REPORT ITU-R BO.2008-1

DIGITAL MULTIPROGRAMME BROADCASTING BY SATELLITE

(Question ITU-R 217/11)

(1995-1998)

1 Introduction

In response to Question ITU-R 217/11, this Report provides background information collected during the preparation of Recommendations ITU-R BO.1211 and ITU-R BO.1294.

These Recommendations are for broadcast of television direct from satellite to small antennas, such as used by a direct-to-home (DTH) system, a satellite master antenna television (SMATV) or a direct-to-cable-head system. However, considerations have been given to related Questions, such as compatibility with the bit rates, channel coding and modulation techniques used by terrestrial, SMATV and cable distribution systems.

The way studies have been organized is summarized in Fig. 1.

A list of acronyms used in this report may be found in § 9.

2 Source coding and multiplexing

It is expected that satellite digital video broadcasting (DVB) systems will draw upon evolving standards, such as:

1) image coding: International Standard ISO/IEC 13818-2;

2) audio coding: Recommendation ITU-R BS.1196;

3) multiplexing: International Standard ISO/IEC 13818-1.

Suppliers of digital multiprogramme television services that are also to be received by SMATV installations should be aware of the bit rate compatibilities required by SMATV systems (Doc. 10-11S/68).

2.1 MPEG-2 video compression architecture

The MPEG-2 video compression standard, ISO/IEC 13818-2, defines a syntax or language which is to be understood by an MPEG-2 compatible decoder. An MPEG-2 data stream describes exactly what actions an MPEG-2 compatible decoder must take to reconstruct the original video sequence.

The overall MPEG-2 architecture and syntax were designed such that an MPEG-2 decoder is a much simpler device than an MPEG-2 encoder. This is very important in broadcast applications where there is typically one encoder for many thousands or millions of decoders. This type of architecture greatly reduces the overall system cost.

For a given application, certain fundamental MPEG-2 parameters can be selected which set static resolution, acquisition time, use of B-frames and other basic characteristics. The range of parameters used in a given system will determine the fundamental compliance requirements for the system's decoders.

Any given video sequence can be encoded in different ways using different compression algorithms into MPEG-2 syntax compliant data streams. Each of these MPEG-2 syntax compliant data streams will be different from each other, and yet when presented to an MPEG-2 compliant decoder they can all result in video output sequences similar to the original encoder input sequence.

FIGURE 1

Organization of work

Question ITU-R 217/11

"Digital multi-programme television emissions within a satellite transponder"

what are : the minimum bit-rate per programme, the performance requirements, the modulation and coding techniques, the multiplexing structure, the link overhead capacity, the interference sensitivity...

Report ITU-R BO.2008

"Digital multiprogramme broadcasting by satellite"

Contains information on :

- Source coding and multiplexing
- Channel coding
- Modulation
- Satellite channel access
- Commonalities with other media
- Example of digital multiprogramme satellite broadcasting systems
- Feasibility of common functional requirements for satellite multiprogramme TV reception

Recommendation ITU-R BO.1211

"Digital multiprogramme emission systems for television, sound and data services for satellites operating in the 11/12 GHz frequency range"

Recommends that the DVB-S framing structure, channel coding and modulation methods as specified should be considered in converging to a world-wide standard for the introduction of digital multi-programme television services from satellites operating in the 11/12 GHz down-link frequency range.

Special Rapporteur

- analyse the commonalities between existing systems
- define and describe the functions of a generic system model
- identify the processes and the minimum set of parameters of the various sub-systems
- define the internal interfaces between the modules of the generic system and the external system interfaces

Annex 1 to Report ITU-R BO. 2008

"Feasibility of common functional requirements for satellite multiprogramme TV reception. *Architecture and cost estimations*"

- Generic reference model for the common functional requirements of a satellite IRD
- Universal elements of a satellite IRD
- Cost estimations
- Summary characteristics of digital multiprogramme TV systems by satellite

Recommendation ITU-R BO.1294

"Common functional requirements for the reception of digital multiprogramme television emissions by satellites operating in the 11/12 GHz frequency range"

recommends :

- that one of the transmission systems described be selected when implementing digital multiprogramme television services via satellite;
- that the universal elements of the common functional requirements of a satellite integrated receiver-decoder (IRD) serve as a basis for implementation of the services in those areas where more than one system coexists or may coexist in the future;
- that further studies be carried out to address the benefits of including other essential satellite IRD functions that are not specified in this Recommendation.

An important point is that the more efficient encoding algorithms can provide better output video quality using fewer bits per sequence than less efficient algorithms. That is, any given video sequence can be compressed to an MPEG-2 syntax compliant bitstream in a variety of ways, some more efficient than others.

MPEG-2 encoders are quite complex devices, and the encoding algorithms used in them are constantly being refined and improved. It is expected that these improvements will continue for some time to come.

MPEG-2 decoders currently deployed in many operational digital multiprogramme systems are designed to be able to properly decode any MPEG-2 syntax compliant data stream. Thus these decoders do not become obsolete as encoders are routinely upgraded with new more efficient encoding algorithms.

Thus MPEG-2 video encoders can be improved and upgraded over time without requiring hardware or software upgrades at the decoder. This is a very valuable characteristic of the MPEG-2 video architecture in that it allows for future technical improvements in MPEG-2 video compression efficiency without requiring changes in the MPEG-2 decoders.

2.2 Statistical multiplexing methods

Techniques have been developed in the broadcast equipment industry to provide for variable bit rate operation of MPEG-2 encoders. This technique takes advantage of the statistical nature of video sequences, allocating more channel capacity to difficult sequences and less channel capacity to easier sequences.

Statistical multiplex algorithms are operational on many systems, but it is believed that significant technical advances are still possible in this field.

2.3 Number of programmes per transponder

The number of programmes that can be carried in a transponder is a function of a number of parameters. These parameters include the available information rate, the type of video source format being used (component or composite), the overall quality of the video source material, the video resolution, the criticality of the video material as it relates to the compression algorithm (i.e., type of programme material), and the desired video quality.

Given the current state of video compression technology, Table 1 provides ranges of information bit rates per programme suitable for providing standard definition TV (SDTV) quality.

TABLE 1

Examples of bit rates per programme for SDTV

Movies	2.5 to 4 Mbit/s
Educational material	2.0 to 4 Mbit/s
General material	3 to 7 Mbit/s
Sports	5 to 11 Mbit/s
Associated audio (two channel stereo)(1)	64 to 256 kbit/s

(1) Significant higher bit rates would be required for multi-channel surround sound.

The number of programmes which can be carried in a transponder can be estimated by allocating the total transponder information bit rate among the video and audio services of choice. Capacity must also be reserved for programme information and conditional access data channels.

It is expected that future advances in compression technology, statistical multiplexing methods and transmission coding could significantly increase the number of programmes currently carried in a given transponder.

2.4 Identification of a strategy to distinguish MPEG-2 transport streams (TS) among applications

In MPEG-2 systems, the private sections can be defined individually according to each application. The framework of the recommendation on service and programme information data for digital broadcasting systems which use the private sections was issued by Working Party 11D in 1994. But different private sections are incorporated into DVB or other systems. In Telecommunication Standardization Study Group 9, studies on programme guides and navigation tools were also started by a Special Rapporteur.

If no unified consideration is carried out, mutual interference among privately defined sections will occur in the receiver. This problem will be avoided if the identification of specific systems is provided in the context of the TS.

This point is thought to be essential for realizing the inter-operability of digital broadcasting systems. Therefore, studies should be carried out in Radiocommunication Study Group 11 in cooperation with related Study Groups, Working Parties and Task Groups within the ITU-R and ITU-T and ISO/IEC, for the realization of a unified strategy.

3 Channel coding

Channel coding includes energy dispersal, outer coding, interleaving, inner coding and baseband shaping.

It is desirable to converge to a common channel coding scheme to enable greater compatibility among different systems as explained in Annex 1.

4 Modulation

Several types of channel modulation techniques are suitable for use on a satellite. The technique used by most systems currently being planned or implemented is QPSK modulation. QPSK modulation provides a reasonable trade-off of power/bandwidth on the satellite, ability to work with non-linearities associated with satellite transponders, and simplicity in implementation of the integrated receiver/decoder (IRD).

Work has also examined compatibility of a satellite modulation technique with modulation techniques used for cable and terrestrial broadcasting systems. Use of the same modulation technique from satellite could provide a means of achieving maximum compatibility for digital emissions.

Orthogonal frequency division multiplexing (OFDM) and single carrier (QAM) or vestigial sideband (VSB) are also currently being investigated for terrestrial broadcasting of digital video. Other investigations [Cominetti et al., 1993] and Doc. 10-11S/136 show that OFDM does not provide the best exploitation of the satellite power resources. Also, these modulation techniques require more power from the transponder and has a high sensitivity to travelling wave tube amplifier (TWTA) non-linear distortions.

It should be noted that these preliminary conclusions for OFDM apply to fixed reception only, with direct antennas, for which multipath propagation and selected fadings are not expected. In the case of portable or mobile reception for television, the advantages of OFDM in terms of selective fading margins might compensate for the losses due to the extra power requirements and non-linear TWTA distortions. However, equalization techniques are also being investigated for QPSK modulation to compensate for multipath signals. If mobile television from satellite is to be investigated, both OFDM and QPSK using equalization need further investigation.

5 Satellite channel access

Two techniques for accommodating multiple television programmes within a single satellite transponder are time division multiplexing access (TDMA) and frequency division multiplexing access (FDMA).

In the case of TDMA, the digitized TV programmes are time multiplexed onto a single carrier, while in the case of FDMA the TV programmes are carried by *N* different independent carriers, sharing the transponder bandwidth. Doc. 10-11S/135 discusses a comparison of these two techniques. QPSK modulation with convolutional code rate 3/4 is assumed in the study, with total useful bit rates between 34 and 45 Mbit/s in a 36 MHz transponder. Similar bit rates could also be accommodated in transponder bandwidths in the range 24 to 33 MHz, modifying the coding rate accordingly. The results show that the *C*/*N* penalty of the FDMA approach is relevant. For example, the FDMA approach requires 2.3 dB (two carriers per transponder) and 5.8 dB (four carriers) additional *C*/*N* with respect to a single TDMA, for an equal total bit rate of 34 Mbit/s.

6 Commonalties with other media

Maximum commonality of digital multiprogramme television broadcasting amongst different delivery media should be pursued; even where transmission environments are quite different, at least the most essential elements can be the same. However, some differences among them are required because of the best optimization of the capabilities of each transmission media.

The media considered are: satellite, cable, SMATV, terrestrial and microwave multipoint distribution system.

The Recommendation ITU-R BO.1211 recommends that the DVB-S framing structure, channel coding and modulation methods should be considered in converging to a worldwide standard for satellite multiprogramme broadcasting services. A draft new Recommendation on digital multiprogramme system for television, sound and data services for cable distribution, which recommends the use of the DVB-C system for distribution on cable, has been submitted to ITU-T. Similarly, a draft new Recommendation on digital multiprogramme, system for television, sound and data services for SMATV distribution, which recommends the use of the DVB-CS system for distribution on satellite master antenna systems has been submitted to ITU-T.

It is expected that whatever the media is, the characteristics of video source coding, audio source coding and transport multiplex may be common ensuring the maximum flexibility of the transport multiplex to be interconnected between different media. The basis could be the MPEG-2 multiplex (the Transport Stream) structure, which is a fixed length packet structure which has 188 bytes of data. Also the MPEG-2 TS has some service information (SI) elements and makes adequate provision for more developed SI systems to be added.

The framing, synchronization and randomization can be common.

When outer coding is needed (depending on the media requirements) the same scheme and ratio should be used. Also, when interleaving is defined (depending on the media) the same depth should be used.

When inner coding is required, it should be selected convolutional and identical code constraint length (*K*). The error correction rate may be selectable to facilitate the optimum design applicable to each system. Most of the systems may allow the user the selection of the forward error correction (FEC) ratio.

The roll-off characteristics for each media may be different to ensure the optimum adaptation to the channel performances.

The concept of the “container” channel should be pursued, thus facilitating the interworking of the signal running through different delivery media.

The modulation scheme depends on the peculiarities of the transmission media. For example, in satellite broadcasting where power is the limiting factor, wider bandwidths may be used; while in the cable distribution systems the use of more spectral efficient modulation schemes may be necessary.

In consequence, the connection of the digital signals from one delivery media to another one may require transmodulation and readaptation of the signal to each channel characteristics. Peculiarities of each media about the transparency of such interconnection may require the need for demultiplexing and remultiplexing (e.g. professional cable systems).

While no limitations on the maximum bit rate to be transmitted through each system seem to be required, apart from the theoretical ones, consideration should be made to the possibilities to ensure the transmission of the bit stream through all channels characteristics (which depends on the transmission media) without the need to process the signal at each interconnection point.

As far as possible, the maximum commonality with the current terrestrial infrastructures (plesiochronous digital hierarchy (PDH), synchronous digital hierarchy (SDH), etc.) should be pursued to allow the feeding of digital multiprogramme signals by the current infrastructures.

Asynchronous transfer mode (ATM) technology is being deployed around the world.

Two methods have been defined to map MPEG-2 TS packets into ATM cells in a consistent manner as presented in ITU-T Recommendation J82, Transport of MPEG-2 constant bit rate television signals in B-ISDN. B-ISDN is based on ATM.

The first method utilises ATM adaptation layer type 1 (AAL type 1). One TS packet is mapped into four ATM cells. The size of the MPEG-2 TS packet (188 bytes) has been specified in relation to the segmentation and reassembly sublayer – protocol data unit (SAR-PDU) payload of the AAL type 1, i.e. 47 octets. As a result a TS packet matches exactly four SAR-PDU payloads when the AAL type 1 is used.

The second method utilises ATM adaptation layer type 5 (AAL type 5). This mapping is referred as $1/N$ mapping : 1 to N MPEG-2 TS packets are mapped into AAL – service data unit (SDU). The value N is established via signalling at call setup. In the absence of signalling, the default AAL-SDU size is 376 octets.

If two consecutive TS packets do not contain a program clock reference (PCR) they can be mapped directly into 8 ATM cells ($N = 2$).

A PCR bearing TS packet must be the last TS packet in the AAL-SDU. When a PCR bearing packet must be sent as the only packet in an AAL-SDU, 44 octets of padding are required to match this packet to 5 ATM cells.

7 Example of digital multiprogramme satellite broadcasting systems

Several systems are either being planned or have already been implemented. A brief description of three systems are as follows. Information on Region 2 experience is provided in Annex 2.

7.1 Digital video broadcasting from satellite System A (DVB-S)

A Memorandum of Understanding for the development of harmonized DVB services in Europe bas been signed by more than 200 entities, including equipment manufacturers, broadcasters, network operators and administrators (Doc. 10-11S/14).

The DVB project has converged on a common system proposal for satellite emissions in the 11/12 GHz frequency range (referred to as DVB-S system) which has been standardized within the European Telecommunications Standardization Institute (ETSI) and has been used by WP 10-11S to produce Recommendation ITU-R BO.1211.

As summarized in Table 3, the European multiprogramme TV system is based on MPEG-2 “main profile at main level” video and sound coding algorithm and on MPEG-2 transport multiplex. A concatenated FEC scheme by Reed-Solomon and convolutional coding, with soft-decision Viterbi decoding, allows very robust RF performance in the presence of noise and interference. Five coding rate steps in the range 1/2 to 7/8, offer different trade-offs between spectrum and power efficiency and can be selected by the operator (see Doc. 10-11S/34). Raised cosine filtering is adopted, together with QPSK modulation and coherent detection. The transmission symbol rate of the system can be chosen by the operator, to optimize the exploitation of the satellite transponder bandwidth (Doc. 10-11S/14).

For relevant system parameters see Annex 1.

7.2 System B (DSS)

System B was first deployed in 1994 to be the first broadcasting-satellite service (BSS) DTH system for the United States of America. In 1996, system B was deployed in several other Region 2 countries using fixed-satellite service (FSS) frequencies.

System B uses satellite emissions in the 11/12 GHz frequency range and is tailored for use in 24 MHz transponders.

As summarized in Table 3, System B uses MPEG-2 main profile main level video syntax, MPEG-1 Layer II audio syntax and the System B transport specification.

For relevant system parameters, see Annex 1.

7.3 System C (GI-MPEG-2)

System C is a DTH digital satellite television system now being widely used in the United States of America. The system carries multiple digital television (and radio) services in time division multiplex (TDM) format. System C evolved from the first digital satellite system deployed in the United States of America, which was originally used for commercial applications.

This system includes renewable access control, impulse pay-per-view, and data services. Virtual channels allow simplified viewer navigation and "surfing" between channels.

For relevant system parameters, see Annex 1.

7.4 Integrated services digital broadcasting (ISDB)

Satellite digital broadcasting system based on ISDB including a function of multiprogramme TV broadcasting has been studied since 1991 and is described in Report ITU-R BO.1227.

The transport multiplexing scheme might depend on the emission media such as satellite, terrestrial and cable because their channels have their own transmission characteristics. However, it is still convenient for the broadcasting systems that their schemes have maximally common part as much as possible.

A transport system based on the buried sync and the convolutional interleaving may be an efficient one when hierarchical transmission is not employed. On the other hand, transport system based on the subframe structure, the additional sync and the block interleaving may be preferable when hierarchical transmission is introduced or commonality among other hierarchical systems is taken into account. Introduction of subframe structure and block interleaving method will be expected to be introduced as a transport multiplexing structure.

Theoretical analyses and hardware experiments have been conducted so far, with regard to the comparison of modulation methods, protection ratios of digital to analogue and digital to digital, the relationship among bit rates, threshold C/N ratios, etc. Technical issues such as how to use programme specific information (PSI) in MPEG-2 systems, 8-PSK modulation techniques, new error correction schemes, coded modulation, hierarchical transmission, channel planning, multimedia services, etc., have also been studied.

An example of system parameters in the case of a 40 Mbit/s experimental transmission system are listed in Table 2.

Following the ISDB concept, merits such as flexibility, expandability, interoperability with other media, etc., can be achieved. Features of ISDB have been introduced into MPEG-2 systems (MPEG-2 Part 1, multiplexing). A hardware system which is capable of statistical multiplexing has already been developed and demonstrated in the NHK Open House and the Asian Broadcasting Union (ABU) General Assembly in Kyoto in September 1994.

8 Feasibility of common functional requirements for satellite multiprogramme TV reception.

Recommendation BO.1294 has been produced on the "Common functional requirements for the reception of digital multiprogramme television emissions by satellites operating in the 11/12 GHz frequency range" with the aim to promote universal receivers capable of decoding signals from various systems in these areas where more than one system coexist or may coexist.

A feasibility analysis have been done in order to understand and evaluate the complexity and cost implications of the potential universal IRD, reaching positive conclusions. For further details see Annex 1.

TABLE 2

Parameters of the 40 Mbit/s experimental system

Modulation scheme	QPSK (absolute detection by frame synchronous code)
Transmission symbol rate	20.48 MBd (40.96 Mbit/s)
Transmission bit rate	31.1 Mbit/s
Raised cosine roll-off factor	0.4 (equally divided between transmitter and receiver)
Error correcting code	Shortened difference set cyclic (SDSC) code (1016,772)
Frame duration	1 ms
Frame structure	Block of 20 packets
Packet size	188 bytes
Framing synchronization	20-byte independent of error correcting coding
Interleaving	Block interleaving
Video coding	MPEG-2, Part 2
Audio coding	MPEG-2, Part 3
Multiplexing	MPEG-2, Part 1
Protection ratios	Suitable for WARC SAT-77 criteria
Service availability	99.9% of the worst-month (comparable to conventional analogue service with 45 cm receiving antennas – as the interference environment permits)

9 List of acronyms

AD	Auxiliary data
ATM	Asynchronous transfer mode
ATSC	Advanced television systems committee
CA	Conditional access
DRAM	Dynamic random access memory
DVB	Digital video broadcasting
DVB-S	DVB satellite
ETS	European telecommunication standard
FEC	Forward error correction
IRD	Integrated receiver decoder
MPEG	Moving Pictures Experts Group
MPEG-2 TS	MPEG-2 transport stream
PCMCIA	Term used to describe a high-speed common interface device
PID	Program identification
PRBS	Pseudo random binary sequence
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RAM	Random access memory
ROM	Read only memory
RS	Reed-Solomon
SCID	Service channel identification
SCTE	Society of Cable and Telecommunications Engineers

REFERENCES

COMINETTI, M., MORELLO, A. and VISINTIN, M. [Summer, 1993] Digital multiprogramme TV and HDTV by satellite. *EBU Tech. Rev.*, **256**.

ANNEX 1

Feasibility of common functional requirements for satellite multiprogramme TV reception

Architecture and cost estimations

(Text prepared by the Special Rapporteur Groups on convergence to world-wide
standard for digital TV. source: Doc 10-11S/87)

1 Introduction

As a consequence of the decisions taken at the Rome meeting of the ITU-R JWP 10-11S held in September 1995, a Special Rapporteur was appointed with the aim to promote the convergence on a world-wide standard for digital multi-programme emission systems for television, sound and data services for satellites operating in the 11/12 GHz frequency range.

JWP 10-11/S asked specifically to perform the following tasks:

– analyse the commonalities between existing systems,

– define and describe the functions of a generic system model,

– identify the processes and the minimum set of parameters of the various sub-systems,

– define the internal interfaces between the modules of the generic system and the external system interfaces.

Within this Annex the feasibility of the universal IRD for satellite multiprogramme TV reception is analysed. The common functional requirements (universal IRD) are designed to potentially receive satellite digital TV signals from the dominant systems in the world: DVB-S, DSS and GI-MPEG-2. These systems have been submitted to the ITU-R by administrations as candidate systems to be recommended by the ITU.

This contribution provides a generic reference model for the common functional requirements of a universal satellite IRD with the aim to analyse the architecture implications for a multistandard receiver as well as estimations on the potential cost of the universal IRD with respect to an IRD prepared for the reception of signals following a unique system.

In § 2 the generic reference model for the common functional requirements of a universal satellite IRD is provided as well as a reference to the typical IRD protocol stack. § 3 analyses the universal elements of the IRD core functions indicating the added complexity of the universal implementation with respect to a unique one. In § 4 cost estimations are provided of the universal IRD as a relative factor with respect to the DVB-S one considering two possible configurations for coexistence of more than one system:

– configuration A – single standard IRD provided with universal elements

– configuration B – multistandard universal IRD.

Finally main conclusions are derived in §5. Additional information is also provided in the Appendices: Summary characteristics of digital multiprogramme TV systems by satellite, list of companies contacted and typical IRD cost splitting.

This Annex has been taken as the background material for Recommendation ITU-R BO.1294 on the common functional requirements for the reception of digital multiprogramme television emissions by satellite operating in the 11/12 GHz frequency range.

2 Generic reference model for the common functional requirements of a satellite IRD

A generic reference model for the common functional requirements of a satellite IRD has been produced in order to analyze the feasibility of the universal elements of a satellite IRD, identifying the applicability of the generic reference model to the three systems currently in use.

This generic model refers to domestic type IRD and does not intend to specify the functions required for professional IRDs.

The generic reference model has been defined based on the functions required for covering all layers of a typical IRD protocol stack. For reference, Fig. 2 presents the typical IRD protocol stack which is based on the following layers:

– *Physical and link layers* covering the typical front-end functions: tuner, QPSK demodulator, convolutional decoding, de-interleaving, Reed-Solomon decoding and energy dispersal removal.

– *Transport layer* responsible for the demultiplexing of the different programmes and components as well as the depacketization of the information (video, audio and data).

– *Conditional access* (CA) functions which control the operation of external decoder functions (common interface for conditional access as an option).

– *Network services* performing the video and audio decoding as well as the management of electronic program guide (EPG) functions and SI and, optionally, data decoding.

– *Presentation layer* responsible, among other things, of the user interface, operation of the remote control, etc.

– *Customer services* covering the different applications based on video, audio and data.

From the protocol stack, the generic reference model for the satellite IRD is derived. Find the generic reference model block diagram in Fig. 3.

Two types of functions are identified in the generic reference model: IRD core functions and other additional essential functions.

– *The IRD core functions* cover the key IRD functions which define the digital TV system. IRD core functions include:

  – demodulation and decoding,

  – transport and demultiplexing,

  – source decoding video, audio and data.

– *The additional essential functions* are required to perform the operation of the system and upgrade it with additional and/or complementary features. These functions are closely related to the service provision. The following functions and blocks could be considered as the additional essential functions and may differentiate one IRD from another:

- satellite tuner,
- output interfaces,
- operative system and applications,
- EPG,
- SI,
- CA,
- display, remote control and different commands,
- ROM, RAM and FLASH memory,
- interactive module,
- microcontroller,
- other functions as teletext, subtitling, etc.

FIGURE 2

Typical IRD protocol stack

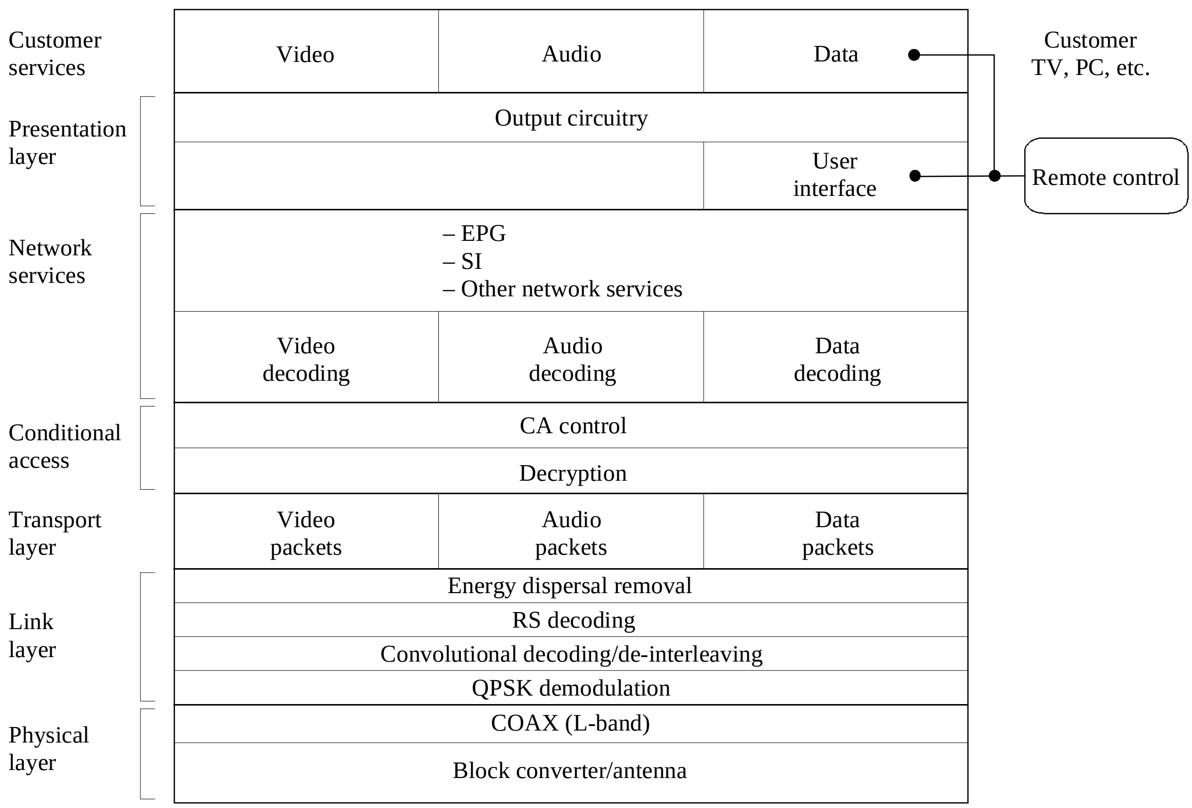

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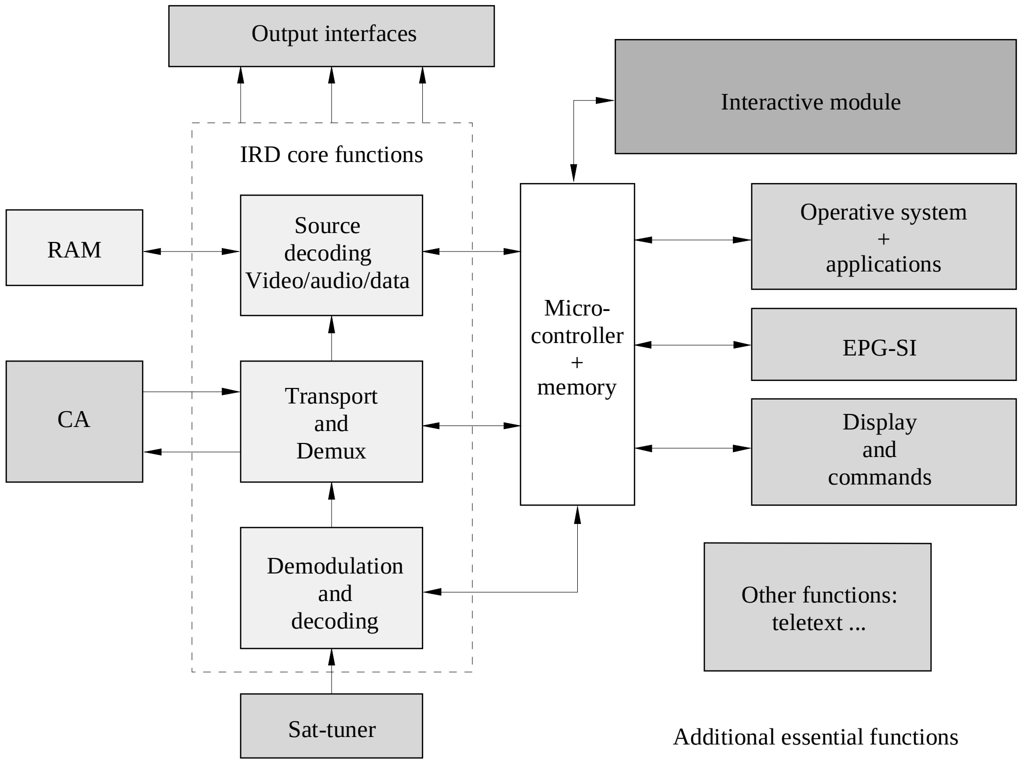
FIGURE 3

Generic reference model for a satellite IRD



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3 Universal elements of a satellite IRD

An analysis of the core and essential functions, their common elements and their particularities, as well as the cost implications of the three systems, concluded on the feasibility to define universal elements for a satellite IRD.

The universal elements of a satellite IRD perform the following functions:

– demodulation and decoding,

– transport and demultiplexing,

– source decoding of video, audio and data.

It is understood that definition of additional essential functions is out of the scope of Recommendation ITU-R BO.1294, because these functions would be specific to each service and very close to the specific implementation by each manufacturer, subject to a number of external and service conditions. Therefore the potential diversity of additional essential functions among satellite IRDs does not impact on the universal elements of the satellite IRD.

Although for the analysis of universal IRD feasibility the functions are split as previously stated, it is noted that from the electronics implementation point of view the manufacturers usually produce block integrations in the following way:

– *Satellite front-end* including satellite tuner demodulation and decoding functions.

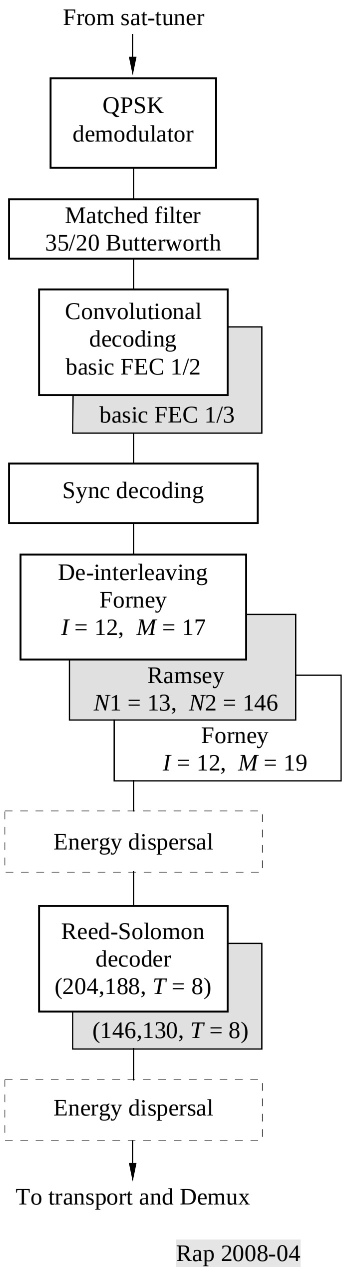
– *Baseband processing* including the functions of transport, demultiplexing, source decoding (video/audio/data), microprocessor, dynamic random access memory (DRAM) required for Demux and FLASH memory required for storing residential software and/or remote software updating.

3.1 Demodulation and decoding

The block diagram of the demodulation and decoding functions for the universal elements of a satellite IRD is presented in Fig. 4. Those overlapped blocks represent functions with common elements for the three systems although with different characteristics. Dashed blocks represent functions not utilized by all these systems.

FIGURE 4

Block diagram for demodulation and channel decoding



The following aspects are highlighted:

– The matched filter should be capable of implementing the following roll-offs: 0.35/0.20/Butterworth filters. It does not imply a noticeable extra complexity at the IRD with respect to a unique roll-off.

– The convolutional decoding should work based on a basic FEC of 1/2 as well as 1/3. It implies a small extra complexity with respect to a unique basic FEC approach, provided the generator polinomial used is the same in the three systems.

– Interleaving should be implemented with a Forney approach with $I = 12$ and $M = 17$ and 19 as well as Ramsey with $N1 = 13$ and $N2 = 146$. It may imply a small extra complexity with respect to implement a unique interleaving approach.

– Energy dispersal should be implemented twice to be applied either before the RS decoder or after and with a different polynomial. It supposes a negligible impact on the complexity.

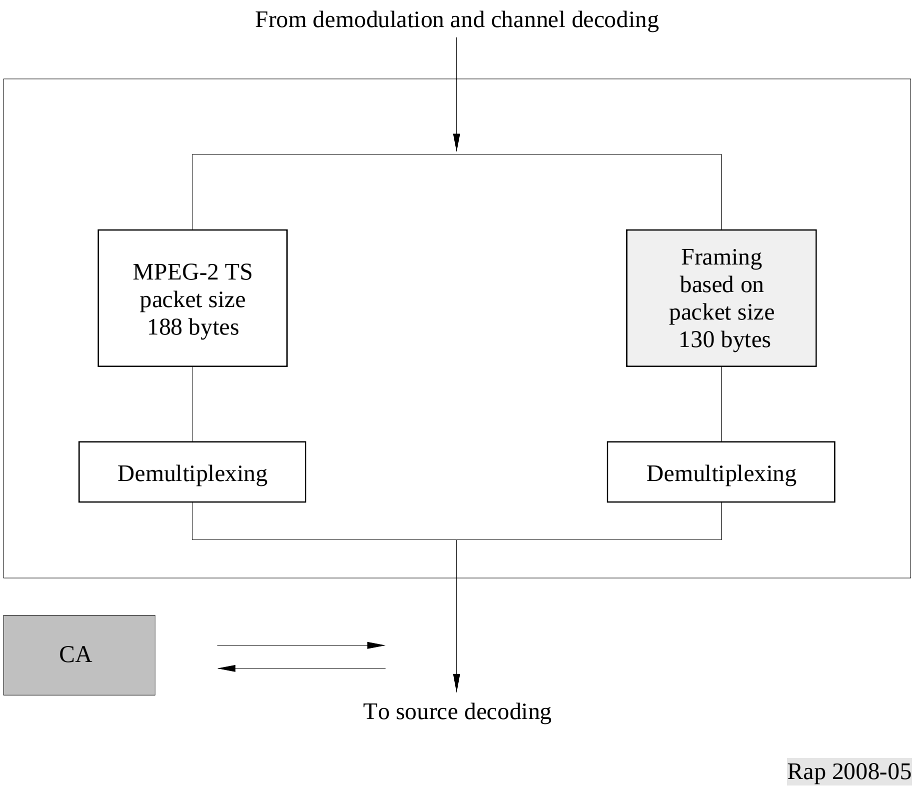
– RS decoder should be implemented with the parameters (204,188, $T = 8$) as well as (146,130, $T = 8$). It implies a negligible extra complexity.

3.2 Transport and demultiplexing

The block diagram of the transport and demultiplexing functions for the satellite IRD is presented in Fig. 5.

FIGURE 5

Block diagram for transport and demultiplexing



The system will be capable of receiving and demultiplexing packets following MPEG-2 transport multiplexer (see ISO/IEC 13818-1) implemented in DVB-S and GI-MPEG-2 systems, as well as transport stream specific characteristics of DSS system.

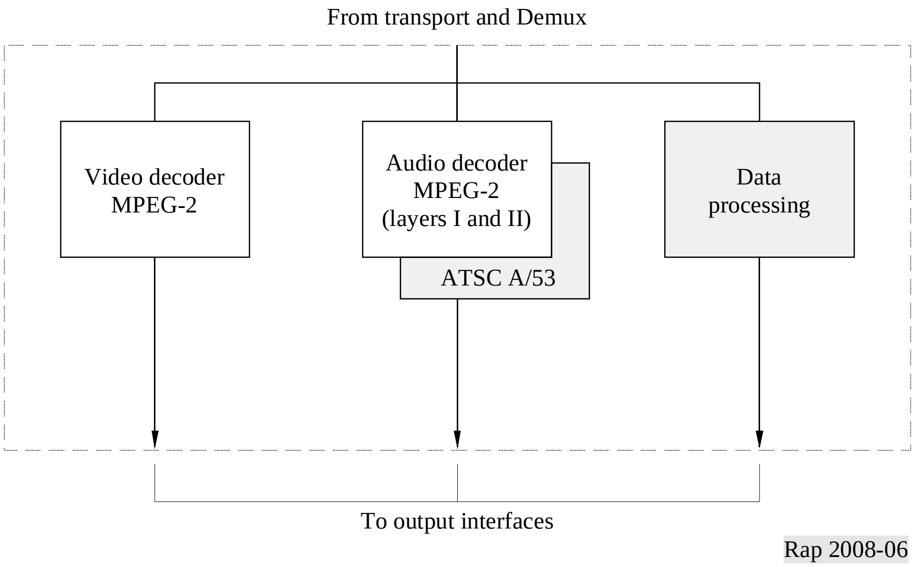
The key issue of the universal transport and Demux is the management of different packet sizes in the framing which is not a very complex amendment with respect to the unique packetization since it is usually programmed by firmware on the chips.

3.3 Source decoding of video, audio and data

The block diagram of the source decoding of video, audio and data functions for the satellite IRD is presented in Fig. 6.

FIGURE 6

Block diagram for source decoding



3.3.1 Video

This universal element of a satellite IRD will decode video MPEG-2 signals which have been encoded as specified in ISO/IEC 13818-2

3.3.2 Audio

This universal element of a satellite IRD will decode audio signals following the formats MPEG-2, Layers I and II (ISO/IEC 13818-3) and ATSC-A/53 Annex B. It is noted that the audio decoder of DSS system (MPEG-1 Layer II) is already implemented in the audio decoder MPEG-2 because this one is backwards compatible with the MPEG-1.

3.3.3 Data

This block addresses the functions to process the data associated to the transport multiplex. This item is out of the scope of Recommendation ITU-R BO.1294.

4 Cost estimations

The cost estimations are based on the functional reference model for the universal IRD. A simplified model has been considered for evaluating costs closer to the block integration approach followed by manufacturing practises.

Based on an extensive campaign of consultations to manufacturers, cost estimations are provided in the following paragraphs.

4.1 Chip cost evaluation

Consultations to manufacturers have provided estimations on the complexity increase for the universal solution of each of the core functions with respect to a unique system implementation (DVB has been taken for reference). Most of the manufacturers state that covering the three alternatives have a minor impact on the final cost of the chips for the core IRD functions. Although it is stated that the cost increase in the chips for incorporating DSS functions to the DVB based ones could be slightly higher than incorporating GI-MPEG-2 functions, the inclusion of universal elements is evaluated as an average of 7% or 22 % increase with respect to the total box, depending on the configuration considered: either a single standard IRD with universal elements or a multistandard universal IRD. These costs could be reduced depending on the economy of scale reached.

It is to be noted the concerns expressed by several manufacturers concerning the licencing issues. This aspect introduces an extra cost uncertainty difficult to assess in this Annex.

4.2 Total IRD cost evaluation

As a basis reference, rough estimations are provided here for the cost/complexity of the several functions in DVB-S IRD as a relative factor of the total box, being considered this one as 100. It is noted that the splitting of cost is influenced by a number of factors and the precise figures are very different depending on several conditions such as production volumes, type of implemented additional essential functions (such as conditional access, electronic programme guide, application software), etc.

Rough estimations for *DVB-S IRD* are:

– Satellite front end including tuner/demodulator/decoding	15%
– DVB baseband process including transport/Demux/DVB video/audio/ data decoding /microprocessor/ DRAM/FLASH memory	25%
– Operational functions and miscellaneous	60%
– *Total DVB IRD*	*100%*

For reference, detailed typical cost splitting estimations are provided in Appendix 3.

It is noted that cost estimations for any unique system IRD, either DVB, DSS or GI-MPEG-2 systems, could be assimilated to the rough estimation provided for the DVB-S IRD.

Based on the inputs from the manufacturers, as well as the discussions held within the Special Rapporteur Group on convergence to a world-wide standard for satellite digital TV, two configurations of the universal elements/universal IRD were defined for applicability when more than one system coexist:

– *Configuration A – single standard IRD provided with universal elements.* Chip set based on universal elements is promoted for achieving a maximum economy of scale. Nevertheless the IRD built with these chips is capable of receiving just one system. The initial cost of IRDs designed for a single system, but equipped with universal elements, has been evaluated as an extra complexity estimated on 7%, nevertheless this cost could be reduced thanks to the potential economy of scale reached. Some manufacturers have stated that the cost increase would not exist for the universal elements, but a cost reduction because of the volume of chip production.

– *Configuration B – multistandard universal IRD.* Total IRD box implemented with the additional essential functions for receiving various systems. The material cost for production of a full universal IRD has been evaluated by GI in an extra complexity of about 16-25% with respect to a GI IRD. As a reference an average of 22% has been taken. This configuration may have applicability in those geographical areas where several digital TV systems coexist or may coexist.

It is understood that in those geographical areas or markets where enough economies of scales are reached, could be the case that none of these configurations for the IRD apply and instead unique system IRDs are promoted.

4.2.1 Configuration A – single standard IRD provided with universal elements

A similar cost estimation has been done, being rather conservative, for a single standard IRD provided with universal elements, considering relative factors to the overall cost, keeping the cost of the single standard IRD (reference DVB-S IRD) as 100 %.

Rough estimations for *single standard IRD provided with universal elements*:

–	Satellite front end including tuner/universal demodulator/decoding	18%
–	Universal baseband process including transport/Demux/DVB video /audio/ data decoding/microprocessor/DRAM/FLASH memory	29%
–	Operational functions and miscellaneous	60%
–	*Total universal IRD*	*107%*

Adding all factors, the total cost of a single standard IRD provided with universal elements could be evaluated as a factor of 1.07 with respect to a single standard IRD one (reference DVB-S IRD).

From the previous figures it can be concluded that although the cost of the universal IRD core functionalities could represent an appreciable extra cost with respect to those required by the DVB-S, the impact in the final cost of the complete IRD is very small due to the relatively high implementation cost of the additional essential functions.

See in Fig. 7, a summary of cost splitting for both the single standard IRD and the single standard IRD provided with universal elements computed as relative costs to the first one (DVB IRD).

FIGURE 7a

Cost splitting for the single standard IRD (reference DVB IRD)

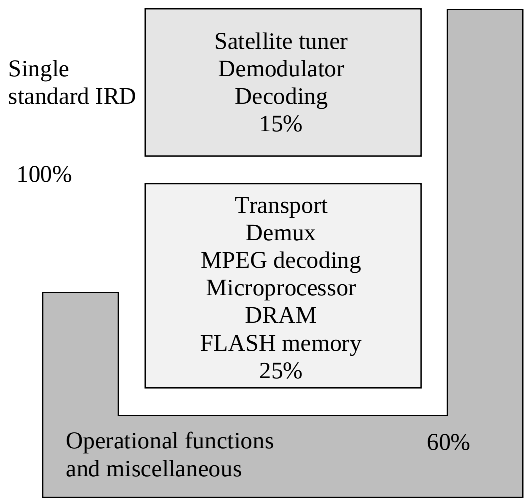
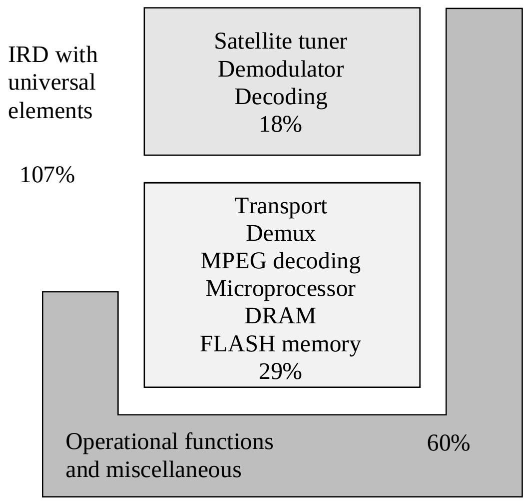


FIGURE 7b

Cost splitting for the IRD provided with universal elements



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As a very generic reference the IRD retail price after two years of introduction in the market may be about 500 $ US. The cost depends mainly on volumes and other very variable market conditions. It may imply that production cost could represent about 300 $ US.

4.2.2 Configuration B – Multistandard universal IRD

Also cost estimations are provided for the multistandar IRD, known also as universal IRD, prepared to receive any of the three types of satellite digital TV systems.

Rough estimations for *universal IRD*:

– Satellite front end including tuner/universal demodulator/decoding 18%

– Universal baseband process including transport/Demux/DVB video/ audio/ data decoding/microprocessor/DRAM/FLASH memory 29%

– Operational functions and miscellaneous 75%

– *Total universal IRD* *122%*

Adding all factors, the total cost of a universal IRD could be evaluated as a factor of 1.22 with respect to the DVB IRD one. It is a very rough estimation depending on a number of factors as volumes, soft and hard capabilities and for the major part licences.

As it is derived from the previous analysis the cost of a universal IRD for the final user is always lower than the addition of the cost of three separated IRD for receiving each of the digital TV systems in those areas where systems coexist and the user wishes to receive signals from more than one system.

See in Fig. 8, a summary of cost splitting for both the single standard IRD and the universal IRDs computed as relative costs to the first one.

FIGURE 8a

Cost splitting for the single standard IRD

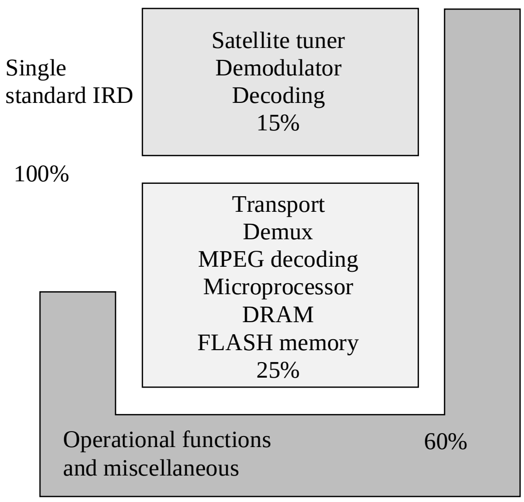
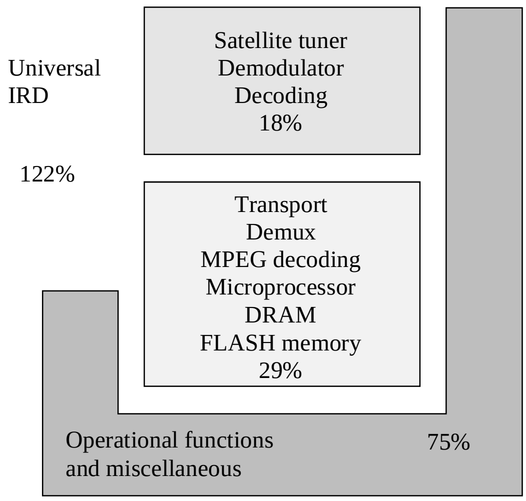


FIGURE 8b

Cost splitting for the universal IRD



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5 Conclusions

From the analysis presented in this Annex the following conclusions can be derived supported on consultations to chip and IRD manufacturers:

– The feasibility of the convergence of the three main digital TV systems in the world: DVB-S, DSS and GI-MPEG-2 into a universal IRD concept has been concluded positively based on a technical assessment for a reliable development of such receiver capable of receiving signals from the three systems. This conclusion can be a very useful tool when planning services for markets/areas where more than one system coexist.

– The functional architecture has been presented in this Annex. IRD core functions have been separated from additional essential functions. The concept of the universal IRD is supported by providing flexible IRD universal elements rather than homogeneous additional essential functions. Additional essential functions will differentiate one IRD from another because they will be matched to the specific requirements or commercial constraints of each system.

– The extra cost of the universal IRD with respect to an IRD built to receive a unique system is negligible and it is masked by the total cost of the IRD. As it has been shown, the dominant cost of the IRD is devoted to the additional essential functions.

– Two configurations, universal IRD and universal elements of the IRD have been proposed. The applicability of those configurations is reinforced by the economy of scales expected for the universal elements and the use of multistandard universal IRDs in those areas where various satellite digital TV systems coexist or may coexist.

– In consequence, the idea to develop a new draft ITU Recommendation on a universal IRD or the common functional requirements of the universal elements capable to receive signals based on DVB-S, DSS and GI-MPEG-2 is feasible. **It is recommended to produce such a new draft Recommendation allowing the world to enjoy a universal concept for receiving digital multiprogramme emissions by satellite.**

BIBLIOGRAPHY

ITU Texts

Doc. 10-11S/85 – Report to 10-11S, 4 October 1996 (Special Rapporteur on Convergence to a Worldwide Standard for Digital Multi programme Emissions by Satellite).

APPENDIX 1

TO ANNEX 1

Summary of characteristics of digital multiprogramme TV systems by satellite

Table 3 provides information on relevant parameters which characterize the systems in use in the world. It includes core functions as well as additional essential functions.

TABLE 3

Summary of characteristics of digital multiprogramme TV systems by satellite

Demodulation and channel decoding			
Function	System A	System B	System C
Randomization for energy dispersal	PRBS: $1 + x^{14} + x^{15}$	None	PRBS: $1 + x + x^3 + x^{12} + x^{16}$ truncated for a period of 4 894 bytes
Synchronous randomization	Yes	N.A.	Yes
Loading sequence into pseudo random binary sequence (PRBS) register	100101010000000	N.A.	0001_h
Place for derandomization application at the IRD	After the Reed-Solomon decoder	N.A.	Before the Reed-Solomon decoder
Reed-Solomon outer code	(204,188, $T = 8$)	(146,130, $T = 8$)	(204,188, $T = 8$)
Reed-Solomon generator	(255,239, $T = 8$)		
Reed-Solomon generator polynomial.	$(x + \alpha^0)(x + \alpha^1)......(x + \alpha^{15})$ where, $\alpha = 02_h$		$(x + \alpha^1)(x + \alpha^2)......(x + \alpha^{16})$ where, $\alpha = 02_h$
Reed-Solomon field generator polynomial.	$x^8 + x^4 + x^3 + x^2 + 1$		
Interleaving	Convolutional, $I = 12$, $M = 17$ (Forney)	Convolutional, $N1 = 13$, $N2 = 146$ (Ramsey II)	Convolutional, $I = 12$, $M = 19$ (Forney)
Inner coding	Convolutional		
Code constraint length	$K = 7$		
Basic code	1/2		1/3
Generator polynomial	171, 133 (octal)		117, 135, 161 (octal)
FEC	1/2, 2/3, 3/4, 5/6 and 7/8	1/2, 2/3 and 6/7	1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 5/11 and 7/8
Signal modulation	QPSK		
Symbol rate	Variable	Fixed	Variable
Symbol rate range	Not specified	20 MBd	19.5 and 29.3 MBd
Occupied bandwidth (–3 dB)	Variable	20 MHz	y MHz where y = symbol rate
Allocated bandwidth (–25 dB)	Variable	25.1 MHz	1.33 y (optionally 1.55 y) (MHz) for y (symbol rate) = 19.5 and 29.3 MBd
Baseband shaping roll-off	0.35 (square root raised cosine)	0.20 (square root raised cosine)	Bandwidth limited 4^{th} Butterworth, standard and truncated-spectrum modes approximately equivalent to $\alpha = 0.55$ and $\alpha = 0.33$, respectively

TABLE 3 *(continued)*

Transport and demultiplexing				
Function		System A	System B	System C
Transport layer		MPEG-2	System B	MPEG-2
Packet size (bytes)		188	130	188
Identification ID (bit)		13 (PID)	12 (SCID)	13 (PID)
Continuity counter (bit)		4 CC		
Adaptation flag (bit)		2 (AD)	4 (Aux)	2 (AD)
Scrambling flag (bit)		2 (S)		
Priority (bit)		1(P)	None	1(P)
Bundle boundary (bit)		1 (PE)		
Error indicating (bit)		1 (E)	4 byte media error field(1)	1 (E)
Payload (bytes)		184	127	184
Sync word byte		47_h	None	47_h
Sync byte inversion		From 47_h to $B8_h$	None	From 47_h to $B8_h$
Statistical multiplexing		Not restricted	Capable	Capable
Master reference clock		27 MHz		
Method of synchronization for video and audio		Time stamping		
Source decoding				
Video source decoding	Syntax	MPEG-2		
	Levels	at least main level		
	Profiles	at least main profile		
Audio source decoding		MPEG-2, Layers I and II	MPEG-1, Layer II (included in MPEG-2)	ATSC A/53 or MPEG-2 Layers I and II
Data source				

TABLE 3 *(end)*

Other characteristics			
Function	System A	System B	System C
Typical transponder bandwidth (MHz)	Not specified	24/27 MHz	24/27/36 MHz
Satellite downlink frequency range	Originally designed for 11/12 GHz, not excluding other satellite frequency ranges		Originally designed for 11/12 GHz and 4 GHz satellite frequency ranges
Compatibility with SMATV	Yes	Some processing is required at the headend when transmodulating to QAM	Yes
Compatibility with existing telecommunications hierarchies	The transport stream could be defined to be accommodated within the existing hierarchies		
Selectable conditional access	Yes		
Service information	ETS 300 468	System B	ATSC A/56 + SCTE DVS/011
EPG	ETS 300 707	System B	User selectable
Teletext	Supported	Not specified	
Subtitling	Supported		
Closed caption	Not specified	Yes	
Delivered TV standards	Not specified	NTSC and PAL M	NTSC and PAL
Aspect ratios	4:3 16:9 (2.12:1 Optionally)	4:3 16:9	4:3 16:9
Video resolution formats	Not restricted, Recommended: 720 × 576 704 × 576 544 × 576 480 × 576 352 × 576 352 × 288	720 × 480 704 × 480 544 × 480 480 × 480 352 × 480 352 × 240	720(704) × 576 720(704) × 480 528 × 480 528 × 576 352 × 480 352 × 576 352 × 288 352 × 240
Frame rates	Not specified	29.97	25 (PAL) 29.97 (NTSC)
Compatibility with other MPEG-2 delivery systems	ISO/IEC 13818	Some processing required	ISO/IEC 13818

(1) Sent with a redundant picture header to indicate uncorrectable error within a picture. Uses ISO MPEG defined sequence error code.

APPENDIX 2

TO ANNEX 1

List of companies contacted (mainly chip and IRD manufacturers)

Company	*Answers received*
NATIONAL SEMICONDUCTORS	☑
SAT-SAGEM	
THOMSON	☑
COMSTREAM	☑
LSI-Logic	☑
TV/COM	
SGS THOMSON	☑
COMATLAS	☑
MITSUBISHI	
HITACHI	☑
PHILIPS	
GEC Plessey	
TEXAS INSTRUMENTS	☑
C. CUBE MICROSYSTEMS	
MOTOROLA	
PIONEER	
STANFORD TELECOM	
TOSHIBA	☑
SCIENTIFIC ATLANTA	☑
COMPRESION LABS Inc.	
GENERAL INSTRUMENTS	☑
BROADCOM	☑
VLSI TECHNOLOGY	☑
DIVICOM	
SIEMENS	

APPENDIX 3

TO ANNEX 1

Typical IRD cost splitting

Production cost	*US $*	*Percentage*
Satellite tuner	20	6.67
Satellite demodulator and decoding	30	10.00
Transport and Demux	15	5.00
Decoding	15	5.00
Microprocessor	20	6.67
Modem for interactive module (low rate)	20	6.67
FLASH memory (8 Mbits) for residential software	10	3.33
DRAM (20 Mbits) for decoding and Demux	15	5.00
Analogue output modulator	5	1.67
PAL encoder	5	1.67
Infrared remote control	10	3.33
Licencies	20	6.67
PC card + plastic box	30	10.00
Connectors	20	6.67
PCMCIA for common interface with CA	10	3.33
Smart card reader	10	3.33
Power supply	10	3.33
Miscellaneous	35	11.67
Total cost	300	100.00

CA module cost, 30-60 $ US, is not considered

Simplified model	*US $*	*Percentage*
Satellite tuner + demodulator + decoding	50	16.67
Trans/Demux/MPEG-2 decoding + RAM/FLASH memory + microprocessor	75	25.00
Others	175	58.33
Total cost	300	100.00

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ANNEX 2

Region 2 experience

1 Introduction

This Annex reviews the status of DTH satellite digital television within the United States of America and, to a limited extent, within Region 2. This review, as summarized herein, revealed a common general architecture, but a wide diversity of transmission formats including the use of two different formats in systems which have been operational since early 1994.

It is noted that standardization of many processes and interfaces already exists and will permit manufacturers to utilize common chip sets and receiver designs.

2 Status of US Systems

2.1 Common architecture

A number of existing and planned DTH digital satellite transmission systems were investigated. These systems include services in both the FSS and the BSS. The FSS systems considered are identified as Systems 3 and 4 in Table 4. The BSS systems considered are identified as Systems 1 and 2 in Table 4.

All services considered had a number of common characteristics as follows:

– deliver NTSC “standard definition” signals;

– deliver audio and digital signals multiplexed with television signals;

– utilize a single multiplexed carrier per transponder with a signal bandwidth of 24-54 MHz;

– utilize a form of QPSK modulation;

– utilize advanced error control including concatenated convolutional and RS coding;

– encode/compress the video using the discrete cosine transform and motion compensation;

– encrypt each program channel separately to permit CA control on a per-channel basis;

– utilize a removable CA module to permit security upgrades.

The IRDs for each service have the protocol layers identified in Fig. 9.

2.2 Summary of system characteristics

Although the technical architectures of the services are similar, their specific implementations create digital receivers which are incompatible. The use of MPEG-2 video compression technology is a de facto standard. The systems tend to utilize different electronic program guide and conditional access implementations. Table 4 summarizes certain key characteristics of each system and the current production of digital receivers in Region 2.

2.3 Near-term evolution

The technical architectures of the US systems are expected to further diverge in the response to competitive pressures. In addition to the channel capacity expansion, the technical architectures may evolve to include the following:

– smaller receive antennas,

– advanced EPG “navigators”,

– advanced data services including “multi-media”,

– Interactive services including various return-path solutions.

TABLE 4

Summary characteristics of examples of multiprogramme emission systems in some countries of Region 2

	Example 1 (System B)	Example 2 (Based on System A)	Example 3 [Predecessor to System C]	Example 4
Service	BSS	BSS	FSS	FSS
Operational	Yes	No	Yes	No
IRDs manufactured(1) (millions)	1.20	–	0.77	–
IRDs installed(1) (millions)	0.74	–	0.54	–
Transponder bandwidth (MHz)	24	24	54	27
Signal bandwidth (MHz)	24	24	Not available	24
Modulation (format)	QPSK	QPSK	QPSK	QPSK
Error control (format)	Convolutional/RS	Convolutional /RS	Convolutional/RS	Convolutional/RS
Transport layer		MPEG-2		MPEG-2
Video encoding	MPEG-2	MPEG-2		MPEG-2
Audio encoding	MPEG-2	MPEG-2		MPEG-2
Statistical multiplexing		Not available		Not available
Encryption		Not available	Not available	Not available
Removable CA module	Yes	Yes	Yes	Yes
EPG		Not available	None	Not available
Delivered TV formats	NTSC, S-Video	NTSC, S-Video	NTSC	Not available
Other services	Audio, data	Audio, data	Audio, data	Audio, data

(1) As of August 1995.

3 Status of certain Region 2 systems

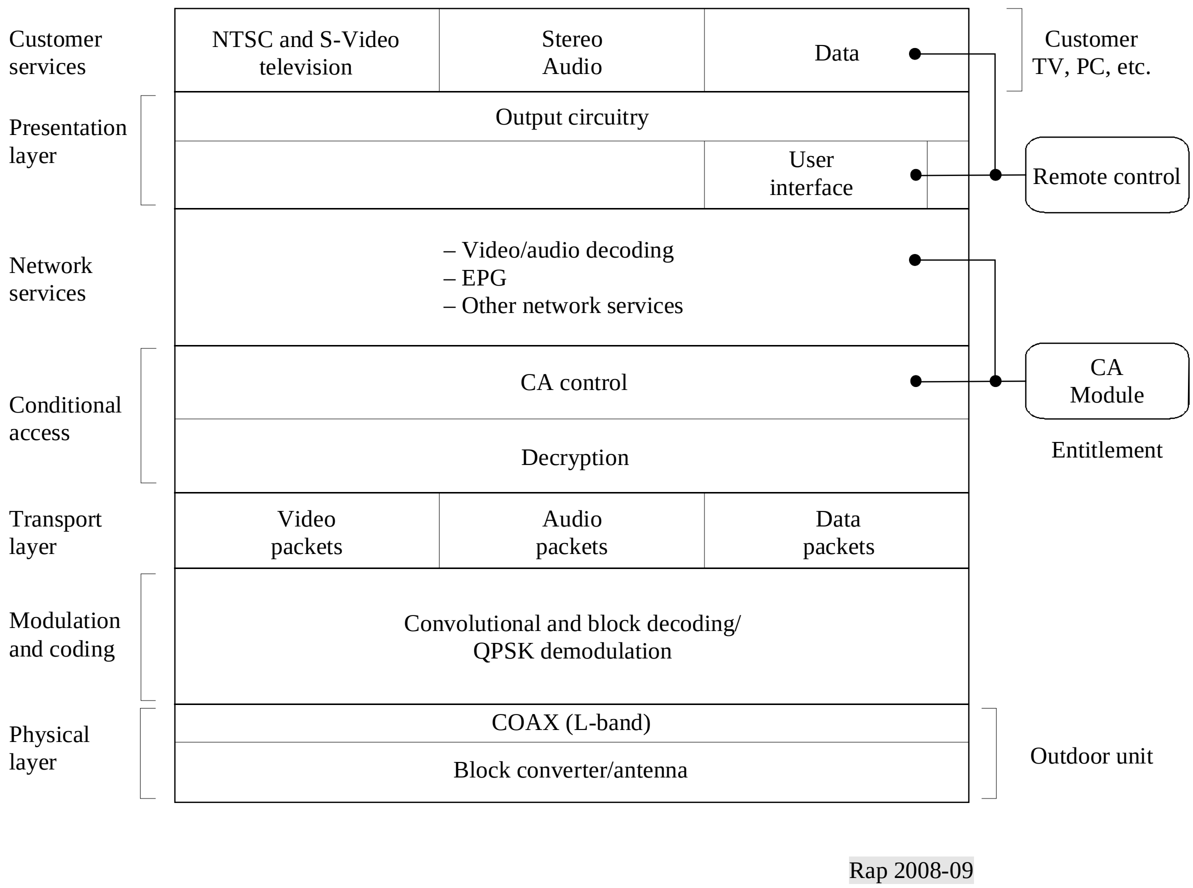
Several US -based firms are participants in DTH satellite television projects in other countries within Region 2.

Other Region 2 projects are underway in Latin America.

All planned services use multi-channel digital delivery via FSS to provide DTH subscription and pay-per-view services.

FIGURE 9

Typical IRD protocol stack



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