European perspectives on digital television broadcasting – Conclusions of the Working Group on Digital Television Broadcasting (WGTB)

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In Europe, a coordinated activity was started in early 1992, which aims at the design of a common system for digital television broadcasting. Under the auspices of a European Launching Group composed of members of eight countries representing a range of organizations involved in the business of television, the Working Group for Digital Television Broadcasting (WGDTB) has defined system approaches for such a digital service.

The findings of the WGDTB are reported and the three systems proposed for study and future implementation are presented. All three are multi–layer systems, which include two or more service levels which are inter–related either in a hierarchical or in a multicast mode.

1. Introduction

The starting point for the preparation of an era of digital television in Europe is clearly defined by the experience with several existing analoge television standards, namely PAL and SECAM, which have been in use in Europe for approximately 25 years, and with D2–MAC and HD–MAC, which for several countries of Europe have been operational or pre–operational on satellite for some time. Although tests have shown that the latter performed quite well for a high percentage of source pictures, it is nonetheless felt that rapid market success would not be achieved.

The design of a standard for digital television broadcasting (DTVB) thus needs to make use of all experience gained with the MAC systems to guarantee a market–driven success this time. DTVB in Europe should be applicable to terrestrial, satellite and cable transmission. Moreover, DTVB should offer several levels of service performance and should be usable for stationary receivers with roof–top antennas or dish antennas as well as for portable or even mobile receivers with small or built–in antennas. Moreover, it should be possible to introduce DTVB in a number of different ways in the individual countries of Europe.

Considerations of quality levels and commonalties between those respective levels are discussed in greater detail in [1].

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Receiving condition	Quality / Resolution			
	HDTV studio	CCIR Rec. 601	SECAM/PAL	VHS
Large screen (static reception, roof–top antenna)	●			
28–inch screen (static reception, roof–top antenna)	●	●		
14–inch screen (portable, “rabbit–ear” antenna)		●	●	
“Watchman” (portable, no antenna)				●
In–car receiver (high speed, mobile reception, car antenna)				●

Table 1
Relative importance of services in the Quality/Resolution – receiving condition matrix.

2. Fields of application for digital television broadcasting in Europe

DTVB is seen as offering promise in four different ways:

– it may deliver high definition television (HDTV) images with good quality via all possible distribution media;

– it may result in a multiplication of the number of programmes available via a given distribution medium;

– it may offer stable pictures to portable receivers with small or built–in antennas;

– it may even deliver stable pictures to mobile receivers, e.g. in buses, trains and cars.

Before starting the systems design activities, a survey was performed concerning the relative importance of all the possible service options for DTVB among the organizations present (*Table 1*). Five types of receivers were assumed to be possible, all individually related to a given receiving condition. It was taken for granted that, for instance, an HDTV receiver with a large screen would always be stationary and thus could be used with a roof–top antenna, cable or satellite dish. In contrast, the small portable receiver with a liquid crystal display (LCD) would either use no visible antenna or just a stub. Four levels of service quality/resolution have been defined, ranging from high definition television (HDTV) studio quality via enhanced definition television (EDTV), standard definition television (SDTV) to limited definition television (LDTV). Each of these levels is described in a very simplified way by the “descriptors” presented in *Table 1*.

It was concluded that out of the 20 possible combinations of receiving condition and quality/resolution, HDTV for stationary large screen receivers was of the most–immediate interest for the Group, followed by HDTV for normal–sized stationary receivers, SDTV for portable receivers and EDTV for normal–sized stationary receivers. Mobile reception of LDTV images with in–car receivers was given lower priority.

The WGDTB succeeded in reducing the number of service options assumed to be relevant for the European television community to four, in the end. These are:

– HDTV for stationary receivers;

– EDTV for stationary receivers;

– SDTV for portable receivers;

– LDTV for mobile receivers.

Another dimension of system definition is the correlation between the four remaining service options described above and the possible transmission media (*Table 2*).

Broadcast satellites are a medium by which digital data can be transmitted to a receiving dish via a clearly–defined and relatively stable channel. Given an appropriate modulation scheme in a wide enough channel bandwidth and a suitable source coding and multiplexing system, all four levels of quality can be made available to a receiver. Thus the number of programmes received can be traded against service quality/resolution.

Cable systems will most probably be used to carry programmes that may be received terrestrially or via satellite or may be specially produced for cable. It is assumed that all quality/resolution levels offered by other media will have to be accommodated on cable (see *Section 4.*).

Transmission medium	Received service quality / Resolution				Receiving condition
	HDTV	EDTV	SDTV	LDTV	
Satellite	✓	✓	✓	✓	Stationary (dish)
Cable	✓	✓	✓	✓	Stationary (cable)
Terrestrial transmitters	✓	✓	(✓) ✓	(✓) (✓) ✓	Stationary (roof–top) Portable (stub antenna) Mobile (car antenna)

Table 2
Fields of application for digital terrestrial television.

3. *Basic technical elements for DTVB services*

Current knowledge about the performance of different television services as a function of net data rate for image, sound and data has been gathered within numerous European R&D projects during recent years. Among these activities are the Scandinavian HD–DIVINE project, the RACE projects dTTb and HD–SAT, both funded by the European Commission, the German project HDTV–T and several others. However, none of these projects has reached a status that would allow a final decision to be made regarding the data rate which would correspond with a given level of quality for a given percentage of programme material to be transmitted. Assumptions therefore had to be made concerning the data rates. For an HDTV service including multichannel digital sound, teletext and other data such as those used for scrambling and conditional access, a bit–rate of 30 Mbit/s is thought to be necessary. Bit–rates of 11 Mbit/s for EDTV, 5.6 Mbit/s for SDTV and 1.5 Mbit/s for LDTV are also assumed. The number and quality of the accompanying sound channels, and the amount of additional data to be made available, are assumed to be reduced in parallel with the image quality of the services.

In Europe, UHF channels are assumed to be the only possible resource for terrestrial transmission of DTVB services. The situation as far as spectrum usage is concerned is very different in different countries. Due to the fact that the public broadcasting organizations in the individual European countries are obliged to transmit their programmes either nation–wide or, at least within a region of each country, to something like 97–100 % of the population, large networks for PAL or SECAM are currently being operated. In a given area more than one UHF or VHF channel can commonly be used to receive one programme. In the individual home, one of these channels therefore is available in nearly all cases. Thus the concept of "taboo" channels does not apply to the same extent as in the United States. In the future, single frequency networks (SFN) should be used for terrestrial DTVB services, if possible, in order to reduce the spectrum consumption for the television services. Orthogonal frequency division multiplex (OFDM), a system used in the European Digital Audio Broadcasting (DAB) service, may be chosen for DTVB for this reason. In any case, the bandwidth of the UHF channels is 8 MHz and it is assumed that 7.5 MHz can be effectively used to transmit a DTVB service.

To accommodate an HDTV service with its net data rate 30 Mbit/s within 7.5 MHz, a modulation system with a spectral efficiency of at least 4 bit/s/Hz needs to be employed. Such a system (e.g. 16 QAM) can be used to transmit television signals from a stationary transmitter to a stationary roof–top antenna with high directivity and in cable systems, but due to its sensitivity to phase and amplitude distortions it is not adequate for satellite systems or for portable or mobile reception.

Based on the experience with DAB, which is particularly suited for transmission to moving vehicles, it has been concluded that an approach for channel coding and modulation needs to be chosen that would result in a spectral efficiency of approximately 1 bit/s/Hz. In the case of the rather less

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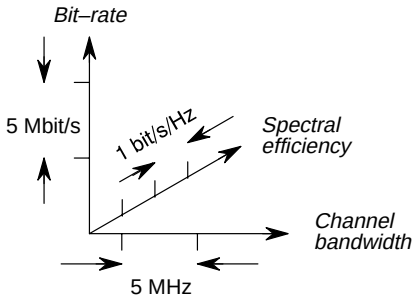
Dr. Reimers is the Chairman of the WGDTB. He is President of the Fernseh– und Kinotechnische Gesellschaft (FKTG).



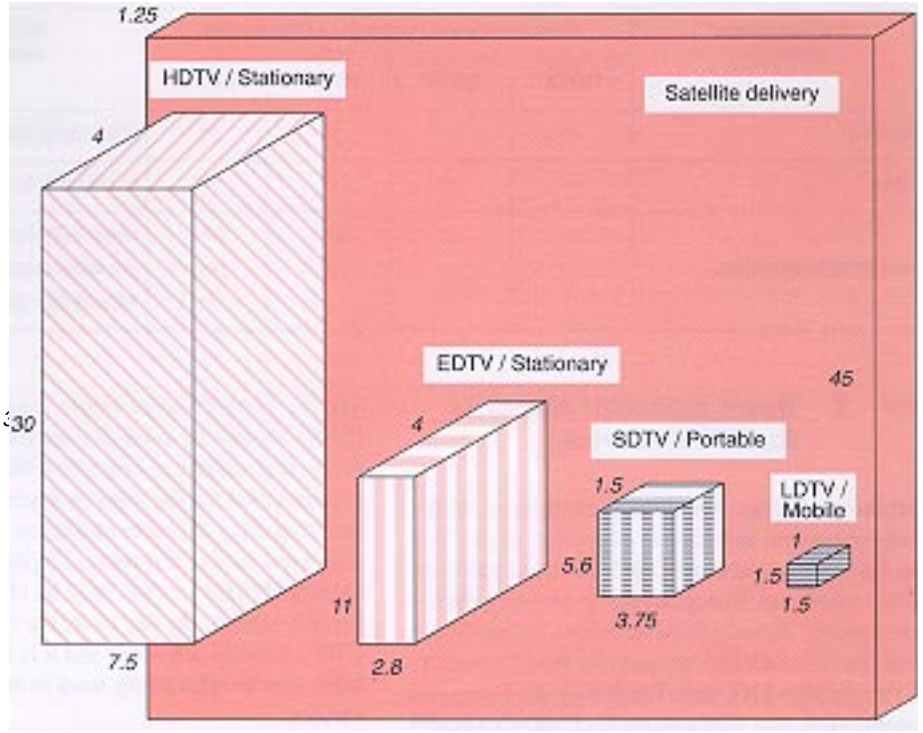


Figure 1
Comparison of soure data rate, channel bandwidth and spectral efficiency for different digital television services.

36 (Fixed satellite service)

approx. 33 for Astra 1E

critical quasi–stationary portable receivers a channel coding and modulation scheme with a somewhat higher spectral efficiency (1.5 bit/s/Hz) could be selected.

For satellite systems with their inherent non–linearities (especially in the TWT amplifier of the spacecraft), QPSK 3/4 has been evaluated and tested. A spectral efficiency of approximately 1.25 bit/s/Hz can be achieved with this modulation scheme. Details are described in [2]. QPSK 3/4 has been used by the WGDTB as the basis for its satellite–related service proposals.

As depicted in *Fig. 1*, the different values for the spectral efficiency of the terrestrial services described so far lead to a bandwidth occupation of 7.5 MHz for HDTV, 2.8 MHz for EDTV, 3.75 MHz for SDTV and 1.5 MHz for LDTV, respectively.

The bandwidth of typical telecommunication satellites used for the direct–to–home transmission of television programmes in Europe is generally 36 MHz (or perhaps 33 MHz in the specific case of a satellite which seems likely to be devoted to DTVB services, namely ASTRA 1 E). Due to the relatively stable channel characteristics and due to the fact that satellite services will always be received by stationary dishes, the satellite channel can be understood as a "data container" with a capacity in the order of 45 Mbit/s (*Fig. 1*).

4. DTVB services for Europe

Based on the considerations described above, three proposals for systems to be studied – and, if feasible, to be developed – have been elaborated.

In *Fig. 2*, two different proposals for terrestrial DTVB systems are shown. One (*Fig. 2a*) is an HDTV service with EDTV and SDTV levels of the same programme content. This configuration has been termed a *multi–layer* proposal. The layering may either be accomplished in a hierarchical form such that the SDTV layer is used as the basic layer for both EDTV and HDTV service and the EDTV layer, together with the SDTV layer, are the basis for the HDTV service, or in a multicast form. *Multicasting* implies that all three layers are individually complete in such a way that, for instance, the HDTV receiver will use the HDTV layer only to decode the HDTV service. The goal involving the availability of the EDTV layer has resulted from the planning of the introduction scenario for the proposed service. Since the cost–price of HDTV receivers will be largely governed by the cost of the display–tube, projection system etc., but will be influenced by the amount of silicon necessary for the decoder electronics as well, it was thought necessary that less–expensive and probably smaller re-

ceivers should be made available than those which would be used to display EDTV images only. The SDTV layer is aiming at the reception of the service by portable receivers. The channel coding and modulation for this layer therefore need to be designed in such a way that ruggedness can be achieved. A spin–off of the inclusion of such a rugged SDTV layer is the introduction of one more level of graceful degradation, irrespective of possible additional levels that may be achieved by forward error correction (FEC). HDTV and EDTV receivers can therefore be designed in such a way that under unfavourable circumstances, when the decoding of the less–rugged HDTV and EDTV layers is not possible, at least SDTV quality can be displayed.

It is evident that such a multilayer approach is not easily accommodated within one 8–MHz channel, and considerable work is currently under way to prove the feasability of the proposal.

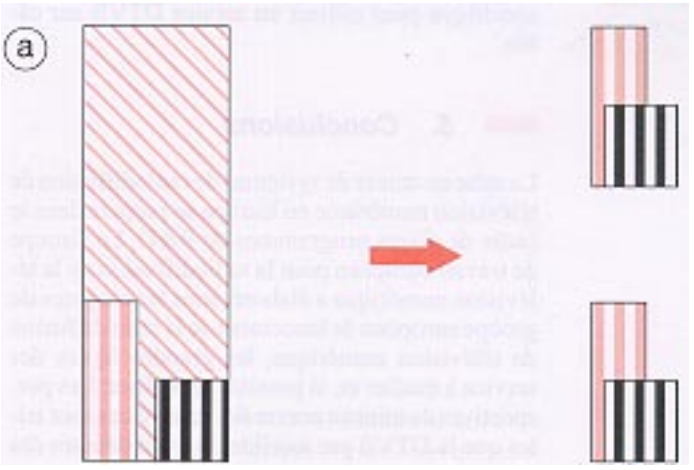
Two of the four promises of DTVB mentioned before in *Section 2* may be fulfilled by the proposal described so far, namely the transmission of HDTV programmes via terrestrial transmitters and the delivery of stable television services to portable receivers. Two of the four are not included, namely the transmission of multiple programmes within one channel and the usability for mobile reception. Therefore reconfigurability of the service has been proposed in such a way that instead of one HDTV programme with embedded additional layers, two EDTV programmes with embedded SDTV layers can be offered. The multiplexing, channel coding and modulation will have to be configured in such a way that the receiver will be capable of decoding the original and the reconfigured services. One interesting spin–off of the concept of reconfigurability is that several introduction scenarios may become possible in different parts of Europe. HDTV may, or may not, be part of the first introductory phase of DTVB; broadcasters may chose to use their network in both configurations at different times of the day etc...

In a number of European countries mobile reception in trains, buses and in cars is expected to become important in the future. Therefore a second proposal, depicted in *Fig. 2b*, was thought worthy of study by some organizations. A multi–layer configuration including the layers EDTV for stationary reception as well as SDTV for portable reception and LDTV for mobile reception should be part of this service. Again, reconfigurability should be provided.

The possible layers and forms of reconfigurability in satellite services will depend mainly, if not exclusively, on the characteristics of the multiplexer (*Fig. 3*). The satellite channel can be considered as a largely homogenous medium for the distribution of digital signals and one data–stream, when protected by an adequate FEC, may transport many levels of service quality to the fixed receiving dish. Therefore – using the same net data rates as described above for the different layers – it may be possible, for example, to transmit one HDTV programme with an embedded EDTV layer plus an additional EDTV programme or up to four EDTV programmes or up to eight SDTV programmes or even up to 30 LDTV programmes or mixes of these possibilities.

Currently, most of the cable systems in Europe are not being operated as a competitive medium bringing to the homes specific programmes that are unique to cable, but instead they are used as alternative carriers for the existing programmes that have been broadcast via satellite or terrestrial transmitters. In the future, this may change in some of the European countries. DTVB signals that are broadcast in 8 MHz UHF channels will most probably be distributed in the original signal

Figure 2
WGDTB proposals for reconfigurable digital terrestrial television services in Europe.



One HDTV programme with embedded coding for reception in EDTV and SDTV

Two independent EDTV programmes, each with embedded coding for SDTV

One EDTV programme with embedded coding for reception in SDTV and LDTV

Two independent EDTV programmes, each with embedded coding for SDTV

One HDTV programme with embedded coding for reception in EDTV, and a second, independent EDTV programme

Four independent EDTV programmes

Eight independent SDTV programmes (Note: other combinations, including LDTV programmes, would be possible.)

Figure 3
A proposal for reconfigurable digital satellite television services in Europe.

format. Programmes that have been received from satellite will most probably have to be reformatted due to the fact that the modulation techniques employed for satellite systems will not be as efficient as they should be in a cable environment and to ensure compatibility with the existing channel allocations. At this time there are no plans to devise a specific format for the use of DTVB service on cable.

5. Conclusions

The introduction of digital television broadcasting systems in Europe is currently being prepared within a number of research and development programmes. A profile for the services to be studied – and, if feasible, developed – has been proposed by the truly multinational European Working Group for Digital Television Broadcasting under the auspices of the European Launching Group for Digital Television Broadcasting. The perspective for the possible introduction of these services is such that DTVB via satellite may start as early as 1995, whereas terrestrial services may start around the 1997 to 1999 time–frame.

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The author would like to thank all members of the WGDTB for the extremely cooperative and efficient work during the past months. Although the number of contributors is too large to name all individuals, the Vice–Chairmen Dr. Ian Childs (BBC) and Mr. Daniel Sauvet–Goichon (TDF), as well as the Secretary Mr. David Wood (EBU), should be mentioned explicitly.

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