Digital television comes down to earth

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In this article, the Authors provide a progress report on the world-wide studies of digital terrestrial television broadcasting, carried out by ITU-R Task Group 11/3.

The final meeting of Task Group 11/3, held in Sydney during November 1996, was highly productive and extremely successful. International agreements – defining a complete digital terrestrial broadcasting system – were finalized. The Reports and Recommendations (standards) have now been forwarded to the parent bodies of Task Group 11/3 for formal approval, which is expected later this year (1997).

1. Introduction

Broadcasting is on the threshold of the great transition from analogue to digital. Eventually, all delivery means will be fully digital – whether satellite, cable, MMDS or terrestrial. Each delivery system brings its own circumstances and problems. Arguably, the most difficult technical environment exists in terrestrial broadcasting. Yet at the same time, it may be the most important means of delivery for digital television for very many years to come.

Today, terrestrial broadcasting forms the bedrock of television services throughout the world and there is a massive investment in it by both broadcasters and the public. One of the greatest technical challenges facing the broadcasting community world-wide has been to develop cost-effective solutions for digital terrestrial television broadcasting. For those who have already made the investment in analogue terrestrial broadcasting, digital *terrestrial* delivery will probably be the least expensive infrastructure to implement for digital broadcasting. It also offers other attractive attributes such as the ability to localize services and to add new data services.

The rewards for the development of a digital terrestrial system are clear and evident. The ITU's Radiocommunications Sector (ITU-R) – which seeks world-wide standards for all broadcasting systems – was inevitably motivated to set up the infrastructure to achieve agreement on world-wide standards for digital terrestrial television broad-

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casting (DTTB), when the need to do so became clear.

In the early part of the decade, the ITU established a Task Group – TG 11/3 – to examine and agree on the totality of issues associated with DTTB:

– planning;

– systems;

– vision coding;

– sound coding;

– data coding, etc.

The work of TG 11/3 was completed successfully in November 1996. This article presents a brief review of its work and achievements.

2. Establishment of Task Group 11/3

ITU-R Task Group 11/3 was charged in January 1992 with developing specifications for digital terrestrial television broadcasting [1]. Chaired by Mr Stanley Baron (USA), it met for the first time in Geneva on 14-18 December 1992. The meeting was attended by more than 115 delegates representing 43 Administrations, international organizations, and scientific/industrial organizations. Prior to the meeting, the Task Group Chairman, working with five Special Rapporteurs – Mr Terry Long (United Kingdom), Mr Osamu Yamada (Japan), Mr Thomas Ryden (Sweden), Mr Richard Barton (Australia) and Mr David Wood (EBU) – generated an Outline of Work [2] and developed a guide for Administrations and other organizations who were preparing documents for consideration by the Task Group[1].

3. DTTB model

The Outline of Work provided a list of issues which the Task Group should consider when preparing its Recommendations. The document also

1. Four of these individuals served as Special Rapporteurs for the life of Task Group 11/3. During 1993, Mr Ryden became Chair of ITU-R Task Group 10/3 and was replaced as Special Rapporteur for Source Coding by Mr Brian Roberts (New Zealand).

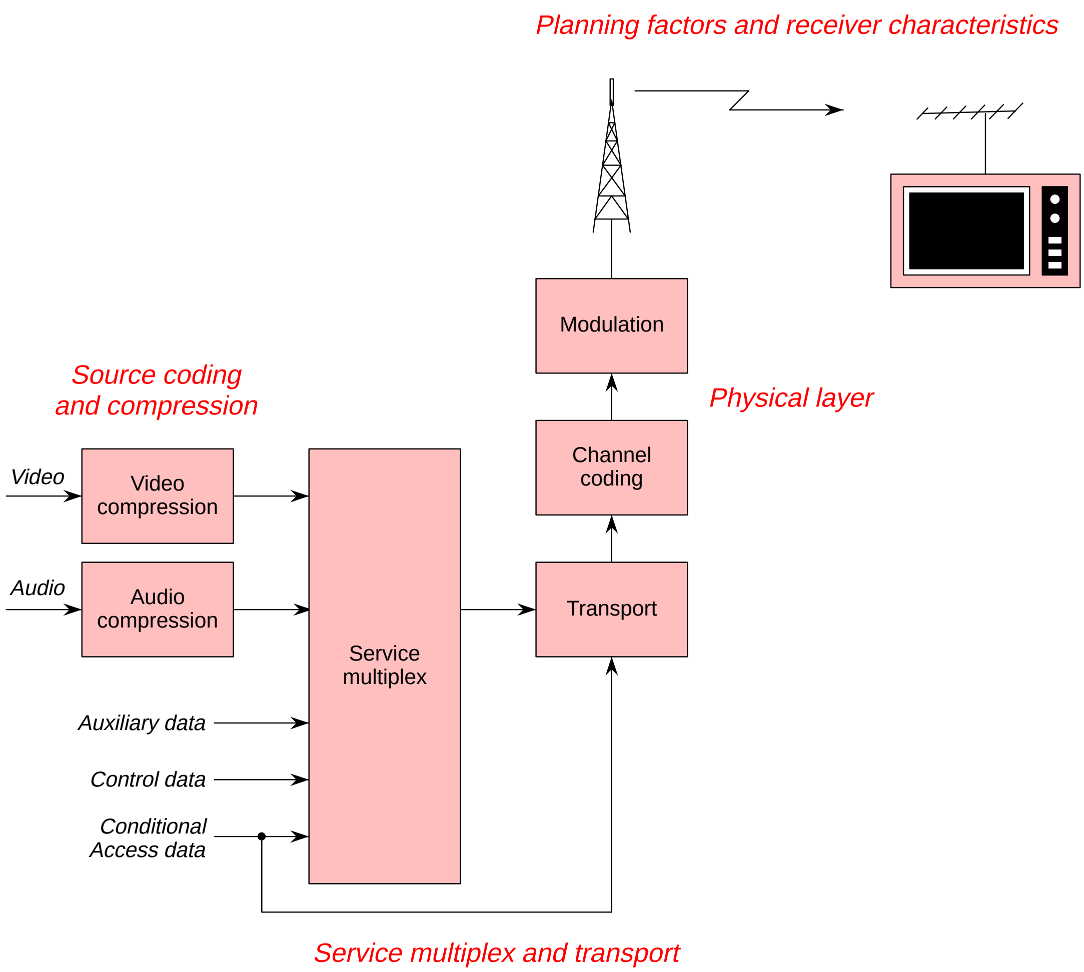


Figure 1
The DTTB system model.

presented (i) a set of draft Recommendations for consideration and (ii) an outline of a report (or several reports) to be generated either as Annexes to Recommendations proposed by the Subgroups, as Reports to carry the work of the Subgroups forward, or in the form of a tutorial Report.

The Outline of Work also included a model of a digital terrestrial television broadcasting system (see *Fig. 1*). The model was divided into four areas of interest (subsystems) and sub-Task Groups were assigned to develop the required Recommendations and Reports, in each case using this model as the basis of their investigations.

The four subsystems (or elements) of the model were as follows:

– source coding and compression;

– service multiplex and transport;

– physical layer;

– planning factors and implementation strategies.

Abbreviations

8-VSB	Eight-vestigial sideband
ATM	Asynchronous transfer mode
ATSC	Advanced Television Systems Committee (USA)
DTTB	Digital terrestrial television broadcasting
DVB	Digital Video Broadcasting
HDTV	High-definition television
IEC	International Electrotechnical Commission
ISO	International Standards Organisation
ITU-R	International Telecommunication Union, Radiocommunication Sector
MMDS	Multipoint microwave distribution system
MP@14	Main Profile at 1440 Level
MP@HL	Main Profile at High Level
MP@ML	Main Profile at Main Level
MPEG	Moving Picture Experts Group
OFDM	Orthogonal frequency division multiplex
SC@14	Spatially Scaleable Profile at 1440 Level
SDTV	Standard-definition television

3.1. Source coding

This subsystem encompasses the initial coding methods or compression systems which are designed to reduce the data-rate created when images are represented by a sequence of values of individual picture samples, or when sound is represented by digital audio samples. Source coding may also include error protection techniques that are appropriate for direct application to the video, audio and ancillary digital data-streams.

Source coding involves processes that reduce the data-rate of the bitstream – containing the image, sound or ancillary data information – in such a way as to be able to recreate a representation of the original source at the receiving point without noticeable or unacceptable degradation. The term "ancillary data" refers to control data, including conditional access, or to data associated with the programme audio and video services – such as closed captioning. Ancillary data can also refer to independent programme services. The purpose of the coder is to convert the audio and video into data, and to minimize the number of bits needed to represent the information.

3.2. Service multiplex and transport

This element refers to the container that is used to carry the data. Usually, the digital datastream is divided into "packets" of information and, thus, a means of uniquely identifying each packet must be provided. This subsystem also defines the appropriate methods of multiplexing the video datastream packets, the audio datastream packets, and the ancillary datastream packets into a single datastream to construct a single programme. Multiplexing also enables different programme datastreams to be combined within a single broadcasting channel for simultaneous delivery. In developing an appropriate transport mechanism, interoperability between digital media such as terrestrial broadcasting, cable distribution, satellite distribution, recording media and computer interfaces must be a prime consideration.

The joint ISO/IEC standards body – the Moving Picture Experts Group – has developed a set of specifications, MPEG-2 [3], for the coding and multiplexing of (interlaced or progressively-scanned) video, audio and data signals. These specifications can be applied *inter alia* to digital broadcasting systems [4].

The MPEG-2 standard was developed for "broadcast-quality" television applications, in which the available channel bandwidth or recording media capacity is relatively limited. The MPEG-2 Transport Stream was also designed to be compatible with the ATM transport mechanism.

The MPEG-2 Transport Stream takes the resulting compressed datastream and adds additional information that can be used by the receiver to recognize and reconstruct the images, sound and ancillary data from the transmitted signal. The channel coder module includes mechanisms by which additional data are added to the multiplexed datastream to provide protection against loss of the signal. The characteristics of the channel coder are selected to support the modulation scheme and the medium through which the data must be transported.

3.3. Physical Layer

This element refers to the means of using the digital datastream information to modulate the transmitted signal. Modulation is a mechanism whereby the protected datastream is imposed on one or more carrier signals for transmission. These transmission systems are referred to as single-carrier and multiple-carrier schemes, respectively.

3.4. Planning factors and implementation strategies

Two considerations are included in this element:

– the characteristics of the transmission media and the receivers;

– the strategies that are appropriate for the introduction and implementation of a DTTB service, taking into account existing broadcasting services.

4. ITU-R Recommendations for DTTB

A set of ITU-R Recommendations has been developed for DTTB and is found in *Table I*. They provide for the following:

4.1. Video coding

The MPEG-2 video-encoding profile/level combinations available as "conformance points" have been reduced to two.

These two profiles/levels are:

– Main Profile at Main Level (MP@ML) which defines standard-definition digital television (SDTV) services;

– Main Profile @ High Level (MP@HL) which provides for both HDTV services and SDTV services.

Area of interest	ITU-R document number	Title
Overall system	Report (11/4)	A Guide to DTTB in the VHF/UHF Bands
	Draft new Rec. (11/2)	The Basic Elements of a Worldwide Family of Common Systems for DTTB
Video coding and compression	Rec. BT.1208, (11/6)	Video Coding for DTTB
Audio coding and compression	Rec. BS.1196 (11/6)	Audio Coding for DTTB
Service multiplex and transport	Rec. BT.1209,(11/8)	Service Multiplex Methods for DTTB
	Draft new Rec. (11/48) [XXE]	Service Multiplex, Transport,and Identification Methods for DTTB
	Draft new Rec. (11/5)	Data Services in DTTB
	Rec. BT.1207, (11/7)	Data Access Methods for DTTB
	Draft new Rec (11A/58) [XXH]	Conditional Access Methods for DTTB
Physical layer	Draft new Rec (11/49) [XXD]	Error Correction, Data Framing, Modulation and Emission Methods in DTTB
	Rec. BT.1206	Spectrum Shaping Limits for DTTB
	Draft new Rec. (11-3/78) [XXK]	Performance of DTTB Emission Equipment
	Draft new Rec. (11-3/78) [XYZ]	Planning Factors Criteria
	Report (11/47)	DTTB Service Coverage and Field Trials
	Report (11/46)	Planning Factors and Implementation Strategy

Table 1
Recommendations and Reports of ITU-R Task Group 11/3.

The MP@HL combination allows scanning formats of up to 1152 active lines and 1920 active-samples-per-line with interlace scanning. There is an MPEG-2 ceiling on the luminance sample-rate for this combination, which means that a progressively-scanned version of this format is not allowed at 50 Hz and 60 Hz frame rates, although progressively-scanned versions of the formats with lower line numbers (such as 720) and at lower frame-rates (such as 24, 25 and 30 Hz) are allowed up to the ceiling on sample-rates.

The number of profile/level combinations, and the specific combinations which must be included, have an impact on the cost of consumer receivers and on the cost of providing programme content.

Agreement was achieved **not** to include the Main Profile at 1440 Level (MP@14) and the Spatially Scalable Profile at 1440 Level (SC@14) at present. The MP@14 Spatially Scalable profile/level had been considered for use in the DVB project, but is no longer being pursued because their cost-benefit analysis showed it not to be worthwhile. MP@HL is the highest MPEG-2 profile/level combination available, and can accommodate all lower non-scaleable layers.

The set of DTTB video subsystem tools are defined in ITU-R BT.1208 and allow content producers to provide programming in conventional, widescreen, and HDTV formats. Single MPEG-2 MP@ML decoders, capable of decoding the complete set of tools defined in ITU-R BT.1208, already exist with the ability to decode both conventional and widescreen television, and chip sets are already provided by many manufacturers.

Single-chip MPEG-2 MP@HL decoders have now been developed but the chip sets are not yet available on the market. When available, they will be capable of decoding the entire set of tools defined in ITU-R. BT.1208, hence satisfying the call from the World Broadcasting Unions for a DTTB system which provides for consumer receivers that are usable world-wide.

4.2. Audio coding

The set of DTTB audio subsystem tools are defined in ITU-R BS.1196 and allow content producers to choose between both the MPEG audio compression system and the AC-3 non-backward-compatible compression and coding tools. Decoders capable of decoding the complete set of tools defined in ITU-R BS.1196 already exist, and chip sets have been announced by several manufacturers. The existence of decoders capable of decoding the entire set of audio tools defined in ITU-R BS.1196 would also satisfy the call for consumer receivers that are usable world-wide.

4.3. Transport level

The service multiplex and transport system that provides the foundation for, and defines, the DTTB system is a subset of the MPEG-2 set. It is defined in ITU-R Draft new Recommendation (11/48) [XXE].

The assignments of packet identification, as described in the North American ATSC standards and the DVB standards, was harmonized to avoid the possibility of decoder mis-interpretation. Systems which conform to the subset of the MPEG-2 transport defined in Rec. [XXE], including the use of the Descriptor Tags and Table ID assignments, would allow the development of decoders capable of decoding the entire set of tools defined in Rec. [XXE]. Such decoders do not yet exist, but their development has been made possible by the decisions taken at the final meeting of Task Group 11/3. When available, these decoders will also satisfy the requirement for unique global broadcasting systems which lead to universal “plug-and-play” consumer appliances.

The ATSC standard (A/57) defines a content numbering system which will allow content producers to keep track of their programmes. It is an extension to the MPEG syntax and complements it. This addition to the MPEG syntax was adopted during the final meeting of TG 11/3 in Sydney and incorporated in Rec. [XXE].

4.4. Physical layer

The Recommendations concerning the DTTB physical layer (channel coding and modulation scheme) are defined in Draft new Recommendation (11/49) [XXD] and take into consideration the existing 6, 7 and 8 MHz allocation of channel assignments and the need to accommodate differing environments and planning factors. The set of ITU-R Recommendations and Reports can be viewed as providing a compatible system solution for DTTB within the practical physical limitations of the current environment of different world-wide channel assignments.

Draft new Recommendation (11/49) [XXD] provides for 8-VSB where a single-carrier modulation technique must be employed, and OFDM where a multi-carrier modulation technique is needed. The development of two modulation techniques has arisen because there are several environments which have different local channel bandwidths (6, 7 or 8 MHz) and differing local planning factors (e.g. frequency congestion).

The 8-VSB solution is simpler, but it is less able to cope with severe multipath conditions than OFDM and it cannot be used with SFNs. Each system is appropriate for its particular environment. The frequency planning environment in Japan is arguably one of the most difficult in the world, and here it may even be necessary to use a further segmented form of OFDM. This will be determined from studies which are currently being carried out in Japan.

5. Multi-programme capability and interoperability with other media

When compared with analogue transmission, compressed digital television systems offer the prospect of considerable improvements in picture quality, while also improving spectrum utilization. Digital modulation can be used to deliver multiple, digitally-compressed SDTV programmes in a single broadcast channel, or HDTV services, or other combinations. A trade-off is involved between picture quality and the number of programmes carried in the transmission channel. The digitally-compressed television signals can be accompanied by digital high-quality sound – monophonic, stereophonic or surround-sound – conditional access information and ancillary data channels.

Task Group 11/3 paid particular attention to constructing a digital architecture that could accommodate both HDTV and SDTV services in the terrestrial broadcasting environment, and which would be interoperable with cable delivery, satellite broadcasting and digital recording media.

The approach taken provides harmonization between services by using a unified common method of video and audio source coding and a unified common service multiplex and transport. As noted above, two application-specific subsets are defined: System A and System B. Decoders that can interpret either subset from the datastream are feasible.

The unified transport datastream is provided with a framing structure, an error protection mechanism, and a modulation scheme which is appropriate to the distribution media. The common transport is seen as a "container" which facilitates the interoperability of the signal through different delivery media. This results in a common datastream after demodulation in the receiver, which simplifies the complexity of the consumer receiver appliance.

6. HDTV production

During the final meeting of TG 11/3, several organizations who operate in a 50 Hz environment gave support to the consideration of a 1080-line HDTV scanning system (one of the scanning formats in the ATSC digital terrestrial standard) as the future basis of international agreement on an HDTV standard for programme interchange. They argued that such an agreement would be beneficial to content producers who have global market concerns. The 720-line progressive-scanning format (also one of the ATSC scanning formats) was thought to be relatively close in performance to the progressive-scanning versions of the 625-line standard, and thus to offer no significant advantage. The 1080-line standard exists in both 50 Hz and 60 Hz versions, is compatible with 24 frames-per-second film, and provides for square pixels in its progressive form. This important debate on the standardization of an HDTV production format will continue in the ITU. Whatever the outcome, the DTTB system will be able to deliver the format to the viewer.

7. Future developments

At its final meeting in Sydney, the Task Group considered the prospects for the continuation of its work. All standards are inevitably subject to refinement and development, and this will be no less the case for the DTTB system. The members expect improvements to be of an evolutionary nature rather than revolutionary, so that consumers are not disenfranchised.

Further, the Task Group expects that the employment of digital compression technology, and the availability of receiver displays supported by a frame-store memory, will eventually enable different temporal rates (50 or 60 Hz, and the various rates employed by computer displays), as well as spatial display scanning structures, to become possible. This will lead to a point in time when content producers can choose a structure that is appropriate for the programme content, and consumer receivers will be able to reproduce that content without the requirement for prior conversion at a production or distribution point. This capability already resides in computer-based systems and is provided for in the ITU's DTTB system Recommendations.

8. Conclusions

Task Group 11/3 has produced a set of Recommendations and Reports that define a rational common set of elements for DTTB. There are different frequency-planning and spectrum-availability environments in the world, and the proposals had to take account of this, together with the need for maximum commonality, as well as commonality with other digital television delivery systems. This commonality provides benefits for two constituencies:

– consumers;

– manufacturers who seek global markets for their products.

The ITU studies drew on both the work and the philosophy of the joint committee of the IEC and the ISO – the Moving Pictures Experts Group (MPEG). The MPEG-2 specifications provide tools that may be grouped together in sets, in different circumstances, to define a system. A similar approach to the work was adopted by the ITU-R when formulating the set of Recommendations for DTTB: these Recommendations also define a set of tools that can be used to provide DTTB services.

Specifically, the subset of MPEG-2 which is defined in the Recommendations of Task Group 11/3 potentially allows for the design of a decoder at the transport layer that can interpret the service multiplex, and can decode the audio and video compression and coding layers, for any system that conforms to the DTTB set of Recommendations. This can establish a "plug-and-play" environment for the consumer without the need to consider the specific subset used, and without precluding those manufacturers who makes less flexible receivers.

The outer layer of the system – the physical layer – provides the channel coding and modulation schemes appropriate for the delivery media. The Recommendations concerning the physical layer for broadcasters take into consideration the existing 6, 7 and 8 MHz channel assignments in the VHF and UHF bands, and the need to accommodate differing channel-assignment environments and planning factors.

Two subsets of the Standard's set of tools have been described in detail:

– System A (based on work in the ATSC in North America);

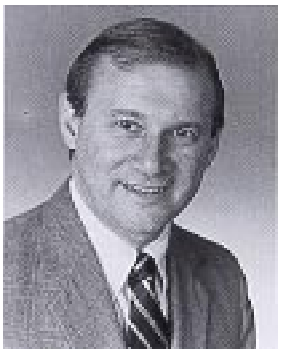
– System B (based on work in the DVB project).

The differences between the two subsets have been minimized and harmonized with respect to the video and audio coding, and the transport levels, so that there are no conflicts, and it is possible to manufacture "plug-and-play" decoders that can process either subset A or subset B.

Mr Stanley Baron *is Managing Director, Television Technology, for the National Broadcasting Company in New York where he is responsible for the evaluation and implementation of new television technology. He has over thirty years of experience in the design and development of digital television systems, and has been awarded patents in the areas of temporal filtering and synthetic video generation. Two of the products he developed have received Technical Emmy Awards and his work has also been widely recognized by bodies such as the NAB, the David Sarnoff Center and the New York Academy of Science.*

Mr Baron serves as Chairman of the ATSC and Chairman of ITU-R Task Group 11/3. He has been elected a Fellow of the SMPTE, a Fellow of the IEEE and an Honorary Fellow of the UK Royal Television Society. Previously, he was President of the SMPTE and served two terms as SMPTE Engineering Vice-President.

Stanley Baron has presented or published over 125 papers on various subjects dealing with real-time video processing and automation. His formal education includes BSEE and MSEE degrees from New York University.



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Mr Wood is Chairman of ITU Working Party 11A (Television Systems and Data Broadcasting) and Chairman of the EC RACE Image Communications Project Line.

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The work done by ITU-R Task Group 11/3 in digital terrestrial television is not by any means the end of the story of digital terrestrial television. However, as Winston Churchill once said, it may be the “end of the beginning” of the story of this most exciting challenge.

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RDS Standards

The Radio Data System (RDS) was developed by the EBU and the specification was initially published in 1984 as EBU doc. Tech 3244. The system is also the subject of ITU-R Recommendation BS.643-2 (1995). The actual RDS standard is CENELEC 50067:1992. This specification has been much upgraded during the last two years and the new version is prEN 50067:1996.

R·D·S
RADIO DATA SYSTEM

The new revised text which was published by CENELEC in September 1996 was prepared by the RDS Forum in close collaboration with Technical Committee 207 of CENELEC and experts from the EBU. Certain elements of text were revised to accord with (i) experience gained with the RDS system and (ii) changes in broadcasting practice since the initial specification was published. An interesting example of these revisions are the new clauses relating to the PS feature. Receivers produced to accord with the new specification will of course be compatible with RDS broadcasts which conform with previous editions of the RDS specification.

The resulting European Standard, when accepted after vote, will replace EN 50067:1992 in Summer 1997.

In the USA, the RBDS specification was adopted in January 1993 as a voluntary national standard, jointly issued by EIA and NAB. This standard includes the RDS system as its major component and European RDS receivers could easily be modified for use in the USA; in the large majority of cases they would even work well if unmodified, especially with the five basic features PI, PS, AF, TP and TA. An up-graded specification was completed at the end of 1996 within the RBDS Subcommittee of the NRSC of EIA/NAB. It has been drawn up with a view to harmonizing, to the largest extent possible, the RBDS specification with the RDS features now specified in Europe (in the new prEN 500067:1996). In the USA, RBDS is now only the name of the American standard. When implemented in receivers, the US system is also called RDS and is identified with the same logo as used in Europe.

A graph showing the number of RDS receivers manufactured world-wide up until 1995 is shown below.