HDTV

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EBU demonstrations of wideband digital HDTV satellite broadcasting technologies at WARC-92

EBU Task Force WARC-DEMS-92*

The article describes the demonstration of 20 GHz wideband digital HDTV satellite broadcasting technologies organized by the EBU during WARC-92. It opens with an explanation of the justification for additional broadcast channels for these services, and continues with the objectives of the demonstration. There follows an outline description of the hardware configuration used and the programme-material shown.

Over 500 WARC-92 delegates and other personalities took this opportunity to preview what wideband digital HDTV will hold in store in the early years of the next millennium.

1. Introduction

Following extensive preparatory work carried out since March 1990, the EBU Members organized a series of large scale demonstrations of wideband digital HDTV technologies on the occasion of the ITU WARC-92 held in February/March 1992 in Torremolinos, Spain. The demonstration was carried out in association with the Retevision, the Eureka-256 project, the RACE Hivits project and other organizations, and benefitted from considerable help from various manufacturers.

The objective of these demonstrations was to show the delegates that fully digital approches to satellite HDTV broadcasting in the vicinity of 20 GHz are technically viable and that prototype equipment is able to provide a picture quality that is essentially transparent to that of the studio signal associated with multi-channel sound and enhanced teletext.

To permit the opening of services offering these advanced features, new "wideband" satellite channels are required; the allocation of a new frequency band for these services of the future was therefore an important target for the EBU Members during the Conference. Responding to the recognised need for a frequency band, the WARC-92 allocated the band 21.4 - 22.0 GHz to Broadcast-satellite service (BSS) in ITU Region 1 for future digital HDTV services, in spite of the very strong competition of other services for these frequencies. No doubt, some merit goes to the convincing success of the EBU demonstrations given to the delegates of WARC-92.

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2. Justification for a wideband HDTV satellite broadcasting system

The search for perfection in broadcasting vision together with associated data and sound signals is focusing on high-definition television (HDTV). Analogue narrowband HDTV emission systems, based on the existing PAL/SECAM or MAC/packet systems, have initially been considered for satellite broadcasting in the existing frequency bands at 11 and 12 GHz. These bands are characterized by the relatively narrow channel bandwidth and very demanding criteria for co-channel and adjacent-channel interference. An additional constraint of "downward compatibility" is imposed to these narrow- band HDTV broadcasting systems. This implies that a new HDTV emission standard must be received and displayed, without additional equipment, using receivers designed for the existing standard.

All these constraints may have a two-fold effect on the design of new HDTV satellite emission systems intended for implementation in existing broadcast channels:

- some quality degradation compared to the studio HDTV quality;
- high complexity, and thus cost, of the HDTV receivers.

New digital HDTV broadcasting systems are being developed by European industry and broadcasters to offer viewers essentially transparent quality available from the HDTV production equipment in use today, even under most difficult propagation conditions usually encountered at frequencies above 10 GHz. Digital HDTV systems offer significantly better prospects than their analogue counterparts in virtually every aspect of television engineering, in particular as regards the intrinsic system quality and service continuity as well as the required emission power, spectrum efficiency and receiver complexity. No compatibility constraints are imposed on these new digital systems.

Novel digital HDTV emission systems provide an opportunity, through technological developments, to improve the quality and increase the quantity and diversity of the services offered to the public. Commonality of the new HDTV format should be maintained as much as possible with the studio standard parameters. Such commonality should ideally be established also with HDTV formats used in other delivery media (terrestrial networks, cable, MVDS, recording, etc.) to avoid unnecessarily complex and thus expensive receivers.

3. EBU Task Force for the HDTV demonstrations

To allow the deployment of wideband HDTV satellite broadcasting services, the allocation of a new frequency band was therefore of paramount importance. The WARC-92 Conference was in fact mandated to allocate a frequency band for wideband HDTV broadcasting services in the vicinity of 20 GHz. The initial suggestion for a demonstration of wideband digital HDTV systems to be given on the occasion of WARC-92 was put forward by the Bureau of the EBU Technical Committee. The EBU Members had for some time been conducting an extensive study programme on wideband HDTV satellite emission system, service planning aspects, vision and audio source coding, propagation phenomena, etc. and the suggestion for a demonstration was made in the light of very positive results of a similar demonstration of digital audio broadcasting given at WARC-ORB(88) in Geneva .

In February 1990 the Bureau established a special Task Force called WARC-DEMS-92, chaired by Dr. M. Cominetti (RAI). Mr. C. Dosch (IRT) was nominated Vice-Chairman of the Group. The Member organizations which participated in the project were RAI, IRT, Retevision, CCETT and BBC.

Following the definition of the objectives, the principal matters to be resolved were as follows:

- provision of the demonstration equipment;
- production of the demonstration programme material;
- provision of a satellite operating at around 20 GHz and a transportable earth station;
- logistics (e.g. suitable premises needed to accommodate the HDTV auditorium, a monitoring room and an equipment room);
- availability of supporting documentation and the promotion of this event;
- the necessary budget provision.

The terms of reference of the Task Force included the following tasks:

- to present the highest image quality achievable with the state-of-the-art production and display technology;

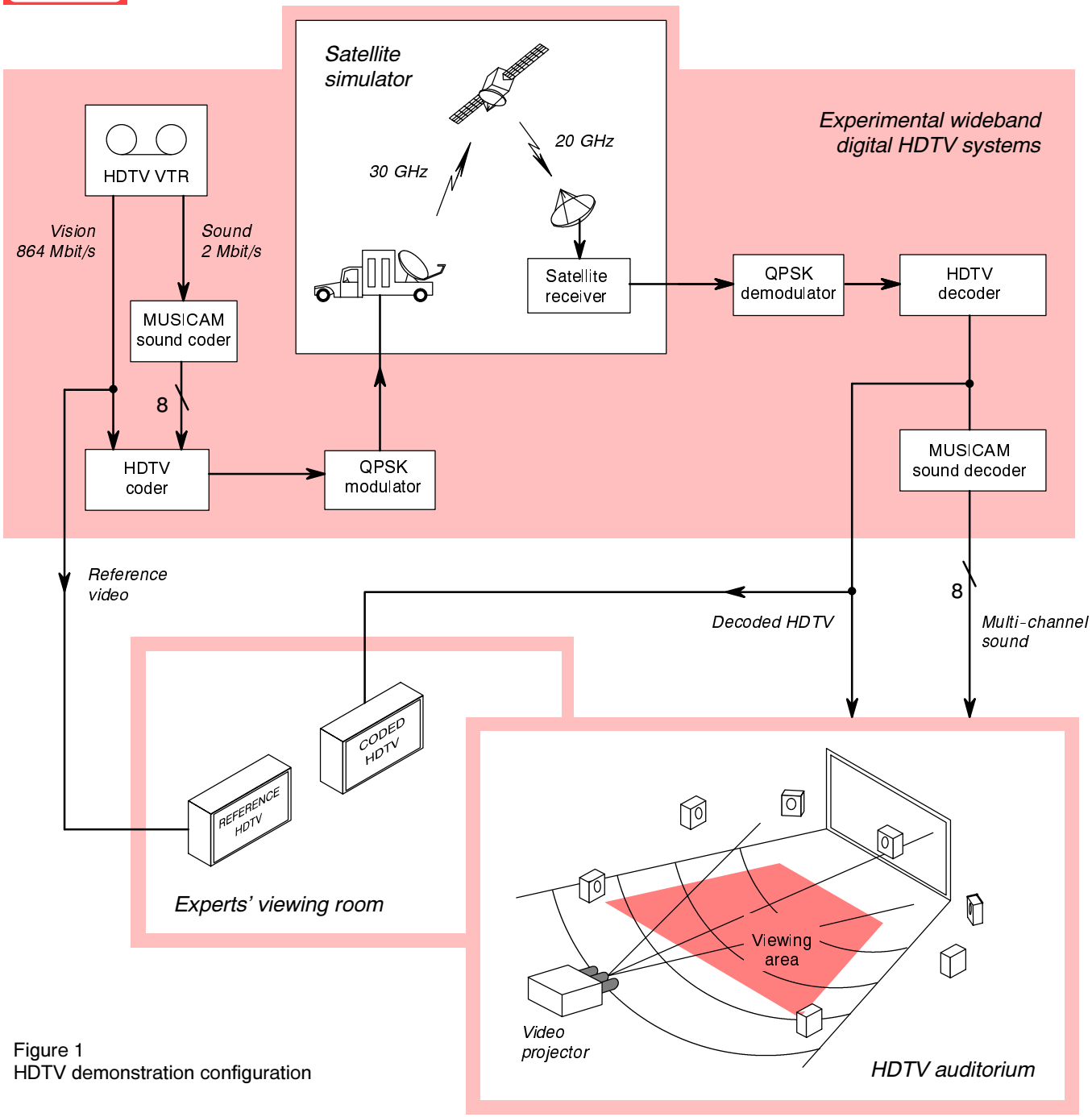


Figure 1
HDTV demonstration configuration

- to demonstrate the benefits of compact-disc quality multi-channel and/or multilingual sound coding techniques;
- to present all the achievements of European industry available to date in the area of advanced HDTV image coding and decoding;
- to present, if possible, the operation of the HDTV codecs in both 1250/50 and 1125/60 formats in order to highlight the universality of digital approaches in terms of a possible unique worldwide emission standard.

In order to accomplish these tasks, the Task Force agreed to carry out the demonstrations at a nominal bit-rate of 140 Mbit/s. This bit rate was also consistent with the formal EBU policy of supporting the request for a new frequency allocation for *wide* RF-band HDTV broadcasting in the 20 GHz frequency range.

The choice of satellite for the demonstration was relatively simple, since the European Space Agency's Olympus satellite has an experimental 20/30 GHz communications payload. The use of

a 140 Mbit/s system, however, required this payload to be operated in its wide-band or semi wide-band configuration*. Following a careful review of the risks involved in the switching operations (after difficulties experienced with the satellite in 1991), ESA decided only to offer the normal channel capacity. This could support 70 Mbit/s rather than full 140 Mbit/s. Consequently, the Olympus satellite could not be used for the demonstrations and a satellite simulator provided by the IRT was employed instead. This simulator had been shown by experiment to represent very accurately the link impairments associated with a real satellite channel.

The participants in the demonstrations showed great understanding regarding this situation, although use of the satellite would certainly have further strengthened the case for a frequency allocation.

The choice of 140 Mbit/s also facilitated a balanced use of the two HDTV codecs available (i.e. Eureka-256 and RACE-Hivits). If a lower bit rate had been chosen only the Eureka codec could have been used, meaning that the operational flexibility and reliability of the demonstration set-up would have been seriously hampered.

4. Demonstration configuration

Fig. 1 shows a conceptual block diagram of the demonstration configuration used to simulate broadcasts of digital high-definition television signals by satellite.

More detailed video and audio distribution diagrams are given in *Fig. 2a/b*.

4.1. HDTV video tape recorders

The first element in the demonstration chain was the digital HDTV video tape recorder (VTR) which consisted of a combination of four D1 digital machines. The source vision and sound data resulting from the programme production in HDTV studios is in excess of 1000 Mbit/s. This bit rate is too high to be recorded on a single D1 VTR, so four suitably-multiplexed D1 VTRs (the so-called "quadriga") are necessary to record the total capacity required for an HDTV signal in its straightforward PCM form.

A separate single HDTV VTR was available to play back the digital 1125/60 programme sequences.

4.2. Video source coding

For the transmission of a total source data capacity of 1 Gbit/s, the bit rate must be reduced substantially, usually by a factor of 8 or more. There are standard hierarchical bit rates for access to the digital networks. One of them, 139.264 Mbit/s, often referred to as 140 Mbit/s, was used in this experiment. Systems for satellite HDTV transmission using this bit rate have been developed in Europe within the Eureka 256 Project, the RACE Hivits project No. 1018 and by the Institut für Rundfunktechnik in conjunction with Siemens. The first two were available for this demonstration. They included motion compensation and a Reed-Solomon (RS) error protection at the source.

Several different techniques have been and are being developed for the bit-rate reduction of video signals. A combination of techniques such as transform coding, motion-compensated interframe prediction and variable-length coding can be used. Many good reviews have been published covering the field of digital coding and bit-rate reduction of television signals. It is expected that further progress may be made shortly in additional data bit reduction while retaining the transparent quality of the video information.

Sound coding for several audio channels associated with the video programme was carried out with the MUSICAM sound coder/decoder system. This system can provide for a range of bit rates ranging between 64 and 192 kbit/s per mono channel. The system has been recently standardized within the ISO MPEG as the ISO 11172-3 layer II audio coding standard. In this experiment, a bit-rate of 160 kbit/s per mono channel provided transparent compact disc quality. Between two and seven sound channels were associated with the video signal.

4.3. Digital modulation

Several digital modulation methods are suitable for this application, and QPSK (quadrature phase shift keying) was used for the demonstration. No specific channel error-correction coding was incorporated in the modulator. Studies of the link-budget have shown that a 140 Mbit/s HDTV transmission via the 30/20 GHz communications

* Semi wide-band mode is an un-specified configuration which couples the relatively narrow-band input stage (bandwidth approximately 140 MHz) with the wide-band output amplifier stage (bandwidth about 700 MHz). This special configuration can be set up by activating only coaxial switches rather than wave-guide switches.

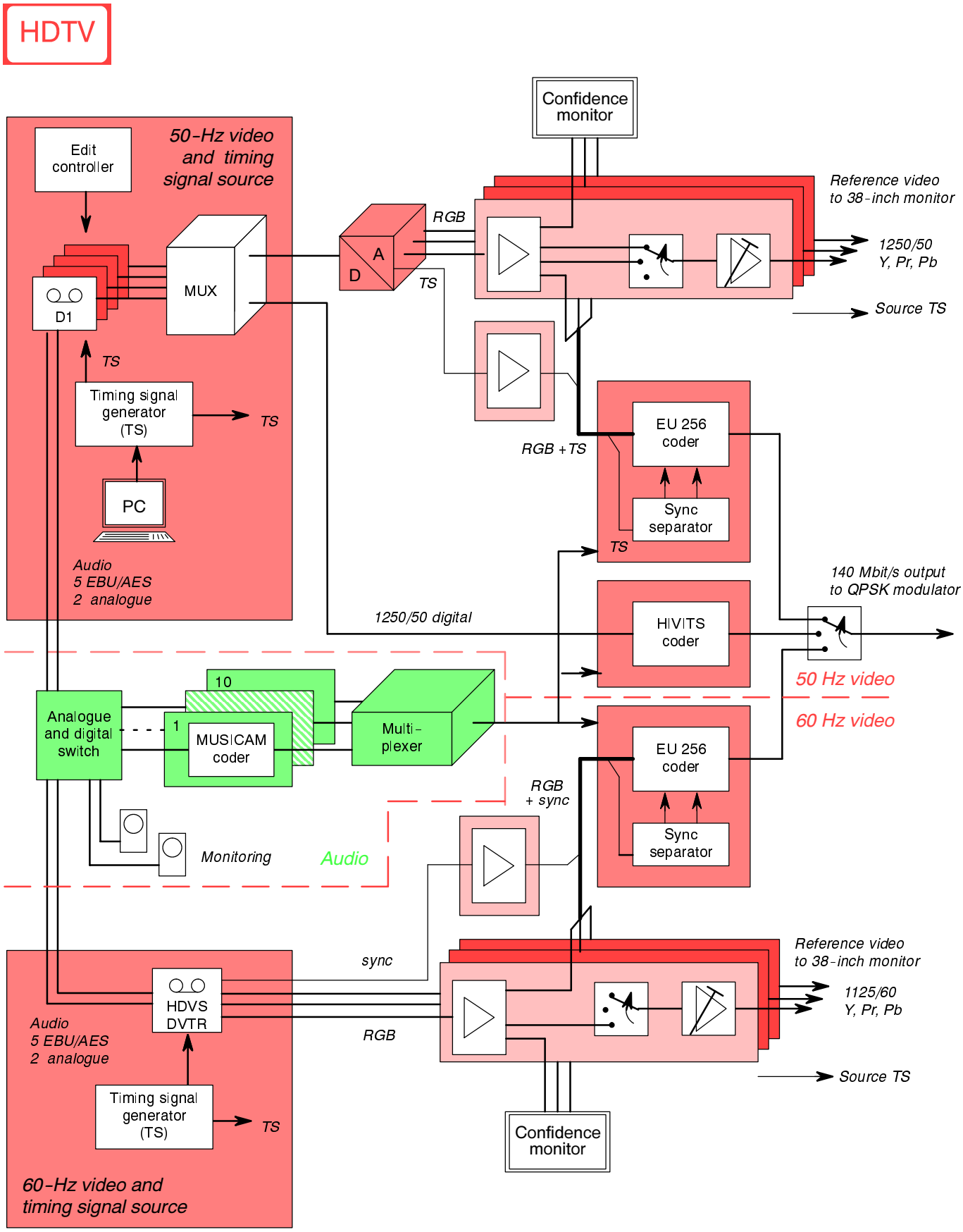


Fig. 2a
Video and audio sources and coding

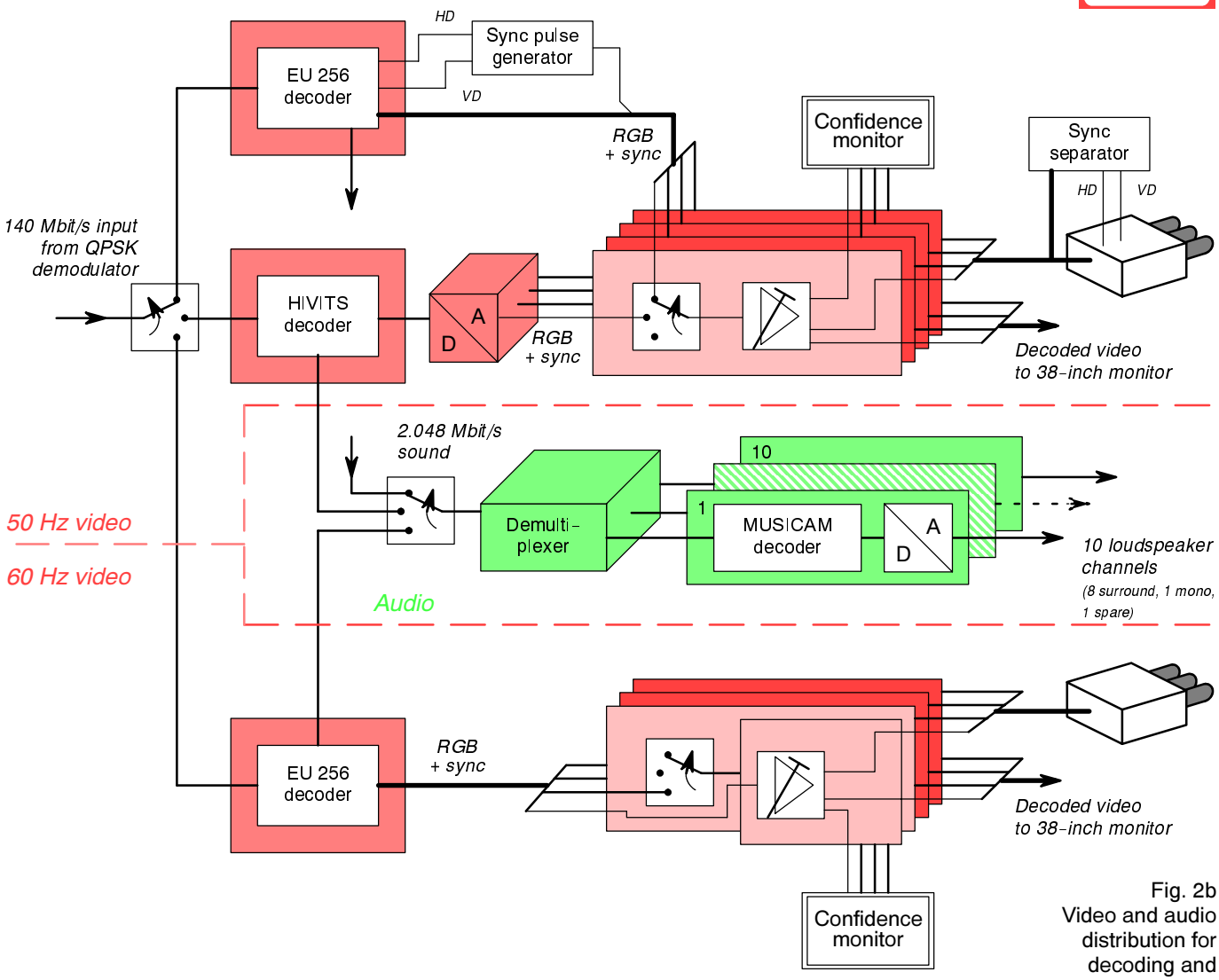


Fig. 2b
Video and audio distribution for decoding and display

payload of the Olympus satellite and using the TDS-7 transportable earth station could be carried out with just sufficient margin. Prior to this demonstration, the RAI Research Centre in Turin successfully completed an experiment at 70 Mbit/s.

4.4. Satellite simulator

The satellite simulator used in the demonstration was representative of a typical satellite transmission chain including the up-converter and high-power amplifier of the transmitting earth station, satellite (low-noise amplifier, input multiplex filter, travelling-wave tube and output multiplex filter) and receiving installation (low-noise amplifier and down-converter). For demonstration purposes, it was possible to inject noise and/or interference in the satellite chain in order to test system ruggedness against interference and noise.

4.5. Displays

The main viewing room was set up in the Don Pablo Hotel in Torremolinos (*Fig. 3*). The room needed some acoustic treatment (e.g. sound absorbent material on the side walls and the curtains). To achieve optimal viewing and listening conditions and allow critical assessments of the quality of picture and sound reproduction, considerable attention was paid to ensuring good congruence between the picture and sound (*Fig. 4*). The projection screen height was 150 cm and width 266 cm, corresponding to the picture aspect ratio of 16:9. The viewing distance was between about 2 and 4 times picture height. In total, four rows of six to seven chairs were accommodated in the room to allow for some 24-28 participants per session.

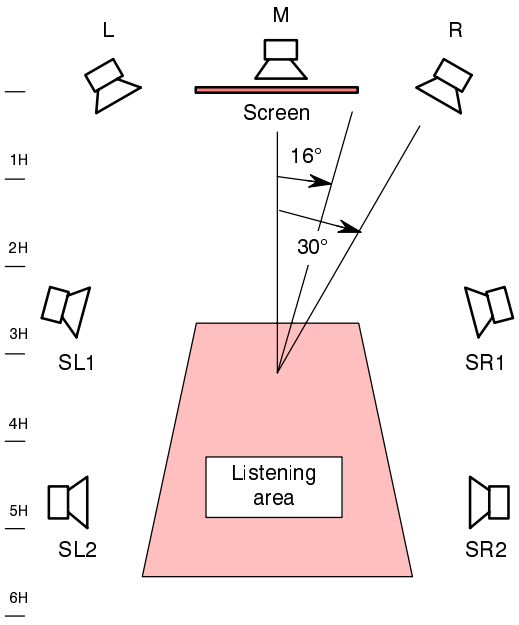
Two HDTV projectors were suspended from the ceiling in an acoustically-screened box, one above the other. One was used for the projection of the

Figure 3
HDTV
Auditorium

1250/50 format pictures, the other for the 1125/60 format pictures.

The loudspeaker arrangement for sound reproduction was set to comply with that recommended by the CCIR, i.e. theee front and two surround channels. The surround channels were split between two loudspeaker pairs, so the complete loudspeaker configuration comprised seven speakers.

Figure 4
Loudspeaker
arrangement
for sound reproduction



A separate monitoring room was also arranged for very critical viewing assessments. Four 38-inch HDTV monitors were set up to allow direct comparison between the source and the processed images, for both 1250/50 and 1125/60 formats. Experts from the EBU were available for detailed technical discussions on subjective evaluations.

All video displays were regularly verified for optimal picture quality by an expert from the Sony Company.

5. The demonstration programme material

A variety of HDTV programme excerpts assembled for this occasion from existing European productions provided an excellent selection of programme material, including sport, ballet, entertainment, advertising, etc.. The demonstration programme material for the 1250/50 format included eight excerpts (see *Table 1*) with total duration of about 24 minutes. This part was compiled by the BBC. The second part of the demonstration consisted of excerpts from a ZDF/BR/IRT production in the 1125/60 format and was about 7 minutes long. On certain source pictures some slight trace of noise was visible due to the fact that the original material had been recorded and copied on analogue VTRs or because of the HDTV camera per-

Item	Title	Origin	Format	Sound channels
1	World Cup Football	RAI / EU-95		2 + comm
2	Prince of Pagodas	BBC		5
3	Alfa Romeo animation	France Ex Machina		2
4	Un Bel di Vedremo	RAI		2
5	1250 Qui dit mieux ...	SFP	1250/50	2
6	Zirkus Knie	NDR / IRT		7
7	Wimbledon Tennis	BBC		5 + comm
8	... Y Sevilla	Omeja / Retevision / Expo 92		Mono
9	Gala World Cup Dancing	ZDF / BR / IRT	1125/60	7

Table 1
Demonstration programme

formance under difficult lighting conditions when shooting the sequences. It can be confirmed, nonetheless, that the 140 Mbit/s HDTV codecs appear essentially transparent to the given source pictures.

The sound configurations were different from one programme excerpt to another, allowing for some comparison. For example, "... y Sevilla" was only available in mono, other sequences were in two, five or up to seven-channel stereophonic sound.

The commentary voice-over was left in the natural language of the originator of each programme. This had the additional benefit of reinforcing the international nature of the demonstration.

6. Outline of the demonstrations

Demonstrations for the WARC'92 delegates took place six times each day, over a six-period at the beginning of the Conference. In addition to these 36 general presentations, several special ones were arranged for the members of Working Party V, Specialist Group V1/RDB, RACE HD-SAT and Eureka Project 256. A total of 531 persons from 96 countries attended the demonstrations. Given that the number of delegates participating at the Conference was about 1500 and that only a small part of it was devoted to broadcasting, the attendance of the EBU demonstrations may be considered as highly satisfactory.

Each presentation lasted about 40 minutes. After a welcoming address by an expert from the EBU, the demonstration programme material, was projected on the large screen in the HDTV auditorium. After the sessions, the EBU experts were available for detailed explanations and discussions. Expert viewing conditions were also available in the monitoring room where source and processed pictures where compared on the 38-inch HDTV monitors.

All visitors to the demonstrations received a compendium of papers on digital HDTV broadcasting, published by the EBU for this occasion.

7. Conclusion

Following the extensive preparatory work during the last two years, the overall results of the EBU demonstrations of wide-band digital HDTV broadcasting may be considered as very positive. The main objective was fully achieved in that the EBU demonstrations showed the technical feasibility, and the numerous advantages, of the fully digital approaches for satellite broadcasting of HDTV at frequencies of about 20 GHz. Several hundred of the WARC-92 delegates participated in the EBU demonstrations and it came as little surprise when the WARC-92 Conference eventually allocated the band 21.4-22.0 GHz to HDTV broadcasting in Region 1. This demonstration also represented a European première of a high-quality multichannel (i.e. up to seven-channel) surround sound reproduction system associated with electronic HDTV pictures.

The frequency allocation will pave the way towards the standardization process of digital HDTV broadcasting system for Europe (and possibly worldwide), the production of VLSI chips allowing the manufacture of relatively inexpensive HDTV receivers, and last, but not least, the production of attractive HDTV programmes for the general public.

Acknowledgements

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Bibliography

Further information concerning the EBU strategy regarding the introduction of digital wideband HDTV satellite services, and the technical systems used in the EBU demonstration at WARC-92, will be found in:

Advanced techniques for satellite broadcasting of digital HDTV at frequencies around 20 GHz
EBU, Geneva, 1992.

More photographs of the demonstration hardware appeared in:

EBU wideband digital HDTV demonstration at WARC-92
EBU Technical Review No. 251, Spring 1992, pp. 20-21.