="jp:tNonNegativeDouble"/>
            <xsd:element name="VERT_SFR" type="jp:tNonNegativeDouble"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.10 – Schema of the Spatial Frequency Response metadata

SPATIAL_FREQ_VAL: Spatial frequency value. This element specifies the list of SFR values.

SPATIAL_FREQ: Spatial frequency value in line widths per picture height units.

HORIZ_SFR: Horizontal SFR value.

VERT_SFR: Vertical SFR value.

N.6.1.5 Colour Filter Array Pattern metadata

This element encodes the actual colour filter array (CFA) geometric pattern of the image sensor used to capture a single-sensor colour image. It is not relevant for all sensing methods. The data contains the minimum number of rows and columns of filter colour values that uniquely specify the colour filter array.

```
<xsd:element name="CFA_PATTERN">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="COLOR_ROW" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="COLOR" maxOccurs="unbounded">
              <xsd:simpleType>
                <xsd:restriction base="xsd:string">
                  <xsd:enumeration value="Red"/>
                  <xsd:enumeration value="Green"/>
                  <xsd:enumeration value="Blue"/>
                  <xsd:enumeration value="Cyan"/>
                  <xsd:enumeration value="Magenta"/>
                  <xsd:enumeration value="Yellow"/>
                  <xsd:enumeration value="White"/>
                </xsd:restriction>
              </xsd:simpleType>
            </xsd:element>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.11 – Schema of the Colour Filter Array Pattern metadata

COLOR_ROW: This element specifies the list of colour values of the CFA pattern.

COLOR: CFA pattern values. The values shall be either Red, Green, Blue, Cyan, Magenta, Yellow, or White.

N.6.1.6 Opto-electronic Conversion Function metadata

This element specifies the Opto-Electronic Conversion Function (OECF). The OECF is the relationship between the optical input and the image file code value outputs of an electronic camera. The property allows OECF values defined in ISO 14524 to be stored as a table of values.

```
 <xsd:element name="OECF">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="LOG_VAL" maxOccurs="unbounded">
          <xsd:complexType>
            <xsd:sequence>
              <xsd:element name="LOG_EXPOSURE" type="xsd:double"/>
              <xsd:element name="OUTPUT_LEVEL" type="jp:tNonNegativeDouble"

maxOccurs="unbounded"/>
            </xsd:sequence>
          </xsd:complexType>
        </xsd:element>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
```

Figure N.12 – Schema of the Opto-electronic Conversion Function metadata

LOG_VAL: This element specifies the list of OECF values.

LOG_EXPOSURE: Optical input log exposure value.

OUTPUT_LEVEL: Image file code value output value.

N.6.1.7 Camera Capture Settings metadata

This element specifies the camera settings used when the image was captured. New generations of digital and film cameras make it possible to capture more information about the conditions under which a picture was taken. This may include information about the lens aperture and exposure time, whether a flash was used, which lens was used, etc. This technical information is useful to professional and serious amateur photographers. In addition, some of these properties are useful to image database applications for populating values useful to advanced imaging applications and algorithms as well as image analysis and retrieval. This element may contain the sub-elements listed below.

```
<xsd:element name="CAMERA_SETTINGS">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:choice minOccurs="0">
        <xsd:element name="EXP_TIME" type="jp:tNonNegativeDouble"/>
        <xsd:element name="R_EXP_TIME" type="jp:tRational"/>
      </xsd:choice>
      <xsd:element name="F_NUMBER" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="EXP_PROGRAM" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="BRIGHTNESS" type="xsd:double" minOccurs="0"/>
      <xsd:element name="EXPOSURE_BIAS" type="xsd:double" minOccurs="0"/>
      <xsd:element name="SUBJECT_DISTANCE" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="METERING_MODE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="SCENE_ILLUMINANT" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="COLOR_TEMP" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="FOCAL_LENGTH" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="FLASH" type="xsd:boolean" minOccurs="0"/>
      <xsd:element name="FLASH_ENERGY" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="FLASH_RETURN" type="xsd:boolean" minOccurs="0"/>
      <xsd:element name="BACK_LIGHT" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Front Light"/>
            <xsd:enumeration value="Back Light 1"/>
            <xsd:enumeration value="Back Light 2"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="SUBJECT_POSITION" type="jp:tPosition" minOccurs="0"/>
      <xsd:element name="EXPOSURE_INDEX" type="xsd:double" minOccurs="0"/>
      <xsd:element name="AUTO_FOCUS" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Auto Focus Used"/>
            <xsd:enumeration value="Auto Focus Interrupted"/>
            <xsd:enumeration value="Near Focused"/>
            <xsd:enumeration value="Soft Focused"/>
            <xsd:enumeration value="Manual"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="SPECIAL_EFFECT" minOccurs="0" maxOccurs="unbounded">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Colored"/>
            <xsd:enumeration value="Diffusion"/>
            <xsd:enumeration value="Multi-Image"/>
            <xsd:enumeration value="Polarizing"/>
            <xsd:enumeration value="Split-Field"/>
            <xsd:enumeration value="Star"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="CAMERA_LOCATION" type="jp:tLocation" minOccurs="0"/>
      <xsd:element name="ORIENTATION" type="jp:tDirection" minOccurs="0"/>
      <xsd:element name="PAR" type="jp:tRational" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.13 – Schema of the Camera Capture Settings metadata

EXP_TIME: Exposure time. This element specifies the exposure time used when the image was captured. The value of this element is stored in seconds.

R_EXP_TIME: Rational exposure time. This element specifies the exposure time used when the image was captured. The value of this element is stored in rational values in seconds.

F_NUMBER: F-Number. This element specifies the lens f-number (ratio of lens aperture to focal length) used when the image was captured.

EXP_PROGRAM: Exposure program. This element specifies the class of exposure program that the camera used at the time the image was captured. Table N.9 lists suggested values for this element.

Table N.9 – Exposure program values

Value	Meaning
Manual	The exposure setting set manually by the photographer.
Program Normal	A general purpose auto-exposure program.
Aperture Priority	The user selected the aperture and the camera selected the shutter speed for proper exposure.
Shutter Priority	The user selected the shutter speed and the camera selected the aperture for proper exposure.
Program Creative	The exposure setting is biased toward greater depth of element.
Program Action	The exposure setting is biased toward faster shutter speed.
Portrait Mode	The exposure setting is intended for close-up photos with the background out of focus.
Landscape Mode	The exposure setting is intended for landscapes with the back-ground in good focus.

BRIGHTNESS: Brightness value. This element specifies the Brightness Value (Bv) measured when the image was captured, using APEX units. The expected maximum value is approximately 13.00 corresponding to a picture taken of a snow scene on a sunny day, and the expected minimum value is approximately –3.00 corresponding to a night scene. If the value supplied by the capture device represents a range of values rather than a single value, the minimum and maximum value may be specified.

EXPOSURE_BIAS: Exposure bias value. This element specifies the actual exposure bias (the amount of over-or underexposure relative to a normal exposure, as determined by the camera's exposure system) used when capturing the image, using APEX units. The value is the number of exposure values (stops). For example, –1.00 indicates 1 eV (1 stop) underexposure, or half the normal exposure.

SUBJECT_DISTANCE: This element specifies the distance between the front nodal plane of the lens and the subject on which the camera was focusing. The camera may have focused on a subject within the scene that may not have been the primary subject. The subject distance may be specified by a single number if the exact value is known. Alternatively, a range of values indicating the minimum and maximum distance of the subject may be set. The value of this element is in meters.

METERING_MODE: This element specifies the metering mode (the camera's method of spatially weighting the scene luminance values to determine the sensor exposure) used when capturing the image. Table N.10 lists suggested values for this element.

Table N.10 – Metering mode values

Value	Meaning
Average	Average mode used.
Center Weighted Average	Center weighted average mode used.
Spot	Spot mode used.
MultiSpot	MultiSpot mode used.
Pattern	Pattern mode used.
Partial	Partial mode used.

SCENE_ILLUMINANT: This element specifies the light source (scene illuminant) that was present when the image was captured. Table N.11 lists suggested values for this element.

Table N.11 – Scene illuminant values

Value	Meaning
Daylight	Daylight illuminant used.
Fluorescent Light	Fluorescent light used.
Tungsten Lamp	Tungsten lamp used.
Flash	Flash used.
Standard Illuminant A	Standard illuminant A used.
Standard Illuminant B	Standard illuminant B used.
Standard Illuminant C	Standard illuminant C used.
D55 Illuminant	D55 illuminant used.
D65 Illuminant	D65 illuminant used.
D75 Illuminant	D75 illuminant used.

COLOR_TEMP: Colour temperature. This element specifies the actual colour temperature value of the scene illuminant stored in units of Kelvin.

FOCAL_LENGTH: This element specifies the lens focal length used to capture the image. The focal length may be specified by using a single number, for a fixed focal length lens or a zoom lens, if the zoom position is known. The value of this element is stored in meters.

FLASH: This element specifies whether flash was used at image capture.

FLASH_ENERGY: This element specifies the amount of flash energy that was used. The measurement units are Beam Candle Power Seconds (BCPS).

FLASH_RETURN: This element specifies whether the camera judged that the flash was not effective at the time of exposure.

BACK_LIGHT: This element specifies the camera's evaluation of the lighting conditions at the time of exposure. Table N.12 lists BACK_LIGHT values used for lighting situations.

Table N.12 – Back light values

Value	Meaning
Front Light	The subject is illuminated from the front side.
Back Light 1	The brightness value difference between the subject centre and the surrounding area is greater than one full step (APEX). The frame is exposed for the subject centre.
Back Light 2	The brightness value difference between the subject centre and the surrounding area is greater than one full step (APEX). The frame is exposed for the surrounding area.

SUBJECT_POSITION: This element specifies the approximate position of the subject in the scene. See Position Type for the format of this element.

EXPOSURE_INDEX: This element specifies the exposure index setting the camera selected.

AUTO_FOCUS: This element specifies the status of the focus of the capture device at the time of capture. Table N.13 lists values used for auto focus status.

Table N.13 – Auto focus values

Value	Meaning
Auto Focus Used	The camera successfully focused on the subject.
Auto Focus Interrupted	The image was captured before the camera had successfully focused on the subject.
Near Focused	The camera deliberately focused at a distance closer than the subject to allow for the super-imposition of a focused foreground subject.
Soft Focused	The camera deliberately did not focus exactly at the subject distance to create a softer image (commonly used for portraits).
Manual	The camera was focused manually.

SPECIAL_EFFECT: Special Effects. This element specifies the types of special effects filters used. It contains a list of filter elements, where the order of the elements in the array indicates the stacking order of the filters. The first value in the array is the filter closest to the original scene. This element specifies the special effect filter used. Legal values are Coloured, Diffusion, Multi-Image, Polarizing, Split-Field, Star.

CAMERA_LOCATION: This element specifies the location of the camera when the picture was taken. See Location Type for the format of this element.

ORIENTATION: This element specifies the orientation of the camera when the picture was taken. See Direction Type for the format of this element.

PAR: Print aspect ratio. This element specifies the print aspect ratio specified by the user when the picture was taken.

N.6.1.8 Scanner Capture metadata

This element specifies scanner capture metadata that may be used for various scanners such as flatbed and film scanners. It optionally contains scanner information, device characterization and scanner capture settings. This element may contain the sub-elements listed below.

```
<xsd:element name="SCANNER_CAPTURE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SCANNER_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="SOFTWARE_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element ref="jp:SCANNER_SETTINGS" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.14 – Schema of the Scanner Capture metadata

SCANNER_INFO: Scanner information. This element specifies information about a particular scanner that was used to digitize an image item. It is recommended that applications are able to create a unique value of the scanner by combining all elements. See Product Details type (N.7.1.21) for the format of this element.

SOFTWARE_INFO: Software information. This element specifies information about the software or firmware used to capture the image. See Product Details type (N.7.1.21) for the format of this element.

SCANNER_SETTINGS: This element specifies the scanner settings used when the image was scanned. The syntax of this element is specified in N.6.1.9.

N.6.1.9 Scanner Settings metadata

This element specifies the scanner settings used when the image was scanned. This element may contain the sub-elements listed below.

```
<xsd:element name="SCANNER_SETTINGS">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="PIXEL_SIZE" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="PHYSICAL_SCAN_RES" type="jp:tDoubleSize" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.15 – Schema of the Scanner Settings metadata

PIXEL_SIZE:	This element specifies the pixel size, in meters, of the scanner.
PHYSICAL_SCAN_RES:	Physical scan resolution. These element specify the physical scanning resolution of the device (not the interpolated resolution of the final output data) in the X (width) and Y (height) directions. The value of these elements are in meters.

N.6.1.10 Software Creation metadata

This element specifies software creation information (e.g., the application name) that created the original image.

```
<xsd:element name="SOFTWARE_CREATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SOFTWARE_INFO"   type="jp:tProductDetails"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.16 – Schema of the Software Creation metadata

SOFTWARE_INFO:	Software information. This element specifies information about the software that created the original image. See Product Details type (N.7.1.21) for the format of this element.

N.6.1.11 Captured Item metadata

This element specifies capture item metadata. It optionally contains reflection print or film. This element may contain the sub-elements listed below.

```
<xsd:element name="CAPTURED_ITEM">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:choice>
        <xsd:element ref="jp:REFLECTION_PRINT" minOccurs="0"/>
        <xsd:element ref="jp:FILM" minOccurs="0"/>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.17 – Schema of the Captured Item metadata

REFLECTION_PRINT:	This element specifies information about a reflection print that was digitally captured. The syntax of this element is specified in N.6.1.12.
FILM:	This element specifies information about the film. The syntax of this element is specified in N.6.1.13.

N.6.1.12 Reflection Print metadata

This element specifies information about a reflection print that was digitally captured. This element may contain the sub-elements listed below.

```
<xsd:element name="REFLECTION_PRINT">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="DOCUMENT_SIZE" type="jp:tDoubleSize" minOccurs="0"/>
      <xsd:element name="MEDIUM" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Continuous Tone Image"/>
            <xsd:enumeration value="Halftone Image"/>
            <xsd:enumeration value="Line Art"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="RP_TYPE" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="B/W Print"/>
            <xsd:enumeration value="Color Print"/>
            <xsd:enumeration value="B/W Document"/>
            <xsd:enumeration value="Color Document"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.18 – Schema of the Reflection Print metadata

DOCUMENT_SIZE: This element specifies the lengths of the X (width) and Y (height) dimension of the original photograph or document, respectively. The values of these elements are given in meters.

MEDIUM: This element specifies the medium of the original photograph, document, or artifact. Legal values include Continuous Tone Image, Halftone Image, and Line Art.

RP_TYPE: Reflection print type. This element specifies the type of the original document or photographic print. Legal values include B/W Print, Colour Print, B/W Document, and Colour Document.

N.6.1.13 Film metadata

This element specifies information on the film that was digitized. This element may contain the sub-elements listed below.

```
<xsd:element name="FILM">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="BRAND" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="CATEGORY" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Negative B/W"/>
            <xsd:enumeration value="Negative Color"/>
            <xsd:enumeration value="Reversal B/W"/>
            <xsd:enumeration value="Reversal Color"/>
            <xsd:enumeration value="Chromagenic"/>
            <xsd:enumeration value="Internegative B/W"/>
            <xsd:enumeration value="Internegative Color"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="FILM_SIZE" type="jp:tDoubleSize" minOccurs="0"/>
      <xsd:element name="ROLL_ID" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="FRAME_ID" type="xsd:positiveInteger" minOccurs="0"/>
      <xsd:element name="FILM_SPEED" type="xsd:positiveInteger" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.19 – Schema of the Film metadata

BRAND: This element specifies the name of the film manufacturer. See Product Details type (N.7.1.21) for the format of this element.

CATEGORY: This element specifies the category of film used. Legal values include Negative B/W, Negative Colour, Reversal B/W, Reversal Colour, Chromagenic, Internegative B/W, and Internegative Colour. The category Chromagenic refers to B/W negative film that is developed with a C41 process (i.e., colour negative chemistry).

FILM_SIZE: This element specifies the size of the X and Y dimension of the film used, and the unit is in meters.

ROLL_ID: This element specifies the roll number or ID of the film. For some film, this number is encoded on the film cartridge as a bar code.

FRAME_ID: This element specifies the frame number or ID of the frame digitized from the roll of film.

FILM_SPEED: This element specifies the film speed of the film. This element is measured in ASA.

N.6.2 Content Description metadata

The Content Description metadata describes the content of the information captured in the image. Those are semantic information typically requiring user input. The value of such information increases as time passes. This element may contain the sub-elements listed below.

```
<xsd:element name="CONTENT_DESCRIPTION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="GROUP_CAPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="CAPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="CAPTURE_TIME" type="jp:tDateTime" minOccurs="0"/>
      <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
      <xsd:element ref="jp:PERSON" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:THING" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:ORGANIZATION" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:EVENT" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:AUDIO" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:DICTIONARY" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.20 – Schema of the Content Description metadata

GROUP_CAPTION: This element specifies the subject or purpose of the image. It may be additionally used to provide any other type of information related to the image.

CAPTION: This element specifies the subject or purpose of the image. It may be additionally used to provide any other type of information related to the image.

CAPTURE_TIME: This element specifies the time and date the image was initially generated. This may be different to the capture device date where the capture device is a scanner that scans the image at a different time to when it was initially captured. See DateTime type (N.7.1.8) for the format of this element.

LOCATION: The element describes the location of the image. This location is the physical location of the image (e.g., address, GPS coordinate), not the position of an object within the image. See Location type (N.7.1.15) for the format of this element.

PERSON: Person Description. This element specifies a person within an image. The syntax of this element is specified in N.6.2.1.

THING: Thing Description. This element specifies the names of tangible things depicted in the image. The syntax of this element is specified in N.6.2.2.

ORGANIZATION: Organization Description. This element specifies an organization within an image. The syntax of this element is specified in N.6.2.3.

EVENT: Event description. This element specifies events depicted in the image. The syntax of this element is specified in N.6.2.4.

AUDIO: This element specifies audio streams associated with an image. The syntax of this element is specified in N.6.2.7.

PROPERTY: This element specifies information used to describe an image or an object within an image. The syntax of this element is specified in N.6.2.8.

DICTIONARY: This element specifies a dictionary of a property. The syntax of this element is specified in N.6.2.9.

COMMENT: This element specifies user- and/or application-defined information beyond the scope of other properties in this group. See Comment element (N.7.3.1) for the format of this element.

N.6.2.1 Person Description metadata

This element specifies a person within an image. See Person type (N.7.1.13) for the format of this element. This element may contain the sub-elements listed below.

```
<xsd:element name="PERSON">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tPerson">
        <xsd:sequence>
          <xsd:element name="POSITION" type="jp:tPosition" minOccurs="0"/>
          <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
          <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>
```

Figure N.21 – Schema of the Person Description metadata

POSITION: This element specifies the position of the person within the image. See Position type (N.7.1.17) for the format of this element.

LOCATION: This element specifies the physical location of the person. This element does not specify the relative position of the person. See Location type (N.7.1.15) for the format of this element.

PROPERTY: This element specifies additional information describing the person. See Property metadata (N.6.2.8) for the format of this element.

N.6.2.2 Thing Description metadata

This element specifies the names and/or properties of tangible things depicted in the image (for example, Washington Monument) or of abstract regions. This element may contain the sub-elements listed below.

```
<xsd:element name="THING">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
      <xsd:element name="POSITION" type="jp:tPosition" minOccurs="0"/>
      <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
      <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:THING" minOccurs="0" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.22 – Schema of the Thing Description metadata

NAME: This element specifies the name of the Thing.

COMMENT: This element specifies user- and/or application-defined information beyond the scope of other properties in the Thing. See Comment element (N.7.3.1) for more information on this element.

POSITION: This element specifies the position of the thing within the image. See Position type (N.7.1.17) for the format of this element.

LOCATION: This element specifies the physical location of the thing. This element does not specify the relative position of the thing within the image. See Location type (N.7.1.15) for the format of this element.

PROPERTY: The Thing also contains multiple Property*s*. These Property*s* describe the thing. See Property metadata (N.6.2.8) for the format of this element.

THING Sub-thing description. The Thing element may contain zero or more Thing elements, with the interpretation that these are sub-things of the containing thing.

ID: This element is the identifier attribute for the Thing.

N.6.2.3 Organization Description metadata

This element specifies an organization depicted within an image. This description can also be used to describe the entire image. See Organization type (N.7.1.14) for the format of this element. This element may contain the sub-elements listed below.

```
<xsd:element name="ORGANIZATION">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tOrganization">
        <xsd:sequence>
          <xsd:element name="POSITION" type="jp:tPosition" minOccurs="0"/>
          <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
          <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>
```

Figure N.23 – Schema of the Organization Description metadata

POSITION: This element specifies the position of the organization within the image. See Position type (N.7.1.17) for the format of this element.

LOCATION: This element specifies the physical location of the organization. This element does not specify the relative position of the organization. See Location type (N.7.1.15) for the format of this element.

PROPERTY: This element specifies additional information describing the organization. See Property metadata (N.6.2.8) for the format of this element.

N.6.2.4 Event Description metadata

This element specifies a description of the event depicted in the image. An Event is the most likely reason why an image is captured. This element may contain the sub-elements listed below unless otherwise stated.

```
<xsd:element name="EVENT">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="EVENT_TYPE" type="jp:tLangString"/>
      <xsd:element name="DESCRIPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
      <xsd:element name="EVENT_TIME" type="jp:tDateTime" minOccurs="0"/>
      <xsd:element name="DURATION" type="xsd:duration" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
      <xsd:element ref="jp:PARTICIPANT" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:EVENT_RELATION" minOccurs="0" maxOccurs="unbounded"/>
      <!-- Sub-events -->
      <xsd:choice minOccurs="0" maxOccurs="unbounded">
        <xsd:element ref="jp:EVENT"/>
        <xsd:element name="EVENT_REF" type="xsd:string"/>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute name="ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.24 – Schema of the Event Description metadata

EVENT_TYPE: Event type. If there is an Event or Sub-event element, the Event type element shall exist. The Event type element may occur only once in a node level of an Event tree or Sub-event branch.

DESCRIPTION: This element specifies a description of the event. This element is used to describe an event in text human readable format.

LOCATION: This element identifies the physical location of the Event and not the position within the image. See Location type (N.7.1.15) for more information on this element.

EVENT_TIME: Event date and time. This element specifies the start time of the event. See DateTime type (N.7.1.8) for the format of this element.

DURATION: This element specifies the duration of the Event.

COMMENT: This element specifies user- and/or application-defined information beyond the scope of other properties in the Event. See Comment element (N.7.3.1) for more information on this element.

PARTICIPANT: This element specifies the participants of the event. A participant may be a Person, an Organization or a Thing. The syntax of this element is specified in N.6.2.5.

EVENT_RELATION: Event relationships. This element specifies relationships to other events. The syntax of this element is specified in N.6.2.6.

Sub-events. The Event element may contain one or more Sub-event elements of the encompassing event. A Sub-event element may contain Sub-events. The sub-event element may be either contained within the event element, or referenced:

EVENT: Sub-event description.

EVENT_REF: Event reference. A reference to the sub-event. This element is a link to one of the other Event elements.

ID: This element specifies the unique identifier for the Event.

N.6.2.5 Participant metadata

This element specifies the participants in the event. A participant may be a Person, an Organization or a Thing.

```
<xsd:element name="PARTICIPANT">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="ROLE" type="jp:tLangString" minOccurs="0"
                                                            maxOccurs="unbounded"/>
      <xsd:choice>
        <xsd:element name="OBJECT_REF" type="xsd:string"/>
        <xsd:element ref="jp:PERSON"/>
        <xsd:element ref="jp:THING"/>
        <xsd:element ref="jp:ORGANIZATION"/>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.25 – Schema of the Participant metadata

ROLE: This element specifies the role of the participant within the event.

OBJECT_REF: Object reference. This element is a reference to a participant. This element is a link to one of the Person, Organization or Thing elements within the Content Description metadata.

PERSON: This element specifies a Person who is a participant of an event yet not depicted within the image. See Person description metadata (see N.6.2.1) for the format of this element.

THING: This element specifies a Thing that is a participant of an event yet not depicted within the image. See Thing description metadata (see N.6.2.2) for the format of this element.

ORGANIZATION: This element specifies the Organization that is a participant of an event yet not depicted within the image. See Organization description metadata (see N.6.2.3) for the format of this element.

N.6.2.6 Event Relationship metadata

This element specifies relationships to other events. These are used for relationships between events that are not directly sub-events of each other. An example of a relationship might be a link to a previous event of the same type.

```
  <xsd:element name="EVENT_RELATION">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="RELATION" type="jp:tLangString" minOccurs="0"

maxOccurs="unbounded"/>
        <xsd:element name="EVENT_REF" type="xsd:string" maxOccurs="unbounded"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
```

Figure N.26 – Schema of the Event Relationship metadata

RELATION: This element specifies a description of the relationship(s) to the other event(s).

EVENT_REF: Event reference. This element is a reference to related events. This element is a link to one of the other Event elements within the Event description metadata.

N.6.2.7 Audio metadata

This element specifies audio metadata associated with an image. Image metadata can contain zero or more audio streams. Each audio stream can contain a comment element describing the audio. A single comment should also be able to describe more than one audio stream.

```
<xsd:element name="AUDIO">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="AUDIO_STREAM" type="xsd:anyURI"/>
      <xsd:element name="AUDIO_FORMAT" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="MIME_TYPE" type="xsd:string" minOccurs="0"/>
      <xsd:element name="DESCRIPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.27 – Schema of the Audio metadata

AUDIO_STREAM:	This element specifies an URI reference to an audio stream. The format of the stream is not defined.
AUDIO_FORMAT:	Audio Stream Format. This element specifies the name of the audio stream format. For example, AIFF, MIDI, MP3 and WAV.
MIME_TYPE:	This element specifies the Internet media type of the audio file.
DESCRIPTION:	This element specifies a description of the audio stream.
COMMENT:	This element specifies user- and/or application-defined information beyond the scope of other properties in the Audio. See Comment element (N.7.3.1) for more information on this element.

N.6.2.8 Property metadata

This element specifies a description of an image or an object within an image. This element shall contain a name and may optionally contain a value and sub-property elements. A Property is either a single word or a small phrase and an optional value. The property is a non-exact language-specific definition of the image or part of the image. This element may contain the sub-elements listed below.

```
<xsd:element name="PROPERTY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="VALUE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
      <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="DICT_REF" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.28 – Schema of the Property metadata

NAME:	This element specifies the name of the Property.
VALUE:	This element specifies the property value. A Property that contains a value cannot contain sub-property elements.
COMMENT:	This element specifies user- and/or application-defined information beyond the scope of other properties in the Property. See Comment element (N.7.3.1) for more information on this element.
PROPERTY:	Sub-property. This element specifies sub-Properties of the encompassing Property. A property that contains sub-properties cannot contain a value.
DICT_REF:	Dictionary reference. This element specifies a reference to a Dictionary (see N.6.2.9).

N.6.2.9 Dictionary Definition metadata

This element specifies the name of a dictionary. A Property may be defined using a specific dictionary. The advantage of this is that there is a single definition for each Property metadata, and that two different Property metadata annotations are not used to define the same thing.

To give an example, a dictionary may define the word "Vehicle" to be used to describe a car, vehicle, truck, automobile, etc. A second example is the use of the word "Date." Date may be used to specify the fruit of the palm "date" and not the definition of date as a day. This element may contain the sub-elements listed below.

```
<xsd:element name="DICTIONARY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="DICT_NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute name="DICT_ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.29 – Schema of the Dictionary Definition metadata

DICT_NAME:	Dictionary name. This element specifies the name of the dictionary.
COMMENT:	This element specifies user- and/or application-defined information beyond the scope of other properties in the Dictionary. See Comment element (N.7.3.1) for more information on this element.
DICT_ID:	Dictionary ID. This element specifies the unique identifier for the dictionary.

N.6.3 History metadata

The History element contains a summary of basic image editing operations that have already been applied to the image and previous version(s) of the image metadata. The History metadata is not designed to be used to reverse (undo) image editing operations. This element may contain the sub-elements listed below.

```
<xsd:element name="HISTORY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:PROCESSING_SUMMARY" minOccurs="0"/>
      <xsd:element ref="jp:IMAGE_PROCESSING_HINTS" minOccurs="0"/>
      <xsd:element ref="jp:METADATA"/>
    <xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.30 – Schema of the History metadata

PROCESSING_SUMMARY:	This element specifies a list of operations previously applied to an image during the course of its workflow. The syntax of this element is specified in N.6.3.1.
IMAGE_PROCESSING_HINTS:	This element specifies a list of the operations previously performed when editing an image. The syntax of this element is specified in N.6.3.2.
METADATA:	Previous metadata. This element specifies a previous version of the metadata that may include metadata about portions of an image that was deleted (e.g., cropped). The syntax of this element is specified in N.6.3.3.

N.6.3.1 Processing Summary metadata

This element specifies a list of the operations performed over the life of the image, listing the operations performed and not the ordering or the number of times each operation is performed.

The processing summary defined below should be considered potential and in all likelihood partial information. That is because the presence of a particular hint, such as "Image Cropped," indicates that the image has been cropped. However, absence of a "Image Cropped" hint is no assurance that the image has never been cropped. This element may contain the sub-elements listed below.

```
<xsd:element name="PROCESSING_SUMMARY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IMG_CREATED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_CROPPED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_TRANSFORMED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_GTC_ADJ" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_STC_ADJ" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_SPATIAL_ADJ" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_EXT_EDITED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_RETOUCHED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_COMPOSITED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_METADATA" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.31 – Schema of the Processing Summary metadata

IMG_CREATED: Digital image created. The presence of this element indicates that the image was created by a metadata-aware application or process. Where a number of operations are performed in the creation of an image (such as removing borders), then these operations should be summarized using Digital Image Created operation and not listed independently. This element is especially useful to show truncation of image metadata. Where this element is not present, the full history of the metadata is known to be incomplete. Presence of this element does not show that the metadata history is complete though.

IMG_CROPPED: Image cropped. The presence of this element indicates that an image editing application, program, or system has cropped the image.

IMG_TRANSFORMED: Image Transformed. The presence of this element indicates that an image has been transformed.

IMG_GTC_ADJ: Global Tone/Colour Adjustment. The presence of this element indicates that a contrast or density adjustment has been applied to the image, or that the image colouring has been adjusted.

IMG_STC_ADJ: Selective Tone/Colour Adjustment. The presence of this element indicates that a contrast or density adjustment has been applied to a selected region of the image.

IMG_SPATIAL_ADJ: Global Spatial Adjustment. The presence of this element indicates that the image has been sharpened, or compressed, or blurred, or re-sampled.

IMG_EXT_EDITED: Pixels Extensively Edited. The presence of this element indicates the image has been edited extensively – enough to change the captured scene content.

IMG_RETOUCHED: Image Retouched. The presence of this element indicates the image pixels have been edited to remove scratches or red-eye, or other minor image blemishes.

IMG_COMPOSITED: Image Composited. The presence of this element indicates the image has been created by compositing an image with another image, or a background, graphic, or text.

IMG_METADATA: Metadata Adjusted. The presence of this element indicates the image metadata has been modified.

N.6.3.2 Image Processing Hints metadata

This element specifies a list of the operations performed when editing an image. They differ from the Processing Summary in that the hints list all the operations in order and the operations may be listed more than once (if the operation was used more than once). The Processing Summary metadata lists all the operations performed during the life of an image while the Image Processing Hints metadata stores the most current set of operations in greater detail. The complete list of operations (and their order) can be generated by combining all Image Processing Hints metadata within a Metadata History tree.

The Image Processing Hints element contains the same elements as the Processing Summary metadata. See Processing Summary (N.6.3.1) for the definition of each element. Each sub-element may appear more than once within each field and each element may contain a textual description of the operation. The Image Processing Hints metadata defined below should be considered potentially partial information. That is because the presence of a particular hint, such as "Image Cropped," indicates that the image has been cropped and other metadata may have been omitted at the same time. However, absence of an "Image Cropped" hint is no assurance that the image has never been cropped.

```
<xsd:element name="IMAGE_PROCESSING_HINTS">
  <xsd:complexType>
    <xsd:sequence>
    <xsd:element name="MODIFIER" type="jp:tProductDetails"minOccurs="0"/>
      <xsd:choice minOccurs="0" maxOccurs="unbounded">
        <xsd:element name="IMG_CREATED" type="jp:tLangString"/>
        <xsd:element name="IMG_CROPPED" type="jp:tLangString"/>
        <xsd:element name="IMG_TRANSFORMED" type="jp:tLangString"/>
        <xsd:element name="IMG_GTC_ADJ" type="jp:tLangString"/>
        <xsd:element name="IMG_STC_ADJ" type="jp:tLangString"/>
        <xsd:element name="IMG_SPATIAL_ADJ" type="jp:tLangString"/>
        <xsd:element name="IMG_EXT_EDITED" type="jp:tLangString"/>
        <xsd:element name="IMG_RETOUCHED" type="jp:tLangString"/>
        <xsd:element name="IMG_COMPOSITED" type="jp:tLangString"/>
        <xsd:element name="IMG_METADATA" type="jp:tLangString"/>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.32 – Schema of the Image Processing Hints metadata

MODIFIER: This element specifies the application (most probably software), that performed the operations listed in Processing Summary (N.6.3.1). See Product Details type (N.7.1.21) for the format of this element.

N.6.3.3 Previous metadata

This element contains a previous version of the metadata (including previous History metadata). The format of this element is defined along with the History metadata (Figure N.30).

Each time a new image is created as a result of editing an image or combining several images, some of the metadata from the previous image(s) may be moved to or referenced by the image history metadata. The contributing image(s) Image Creation, Content Description, History and IPR metadata may be recorded in a Previous metadata element. Careful consideration shall be made with regards to this previous metadata, particularly previous IPR metadata.

```
<xsd:element name="METADATA">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:BASIC_IMAGE_PARAM" minOccurs="0"/>
      <xsd:element ref="jp:IMAGE_CREATION" minOccurs="0"/>
      <xsd:element ref="jp:CONTENT_DESCRIPTION" minOccurs="0"/>
      <xsd:element ref="jp:HISTORY" minOccurs="0"/>
      <xsd:element ref="jp:IPR" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.33 – Schema of the Previous metadata

BASIC_IMAGE_PARAM: This element specifies references to previous versions of the image. The syntax of this element is specified in N.6.3.4.

IMAGE_CREATION: This element specifies the image creation information. The syntax of this element is specified in N.6.1.

CONTENT_DESCRIPTION: This element specifies the content description information. The syntax of this element is specified in N.6.2.

HISTORY: This element specifies previous history metadata. The syntax of this element is specified in N.6.3.

IPR: This element specifies image intellectual property. The syntax of this element is specified in N.6.4.

N.6.3.4 Image Referencing metadata

This element specifies information for referencing previous versions of the image. This element may contain the sub-elements listed below.

```
<xsd:element name="BASIC_IMAGE_PARAM">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="BASIC_IMAGE_INFO" minOccurs="0"/>
        <xsd:complexType>
          </xsd:sequence>
            <xsd:element name="FILE_FORMAT " minOccurs="0"/>
              <xsd:complexType>
                </xsd:sequence>
                  <xsd:element name="FILE_NAME" type="xsd:anyURI" minOccurs="0"/>
                  <xsd:element name="FORMAT_TYPE" type="xsd:string" minOccurs="0"/>
                  <xsd:element name="NIME_TYPE" type="xsd:string" minOccurs="0"/>
                  <xsd:element name="VERSION" type="xsd:string" minOccurs="0"/>
                </xsd:sequence>
              <xsd:complexType>
            </xsd:element>
            <xsd:element ref="jp:IMAGE_ID" minOccurs="0"/
          </xsd:sequence>
          <xsd:attribute ref="jp:TIMESTAMP"/>
          <xsd:attribute ref="xml:lang"/>
        <xsd:complexType>
      </xsd:element>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  <xsd:complexType>
</xsd:element>
```

Figure N.34 – Schema of the Image Reference metadata

FILE_NAME: This field specifies the name of an image file.

FORMAT_TYPE: File Format Type. This field specifies the file format of the image.

MIME_TYPE: This field specifies the Internet media type of the image file.

VERSION: This field specifies the version of the file format.

IMAGE_ID: This element specifies the image identifier. The syntax of this element is specified in N.6.5.

N.6.4 Intellectual Property Rights metadata

This element specifies Intellectual Property Rights (IPR) related information associated with the image such as moral rights, copyrights as well as exploitation information.

Moral rights are those rights attached to the creation process; therefore, moral rights persistently pertain to the author or creator of the art work, whereas copyrights can be repeatedly transferred to different owners, under exploitation conditions which are also part of the IPR and exploitation metadata. Additional information such as conditions of use, names, content description, dates, as well as IPR-related administrative tasks, identification (e.g., a unique inventory number) and contact point for exploitation are also considered important metadata.

Use and interpretation of this information is beyond the scope of this Recommendation | International Standard. Nothing in this Recommendation | International Standard should be taken to imply or to waive legal obligations or restrictions that may apply within any particular jurisdiction.

NOTE – Implementors should take into account the World Intellectual Property Organization (WIPO) documents listed in the References and other WIPO publications, if appropriate.

This element may contain the sub-elements listed below.

```
<xsd:element name="IPR">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:IPR_NAMES" minOccurs="0"/>
      <xsd:element ref="jp:IPR_DESCRIPTION" minOccurs="0"/>
      <xsd:element ref="jp:IPR_DATES" minOccurs="0"/>
      <xsd:element ref="jp:IPR_EXPLOITATION" minOccurs="0"/>
      <xsd:element ref="jp:IPR_IDENTIFICATION" minOccurs="0"/>
      <xsd:element ref="jp:IPR_CONTACT_POINT" minOccurs="0"/>
      <xsd:element name="IPR_HISTORY" minOccurs="0">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element ref="jp:IPR" minOccurs="0" maxOccurs="unbounded"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.35 – Schema of the Intellectual Property Rights metadata

IPR_NAMES: This element specifies names related to the represented image. The syntax of this element is specified in N.6.4.1.

IPR_DESCRIPTION: This element specifies the description of the content such as the title and caption. The syntax of this element is specified in N.6.4.2.

IPR_DATES: This element specifies the IPR-related date information. The syntax of this element is specified in N.6.4.3.

IPR_EXPLOITATION: This element specifies exploitation information such as type of protection, use restriction and obligations to exploit an image. The syntax of this element is specified in N.6.4.4.

IPR_IDENTIFICATION: This element specifies an identifier of an image that is a link to a place where additional information is kept. The syntax of this element is specified in N.6.4.6.

IPR_CONTACT_POINT: This element specifies the contact point of the right holder. The syntax of this element is specified in N.6.4.9.

IPR_HISTORY: This element contains previous IPR metadata. The content is specified in N.6.4.10.

N.6.4.1 IPR Names metadata

This element specifies names related to the represented image. These names include different categories, such as the creator, photographer, and producer, all who claim rights. People appearing within the image amy also be named, as there are restrictions on publishing the image of a person who has not consented to publication that varies from country to country. "Who," "what," and "where" (i.e., the subject of the image) can also be names in the title of the image.

A name may be either a Person, an Organization, or a reference to a name or a person. See Person type (N.7.1.13) and Organization type (N.7.1.14), respectively for the format of this element. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_NAMES">
  <xsd:complexType>
    <xsd:choice maxOccurs="unbounded">
      <xsd:element ref="jp:IPR_PERSON"/>
      <xsd:element ref="jp:IPR_ORG"/>
      <xsd:element ref="jp:IPR_NAME_REF"/>
    </xsd:choice>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<xsd:element name="IPR_PERSON">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tPerson">
        <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>

<xsd:element name="IPR_ORG">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tOrganization">
        <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>

<xsd:element name="IPR_NAME_REF">
  <xsd:complexType>
    <xsd:simpleContent>
      <xsd:extension base="xsd:string">
        <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
</xsd:element>
```

Figure N.36 – Schema of the IPR Names metadata

IPR_PERSON: Person. This element specifies the person description. See Person type (N.7.1.13) for the format of this element.

IPR_ORG: Organization. This element specifies the organization description. See Organization type (N.7.1.14) for the format of this element.

IPR_NAME_REF: Name reference. This element specifies a reference to a person or organization within the IPR metadata.

DESCRIPTION: This element is the description of the name. Table N.14 lists suggested values for this element which have the following meaning.

Table N.14 – Name description values

Value	Meaning
Original Work Author	This value specifies that the element is the name of the author who created the original work that is represented in the image (e.g., painter sculptor, architect, etc.), when the image is not a creation itself. By contrast, a photograph of a sunset will be considered as a creation of the photographer. An original work author may be "anonymous."
Image Creator	This value specifies that the element is the name of the image creator. The image creator may be, for example, the photographer who captured the original picture on film, the illustrator or graphic artist who conducted the image-creation process, etc.
Right Holder	This value specifies that the element is the name of the intellectual property right holder of the image. The right holder may be the author of the image, a stock photo agency, or vendor. He is the one to sell the license to anyone willing to exploit the image, such as a publisher who will also sell the result or an end user in a pay-per-view process. The right holder has acquired the rights from the creator or previous right holder in a transaction which usually has been registered officially.
Represented Individuals	This value specifies that the element is the name of an individual shown in the image. This may be used as a description of the image or because privacy rights may require that individuals depicted grant consent to publish their image. In such an example, this descriptive element may result in restriction of use for the image, as well as describing the image contents.

N.6.4.2 IPR Description metadata

This element specifies the description of the content. It may be desirable to have a complementary explanation about the content of the image in order to exploit the content. For instance, a technical description of the content may help users in understanding and, therefore, valuing the content of an image (e.g., circumstances under which the image was taken). The format is vendor specific. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_DESCRIPTION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_TITLE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_LEGEND" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_CAPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="COPYRIGHT" type="jp:tLangString" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.37 – Schema of the IPR Description metadata

IPR_TITLE: Title of image. This element specifies the title of the image. It is a string that may be used, for instance, as a caption when printing. When the author creates the title, he may add meaning to the image. However, titles are not necessarily significant of IPR. This is determined on a case-by-case basis.

IPR_LEGEND: Legend. This element specifies the legend, a caption added to the picture, e.g., at the back of a photograph, written by the photographer to later classify the photos. It is generally a more detailed or technical description of what appears in the image. This element may answer the question, "why?" An example is saying, "image taken at dawn to test a 135 mm. zoom on stand."

IPR_CAPTION: Caption. This element specifies the caption of the image. This element addresses the text which has been added as complementary information to assist in understanding the image's content (e.g., second draft by Durer for a study on a Biblical scene). The caption often has a tutorial motivation.

COPYRIGHT: Copyright. This element specifies the copyright notice of the image. Usually this element defines the right holder who wants to be identified, saying e.g., "copyright agency XYZ." This is an indication that the property of the image is well defined and that the contact point is the designated agency.

N.6.4.3 IPR Dates metadata

This element specifies the IPR-related date information. There are a variety of valid DateTime formats. For example, a date may be an exact year, possibly with month and day, sometimes with hour, minute, second and thousandth (i.e., ISO timestamp, which is always GMT time). However, date may also be less delimiting. For example, the date may be "first half of the fifteenth century," "late middle-age," "early Roman," etc.

Professional applications may prefer an exact date, whereas specifying a year ± 5 years may satisfy users of early century photographs.

This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_DATES">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_DATE" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:complexContent>
            <xsd:extension base="jp:tDateTime">
              <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
            </xsd:extension>
          </xsd:complexContent>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.38 – Schema of the IPR Dates metadata

IPR_DATE: The date element contains a date of arbitrary precision. See DateTime type (N.7.1.8) for the format of this element. The comment element defined in the DataTime type may be used for describing more information on the element.

DESCRIPTION: This element is the description of the date. The precision of IPR Dates may vary in accuracy depending on the age of the operation or item and other information known at the time of the metadata generation. Table N.15 lists suggested values for this element which have the following meaning.

Table N.15 – Date description values

Value	Meaning
Original Work Creation	This value specifies that the element is the date that the original work was created. All types of dates may appear here, as stated above.
Picture Taken	This value specifies that the element is the date that the picture was taken. Some digital cameras insert this information automatically.
Scanned	This value specifies that the element is the date that the image was scanned.
Processed	This value specifies that the element is the date that the image was processed.
Modified	This value specifies that the element is the date when any kind of modification was made to the original work. This element will store the most recent modification date. Although it is valid to have more than one modification date in this section, it would be more common that the entire IPR is updated during the modification, and the previous modifications moved to the IPR history. The processing tool may generate this date automatically.
Last Modified	This value specifies the last date the image was modified. This date should be easily found, because there may be either an automatic process putting this element and replacing the previous "last modification" as a "history element" or a manual process where the operator has to do the same operation by hand.

N.6.4.4 IPR Exploitation metadata

This element specifies metadata to identify IPR protection mechanisms, specific restrictions imposed by the right holder or obligations resulting from the use of the image, and the IPR management system in use for this IPR metadata. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_EXPLOITATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_PROTECTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_USE_RESTRICTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_OBLIGATION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:IPR_MGMT_SYS" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.39 – Schema of the IPR Exploitation metadata

IPR_PROTECTION: This element either indicates that there is a watermark, that the image is registered, or that the image is protected by some other means. A value of zero specifies that the image is not protected and contains no watermark. Values between 1 and 255 are reserved for JPEG Utilities Registration Authority (JURA) use. Other values may exist. If this element is not present, then the watermark content (or its presence) is undefined.

IPR_USE_RESTRICTION: This element specifies the use restrictions of an image. Use restrictions may apply to an image that is not allowed outside the factory for industrial applications, or for which exclusive rights of copy have been delegated to a unique agency, or for which prior authorization of represented people is mandatory before publishing. Other restrictions may exist.

IPR_OBLIGATION: This element specifies the obligations of exploiting an image. Obligation may concern any mandatory condition for exploiting the content of a file. For example, the copyright information may be required to be written on the side of any printout for photographs; other obligations may concern the need to get allowance from persons represented on a picture if the picture is published. Obligations may vary with time. For example, it may be forbidden to publish a photograph before a given date, etc.

IPR_MGMT_SYS: IPR management system. This element specifies what management system is used. The syntax of this element is specified in N.6.4.5.

N.6.4.5 IPR Management System metadata

IPR Management Systems such as IPMP (Intellectual Property Management & Protection) or ECMS (Electronic Copyright Management System) use these elements to determine where information is kept regarding the management system. An example use of these elements is to track the usage of an image. During transfer, an agency determines the owner of the image from the management systems elements. It already knows the consumer, and uses this information to charge the user and credit the owner the amount as determined by the management system. This information is commonly stored on a server describing the IPR of the image, and depending upon whether IPR licensing is mandatory or recommended, there shall be a link to where all information about it is kept. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_MGMT_SYS">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_MGMT_TYPE" type="xsd:string" minOccurs="0"/>
      <xsd:element name="IPR_MGMT_SYS_ID" type="xsd:string" minOccurs="0"/>
      <xsd:element name="IPR_MGMT_SYS_LOCATION" type="xsd:anyURI" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.40 – Schema of the IPR Management Systems metadata

IPR_MGMT_TYPE: The type of IPR Management System being used.

IPR_MGMT_ID: Information of an ID.

IPR_MGMT_LOCATION: Information of the location. E.g., URL.

N.6.4.6 IPR Identification metadata

This element specifies a link to a place (e.g., secured database or other storage place) where critical information is kept. The identifier identifies a content; therefore, if an image is cropped, modified or made into a new image, then the image shall be registered again, and a new identifier shall be acquired, because there are now two objects instead of merely one. However, the parent image shall appear in the metadata set of the child. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_IDENTIFICATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:IPR_IDENTIFIER" minOccurs="0"/>
      <xsd:element ref="jp:LICENCE_PLATE" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.41 – Schema of the IPR Identification metadata

IPR_IDENTIFIER: Generic IPR identifier. This element contains a generic purpose IPR identifier. The syntax of this element is specified in N.6.4.7.

LICENCE_PLATE: This element specifies License plate of the content. The syntax of this element is specified in N.6.4.8.

N.6.4.7 Generic IPR Identifier metadata

This element specifies a generic IPR identifier. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_IDENTIFIER">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_ID_MODE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_ID" type="jp:tLangString" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.42 – Schema of the IPR Identifier metadata

IPR_ID_MODE: This element specifies the identification mode.

IPR_ID: This element specifies the identification. The Mode element describes the content of this element.

N.6.4.8 License Plate metadata

This element specifies the license plate of the original image, defined in ISO/IEC 10918-3. The combination of the elements in the license plate contains a globally unique identifying sequence of numbers. This element may contain the sub-elements listed below.

```
<xsd:element name="LICENCE_PLATE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="LP_COUNTRY" type="xsd:string" minOccurs="0"/>
      <xsd:element name="LP_REG_AUT" type="xsd:string" minOccurs="0"/>
      <xsd:element name="LP_REG_NUM" type="xsd:string" minOccurs="0"/>
      <xsd:element name="DELIVERY_DATE" type="xsd:dateTime" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.43 – Schema of the License Plate metadata

LP_COUNTRY: This element specifies the country of registration. The element contains the country code (3-digit number) for the License Plate as defined in ISO 3166-1.

LP_REG_AUT: This element specifies the registration authority number for the License Plate.

LP_REG_NUM: This element specifies the registration number for the License Plate.

LP_DELIVERY_DATE: This element specifies when the License Plate was delivered to the registrant by the Registration Authority.

N.6.4.9 IPR Contact Point metadata

This element specifies the contact point of the right holder. It includes a way to contact the current right holder in order to acquire the rights under the form of a licence. Such information may be a postal address, URL or any phone or fax number that is a non-ambiguous link to the right holder.

A contact point may be either a Person, an Organization, or a reference to a name or a person. This element may contain the sub-elements listed below.

```
<xsd:element name="IPR_CONTACT_POINT">
  <xsd:complexType>
    <xsd:choice>
      <xsd:element ref="jp:IPR_PERSON"/>
      <xsd:element ref="jp:IPR_ORG"/>
      <xsd:element ref="jp:IPR_NAME_REF"/>
    </xsd:choice>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.44 – Schema of the IPR Contact Point metadata

IPR_PERSON: This element specifies the person description. The syntax of this element is specified in N.6.4.1.

IPR_ORG: Organization. This element specifies the organization description. The syntax of this element is specified in IPR Names (see N.6.4.1).

IPR_NAME_REF: Name Reference. This element specifies a reference to a person or organization within the IPR metadata. This element is a link to one of the Person or Organization elements within the IPR Names metadata (see N.6.4.1).

DESCRIPTION: This element is the description of the contact point that is an additional value for the person or organization in Table N.14. The value listed in Table N.16 is added and has the following meaning.

Table N.16 – Additional name description values

Value	Meaning
Collection	This value is a link to a collector, museum, group, institution, etc. The contact point may be a link to a name specified in IPR Names.

N.6.4.10 IPR History metadata

This element specifies previous IPR metadata. The format of this element is defined along with the Intellectual Property Rights metadata (Figure N.35).

Each time the IPR information of an image is changed, some of the IPR metadata defined through N.6.4.1 and N.6.4.9 may be moved to this IPR History metadata element. The IPR History metadata stores all IPR metadata-related modifications.

N.6.5 Image Identifier metadata

This element specifies an image identifier that uniquely identifies the image. The format may be globally unique (e.g., UUID), vendor or application dependent. This element may contain the sub-elements listed below.

```
<xsd:element name="IMAGE_ID">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="UID" type="xsd:string" minOccurs="0"/>
      <xsd:element name="ID_TYPE" type="xsd:anyURI" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.45 – Schema of the Image Identifier metadata

UID:	Unique Identifier. This element specifies the unique identifier of an image. The ID_TYPE element specifies the format of the field.
ID_TYPE:	Unique Identifier Type. This element specifies the type of the UID element as a URI.

N.7 Fundamental type and element definitions

XML Schema Part 2 defines many built-in and derived datatypes, however, they are not sufficient to specify various metadata elements defined in this Recommendation | International Standard. This clause defines the common types and elements that are referenced within other metadata boxes. The types and elements defined are intended only to be used or referred to in other schemas, and have no intrinsic significance.

N.7.1 Defined types

N.7.1.1 Non-negative double type

This type is used for double numbers greater than or equal to zero.

```
<xsd:simpleType name="tNonNegativeDouble">
  <xsd:restriction base="xsd:double">
    <xsd:minInclusive value="0"/>
  </xsd:restriction>
</xsd:simpleType>
```

Figure N.46 – Schema of the non-negative double type

N.7.1.2 Rational type

This type is used to define rational numbers. It contains an enumerator and denominator in a single string.

```
<xsd:simpleType name="tRational">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="(\-|\+)?[0-9]+/[0-9]+"/>
  </xsd:restriction>
</xsd:simpleType>
```

Figure N.47 – Schema of the rational type

N.7.1.3 String including language attribute type

This type is used to when an element requires a string and a language attribute definition. The content of this element is intended to store human readable data.

```
<xsd:complexType name="tLangString">
  <xsd:simpleContent>
    <xsd:extension base="xsd:string">
      <xsd:attribute ref="xml:lang"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
```

Figure N.48 – Schema of the string including language attribute type

N.7.1.4 Degree type

This type specifies a direction in degrees and fractions of degrees. The exact meaning of the values is dependant on usage.

```
<xsd:simpleType name="tDegree">
  <xsd:restriction base="xsd:double">
    <xsd:minExclusive value="-180"/>
    <xsd:maxInclusive value="180"/>
  </xsd:restriction>
</xsd:simpleType>
```

Figure N.49 – Schema of the degree type

N.7.1.5 Half degree type

This type specifies a direction in degrees and fractions of degrees. The exact meaning of the values is dependant on usage. This type defines a smaller range than Degree Type (see N.7.1.4).

```
<xsd:simpleType name="tHalfDegree">
 <xsd:restriction base="xsd:double">
  <xsd:minExclusive value="-90"/>
  <xsd:maxInclusive value="90"/>
 </xsd:restriction>
</xsd:simpleType>
```

Figure N.50 – Schema of the half degree type

N.7.1.6 Double size type

This type specifies a size in double coordinates.

```
<xsd:complexType name="tDoubleSize">
  <xsd:sequence>
    <xsd:element name="WIDTH" type="jp:tNonNegativeDouble"/>
    <xsd:element name="HEIGHT" type="jp:tNonNegativeDouble"/>
  </xsd:sequence>
</xsd:complexType>
```

Figure N.51 – Schema of the double size type

N.7.1.7 Integer size type

This type specifies a size in integer coordinates (e.g., pixels).

```
<xsd:complexType name="tIntSize">
  <xsd:sequence>
    <xsd:element name="WIDTH" type="xsd:positiveInteger"/>
    <xsd:element name="HEIGHT" type="xsd:positiveInteger"/>
  </xsd:sequence>
</xsd:complexType>
```

Figure N.52 – Schema of the integer size type

N.7.1.8 DateTime type

This type specifies a partial or exact date. A date can include either a specific day (e.g., 26 January 2000), or a more broad definition such as "Winter." A date may or may not include a time. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tDateTime">
  <xsd:sequence>
    <xsd:choice minOccurs="0">
      <xsd:element name="EXACT" type="xsd:dateTime"/>
      <xsd:element name="DATE" type="xsd:date"/>
      <xsd:sequence>
        <xsd:element name="MONTH" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:positiveInteger">
              <xsd:minInclusive value="1"/>
              <xsd:maxInclusive value="12"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="YEAR" type="xsd:gYear" minOccurs="0"/>
        <xsd:element name="CENTURY" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:integer"/>
          </xsd:simpleType>
        </xsd:element>
      </xsd:sequence>
    </xsd:choice>
    <xsd:element name="WEEK_DAY" type="xsd:string" minOccurs="0"/>
    <xsd:element name="SEASON" type="xsd:string" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.53 – Schema of the DateTime type

EXACT:	This element contains an exact date and a time.
DATE:	This element contains a date (excluding the time of day).
MONTH:	This element contains a month of the year. An integer value is used rather than a string to be consistent with the other elements contained in the DateTime type. The value for January shall correspond to 1 and December to 12.
YEAR:	This element contains a calendar year. Positive values used for AD and negative values for BC. The year zero is not valid.
CENTURY:	This element contains the century that an event occurred. For example, the twentieth century is stored as "19." The century zero is not valid.
WEEK_DAY:	This element is a text description of the day. Examples include, "Monday" and "Friday."
SEASON:	This element is a text description of a season. Examples include, "Spring," "Summer," "Autumn," and "Winter."
COMMENT:	See Comment element (N.7.3.1) for more information on this element. Examples include "Easter Sunday," "Morning," "Just after lunch."

N.7.1.9 Address type

This type specifies the address of an object or location. For example, it may be used to describe the address an image was captured, or the address of the intellectual property owner of an image. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tAddress">
  <xsd:sequence>
    <xsd:element name="ADDR_NAME" type="jp:tLangString" minOccurs="0"/>
    <xsd:element name="ADDR_COMP" minOccurs="0" maxOccurs="unbounded">
      <xsd:complexType>
        <xsd:simpleContent>
          <xsd:extension base="jp:tLangString">
            <xsd:attribute name="TYPE" type="xsd:string"/>
          </xsd:extension>
        </xsd:simpleContent>
      </xsd:complexType>
    </xsd:element>
    <xsd:choice minOccurs="0">
      <xsd:element name="ZIPCODE" type="xsd:string"/>
      <xsd:element name="POSTCODE" type="xsd:string"/>
    </xsd:choice>
    <xsd:element name="COUNTRY" type="jp:tLangString" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="TYPE" type="xsd:string"/>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.54 – Schema of the Address type

ADDR_NAME: Address name. It is a descriptive element for the address.

ADDR_COMP: Address component. Multiple elements are used to specify the complete address. The order of the address elements specifies the full address. A full address shall be generated by concatenating the separate address elements. For example, if the type is a "state", this element contains the name of the state. Where the type is a "street," this element contains the name of the street. ISO 3166-2 lists country subdivision codes. These codes may be used in this element, when the element is being used to specify a country subdivision.

TYPE: This is the name of this part of the address. Examples include "street" or "state." ISO 3166-2 specifies country subdivisions and the types of these divisions. These subdivision types may be used to specify the address type. Suggested values and their corresponding meanings are listed in Table N.17. Multiple values shall not be specified within a single element.

Table N.17 – Address component type values

Value	Meaning
Unit	The unit number of the address to identify a house or a house name relative to a street.
Room	The room number within a building or an apartment.
Street	The street address in a postal address. Examples are street name, avenue and house number.
Postbox	The post office box number
City	The locality of a.geographic area.
State	The name of a geographical subdivision. Other terms such as "Province", "Prefecture", "County" may be used instead.

ZIPCODE/POSTCODE: This element specifies the postcode (or zip code) of the address. This element is not limited in length. The element has the title "Postcode" or "Zip code." An address cannot contain both a postcode and a zip code.

COUNTRY: This element specifies the country of the address. The element can either contain the country code as defined in ISO 3166-1 or a string identifying the country. The ISO 3166-1 country code is preferred.

TYPE: This element specifies the type of the whole address. The address type would include whether the address is a home address or a business address. Suggested type values are listed in Table N.18. Multiple type values may be specified delimited with a comma (",").

Table N.18 – Address type values

Value	Meaning
Domestic	The domestic delivery address.
International	The international delivery address.
Postal	The postal delivery address.
Home	The delivery address for a residence.
Work	The delivery address for a place of work.

N.7.1.10 Phone number type

This type specifies a phone number. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tPhone">
  <xsd:sequence>
    <xsd:element name="COUNTRY_CODE" type="xsd:string" minOccurs="0"/>
    <xsd:element name="AREA" type="xsd:string" minOccurs="0"/>
    <xsd:element name="LOCAL" type="xsd:string" minOccurs="0"/>
    <xsd:element name="EXTENSION" type="xsd:string" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="TYPE" type="xsd:string"/>
  <xsd:attribute ref="jp:TIMESTAMP"/>
</xsd:complexType>
```

Figure N.55 – Schema of the Phone number type

COUNTRY_CODE: This element contains the country code part of a phone number. This phone code does not include any prefix such as "00" used to dial international numbers, but instead just the international country code. This element also does not include a leading "+."

AREA: This element contains the local area code part of a phone number. This area code does not include leading zeros (or other digits) used to dial an interstate number from within a country. It appears as it would be appended directly to a country code.

LOCAL: This element contains the local phone number.

EXTENSION: This element contains the extension part of the phone number.

TYPE: This element defines the type of the phone number. The phone number type would include whether the phone number is a home phone number or a business phone number. Suggested type values are listed in Table N.19. Multiple type values may be specified delimited with a comma (",").

Table N.19 – Phone number type values

Value	Meaning
Home	Phone number associated with a residence.
Message	Phone number that has voice message support.
Work	Phone number associated with a place of work.
Voice	Phone number indicating a voice telephone.
Cell	Cellular telephone number.
Video	Video conference telephone number.
BBS	Bulletin board system telephone number.
Modem	A modem connected telephone number.
Car	A car-phone telephone number.
ISDN	ISDN service telephone number.
PCS	Personal communication service telephone number.

N.7.1.11 Email address type

This type specifies an email address. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tEmail">
  <xsd:simpleContent>
    <xsd:extension base="jp:tLangString">
      <xsd:attribute name="TYPE" type="xsd:string"/>
      <xsd:attribute ref="jp:TIMESTAMP"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
```

Figure N.56 – Schema of the Email address type

TYPE: This element contains the type of the email address.

N.7.1.12 Web address type

This type specifies a web page address. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tWeb">
  <xsd:simpleContent>
    <xsd:extension base="jp:tLangString">
      <xsd:attribute name="TYPE" type="xsd:string"/>
      <xsd:attribute ref="jp:TIMESTAMP"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
```

Figure N.57 – Schema of the Web address type

TYPE: This element contains the type of the web page.

N.7.1.13 Person type

This type specifies a person. The sub-elements are compatible with the vCard description defined in RFC 2426. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tPerson">
  <xsd:sequence>
    <xsd:element name="NAME_TITLE" type="jp:tLangString" minOccurs="0"/>
    <xsd:element name="PERSON_NAME" minOccurs="0" maxOccurs="unbounded">
      <xsd:complexType>
        <xsd:sequence>
          <xsd:element name="NAME_COMP" maxOccurs="unbounded">
            <xsd:complexType>
              <xsd:simpleContent>
                <xsd:extension base="xsd:string">
                  <xsd:attribute name="TYPE" use="optional" default="Given">
                    <xsd:simpleType>
                      <xsd:restriction base="xsd:string">
                        <xsd:enumeration value="Prefix"/>
                        <xsd:enumeration value="Given"/>
                        <xsd:enumeration value="Family"/>
                        <xsd:enumeration value="Suffix"/>
                        <xsd:enumeration value="Maiden"/>
                      </xsd:restriction>
                    </xsd:simpleType>
                  </xsd:attribute>
                </xsd:extension>
              </xsd:simpleContent>
            </xsd:complexType>
          </xsd:element>
        </xsd:sequence>
        <xsd:attribute ref="jp:TIMESTAMP"/>
        <xsd:attribute ref="xml:lang"/>
      </xsd:complexType>
    </xsd:element>
    <xsd:element name="NICK_NAME" type="xsd:string" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="JOB_TITLE" type="xsd:string" minOccurs="0"/>
    <xsd:choice minOccurs="0">
      <xsd:element name="PERSON_ORG" type="jp:tOrganization"/>
      <xsd:element name="ORG_REF" type="xsd:string"/>
    </xsd:choice>
    <xsd:element name="ADDRESS" type="jp:tAddress" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="PHONE" type="jp:tPhone" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="EMAIL" type="jp:tEmail" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="WEB" type="jp:tWeb" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="BIRTH_DATE" type="xsd:date" minOccurs="0"/>
    <xsd:element name="AGE" type="xsd:duration" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="ID" type="xsd:string"/>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.58 – Schema of the Person type

NAME_TITLE: The element contains the person's title.

PERSON_NAME: This element specifies a framework to describe a person's name. A person's name is composed of multiple name components (e.g., given name(s) and family name(s)). The order of the name component elements specifies the full name of the person. For example, in languages where the family name is usually placed before the given name, then they would appear in this order in the file.

NAME_COMP: Name component. This element contains a single portion (word) of the name of a person. A name component element may contain a single initial rather than a complete word. To specify the full name of a person, multiple name component elements are used. This element contains a type as specified below.

TYPE: Name component type. This element defines the type of the Name Component element. This element would include whether the name component is a Suffix, Prefix, Given or Family name. Suggested values and their corresponding meanings are listed in Table N.20. Multiple values shall not be specified within a single type filed.

Table N.20 – Name component type values

Value	Meaning
Prefix	A personal title. (e.g., Dr., Sir)
Given	A name construct that is normally given to an individual by the parent or is chosen by the individual. This is the default value of the name component type.
Family	A name component that is normally inherited by their parent or assumed by marriage.
Suffix	A generation qualifier (e.g., Jr., III), decorations and awards. (e.g., Q.C., Ph. D)
Maiden	A name component of a woman's family name before getting married.

NICK_NAME: This element specifies a nick name of the person. E.g., "Jimmy."

JOB_TITLE: This element specifies the person's job title.

ORGANIZATION: This element specifies the organization for which a person is a member of. The organization element may be either contained within the person element, or referenced.

ORG_REF: Organization reference. A reference to the organization. This element is a link to one of the Organization elements within the metadata.

ADDRESS: This element specifies address information for the person. For example, it can contain a home address or a work address. It does not necessarily contain the address depicted within the image, but instead information about the person. See Address type (N.7.1.9) for the format of this element.

PHONE: Phone number. This element specifies phone number information for the person. See Phone number type (N.7.1.10) for the format of this element.

EMAIL: Email address. This element specifies an email address for a person. See Email address type (N.7.1.11) for the format of this element.

WEB: Web page. This element contains a web page for a person. See Web address type (N.7.1.12) for the format of this element.

BIRTH_DATE: Date of birth. This element specifies the birth date of the person. This element shall specify an exact date. For non-specific information the Comment element shall be used.

AGE: This element contains the age of a person.

COMMENT: This element specifies user- and/or application-defined information beyond the scope of other properties in the person type. See Comment element (N.7.3.1) for more information on this element.

ID: This element specifies the unique identifier for the person.

N.7.1.14 Organization type

This type specifies an organization. The sub-elements are compatible with the vCard description defined in RFC 2426. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tOrganization">
  <xsd:sequence>
    <xsd:element name="ORG_NAME" type="jp:tLangString" minOccurs="0"/>
    <xsd:element name="ADDRESS" type="jp:tAddress" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="PHONE" type="jp:tPhone" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="EMAIL" type="jp:tEmail" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="WEB" type="jp:tWeb" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="LOGO_FILE" type="xsd:anyURI" minOccurs="0"/>
    <xsd:element name="LOGO_FORMAT" type="xsd:string" minOccurs="0"/>
    <xsd:element name="MIME_TYPE" type="xsd:string" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="ID" type="xsd:string"/>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.59 – Schema of the Organization type

ORG_NAME: Organization name. This element specifies the name of the organization.

ADDRESS: This element specifies address information for the organization. It does not necessarily contain the address depicted within the image, but instead information about the organization. See Address type (N.7.1.9) for the format of this element.

PHONE: Phone number. This element specifies phone number information. See Phone number type (N.7.1.10) for the format of this element.

EMAIL: Email address. This element specifies an email address for an Organization. See Email address type (N.7.1.11) for the format of this element.

WEB: Web page. This element specifies a web page for an Organization. See Web address type (N.7.1.12) for the format of this element.

LOGO_FILE: This element specifies a reference to a logo file of the organization.

LOGO_FILE_FORMAT: This element specifies the name of the logo file format. For example, EPS, JP2 and TIFF.

MIME_TYPE: This element specifies the Internet media type of the logo file.

COMMENT: This element specifies user- and/or application-defined information beyond the scope of other properties in the organization type. See Comment element (N.7.3.1) for more information on this element.

ID: This element specifies the unique identifier for the organization.

N.7.1.15 Location type

This type specifies the physical location of an object or a scene. For example, it may be used to describe an object within an image, or the location of a camera at the time of capture. The Location is the physical location, whereas the Position is the position of an object relative to the image.

```
<xsd:complexType name="tLocation">
  <xsd:sequence>
    <xsd:element ref="jp:COORD_LOC" minOccurs="0"/>
    <xsd:element name="ADDRESS" type="jp:tAddress" minOccurs="0"/>
    <xsd:element ref="jp:GPS" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.60 – Schema of the Location type

COORD_LOC: Coordinate location. This element specifies the exact longitude, latitude and altitude of an object. The syntax of this element is specified in N.7.1.15.1.

ADDRESS: This element specifies the location of an object using an address. See Address type (N.7.1.9) for the format of this element.

GPS: Global Positioning System. This element specifies location information received from a GPS receiver. The syntax of this element is specified in N.7.1.15.2.

COMMENT: This element specifies the location of an object that cannot be described using the other location elements. For example, "Under the table." See Comment element (N.7.3.1) for the format of this element.

N.7.1.15.1 Coordinate location

This element specifies the terrestrial location (altitude/longitude/latitude) of an object. It may be used to describe the content of an image along with the location of a camera.

While the coordinate location may have come from a GPS (and a GPS block may or may not be present in the metadata), the values in the coordinate location may have come for some other means. For this reason, the location information is a more general system for storing the location than the GPS system. The location information and the raw GPS data are stored in different formats.

GPS is one of a number of methods that may be used to determine a location. If the GPS information is filled in, it is expected that the coordinate location is also specified. A reader shall only look in a single place to determine the coordinate location (this element).

The meridian through Greenwich (Great Britain) is defined with the value longitude *l* = 0. The longitude *l* of a point *P* on the surface is the angle between the planes through its meridian and the Greenwich meridian. The longitude is counted from Greenwich up to *l* = ± 180° in east(+) and west(–) directions.

The latitude *j* of a point *P* is the angle between a line normal to its parallel and the equatorial plane (*j* = 0). On a sphere this normal line will be the connecting line between its center and the point *P*. On the elliptical earth this line will only pass the center if *P* is situated at the equator. The latitude is counted from the equator up to *j* = ± 90° in north (+) and south (–) directions.

```
<xsd:element name="COORD_LOC">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="LONGITUDE" type="jp:tDegree" minOccurs="0"/>
      <xsd:element name="LATITUDE" type="jp:tHalfDegree" minOccurs="0"/>
      <xsd:element name="ALTITUDE" type="xsd:double" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
  </xsd:complexType>
</xsd:element>
```

Figure N.61 – Schema of the Coordinate location element

LONGITUDE:	This element specifies the longitude, represented in double degrees and fractions of degrees. E.g., "138,700," "–122,450."
LATITUDE:	This element specifies the latitude, represented in double degrees and fractions of degrees. E.g., "35,383," "37,767."
ALTITUDE:	This element would contain the distance in meters. Zero is sea level, positive is above, and negative is below.

N.7.1.15.2 Raw GPS Information

The information in these elements is expected to be imported from a GPS system and is compatible with NMEA-0138. For this reason, the elements are not consistent with other metadata elements. For example, a distance on the GPS elements may be stored in miles, while all other metadata distances are stored in meters. These elements are compatible with Exif version 2.1.

If information for latitude, longitude and altitude are present in the raw GPS information, the matching elements in the Coordinate location shall be filled in.

This element may contain the sub-elements listed below.

```
<xsd:element name="GPS">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="GPS_LAT_REF" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="N"/>
            <xsd:enumeration value="S"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_LATITUDE" minOccurs="0">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="D" type="xsd:nonNegativeInteger"/>
            <xsd:element name="M" type="xsd:nonNegativeInteger"/>
            <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="GPS_LONG_REF" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="E"/>
            <xsd:enumeration value="W"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_LONGITUDE" minOccurs="0">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="D" type="xsd:nonNegativeInteger"/>
            <xsd:element name="M" type="xsd:nonNegativeInteger"/>
            <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
      <xsd:element name="GPS_ALTITUDE" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="GPS_TIME" type="xsd:dateTime" minOccurs="0"/>
      <xsd:element name="GPS_SATELLITES" type="xsd:string" minOccurs="0"/>
      <xsd:element name="GPS_STATUS" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="A"/>
            <xsd:enumeration value="V"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_MEASURE_MODE" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:positiveInteger">
            <xsd:minExclusive value="2"/>
            <xsd:maxInclusive value="3"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_DOP" type="jp:tNonNegativeDouble" minOccurs="0"/>
```

Figure N.62 – Schema of the Raw GPS Information element

```
<xsd:element name="GPS_SPEED_REF" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="K"/>
      <xsd:enumeration value="N"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="GPS_SPEED" type="jp:tNonNegativeDouble" minOccurs="0"/>
<xsd:element name="GPS_TRACK_REF" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="T"/>
      <xsd:enumeration value="M"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="GPS_TRACK" type="jp:tNonNegativeDouble" minOccurs="0"/>
<xsd:element name="GPS_IMAGE_DIR_REF" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="T"/>
      <xsd:enumeration value="M"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="GPS_IMAGE_DIR" type="jp:tNonNegativeDouble" minOccurs="0"/>
<xsd:element name="GPS_MAP_DATUM" type="xsd:string" minOccurs="0"/>
<xsd:element name="GPS_DEST_LAT_REF" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="N"/>
      <xsd:enumeration value="S"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="GPS_DEST_LATITUDE" minOccurs="0">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="D" type="xsd:nonNegativeInteger"/>
      <xsd:element name="M" type="xsd:nonNegativeInteger"/>
      <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
<xsd:element name="GPS_DEST_LONG_REF" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="E"/>
      <xsd:enumeration value="W"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="GPS_DEST_LONGITUDE" minOccurs="0">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="D" type="xsd:nonNegativeInteger"/>
      <xsd:element name="M" type="xsd:nonNegativeInteger"/>
      <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
<xsd:element name="GPS_DEST_BEARING_REF" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="T"/>
      <xsd:enumeration value="M"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="GPS_DEST_BEARING" type="jp:tNonNegativeDouble" minOccurs="0"/>
```

Figure N.63 – Schema of the Raw GPS Information element *(continued)*

```
      <xsd:element name="GPS_DEST_DISTANCE_REF" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="K"/>
            <xsd:enumeration value="N"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_DEST_DISTANCE" type="jp:tNonNegativeDouble" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

Figure N.64 – Schema of the Raw GPS Information element *(concluded)*

GPS_LAT_REF: GPS Latitude Reference. This element specifies whether the GPS Latitude is North or South. Table N.21 lists legal values of this element.

Table N.21 – Latitude reference values

Value	Meaning
N	North Latitude
S	South Latitude

GPS_LATITUDE: GPS Latitude. This element contains the latitude of the GPS receiver. Table N.22 lists legal values of this element.

Table N.22 – Latitude values

Value	Meaning
D	The number of degrees of latitude.
M	The number of minutes of latitude.
S	The number of seconds of latitude.

GPS_LONG_REF: GPS Longitude Reference. This element specifies whether the GPS Longitude is East or West. Table N.23 lists legal values of this element.

Table N.23 – Longitude reference values

Value	Meaning
E	East longitude
W	West longitude

GPS_LONGITUDE: GPS Longitude. This element contains the longitude of the GPS receiver. Table N.24 lists legal values of this element.

Table N.24 – Longitude values

Value	Meaning
D	The number of degrees of longitude.
M	The number of minutes of longitude.
S	The number of seconds of longitude.

GPS_ALTITUDE: GPS Altitude. This element contains the altitude of the GPS receiver. The altitude reading is given in meters relative to sea level (geoid).

GPS_TIME: GPS Time. This element contains the time of the GPS location was determined. This element is in Greenwich Mean Time. This is not necessarily the camera capture time.

GPS_SATELLITES: GPS Satellites. This element contains information about the satellites used to determine the camera position. This element can be used to describe the number of satellites, their ID number, angle of elevation, azimuth, SNR and other information. The format is not specified.

GPS_STATUS: GPS Status. This element contains information on the GPS receiver at time of image capture. Table N.25 lists legal values of this element.

Table N.25 – GPS Status values

Value	Meaning
A	Measurement is in progress.
V	Measurement is interrupted.

GPS_MEASURE_MODE: GPS Measure Mode. This element contains information on the measurement mode used to determine the GPS location. Table N.26 lists legal values of this element.

Table N.26 – GPS Measure mode values

Value	Meaning
2	2 dimensional measurement.
3	3 dimensional measurement.

GPS_DOP: GPS Data Degree of Precision (DOP). This element contains a value indicating the GPS DOP. An HDOP (horizontal degree of precision) value is written during a two-dimensional measurement, and a PDOP (3D degree of precision) value is written during a three-dimensional measurement.

GPS_SPEED_REF: GPS Speed Reference. This element contains the units of measure for the GPS Speed element. Table N.27 lists legal values of this element.

Table N.27 – GPS Speed reference unit values

Value	Meaning
K	Kilometers per hour
N	Knots

GPS_SPEED: GPS Speed. This element contains a value indicating the speed of the GPS receiver. The value units are defined by the GPS Speed Reference.

GPS_TRACK_REF: GPS Track Reference. This element contains the reference for the GPS Track element. Table N.28 lists legal values of this element.

Table N.28 – Direction reference values

Value	Meaning
T	True north
M	Magnetic north

GPS_TRACK: GPS Track. This element contains the value in degrees indicating the direction of the GPS receiver movement. 0 indicates North and 90 indicate East.

GPS_IMAGE_DIR_REF: GPS Image Direction Reference. This element contains the reference for the GPS Image Direction element. Table N.28 lists legal values of this element.

GPS_IMAGE_DIR: GPS Image Direction. This element contains the value in degrees indicating the direction the camera is facing at the time of taking the picture. 0 indicates North and 90 indicate East.

GPS_MAP_DATUM: GPS Map Datum. This element specifies the geodetic survey data used by the GPS receiver. For example, if the survey data is restricted to Japan, the value of this tag is "TOKYO" or "WSG-84."

GPS_DEST_LAT_REF: GPS Destination Latitude Reference. This element specifies whether the GPS Destination Latitude is North or South. Table N.21 lists legal values of this element.

GPS_DEST_LATITUDE: GPS Destination Latitude. This element contains the destination latitude of the GPS receiver. Table N.22 lists legal values of this element.

GPS_DEST_LONG_REF: GPS Destination Longitude Reference. This element specifies whether the GPS Destination Longitude is East or West. Table N.23 lists legal values of this element.

GPS_DEST_LONGITUDE: GPS Destination Longitude. This element contains the destination longitude of the GPS receiver. Table N.24 lists legal values of this element.

GPS_DEST_BEARING_REF: GPS Destination Bearing Reference. This element contains the reference for the GPS Destination Bearing element. Table N.28 lists legal values of this element.

GPS_DEST_BEARING: GPS Destination Bearing. This element contains the value in degrees indicating the direction of the destination from the GPS receiver. 0 indicates North and 90 indicate East.

GPS_DEST_DISTANCE_REF: GPS Destination Distance Reference. This element contains the units of measure for the GPS Destination Distance element. Table N.29 lists legal values of this element.

Table N.29 – GPS Destination distance reference unit values

Value	Meaning
K	Kilometers per hour
N	Knots

GPS_DEST_DISTANCE: GPS Destination Distance. This element contains a value indicating the distance to the destination from the GPS receiver. The value units are defined by the GPS Destination Distance Reference.

N.7.1.16 Direction type

This type specifies a three-dimensional heading. While this type is primarily used to specify the direction a camera is facing, it may also be used to specify information about an object in a scientific photograph for example. When calculating the direction the camera is facing, first the yaw is applied, then the pitch, then the roll. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tDirection">
  <xsd:sequence>
    <xsd:element name="YAW" type="jp:tDegree" minOccurs="0"/>
    <xsd:element name="PITCH" type="jp:tHalfDegree" minOccurs="0"/>
    <xsd:element name="ROLL" type="jp:tDegree" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.65 – Schema of the Direction type

YAW: This element is the direction the capture device is facing. The element is measured in degrees. North is 0, East is 90, South 180 and West is –90.

PITCH: This element is a measure of the elevation angle of the capture device. This element is a Double value between –90 and +90, also measured in degrees. 0 facing horizontal. 90 is facing vertically straight upwards, and –90 vertically downwards.

ROLL: This element is a measure of the rotation angle of the capture device. This element is a Double value between –180 and 180, also measured in degrees. 0 facing horizontal. 90 where the device is rotated clockwise and the left of the device is facing upwards, and –90 where the device is rotated anti-clockwise. 180 is upside down.

COMMENT: This element specifies user- and/or application-defined information beyond the scope of other properties in the direction types. For example, "Upwards," "To the left." See Comment element (N.7.3.1) for more information on this element.

N.7.1.17 Position type

This type is used to specify the position of an object, within an image. The Position type can be one of the following:

- An x, y single point.
- A rectangular area (specified as an x, y, width and height).
- A set of splines that represent an area of the image.
- A free-text comment element.

The image is described in a Cartesian system, with the X-axis horizontal and pointing to the right, the Y-axis vertical and pointing downward, and the origin at the upper left corner. The scale is such that the height of the image is normalized to 1.0. To keep the scale of the X-axis and the Y-axis the same, the image width (R) is its aspect ratio (width/height). Thus, a square part of any image has equal width and height in this coordinate system. The metadata coordinate system refers to the image area on the reference grid as defined in ITU-T T.800 | ISO/IEC 15444-1. See Figure B.1 in ITU-T T.800 | ISO/ IEC 15444-1 for an illustration of the image area. Coordinate (0, 0) refers to the top left of pixel (XOsiz, YOsiz) and coordinate (R, 1) refers to the bottom right of pixel (Xsiz–1, Ysiz–1) on the reference grid where XOsiz, YOsiz, Xsiz and Ysiz are the values of the respective fields in the SIZ marker (see A.2.3) in the codestream. Other coordinates map linearly into this image area.

This information may become useless if the image is cropped or manipulated. See Location type (N.7.1.15) for the difference between the Position and Location types.

```
<xsd:complexType name="tPosition">
  <xsd:sequence>
    <xsd:choice minOccurs="0">
      <xsd:element name="POINT" type="jp:tPoint"/>
      <xsd:element name="RECT" type="jp:tRect"/>
      <xsd:sequence>
        <xsd:element name="RECT" type="jp:tRect"/>
        <xsd:element name="REGION" type="jp:tRegion"/>
      </xsd:sequence>
    </xsd:choice>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
</xsd:complexType>
```

Figure N.66 – Schema of the Position type

POINT: Single point. This element specifies a single point in the coordination system. See Point type (N.7.1.18) for more information of this element.

RECT: Rectangular region. This element specifies a rectangular region in the coordinate system. See Rect type (N.7.1.19) for more information of this element.

REGION: Arbitrary region. This element specifies an arbitrary region. See Region type (N.7.1.20) for more information on this element.

COMMENT: This element can describe the position of an object less accurately than one of the above methods. For example, this element may contain "Bottom left-hand corner" or "Second from the left in the top row." See Comment element (N.7.3.1) for more information on this element.

N.7.1.18 Point type

This type specifies details about a single point on an image. This type is used to describe a single point in the coordinate system. This type shall contain the sub-elements listed below.

```
<xsd:complexType name="tPoint">
  <xsd:sequence>
    <xsd:element name="X" type="jp:tNonNegativeDouble"/>
    <xsd:element name="Y" type="jp:tNonNegativeDouble"/>
  </xsd:sequence>
</xsd:complexType>
```

Figure N.67 – Schema of the Point type

X:	This element specifies the X coordinate of the point.
Y:	This element specifies the Y coordinate of the point.

N.7.1.19 Rect type

This type specifies details about a rectangular region on an image. This type is used to describe a rectangular region in the coordinate system. See Point type (N.7.1.18) for the base format of this type. Additionally, this type shall contain the sub-elements listed below.

```
<xsd:complexType name="tRect">
  <xsd:complexContent>
    <xsd:extension base="jp:tPoint">
      <xsd:sequence>
        <xsd:element name="WIDTH" type="jp:tNonNegativeDouble"/>
        <xsd:element name="HEIGHT" type="jp:tNonNegativeDouble"/>
      </xsd:sequence>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
```

Figure N.68 – Schema of the Rect type

X:	The left of the rectangle.
Y:	The top of the rectangle.
WIDTH:	The width of the rectangular (to the right of X).
HEIGHT:	The height of the rectangular (below Y).

N.7.1.20 Region type

This type specifies details about an arbitrary region on an image. This type consists of a start point and one or more segments. Each segment may be either a straight line (specified using a point), or a spline.

Where an arbitrary region is specified, a Rectangular Region shall also be specified (which is the bounding box of the Arbitrary Region). A standard JPX compliant metadata reader or editor has the option of not using the Arbitrary Region, even if the Rectangular Region is used.

This type shall contain the sub-elements listed below.

```
<xsd:complexType name="tRegion">
  <xsd:sequence>
    <xsd:element name="POINT" type="jp:tPoint"/>
    <xsd:choice minOccurs="0" maxOccurs="unbounded">
      <xsd:element name="POINT" type="jp:tPoint"/>
      <xsd:element name="SPLINE">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="X1" type="jp:tNonNegativeDouble"/>
            <xsd:element name="Y1" type="jp:tNonNegativeDouble"/>
            <xsd:element name="X2" type="jp:tNonNegativeDouble"/>
            <xsd:element name="Y2" type="jp:tNonNegativeDouble"/>
            <xsd:element name="X" type="jp:tNonNegativeDouble"/>
            <xsd:element name="Y" type="jp:tNonNegativeDouble"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:choice>
  </xsd:sequence>
</xsd:complexType>
```

Figure N.69 – Schema of the Region type

POINT:	Start Point: This is the starting point of the spline in the coordinate system. See Point type (N.7.1.18) for the format of this element.
POINT:	This element specifies a line starting at the end of the previous spline and ending at the new point. See Point type (N.7.1.18) for the format of this element.
SPLINE:	This element specifies a Bezier curve starting at the end of the previous spline, and ending at the new end point (x, y), with x1, y1 and x2, y2 being the first and second control points of the spline respectively.

N.7.1.21 Product details type

This type specifies details about a product (hardware or software). By combining these three elements, a unique value shall be created. This type may contain the sub-elements listed below.

```
<xsd:complexType name="tProductDetails">
  <xsd:sequence>
    <xsd:element name="MANUFACTURER" type="jp:tOrganization" minOccurs="0"/>
    <xsd:element name="MODEL" type="xsd:string" minOccurs="0"/>
    <xsd:element name="SERIAL" type="xsd:string" minOccurs="0"/>
    <xsd:element name="VERSION" type="xsd:string" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>
```

Figure N.70 – Schema of the Product Details type

MANUFACTURER:	Manufacturer name. This element specifies the name of the manufacturer or vendor of the product. It is recommended to set the manufacturer name shown on the device. See Organization type (N.7.1.14) for the format of this element.
MODEL:	Model name. This element specifies the model name or number of the product.
SERIAL:	Serial Number. This element specifies the serial number of a product.
VERSION:	Version Number. This element specifies the version number of a product.

N.7.2 Defined attributes

N.7.2.1 Language attribute

The attribute is formatted according to RFC 3066. When a metadata element has a Language attribute, it specifies the language in which the metadata is stored. English (e.g., "en") is assumed where the language is not specified.

Where an element specifies a Language attribute, and also sub-elements, the Language of the sub-elements is the same as the enclosing element unless the Language attribute is specified separately within the sub-element.

```
<xsd:attribute name="xml:lang" type="xsd:language"/>
```

Figure N.71 – Schema of the Language attribute

xml:lang: This element contains a string values that is RFC 3066 compliant. The syntax of this element shall match the Language Identification format of XML 1.0.

N.7.2.2 Timestamp attribute

When a metadata element contains a Timestamp attribute, it specifies the time that the metadata was generated. Where an element specifies a Timestamp attribute, and also sub-elements, the Timestamp of the sub-elements is the same as the enclosing element unless the Timestamp attribute is specified separately within the sub-element.

```
<xsd:attribute name="TIMESTAMP" type="xsd:dateTime"/>
```

Figure N.72 – Schema of the Timestamp attribute

TIMESTAMP: This element contains a string that is ISO 8601 compliant.

N.7.3 Defined elements

N.7.3.1 Comment element

The Comment element is used to specify extra information to the element it contains that cannot be described otherwise within the defined metadata. It is recommended that the Comment element is used as a last resort only when the other metadata elements are not suitable to store a specific piece of metadata.

The content of this element is intended to store human readable data. Storing non-human readable data can be performed using other metadata extension methods.

```
<xsd:element name="COMMENT">
  <xsd:complexType>
    <xsd:simpleContent>
      <xsd:extension base="jp:tLangString">
        <xsd:attribute ref="jp:TIMESTAMP"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
</xsd:element>
```

Figure N.73 – Schema of the Comment element

N.8 JPX extended metadata document type definition

```
<!--
    Copyright (C) ISO/IEC 2001 – All rights reserved.

    Permission to copy in any form is granted for use with validating and conforming
    systems and applications as defined in ISO/IEC 15444-2:2001, provided this
    copyright notice is included with all copies.
-->

<!-- ===================================================================== -->
<!-- Fundamental Type and Element Definitions                              -->
<!-- ===================================================================== -->

<!-- HUMAN_SCHEMA_DTD_LOCATION:http://www.jpeg.org/metadata/15444-2.PDF -->

<!-- Attribute definitions -->

<!ENTITY % att-timestamp                    "TIMESTAMP CDATA #IMPLIED">
<!ENTITY % att-lang                         "xml:lang CDATA #IMPLIED">
<!ENTITY % att-lang-ts                      "%att-lang; %att-timestamp;">
<!ENTITY % att-lang-ts-id                   "%att-lang-ts; ID CDATA #IMPLIED">

<!-- Geometric Type -->
```

```
<!ENTITY % size                              "(WIDTH, HEIGHT)">

<!-- Date Type -->

<!ENTITY % jp2-tDateTime                     "(EXACT | DATE |
                                              (MONTH?, YEAR?, CENTURY?)),
                                             WEEK_DAY?, SEASON?, COMMENT?">

<!ELEMENT EXACT                              (#PCDATA)>
<!ELEMENT DATE                               (#PCDATA)>
<!ELEMENT MONTH                              (#PCDATA)>
<!ELEMENT YEAR                               (#PCDATA)>
<!ELEMENT CENTURY                            (#PCDATA)>
<!ELEMENT WEEK_DAY                           (#PCDATA)>
<!ELEMENT SEASON                             (#PCDATA)>

<!--  Address type -->

<!ENTITY % jp2-tAddress                     "(ADDR_NAME?, ADDR_COMP*,
                                             (POSTCODE | ZIPCODE)?,
                                             COUNTRY?)">
<!ELEMENT ADDRESS                            %jp2-tAddress;>
<!ATTLIST ADDRESS                            TYPE CDATA #IMPLIED
                                             %att-lang-ts;>

<!ELEMENT ADDR_NAME                         (#PCDATA)>
<!ATTLIST ADDR_NAME                         %att-lang;>

<!ELEMENT ADDR_COMP                         (#PCDATA)>
<!ATTLIST ADDR_COMP                         TYPE CDATA #IMPLIED>

<!ELEMENT POSTCODE                          (#PCDATA)>
<!ELEMENT ZIPCODE                           (#PCDATA)>

<!ELEMENT COUNTRY                           (#PCDATA)>
<!ATTLIST COUNTRY                           %att-lang;>

<!--  Phone number type -->

<!ENTITY % jp2-tPhone                      "(COUNTRY_CODE?, AREA?,
                                            LOCAL?, EXTENSION?)">
<!ATTLIST PHONE                             TYPE CDATA #IMPLIED
                                            %att-timestamp;>
<!ELEMENT PHONE                             %jp2-tPhone;>

<!ELEMENT COUNTRY_CODE                      (#PCDATA)>
<!ELEMENT AREA                              (#PCDATA)>
<!ELEMENT LOCAL                             (#PCDATA)>
<!ELEMENT EXTENSION                         (#PCDATA)>

<!-- Email Address Type-->

<!ELEMENT EMAIL                              (#PCDATA)>
<!ATTLIST EMAIL                              TYPE CDATA #IMPLIED>

<!-- Web Address Type-->

<!ELEMENT WEB                                (#PCDATA)>
<!ATTLIST WEB                                TYPE CDATA #IMPLIED>

<!-- Organization type -->

<!ENTITY % jp2-tOrganization                "(ORG_NAME?,
                                             ADDRESS*, PHONE*, EMAIL*, WEB*,
                                             LOGO_FILE?, LOGO_FORMAT?, MIME_TYPE?,
                                             COMMENT?)">

<!ELEMENT ORG_NAME                           (#PCDATA)>
<!ATTLIST ORG_NAME                           %att-lang;>

<!ELEMENT LOGO_FILE                          (#PCDATA)>
<!ELEMENT LOGO_FORMAT                        (#PCDATA)>
<!ELEMENT MIME_TYPE                          (#PCDATA)>
```

```
<!-- Person Type-->

<!ENTITY % jp2-tPerson                    "(NAME_TITLE?,
                                           PERSON_NAME*, NICK_NAME*,
                                           JOB_TITLE?,
                                           (PERSON_ORG | ORG_REF)?,
                                           ADDRESS*, PHONE*, EMAIL*, WEB*,
                                           BIRTH_DATE?, AGE?,
                                           COMMENT?)">

<!ELEMENT NAME_TITLE                      (#PCDATA)>
<!ATTLIST NAME_TITLE                      %att-lang;>

<!ELEMENT PERSON_NAME                     (NAME_COMP+)>
<!ATTLIST PERSON_NAME                     %att-lang-ts;>

<!ELEMENT NAME_COMP                       (#PCDATA)>
<!ATTLIST NAME_COMP                       TYPE (Prefix | Given | Family |
                                                Suffix | Maiden) "Given">

<!ELEMENT NICK_NAME                       (#PCDATA)>
<!ELEMENT JOB_TITLE                       (#PCDATA)>

<!ELEMENT PERSON_ORG                      %jp2-tOrganization;>
<!ATTLIST PERSON_ORG                      %att-lang-ts-id;>

<!ELEMENT ORG_REF                         (#PCDATA)>

<!ELEMENT BIRTH_DATE                      (#PCDATA)>
<!ELEMENT AGE                             (#PCDATA)>

<!-- Location type -->

<!ENTITY % jp2-tLocation                 "(COORD_LOC?, ADDRESS?,
                                          GPS?, COMMENT?)">
<!ELEMENT LOCATION                        %jp2-tLocation;>
<!ATTLIST LOCATION                        %att-lang-ts;>

<!ELEMENT COORD_LOC                      (LONGITUDE?, LATITUDE?, ALTITUDE?)>
<!ATTLIST COORD_LOC                       %att-timestamp;>

<!ELEMENT LONGITUDE                       (#PCDATA)>
<!ELEMENT LATITUDE                        (#PCDATA)>
<!ELEMENT ALTITUDE                        (#PCDATA)>

<!-- GPS type -->

<!ELEMENT GPS                            (GPS_LAT_REF?, GPS_LATITUDE?,
                                          GPS_LONG_REF?, GPS_LONGITUDE?,
                                          GPS_ALTITUDE?, GPS_TIME?,
                                          GPS_SATELLITES?, GPS_STATUS?,
                                          GPS_MEASURE_MODE?, GPS_DOP?,
                                          GPS_SPEED_REF?, GPS_SPEED?,
                                          GPS_TRACK_REF?, GPS_TRACK?,
                                          GPS_IMAGE_DIR_REF?, GPS_IMAGE_DIR?,
                                          GPS_MAP_DATUM?,
                                          GPS_DEST_LAT_REF?,
                                          GPS_DEST_LATITUDE?,
                                          GPS_DEST_LONG_REF?,
                                          GPS_DEST_LONGITUDE?,
                                          GPS_DEST_BEARING_REF?,
                                          GPS_DEST_BEARING?,
                                          GPS_DEST_DISTANCE_REF?,
                                          GPS_DEST_DISTANCE?)>

<!ELEMENT GPS_LAT_REF                    (#PCDATA)>
<!ELEMENT GPS_LATITUDE                   (D, M, S?)>
<!ELEMENT GPS_LONG_REF                   (#PCDATA)>
<!ELEMENT GPS_LONGITUDE                  (D, M, S?)>
<!ELEMENT GPS_ALTITUDE                   (#PCDATA)>
<!ELEMENT GPS_TIME                       (#PCDATA)>
<!ELEMENT GPS_SATELLITES                 (#PCDATA)>
<!ELEMENT GPS_STATUS                     (#PCDATA)>
<!ELEMENT GPS_MEASURE_MODE               (#PCDATA)>
<!ELEMENT GPS_DOP                        (#PCDATA)>
<!ELEMENT GPS_SPEED_REF                  (#PCDATA)>
<!ELEMENT GPS_SPEED                      (#PCDATA)>
```

```
<!ELEMENT GPS_TRACK_REF                       (#PCDATA)>
<!ELEMENT GPS_TRACK                           (#PCDATA)>
<!ELEMENT GPS_IMAGE_DIR_REF                   (#PCDATA)>
<!ELEMENT GPS_IMAGE_DIR                       (#PCDATA)>
<!ELEMENT GPS_MAP_DATUM                       (#PCDATA)>
<!ELEMENT GPS_DEST_LAT_REF                    (#PCDATA)>
<!ELEMENT GPS_DEST_LATITUDE                   (D, M, S?)>
<!ELEMENT GPS_DEST_LONG_REF                   (#PCDATA)>
<!ELEMENT GPS_DEST_LONGITUDE                  (D, M, S?)>
<!ELEMENT GPS_DEST_BEARING_REF                (#PCDATA)>
<!ELEMENT GPS_DEST_BEARING                    (#PCDATA)>
<!ELEMENT GPS_DEST_DISTANCE_REF               (#PCDATA)>
<!ELEMENT GPS_DEST_DISTANCE                   (#PCDATA)>

<!ELEMENT D                                   (#PCDATA)>
<!ELEMENT M                                   (#PCDATA)>
<!ELEMENT S                                   (#PCDATA)>

<!-- Direction type-->

<!ENTITY % jp2-tDirection                    "(YAW?, PITCH?, ROLL?, COMMENT?)">
<!ELEMENT DIRECTION                           %jp2-tDirection;>
<!ATTLIST DIRECTION                           %att-lang-ts;>

<!ELEMENT YAW                                 (#PCDATA)>
<!ELEMENT PITCH                               (#PCDATA)>
<!ELEMENT ROLL                                (#PCDATA)>

<!-- Position type -->
<!ENTITY % jp2-tPosition                     "((POINT | RECT | (RECT, REGION))?,
                                              COMMENT?)">
<!ELEMENT POSITION                            %jp2-tPosition;>
<!ATTLIST POSITION                            %att-lang-ts;>

<!ELEMENT POINT                               (X, Y)>
<!ELEMENT RECT                                (X, Y, WIDTH, HEIGHT)>
<!ELEMENT SPLINE                              (X1, Y1, X2, Y2, X, Y)>
<!ELEMENT REGION                              (POINT, (POINT | SPLINE)*)>

<!ELEMENT X                                   (#PCDATA)>
<!ELEMENT Y                                   (#PCDATA)>
<!ELEMENT WIDTH                               (#PCDATA)>
<!ELEMENT HEIGHT                              (#PCDATA)>
<!ELEMENT X1                                  (#PCDATA)>
<!ELEMENT Y1                                  (#PCDATA)>
<!ELEMENT X2                                  (#PCDATA)>
<!ELEMENT Y2                                  (#PCDATA)>

<!-- Product Details Type -->

<!ENTITY % jp2-tProductDetails                "(MANUFACTURER?, MODEL?, SERIAL?, VERSION?)">

<!ELEMENT MANUFACTURER                        %jp2-tOrganization;>
<!ATTLIST MANUFACTURER                        %att-lang-ts-id;>
<!ELEMENT MODEL                               (#PCDATA)>
<!ELEMENT SERIAL                              (#PCDATA)>
<!ELEMENT VERSION                             (#PCDATA)>

<!-- Comment element -->

<!ELEMENT COMMENT                             (#PCDATA)>
<!ATTLIST COMMENT                             %att-lang-ts;>


<!-- ====================================================================== -->
<!-- Image Creation Metadata                                                  -->
<!-- ====================================================================== -->

<!ELEMENT IMAGE_CREATION                      (GENERAL_CREATION_INFO?,
                                               CAMERA_CAPTURE?,
                                               SCANNER_CAPTURE?,
                                               SOFTWARE_CREATION?,
                                               CAPTURED_ITEM?)>
<!ATTLIST IMAGE_CREATION                       %att-lang-ts;>

<!-- General Image Creation -->
```

```
<!ELEMENT GENERAL_CREATION_INFO          (CREATION_TIME?, IMAGE_SOURCE?,
                                          SCENE_TYPE?, IMAGE_CREATOR?,
                                          OPERATOR_ORG?, OPERATOR_ID?)>
<!ATTLIST GENERAL_CREATION_INFO           %att-lang-ts;>

<!ELEMENT CREATION_TIME                   (#PCDATA)>

<!ELEMENT IMAGE_SOURCE                    (#PCDATA)>
<!ATTLIST IMAGE_SOURCE                    %att-lang;>

<!ELEMENT SCENE_TYPE                      (#PCDATA)>
<!ATTLIST SCENE_TYPE                      %att-lang;>

<!ELEMENT IMAGE_CREATOR                   %jp2-tPerson;>
<!ATTLIST IMAGE_CREATOR                   %att-lang-ts-id;>

<!ELEMENT OPERATOR_ORG                    %jp2-tOrganization;>
<!ATTLIST OPERATOR_ORG                    %att-lang-ts-id;>

<!ELEMENT OPERATOR_ID                     (#PCDATA)>
<!ATTLIST OPERATOR_ID                     %att-lang;>

<!-- Camera capture -->

<!ELEMENT CAMERA_CAPTURE                 (CAMERA_INFO?, SOFTWARE_INFO?,
                                          LENS_INFO?, DEVICE_CHARACTER?,
                                          CAMERA_SETTINGS?, ACCESSORY*)>
<!ATTLIST CAMERA_CAPTURE                  %att-lang-ts;>

<!ELEMENT CAMERA_INFO                     %jp2-tProductDetails;>
<!ATTLIST CAMERA_INFO                     %att-lang-ts;>

<!ELEMENT SOFTWARE_INFO                   %jp2-tProductDetails;>
<!ATTLIST SOFTWARE_INFO                   %att-lang-ts;>

<!ELEMENT LENS_INFO                       %jp2-tProductDetails;>
<!ATTLIST LENS_INFO                       %att-lang-ts;>

<!ELEMENT DEVICE_CHARACTER               (SENSOR_TECHNOLOGY?,
                                          FOCAL_PLANE_RES?,
                                          SPECTRAL_SENSITIVITY?,
                                          ISO_SATURATION?, ISO_NOISE?,
                                          SPATIAL_FREQ_RESPONSE?,
                                          CFA_PATTERN?, OECF?, MIN_F_NUMBER?)>
<!ATTLIST DEVICE_CHARACTER                %att-lang-ts;>

<!ELEMENT SENSOR_TECHNOLOGY               (#PCDATA)>

<!ELEMENT FOCAL_PLANE_RES                 %size;>

<!ELEMENT SPECTRAL_SENSITIVITY            ANY>
<!ELEMENT ISO_SATURATION                  (#PCDATA)>
<!ELEMENT ISO_NOISE                       (#PCDATA)>

<!ELEMENT SPATIAL_FREQ_RESPONSE           (SPATIAL_FREQ_VAL+)>
<!ELEMENT SPATIAL_FREQ_VAL                (SPATIAL_FREQ, HORIZ_SFR, VERT_SFR)>
<!ELEMENT SPATIAL_FREQ                    (#PCDATA)>
<!ELEMENT HORIZ_SFR                       (#PCDATA)>
<!ELEMENT VERT_SFR                        (#PCDATA)>

<!ELEMENT CFA_PATTERN                     (COLOR_ROW+)>
<!ELEMENT COLOR_ROW                       (COLOR+)>
<!ELEMENT COLOR                           (#PCDATA)>

<!ELEMENT OECF                            (LOG_VAL+)>
<!ELEMENT LOG_VAL                         (LOG_EXPOSURE, OUTPUT_LEVEL+)>
<!ELEMENT LOG_EXPOSURE                    (#PCDATA)>
<!ELEMENT OUTPUT_LEVEL                    (#PCDATA)>

<!ELEMENT MIN_F_NUMBER                    (#PCDATA)>

<!-- Camera Capture Settings -->
```

```
<!ELEMENT CAMERA_SETTINGS                ((EXP_TIME | R_EXP_TIME)?,
                                          F_NUMBER?, EXP_PROGRAM?,
                                          BRIGHTNESS?, EXPOSURE_BIAS?,
                                          SUBJECT_DISTANCE?, METERING_MODE?,
                                          SCENE_ILLUMINANT?, COLOR_TEMP?,
                                          FOCAL_LENGTH?, FLASH?,
                                          FLASH_ENERGY?, FLASH_RETURN?,
                                          BACK_LIGHT?, SUBJECT_POSITION?,
                                          EXPOSURE_INDEX?, AUTO_FOCUS?,
                                          SPECIAL_EFFECT*, CAMERA_LOCATION?,
                                          ORIENTATION?, PAR?)>
<!ATTLIST CAMERA_SETTINGS                 %att-lang-ts;>

<!ELEMENT EXP_TIME                        (#PCDATA)>
<!ELEMENT R_EXP_TIME                      (#PCDATA)>
<!ELEMENT F_NUMBER                        (#PCDATA)>
<!ELEMENT EXP_PROGRAM                     (#PCDATA)>
<!ATTLIST EXP_PROGRAM                     %att-lang;>
<!ELEMENT BRIGHTNESS                      (#PCDATA)>
<!ELEMENT EXPOSURE_BIAS                   (#PCDATA)>
<!ELEMENT SUBJECT_DISTANCE                (#PCDATA)>
<!ELEMENT METERING_MODE                   (#PCDATA)>
<!ATTLIST METERING_MODE                   %att-lang;>
<!ELEMENT SCENE_ILLUMINANT                (#PCDATA)>
<!ATTLIST SCENE_ILLUMINANT                %att-lang;>
<!ELEMENT COLOR_TEMP                      (#PCDATA)>
<!ELEMENT FOCAL_LENGTH                    (#PCDATA)>
<!ELEMENT FLASH                           (#PCDATA)>
<!ELEMENT FLASH_ENERGY                    (#PCDATA)>
<!ELEMENT FLASH_RETURN                    (#PCDATA)>
<!ELEMENT BACK_LIGHT                      (#PCDATA)>
<!ELEMENT SUBJECT_POSITION                %jp2-tPosition;>
<!ATTLIST SUBJECT_POSITION                %att-lang-ts;>
<!ELEMENT EXPOSURE_INDEX                  (#PCDATA)>
<!ELEMENT AUTO_FOCUS                      (#PCDATA)>
<!ELEMENT SPECIAL_EFFECT                  (#PCDATA)>
<!ELEMENT CAMERA_LOCATION                 %jp2-tLocation;>
<!ATTLIST CAMERA_LOCATION                 %att-lang-ts;>
<!ELEMENT ORIENTATION                     %jp2-tDirection;>
<!ATTLIST ORIENTATION                     %att-lang-ts;>
<!ELEMENT PAR                             (#PCDATA)>

<!ELEMENT ACCESSORY                       %jp2-tProductDetails;>
<!ATTLIST ACCESSORY                       %att-lang-ts;>

<!-- Scanner Capture -->

<!ELEMENT SCANNER_CAPTURE                (SCANNER_INFO?, SOFTWARE_INFO?,
                                          SCANNER_SETTINGS?)>
<!ATTLIST SCANNER_CAPTURE                 %att-lang-ts;>

<!ELEMENT SCANNER_INFO                    %jp2-tProductDetails;>
<!ATTLIST SCANNER_INFO                    %att-lang-ts;>

<!ELEMENT SCANNER_SETTINGS               (PIXEL_SIZE?, PHYSICAL_SCAN_RES?)>
<!ATTLIST SCANNER_SETTINGS                %att-timestamp;>

<!ELEMENT PIXEL_SIZE                      (#PCDATA)>
<!ELEMENT PHYSICAL_SCAN_RES               %size;>

<!-- Software Creation -->
<!ELEMENT SOFTWARE_CREATION               (SOFTWARE_INFO?)>

<!-- Captured Item -->

<!ELEMENT CAPTURED_ITEM                  (REFLECTION_PRINT | FILM)>
<!ATTLIST CAPTURED_ITEM                   %att-lang-ts;>

<!-- Reflection print -->

<!ELEMENT REFLECTION_PRINT               (DOCUMENT_SIZE?, MEDIUM?, RP_TYPE?)>

<!ELEMENT DOCUMENT_SIZE                   %size;>
<!ELEMENT MEDIUM                          (#PCDATA)>
<!ELEMENT RP_TYPE                         (#PCDATA)>

<!-- Film -->
```

```
<!ELEMENT FILM                          (BRAND?, CATEGORY?, FILM_SIZE?,
                                         ROLL_ID?, FRAME_ID?, FILM_SPEED?)>
<!ATTLIST FILM                           %att-lang-ts;>

<!ELEMENT BRAND                          %jp2-tProductDetails;>
<!ATTLIST BRAND                          %att-lang-ts;>
<!ELEMENT CATEGORY                       (#PCDATA)>
<!ELEMENT FILM_SIZE                      %size;>
<!ELEMENT ROLL_ID                        (#PCDATA)>
<!ATTLIST ROLL_ID                        %att-lang;>
<!ELEMENT FRAME_ID                       (#PCDATA)>
<!ELEMENT FILM_SPEED                     (#PCDATA)>



<!-- ====================================================================== -->
<!-- Content Description                                                    -->
<!-- ====================================================================== -->

<!ELEMENT CONTENT_DESCRIPTION           (GROUP_CAPTION?, CAPTION?,
                                         CAPTURE_TIME?, LOCATION?,
                                         PERSON*, THING*, ORGANIZATION*,
                                         EVENT*, AUDIO*, PROPERTY*,
                                         DICTIONARY*, COMMENT?)>
<!ATTLIST CONTENT_DESCRIPTION            %att-lang-ts;>



<!ELEMENT GROUP_CAPTION                  (#PCDATA)>
<!ATTLIST GROUP_CAPTION                  %att-lang;>

<!ELEMENT CAPTION                        (#PCDATA)>
<!ATTLIST CAPTION                        %att-lang;>

<!ELEMENT CAPTURE_TIME                  (%jp2-tDateTime;)>
<!ATTLIST CAPTURE_TIME                   %att-lang-ts;>

<!-- Person -->

<!ELEMENT PERSON                        (%jp2-tPerson;, POSITION?,
                                         LOCATION?, PROPERTY*)>
<!ATTLIST PERSON                         %att-lang-ts-id;>

<!-- Thing -->

<!ELEMENT THING                         (NAME?, COMMENT?, POSITION?,
                                         LOCATION?, PROPERTY*, THING*)>
<!ATTLIST THING                          %att-lang-ts-id;>

<!-- Organization -->

<!ELEMENT ORGANIZATION                  (%jp2-tOrganization;, POSITION?,
                                         LOCATION?, PROPERTY*)>
<!ATTLIST ORGANIZATION                   %att-lang-ts-id;>

<!-- Event -->

<!ELEMENT EVENT                         (EVENT_TYPE?, DESCRIPTION?,
                                         LOCATION?, EVENT_TIME?, DURATION?,
                                         COMMENT?, PARTICIPANT*,
                                         EVENT_RELATION*,
                                         (EVENT | EVENT_REF)*)>
<!ATTLIST EVENT                          %att-lang-ts-id;>

<!ELEMENT EVENT_TYPE                     (#PCDATA)>
<!ATTLIST EVENT_TYPE                     %att-lang;>

<!ELEMENT DESCRIPTION                    (#PCDATA)>
<!ATTLIST DESCRIPTION                    %att-lang;>

<!ELEMENT EVENT_TIME                    (%jp2-tDateTime;)>
<!ATTLIST EVENT_TIME                     %att-lang-ts;>

<!ELEMENT DURATION                       (#PCDATA)>
```

```
<!ELEMENT PARTICIPANT                       (ROLE+,
                                             (OBJECT_REF | PERSON | THING | ORGANIZATION))>
<!ATTLIST PARTICIPANT                        %att-lang;>

<!ELEMENT ROLE                               (#PCDATA)>
<!ATTLIST ROLE                               %att-lang;>

<!ELEMENT OBJECT_REF                        (#PCDATA)>

<!ELEMENT EVENT_RELATION                    (RELATION*, EVENT_REF+)>

<!ELEMENT RELATION                           (#PCDATA)>
<!ATTLIST RELATION                           %att-lang;>

<!ELEMENT EVENT_REF                          (#PCDATA)>

<!-- Audio -->

<!ELEMENT AUDIO                             (AUDIO_STREAM?, AUDIO_FORMAT?,
                                             MIME_TYPE?, DESCRIPTION?, COMMENT?)>
<!ATTLIST AUDIO                              %att-lang-ts;>

<!ELEMENT AUDIO_STREAM                       (#PCDATA)>
<!ELEMENT AUDIO_FORMAT                       (#PCDATA)>

<!-- Property -->

<!ELEMENT PROPERTY                          (NAME?, VALUE*, COMMENT?, PROPERTY*)>
<!ATTLIST PROPERTY                           %att-lang-ts;
                                             DICT_REF CDATA #IMPLIED>

<!ELEMENT NAME                              (#PCDATA)>
<!ATTLIST NAME                               %att-lang;>

<!ELEMENT VALUE                             (#PCDATA)>
<!ATTLIST VALUE                              %att-lang;>

<!-- Dictionary Reference -->

<!ELEMENT DICTIONARY                        (DICT_NAME?, COMMENT?)>
<!ATTLIST DICTIONARY                         %att-lang-ts-id;>

<!ELEMENT DICT_NAME                          (#PCDATA)>
<!ATTLIST DICT_NAME                          %att-lang;>

<!-- ====================================================================== -->
<!-- History                                                                -->
<!-- ====================================================================== -->

<!ELEMENT HISTORY                           (PROCESSING_SUMMARY?,
                                             IMAGE_PROCESSING_HINTS?, METADATA*)>
<!ATTLIST HISTORY                            %att-lang-ts;>
<!ELEMENT METADATA                           (BASIC_IMAGE_PARAM?, IMAGE_CREATION?,
                                              CONTENT_DESCRIPTION?,
                                              HISTORY?,
                                              IPR?)>

<!-- Summary -->

<!ELEMENT PROCESSING_SUMMARY                (IMG_CREATED?, IMG_CROPPED?,
                                             IMG_TRANSFORMED?, IMG_GTC_ADJ?,
                                             IMG_STC_ADJ?, IMG_SPATIAL_ADJ?,
                                             IMG_EXT_EDITED?, IMG_RETOUCHED?,
                                             IMG_COMPOSITED?, IMG_METADATA?)>
<!ATTLIST PROCESSING_SUMMARY                 %att-timestamp;>

<!ELEMENT IMAGE_PROCESSING_HINTS(MODIFIER?, (IMG_CREATED | IMG_CROPPED |
                                             IMG_TRANSFORMED | IMG_GTC_ADJ |
                                             IMG_STC_ADJ | IMG_SPATIAL_ADJ |
                                             IMG_EXT_EDITED | IMG_RETOUCHED |
<!ELEMENT MODIFIER%jp2-tProductDetails;>     IMG_COMPOSITED | IMG_METADATA)*)*>
<!ATTLIST IMAGE_PROCESSING_HINTS             %att-lang-ts;>
```

```
<!ELEMENT IMG_CREATED                          (#PCDATA)>
<!ELEMENT IMG_CROPPED                          (#PCDATA)>
<!ELEMENT IMG_TRANSFORMED                      (#PCDATA)>
<!ELEMENT IMG_GTC_ADJ                          (#PCDATA)>
<!ELEMENT IMG_STC_ADJ                          (#PCDATA)>
<!ELEMENT IMG_SPATIAL_ADJ                      (#PCDATA)>
<!ELEMENT IMG_EXT_EDITED                       (#PCDATA)>
<!ELEMENT IMG_RETOUCHED                        (#PCDATA)>
<!ELEMENT IMG_COMPOSITED                       (#PCDATA)>
<!ELEMENT IMG_METADATA                         (#PCDATA)>

<!-- Previous -->
<!ELEMENT BASIC_IMAGE_PARAM                   (BASIC_IMAGE_INFO)>
<!ATTLIST BASIC_IMAGE_PARAM                    %att-lang-ts;>

<!ELEMENT BASIC_IMAGE_INFO                    (FILE_FORMAT?, IMAGE_ID?)>
<!ATTLIST BASIC_IMAGE_INFO                     %att-lang-ts;>



<!-- ============================================================== -->
<!-- Intellectual Property Rights                                   -->
<!-- ============================================================== -->

<!ELEMENT IPR                                 (IPR_NAMES?, IPR_DESCRIPTION?,
                                               IPR_DATES?, IPR_EXPLOITATION?,
                                               IPR_IDENTIFICATION?,
                                               IPR_CONTACT_POINT?, IPR_HISTORY?)>
<!ATTLIST IPR                                  %att-lang-ts;>

<!-- IPR people -->

<!ELEMENT IPR_NAMES                           (IPR_PERSON?, IPR_ORG?, IPR_NAME_REF?)+>
<!ATTLIST IPR_NAMES                            %att-lang-ts;>

<!ELEMENT IPR_PERSON                           %jp2-tPerson;>
<!ATTLIST IPR_PERSON                           DESCRIPTION CDATA #IMPLIED
                                               %att-lang-ts-id;>

<!ELEMENT IPR_ORG                              %jp2-tOrganization;>
<!ATTLIST IPR_ORG                              DESCRIPTION CDATA #IMPLIED
                                               %att-lang-ts-id;>

<!ELEMENT IPR_NAME_REF                        (#PCDATA)>
<!ATTLIST IPR_NAME_REF                         DESCRIPTION CDATA #IMPLIED>

<!-- IPR description -->

<!ELEMENT IPR_DESCRIPTION                     (IPR_TITLE?, IPR_LEGEND?,
                                               IPR_CAPTION?, COPYRIGHT?)>

<!ELEMENT IPR_TITLE                           (#PCDATA)>
<!ATTLIST IPR_TITLE                            %att-lang-ts;>

<!ELEMENT IPR_LEGEND                          (#PCDATA)>
<!ATTLIST IPR_LEGEND                           %att-lang-ts;>

<!ELEMENT IPR_CAPTION                         (#PCDATA)>
<!ATTLIST IPR_CAPTION                          %att-lang-ts;>

<!ELEMENT COPYRIGHT                           (#PCDATA)>
<!ATTLIST COPYRIGHT                            %att-lang-ts;>



<!ELEMENT IPR_DATES                           (IPR_DATE+)>
<!ATTLIST IPR_DATES                            %att-lang-ts;>

<!ELEMENT IPR_DATE                            (%jp2-tDateTime;)>
<!ATTLIST IPR_DATE                             DESCRIPTION CDATA #IMPLIED
                                               %att-lang-ts;>

<!-- IPR exploitation -->
```

```
<!ELEMENT IPR_EXPLOITATION              (IPR_PROTECTION?,
                                         IPR_USE_RESTRICTION?,
                                         IPR_OBLIGATION?,
                                         IPR_MGMT_SYS?)>
<!ATTLIST IPR_EXPLOITATION               %att-lang-ts;>

<!ELEMENT IPR_PROTECTION                (#PCDATA)>

<!ELEMENT IPR_USE_RESTRICTION           (#PCDATA)>
<!ATTLIST IPR_USE_RESTRICTION            %att-lang;>

<!ELEMENT IPR_OBLIGATION                (#PCDATA)>
<!ATTLIST IPR_OBLIGATION                 %att-lang;>

<!-- IPR management system -->

<!ELEMENT IPR_MGMT_SYS                  (IPR_MGMT_TYPE?,
                                         IPR_MGMT_SYS_ID?,
                                         IPR_MGMT_SYS_LOCATION?)>
<!ATTLIST IPR_MGMT_SYS                   %att-lang-ts;>

<!ELEMENT IPR_MGMT_TYPE                 (#PCDATA)>
<!ELEMENT IPR_MGMT_SYS_ID               (#PCDATA)>

<!ELEMENT IPR_MGMT_SYS_LOCATION         (#PCDATA)>



<!-- IPR identification -->

<!ELEMENT IPR_IDENTIFICATION            (IPR_IDENTIFIER?,
                                         LICENCE_PLATE?)>
<!ATTLIST IPR_IDENTIFICATION             %att-lang-ts;>

<!ELEMENT IPR_IDENTIFIER                (IPR_ID_MODE?, IPR_ID?)>

<!ELEMENT IPR_ID_MODE                   (#PCDATA)>
<!ATTLIST IPR_ID_MODE                    %att-lang;>
<!ELEMENT IPR_ID                        (#PCDATA)>
<!ATTLIST IPR_ID                         %att-lang;>

<!ELEMENT LICENCE_PLATE                 (LP_COUNTRY?,
                                         LP_REG_AUT?,
                                         LP_REG_NUM?,
                                         LP_DELIVERY_DATE?)>

<!ELEMENT LP_COUNTRY                    (#PCDATA)>
<!ELEMENT LP_REG_AUT                    (#PCDATA)>
<!ELEMENT LP_REG_NUM                    (#PCDATA)>
<!ELEMENT LP_DELIVERY_DATE              (#PCDATA)>

<!-- IPR contact point -->

<!ELEMENT IPR_CONTACT_POINT             (IPR_PERSON | IPR_ORG | IPR_NAME_REF)>
<!ATTLIST IPR_CONTACT_POINT              %att-lang-ts;>

<!-- IPR History -->

<!ELEMENT IPR_HISTORY                   (IPR+)>
<!ATTLIST IPR_HISTORY                   %att-lang-ts;>



<!-- ================================================================== -->
<!-- Image Identifier                                                   -->
<!-- ================================================================== -->

<!ELEMENT IMAGE_ID                       (UID?, ID_TYPE?)>
<!ELEMENT UID                            (#PCDATA)>
<!ELEMENT ID_TYPE                        (#PCDATA)>
```

N.9 JPX extended metadata XML Schema

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE xsd:schema PUBLIC "-//W3C//DTD XMLSchema 200102//EN"

"http://www.w3.org/2001/XMLSchema.dtd" [
  <!ENTITY % p 'xsd:'>
  <!ENTITY % s ':xsd'>
]>


<!--
    Copyright (C) ISO/IEC 2001 – All rights reserved.

    Permission to copy in any form is granted for use with validating and conforming
    systems and applications as defined in ISO/IEC 15444-2:2001, provided this
    copyright notice is included with all copies.
-->


<!-- HUMAN_SCHEMA_DTD_LOCATION:http://www.jpeg.org/metadata/15444-2.PDF -->


<xsd:schema targetNamespace="http://www.jpeg.org/jpx/1.0/xml"
            xmlns:jp="http://www.jpeg.org/jpx/1.0/xml"
            xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:xml="http://www.w3.org/XML/1998/namespace"
             xmlns="http://www.jpeg.org/jpx/1.0/xml"
             elementFormDefault="qualified">


   <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     -  Fundamental Metadata Types, Fields and Attributes
     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -->


   <!--
     -  See section Annex N.7.2.1 Language attribute
     -->
   <!-- Import the xml:lang attribute definition defined by W3C -->
   <xsd:import namespace="http://www.w3.org/XML/1998/namespace"
                                    schemaLocation="http://www.w3.org/2001/xml.xsd"/>


   <!--
     -  See section Annex N.7.2.2 Timestamp attribute
     -->
   <xsd:attribute name="TIMESTAMP" type="xsd:dateTime"/>


   <!--
     -  See section Annex N.7.1.3 String including language attribute type
     -->
   <xsd:complexType name="tLangString">
     <xsd:simpleContent>
       <xsd:extension base="xsd:string">
         <xsd:attribute ref="xml:lang"/>
       </xsd:extension>
     </xsd:simpleContent>
   </xsd:complexType>


   <!--
     -  See section Annex N.7.1.1 Non-negative double type
     -->
   <xsd:simpleType name="tNonNegativeDouble">
     <xsd:restriction base="xsd:double">
       <xsd:minInclusive value="0"/>
     </xsd:restriction>
   </xsd:simpleType>


   <!--
     -  See section Annex N.7.1.2 Rational type
     -->
   <xsd:simpleType name="tRational">
     <xsd:restriction base="xsd:string">
       <xsd:pattern value="(\-|\+)?[0-9]+/[0-9]+"/>
     </xsd:restriction>
   </xsd:simpleType>


  <!--
    -  See section Annex N.7.1.4 Degree type
    -->
  <xsd:simpleType name="tDegree">
    <xsd:restriction base="xsd:double">
      <xsd:minExclusive value="-180"/>
      <xsd:maxInclusive value="180"/>
    </xsd:restriction>
  </xsd:simpleType>
```

```
<!--
  -  See section Annex N.7.1.5 Half degree type
  -->
<xsd:simpleType name="tHalfDegree">
 <xsd:restriction base="xsd:double">
  <xsd:minExclusive value="-90"/>
  <xsd:maxInclusive value="90"/>
 </xsd:restriction>
</xsd:simpleType>


<!--
  -  See section Annex N.7.1.6 Double size type  and
  -->
<xsd:complexType name="tDoubleSize">
  <xsd:sequence>
    <xsd:element name="WIDTH" type="jp:tNonNegativeDouble"/>
    <xsd:element name="HEIGHT" type="jp:tNonNegativeDouble"/>
  </xsd:sequence>
</xsd:complexType>


<!--
  -  See section Annex N.7.1.7 Integer size type
  -->
<xsd:complexType name="tIntSize">
  <xsd:sequence>
    <xsd:element name="WIDTH" type="xsd:positiveInteger"/>
    <xsd:element name="HEIGHT" type="xsd:positiveInteger"/>
  </xsd:sequence>
</xsd:complexType>


<!--
  -  See section Annex N.7.1.8 DateTime type
  -->
<xsd:complexType name="tDateTime">
  <xsd:sequence>
    <xsd:choice minOccurs="0">
      <xsd:element name="EXACT" type="xsd:dateTime"/>
      <xsd:element name="DATE" type="xsd:date"/>
      <xsd:sequence>
        <xsd:element name="MONTH" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:positiveInteger">
              <xsd:minInclusive value="1"/>
              <xsd:maxInclusive value="12"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="YEAR" type="xsd:gYear" minOccurs="0"/>
        <xsd:element name="CENTURY" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:integer"/>
          </xsd:simpleType>
        </xsd:element>
      </xsd:sequence>
    </xsd:choice>
    <xsd:element name="WEEK_DAY" type="xsd:string" minOccurs="0"/>
    <xsd:element name="SEASON" type="xsd:string" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.9 Address type
  -->
<xsd:complexType name="tAddress">
  <xsd:sequence>
    <xsd:element name="ADDR_NAME" type="jp:tLangString" minOccurs="0"/>
    <xsd:element name="ADDR_COMP" minOccurs="0" maxOccurs="unbounded">
      <xsd:complexType>
        <xsd:simpleContent>
          <xsd:extension base="jp:tLangString">
            <xsd:attribute name="TYPE" type="xsd:string"/>
          </xsd:extension>
        </xsd:simpleContent>
      </xsd:complexType>
    </xsd:element>
    <xsd:choice minOccurs="0">
      <xsd:element name="ZIPCODE" type="xsd:string"/>
      <xsd:element name="POSTCODE" type="xsd:string"/>
    </xsd:choice>
    <xsd:element name="COUNTRY" type="jp:tLangString" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="TYPE" type="xsd:string"/>
  <xsd:attribute ref="jp:TIMESTAMP"/>
```

```
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.10 Phone number type
  -->
<xsd:complexType name="tPhone">
  <xsd:sequence>
    <xsd:element name="COUNTRY_CODE" type="xsd:string" minOccurs="0"/>
    <xsd:element name="AREA" type="xsd:string" minOccurs="0"/>
    <xsd:element name="LOCAL" type="xsd:string" minOccurs="0"/>
    <xsd:element name="EXTENSION" type="xsd:string" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="TYPE" type="xsd:string"/>
  <xsd:attribute ref="jp:TIMESTAMP"/>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.11 Email address type
  -->
<xsd:complexType name="tEmail">
  <xsd:simpleContent>
    <xsd:extension base="jp:tLangString">
      <xsd:attribute name="TYPE" type="xsd:string"/>
      <xsd:attribute ref="jp:TIMESTAMP"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.12 Web address type
  -->
<xsd:complexType name="tWeb">
  <xsd:simpleContent>
    <xsd:extension base="jp:tLangString">
      <xsd:attribute name="TYPE" type="xsd:string"/>
      <xsd:attribute ref="jp:TIMESTAMP"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.13 Person type
  -->
<xsd:complexType name="tPerson">
  <xsd:sequence>
    <xsd:element name="NAME_TITLE" type="jp:tLangString" minOccurs="0"/>
    <xsd:element name="PERSON_NAME" minOccurs="0" maxOccurs="unbounded">
      <xsd:complexType>
        <xsd:sequence>
          <xsd:element name="NAME_COMP" maxOccurs="unbounded">
            <xsd:complexType>
              <xsd:simpleContent>
                <xsd:extension base="xsd:string">
                  <xsd:attribute name="TYPE" use="optional" default="Given">
                    <xsd:simpleType>
                      <xsd:restriction base="xsd:string">
                        <xsd:enumeration value="Prefix"/>
                        <xsd:enumeration value="Given"/>
                        <xsd:enumeration value="Family"/>
                        <xsd:enumeration value="Suffix"/>
                        <xsd:enumeration value="Maiden"/>
                      </xsd:restriction>
                    </xsd:simpleType>
                  </xsd:attribute>
                </xsd:extension>
              </xsd:simpleContent>
            </xsd:complexType>
          </xsd:element>
        </xsd:sequence>
        <xsd:attribute ref="jp:TIMESTAMP"/>
        <xsd:attribute ref="xml:lang"/>
      </xsd:complexType>
    </xsd:element>
    <xsd:element name="NICK_NAME" type="xsd:string" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="JOB_TITLE" type="xsd:string" minOccurs="0"/>
    <xsd:choice minOccurs="0">
      <xsd:element name="PERSON_ORG" type="jp:tOrganization"/>
      <xsd:element name="ORG_REF" type="xsd:string"/>
    </xsd:choice>
    <xsd:element name="ADDRESS" type="jp:tAddress" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="PHONE" type="jp:tPhone" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="EMAIL" type="jp:tEmail" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="WEB" type="jp:tWeb" minOccurs="0" maxOccurs="unbounded"/>
    <xsd:element name="BIRTH_DATE" type="xsd:date" minOccurs="0"/>
    <xsd:element name="AGE" type="xsd:duration" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
```

```
    </xsd:sequence>
    <xsd:attribute name="ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.7.1.14 Organization type
    -->
  <xsd:complexType name="tOrganization">
    <xsd:sequence>
      <xsd:element name="ORG_NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="ADDRESS" type="jp:tAddress" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element name="PHONE" type="jp:tPhone" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element name="EMAIL" type="jp:tEmail" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element name="WEB" type="jp:tWeb" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element name="LOGO_FILE" type="xsd:anyURI" minOccurs="0"/>
      <xsd:element name="LOGO_FORMAT" type="xsd:string" minOccurs="0"/>
      <xsd:element name="MIME_TYPE" type="xsd:string" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute name="ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.7.1.15 Location type
    -->
  <xsd:complexType name="tLocation">
    <xsd:sequence>
      <xsd:element ref="jp:COORD_LOC" minOccurs="0"/>
      <xsd:element name="ADDRESS" type="jp:tAddress" minOccurs="0"/>
      <xsd:element ref="jp:GPS" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.7.1.15.1 Coordinate location
    -->
  <xsd:element name="COORD_LOC">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="LONGITUDE" type="jp:tDegree" minOccurs="0"/>
        <xsd:element name="LATITUDE" type="jp:tHalfDegree" minOccurs="0"/>
        <xsd:element name="ALTITUDE" type="xsd:double" minOccurs="0"/>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
    </xsd:complexType>
  </xsd:element>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.7.1.15.2 Raw GPS Information
    -->
  <xsd:element name="GPS">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="GPS_LAT_REF" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:string">
              <xsd:enumeration value="N"/>
              <xsd:enumeration value="S"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="GPS_LATITUDE" minOccurs="0">
          <xsd:complexType>
            <xsd:sequence>
              <xsd:element name="D" type="xsd:nonNegativeInteger"/>
              <xsd:element name="M" type="xsd:nonNegativeInteger"/>
              <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
            </xsd:sequence>
          </xsd:complexType>
        </xsd:element>
        <xsd:element name="GPS_LONG_REF" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:string">
              <xsd:enumeration value="E"/>
              <xsd:enumeration value="W"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="GPS_LONGITUDE" minOccurs="0">
          <xsd:complexType>
```

```
      <xsd:sequence>
        <xsd:element name="D" type="xsd:nonNegativeInteger"/>
        <xsd:element name="M" type="xsd:nonNegativeInteger"/>
        <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
  <xsd:element name="GPS_ALTITUDE" type="jp:tNonNegativeDouble" minOccurs="0"/>
  <xsd:element name="GPS_TIME" type="xsd:dateTime" minOccurs="0"/>
  <xsd:element name="GPS_SATELLITES" type="xsd:string" minOccurs="0"/>
  <xsd:element name="GPS_STATUS" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="A"/>
        <xsd:enumeration value="V"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_MEASURE_MODE" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:positiveInteger">
        <xsd:minExclusive value="2"/>
        <xsd:maxInclusive value="3"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_DOP" type="jp:tNonNegativeDouble" minOccurs="0"/>
  <xsd:element name="GPS_SPEED_REF" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="K"/>
        <xsd:enumeration value="N"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_SPEED" type="jp:tNonNegativeDouble" minOccurs="0"/>
  <xsd:element name="GPS_TRACK_REF" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="T"/>
        <xsd:enumeration value="M"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_TRACK" type="jp:tNonNegativeDouble" minOccurs="0"/>
  <xsd:element name="GPS_IMAGE_DIR_REF" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="T"/>
        <xsd:enumeration value="M"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_IMAGE_DIR" type="jp:tNonNegativeDouble" minOccurs="0"/>
  <xsd:element name="GPS_MAP_DATUM" type="xsd:string" minOccurs="0"/>
  <xsd:element name="GPS_DEST_LAT_REF" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="N"/>
        <xsd:enumeration value="S"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_DEST_LATITUDE" minOccurs="0">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="D" type="xsd:nonNegativeInteger"/>
        <xsd:element name="M" type="xsd:nonNegativeInteger"/>
        <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
  <xsd:element name="GPS_DEST_LONG_REF" minOccurs="0">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="E"/>
        <xsd:enumeration value="W"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:element>
  <xsd:element name="GPS_DEST_LONGITUDE" minOccurs="0">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="D" type="xsd:nonNegativeInteger"/>
        <xsd:element name="M" type="xsd:nonNegativeInteger"/>
        <xsd:element name="S" type="jp:tNonNegativeDouble" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
  <xsd:element name="GPS_DEST_BEARING_REF" minOccurs="0">
    <xsd:simpleType>
```

```
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="T"/>
            <xsd:enumeration value="M"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_DEST_BEARING" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="GPS_DEST_DISTANCE_REF" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="K"/>
            <xsd:enumeration value="N"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="GPS_DEST_DISTANCE" type="jp:tNonNegativeDouble" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.16 Direction type
  -->
<xsd:complexType name="tDirection">
  <xsd:sequence>
    <xsd:element name="YAW" type="jp:tDegree" minOccurs="0"/>
    <xsd:element name="PITCH" type="jp:tHalfDegree" minOccurs="0"/>
    <xsd:element name="ROLL" type="jp:tDegree" minOccurs="0"/>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.17 Position type
  -->
<xsd:complexType name="tPosition">
  <xsd:sequence>
    <xsd:choice minOccurs="0">
      <xsd:element name="POINT" type="jp:tPoint"/>
      <xsd:element name="RECT" type="jp:tRect"/>
      <xsd:sequence>
        <xsd:element name="RECT" type="jp:tRect"/>
        <xsd:element name="REGION" type="jp:tRegion"/>
      </xsd:sequence>
    </xsd:choice>
    <xsd:element ref="jp:COMMENT" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
</xsd:complexType>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.18 Point type
  -->
<xsd:complexType name="tPoint">
  <xsd:sequence>
    <xsd:element name="X" type="jp:tNonNegativeDouble"/>
    <xsd:element name="Y" type="jp:tNonNegativeDouble"/>
  </xsd:sequence>
</xsd:complexType>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.19 Rect type
  -->
<xsd:complexType name="tRect">
  <xsd:complexContent>
    <xsd:extension base="jp:tPoint">
      <xsd:sequence>
        <xsd:element name="WIDTH" type="jp:tNonNegativeDouble"/>
        <xsd:element name="HEIGHT" type="jp:tNonNegativeDouble"/>
      </xsd:sequence>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.20 Region type
  -->
<xsd:complexType name="tRegion">
  <xsd:sequence>
    <xsd:element name="POINT" type="jp:tPoint"/>
    <xsd:choice minOccurs="0" maxOccurs="unbounded">
      <xsd:element name="POINT" type="jp:tPoint"/>
      <xsd:element name="SPLINE">
        <xsd:complexType>
```

```
          <xsd:sequence>
            <xsd:element name="X1" type="jp:tNonNegativeDouble"/>
            <xsd:element name="Y1" type="jp:tNonNegativeDouble"/>
            <xsd:element name="X2" type="jp:tNonNegativeDouble"/>
            <xsd:element name="Y2" type="jp:tNonNegativeDouble"/>
            <xsd:element name="X" type="jp:tNonNegativeDouble"/>
            <xsd:element name="Y" type="jp:tNonNegativeDouble"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:choice>
  </xsd:sequence>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.1.21 Product details type
  -->
<xsd:complexType name="tProductDetails">
  <xsd:sequence>
    <xsd:element name="MANUFACTURER" type="jp:tOrganization" minOccurs="0"/>
    <xsd:element name="MODEL" type="xsd:string" minOccurs="0"/>
    <xsd:element name="SERIAL" type="xsd:string" minOccurs="0"/>
    <xsd:element name="VERSION" type="xsd:string" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute ref="jp:TIMESTAMP"/>
  <xsd:attribute ref="xml:lang"/>
</xsd:complexType>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.7.3.1 Comment element
  -->
<xsd:element name="COMMENT">
  <xsd:complexType>
    <xsd:simpleContent>
      <xsd:extension base="jp:tLangString">
        <xsd:attribute ref="jp:TIMESTAMP"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
</xsd:element>



<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1 Image Creation metadata
  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -->
<xsd:element name="IMAGE_CREATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:GENERAL_CREATION_INFO" minOccurs="0"/>
      <xsd:element ref="jp:CAMERA_CAPTURE" minOccurs="0"/>
      <xsd:element ref="jp:SCANNER_CAPTURE" minOccurs="0"/>
      <xsd:element ref="jp:SOFTWARE_CREATION" minOccurs="0"/>
      <xsd:element ref="jp:CAPTURED_ITEM" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.1 General Creation Information metadata
  -->
<xsd:element name="GENERAL_CREATION_INFO">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="CREATION_TIME" type="xsd:dateTime" minOccurs="0"/>
      <xsd:element name="IMAGE_SOURCE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="SCENE_TYPE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IMAGE_CREATOR" type="jp:tPerson" minOccurs="0"/>
      <xsd:element name="OPERATOR_ORG" type="jp:tOrganization" minOccurs="0"/>
      <xsd:element name="OPERATOR_ID" type="jp:tLangString" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>


<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.2 Camera Capture metadata
  -->
<xsd:element name="CAMERA_CAPTURE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="CAMERA_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="SOFTWARE_INFO" type="jp:tProductDetails" minOccurs="0"/>
```

```
          <xsd:element name="LENS_INFO" type="jp:tProductDetails" minOccurs="0"/>
          <xsd:element ref="jp:DEVICE_CHARACTER" minOccurs="0"/>
          <xsd:element ref="jp:CAMERA_SETTINGS" minOccurs="0"/>
          <xsd:element name="ACCESSORY" type="jp:tProductDetails" minOccurs="0"

maxOccurs="unbounded"/>
        </xsd:sequence>
        <xsd:attribute ref="jp:TIMESTAMP"/>
        <xsd:attribute ref="xml:lang"/>
      </xsd:complexType>
    </xsd:element>


    <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
      -  See section Annex N.6.1.3 Device Characterization metadata
      -->
    <xsd:element name="DEVICE_CHARACTER">
      <xsd:complexType>
        <xsd:sequence>
          <xsd:element name="SENSOR_TECHNOLOGY" minOccurs="0">
            <xsd:simpleType>
              <xsd:restriction base="xsd:string">
                <xsd:enumeration value="One-Chip Color Area"/>
                <xsd:enumeration value="Two-Chip Color Area"/>
                <xsd:enumeration value="Three-Chip Color Area"/>
                <xsd:enumeration value="Color Sequential Area"/>
                <xsd:enumeration value="Trilinear"/>
                <xsd:enumeration value="Color Sequential Linear Sensor"/>
              </xsd:restriction>
            </xsd:simpleType>
          </xsd:element>
          <xsd:element name="FOCAL_PLANE_RES" type="jp:tDoubleSize" minOccurs="0"/>
          <xsd:element name="SPECTRAL_SENSITIVITY" type="xsd:string" minOccurs="0"/>
          <xsd:element name="ISO_SATURATION" type="jp:tNonNegativeDouble" minOccurs="0"/>
          <xsd:element name="ISO_NOISE" type="jp:tNonNegativeDouble" minOccurs="0"/>
          <xsd:element ref="jp:SPATIAL_FREQ_RESPONSE" minOccurs="0"/>
          <xsd:element ref="jp:CFA_PATTERN" minOccurs="0"/>
          <xsd:element ref="jp:OECF" minOccurs="0"/>
          <xsd:element name="MIN_F_NUMBER" type="jp:tNonNegativeDouble" minOccurs="0"/>
        </xsd:sequence>
        <xsd:attribute ref="jp:TIMESTAMP"/>
        <xsd:attribute ref="xml:lang"/>
      </xsd:complexType>
    </xsd:element>


    <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
      -  See section Annex N.6.1.4 Spatial Frequency Response metadata
      -->
    <xsd:element name="SPATIAL_FREQ_RESPONSE">
      <xsd:complexType>
        <xsd:sequence>
          <xsd:element name="SPATIAL_FREQ_VAL" maxOccurs="unbounded">
            <xsd:complexType>
              <xsd:sequence>
                <xsd:element name="SPATIAL_FREQ" type="jp:tNonNegativeDouble"/>
                <xsd:element name="HORIZ_SFR" type="jp:tNonNegativeDouble"/>
                <xsd:element name="VERT_SFR" type="jp:tNonNegativeDouble"/>
              </xsd:sequence>
            </xsd:complexType>
          </xsd:element>
        </xsd:sequence>
      </xsd:complexType>
    </xsd:element>


    <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
      -  See section Annex N.6.1.5 Color Filter Array Pattern metadata
      -->
    <xsd:element name="CFA_PATTERN">
      <xsd:complexType>
        <xsd:sequence>
          <xsd:element name="COLOR_ROW" maxOccurs="unbounded">
            <xsd:complexType>
              <xsd:sequence>
                <xsd:element name="COLOR" maxOccurs="unbounded">
                  <xsd:simpleType>
                    <xsd:restriction base="xsd:string">
                      <xsd:enumeration value="Red"/>
                      <xsd:enumeration value="Green"/>
                      <xsd:enumeration value="Blue"/>
                      <xsd:enumeration value="Cyan"/>
                      <xsd:enumeration value="Magenta"/>
                      <xsd:enumeration value="Yellow"/>
                      <xsd:enumeration value="White"/>
                    </xsd:restriction>
                  </xsd:simpleType>
                </xsd:element>
              </xsd:sequence>
            </xsd:complexType>
          </xsd:element>
```

```
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.1.6 Opto-electronic Conversion Function metadata
    -->
  <xsd:element name="OECF">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="LOG_VAL" maxOccurs="unbounded">
          <xsd:complexType>
            <xsd:sequence>
              <xsd:element name="LOG_EXPOSURE" type="xsd:double"/>
              <xsd:element name="OUTPUT_LEVEL" type="jp:tNonNegativeDouble"

maxOccurs="unbounded"/>
            </xsd:sequence>
          </xsd:complexType>
        </xsd:element>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.1.7 Camera Capture Settings metadata
    -->
  <xsd:element name="CAMERA_SETTINGS">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:choice minOccurs="0">
          <xsd:element name="EXP_TIME" type="jp:tNonNegativeDouble"/>
          <xsd:element name="R_EXP_TIME" type="jp:tRational"/>
        </xsd:choice>
        <xsd:element name="F_NUMBER" type="jp:tNonNegativeDouble" minOccurs="0"/>
        <xsd:element name="EXP_PROGRAM" type="jp:tLangString" minOccurs="0"/>
        <xsd:element name="BRIGHTNESS" type="xsd:double" minOccurs="0"/>
        <xsd:element name="EXPOSURE_BIAS" type="xsd:double" minOccurs="0"/>
        <xsd:element name="SUBJECT_DISTANCE" type="jp:tNonNegativeDouble" minOccurs="0"/>
        <xsd:element name="METERING_MODE" type="jp:tLangString" minOccurs="0"/>
        <xsd:element name="SCENE_ILLUMINANT" type="jp:tLangString" minOccurs="0"/>
        <xsd:element name="COLOR_TEMP" type="jp:tNonNegativeDouble" minOccurs="0"/>
        <xsd:element name="FOCAL_LENGTH" type="jp:tNonNegativeDouble" minOccurs="0"/>
        <xsd:element name="FLASH" type="xsd:boolean" minOccurs="0"/>
        <xsd:element name="FLASH_ENERGY" type="jp:tNonNegativeDouble" minOccurs="0"/>
        <xsd:element name="FLASH_RETURN" type="xsd:boolean" minOccurs="0"/>
        <xsd:element name="BACK_LIGHT" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:string">
              <xsd:enumeration value="Front Light"/>
              <xsd:enumeration value="Back Light 1"/>
              <xsd:enumeration value="Back Light 2"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="SUBJECT_POSITION" type="jp:tPosition" minOccurs="0"/>
        <xsd:element name="EXPOSURE_INDEX" type="xsd:double" minOccurs="0"/>
        <xsd:element name="AUTO_FOCUS" minOccurs="0">
          <xsd:simpleType>
            <xsd:restriction base="xsd:string">
              <xsd:enumeration value="Auto Focus Used"/>
              <xsd:enumeration value="Auto Focus Interrupted"/>
              <xsd:enumeration value="Near Focused"/>
              <xsd:enumeration value="Soft Focused"/>
              <xsd:enumeration value="Manual"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="SPECIAL_EFFECT" minOccurs="0" maxOccurs="unbounded">
          <xsd:simpleType>
            <xsd:restriction base="xsd:string">
              <xsd:enumeration value="Colored"/>
              <xsd:enumeration value="Diffusion"/>
              <xsd:enumeration value="Multi-Image"/>
              <xsd:enumeration value="Polarizing"/>
              <xsd:enumeration value="Split-Field"/>
              <xsd:enumeration value="Star"/>
            </xsd:restriction>
          </xsd:simpleType>
        </xsd:element>
        <xsd:element name="CAMERA_LOCATION" type="jp:tLocation" minOccurs="0"/>
        <xsd:element name="ORIENTATION" type="jp:tDirection" minOccurs="0"/>
        <xsd:element name="PAR" type="jp:tRational" minOccurs="0"/>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>
```

```
<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.8 Scanner Capture metadata
  -->
<xsd:element name="SCANNER_CAPTURE">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SCANNER_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="SOFTWARE_INFO" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element ref="jp:SCANNER_SETTINGS" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.9 Scanner Settings metadata
  -->
<xsd:element name="SCANNER_SETTINGS">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="PIXEL_SIZE" type="jp:tNonNegativeDouble" minOccurs="0"/>
      <xsd:element name="PHYSICAL_SCAN_RES" type="jp:tDoubleSize" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.10 Software Creation metadata
  -->
<xsd:element name="SOFTWARE_CREATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SOFTWARE_INFO"   type="jp:tProductDetails"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.11 Captured Item metadata
  -->
<xsd:element name="CAPTURED_ITEM">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:choice>
        <xsd:element ref="jp:REFLECTION_PRINT" minOccurs="0"/>
        <xsd:element ref="jp:FILM" minOccurs="0"/>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.12 Reflection Print metadata
  -->
<xsd:element name="REFLECTION_PRINT">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="DOCUMENT_SIZE" type="jp:tDoubleSize" minOccurs="0"/>
      <xsd:element name="MEDIUM" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Continuous Tone Image"/>
            <xsd:enumeration value="Halftone Image"/>
            <xsd:enumeration value="Line Art"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="RP_TYPE" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="B/W Print"/>
            <xsd:enumeration value="Color Print"/>
            <xsd:enumeration value="B/W Document"/>
            <xsd:enumeration value="Color Document"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
```

```
<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.1.13 Film metadata
  -->
<xsd:element name="FILM">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="BRAND" type="jp:tProductDetails" minOccurs="0"/>
      <xsd:element name="CATEGORY" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="Negative B/W"/>
            <xsd:enumeration value="Negative Color"/>
            <xsd:enumeration value="Reversal B/W"/>
            <xsd:enumeration value="Reversal Color"/>
            <xsd:enumeration value="Chromagenic"/>
            <xsd:enumeration value="Internegative B/W"/>
            <xsd:enumeration value="Internegative Color"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="FILM_SIZE" type="jp:tDoubleSize" minOccurs="0"/>
      <xsd:element name="ROLL_ID" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="FRAME_ID" type="xsd:positiveInteger" minOccurs="0"/>
      <xsd:element name="FILM_SPEED" type="xsd:positiveInteger" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>



<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.2: Content Description metadata
  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -->
<xsd:element name="CONTENT_DESCRIPTION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="GROUP_CAPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="CAPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="CAPTURE_TIME" type="jp:tDateTime" minOccurs="0"/>
      <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
      <xsd:element ref="jp:PERSON" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:THING" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:ORGANIZATION" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:EVENT" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:AUDIO" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:DICTIONARY" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.2.1 Person Description metadata
  -->
<xsd:element name="PERSON">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tPerson">
        <xsd:sequence>
          <xsd:element name="POSITION" type="jp:tPosition" minOccurs="0"/>
          <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
          <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
        </xsd:sequence>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.2.2 Thing Description metadata
  -->
<xsd:element name="THING">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
      <xsd:element name="POSITION" type="jp:tPosition" minOccurs="0"/>
      <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
      <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
      <xsd:element ref="jp:THING" minOccurs="0" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
```

```
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.2.3 Organization Description metadata
    -->
  <xsd:element name="ORGANIZATION">
    <xsd:complexType>
      <xsd:complexContent>
        <xsd:extension base="jp:tOrganization">
          <xsd:sequence>
            <xsd:element name="POSITION" type="jp:tPosition" minOccurs="0"/>
            <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
            <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
          </xsd:sequence>
        </xsd:extension>
      </xsd:complexContent>
    </xsd:complexType>
  </xsd:element>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.2.4 Event Description metadata
    -->
  <xsd:element name="EVENT">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="EVENT_TYPE" type="jp:tLangString"/>
        <xsd:element name="DESCRIPTION" type="jp:tLangString" minOccurs="0"/>
        <xsd:element name="LOCATION" type="jp:tLocation" minOccurs="0"/>
        <xsd:element name="EVENT_TIME" type="jp:tDateTime" minOccurs="0"/>
        <xsd:element name="DURATION" type="xsd:duration" minOccurs="0"/>
        <xsd:element ref="jp:COMMENT" minOccurs="0"/>
        <xsd:element ref="jp:PARTICIPANT" minOccurs="0" maxOccurs="unbounded"/>
        <xsd:element ref="jp:EVENT_RELATION" minOccurs="0" maxOccurs="unbounded"/>
        <!-- Sub-events -->
        <xsd:choice minOccurs="0" maxOccurs="unbounded">
          <xsd:element ref="jp:EVENT"/>
          <xsd:element name="EVENT_REF" type="xsd:string"/>
        </xsd:choice>
      </xsd:sequence>
      <xsd:attribute name="ID" type="xsd:string"/>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.2.5 Participant metadata
    -->
  <xsd:element name="PARTICIPANT">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="ROLE" type="jp:tLangString" minOccurs="0"
                                                                 maxOccurs="unbounded"/>
        <xsd:choice>
          <xsd:element name="OBJECT_REF" type="xsd:string"/>
          <xsd:element ref="jp:PERSON"/>
          <xsd:element ref="jp:THING"/>
          <xsd:element ref="jp:ORGANIZATION"/>
        </xsd:choice>
      </xsd:sequence>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.2.6 Event Relationship metadata
    -->
  <xsd:element name="EVENT_RELATION">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="RELATION" type="jp:tLangString" minOccurs="0"

maxOccurs="unbounded"/>
        <xsd:element name="EVENT_REF" type="xsd:string" maxOccurs="unbounded"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>


  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.2.7 Audio metadata
    -->
  <xsd:element name="AUDIO">
    <xsd:complexType>
      <xsd:sequence>
```

```
      <xsd:element name="AUDIO_STREAM" type="xsd:anyURI"/>
      <xsd:element name="AUDIO_FORMAT" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="MIME_TYPE" type="xsd:string" minOccurs="0"/>
      <xsd:element name="DESCRIPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.2.8 Property metadata
  -->
<xsd:element name="PROPERTY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="VALUE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
      <xsd:element ref="jp:PROPERTY" minOccurs="0" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="DICT_REF" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.2.9 Dictionary Definition metadata
  -->
<xsd:element name="DICTIONARY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="DICT_NAME" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:COMMENT" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute name="DICT_ID" type="xsd:string"/>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>



<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.3 Metadata History metadata
  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -->
<xsd:element name="HISTORY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="jp:PROCESSING_SUMMARY" minOccurs="0"/>
      <xsd:element ref="jp:IMAGE_PROCESSING_HINTS" minOccurs="0"/>
      <xsd:element name="METADATA" minOccurs="0" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element ref="jp:IMAGE_CREATION" minOccurs="0"/>
            <xsd:element ref="jp:CONTENT_DESCRIPTION" minOccurs="0"/>
            <xsd:element ref="jp:HISTORY" minOccurs="0"/>
            <xsd:element ref="jp:IPR" minOccurs="0"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.3.1 Processing Summary metadata
  -->
<xsd:element name="PROCESSING_SUMMARY">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IMG_CREATED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_CROPPED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_TRANSFORMED" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
      <xsd:element name="IMG_GTC_ADJ" minOccurs="0">
        <xsd:complexType/>
      </xsd:element>
```

```
        <xsd:element name="IMG_STC_ADJ" minOccurs="0">
          <xsd:complexType/>
        </xsd:element>
        <xsd:element name="IMG_SPATIAL_ADJ" minOccurs="0">
          <xsd:complexType/>
        </xsd:element>
        <xsd:element name="IMG_EXT_EDITED" minOccurs="0">
          <xsd:complexType/>
        </xsd:element>
        <xsd:element name="IMG_RETOUCHED" minOccurs="0">
          <xsd:complexType/>
        </xsd:element>
        <xsd:element name="IMG_COMPOSITED" minOccurs="0">
          <xsd:complexType/>
        </xsd:element>
        <xsd:element name="IMG_METADATA" minOccurs="0">
          <xsd:complexType/>
        </xsd:element>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.3.2 Image Processing Hints metadata
    -->
  <xsd:element name="IMAGE_PROCESSING_HINTS">
    <xsd:complexType>
      <xsd:sequence>
      <xsd:element name="MODIFIER" type="jp:tProductDetails" minOccurs="0"/>
        <xsd:choice minOccurs="0" maxOccurs="unbounded">
          <xsd:element name="IMG_CREATED" type="jp:tLangString"/>
          <xsd:element name="IMG_CROPPED" type="jp:tLangString"/>
          <xsd:element name="IMG_TRANSFORMED" type="jp:tLangString"/>
          <xsd:element name="IMG_GTC_ADJ" type="jp:tLangString"/>
          <xsd:element name="IMG_STC_ADJ" type="jp:tLangString"/>
          <xsd:element name="IMG_SPATIAL_ADJ" type="jp:tLangString"/>
          <xsd:element name="IMG_EXT_EDITED" type="jp:tLangString"/>
          <xsd:element name="IMG_RETOUCHED" type="jp:tLangString"/>
          <xsd:element name="IMG_COMPOSITED" type="jp:tLangString"/>
          <xsd:element name="IMG_METADATA" type="jp:tLangString"/>
        </xsd:choice>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>



 <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.4 Intellectual Property Rights metadata
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -->
  <xsd:element name="IPR">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element ref="jp:IPR_NAMES" minOccurs="0"/>
        <xsd:element ref="jp:IPR_DESCRIPTION" minOccurs="0"/>
        <xsd:element ref="jp:IPR_DATES" minOccurs="0"/>
        <xsd:element ref="jp:IPR_EXPLOITATION" minOccurs="0"/>
        <xsd:element ref="jp:IPR_IDENTIFICATION" minOccurs="0"/>
        <xsd:element ref="jp:IPR_CONTACT_POINT" minOccurs="0"/>
        <xsd:element name="IPR_HISTORY" minOccurs="0">
          <xsd:complexType>
            <xsd:sequence>
              <xsd:element ref="jp:IPR" minOccurs="0" maxOccurs="unbounded"/>
            </xsd:sequence>
          </xsd:complexType>
        </xsd:element>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.4.1:IPR Names metadata
    -->
  <xsd:element name="IPR_NAMES">
    <xsd:complexType>
      <xsd:choice maxOccurs="unbounded">
        <xsd:element ref="jp:IPR_PERSON"/>
        <xsd:element ref="jp:IPR_ORG"/>
        <xsd:element ref="jp:IPR_NAME_REF"/>
      </xsd:choice>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
```

```
</xsd:element>

<xsd:element name="IPR_PERSON">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tPerson">
        <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>

<xsd:element name="IPR_ORG">
  <xsd:complexType>
    <xsd:complexContent>
      <xsd:extension base="jp:tOrganization">
        <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
</xsd:element>

<xsd:element name="IPR_NAME_REF">
  <xsd:complexType>
    <xsd:simpleContent>
      <xsd:extension base="xsd:string">
        <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.4.2 IPR Description metadata
  -->
<xsd:element name="IPR_DESCRIPTION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_TITLE" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_LEGEND" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_CAPTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="COPYRIGHT" type="jp:tLangString" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.4.3 IPR Dates metadata
  -->
<xsd:element name="IPR_DATES">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_DATE" maxOccurs="unbounded">
        <xsd:complexType>
          <xsd:complexContent>
            <xsd:extension base="jp:tDateTime">
              <xsd:attribute name="DESCRIPTION" type="xsd:string"/>
            </xsd:extension>
          </xsd:complexContent>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.4.4 IPR Exploitation metadata
  -->
<xsd:element name="IPR_EXPLOITATION">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="IPR_PROTECTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_USE_RESTRICTION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element name="IPR_OBLIGATION" type="jp:tLangString" minOccurs="0"/>
      <xsd:element ref="jp:IPR_MGMT_SYS" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute ref="jp:TIMESTAMP"/>
    <xsd:attribute ref="xml:lang"/>
  </xsd:complexType>
</xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  -  See section Annex N.6.4.5 IPR Management System metadata
```

```
    -->
  <xsd:element name="IPR_MGMT_SYS">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="IPR_MGMT_TYPE" type="xsd:string" minOccurs="0"/>
        <xsd:element name="IPR_MGMT_SYS_ID" type="xsd:string" minOccurs="0"/>
        <xsd:element name="IPR_MGMT_SYS_LOCATION" type="xsd:anyURI" minOccurs="0"/>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.4.6 IPR Identification metadata
    -->
  <xsd:element name="IPR_IDENTIFICATION">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element ref="jp:IPR_IDENTIFIER" minOccurs="0"/>
        <xsd:element ref="jp:LICENCE_PLATE" minOccurs="0"/>
      </xsd:sequence>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.4.7 Generic IPR Identifier metadata
    -->
  <xsd:element name="IPR_IDENTIFIER">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="IPR_ID_MODE" type="jp:tLangString" minOccurs="0"/>
        <xsd:element name="IPR_ID" type="jp:tLangString" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.4.8 License Plate metadata
    -->
  <xsd:element name="LICENCE_PLATE">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="LP_COUNTRY" type="xsd:string" minOccurs="0"/>
        <xsd:element name="LP_REG_AUT" type="xsd:string" minOccurs="0"/>
        <xsd:element name="LP_REG_NUM" type="xsd:string" minOccurs="0"/>
        <xsd:element name="DELIVERY_DATE" type="xsd:dateTime" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>

  <!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.4.9 IPR Contact Point metadata
    -->
  <xsd:element name="IPR_CONTACT_POINT">
    <xsd:complexType>
      <xsd:choice>
        <xsd:element ref="jp:IPR_PERSON"/>
        <xsd:element ref="jp:IPR_ORG"/>
        <xsd:element ref="jp:IPR_NAME_REF"/>
      </xsd:choice>
      <xsd:attribute ref="jp:TIMESTAMP"/>
      <xsd:attribute ref="xml:lang"/>
    </xsd:complexType>
  </xsd:element>

<!-- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    -  See section Annex N.6.5 Image Identifier metadata
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -->
  <xsd:element name="IMAGE_ID">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="UID" type="xsd:string" minOccurs="0"/>
        <xsd:element name="ID_TYPE" type="xsd:anyURI" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>

</xsd:schema>
```

Annex O

Examples and guidelines, extensions

(This annex does not form an integral part of this Recommendation | International Standard)

O.1 Arbitrary decomposition examples

Figure O.1 shows an example wavelet decomposition achieveable through this Recommendation | International Standard along with the appropriate syntax strings $d_\theta()$, $d_R()$ and $d_S()$ (see Annex F). Figures O.2 through O.14 show how each syntax string element is interpreted in order to obtain the full decomposition structure in Figure O.1, with the elements underlined that lead to the stage shown. Sub-band labels are then inserted as the θ_{cnt} variable from Figure F.13 reaches its maximum value or a syntax element of zero is encountered in the $d_S()$ string. Figure O.15 shows a more complicated decomposition which was developed by the United States Federal Bureau of Investigation (FBI) for compression of fingerprint images and Figures O.16 through O.30 show the interpretation of the syntax elements. To alleviate crowding, most of the sub-bands in the three lowest resolutions of Figure O.15 are labelled with superscript indices which indicate the actual sub-band labels via Table O.1. Finally, Figure O.31 shows the so-called SPACL (an acronym for the "Signal Processing and Coding Lab" at the University of Arizona) decomposition.

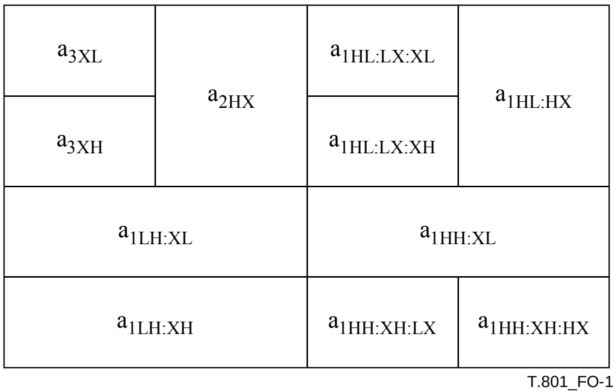


Figure O.1 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = 31$; $I_S = 9$, $d_S() = 320300203$

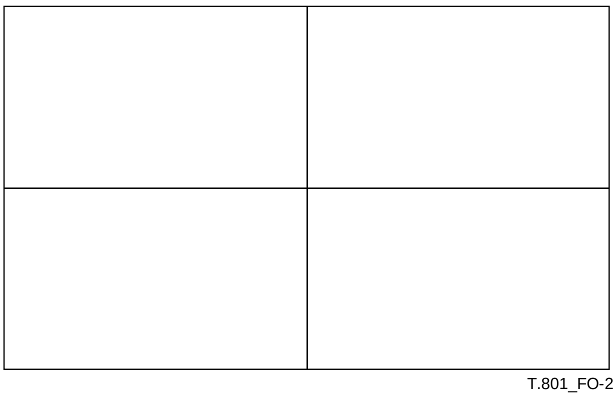
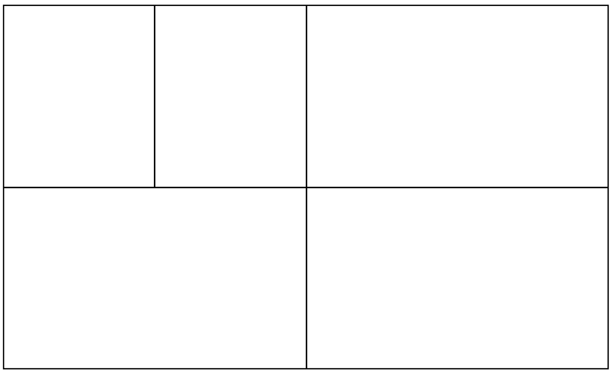
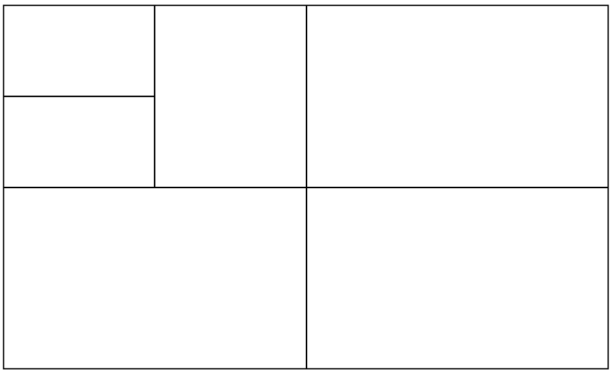


Figure O.2 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = \underline{1}23$; $I_\theta = 2$, $d_\theta() = 31$; $I_S = 9$, $d_S() = 320300203$



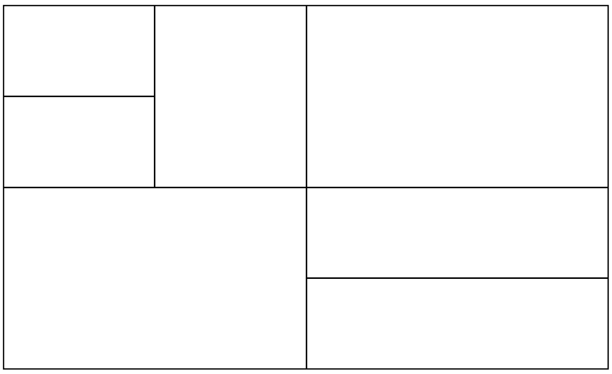
T.801_FO-3

Figure O.3 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 1\underline{2}3$; $I_\theta = 2$, $d_\theta() = 31$; $I_S = 9$, $d_S() = 320300203$



T.801_FO-4

Figure O.4 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 12\underline{3}$; $I_\theta = 2$, $d_\theta() = 31$; $I_S = 9$, $d_S() = 320300203$



T.801_FO-5

Figure O.5 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = \underline{3}1$; $I_S = 9$, $d_S() = \underline{3}20300203$

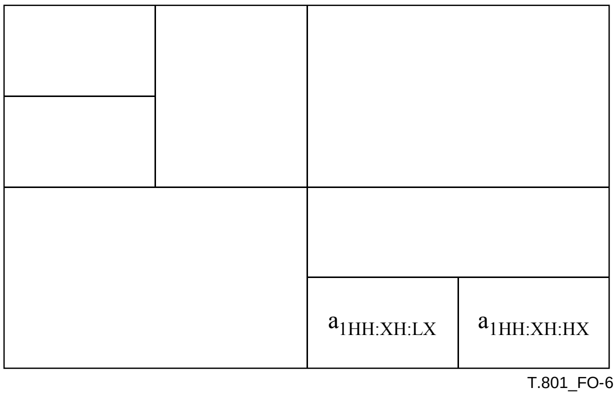


Figure O.6 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = \underline{3}1$; $I_S = 9$, $d_S() = 3\underline{2}0300203$

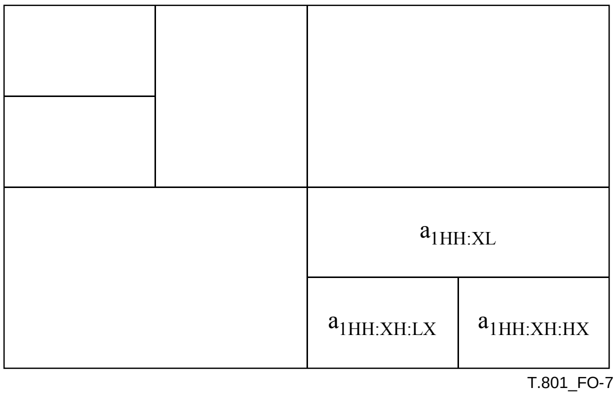


Figure O.7 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = \underline{3}1$; $I_S = 9$, $d_S() = 32\underline{0}300203$

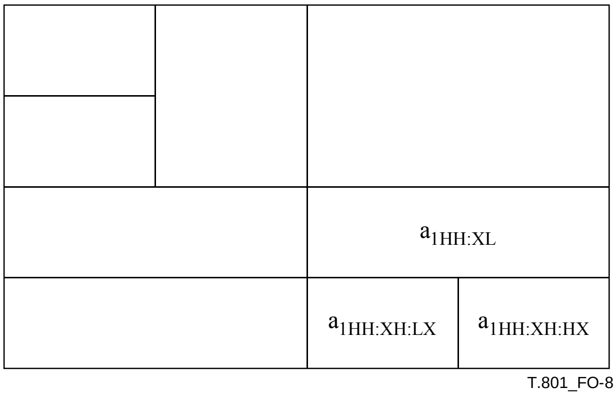


Figure O.8 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = \underline{3}1$; $I_S = 9$, $d_S() = 320\underline{3}00203$

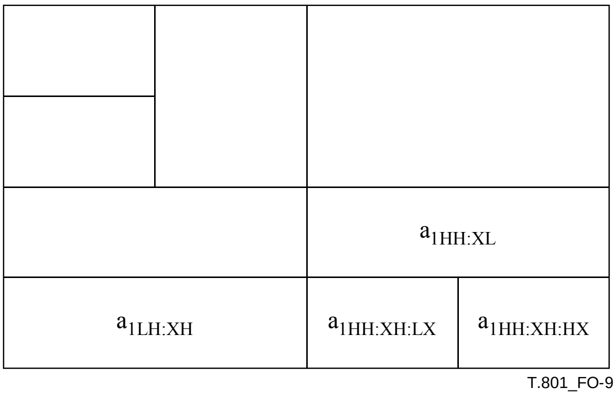


Figure O.9 – Sample wavelet decomposition: N_L = 3; I_R = 3; $d_R()$ = 123; I_θ = 2, $d_\theta()$ = $\underline{3}1$; I_S = 9, $d_S()$ = $3203\underline{0}0203$

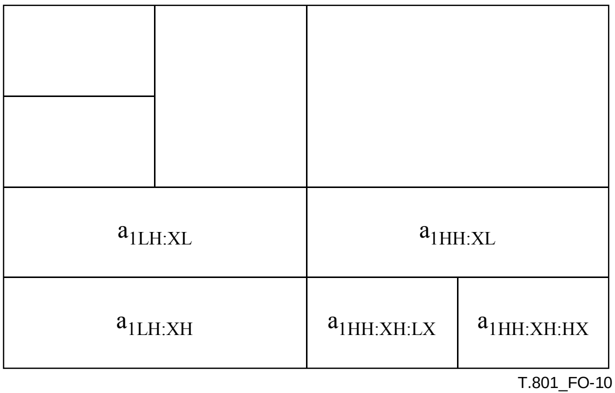


Figure O.10 – Sample wavelet decomposition: N_L = 3; I_R = 3; $d_R()$ = 123; I_θ = 2, $d_\theta()$ = $\underline{3}1$; I_S = 9, $d_S()$ = $32030\underline{0}203$

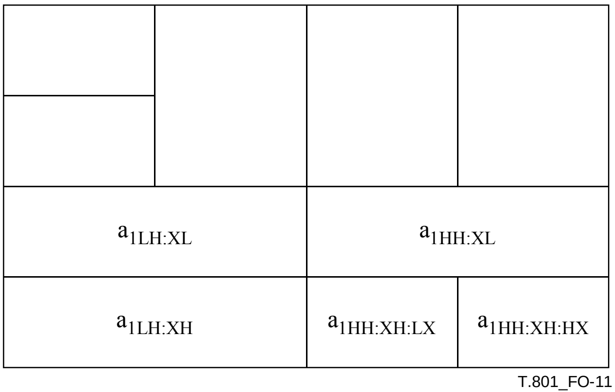


Figure O.11 – Sample wavelet decomposition: N_L = 3; I_R = 3; $d_R()$ = 123; I_θ = 2, $d_\theta()$ = $\underline{3}1$; I_S = 9, $d_S()$ = $320300\underline{2}03$

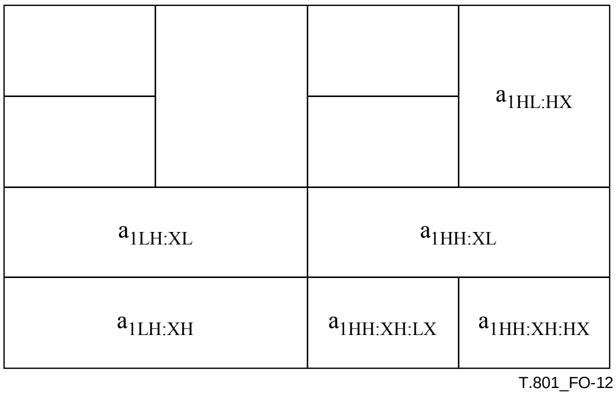


Figure O.12 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = \underline{3}1$; $I_S = 9$, $d_S() = 3203002\underline{0}3$

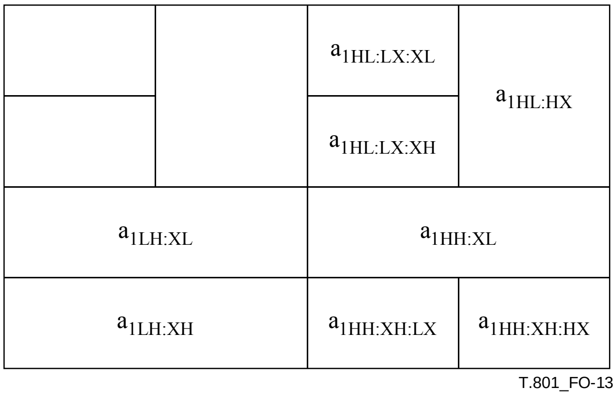


Figure O.13 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = \underline{3}1$; $I_S = 9$, $d_S() = 32030020\underline{3}$

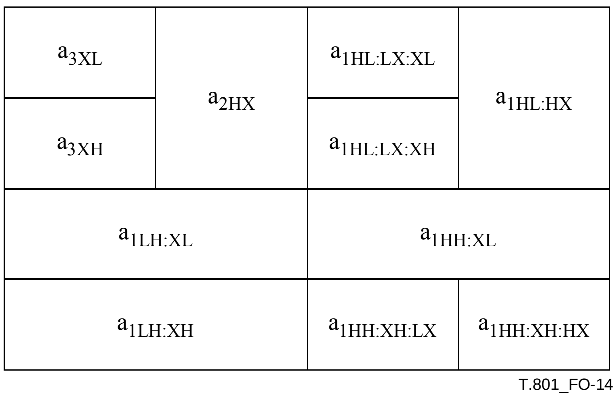


Figure O.14 – Sample wavelet decomposition: $N_L = 3$; $I_R = 3$; $d_R() = 123$; $I_\theta = 2$, $d_\theta() = 3\underline{1}$; $I_S = 9$, $d_S() = 320300203$

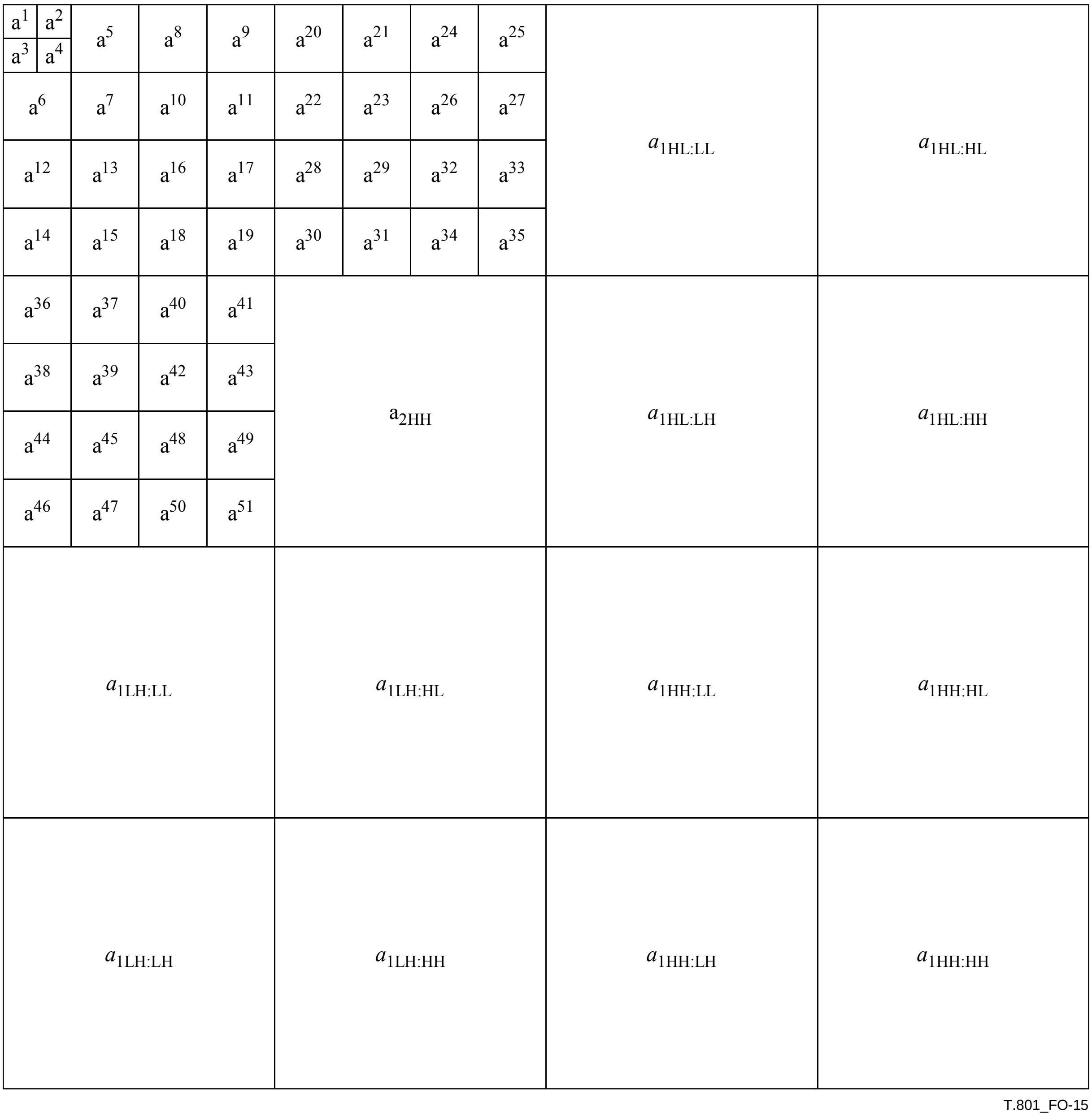


Figure O.15 – FBI decomposition: N_L = 5; I_R = 0; d_R() = 0 (since I_R = 0, I_R and d_R() get reset in Figure F.11 to I_R = 5 and d_R() = 11111); I_θ = 4, d_θ() = 2321; I_S = 17, d_S() = 11101111111111111

Table O.1 – Sub-band labels for Figure O.15.

Superscript label	Sub-band label
a^{1}	a_{5LL}
a^{2}	a_{5HL}
a^{3}	a_{5LH}
a^{4}	a_{5HH}
a^{5}	a_{4HL}
a^{6}	a_{4LH}
a^{7}	a_{4HH}
a^{8}	$a_{3HL:LL}$
a^{9}	$a_{3HL:HL}$
a^{10}	$a_{3HL:LH}$
a^{11}	$a_{3HL:HH}$
a^{12}	$a_{3LH:LL}$
a^{13}	$a_{3LH:HL}$
a^{14}	$a_{3LH:LH}$
a^{15}	$a_{3LH:HH}$
a^{16}	$a_{3HH:LL}$
a^{17}	$a_{3HH:HL}$

Superscript label	Sub-band label
a^{18}	$a_{3HH:LH}$
a^{19}	$a_{3HH:HH}$
a^{20}	$a_{2HL:LL:LL}$
a^{21}	$a_{2HL:LL:HL}$
a^{22}	$a_{2HL:LL:LH}$
a^{23}	$a_{2HL:LL:HH}$
a^{24}	$a_{2HL:HL:LL}$
a^{25}	$a_{2HL:HL:HL}$
a^{26}	$a_{2HL:HL:LH}$
a^{27}	$a_{2HL:HL:HH}$
a^{28}	$a_{2HL:LH:LL}$
a^{29}	$a_{2HL:LH:HL}$
a^{30}	$a_{2HL:LH:LH}$
a^{31}	$a_{2HL:LH:HH}$
a^{32}	$a_{2HL:HH:LL}$
a^{33}	$a_{2HL:HH:HL}$
a^{34}	$a_{2HL:HH:LH}$

Superscript label	Sub-band label
a^{35}	$a_{2HL:HH:HH}$
a^{36}	$a_{2LH:LL:LL}$
a^{37}	$a_{2LH:LL:HL}$
a^{38}	$a_{2LH:LL:LH}$
a^{39}	$a_{2LH:LL:HH}$
a^{40}	$a_{2LH:HL:LL}$
a^{41}	$a_{2LH:HL:HL}$
a^{42}	$a_{2LH:HL:LH}$
a^{43}	$a_{2LH:HL:HH}$
a^{44}	$a_{2LH:LH:LL}$
a^{45}	$a_{2LH:LH:HL}$
a^{46}	$a_{2LH:LH:LH}$
a^{47}	$a_{2LH:LH:HH}$
a^{48}	$a_{2LH:HH:LL}$
a^{49}	$a_{2LH:HH:HL}$
a^{50}	$a_{2LH:HH:LH}$
a^{51}	$a_{2LH:HH:HH}$

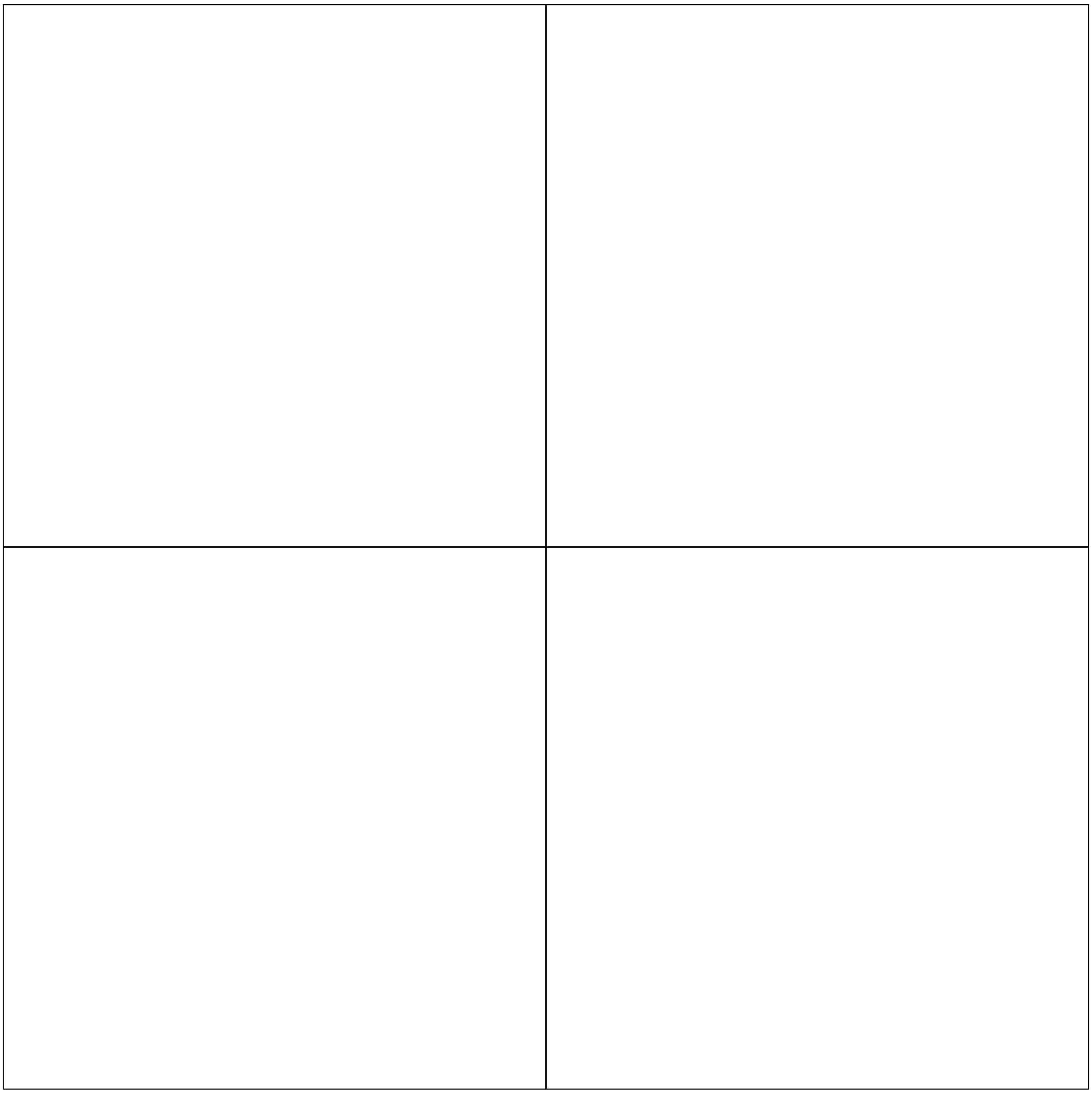
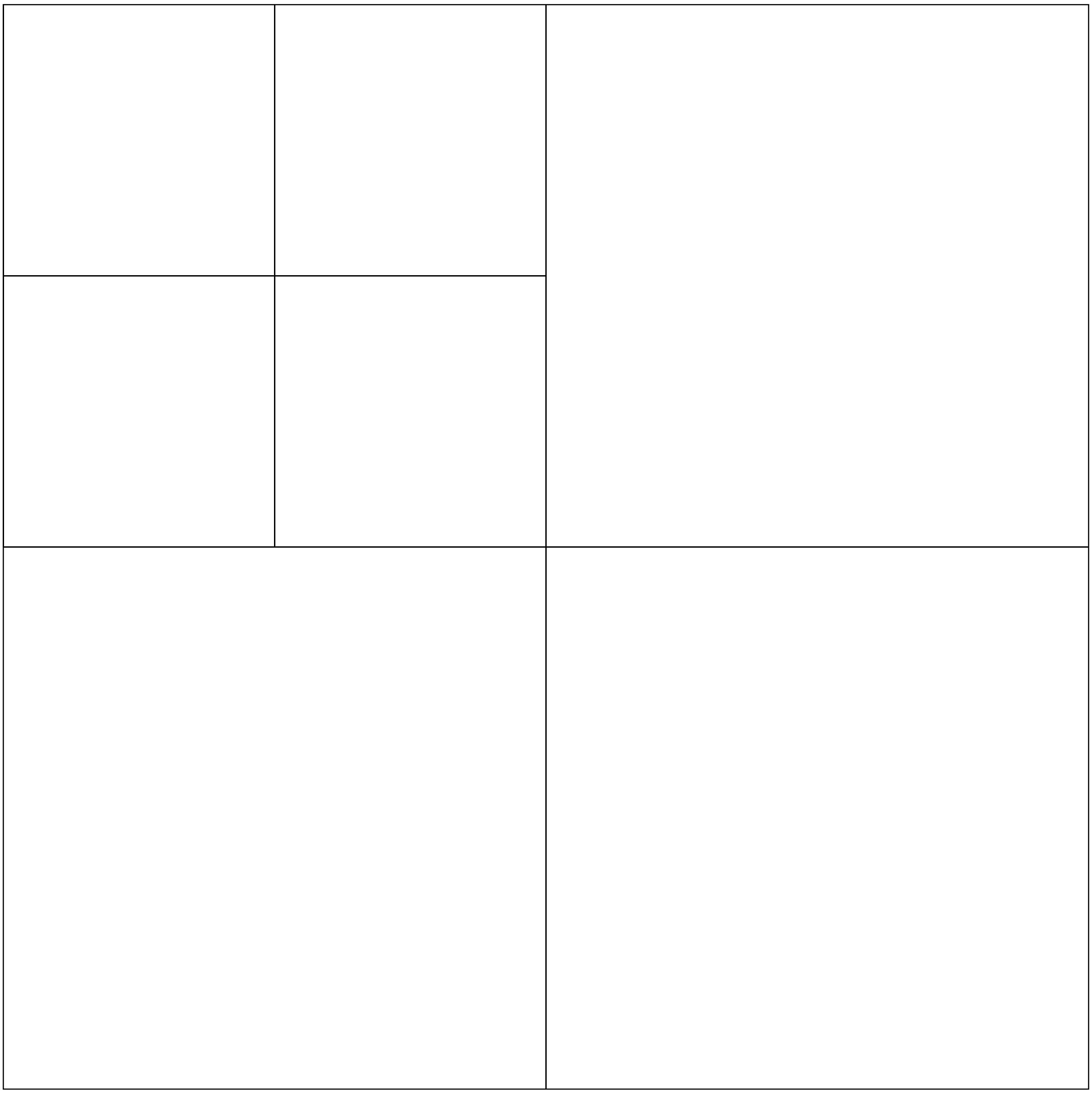


Figure O.16 – FBI decomposition: N_L = 5; I_R = 5 and $d_R() = \underline{1}1111$; I_θ = 4, $d_\theta()$ = 2321; I_S = 17, $d_S()$ = 11101111111111111



T.801_FO-17

Figure O.17 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 1\underline{1}111$; $I_\theta = 4$, $d_\theta() = 2321$; $I_S = 17$, $d_S() = 11101111111111111$

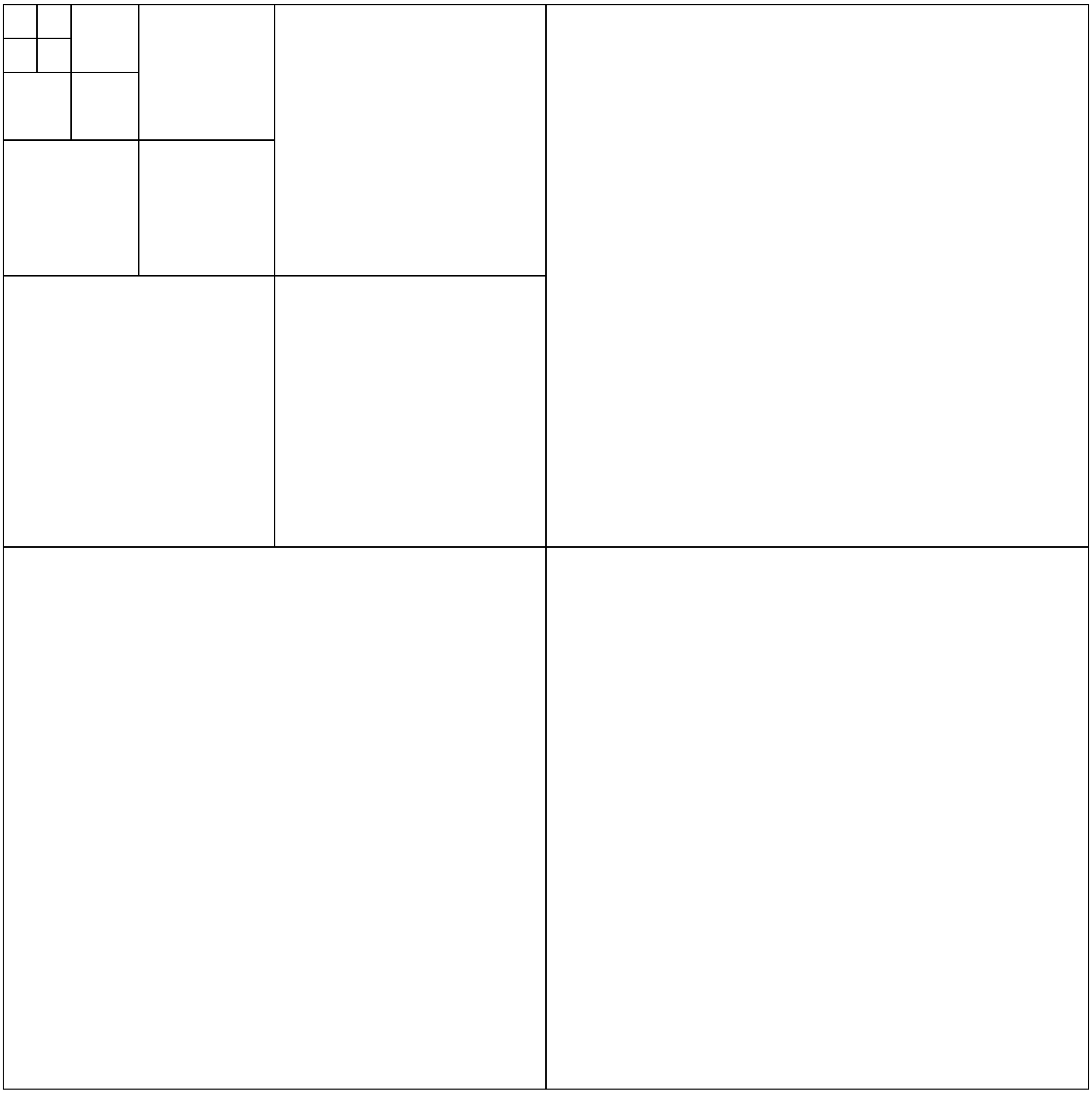


Figure O.18 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11<u>111</u>; I_θ = 4, $d_\theta()$ = 2321; I_S = 17, $d_S()$ = 11101111111111111

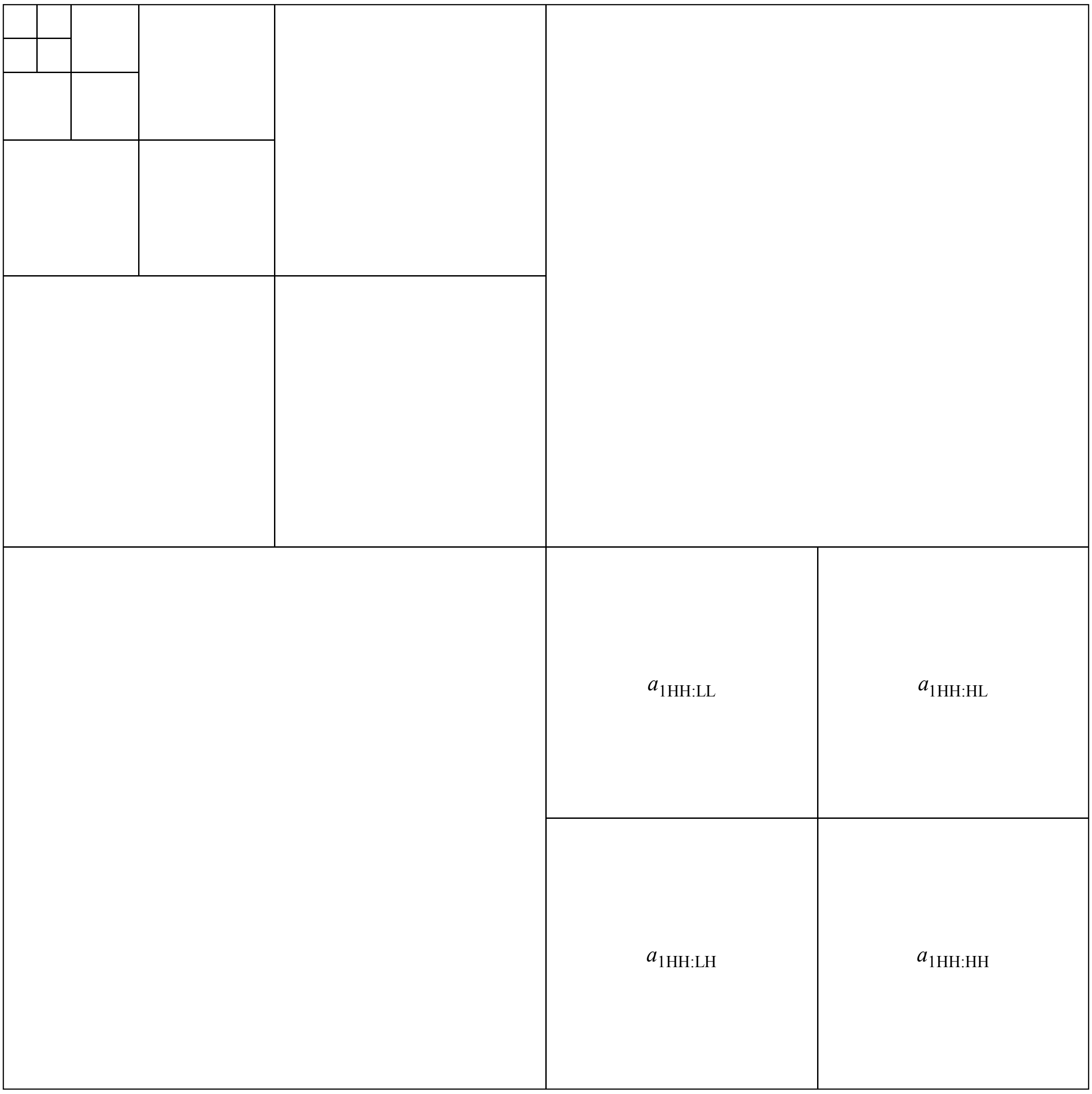


Figure O.19 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11111; I_θ = 4, $d_\theta()$ = $\underline{2}$321; I_S = 17, $d_S()$ = $\underline{1}$1101111111111111

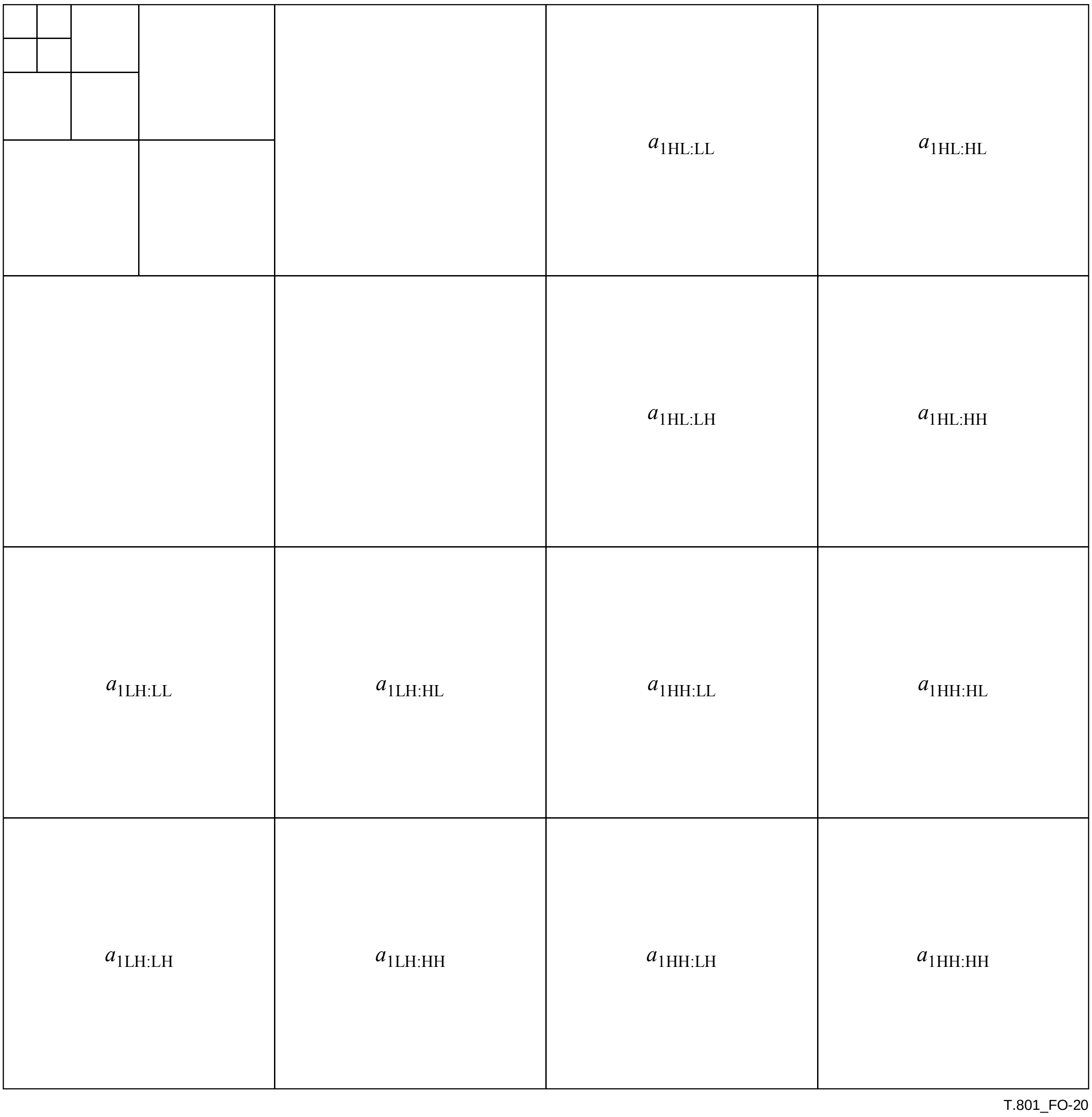


Figure O.20 – FBI decomposition: N_L = 5; I_R = 5 and d_R() = 11111; I_θ = 4, d_θ() = $\underline{2}$321; I_S = 17, d_S() = 1$\underline{11}$01111111111111

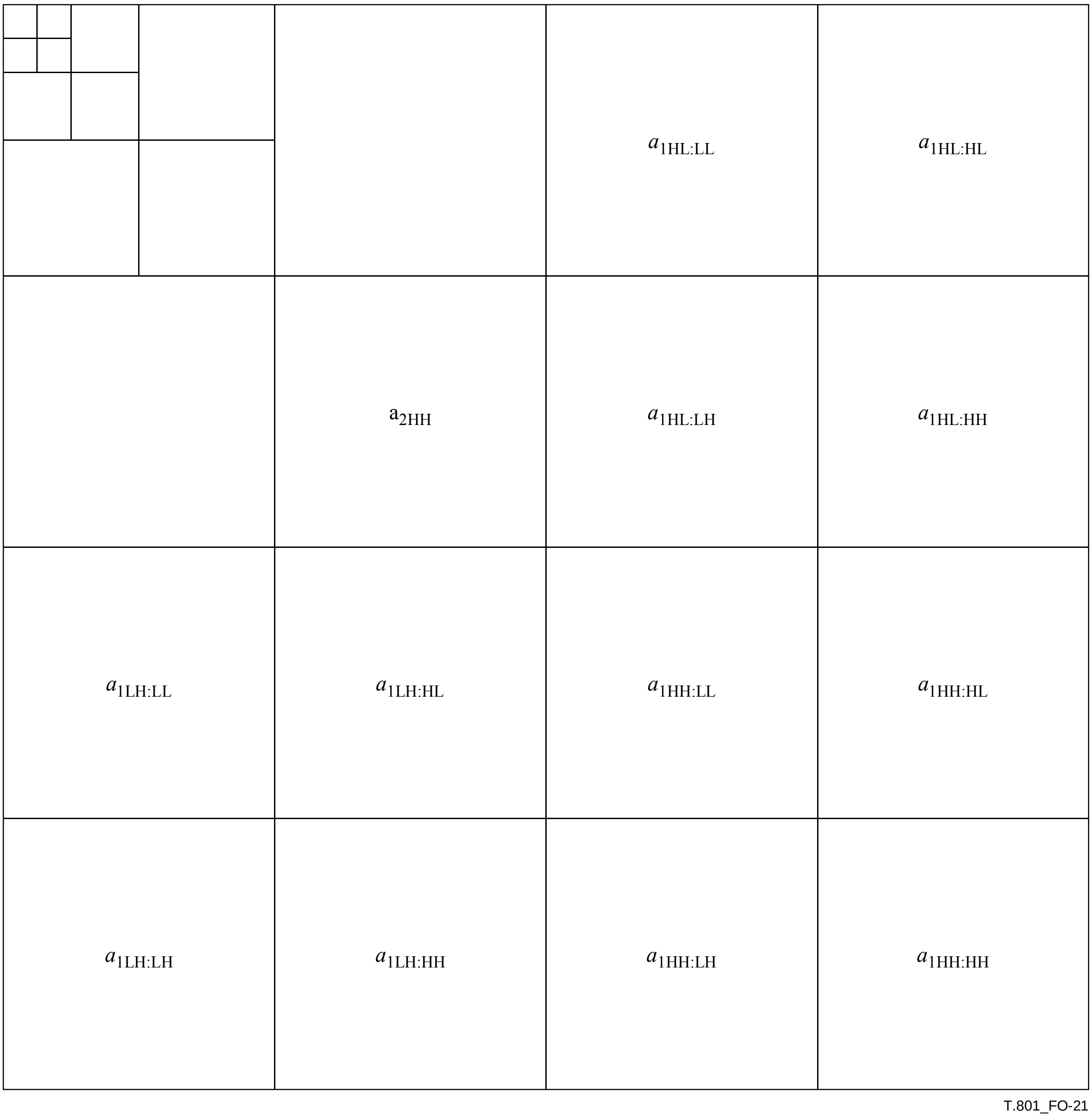


Figure O.21 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11111; I_θ = 4, $d_\theta()$ = 2$\underline{3}$21; I_S = 17, $d_S()$ = 111$\underline{0}$1111111111111

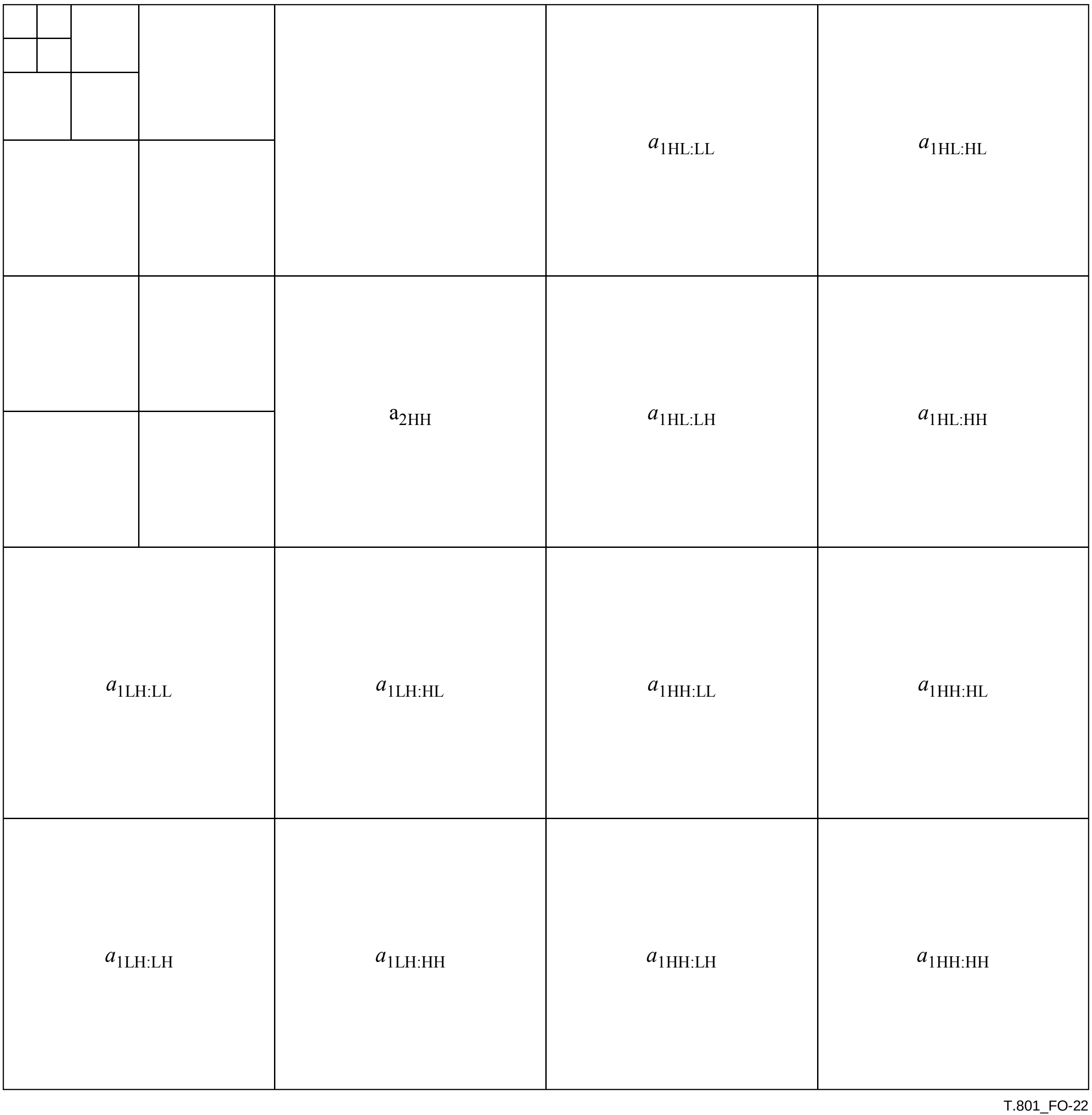


Figure O.22 – FBI decomposition: N_L = 5; I_R = 5 and d_R() = 11111; I_θ = 4, d_θ() = 2$\underline{3}$21; I_S = 17, d_S() = 1110$\underline{1}$111111111111

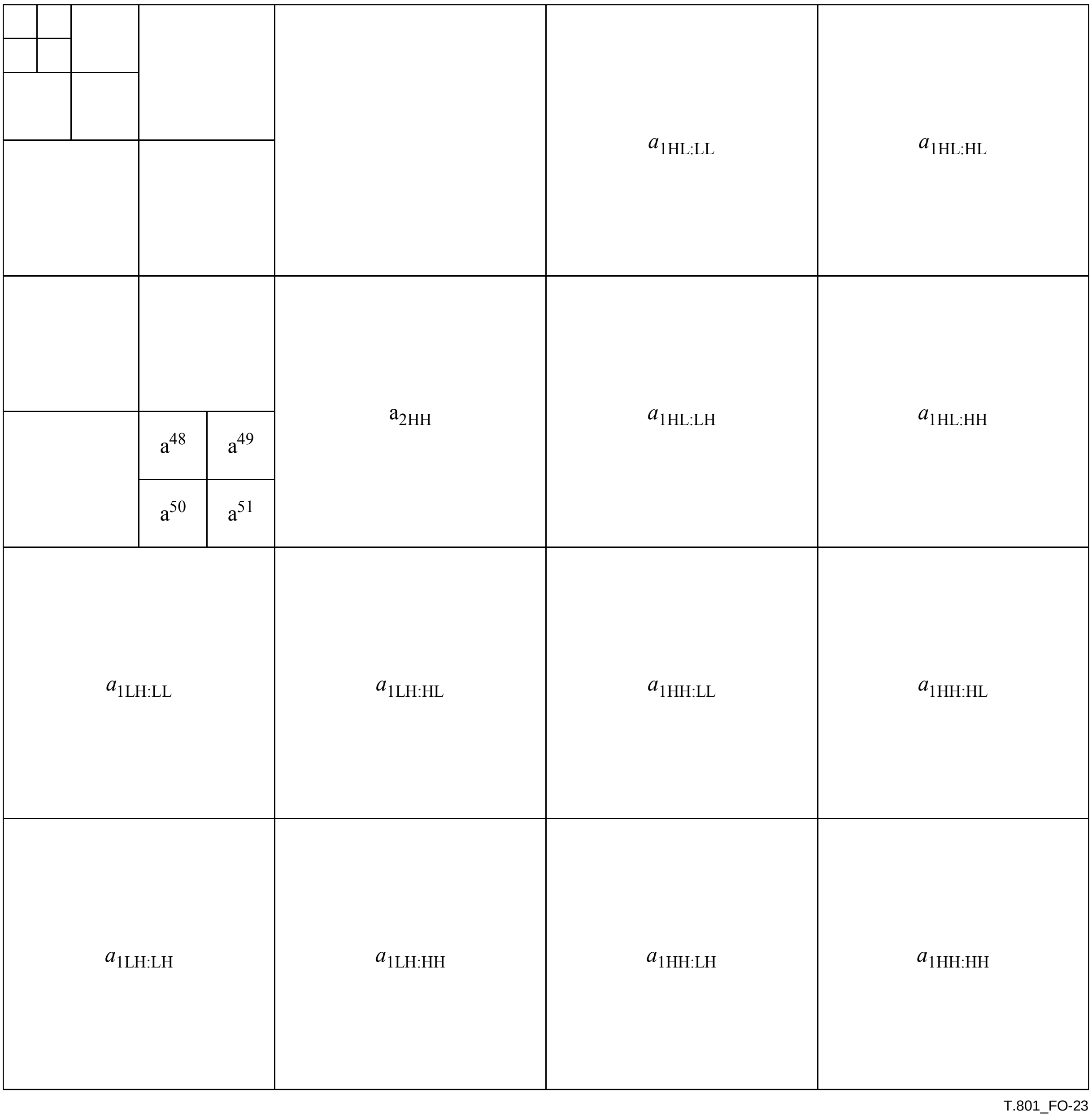


Figure O.23 – FBI decomposition: $N_L = 5$; $I_R = 5$ and $d_R() = 11111$; $I_\theta = 4$, $d_\theta() = 2\underline{3}21$; $I_S = 17$, $d_S() = 11101\underline{1}11111111111$

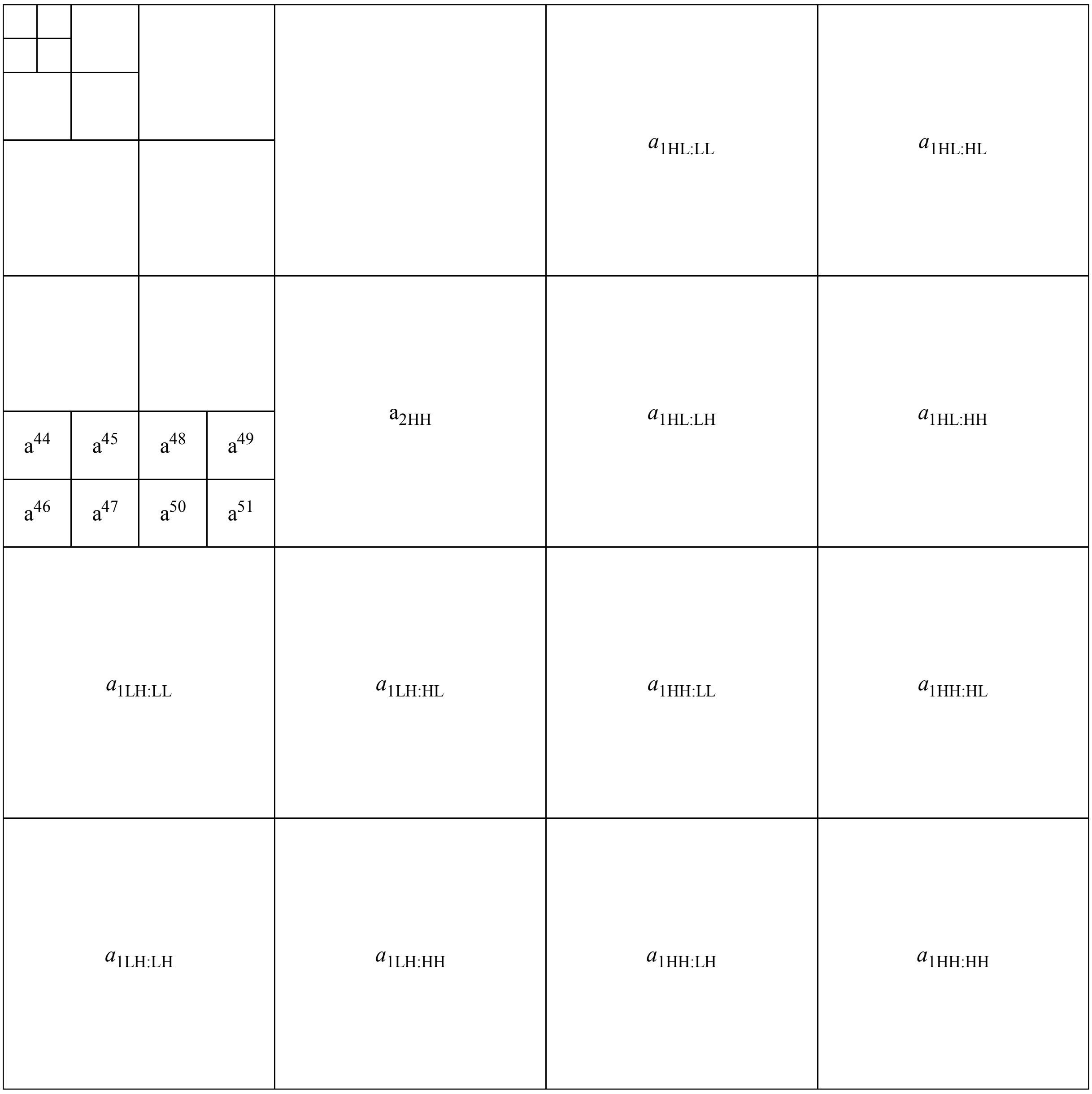
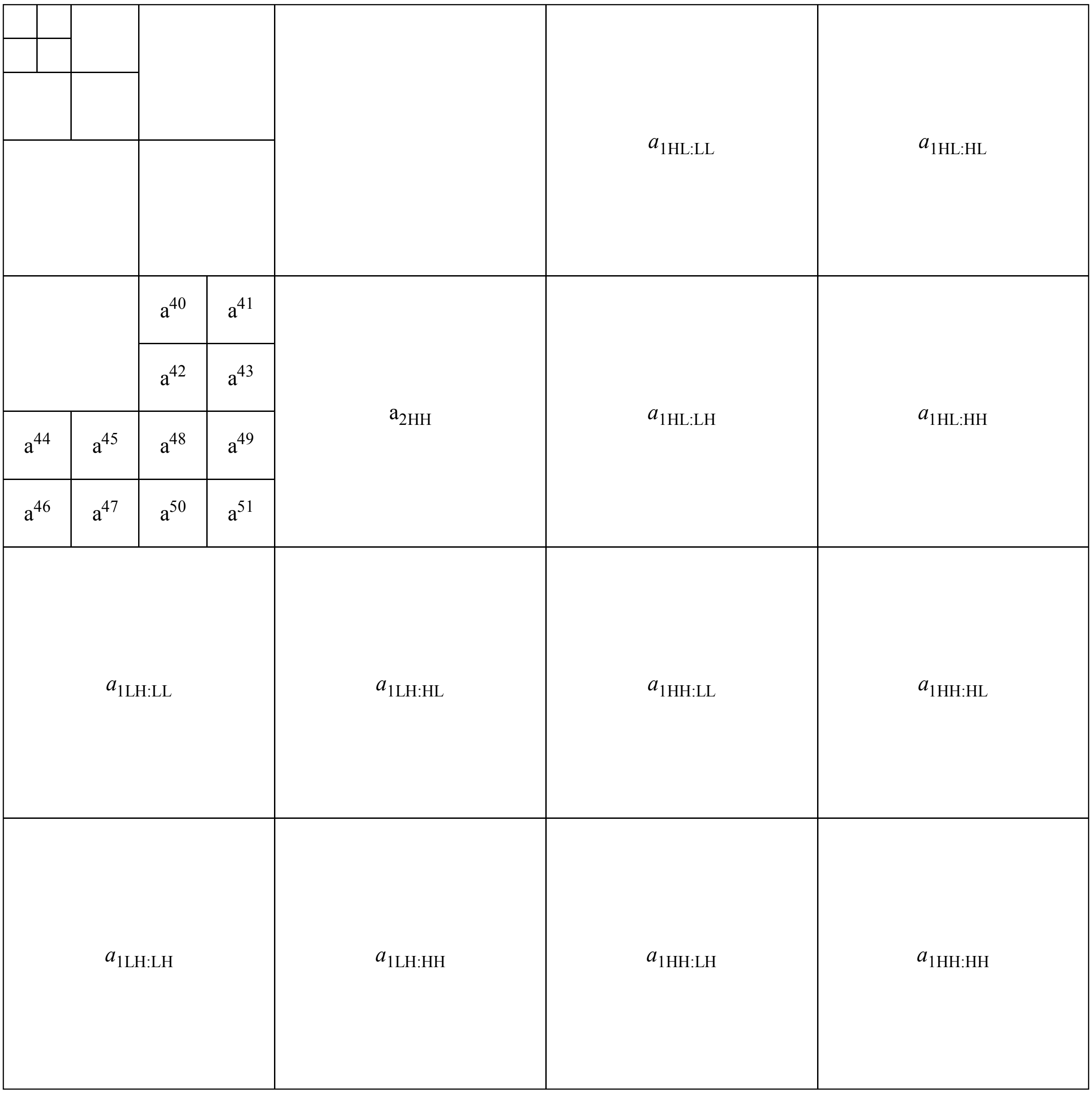
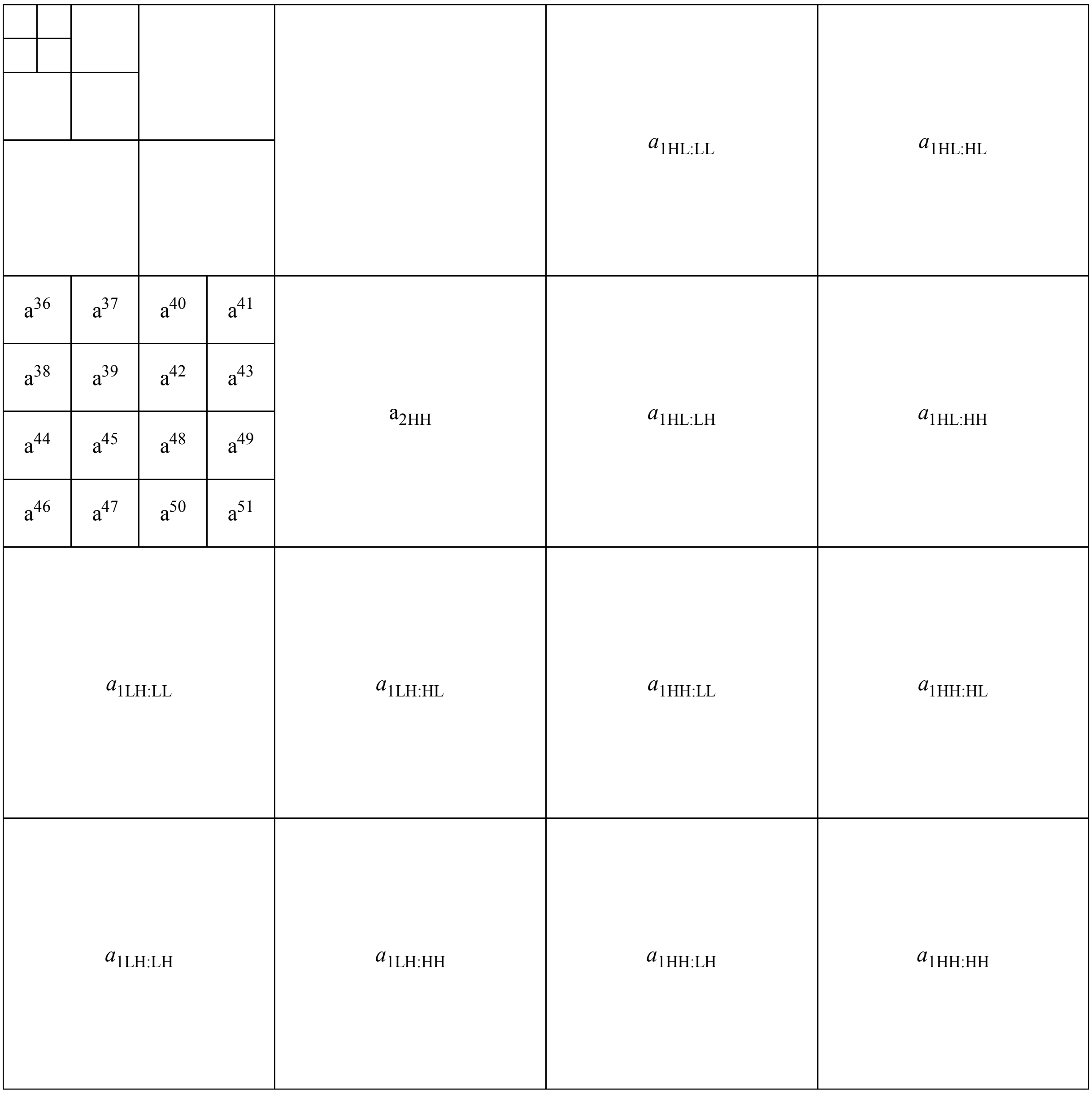


Figure O.24 – FBI decomposition: N_L = 5; I_R = 5 and d_R() = 11111; I_θ = 4, d_θ() = $2\underline{3}21$; I_S = 17, d_S() = $111011\underline{1}1111111111$



T.801_FO-25

Figure O.25 – FBI decomposition: N_L = 5; I_R = 5 and d_R() = 11111; I_θ = 4, d_θ() = 2$\underline{3}$21; I_S = 17, d_S() = 1110111$\underline{1}$111111111



T.801_FO-26

Figure O.26 – FBI decomposition: N_L = 5; I_R = 5 and d_R() = 11111; I_θ = 4, d_θ() = $2\underline{3}21$; I_S = 17, d_S() = $11101111\underline{1}11111111$

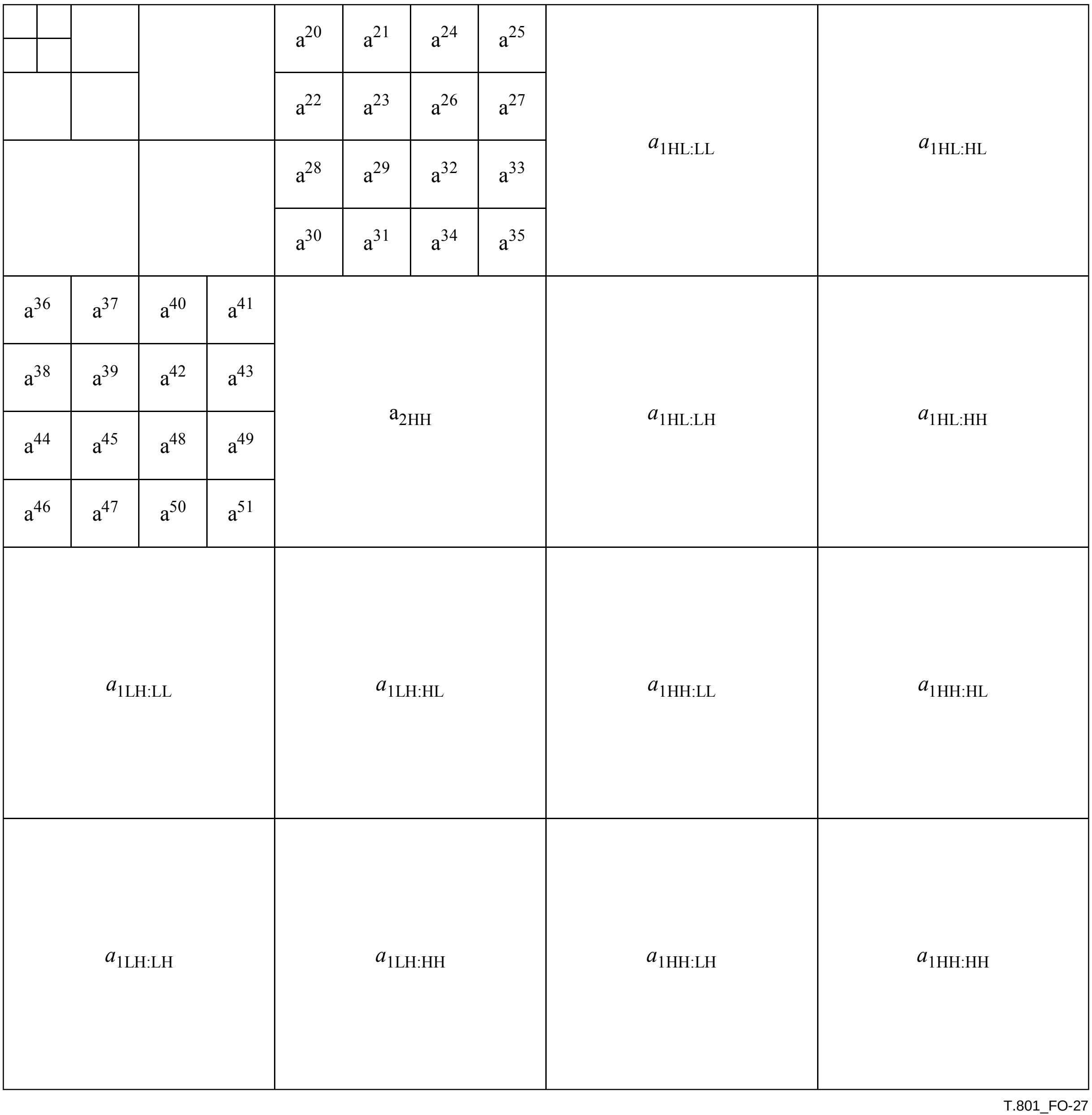
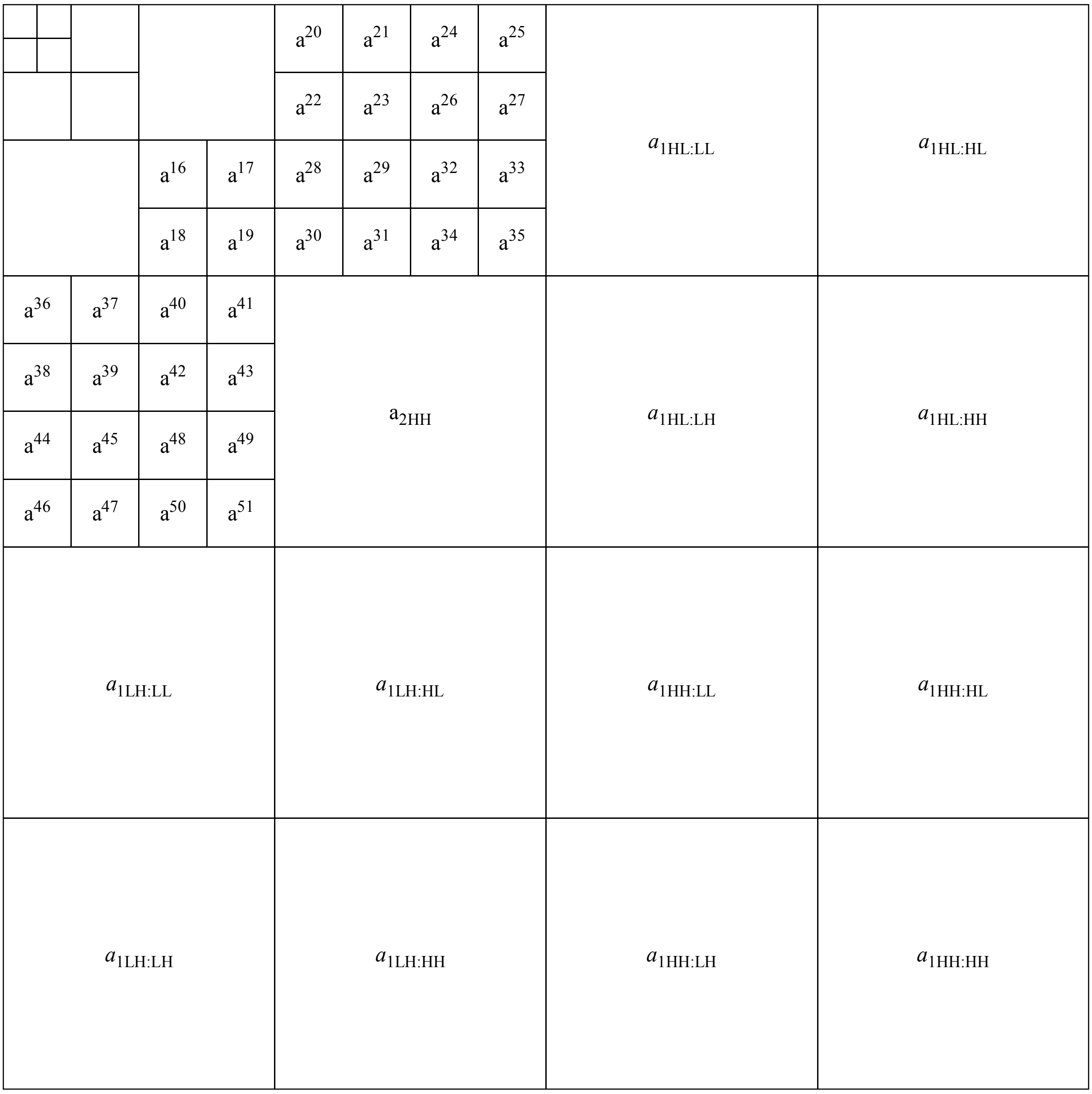
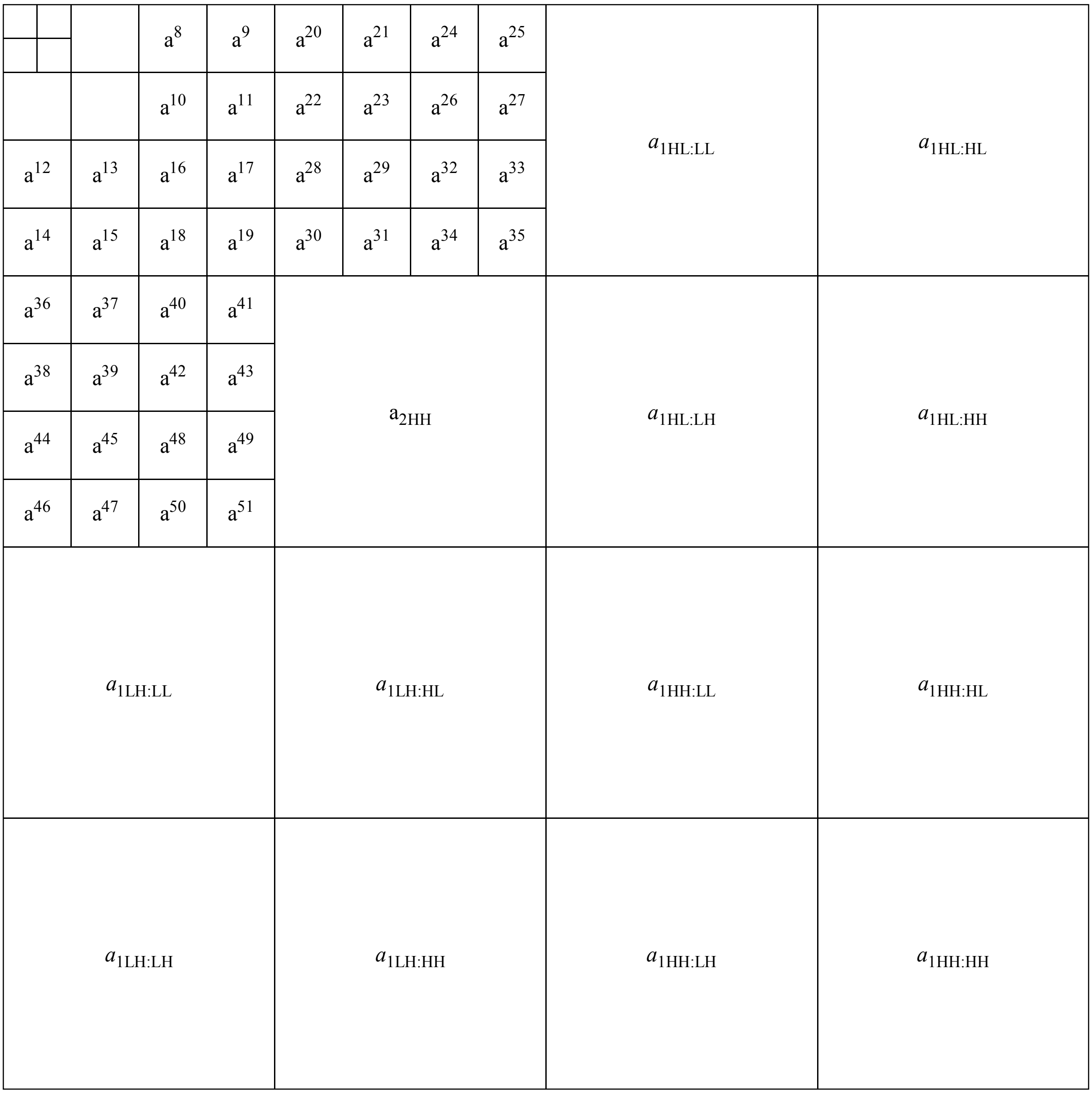


Figure O.27 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11111; I_θ = 4, $d_\theta()$ = $2\underline{3}21$; I_S = 17, $d_S()$ = $111011111\underline{11111}111$



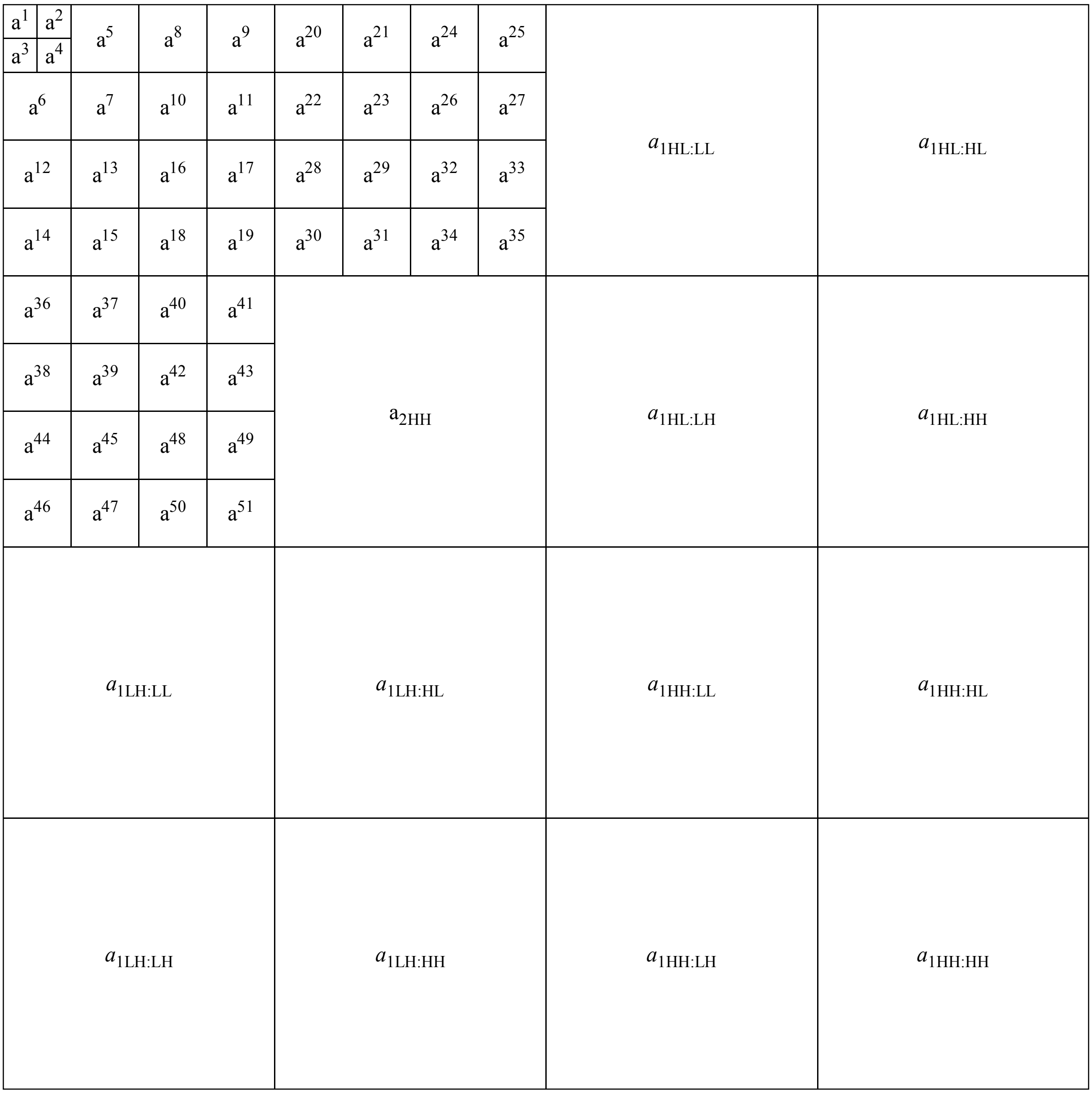
T.801_FO-28

Figure O.28 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11111; I_θ = 4, $d_\theta()$ = 23$\underline{2}$1; I_S = 17, $d_S()$ = 11101111111111$\underline{1}$11



T.801_FO-29

Figure O.29 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11111; I_θ = 4, $d_\theta()$ = 23$\underline{2}$1; I_S = 17, $d_S()$ = 111011111111111$\underline{11}$



T.801_FO-30

Figure O.30 – FBI decomposition: N_L = 5; I_R = 5 and $d_R()$ = 11111; I_θ = 4, $d_\theta()$ = $232\underline{1}$; I_S = 17, $d_S()$ = 11101111111111111

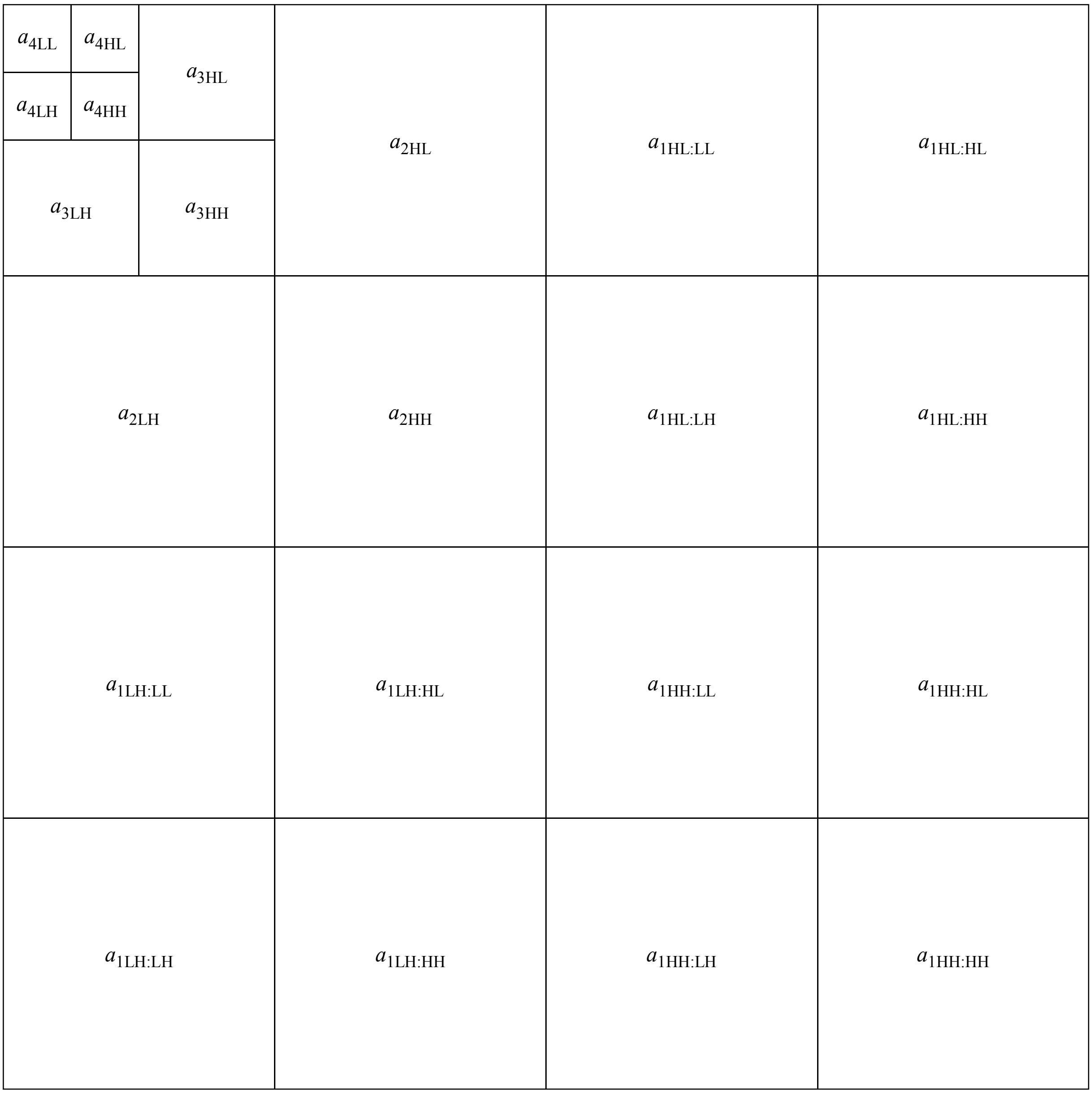


Figure O.31 – SPACL decomposition: $N_L = 4$; $I_\theta = 2$, $d_\theta() = 21$; $I_R = 0$, $I_S = 0$

O.2 Odd Tile Low Pass First (OTLPF) convention

This subclause shows how to reduce the tile boundary artefacts by using the OTLPF convention and how to implement the OTLPF convention by selecting the TSSO option with SSO and TBDWT options turned off.

It has been demonstrated [10] that tile boundary artefacts can be significantly reduced by avoiding high pass coefficients at the start and end of the tiles. As defined in ITU-T Rec. T.800 | ISO/IEC 15444-1, the low pass coefficients are always located on the even coordinates and the high pass coefficients are located on the odd coordinates of the reference grid regardless of the image and tile positions. Hence, to reduce tile boundary artefacts the tiles should start and end on even coordinates of the reference grid. However, this cannot be done without selecting the TSSO option as demonstrated below.

O.2.1 Example one (even tile sizes)

Assume an image of 512×512 samples, with tile sizes of XTsiz = YTsiz 128 and XOsiz = YOsiz = XTOsiz = YTOsiz = 0. If the TSSO is not selected, the tile boundary coordinates for each tile in the *x* and *y* directions are:

$$tx_0 x(x,\ q) = ty_0(p,\ y) = \{0,\ 128,\ 256,\ 384\} \quad \text{(O-1)}$$

$$tx_1(x,\ q) - 1 = ty_1(p,\ y) - 1 = \{127,\ 255,\ 383,\ 511\} \quad \text{(O-2)}$$

Each tile starts with an even coordinate at the top, left corner (Equation O-1) and ends with an odd coordinate at the bottom, right corner (Equation O-2). Hence all tiles start with low pass coefficients and end with high pass coefficients in both *x* and *y* directions. This will result in large tile boundary errors at the right and bottom boundaries of each tile.

O.2.2 Example two (odd tile sizes)

For the same conditions as defined in example one but with tile sizes of XTsiz = YTsiz = 129, the following exists:

$$xt_0(x,\ q) = ty_0(p,\ y) = \{0,\ 129,\ 257,\ 387\} \quad \text{(O-3)}$$

$$tx_1(x,\ q) - 1 = ty_1(p,\ y - 1) = \{128,\ 257,\ 386,\ 511\} \quad \text{(O-4)}$$

This shows that the first tile starts (0, 0) and ends (128, 128) with even coordinates hence having low pass coefficients at the boundaries for this tile. This will produce a better reconstructed tile as errors at all four boundaries now have the same order of magnitude as those inside the tile. The next tile starts (129, 0) and ends (257, 128) at odd coordinates hence having high pass coefficients at tile boundaries. This results in large errors at the tile boundaries in the reconstructed tile. This situation alternates for all tiles across the whole image.

Hence it can be seen that, by using an odd tile size and having low pass coefficients first, the tile will automatically end with low pass coefficients and artefacts at the tile boundaries can be reduced significantly. This technique is called the Odd Tile Low Pass First (OTLPF) convention.

The next example shows how the TSSO can be used to make every TSSO tile fulfil the two conditions of odd tile-size and low pass first.

O.2.3 Example three (TSSO/OTLPF)

For the same conditions as defined in example one, the tile sizes are XTsiz = YTsiz = 128, but now the tiles are overlapped to the right and to the bottom for one sample. Thus,

$$tx_0(x,\ q) = ty_0(p,\ y) = \{0,\ 128,\ 256,\ 384\} \quad \text{(O-5)}$$

$$tx_1(x,\ q) - 1 = ty_1(p,\ y) - 1 = \{128,\ 256,\ 384,\ 511\} \quad \text{(O-6)}$$

The first tile starts (0, 0) and ends (128, 128) with even coordinates and, because of the overlap, the next tile also starts (128, 0) and ends (256, 128) at even coordinates. In this way, every tile starts and ends on even coordinates on the reference grid. As every tile now starts and ends on even coordinates, every tile starts and ends with low pass coefficients at all four tile boundaries and the tile boundary artefacts will be significantly reduced. The exception in this case will be the last tiles on the right-hand and/or on the bottom of the image. Since they are on the boundaries of the image, there is no extra sample for overlap.

In order to achieve the best reduction in tile boundary artefacts, it is necessary to choose the tile parameters as follows:

$$XTsiz = m \cdot Rx \cdot 2^{N_L},\ YTsiz = n \cdot Ry \cdot 2^{N_L} \quad \text{(O-7)}$$

where *m* and *n* are integers greater than zero, N_L is the decomposition level, *Rx* and *Ry* are the lowest common multiples of sub-sampling factors $XRsiz^i$ and $YRsiz^i$ respectively for all components (in the commonly used 4:1:1 format *Rx* = *Ry* = 2).

O.3 Multiple component collection example

Figure O.32 depicts two transformations applied to two component collections, with input component lists $Cmcc^0$ = [4, 1, 5], $Cmcc^1$ = [2, 3, 0] and output component lists $Wmcc^0$ = [5, 4, 3, 6], $Wmcc^1$ = [2, 1, 0]. This example illustrates a transformation stage with six inputs and seven outputs that permutes both the input and output components.

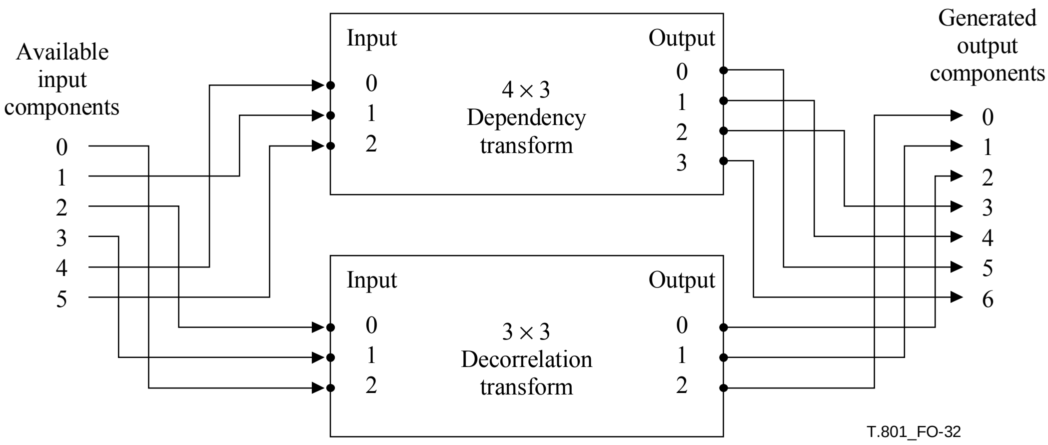


Figure O.32 – Component collection example

O.3.1 Array-based multiple component transform example

The example presented here exercises much of the flexibility and functionality of the multiple component transformation processes presented in Annex J and their supporting syntax in Annex A. We consider here not only the codestream syntax required by the decoder to properly interpret the codestream, but also some of the decisions an encoder might face.

The hypothetical multiple component image we wish to encode is a seven component multispectral image. Figure O.33 shows the original image components that are encoded in the codestream. The encoder analyzed the multiple component image decided that components 0, 1, 2, and 4 would be processed with an array-based decorrelation transform, components 5 and 3 with an array-based dependency transform, and component 6 with no transform. Furthermore, the encoder decided to predict component 3 from component 5 in the dependency transform; only the residual prediction errors for component 3 are present in the codestream.

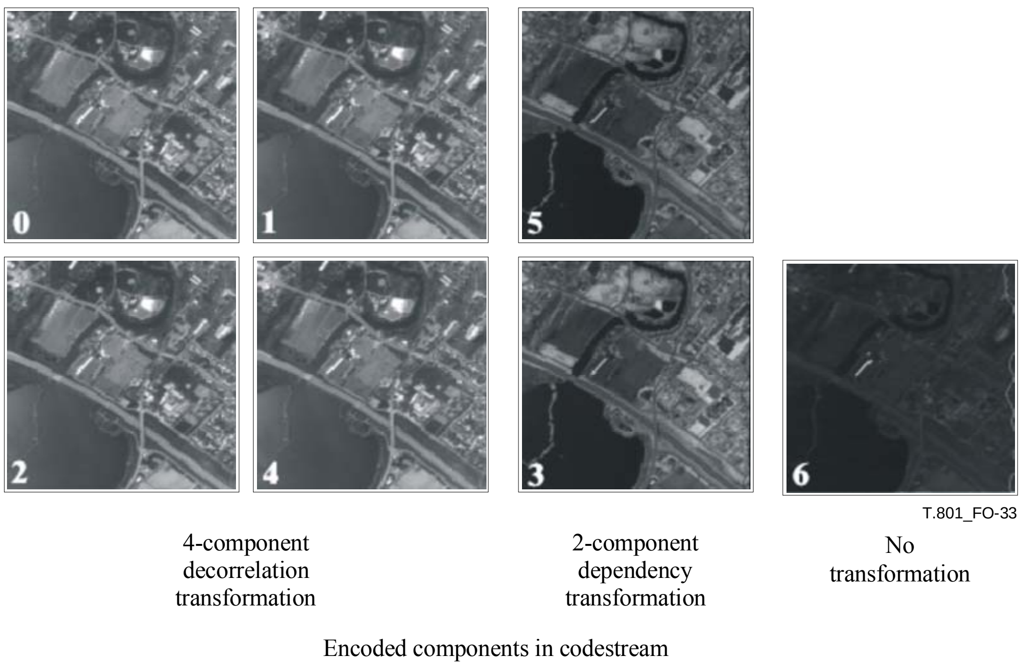


Figure O.33 – Original image components

Figure O.34 illustrates the processing choices made by the encoder. Both the input and output component collection lists have been permuted during the forward multiple component transformation. The multiple component transformation arrays and input and output component collection lists that the encoder used are not present in the compressed codestream. Instead, it is the responsibility of the encoder to generate the necessary *inverse* decorrelation and dependency transformation arrays, as well as the appropriate component collection lists, such that the decoder may successfully invert the transformation process.

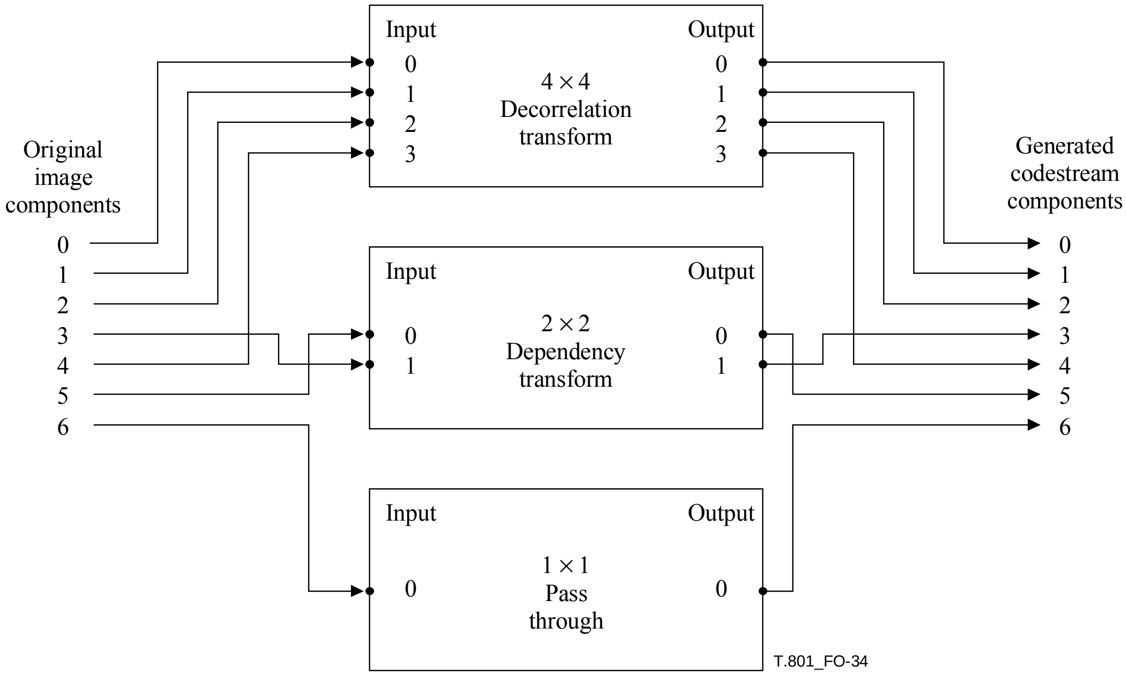


Figure O.34 – Encoder multiple component transform decisions

Figure O.34 is the encoder analog to Figure J.2 in which there is only one stage of multiple component transformation. In that single transformation stage, there are three distinct operations that are carried out on subsets of the input image components. If an encoder wishes to create new components not present in the original image and place them in the codestream, it can simply do so. If an encoder wishes a decoder to create additional components not present in the original image or in the codestream, this may be accomplished by manipulation of the inverse decorrelation and/or dependency transformation arrays and component collection lists.

Equation J-13 describes the forward dependency transformation processing of the encoder. In these equations, *W* indicates an (original) input image component, and *C* is a transformed component that is passed to the spatial wavelet transform engine. These components are ultimately those that are encoded in the codestream. Equation J-3 describes the forward decorrelation transformation processing of the encoder. In these equations, *W* again indicates an input image component, and *C* is a transformed component that is passed to the spatial wavelet transform engine.

The inversion of these transformations by the decoder can be accomplished with three component collections grouped into a single transformation stage. Such an inversion would be straightforward. However, to make the example more interesting, we will have the encoder provide information for the creation of four additional components (to make a total of 11 output components). These components include a one component panchromatic representation of the multispectral image and a three component false colour representation of the multispectral image. Although there are only seven components encoded in the codestream, the decoder will produce eleven during the course of two inverse multiple component transformation stages. We will further require that these four additional components be the first four components in the reconstructed multiple component image. One might imagine that at a higher file format level, we could signal the significance of the first four components and state that decoding these components is optional. Such information would enable the decoder to select which representation of the image is desired; panchromatic, false colour, or full multispectral. However, inclusion of metadata to enable this functionality is beyond the scope of this Recommendation | International Standard.

Figure O.35 shows the portion of the inverse transformation associated with the array-based decorrelation transform that operated on a subset of the original seven multispectral image components. If one looks at the numbering of the intermediate components, $I_1(i)$, we see that the inverse transformed components are stored in their original locations. The intermediate components generated by this inverse decorrelation transformation are really reconstructed image components, since none of them will be further modified by the subsequent transformation stage. The locations of these components will change, however, since the additional components that will be created will be placed in front of them. On the right-hand side of Figure O.35, the MCC component collection parameters are given for the inverse decorrelation transform. To complete the specification of the transform, MCT marker segments must be present in the main or appropriate first tile-part header and contain the decorrelation transform array and decorrelation offset array (see A.3.7). The indices associated with both of these arrays is one ($Tmcc^i$ = 0x000101).

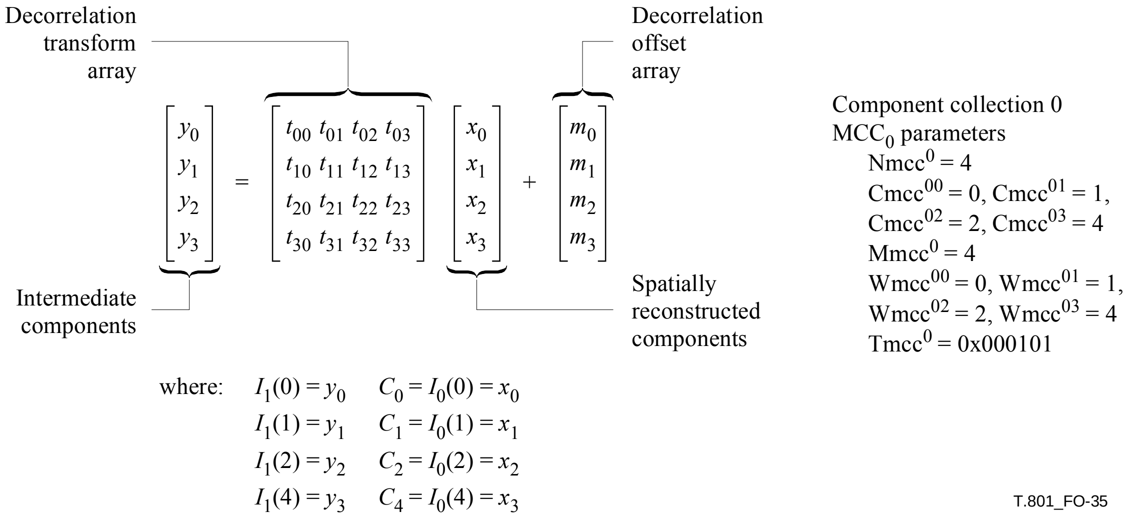


Figure O.35 – Decorrelation transformation array (MCC_0 component collection 0 parameters)

Figure O.36 shows the inverse dependency transformation for codestream components 5 and 3. The inverse transformation generates intermediate components 5 and 3. Again, these components really correspond to reconstructed image components 5 and 3, respectively. The inverse dependency transformation has been placed into component collection 1 in the first MCC marker segment.

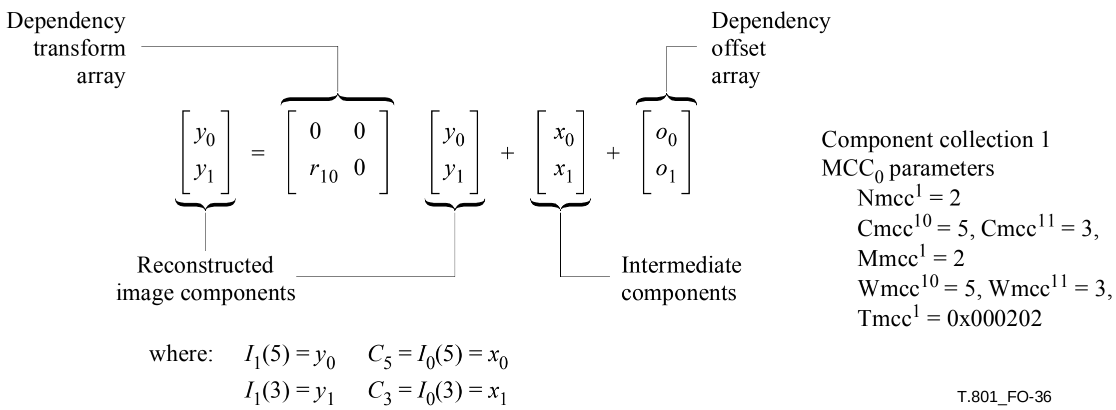


Figure O.36 – Dependency transformation (MCC_0 component collection 1 parameters)

Component collection 2 for the first MCC marker segment is given in Figure O.37. This component collection does not have any inverse transformation and consists of only a single component. The component simply passed through. This is achieved by specifying a null transformation array and a null offset array in the Tmcc field. (The transformation will be null regardless of whether the transformation type in the Xmcc field is set to a decorrelation transformation or a dependency transformation.)

Component collection 2 MCC_0 parameters

$Nmcc^0 = 1$
$Cmcc^{00} = 6$
$Mmcc^0 = 1$
$Wmic^{00} = 6$
$Tmic^0 = 0x000000$

Figure O.37 – Passing through intermediate components (MCC_0 component collection 2 parameters)

Figure O.38 illustrates the flow of components through the transformation stage associated with MCC_0. One might think of the seven component multispectral image as three distinct component collections (a decorrelation collection, a dependency collection, and a pass-through collection); from a codestream syntax point of view, it was handled with a single transformation stage requiring three different component transformations. It will sometimes be possible to make different choices for the organization of component collections within a transform stage. Such decisions regarding component collection membership may have implications on the size of the transformation arrays. In certain circumstances, using a greater number of smaller component collections may reduce transformation array overhead in the codestream.

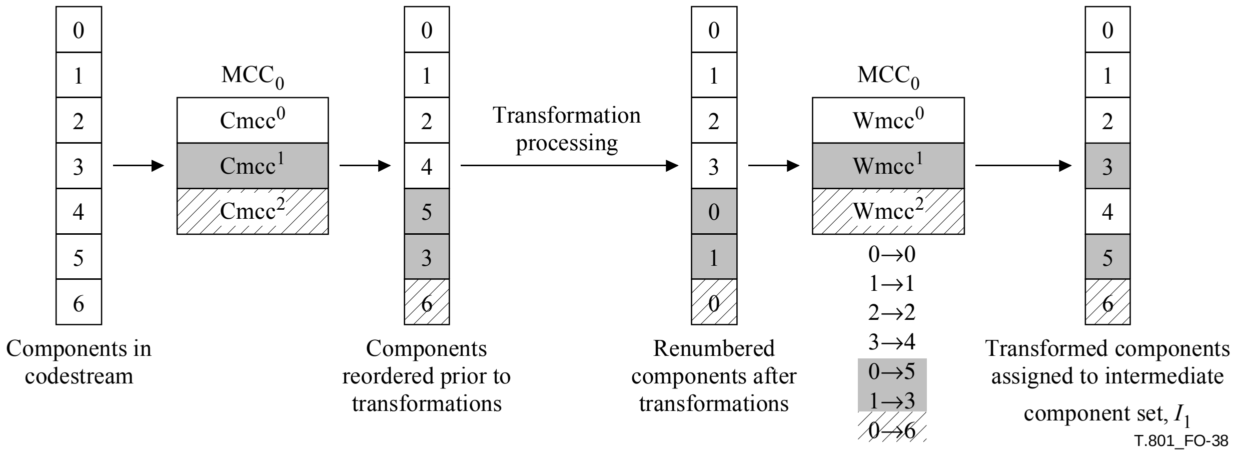


Figure O.38 – Component collections in MCC_0, transformation processing stage 0

Up until this point we have neglected the fact that the encoder was going to include instructions for the decoder to create four additional reconstructed image components. The first MCC marker segment has been used to reconstruct the original image components, but we must include an additional stage to generate the additional components. Equation O-8 gives the form of the additional panchromatic component, Y_L^{1b}, and the three additional false colour components; Y_R^{3b}, Y_G^{3b}, and Y_B^{3b}. Given the form of the additional components, we are again confronted with a choice regarding component collections and transformations. We could create a separate component collection for each of the equations, and thus provide a 3 × 3 array-based transformation and a 1 × 3 array-based transformation. Alternatively, we could create a component collection that performs a 4 × 4 array-based transformation encompassing all of the additional components. We choose the latter strategy.

$$\begin{aligned} Y_L^{1b} &= \beta_0(W_0 - \mu_{W_0}) + \beta_1(W_1 - \mu_{W_1}) + \beta_2(W_2 - \mu_{W_2}) + \mu_{Y_L^{1b}} \\ &= \beta_0 W_0 + \beta_1 W_1 + \beta_2 W_2 + \zeta \end{aligned}$$

$$\begin{aligned} Y_B^{3b} &= \alpha_0(W_0 - \mu_{W_0}) + \mu_{Y_B^{3b}} = \alpha_0 W_0 + \gamma_0 \\ Y_G^{3b} &= \alpha_1(W_1 - \mu_{W_1}) + \mu_{Y_G^{3b}} = \alpha_1 W_1 + \gamma_1 \\ Y_R^{3b} &= \alpha_2(W_5 - \mu_{W_5}) + \mu_{Y_R^{3b}} = \alpha_2 W_5 + \gamma_2 \end{aligned} \quad \text{(O-8)}$$

The W_i in this equation represents original input image components. After the first stage of the inverse transformation, those components correspond to the intermediate components, $I_1(i)$. Figure O.39 shows how the additional components are created in a decorrelation transformation associated with component collection zero of the second transformation stage. The $R(i)$ in the figure refer to the output image components from the completed inverse multiple component transformation process. (The notation is to distinguish these from the original image components. The original image components, W_i, will be a subset of the $R(i)$.)

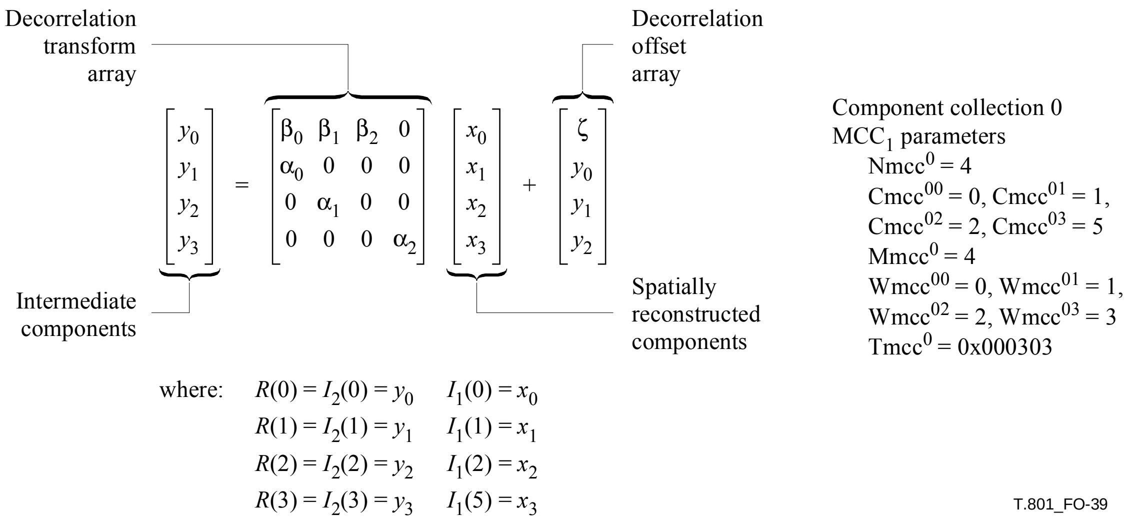


Figure O.39 – Decorrelation transformation array (MCC_1 component collection 0 parameters)

Figure O.40 shows the component collection information required to order the original image components after the additional created components. The components undergo no transformation (as indicated by null transformation and offset array indices), but are permuted by the indexing in the $Wmcc^{1j}$ fields. Figure O.41 shows the flow of components through the MCC component collection associated with the second stage of the inverse component transformation. As mentioned earlier, all transformation arrays must be included in the codestream in MCT marker segments with indices corresponding to those referenced in the corresponding MCC marker segments.

Component collection 1 MCC_1 parameters

$Nmcc^1 = 7$

$Cmcc^{10} = 0$, $Cmcc^{11} = 1$, $Cmcc^{12} = 2$,

$Cmcc^{13} = 3$, $Cmcc^{14} = 4$, $Cmcc^{15} = 5$,

$Cmcc^{16} = 6$

$Mmcc^1 = 7$

$Wmcc^{10} = 4$, $Wmcc^{11} = 5$, $Wmcc^{12} = 6$,

$Wmcc^{13} = 7$, $Wmcc^{14} = 8$, $Wmcc^{15} = 9$,

$Wmcc^{16} = 10$

$Tmcc^1 = 0x000000$

Figure O.40 – MCC_1 component collection 1 (7 components passed through)

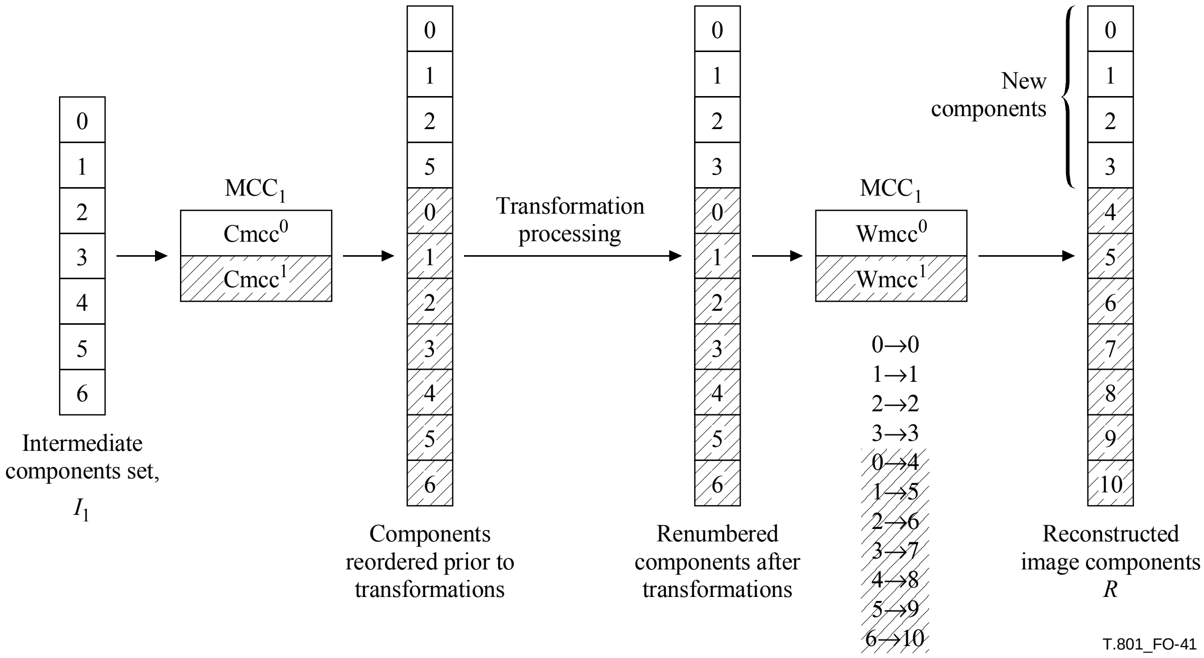


Figure O.41 – Component collections in MCC_1, transformation processing stage 1

Finally, the encoder must include an MCO marker segment that specifies the order of the transformation stages. Each of the two MCC marker segments that have been described must be assigned an index. As shown in Figure O.42, those indices must appear in the MCO marker segment in the order of transformation stage application.

MCO parameters

$Nmco = 2$

$Imcc^0$ = Index of MCC_0

$Imcc^1$ = Index of MCC_1

Figure O.42 – MCO marker segment for inverse multiple component transformation

Figures O.35, O.36, O.37, O.39, O.40 and O.42 represent the complete set of inverse decorrelation transformation arrays, inverse dependency transformation arrays, MCC marker segment parameters, and MCO marker segment parameters for the eleven reconstructed image components in this example.

The following observations can be made regarding component collections:

- The $Wmcc^i$ parameters determine the final ordering of the reconstructed image components.
- $Wmcc^i$ may be used to create space for new components that do not exist in the codestream. The new components themselves may be generated by the decorrelation and/or dependency transformation processes.
- Input components can be reused in different component collections. Output components must be kept distinct across all component collections in any given MCC marker segment.
- If an MCC marker segment references an input or output component whose value has not been assigned, that component should be treated as a NULL component (i.e., full of zeros).
- Processing order in the inverse dependency transformation is important. An encoder is required to form the dependency transform array such that the matrix is non-zero below the array diagonal. This structure allows the array to be applied line-by-line from top to bottom.
- One can do more than decorrelation and simple prediction with the multiple component transformation marker syntax.

O.3.2 Unitary decorrelation transformation factorization and reversible decorrelation transformation

As described in J.3.1.1.3, this Recommendation | International Standard supports an array-based reversible decorrelation transformation for multiple component compression. In many multiple component applications, especially those involving multiple bands of radiometric data, numerically lossless compression is strongly preferred to lossy compression. In those cases, a floating point decorrelation transformation cannot be tolerated, as it naturally suffers from round-off errors. True reversibility can be obtained only under strict conditions.

Fortunately, unitary transformations form a large subset of typically encountered decorrelation transformations. Recently, a technique was developed to factor any unitary transformation matrix into a series of single-row elementary reversible matrices (SERMs). The SERMs operate sequentially on the data, and at each stage alter exactly one of the input samples. For an N × N transformation, N+1 SERMs are produced. The result of the transformation is an integer approximation to what would otherwise be a floating point result. However, the transformation can be exactly reversed simply by reversing the order of the N+1 SERM operations.

To illustrate the factorization process, consider an image consisting of three components. The correlation matrix of the three components was analyzed to form a Karhunen-Loeve transformation matrix. Following Hao's notation, the transformation matrix is given by $A = \begin{bmatrix} 0.766 & -0.303 & -0.567 \\ 0.271 & -0.648 & 0.712 \\ 0.583 & 0.699 & 0.414 \end{bmatrix}$. The factorization process is carried out in two steps.

First, a modified LU decomposition of A is performed. In this step, the matrix A is factored into $A = LUS_0D$, where L is lower diagonal with unit diagonal, U is upper diagonal with unit diagonal, D is diagonal with unit entries (except that the last entry may also be equal to –1), and S_0 is a SERM that alters only the last entry of an input vector. For the given matrix A, the factorization steps are as follows.

$$\begin{bmatrix} 0.766 & -0.303 & -0.567 \\ 0.271 & -0.648 & 0.712 \\ 0.583 & 0.699 & 0.414 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -0.413 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & -0.303 & -0.567 \\ -0.022 & -0.648 & 0.712 \\ 0.412 & 0.699 & 0.414 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0.022 & 1 & 0 \\ -0.412 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.766 & -0.303 & -0.567 \\ 0.271 & -0.648 & 0.712 \\ 0.583 & 0.699 & 0.414 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -0.413 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & -0.303 & -0.567 \\ 0 & -0.654 & 0.699 \\ 0 & 0.824 & 0.648 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0.022 & 1 & 0 \\ -0.412 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.766 & -0.303 & -0.567 \\ 0.271 & -0.648 & 0.712 \\ 0.583 & 0.699 & 0.414 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -0.413 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 2.366 & 1 \end{bmatrix} = \begin{bmatrix} 1 & -1.644 & -0.567 \\ 0 & 1 & 0.699 \\ 0 & 2.356 & 0.648 \end{bmatrix}$$

$$\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & -2.356 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0.022 & 1 & 0\\-0.412 & 0 & 1\end{bmatrix}\begin{bmatrix}0.766 & -0.303 & -0.567\\0.271 & -0.648 & 0.712\\0.583 & 0.699 & 0.414\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\-0.413 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 2.366 & 1\end{bmatrix}=\begin{bmatrix}1 & -1.644 & -0.567\\0 & 1 & 0.699\\0 & 0 & -1\end{bmatrix}$$

$$\begin{bmatrix}1 & 0 & 0\\0.022 & 1 & 0\\-0.465 & -2.356 & 1\end{bmatrix}\begin{bmatrix}0.766 & -0.303 & -0.567\\0.271 & -0.648 & 0.712\\0.583 & 0.699 & 0.414\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\-0.413 & 2.366 & 1\end{bmatrix}=\begin{bmatrix}1 & -1.644 & 0.567\\0 & 1 & -0.699\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & -1\end{bmatrix}$$

$$\begin{bmatrix}0.766 & -0.303 & -0.567\\0.271 & -0.648 & 0.712\\0.583 & 0.699 & 0.414\end{bmatrix}=\begin{bmatrix}1 & 0 & 0\\-0.022 & 1 & 0\\0.412 & 2.356 & 1\end{bmatrix}\begin{bmatrix}1 & -1.644 & 0.567\\0 & 1 & -0.699\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\-0.413 & 2.366 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & -1\end{bmatrix}$$

$$A = LUS_0D$$

Given the matrices L, U, and D in the above factorization, their product is now reduced to the identity through a series of post-multiplications. Each of the post-multipliers is a SERM. From the above, the product $LU=\begin{bmatrix}1 & -1.644 & 0.567\\-0.022 & 1.037 & -0.712\\0.412 & 1.679 & -0.414\end{bmatrix}$. This factorization proceeds as follows.

$$\begin{bmatrix}1 & -1.644 & 0.567\\-0.022 & 1.037 & -0.712\\0.412 & 1.679 & -0.414\end{bmatrix}\begin{bmatrix}1 & 1.644 & -0.567\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}=\begin{bmatrix}1 & 0 & 0\\-0.022 & 1 & -0.699\\0.412 & 2.356 & -0.648\end{bmatrix}$$

$$\begin{bmatrix}1 & -1.644 & 0.567\\-0.022 & 1.037 & -0.712\\0.412 & 1.679 & -0.414\end{bmatrix}\begin{bmatrix}1 & 1.644 & -0.567\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0.022 & 1 & 0.699\\0 & 0 & 1\end{bmatrix}=\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0.465 & 2.356 & 1\end{bmatrix}$$

$$\begin{bmatrix}1 & -1.644 & 0.567\\-0.022 & 1.037 & -0.712\\0.412 & 1.679 & -0.414\end{bmatrix}\begin{bmatrix}1 & 1.644 & -0.567\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0.022 & 1 & 0.699\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\-0.465 & -2.356 & 1\end{bmatrix}=\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}$$

The three SERMs in this portion of the factorization can now be substituted for LU to obtain the complete factorization.

$$A=\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0.465 & 2.356 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\-0.022 & 1 & -0.699\\0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & -1.644 & 0.567\\0 & 1 & 0\\0 & 2.366 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\-0.413 & 2.366 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & -1\end{bmatrix}$$

$$A = S_3S_2S_1S_0D$$

Given an input vector corresponding to the values of the three components at a given spatial location, this factorization can be used to produce an integer approximation to the floating point transformation. At each stage of the multiplication, only one element of the result vector is changed. If a rounding rule is applied to that element of the vector before the next stage is computed, then the input to any given stage is integer valued. Furthermore, the operations can be reversed exactly by using the same rounding rule and simply reversing the order of the stages. For example, if $C = \lfloor S_3 W \rfloor$, then $W = \lfloor S_3^{-1} C \rfloor$. Notice that the inverse of a SERM is easily formed by negating its off-diagonal entries. Alternatively, the entries can be left as they are in the forward transformation, but for the inverse the sum of the off-diagonal contributions is subtracted from, instead of added to, the entry to be changed. This Recommendation | International Standard requires the decoder to subtract the off-diagonal contributions. Thus, in forming the codestream array information, the encoder need only supply the SERMs in the proper order for inverse processing.

While this transformation process is theoretically entirely reversible, in practice the finite precision of floating point arithmetic may occasionally cause a sum to be rounded to different values during the forward and inverse transformations. (For example, suppose a sum is generated as 0.4999 during the forward transformation, but, due to order of operations and floating point arithmetic rules of the decoder, the sum is generated as 0.50001 during the inverse transformation.) To guarantee reversibility across platforms, the SERM entries must be quantized. Thus this Recommendation | International Standard provides for a scale factor associated with each SERM. The scale factor is conveyed through knowledge of the position of the element being changed. The scale factor concept is illustrated below.

Conceptually, the SERMs in the factorization can be thought of as being 'stacked' into a non-square array. The array no longer represents a matrix multiplication in the conventional sense. Rather, it is understood that at each stage, one element of the input vector is altered. In the above example, the four SERMs can conceptually be replaced by the following array:

$$S = \begin{bmatrix} -0.413 & 2.366 & -1 \\ 1 & -1.644 & 0.567 \\ -0.022 & 1 & -0.699 \\ 0.465 & 2.356 & 1 \end{bmatrix}$$

An encoder using this array to hold the SERMs would recognize that to perform the reversible decorrelation transformation, the first row of the transformation adjusts the value of the last input sample only. The second row adjusts only the first input sample, the third row adjusts only the second, etc. Reversing the order of operations for the decoder conceptually corresponds to reversing the order of the rows of this array:

$$S^{-1} = \begin{bmatrix} 0.465 & 2.356 & 1 \\ -0.022 & 1 & -0.699 \\ 1 & -1.644 & 0.567 \\ -0.413 & 2.366 & -1 \end{bmatrix}$$

This is in fact the form of the array expected by the decoder.

Next, an appropriate scale factor must be chosen for each row. The scale factor must be an exact power of 2. Its value is determined from the desired approximation fidelity and the available bit depth. In this example, a scale factor of 256 is chosen for each row of the SERM array. The resulting quantized forward transformation SERM array is given by:

$$QS = \begin{bmatrix} -105 & 605 & -256 \\ 256 & -420 & 145 \\ -5 & 256 & -178 \\ 119 & 603 & 256 \end{bmatrix} = \begin{bmatrix} -0.4102 & 2.3633 & -1 \\ 1 & -1.6406 & 0.5664 \\ -0.0195 & 1 & -0.6953 \\ 0.4648 & 2.3555 & 1 \end{bmatrix} \cdot 256 = QS_{eff} \cdot 256$$

The array QS_{eff} is the effective set of SERM coefficients that will be applied by the reversible transformation process. The inverse transformation array, QS_{eff}^{-1} is still formed by reversing the rows of the forward transformation array:

$$QS_{eff}^{-1} = \begin{bmatrix} 119 & 603 & 256 \\ -5 & 256 & -178 \\ 256 & -420 & 145 \\ -105 & 605 & -256 \end{bmatrix}$$

This array must be included in the codestream in an MCT marker segment. The entries in the array appear in raster order within the marker segment.

With the quantized forward transformation array now determined, the reversible transformation can be applied. The forward transformation equations are given in Annex J, Equations J-7 through J-10. Each step of the transformation consists of:

1) computing a weighted sum of the samples that are not altered in the step;
2) scaling the sum by the scaling factor and either adding or subtracting the altered sample from that sum; and
3) substituting the result for the sample to be altered.

The substitution is performed prior to the next stage of the transformation. The input samples are possibly shifted by and offset prior to computation of the transformation.

Suppose that at a particular spatial location, the three component samples are given by a vector $W = \begin{bmatrix} 136 \\ 87 \\ 83 \end{bmatrix}$. Suppose further that no additive offsets are used, i.e., $o_i = 0$, $i = 0, 1, 2$, in Equation J-7. The following sequence shows how the transformation is carried out step by step.

$$P = W - \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = W = \begin{bmatrix} 136 \\ 87 \\ 83 \end{bmatrix}$$

$$S_0 = 105 \cdot 136 + 605 \cdot 87 + \frac{|-256|}{2} = 38227$$

$$PT_0 = \left\lfloor \frac{|38227|}{|-256|} \right\rfloor - 83 = 66, P = \begin{bmatrix} 136 \\ 87 \\ 66 \end{bmatrix}$$

$$S_1 = 87 \cdot -420 + 66 \cdot 145 + \frac{256}{2} = -26842$$

$$PT_1 = -\left\lfloor \frac{|-26842|}{256} \right\rfloor + 136 = 31, P = \begin{bmatrix} 31 \\ 87 \\ 66 \end{bmatrix}$$

$$S_2 = 31 \cdot -5 + 66 \cdot -178 + \frac{256}{2} = -11775$$

$$PT_2 = -\left\lfloor \frac{|-11775|}{256} \right\rfloor + 87 = 41, P = \begin{bmatrix} 31 \\ 41 \\ 66 \end{bmatrix}$$

$$S_2 = 31 \cdot 119 + 41 \cdot 603 + \frac{256}{2} = 28540$$

$$PT_1 = \left\lfloor \frac{|28540|}{256} \right\rfloor + 66 = 177, P = \begin{bmatrix} 31 \\ 41 \\ 177 \end{bmatrix}$$

$$C = \begin{bmatrix} 31 \\ 41 \\ 177 \end{bmatrix}$$

The original floating point transformation matrix would have provided a result of $AW = A\begin{bmatrix} 136 \\ 87 \\ 83 \end{bmatrix} = \begin{bmatrix} 30.754 \\ 39.576 \\ 174.463 \end{bmatrix}$. The small differences between the full floating point transformation and its integer approximation will in general produce some change in compression efficiency. However, unlike the floating version, the integer transformation is completely reversible.

O.3.3 Dependency transformation, irreversible and reversible

As described in J.3.1.2, this Recommendation | International Standard supports an array-based dependency transformation for multiple component compression. In some multiple component applications, simple component differencing may adequately remove correlation in the component direction. In others, the data source may produce samples in component order, thus creating an advantage for a transformation that relies only on previously observed samples. In these cases, the constraints of the array-based dependency transformation may be well-matched to the processing paradigm. The dependency transformation can be performed irreversibly or reversibly. In this subclause, an example of an irreversible dependency transformation will be presented. The same transformation coefficients will then be converted to meet the constraints of the reversible dependency transformation and will be applied to the same example data.

In this example, the input will consist of four image components. It is known from source characteristics that the four samples at a particular spatial location will all be approximately the same value. That value, however, is known to change from spatial location to spatial location. It is therefore desirable to approximate the value of the *i*th component by the mean of components 0 through $i - 1$. The desired prediction equations are given below, assuming that the input component samples are denoted as W_i and the transformed components are denoted as C_i:

$$C_0 = W_0$$
$$C_1 = W_1 - W_0$$
$$C_2 = W_2 - 0.5W_0 - 0.5W_1$$
$$C_3 = W_3 - 0.333W_0 - 0.333W_1 - 0.333W_2$$

Comparing these equations with J.3.1.2.2, Equation J-13, it is observed that $o_i = 0$, $i = 0, 1, 2, 3$, and:

$$T = \begin{bmatrix} 1 & & \\ 0.5 & 0.5 & \\ 0.333 & 0.33 & 0.33 \end{bmatrix} = \begin{bmatrix} t_{10} & & \\ t_{20} & t_{21} & \\ t_{30} & t_{31} & t_{32} \end{bmatrix}$$

These values of t_{ij} used in Equation J-13 are those contained in the array . (These are the same transformation array values that are required to appear in an MCT marker segment for the decoder.) Given an input sample $W = \begin{bmatrix} 112 \\ 108 \\ 101 \\ 107 \end{bmatrix}$ at a particular spatial location, the forward irreversible dependency transformation is carried out in the steps that follow.

$$C_0 = 112$$
$$C_1 = 108 - 1 \cdot 112 = -4$$
$$C_2 = 100 - 0.5 \cdot 112 - 0.5 \cdot 108 = -10$$
$$C_3 = 107 - 0.333 \cdot 112 - 0.333 \cdot 108 - 0.333 \cdot 100 = -0.333$$

These transformed samples would then be passed to the spatial wavelet transform. The value of C_3 would be converted to an integer prior to the spatial wavelet transform. In the case of the irreversible array-based component transformations, no rule has been specified for this conversion, though rounding or truncation would be typical choices.

To extend the example, suppose that it is desired to implement an approximation to the same transformation in a reversible fashion. To accomplish this, a scale factor is selected for each step in the transformation. The scale factor must be a power of 2, and is chosen based on the precision of the data and the desired fidelity of the approximation. No scale factor is required for the first step, since this step simply maps the first input component to the first output component. There is only one array coefficient required in the second step, the computation of C_1. A scale factor of 1 provides an exact representation of t_{10}. In the third step, the two array coefficients are already a power of 2, namely 2^{-1}. Therefore, the scale factor for the second step can be chosen as 2. In the last step, a scale factor of 512 is selected to achieve an adequate approximation to the required coefficients. The quantized transformation coefficient array, *QT*, is given below, where the scale factors for the steps are also included as the diagonal entries in the array.

$$QT = \begin{bmatrix} 1 & 1 & & \\ 1 & 1 & 2 & \\ 171 & 171 & 171 & 512 \end{bmatrix} = \begin{bmatrix} t_{10} & t_{11} & & \\ t_{20} & t_{21} & t_{22} & \\ t_{30} & t_{31} & t_{32} & t_{33} \end{bmatrix}$$

In applying the steps involved in the reversible dependency transformation (Equation J-16 in J.3.1.2.4), these quantized coefficients will correspond to effective transformation coefficients:

$$T_{eff} = \begin{bmatrix} 1 & & \\ 0.5 & 0.5 & \\ 0.33398 & 0.33398 & 0.33398 \end{bmatrix}$$

The transformation is carried out according to Equation J-16 in the steps that follow.

$$C_0 = 112$$

$$S_1 = 1 \cdot 112 + \left\lfloor \frac{1}{2} \right\rfloor = 112$$

$$C_1 = -\left\lfloor \frac{|112|}{1} \right\rfloor + 108 = -4$$

$$S_2 = 1 \cdot 112 + 1 \cdot 108 + \left\lfloor \frac{2}{2} \right\rfloor = 221$$

$$C_2 = -\left\lfloor \frac{|221|}{2} \right\rfloor + 100 = -10$$

$$S_3 = 171 \cdot 112 + 171 \cdot 108 + 171 \cdot 100 + \left\lfloor \frac{512}{2} \right\rfloor = 55147$$

$$C_3 = -\left\lfloor \frac{|55147|}{512} \right\rfloor + 107 = 0$$

In general, there will be small differences between the transformed values obtained from the reversible transform and rounded values obtained from the irreversible implementations. There may be some change in compression efficiency associated with these differences.

O.4 Background to enhancement of quantization

Remote sensing applications require a low-memory, high-throughput implementation of JPEG 2000 for use on board spacecraft and aircraft. This implementation, known as the scan-based mode, has already been demonstrated for ITU-T Rec. T.800 | ISO/IEC 15444-1. Images are processed as collections of a small number of lines, known as scan elements. In tests of the scan-based mode, it has been shown that the use of precincts rather than tiles as scan elements gives better image quality, because small tiles tend to produce boundary artefacts.

For high-quality lossy compression, it is desirable to add quantization methods to the scan-based mode. In order to maintain high throughput, the quantization must be performed with single-pass rate control (no iteration). But effective single-pass rate control over the image as a whole can be achieved only if trellis-coded quantization (or explicit scalar quantization) is performed on a precinct-by-precinct basis, with different step sizes for each precinct.

In order to enable this procedure, new syntax is used to signal the step sizes on a precinct-by-precinct basis. Since a long image divided into short precincts may contain many tile parts, it is also desirable to increase the maximum value of the tile part index (currently 254).

Bibliography

Visual masking

[1] JONES (P.), DALY (S.), GABORSKI (R.), RABBANI (M.): Comparative study of wavelet and DCT decompositions with equivalent quantization and encoding strategies for medical images, *SPIE Proceedings of Conference on Medical Imaging*, Vol. 2431, pp. 571-582, San Diego, February 1995.

[2] DALY (S.), ZENG (W.), LI (J.), LEI (S.): Visual weighting in wavelet compression for JPEG2000, *SPIE Proc. Conf. Image and Video Com. and Pro*c., Vol. 3974, pp. 66-80, San Jose, January 2000.

[3] ZENG (W.), DALY (S.), LEI (S.): Point-wise extended visual weighting for JPEG2000 image compression, *IEEE Int. Conf. Image Proc. (ICIP 2000)*, Vancouver, Canada, September 2000.

Quantization and entropy coding

[4] MARCELLIN (M. W.), FISCHER (T. R.): Trellis Coded Quantization of Memoryless and Gauss-Markov Sources, *IEEE Trans Commun*., January 1990.

[5] FISCHER (T. R.), WANG (M.): Entropy Constrained Trellis Coded Quantization, *IEEE Trans. Inform. Th*., March 1992.

[6] KASNER (J. H.), MARCELLIN (M. W.), HUNT (B. R.): Universal trellis coded quantization, *IEEE Trans. Image Proc.*, Vol. 8, No. 12, pp. 1677-87, December 1999.

[7] BILGIN (A.), SEMENTILLI (P. J.), MARCELLIN (M. W.): Progressive Image Coding Using Trellis Coded Quantization, *IEEE Trans. Image Proc.*, Vol. 8, No. 11, pp. 1638-1643, November 1999.

Wavelet transform

[8] Wavelet Scalar Quantizer (WSQ) Gray-scale Fingerprint Image Compression Specifications, version. 2.0, *Document #IAFIS-IC-0110v2, United States Federal Bureau of Investigation*, 16 February 1993.

[9] BRISLAWN (C. M.): Classification of nonexpansive symmetric extension transformations for multirate filter banks, *Appl. Comput. Harmonic. Analysis*, Vol. 3, pp. 337-57, 1996.

[10] WEI (J. X.), PICKERING (M. R.), FRATER (M. R.), ARNOLD (J. F.): A New Method for reducing Boundary Artifacts in Block-Based Wavelet Image Compression, *SPIE Visual Com. and Image Proc.*, pp. 1290-1295, Perth, Australia, 20 June 2000.

Region of interest coding and shape coding

[11] CHRISTOPOULOS (C.), ASKELOF (J.), LARSSON (M.): Efficient region of interest encoding techniques in the upcoming JPEG2000 still image coding standard, *IEEE Int. Conf. Image Proc. (ICIP 2000)*, 10-13 September 2000, Vancouver, Canada.

[12] NISTER (D.), CHRISTOPOULOS (C.): Lossless region of interest coding, *Signal Processing*, Vol. 78, No. 1, pp. 1-17, October 1999.

[13] CHRISTOPOULOS (C.A.), PHILIPS (W.), SKODRAS (A.N.), CORNELIS (J.): Segmented Image Coding: techniques and experimental results, *Signal Processing*, Vol. 11, No. 1, pp. 63-80, 1997.

Multiple component transformation

[14] HAO (P.), SHI (Q.): Matrix factorizations for reversible integer mapping, *IEEE Transactions on Signal Processing*, Vol. 49, No. 10, at press, 2001.

Post-processing

[15] SHEN (M.), JAY KUO (C.-C.): Artifact Reduction in Low Bit Rate Wavelet Coding with Robust Non-linear Filtering, *Proc. of IEEE 1998 Workshop on Multimedia Signal Processing (MMSP-98)*, Los Angeles, California, 7-9 December 1998.

Index

Patent statement

(This annex does not form an integral part of this Recommendation | International Standard)

There is the possibility that, for some of the processes specified in this Recommendation | International Standard, conformance or compliance may require use of an invention covered by patent rights.

By publication of this Recommendation | International Standard, no position is taken with respect to the validity of this claim or of any patent rights in connection therewith. Information regarding such patents can directly be obtained from the organizations listed below in Table Patent-1. The table summarizes the formal patent and intellectual property rights statements that have been received by these organizations.

Table Patent-1 – Received intellectual property rights statements

Number	Company
1	Algo Vision
2	Canon Incorporated
3	Digital Accelerator Corporation
4	Telefonaktiebolaget L M Ericsson
5	Hewlett Packard Company
6	International Business Machines, Inc.
7	LizardTech, Incorporated
8	LuraTech
9	Mitsubishi Electric Corporation
10	Motorola Corporation
11	PrimaComp Incorporated
12	Rensselaer Polytechnic Institute (RPI)
13	Ricoh Company, Limited
14	Sarnoff Corporation
15	Sharp Corporation
16	Sony Corporation
17	TeraLogic Incorporated
18	University of Arizona
19	Washington State University

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series B	Means of expression: definitions, symbols, classification
Series C	General telecommunication statistics
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	**Terminals for telematic services**
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks and open system communications
Series Y	Global information infrastructure and Internet protocol aspects
Series Z	Languages and general software aspects for telecommunication systems

Geneva, 2003