REPORT ITU-R BO.1227-2

SATELLITE-BROADCASTING SYSTEMS OF INTEGRATED SERVICES DIGITAL BROADCASTING

(Questions ITU-R 101/10 and ITU-R 101/11)

(1990-1994-1998)

1 Introduction

The progress of digital technology such as multimedia and digital television has made the general public more and more accustomed to high-quality, reliable and easy-to-use consumer digital devices. This, as a matter of course, has likewise prompted consumers to seek the advantages inherent in the digitalization of broadcasting. Integrated services digital broadcasting (ISDB) enables the transmission of various kinds of information, digitally encoded and systematically integrated in a single digital broadcasting channel.

This Report discusses the basic concept and technical considerations of the ISDB system.

2 Concept of ISDB system

In the ISDB system, many kinds of information such as video, audio, teletext, still pictures, facsimile, computer software and even high definition television (HDTV), from different origination sources, are digitally encoded, systematically integrated, and transmitted by a single digital broadcasting channel. Digitalization in the ISDB system not only makes possible high-quality transmission but also allows greater flexibility and efficiency in operation. It also makes possible the provision of multimedia services, and simplifies both information selection and access for the user.

It could become possible at some point in the future to incorporate into ISDB almost all kinds of broadcasting services now or under development.

3 Basic functions

It is desirable for ISDB to realize the following functions:

3.1 Flexibility

– Many kinds of signals, from high-speed video signals to low-speed data signals, and the combination of them should be able to be multiplexed on the same transmission channel.
– Various service signals which have a wide variety of transmission rates should be able to be transmitted.
– Organization of service should be able to be arranged freely.
– Signals should be able to be multiplexed based on their priorities.
– The grade of service quality should be able to be selected for each receiver.

3.2 Extensibility

– New services should be able to be introduced easily in the future.
– New broadcasters should be able to take part in the broadcasting business easily.

3.3 Inter-operability

– Transcoding among various digital broadcasting systems should be able to be done with ease.
– Interconnection with other systems such as the communication system, package media, or computer system should be able to be easily established.
– The multiplex method should be applied to a variety of transmission channels with widely-spread transmission capacity.

3.4 Emission characteristics

– Efficient emission should be realized.

– Good emission quality, such as robustness against channel errors, should be obtained.

– Stable synchronization should be regenerated.

– Recovery time should be short after interruption.

– Signals should be transmitted with minimum delay.

3.5 Reception

– Programmes should be able to be easily selectable.

– Services should be able to be multiplexed and demultiplexed easily.

– Signal components should be able to be displayed synchronously with each other.

– Links among services or signal components should be able to be established.

– Waiting time after selecting channel should be able to be decreased.

– Common receiver should be able to be realized for all transmission media.

3.6 Conditional access

– A wide range of applications requiring conditional access should be able to be introduced.

3.7 Other requirements

– Operational costs for broadcasters should be reduced.

– The receiver circuitry should be made simple and low-cost.

4 Technical considerations

4.1 Emission aspects

Use of a direct broadcasting satellite is considered an effective medium for ISDB. The service requires a wide bandwidth channel and at present almost all of the terrestrial broadcasting frequencies are in use in some areas. Broadcasting satellites would also more effectively serve ISDB’s goal of economically providing consistent high-quality, reliable services over broad geographical areas.

A transmission system for satellite ISDB and the results of experimental measurements on this system carried out by Japan are described in Annexes 1 and 2. A comparison between satellite digital multi-programme transmission systems and the ISDB system is presented in Annex 3.

4.2 Framework of ISDB transport system

In order to meet the functions mentioned in § 3, it is appropriate that the service transport methods for ISDB have the following functions:

– multiplexing a variety of digitized video or audio signals and various kinds of data so that the signals are transmitted on a single channel and are received separately at the receiver;

– optionally, error correction coding for the signals transmitted on various kinds of channels, so that they can be received correctly under various receiving conditions, such as severe noise or interference;

– modulating the digital signals, which are integrated into a single bit-stream including the error correcting codes, by means of the multiplexing methods, using appropriate modulation and emission methods based on the characteristics of each transmission channel;

– introducing conditional access systems which can be applied to each of the various kinds of digital signals, using appropriate conditional access systems;

– data access method for the transport method mentioned above which enables easy reception of the desired service or programme at the receiving side.

4.3 Service multiplex methods

There are basically two service multiplex methods: structured transmission and packet transmission.

4.3.1 Structured transmission method

In the structured transmission method, data corresponding to each service are located in fixed positions in the transmission frame. This method has the following characteristics:

– it allows for optimum transmission of each service, assigning it to an appropriate frame area and position according to the required transmission rate;

– the desired data can be easily separated, because data can be identified based on their position in the frame;

– transmission efficiency is high if the transmission rate of each service is constant;

– it has poor extensibility, because it is difficult to accommodate new services once the system has been specified.

4.3.2 Packet transmission method

A packet consists of a header and data field for each particular service. The header indicates data attributes. In the packet transmission method, the packet is located arbitrarily in the transmission frame. This method has the following characteristics:

– various services can be specified with a common transmission protocol and handled in the same manner;

– it requires data separation processing to select the desired packets from all transmitted packets;

– transmission efficiency is high, because it allows for optimum transmission of variable bit rate services, thus compensating for the somewhat higher overhead due to the presence of packet headers;

– new services can be easily added, which means that it provides high extensibility and flexibility.

For obtaining robustness against transmission error, the transmitted data should be constructed within the transmission frame which has periodicity. The frame should have a frame synchronization code which has sufficient length for regenerating synchronization quickly and reliably. The depth of interleaving, the method of randomizing transmission signals, and the schemes for error correction should be determined based on the requirements for each system and the transmission channel characteristics.

4.4 Information identification function

ISDB makes it possible to integrate and transmit a large variety of services.

Such features underscore the importance of identification and index capabilities. These would enable the user easily to receive, select, use directly, or store automatically and retrieve the required information.

4.5 Other aspects

Other aspects are also expected to be studied and combined in an optimum manner to develop ISDB. These would include:

– source coding;

– channel coding;

– digital modulation;

– conditional access; and

– the concept of a universal receiver.

5 Conclusion

ISDB is expected to be able to include various services such as multimedia, multichannel television and HDTV. A practical, well-organized model should be studied for implementing future broadcasting systems.

ANNEX 1

Transmission system for satellite ISDB

1 Block definition

Multiple MPEG-2 transport streams (MPEG-TSs) from MPEG-2 multiplexers are processed as the input signals to the system. This block contains the following processes:

– combined transport for making a transport frame structure,

– outer forward error correcting (FEC) coding (i.e. Reed-Solomon (RS)),

– randomization for energy dispersal,

– interleaving,

– control code transmission and multiplexing configuration control (TMCC) encoding and its channel coding,

– insertion burst signal for stable carrier recovery under low receiving carrier-to-noise ratio, *C/N*,

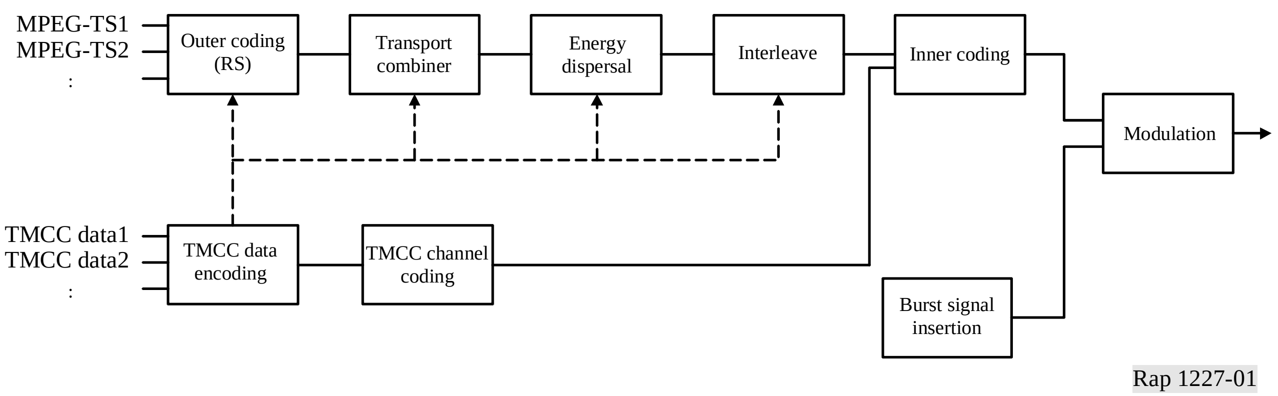
– inner FEC (i.e. trellis or convolutional code),

– modulation.

Detailed information for such processes is described in Fig.1.

FIGURE 1

Block diagram of transmission system



2 Transport combiner

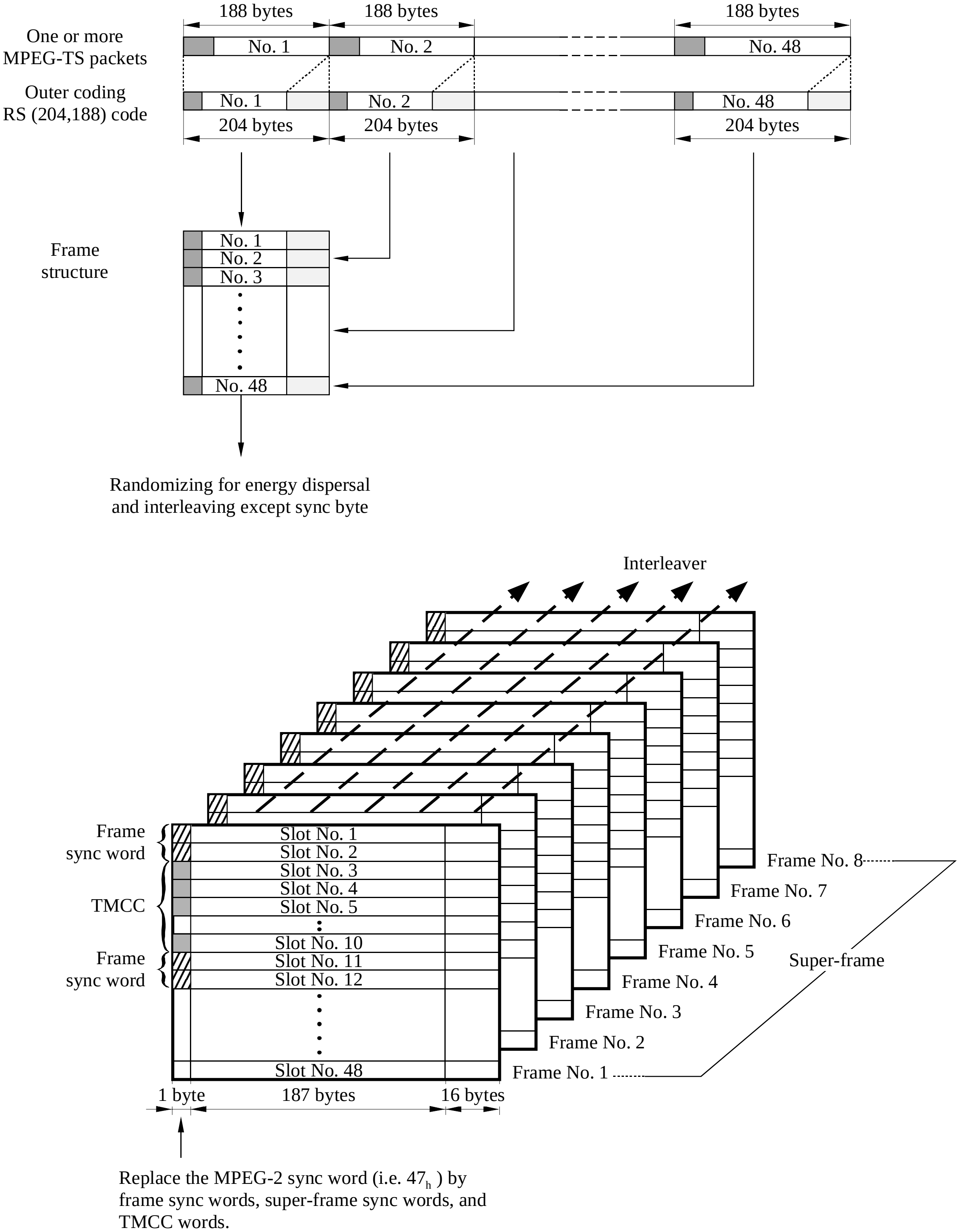
2.1 Framing structure

The transport combiner receives a maximum of eight MPEG-TS from MPEG-2 multiplexers and composes a frame that consists of 48 TS packets with outer coding parity bits. A super-frame coming from 8 frames according to the control code derived from the MPEG-2 multiplexers. Each absolute row in the frame is called “slot”. The transport combiner replaces the MPEG-2 synchronization word (i.e. 0×47) at the top of each packet by frame sync words, super-frame sync words, and control words termed TMCC.

The transport combiner also generates a frame sync pulse (FP) and a super-frame sync pulse (SF) and distributes them to each process. A block diagram of the frame structure is shown in Fig. 2.

FIGURE 2

Block diagram of the frame structure



Rap 1227-02

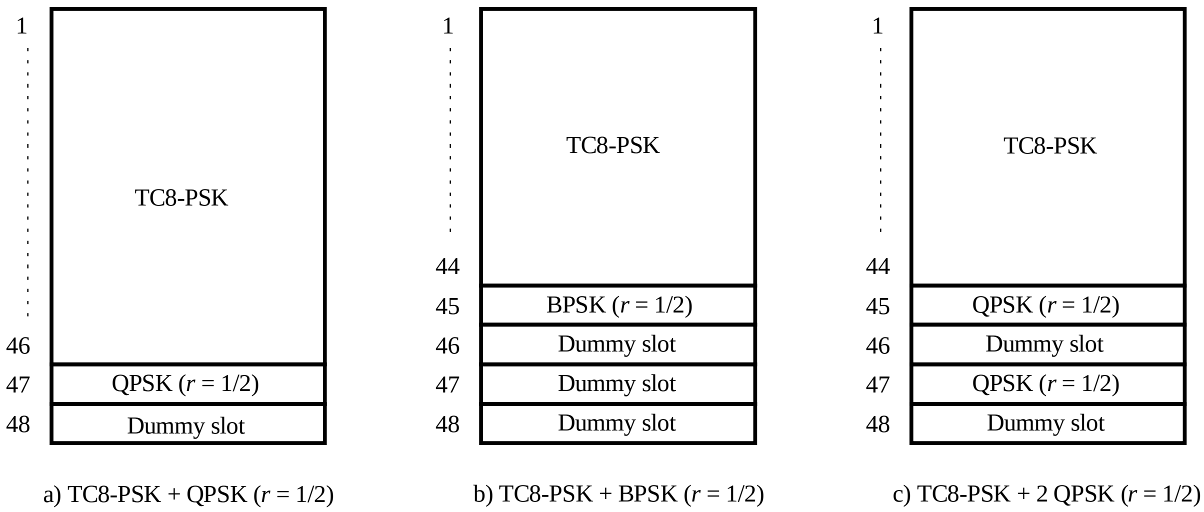
2.2 Slot assignment

In the case where more than one modulation scheme is adopted for one carrier, slots which are transmitted by each modulation scheme are arranged in frame in decreasing order of rate of frequency utilization (e.g. TC8-PSK → QPSK(3/4) → QPSK(1/2) → BPSK(1/2)).

Program data which are transmitted by trellis coded octophase shift keying (TC8-PSK) are assigned to a part of the frame by slots and are able to occupy all the assigned slots. On the other hand, program data which are transmitted by quaternary PSK (QPSK) with an inner code rate of *n/m* are assigned to a part of the frame by *m* slots and are able to occupy *n* slots in *m* slots. The *m-n* slots called "dummy slots" are not used for data transmission. Program data which are transmitted by binary PSK (BPSK) with an inner code rate of 1/2 are assigned to a part of the frame by four slots and are able to occupy one slot in four slots. Three slots are dummy slots. Dummy slots are used to maintain processing clock frequency in any frame structure (see Fig. 3).

FIGURE 3

Example of slot assignment



Rap 1227-03

3 Outer Code

A RS (204,188, $T = 8$) shortened code is applied to each transport packet (188 bytes). The shortened RS code may be implemented by adding 51 bytes, all set to zero, before the information bytes at the input of a (255,239) encoder. After the RS coding procedure these null bytes are discarded.

– Code generator polynomial: $g(x) = (x + \lambda^0)\,(x + \lambda^1)\,(x + \lambda^2)\,\ldots\,(x + \lambda^{15})$, where $\lambda = 02_{hex}$

– Field generator polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$.

4 Randomization

For the purpose of energy dispersal, the polynomial for the pseudo-random binary sequence (PRBS) is adopted. The PRBS generator is:

$$1 + x^{14} + x^{15}$$

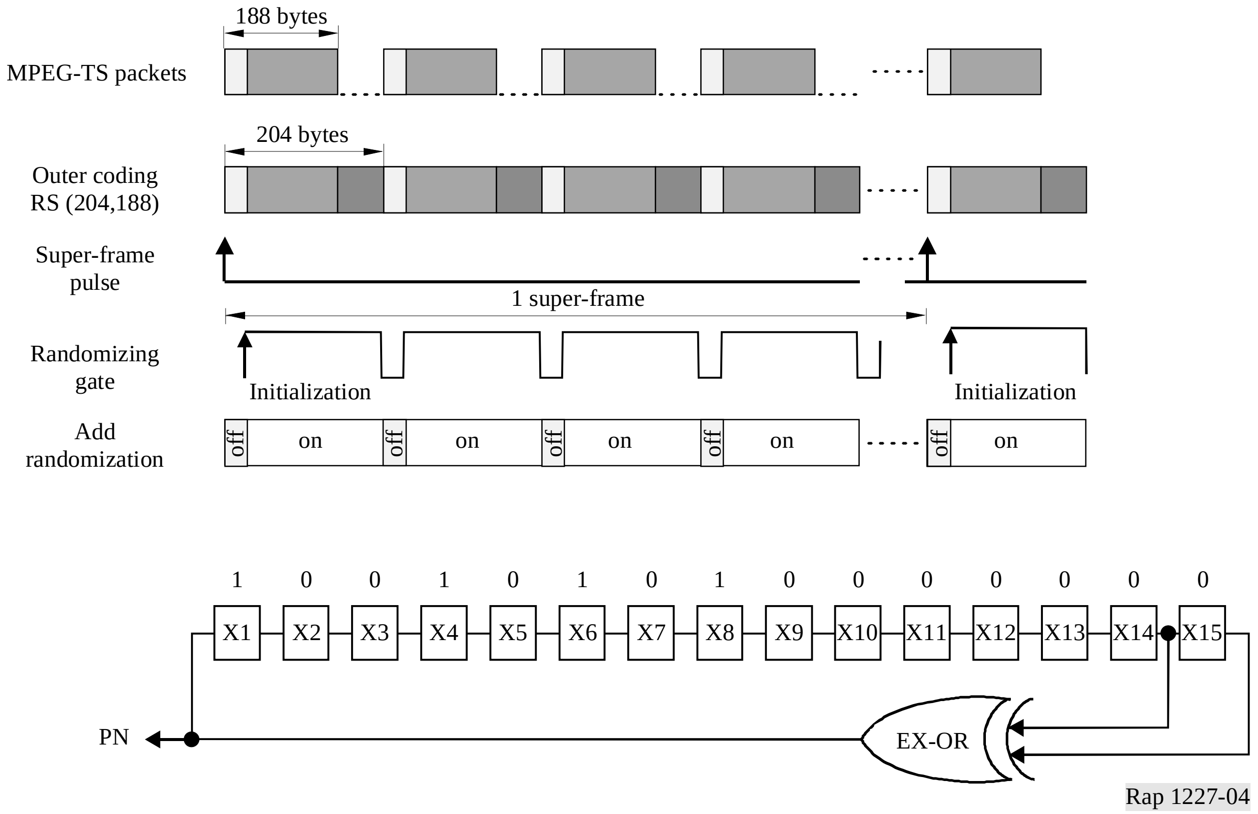
Loading of the sequence "100101010000000" into the PRBS registers, as indicated in Fig. 4, is initiated at the second byte of every super-frame.

The PRBS is added to the data of each slot except the first byte of every slot. During the first byte of every slot, the PRBS generation continues, but its output is disabled, leaving this byte unrandomized.

When modulation schemes except TC8-PSK are adopted, the frame contains dummy slots. In this case, the randomization is also implemented for dummy slots.

FIGURE 4

Randomizer schematic diagram



PN : pseudo-noise

5 Interleaving

Block interleaving with 8 × 203 bytes is applied to the slots following the conceptual scheme shown in Fig. 5. The first byte of the slot is not interleaved. The interleaver writes 203 bytes in the *i*-th slot of all frames composing one super-frame, to the interleave matrix horizontally. And the interleaver reads the data every 203 bytes from the matrix vertically and puts the data back into the slots. Table 1 shows the write/read addresses of *i*-th slot.

FIGURE 5

Conceptual scheme of interleaving

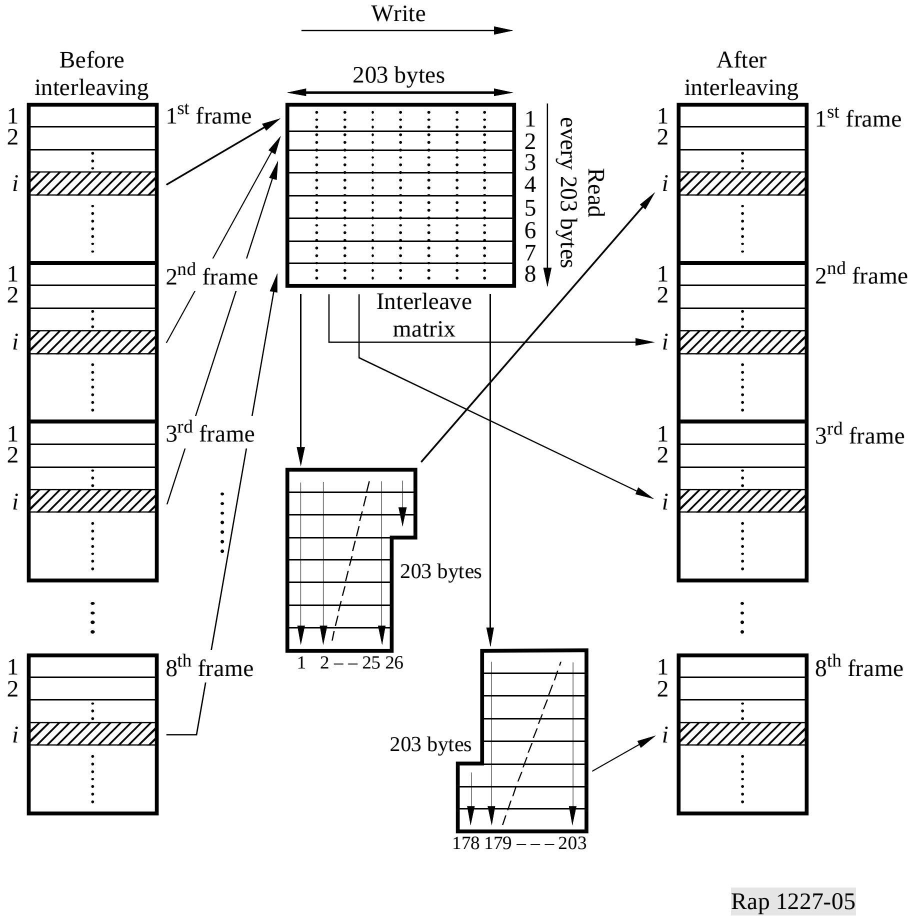


TABLE 1

Write/read addresses of *i*-th slot

Write addresses of *i*-th slot (frame – byte)

		1st byte	2nd byte		203rd byte
1st frame	:	1-1	1-2	…	1-203
2nd frame	:	2-1	2-2	…	2-203
3nd frame	:	3-1	3-2	…	3-203
4th frame	:	4-1	4-2	…	4-203
5th frame	:	5-1	5-2	…	5-203
6th frame	:	6-1	6-2	…	6-203
7th frame	:	7-1	7-2	…	7-203
8th frame	:	8-1	8-2	…	8-203

TABLE 1 *(end)*

Read addresses of *i*-th slot (frame – byte)

		1st byte	2nd byte		203rd byte
1st frame	:	1-1	2-1	…	3-26
2nd frame	:	4-26	5-26	…	6-51
3nd frame	:	7-51	8-51	…	1-77
4th frame	:	2-77	3-77	…	4-102
5th frame	:	5-102	6-102	…	7-127
6th frame	:	8-127	1-128	…	2-153
7th frame	:	3-153	4-153	…	5-178
8th frame	:	6-178	7-178	…	8-203

6 TMCC

6.1 Summary of the TMCC

The TMCC is structured with 8-byte TMCC information per 1 transmission frame and a 2-byte TAB1 and TAB2 pair, added before and after it. This TAB1 and TAB2 pair shares the synchronized words. The transmission frame is structured by the TMCC and main signal parts.

The first frame allocates the synchronized word, W1, before the TMCC information, and W2 after it.

W1 is the synchronized word for transmission frame synchronization, and W2 is that for identifying the header frame of a super-frame. Before the TMCC information between the second frame and the 8th frame, a W1 is allocated, and after it, a W3 allocated. W3 is related to W2, W3 = !W2 (all inverted bits are W2). The TMCC information is terminated when one super-frame has been transmitted.

Parity bytes are added in the 7th and the 8th frames.

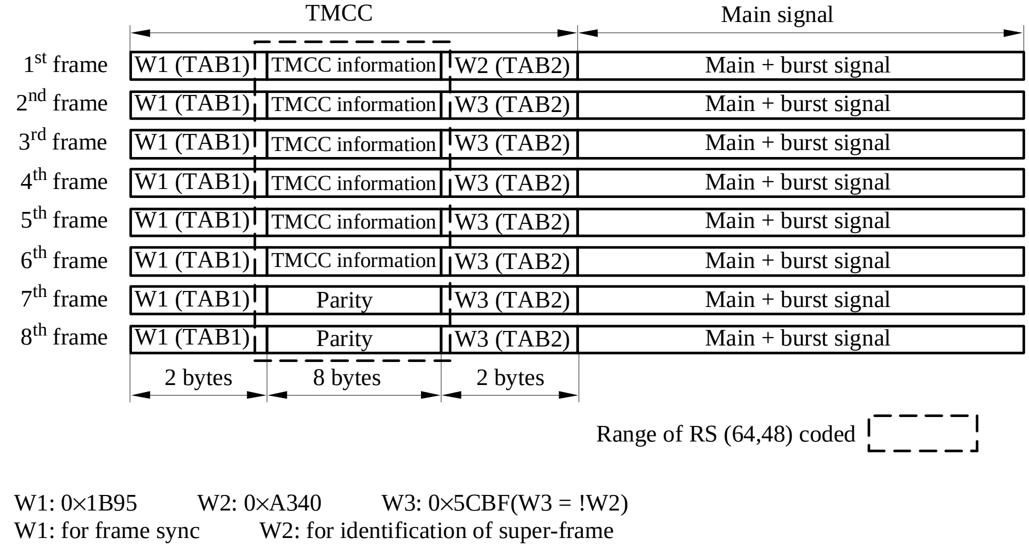
Synchronized words are assigned as follows.

W1: 0×1B95	W2: 0×A340	W3: 0×5CBF	(W3 = !W2)
w1: 0×ECD28	w2: 0×0B677	w3: 0×F4988	(w3 = !w2)

Here, W1, W2 and W3 are synchronized words before convolution, and w1, w2 and w3 are those after convolution.

FIGURE 6

The structure of the super-frame



Rap 1227-06

6.2 Bit assignment of TMCC

The TMCC is a fixed length signal with 384 bits which transmits information regarding TS allocation and transmission scheme for each transmission slot.

When the transmission scheme is changed, new TMCC information is transmitted within 2 super-frames prior to the actual switching time. Hence, the minimum renewal time interval of the TMCC is 2 super-frames. In order to ensure the reception of this control information, the receiver always needs to control the TMCC. Figure 7 shows the structure of TMCC bit assignment. The detailed assignment for each part is described below.

FIGURE 7

The structure of the TMCC

Order of change	Transmission mode/slot information	Relative TS/ slot information	Relative TS/ TS_ID corresponding table	Transmitter/ receiver control information	Expanded information
5 bits	40 bits	144 bits	128 bits	5 bits	62 bits

Rap 1227-07

6.2.1 Order of change

The order of change is the signal incremented by ones when the TMCC is changed. It is returned to zero after the value reaches 11111.

6.2.2 Transmission mode/slot information

The transmission mode shows the combination of modulation scheme and internal code as shown in Table 2. It allocates transmission modes 1 to 4 corresponding to the order of transmission mode in the main signal (in line with the modulation scheme with number of phases and internal coded system with higher efficiency). If less than 4 schemes are used, “1111” is assigned as the transmission mode.

FIGURE 8

The structure of transmission mode/slot information

Transmission mode 1	Allocation for transmission mode 1 slot number	Transmission mode 2	Allocation for transmission mode 2 slot number	Transmission mode 3	Allocation for transmission mode 3 slot number	Transmission mode 4	Allocation for transmission mode 4 slot number
4 bits	6 bits	4 bits	6 bits	4 bits	6 bits	4 bits	6 bits

Rap 1227-08

TABLE 2

Transmission mode

Value	Transmission mode
0000	Reserve
0001	BPSK(1/2)
0010	QPSK(1/2)
0011	QPSK(2/3)
0100	QPSK(3/4)
0101	QPSK(5/6)
0110	QPSK(7/8)
0111	TC8-PSK(2/3)
1000-1110	Reserve
1111	Not assigned

The number of allocated slots consists of the number of dummy slots allocated for the transmission mode, which the field just before it shows. Regarding the number of slots allocated to each transmission mode, special attention should be paid, such that total number of slots allocated simultaneously within one frame be 48 considering the unit of minimum combination slot as shown in Table 3.

TABLE 3

The unit of minimum combination slot by each transmission mode

Transmission mode	The unit of minimum combination slot	Number of effective slot	Number of dummy slot
BPSK(1/2)	4	1	3
QPSK(1/2)	2	1	1
QPSK(2/3)	3	2	1
QPSK(3/4)	4	3	1
QPSK(5/6)	6	5	1
QPSK(7/8)	8	7	1
TC8-PSK(2/3)	1	1	0

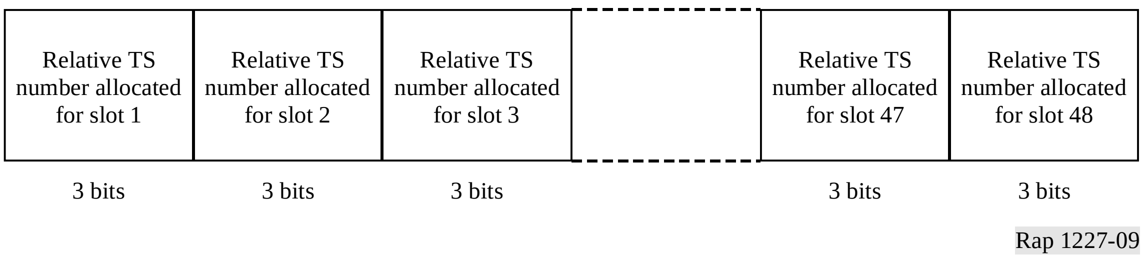
6.2.3 Relative TS/slot information

The relative TS/slot information indicates the relation between the actual assigned TS and the slot position. This information is transmitted consecutively in each slot beginning at slot 1.

The relative TS number takes 3 bits in order to be able to transmit a maximum of 8 TSs on one modulated carrier.

FIGURE 9

The structure of relative TS/slot information

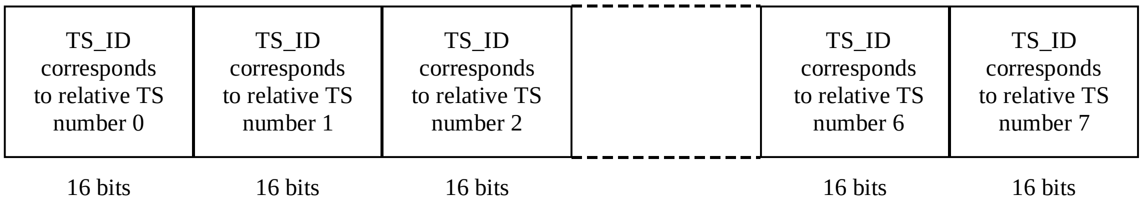


6.2.4 Relative TS/TS_ID table

The relative TS/TS_ID table is referred to when the relative TS number is converted to the actual TS_ID of the MPEG-2 systems.

FIGURE 10

The structure of relative TS/TS_ID table



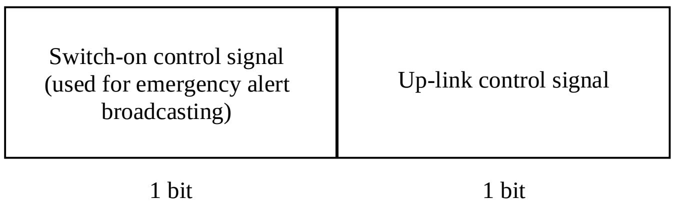
Rap 1227-10

6.2.5 Transmitter/receiver control information

The transmitter/receiver control information is transmitted as the control signal used for switching on the receiver for emergency alert broadcasting and for the up-link station.

FIGURE 11

The structure of transmitter/receiver control information



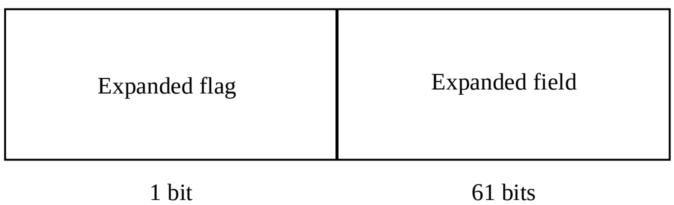
Rap 1227-11

6.2.6 Expanded information

Expanded information is used for the future expansion of the TMCC. When the TMCC is expanded, the expanded flag will be equivalent to 1, and the following field will become effective. If the expanded flag is zero, the expanded field will be stuffed at 1.

FIGURE 12

The structure of expanded information



Rap 1227-12

6.3 Outer code for TMCC

– RS (64,48) code,

– coded by super-frame,

– both TAB1 and TAB2 are not coded,

– the RS (64,48) code comes from the code RS (255,239).

191 zeros are added to the input data, and, after coding, these are deleted,

– code generator polynomial: $g(x) = (x + \lambda^0)\ (x + \lambda^1)\ (x + \lambda^2) \dots (x + \lambda^{15})$, where $\lambda = 02_h$

– field generator polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$.

6.4 Energy dispersal for TMCC

Energy dispersal is conducted before convolutional coding and after RS coding. The PN generator starts from the top of a 3-byte super-frame, and works freely during the synchronized word period. However, during synchronized word period, the signal is not added. This system is shown in Fig. 14.

The energy dispersal equation is as follows:

– Generation polynomial expression: $1 + x^{14} + x^{15}$.

– Initial value for registers: (100101010000000).

FIGURE 13

Point at which energy dispersal is conducted

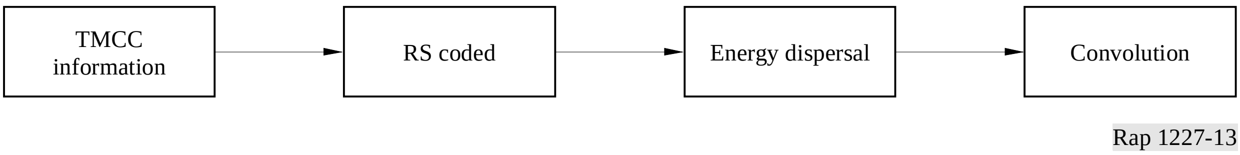
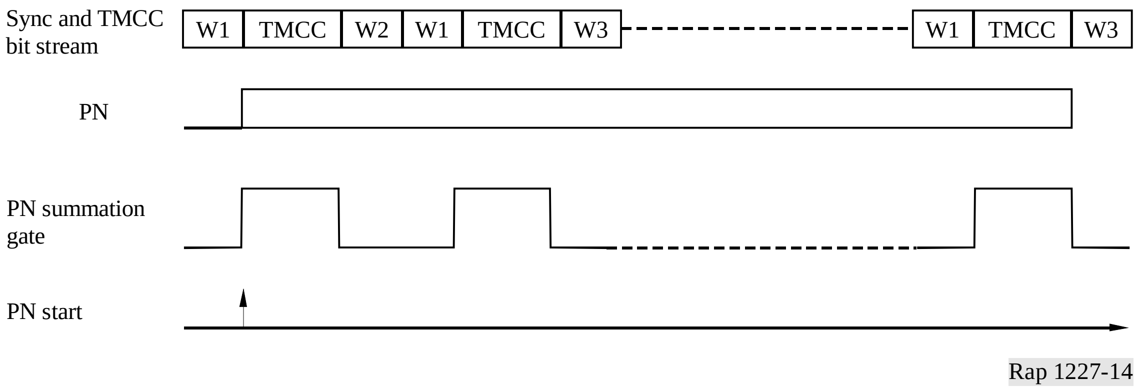


FIGURE 14

Addition of energy dispersal



7 Burst signal

In order to be able to receive the TMCC and main signal except 8-PSK even under a low *C/N* environment, a burst signal of 4 symbols is inserted next to each of the 203-symbol main signals. The burst signal is a randomized BPSK signal defined as follows:

– 9th PN ($G_{pn} = x^9 + x^4 + 1$, initial value (111101101)),

– reset by frame,

– PN generator is stopped except during the burst period.

Figure 16 shows a schematic diagram of PN generation for the burst signal. The status of the register is that just after having sent a reset pulse. The output of EX-OR becomes a first burst symbol within frames.

FIGURE 15

Burst multiplexing scheme and PN generation timing

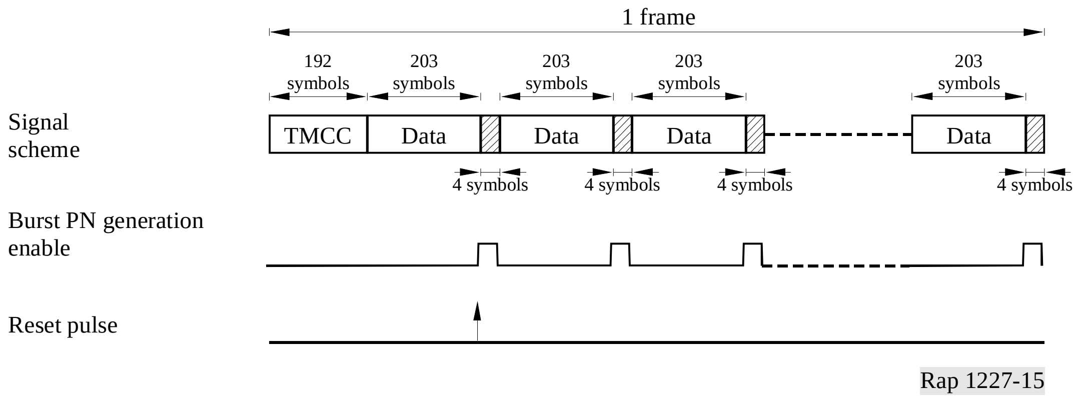
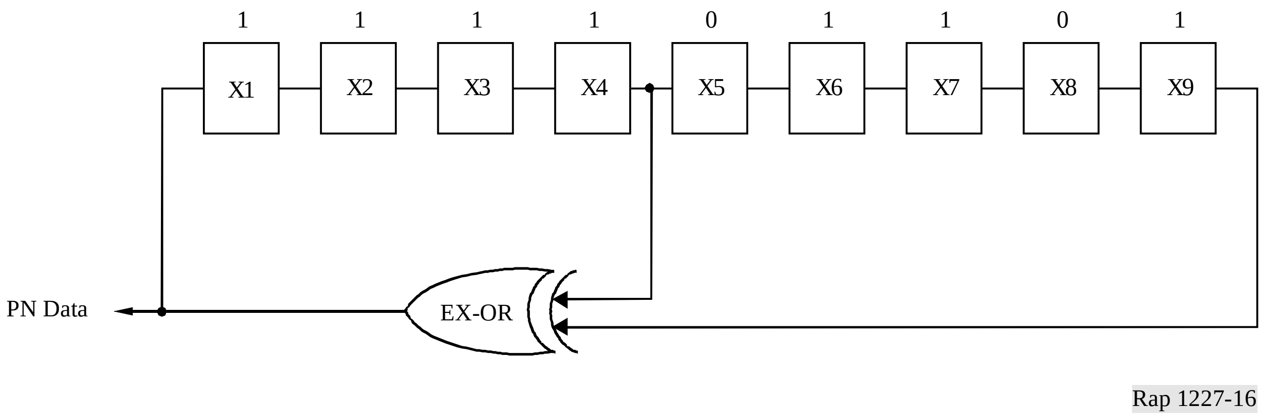


FIGURE 16

PN generator for burst signal



8 Inner code

8.1 Main signal

Inner code for the main signal can be selected from:

– trellis code (*r* = 2/3) for 8-PSK,

– convolutional code for QPSK (*r* = 1/2, 2/3, 3/4, 5/6, 7/8):
(*r* = 1/2 (original code): constraint length = 7, generator polynomial = 171, 133 octal),

codes of rate 2/3, 3/4, 5/6 and 7/8 are punctured from original generator polynomial,

– convolutional code for BPSK (*r* = 1/2): constraint length = 7, generator polynomial = 171, 133 octal.

The convolutional encoder is shown in Fig. 17. Output bits of C0 and C1 are generated from the input bit stream B0. D means 1 bit delay and operators have a modulo-two addition. For convolutional code, these output bits are directly mapped to QPSK and BPSK mapping, as shown in Figs. 18 and 19 respectively. For TC8-PSK, an additional bit B1 is used for 8-PSK mapping.

FIGURE 17

Trellis/convolutionnal encoder

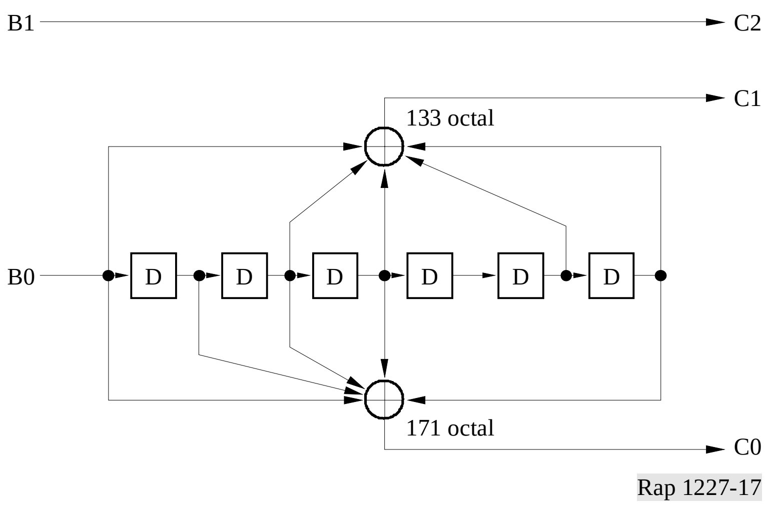
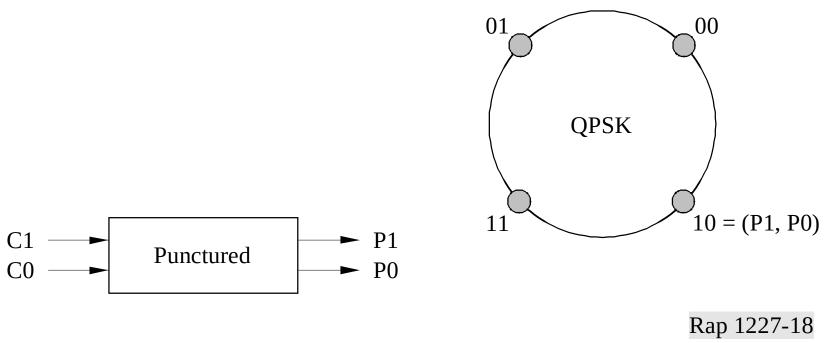


Figure 18 shows the punctured mapping system for QPSK signals. Table 4 describes detailed punctured mapping. The punctured phase for each code agrees to the top of the first assigned slot.

FIGURE 18

QPSK mapping



8.2 TMCC

Inner code for TMCC uses:

– the convolutional code for BPSK (r = 1/2) constraint length = 7, generator polynomial = 171, 133 octal.

The convolutional encoder is used to input B0 and for output of C0 and C1 as shown in Fig. 17.

These output bits are directly mapped to BPSK mapping.

TABLE 4

Punctured pattern

(P1 and P0 are generated from input signals by the puncture pattern.)

Input	C1(133)	X1	X2	X3	X4	X5	X6	X7	X8	X9
	C0(171)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
1/2	Puncture	O	O	O	O	O	O	O	O	O
	pattern	O	O	O	O	O	O	O	O	O
	P1	X1	X2	X3	X4	X5	X6	X7	X8	X9
	P0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
2/3	Puncture	O	O	O	O	O	O	O	O	O
	pattern	O	X	O	X	O	X	O	X	O
	P1	X1	Y3	X4		X5	Y7	X8		X9
	P0	Y1	X2	X3		Y5	X6	X7		Y9
3/4	Puncture	O	O	X	O	O	X	O	O	X
	pattern	O	X	O	O	X	O	O	X	O
	P1	X1	Y3		X4	Y6		X7	Y9	
	P0	Y1	X2		Y4	X5		Y7	X8	
5/6	Puncture	O	O	X	O	X	O	O	X	O
	pattern	O	X	O	X	O	O	X	O	X
	P1	X1	Y3	Y5			X6	Y8	Y10	
	P0	Y1	X2	X4			Y6	X7	X9	
7/8	Puncture	O	O	O	O	X	O	X	O	O
	pattern	O	X	X	X	O	X	O	O	X
	P1	X1	X3	Y5	Y7				X8	X10
	P0	Y1	X2	X4	X6				Y8	X9

O: transmission bit X: deleted bit

9 Modulation scheme

9.1 Main signal

The modulation scheme for main signal can be selected from:

– trellis coded 8-PSK (r = 2/3, pragmatic code)

– QPSK with convolutional code(r = 1/2, 2/3, 3/4, 5/6 and 7/8), and

– BPSK with convolutional code (r = 1/2).

When using several modulation schemes in one transmission frame simultaneously, these are arranged in order of higher spectrum efficiency.

9.2 TMCC

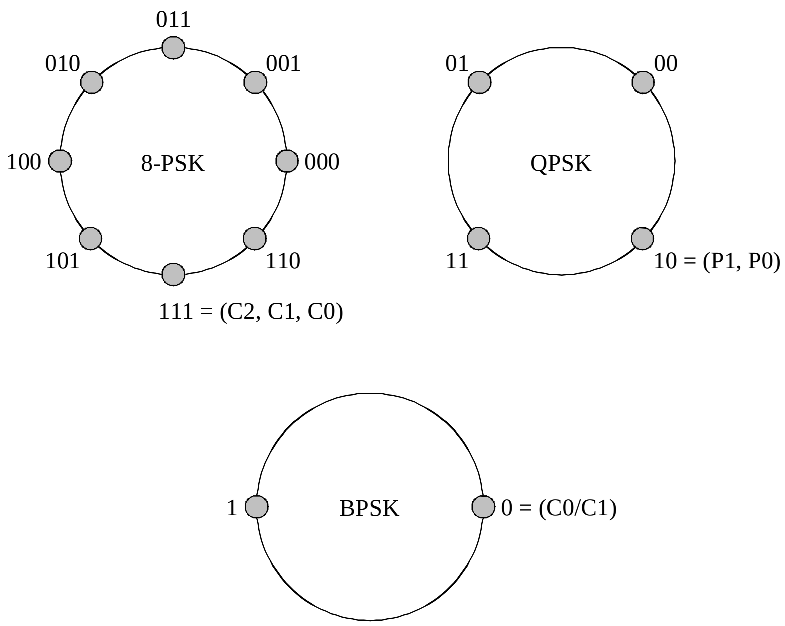
The modulation scheme of BPSK with convolutional code (r = 1/2) is used for the TMCC.

9.3 Symbol mapping

Symbol mapping for each modulation scheme is shows in Fig. 19. The definition of each bit is the same as in Fig. 17. In the case of BPSK, encoded bits C0 and C1 are mapped in this order after the parallel/serial converter.

FIGURE 19

Symbol mapping for each modulation scheme



Rap 1227-19

9.4 Roll-off rate

For spectrum shaping at the modulator, the following characteristics are used:

– square root raised cosine,

– roll off rate of 0.35,

– aperture equalization of *x*/sin(*x*) assigned to transmitter filter.

ANNEX 2

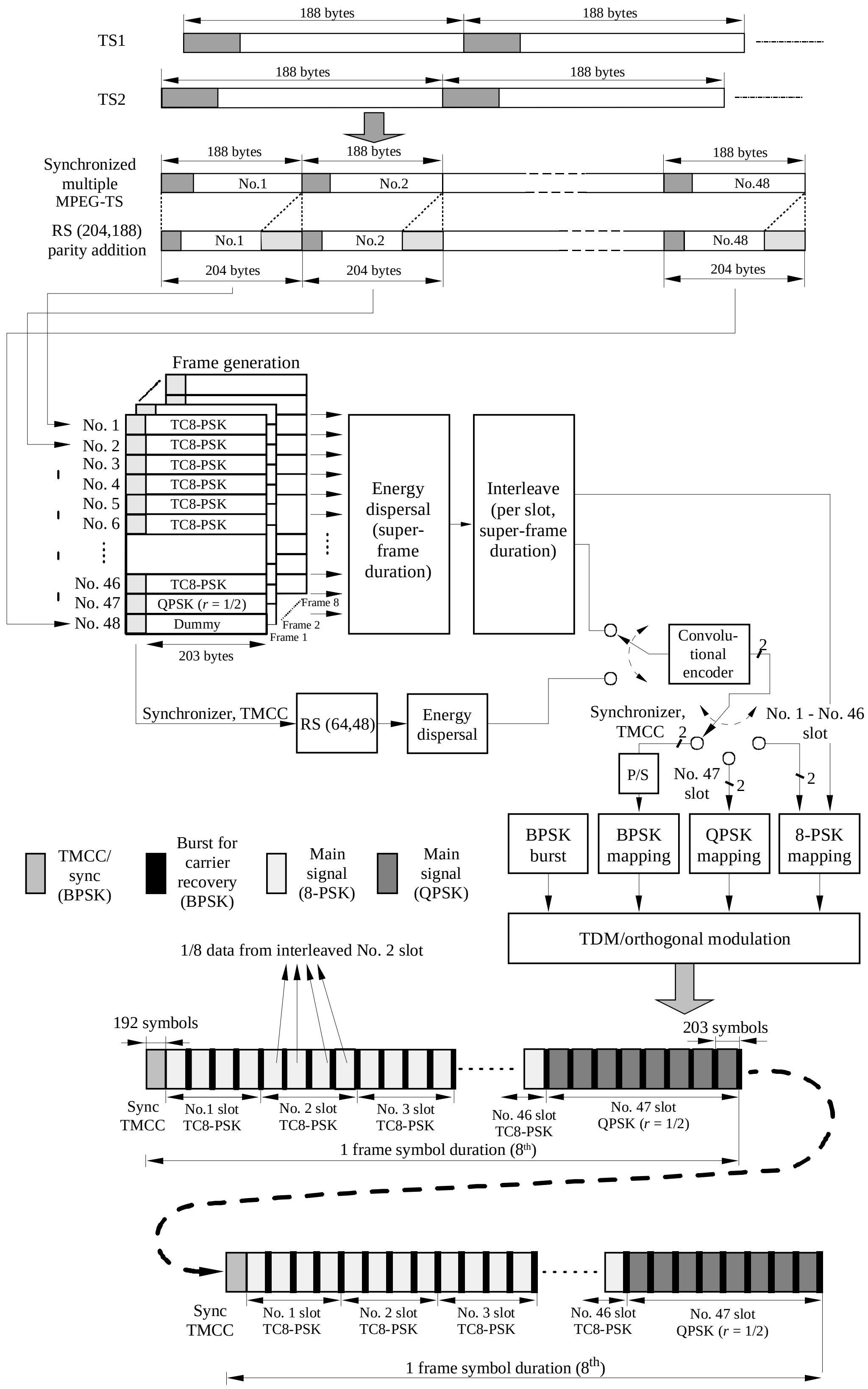
Transmission signal generation and experimental result of ISDB in Japan

Figure 20 shows an example of signal processing for the system. The absolute position in a frame, called a “slot”, is a unit that assigns the modulation scheme for each packet. The figure shows the case in which 46 slots are assigned for TC8-PSK and one slot is assigned for QPSK ($r = 1/2$). Here, a dummy slot, which is not used for data transmission, is assigned for a constant baseband signal processing when less spectrum efficient modulation schemes are simultaneously used. Two independent MPEG-TS are assumed in this case.

Multiple MPEG-TS are combined into a single bit stream and encoded using a RS (204,188) outer FEC code. Each frame has 48 slots, and 8 frames make one super-frame to define the duration of energy dispersal and interleaving. The modulation schemes can be varied by super-frame if necessary.

FIGURE 20

An example of transmission signal generation in the system



TDM: time-division multiplex

Rap 1227-20

On the other hand, synchronization words and TMCC information are processed separately from the main signal. Synchronization words are used for frame sync and super-frame sync. The first byte of each packet, which is the original

MPEG-TS packet sync 0 × 47, is replaced by sync words and the TMCC signal. This byte is again replaced by the original MPEG-TS packet sync after the demodulation process. The TMCC signal is protected by RS (64,48).

The bit stream of sync words, TMCC and main signals are continuously put into a convolutional encoder. The output from the convolutional encoder is put into the modulation mapper appropriately selected for the modulation schemes.

A burst signal is inserted to the time division multiplexer to achieve stable carrier recovery for a very low *C/N* environment.

An experimental result of the ISDB system by Japan described in Annex 1 is shown in Fig. 21. The experiment shows that two HDTV programs can be received. In addition, sound programs can be used under very low *C/N* environments when mode 2 and mode 3 are selected.

FIGURE 21

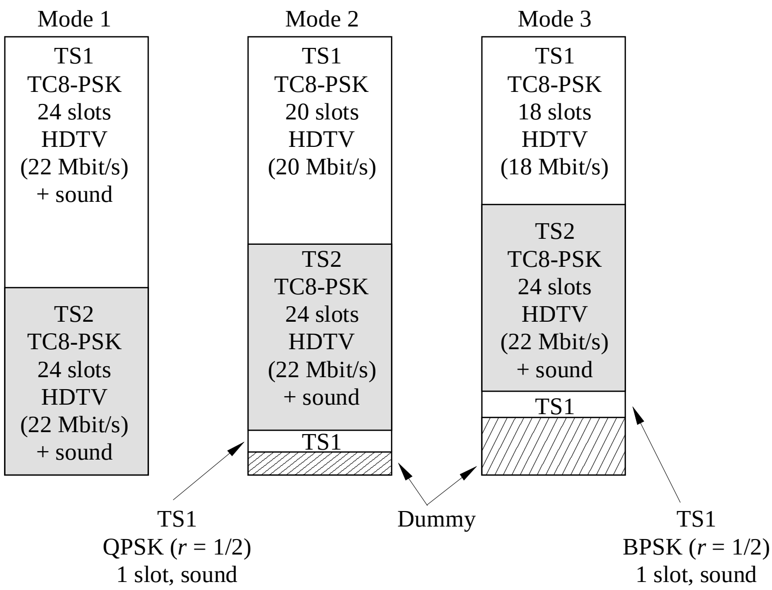
An example system and summary of experimental results

Symbol rate (MBd)	Highest information rate[(1)] (Mbit/s)	Modulation scheme [(2)]
22.152	40.044	TC8-PSK
26.988	48.786	QSPK (*r* = 1/2, 2/3, 3/4, 5/6, 7/8),
28.860	52.170	BPSK (*r* = 1/2)

[(1)] When all slots are assigned for TC8-PSK.

[(2)] Four modulation schemes can be selected out of indicated schemes.

a) Example systems



b) Experimental frame structure (26.988 MBd)

Modulation scheme	Service limit *C/N*
TC8-PSK QPSK (*r* = 1/2) BPSK (*r* = 1/2)	Approximately 11 dB Approximately 4 dB Approximately 1 dB

c) Performance

Rap 1227-21

ANNEX 3

Comparison between multi-programme satellite broadcasting systems and ISDB transmission system

For the useful information to advanced multimedia services, comparison between multi-programme satellite broadcasting services which are described in Recommendation ITU-R BO.1294 is listed in Table 5.

TABLE 5

Comparison between digital multi-programme systems and ISDB

	System A	System B	System C	ISDB
Modulation scheme	QPSK	QPSK	QPSK	TC8-PSK/QPSK/BPSK
Symbol rate (MBd)	Not specified	Fixed 20	Variable 19.5 and 29.3	22.152 26.988 28.860
Necessary bandwidth (–3 dB) (MHz)	Not specified	20 MHz	19.5 and 29.3 MHz	27/33/36 MHz (99% energy bandwidth)
Roll-off rate	0.35 (raised cos)	0.2 (raised cos)	0.55 and 0.33 (4^{th} order Butterworth filter)	0.35 (raised cos)
FEC (outer code)	RS (204,188)	RS (146,130)	RS (204,188)	RS (204,188)
FEC (inner code)	Convolutional	Convolutional	Convolutional	Convolutional, trellis (8-PSK: TCM 2/3)
Constraint length	$K = 7$	$K = 7$	$K = 7$	$K = 7$
Inner coding rate	1/2, 2/3, 3/4, 5/6, 7/8	1/2, 2/3, 6/7	1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 5/11, 7/8	1/2, 3/4, 2/3, 5/6, 7/8
Energy dispersal	PRBS: $1 + x^{14} + x^{15}$		PRBS: $1 + x + x^3 + x^{12} + x^{16}$	PRBS: $1 + x^{14} + x^{15}$
Reset timing	Before RS encoder		After RS encoder	After RS encoder
Interleaving	Convolutional (depth = 12)			Block (depth = 8)
Transmission control				TMCC
Frame structure				48 slot/frame 8 frame/super-frame
Packet size (bytes)	188	130	188	188
Transport layer	MPEG-2	Non MPEG	MPEG-2	MPEG-2