

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.

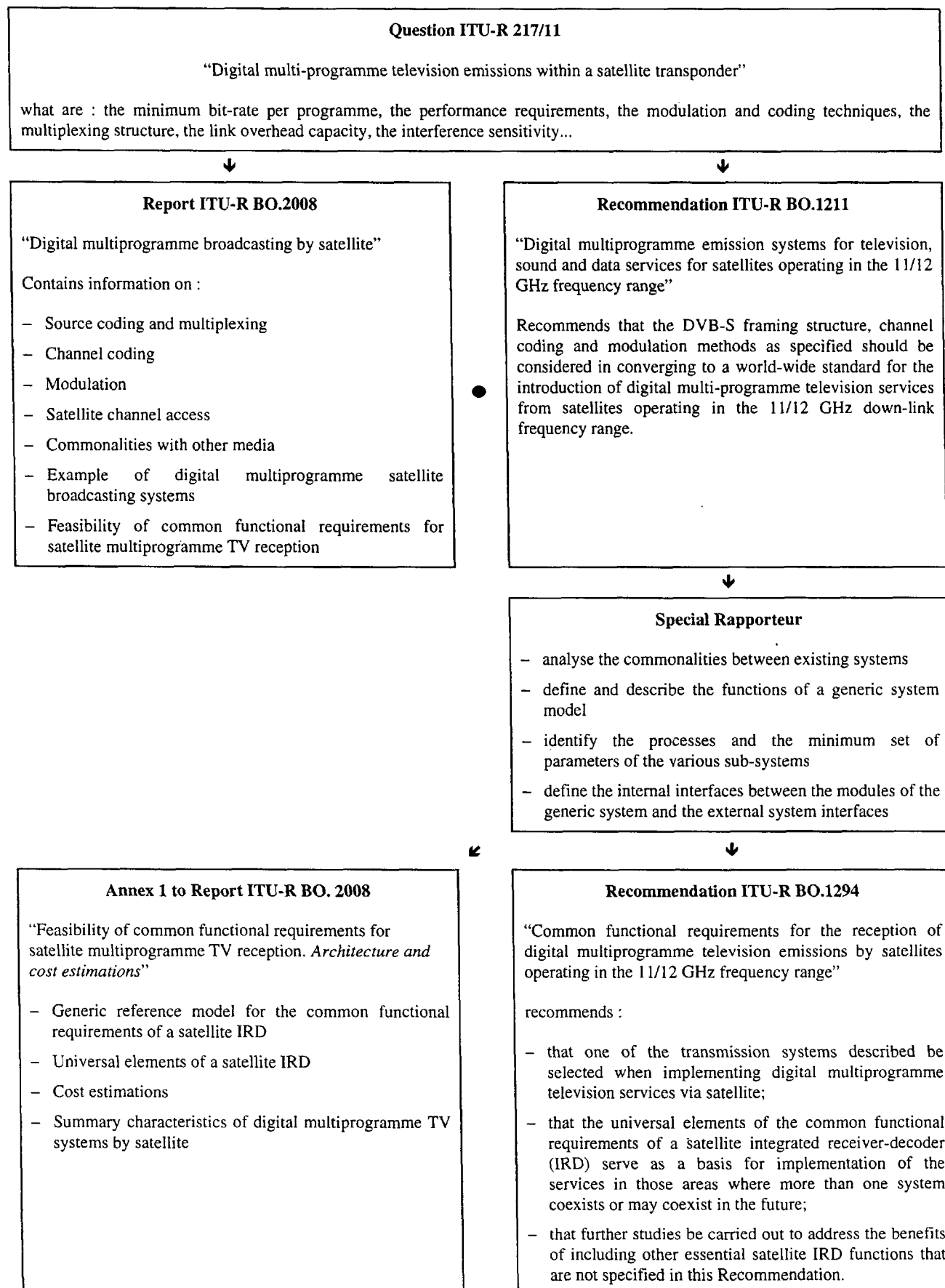
The overall MPEG-2 architecture and syntax were designed such that an MPEG-2 decoder is a much simpler device than an MPEG-2 encoder. This is very important in broadcast applications where there is typically one encoder for many thousands or millions of decoders. This type of architecture greatly reduces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



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 fades 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 B0.1211 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 has 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)

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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.