A Global Approach to studies in television broadcasting

M.I. Krivocheev

Chairman, ITU–R Study Group 11

Detailed technical investigations are in progress, worldwide, concerning new television broadcasting systems. These range from relatively simple enhancements of today's systems, to futuristic concepts for digital stereoscopic and 3–D HDTV.
It is necessary to establish a clear view of the opportunities presented by these varied developments, and the time is right to formulate the tasks and strategies that will pave the way into the 21st century.
The world forum for standard–setting in this field is the ITU Radiocommunication Sector (ITU–R), and Study Group 11 (Television broadcasting) in particular. Here, in a wide–ranging reflection on options and opportunities for the immediate and longer–term future, the Chairman of Study Group 11 first outlines the work now being carried out within the ITU. There follows a discussion on the new approaches and strategies that characterize the forthcoming Study Period (1994–95), and on the challenges that lie ahead.

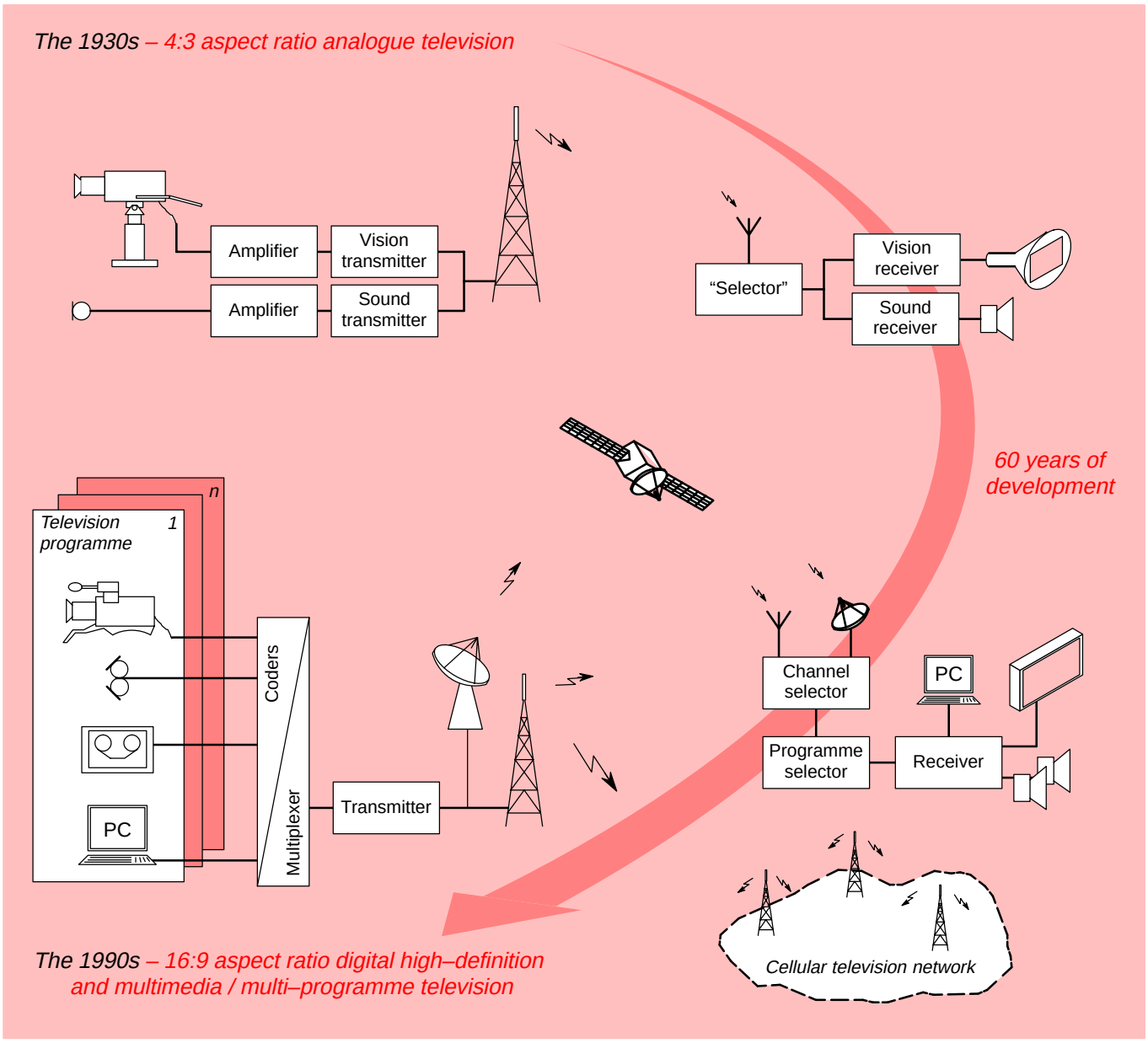
1. Introduction

We have now arrived at a new era in television broadcasting, with many developments arising from work being done on HDTV and digital television systems (see *Fig. 1*).

In addition to conventional television, the broadcasting environment in the coming years may include enhanced definition television (EDTV), analogue and digital HDTV broadcasting by satellite and terrestrial transmitters, as well as digital multi–channel broadcasting by satellite. New television systems that can be accommodated within existing environments will have to be developed; new receivers which are usable in all environments – and are not made redundant as technology changes – will be needed.

With new innovations, it should also be possible for the future television receiver to become a two–way device, using narrow–band digital return channels; low–power transmitters would be provided for the feedback path. Interactive television could be of value not only to broadcasters (in providing instant audience reaction) but also to the operators of other services outside broadcasting, which could have important commercial implications.

Original language: English
Manuscript received 31/3/94.



These ideas are brought together in *Fig. 2* which shows a proposed new concept for the television systems and receivers of the future. The concept provides for additional information possibilities, broader interactive operations and a wider approach to mediametric systems.

As we move towards the standardization of such new systems, the author recommends the adoption of a *Global Approach*. The idea is to try to look at the development of a particular system in the context of the totality of new developments in related areas. After looking at all methods of delivering pictures to the consumer, it is important to design as much compatibility and inter–operability into the system as possible. These systems should be developed in close collaboration with leading international organizations, to achieve harmonisation of television broadcasting interests with numerous non–broadcast television applications.

These considerations in turn introduce new challenges in terms of spectrum management for television broadcasting; i.e. the determination of power levels, interference and sharing criteria, and the protection ratios for terrestrial and satellite systems. These matters, like the system choices mentioned above, all require extensive coordination among the countries involved and between organizations within countries.

Figure 1
60 years of television system development.

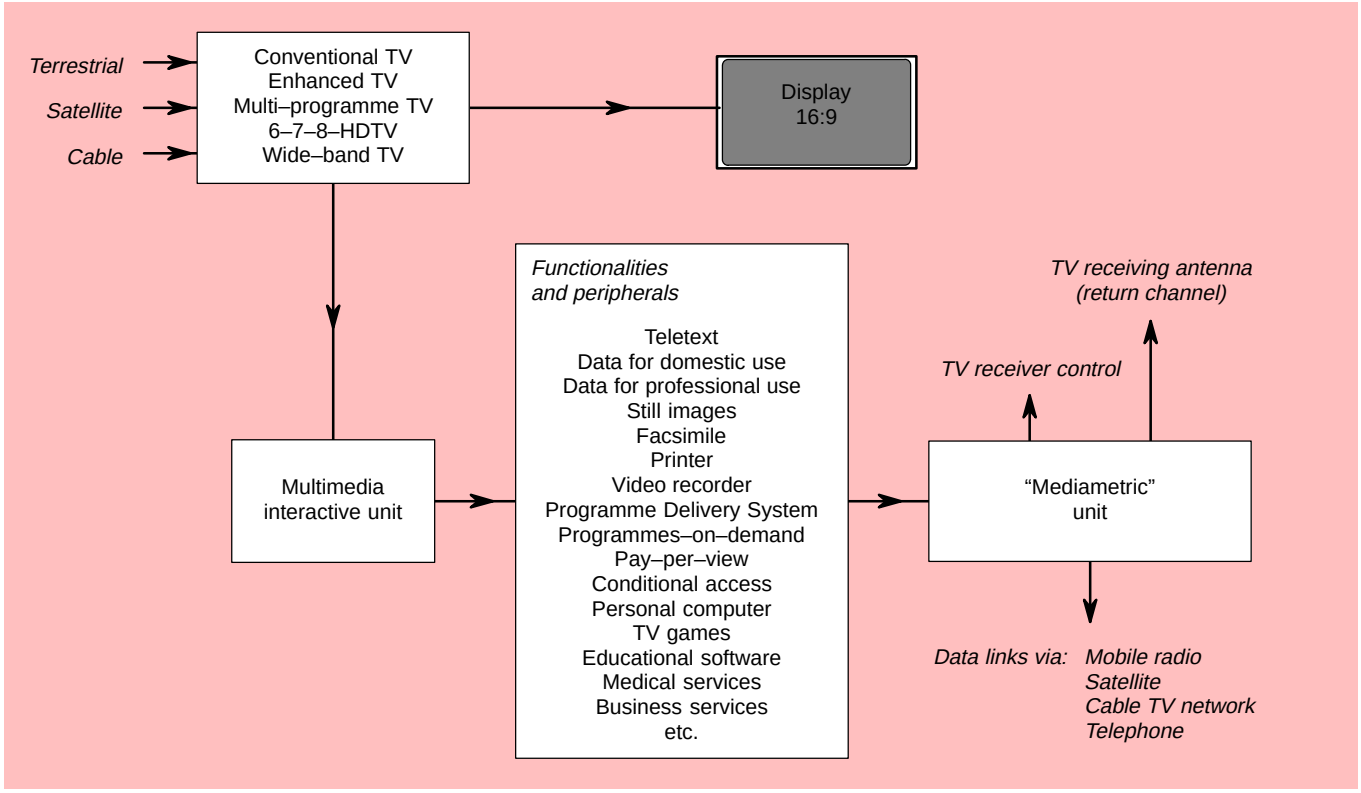


Figure 2
A concept for television systems and receivers of the future, based on the Global Approach.

2. Recent landmarks in television broadcasting

On 25 November 1991, regular programmes started on the Japanese analogue 1125–line HDTV system, 22 years after Japan made its first contributions on HDTV to the International Radio Consultative Committee (CCIR)[1]. Soon afterwards, in February 1992, the European 1250–line HD–MAC standard was used at the Olympic Games in Albertville, France, some 25 years after the start of colour television transmissions in Europe.

On 23 March 1992, in Washington, demonstrations were given of a digital HDTV transmission carried in the same bandwidth as that occupied by a standard NTSC television transmission; this event took place some 40 years after the NTSC colour system had been demonstrated to be compatible with existing monochrome channels.

A little later, on 21 August 1992, a demonstration of the feasibility of multi–programme television (MPTV) was given with the simultaneous transmission of two digitally–compressed NTSC programmes in one conventional channel; the demonstration linked New Jersey in the USA with Moscow via a Russian satellite transponder.

Also in the recent past, standards for the 16:9 aspect ratio and for television colorimetry have been established within the CCIR which will encourage the development of new types of receiver. This will have substantial economic implications since there are nearly 1 000 million television receivers in the world today.

This brief historical review illustrates that today's choices for tomorrow's television systems are a critical matter for viewers worldwide, as well as for broadcasters, telecommunications companies, the television manufacturing industry and national governments.

3. ITU–R Study Group 11

3.1. Rôle and objectives

The International Telecommunication Union (ITU), and the Radiocommunication Sector (ITU–R) in particular, is the most important body for worldwide standardization of broadcasting systems. In as much as this organization establishes the framework for the development of future television broadcasting standards, it will be helpful to understand its structure, objectives and time–scales.

1. Now the ITU Radiocommunication Sector (ITU–R).

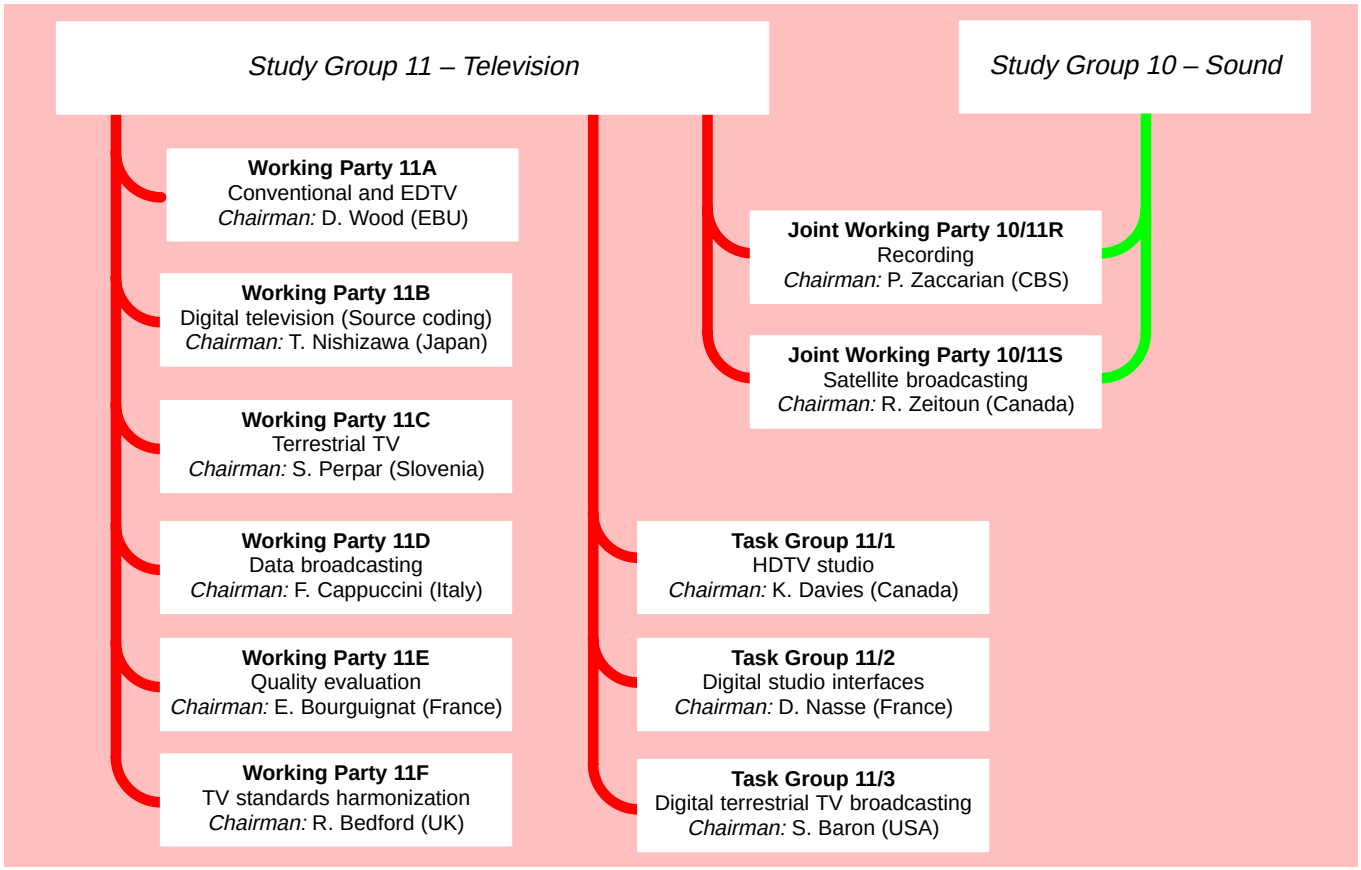


Figure 3
Structure of Study Group 11 of the ITU Radiocommunication Sector.

The first ITU Radiocommunication Assembly (formerly the Plenary Assembly of the CCIR) took place in Geneva from 8 to 16 November, 1993. The Assembly adopted the report *ITU–R, 1993, Doc. 11/1001* covering the period 1990–1993, which had been prepared by ITU–R Study Group 11 (formerly CCIR Study Group 11).

The Radiocommunication Assembly defined the scope of the activities of Study Group 11 (Broadcasting Service – Television) for the next Study Period (1994–1995) and proceeded to elect its Chairman and Vice–Chairman (*box 1*).

1

ITU–R Study Group 11
(Broadcasting Service – Television)
Study Period 1994–1995

Scope:

International exchange of programmes and systems of the broadcasting and broadcasting–satellite services, including video frequency and recording equipment, as well as the overall performance of the means of delivering signals to the general public, when they are for television, data and associated ancillary services.

Chairman:	Prof. Dr. M. Krivocheev, RUS
Vice–Chairmen:	Mr. T. Nishizawa, J
	Mr. Kang Songshi, CHN
	Mr. R. Zeitoun, CAN

Fig. 3 shows the current structure of Study Group 11, showing its Task Groups and Working Parties, as well as its links with Study Group 10 (Broadcasting Service – Sound).

Recently, a Joint Steering Committee Meeting of Study Groups 10 and 11 was held, which included representatives from Broadcasting Unions around the world (see *box 2*).

2

Broadcasting Unions representation at the Joint Steering Committee of ITU–R Study Groups 10 and 11 (February 1994, Geneva)

European Broadcasting Union (EBU)	Mr. David Wood
Asia–Pacific Broadcasting Union (ABU)	Mr. Rukmin Wijemanne
Arab States Broadcasting Union (ASBU)	Mr. Abdelrahim Suleiman
North American National Broadcasters' Association (NANBA)	Mr. Ken Davies
International Association of Broadcasting (IAB)	Ms. Liliana Nakonechnyj
Organización de la Televisión Iberoamericana (OTI)	Mr. Eduardo Gavilan
Conference of World Broadcasting Unions	Mr. Eduardo Gavilan (Chairman, Inter–Union Standing Technical Committee)

.

This was an important step forward for the ITU at a time when technical developments are having a significant impact on the broadcasters. In addition, it enabled links to be forged with several developing countries who were not directly involved with the ITU but were closely associated with the rest of the Broadcasting Unions.

Mr. David Wood (EBU, and Chairman of ITU–R Working Party 11A) was asked to assist a group which will formulate proposals, including the requirements of the regional broadcasting Unions and Associations, for the next Joint Steering Committee, in October 1994.

3.2 Presentation of ITU–R studies

We start the new Study Period, 1994–1995, having published nearly seventy Recommendations and one hundred Questions[2]. From among the multitude of texts produced by the Group, the Author has selected for closer examination in this article just a few of the most important Recommendations and Questions, the adoption of which entailed a great deal of intensive work to overcome sharp differences of opinion before arriving at an international consensus. Besides reflecting the official texts, the Author is also happy to share some of his personal ideas and viewpoints.

We may consider three aspects of the work carried out by the Group:

– work carried out within the various Task Groups and Working Parties;

– the new approaches and strategies that characterize the forthcoming Study Period (1994–95);

– the new challenges awaiting us, as we aim to support broadcasting organizations and manufacturing industry alike in their development of new products and services.

The first two aspects are covered in *Section 4* and the third one in *Section 5*.

In all discussion of present and future television broadcasting, it is important to establish a common understanding of the various expressions used to describe systems and quality levels. The ITU terminology is set out in *box 3*.

2. At the time of drafting this article, a full list of the new reference numbers of Reports, Recommendations and Questions of the ITU Radiocommunication Sector was not available. A simplified form of presentation has therefore been used throughout the article; for example, "Recommendation 470" refers to the text which was formerly "CCIR Recommendation 470" and is now "Recommendation ITU–R BT.470".

Terminology **3**

The terminology used to describe analogue and digital quality levels is described in ITU–R texts as follows:

Analogue television systems

The phrase "Conventional Television Systems" is used extensively in ITU–R texts to signify the analogue PAL, SECAM and NTSC television systems, as defined in Recommendation 470.

Digital television systems

In digital television, the quality achievable at the receiver depends upon the picture source standard, the particular digital coding system and the bit–rate employed.

Quality levels for digital television are defined as follows (doc. 11/174):

HDTV quality, where the potential exists for the delivery of a picture which is subjectively identical with the interlaced HDTV studio standard. Quality shall remain consistent with this for a given proportion of television programme material (where this is a percentage in the high nineties, but is yet to be identified).

EDTV quality, where the potential exists for the delivery of a picture which is subjectively indistinguishable from the 4:2:2 level of Recommendation 601. This quality shall be maintained for a given proportion of television programme material (where this is a percentage in the high nineties, but is yet to be identified).

SDTV quality, where the quality is approximately equivalent to that of current PAL or SECAM. This equivalent quality may be achieved from pictures sourced at the 4:2:2 level of Recommendation 601 and subjected to processing as part of the bit–rate compression. The results should be such that, when judged across a representative sample of programme material, subjective equivalence with PAL and SECAM is achieved.

LDTV quality, where the quality is equivalent to that obtainable with the MPEG–1 system, which operates on a source resolution approximately 1/4 that of the 4:2:2 level of Recommendation 601. This quality is considered by some to resemble that of VHS (albeit over a relatively small proportion of programme material).

Note 1

Documents currently under consideration state that:

– the phrase "conventional definition TV" should be replaced by "standard definition TV";

– the abbreviation "CDTV" should be replaced by the abbreviation "SDTV".

Note 2

NTSC should be added to the definition of SDTV above

4. Current ITU–R studies

This *Section* briefly reviews recent developments within Study Group 11 and, as such, establishes the "starting point" for the work ahead.

4.1. Conventional television systems

Report 624 on Television Systems (for terrestrial broadcasting) has been revised by Working Party 11A and included in Recommendation 470.

In the field of television network planning, the relevant Recommendations have been modified and improved. Recommendation 665 on protection methods has been enlarged. Recommendation 417 on the minimum field strengths used for planning has been extended to take account of boundary areas having low population density. Also, Recommendation 419 on the directivity of television receiving antennas has been enlarged to cover orthogonal polarization uses. These Recommendations, which form the basis for frequency planning, are of extreme importance to countries introducing new terrestrial broadcasting services.

Recommendation 804 "Characteristics of television receivers essential for frequency planning with PAL/SECAM/NTSC television systems" gives the reference receiver parameters and also some important receiving antenna parameters. References are made to documents of the International Electrotechnical Committee (IEC) and the International Special Committee on Radio Interference (CISPR) which define these parameters and give appropriate measuring methods.

Also, current intermediate frequency (IF) values for different television systems are given, enabling planning engineers to calculate protection ratios for some very specific circumstances.

A draft new Recommendation deals with planning methods for 625–line terrestrial television in the VHF/UHF bands, while another new draft describes ghost–cancelling signals. The latter seem to be important for some countries having difficulties with multipath propagation due to specific terrain configurations.

Another important network planning text is contained in new Recommendation 805, which also deals with ghosting; it gives an assessment of the impairment to television reception caused by a single wind turbine generator and defines the methods to be used for assessing the potential interference from such an installation.

In the next Study Period, more information is expected about protection ratios from and to new television systems, including digital systems operating in "simulcast mode".

4.2. Enhanced television systems

The relative quality requirements of high, extended, conventional and low definition television are shown in *Fig. 4.*

Since the development of enhanced television services is likely to be different from country to country – due to various factors such as telecommunications policy, socio–economic impact and industrial development – it is necessary for Study Group 11 to offer the widest choice of options that will assure the desired transition from conventional television to HDTV. In the light of this strategy, a consolidation of new enhanced systems is expected in the forthcoming Study Period. Advanced tests and de-

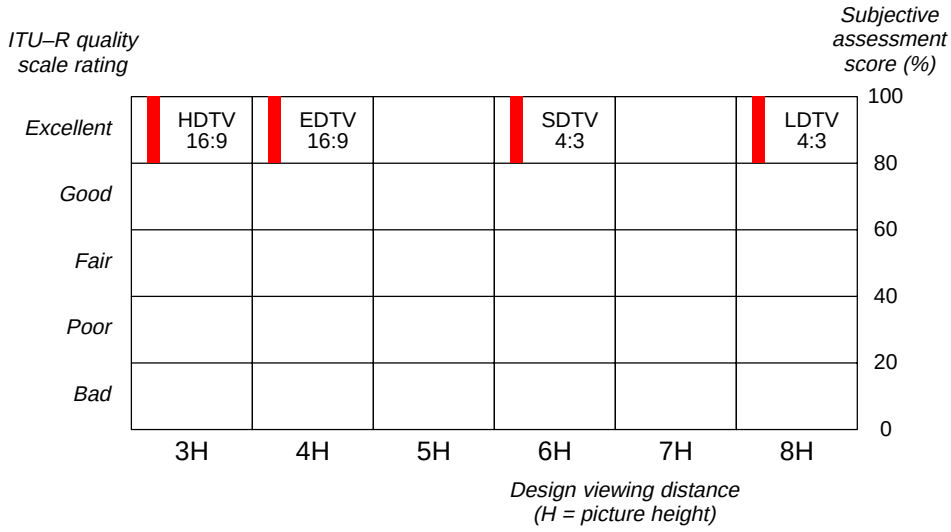


Figure 4
Relative quality windows of HDTV, EDTV, SDTV and LDTV.

velopments have already been reported on enhanced NTSC and PAL systems.

Working Party 11A has prepared a draft new Recommendation on widescreen signalling, which has been submitted to Study Group 11 for approval. It has also prepared a draft new Recommendation "Enhanced compatible widescreen TV, based on conventional TV systems", intended to cover all enhanced widescreen television systems. This draft Recommendation suggests common features of all systems, 525–line and 625–line, and gives some details of the modules to be used for enhanced systems. It should be the key document for enhanced widescreen television, and it may be possible, in about one year from now, to expand the annexes to this Recommendation with significantly more information.

One of the most immediate subjects for study is surely represented by the impact of new receivers in 16:9 aspect ratio, already mentioned in Recommendation 709. Study Group 11 will be formulating proposals on a coordinated international approach to the implementation of the 16:9 format in its various aspects; broadcast transmission, television receivers, video recorders, optical discs, programme exchange, etc. Widescreen television receivers also open the door for the introduction of new electronic still picture photography, in 16:9 format (*Question 201/11*).

A Recommendation on the use of 16:9 letterbox systems should be completed during 1994, based on input material from Japan and Germany. A key unresolved issue concerns the number of active samples per line to be used in widescreen SDTV systems and the groups have been asked to look at this issue. It is also hoped to have proposals for a system to carry component signals transparently through a composite environment. A group drawn from several Working Parties will look at the specification of sound/vision delay. A handbook on enhanced systems is in preparation. Two internal reports, covering alternative broadcasting strategies and the transition from SECAM to PAL, are thought to be of interest to developing countries and therefore worthy of a wider distribution.

4.3. Digital television

The digital TV studio production standards adopted by Study Group 11 already represent a major step forward to meet the needs of different countries. The majority of new studio equipment is based on digital techniques and the availability of reference ITU–R standards will surely help in achieving economic performance and quality.

Modifications were made by Working Party 11B to Recommendation 601 to include the 4:4:4 member of the coding family. It is required in complex processing where additional resolution is needed, for example in high–quality chromakey operations.

Recommendation 656 on studio interfaces for the 4:2:2 level now incorporates recent and widely–accepted developments in serial interfaces and in ancillary signals (Task Group 11/2). It is followed by a new Recommendation specifying parallel and serial interfaces for the 4:4:4: level.

Four draft new Recommendations and two draft revisions of existing Recommendations have been prepared. Among them are two required to be used as a basis for the testing of codecs based on Recommendation 721: "User requirements for the transmission, through contribution and primary distribution networks, of digital television signals defined according to Recommendation 601", and Recommendation 723: "Test pictures and sequences for subjective assessments of digital codecs conveying signals produced according to Recommendation 601".

These new Recommendations, in conjunction with one on the avoidance of interference, are important documents that should assist engineers involved in the design, installation and operation of digital TV systems.

The definition of the users' requirements in the digital coding domain represents a reference for any further development of video coding techniques. In this context, the activities carried out by our Ad–Hoc Group on digital coding, in conjunction with the ISO/IEC Moving Pictures Expert Group (MPEG), should be considered as one of the highest priorities.

One of the important future tasks is the completion of the following draft new Recommendations concerning generic coding techniques:

– Generic bit–rate reduction coding of digital TV signals (CDTV, EDTV and HDTV) for contribution, primary and secondary distribution, transmission (terrestrially and by satellite), and related applications;

– Standards for generic bit–rate reduction coding systems;

– Evaluation methods for bit–rate reduction codecs for CDTV, EDTV and HDTV signals to be used for various parts of the broadcasting chain.

In addition to the above draft new Recommendations, the following two draft new Questions have been produced on generic bit–rate reduction coding and digital broadcasting:

– Application of new concepts in digital television encoding;

– Acquisition and recovery times in digital television encoding.

4.4. Data broadcasting

A revision of Recommendation 653 on teletext systems was approved. This Recommendation is a unique encyclopaedia of world teletext systems.

Advances are expected in the provision of teletext services along with digital television systems, multi–programme television (MPTV) and in an HDTV environment. In view of the large coverage areas of television stations, new possibilities open up for the broadcaster to provide considerably larger streams of various types of digital information, in the most speedy and cost–effective way, to both the public and the business user. It is thus possible to envisage a new concept for the transmitting of large volumes of data in a television channel, which can be accessed and printed on demand using interactive methods within a conditional access system (ITU–R, 1993, Doc 11/1001, Section 10.3).

The adoption of the 16:9 format will have an impact on teletext and other data broadcasting services and will be reflected in a number of forthcoming Recommendations.

In connection with studies on the transmission of still images, a new concept for portable radios has been suggested – the addition of a small video display with memory which could be used for pictures, data and other video information. Other applications of teletext, in conjunction with the broadcasting of still–image services, are foreseen in a more integrated broadcasting–computer digital environment.

Working Party 11D has prepared Recommendations on the following data broadcasting topics:

– A Programme Delivery Control (PDC) system for video recording at home. It will allow viewers to programme accurately their VCR to record any selected programme, by means of data signals inserted in the vertical blanking interval (VBI). This Recommendation should be of interest to the consumer equipment sector, worldwide.

– Conditional access broadcasting systems. This Recommendation covers the fundamental principles of conditional access systems, which are important for the new forms of programme delivery.

– The broadcasting of time and date information in coded form. The draft Recommendation establishes that all coded broadcast time and date signals should be expressed in accordance with Recommendations 457 and 460.

4.5. HDTV

4.5.1. Basic parameters

At the XVIth Plenary Assembly of the CCIR (Dubrovnik, 1986), the Author proposed a *global approach* to HDTV. The model takes into account the different broadcasting interests, the many possible uses of HDTV and the necessity for harmonisation between broadcasting and non–broadcasting applications (Doc 11/164; Doc 11/173; Period 1986–1990).

As the first step in this direction, Recommendation 709: “Basic parameter values for the HDTV standard for the studio and for international programme exchange” was developed. It gave for the first time many of the basic parameters for the HDTV standard. In particular, it fixed a wide aspect ratio (16:9), colorimetric parameters, luminance characteristics and bit–rates for interlaced and progressive scanning, etc. A supplement to this Recommendation is planned, detailing a number of new picture characteristics and scanning parameters.

Recent developments in several countries (and within the MPEG) indicate that it may be possible in the near future to agree on all the outstanding parameter values in Recommendation 709, possibly in 1995. A Recommendation on the digital HDTV standard, prepared by Task Group 11/1, would need to be harmonised with those used in other media, notably in computer applications; this might also be agreed in 1995. A draft Recommendation on the bit–rate reduction method to be used for interconnections in HDTV studios would naturally follow, probably in 1995 as well.

4.5.2. *Wide–band HDTV*

The function of the wide–band HDTV (WB–HDTV) interface is to provide "transparent" HDTV transmissions (Joint Working Party 10–11S, Recommendation 788). A standard 140 Mbit/s (or lower) digital channel may be used to provide for the simultaneous transmission of video signals with sound, error protection and other signals.

The wide–band HDTV system, designed to display video information on large wide–format screens, may be of interest in many fields of human activity. Large screens carrying high–quality pictures would most certainly find a use in large public places, such as airports and railway stations, to display both operational and commercial (advertising) information. Probably, such a system could also find wide applications in the field of education, and at public gatherings such as conventions, concerts, exhibitions, etc.

4.5.3. *Narrow–band HDTV*

Along with these WB–HDTV studies, current progress in bit–rate reduction techniques and new types of modulation are having an impact on the development of new broadcast systems. From the standpoint of maintaining existing terrestrial networks and frequency plans, the requirements of the narrow–band HDTV (NB–HDTV) interface are determined by the nominal channel bandwidths adopted in different countries. This leads to the so–called *HDTV 6–7–8* concept. (The same concept is also being applied currently to enhanced television, as the so–called *ETV 6–7–8* concept.)

Presently, there are three standard television channel bandwidths:

– 6.0 MHz, as used by systems M, N (NTSC, PAL);

– 7.0 MHz, as used by system B (PAL, SECAM);

– 8.0 MHz, as used by systems G, H, I, D, K, K1, L (SECAM, PAL).

The difference between the bandwidths of 6, 7 and 8 MHz channels might in principle give rise to the development of three HDTV 6–7–8 systems, each fully using the bandwidth of its respective channel, i.e. HDTV–6, HDTV–7 and HDTV–8. It is therefore desirable that the HDTV testing centres in different countries include comprehensive tests of HDTV 6–7–8 systems in their work programmes and submit their results to Study Group 11 for international discussion.

These tests might assess whether sufficiently high picture quality can be provided by the narrower–band systems and whether a 1– or 2–MHz increment in the bandwidth for domestic reception is a critical factor. This evaluation might assist in the adoption of worldwide standards.

The first answer to this – consolidated in the approval of the first Recommendation on digital terrestrial TV – represents a milestone in the activities of the ITU–R. In effect, Recommendation 798 is fully in line with a global approach to HDTV and responds to the demands of administrations (especially of developing countries) to continue to use their existing or planned television and cable networks to broadcast future HDTV services.

When, some years ago, the Author proposed the HDTV 6–7–8 concept, several experts considered it to be a fantasy. However, the recent demonstrations of digital television in Alexandria by the HD–DIVINE consortium, and by others in Europe, show that narrow–band transmission of digital HDTV in 6, 7 and 8 MHz channels is not a fantasy but a reality.

However, time is limited and therefore Study Group 11 should actively respond before Regions adopt their own standards, which would hinder this common feature.

4.6. *Multi–programme digital television (MPTV)*

The digital television systems presently being examined by Study Group 11 offer significant improvements over conventional television in many respects, such as wide screens, increased resolution, cross–colour elimination, etc. In the years to come, these design goals will match the rising expectations of the viewer by a generalised use of digital techniques in both the programme generation area and in the user's equipment (receivers, video recorders, etc). However the time–scale that might be adopted for the implemention of new digital television systems may vary from country to country according to specific requirements and therefore different approaches might need to be considered.

One of these possibilities is represented by multi–programme digital television (MPTV). Based on the HDTV 6–7–8 methodology, an *MPTV 6–7–8* concept has been proposed by the Author and is currently being considered in various countries for delivery to the public. Instead of transmitting *single* conventional, enhanced or high–definition programmes over a standard satellite, terrestrial or cable link, the *MPTV 6–7–8* concept delivers a cer-

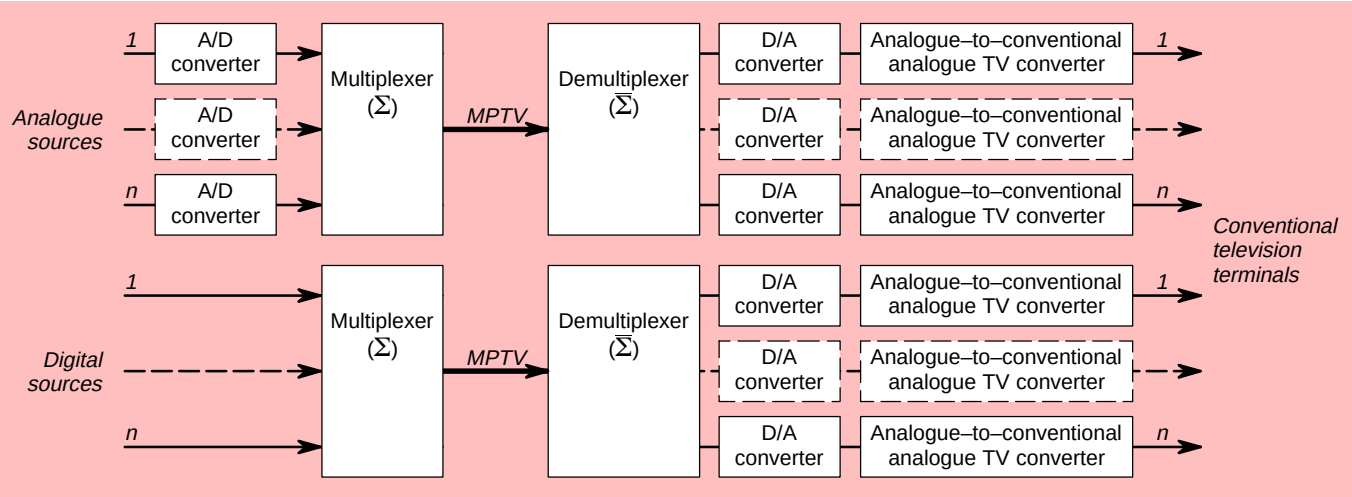


Figure 5
Analogue and digital multiplexing in the MPTV concept.

tain *number* (N) of conventional digitally–compressed television programmes over that link (see *Fig. 5*):

$$\sum_{1}^{N}(conv.TV) \rightarrow MPTV \rightarrow N_x(conv.TV)$$

MPTV can be achieved in a variety of ways, eg:

– *N* compressed television programmes transmitted on *N* carriers;

– *N* television programmes multiplexed together and transmitted on a single carrier.

These digitally–compressed television signals will be accompanied by digital high–quality sound, coded conditional access information, and ancillary data channels.

Since the development of these systems would be beneficial to the end–user only if it is carried out in an orderly international context where appropriate standards can be set, Study Group 11 should be in a position to respond promptly to this need by preparing new Questions on the subject. It is particularly necessary to formulate the requirements of the complete channel (the scalable picture and

Draft New Report **4**

Work towards a Recommendation on multi–programme television broadcasting by satellite

(Draft new Question [Doc. 10–11S/TEMP/67(Rev. 1)])

1. Introduction

In response to Question [10–11S/TEMP/67(Rev. 1)], this Report provides preliminary information towards the development of a Recommendation on multi–programme television broadcasting by satellite. A draft of a possible new Recommendation is given in Annex 2, the considerations of which are of interest to this Report. Preliminary studies on this topic are summarised below.

2. Multiplexing techniques

There are several multiplexing techniques available for accommodating multiple television programmes within a single transponder. Three of these techniques are discussed below: time division multiplexing (TDM) and two forms of frequency division multiplexing (FDM).

In the case of TDM, the TV programmes are time multiplexed on a single carrier, while in the case of FDM, 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 and 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 carrier/noise (C/N) penalty of the FDM approach is relevant. For example, the FDM approach requires additional C/N ratios of 2.3 dB (two carriers per transponder) and 5.8 dB (four carriers), with respect to TDM, for an equal total bit–rate of 34 Mbit/s.

Within FDM, orthogonal frequency division multiplex (OFDM) modulation – both for digital terrestrial television systems and for satellite channels – potentially would allow the achievement of maximum commonality for digital emissions on the various media (terrestrial, cable, satellite). However, in light of investigations [1] and Doc. 10–11S/136, it can be concluded that this modulation technique does not seem to provide the best exploitation of the satellite power resources, because of its high sensitivity to non–linear distortions in the travelling wave tube amplifier (TWTA). It should be noted that these preliminary conclusions apply to fixed reception only, with directional antennas, for which multipath propagation and selective fadings are not expected. In the case of portable or mobile reception (such as for the case of digital audio broadcasting by satellite), the advantages of OFDM in terms of selective fading margins could largely compensate for the losses due to the sensitivity to non–linear TWTA distortions.

[1] Cominetti, M., Morello, A. and Visintin, M. – “Digital multi–programme TV and HDTV by satellite”, EBU Tech. Review No.256, Summer 1993.

sound quality) as a function of the occupied percentage of a single standard channel bandwidth. It is also important to develop standards for the various portions of the channel used to transmit digital MPTV signals.

During the meeting of Joint Working Party 10/11S in October 1993, a statement from the European Broadcasting Union (Doc. 10–11S/147) was presented, entitled "Digital multi–programme TV broadcasting within a satellite transponder". The statement referred to a Memorandum of Understanding for the development of harmonised digital video broadcasting (DVB) services in Europe. It also indicated that the EBU intends to submit to the ITU–R a draft new Recommendation on digital multiprogramme television broadcasting by satellite on a worldwide basis. This will be an important step towards the establishment of *integrated services digital broadcasting* (ISDB) which is intended in the longer term to provide the user with a multimedia service through a combination of broadcasting facilities, telecommunications and computer systems. The draft new Report on this matter is reproduced in *box 4*, and the corresponding draft new Recommendation in *box 5*.

Finally, on this topic, MPTV also opens up new possibilities for multi–programme cinema television.

4.7. Interactive television

A further area to be studied is the development of interactive television systems which, by means of telephone lines, cable or a small digital transmitter built into the television receiver, would enable viewers and users of large volumes of digital television data to transmit different types of information back to the corresponding collection and processing centres.

Interactive broadcasting computer systems constitute a new field of study (see *Fig. 2*). Their development will be facilitated by MPTV systems,

Preliminary draft new Recommendation **5**

On digital multi–programme television broadcasting by satellite

(Question 10–11S/TEMP/67(Rev.1))

[The ITU Radiocommunication Assembly],

considering

a) that digital emissions of multi–programme TV signals are technically possible owing to the advances in video compression techniques (a data rate from 40 Mbit/s to about 60 Mbit/s can, for example, be accommodated in a 27 MHz wide channel);

b) that digital emissions may require less protection against interference than analogue emissions and thus, by virtue of this technique, spectrum efficiency may be improved;

c) that the digital multiplex can provide greater flexibility as to what concerns the number of programmes and the total data rate associated with each programme contained in the same multiplex;

d) that digital compression techniques for the sound allows the transmission of CD–quality multichannel sound for multilanguage and for surround sound application with relatively low data rates (typically 100 kbit/s per monophonic sound),

considering further

e) that multi–programme satellite broadcasting services are currently planned and will begin operation by 1994 in the United States and 1995 in Europe;

f) that the ITU has been studying integrated services digital broadcasting (ISDB) for many years;

g) that the ISO/IEC is currently standardizing vision and sound compression as well as multiplexing techniques for multiprogramme television and sound transmissions (ISO/IEC JTC 1/SC 29 MPEG–2 family);

h) that for the purpose of standardization of multiprogramme satellite broadcasting and cable distribution in Europe, a memorandum of understanding has been signed by more than a hundred entities (manufacturers, broadcasters, operators and research centres) and that a draft European Telecommunications Standard will be ready for public enquiry in early 1994,

Noting – that the interest of the general public will best be served by a development of an open system which could allow receiver technology to be used throughout the world.

[unanimously] recommends

1. that the multiplex should be flexible enough to allow, in compatible form, the association of all or of part of the available data rate to one or several broadcasting services sharing the same multiplex;

2. that all types of broadcasting (television, sound radio, data services) could be accommodated by the emission system;

3. that the system to be used should conform with the system described in the attached annex.

(*Annex* to be developed)

which substantially increase the number of programmes provided. The viewer could order these computer services by telephone, or via satellite or mobile radio communication systems of the future, and receive them as "real–time" broadcasts or as recordings down–loaded from a video library ("videotheque").

Last year, the Author proposed the study of a new global approach to interactive systems using over–air circuits from the viewer's receiver (transmitted, in many cases, using the existing receiving antenna) to transmit various signals back to the computer centre (ITU–R 1993, Doc. 11/1001, Section 10.6). Such approaches would also facilitate the development of so–called *mediametric services*, including commercial and audience research systems to collect and process information about the television programmes being received, viewers' assessments of programme quality, etc.

Following this proposal, Working Party 11C prepared a draft new Question on "Interactive TV broadcasting systems": Doc. 11/216 Rev. 2 (see *box 6*). It is envisaged that broadcasting systems will also be used for other purposes, so it seems to be of great advantage to incorporate the broadcasting receiver into interactive systems. For such purposes, the return channel seems to be an important part of the system; good isolation would be required between the received and transmitted signals and, therefore, good frequency separation would be needed. With the development of such interactive systems on one side, and modern communication technologies on the other (including cellular digital radio communication, low earth orbit satellite (LEOS) links, etc.) a common technical approach could be feasible.

Even if the viewers who have access to the one billion television receivers in the world are slow to embrace these new developments, and even if television data users only gradually begin to "plug into" interactive systems, there will nonetheless be sufficiently rapid growth of demand to justify new studies on the establishment and effective operation of hundreds of thousands of narrow–band digital return channels.

It is therefore reasonable to suggest that this new, major and specific load should already have been taken into account at the present stage in the development of future public land–mobile telecommunications systems (FPLMTS). Given the need to

6

Draft New Question [Doc. 11/216, rev. 2]

Interactive Television Broadcasting Systems*

The ITU Radiocommunication Assembly,

considering

a) the progress in information processing and transmission technologies;

b) the rapid progress towards enhanced and digital television delivery systems using terrestrial, cable, satellite and network channels;

c) the need within such systems for interactivity for a variety of purposes;

d) the development of transmission methods suitable for use in receiving from viewers information related to the programme material (vision, sound and data);

e) the large number of domestic receivers likely to be impacted by the adoption of interactive services,

decides that the following Questions should be studied

1. What are the possible channels to return data from the receiver to the broadcaster and other users of such data for different reception media (e.g. cable, common antenna, terrestrial or satellite reception)?
2. What interactive services are likely to be needed and what are the requirements for the return data channel?
3. What are the appropriate management methods and modulation/transmission techniques for such channels?
4. For the systems using radio–reception, what allocated frequencies may be best suited and what are the planning objectives for such return channels?
5. What possibilities exist for the harmonious use of other data communications channels (e.g. switched network, personal communication service (PCS), LEOS etc) to provide the return channel for interactive broadcasting?**

---

* This Question should be brought to the attention of the IEC, the ISO and the Telecommunication Standardization Bureau of the ITU.

** See also Recommendation ITU–R M.687 and Recommendations ITU–T S 750, 751, 770 and 771.

integrate such terrestrial and satellite systems, it will be necessary to consider ways in which the relevant satellite systems currently under development (eg: LEOS) can be designed to cope with the large information volumes.

This new draft Question dealing with interactive television systems is considered to be of interest to developing countries. The television receiver will be connected over return channels to various information centres such that it may be used for a wide variety of applications which will emerge in the future. In this way, television receivers will become one of the most important telecommunication elements with which to communicate to and from the viewer's home.

Broadcasters and programme providers should see interactive television as a challenge and opportunity. The challenge will be to create programme material in an imaginative way for an interactive environment. The opportunity will be that of sharing in this important new service.

Document 11/216, rev. 2 (see *box 6*) is also being drawn to the attention of ITU–R Study Groups 8 and 9, concerned with radio mobile services and fixed services, respectively. After approval by correspondence, the new Question will be directed to Working Party 11C. A review of the subject as seen by broadcasters, information services and other commercial interests is already in preparation. The EBU and the administrations of Canada, France, Germany, the United Kingdom and the USA have indicated that they would wish to contribute to these studies; others will be welcome. For its part, Study Group 9 has prepared a further Question dealing with interactive television in relation to secondary distribution networks; the two Working Parties will send their Questions to one another for information.

It should be borne in mind that the return channel could well be of benefit to other agencies besides the broadcasters, and the attention of ITU–T Study Group 9 will also need to be drawn to this work. A study of ITU–T Recommendations 750, 751, 771, 707 and Annex 1 to Recommendation M.687 would be worthwhile in this context.

4.8. Video recording

Programme exchange is a major area of concern, including the question of formats to be used for video recorders and telecines. Joint Working Party 10/11R will continue to monitor technological progress on tape recording formats, video discs, memory and storage devices, and the use of film for "conventional" television applications. Where necessary, the existing Recommendations on these subjects will be updated or new ones developed.

In spite of the existence of Recommendation 657, one objective that still eludes all efforts is the standardization of a *single* tape recording format for the international exchange of conventional television programmes; efforts will need to be spent to identify and specify such a format (which will certainly be a digital one).

A new item of work, which is quite high in priority, is the specification of a universal system for machine–readable identification codes for sound and television recordings (and for film in television). This will be a further development of work already done some while ago but will take into account the computerised environment in which broadcasters now work.

Methods of recording widescreen 525/625–line programmes for international exchange will need to be studied with a view to the establishment of Recommendations. The conclusion might be confirmation that the system specified in Recommendation 657 is suitable for this purpose. In addition, the possibility of endorsing the use of Super–16 film for the international exchange of widescreen programmes will be investigated.

As soon as a draft Recommendation on the HDTV standard (or standards) to be used in the studio has been issued, consideration will have to be given to a recommendation on a recording format (or formats) for the exchange of HDTV programmes.

The advent of other new digital television systems, including HDTV, EDTV, LDTV widescreen television etc, coupled with the use of digital compression in video recordings, calls for a number of further studies in this field. In particular, they would be addressed at the evaluation and standardization of signal parameters at the recorder output and the digital programme storage devices which might be used.

4.9. TV measurements

All new technologies depend on quality assessment for the process of system selection. This will be important particularly in the current Study Period when several new systems will be selected for adoption. It has been observed that the establishment of monitoring techniques and appropriate devices must precede the implementation of new television system. By the time such systems are brought into service, a usable measurement database should be available.

New measuring signals, and methods for processing them, will be required to measure existing 6–, 7– and 8–MHz channels and their ability to accommodate the planned transmission of signals for enhanced television systems such as HDTV 6–7–8 and MPTV 6–7–8. Such signals will also contain analogue/digital or fully–digital picture information, digital sound and additional information signals, test signals and other types of signals.

The subjective assessment of digital television systems requires a somewhat different methodology; the picture content failure characteristics, and the probability of occurrence, play a very important part. Channel monitoring in the transmission of digital television signals with scalable picture quality will require new approaches to digital "test line" technology, weighting functions and the basic design of quality meters. It requires a new family of television measuring devices, based on the statistical processing of a large number of picture image files and on the development of optimised algorithms for their processing.

5. The way forward for digital television

5.1. Common standards

Scientists from all the world regions are actively investigating the technologies involved in digital television broadcasting. At this point in time, however, no major services are in operation. Therefore, the opportunity still exists to provide the global community with a set of Recommendations that will maximise the probability of arriving at a common standard. *Part 1* of the *Bibliography* gives a list of important draft new Recommendations relevant to this topic.

Digital television systems will be built up of many sub–elements. To make the issue of commonality more manageable, it may be helpful to consider, for each sub–element:

– how important it is to have worldwide agreement;

– how difficult this might be to achieve.

In this way, the process could commence with common standards, by concentrating on those elements which offer the best combination of priority and ease of agreement. The remaining standardization measures could then be pursued, step by step.

To develop a means of identifying the best opportunities for a common approach, a document "Prospects for a common worldwide digital terrestrial TV system" has been produced by Task Group 11/3. It discusses the process which may lead to the establishment of a common standard by concentrating on those elements which offer the best combination of priority and ease of agreement.

It is certainly a simplification, but two major dimensions of commonality should be considered:

– the *international* dimension, which relates to the use of the same systems in different regions of the world;

– the *application* dimension, concerned with the use of the same systems by different bearers, eg: terrestrial, satellite, cable, B–ISDN, etc.

Simplifying again, the digital system could be considered as being formed by the following sub–elements:

– modulation system;

– channel coding system;

– multiplexing system;

– baseband sound system;

– baseband data coding.

The future work of Study Group 11 on digital terrestrial television broadcasting will extend the work performed to date in achieving a set of consistent Recommendations and standards in the four areas of interest:

– source coding and compression;

– service multiplex and transport layer;

– modulation and the physical layer;

– planning factors and implementation strategies.

A new Question 205/11: "Parameters for integrated services digital broadcasting (ISDB)" has been prepared by Working Party 11D on this topic.

Task Group 11/3 has produced two draft Recommendations on the criteria required for planning digital terrestrial television services, and on the basic objectives for the planning and implementation of services. These may be considered as a starting point for setting up new regional radio conferences to plan the future terrestrial television broadcasting networks.

5.2 Alternative strategies for terrestrial broadcasting

A critical question which television broadcasters have to answer relates to the choice of future strategy in broadcasting systems. As both the technological possibilities and the expectations of viewers increase, broadcasters will be confronted with several alternative strategies or scenarios on which to base their future services.

At first sight, it appears that the options available could probably be classified in two groups:

– compatible analogue widescreen extensions of the current composite television systems;

– digital (and therefore non–compatible) HDTV or conventional systems.

The reality is rather more complex, largely because in some circumstances not all the options will be open and also because the issue of where HDTV stops and starts in quality terms can be difficult to quantify.

It is always acknowledged that the success of the new system will be linked to a multi–dimensional set of factors, which include the quality increment provided, the range and quality of the programmes available, and the economic climate. With so many variables, the establishment of a meaningful model of the probable success of the system is very difficult. Nevertheless, it is necessary to begin somewhere ...

Accordingly, Study Group 11 has begun a discussion of the advantages and disadvantages of the alternative routes forward for terrestrial television, and hopes that this will provide some food for thought and helpful indications (Doc. 11A/TEMP/17(Rev. 1)–E, October 1993).

To illustrate the spectrum of opinion involved in these discussions, four preliminary scenarios have been identified as described in *box 7*. It should be noted that the points made in describing the scenarios have been selected to represent a forthright statement of all the possible arguments in favour of the scenario, without attempting to achieve a balanced point of view.

In the light of such a diversity of scenarios, some technical analysis will be helpful before seeking to choose the best route forward for terrestrial broadcasting in any particular socio–economic and technological environment. Four factors merit particular attention:

– The extent to which it will be technically possible to provide the required coverage with digital systems, and with what quality, while analogue systems are still being broadcast. The importance of portable reception, and how it might be improved by using digital systems, also needs to be considered.

– An appraisal of the relative costs of providing a service in HDTV compared to providing a service in a widescreen format and the revenue sources that would be available to offset the costs.

– The degree of deterrence caused by the letterbox format for viewers with 4:3 receivers.

– The extent to which a widescreen receiver designed for an enhanced composite service can be adapted easily to receive a digital service, or vice versa.

Even with this information, the choice will not be a simple one. In the short term, it may be most prudent to pursue standardization of both enhanced and digital systems, so that the best strategic decisions can be made at the time financial resources allow the extension of services.

5.3. Global approach to the digital television chain

The complex interaction among all the components of the digital broadcasting chain should be kept in mind when specifying the characteristics and performance of any section. This implies that a *global approach* to digital systems should be envisaged (ITU–R 1993, Doc 11/1001, Section 10.7).

It is proposed that a definition should be established for the characteristics of a unique digital broadcasting space – from the source to the end user's screen; a space where the specific sections could be optimised not only individually but also within the overall system characteristics (scalable picture quality via a variable process of coding–decoding; adaptation of the system to suit various transmission and reception conditions, etc).

The interests of society would best be served by developing flexible and reconfigurable digital satellite systems which allow the broadcasting of a range of picture qualities and bit–rates and different degrees of robustness. This should be considered particularly for new services operating in the recently–agreed spectrum around 20 GHz and may also be valuable for digital services operating in the 12 GHz band. Hence, we should study new concepts of digital television systems which might

7

Provisional scenarios envisaged for the introduction of digital terrestrial television broadcasting.

Scenario 1: Unique use of digital systems

1.1 There is no room in the terrestrial television market for different standards, and a plurality of standards is not in the public interest.

1.2 The introduction of digital systems is inevitable, sooner or later, and analogue systems can only be an interim solution. In the long run, the cheapest solution is to avoid interim standards, and the most efficient approach is to go straight to digital without passing enhanced analogue systems.

1.3 Digital technology is superior, in the sense that it will give clearer picturers with lower signal strengths.

1.4 The use of helper signal systems and letterbox transmission will never be possible for countries who use the black bands for subtitles.

Scenario 2: Use of both enhanced composite systems and digital terrestrial systems

2.1 Digital terrestrial HDTV is really many years away, and there is a significant window of opportunity for analogue widescreen systems before then. This is because of the time it will take to develop the digital system, due to today's limited display technology, and because it will take time to convert production to full HDTV.

2.2 With today's affordable and practical displays, the public will not be able to tell the difference between enhanced analogue quality and HDTV. It will be a few years until the quality benefits of digital HDTV are apparent. In any event, for feature films, which are the most important programme material in terms of audience size, it is nearly impossible to tell EDTV from HDTV.

2.3 Even if digital services providing less than HDTV quality are introduced quickly, the existing analogue transmission systems will continue to have a long life and they will need to be upgraded to provide enhanced quality on widescreen receivers.

2.4 Getting the public and broadcasters accustomed to widescreen services (whether delivered by enhanced composite or digital means, or both) will serve well the subsequent introduction of digital HDTV.

Scenario 3: Use only enhanced systems on terrestrial networks (and possibly use digital systems only for satellite and cable)

3.1 There is no room in the terrestrial market for several standards, and a plurality of standards is not in the public interest.

3.2 Planning difficulties will make complete digital terrestrial coverage, especially with HDTV, impossible for most of Europe. Public broadcasting is founded on universal availability. It will never be possible to switch off the analogue composite broadcasts. Analogue broadcasts will always be needed and, to compete, will need to be widescreen.

3.3 All that the public wants, in terms of HDTV quality or multichannel programme choice (in addition to the terrestrial networks), will be provided by digital services on satellite or cable. Portable reception of terrestrial television is already adequate with existing analogue systems. There is therefore no need to introduce digital TV terrestrially. Furthermore, satellite systems will provide digital coverage for new services at much less cost than installing thousands of new digital terrestrial transmitters.

3.4 Enhanced composite systems will provide all the public may want or be able to appreciate from terrestrial television, for very many years to come. There is no evidence that the public can distinguish EDTV from HDTV, particularly for feature films which are one of the most audience–attractive types of programme.

3.5 The expense of introducing digital HDTV terrestrially will not be justified by the revenue received. EDTV will be much less expensive for the broadcaster.

Scenario 4: Retain existing 4:3 systems on terrestrial services (and possibly use digital systems only for satellite and cable)

4.1 There is no room in the terrestrial market for several standards, and a plurality of standards is not in the public interest.

4.2 Planning difficulties will make complete digital terrestrial coverage, especially with HDTV, impossible for most of Europe. Public broadcasting is founded on universal availability. It will never be possible to switch off the analogue composite broadcasts. Analogue broadcasts will be needed for a long while to come.

4.3 All that the public wants, in terms of HDTV quality or multichannel programme choice (in addition to the terrestrial networks), will be provided by digital services on satellite or cable. Portable reception of terrestrial television is already adequate with existing analogue systems. There is therefore no need to introduce digital TV terrestrially. Furthermore, satellite systems will provide digital coverage for new services at much less cost than installing thousands of new digital terrestrial transmitters.

4.4 Broadcasts in letterbox format would be foolish, because they will inevitably be annoying to 4:3 viewers who will form the majority for many years at least.

4.5 Analogue widescreen broadcasts will always be a difficult compromise for production, because the same picture needs to be received on sets with limited resolution and small screen size.

cover the range of requirements from transparent WB–HDTV for large screens, to MPTV systems – and even extending to individual reception of a single conventional television programme!

There will be a need to study optimal distribution of terrestrial digital television and radio programmes, cellular networks, their interrelation with branched networks created for mobile radio communication services, and so on. All this points to the possibility of studying a new concept for dovetailing and harmonising terrestrial and satellite networks intended for digital television (DTV) broadcasting and digital audio broadcasting (DAB), as well as other related networks (ITU–R 1993, Doc 11/1001, Section 10.10).

5.4 Satellite broadcasting

5.4.1. Background

At the 1977 World Administrative Radio Conference (WARC–77), a frequency Plan was established by the ITU which regulates the use of broadcasting satellite services (BSS) in the frequency bands 11.7–12.5 GHz (Region 1) and 11.7–12.2 GHz (Region 3). With a few exceptions, the Plan assigned five channels to each country, based on frequency modulation of the analogue television systems PAL, SECAM and NTSC, and one FM sound sub–carrier. In accordance with Appendix 30 of the Radio Regulations, modulation systems with other characteristics are not precluded "provided that the use of such characteristics does not cause greater interference than that caused by the system considered in the appropriate Regional Plan".

Since 1977, new advanced analogue television standards have been developed, such as:

– the MAC/packet family with its compatible evolution towards HDTV through the HD–MAC standard;

– the MUSE system.

Both of these systems allow a widescreen format (16:9) with digital sound and they both operate in accordance with the Appendix 30 provisions.

Digital systems, including HDTV, are now under development which may also be used at 12 GHz. Furthermore, improvements have been made in satellite technology which reduce the need to select orbital positions as a function of service availability during eclipses.

Direct to home (DTH) services in the Fixed Satellite Service (FSS) band are no longer penalised by the relatively low eirps allowed in these bands, as a result of the vastly–improved sensitivity of modern receivers today, and they offer a very efficient and economic approach. These services have achieved encouraging audience results, because of the large number of channels available from a single satellite and because of the wide, often regional, coverages.

5.4.2. Advantages of digital transmission

Apart from improving the antenna characteristics of the home receiver terminal, the capacity and hence the flexibility of the existing Plan can only be increased by applying systems requiring less protection than the FM reference system. Such a solution is offered by the adoption of digital modulation. This approach has the additional advantage of reducing the power requirements on board the satellite. The use of digital systems would significantly reduce any inter–Regional sharing problems around 12 GHz.

The growing interest in digital picture coding and compression techniques is based on the most recent results which have proved the feasibility of multi–programme television transmission via satellite in the 12 GHz band.

The introduction of digital techniques would allow an improvement in the channel capacity. Each individual WARC–77 channel assigned to a service area could provide a number of EDTV programmes (with a bit–rate of about 11 Mbit/s for each programme) or an even larger number of SDTV programmes (5.5 Mbit/s for each programme). These would be time multiplexed on a single carrier.

As an alternative to the MPTV transmission, at least one HDTV programme could be transmitted.

A WARC–77 channel allows the transmission of a useful bit–rate of about 60 Mbit/s, using TCM–8 PSK (2/3) modulation. This arrangement still complies with the levels of co–channel (CCI) and adjacent–channel (ACI) interference required by the Plan (i.e. with the protection ratios required for the analogue reference system).

Other modulation and channel–coding systems are being proposed, based on QPSK modulation, convolutional punctured inner codes and Reed–Solomon outer codes. These systems, although less spectrum–efficient, require lower carrier–to–noise (C/N) and carrier–to–interference (C/I)

Wanted signal	Unwanted signal	Protection ratio	
		Co–channel (CCI)	Adjacent–channel (ACI)
PAL/FM	PSK (R_S = 30 Mbaud)	25 (19)	14 (11)
D2–MAC	PSK (R_S = 30 Mbaud)	23 (18)	15 (12)
8–PSK TCM 2/3 (R_S = 30 Mbaud)	D2–MAC	17 (17)	11 (13.5)
8–PSK TCM 2/3 (R_S = 30 Mbaud)	PSK (R_S = 30 Mbaud)	16	11.5

Note: A frequency deviation of 13.5 MHz/V is normally used for analogue signals. Figures in brackets refer to a frequency deviation of 22 MHz/V and 33 MHz receiver bandwidth.

R_S = modulator symbol rate.

Table 1
Protection ratios of analogue and digital television systems, assuming the WARC–77 channel matrix.

ratios than TCM–8 PSK (2/3) at 60 Mbit/s, and will be considered in the following as a "worst case" against which to compare the protection ratios and power requirements of other systems.

Table 1 gives the protection ratios of the example digital system (with a useful bit–rate of 60 Mbit/s) and compares the results with those for analogue PAL and MAC at the threshold of visibility (C/N = 30 dB for the analogue systems).

It should be noted that the figures of *Table 1* refer to a 38 MHz satellite OMUX filter (–3 dB bandwidth). The protection ratios have been measured using a 27 MHz receiving filter for the analogue signal, while a receiving filter of 30 MHz has been assumed for the digital signals.

From further studies, it appears that HDTV could also be broadcast in a WARC–77 channel at bit–rates of about 45 Mbit/s, with QPSK modulation and rate 3/4 forward error–correction (FEC), without prejudice to the existing Plan.

With the same modulation parameters, and again without prejudice to the existing Plan, it could be possible in some cases to transmit bit–rates of 70 to 140 Mbit/s by merging two or three standard BSS channels with the same polarization. This of course would be subject to the geographical situation and to any previously–planned operating conditions, and the agreement of the administrations concerned.

This form of channel grouping could be done by inserting these carriers into the channelling scheme of the present Plan. The transmission of these carriers would result in a trade–off between the C/I and C/N margins: a sizeable improvement would be obtained in the C/I margin at the cost of a slight degradation of the C/N margin (less than 0.4 dB). Overall, the corresponding modifications of the Plan would generally result in an improvement in the interference situation.

Conversely, 45 Mbit/s carriers would not suffer excess interference from the normal carriers of the Plan. In the case of 70 Mbit/s or 140 Mbit/s HDTV transmission, it is difficult to draw a general conclusion. However, the analysis of a few examples in the most congested area of the Plan (orbital positions from 31°W to 5°E) indicates that this situation should result in interference levels well within the acceptable criterion, at least for the 70 Mbit/s HDTV carriers.

The present evolution shows that HDTV carriers transmitted in the Plan assignments tend to use a lower eirp than the nominal Plan value, for example 57 dBW instead of 61 dBW.

5.4.3. Factors affecting a possible revision of the WARC–77 Plan

All the factors discussed above have contributed to the need for a modernisation of the WARC–77 Plan. By adopting digital techniques, the capacity and the flexibility of the Plan can already be substantially improved, without the need for change. By keeping the Plan as it stands, but using digital modulation, each assigned channel could provide increased programme capacity for normal–definition pictures. As a result of the lower requirements regarding protection ratios, wider coverages could be achieved. Furthermore, the overall capacity could be increased even more if, eventually, the Plan itself were to be revised.

A revision of the WARC–77 Plan for Regions 1 and 3 should (in accordance with Resolution 524):

– maintain each country's assigned BSS capacity in the Plan, as a minimum;

– provide for the needs of new countries;

– protect notified systems which are in conformity with Appendices 30 and 30A;

– take account, as far as possible, of systems which have been communicated to the IFRB under Article 4 of Appendices 30 and 30A.

Further key considerations in any revision of the WARC–77 Plan should be the following:

– required C/N ratio;

– new protection ratios for analogue television systems;

– planning requirements of broadcasting of digital television signals;

– possibility of improving the channel capacity by the introduction of digital multi–programme television transmissions;

– improved receiver antenna characteristics;

– a new orbital planning concept which establishes the coexistance of planned orbital locations and non–planned resources;

– needs for some administrations to implement multi–mission payloads (BSS, FSS, ...).

Detailed planning targets should be:

– to define the picture impairment grade of the received signal, in terms of nominal quality and service continuity, taking into account the experience gained with satellite broadcasting up until now. The nature of the service (whether conventional television or HDTV, whether analogue or digital) should also be taken into account;

– to define, in accordance with the preceding point, the reception quality objectives (the signal–to–noise (S/N) ratio or bit–error rate, threshold margin and the protection ratios);

– to continue to permit (within the restrictions of the protection ratios) changes to the modulation scheme of an RF channel;

– to introduce the principle of supranational coverages in addition to national coverage;

– to explore maximum commonality of parameters between BSS and FSS (modulation parameters, eirp, antenna diameters, polarization);

Several lines of action seem possible (individually or in combination):

a) To utilize each RF channel to broadcast arbitrarily, on the same channel, an analogue or a digital television signal. To this end, the coding and modulation characteristics of the digital signal must be compatible with the system parameters (C/N ratio, channel bandwidth and protection ratios) agreed for analogue broadcasting. These parameters must be compatible for both the digital–versus–digital and the digital–versus–analogue (and vice versa) cases.

   Analogue broadcasting cannot be neglected and consequently should be assumed to coexist with the digital service for a certain number of years; the set of C/N and protection ratio values to be chosen should be valid both for analogue and digital systems, assuring at the same time their mutual compatibility. In choosing the C/N and protection ratio values for analogue systems, the experience gained in the direct–to–home transmissions in both the BSS band and in the FSS band should be taken into account.

b) To reserve a suitable continuous sub–band in the centre of the 11.7–12.5 GHz band and to adequately re–plan it. It should be noted that all administrations sharing the same orbital position would be affected equally. Initially, it thus seems suitable to reserve a continuous band from channel 17 to 24. The inherent repetition of assigned channels in the WARC–77 Plan makes it possible to free a continuous central band having a width of an integer multiple of 153 MHz (153 MHz – 8 channels, 306 MHz – 16 channels etc.). Eventually, this centre band could be extended to coincide with the entire 11.7 – 12.5 GHz band. This approach could be especially useful if digital broadcasting services with high bit–rates are to be introduced (e.g. studio–quality HDTV).

   The continuous central band could be utilized for two purposes:

   – to realize supranational coverage from the same orbital position of the WARC–77 Plan, utilizing the existing RF channels (at the same time both for analogue and digital broadcasting);

   – to completely re–plan the WARC–BS–77 Plan in order to realize a more suitable digital broadcasting system. In particular, a virtually–transparent studio–quality HDTV service could be implemented in such a frequency slot.

c) Due to the fact that all satellite network operators may not be satisfied with the minimum number of channels alloted, the coverage areas, etc., and bearing in mind the present demand for the future use of the BSS band in Europe (Europesat, Kepler, UK–DBS, DBL, HISPASAT–2, etc), it would be convenient, in order to facilitate the coordination, to consider a more–general revision based on a new planning approach.

   This new planning approach implies that new orbital positions (or arcs) be determined in order to permit an analogue/digital broadcasting system, without causing harmful interference to the already–planned orbital positions and channels. To this end, the protection ratio values to be respected are to be determined in advance

(i.e. to confirm the WARC–77 Plan values or to determine new values). In addition it could be possible to use the aggregate interference criteria in the establishment of a newly–revised plan, and subsequently to use a single C/I ratio criteria for modifications to the revised Plan. Due to interest in providing Integrated Services Digital Broadcasting (ISDB), provisions for such use on specific channels could be made, which do not cause more interference to, or require more protection from, television use.

To permit new or enlarged coverages and/or new orbital positions to be introduced easily, it is necessary to have the appropriate regulatory procedures. In particular, suitable modification procedures are required which should specify the limitations needed to protect other services in terms of the C/I values required by those services, rather than in terms of permitted relative increases in power flux density (PFD) values.

The adoption of the shaped antenna technique may be helpful in solving difficult national coverage situations or in introducing supranational coverage, although it could raise some political and administrative problems. In fact, while the unavoidable spillover radiation of an elliptical antenna is well defined, the situation is different for shaped antennas. However, a realistic PFD contour on the surface of the earth cannot, in all likelihood, be defined prior to construction of a real satellite.

In principle, and in the light of the above considerations, it would be possible to distiguish *a priori* the two scenarios shown in *box 8*.

Many administrations are of the opinion that the rigidity of procedures is the main reason for the lack of flexibility in the current Plan. Some administrations consider that a complete review of WARC–77 procedures would give the wanted flexibility to the Plan. However, it is also seen that many approaches could be adopted and further investigations are required for the feasibility of each.

5.4.4. Action in the ITU

At the World Administrative Radio Conference in 1992, it was noted that improvements in the utilization of the 12 GHz planned bands may enable countries, in particular those which have high rainfall climatic zones, to accommodate their HDTV broadcasting satellite service (BSS) needs, or part of their needs, in that band.

In particular, Resolution COM 5/3 (WARC–92) invited the Radiocommunication Sector to study, as a matter of priority, the technical possibilities for improving the efficiency and flexibility of the Plans for Regions 1 and 3, and to study the particular needs of high rainfall climatic zones for HDTV and the technical methods which could be used to implement this service in the 12 GHz band.

At the first World Radiocommunication Conference (WRC–93), held in Geneva in November 1993, it was decided to include items in the agendas for WRC–95 and WRC–97 concerning a review of the Plan for satellite television broadcasting in Regions 1 and 3 established by WARC–77. The main arguments put forward in this request were the considerable progress made in the technical means and methods for the transmission of television information, and also the emergence of a large number of new ITU Member States wishing to have their interests reflected in the Plan.

It was specified that, in conducting the review, there should be due regard to the advantage of taking into account the orbital arcs of the existing Plan, and this refers to possible sharing of the orbital positions of satellites in the broadcasting–

8

Possible scenarios for a revision of the WARC–77 Plan

Scenario A: Conserve the current Plan

In this scenario, the current orbital positions and the assigned channels, beams and polarizations associated with each assignment would be retained. However, an update of the technical assumptions would be made, according to present–day technology (better satellite antenna performance and side lobes, etc); this would improve the flexibility of the Plan and facilitate the additional requirements of new countries.

Scenario B: Draw up a new Plan

This scenario is based on updating the technical parameters used for the establishment of the current WARC–77 Plan. It would imply the introduction of new orbital locations, or moving some of the previous ones. Any new Plan would need to facilitate the addition of requirements from other systems (different coverages, different number of channels, etc). Provision to ease the implementation of future amendments, modifications or additions to both current and future assignments would be ensured, through a review of the regulatory procedures.

satellite service (BSS) and the fixed–satellite service (FSS) bands. It was recommended that actual decisions relating to this review should be taken at WRC–97

Selected Recommendations for satellite broadcasting, prepared by Joint Working Party 10–11S, are listed in *Part 2* of the *Bibliography*. It has also prepared a draft new Report "Work towards a Recommendation on the review of the BSS frequency plans" (Doc. 11/207, December 1993).

5.5 3–D television

An experimental field–sequential stereoscopic television system has already been developed in Japan, utilizing HDTV equipment. Test results showed that the required field frequency for stereoscopic television is greater than 110 Hz and a system with a field rate of 120 Hz has since been demonstrated to the public.

Study Group 11 has stipulated that a practical stereoscopic television system requires:

- orthoscopic three–dimensional display (the depth of the scene should appear natural and without viewer discomfort);
- group viewing (almost any location in the room should provide good stereoscopic viewing);
- compatibility (three–dimensional receivers should display a stereoscopic transmission in full depth and a two–dimensional transmission, monoscopically; existing two–dimensional receivers should display a stereoscopic transmission monoscopically);
- non–degraded picture (colorimetry and resolution of a stereoscopic service should be comparable to a conventional service);
- minimum modification of video standards (existing specifications should not require extensive revision);
- moderate price.

One of the main limitations in the use of current 3–D systems is the need to use spectacles to provide different pictures for the left and right eyes. Studies of auto–stereoscopic displays, which would not require glasses, are under way in several parts of the world. Study Group 11 will study the number of source and display channels needed for effective auto–stereoscopic systems, and methods to matrix these channels for transmission. Progress in this field will also require close cooperation with other bodies in order to harmonise standards for broadcast and non–broadcast applications. Two Special Rapporteurs, from Germany and Japan, have been appointed in this area.

5.6. Harmonisation with non–broadcast applications

The first Recommendation on "Harmonisation of digital methods for delivery systems for TV services to the home" has been prepared. Rapidly–increasing mass production of computers and new 16:9 format receivers has highlighted the importance and urgency of work in Task Group 11/4 to harmonise television broadcasting technologies with their counterparts in computer systems and elsewhere. This Task Group has been transformed into Working Party 11F.

Prospects for video–conferencing developments also call for the need for further action to harmonise standards between the respective broadcast and non–broadcast technologies. This work has to be done in close cooperation with the telecommunication standards sections of the IEC and the ISO.

In some applications (computer graphics, printing, the cinema, etc), an extremely high resolution tele-

Professor Dr. Mark I. Krivocheev *is an academician and Head of a Scientific Department concerned with Television in the Radio Research Institure (NIIR) in Moscow, Russian Federation.*

In 1946, Professor Krivocheev designed a scanning unit which, for the first time, achieved the display of a new standard 625–line raster. He headed the studio production complex of the Moscow TV Centre. On 3 September 1948, he made history by pressing the button which inaugurated the world's first 625–line transmission. The first frequency plan for television stations in the former USSR was prepared by Professor Krivocheev in 1951. He is the originator or co–originator of more than 90 inventions and patents in television technology and his books and papers have been published in many countries.

Professor Krivocheev has been a participant and leader in international television studies in the framework of the ITU since 1948, serving as Vice–Chairman of Study Group 11 from 1970 and Chairman since 1974. His contributions have been widely recognised by national and international bodies. He holds Honorary Membership of the A.S. Popov Society, the IEEE, the Institute of Television Engineers of Japan (ITEJ) and the Fernseh– und Kinotechnischen Gesellschaft (FKTG). He is an Honorary Fellow of the British Kino, Sound and TV Society (BKSTS), and a Fellow of the Society of Motion Picture and Television Engineers (SMPTE) and of the Chinese Institute of Electronics (CIE).

vision system is expected. Studies on digital image architecture are being conducted in some organizations. Working Group 11F should start studying the relationship that exists between broadcasting and non–broadcasting systems with extremely high resolution imagery, and considering what kind of parameters – such as programme origination, transmission and display terminals – should be determined for these systems.

A Special Rapporteur has been appointed to progress the computer work. Initially, there was considerable cooperation from computer experts but differences between them and broadcasting experts have emerged on how the development of HDTV should be progressed. With the rapid development of digital television, many of these problems are easing and hopefully will be removed in due course. The requirements of high resolution imagery (HRI) are also being addressed.

Coordination with the MPEG is working well; relevant ITU–R material has been conveyed to the MPEG and now appears in its output documents. Liaison has also been pursued with the ISO on transmission techniques; the telecommunications world is increasingly interested in the use of television displays. A further Special Rapporteur has been appointed to develop links with organizations developing video–phones and video–conferencing systems.

Links have also been established with the ISO and with the ISO/IEC Joint Technical Advisory Group (JTAG) over colorimetric issues (which are also of concern to Task Groups 11/1 and 11/3).

A further important area is concerned with the interfaces in the home between various equipments such as cameras, recorders, satellite receivers etc., for which harmonisation is also being sought.

6. Conclusions

The important results achieved by Study Group 11 have confirmed its vitality as an international forum for broadcasting activities.

The Study Group will play a dominant role in the new era of digital television, HDTV and high–resolution imagery (HRI) that will characterise the 21st century. It will be an ideal international framework for the worldwide recognition of these studies, bringing new important challenges for the broadcasting, computer, multi–media and telecommunications industries.

Acknowledgement

Special acknowledgements must be paid to the Vice–Chairmen of the Group and also to the Chairmen and Vice–Chairmen of the Working Parties and Task Groups, for their personal contributions to the success of Study Group 11. The Author's thanks also go to all the contributors and participants at the November 1993 meeting of the ITU Radiocommunication Assembly.

Special thanks are addressed to the ITU–R secretariat, in particular to Mr. R.C. Kirby (Director), Mr. R.L. Nickelson, Mr. G. Rossi and Mrs R. Zecha for their valuable and efficient support.

Bibliography

Part 1 – ITU–R Recommendation and ITU–R Draft Recommendations relating to digital terrestrial television broadcasting

Recommendation 798: **Digital television terrestrial broadcasting in the VHF/UHF bands**

Draft Recommendation: **Video coding for digital terrestrial television broadcasting**

Draft Recommendation: **Error correction methods for digital terrestrial television broadcasting**

Draft Recommendation: **Service transport methods for digital terrestrial television broadcasting**

Draft Recommendation: **Service multiplex methods for digital terrestrial television broadcasting**

Draft Recommendation: **Modulation and emission methods for digital terrestrial television broadcasting**

Draft Recommendation: **Criteria required for planning digital terrestrial television services in the VHF/UHF television bands**

Part 2 – ITU–R Recommendations relating to satellite broadcasting

Recommendation 650: **Standards for conventional TV systems for satellite broadcasting in the channels defined by Appendix 30 of the Radio regulations**

Recommendation 652: **Reference patterns for earth station and satellite antennas for the broadcasting–satellite service in the 12 GHz band and for the associated feeder links in the 14 GHz and 17 GHz bands**

Recommendation 788: **Coding rate for the wide RF–band HDTV broadcasting–satellite service**

Recommendation 790: **Characteristics of receiving equipment and calculation of receiver figure–of–merit (G/T) for the broadcasting–satellite service**

Recommendation 792: **Interference protection ratios for the broadcasting–satellite service (Television) in the 12 GHz band**

Recommendation 794: **Techniques for minimizing the impact on the overall BSS system performance due to rain along the feeder–link path**

Part 3 – Other ITU–R Recommendations referred to in the article

Recommendation 417: **Minimum field strengths for which protection may be sought in planning a television service**

Recommendation 419: **Directivity of antennas in the reception of television broadcasting**

Recommendation 470: **Television systems**

Recommendation 601: **Encoding parameters of digital television for studios**

Recommendation 653: **Teletext systems**

Recommendation 656: **Interfaces for digital component video signals in 525–line and 625–line television systems**

Recommendation 709: **Basic parameter values for the HDTV standard for the studio and for international programme exchange**

Recommendation 721: **Transmission of component–coded digital television signals for contribution–quality applications at bit–rates near 140 Mbit/s**

Recommendation 723: **Transmission of component–coded digital television signals for contribution–quality applications at the third hierarchical level of CCITT Recommendation G.702**

Recommendation 804: **Characteristics of television receivers essential for frequency planning with PAL/SECAM/NTSC television systems**
