INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

CCIR

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CONCLUSIONS OF THE EXTRAORDINARY MEETING OF STUDY GROUP 11 ON HIGH-DEFINITION TELEVISION

INTERNATIONAL TELECOMMUNICATION UNION

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NOTE BY THE DIRECTOR, CCIR

CONCLUSIONS OF THE EXTRAORDINARY MEETING OF CCIR STUDY GROUP 11 ON HDTV

(Geneva, 10-16 May, 1989)

The attached texts represent the conclusions of CCIR Study Group 11, reached at its recent Extraordinary Meeting on HDTV. They may be updated at the Final Meeting of this Study Group, on the basis of further contributions and discussions, and taking into account the limited time available. While provisional numbers have been assigned to the draft Recommendations and the new Reports, it was the decision of the Study Group to assign the definitive number 801-3 to the Report on the present state of high-definition television.

The new or modified texts assembled in this document are analogous to the Conclusions of an Interim Meeting. Study Group 11 requested inclusion of Report AQ/11, prepared at the Interim Meeting, 1987, in order to present all documents on HDTV in this booklet.

As it has not been possible to check all cross-references between CCIR texts in the time available for the preparation of this document, the reader is advised to consult the "Status of texts" whenever a reference is made in a given text to any other Recommendation, Report, Question, Study Programme, Decision or Opinion contained in the Volumes of the XVIth Plenary Assembly (Dubrovnik, 1986). In particular, references to other CCIR texts, contained in the body of draft new or modified texts may not reflect the status of such texts following the Interim Meeting. The Conclusions of the 1987 Interim Meetings should also be taken into account (Docs. 11/276, 11/277 and 10-11S/99).

At the request of Study Group 11, these conclusions are also exceptionally being made available for sale on a general basis, as they are a compendium of present world-wide activities in all aspects of HDTV.

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INTRODUCTION BY THE CHAIRMAN OF STUDY GROUP 11

1. Introduction to the Extraordinary Meeting

1.1 Background

In this era of rapid technological change, it is widely recognized that international standardization and coordinated planning for the introduction of new systems and services assume critical importance. The rapid acceleration in the work leading to the introduction of advanced television systems such as HDTV provides an important example in the way in which the CCIR has responded to the challenge of change through the identification of the processes and decision-making mechanisms necessary to produce timely and coordinated action for the development of HDTV studio, emission and transmission standards.

As part of this process, the CCIR decided at its XVIth Plenary Assembly (Dubrovnik 1986), to schedule an Extraordinary Meeting of Study Group 11 on HDTV for the purpose of expediting the considerable number of activities taking place in this area. The Extraordinary Meeting represented the first world-wide forum where HDTV was considered in its entirety and in detail, and provided a framework for studying constraints and the interrelationship between the various items. By means of Decision 74, the global approach of Study Group 11 towards HDTV was emphasized including the role of high-definition television in the "Information Society" of the next century. A key component of this global emphasis is the harmonization of standards and operating practices for high-definition television production, and for non-broadcast high-definition television equipment intended for consumer application. In this regard, the need for coordination of standardization on the international level becomes essential, particularly among organizations concerned with information technology such as the ITU, IEC and ISO.

Within the context of the increasing need for global harmonization and cooperation in telecommunication matters, it is very noteworthy that the Extraordinary Meeting of Study Group 11 was held at a time when the Information Forum (London, 17 April - 12 May 1989), convened in accordance with the Declaration adopted at the Vienna Conference on the Security of Europe, was completing its work. At the Forum, attention was drawn to the necessity of adopting common international technical parameters for audio and visual facilities and telecommunication networks in order to facilitate the exchange and dissemination of information. In these circumstances the activities of Study Group 11 in the work leading to the establishment of a unified set of HDTV parameters play a special role.

1.2 Organization

Analysing the situation on the development of HDTV technology and the need for adequate preparation of the Extraordinary Meeting, the Director, CCIR, and the Chairman of Study Group 11 found it appropriate to establish an HDTV Coordination Group consisting of the Chairmen of the Interim Working Parties and Joint Interim Working Parties engaged in preparatory work for the Extraordinary Meeting. At its second meeting in January 1989 the Coordination Group proposed a structure for the Extraordinary Meeting as well as the chairmanships of the Working Groups. In addition, the agenda of the meeting, as specified in Decision 74, was confirmed as follows:

"1. to advise the Director, CCIR, that the Extraordinary Meeting of CCIR Study Group 11 be convened in 1989 in [Geneva] for not more than one week commencing not later than May, 1989;

2. that the agenda for the meeting shall be the following:

taking note of the general terms of reference of CCIR Study Group 11, Question 27/11 and the Study Programmes which derive from it;

2.1 to consider the progress made in the basic parameters of a worldwide HDTV system since the Interim Meeting of Study Group 11 in November 1987, taking into account:

- reports of CCIR Working Parties IWP 11/4, 11/5, 11/6, 11/7, JIWPs 10-11/3, 10-11/4 and 10-11/5;

- decisions reached at the WARC ORB-88 Conference on HDTV emission and planning Questions and their ramifications for the work of Study Group 11;

- submissions from administrations;

2.2 to prepare the recommendation of a full set of relevant digital and analogue parameters for a single worldwide HDTV standard within the framework of Decision 58-2. This should take into account the new Report AU/11 "A global approach to HDTV systems";

2.3 to consider proposed methods for the emission of HDTV signals and to review the possibilities for the specification of the baseband signal formats in digital and analogue form to be used for emission;

2.4 to review the possibilities for the specification of the baseband signal formats in digital and analogue form to be used for the international exchange of HDTV programmes via transmission links;

2.5 to define what further actions towards a worldwide HDTV system may be required in preparation for the Final Meeting of Study Group 11 in [xx 1989] in particular the future work of IWPs 11/4, 11/5, 11/6, 11/7, JIWP 10-11/3, 10-11/4, 10-11/5 and coordination with the CMTT".

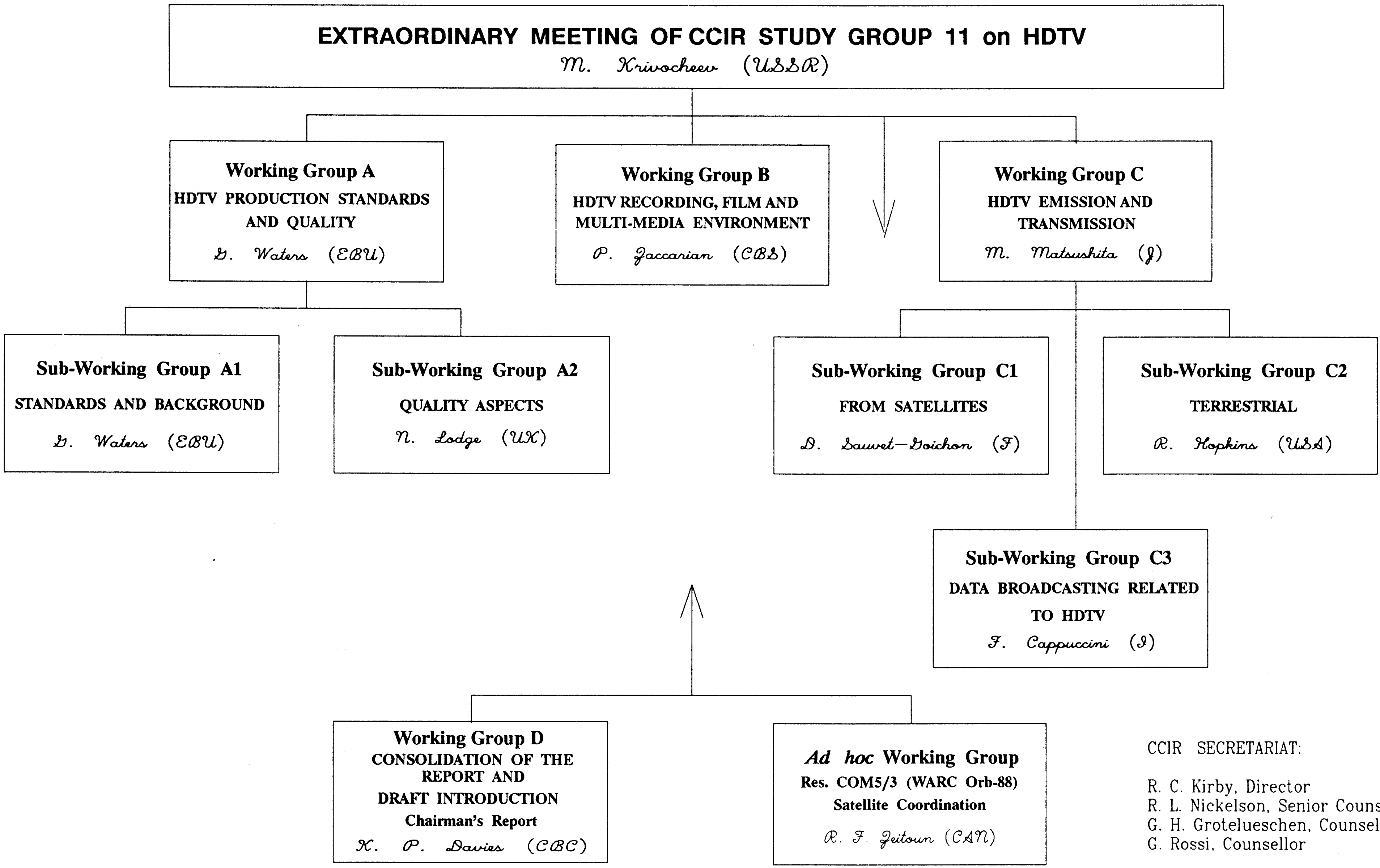
It was also considered to be desirable to take account of developments in HDTV quality assessments, definitions of HDTV interfaces and in HDTV recording.

The following was adopted as the meeting structure (see Fig. 1).

2. Preparatory work

Significant work was accomplished by the Interim Working Parties of Study Group 11 in preparation for the Extraordinary Meeting.

IWP 11/4 (Chairman D. Wood (EBU), Vice-Chairman B. Jones (United States of America)) prepared a document on recommended methods for subjective assessment of HDTV quality, and produced a draft Recommendation on subjective assessment methodology.



CCIR SECRETARIAT:

R. C. Kirby, Director
R. L. Nickelson, Senior Counsellor
G. H. Grotelueschen, Counsellor
G. Rossi, Counsellor

FIGURE 1

IWP 11/5 (Chairman S. Dinsel (Federal Republic of Germany)) prepared reports on protection ratios applicable to HDTV used in terrestrial systems and on compatibility of new HDTV systems with existing terrestrial services.

IWP 11/6 (Chairman Y. Tadokoro (Japan), Vice-Chairmen R. Green (United States of America) and W. Habermann (Federal Republic of Germany)) produced a proposal for a draft Recommendation for an HDTV studio standard, and a report on a wide range of knowledge of HDTV techniques and technology to form a possible basis for a major update of existing CCIR texts concerning HDTV.

IWP 11/7 (Chairman A.N. Heightman (United Kingdom), Vice-Chairmen K.P. Davies (Canada) and T. Saito (Japan)) contributed to IWP 11/6 a document on possible approaches to encoding parameters for HDTV.

IWP 11/8 (Chairman Wu Xianlun (People's Republic of China), Vice-Chairman A.N. Heightman (United Kingdom)) agreed that there is a formal need for a Study Programme concerning the digital aspects of HDTV.

The Chairman of JIWP 10-11/1, D. Sauvet-Goichon (France), prepared a summary report on the results of WARC ORB-88 relevant to the Extraordinary Meeting.

JIWP 10-11/3 (Chairman Ö. Mäkitalo (Sweden), Vice-Chairmen G. Chouinard (Canada) and T. Nishizawa (Japan)) prepared a report on HDTV satellite broadcasting addressing system characteristics, frequency sharing and propagation up to 23 GHz.

JIWP 10-11/4 (Chairman P. Zaccarian (CBS)) continued studies and submitted contributions on the recording of HDTV programmes, the use of film for HDTV, and the harmonization of broadcast and non-broadcast equipment.

JIWP 10-11/5 (Chairman F. Cappuccini (Italy)) reported that an enhancement of data broadcasting compatibility and performance should be realized in the development of HDTV systems.

In addition to the valuable contributions of the IWPs, the Extraordinary Meeting received many excellent contributions from administrations and others, which highlighted the progress that continues to be made in the development of HDTV.

Included were two proposals for a draft Recommendation for a studio standard and contributions on the strategies leading to a unique world-wide studio standard. These and other contributions take into account the fact that the CCIR's task of recommending standards for high definition television has been made somewhat difficult by the diversity of objectives foreseen for HDTV in different parts of the world over the past few years. There are differences in approach in terms of technology, support systems, and compatibility. As examples of this, for some administrations, the use of HDTV for production of motion pictures and their subsequent distribution via satellites is the most immediate need. For other administrations, there is greater emphasis on satellite broadcasting, although here considerable differences exist in the time-scales foreseen for services, and the frequency bands to be used. In other areas terrestrial broadcasting is the dominant consideration.

3. Results of the Extraordinary Meeting

The Extraordinary Meeting examined about 80 contributions, some quite extensive, from both administrations and the relevant IWPs and JIWPs of Study

Group 11, concerning all major aspects of HDTV from the image through production and emission to the display. A total of four draft Recommendations, ten new or updated Reports and a number of important changes to Study Programmes and Decisions were adopted. They cover the specific requirements of the meeting agenda and in addition, certain other aspects of the interface of HDTV with global television and telecommunications systems.

The meeting also considered the future work of Study Group 11, leading to proposed changes to Study Programmes and Decisions and to a report addressing the strategic aspects of achieving a unified single world standard.

3.1 Basic parameters of the world-wide HDTV system

In item 2.1 of the meeting agenda, the Extraordinary Meeting is charged with a consideration of the progress made in the basic parameters of a world-wide HDTV system. Within this framework, the Extraordinary Meeting prepared Report 801-3 which contains an extensive review of the most important aspects of world-wide HDTV development.

It is based, as requested, on the work of IWPs and JIWPs; especially IWP 11/6 and contributions received. The report addresses the definition and objectives of HDTV and the rapidly advancing technology. Included in the text are the essential details of two HDTV systems that have been developed for broadcasting use and which have been considered by Study Group 11 as proposals for a draft Recommendation for the studio standard.

In the preparation of this report, Study Group 11 noted the expanding range of application for HDTV and its interrelationship with world-wide development of image communications. A new Report XK/11 examines these issues in more detail.

The measurements of the HDTV system are important to its successful development. Advances in this area are reflected in draft Recommendation XB/11 concerning subjective measurements and in Reports AT/11 (MOD Ex) and XF/11 concerning, respectively, subjective and objective measurements. The adoption of these texts is a major step forward, representing a world-wide agreement on the procedures, analysis and context of HDTV measurements.

3.2 Recommendation for a single world-wide HDTV studio standard

The 1986 Plenary Assembly and item 2.2 of the agenda for the Extraordinary Meeting of Study Group 11, from the Interim Meeting of 1987, place a high priority on the establishment of a full set of parameter values, both analogue and digital, for the single world-wide HDTV standard, taking account of the global approach to HDTV systems. The Study Group has examined all aspects of this request in considerable detail and from both technical and operational viewpoints.

The current results of this work are shown in draft Recommendation XA/11 and further information concerning these parameter values is included in Part 5 of Report 801-3.

In the preparation of this Recommendation the Extraordinary Meeting took account of many contributions and of a particularly valuable report from IWP 11/6. This contains an in-depth analysis of the current situation and trends in HDTV development and the implementation of services.

From these analyses, from proposals by some administrations, and from the information existing in CCIR texts, the Extraordinary Meeting concluded that it would be advantageous to study more carefully the remaining relevant parameter values in a continuation of the work up to, and possibly beyond, the Final Meeting, thus allowing the inclusion of anticipated important material.

In view of the importance of these studies, the Extraordinary Meeting has taken appropriate steps to instruct the relevant IWPs and JIWPs to undertake them. Additional discussion of the current context of HDTV is found earlier in this report, and § 4 below details the further work on this matter.

3.3 Methods of emission

In accordance with agenda item 2.3, the Extraordinary Meeting of Study Group 11 made considerable progress on emission standards and related matters, such as data broadcasting in the HDTV environment. A new emphasis in the work of the Extraordinary Meeting is placed on terrestrial broadcasting methods for HDTV. The methods for satellite broadcasting are already well covered in CCIR texts but were substantially updated. Among its conclusions, it was found that techniques exist for the broadcasting by satellite of HDTV over a range of frequencies up to 23 GHz, and that neither the characteristics of satellite broadcasting systems, nor their interference susceptibility should directly restrict the characteristics of the studio standard used as source of programme material. Section 7 of Report 801-3 contains the updated information regarding HDTV emission, while § 8 contains the updated information regarding data broadcasting. Further work on this latter matter is considered later in § 4 of this introduction.

With regard to baseband formats for HDTV emission, current CCIR texts, such as Report 1075 (MOD I) and the contents of Part 7 of Report 801-3 provide much useful information.

3.4 International exchange of programmes

Agenda item 3.4 requests studies concerning the international programme exchange. Methods for the international exchange of programmes on transmission links are rapidly developing and this was reflected in the contributions considered. The conclusions are found in Part 9 of Report 801-3, with the current situation regarding baseband formats described.

Methods for the international exchange of programmes using recorded media (film, tape, disc) are more advanced and considerable progress was made by the Extraordinary Meeting in achieving agreement on several matters.

Draft Recommendation XC/11 was adopted concerning the recording of HDTV images on film. Draft Recommendation XD/11 was adopted regarding the exchange of HDTV programmes on tape. The Extraordinary Meeting adopted also Reports XG/11 and XK/11 documenting aspects of the recording of HDTV on tape in the studio and domestic environments respectively. The use of film as a source for HDTV programmes is considered in Report XJ/11, entitled "Scanned area of film for HDTV", and by an update to Report 294-6.

3.5 Future actions in preparation for the Final Meeting of Study Group 11

The actions of Study Group 11 and its relevant Interim Working Parties and Joint Interim Working Parties up until the Final Meeting (October 1989) was considered by the Extraordinary Meeting, in accordance with agenda item 3.5, in the light of important and accelerated studies to be undertaken.

Report XE/11 presents the details of the strategies to be followed, while an early meeting of the Coordinating Group is arranged to put in place all details of the IWP and JIWP work, in the light of the Extraordinary Meeting conclusions.

In addition, some proposals were adopted concerning important changes to Study Programmes and some small changes to Decisions 58 and 72.

3.6 Consideration of the results of WARC ORB-88

The Extraordinary Meeting adopted a text containing information on Resolution COM5/3 (WARC ORB-88) relevant to the Plenipotentiary Conference (Nice, 1989). It outlines the status of CCIR studies on satellite HDTV emissions up to the time of the Extraordinary Meeting and indicates that further studies, requested by Resolution COM5/3 should be available during the next CCIR study period, in the early part if necessary.

3.7 Satellite news gathering (SNG)

A note to the Chairman of JIWP CMTT/4-10-11/1 was adopted requesting the consideration of HDTV in their studies without hindering their current studies. Text on the development of SNG is included in Part 9 of Report 801-3.

4. Future work

The future work of Study Group 11 concerning HDTV should further extend the results already obtained in order to achieve consistant standards. In particular, a unique studio standard is a clearly identified need and must continue to be the main target.

The draft Recommendation XB/11 and Report AT/11 (MOD Ex) have laid down a firm basis on HDTV quality assessments and measurements. This should facilitate progress on the establishment of these parameter values as yet uncompleted in draft Recommendation XA/11 describing the picture format and other parameters. Further, they make possible initiating work on related areas in order to generate subsequently draft Recommendations on these subjects (as an example, colorimetry is already identified as a particularly promising subject on which progress is expected during the Final Meeting). All participants of Study Group 11 are therefore invited to carry on with tests and experiments (including comparison tests) in order to achieve this goal.

The fact that the implementation of HDTV systems and the context of HDTV in general is rapidly changing was noted to be having a major effect on the general framework of Study Group 11. There have been significant achievements since 1987 and further developments are expected in the short term as several international events are scheduled for the near future and are expected to be important milestones.* In its work, the Extraordinary Meeting addressed all tasks assigned in Document 74, based on currently available contributions. It is proposed to add, at the time of the Final Meeting, any relevant new information that might be contributed.

* Major technical events related to HDTV occurring in this time period include:
International TV Symposium and Electronic Cinema Festival (Montreux), BKSTS Convention (London), IFA (Berlin), HDTV International Workshop (Turin), ITUCOM (Geneva), IREE Conference (Melbourne), NHK Open House (Tokyo), HDTV Conference (New York).

Even more up-to-date information is expected to be incorporated into CCIR Study Group 11 texts for the XVIIth Plenary Assembly. Considering the work already achieved and the expected information, it seems that the instructions given to the various IWPs and JIWPs as defined by the relevant Decisions are generally satisfactory but some must now reflect consequential changes resulting from Report XE/11.

These developments should be considered together with the increasing complexity of the relationship between all sectors of activity. Despite the substantial progress achieved since 1987, not all the studies on HDTV may be completed before the XVIIth Plenary Assembly. Some administrations request that the completion of certain parameters be extended into the next study period, but all agree an effort should be made to specify most of them before the end of this study period.

The complexity of the task to be carried out suggests that great care should be taken to ensure harmonization within Study Group 11, as well as with other closely related organizations to guarantee both consistancy and relevancy. The necessity is clearly identified to take adequately into account the increasingly strong relationship between broadcast and non-broadcast activities and particularly their equipment and specifications. This addresses mainly consumer and telecommunication equipment. Study Group 11 therefore invites the relevant organizations involved with standardization activities on aspects of these matters related to HDTV, to cooperate in order to achieve maximum efficiency of the work of all parties. The establishment of an ad hoc Group could be considered, to be set up during the Final Meeting of Study Group 11, in order to ensure harmonization with other relevant activities of the ITU (CMTT and the appropriate CCITT Study Groups) and with the IEC and the ISO. Meanwhile, all participants in Study Group 11 are encouraged to submit contributions to the Final Meeting on this subject.

5. Conclusions

The Extraordinary Meeting of Study Group 11 successfully completed all items of its agenda, produced four draft Recommendations on HDTV and a total of ten new or updated Reports. The conclusions of this meeting are particularly noteworthy, being the first consolidated report that reflects all aspects of the world-wide harmonization taking place in HDTV. This work was only made possible by the collaboration of many administrations and other CCIR participants in IWPs, in Extraordinary Meeting planning and organization and during the Extraordinary Meeting itself. The many valuable contributions and the dedicated work of all participants must also be acknowledged as an essential part of this landmark meeting on HDTV. The results will doubtless be seen in themselves as another large step along the road to world-wide implementation of a fully harmonized HDTV system linking mankind globally.

SECTION 11ExA - DRAFT RECOMMENDATIONS

DRAFT
RECOMMENDATION XA/11

A NUMBER OF BASIC PARAMETER VALUES FOR THE HDTV STANDARD FOR THE STUDIO AND FOR INTERNATIONAL PROGRAMME EXCHANGE

(Question 27/11)

The CCIR,

CONSIDERING

(a) that high-definition television (HDTV) is a subject of intense current interest and activity in the world;

(b) that this work is the subject of Question 27/11 and the Study Programmes which derive from it;

(c) that the parameter values of an HDTV studio standard need to be chosen to facilitate:

- the introduction of HDTV services, and

- the international exchange of programmes,

RECOMMENDS

that the following parameters be used in the generation of signals in high-definition studios and for the international exchange of programmes.

1. Opto/electronic conversion

<table>
<tr><th rowspan="2">Item</th><th colspan="2">Characteristics</th></tr>
<tr><th>Parameter</th><th>Value</th></tr>
<tr><td>1.1</td><td>Opto-electronic transfer characteristic before non-linear precorrection</td><td>Assumed linear</td></tr>
<tr><td>1.2</td><td>Electro-optical transfer characteristic</td><td>Under study
See Annex, § 1</td></tr>
<tr><td>1.3</td><td>Assumed chromaticity coordinates (CIE 1931) for primary colours</td><td>Under study
See Annex, § 1</td></tr>
<tr><td>1.4</td><td>Assumed chromaticity for equal primary signals - $E_R = E_G = E_B$ (Reference white)</td><td>D_{65}
x: 0.3127
y: 0.3290</td></tr>
</table>

Note.- The parameter values recommended are drawn from the 1125/60 and the 1250/50 proposals given in Report 801-3, Part 5.

2. Image characteristics

<table>
<tr><th rowspan="2">Item</th><th colspan="2">Characteristics</th></tr>
<tr><th>Parameter</th><th>Value</th></tr>
<tr><td>2.1</td><td>Picture aspect ratio (H/V)</td><td>16:9</td></tr>
<tr><td>2.2</td><td>Pixels per active line</td><td>1920</td></tr>
<tr><td>2.3</td><td>Pixel arrangement</td><td>orthogonal</td></tr>
<tr><td>2.4</td><td>Pixel aspect ratio (h/v)</td><td>Under study
See Annex, § 2</td></tr>
<tr><td>2.5</td><td>Active lines per picture</td><td>Under study
See Annex, § 2</td></tr>
</table>

3. Scanning characteristics

Item	Characteristics	
	Parameter	Value
3.1	Order of pixel scanning	Left to right Top to bottom
3.2	Picture rate	Under study See Annex, § 3
3.3	Interlace ratio	Under study See Annex, § 3

4. Signal format

Item	Characteristics	
	Parameter	Value
4.1	Conceptual non-linear precorrection of primary signals	$\gamma = 0.45$
4.2	Derivation of luminance, Signal E'_Y	Under study See Annex, § 4
4.3	Derivation of colour-difference signals (analogue coding) E'_{P_B}, E'_{P_R}	$E'_{P_R} = a(E'_R - E'_Y)$ $E'_{P_B} = b(E'_B - E'_Y)$ (1)
4.4	Derivation of colour-difference signals (digital coding) C_1, C_2	$C_1 = c(E'_R - E'_Y)$ $C_2 = d(E'_B - E'_Y)$ (1)

(1) The coefficients a, b, c, d, are related to the values contained in items 1.3 and 1.4. The derivation is similar, but the values differ due to the scaling.

5. Analogue representation (Levels are specified in millivolts measured across a 75 ohm termination)

Item	Characteristics	
	Parameter	Value
5.1	Nominal level - E'_Y, E'_G, E'_R, E'_B	Ref. Black - 0 Ref. White - 700 Under study
5.2	Nominal level - E'_{P_B}, E'_{P_R}	Under study See Annex, § 5
5.3	Sync format	Tri-level bipolar (see Fig. 1)
5.4	Timing reference	(see Fig. 1)
5.5	Sync level	$\pm$ 300
5.6	Horizontal blanking period	Under study See Annex, § 5
5.7	Vertical blanking period	Under study See Annex, § 5

6. Digital representation

Item	Characteristics	
	Parameter	Value
6.1	Coded signals	R, G, B or Y, C_1, C_2
6.2	Samples per active line R, G, B, Y C_1, C_2	 1920 960
6.3	Samples per full line R, G, B, Y C_1, C_2	Under study See Annex, § 6
6.4	Sample structure R, G, B, Y	Orthogonal, line picture repetitive
6.5	Sample structure C_1, C_2	Cosited with each other and with alternate luminance samples
6.6	Signal coding	Uniformly quantized PCM with at least 8 bits per sample Under study See Annex, § 6
6.7	Nominal level - R, G, B, Y	Ref. Black - Under study Ref. White - See Annex, § 6
6.8	Nominal level - C_1, C_2	Ref. Black - Under study Ref. Peak - See Annex, § 6
6.9	Synchronizing words	Under study See Annex, § 6
6.10	Sampling frequency R, G, B, Y	Sampling frequency is an integer multiple of 2.25 MHz
6.11	Sampling frequency C_1, C_2	Colour difference sampling frequency to be 1/2 luminance sampling frequency

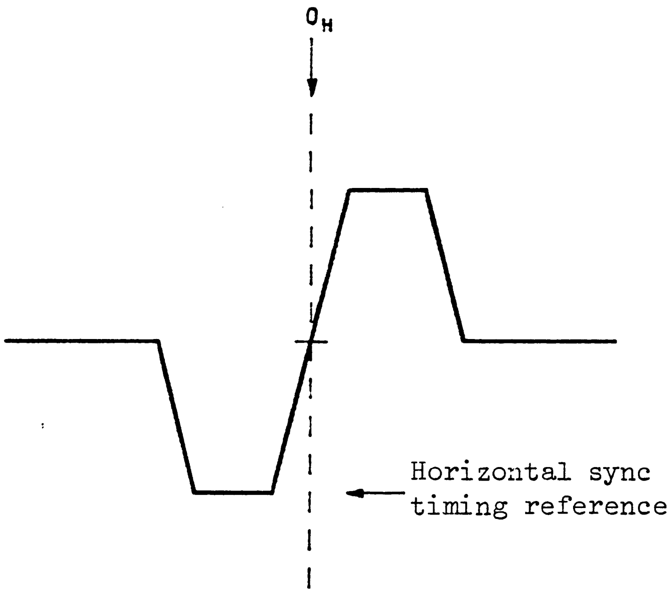


FIGURE 1 - *Sync format and timing reference*

(The waveform is skew-symmetric about O_H point)

ANNEX

NOTES ON THE OUTSTANDING HDTV STUDIO PARAMETER VALUES

1. Opto/electronic conversion

Document [CCIR, 1986-90a] states that primary colours giving a wider gamut, based on NTSC red and green and EBU blue, have been rejected on grounds of current practice and technical constraints. It is the opinion of EBU that the opportunity should not be missed for choosing a wider colour gamut. A similar opinion is described in [CCIR, 1986-90b] and [CCIR, 1986-90c].

One choice [CCIR, 1986-90d] is related to actual CRT displays. Another choice [CCIR, 1986-90e] is defined in order to carry a maximum of real surface colours even if currently not reproducible by present displays.

[CCIR, 1986-90d]			[CCIR, 1986-90e]		
	x	y		x	y
R	0.630	0.340	R	0.6915	0.3083
G	0.310	0.595	G	0.0000	1.0000
B	0.155	0.070	B	0.1440	0.0297

There is also an agreement on the opto-electronic transfer characteristics of the source before the non-linear precorrection of item 1.1: it is assumed to be linear [CCIR, 1986-90a, e, d].

The assumed overall transfer characteristic is different (depending on the assumed gamma of the reproducer). In [CCIR, 1986-90e] it is 1.26. In [CCIR, 1986-90d] the overall gamma is 1.

In this last proposal, precise equations of the reference camera and a reference reproducer are defined, specifying a maximum gain of 4 in the camera non-linear precorrection. It is noted that this will limit the contrast range achievable (with an overall gamma of 1) to 40:1 but it does provide a small reduction of noise and an improved accuracy of conversion between linear and non-linear forms.

Even if defined in a different way, there is an agreement on the conceptual non-linear precorrection of signals following a power law with an exponent gamma = 0.45 [CCIR, 1986-90a, d and e].

IWP 11/6 has established an Expert Group to propose values for parameters of colorimetry and transfer characteristics. See [CCIR, 1986-90f].

2. Image characteristics

There has been extensive discussion of those aspects of a standard that are related to the way in which the television picture is to be constructed to achieve a single world-wide studio standard as desired by all administrations.

The difficulty lies in a determination as to a means of reaching that goal, particularly because of the problems associated with the field or picture frequency.

In addition to the direct one-step approach to a single standard, papers have been presented suggesting two essential approaches to the above problems. One of these is a "common image format" standard which could be used at a picture or field frequency to suit applications. The other is based on the "common data rate" concept inherent in Recommendation 601.

The "common image format" standard approach is based on the long-term desirability of a picture structure that is not tied to the current television format in the expectation that a multiplicity of information sources will be available to the consumer and that the present scanning structure may not be an optimum form of display. One proposal is a structure of 1920 horizontal pixels per active line (related to Recommendation 601) by 1080 vertical pixels per picture results in square pixels.

The "common data rate" approach recognizes the possible economic and operational problems of moving away from present scanning formats (i.e., 625/50 and 525/59.94) in the short- to medium-term. Such an approach may be considered as a path to a single world-wide studio standard and not as an end in itself [CCIR, 1986-90g].

The parameters on which no agreement has yet been reached and on which urgent studies are required are those of:

- Spatial characteristics
  - pixel shape or pixel aspect ratio - a square pixel is seen as a desirable objective but leads to line standards that are not directly relatable to the current formats;
  - number of active lines per picture - this parameter is set by definition if pixel shape is determined to have a fixed value;
- Temporal characteristics
  - interlace - this can affect the spatial characteristics;
  - picture rate - see § 3 below;
  - sampling frequency - this is a function of line rate, picture rate and the number of samples per line. Some contributions state that there are significant economic and operational advantages to be gained by the adoption of formats having equal data rates.

The parameter values for the picture aspect ratio (16:9) and the number of samples per active line (1920) are agreed and hence, for the case of "common image format", the number of active lines per picture and pixel aspect ratio are mutually interdependent. In the case of "common data rate", the total number of lines and the picture rate are interrelated and related with the common sampling frequency.

Document [CCIR, 1986-90h] states that 1792 samples per active line and 1024 active lines per frame produce square pixels. Also, the numbers are multiples of 256, a more convenient number when computer applications are envisaged and CCD sensors and digital flat panel displays are employed. This also modifies the aspect ratio to be 7:4, however, this is very close to 16:9.

3. Scanning characteristics

There are two major factors to be considered in the selection of a picture rate:

- motion portrayal; and
- the relationship with film and with current future TV systems.

Motion portrayal is influenced mainly by the picture rate selected and dynamic resolution is improved by the introduction of shuttering in the camera.

Both the picture rate and the interlace ratio are significant for a number of well known reasons.

4. Signal format

In [CCIR, 1986-90e] the colorimetry of the system is based on constant luminance and new primaries. Care was taken in the definition of these primaries in order to allow a compatible emission of the HDTV signals in an HDMAC form.

The influence of such a new concept on component signals is important and a background of this choice is given in [Melwig and Schafer, 1988]. The better separation, by constant luminance coding, of luminance and chrominance signals allows an increased sharpness in colour and increased resistance to interference on the chrominance channel. The concept opens the doors to an improved use of new display technologies with an enlargement of the reproducible colours.

Current television systems (see Report 624) derive the transmitted luminance and colour difference signals by the linear matrixing of the gamma-corrected primary signals E'_R, E'_G, E'_B as illustrated in Fig. A2 of [CCIR, 1986-90i]. The same principle is employed in the HDTV system described in [CCIR, 1986-90d] and in [CCIR, 1986-90a]. This approach gives good performance over a wide range of natural pictures and has a simple implementation.

[CCIR, 1986-90d]	[CCIR, 1986-90e]
$E'_Y = 0.212\ E'_R + 0.701\ E'_G + 0.087\ E'_B$	$E'_Y = (0.3392\ E_R + 0.6217\ E_G + 0.0391\ E_B)^{0.45}$
$E'_{P_R} = \dfrac{E'_R - E'_Y}{1.576}$	$E'_{C1} = 1.8\ (E'_R - E'_Y)$
$E'_{P_B} = \dfrac{E'_B - E'_Y}{1.826}$	$E'_{C2} = 0.8\ (E'_B - E'_Y)$

Full derivation of the E'_Y signal using the "constant luminance" principle is shown in [CCIR, 1986-90i]. The main difference, apart from the coefficient related to two sets of primaries, is in the derivation of the luminance signal where in one case a non-linear precorrection is applied before matrixing and in the other case after.

This is also being addressed by the Expert Group of IWP 11/6.

5. Analogue representation

It is common practice in current television systems to base composite video levels on a 1 V peak-to-peak amplitude, resulting in the picture component of the signal being of 700 mV peak-to-peak amplitude.

The HDTV system described in § 2.2 of Report AZ/11 is specified following this practice, with the luminance signal between 0 and 700 mV and the colour difference signals (bipolar) being between 0 and ± 350 mV. The system described in [CCIR, 1986-90e] specifies the luminance signal to lie between 0 and 1000 mV and the colour difference signals to lie between 0 and ± 650 mV. The variation between 0 and 1000 mV leads to a simpler relationship between equations and signals without impairing the processes.

6. Digital representation

These values are currently under study in IWP 11/7.

REFERENCES

MELWIG, R. and SCHÄFER, H. [1988] Colorimetry and constant luminance coding in a compatible HD-MAC system. IEE London Conference Publication No. 243 (IBC 88).

CCIR Documents

[1986-90]: **a**. 11/126 (EBU); **b**. IWP 11/6-2081 (USA); **c**. IWP 11/6-2073 (Canada); **d**. IWP 11/6-2030 (Japan); **e**. IWP 11/6-2023(Rev.1) (Belgium *et al*.); **f**. IWP 11/6-2108 (Canada); **g**. IWP 11/6-2048 (BBC); **h**. IWP 11/6-1041 (Italy); **i**. IWP 11/6-2061 (France).

DRAFT
RECOMMENDATION XB/11

SUBJECTIVE ASSESSMENT METHODS FOR IMAGE QUALITY IN HIGH-DEFINITION TELEVISION

(Questions 3/11 and 27/11)

The CCIR,

CONSIDERING

(a) that a number of Administrations and organizations throughout the world are currently evaluating high-definition television systems, and that in many parts of the world HDTV broadcasting is likely to become the primary medium of the next century;

(b) that subjective assessments are a vital element in HDTV system design and selection;

(c) that CCIR Recommendation 500-3 (MOD I) outlines a number of preferred subjective assessment methods for conventional television systems (625/50 and

525/60), many of the methodological details of which are also appropriate in the context of HDTV;

(d) that, nevertheless, it may be thought helpful to make clear the assessment methods and viewing conditions appropriate for HDTV, in the key areas currently under study, by a separate Recommendation,

[UNANIMOUSLY] RECOMMENDS

1. that subjective assessments of image quality of high-definition television systems should be made with the viewing conditions given in the Annex;

2. that subjective assessments of the overall quality of an HDTV image delivered by an emission system should be made using a double-stimulus continuous-quality scale method (Recommendation 500-3 (MOD I)) with the HDTV studio standard as reference*;

3. that assessments of the failure characteristics of an HDTV emission system should be made using a double-stimulus impairment scale method (Recommendation 500-3 (MOD I)) with either the image of the HDTV studio or the image of the unimpaired emission as reference*;

4. that, in the absence of a high-quality reference, the graphic scaling method or the ratio scaling/magnitude estimation method should be considered for assessments of overall quality of the image (before or after processing) provided by an HDTV studio system (see Report 1082 (MOD I));

5. that, when a high-quality reference is available, the double-stimulus continuous quality method (Recommendation 500-3 (MOD I)) should be considered for assessments of overall quality of the image (before, or after processing) provided by an HDTV studio system*;

6. that, in the interpretation of the results of particular studies, due note be taken of any real limitations that current technology may impose upon the results of the study (e.g., bounding effects of pick-up or display devices);

7. that care must be taken to distinguish the influence of the display format from that of the basic system format (e.g., any up-conversion). Assessments may be performed in order to take account of the different formats if applicable and appropriate.

* Report 1082 (MOD I) should be consulted for advice on possible linguistic differences in the use of the terms for quality and impairment.

ANNEX

TABLE I

Condition	Item	Values (1)
a	Ratio of viewing distance to picture height	3
b	Peak luminance on the screen (cd/m^2) (2)	150-250
c	Ratio of luminance of inactive tube screen (beams cut off) to peak luminance(3)	$\leq$ 0.02
d	Ratio of the luminance of the screen when displaying only black level in a completely dark room, to that corresponding to peak white (4)	approximately 0.01
e	Ratio of luminance of background behind picture monitor to peak luminance of picture	approximately 0.15
f	Illumination from other sources (5)	low
g	Chromaticity of background	D_{65}
h	Angle subtended by that part of the background which satisfies the specification above (6). This should be preserved for all observers.	53° H x 83° W
i	Arrangement of observers	within $\pm$ 30° horizontally from the centre of the display. The vertical limit is under study
j	Display size (7)	1.4 m (55 in)

(1) Values b and j are as specified in CCIR Report AT/11 (MOD Ex). As it may not be possible currently to achieve these conditions fully for tests, alternative values are given on an interim basis. It should be recognized, however, that the results of tests conducted under the interim conditions may not be, in general, comparable with those obtained in situations in which Report AT/11 (MOD Ex) presentation objectives apply.

(2) Peak luminance on the screen corresponding to the video signal with 100% amplitude. Values $\geq$ 70 cd/m^2 should be used until the specified level becomes technically feasible.

(3) This item could be influenced by the room illumination, as well as the contrast range of the display.

(4) Black level corresponds to the video signal with 0% amplitude.

(5) Room illumination should be set in order to make it possible to satisfy the conditions c and e.

(6) A minimum of 28° high x 48° wide is recommended.

(7) Values $\geq$ 76.2 cm (30") should be used if displays of the specified size are not available.

DRAFT
RECOMMENDATION XC/11*

RECORDING OF HDTV IMAGES ON FILM

(Question 18-2/11, Study Programme 18T-1/11)

The CCIR,

CONSIDERING

(a) the need of broadcasters and programme producers to transfer HDTV programmes to 35 mm films;

(b) the 16:9 aspect ratio established for HDTV image;

(c) the contents of ISO Standard 2906 concerning the image area produced by the camera aperture in 35 mm motion picture film,

[UNANIMOUSLY] RECOMMENDS

that when HDTV pictures are transferred to 35 mm film, the dimensions of the image on the film be as shown in Fig. 1 and Table I.

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* This Recommendation should be brought to the attention of the ISO.

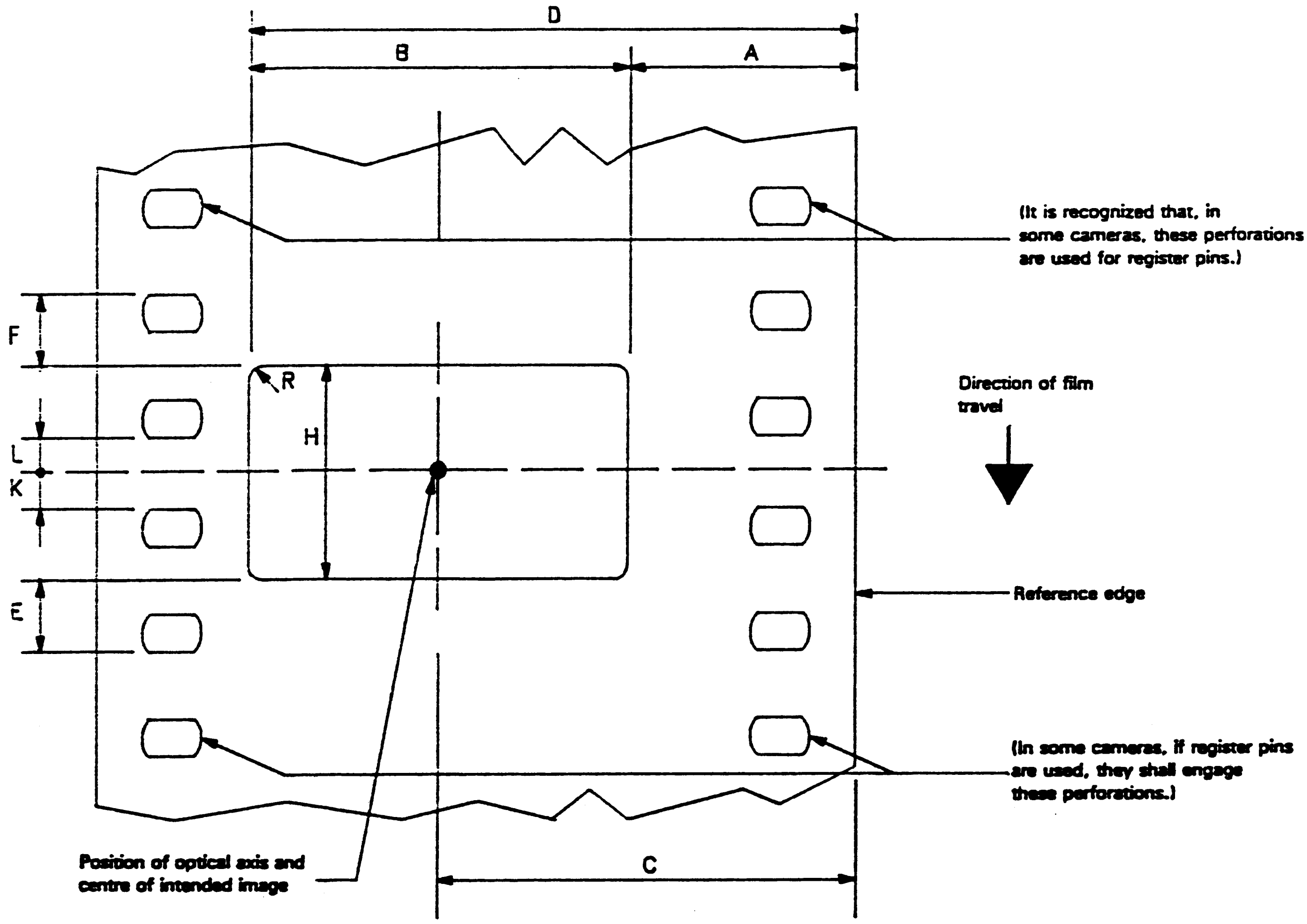

FIGURE 1 - *HDTV image on film*

TABLE I - *Numerical values of the HDTV image on film*

Dimension	mm
A (max)	7.80 *
B (min)	21.95 *
C (nominal)	18.75 *
D (min)	29.75 *
H	12.34 + 0.05 - 0.00
R (max)	0.8
K, L	approximately equal *
E, F	equal ± 0.1 *

* As specified in ISO Standard 2906

Note 1. - The measurements of the image are to be made on recently exposed and processed film.

Note 2. - The horizontal edge of the image shall be at substantially 90° to the edge of the film with the vertical edge parallel to the edge of the film.

Note 3. - Figure 1 shows the film image seen from the inside of the camera looking towards the lens.

REFERENCES

ISO [1984] ISO Standard 2906 - cinematography. Image area produced by the camera aperture on 35 mm motion-picture film.

DRAFT
RECOMMENDATION XD/11

INTERNATIONAL EXCHANGE OF PROGRAMMES ELECTRONICALLY PRODUCED BY MEANS OF HIGH-DEFINITION TELEVISION
(Question 18/11)

The CCIR,

CONSIDERING

(a) that there will be a need to exchange programmes produced in high definition television among broadcasters;

(b) that the programmes produced in high definition television and stored on videotape can be converted to 35 mm film at 24/25 frames/s but with some loss of spatial and significant loss of temporal resolution capability;

(c) that the conversion from film to high definition television may also result in additional loss of spatial resolution,

[UNANIMOUSLY] RECOMMENDS

that when programmes produced in high definition television are exchanged between broadcasters, in order to preserve the best quality, they should be exchanged in video form, e.g. live or videotape.

SECTION 11ExB - REPORTS

REPORT 801-3

THE PRESENT STATE OF HIGH-DEFINITION TELEVISION

PART 1 - INTRODUCTION

Television is one of the most widely available means of communication. Large screen, high-definition television is the target for the next step in television, and may bring about a new standard system which will be common throughout the world. It will perform the same function better and will also provide a powerful tool for other uses. These will include film production for the cinema and for television, printing, medical applications and scientific work.

The move to HDTV production offers new opportunities to simplify programme exchange and to bring together the production of programmes for television and for the cinema. A single standard would be beneficial to producers, as well as broadcasting organizations.

Figure 1, which is based on a suggestion by Prof. Krivocheev, is a simplified schematic of the expected future environment for HDTV, as it relates to broadcasting. The central element is the HDTV production centre, whose activities in programme production and programme exchange will be similar to those of today's production centre. While most of these activities will be in high definition, provision must be made to work with a number of other contribution formats, such as current 525- or 625-line television in analogue or digital forms, film, etc. The introduction of high-definition television offers a new opportunity to simplify the exchanges of both recorded and live programme material.

A feature of HDTV production is the capability to produce films suitable for projection in the cinema. Thus a high-quality video-to-film transfer process will be particularly important for the production centre.

HDTV signals from the production centre will pass to the delivery network at the broadcast distribution interface. Delivery to the viewer may use one of a number of possible methods including terrestrial broadcasting (e.g., VHF or UHF), satellites, cables (e.g., coaxial or fibre - optical fibres are considered to be one of the most promising transmission media for wideband HDTV) or pre-recorded media (e.g., cassettes or disks). Each has particular characteristics and, as a consequence, the HDTV signal must be converted into a form appropriate for each delivery method. This will be accomplished in an encoder or converter between the HDTV signal at the broadcast interface and the delivery medium.

The viewer's choice of delivery method may have some impact on the level of enhanced TV or HDTV service that he receives. The levels may include full-bandwidth HDTV, bandwidth-reduced HDTV, or enhanced 525- or 625-line television. (See also Report XK/11.)

The HDTV receiver in the home must be able to display the enhanced TV or HDTV services and it would be advantageous if it could also display other services such as 525- or 625-line television. Such a receiver would include the necessary signal processing to reconstruct, as accurately as possible, the image presented at the broadcast distribution interface. This processing may also include display up-conversion, noise filtering, etc. Depending on the broadcasting strategy adopted, 525- or 625-line home receivers may be able to derive a usable signal from the enhanced TV or HDTV service.

For operational considerations and from experience, it is clearly important that the interrelationships between each part of the HDTV network (from production, through contribution and distribution to emission) are taken into account in an overall evaluation of the complete HDTV system. Furthermore, it is necessary to form a view of how the new HDTV system would be implemented. This should bear in mind already existing arrangements for conventional television, and the operational and economic benefits/penalties that might arise under differing assumptions regarding studio, transmission emission standards and the distribution methods available.

Finally, the technology required for the complex signal processing involved in the broadcasting chain is keeping pace with the development of HDTV and benefits from its synergism with the technologies of data processing and of telecommunications. The evolution of suitable display devices for the home receiver still requires considerable effort.

At present, the first results on studies related to Study Programme 18U/11 have been collected [CCIR, 1986-90a]. It must be recognized that these studies must be intensified in close cooperation with such organizations as the IEC and ISO to take fully into account the requirements for implementation of HDTV for media other than broadcasting, i.e. cinema, printing, medical applications, scientific work and videoconferencing.

In addition, the transmission of HDTV signals via new digital transmission channels or networks has to be considered and taken into account, for instance, as defined in CCITT Recommendation I.121 "Broadband aspects of ISDD", adopted by the IXth CCITT Plenary Assembly at the end of 1988. For such new networks, the definition of new services, including those related to HDTV, have to be defined as expressed in a liaison statement [CCIR, 1986-90b] from CCITT Study Group I to CCIR Study Group 11.

Further progress in these studies may help the CCIR to complete the task of defining a full set of parameters of a single world-wide HDTV production standard.

This Report summarizes results of studies and experiments obtained in the world in technical developments under Question 27/11. See also Report 630 for video recording, and Report 1075 for satellite broadcasting.

Report XF/11 on objective measurements, Report AT/11 (MOD Ex) on subjective assessment, Report XE/11 on future developments of HDTV and Report XK/11 on the release of programmes in a multi-media environment are also relevant.

REFERENCES TO PART 1

CCIR Documents

[1986-90]: a. 11/336 (JIWP 10-11/4); b. 11/394 (CCITT).

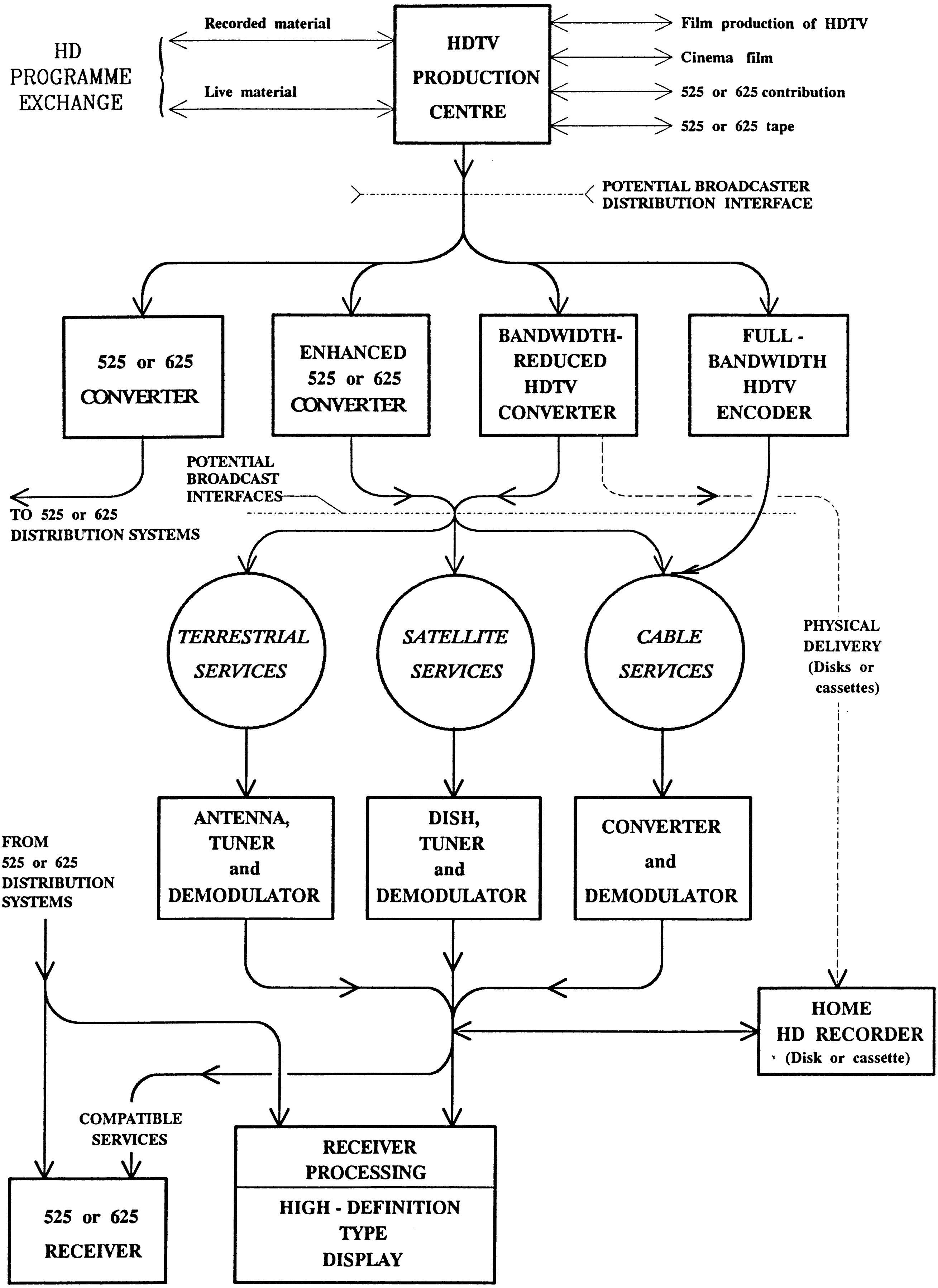

FIGURE 1 - *HDTV delivery - the future environment*

PART 2 - CCIR ACTIVITIES

The study of HDTV has been a concern in the CCIR for some years, with initial work on the basic principles of HDTV displays done during the 1974-1978 study period. The pace of the work has increased rapidly since that time and the study of all aspects of HDTV - from the camera, through recording, production, and emission, to the display - has been a serious and urgent concern. Work in the CCIR on HDTV has centred on Study Group 11, but recording and satellite emission studies are performed jointly with Study Group 10 in Joint Working Groups 10-11/R and 10-11/S, respectively. Transmission is studied in the CMTT.

The structures under which the work has been done, together with an indication of progress in the work, are briefly summarized as follows:

1. Early progress (1974-1986)

Work in the CCIR on HDTV began with adoption of Question 27/11 on high definition television.

Following adoption of Question 27/11, a number of Questions, Study Programmes, Resolutions and Decisions were adopted and/or modified to recognize, and to promote appropriate consideration of, HDTV.

In Study Group 11, two Study Programmes were created in response to Question 27/11: 27A/11, which concerns the compatibility of HDTV with existing standards and broadcast channel assignments, and 27B/11, which concerns display technologies for HDTV.

During the period 1974-1986, Questions 1/11 on colour television standards and 2/11 on the exchange of television programmes were modified to consider HDTV. Study Programmes 2B/11 on conversion among scanning standards, and 3A/11 on subjective quality assessments also took note of HDTV.

In addition, Study Group 11 adopted Decision 58, which established IWP 11/6 to study HDTV and made provision for HDTV in Decisions 60 (IWP 11/7 on digital television) and 66 (IWP 11/4 on subjective assessments), and in conjunction with Study Group 10, Decision 59 on video recording. The XVIth Plenary Assembly adopted Resolution 96, which anticipated the need for an Extraordinary Meeting on HDTV during the latter part of the 1986-1990 study period.

In conjunction with Study Group 10, Study Group 11 adopted two Study Programmes on HDTV recording, 18S/11 (Recording of HDTV programmes) and 18T/11 (Recording of HDTV on film). Furthermore, the Study Groups modified Questions 2/10 and 11 (System characteristics for satellite service) and created or modified Study Programmes 1E/10 and 11 (Sharing studies), 2F/10 and 11 (Satellite television standards), 2M/10 and 11 (Satellite broadcasting of HDTV and 2N/10 and 11 (Integrated services) to take account of the need for studies in HDTV. In addition, the Study Groups prepared Decision 51 (JIWP 10-11/3, Satellite broadcasting of HDTV) to stimulate studies on satellite broadcasting of HDTV.

2. Progress since 1986

Prior to the 1987 Interim Meetings, considerable work was done in Study Group 11 on HDTV, particularly in IWP 11/6. Moreover, at the Interim Meetings, the Chairman of Study Group 11 initiated a review of Questions, Study Programmes, and Decisions in order to stimulate and coordinate work in HDTV. As a result, Study Programmes 25H/11 (Filtering and sampling in digital encoding), 25M/11 (Measurement and monitoring) and 25J/11 (now AL/11, Bit rate reduction in digital coding) were modified to consider aspects of HDTV. Furthermore, two new draft Study Programmes were adopted to include aspects of HDTV: 25N/11 on interfaces for digital signals and 3E/11 on subjective assessment of HDTV. The Study Group also adopted Decision 74 which called for the Extraordinary Meeting on HDTV and modified Decisions 42 (IWP 11/5, Protection ratios), 58 (IWP 11/6, HDTV standards), 60 (IWP 11/7, Digital television) and 66 (JIWP 11/4, Subjective assessment) to permit additional work and coordination of activities.

At the Interim Meeting, Study Group 11 retained Report 801-2 (The present state of high definition television) which had been prepared in the previous study period. It also prepared four new Reports on aspects of HDTV: AW/11 (Approaches to a unified world-wide digital HDTV studio standard), AZ/11 (A progress report on high definition television), AU/11 (A global approach to HDTV systems) and AT/11 (The subjective assessment of high definition television pictures). JWG 10-11/S updated Report 1075 (High definition television by satellite). JWG 10-11/R adopted Report AQ/11 (Recording of HDTV programmes on cinematographic film).

In conjunction with Study Group 10, Study Group 11 further modified Study Programme 18T/11 (Recording of HDTV on film) to take account of the need for international exchanges and prepared new Study Programme 18U/11 (Transfer of HDTV programmes to non-broadcast consumer media) to take account of non-broadcast uses. Furthermore, the Study Groups amended Decision 51 (JIWP 10-11/3, Satellite broadcasting of high-definition television (HDTV) signals and accommodation of several audio and/or data signals and/or picture signals in terrestrial and satellite broadcasting channels) to take further account of the need for greater study and coordination in HDTV. JIWP 10-11/5, in the context of Decision 72, presented contributions on data broadcasting in an HDTV environment.

At the Extraordinary Meeting, Study Group 11 reviewed existing Questions, Study Programmes and Decisions with a view to further responding to its responsibilities in HDTV. The specifics of the Study Group's progress at the Extraordinary Meeting are given in the remainder of this document.

PART 3 - GENERAL CONSIDERATIONS OF HDTV SYSTEMS

1. Definition of high-definition television

A high-definition system is a system designed to allow viewing at about three times the picture height, such that the system is virtually, or nearly, transparent to the quality of portrayal that would have been perceived in the original scene or performance by a discerning viewer with normal visual acuity. Such factors include improved motion portrayal and improved perception of depth.

This generally implies in comparison with conventional television systems:

- spatial resolution in the vertical and horizontal directions of about twice that available with Recommendation 601;

- any worthwhile improvements in temporal resolution beyond that achievable with Recommendation 601;

- improved colour rendition;

- a wider aspect ratio; and

- multi-channel high fidelity sound.

Note. - Sound systems for HDTV are the subject of Question 47/10.

2. Media outlets to be supplied by HDTV

HDTV production will be used to provide source signals for a variety of media outlets. These could include the following possibilities:

- BSS in the bands above 12 GHz;

- services in one or more WARC BS-77 channels;

- services in one or more RARC BS-83 channels;

- motion picture origination;

- electronic displays in theatres;

- terrestrial broadcast services or cable networks; and

- domestic tape or disc systems.

A single standard could be beneficial to programme producers as well as broadcasting organizations and viewers.

This Report summarizes results of studies and experiments obtained in the world in technical developments under Question 27/11. See also Report 630 for video recording, and Report 1075 for satellite broadcasting.

3. Picture presentation objectives

3.1 *Preferred angle of view*

When observers are closer to pictures, the area occupied by the pictures in their viewing field increases, and this gives observers an increased feeling of involvement in the space created by pictures. This increased sensation of reality becomes apparent when the viewing angle exceeds 20° [CCIR, 1982-86a].

3.2 *Viewing distance*

Experiments using still-picture slides show that viewing distances of $2H$ to $3H$ (H stands for the picture height) are preferred. This corresponds to a viewing angle of 40° to 30°. When pictures are moving, however, the preferred viewing distance is closer to $3H$, because of the additional factor of dizziness.

If the viewing distance is too small, observers experience eye fatigue after a certain time. It is therefore desirable to limit the minimum viewing distance to 2 m [CCIR, 1982-86a].

3.3 *Display size*

From subjective assessments on the sensation of reality with different sizes of picture and with various viewing angles, it seems that larger size pictures generate a larger sensation of reality for a constant viewing angle and a picture area of more than 0.8 m^2 can be considered appropriate for HDTV [CCIR, 1982-86a].

3.4 *Contrast and brightness*

From various experiments on television picture display, it is considered appropriate to take 50:1 as the minimum contrast ratio for HDTV.

Taking account of the effect of ambient illumination on the screen, a peak picture brightness of 150-250 cd/m^2 can be considered appropriate as the brightness for HDTV [CCIR, 1982-86a, b].

4. Fundamental considerations on basic parameters

4.1 *Aspect ratio*

Wider aspect ratios increase the observers involvement in the pictures. Various psychophysical experiments have shown that, depending upon the size of the picture, a wider aspect ratio ranging from 5:3 (1.67:1) to 2:1 would be attractive for HDTV. Experimental equipment has been made with an aspect ratio of 5:3 [CCIR, 1982-86a].

Further studies by one administration have shown that by increasing the aspect ratio to 16:9 (5.33:3, 1.78:1) and using the traditional movie industry technique of "shoot-and-protect" (centering the action in the smallest common area), compatibility can be achieved with most current movie film of aspect ratios ranging from 4:3 (1.33:1) to 2.35:1 [CCIR, 1982-86c].

4.2 *Horizontal sampling*

The definition of HDTV given in § 3.3 defines the horizontal resolution for HDTV as being twice that of current conventional television systems. Recommendation 601 defines a sampling system for the current 625/50 and 525/60 television standards as requiring 720/360 samples (luminance signal/colour difference signal) for the digital active line period. To achieve twice the resolution would require 1440/720 samples per digital active line period for a picture with the same aspect ratio.

For the wider aspect ratio being discussed for HDTV, the number of samples per digital active line period must be increased by the ratio of the new aspect ratio to the current 4:3 aspect ratio. For example, in the case of an aspect ratio of 16:9, the corresponding number of samples per digital active line period would be 1920/960.

The total number of samples per line would include the number of samples required for the line-blanking period. Although the need for line-blanking period can be eliminated by the use of appropriate stores, there are practical limitations in electron-beam cameras and in display devices which make a line-blanking period essential in the short term [CCIR, 1982-86b].

4.3 *Vertical sampling (number of active lines per frame)*

Various studies, relating visual acuity to static vertical resolution and the viewing distance, have shown that the static vertical resolution, as viewed on a television monitor, is affected by the scanning method (interlace or sequential), the frame/field rate and the persistence of the display device.

In an experiment using a monochrome system with a 69 cm (27 in) high-resolution cathode-ray tube display, sharpness improvement by increasing the number of lines began to saturate at about 1500 lines with 2:1 interlace for a viewing distance of $3H$ [CCIR, 1978-82a], and with 2125 lines, sufficient sharpness was obtained at a viewing distance of $2H$ [CCIR, 1974-78].

For a television picture with 2:1 interlace and a viewing distance of three times picture height, at least 1000 active lines are required to achieve twice the vertical resolution of current television systems [CCIR, 1982-86b].

It has been shown in recent studies that with more than 1000 active lines, the resolution would compare favourably with that of 35 mm film theatrical presentation, which has historically been perceived as the high quality presentation format [Hayashi, 1981; Kaiser *et al.*, 1985].

If the number of active lines is greater than 1024, an additional bit is required in the address circuit of picture processing equipment [CCIR, 1978-82b].

4.4 *Temporal sampling (field frequency)*

There are two distinct issues associated with this topic. The first is dynamic resolution which refers to the spatial resolution for images which move. The second is repetition rate which is determined by the criterion of smooth motion portrayal.

The dynamic resolution is determined by the integration time of the photo-sensitive material used in the camera and the temporal sampling rate determined by the field frequency [CCIR, 1982-86b].

Tests by the BBC using camera pictures sequentially scanned and displayed at 50, 60, 70 and 80 Hz frame-rates have demonstrated a progressive improvement in quality on moving picture detail as the field rate is increased. Picture quality at 80 Hz was judged to be two grades better than at 50 Hz, and one grade better than at 60 Hz for representative rates of continuous motion [Childs and Tanton, 1985; CCIR, 1982-86d].

Dynamic resolution can also be improved by reducing integration time by shuttering. Experiments carried out with 60 Hz cameras have shown that the integration time can be reduced by 25% without impairing motion portrayal and with corresponding improvement in dynamic resolution. Camera sensitivity and temporal aliasing penalties should be studied further [CCIR, 1982-86b].

The field and frame frequency of the television signal also determines, in a simple system, the refresh rate of the display. It influences the perception of large area flicker [CCIR, 1982-86e]. It is, however, not essential that the refresh rate be the same as the television signal field-rate. This is discussed further in § 4.8 below.

4.5 *Scanning structure (interlace or sequential scanning)*

It has been reported that the distraction caused by scanning lines with a 2:1 interlace is about the same as that caused by sequential scanning with 40% fewer lines [CCIR, 1978-82a]. However, under these conditions the sequentially scanned signal would require 20% more bandwidth.

The interlaced scanning structure under certain conditions may introduce a display artifact referred to as "interline twitter" and "line crawl"; these artifacts are also related to the sources and display characteristic as well as to the frame-rate and the number of scanning lines per frame. It is desirable to avoid the occurrence of these artifacts. In interlaced systems, the spatially adjacent lines are dislocated in time, thereby introducing complexities in signal processing [CCIR, 1982-86b].

In the case of a basic interlaced studio standard, the hierarchical progression of interlace to sequential scanning may be considered in two ways. It may be possible to use sequential scan in parts of the studio chain or in the display where the two-fold increase in bandwidth requirement can be accommodated. The other use of a hierarchical approach would be to evolve from interlace to sequential in the future as the technological constraints imposed by doubling the bandwidth requirement become less severe [CCIR, 1982-86b].

4.6 *Colorimetric aspects*

It is very important to establish an optimum colorimetric system within the HDTV system in order to provide high colour fidelity. Compatibility with existing conventional systems may be regarded as a second priority.

Discussions on the colorimetric aspects can be found in [CCIR, 1982-86b and f; Powell, 1985]. The following are the main issues considered:

4.6.1 *Choice of primary colours*

Sets of primary colours have been proposed which include XYZ primaries, the present EBU phosphors and the present NTSC phosphors.

It was suggested that the colour primaries selected should be widely separated so as to reproduce the widest possible range of colours, yet not so widely separated that they cannot be realized by available phosphors with sufficiently good conversion efficiency.

Further study is needed, preferably in association with manufacturers of picture tubes, to establish whether more recently developed phosphors can provide a better set of primaries, and if so, whether they would be sufficiently different from one of the two existing standards to justify change [CCIR, 1982-86b].

4.6.2 *System reference white*

There seems to be general agreement to adopt illuminant D65 for the reference white of the HDTV system. An adaptively switched white balance has also been proposed [CCIR, 1982-86b].

4.7 *Gamma correction*

In order to fulfill the constant luminance principle, a system having gamma correction only at the receiver has been considered in contrast to the current television system where gamma precorrection is applied before luminance and colour-difference signal matrixing [CCIR, 1982-86b]. When displays other than CRT are used, or inter-system conversion is required, the required additional corrections add further distortions [CCIR, 1982-86f].

In the new proposal, processing is carried out with signals which are linearly proportional to the light input. However, a non-linear transmission-reception amplitude characteristic must be introduced, otherwise dark areas of the picture become more sensitive to transmission noise. Further discussion can be found in [CCIR, 1982-86b; Schafer and Golz, 1984; Yuyama and Yano, 1984].

4.8 *Display flicker*

Subjective tests carried out by one administration have shown that, using CRT technology, for a screen brightness of 150 cd/m^2 and a field-rate 60 Hz, large area flicker is visible but not disturbing. At a field-rate of 50 Hz and a screen brightness of 60 cd/m^2 the flicker was judged annoying [CCIR, 1982-86b]. Another administration carried out tests using a light source and a variable duration shutter. The tests showed that large area flicker at a brightness of 200 cd/m^2 became imperceptible at frequencies greater than 80 Hz [CCIR, 1982-86e].

New display devices under development (e.g. light valves) show display characteristics different from those of CRT based systems and may therefore provide improved flicker behaviour.

Using frame stores and, when necessary, interpolation electronics, the display refresh rate can be higher than the television signal field-rate [CCIR, 1982-86b]. This allows for the possibility of removing large area flicker by display processing, however, it is likely to impose a cost penalty, and possibly a quality penalty [CCIR, 1982-86g].

4.9 *Lighting flicker*

In an environment where the shooting field-rate is not the same as the local electrical mains frequency, beat frequency flicker can occur in certain circumstances. This situation has long existed in Japan, and techniques used for reducing the visibility of this flicker have been reported [CCIR, 1982-86b and h]. This problem is probably solvable, and need not weigh heavily in the choice of field-rate, although further work is required to confirm this [CCIR, 1982-86g].

4.10 *Hum*

Power-supply hum effects on vision can be removed by proper design of equipment [CCIR, 1982-86i].

4.11 *Bandwidth and noise considerations*

Subjective evaluation tests regarding the required bandwidth were carried out for the 1125-line system as a first step of the study. Values of 20 MHz and 7 MHz were obtained for the luminance and colour-difference signal respectively [CCIR, 1974-78].

A noise weighting function which can be applied to systems which differ in the number of lines and in aspect ratio has been reported, and is being used for the calculation of transmission parameters [CCIR, 1978-82a].

5. **HDTV operations including motion picture production**

5.1 *Studio production*

Many documents describe or relate production experiences or commercial productions in North America, Japan and Europe, using 1125/60/2 HDTV equipment, in the range from sporting events to full-length features for cinematographic distribution [CCIR, 1986-90a and b] and more particularly, [CCIR, 1986-90c] reports that drama programme was produced film style, in a successful manner both technically and economically, with further satisfactory conversion into NTSC and PAL.

[CCIR, 1986-90d] reports CBS experience with drama production on location for release in the NTSC format. Results were also excellent on all accounts: resulting picture quality, cost, reliability of equipment, and the ability for film crews to conduct the field shoot.

[CCIR, 1986-90e] reports that another drama entitled "long way from home" was produced entirely by electronic means, giving to people from TV production the occasion to learn much about, not only the special effects, but also how to cope with HDTV including production techniques, control of production process and artistic designs.

In [CCIR, 1986-90f], it is also reported that 1250/50/2 HDTV equipment was used before the IBC 88 (Brighton) for programme production by the RAI, ITVA and the BBC.

5.2 *HDTV and film* [CCIR, 1986-90g]

A 90-min feature-length film, "Julia and Julia", produced on HDTV by RAI was converted into a 35 mm film shown on the screen throughout the world. In Japan, motion pictures, parts of which had been made through special effects on HDTV and montaged onto a 35 mm film, were released for theatres under the titles of "Saiyuki" and "Teito Monogatari", among others. HDTV was used to make a total of 10 to 20 min of each of these movies.

5.3 *Non-broadcast applications*

[CCIR, 1986-90g] reports on the interest of non-television broadcasting industries in the application of high definition television technology. If the HDTV production standards can be established to meet the needs of the varied non-broadcast industries there can be significant benefits to all from the resulting larger market for HDTV equipment.

Printing

One publishing company has put on sale a book consisting of images originating on HDTV videotapes and transferred to magnetic data tapes for printing. Pictorial postcards made in a similar way are also on the market. An HDTV test chart for electronic publishing is also being provided.

Events with HDTV theatres

At a restaurant in Tokyo, a drama on 35 mm film "Teito Monogatari" was shown through an HDTV telecine and 110-in rear-projection display. In another instance, HDTV programmes were transmitted from Tokyo to Nagoya through a communication satellite using the MUSE signal and shown on large screens for a test of programme distribution to remote theatres [CCIR, 1986-90h].

5.4 *Cable distribution*

Document [CCIR, 1986-90i] describes the current status of television distribution in the United States of America and points out the importance of cable distribution in the HDTV environment. The document reports that in the United States of America approximately 83% of the television homes are passed by cable lines and could receive cable feeds if desired. At present, approximately 52% of these television homes subscribe to cable.

Document [CCIR, 1986-90j] describes experiences with MUSE CATV transmission. Two different transmission experiments are described, FM transmission and VSB-AM transmission. The FM transmission experiment was performed with 400 MHz frequency modulation. When a two-hop microwave link was connected in tandem with an optical fibre link and nine trunk amplifiers at the far end, the unweighted S/N was over 50 dB and the television pictures were said to be excellent.

An experiment on CATV transmission with VSB-AM modulation was also performed with no deteriorations observed either in the MUSE signal, or in the conventional television signals.

In [CCIR, 1986-90k], it is reported that AM/VSB and FM/VSB have been proposed for HDMAC cable distribution. AM/VSB is applied to the time multiplex baseband signal. The use of a channel spacing of 12 MHz has been demonstrated and is recommended as a common standard. The VSB Nyquist filtering is in the range of = 500 kHz around the carrier and for compatible reception shall be the same as for MAC/packet distribution. The HD-Nyquist roll-off factor and the sharing between transmitter and receiver is under study. FM/VSB has also been demonstrated. It requires the use of a channel spacing of 16 MHz. Modulation parameters are under study.

6. Operational considerations and experiences

6.1 *Operational consideration on standards conversion in relationship with conventional TV and HDTV emission standards*

Decision 58-1 requests studies that will lead to a single world standard for the production studio and for the international exchange of HDTV programmes. Studies have concluded that there also exists an identifiable relationship between the parameters in § 1.1 of Part 5 and emission systems.

Only the problem of introducing a 60 Hz based HDTV studio standard into a 50 Hz broadcasting environment was studied [CCIR, 1986-90l]. The study had the objective of establishing whether the advantages of a common 60 Hz production standard would outweigh any technical, economic, or operational disadvantage of having different field-rates for production and emission.

For example, [CCIR, 1986-90m] argues that converting from 60 Hz to a 625/50 TV standard requires an expensive field rate standards converter, whereas the use of 50 Hz HDTV needs a line rate standards converter which is 10 to 40 times less expensive.

In Document [CCIR, 1986-90m] it is stated that broadcasting at 50 f/s of film originated material will lead to cascaded temporal interpolation (24 f/s to 60 f/s to 50 f/s). This could result in complex and possibly costly processing to avoid impairments.

This is why, over a period of several years, the EBU studied various aspects of standards conversion [CCIR, 1986-90n]. Initially a technical appraisal was made which concluded that HDTV to HDTV frame rate conversion at high quality should be possible in future, though relatively expensive, through the use of motion estimation and compensation. This was followed by a study of the operational and economic consequences of using the same or different field rates for production and emission of HDTV in a 50 Hz environment. This concluded that of the scenarios examined the use of a 60 Hz field rate for HDTV production, in a 50 Hz environment, was the least favourable scenario. The extent to which a 50 Hz - 50 Hz situation was more favourable than a 60 Hz - 60 Hz situation depended on the broadcaster's configuration.

Document [CCIR, 1986-90o] reports that similar studies have been pursued [CCIR, 1986-90p] on a simplified model of a national network and its evolution towards DBS programme provision. Two options for the choice of HDTV studio field rate are compared:

Option A: HDTV studio standard has the same field rate of the HDTV emission standard (i.e., 50 Hz);

Option B: HDTV studio standard has a different field rate from the HDTV emission standard (i.e., 60 Hz).

There were five possible standards conversions under these options.

A preliminary conclusion is that Option A is clearly more attractive than Option B since line-rate converters are both cheaper and capable of higher performance than field rate converters. Furthermore, the number of converters for category 5 is very much lower than for categories 2, 3 and 4.

Finally, it is noted that a similar argument would apply in 60 Hz countries, if there were a 50 Hz studio standard.

This preliminary conclusion raises the question for some administrations as to whether the relative benefits of a pair of production standards (based upon Recommendation 601) would exceed those of a single world-wide production standard [CCIR, 1986-90p].

6.2 *Operational considerations on film-to/from-video transfers*

Document [CCIR, 1986-90q] reports on studies that show that when operated under the same conditions HDTV cameras have similar transfer characteristics of 35 mm colour film.

Document [CCIR, 1986-90r] reports on the work of the SMPTE in their investigation of using 30 f/s for film production and distribution. The conclusions of the SMPTE Study Group are that the increase in frame rate from 24 f/s to 30 f/s significantly improves the quality of the projected images by virtue of permitting higher screen brightness without full-field flicker and by increasing the dynamic resolution.

Document [CCIR, 1986-90s] states that in the production of programmes there is a trend in film production for television towards original capture at 30 f/s, so that there would be only one temporal conversion in going to a 24 f/s or 25 f/s system.

[CCIR, 1986-90s] points out that 63% (3640 hours) of the total hours of programming produced in "Hollywood" are for "first run" TV distribution in the United States of America at a field rate of 60 Hz and then are distributed world-wide in various formats. The remaining hours of programming are for presentation in the cinema.

The document goes on to consider frame-rate-related performance parameters and concludes that the 1125/60 studio systems of Annex II of Report 801 is a superior system from the viewpoint of conversion to other formats.

*HDTV to film transfer**

[CCIR, 1986-90t] states that the converters from 1125/60/2:1 HDTV to 24-frame film system, have been developed and are currently being used satisfactorily.

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* For further information see draft Recommendation XC/11.

[CCIR, 1986-90m] states that the combination of film and HDTV-60 Hz originated material for final release on film, will lead to the cascading of temporal interpolations (24 f/s to 60 f/s to 24 f/s) unless special precautions are taken to avoid impairments.

Document [CCIR, 1986-90m] also argues that the use of a 50 Hz studio standard would ease and therefore reduce costs of this process and more generally ease the combination of film and HDTV production. (In particular, no artifacts caused by cascading temporal interpolation should be foreseen.)

In the case of the transfer of electronically recorded signals onto film, the interlaced nature of conventional television standards causes additional problems, since vertically adjacent lines on the final film frame originate from different television fields. This results in "combing" being produced on the edges of moving objects; there is also an increased level of motion blur due to the effective exposure period produced when two television fields are combined. Alternatively, the combing and motion blur can be eliminated by recording only a single television field instead of a pair; in this case the penalties are a loss of vertical resolution and an increase in the visibility of line structure in the final image [CCIR, 1986-90u].

Film to HDTV transfer *

The film frame rate used internationally for motion picture films is 24 f/s. Present-day practice for broadcasting such films varies between countries with 50 Hz field rate television systems and those with 60 Hz systems. In countries having a 60 Hz field frequency, two successive film frames are used to form five television fields; this is accomplished by repeating the first frame twice and the second three times. The effect of the repetition process is to produce beat-frequency judder at 12 Hz on moving objects; this is, of course, in addition to the normal 24 Hz judder due to the film frame rate itself. More sophisticated techniques have been reported [Childs, 1985], which use temporal interpolation to smooth out the judder, but a compromise between judder and excessive motion blur is always necessary.

In countries having 50 Hz field frequencies, films are almost invariably shown at a slightly increased speed of 25 f/s, in order to simplify the conversion process [CCIR, 1986-90u].

[CCIR, 1986-90v] reviews the HDTV-film interface in viewpoints of the difference between 24 and 25 f/s, degradation due to field repetition in 50 Hz system, and a possible solution with motion compensation technologies. It expresses a view that the interface issue cannot be a decisive factor to choose 50 Hz for the field rate of the world-wide unique HDTV studio standard.

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* For further information see Reports 294 and XJ/11.

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[1974-78]: 11/38(CMTT/13) (Japan).

[1978-82]: **a.** 11/76 (CMTT/58) (Japan); **b.** 11/317 (USSR).

[1982-86]: **a.** 11/269 (Japan); **b.** 11/398 (IWP 11/6); **c.** 11/258 (USA); **d.** 11/283 (United Kingdom); **e.** 11/304 (France); **f.** 11/377 (Canada); **g.** 11/405 (EBU); **h.** 11/403 (Japan); **i.** 11/329 (EBU).

[1986-90]: **a.** IWP 11/6-1034 (CBS); **b.** IWP 11/6-2029 (CBS); **c.** IWP 11/6-1017 (Canada); **d.** IWP 11/6-2024 (CBS); **e.** IWP 11/6-2036 (Japan); **f.** IWP 11/6-2056 (Rev. 1) (Thomson CSF); **g.** IWP 11/6-2025 (CBS); **h.** IWP 11/6-2032 (Japan); **i.** IWP 11/6-2019 (USA); **j.** IWP 11/6-2041 (Japan); **k.** IWP 11/6-2096 (France); **l.** IWP 11/6-1040 (EBU); **m.** 11/160 (France); **n.** IWP 11/6-2008 (EBU); **o.** IWP 11/6-1033 (CBS); **p.** IWP 11/6-1062 (UK); **q.** IWP 11/6-2027 (CBS); **r.** 11/135 (CBS); **s.** 11/133 (CBS); **t.** IWP 11/6-1066 (Japan); **u.** IWP 11/6-2046 (Belgium et al.); **v.** IWP 11/6-2087 (Japan).

PART 4 - ASSESSMENT OF HDTV QUALITY

1. Introduction

Aspects of the subjective and objective assessment of HDTV were examined at the Extraordinary Meeting of Study Group 11. Ten documents were considered in addition to existing CCIR texts. Particularly significant to the work were the thorough contributions on subjective assessment received from Interim Working Party 11/4 and a draft new Report on objective measurement from IWP 11/6.

In the interest of presenting a concise and readable report of the activities of the Extraordinary Meeting of Study Group 11, in HDTV quality aspects: first, the meeting adopted Report AT/11 (MOD Ex) (The subjective assessment of systems associated with an HDTV environment) and Report XF/11 (Measurements in HDTV).

The Extraordinary Meeting also adopted the following texts:

- draft Recommendation of subjective assessment methods for image quality in HDTV (Draft Recommendation XB/11);
- new Study Programme 3E/11 on subjective assessment procedures for signals originating in an HDTV studio;
- new Study Programme 27C/11 on objective measurement in an HDTV environment.

The text of Decision 66-1 (MOD I) was also examined by the meeting, but was still found to be complete and relevant and no modifications were proposed.

2. Summary of draft new Report AT/11 (MOD Ex)

Report AT/11 (MOD Ex) is a dossier of current knowledge on subjective assessment methods for high-definition television. The document considers assessments of HDTV studio formats, of conventional studio pictures derived from HDTV studio formats, of HDTV emission systems derived from HDTV studio formats, and of compatible pictures received in HDTV emissions. The document also considers comparative assessments of HDTV studio formats and of HDTV emission formats.

2.1 HDTV studio formats

For assessments of basic quality, the double stimulus continuous quality scale method (DSCQ) is suggested. The reference should provide quality superior to that of the system under test (e.g., a directly viewed scene or performance). The test materials should permit attribution of subjective reactions to specific attributes, such as: static and dynamic resolution; luminance, colour, and motion rendition; flicker, etc.

For assessments of quality following various types of downstream processing, different methods are suggested. Assessments of colour matte could use the double stimulus impairment scale method (DSI), with test materials critical for colour matte operations. For slow motion and other picture manipulations, in the absence of a high-quality reference, the ratio scaling method has been suggested and alternative methods are under study. For HDTV-HDTV studio standard conversions, primary assessments might use the DSCQ method with briefly presented critical test materials, while auxiliary assessments might use the single stimulus continuous quality scale method (SSCQ) with lengthier presentations of less critical material.

In all cases, viewing conditions would be as given in draft Recommendation XB/11 (Subjective Assessment Methods for Image Quality in HDTV). In interpreting the results, however, it is necessary to allow for possible influences in the technical state of implementation of the HDTV studio system.

2.2 Conventional studio formats derived from HDTV studio formats

For evaluations of the small impairments and the limited range of impairments to be expected, the DSCQ method is thought the most useful. In the tests, assessors would view pairs of presentations, of which one would be prepared directly in the conventional format, while the other would be converted from the HDTV studio format. The viewing conditions should be in accordance with those given in Recommendation 500-3 (MOD I).

2.3 HDTV emission systems

For basic quality, primary assessments might use the DSCQ method with the studio system as reference, while auxiliary assessments might use the SSCQ method. In the former case, displays would be brief and use material that was "critical, but not unduly so" while, in the latter case, displays would be lengthier and would use material representative of normal programming.

For assessments of failure characteristics, echo behaviour, and interference, the DSI method might be used, with the studio system and/or the unimpaired emission format as reference. The test materials would be brief and "critical, but not unduly so".

For all evaluations, the viewing conditions would be as given in draft Recommendation XB/11 (Subjective Assessment Methods for Image Quality in HDTV).

2.4 Compatible pictures received in HDTV emissions

For basic quality, the DSCQ method might be used with material prepared directly in the conventional emission format and/or material converted directly from the HDTV studio format as reference. For failure characteristics, echo behaviour, and interference, the DSI method might be used, with material prepared directly in the conventional emission format (but not otherwise impaired) and/or material converted directly from the HDTV studio format (but not otherwise impaired) as reference.

The viewing conditions would be as given in Recommendation 500-3 (MOD I).

2.5 Comparative assessments of HDTV studio formats

For these assessments, three approaches may be considered.

In direct comparisons, candidate studio formats would be compared directly on a side-by-side basis. Issues have been raised concerning the appropriateness of such procedures; these are given in [CCIR, 1986-90a, b].

In indirect comparisons, candidate studio formats would be tested alternately against common, directly-viewed reference scenes. Depending upon the range of quality seen, either the DSCQ or the DSI method would be used. The viewing conditions would be as given in draft Recommendation XB/11. It should be noted that, in this case, it is essential to maintain constant source material across the systems tested. It is also considered useful to ensure that source scenes are composed to permit attribution of subjective judgements to particular factors in design (see § 2.1).

In theoretical comparisons, candidate studio systems are placed, parameter-by-parameter, in terms of degree of adherence to the relevant psychophysical ideals. Examples of this approach are given in [CCIR, 1986-90c, d].

It is thought essential in comparative tests to take account of possible influences of technical state of implementation.

2.6 Comparative assessments of HDTV emission formats

These might proceed as described in § 2.3, with the exception that the intent is to compare across systems, the basic quality, the failure characteristics, the echo performance, and the interference performance.

3. Summary of draft new Report XF/11 on objective measurement

Draft new Report XF/11, drawing on [CCIR, 1986-90e, f, g], considers the important topic of the objective measurement of high-definition television signal parameters. It addresses three areas for attention: first, the examination of the transfer characteristics of distortions occurring over a number of time-durations; second, proposals for the nature of the test signals to be used for characterizing the HDTV video signal; and third, suggestions for elements of test patterns for HDTV and examples of such patterns.

This new Report is complemented by four detailed diagrams of example test signals and two pictures of example test patterns.

REFERENCES TO PART 4

CCIR Documents

[1986-90]: **a.** IWP 11/4-160(IWP 11/4); **b.** IWP 11/4-161 (France); **c.** IWP 11/4-146 (France); **d.** IWP 11/4-172 (Canada); **e.** 11/340 (USSR); **f.** 11/341 (USSR); **g.** 11/342 (USSR).

PART 5 - STUDIO STANDARDS AND ASSOCIATED EQUIPMENT

PART 5.1 - DEVELOPMENT REPORTS ON STUDIO STANDARDS AND ASSOCIATED EQUIPMENT

Considerable progress has been made in the production of studio equipment designed around two draft Recommendations which have been submitted to the CCIR. While neither set of parameters in those drafts have been agreed by the CCIR as being acceptable as a single worldwide standard, both have sufficient support for practical use in specific areas to encourage manufacturers to produce equipment.

1.1 Proposal based on an 1125/60 system

The following proposal for a draft Recommendation for an HDTV studio standard based on 60 Hz was submitted to the CCIR, initially in 1985 and has reached the level of implementation indicated in Tables [I to V].

CONSIDERING

(a) that an HDTV studio standards must provide pictures with approximately twice the horizontal and vertical spatial resolution of, and a larger aspect ratio than, studio sources using existing standards;

(b) that there exists a broad range of applications for HDTV;

(c) that there has been substantial progress made in high-definition television technology for production equipment;

(d) that an HDTV studio standard should make possible a major improvement in quality over conventional 525/625 systems, when viewed on a large screen of 1 m diagonal size or larger;

(e) that an HDTV studio standard should make possible large-screen viewing with a spatial resolution comparable to 35 mm cinematographic film;

(f) that HDTV signals will be used as sources for current and proposed broadcast television systems and for motion picture film;

(g) that an HDTV studio standard must be specified in digital form with a simple relationship to Recommendation 601;

(h) that the transfer to and from film can be provided with adequate quality;

RECOMMENDS

that the following standard parameters be used for generation of signals in high-definition television studios

1.1.1 Basic characteristics of the video signal.

The video signal represents a scanned raster with the characteristics shown in Table I:

TABLE I - BASIC CHARACTERISTICS OF VIDEO SIGNALS

ITEM	CHARACTERISTICS	
1	Number of lines per frame	1125
2	Number of picture lines per frame	1035
3	Interlace ratio	2:1
4	Aspect ratio (H:V)	16:9
5	Field frequency (fields/sec)	60.00
6	Line frequency (Hz)	33750

Colorimetric characteristics.

TABLE II

ITEM	CHARACTERISTICS	
1	Assumed chromaticity coordinates (CIE 1931) for primary colours of display.	x y R 0.630 0.340 G 0.310 0.595 B 0.155 0.070
2	Chromaticity for equal primary signals. ($E'_R = E'_G = E'_B$ i.e. Reference white) (1)	Illuminant D_{65} x y 0.3127 0.3290
3	Electro-optical transfer characteristic of reference reproducer.	$L=((V+0.1115)/1.1115)^{(1/0.45)}$ for $V \geq 0.0913$ $L=V/4.0$ for $V < 0.0913$ (2)
4	Assumed gamma of ref. reproducer for which pre-correction of primary signal is made.	2.2 (approx.)
5	Opto-electronic transfer characteristic of reference camera.	$V=1.1115 x L^{(0.45)}-0.1115$ for $L \geq 0.0228$ $V=4.0 x L$ for $L < 0.0228$

TABLE II (continued)

ITEM		
6	Transmitted signals	$\begin{bmatrix}E'_G\\E'_B\\E'_R\end{bmatrix}=\begin{bmatrix}1.000&-0.227&-0.477\\1.000&1.826&0.000\\1.000&0.000&1.576\end{bmatrix}\begin{bmatrix}E'_Y\\E'_{P_B}\\E'_{P_R}\end{bmatrix}$ $\begin{bmatrix}E'_Y\\E'_{P_B}\\E'_{P_R}\end{bmatrix}=\begin{bmatrix}0.701&0.087&0.212\\-0,384&0.500&-0.116\\-0.445&-0.055&0.500\end{bmatrix}\begin{bmatrix}E'_G\\E'_B\\E'_R\end{bmatrix}$ (1) (3)
7	Scaling of colour difference signals (derived)	$E'_{P_R} = \dfrac{E'_R-E'_Y}{1.576}$ $E'_{P_B} = \dfrac{E'_B-E'_Y}{1.826}$

Note 1: E'_R, E'_G, E'_B are the signals appropriate to drive the primaries of the reference reproducer (having been pre-corrected for the reproducer's electro-optical transfer characteristic).

Note 2: L - light level

V - video signal level

Note 3: E'_Y, E'_{P_R}, E'_{P_B} can be derived from E'_R, E'_G, E'_B through a linear matrix.

1.1.2 Analogue representation

The image is represented by three parallel, time-coincident video signals. Each incorporates a synchronizing waveform.

The signals shall be either of the following sets:

$$\begin{bmatrix} E'_G \text{ "green"} \\ E'_B \text{ "blue"} \\ E'_R \text{ "red"} \end{bmatrix} \qquad \begin{bmatrix} E'_Y \text{ "luminance"} \\ E'_{P_B} \text{ "blue colour difference"} \\ E'_{P_R} \text{ "red colour difference"} \end{bmatrix}$$

The video signals are fully described in Table III, IV and figure 1.

TABLE III

ITEM	CHARACTERISTICS		
1	Nominal levels of E'_Y and $E'_G E'_R E'_B$ with sync	Reference black level (mV) Reference white level (mV) Synchronizing level (mV) (1)	0 700 ± 300 (Tri-level bipolar)
2	Nominal levels of $E'_{P_R} E'_{P_B}$ with sync	Reference zero level (mV) Reference peak level (mV) Synchronizing level (mV) (1)	0 ± 350 ± 300 (Tri-level bipolar)
3	Bandwidth	E'_R, E'_G, E'_B	30 MHz (Nominal)
		E'_Y E'_{P_B}, E'_{P_R}	30 MHz (Nominal) 15/30 MHz (Nominal) (2)

Note 1: Based on a 75 ohm (nominal) circuit impedance.

Note 2: 15 MHz applies when derived from digital sources.

1.1.3 Analog timing and synchronization.

TABLE IV

ITEM	CHARACTERISTICS		
1	Synchronizing signal form	Tri-level bipolar	
2	Nominal line-blanking interval (μs)	3.77	
3	Field-blanking period	45 H	
4	Reference clock frequency (MHz)	74.25 $\pm$ 10 ppm	
5	Reference clock period t (nsec)	t = 13.47 = H/2200	
6	H line timing (see figure 1)		
	Rising edge of sync (timing reference)	0	
	Trailing edge of sync	44	
	Start of active video	192	
	End of active video	2112	
	Leading edge of sync	2156	
	Figure 1:	Reference clock periods	time (derived) (μsec.)
	a	44	0.593
	b	88	1.185
	c	44	0.593
	d	132	1.778
	e	192	2.586
	f (Sync rise time)	4	0.054
	Total line	2200	29.63
	Active line	1920	25.86

FIGURE 1: Analog Synchronizing Signal Waveform

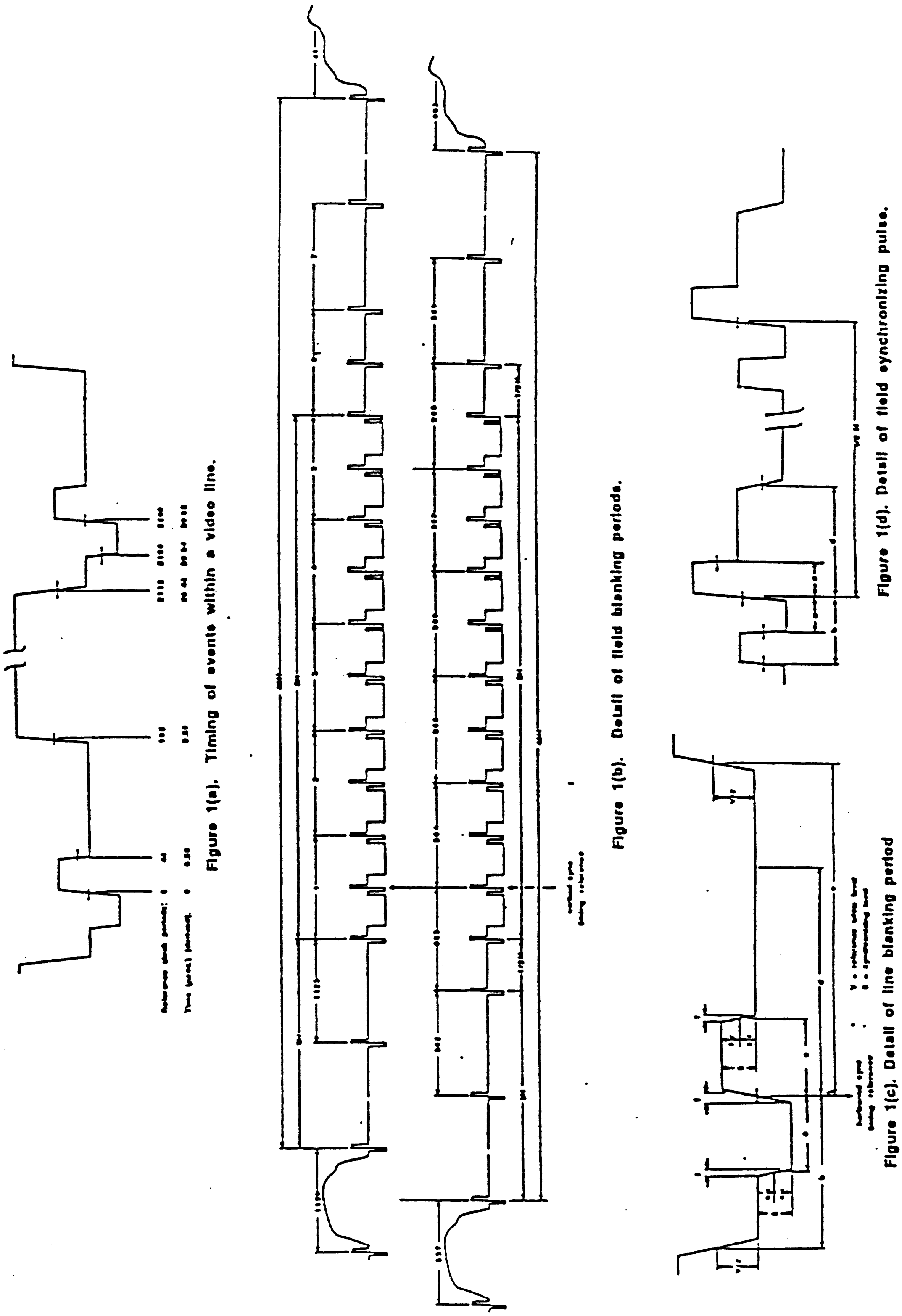

Figure 1(a). Timing of events within a video line.

Figure 1(b). Detail of field blanking periods.

Figure 1(c). Detail of line blanking period

Figure 1(d). Detail of field synchronizing pulse.

1.1.4 Digital representation

The video signals are represented in digital form by table V.

TABLE V

ITEM	CHARACTERISTICS	
1	Coded signals: Y, C_R, C_B	These signals are obtained from gamma pre-corrected signals, namely: E'_Y, $E'_R-E'_Y$, $E'_B-E'_Y$
2	Number of samples per total line: - luminance signal (Y) - each color-difference signal (C_R, C_B)	 2200 1100
3	Sampling structure	Orthogonal, line, field and frame repetitive. C_R and C_B samples co-sited with odd (1st, 3rd, 5th, etc.) Y samples in each line.
4	Sampling frequency: - luminance signal (MHz) - each colour-difference signal (MHz)	 74.25 (nominal) 37.125 (nominal)
5	Form of coding	Uniformly quantized PCM, N bits per sample, for the luminance signal and each color-difference signal (1)
6	Number of samples per digital active line: - luminance signal - each color-difference signal	 1920 960

TABLE V (continued)

ITEM	CHARACTERISTICS		
7	Analogue-to-digital horizontal timing relationship: - from end of digital active line to O_H	To be determined	
8	Correspondance between video signal levels and quantization levels: - scale - luminance signal - each color-difference signal	 0 to (2^N-1) Study required Study required	 (1)
9	Code-word usage	Study required	

Note 1: N is number of bits required. (Required further study)

1.2 Proposal based on a 1250/50 system

The following proposal for a draft Recommendation for an HDTV studio standard based on 50 Hz was submitted to the CCIR, initially in 1987 and has reached the level of development indicated in Tables [I-VII] /CCIR, 1986-90a/.

CONSIDERING

(a) that an HDTV studio standard must provide pictures with approximately twice the horizontal and vertical spatial resolution of, and a larger aspect ratio than studio sources using existing standards,

(b) that there exists a broad range of applications for HDTV,

(c) that there has been substantial progress made in High Definition Television technology for production equipment,

(d) that a multiplicity of standards will cause difficulties among broadcasters in the future,

(e) that HDTV sources will also be used for current and currently proposed broadcast television systems,

(f) that a conversion to existing 625/50 and 525/60 standards can be provided with good quality,

(g) that an HDTV studio standard must be specified in digital form with a simple relationship to Recommendation 601,

(h) that a 50 Hz field rate has advantages for the transfer to and from the existing film standard, which will continue to be an exchange format,

(i) that motion portrayal is satisfactory with field rates of 50 Hz or greater,

(j) that for a given bandwidth and interlace factor a 50 Hz field rate provides greater spatial resolution that higher field rates,

(k) that a majority of countries currently use emission standards based upon a 50 Hz field rate,

(l) that HDTV emission, transmission and studio standards are being considered in parallel,

(m) that all parameters of an HDTV studio standard should be optimized with regard to conversion into the respective HDTV emission standard (either based on 50 or 59.94/60 Hz).

RECOMMENDS

That the following standard parameter values be used for generation of signals for High Definition Television production and for the international exchange of High Definition Television programmes :

1.2.1 SCANNING PARAMETERS

TABLE I

Item	CHARACTERISTICS *	
1.1	Total number of lines per picture	1250
1.2	Number of active lines per picture	1152
1.3	Scanning method	Progressive 1 : 1
1.4	Aspect ratio	16 : 9
1.5	Field frequency	50 Hz
1.6	Line frequency	62,5 kHz

* This is the target standard. The first implementation may be based on a bandwidth reduced system. A bandwidth reduced system is described in § 2.2.2.

1.2.2 COLORIMETRY AT THE STUDIO INTERFACE

The content of section 2, 3 and 4 is in line with studies under completion, but the confidence given to these results, still subject to confirmative tests, is high enough now to introduce this information.

TABLE II

Item	CHARACTERISTICS			
2.1.	Chromaticity coordinates of primaries at the studio interface (1) (2)	Red Green Blue	x 0.6915 0.0000 0.1440	y 0.3083 1.0000 0.0297
2.2.	Chromaticity coordinates of reference white : illuminant D_{65} (2)	D_{65}	x 0.3127	y 0.3290

Note 1
Red and blue primaries are monochromatic (620 nm and 460 nm) real colours, "Green" is a non-real colour called "green" for reason of simplicity.

Note 2
Figure 1 gives the position of the studio interface where primaries are labeled R, G, B and the signals balanced for a D_{65} white reference.

1.2.3 TRANSFER CHARACTERISTICS

See section 2 heading.

TABLE III

Item	CHARACTERISTICS	
3.1.	Opto-electronic transfer reference source	Linear Gamma = 1
3.2.	Overall electro-optical transfer characteristic of the HDTV Chain	Gamma = 1.26 (3)
3.3.	Non-linear preemphasis of the primaries and luminance signals at the studio interface	Gamma = 0.45

Note 3
It assumes a conventional CRT display having a gamma of 2.8 and source signals precorrected with the same law than the non-linear preamphasis given in item 3.3.

1.2.4 ANALOGUE SIGNAL REPRESENTATION

See section 2 heading

The analogue picture signal comprises 3 parallel, time-coincident voltage signals from one or other of the two following sets (fig.2) :

(i)	E_R	"red"	or	(ii)	E'_Y	"luminance"
	E_G	"green"			E'_{C1}	"colour difference 1"
	E_B	"blue"			E'_{C2}	"colour difference 2"

* The impedance of the source is 75 ohms.

* The mark ' denotes non-linear pre-emphasis of the linear primary or luminance signals (see parameter 3.3)

* Generally, it is necessary to precorrect the primary signals E_R, E_G and E_B before applying them to a display : in practice 4 gamma-correctors are used in a camera to obtain E'_Y, E'_R, E'_G and E'_B.

TABLE IV

Item	CHARACTERISTICS		
4.1	Pre-emphasis equation for primary signals	$E'_R = E_R^{0.45}$ $E'_G = E_G^{0.45}$ $E'_B = E_B^{0.45}$	volts volts volts
4.2	Luminance signal equation	$E'_Y = (0.3392\ E_R + 0.6217\ E_G + 0.0391\ E_B)^{0.45}$ where E_R, E_G, & E_B vary from 0.0 to 1.0	
4.3	Colour-difference signal equation	$E'_{C1} = 1.8\ (E'_R - E'_Y)$ $E'_{C2} = 0.8\ (E'_B - E'_Y)$	
4.4	Nominal signal levels of E'_Y, E'_R, E'_G, & E'_B	Reference black level Reference white level	0 mV 1000 mV
4.5	Nominal signal levels of E'C1 & E'C2 (Note 4)	Reference achromatic level Reference peak level	0 mV +/-650 mV
4.6	Nominal signal bandwidth	E_R, E_G, E_B & E'_Y E'_{C1} & E'_{C2}	60 MHz 30 MHz

Note 4

* E'_{C1} & E'_{C2} represent E'_{C1} & E'_{C2} clipped to the peak level.

1.2.5 DIGITAL SIGNAL REPRESENTATION

Only set (ii) is considered presently for digitization. The necessary number of bits per sample for E_R, E_G, E_B signals in still under study.

TABLE V

Item	CHARACTERISTICS	
5.1	Coding form and word-length for Y, C_1, C_2.	E'_Y, E'_{C1} & E'_{C2} uniformly quantized PCM with at least 8 bits/sample for Y 8 bits/sample for C1 or C2
5.2	Sampling structures : - Luminance signal - Colour-difference signal	Orthogonal line and picture repetitive. Line quincunx, picture repetitive. C1 and C2 samples cosited each other and with odd numbered Y samples on odd numbered lines, with even numbered Y samples on even numbered lines.
5.3	Number of samples per digital active line. - Luminance signal - Colour-difference signal	1920 960
5.4	Total number of samples per full line - Luminance signal - Colour difference signal	2304 1152
5.5	Sampling frequency - Y - C_1 & C_2	144 MHz 72 MHz
5.6	Analogue-to-digital horizontal timing relationship from end of digital active line to O_H	Under study
5.7	Correspondence between video signal levels and quantization levels : - Scale - Luminance signal - Colour difference signal	Under study
5.8	Code-word usage	Under study

1.2.6 ANALOGUE SYNCHRONIZING WAVEFORM

1.2.6.1 *Details of the line synchronizing signals (see fig. 3)*

a) Synchronizing waveform

— Bipolar tri-level sync
— Amplitude ± 300 mV peak into 75 ohms.

b) Timing

Reference clock frequency : 2,25 MHz

TABLE VI

Symbols	CHARACTERISTICS	µs	2,25 MHz periods
H	Nominal line period	16	36
a	Line blanking interval	2.667	6
b	Interval between time datum (O_H) and back edge of line-blanking pulse	1.778	4
c	Front porch	0.889	2
d	Synchronizing pulses	0.444	1
f	Build up times (10 % to 90 %)	Under study.	

1.2.6.2 *Details of the frame synchronizing signals (see fig. 4 and 5)*

Reference : line period **H** = 16 µs

TABLE VII

Symbol	CHARACTERISTICS	Time	Line periods
v	Frame period	20 ms	1250
j	Frame blanking interval	1.568 ms	98
q'	Duration of frame synchronizing pulse.	8 µs	1/2

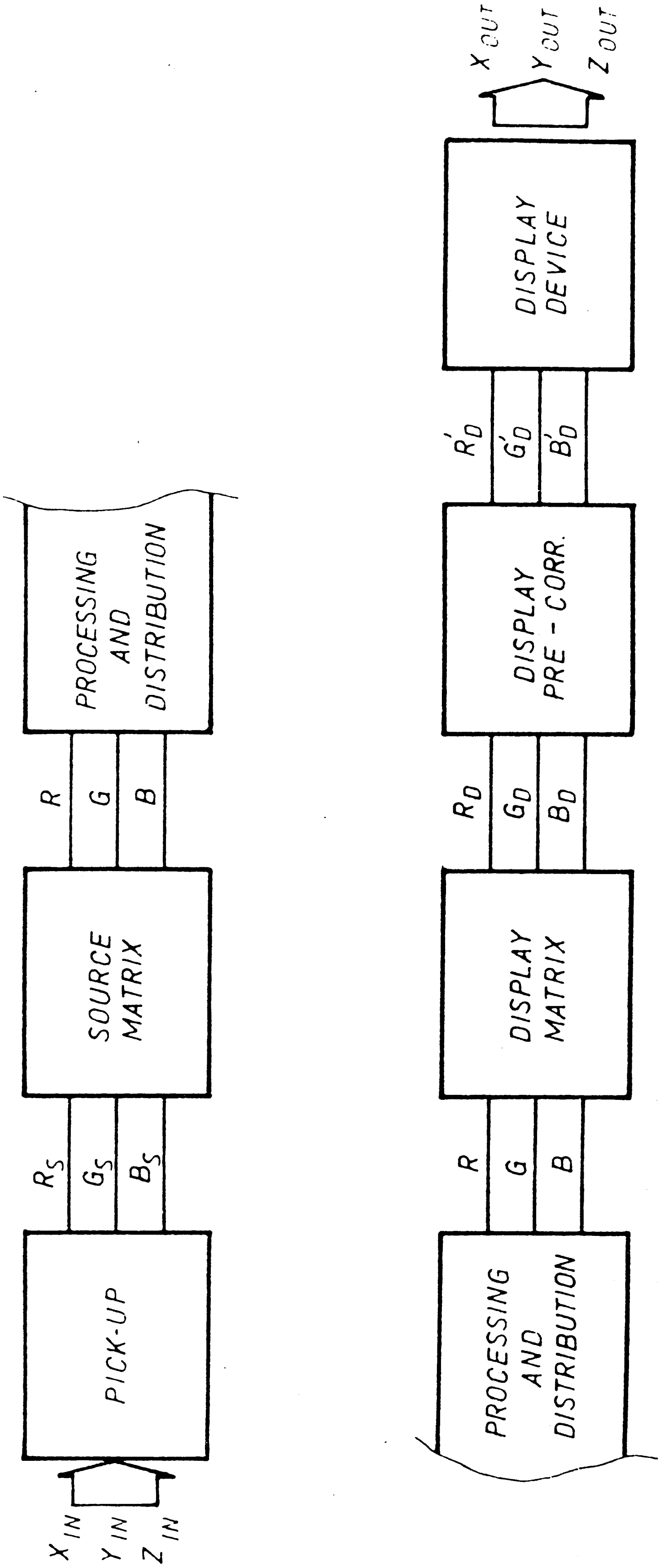

FIG. 1 A COLORIMETRIC SCHEMATIC OF A TELEVISION CHAIN

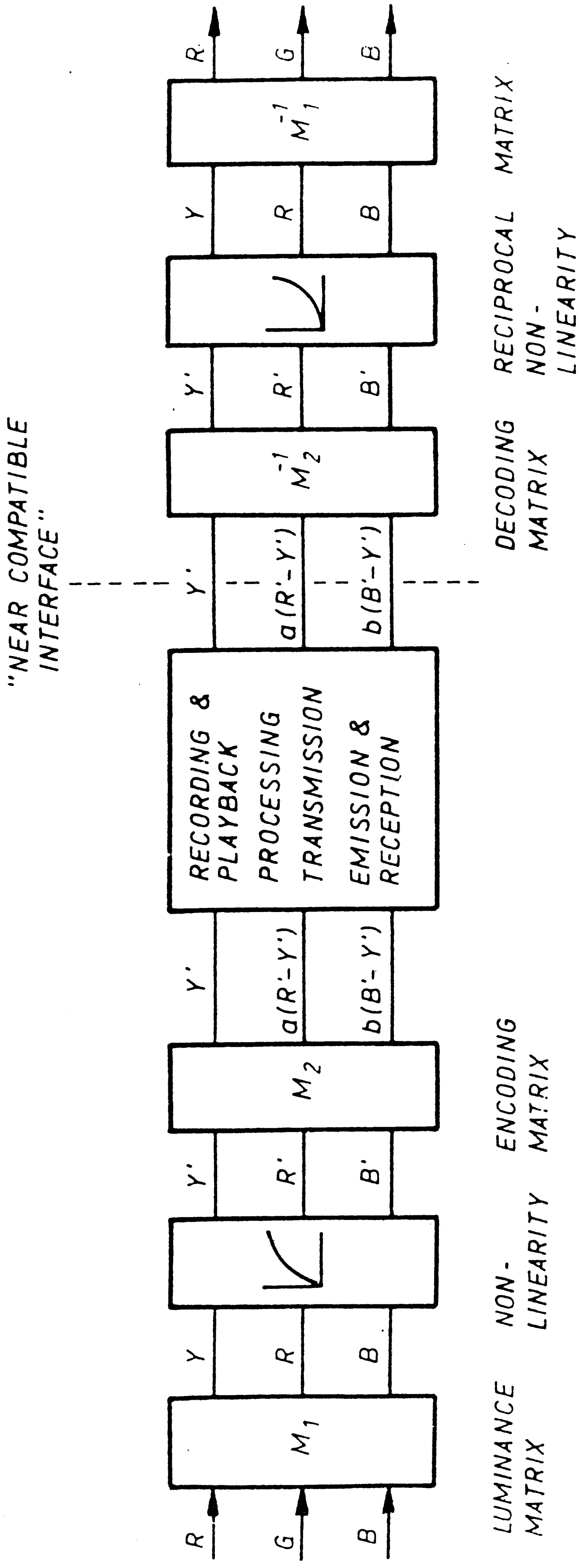

FIG 2. PROCESSING AND DISTRIBUTION

89-0086

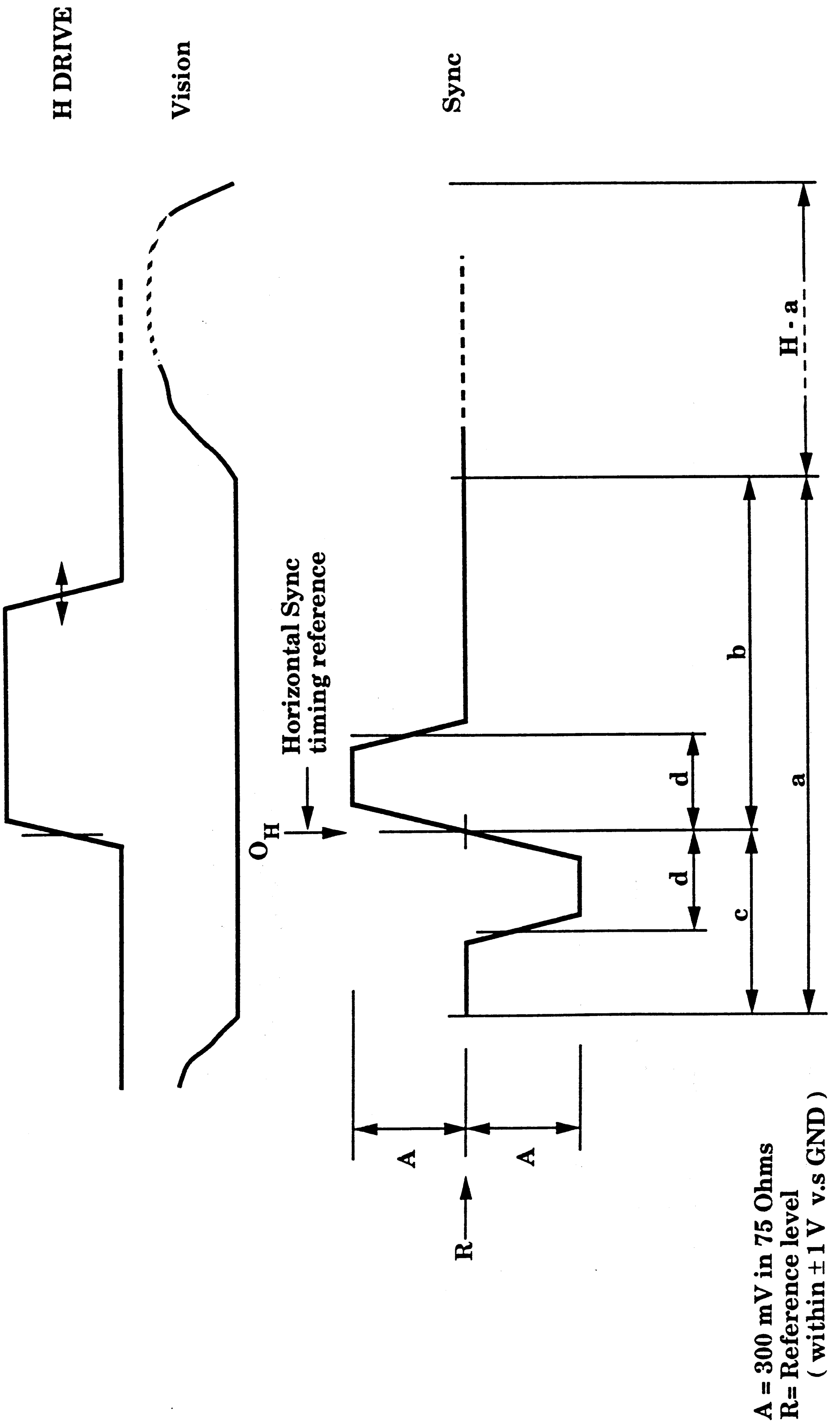

Figure 3 : Detail of line synchronizing signal

89-0087

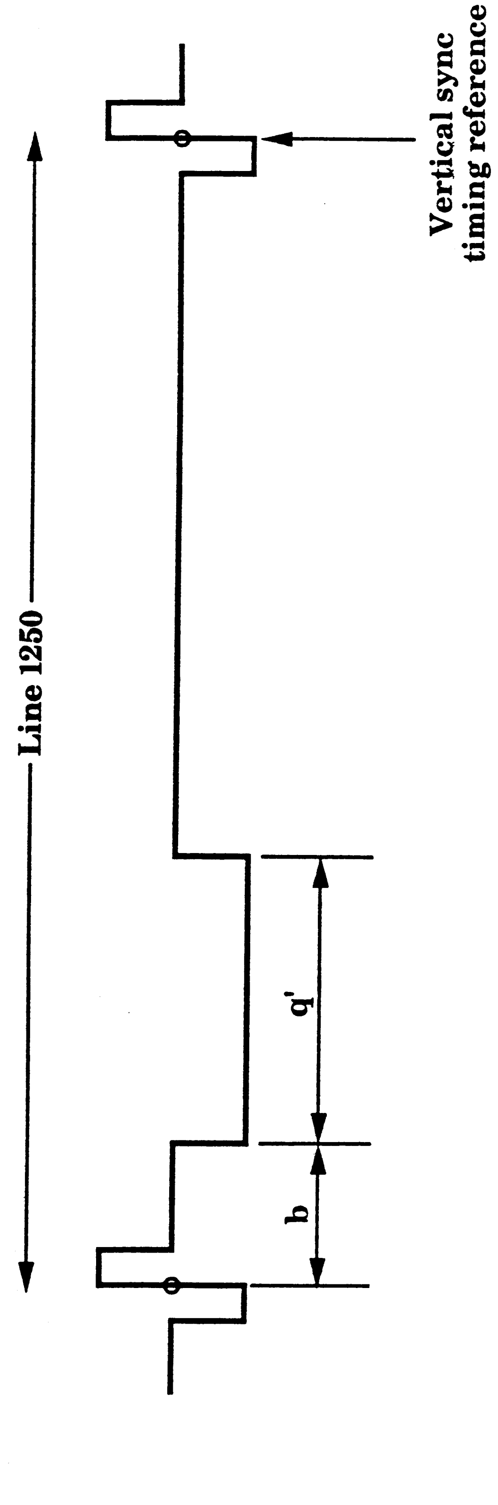

Figure 4 : Detail of frame synchronizing signal

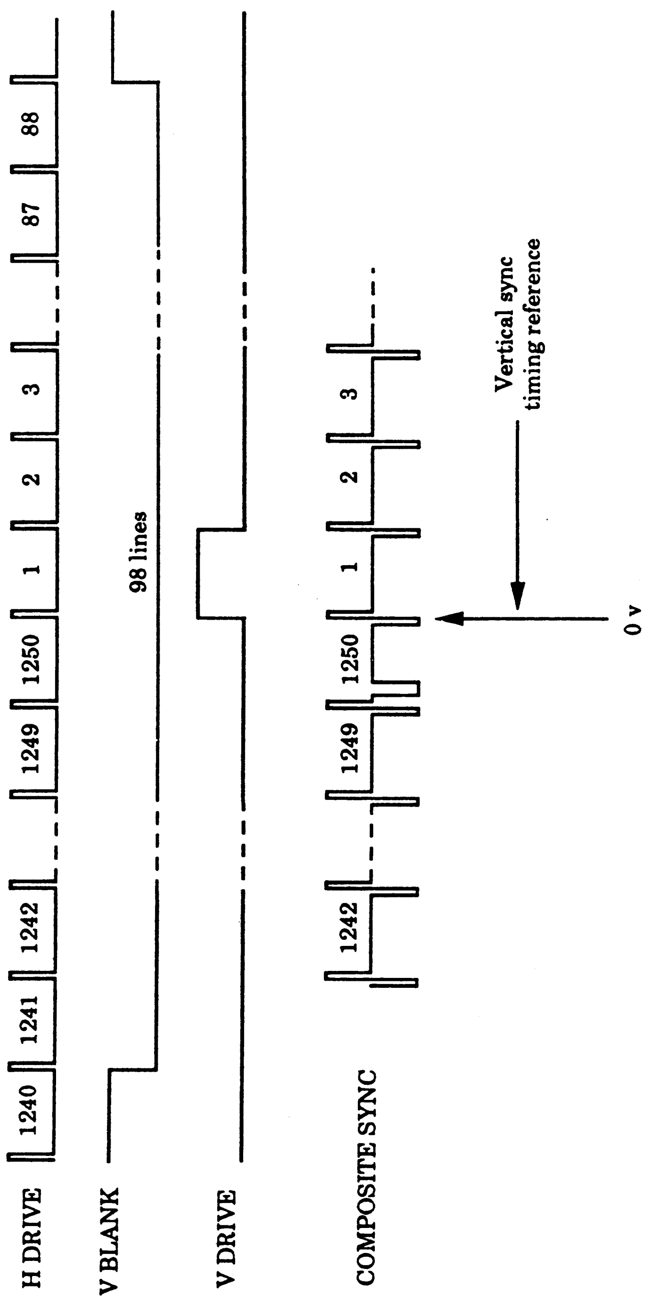

Figure 5 : Detail of vertical blanking interval and derived signals.

PART 5.2 - DEVELOPMENT OF EQUIPMENT (EXCEPT FOR CONVERTERS AND RECORDERS)

2.1 Studio equipment of the 1125/60 HDTV system [CCIR, 1986-90b]

The developments described in the following sections complement a full range of production equipment including cameras, recorders, special effects devices, etc., that are commercially available.

2.1.1 Cameras

a) HDTV portable camera

An HDTV portable camera using Saticon tubes has been developed. Features of it include a high resolution of 1200 lines with a high sensitivity of F:4.5 at 2,000 lux, compact and light weight of only 8 kg and an economical power consumption of only 35 W.

One-inch Saticon tubes with static focussing and static deflection have been employed. The photoconductive layer used is an improved one, and its sensitivity is 1.5 times in the green channel, 2 times in the red channel compared to the conventional Saticon layer. The preamplifier has also been improved by using a high performance JFET.

b) HARP* cameras for HDTV

An HDTV hand-held camera using 2/3-inch HARP tubes has been developed. The sensitivity of it is ten times greater than that of conventional HDTV cameras, and it can be operated at F:2.8 under 200 lux. This camera provides high quality pictures even in such cases with low levels of illumination as outdoor sporting events, show stages in areas of theatres.

A low noise GaAs FET preamplifier is used to obtain good signal-to-noise ratio (45 dB). Ease of registration adjustment has been realized employing an automatic on-line system. Applications of LSI technology and compact circuit design realized a light weight hand-held camera (6.5 kg).

c) Solid-state pick-up devices

Solid-state image pick-up devices which meet the 1125/60 studio standard have been developed. They include a one-inch format CCD image sensor with two million picture elements, and a laminated CCD image sensor. A next-generation solid-state HDTV colour camera using one of those has been developed. It is compact and twice as sensitive as conventional models.

2.1.2 HDTV video-matte system

An HDTV video-matte system has been developed. This system provides a new production technique in HDTV picture synthesis. A key signal for the synthesis is generated by means of computer graphics and displayed on an HDTV monitor. So it is possible to synthesize two pictures without any blue background, for example, taken at remote locations.

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* HARP: High gain avalanche rushing photoconductor.

The equipment has already been put into practical use in drama production, and feature film production using HDTV techniques, and creates a synthesized picture so real and natural that it makes viewers feel as if they are watching a real scene.

2.1.3 OB van for HDTV

A recent HDTV OB van is designed for use in live broadcast and in real time editing with such programmes as sporting events, theatrical performances and festivals. It is made so as to be able to move easily from one site to the other, and yet has the necessary environment for long time production to be maintained with a wide production room (3 m in its length) and large monitors (30 in in diagonal).

It is equipped with three cameras with an extension up to 1,500 m by optical fibre transmission, two VTRs, one opaque scanner, an analogue video switcher with eight inputs including three-mix, wipe, superpose and soft chromakey functions, a four channel audio mixer with eight inputs and an FPU transmitter of 42 GHz with TCI video encoder.

2.2 Studio equipment for the 1250/50 HDTV system [CCIR, 1986-90c]

Document [CCIR, 1986-90d] proposes a hierarchy of formats within the studio, simply related to Recommendation 601. All members of the hierarchy are evolutive with a high level of compatibility at least from one member to the next.

2.2.1 Progressive (HDP and HDQ) equipment*

This studio equipment at prototype level included:

- a monochrome camera that was demonstrated in Montreux, 1987 [CCIR, 1986-90e; Boyer and Eouzan, 1987];

- two colour cameras with different lens type, and one inch Saticon pick-up tube, demonstrated at the Brighton IBC 88.

  The development of the HDP camera was a milestone of the EU95 project, in particular, its sensitivity is nearly the same as that of an interlace camera, with a weighted S/N ratio quite equivalent. It includes a 2D digital aperture correction system on the channel, working at 144 MHz with 8 bit quantization and a convolution mask of 3 lines x 5 pixels;

- 144 MHz A/D and D/A conversion equipment;

- HDP/HDQ and HDQ/HDP converters (filter and interpolator). Converters include luminance and colour difference processors. The luminance processor is a bidimensional diagonal filter that allows subsequent quincunxial subsampling. The colour processor is a vertical filter that allows vertical subsampling. At the filter output, luminance samples are interleaved and a 16 to 32 μs line rate conversion is carried out. This provides at the output of the filter an HDQ multiplex, with the structure and clock frequency conforming to that of the HDI multiplex;

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* Explanatory note for description of studio equipment for the 1250/50 HDTV system:

<u>HDP standard</u> [CCIR, 1986-90f]

High-definition progressive scan with orthogonal sampling for the luminance signal and quincunx sampling for each colour-difference signal.

<u>HDQ</u>

High-definition progressive format that is derived from the HDP standard by luminance diagonal prefiltering resulting in spatial quincunx sampling and by colour-different vertical prefiltering resulting in orthogonal sampling. It allows to save half the bandwidth or data rate of HDP.

<u>HDI</u>

High-definition interlace format with orthogonal sampling for luminance and colour-difference signals. The data rate of HDI is equivalent to the data rate of HDQ.

- for interconnection of equipment within a production centre and for point-to-point interstudio links, commercially available equipment with a 60 MHz bandwidth has been used for RGB parallel transmission of 1250/50/1:1 HDTV signals in analogue form. Transmission equipment for HDTV signals in digital form with bit rate reduction has also been implemented [CCIR, 1986-90g].

Document [CCIR, 1986-90h] gives the characteristics of the HDQ format which is a bandwidth limited digital implementation of the HDP standard, in order to use the current digital recording and processing technology within the studio. The document further explains that HDQ and HDI, having the same bit rate, achieve a high degree of commonality and could use the same digital signal interface and that therefore many pieces of equipment, such as switchers, mixers and recorders can be used in both HDI and HDQ environments.

2.2.2 Interlaced (HDI) equipment*

- Cameras

  Cameras including 2-dimensional digital aperture and contour correction units with performances in sensitivity and S/N ratio according to the present state-of-the-art using one-inch Saticon type pick-up tubes have been developed.

- Mixers and switchers

  Simple switchers and mixers in analogue components were demonstrated. New versions of mixers with colour-matte facilities are in an advanced state of development.

- OB vans

  A set of operational equipment was demonstrated at the IBC 88 and was based on two OB vans including cameras, mixers, telecines and VTRs mentioned in other sections.

  An HDTV OB van in the interlaced version of the 1250/50 standard as described in [CCIR, 1986-90i] is currently being built up for RTVE. This OB van is designed for the production of experimental HDTV programmes in general and mainly for sports events. It has synchronization and monitoring facilities to work together with another OB van of similar characteristics [CCIR, 1986-90j].

[CCIR, 1986-90i] describes the parameters of the interlace version of the 1250/50 studio standard currently used in Europe on an experimental basis (see § 1.2 of Part 5).

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* See footnote on previous page and the footnote to Table I, Part 5, §2.1

2.2.3 Components

Some critical components for HDTV have been studied and future developments are in progress. They include zoom lenses for HDTV cameras, CCD line arrays for slide scanners and for telecines with 2048 pixels, a one-inch Primicon* pick-up tube with electromagnetic focalization and electrostatic deflection. A 1¼ inch Plumbicon tube has also been developed. A CCD line array with 5184 pixels for slide scanners is under development.

2.2.4 Interfaces for the digital environment

Document [CCIR, 1986-90k] suggests that with a simple and powerful motion estimator located within the studio close to the source, each equipment whose performance is affected by motion knowledge will use "motion vector" information to an appropriate degree by means of hierarchical processing. The target is to reach by this way a reduced bit rate for the motion information depending upon the application to avoid loss of relevant motion information when cascading processing is necessary.

Examples of related applications in production areas, especially at input/output interfaces, are field rate standard conversion, slow-motion, film transfer and coding for transmission or emission. The motion data can, for example, be inserted into the vertical blanking interval of the video signal, recorded on tapes and used for programme exchange.

2.2.5 Other developments

Submissions were received reporting that:

"A progressive scanning implementation affects mainly the camera, the A/D conversion equipment and the recorder within the studio. For the other items of studio equipment, mainly the mixer and associated special effects, little change is necessary when going from interlace to progressive scanning [CCIR, 1986-901]. As said in [CCIR, 1986-90m] a first implementation will be based on digital HDQ format to use 1.15 Gbit/s digital VTR whose feasibility has been demonstrated."

"[CCIR, 1986-90n] states that improved motion performance for a 50 Hz HDTV camera can be obtained with synchronous shuttering and that this improvement will be most marked when used in combination with motion compensated display up-conversion."

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* Primicon: Trade mark from TCSF.

2.3 Displays

2.3.1 Directly-viewed tube displays

CRTs are being developed in Japan giving priority to an enlargement in size and an improvement in resolution. With regard to the size enlargement, a 40 in CRT was developed in 1985 and introduced at "EXPO 1985", Tsukuba, Japan. This CRT weighed about 80 kg and had an aspect ratio of 5:3. In 1987, a 41 in CRT with an aspect ratio of 16:9 was developed. It weighed 105 kg and achieved a brightness of 95 cd/m^2 for all-white signals. Equipped with digital convergence, a display using this CRT achieved a reduced convergence error of 0.5 mm or less in all parts of the screen. The total weight and external dimensions of the display were 170 kg and 1,030(W) x 760(H) x 850(D) mm.

In 1987, a 32 in CRT was developed with the shadow mask of the Invar steel. It attained a peak brightness of 230 cd/m^2 [CCIR, 1985-90o].

[CCIR, 1986-90p] describes the basic characteristics of displays for the 1125 line 60 field high-definition television system (Report 801-2, Annex II, Report AZ/11, § 2.2). The document also reports that direct view CRT displays with brightness of over 100 cd/m^2 are currently available in sizes up to 750 mm measured diagonally.

CRT displays with a diagonal dimension of 931 mm are also available with brightness values in the order of 68 cd/m^2.

Colour picture monitors using 51 cm, 76 cm and 81 cm (20-in, 30-in and 32-in) tubes with the 16:9 aspect ratio were developed in 1988 in Belgium, the Federal Republic of Germany, France, Italy, the Netherlands, and the United Kingdom. Using phosphor dot pitches of around 0.3 mm and video bandwidths of about 60 MHz in the first available designs, horizontal resolutions of 1000 lines, or greater than 1400 picture elements per active line, and vertical resolution commensurate with 1250 total scanning lines were achieved. The approximate picture peak-luminance and contrast ratios were up to 90 cd/m^2 and 50:1 respectively. Apart from providing 2:1 interlaced scanning with 1250 lines per picture and 50 Hz field rate (1250/50/2:1) with a line scan frequency of 31 kHz, operation at 62 kHz was also demonstrated to give 1250 lines progressive scanning at a 50 Hz field rate (1250/50/1:1) or 1250 line, 2:1 interlaced scanning at 100 Hz field rate (1250/100/2:1) as options to eliminate interline flicker or large area flicker, respectively. The techniques used included bidirectional scan techniques [CCIR, 1986-90c and q].

2.3.2 Projection type displays

Projection displays using small CRTs (7-9 in) for the picture source are available with screen sizes up to 3,000 mm and with a peak luminance of over 100 cd/m^2 and a screen gain of 13 [CCIR, 1986-90p].

A 50 in rear projection display, using 7 in projection tubes, has attained a peak luminance of 400 cd/m^2 while the depth of equipment remains as small as 65 cm. In addition, a high contrast ratio of 35:1 or higher is attained by filling the gaps between the projection tubes and lenses with a material which has almost the same refractive index as glass. From 50 to 110-in displays of this kind were developed with a simplified automatic convergence alignment.

A 180-in display, using three 12-in projection tubes, shows a peak luminance of 55 cd/m^2 with a screen gain of 3.5. This display can be used with other projection sizes of up to 200 in. A 200-in display has also been developed using six 9-in projection tubes. It showed a peak luminance of 40 cd/m^2 [CCIR, 1986-90o].

Very large screen displays using light valve and Schlieren optic technology suitable for use in electronic theatres are available from several sources [CCIR, 1986-90p].

Whether for consumer or for professional applications, displays with a diagonal dimension greater than about 100 cm are currently provided by projection systems. Several cathode ray tube projection systems were completed in 1988, in Belgium, the Federal Republic of Germany, Italy and the Netherlands.

The nature and parameter values of a typical example designed with consumer requirements taken as a high priority are as follows: a rear projection technique was chosen to enhance stability, brightness and contrast, and to maximize the dimensional suitability of the equipment for use in the home; the picture diagonal was 127 cm (50 in) with a 16:9 aspect ratio and a 1250 line interlaced scanning system operating at the 50 Hz field rate (1250/50/2:1); the peak luminance of 400 cd/m^2 was nearly as high as that available with conventional 625-line receivers. Of perhaps more importance was the stable attainment of a relatively high contrast ratio of 50:1.

A second example has been a front projector designed to give a large screen diagonal with a 16:9 aspect ratio; 250 cm (98 in) was achieved. The use of an automatic deflection circuit, ranging from 16 kHz to 62 kHz line rate and from 50 Hz to 100 Hz field rate, enabled the display of both 1250/5/2:1 and 1250/100/2:1 scanning. A peak luminance of 300 cd/m^2 with a screen gain of 10 and a screen gain of ... and a modulation transfer function of 10% at 1000 TV lines are reachable in performance [CCIR, 1986-90c and q].

2.3.3 HDTV displays under development

A flat tension mask CRT has been developed in the United States that, it is claimed, increases brightness by up to 80% and contrast ratio by up to 70% over conventional designs. The thin metal mask is stretched and held flat under tension behind the tube's flat glass faceplate. This arrangement should be more stable during high mask temperatures. There are plans to apply this technology to large size HDTV displays.

The United States is developing a solid-state light valve. An array of thin film CMOS transistors laid down in the form of a television raster produces a 20 V electrostatic deforming field. On top of the integrated circuit is a deformable layer and a reflective thin film. Electrostatic forces deform these layers producing a physical representation of the television image. A separate light source and Schlieren optics could project the image on the screen. A colour projector would use three simultaneous modulators into a single objective lens [CCIR, 1986-90p].

A flat-panel display is desirable to assist the spread of HDTV receivers into many homes. Gas-discharge displays offer the highest feasibility for realization of such panels from the viewpoints of produceability of large size panels, the fast operating speed applicable to HDTV. A 20-in DC gas-discharge panel with internal memory has recently been fabricated in the first step towards the development of an HDTV flat-panel display. This study showed the possibility of realizing a larger flat panel HDTV display. A 4-in liquid crystal colour display using amorphous silicon TFTs has also been developed [CCIR, 1986-90b and r].

2.3.4 Display up-conversion

[CCIR, 1986-90s] discusses the problems of reducing full field flicker resulting from a temporal sampling rate by increasing the display refresh rate. This approach requires the use of motion adaptive temporal rate conversion to minimize motion artefacts. It further points out the need for this technology in all studio receivers where it may not be practical to use digital assistance signal approach.

One problem associated with large CRT displays is that of large area flicker. Larger and wider screens make this an important area of concern in HDTV viewing and it may be necessary to display the received picture at a different field rate from the transmitted field rate of 50 Hz. Subjective tests have indicated that display field frequencies of about 80 Hz and above are necessary in order to eliminate the effect of flicker at the screen luminances and distances that are likely to be encountered [Bourguignat, 1985].

To remove both large area flicker and interline twitter, picture repetition can be used instead of field repetition. This algorithm, known as AB-AB up-conversion, is successful in displaying still elements of the picture but, as information is being presented in the wrong order, the portrayal of moving objects is not satisfactory, due to judder.

MAC and High Definition MAC channels are capable of carrying significant amounts of data and so DATV [Storey, 1986] can be used, which offers the possibility of enhanced, more sophisticated forms of up-conversion while keeping receiver cost increases low. The presence of DATV channel allows the studio to pass instructions to the receiver which can overcome the problems of simple field or picture repetition up-conversion.

One way in which this has been achieved is by using motion adaptive conversion. In this system the up-converter can select either the field repetitive or picture repetitive mode of display on receipt of information passed via the DATV chain. The field repetitive mode can be used for the moving elements of the picture and the picture repetitive mode for the still areas. Studies have also been carried out on the use of pre-processing to improve the movement performance of the AB-AB mode in areas of slow movement.

Equipment from the Netherlands, the Federal Republic of Germany and Italy was demonstrated in 1988 which included several types of 50/100 Hz display up-converter. One employed a fixed AA-BB up-conversion algorithm which had no accompanying DATV information. A second up-converter used a motion-adaptive AA'-B'B/AB-AB algorithm, with the mode switching controlled by the transmitted DATV signal. Both equipments operated digitally at HDTV clock rates on component signals [CCIR, 1986-90q].

2.3.5 Consumer-use display

A large screen high-resolution display is necessary for an HDTV reception system. This is also a key factor for determining the speed at which HDTV becomes popular. Direct-view displays using large-size cathode-ray tubes (CRTs) with diagonals of 51 to 104 cm (26 to 41 in) have been developed with an aspect ratio of about 16:9. For example, recently developed 51 to 104 cm CRT displays have sufficient brightness (90 to 230 cd/m^2) and resolution for home use.

Projection displays using CRTs have also been developed with diagonals of over 100 cm. For rear projection displays, almost sufficient brightness and resolution have been obtained with 127-178 cm diagonals at a brightness of about 400 cd/m^2. Even larger displays were designed for viewing by large numbers of people.

To solve the problem of large-area flicker for 50 Hz field systems, especially for large screens, field rate up-conversion was investigated and several up-converters and displays were demonstrated in September 1988 (IBC 88, Brighton, United Kingdom).

Both direct view and projection displays for the converted signal on the display standard of 1250/100/2:1 with 62.5 kHz line frequency and a video bandwidth of about 60 MHz were built and demonstrated.

Another front projector designed to give a large screen made use of an automatic deflection circuit, ranging from 16 kHz to 62 kHz line rate and from 50 Hz to 100 Hz field rate, and enabled the display of both 1250/50/2:1 and 1250/100/2:1 scanning.

The simplest method of achieving field rate up-conversion is to repeat the fields producing two consecutive odd fields followed by two consecutive even fields. However, to remove problems such an interline twitter, reduction of resolution and judder, sophisticated techniques such as interpolation, picture reception and usage of DATV control signals may have to be applied.

ANNEX

(to Part 5.2)

THE FIRST IMPLEMENTATION OF THE 1250/50 HDTV PRODUCTION SYSTEM

The 1250/50 HDTV studio standard is based on a progressive scanning method. The first implementation of this target standard may be based on a bandwidth reduced system which takes into account the present status of available technology. The 2:1 interlace version described in this Annex in both analogue and digital forms meets this criteria.

Equipment operating according to these parameters has been demonstrated and is currently used in Europe for the production of experimental HDTV programmes. The specific parameter values for the interlace version are given below (the numbers between parentheses relate to the items in § 1.2):

a) line frequency (1.6) - 31 250 Hz

b) Colorimetry (2) - according to EBU specification (EBU Tech. 3213)

c) Pre-emphasis (4.1) - according to Recommendation 601

d) luminance signal equation (4.2) - according to Recommendation 601

e) colour-difference signal equation (4.3) - according to Recommendation 601

f) nominal signal levels (4.4/4.5) - according to EBU specification (EBU Technical Standard No. 10)

g) nominal signal bandwidth (4.6) - half those of the target standard

h) sampling structure of the colour-difference signal (5.2) - according to Recommendation 601

i) sampling frequencies (5.5) - half those of the target standard

j) analogue-to-digital horizontal timing relationship from end of digital active line to O_H (5.6) - 128 T (T = sampling period)

k) correspondence between video signal levels and quantization levels (5.7) - according to Recommendation 601

l) code word usage (5.8) - according to Recommendation 601

m) frame period - 40 ms (1250 line periods)

n) frame blanking interval - 1.56 ms (49 line periods)

o) duration of the frame synchronizing pulse - 8 μs (¼ line period)

All other parameter values - according to the target standard (§ 1.2)

PART 5.3 - STANDARDS CONVERSION

3.1. HDTV-HDTV standards conversion

Whatever the HDTV studio standard is in the future, high quality standards conversion will be necessary: on one hand, in the case of a single world-wide HDTV studio standard, standards conversion is required where different field rates apply for the studio and for emission. On the other hand, if different HDTV studio standards coexist, standards conversion will be inevitable between these HDTV standards.

[CCIR, 1986-90t] reports that a study of the conversion from 1250 lines 50 Hz to 1050 lines 59.94 Hz has been performed to assess the quality of converted 59.94 Hz pictures originally produced according to the European production proposal.

For such a conversion, it is obvious that conventional converters do not perform satisfactorily: these converters create important visible defects especially on moving objects, which represent the normal situation in TV scenes. That is why a motion compensation technique must be introduced to cope with the interpolation of moving objects (particularly with fast and complex motions).

Algorithms have been developed in parallel with hardware architecture design, according to the following functions or blocks.

a) Interlaced to sequential conversion

The input format of the standard converter is 1250/50/1:1; it is issued either from a progressive source or from the output of an interlaced to sequential converter.

b) Motion estimation

It consists of a description of motion measured between two successive images in the 50 Hz sequence; the input format to the motion estimator is 1250/50/1:1. Among the different classes of motion estimators, the differential method is attractive because it offers a good compromise between complexity and performance. Two recursive schemes using the differential method have been developed to compute local displacements like those encountered in rotating or zooming scenes on either a block basis or a pixel basis [Robert et al., 1988].

c) Motion assignment

One motion vector is assigned to each pixel of the image to be generated. Linear motion is assumed between two successive input images.

d) Failure detection

It has to identify the pixels where measured motion is not reliable in the sense that some risks of visible defects created by the corresponding motion compensating interpolation exist.

e) Motion adaptative interpolation

Two types of interpolation are considered corresponding to the motion compensating mode and the fall back mode. The choice between these two interpolators is driven by the failure detector; pixels for which motion is relevant (no failure detection) are generated by the motion compensating interpolator. Pixels where motion is not reliable (failure has been detected) are generated by the fall back mode.

Results

To assess the performance of the algorithmic procedure, a large number of representative picture sequences in a down-scaled format (625/50 to 525/59.94) has been processed using computer simulation. The results of these have been submitted for expert advice and demonstrated at IBC 88 in Brighton. The opinion of experts and visitors is that these results are excellent with performance superior to any previously demonstrated work in this field. The demonstrated processing shows very good performance from the point of view of both sharpness and motion rendition with no perceptible artifacts even when reduce speed (slow-motion) is used after conversion to look at pictures. These results form the basis of a transparent standard conversion.

In addition it must be repeated that the computer simulations have been carried out under the constraint of hardware design. This hardware is now in its built-up phase.

3.2 HDTV - conventional TV standards conversion

Tests by the BBC on the field-rate conversion of picture signals, using time-invariant (non-adaptive) interpolation, have demonstrated that an appreciably higher quality of converted picture is attainable with conversion from an 80 Hz field-rate to 60 or 50 Hz than when converting between 60 and 50 Hz. Conversion from 80 Hz was judged to give a picture quality up to two grades better than 60 to 50 Hz or 50 to 60 Hz conversion with similar picture material. In each case however, converted pictures were deemed to be inferior to pictures originated on the output standards [Childs and Tanton, 1985].

A new standards converter from 1125/60/2:1 HDTV to 625/50/2:1 PAL, based on motion-adaptive techniques has been developed in Japan. In the system, a sequentially scanned 625/60 signal is obtained first from the original 1125/60 signal by means of a two-field interpolator or an intra-field line interpolator. Then, field-rate conversion from 625/60 sequential to 625/50 sequential is achieved by means of a complex system, which selects the output of either one of four motion compensated processes or a linear-interpolation process. The selector is controlled by a motion signal. Finally, the signal undergoes sequential-to-interlace conversion [CCIR, 1982-86a].

Subjective tests have been carried out in several countries using a single stimulus subjective assessment technique and the five-grade quality scale. Since movement rendition was a critical issue, the test pictures consisted of moving sequences classified as "critical but not unduly so" [CCIR, 1982-86b and c].

During tests in Japan, the motion portrayal of the converted pictures was assessed to almost the same as that of direct PAL pictures except for the rotating disc sequences (the appearance of scenes similar to the rotating discs was measured as 0.04% of programme time in two Japanese television channels during one week). In some sequences, the converted pictures were evaluated higher than the direct PAL pictures. On average, the converted pictures were scored approximately 4.2, and the difference between the converted pictures and the direct PAL pictures was approximately 0.35 using the five-grade quality scale in the assessment made by experts [CCIR, 1982-86a].

Similar tests carried out in Europe have shown that the motion portrayal quality difference between PAL direct and the converted pictures was still perceptible (between zero and one grade). However, considering the future, the results of the subjective assessments and an initial analysis of potential areas of evolution of the performance of this converter, lead the EBU specialists to believe that a quality essentially equivalent to PAL quality will be possible within a reasonable period of time [CCIR, 1982-86c].

It was also reported that the motion portrayal quality of the PAL converted pictures was significantly better (between 1.5 and 3.5 grades) than motion portrayal at 25 Hz picture update rate (representative of film as scanned by a telecine) [CCIR, 1982-86c].

Conversion from 1125/60/2:1 HDTV to the 625/50 4:2:2 digital studio standard has been done and the subjective assessment of the quality of conversion with respect to motion portrayal has been accomplished recently [Wood and Habermann, 1986]. Document [CCIR, 1986-90u] states that for the seven scenes studied, the loss of quality introduced by standards conversion varies from 0.56 of a grade (scene 12) to 0.98 of a grade (scene 2), the mean impairment being approximately 0.7 of a grade. Compared to the conversion from 1125/60/2:1 to PAL previously evaluated, the 4:2:2 conversion results show a higher average degradation. (A mean degradation of 0.7 of a grade for conversion to 4:2:2 compared to a mean degradation of 0.5 of a grade for conversion to PAL for the same seven scenes.) This may be attributed to the concealing effects of PAL (e.g. cross-colour, cross-luminance) on small errors in the presentation of motion.

A production made in Canada, generally based on the parameters noted in Report 801-2, Annex II, will be shown in the 525-line NTSC television standard and has already been purchased by four national broadcasters, two of which operate in the 625-line 50 Hz PAL standard [CCIR, 1986-90v].

In Japan, HDTV has been implemented in accordance with 1125/60.00 standard, whereas NTSC system defines its field frequency as 59.94 Hz. In order to tackle this field frequency difference between HDTV and NTSC, 1125/60.00 to 525/59.94 standard converters have been developed and put into actual use. In carrying out that conversion, after the line rate conversion from 1125/60 to 525/60, the image data are written into frame memory storage and then read out according to 59.94 NTSC sync by the frame skips which can be done during a transition to commercial message, a fade to black, a scene cut, and a still picture [CCIR, 1986-90w].

3.3 Consumer-use converters

MUSE to 525-line standards converter

Considering compatibility to the existing receiver/display, a MUSE to 525-line standards converter, intended for use with consumer receivers was developed and demonstrated. This is of small size (made up of four 20 cm by 30 cm circuit boards).

The resultant 525-line picture converted with this converter has, on average, higher quality than the normal picture originated with NTSC standard, although it has some flicker at the edge, with less interference than that caused by the NTSC cross-colour. It has a simple circuit construction and it will be made available at a lower price by using LSI technology. The development of this MUSE to 525-line standards converter gave some prospect to HDTV broadcasting in the 1125-line system which can be received utilizing conventional 525-line receivers.

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PART 6 - RECORDING OF HDTV PROGRAMMES

1. Tape systems*

a) Analogue VTR

An open-reel analogue VTR system based on a one-inch type C format has commonly been used as the first-generation studio-use HDTV VTR. Made up of VTRs and a time-based corrector/processor unit, this system records for a maximum of one hour on a one-inch oxide-coated tape loaded in an 11.75-inch reel. The system uses component signals for input/output, and records RGB signals so that an excellent picture quality is secured.

- VTRs

The analogue VTRs, based on a B-format tape deck perform component recording featuring a 20 MHz bandwidth for the luminance component and 10 MHz for each colour difference. One hour recording is provided on a 12.5-inch open reel with 26 μm tapes. Time code based editing is provided. Within a window of 20 μs, the residual time base error is ± 3.5 μs. S/N ratio is $\geq$ 40 dB unweighted. Operating modes are record, play, shuttle, assemble and insert. Three audio channels are available, one of them time-code compatible.

b) Digital VTR

A digital VTR using metal particle tape, which has a high recording capability of 1.188 Gbit/s has been developed. The transport mechanism used is of one-inch C type. The sampling frequencies of the input/output signals are 74.25 MHz for the luminance signal and 37.125 MHz for the two colour difference signals as they are specified in the 1125/60 studio standard. This VTR is capable of having eight digital audio channels, and is the first HDTV VTR which is facilitated with slow-motion function.

c) Analogue cassette VTR

Analogue HDTV VTR using a ½-inch cassette is being developed and some prototype machines have already been completed. Major areas of application aimed at with this equipment are, in addition to broadcast applications, distribution of HDTV programmes for video theatres, educational purposes, medical uses, printing industries and so on.

It can accommodate a luminance signal of 20 MHz bandwidth, line-sequential colour signals of 7 MHz bandwidth and four channels of PCM sound with 48 kHz sampling and 16 bit/sample resolution. This equipment will be available on the market around the summer of 1989.

2. Disc systems

a) HDTV video disc player

A video disc player which offers a wide bandwidth high definition video and two channel PCM audio has been developed. It provides a 15 min playback per one side of 30 cm CLV disc (in contrast to 8 min/side with CAV disc). The bandwidths are 20 MHz for the luminance signal (Y), 6 MHz each for the colour-difference signals (Pb/Pr). A high signal-to-noise ratio of 42 dB (Y) has been obtained.

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* Further information is contained in Report XG/11.

For the audio signal, the bandwidth of 20 Hz to 20 kHz, and the dynamic range of 90 dB are attained. The harmonic distortion is less than 0.05% and the channel crosstalk is -80 dB.

b) HDTV still picture disc system

A digital disc system which reproduces HDTV digital still pictures with CD-ROM type disc has been developed.

One disc of CD-ROM type can store 240 still pictures.

For the audio signal, such separate CDs as available on the market can be used in a synchronous operation mode provided by the system.

Such functions are also included as cut-change, wipe-change, up/down scroll and a multiplexing with segmented pictures, and enable us to give vividness in effect as if they were moving pictures.

3. Film systems

3.1 Telecines

A frame-rate converter for HDTV laser telecine has been developed using an experienced motion compensation technology which had been studied originally as a development of HDTV to PAL standards converter.

In the new converter, the amount and the direction of motion in the picture are detected from two consecutive frames of a film in a form of motion vectors. For the detection, the pattern matching method was used.

It has been found that the problem of motion judder due to field repetition or 2-3 pull-down in conventional telecine can be solved by using this type of converter so that natural smooth motion in the picture can be reproduced on video displays.

A flying spot telecine using 35 mm print film running at 25 film frames per second produced 1250/50/2:1 high quality pictures complete with preprogrammable colour and position correction.

[CCIR, 1986-90a] reviews the progress in the development of equipment for television scanning of film. Of particular significance is the introduction of adaptive motion compensation to provide a major improvement in the portrayal of motion. With the introduction of motion compensation the question of the best "interface" between film and video becomes a non-issue. JIWP 10-11/4 has proposed a revision to Report 294-6(MOD I) to include the recent developments in television film scanners.

3.2 CCD slide scanner

Scanning is performed progressively using a 2048 pixel/line array sensor. Digitizing of RGB signals with 12 bit quantization is carried out. A digital gamma correction function is implemented. The system also includes storage and colorimetric processing operating at 72 MHz.

4. Consumer-use recorders*

4.1 Video cassette recorders

[CCIR, 1986-90b] reports the development in the Netherlands of a video cassette recorder using a VHS transport which was demonstrated in 1988 recording/replaying an HDMAC signal [Weissensteiner, 1988]. It achieved a bandwidth of about 12 MHz and an unweighted video signal-to-noise ratio of 42 dB by using four heads, two frequency-modulated recording channels and digital video and audio processing, with a residual timing error of < 15 ns. It was able to record 80 min of HDMAC (or MAC) signal on one ½-inch metal particle tape and included drop-out compensation. Compatible options gave the facility of recording/replaying PAL, SECAM or NTSC signals. A MUSE VCR for consumer use has already been developed.

4.2 Disc systems

Disc systems that record and play back a MUSE signal have also been developed and can accommodate 60 min of HDTV programming on both sides of a 30 cm CLV (constant linear velocity) disc.

The disc player can be used in combination with MUSE decoders in receivers and is expected to find a variety of applications in many fields as a long time playing medium of HDTV. Discs with customer's video materials can also be made.

[CCIR, 1986-90b] reports the development of HDMAC. A video disc player was developed in the Netherlands, based on existing optical laser and disc techniques [Horstman, 1988]. Its bandwidth is about 12 MHz with an unweighted signal-to-noise ratio of 32 dB and a residual timing error of < 7 ns. The playing time is 25 min per side for a 30 cm (12 inch) diameter disc.

4.3 Still-picture disc player

A digital MUSE video disc for still pictures, called CD-HV has been developed. A 12 cm disc in conformity with the CD-ROM standard is used.

Thus, about 640 still pictures with digital stereo sounds can be accommodated in a single disc. It can be played back either in sequential playback mode with 60 min of playing time for one disc, or random access mode with an average access time of 4.5 s [CCIR, 1986-90c].

* See also Report XL/11.

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PART 7 - EMISSION OF HDTV SIGNALS

1. Satellite broadcasting

1.1 Introduction

In this Chapter a progress report of a general nature is presented related to studies on radio frequency and emission technical parameters including modulation, channel coding and multiplexing of HDTV broadcasting primarily from the point of view of satellite broadcasting undertaken in consultation with competent Interim Working Parties of Study Group 11. Such studies were undertaken concerning the following aspects:

- narrow RF-band system with FM;
- wide RF-band system with FM;
- digitally-modulated system;
- inter- and intra-service sharing aspects from the viewpoint of the broadcasting-satellite service;
- broadcasting techniques for several audio signals and/or data signals associated with HDTV signals in satellite-broadcasting channels.

1.2 HDTV signal emission techniques

1.2.1. General

The important features of HDTV studio systems as envisaged in Part 3 of this Report and relevant to the design of broadcasting systems are:

- spatial resolution in the vertical and horizontal directions of about twice that available with Recommendation 601;
- improvements in temporal resolution beyond that achievable with Recommendation 601 with no significant cost penalties;
- improved colour rendition;
- separate colour-difference and luminance signals;
- a wider aspect ratio with display on a large screen;
- multi-channel high fidelity sound.

The radio frequency bandwidth required is a function of the baseband bandwidth of the coded signal. Satellite systems are power limited and it is important that the spectral efficiency be optimized as far as possible.

The objective of any HDTV emission standard is to reproduce as faithfully as possible the signals derived in the studio.

The emission standards may be subject to the restrictions of planning as is the case for the 12 GHz band which uses channel bandwidths of 24 or 27 MHz.

Alternatively, other constraints may apply if a new frequency band is allocated in accordance with Resolution COM5/3 of the WARC ORB-88.

The technology used in these two cases may differ.

The main problems to be addressed in relation to emission techniques are:

- noise;
- interference;
- channel distortion.

The main source of degradation to picture quality is caused by the increased levels of noise during times when the signal is attenuated by hydrometeors (see § 4 of CCIR Report 1075). Careful attention must be paid to the question of trade-off between signal quality (carrier-to-noise ratio) and the time this is achieved or exceeded. Different trade-offs may be appropriate in different rain zones.

In the 12 GHz bands, the BSS Plans have stringent protection ratios so that interference, at worst, is just perceptible. Any HDTV signal in these or other bands will also have to respect this requirement. However, the sensitivity to interference may be different because of the different type of coding and changed viewing conditions. Also the effect of interference on digital signals may need to be treated differently. This is discussed further in § 11 of CCIR Report 1075.

The effect of channel distortions on the quality of the received signal must also be included in the system design. Quality objectives are given in § 2 of CCIR Report 1075.

The effects of noise, interference and channel distortion will each vary, depending on the emission standard adopted.

The following sections describe HDTV signal emission techniques, leading to examples of emission formats and their required radio frequency characteristics.

1.2.2 Multiplexing and bandwidth reduction techniques

Multiplexing of luminance and colour-difference signals may be FDM or TDM, but TDM signals are less susceptible to FM noise and differential gain and phase when applied to BSS (see Report 1074). For this reason, most of the proposed HDTV transmission formats use a TDM scheme.

Compression ratios of luminance and chrominance are between 2:1 and 4:1. Colour-difference signals are multiplexed with the line-alternating method. Adoption of quasi-constant luminance processing is effective for reduction of the impairment caused by noise in the transmission path.

Currently proposed HDTV studio standards have a video bandwidth or bit rate 4 to 5 times higher than the conventional analogue (Report 624) and digital standards (Recommendation 601). There is insufficient radio spectrum to permit a 4 to 5 fold increase in RF bandwidth, and compression techniques which enable an HDTV signal to fit into a relatively narrower bandwidth channel, of the order of once or twice the width of those already planned in the 12 GHz bands, are required.

Sub-sampling is a widely used approach for bandwidth reduction of a signal by discarding some of the information present in the original signal without causing serious picture quality degradation. Diagonal or quincunx sub-sampling in the two-dimensional spatial domain is most common for this purpose. Temporal domain sub-sampling can be applied to the diagonal sub-sampling when further reduction of bandwidth is required for narrow-band transmission. This method is called multiple sub-sampling or 3D sub-sampling.

Two-dimensional spatial filtering for band-reduction is also possible without using sub-sampling technique as follows:

a sequence repeating in several line periods (e.g. 2 to approximately 4) at horizontal rate is used in which each line has a different horizontal bandwidth. For transmission, each line is time expanded, uncompressed or compressed depending on the horizontal bandwidth.

Line-column conversion (line or field shuffling) is proposed for the purpose of increasing the vertical sampling rate combined with sub-sampling in case of using a rather small number of scanning lines such as 525 or 625 lines for transmission in compatible HDTV emission systems.

In this case compatibility improvement for edge crawling in stationary areas is done by vertical intra-field filtering.

It is also possible using appropriate digital filters to reduce the number of lines in the transmission format (typically by 35%), by interface to sequential scan conversion. The principle is based upon the fact that interlace scanning, in particular, does not provide the full quality potential which can theoretically be attributed to the relevant number of lines.

Reduction of information for the colour-difference signal is proposed by reducing the frame rate to 12 or 15 f/s (frames per second). The same technique is also applied for luminance signals by transmitting high spatial components with a low temporal rate of 7.5 to approximately 15 f/s.

Motion adaptive control of pre-and post-filtering and/or sampling structure is widely used for better picture quality.

The most simple motion adaptive coding scheme is a 2-branch scheme: one branch for low temporal activity picture areas and another branch for higher temporal activity picture areas.

The choice of the branch, which achieves for each small sub-area of the picture, the best possible combination of spatial and temporal information, is signalled to the decoder via the digitally-assisted television (DATV) channel. The choice of the branch for each pixel can also be done by motion detection at the receiver. The 2-branch coding scheme could be improved by increasing the number of branches.

Motion compensation techniques are also effective for the temporal interpolation of sub-sampled signals in case of uniform motion such as camera panning or tilting. The effectiveness of motion compensation techniques can be further enhanced using more extensive digital assistance, DATV, to control the receiver.

Motion detection and measurement are performed at the coder on the uncorrupted source signal and a digital motion control signal is transmitted with the compressed (analogue) video signal to select the decoding mode in the receiver. Most of the complexity is now moved to the broadcaster's transmitter which should permit the manufacturing of lower cost, higher performance receivers.

For all digital HDTV transmission systems, additional compression techniques such as predictive coding (intra- and inter-field/frame DPCM), transform coding and entropy coding can be applied, as already with conventional digital television transmission (see Report 1089). However the higher data rates involved with HDTV require state-of-the-art technology and studies are at an early stage.

1.2.3 Sound and data multiplexing techniques

Due to requirements of quality and the need for secure scrambling, sound information should be transmitted in digital form. The sound/data multiplex may comprise several sound channels and auxiliary data for other purposes.

Adequate transmission capacity should be reserved for data services (i.e., teletext, multilingual subtitling and others; see CCIR Report 802-2) which could offer enhanced presentation features and require the adoption of suitable error protection strategies.

The currently required bit rates are in the range from 1.35 to 3.4 Mbit/s, depending on the coding scheme and the error protection method used. A certain amount of capacity for additional data should be provided, including that required for any digitally-assisted television control systems and auxiliary data intended for service identification and conditional access purposes.

1.2.4 Conditional access

Conditional access systems are necessary to make access reliably available to those authorized to receive some, or all, of the programmes and information carried by broadcasting satellites, while preventing unauthorized access. Information on conditional access is contained in CCIR Reports 1074 (MOD I) - Satellite transmission and 1079 (MOD I) - General characteristics of a conditional access broadcasting system.

The entire system architecture of a conditional access system must be designed to provide an extremely high level of security.

Many system elements are essential to provide this security. Among them is the use of a "strong" encryption algorithm (i.e. it should not be possible to deduce the algorithm even when both the clear and encrypted versions of a message are known).

Typically conditional access data will consist of a number of layers of encrypted key information. It is sent to each subscriber in turn and is known as "over-air addressing data". The required amount of data may be reduced if subscribers share the same key.

1.2.5 Modulation techniques

CCIR Report 1075 gives information about various modulation techniques for satellite broadcasting. Both analogue FM and digital modulation techniques are discussed.

1.2.5.1 FM systems

For analogue FM, pre-emphasis is normally used to improve the S/N by compensating for the triangular nature of the demodulated noise spectrum. New developments have taken place which allow signal-to-noise ratio improvements for FM by means of non-linear pre/de-emphasis. Adaptive emphasis may also be employed for the same purpose.

Non-linear emphasis for MUSE system

When the MUSE signal is transmitted with frequency modulation, a non-linear emphasis is effectively used. The non-linear emphasis characteristics can be defined by the composition of the de-emphasis circuit to be used in receivers. (See Annex II of Report 1075). An improvement of 9.5 dB in the received unweighted signal-to-noise ratio was reported.

Compatible non-linear emphasis for C-D-D2MAC and HDMAC

E7 is a frequency dependent instantaneous compander system. It is "compatible" in the sense that it has no effect at low video frequencies, so the static deviation of the FM signal is not affected. Receivers not equipped with E7 de-emphasis can display a virtually unimpaired picture from a transmission with E7 pre-emphasis. In this situation there is a slight crispening of the picture. Most observers appear to judge this as an improvement of the picture quality. An improvement equivalent to 4.5 dB in the received carrier-to-noise ratio was reported.

1.2.5.2 Digital systems

Taking into account the impact of digital technology on the broadcast field and the consumer TV market, digital modulation could be the most appropriate technique for providing a future world-wide HDTV emission system.

Typical bit rates for coded signals range between 140 and 160 Mbit/s (CCIR Report 1075) calling for the use of modulation with high spectral efficiency. Suitable modulations are 4 PSK, 8 PSK, 16 QAM and even possibly 64 QAM, which give a range of trade-offs between power, bandwidth requirement and ease of sharing.

A fundamental characteristic of these modulation methods is their greater ruggedness against interference compared with FM modulation. However, further studies are necessary to evaluate the influence of a non-linear satellite channel on system performance, especially as to high-order digital modulation (16-64 QAM).

Another important feature of digital systems is their capability to provide a constant high picture quality, provided a suitable margin against noise and interference is assured, to maintain a sufficient bit error ratio.

1.2.6 Formats for HDTV broadcasting

At the present time administrations studied the relative merits of a number of alternative approaches to the introduction of HDTV broadcasting. The following sub-sections are intended to reflect the views which are being considered in each case. A consensus on one approach world-wide could be in the public's interest and assist standardization.

1.2.6.1 Introduction of HDTV via existing conventional scanning formats

Document [CCIR, 1986-90a] explains that, along with alternative strategies, a study is being made of what is termed an evolutionary approach to HDTV broadcasting. In essence, an HDTV emission format would be used (termed HDMAC) which would still allow reception, virtually unimpaired, on 625/50/MAC/packet DBS receivers. In other words the system would be compatible to the European DBS services planned to begin in 1987/1988. For minimum impairments to picture quality, a single HDTV studio standard having adequate headroom, using a field frequency conforming to the MAC/packet standard, and having preferably twice the number of active lines, is desirable [Sandbank and Stone, 1987; Storey, 1986].

1.2.6.2 Direct introduction of HDTV via a non-compatible scanning format

Document [CCIR, 1986-90b] notes that for HDTV broadcasting using a scanning format as specified in § 1.1 of Part 5.1, the MUSE system has been developed. Some administrations believe that by this method few limitations are imposed for full utilization of the system, as restrictions due to compatibility do not exist and as a result, new technology can be used to optimize the emission system; the picture quality is expected to be superior to that of the compatible approach within the same RF bandwidth.

1.2.6.3 Introduction of HDTV via agile conventional receivers

Documents [CCIR, 1986-90c and d] describe a scenario which could lead to a common world-wide HDTV broadcasting chain, and, nevertheless, give room for an evolutionary development of present day television systems. If receivers were developed, and made publicly available, which could automatically configure to either a 625/50 MAC/packet or a 525/60 MAC/packet signal, then, at a later date, a 60 Hz/HDMAC system could be introduced, in the confidence that normal receivers would still receive a normal service from the HDMAC signal. Conventional television production and emission could be at either 50 or 60 Hz.

1.3. HDTV satellite-broadcasting systems and spectrum considerations

1.3.1 Narrow RF-bandwidth

Narrow RF-band HDTV systems are intended for transmission in the planned 12 GHz bands where both channel bandwidth and protection ratio requirements need to be met. These kinds of systems require extensive signal processing, thus added system complexity, to achieve relatively high degrees of bandwidth compression in order to allow the HDTV signal to fit into a single 24/27 MHz channel. However, for these systems, the resolution in moving areas of the picture will be approximately one half of the resolution for static pictures. Studies indicated that an extremely high bit rate compression (10:1) would be needed to fit a fully digital HDTV signal in a 24/27 MHz channel. Narrow RF-band HDTV systems are therefore considered to use analogue modulation.

1.3.2 Wide RF-bandwidth

In order to be free from the limitations inherent in narrow RF-band systems and to be able to provide improved system performance (e.g., picture quality and motion portrayal as close as possible to that of the studio signal), it will be necessary to increase the video baseband bandwidth and consequently the RF bandwidth. Such wide RF-band systems, for which both analogue and digital modulation are considered, require an RF channel bandwidth typically in the order of 50-120 MHz. These bandwidth requirements are such that wide RF-band systems could only be implemented in a frequency band not subject to the planning constraints of the 12 GHz bands except for some countries in Region 2.

1.3.3 Inter- and intra-service sharing

The study of sharing will put constraints on HDTV emission standards, but there is no evidence to link sharing considerations directly with any choice of studio standard.

When considering interference into other systems, the most important parameter is whether analogue or digital modulation is used. Other factors are less important.

Interference into HDTV systems will be affected not only by the choice of analogue or digital modulation, but also by the receiver processing associated with any bandwidth reduction or bit rate reduction techniques which may be used.

Some guidance may be appropriate to help in the choice of the studio standard. It is important to avoid low useful energy content in specific time or frequency slots of the emission signal format.

Sections 1.3.3.1 and 1.3.3.2 give results of recent studies on sharing.

1.3.3.1 Interference within the same service

Sharing within the HDTV service is discussed in Report 1075 (MOD I) and the CCIR report to the Second Session of the WARC ORB-88.

Not all protection ratios for the various candidate HDTV systems have yet been determined. Further study is required on this important subject not only for the case of interference assessment between HDTV transmissions but also for interference assessment between HDTV and conventional formats such as NTSC, PAL, SECAM and MAC. For HDTV systems intended for use in the 12 GHz band, protection ratios must comply with the requirements of the WARC BS-77 and the RARC-83.

It is expected, however, that for analogue HDTV systems, the co-channel protection ratios will be of the same order as for coventional systems and will also be less as the frequency deviation is increased.

HDTV systems using simple digital techniques (e.g., BPSK or QPSK) will be more tolerant to interference and cause less interference to analogue systems than analogue systems. High order digital systems (such as 16 QAM) may not show the same advantages. The main parameter that needs to be considered in the digitally modulated systems that may have some bearing on spectrum usage is the required bit rate. Reducing the bit rate would be in line with efficient spectrum use.

1.3.3.2 Sharing with other services

Sharing with other services is discussed in Reports 631 (MOD I), 807 and 951, and in the CCIR report to the Second Session of the WARC ORB-88.

In COM5/3, the WARC ORB-88 extended the range of frequencies to be considered as possible candidates for a new HDTV band to include 12.7 to 23 GHz.

Studies of sharing with the services in this range have not been completed. Recent studies by ESA at frequencies of 20 GHz provide new information on the prospects, as well as the problems, of sharing between the BSS and other services.

1.4. HDTV receiving techniques

1.4.1 Satellite broadcasting receivers

1.4.1.1 Required figure-of-merit for the receiver

The link budgets of the HDTV satellite broadcasting down link and its general equation are described in § 9 of Report 1075 (MOD I).

According to examples of link budget for various transmission systems, as shown in Table IX of Report 1075 (MOD I), it is considered that receiver figure-of-merit is appropriately 13 dB for 12 GHz, and 17 dB for 23 GHz.

Required power flux-density which gives an acceptable quality of reception depends on various parameters such as satellite e.i.r.p., size of the service area, acceptable time of service degradation vs. rain attenuation. It is noted that the choice of the required e.i.r.p. of the figure-of-merit depends on the emission signal format and type of modulation, including the effect of emphasis.

In order to achieve the desired e.i.r.p., a high power TWT is necessary. Recent studies predict that an output power of 500 W will be possible for space-qualified TWTs in the 20 GHz band within a ten year time-scale.

1.4.1.2 Figure-of-merit

The figure-of-merit of the receiving equipment depends on the antenna gain and noise figure of the receiver.

There is a compromise to resolve the problem of using higher frequencies: if the antenna diameter is maintained constant, there is a rapid increase in the pointing accuracy needed. Whilst, if it is reduced in proportion to the wavelength, there is a severe reduction in antenna aperture. It is also noted that the effect of the noise increase due to rain attenuation shall not be neglected for calculation of the figure-of-merit.

Referring to Report 473-4 (MOD I), the most commonly accepted receiver noise figure in the 12 GHz band is between 2.5 and 4 dB. With recent advancement of semiconductor devices such as the high electron mobility transistor (HEMT), 1.5 dB noise figure is now available. Therefore, a figure-of-merit based on a 2.5 dB noise figure is appropriate as a conservative value, and even 1.5 dB would be possible, enabling the use of smaller antennas.

A large number of low-noise amplification elements which can be applied for the 20 GHz range are being developed, with special interest in the HEMT. At 20 GHz using HEMTs, a single-element noise factor (NF) of 1 dB and amplifier NF of 2 dB have been achieved.

Results of figure-of-merit calculation based on the above conditions are given in Table I, calculated according to the definition of the usable figure-of-merit given in Annex I to Report 473-4 (MOD I) neglecting, however, pointing loss, polarization effects and equipment aging.

TABLE I

Example of figure-of-merit

Frequency (GHz)	12	23	42
Antenna diameter (m)	0.9	0.9	0.5
Half power beamwidth (degree)	1.9	1.0	1.0
Antenna gain (dB) (η = 65%)	39.2	44.6	44.2
Noise figure (dB)	2.5	4.0	7.0
Figure-of-merit (dB(K^{-1}))	13.1 (1)	17.0 (2)	12.2

(1) A 16 dB (K^{-1}) figure-of-merit is expected assuming 1.2 m diameter antenna and 2.5 dB noise figure in clear sky.

(2) An 18 dB (K^{-1}) figure-of-merit is expected assuming 0.9 m diameter antenna and 4 dB noise figure in clear sky.

1.4.1.3 IF and demodulator stage

For the analogue system, the IF and demodulator stage for HDTV reception is very similar to the conventional TV demodulator, as has been verified with a number of receivers and field tests. Whereas a conventional discriminator is commonly used, a threshold extension demodulator (phase-lock loop or adaptive filter, etc.) may also be used and offers up to approximately 3 dB of threshold improvement for FM systems.

For an overall digital signal, it is expected that the error performance can be improved by using complex decoding strategies.

1.4.2 HDTV decoders

1.4.2.1 General considerations

Most HDTV systems use digital processing, employing frame stores in order to achieve large-scale bandwidth compression. The required number of logic gates would be several tens of thousands and the necessary capacity of the store would be of the order of 10 Mbit.

Since the reduction of receiver cost depends on how efficiently large-scale integrated circuitry (LSI) can be introduced to signal processing, development of LSI for the MUSE decoder and related technologies is rapidly progressing. Recent trends towards larger capacity of the stores, from 1 Mbit to more than 4 Mbit, and towards digitization of conventional television receivers are expected to expedite the development of LSI circuitry for HDTV receivers.

1.4.2.2 MUSE decoder

As for the MUSE decoder, internal clock frequencies range from 16.2 MHz to 48.6 MHz, and the amount of memory capacity is about 20 Mbit for use in such functions as interpolation and motion detection. Experimental decoders using discrete parts, including medium-scale ICs, are produced by many different manufacturers. They have been constructed in a reasonably small size and are light-weight (e.g. volume $0.084 m^3$, weight 50 kg) to serve as portable models.

HDTV receiving equipment also plays an important role in the development of other consumer equipment. For example, the MUSE receiver has a built-in memory with a capacity of about 20 Mbit. Attempts are being made to connect it to personal computers and other image processing equipment.

Successful interfacing with other devices will make the MUSE receiver multi-functional, enabling it to serve as a total information terminal in the home.

1.4.2.3 HDMAC decoder

The HDMAC decoder digitizes the input signal with a clock-frequency of 20.25 MHz, since the Nyquist frequency point is situated at 10.125 MHz. The output sampling frequency is 54 MHz for luminance on the 1250/50/2 display standard.

The DATV concept allows all the intelligent decision circuitry to be placed in the encoder. Consequently, the decoder complexity is decreased and will benefit from future improvements in the coding process [CCIR, 1986-90e,f].

1.4.3 Other characteristics of receiving equipment

Display

A large screen high resolution display is necessary for an HDTV reception system. This is a key factor of determining the speed at which HDTV becomes popular. Direct-view displays using large size cathode-ray tubes (CRTs) with diagonal length of 66 to 104 cm have been developed with an aspect ratio of about 5:3. For example a recently developed 81 and 104 cm type CRT display has sufficient brightness of 150 to 200 cd/m^2 and sufficient resolution for home use.

Projection displays using CRTs have also been developed for screen sizes of over 102 cm. For rear projection displays, almost sufficient brightness and resolution have been obtained with 127 to 178 cm type displays at a brightness of 150 cd/m^2. Moreover 254 to 508 cm types designed for viewing by a large number of people have been made available.

1.5 Example of HDTV satellite emission systems

1.5.1 Example of HDTV formats and their required RF bandwidth

Table II gives examples of HDTV transmission formats. The first two examples are for narrow RF bandwidth systems described in § 3.1.

The remaining examples are for wide RF-bandwidth systems described in § 3.2 and require a wider bandwidth which could possibly be accommodated in the 23 GHz band (in Regions 2 and 3) or in a suitable new world-wide frequency band yet to be allocated.

The third and fourth columns show the possibilities for various analogue systems (including MAC/packet compatible systems) intended to give good quality but their bandwidth requirements are such that they could only be implemented in a frequency band not subject to the planning constraints of the 12 GHz band. A band in the 20 GHz range suitable for wide RF-bandwidth systems is therefore suggested.

1.5.1.1 MUSE (system 1) [Ninomiya et al., 1987]

System 1 is the MUSE system developed in Japan for HDTV broadcasting using a single planned channel.

Properties of the human visual system are effectively taken into the design. The technique of motion compensation is applied for the purpose of improving the effect of subsampling in the case of uniform movement in the picture.

The baseband signal bandwidth is 8.1 MHz. It uses 4:1 dot-interlaced subsampling which employs inter-field and inter-frame offsets.

A technology for analogue sampled value transmission is used including automatic waveform equalization at an encoder and a receiver.

Basic video characteristics of MUSE system are summarized in Table II.

Figure 1(a) shows the filter arrangements for the luminance signal, in which different paths are illustrated for stationary portions and moving portions of the picture. Figure 1(b) shows the filter arrangement for the colour-different signals. These are shown separately just for simple explanation. In the actual encoder, however, the luminance and the colour-difference signals are combined into a TCI signal, and processed simultaneously. The luminance signals for stationary portions and for moving portions are also mixed into a single signal in the process. Therefore, the output signal is a single MUSE signal.

Figure 1(c) intends to show the sampling pattern applied in the MUSE system, and original sampling frequency is taken as 48.6 MHz. However, in the actual encoder, a frequency conversion from 44.55 MHz to 48.6 MHz takes places before the original sampling. This is shown as "TC" in Figs. 1a and 1b.

Figure 2 shows transmissible range in the spatial frequency domain. In this case, the frequency conversion mentioned above has already been taken into account.

Figure 3 shows the video signal in TCI format used in the system.

Figure 4 shows structure of MUSE signal.

The control signals, including motion vector, and digital sound/data signals are multiplexed into the baseband video signal during the field-blanking period as shown in Figure 4.

Sound/data signals are transmitted by inserting them into the field-blanking period. The baseband multiplexing has been adopted with advantages including suitability to cable distribution systems. The bit rate is 1.35 Mbit/s, and either four channels of 32 kHz sampled sound signal or two channels of 48 kHz sampled signal can be transmitted by the use of the technique.

In this system, differential PCM signal is near-instantaneously companded. The sound quality of the resulting signal with 32 kHz sampling and 15-to-8 bit companding is slightly better than that of 14 bit uniform PCM with 32 kHz sampling.

With this method, two channels of 20 kHz bandwidth, 16 bit PCM quality sound can also be transmitted as an alternative by 48 kHz sampling 16-to-11 bits companding within the same channel capacity.

A synchronization system which provides an accurate resampling phase is used. A positive synchronization signal eliminates the synchronization pulse loss of 3 dB. The line-sychronizing signal is shown in Figure 5(a) and the frame-synchronizing signal in Figure 5(b).

Non-linear emphasis is applied to improve emphasis gain, up to 9.5 dB.

Quasi-constant luminance processing is applied.

Using this method, crosstalk between the chrominance and the luminance signal can be reduced remarkably, and the S/N for highly colour-saturated pictures can be improved. This leads to a lower necessary received C/N of about 17 dB at the threshold perceptible level of noise.

Characteristics of non-linear emphasis and quasi-constant luminance processing of the MUSE are described in Annex II to Report 1075.

An experiment of HDTV transmission through a single television channel (27 MHz bandwidth) of BS-2 is being carried out in Japan using the MUSE system as shown in § 5.2

This technique of bandwidth compression can also be applied to other HDTV equipment. Such equipment of consumer use as VTRs and video-disc players using MUSE, have already been developed.

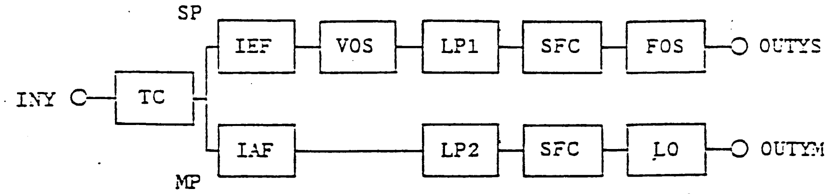

FIGURE 1(a) - Filter arrangement for the luminance signal

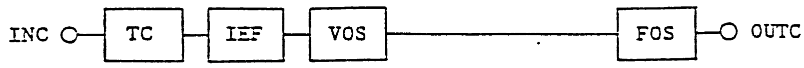

FIGURE 1(b) - Filter arrangement for the colour-difference signals

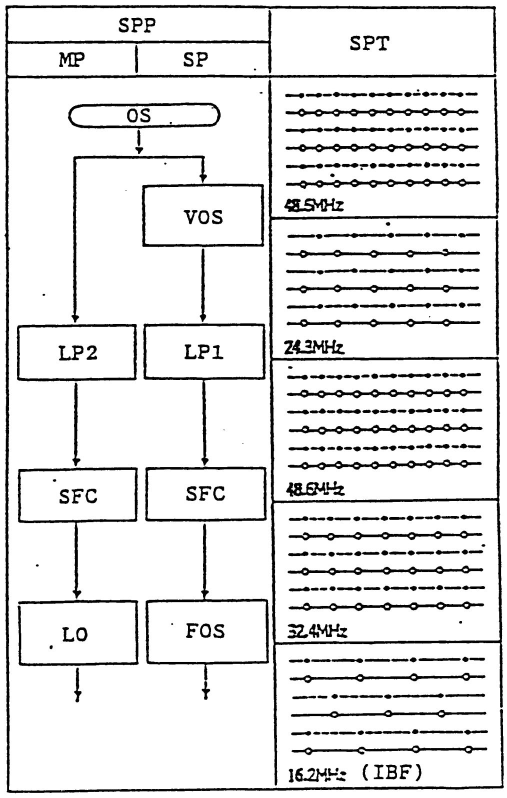

FIGURE 1(c) - Sampling pattern

FIGURE 1 - Principle of MUSE system

TC	:	time compression
SP	:	stationary portion
MP	:	moving portion
IEF	:	interfield prefiltering
IAF	:	intrafield prefiltering
VOS	:	field-offset subsampling
LP1	:	12 MHz low-pass filtering
LP2	:	16 MHz low-pass filtering
SFC	:	sampling frequency conversion
FOS	:	frame-offset subsampling
LO	:	line-offset subsampling
INY	:	luminance signal input
INC	:	colour-dffierence signal input
OUTYS	:	luminance signal output for staionary portions
OUTYM	:	luminance signal output for moving portions
OUTC	:	colour-difference signal output
SPP	:	signal processing procedure
SPT	:	sampling pattern
OS	:	original sampling
(IBF)	:	invert by frame
- O -	:	odd field
--●--	:	even field

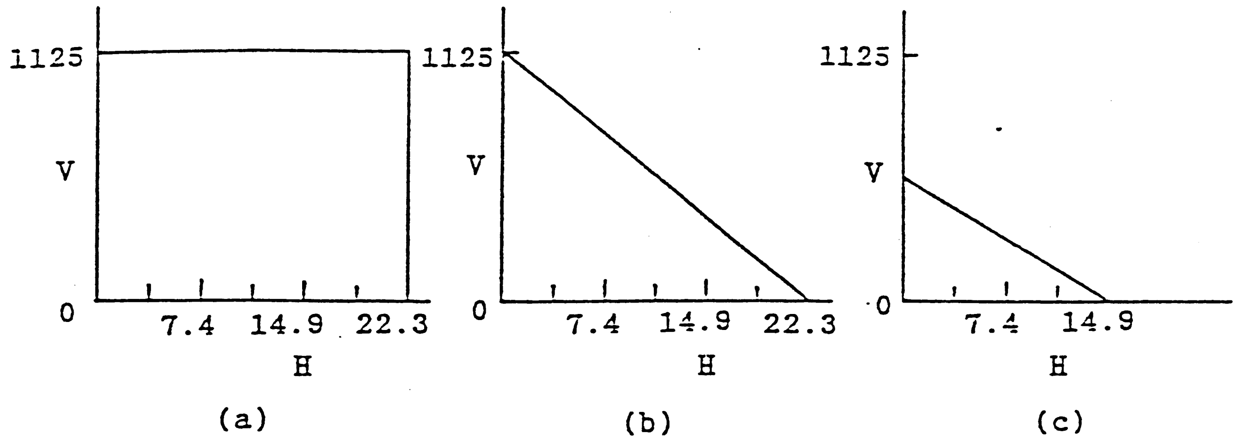

FIGURE 2 - Transmissible range in spatial frequency domain

(a) Original sampling
(b) Interframe and interfield interpolation for stationary portions
(c) Intrafield interpolation for moving portions
H : horizontal frequency (MHz)
V : vertical frequency

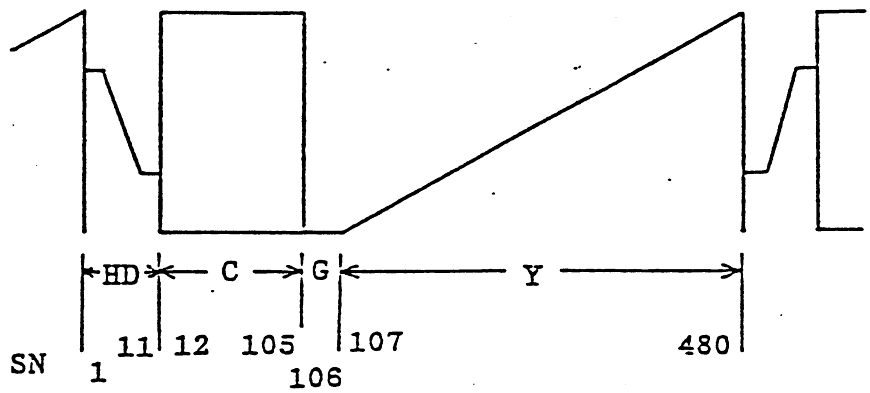

FIGURE 3 - Video signal in TCI format

HD : line-synchronizing signal
C : colour-difference signals (line-sequential)
G : guard area
Y : luminance signal
SN : sample number

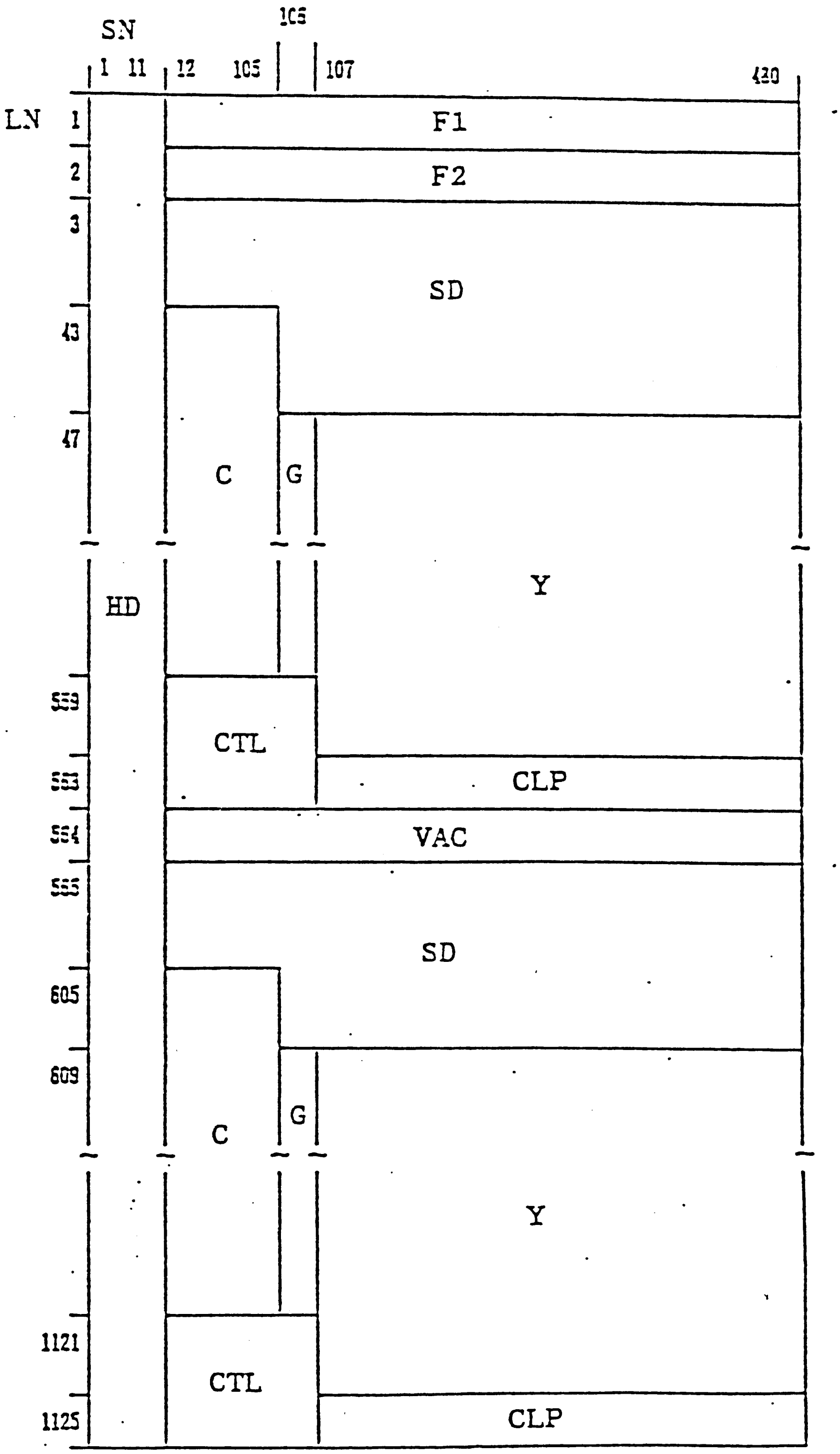

FIGURE 4 - Signal allocation map

SN : sample number
HD : line-synchronizing signal
SD : sound and data signals
C : colour-difference signals (line-sequential)
Y : luminance signal
CLP : clamp level (128/256)

LN : line number
F1 : VITS No. 1 and Frame Pulse No. 1
F2 : VITS No. 2 and Frame Pulse No. 2
G : guard area
CTL : control signals
VAC : vacant

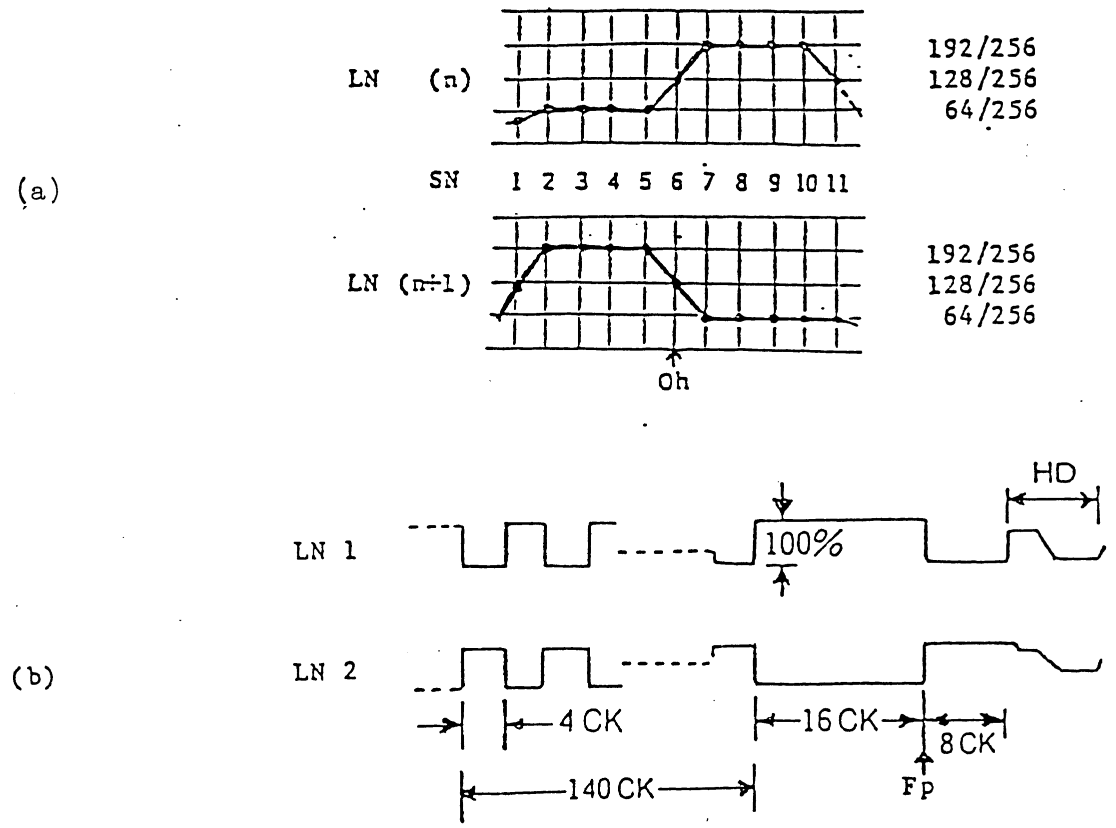

FIGURE 5 - Synchronizing signals

(a) Line-synchronizing signal

LN (n): n th line

LN(n+1): (n+1) th line

SN : sample number

Oh : timing reference for line synchronization

(b) frame-synchronizing signal

LN : line number

HD : line-synchronizing signal

Fp : frame-pulse point

CK : one clock-time duration at 16.2 MHz

TABLE II - Basic video characteristics of MUSE system

System description		motion-compensated multiple subsampling system (multiplexing of Y and C signals is done in TCI format)
Scanning rate		1125 lines/ 60 fields/ 2:1 interlace
Bandwidth of transmitting baseband signal		8.1 MHz
Sampling clock rate		16.2 MHz
Reproduced signal bandwidth	Y signal	22 MHz (for stationary portions of picture) 14 MHz (for moving portions of picture) *
	C signals	7.0 MHz (for stationary portions of picture) 3.5 MHz (for moving portions of picture) *
Synchronizing signal		positive polarity with respect to video signal polarity

* These values should be 16 MHz for Y and 4 MHz for C respectively, if a perfect digital two-dimensional filter could be used.

1.5.1.2 The HDMAC/packet system (system 2)

1.5.1.2.1 Design consideration

HDMAC is designed to meet the highest quality criteria to allow the introduction of HDTV services on existing MAC/packet services, or directly as new services. [CCIR, 1986-90e,g] describe the design consideration of HDMAC bandwidth reduction.

These include the performance of the system with respect to the received HDTV picture quality, the full utilization of current technological capabilities, the feasibility of system development as technology advances, and the economic viability and suitability of the system with respect to its adoption, and subsequent use, by broadcasters and viewers. As a consequence, receiver manufacturers can produce and market HDMAC receivers as an extension to their product range, without making existing products obsolete. Additionally, the HDMAC product range is broadened by the potential for display up-conversion. The use of DATV significantly reduces the complexity of HDMAC decoders, and therefore their cost; and makes their behaviour uniform, regardless of channel distortions.

HDMAC is optimized to allow HDTV services on WARC BC-77 emission channels (1), while preserving the compatibility with the MAC/packet system.

These constraints involve the EUREKA 95 project in global tradeoffs between the receiver complexity, the quality of the high-definition picture, generated with the 1250 line/50 field scanning standard, and the quality of the compatible picture viewed on domestic MAC/packet receivers.

This system is designed to employ spectrum folding, subsampling and motion adoption to preserve the resolution of both static and tracked motion for high-definition reception [Hurault and Arragon, 1988].

1.5.1.2.2 System description

The specification in Europe of a high-definition television system (HDTV), studied in the context of the European EUREKA 95 project, is based for its complete description, on the specification of the MAC/packet family which is presented in Report 1073 [CCIR, 1986-90h].

The time division multiplex is used for picture/sound/data multiplexing for HDMAC transmissions which include two members of the MAC/packet family: D-HDMAC/packet and D2-HDMAC/packet systems. These two systems are suited for use in satellite broadcasting and any transmission medium which guarantees a baseband of about 11 MHz.

1.5.1.2.2.1 Structure of the multiplex

The structure of the multiplex is based on a 40 ms digital frame which contains 625 lines of 64 μs each. The multiplex is composed of three main components (see Fig. 6):

- the HDMAC vision signal;
- the line blanking interval (LBI) data burst, which carries the sound/data multiplex;
- the field blanking interval (FBI) data burst, which carries the DATV/data multiplex.

1.5.1.2.2.2 Sound

Sound is coded according to the MAC/packet specification. The available capacity in the LBI is equivalent to four high-quality or eight medium-quality sound channels compatible with MAC/packet for the D2 system and eight high-quality or sixteen medium-quality sound channels compatible with MAC/packet for the D system.

1.5.1.2.2.3 Vision

Document [CCIR, 1986-90i] gives the baseband characteristics (summarised in Table III). The modulation parameters of the emitted HDMAC signal are given in Tables IV and V.

1.5.1.2.2.4 General video characteristics of the HDMAC vision signal

See Table III.

1.5.1.2.2.5 Bandwidth reduced signal

Multi-branch coding is used for HDMAC band reduction [Vreeswijk *et al.*, 1988; Arragon *et al.*, 1988; Pele and Choquet, 1988].

In order to select the optimum HDMAC BR (bandwidth reduction) algorithm, the subjective assessment of picture quality, together with other factors has been considered.

Document [CCIR, 1986-90e] reports on the subjective assessments that were performed by five laboratories throughout Europe and that led the Eureka EU 95 project to select the final HDMAC bandwidth reduction system. Seven candidates' algorithms were evaluated. Eight scaled-down moving picture sequences were used covering a range of possible source material (originated in 1250- and 625-line interlaced video cameras, 25 and 50 pictures/s film). For the tests a double stimulus method was used with continuous graphical quality-scaling (in line with IWP 11/4 methods). The ranking order for the seven algorithms was generally the same for each of the five laboratories that undertook the tests and there was a high degree of correlation for the quantitative differences between the mean grades. The results gave confidence in the method and the validity of the ranking order.

The HDMAC BR codec uses three luminance coding branches, all using quincunx subsampling lattices;

- an 80 ms branch with HD resolution for stationary areas;
- a 40 ms motion compensated branch for velocities up to 12 samples per 40 ms;
- a 20 ms branch for rapid motion and sudden picture changes except when in 25 picture/s film mode.

The transmissible range of spatial frequency is given in Fig. 7 for all modes. To carry the information contained in a 1250 line HD system through a 625 line MAC/packet channel, a process, termed "shuffling", is used.

The 40 ms branch is motion compensated. One motion vector is emitted for each block of 16 samples by 16 lines on the HD grid via the DATV data.

The HDMAC BR codec uses three colour-difference coding branches, the first and third using a quincunx, the second an orthogonal subsampling lattice:

- an 80 ms branch with HD resolution for stationary areas;
- a 40 ms branch for rapid motion and sudden picture changes;
- a 20 ms branch for rapid motion and sudden picture changes, except when in 25 picture/s film mode.

The transmissible range of spatial frequency is given in Fig. 8 for all the modes. Intra-field shuffling is used for the 80 and 20 ms branches and inter-field for the 40 ms branch.

A film mode option is implemented, which only activates the 80 and 40 ms branches. In this way maximum benefit is taken from the knowledge that 25 pictures/s film is the source material.

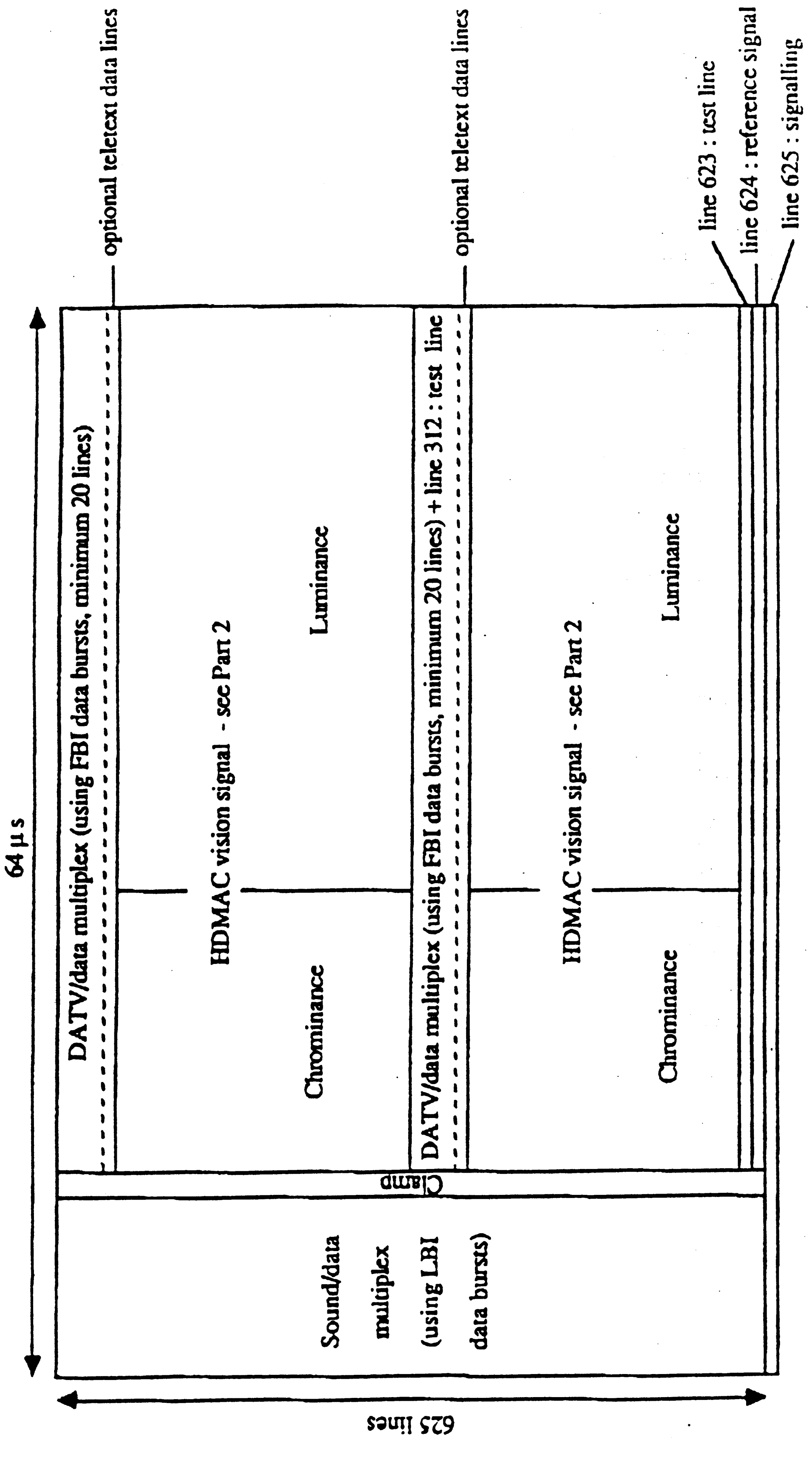

FIGURE 6 - General HDMAC/packet TDM structure

TABLE III - General video characteristics of the HDMAC vision signal

Number of emitted lines per picture :	625
Number of fields per second :	50
Interlace ratio :	2:1
Analog bandwidth approximately :	11 MHz[1]
Aspect ratio :	16:9 (associated with panning information for compatible 4:3 displays).
Compression ratios	
luminance :	3:2
colour difference :	3:1
Sampling frequency :	20.25 MHz[2]
High definition reception :	
Luminance resolution	
horizontal	
static and tracked motion :	620 c/apw[3]
untracked motion :	310 c/apw
vertical	
static :	400 c/apw[3]
motion :	200 c/apw
Compatible reception :	
Samples per active lines	
luminance :	697
colour difference :	349

Note 1 : Allowing for practicable Nyquist filter

Note 2 : Conventional MAC sampling frequency

Note 3 : Cycles per active picture width/picture height

TABLE IV - HDMAC modulation parameters for DBS

Nominal vision signal bandwidth :	10.125 MHz at -3 dB
Nominal channel bandwidth :	27 MHz
Modulation :	FM
Polarity of frequency modulation :	positive
DC component :	preserved
Pre-emphasis characteristics:	non linear process applied only to HDMAC samples and linear applied to all the multiplex (same as for MAC)
Frequency deviation :	13.5 MHz at the cross-over frequency of the linear pre-emphasis network (1.37 MHz).
Energy dispersal :	triangular frame synchronous waveform (corresonding carrier deviation : 600 kHz peak-to-peak)

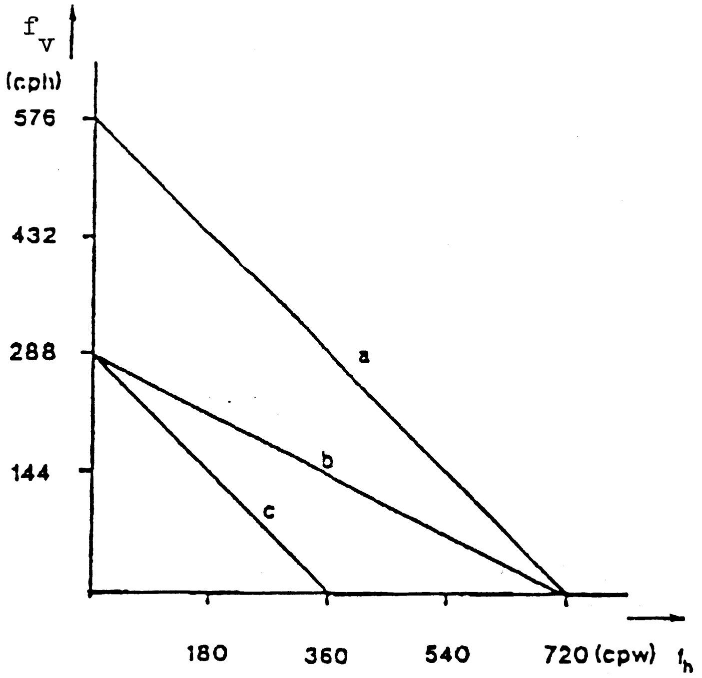

FIGURE 7 - Transmissible range in spatial frequency domain for the luminance sampling patterns

(a) 80 ms mode
(b) 40 ms mode
(c) 20 ms mode

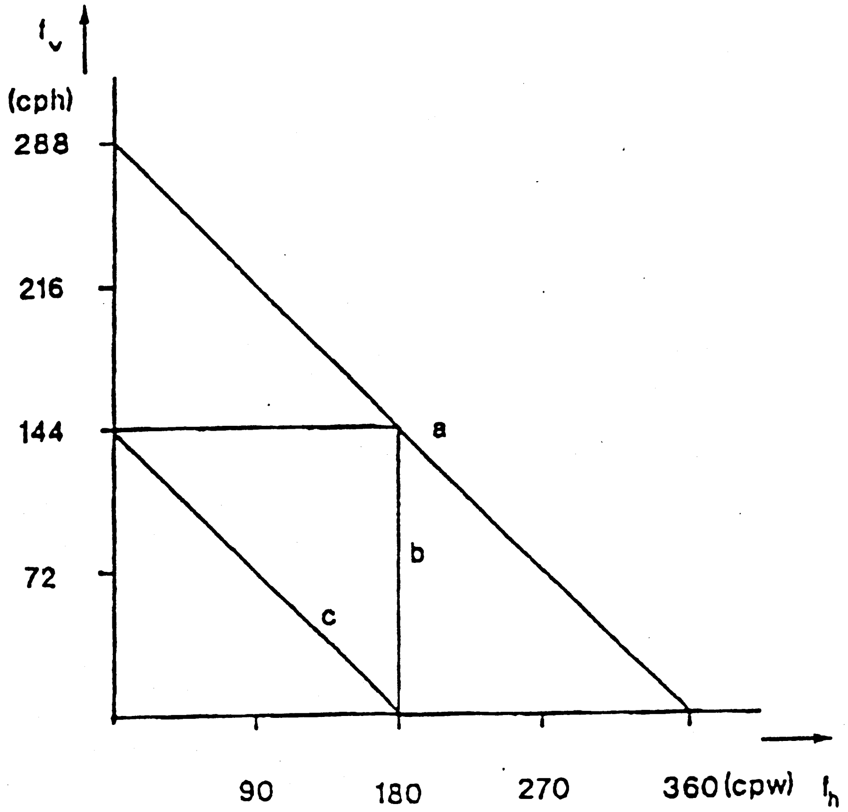

FIGURE 8 - The transmissible range of the colour-difference spatial frequency spectrum

(a) 80 ms mode
(b) 40 ms mode
(c) 20 ms mode

The branch selection information is conveyed, after formatting by the DATV data [Storey, 1986].

DATV information that contains the branch switching signal allows for 1,700 possibilities, coded in 11 bit long codewords. The five route/80 ms period coding results in a bit rate of 891 kbit/s. The colour-difference switching information is derived from the luminance DA data.

Compatibility improvement for edge crawling in stationary areas is done by vertical intra-field filtering, with an attenuation of 6 dB.

1.5.1.3 System 3

System 3 is proposed as a development of HD-MAC for a wideband RF-channel of up to twice the bandwidth of the existing planned channels. It would provide improved high-definition quality, possibly with a simplified receiver. There are two options, one based on 54 MHz sampling which would be compatible with System 2 HD-MAC receivers and one based on 72 MHz sampling which would provide higher performance with much greater use of DATV, but is not completely compatible.

1.5.1.4 System 4

System 4 is a non-compatible 60 Hz based system using the same sampling structure as the MUSE system, but with a 2-field instead of a 4-field sequence. The spatial static resolution is the same as in MUSE, while that on moving areas is greater.

1.5.1.5 System 5

System 5 is an all-digital example which is not compatible with MAC/packet receivers, but retains compatibility at source with the CCIR Recommendation 601 625-line standard. Using 4-PSK modulation, the required bandwidth could be as high as 120 MHz, but if 16 QAM were used an RF-bandwidth between 50 and 60 MHz is possible.

1.5.1.6 Other systems under development

1.5.1.6.1 HDS-NA

This is a time multiplexed analogue component satellite transmission format. A sequence repeating in four line periods at horizontal rate is used to transmit the components which result from processing. These components include: 16.8 MHz luminance information (time-expanded), reduced bandwidth uncompressed (9.5 MHz) luminance, two line difference signals representing luminance minus the average of the line before and the line after, low pass filtered, two alternate line chrominance signals compressed 2:1 and 4:1 alternatively, and a burst of digital audio for two stereo pairs with two level coding. Resolution is 480 lines per picture height (L/PH) vertical and 495 L/PH horizontal. The baseband bandwidth is 9.5 MHz, recommended deviation is 12 MHz/V peak in an IF bandwidth of 27 MHz. Weighted S/N of 48 dB is produced by a C/N of 17.7 dB.

1.5.1.6.2 HD-B-MAC

Intended for satellite transmission, an enhancement of the CCIR B-MAC standard, it is compatible with standard B-MAC decoders, which produce an NTSC output. Pan/scan compatibility is implemented. 2:1 decimation is performed to provide a high resolution 525-line signal which is sub-sampled at alternate sites on adjacent lines, filtering diagonal information. Spectrum folding provides extended luminance resolution while reducing baseband bandwidth. Luminance multiplexing compression is 3:2. Similar processing is applied to the chrominance signals, which are compressed 3:1. Luminance resolution is claimed at 954 L/PW horizontal and 480 L/PH vertical. The receiver is expected to employ adaptive line doubling. Baseband bandwidth is 10.7 MHz.

1.5.1.6.3 Spectrum compatible HDTV

This system is designed for use on terrestrial channels. Proposed is transmission of HDTV processed from a 787.5/59.94 progressively-scanned source through two 3 MHz bandwidth component pairs and a data channel.

For satellite transmission, these components, of which there are 262.5 pairs, each 63.5 μs, are time division multiplexed, with a maximum baseband bandwidth of 6 MHz.

A data channel, which is time division multiplexed in the equivalent of the NTSC vertical blanking intervals, describes low frequency component video below 200 kHz, synchronization, and a stereo pair with SAP channel. Luminance is processed in four spatio-temporal bands, from 59.94 Hz frame rate for low frequencies, to 11.988 Hz for high frequencies. Colour difference signals are refreshed at 11.988 Hz and at one third horizontal and vertical resolution of luminance. The system, designed for a 5:3 aspect ratio with 16:9 possible, claims static resolution of 720 L/PH vertical and 1020 L/PW horizontal.

As a result of the spectrum efficiency obtained through the digital transmission of low frequency average picture information, a 3 to 5 dB improvement in noise performance over the same NTSC transmission link is claimed.

TABLE V

Characteristics of example HDTV satellite broadcasting systems

Parameter	System 1 (MUSE)	System 2 (HD-MAC)	System 3	System 4	System 5
Aspect ratio	16:9	16:9	16:9	16:9	16:9
Picture rate (Hz)	30	25[1]	25	30	25
Active lines/picture	1035	1152	1152	1035	1152
Basic sampling frequency (MHz)	48.6	54	54 or 72	64.8	72
Active samples/line:[4] luminance colour difference	 1122 280	 1440 720	 1440 or 1920 720 or 960	 1496 748	 1920 960
Type of coding	analogue	analogue	analogue possibly with digital assistance (DATV)	analogue possibly with DATV	digital
Compression method	motion-adaptive sub-sampling motion-compensation	motion-adaptive sub-sampling with motion compensation	motion-adaptive sub-sampling possibly with motion-compensation	motion-adaptive sub-sampling	sub-sampling and adaptive-predictive transform variat length coding
Maximum luminance and width (MHz)[2]	22	21	21 or 24	20	21-24
Maximum colour difference bandwidth (MHz)[2]	7	10.5	10.5 or 12	7	10.5-12
Luminance sub-sampling (horizontal)	2:1	2:1	2:1	2:1	3:2
Colour difference sub-sampling (horizontal)	2:1	2:1	2:1	4:1	3:1
Colour difference sub-sampling (vertical)	2:1	2:1	2:1	2:1	2:1
Luminance compression	1:1	3:2	3:2	1-1.25:1	8:3[7]
Colour difference compression	4:1	3:1	3:1	4-5:1	8:2[7]
Transmitted base bandwidth (MHz)[3]	8.1	10.125	18	16.2	-
Digital assistance (Mbit/s)	-	1-2	up to 8	0-8	included in vide bit rate
Coded video bit rate (Mbit/s)	-	-	-	-	127-147
Digital sound/data multiplex (Mbit/s)	1.35	1.5 or 3	1 to 4	2.6	2.5
Sound signal bandwidth (kHz)	20/15	15	≥ 15	To be specified	To be specified
Sampling frequency (kHz)	48/32	32	≥ 32	To be specified	To be specified
Number of sound channels	2/4	2/4 or 4/8	-	-	To be specified
Coding/modulation method	DPCM/ternary	PCM/duobinary	≥ 2/4	To be specified	To be specified
Companding law	15-to-8 (8 ranges) /16-to-11 (6 ranges)	Linear 14/ 14-10 NICAM	Linear 14/14-10 NICAM or to be specified	To be specified	To be specified
Digital time compression	13.5:1	6.6:1	6.6 or 6:1	12.5:1	-
Error protection coding	included above	included above	included above	included above	10.5
Symbol rate (Mbaud)	12.15 Ternary	-	-	-	-
Instantaneous bit rate (Mbit/s)	-	10.125/ 20.25[5][6]	54[4] or 72[4,5]	32.4-40.5	140-160
Type of modulation and deviation, ΔF_L (MHz)	FM 10.2	FM 9.55	FM or FM + 4 PSK family 9.55 to 18	FM 16 or 22	Digital (a) 4PSK (b) 8PSK (c) 16QAM
Required RF bandwidth(MHz)	27/24	27	45-54	45-54	(a) 105-120[8] (b) 70-80[8] (c) 52.5-60[8]

Notes to Table V:

(1) Display in an HDTV receiver would normally be after suitable up-conversion, for example, 1250/100/2:1, (lines/field rate/interlace).

(2) Some loss of resolution will occur in moving areas of the picture, related to the nature and/or speed of motion, this will be much less for wideband systems.

(3) -6 dB point for overall transmission path.

(4) Source format.

(5) During digital transmission periods.

(6) Compatible with MAC/packet family of CCIR Report 1073.

(7) Reduction in mean quantization accuracy, bits/sample.

(8) Shaping factor 1.5.

1.5.1.7 Downward compatibility

Compatibility is defined as follows:

A new emission standard is "compatible" with an already existing emission standard if signals according to the new standard can be received and displayed, without additional equipment, with receivers designed for the existing standard. The quality should be about the same as the quality when a signal according to the already existing standard is emitted.

One approach for compatibility between conventional television and high-definition television is two-channel transmission systems. All signals necessary for receiving by conventional receivers are carried out by one of the two channels. The augmentation channel carries the additional information to permit picture reconstruction of HDTV.

In a system proposed in North America by the New York Institute of Technology (VISTA), an augmentation channel providing high spatial and low temporal resolution is proposed, to be combined with the high temporal resolution of the NTSC picture. Aspect ratio is 16:9 or 5:3, achieved by reducing horizontal blanking and decreasing the number of active lines. Static resolution is 800 lines horizontal and 900 lines vertical. The augmentation channel is transmitted as time multiplexed components, with a bandwidth of 5.3 MHz. Two satellite channels are suggested for transmission.

In Europe, active studies are under way concerning HDTV systems which can be received compatibly by MAC/packet receivers, with the normal quality of the latter signals. If the high-definition television signal possesses characteristics at the low frequencies of the spectrum identical to those of the existing MAC signals as in two of the examples of Table V, compatibility between the two types of service will be possible.

[CCIR, 1986-90j] indicates that the choice in the European Community is for a system which is compatible with the MAC/packet family of transmission standards. Compatibility with the European DBS emission standard is considered vital for the commercial introduction of high-definition television programmes, allowing consumers to see HDTV broadcasts on their conventional DBS sets and to make a choice of when to upgrade to HDTV. MAC/packet compatible HDTV (HDMAC) was demonstrated at IBC Brighton and with further use of digital assistance techniques. Experts in Europe are confident that compatible HDTV can at least match the quality of non-compatible systems using similar bandwidth transmission systems. With the development of consumer equipment to this HDMAC standard, probably with displays operating at 100 Hz, the options of the consumer receiving DBS programmes will range from 4:3 PAL/SECAM and MAC to 16:9 MAC and HDMAC.

The EBU [CCIR, 1986-90k] would support the HDMAC system provided that it achieves an acceptable balance between HDTV and compatible MAC picture quality, provides full service continuity for data services, provides compatibility with the WARC-77 Plan and provides compatibility with MAC/packet receivers.

Although the MUSE system is not downwardly-compatible with conventional TV systems, a MUSE to 525-line standards converter, intended for use with consumer receivers was developed and demonstrated. This is of small size (made up of four 20 cm by 30 cm circuit boards).

The resultant 525-line picture converted with this converter has, on average, higher quality than the normal picture originated with NTSC standard, although it has some flicker at the edge, with less interference than that caused by the NTSC cross-colour. It has a simple circuit construction and it will be made available at a lower price by using LSI technology. The development of this MUSE to 525-line standards converter gave some prospect to HDTV broadcasting in the 1125-line systems which can be received utilizing conventional 525-line receivers.

1.5.2 Experiment and demonstrations of HDTV satellite broadcasting systems

A satellite transmission experiment of the MUSE signal was carried out in 1986 on a single 12 GHz WARC BS-77 channel by using the 100 W Japanese broadcasting satellite in operation, BS-2.

Modulation parameters and link budget for transmission are reported in Tables VI and VII.

In this way a C/N of around 17 dB was obtainable for 99% of the worst month in most of Japan with antennas in the range of 0.7-0.9 m in diameter. This gave good picture quality. Further details are described in Annex V of Report 1075.

The experiment was also carried out in seven rounds from 1987 to 1988, using the BS-2b broadcasting satellite in operation.

The eleven Japanese television receiver manufacturers and NHK took part in the experiment. The MUSE signals were received and measured in Tokyo, Osaka, Nagoya, and their vicinities.

All the receivers produced by the manufacturers participating in the experiment showed good reception capability of MUSE signals. The signals were received with little aliasing and little ringing. Tests for sound mode switching controlled with codes also went well.

The tests produced received C/N ratios of 17 to 21 dB under clear weather, which were corresponding to, or better than, the limit of perception for noise impairment. The S/N ratios of baseband signal demodulated with the tuners were almost coincident with theoretical values (C/N + 11.9 dB).

Bit error ratios of digital sound/data signals were 10^{-3} or better at a C/N of 10 dB. They were measured under a low C/N condition deliberately provided with an attenuator inserted after the receiving antenna. No extreme picture degradation was observed with this C/N condition of 10 dB.

Picture quality was evaluated as more than grade 4 in the 5-grade scale using test materials extracted from HDTV programmes and still pictures. The sound was evaluated as grade 5 for all cases.

The modulation parameters used in this experiment were confirmed as adequate for practical use.

It was also confirmed that the DBS tuner developed for the reception of conventional television could be used for that of HDTV with minor modifications.

Further demonstrations took place in Japan in 1987 using the present BS-2b on a time-sharing basis with the current transmission of the conventional television broadcasting service and another demonstration in Canada and the United States in October 1987 using Anik-C and RCA-K1 communication satellites delivering the signal to seven cities.

Among other programmes broadcast in HDTV, the most attractive event was the Seoul Olympic Games in 1988. At opening and closing ceremonies, live satellite broadcasting using BS-2b was carried out with HDTV programmes relayed through the Intelsat to Japan from Seoul, Korea. Other sporting events were recorded on video tape and also broadcast in HDTV through the BS-2b satellite the next day. The total amount of broadcasting was 73 hours 20 minutes in 17 days.

The broadcasts were received with parabolic antennas of 75 cm to 160 cm in diameter depending on the location, and pictures were demonstrated at 81 locations throughout Japan in department stores or public facilities by using 205 various display equipments. About 3.7 million people in total observed HDTV, and were impressed with the excitement of the games conveyed by HDTV.

TABLE VI

Modulation parameters for MUSE to supplement Table II

Sound and data signal modulation	ternary PCM multiplexing in field-blanking period
Polarity of frequency modulation	positive
DC component	preserved
Pre-emphasis characteristics	Non-linear emphasis
Energy dispersal (kHz)	triangular frame synchronous waveform

TABLE VII

Link budget for MUSE transmission of 1125/60 system

Frequency	(GHz)	12
Type of modulation		FM
Equivalent RF bandwidth	(MHz)	27
C/N (exceeded for 99% of the worst month)	(dB)	17.0
S/N unweighted	(dB)	39.0
Figure of merit G/T	(dB/K)	16.0
Required power flux-density (edge of beam - exceeded for 99% of the worst month)	(dBW/m^2)	-110.5
Free-space attenuation	(dB)	205.6
Rain attenuation	(dB)	2.0
Atmospheric absorption	(dB)	0.1
Feeder-link noise contribution	(dB)	0.3
Edge of coverage of area factor	(dB)	3.0
Required e.i.r.p. from satellite (beam centre)	(dBW)	57.7
Satellite antenna beamwidth (-3 dB)	(degrees)	1.3 x 1.8
Satellite antenna gain (beam centre)	(dBi)	40.0
Losses (feeder, filters, etc.)	(dB)	2.3
Required TWTA power	(dBW)	20.0
	(W)	100

[CCIR, 1986-90f] describes the D2-HDMAC compatible emission system. This document reports on transmission by means of the French satellite Telecom 1C during the IBC demonstration in September 1988. The D2-HDMAC/packet multiplexer, demultiplexer and the satellite transmissions are outlined. Furthermore, the document gives the structure of the data multiplex, where the available bit rate for the digital assistance data is 1.164 Mbit/s. A 656+ interface, the synchronization, Nyquist filtering, non-linear pre-emphasis and de-emphasis are discussed.

[CCIR, 1986-901] summarizes the technical investigations concerning HDMAC satellite broadcasting within a 27 MHz channel of the 12 GHz WARC 77 Plan. The results obtained with the first experimental HDTV chain were in the framework of the HDTV European project Eureka 95.

Most of the tests have been done with a satellite simulator.

Also, experiments of D2-HDMAC transmission through a real satellite have been carried out in France using the DBS satellite TDF-1. The D2-HDMAC/packet signal was sent to the TDF-1 earth station through an FM microwave link with 14 hops. The signal was received by a commercially available receiving station with a 55 cm parabolic antenna. The noise figure of the SHF converter was equal to around 2 dB.

With regard to the effect of noise on the decoded (baseband) signal, the picture impairment has been evaluated by means of the satellite simulator for different values of the C/N ratio in a 27 MHz bandwidth. The tests have been done only with still pictures and with the 88 algorithm either in the static mode (80 ms branch) or in the moving mode (20 ms branch). The method which has been used was the EBU method with non-expert observers as described in CCIR Recommendation 500. The results obtained are given in Figure 9. The dashed lines indicate the confidence interval (5%) of the mean results (continuous line) obtained from 15 observers. The measured C/N was equal to 21 dB in a 27 MHz bandwidth, which corresponds for the HDMAC signal to a grade better than 4.5 on the impairment scale.

With the French satellite TDF-1, a received C/N of 17 dB is obtainable for 99% of the worst month in all the national coverage with a 55 cm receiving antenna. Thus an HDMAC signal of quite excellent quality can be received with a small receiving antenna using a 12 GHz WARC channel.

[CCIR, 1986-90m] deals with the compliance of the HDMAC signal with the protection ratios for the broadcasting-satellite service in the 12 GHz band.

Measurements of first adjacent channel (+/- 19.18 MHz) and co-channel interference levels giving just perceptible impairment on vision have been done in the two following configurations:

a) HDMAC interfering with HDMAC;

b) HDMAC interfering with the reference WARC-77 system (SECAM with a sound sub-carrier).

From these tests, the following conclusions can be drawn:

a) When the wanted signal is the WARC reference signal, then the minimum protection ratios required by the WARC-77 are met with a margin greater than 9 dB. The HDMAC signal is not more critical than a conventional MAC signal.

b) Two HDMAC signals can coexist in the WARC-77 broadcasting Plan.

Summary and conclusions

It is found that techniques exist for the broadcasting by satellite of HDTV over a range of frequencies up to about 23 GHz. Several separate possibilities exist and have been studied in detail. These techniques comprise bandwidth reduction, channel coding, multiplexing, modulation and reception. The technology for implementation of these techniques is available now, and technology for the satellite either is available now (as is the case for the 12 GHz band) or is expected to be available within the next ten years if high power levels are needed at 23 GHz.

Indications are that RF parameters and sharing may put constraints on the emission format. Nevertheless neither the characteristics of satellite broadcasting systems, nor their interference susceptibility should directly restrict the characteristics of the studio standard used as source of programme material. However, definition of that studio standard should precede the definition of any subsidiary standards if signal degradation and the costs of conversion are to be minimized.

For satellite broadcasting, the 12 GHz bands have been planned based on channel widths of 24 MHz in Region 2 and 27 MHz in Regions 1 and 3. In order to transmit HDTV within these channels, the source signals must be reduced in bandwidth through extensive signal processing. Two narrow RF-band systems (MUSE, HD-MAC) provide such signal compression at the expense of some reduction in the resolution of moving areas of the picture. Any HDTV studio standard should allow for the implementation of the kind of compression techniques described in this report.

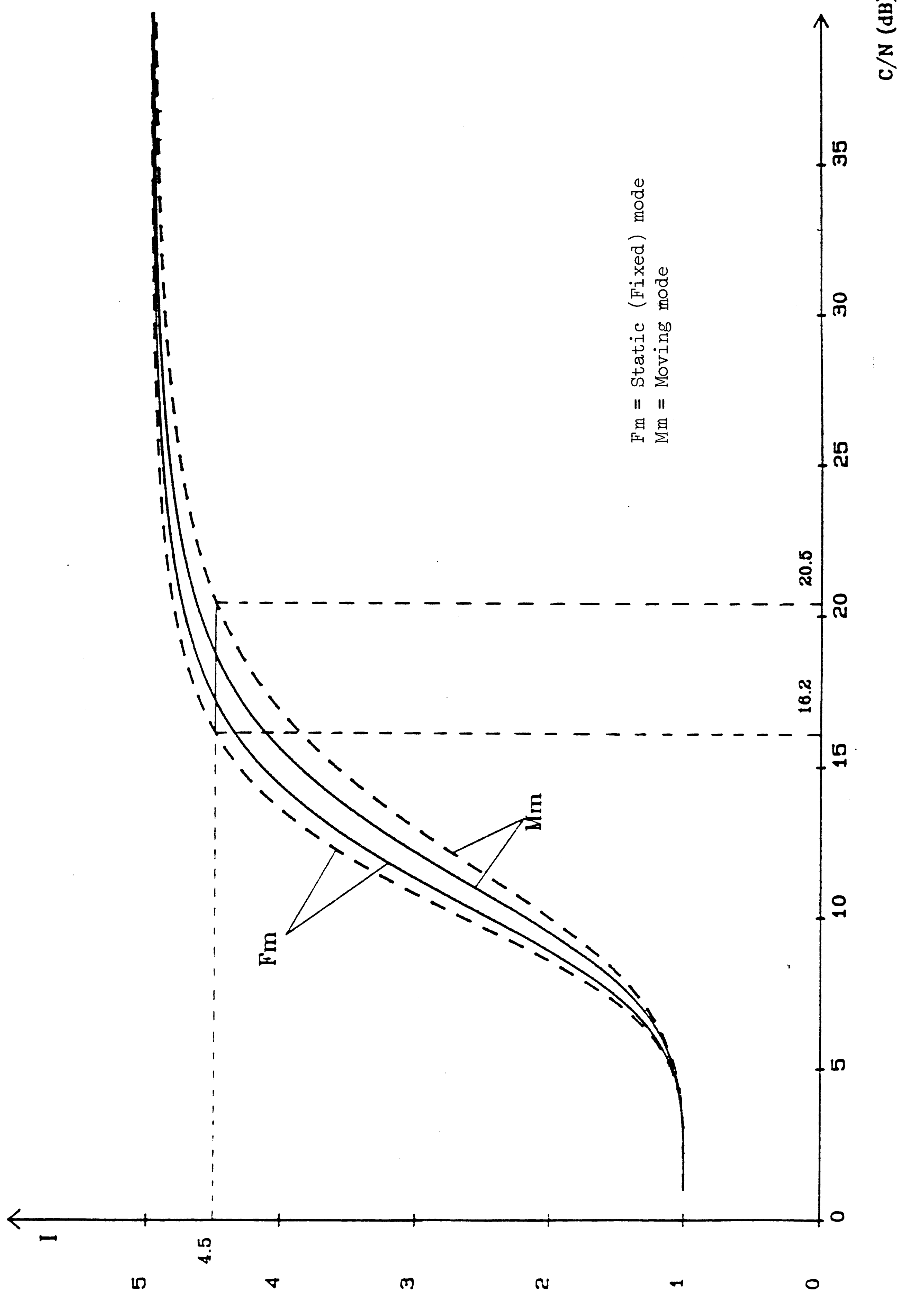

FIGURE 9

Impairment grade of the HDMAC picture signal as a function of the C/N ratio in 27 MHz

For satellite broadcasting of wider RF-band HDTV service on a world˜wide basis, potentially providing quality close to that of the studio standard, it was recognized at the WARC ORB-88 that a new frequency band would be required as the bandwidth of the channel required to broadcast a wide RF-band HDTV signal is not yet determined, there is flexibility to accommodate a range of system parameters. This means that no specific constraint would need to be imposed on the HDTV studio standard to allow satellite emission in such band. However, it is preferable that an HDTV studio standard be specified before developing the world-wide satellite broadcasting standard considered desirable by WARC ORB-88.

Techniques which will allow the broadcasting of HDTV by satellite have been identified. These techniques make use of technology which is now available in the case of bandwidth reduction, modulation and reception techniques. In particular, studies of MUSE and HD-MAC in Japan and Europe respectively have led to the technology required for the complete studio-receiver chain. Systems have been developed and demonstrated. Cost reduction considerations in view of developing consumer equipment have already been included in the process; thus standardization of the studio production and emission formats is urgently needed. For broadcasting at frequencies up to 23 GHz, satellite technology should not be a limiting factor on the choice of an emission standard, and also will not as a consequence affect choice of the studio standard.

The CCIR considers it necessary to continue to study radio frequency and emission technical parameters including modulation, channel coding and multiplexing of HDTV satellite broadcasting. Further study is required to determine:

i) system parameters for wide RF-band analogue and digital high definition television transmissions by satellite;

ii) propagation characteristics for bands suitable for wide RF-band high definition television transmissions;

iii) inter- and intra-service sharing and interference, interregional sharing.

The progress of these studies is expected to allow definitive results before the end of the next CCIR study period.

2. Terrestrial emission of HDTV including cable distribution

2.1 Introduction

The majority of the world's consumers of television broadcasting receives television via terrestrial broadcast. Widespread adoption of higher definition television will depend, for many administrations, on ready consumer access to terrestrial broadcasts.

The task of recommending HDTV emission standards is rendered difficult by the diversity of strategies in different parts of the world where satellite transmission, terrestrial emission and cable distribution have different requirements and priorities. Basic statements for HDTV emission standards are:

- the numbers of emission standards should be limited;
- AM-VSB is one of the preferable modulation types with respect to the bandwidth saving;
- it would be preferable for the HDTV standard for terrestrial and cable transmission to be similar;
- existing networks should not be adversely affected by introduction of HDTV;
- each type of receiver compatibility, channel compatibility or baseband compatibility is advantageous;
- the whole studio-satellite/transmitter-cable-receiver chain should be taken into account when proposing the HDTV signal standard.

2.2 HDTV approaches in an NTSC environment

In the United States, the television industry has the objective of preserving the public's investment in current television equipment during a transition period for HDTV. A further goal is to preserve the diversity of television distribution media.

The feasibility of broadcasting HDTV terrestrially has been demonstrated by an experiment conducted over a three week period in Washington D.C., in January 1987. The experiment is part of a continuing project by segments of the United States broadcast industry to develop a system for terrestrial HDTV broadcasting. It was shown that such programmes could be delivered to viewers using two contiguous 6 MHz UHF television channels, employing conventional VSB-AM.

Additionally, terrestrial HDTV was also demonstrated using FM modulation in the 13 GHz band during the same period. In this project, the MUSE system was used.

In Japan, for the existing 6 MHz NTSC system, 9 and 12 MHz channel compatible systems are being studied and experiments have been carried out using existing cable networks.

2.2.1 Current status of United States television distribution

Television programmes for entertainment and information are available to most United States viewers in their homes by all of the available distribution means. Currently there are approximately 89 million homes with over 160 million television receivers that receive television broadcasts supplied by 1,060 commercial television stations and 342 non-commercial stations. They are about equally distributed between the VHF and UHF bands, 668 VHF and 734 UHF stations.

2.2.2 Approaches to HDTV distribution to the viewer

In the United States, there is agreement [CCIR, 1986-90n] that the introduction of HDTV should not adversely affect the unique character of the television industry. To achieve this goal, terrestrial broadcasting must be given the opportunity to compete with the other methods of television programme distribution. This fundamental objective was affirmed in the 1 September 1988

Tentative Decision and Further Notice of Inquiry of the United States Federal Communications Commission (FCC) which contains the following tentative findings:

- providing for terrestrial broadcast use of ATV (advanced television) techniques would benefit the public;
- tentatively concludes that the benefits of this technology can be realized by the public most quickly if existing broadcasters are permitted to implement ATV;
- any spectrum capacity needed for terrestrial broadcasting of ATV must be obtained from the spectrum now allocated to terrestrial broadcast television (VHF and UHF);
- finds that existing service to viewers utilizing NTSC receivers must be continued irrespective of the actual manner in which ATV services are delivered, at least during a transition period. This can be accomplished either by transmitting ATV signals that can be received directly by NTSC receivers or by simulcasting NTSC and incompatible ATV signals on separate channels;
- systems requiring more than 6 MHz to broadcast a signal not compatible with NTSC receivers will not be authorized [CCIR, 1986-90o];
- finds it in the public interest not to retard the independent introduction of ATV in other services or on non-broadcast media, but (the FCC is) sensitive to the benefits of compatibility between equipment associated with the various video delivery methods.

2.2.3 Spectrum for ATV options

For terrestrial broadcasting in the United States the investigations are currently concentrating on four options:

A) the use of a single 6 MHz channel compatible with NTSC;

B) the use of a single 6 MHz channel compatible with NTSC and an additional 3 MHz augmentation channel not necessarily contiguous with the 6 MHz channel to carry information to augment the base channel information when generating the HDTV picture in HDTV receivers;

C) the same as option B, except the augmentation channel [CCIR, 1986-90n] is 6 MHz wide;

D) each terrestrial broadcaster would be provided with an additional 6 MHz frequency band for a simulcast non-compatible ATV signal.

The United States has done studies [CCIR, 1986-90p] to determine the availability of spectrum under different conditions.

The analyses were done using a specially developed computer program which permits the examination of channels under different conditions. The studies presumed that advances in the technology for delivering ATV service may allow the minimum distance separations for ATV stations to be less than those currently required. The UHF taboos have been ignored*. Only the separation distances required to reduce adjacent and co-channel interference were observed.

It should be recognized also that the studies are preliminary in nature. For example, no consideration was given to the effects of using alternative sites for broadcasting ATV signals or the use of terrain shielding, or power reduction as a means to implement ATV for 100% of the stations.

The computer analyses were carried out to determine the number of stations which could be assigned for the following situations:

a) where contiguous spectrum (both 6 MHz and 3 MHz) can be assigned;

b) where UHF or VHF stations can be assigned (VHF stations augmented in UHF and vice versa, no preference for contiguous);

c) same as b), but as much contiguous spectrum as possible;

d) as much contiguous spectrum as possible.

The best results were for b). They show that 100% (96%) of all existing stations can be provided with an additional 3 MHz (6 MHz) supplemental (non-contiguous) if the minimum co-channel separation distance for the ATV stations is reduced to 160 km. On the other hand, if the current separations are maintained (249 - 353 km), the percentages would be 77% for 3 MHz and 60% for 6 MHz. For providing the same service area, these results imply the need for a system requiring a significantly smaller protection ratio than NTSC.

[CCIR, 1986-90q] reports the most recent progress towards introduction of Advanced Television (ATV) services in the United States. The new studies ignored adjacent channel protection, as well as the UHF taboos. It was also determined that the best spectrum approach to accommodating ATV systems needing an additional 6 MHz has the following characteristics:

1) the additional spectrum is not necessarily contiguous;

2) HDTV systems for terrestrial broadcasting must be able to operate at closer than present spacings.

---

* The UHF taboos are: intermodulation, cross-modulation and half-IF ($n \pm 2$, 3, and 4 channels), local oscillator ($n \pm 7$ channels), IF beat ($n \pm 8$ channels), sound image ($n \pm 14$ channels), vision image ($n \pm 15$ channels).

The preliminary indications are that 99.7% of all existing television stations can be accommodated at a minimum co-channel spacing of 160 km (100 miles). [CCIR, 1986-90q] also describes a number of approaches under investigation by the United States regarding the modification or elimination of the existing NTSC UHF taboos. These include:

1) changes in receiver design;

2) change in minimum taboo transmitter spacings;

3) changes in the transmission system.

An example of one proposed system accommodating the UHF taboos is shown in Table VIII below. It indicates the wanted-to-unwanted signal protection ratios for just perceptible interference for the case of an HDTV signal to an NTSC receiver.

TABLE VIII

Wanted-to-unwanted signal protection ratios

Co-channel	+14 to +6 dB
Adjacent channel (n ± 1)	-30 dB
Intermodulation (n ± 2, n ± 3, n - 4)	-40 dB
Half IF (n + 4)	-30 dB
IF beat (n ± 7, n ± 8)	-45 dB
Sound image (n + 14)	-45 dB
Vision image (n + 15)	-45 dB

Note 1 - Wanted signal level: -45 dBm.

Note 2 - Based on measurements of seven television receivers representative of existing receiver population.

2.2.4 Proponent systems [CCIR, 1986-90p]

ATV systems proposed for consideration in the different categories are indicated in Table IX:

TABLE IX

VHF/UHF Spectrum Required	Technology	Comments	Number of Proponents
6 MHz	"NTSC-Compatible"	NTSC TV set displays ATV signal as NTSC signal. ATV set would display either ATV programmes or NTSC programmes.	7
9 MHz	Standard NTSC + 3 MHz Augmentation	NTSC TV set displays the standard NTSC portion of the signal. ATV set would display either ATV or NTSC programmes.	4
	"Non-Compatible" *	NTSC TV set requires converter for NTSC display of ATV programme. ATV set would display either ATV or NTSC programmes.	2
12 MHz	Standard NTSC + 6 MHz Augmentation	NTSC TV set displays only the standard NTSC portion of the signal. ATV set would display either ATV or NTSC programmes.	4
	"SIMULCAST" Standard NTSC + 6 MHz "Non-Compatible"	NTSC TV set displays only the NTSC programme. ATV set could receive ATV programmes and NTSC programmes.	3

* Not permitted for terrestrial broadcasting by FCC Tentative Decision.

Several systems have been proposed for terrestrial, cable and satellite broadcasting of HDTV in the United States. Some organizations have proposed more than one system. An article [Hopkins and Davies, 1989] gives information on these proposals and describes the activities of involved committees in North America. Table X is a summary of the systems presented to the FCC in November 1988.

TABLE X - Summary of systems proposed to FCC Advisory Committee

	AVE	BTA	DSRC		DEL	FAR	HRS	NHK			MIT		NYIT	NAP		OCS	PS	QTV	SA	ZEN
			ACTV I	ACTV II				MUSE 6	MUSE 9	NAROW MUSE	RC	CC		HD MAC	HD NTSC					
SPECTRUM CATEGORY	A	A	A	C	A	A	A	A	B	D	A	D	B/C	*	B	C	A	A	*	D
RF BANDWIDTH (MHZ)	6	6	6	12	6	6	6	6	9	12	6	12	9/12	*	9	12	6	6	*	12
H-RESOLUTION (TVL/PH)	660	NTSC	400	600	660	330	NTSC	422	422	568	300	675	750	495	495	?	?	NTSC	534	612
V-RESOLUTION (TVL/PH)	660	NTSC	480	800	660	400	NTSC	690	690	650	600	762	900	480	480	?	?	NTSC	480	720
FULL DIAGONAL RESOLUTION	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	?	?	NO	NO	NO
FULL TEMPORAL RESOLUTION	NO	YES	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	?	YES	YES	NO
WIDE SCREEN	YES	NO	YES	YES	YES	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES
INTEGRATED SIDE PANELS	NO	N/A	NO	NO	YES	N/A	N/A	YES	YES	YES	YES	YES	YES	YES	NO	N/A	YES	N/A	YES	YES
SEPARATE COLOR	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	YES	NO	NO	?	NO	YES	YES
FIELD STORE REQUIRED	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	OPT	OPT	YES	?	NO	YES	YES

N/A - NOT APPLICABLE ? - NOT SPECIFIED

ORGANIZATIONS PROPOSING SYSTEMS

AVE	AVELEX
BTA	BROADCASTING TECHNOLOGY ASSOCIATION
DSRC	DAVID SARNOFF RESEARCH CENTER
DEL	DEL REY GROUP
FAR	FAROUDJA LABORATORIES
HRS	HIGH RESOLUTION SCIENCES
NHK	JAPAN BROADCASTING CORPORATION
MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NYIT	NEW YORK INSTITUTE OF TECHNOLOGY
NAP	NORTH AMERICAN PHILIPS CORPORATION
OCS	OSBORNE ASSOCIATES
PS	PRODUCTION SERVICES
QTV	QUANTICON
SA	SCIENTIFIC ATLANTA
ZEN	ZENITH ELECTRONICS CORPORATION

SPECTRUM CATEGORY OF PROPOSED SYSTEMS

A = 6 MHZ NTSC COMPATIBLE
B = 6 MHZ NTSC + 3 MHZ AUGMENTATION SIGNAL
C = 6 MHZ NTSC + 6 MHZ AUGMENTATION SIGNAL
D = SIMULCAST (6 MHZ NTSC IN ONE CHANNEL, 6 MHZ NON-COMPATIBLE SELF-CONTAINED ATV SIGNAL IN SECOND CHANNEL)
* = SATELLITE DESIGN, REQUIRES ONE TRANSPONDER

November 1988

2.3. Approach using HDMAC system

The HDMAC system has been proposed for satellite as well as for cable and terrestrial distribution.

The possibility of delivering HDTV through terrestrial broadcasting has been studied by using HDMAC signals [CCIR, 1986-90r]. The characteristics of the MAC signal allow the use of VHF and UHF channels with amplitude modulation offering the possibility of a development of a high-definition television service based on already available technologies. Moreover, if the high-definition television signal possesses characteristics at baseband such that the low frequencies of the spectrum are identical to those of the existing MAC signal, compatibility between the two types of service, D or D2-MAC/packet and high-definition television, will be possible. So far, the D or D2-MAC/packet standards offer an evolutionary path. The evolution is characterized as "compatible", since the first generation of D or D2-MAC/packet receivers will be able to interpret the lower part of the spectrum as that of a signal meeting the existing D or D2-MAC/packet standard. Due to the existence of an installed base of D or D2-MAC/packet decoders (equipped with baseband and BSS inputs) provided for satellite broadcasting at 12 GHz, this compatibility will make it possible, from the outset of the broadcasting of high-definition television programmes, to reach a large audience, thus permitting a gradual growth in receiver sales without compromising the economy of the system.

Based on previous experiments and simulations of an AM vestigial sideband channel in UHF with D2-MAC/packet signals, it is reported that an emission of HDTV (HDMAC) compatible with D or D2-MAC/packet decoders is made possible in a terrestrial AM vestigial sideband channel having a total width of 12 MHz to allow a Nyquist filtering of the baseband around 10.125 MHz either for digital assistance or video.

2.3.1 AM/VSB systems

The following parameters are the result of studies and first transmission measurements on cable [CCIR, 1986-90s].

2.3.1.1 Nyquist filtering of vision carrier at the transmitter

The system for HDMAC signals is compatible with 625-line D2/DMAC system.

Channel width: 12 MHz

Modulation type: Vestigial sideband amplitude modulation (AM/VSB)

Nyquist filtering: Vision carrier ±500 kHz at transmitter

Modulation polarity: Identical to existing D2/DMAC system

Modulation levels		Negative	Positive
Video signal -	white level	10%	100%
	black level	100%	10%
	clamp level	55%	55%

Data signal	"1"	19%
	"1"	91%
	"0"	55%

Receiver detection: Synchronous

Phase characteristic: Transmitter and receiver linear

An improvement of up to 5 dB of the S/N and signal-to-interference ratio can be reached when the Nyquist filtering is moved from the receiver to the transmitter site.

The system with a transmitter Nyquist filter was tested successfully for cable distribution.

2.3.1.2 Nyquist filtering of video carrier at the receiver

Same parameters as in § 2.3.1.1 except

Nyquist filtering: Video carrier ±750 kHz at the receiver

2.3.2 FM/VSB systems

Under consideration.

2.4 Other systems under development

[CCIR, 1986-90t] entitled "HDTV transmission system" describes a single-channel transmission system with an intermediate (down) conversion of a number of lines and with a reflected modulation, which has been proposed and is under study in the USSR.

2.5. Protection ratios

Since it is understood that existing networks should not be affected by the introduction of new HDTV systems, protection ratios must not exceed those currently in use (Recommendation 655). It can be expected that the required protection ratios for most HDTV systems will not be greater because of the envisaged structure of HDTV signals, e.g. absence of normal synchronizing pulses.

Protection ratio figures for HDTV systems affected by HDTV on conventional TV systems are not available today. For conventional TV systems affected by HDTV emission, only limited information is available. More measurements are needed. These measurements shall be made with "modern" receiver types. The term "modern receiver" depends on the life-time of TV receivers from the introduction date of HDTV in the different countries. Cable transmission systems employing adjacent channel operation require stronger protection ratio figures than those given in Recommendation 655. For this special case we have to define a new type of continuous interference which is 100% of time. Most interference on cable is present 100% of the time.

When in cable systems adjacent channel operation is applied then interference is present for 100% of time. In such systems a signal level difference of approximately 3 dB is allowed between adjacent channels and 6 dB between image channels. The interference should be limited to a certain impairment grade.

3. Multi-media distribution environment

When conventional television was standardized and implemented many decades ago, terrestrial broadcasting was the only medium that could be used to deliver the service to the homes. Consequently, the emission formats were optimized for such a medium and television receivers were dedicated to off-air reception.

Today, many broadcasting/distribution media can be used in parallel with conventional terrestrial broadcasting to deliver television to the home.

Consider the variety of broadcasting/distribution media that will co-exist and will be used to deliver television to the home. They include:

- terrestrial broadcasting;
- satellite broadcasting;
- cable distribution ("CATV");
- multipoint, multi-channel distribution (MMDS);
- optical fibre distribution (analogue and digital);
- pre-recorded distribution (VCR + cassette tapes, video discs).

Most of the broadcasting/distribution media may eventually be used to distribute HDTV to the home.

This diversity of media will undoubtedly continue and increase. For one thing, the present systems of terrestrial television broadcasting will need to be maintained for a significant time. Moreover, existing and future higher definition television systems will also need to co-exist for a period. This diversity will result in the existence of many interfaces between the media, as shown in Figure 13.

Such diversity could result in difficulties of converting from a studio/production HDTV standard, and in converting from one delivery format to another. The inevitable consequence would be higher system and receiver cost and complexity, or a degradation of picture quality, or a combination of both.

But the development of these new standards for HDTV broadcasting/distribution needs to take into account not only this multi-media environment, but the characteristics and capabilities of each of the several media in choosing formats, that are not only easily convertible between media but which make most efficient use of each delivery medium and lead to receiver implementation of minimum complexity.

Since different delivery media have different spectrum capacity and different transmission channel impairments, different types of modulation will be used and the optimum use of the transmission channel will imply that the signal quality and service capacity (e.g. number of audio channels) delivered on some media will be greater than on others. This should lead to the establishment of a hierarchy of related formats optimized for the different media they will be carried on.

This hierarchy would ensure that easy conversion can be made between these different transmission standards and that a common baseband signal representation can be generated and thus common baseband processing can be used in the receiver. An example of the use of a common baseband format is HD-MAC developed by the European Eureka 95 programme. The same baseband signal can be used for satellite broadcasting, terrestrial broadcasting, cable and fibre optic systems as well as home recorders and communication systems. As indicated in Fig. 13 (interface F.1), the common baseband representation would allow for common use of complex circuitry such as picture processor, sound processor and control circuits irrespective of the medium on which the signal is received.

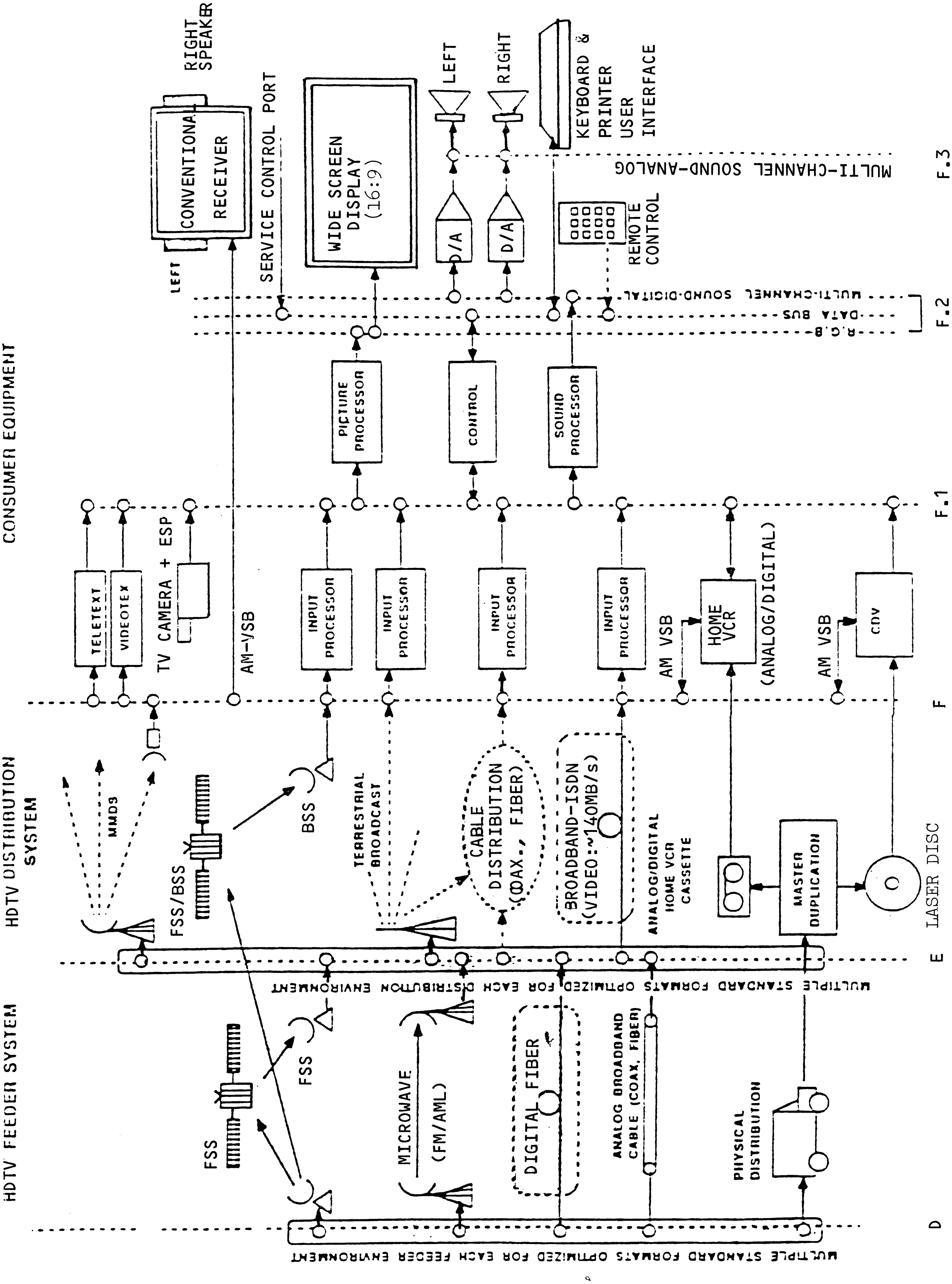

FIGURE 1 - High-definition television system architecture

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[1986-90]: **a.** IWP 11/6-1029 (EBU); **b.** IWP 11/6-1025 (Japan); **c.** IWP 11/6-1019 (Canada); **d.** IWP 11/6-1040 (EBU); **e.** IWP 11/6-2013 (Netherlands); **f.** IWP 11/6-2062 (France); **g.** IWP 11/6-2086 (France, Netherlands, UK); **h.** IWP 11/6-2096 (France); **i.** IWP 11/6-1063 (UK); **j.** 11/356 (Spain); **k.** 11/346 (EBU); **l.** IWP 11/6-2098 (France); **m.** IWP 11/6-2097 (France); **n.** IWP 11/6-2019(Rev.1) (USA); **o.** IWP 11/6-2016(Rev.1) (USA); **p.** IWP 11/6-2021 (USA); **q.** IWP 11/6-2085 (USA); **r.** 11/15 (France); **s.** IWP 11/5-88/9 (Chairman, IWP 11/5); **t.** 11/344 (USSR).

PART 8 - DATA BROADCASTING SERVICES IN THE HDTV ENVIRONMENT

In its studies on data broadcasting in HDTV, JIWP 10-11/5 recognized that improvements in the video picture should be harmonized with balanced improvements in the sound and data components [CCIR, 1986-90a]. These improvements should allow the evolution of present teletext services towards the use of more sophisticated presentation features (dynamically redefinable character sets (DRCS), geometric, photographic), new display formats (e.g. 80 characters/row, wide aspect ratio) accompanying sound, data for processing and new applications.

[CCIR, 1986-90b] points out the need to consider the capacity requirements of the programme sound and data broadcasting services at the same time as the HDTV emission format is developed and to adopt a digital multiplex structure allowing flexible reallocation of the capacity for either sound or data services [Chouinard, 1987]. The document also indicates the need to consider conditional access requirements for vision, sound and data.

The need to allocate adequate transmission capacity for data services and to adopt a flexible digital multiplex, as well as to provide for conditional access is also indicated in § 1.2.3 and 1.2.4 of Part 7 of this Report.

The consideration of a flexible digital multiplex carrying different data services would require the study of the features of an intelligent receiver which would allow interconnection to a personal computer, as indicated in [CCIR, 1986-90a,b], in order to achieve the best exploitation of the service resources.

[CCIR, 1986-90c] suggests an approach for the insertion of data broadcasting services in the HDMAC system whose basic characteristics are given in [CCIR, 1986-90d]. The opinion expressed in the above document is that the use of the field blanking interval of HDMAC signals for DATV data allows only two lines per field for data broadcasting services. This reduced capacity should be assigned to multilingual subtitling, while teletext should be conveyed through the digital sound/data packet multiplex, in both D and D2 versions. In order to ensure full service continuity in the evolution from D/D2-MAC/packet system [CCIR, 1988] to HDMAC, teletext services should be provided in the digital sound/data/multiplex from the beginning of MAC/packet transmission. Teletext decoders should therefore be developed with the capability of receiving data from both the field blanking interval and the digital packet multiplex.

A further document, [CCIR, 1986-90e] draws attention to some requirements for broadcasting of data in the context of HDMAC, namely, the need to ensure the largest flexibility in the management of the overall capacity (e.g. by sharing the capacity); the coexistence of various data services in every subframe (even at different bit rates, e.g. 10.125 Mbit/s and 20.25 Mbit/s); a proper operation of HDTV receivers by giving the highest priority to DATV data.

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PART 9 - TRANSMISSION OF HDTV FOR INTERNATIONAL PROGRAMME EXCHANGE*

1. Introduction

This chapter deals with the transmission of HDTV. One part deals with the satellite transmission of HDTV and the other deals with the terrestrial transmission of HDTV. The future work in this area will need to be coordinated with the CMTT.

2. Satellite transmission of HDTV

Long distance HDTV transmissions, such as those made possible by satellites, are essential for the international exchange and distribution of programmes. There has already been demonstrations of such capability and it continues to be under study.

2.1 FM transmission

At the 1987 International Colloquium on HDTV held in Ottawa, Canada, the papers and workshops were supported by an extensive series of demonstrations, including broadcasts from live and tape material using the MUSE-E technique by satellite, CATV, cable, optical fibre and optical disc. The demonstrations also included inter-studio transmission of HDTV using the newly developed MUSE-T technique with a 54 MHz transponder on the Canadian Anik-C satellite. Following the Colloquium, the MUSE-E equipment and a 27 MHz ANIK-C satellite transponder were used for a period of two weeks for national and international HDTV broadcasts to the public for demonstrations and survey. Three sites in Canada and four sites in the United States were included, resulting in upwards of 100,000 people being introduced to HDTV [CCIR, 1986-90a].

HD-MAC was demonstrated during the IBC in 1988.

Signals from HDTV VTRs and from cameras were bandwidth reduced and transmitted via a satellite channel or millimetre wave link as HD-MAC. The signals were decoded and displayed as HDTV pictures.

In addition, the HD-MAC signals were displayed on D2-MAC receivers showing the compatible picture. HD-MAC VCR and compact disc video were both demonstrated during the presentation.

Implementation of HD-MAC in cable systems is being investigated.

Long distance HDTV transmission circuits are essential to an operational broadcasting system for the exchange and distribution of programmes.

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* International exchange on video tape is considered in draft Recommendation XD/11 and Report XH/11.

Along with emission experiments on broadcasting satellites, transmission experiments on communication satellites and other media have also been carried out in Japan since 1987. Based on the results obtained through these experiments, international transmission from Japan to Australia using three satellite links, and from Korea to Japan using two satellite links was carried out in 1988. Although the RF-bandwidth of the satellite repeaters were different, frequency modulated MUSE signals with 27 MHz bandwidth were transmitted from end-to-end with interfaces at IF between the different segments of this multi-media, multi-hop transmission to eliminate degradation caused by the modulation and demodulation process.

Special precautions concerning waveform distortion were taken to correct both IF and baseband characteristics. Accumulated IF amplitude and group delay distortion were equalized at the receiving end, and the baseband equalization was performed with an equalizer in the MUSE encoder. The tap coefficients calculated from the test pulse signal in the vertical blanking interval measured at the receiving end were sent back through the telephone circuit. In addition to this equalization, a final equalization was performed by an automatic equalizer in the decoder.

In July 1988, a multi-hop experimental transmission was carried out between Japan and Australia using first the CS-2b (6/4 GHz) in Japan, then INTELSAT-V (F-1, 6/4 GHz), to Australia, followed by a final satellite hop over AUSSAT K2 (14/12 GHz), and finally by two terrestrial radio links in the 42 GHz band (see Fig. 1). The measured C/N for the overall modulation/demodulation section was 17.6 dB which was almost identical to the calculated value of 17.3 dB. The overall IF frequency characteristics measured after equalization were 0.5 dB p-p amplitude variation and 10 ns p-p group delay. No degradation was measured on the DCPM encoded audio signal in the vertical blanking interval because the overall C/N was high (17.6 dB). Satisfactory waveform transmission characteristics were obtained due to the IF and baseband equalization.

Major programmes of the Seoul Olympic Games held in September 1988 were transmitted in the form of HDTV from Korea (Rep. of) to Japan. HDTV programmes were encoded to MUSE and frequency modulated at the International Broadcasting Center, then transmitted using coaxial cable to the earth station, using INTELSAT-V (F-1, 14/11 GHz) to the NHK Broadcasting Center, Yoyogi, Tokyo, Japan, or the KDD Yamaguchi earth station for site diversity. Received IF signals were fed to the feeder-link transmitter for the BS-2 to distribute 81 receiving points within Japan (see Fig. 2). Other HDTV signals from a VTR in the Broadcasting Center were encoded to MUSE, modulated and fed to the NTT earth station and transmitted through CS-3 (30/20 GHz) to seven NTT earth stations and thence by transportable microwave link (11 GHz) to HDTV demonstration sites.

The measured overall C/N after two-tandem transmissions between Korea and Japan measured at the satellite broadcasting receiver with 75 cm diameter antenna was 17.9 dB compared with the calculated value of 18.3 dB. The overall IF frequency characteristics after equalization were 0.5 dB p-p amplitude variation and 5 ns p-p group delay. Satisfactory waveform transmission characteristics were also obtained after equalization.

These experiments confirmed the applicability of long distance and mixed-media transmission of HDTV signals to domestic and international connections.

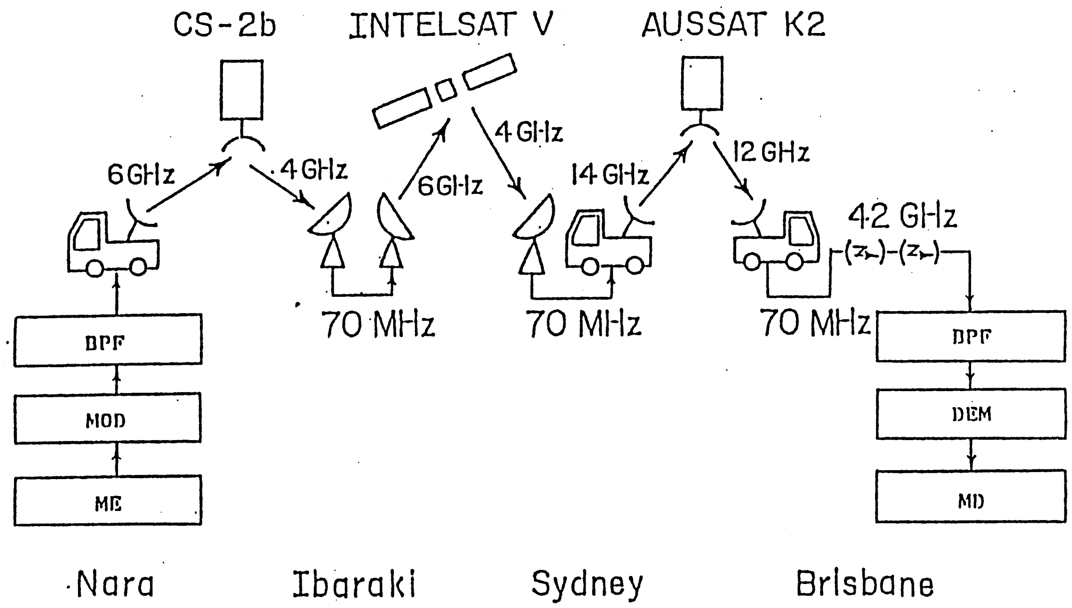

FIGURE 1 - System configuration for the transmission from Japan to Australia

ME : MUSE encoder
MOD : FM modulator
BPF : 27 MHz band-pass filter
DEM : FM demodulator
MD : MUSE decoder

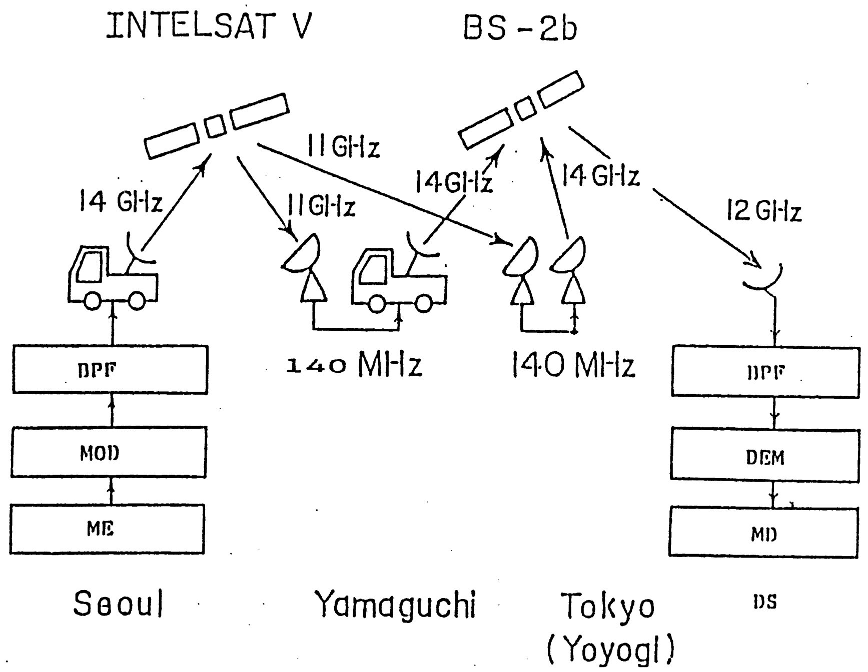

FIGURE 2 - System configuration for the transmission from Korea to Japan

ME : MUSE encoder
MOD : FM modulator
BPF : 27 MHz band-pass filter
DEM : FM demodulator
MD : MUSE decoder
DS : 81 demonstration sites

2.2 Digital transmission

IWP 11/7 reports in [CCIR, 1986-90b] studies which suggest that bit rate reduction techniques (DPCM, DCT) currently used for conventional television may well be suitable for HDTV, and a 140 Mbit/s system has been developed based on a 1125/60/2:1 source. A 140 Mbit/s codec for HDMAC signals has also been developed. The different requirements of contribution and distribution networks are discussed.

Furthermore, it is outlined in [CCIR, 1986-90c] that the investigations performed in the IWP 11/7 made evident the existence of various bit rate reduction techniques which will enable digital HDTV transmission to be effected at about 140 Mbit/s. Practical work currently in progress on codecs for the 4:2:2 level of Recommendation 601 should yield further relevant information. Final decisions as to standard methods can be expected to depend on the digital parameters chosen for the studio and for the international exchange of HDTV programmes.

The HDMAC bandwidth reduction coding principles are described in [CCIR, 1986-90d]. By these HDMAC is optimized to allow for introduction of HDTV services on WARC 77-BS channels. DATV and multibranch coding is used. The selection of the system was based on the result of subjective assessments.

[CCIR, 1986-90e] describes different systems of digital MUSE transmission with either PCM or DPCM coding and bit rates of 135 Mbit/s and 100 Mbit/s, respectively.

The digital transmission of the MUSE signal on distribution links is advantageous where MUSE is the destination system, in contrast to the contribution links which may be otherwise optimized.

A bit-rate reduction codec for HDTV was developed. This can transmit 1125 line/60 Hz HDTV signals at 97.728 Mbit/s, which is the 4th level bit-rate in the Japanese digital hierarchy. This codec is also applicable to the H4 channel rate (about 135 Mbit/s) coding for broadband ISDN. This codec employs adaptive prefiltering for noise reduction, extrapolative/interpolative coding with adaptive intrafield/interframe prediction and variable word length coding [Yashima and Sawada, 1987; Sawada and Yashima, 1988; Yashima and Sawada, 1989; CCIR, 1986-90f].

97.728 Mbit/s HDTV transmission was demonstrated using a prototype of this bit-rate reduction codec and actual optical fibre transmission lines. The HDTV baseband signals used are component signals of Y, P_R and P_B with bandwidths of 20 MHz, 7 MHz and 7 MHz, respectively [Yashima and Sawada, 1989; CCIR, 1986-90f].

[CCIR, 1986-90g] outlines 120/140 Mbit/s HDTV coding systems, implemented in hardware for practical applications. This system is designed for the purpose of transmitting HDTV signals through the 72 MHz bandwidth transponders of the INTELSAT satellite or the HD hierarchy of an optical fibre cable. The main bit rate reduction techniques employed are:

- removal of blanking intervals and line-alternate processing for two-colour components;

- a 1/2 sub-Nyquist sampling with a line offset structure; and
- intra-field DPCM with an adaptive noise shaping filter and an adaptive quantizer.

Although the MUSE system has been developed for the purpose of an analogue transmission, most of the signal processings in the system are carried out in digital form, and fit easily to the digital transmission. In the MUSE system, a technique of sub-sampling in the time domain is already used, but the compression of amplitude information is not yet performed, and may be applicable for further processings in the digital transmission.

2.3 Transmission interface considerations

In many cases links of several different media will be used in the chain from programme originator to the final viewer. For example, a national television network may receive a programme over coaxial or optical fibre networks, or by systems in the fixed service and fixed-satellite service, and then distribute it to their affiliated TV stations by the same or even different cable, fixed service or fixed-satellite system, which then broadcast the programming terrestrially.

Even broadcasting-satellite systems may receive their programming material from the multiplicity of sources mentioned above, and in the case of the community reception mode, distribute it beyond the BSS earth station in a variety of ways.

Such connections give rise to interface situations, that is, to places where formats may have to be connected. To permit conversion, the characteristics of the formats must be known. To make those conversions easily, and with minimal degradation in picture quality, the formats should be developed as part of a unified set of formats.

A specific example can be cited of interfaces that will arise involving satellite emission. In 1990 it is planned to inaugurate HDTV using the GS-3 satellite of Japan.

During these operations it may be necessary to provide a studio-transmitter link involving transmission links from a local station originating a programme to the BS-3 earth station. Such links might use MUSE, the HDTV format for the BS-3 emissions, but they might also use different formats.

Two PCM and one DPCM formats have been considered for MUSE transmission.

One PCM method encodes video, sound and control signals in the MUSE format. With 8 bits/sample for luminance and colour difference signals, it requires a net bit rate of about 117 Mbit/s. A second PCM format, simpler but less efficient, is also based on 8 bits/sample and requires a new bit rate around 130 Mbit/s. A DPCM format based on 6 bits/sample/sample would require only around 88 Mbit/s.

All these formats could be accommodated in the ISDN H4 level (132 Mbit/s minimum) with varying amounts left over for error correction.

A bit rate reduction codec for HDMAC signals which fits the H4 transmission level near 140 Mbit/s has been developed [CCIR, 1986-90h].

In summary, the continuation and expansion of a domestic, regional and international system of television programme delivery through diverse media calls for defining interfaces between the media. It also dictates the need for a hierarchical set of transmission and emission formats that can take best advantage of the different characteristics of each media and can also be converted from one format to the other with minimal degradation and at reasonable cost.

2.4 Satellite news gathering

The technique of satellite news gathering (SNG) is a means for the international exchange of programme material, and an increasing amount of television transmissions are provided by these capabilities, particularly of such international events as the Olympic Games. The CCIR is carrying out studies in this area in JIWP CMTT-4-10-11/1.

The work of this JIWP has been focused on preparation of a Report and Recommendation. The Report has been prepared, taking into account the characteristics of television systems in operation today. These systems use the capabilities of existing 4/6 and 11/12/14 GHz-band communication satellites which are in the geostationary orbit, and have very well known characteristics. They have been used as the basis for preparing a Report containing the technical and operational requirements of SNG which generally encompass the use of rapidly deployable, portable uplinks for events lasting from a few hours to several days.

SNG has been using fixed-satellite spectrum allocations. In examining the material in the draft report of JIWP 10-11/3 to the Extraordinary Meeting as it might apply to SNG, the following subjects appear to require some re-evaluation and subsequent modification if and when SNG is to use HDTV. Some areas which may require study are:

2.4.1 Link budget

HDTV requires more energy density. Link budget considerations range from larger up-link e.i.r.p., larger C/N, and thus more power/larger antenna gain from the satellites and earth stations.

2.4.2 Spectrum

Depending on what type of transmission format is chosen for HDTV, and the quality, it may be necessary to increase the amount of bandwidth required for a SNG/HDTV transmission, compared to that required today.

2.4.3 Orbit spacing

The impact of increased power density, it may not be possible to transmit HDTV signals on satellites which are closely spaced in the geostationary orbit.

2.4.4 Off-axis e.i.r.p. density

It may not be possible to retain the emission limits suggested for today's SNG up-link transmissions.

2.5 Conclusions

One or more closely related transmission/emission formats, optimized for use in diverse programme delivery media, may also be derived from the studio standard.

Definition of that studio standard should precede the definition of any subsidiary standards if signal degradation and the costs of conversion are to be minimized.

The continuation and expansion of a domestic, regional and international system of television programme delivery through diverse media calls for defining interfaces between the media. It also dictates the need for a hierarchical set of transmission and emission formats that can take best advantage of the different characteristics of each medium and can also be converted from one format to the other with minimal degradation and at reasonable cost.

Easy convertibility between any such formats should also be required to reduce the cost and complexity of home receivers intended to receive programmes from the different delivery media.

3. Terrestrial transmission of HDTV

3.1 Introduction

There is great progress being made in the terrestrial transmission of HDTV. This is illustrated through the experiments and development of various signal formats which have been reported.

3.2 Experimental signal formats for HDTV transmission

In a frequency division multiplexed composite signal, called HLO-PAL (Half-Line Offset PAL), the colour-difference sub-carrier signal corresponding to the narrow-band colour-difference signal (C_n) is located adjacent to the luminance signal (Y); while another signal corresponding to the wide-band colour-difference (C_u) is located around the same sub-carrier, and its lower sideband is partly interleaved with the luminance signal with a half-line offset. This signal has been used widely for distribution and transmission tests of the HDTV signals [CCIR, 1982-86a].

In a time division multiplexed signal, called TCM (time compression multiplexing) signal, the colour-difference signals are compressed, and the luminance signal and one of the colour-difference signals are multiplexed. Thus, colour-difference signals are transmitted line-sequentially. The proposed TCM signal bandwidth for a 1125-line system is 20 MHz [Tsuboi *et al.*, 1985].

In another time division multiplexing signal, called TCI (Time Compressed Integration) signal, there are several versions depending on the simultaneous or sequential arrangement of colour-difference signals and on the difference compression ratios [Fujio and Kubota, 1982].

A scan conversion system for HDTV with motion-adaptive techniques, called FCFE (Frame Conversion Fineness Enhance), has also been developed. It converts 2:1 interlaced scanning to progressive scanning at the receiver. This is considered to be useful for the reduction of bandwidth required for HDTV transmission [CCIR, 1982-86a, b and c].

A bandwidth reduction system, called MUSE (Multiple Sub-sampling Encoding) system, has been developed to transmit HDTV signals via satellite using a single channel in the 12 GHz band. The baseband signal bandwidth is 8.1 MHz. It uses 4:1 dot-interlaced sub-sampling which employs inter-field and inter-frame offsets. More general description can be found in Report 1075.

It is reported that non-linear pre- and de-emphasis has been used very effectively in FM transmission of HDTV signals [Fujio and Kubota, 1982].

Digital transmission has been discussed [Phillips and Harvey, 1978; CCIR, 1978-82], and it could become competitive with analogue FM transmission in the future, with regard to the required bandwidth and transmitter power.

3.3 Bit rate reduction methods for HDTV

3.3.1 Introduction

In accordance with Decision 60-2, IWP 11/7 is studying aspects of the digital transmission of high definition television signals, for which bit rate reduction is an essential process. This work is able to build upon the results of the studies into methods for the 4:2:2 level of Recommendation 601 reported in Report 1089 (MOD I), and on the related work in hand at present on standard algorithms and codec specifications for 34, 45 and 140 Mbit/s transmission.

Studies are being aimed at both contribution and distribution networks, and take account of Decision 18-6. A distinction between these applications is not always easy to make. Broadly speaking, contribution applications are those for inter-studio traffic requiring signals of such fidelity that they can withstand studio post-processing and passage through more than one digital coding/decoding operation. In distribution between broadcasters, component video signals from a source centre are coded for transmission. In distribution to viewers, coding is applied to signals which have already been coded into analogue or digital formats, and it forms the final method of delivery to the home. Often the choice of distribution to viewers will be influenced by the economics of a low-cost decoder in the home.

At this time, some of the transmission techniques used for distribution of programmes to broadcasters are still under study with respect to adequacy of quality.

3.3.2 Distribution between broadcasters

[CCIR, 1986-90g] describes the outline of a 120/140 Mbit/s HDTV coding system, which has already been implemented by a compact hardware for practical appreciations. More information may be found in the satellite transmission section "Digital Transmission" (§ 2.2 of Part 9).

[CCIR, 1986-90i] describes some preliminary results obtained using the DCT algorithm. It is concerned with HDTV signals with parameter values as proposed in [CCIR, 1986-90j] employing progressive scanning and resulting in a bit rate of 2304 Mbit/s. It refers to the intensive work carried out during the present Study Period aimed at the specification of a contribution 34/45 Mbit/s codec for conventional digital signals conforming to Recommendation 601. It states that the promising results obtained have lead several organizations to apply such bit rate reduction techniques to HDTV signals, the target being HDTV contribution codecs at 140 Mbit/s. It points out that simple extrapolation of these results may not be appropriate since (a) a higher compression ratio is required, (b) progressive scanning yields a richer information content and (c) because of the high data rate, specific algorithm restraints must be taken into account in order to make the algorithms implementable in compact hardware.

The extra studies required to adapt the conventional codecs to HDTV are being presently addressed by some European cooperative projects. Simulations are being performed based on the DCT coding algorithm proposed by a DCT Expert Group. Whilst some further work has to be carried out, it states that extension of the algorithm has yielded promising results for both interlaced and progressive scan HDTV formats. Its conclusion is that 140 Mbit/s can be considered a possible channel for the transmission of HDTV in both formats, enabling all the benefits of progressive scanning to be retained in transmission.

[CCIR, 1986-90k] gives a summary on NI-DPCM sound decoding systems, which could find application in studio facilities too. A 48 kHz, 16-to-11 bit NI-DPCM and a 32 kHz, 15-to-8 NI-DPCM are reported to be capable of reproducing about the same quality as 48 kHz, 16 bits linear PCM and 32 kHz, 14-to-10 NI-PCM used in Japanese satellite broadcasting, respectively.

3.3.3 Distribution to viewers

A bit rate reduction codec for HD-MAC signals has been developed within the European Eureka-95 project and is described in [CCIR, 1986-90h]. The technique employs a hybrid of 8-bit PCM and 5-bit DPCM with a reflected quantizer, to reduce the bit rate of an HD-MAC multiplex to the H4 transmission level of about 140 Mbit/s. The method has a simple implementation, is rugged in the presence of transmission errors and can convey HD-MAC signals while still in their scrambled form. Such a codec was demonstrated at IBC 88 in Brighton, UK, where digitised HD-MAC was transmitted over 2 kms of optical fibre.

[CCIR, 1986-90l] contains an overview of digital transmission of the MUSE signal (see Report 1075 (MOD I), Annex II, for details of the MUSE signal). The digital transmission system described is considered to be an advantageous one especially when the destination requires a MUSE-encoded signal only. The document states that the digital transmission of the MUSE signal is possible with a bit rate of around 135 Mbit/s by the MUSE-DPCM scheme. Further refinement and implementation are under way.

In [CCIR, 1986-90m] different subjective effects of the bit errors depending on three different coding schemes for HDTV still picture transmission are reported. For linear PCM component signals, for a sub-sampled PCM signal and for a sub-sampled DPCM signal, relative values of bit error rates, at which the subjective impairments are judged to be equal, were found to be 1, 1/6 and 1/10 respectively, in terms of the just perceptible limit of the impairment.

3.4 Short-distance transmissions

3.4.1 Cable and fibre-optic transmission

At the International Broadcast Fair, 1987, Berlin, a transmission of 1125/60/2:1 HDTV signals over a 1.152 Gbit/s fibre-optic link was demonstrated. The total video signal bit rate was 864 Mbit/s (sampling frequency for the luminance signal 54 MHz, for the colour difference signals 27 MHz each). The remaining channel capacity was partly used for stereo sound and error protection [CCIR, 1986-90 a].

[CCIR, 1986-90n] describes a digital HDTV signal transmission system on monomode optical fibre. This transmission system offers the possibility of conveying, in a serial form, a digital data stream at 144 Mbit/s rate issued from either a 1250/50/2 HDTV colour source (HDI standard) or from a diagonally prefiltered HDTV 1250/50/1:1 colour source HDQ standard). The serial line data rate is 1.296 Gbit/s. The document claims that in the near future an extension of the system towards a transmission system which can convey two digital data streams at a 144 Mbit/s rate will be performed. This extension would permit carrying the HDTV picture delivered by a 1250/50/1:1 HDTV source (HDP). It would lead to a 2.592 Gbit/s serial data rate.

An optical fibre transmission is used to transmit HDTV component signals from Seoul Main Stadium to International Broadcasting Centre. The actual distance of the cable was 34 km. The baseband signal used to this section was a component video signal of the luminance signal (Y) and the colour-difference signals (Pb and Pr).

Frequency modulated component video signals and PCM audio signals of HDTV were frequency-division multiplexed and then modulated a laser diode. An optical repeater was placed in the middle of the path. The unweighted signal-to-noise ratios obtained with the video signals were better than 55 dB.

MUSE signals were transmitted through an optical fibre from the Broadcasting Centre to some demonstration sites in downtown Tokyo during 1988 Seoul Olympic Games. In the system, a SWFM-IM (square wave frequency modulation - intensity modulation) was employed.

3.4.2 CATV distribution

CATV networks are also an important distribution medium of HDTV programmes to the general public. For this purpose, several methods have been proposed, and some experimental results have been reported.

The choice of an HDTV transmission system for the CATV network depends on various criteria such as the required RF signal bandwidth, the necessary guard band to avoid adjacent channel interference, the required C/N before demodulation, and the complexity of the subscriber's receiver, etc. Taking these criteria into account, an FM transmission system and an AM-VSB system were examined and experiments were carried out using both.

Large scale HDTV distribution experiments were carried out by the CATV Hi-Vision Promoting Association of Japan from 28 October to 3 November 1988. The HDTV signal was encoded to MUSE, frequency modulated on a 400 MHz carrier and combined with the conventional CATV signals being fed into the network. The modulated MUSE signal was also sent to another head/end through a two-hop microwave link in the 23 GHz band and the received signal was further relayed through an optical fibre link about 21 km long to another trunk route of the

CATV network. HDTV signals were monitored at eight major check points, all of which observed excellent quality signals. The unweighted S/N was over 50 dB at the farthest point in the CATV facilities after a two-hop microwave link, one optical fibre link and nine trunk amplifiers.

The required RF-bandwidth of an AM-VSB system is 12 MHz and no guard bands are necessary. However, a higher C/N value is needed, which increases the load on the trunk amplifiers. In the case of distributing the MUSE signal received from the broadcasting satellite, a mode converter which includes recovery from the non-linear emphasis may be necessary. This system was also demonstrated at the Annual Convention of the NCTA (National Cable Television Association) in the United States, using existing CATV facilities. This demonstration confirmed that there was no mutual interference between a MUSE signal and conventional TV signals.

The above results indicate that, in practice, either method can be used depending on the situation encountered.

[CCIR, 1986-90d] describes HDMAC bandwidth reduction coding principles for the emission of HDTV pictures derived from the proposed 1250/50/1 standard and is a status report on the studies in the Eureka-95 project. It states that HDMAC is optimized to allow the introduction of HDTV services on WARC 77-BS channels while preserving compatibility with the MAC/packet system. The methods of bandwidth reduction employed are discussed including the DATV (digitally-assisted television) concept and multi-branch coding. Some design trade-offs are highlighted, and reference is made to the subjective assessments which have led to the system being adopted by the Eureka project. It proposes that Report AZ/11 should be modified to take account of the document.

In [CCIR, 1986-90o], it is reported that AM/VSB and FM/VSB have been proposed for HDMAC cable distribution. AM/VSB is applied to the time multiplex baseband signal. The use of a channel spacing of 12 MHz has been demonstrated and is recommended as a common standard. The VSB Nyquist filtering is in the range of ≈ 500 kHz around the carrier and for compatible reception shall be the same as for MAC/packet distribution. The HD-Nyquist roll-off factor and the sharing between transmitter and receiver is under study. FM/VSB has also been demonstrated. It requires the use of a channel spacing of 16 MHz. Modulation parameters are under study.

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PART 10 - CONSUMER EQUIPMENT FOR HDTV

1. Introduction

This Part of the Report deals with domestic equipment for HDTV.

[CCIR, 1986-90a] stresses, in § 6.1, the need for considering the characteristics of all the potential delivery media for HDTV to the viewer's home in parallel in order to minimize receiver complexity through maximum circuit commonality such as picture processor, sound processor and control circuits leading to a minimum cost of the equipment.

2. Consumer-use display

A large screen high-resolution display is necessary for an HDTV reception system. This is also a key factor for determining the speed at which HDTV becomes popular. Direct-view displays using large-size cathode-ray tubes (CRTs) with diagonals of 51 to 104 cm (26 to 41 in) have been developed with an aspect ratio of about 16:9. For example, recently developed 51 to 104 cm CRT displays have sufficient brightness (90 to 230 cd/m^2) and resolution for home use.

Projection displays using CRTs have also been developed with diagonals of over 100 cm. For rear projection displays, almost sufficient brightness and resolution have been obtained with 127-178 cm diagonals at a brightness of about 400 cd/m^2. Even larger displays were designed for viewing by large numbers of people.

To solve the problem of large-area flicker for 50 Hz field systems, especially for large screens, field rate up-conversion was investigated and several up-converters and displays were demonstrated in September 1988 (IBC 88, Brighton, United Kingdom).

Both direct view and projection displays for the converted signal on the display standard of 1250/100/2:1 with 62.5 kHz line frequency and a video bandwidth of about 60 MHz were built and demonstrated.

Another front projector designed to give a large screen made use of an automatic deflection circuit, ranging from 16 kHz to 62 kHz line rate and from 50 Hz to 100 Hz field rate, and enabled the display of both 1250/50/2:1 and 1250/100/2:1 scanning.

The simplest method of achieving field rate up-conversion is to repeat the fields producing two consecutive odd fields followed by two consecutive even fields. However, to remove problems such as interline twitter, reduction of resolution and judder, sophisticated techniques such as interpolation, picture reception and usage of DATV control signals may have to be applied.

3. Consumer-use receivers

3.1 General

Receiving equipment is an important sub-system in the HDTV broadcasting system, since it comprises the major part of the system's expense, and it determines system acceptability.

Receiving equipment of the HDTV broadcasting system, as well as the conventional system, basically consists of front-end units including an antenna, down converter, IF and demodulation stage, and a display. The front-end units are generally similar to those of conventional television receivers and are dependent on each broadcasting media. In the case of the narrow RF-band satellite broadcasting using the MUSE system, existing front-end units can be used commonly, or with some modification. This is verified through a number of receivers and field tests.

Special consideration is given to other receiving equipment, and is described in the following sections.

3.2 HDTV decoders

3.2.1 General considerations

Most HDTV systems use digital processing, employing frame stores in order to achieve large-scale bandwidth compression. The required number of logic gates would be several tens of thousands and the necessary capacity of the store would be of the order of 10 Mbit.

Since the reduction of receiver cost depends on how efficiently large-scale integrated circuitry (LSI) can be introduced to signal processing, development of LSI for the MUSE decoder and related technologies is rapidly progressing. Recent trends towards larger capacity of the stores, from 1 Mbit to more than 4 Mbit, and towards digitization of conventional television receivers are expected to expedite the development of LSI circuitry for HDTV receivers.

3.2.2 MUSE decoder

As for the MUSE decoder, internal clock frequencies range from 16.2 MHz to 48.6 MHz, and the amount of memory capacity is about 20 Mbit for use in such functions as interpolation and motion detection. Experimental decoders using discrete parts, including medium-scale ICs, are produced by many different manufacturers. They have been constructed in a reasonably small size and are light-weight (e.g. volume $0.084 m^3$, weight 50 kg) to serve as portable models.

HDTV receiving equipment also plays an important role in the development of other consumer equipment. For example, the MUSE receiver has a built-in memory with a capacity of about 20 Mbit. Attempts are being made to connect it to personal computers and other image processing equipment.

Successful interfacing with other devices will make the MUSE receiver multi-functional, enabling it to serve as a total information terminal in the home.

3.2.3 HDMAC decoder

The HDMAC decoder digitizes the input signal with a clock-frequency of 20.25 MHz, since the Nyquist frequency point is situated at 10.125 MHz. The output sampling frequency is 54 MHz for luminance in the 1250/50/2 display standard.

The DATV concept allows all the intelligent decision circuitry to be placed in the encoder. Consequently, the decoder complexity is much less and benefits from future improvement in the coding process [CCIR, 1986-90b and c].

4. Consumer-use converters

MUSE to 525-line standards converter

Considering compatibility with the existing receiver and displays, a MUSE to 525-line standards converter, intended for use with consumer receivers was developed and demonstrated. This is of small size (made up of four 20 cm by 30 cm circuit boards).

The resultant 525-line picture from this converter has, on average, higher quality than the normal picture originated with NTSC standard, although it has some flicker at the edge, with less interference than that caused by the NTSC cross-colour. It has a simple circuit construction and it will be made available at a lower price by using LSI technology. The development of this MUSE to 525-line standards converter gave some prospect to HDTV broadcasting in the 1125-line system which can be received utilizing conventional 525-line receivers.

5. Consumer-use recorders

5.1 Video cassette recorders

[CCIR, 1986-90d] reports the development in the Netherlands of a video cassette recorder using a VHS transport which was demonstrated in 1988 recording/replaying an HDMAC signal [Weissensteiner, 1988]. It achieved a bandwidth of about 12 MHz and an unweighted video signal-to-noise ratio of 42 dB by using four heads, two frequency-modulated recording channels and digital video and audio processing, with a residual timing error of < 15 ns. It was able to record 80 min of HDMAC (or MAC) signal on one ½-inch metal particle tape and included drop-out compensation. Compatible options gave the facility of recording/replaying PAL, SECAM or NTSC signals.

A MUSE VCR for consumer use has already been developed [Ninomiya et al., 1987].

5.2 Disc systems

Disc systems that record and play back a MUSE signal have also been developed and can accommodate 60 min of HDTV programming on both sides of a 30 cm CLV (constant linear velocity) disc. The disc player can be used in combination with MUSE decoders in receivers and is expected to find a variety of applications in many fields as a long time playing medium of HDTV. Discs with customer's video materials can also be made.

[CCIR, 1986-90d] reports the development of HDMAC. A video disc player was developed in the Netherlands, based on existing optical laser and disc techniques [Horstman, 1988]. Its bandwidth is about 12 MHz with an unweighted signal-to-noise ratio of 32 dB and a residual timing error of < 7 ns. The playing time is 25 min per side for a 30 cm (12 in) diameter disc.

5.3 Still-picture disc player

A digital MUSE video disc for still pictures, called CD-HV, has been developed. A 12 cm disc in conformity with the CD-ROM standard is used. Thus, about 640 still pictures with digital stereo sounds can be accommodated in a single disc. It can be played back either in sequential playback mode with 60 min of playing time for one disc, or random access mode with an average access time of 4.5 s [CCIR, 1986-90e].

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DRAFT
REPORT XE/11

FUTURE DEVELOPMENT OF HDTV

(Question 27/11)

1. Introduction

The Extraordinary Meeting of Study Group 11, May 1989, identified studies that need to be undertaken as expeditiously as possible in order to further build on the agreements already achieved. This Report outlines:

1) approaches to a single world-wide HDTV studio standard;

2) further activities to be undertaken.

2. Approaches to a single world-wide HDTV studio standard

2.1 Concepts for approaches to a single world-wide digital HDTV studio standard

The long-term future of HDTV lies in the digital domain, and equally the long-term future of HDTV standards should lie with unique world-wide standards. In order to achieve this, a number of alternative routes were identified at the 1987 CCIR Interim Meeting. They were as follows:

a) The concept of a "virtual studio standard"

In this concept, there is a unique format for a digital data bus which is used to transport and record HDTV signals. The source and destination could communicate using the unified standard by means of gateways, which perform the appropriate standards conversion.

A "virtual studio standard" [Miceli, 1986; Fierro and Miceli, 1987], may be considered as a common standard for the purpose of exchanging programmes. Consequently, its characteristics should be chosen in order to allow the minimum of artifacts resulting from possible double conversions.

Some general characteristics of the virtual studio standard would include:

a) it should be digital, because of the greater flexibility and the most powerful processing capability allowed;

b) it should be independent of the physical studio equipment and therefore from the current technology;

c) it should allow enough headroom for production, the standards conversion process and for accommodating future needs;

d) it should lead to manageable bit rates.

The overall system performance between source and destination at any time, will be dependent on the characteristics of the actual equipment in the video chain at that time. Therefore, the system performance can be further improved, without affecting the coding structure, by simply improving the local characteristics of the weakest devices along the video path.

As an example of the possible application of this concept, consider the case of an image format of 1920 x 1080 pixels which is currently proposed as a "common image format". Another format which has also been proposed features 1920 x 1152 active pixels. A line interpolation process is necessary to convert a picture between the two formats. [CCIR, 1986-90a] states that this converter takes the form of a set of 15 (for the interpolation from 1152 to 1080) or 16 interpolators (in the opposite case), each one being a digital filter (FIR) with a number of taps ranging from 20 to 32, the latter figure being chosen for minimum distortion. The converter complexity is likely to be relatively modest.

b) The concept of a totally unique parameter set from the outset (adoption of an existing proposal in digital form)

In this scenario there would be, from the outset, a direct and universal adoption of a single studio standard. This could arguably be based on 50 Hz, 60 Hz, or even some other value. Factors which could affect the choice include motion portrayal, existing practices and display technology.

Examples of possible values can be found in Part 5 of Report 801-3.

c) The concept of a two-step approach

This scenario relies on the widespread introduction of switchable (50 Hz-based/60 Hz-based) HDTV studio equipment. This would not dispense with the need for standards conversion in HDTV programme exchange between countries using different standards, but it would lead to the possibility of the universal use of one or other systems in the course of time.

2.2 Recent studies in possible approaches to the development of a single world-wide HDTV standard

This section examines some approaches to a unified world-wide HDTV standard from the viewpoint of digital technology and outlines approaches that could be considered to achieve the goals of a single world-wide standard.

[CCIR, 1986-90b] from IWP 11/7 also discussed related studies for digital formats. Three approaches to achieve ultimately a "unique world-wide standard" for studio production and international programme exchange on the basis of the single picture rate are:

- the adoption of a single "unique" standard meeting the goals of Decision 58-2;
- the adoption of standards based on the "common image format" leading to the future adoption of a single standard;
- the adoption of a "dual" standard including two picture rates leading to a two-step approach. The use of switchable studio equipment could lead in the future, to the selection of one system based on one of the two parts of the dual standard.

Contributions have been received from a number of administrations further developing these concepts.

2.2.1 A unique standard

All administrations have stated their preference for a single world-wide studio standard for HDTV and a clear statement is found in Decision 58-2 to this effect.

As can be found in [CCIR, 1986-90c], the WARC ORB-88 expressed in one of the "considerings" of Resolution COM5/3 the wish for a unique world-wide standard for the satellite broadcasting of HDTV in view of a world-wide frequency band allocation. [CCIR, 1986-90c] concludes that a unique world-wide studio standard should be pursued further.

In [CCIR, 1986-90d] an analysis is made with respect to the status of development of progress on the basic parameters in accordance with the considerings g) and m) of Decision 74, and the information contained in Part 5 of Report 801-3. On the basis of the information in this document, the United States concluded that a single world standard should be based on 1125/60 [CCIR, 1986-90e]. The United States now believes [CCIR, 1986-90f] that it is apparent that unanimous agreement on a complete set of parameter values for a single world-wide HDTV studio standard is not possible during the 1986-1990 study period. Therefore, the United States proposed that the adoption of a single world-wide HDTV studio standard be extended to the 1990-1994 study period.

A proposed draft Recommendation supported by 11 administrations for parameter values for a single world-wide programme standard (1250/50/1:1) is given in [CCIR, 1986-90g]. The parameter values proposed have a particularly simple relation to the 50 Hz parameters of Recommendation 601, provide for ease of processing, and ease of transfer to and from film.

Document [CCIR, 1986-90h] states that 60 Hz meets the objectives of Recommendation 601 compatibility better than 59.94 Hz.

In [CCIR, 1986-90i] the EBU explains that, if agreement could be reached on a single world-wide standard for programme exchange, technical and economic considerations suggest on balance that it would be most beneficial if it could be based on a temporal rate of 50 Hz. The EBU will continue its dialogue with other international bodies in order to take advantage of technological developments which will assist the process of convergence, and the EBU would encourage allowing adequate time to investigate all possible approaches which may lead to a single world-wide standard.

Documents [CCIR, 1986-90j, k] state that 50 fields per second is inferior to 60 fields per second as far as motion portrayal and large area flicker are concerned. Document [CCIR, 1986-90l] states that 50 fields per second or greater give satisfactory motion portrayal.

Documents [CCIR, 1986-90j, k, m] report that 60 fields per second was found to be an excellent balance between bandwidth utilization and low levels of flicker and provides a superior flicker performance to 50 fields/second. Document [CCIR, 1986-90n] argues that flicker is not a production problem but a display problem. In Document [CCIR, 1986-90o] it is claimed that interlace scanning furnishes the best picture quality for a given bandwidth, but that it could be possible to develop an extension to sequential scanning as technology develops.

Documents [CCIR, 1986-90p, q] develop arguments in favour of progressive scanning. Document [CCIR, 1986-90r] proposes that a 1:1 scanning system should be the standard from the outset, and that as an interim measure in some cases bandwidth reduction (e.g. 2:1 interlaced scanning) may be used until suitable technology is developed.

In [CCIR, 1986-90s] are summarized the essential reasons for the need for a world-wide unique studio standard for high definition television.

[CCIR, 1986-90t] points out that there is no doubt that all administrations support the concept of having a single, world-wide HDTV standard for programme production and exchange. However, total agreement may not be possible at this time.

[CCIR, 1986-90u] points out that an HDTV standard that meets the needs expressed in CCIR documentation can most efficiently be implemented with an image format of 1920 pixels per line by 1080 active lines. It further points out that the use of additional active lines, which go beyond the current limitation of camera technologies, is not justified and expresses the opinion that an HDTV system with equal potential horizontal and vertical resolution is the optimum for broadcast programme production and other HDTV applications.

In [CCIR, 1986-90v] EBU states that it remains convinced of the value of a totally unique standard, but is studying other approaches against the possibility that it cannot be achieved.

[CCIR, 1986-90w] points out that approaches based on common image formats and common data-rate merit careful study as they could lead to a universally acceptable alternative means of providing HDTV programme sources should the attainment of a unique standard prove to be impossible until direct digital distribution of TV is established. Studies should take into account compatibility with present scanning standard, problems of operating with different aspect ratios for conventional and HDTV, and ease of standards conversion.

2.2.2 A common image (unified) approach

This approach is based on the definition* of a "common image" that can be used in systems having differing frame rates or scanning methods. The image commonality includes aspect ratio, number of active lines, number of pixels per active line, colorimetry, transfer characteristics, etc.

* This definition requires further study.

[CCIR, 1986-90x] suggests that an image frame with 2 250 000 samples will simplify the task of ensuring compatibility with Recommendation 601 and proposes a common image format based on 1080 active scanning lines per frame. This number of scanning lines is derived from a pixel shape of 1:1. No three parameters can be chosen without automatically defining the fourth as illustrated below:

Active horizontal pixels, aspect ratio active vertical pixels and pixel shape ratio are interrelated by the formula:

$$\frac{\text{active horizontal pixels}}{\text{active vertical pixels}} = \frac{\text{aspect ratio}^*}{\text{pixel shape ratio}^*}$$

[CCIR, 1986-90y] points out that this pixel shape has advantages for electronic image processing and for a wide variety of non-broadcast applications.

[CCIR, 1986-90z] points out that a common image approach to the HDTV standard is at once economical, logical and technically sound, being based on the natural unit of TV and film production, the time-discrete image sample, the "frame". This fact is favourable to the development of common semi-conductor devices and equipment and to the interchange of HDTV programme material. It is believed that the common image approach is the only one, short of immediate adoption of a "unique" standard, that will lead to the eventual adoption of the desired single world-wide standard.

The common image format is effectively an electronic equivalent of a 35 mm film image and so it allows flexibility in the choice of picture rate. The actual rate will depend on the application, but all picture rates employed in current image display systems could be accommodated [CCIR, 1986-90y]. Furthermore, a common image approach might allow simpler standards conversion between HDTV systems operating at different field rates as only temporal conversion would be required [CCIR, 1986-90aa].

[CCIR, 1986-90ab] outlines two example common image format systems. The first uses 1152 active lines and 1200 total lines, and both interlaces and sequential scanning are considered. The second uses 1080 active lines and 1125 total lines, both with interlaced scanning. The EBU is currently investigating common image formats which also have a common data rate.

[CCIR, 1986-90ac] states that the common image format approach does not, in principle, require the sampling rate to be a multiple of 2.25 MHz and, in general, diverges from simple relationships to Recommendation 601. Additionally, some proposals based upon a sampling-rate multiple of 2.25 MHz could lead to unrealistically short line-blanking times. Whilst the possible long-term benefits of common CCD pick-up devices are noted, the short- to medium-term difficulties in achieving simple conversion to HDTV emission standards and in providing switchable studio processing equipment (VCRs etc.) are thought to be major disadvantages.

However, it is shown in [CCIR, 1986-90ad] that it is possible to have both a common image structure and overall common data rate by enclosing the proposed common active image structure within the appropriate full frame structures of current proposals through the use of different but quite realistic values for horizontal and vertical blanking.

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* Picture and pixel aspect ratio are defined by width ÷ height.

In [CCIR, 1986-90f] the United States expresses its belief that the concept of a "common image format" should be explored as an interim step in the development of a future single world-wide HDTV studio standard.

[CCIR, 1986-90ae] points out that while the common image format concept implies that the horizontal and vertical active portions of the image are the same for all members of the family, the blanking periods, total line period, and total number of lines can be varied between members of the family to provide compatibility with existing picture rates, provide for vertical anti-aliasing, and ease selection of a sampling rate that is an integer multiple of 2.25 MHz.

In [CCIR, 1986-90af], results of a parametric study are presented on the complexity of vertical interpolation/decimation for conversion between a proposed common image approach using 1080 active lines and the conventional television standards, their double scanning version and the "letterbox" presentation of down-converted HDTV on conventional displays. These studies assume intra-frame conversion with no temporal component. An attempt is made at reducing the line conversion complexity by using a polyphase structure with variable coefficients for the filter implementation. The complexity of the filter can be reduced drastically compared to its direct implementation and it has no direct relationship with the numerical values of the line conversion ratios. For this filter implementation, the calculation rate is directly related to the clock frequency of the output format.

It is found that conversion to conventional television formats from their line-doubled version requires typically the same number of coefficients as for conversion from the 1080 line common image format to these line doubled versions. Conversion from 1080 lines to the conventional television formats requires twice as many coefficients resulting in no more than twice the complexity of the simple conversion between conventional television standards and their line-doubled version.

2.2.3 A common data rate (dual-standard) approach

In the first step of this approach, HDTV standards based on 50 Hz and 59.94 Hz field rates related to current emission standards would be adopted, but having a maximum of commonality in other parameters such as line frequency and sampling frequency, based on the principles of Recommendation 601, leading to a common data rate. Proposals have also been made using 50 Hz and 60 Hz field rates.

[CCIR, 1986-90ag] provides a discussion of two examples based upon a common sampling frequency of 74.25 MHz which enable 1125/60 duality with two variants of a 50 Hz field rate system. The first variant uses 1250 lines and provides both countries with a very simple relationship to Recommendation 601 based emission standards. The second variant was 1375 lines which provides higher vertical resolution and offers the feasibility of matrix picture screens consisting of 15 x 10 blocks of 128 x 128 picture elements.

In [CCIR, 1986-90ah] the criteria and advantages of an appropriately chosen dual-mode HDTV studio standard are examined taking into account the importance of commonality and the significance of a natural relationship with Recommendation 601. It is shown that then a particular set of parameters arise in a natural way that preserves the same common features, those of sampling rate and active horizontal sampling sites, while exhibiting ease of conversion to the 4:2:2 signal by applying a relation factor of 2 in both horizontal and vertical dimensions: this pair of HDTV standards is 1250/50/1:1 - 1050/59.94/1:1. It is proposed to use the high definition progressive quincunx signal representation for this pair. Progressive scan and quincunx sampling allow, while limiting the data rate, to preserve all benefits of progressive scanning. This is particularly important from the point of view of vertical resolution and motion portrayal, and leads to significant improvement of the standards conversion performance. Moreover, this interface format is identical to that resulting from interlaced scanning; this last could be used in the short-term introductory phase of HDTV on the basis of existing equipment.

[CCIR, 1986-90ac] provides a discussion of approaches for a dual-mode HDTV studio standard based upon Recommendation 601. It argues that the main considerations in Recommendation 601 are those of a) common sampling structure, b) common sample mode and c) common number of samples per active line, and goes on to discuss four examples of possible dual standard parameter sets [1250/50 and 1050/59.94, 1250/50 and 1125/60; 1375/50 and 1125/60; 1200/50 and 1001/59.94 and 1000/60]. It concludes that the most logical set is that of 1250/50 and 1050/59.94 implemented either in a common orthogonal or a quincunx sampling structure.

[CCIR, 1986-90ai] provides some technical details of the 1375/50/2:1 system described as version 2 in Document [CCIR, 1986-90ag], and also includes some theoretical considerations concerning its interfacing to the 625/50/2:1 system.

[CCIR, 1986-90ab] gives three examples of common data rate systems. The first is a (horizontally and vertically) scaled-up version of CCIR Recommendation 601. The second achieves the same overall bit rate, but uses sequential scanning and quincunx sampling. The third is a system, proposed for study by the OIRT, based on the 1125/60/2:1 system with a 1375/50/2:1 partner.

[CCIR, 1986-90aj] gives an example of a common data rate system involving 1375/60 and 1155/59.94 partners. The number of active lines are respectively 1280 and 1080.

In [CCIR, 1986-90z] it is stated that the dual standard approach inherently penalizes one of the resulting dual standards in spatial resolution and does not lead to convergence on a future single standard for economic reasons related to equipment replacement.

[CCIR, 1986-90ak] also addresses the subject.

2.2.4 Implications for equipment development

The video recorder is an essential element in the production and exchange of HDTV programmes. [CCIR, 1986-90al] underlines the need to examine the constraints imposed by digital tape recording on the parameters of the HDTV standard. It further concludes that these constraints are not decisive in the choice between "unique", "common image", and "dual-standard" approaches to achieve the HDTV standard.

3. Future activities to be undertaken

The CCIR considers it necessary to continue studies in the following areas:

i) HDTV quality assessments and measurements;

ii) colorimetry parameters for inclusion in draft Recommendation XA/11;

iii) basic parameters of picture representation for inclusion in draft Recommendation XA/11;

iv) the specifications for operation of HDTV telecines must be transformed from the form of a Report to the form of a Recommendation;

v) an analogue HDTV video tape studio recording format for programme exchange must be specified in the form of a Recommendation;

vi) similar work must also be done for a digital HDTV video tape recording format;

vii) in consideration of the importance of multimedia release for HDTV productions, harmonization of HDTV interfaces for professional and for consumer applications must be pursued in cooperation with the IEC and ISO;

viii) harmonization of standards and operating practices for HDTV production, and for non-broadcast HDTV equipment intended for consumer applications. The activity requires appropriate liaison with the CMTT, the appropriate CCITT Study Groups, the IEC and the ISO.

The CCIR also considers it necessary to continue to study radio frequency and emission technical parameters including modulation, channel coding and multiplexing of HDTV satellite broadcasting. Further study is required to determine:

i) system parameters for wide RF-band analogue and digital high definition television transmissions by satellite;

ii) propagation characteristics for bands suitable for wide RF-band high definition television transmissions;

iii) inter- and intra-service sharing and interference, interregional sharing.

The progress of these studies is expected to allow definitive results before the end of the next CCIR study period.

More studies on terrestrial HDTV emissions will be carried out. In particular, more measurements to determine the appropriate protection ratio for terrestrial and satellite HDTV systems are required.

A new item has been introduced in Decision 72, concerning data broadcasting services, calling for the carrying out of studies on the presentation layer requirements for data services associated with HDTV signals.

The structure of a new draft Report on data broadcasting in an HDTV environment was prepared. It deals with the harmonized evolution of sound and data services accompanying HDTV and includes a basic model for HDTV signal distribution. Much work needs to be done to build on this structure in future.

Work should continue on these further studies with a view to defining as many parameters as possible by the time of the Final Meetings.

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c. IWP 11/6-2068 (JIWP 10-11/3); **d.** IWP 11/6-2020 (USA);
e. IWP 11/6-2030 (Japan); **f.** IWP 11/6-2093 (USA);
g. IWP 11/6-2023(Rev.1) (Belgium et al.);
h. IWP 11/6-1018 (Canada); **i.** 11/346 (EBU); **j.** IWP 11/6-1031 (USA);
k. IWP 11/6-1066 (Japan); **l.** IWP 11/6-1064 (UK/Netherlands);
m. IWP 11/6-1033 (CBS); **n.** 11/160 (France); **o.** IWP 11/6-1036 (CBS);
p. IWP 11/6-1049 (France); **q.** IWP 11/6-1055 (Thomson-CSF);
r. IWP 11/6-1054 (Thomson-CSF); **s.** IWP 11/6-2031 (Japan);
t. IWP 11/6-2014 (Canada); **u.** IWP 11/6-2094 (CBC);
v. IWP 11/6-2010 (EBU); **w.** IWP 11/6-2092 (BBC/UKIBA);
x. IWP 11/6-2045 (Australia); **y.** IWP 11/6-2079 (Australia);
z. IWP 11/6-2076 (Canada); **aa.** IWP 11/6-2078 (Australia);
ab. IWP 11/6-2072 (EBU); **ac.** IWP 11/6-2064 (IBA);
ad. IWP 11/6-2074 (Canada); **ae.** IWP 11/6-2071 (NBC);
af. 11/358 (Canada); **ag.** IWP 11/6-2011 (OIRT);
ah. IWP 11/6-2054 (Thomson-CSF); **ai.** IWP 11/6-2067 (USSR);
aj. IWP 11/6-2103 (OIRT); **ak.** 11/362 (France/Netherlands);
al. IWP 11/6-2075 (Canada).

DRAFT
REPORT XF/11

MEASUREMENTS IN HDTV*

(Question 27/11, Study Programme 27C/11)

1. Introduction

High definition television (HDTV) is currently under development. Measurement of HDTV parameters represents a new task, and such measurement techniques should be defined in advance of the development and implementation of the associated hardware.

2. General considerations

In generating HDTV signals, the luminance components require a bandwidth of approximately 30 MHz (for progressive scanning the bandwidth is approximately 60 MHz) and the colour-difference signals occupy a bandwidth of the order of 15 MHz each (30 MHz for progressive scanning).

[CCIR, 1986-90a] states that the requirements for accuracy in the generation and transmission of HDTV signals (before and after coding) increase significantly since their distortion is more noticeable on large screens. The specific features of HDTV measurements are primarily conditioned by the wideband nature of the signals used [Krivocheev and Dvorkovitch, 1989].

[CCIR, 1986-90a] further states that HDTV signal distortions may also be due to inadequate transient response and the static and dynamic non-linearity characteristics of the HDTV signal encoding and transmission equipment, as well as different types of additive and multiplicative interference. Given the broad band of frequencies and the need for accurate control of signal level, digital processing techniques are required to allow adequate assessment of the signal. A mathematical treatment of the situation is provided in [CCIR, 1986-90a,b].

3. Testing methods

[CCIR, 1986-90a] suggests that the following transfer characteristics must be examined:

- very long-time distortions due to scene changes (at frequencies below the frame or field frequency);
- long-time distortions (at frame or field frequencies and their harmonics);
- line-time distortions (at the line frequency and its harmonics);
- short-time distortions (at low to medium video frequencies);
- very short-time distortions of fine details (at the upper video frequencies).

The requirements for a series of test patterns and test signals adequate to accomplish the above have been studied and described in [Krivocheev, 1976; Dvorkovitch, 1988a and b; Krivocheev and Dvorkovitch, 1989; CCIR, 1986-90a].

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* See Recommendation 567-1 concerning test signals for conventional television systems.

Test signals have also been proposed in [CCIR, 1986-90b]:

- a multiburst sequence with two references for use in measuring the amplitude-frequency response* (Fig. 1);

- a complex signal sequence used to measure the transfer functions and the pulse characteristics of the luminance channel and the colour-difference channels* (Fig. 2);

- a sweep frequency waveform used to measure the continuous amplitude-frequency response and group delay (Fig. 3);

- a pair of step signals carrying pulsed signals of different polarities and sine test tones of different video frequencies, respectively, for evaluating static and dynamic non-linear distortions (Fig. 4).

[CCIR, 1986-90c] suggests elements of possible test patterns for high definition television and proposes examples of test patterns (Figs. 5 and 6):

- an HDTV test pattern consisting of black and white parallel lines of varying resolution and at different angles to the horizontal and vertical axes. This may be used for resolution estimation;

- an HDTV test pattern consisting of a circle of a specified diameter on a field of dots and orthogonal lines. This may be used in determining fixed pattern noise and raster distortions.

* The groups of elements contained in this signal could be arranged either alternatively in the interval of one line of the signal or sequentially in several lines of the signal.

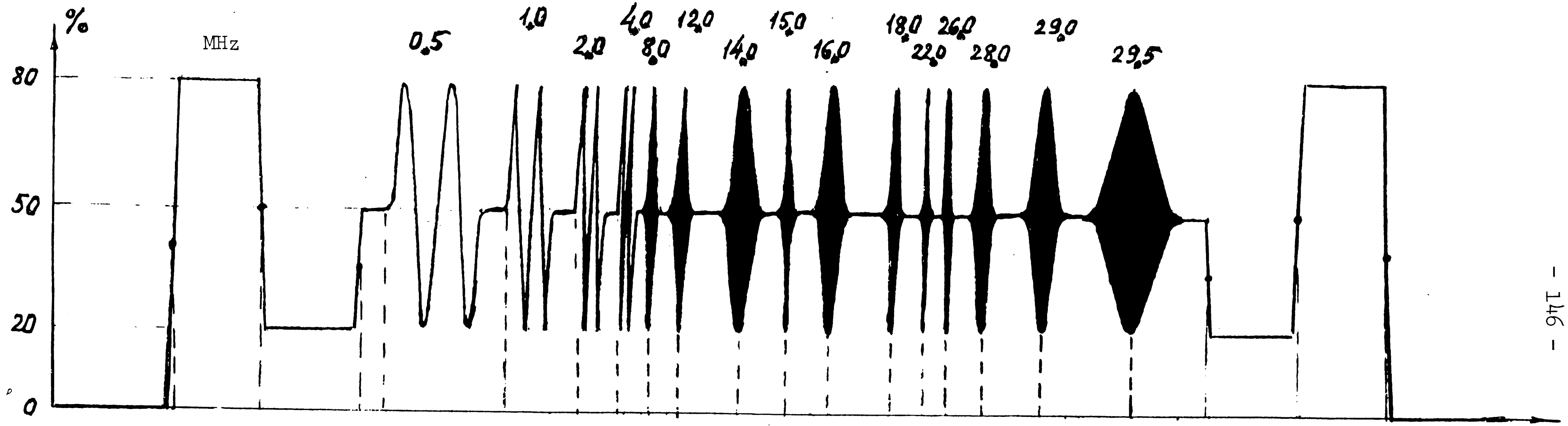

FIGURE 1

Test signal for measuring the amplitude-frequency response at a number of frequencies

Note: $T = 16.67$ ns

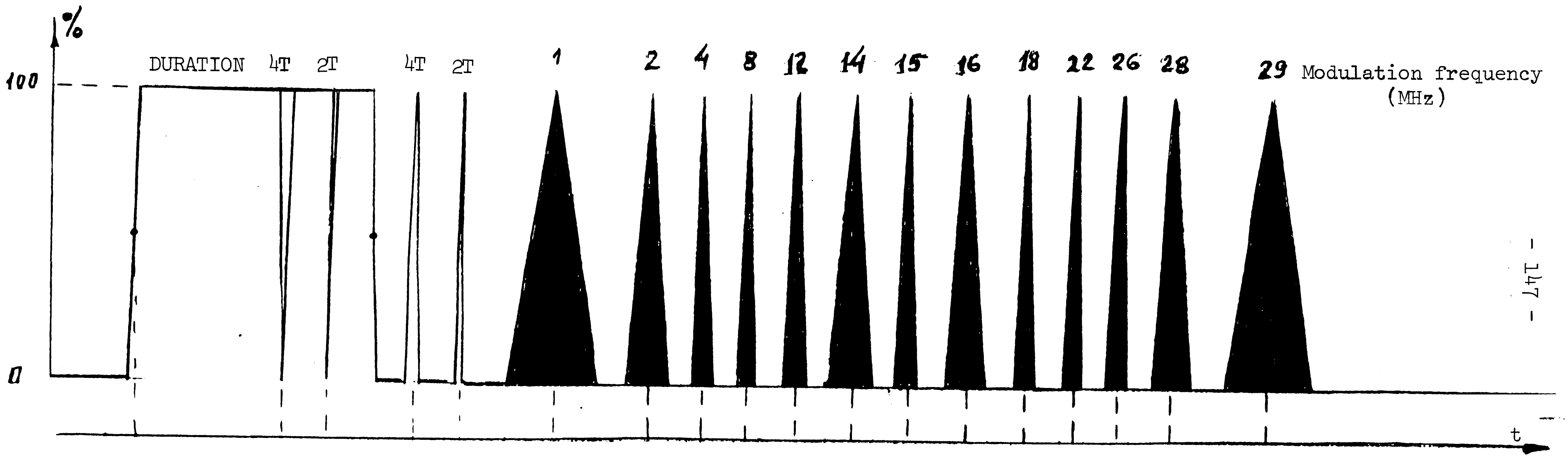

FIGURE 2

Test signal for the measurement of transfer functions and pulse characteristics

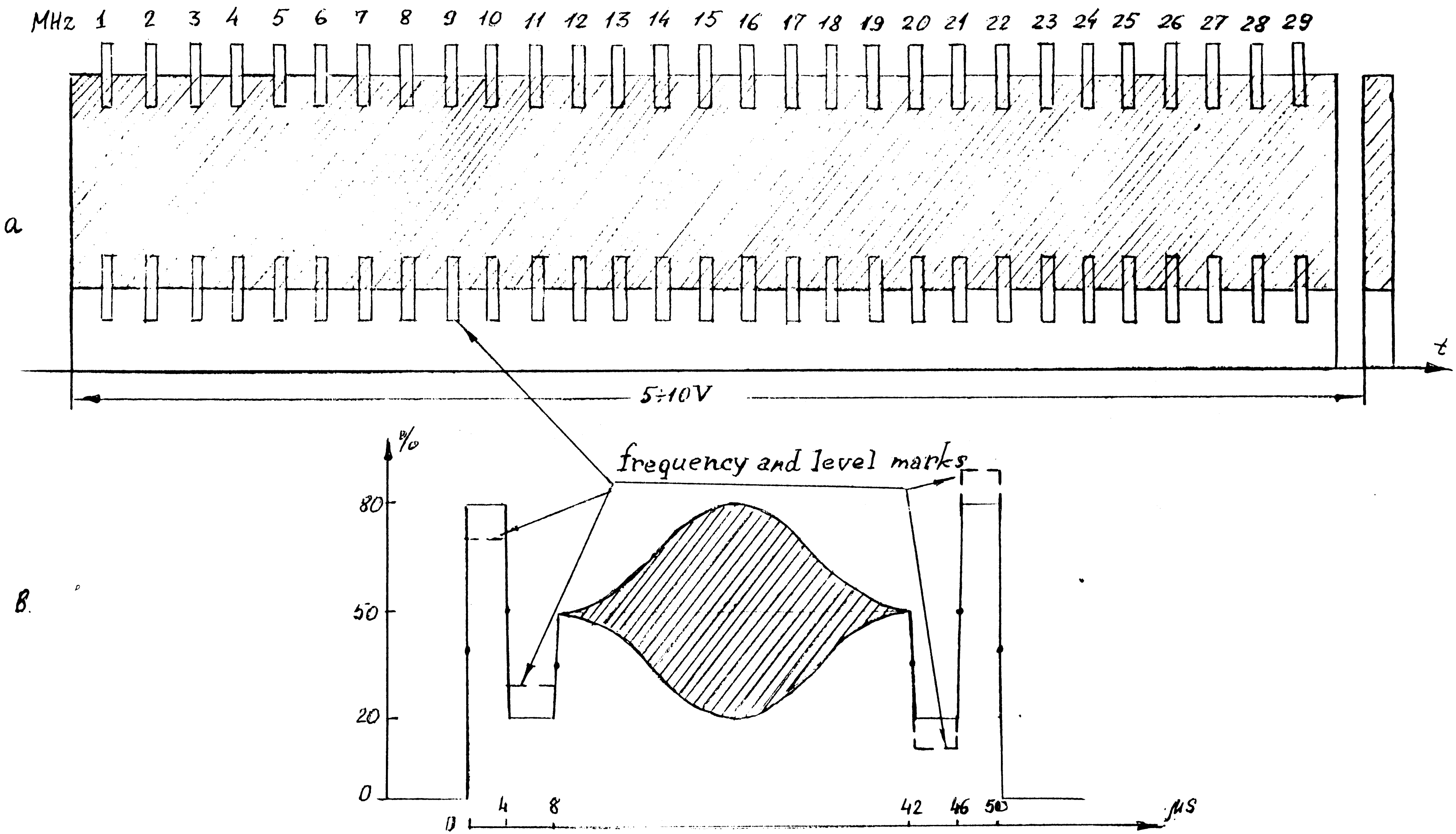

FIGURE 3 - Test signal for the measurement of continuous amplitude-frequency response and group delay

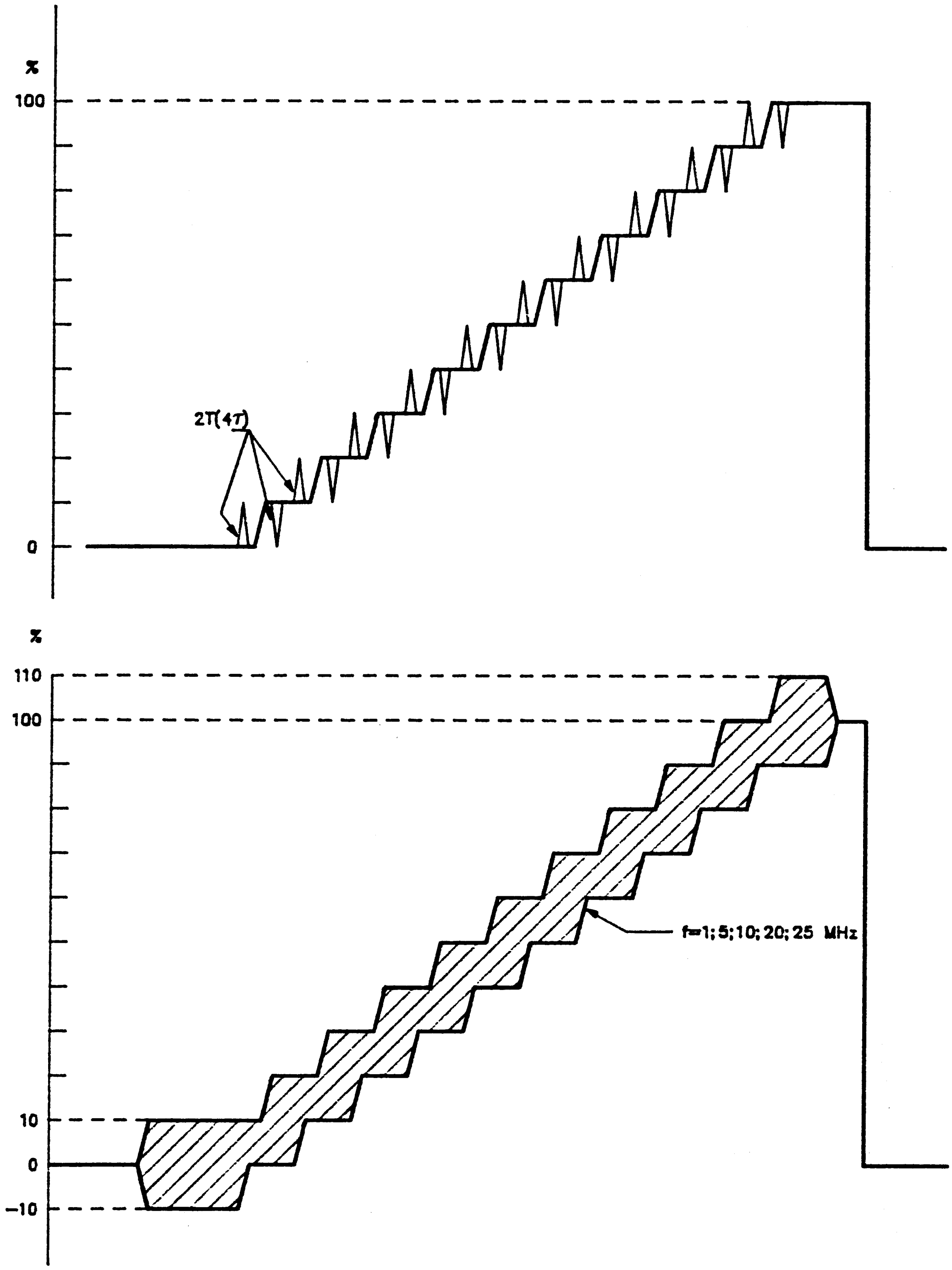

FIGURE 4 - <u>Test signals for the measurement of non-linear distortions</u>

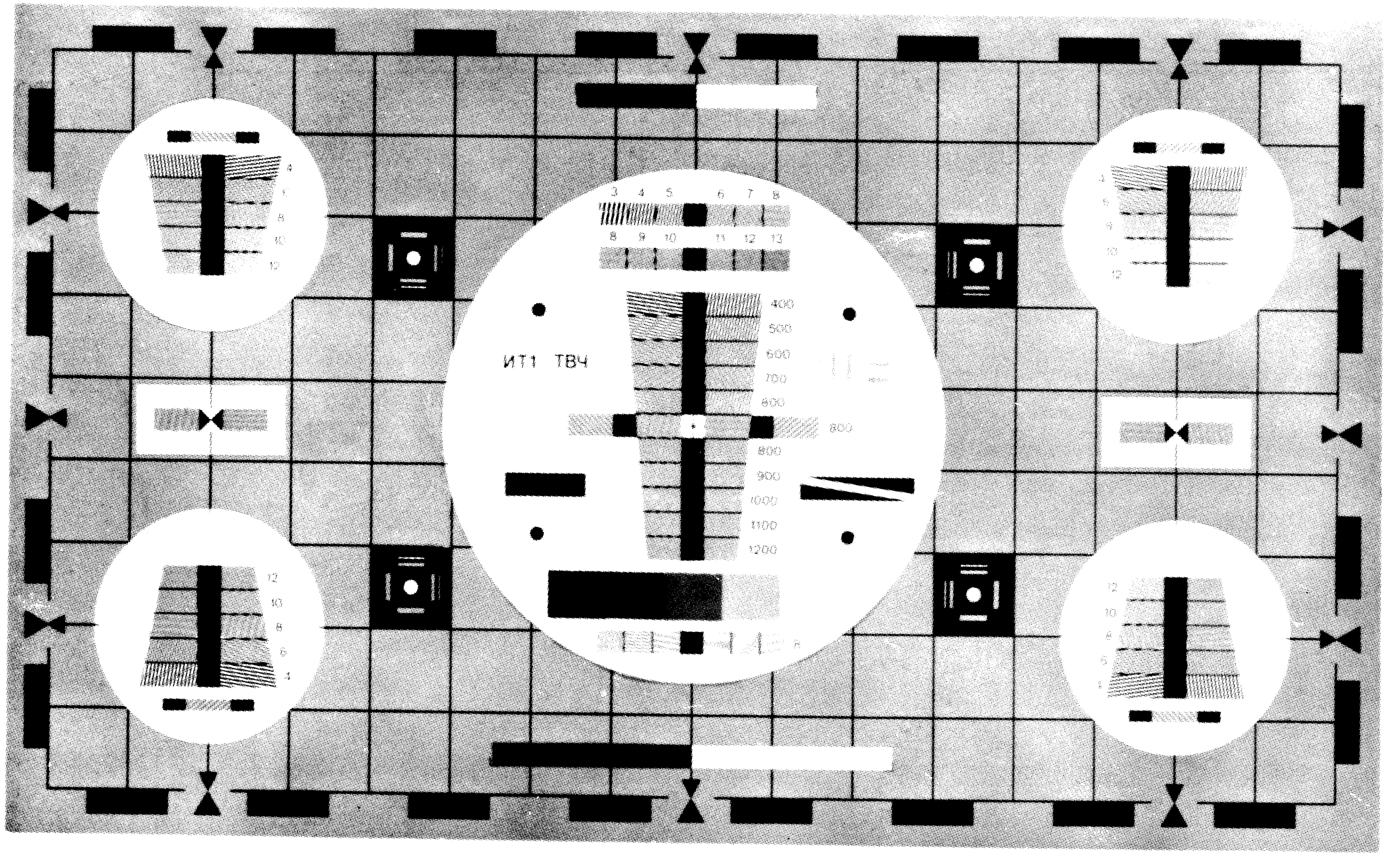

FIGURE 5 - Resolution Test Chart for HDTV

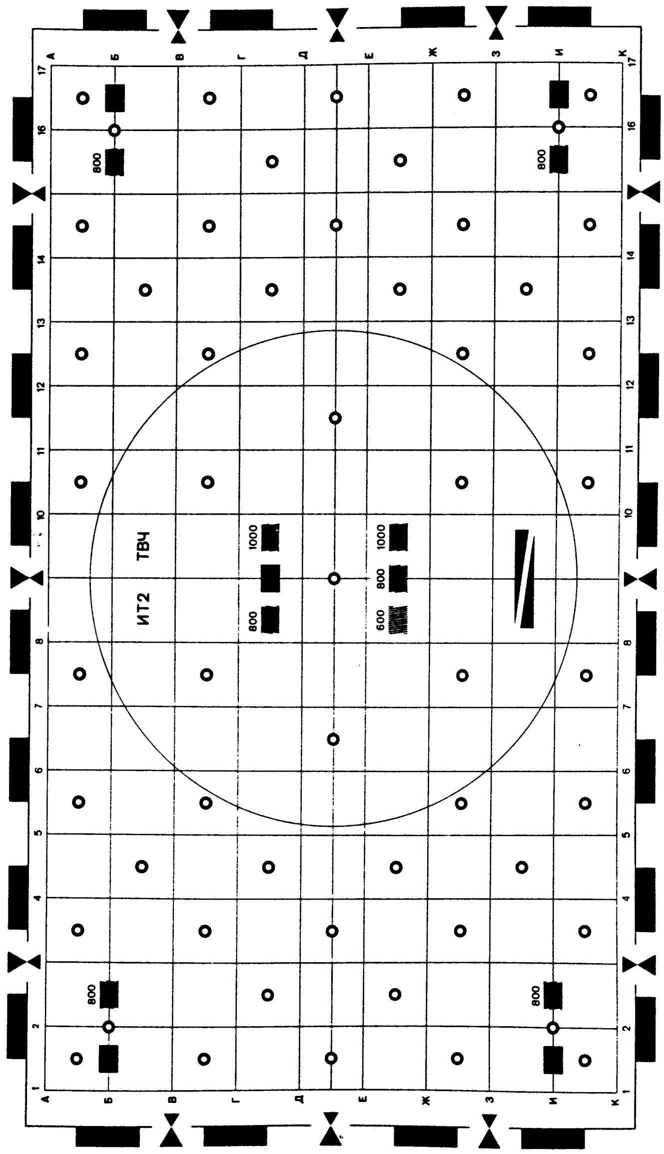

FIGURE 6 - Linearity Test Chart for HDTV

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DRAFT
REPORT AT/11(MOD Ex)

THE SUBJECTIVE ASSESSMENT OF HDTV PICTURES

(Question 3/11; Study Programme 3E/11)

1. Introduction

Methods used in subjective tests of conventional television systems are described in Recommendation 500-3 (MOD I) and in Report 1082 (MOD I). The main concepts of assessment methodology apply equally to all forms of television, but the way in which the detailed specifications of the methods for conventional television apply to HDTV requires careful study.

According to Decision 66-1, IWP 11/4 is to examine developments in HDTV and to determine what changes, if any, to subjective test methods are required to accommodate these developments. The IWP has yet to complete its studies in this regard.

Before proceeding, it is important to stress the following points:

- Picture quality is not the only factor which needs to be considered in the selection of standards. Other factors such as system complexity, availability, future possibilities, etc., must be part of the overall equation.

- The results of subjective assessment experiments are not in themselves laws of physics. They offer guidance for a given set of test conditions, and are not absolute facts about a system.

- The conceptual differences between the quality and impairment scale terms currently used are not uniform; but, traditionally, processing of results uses the approximation that they are so. Studies on alternative assessment methods with fewer shortcomings are being made, but interpretation of the results of current methods must take account of the shortcomings. More information is available in Report 1082 (MOD I).

- The key element in subjective assessments is often the selection of test material. Guidelines call for material which is critical but not unduly so. Deciding what could be critical needs a full understanding of how HDTV systems work. Systems-oriented IWPs (IWPs 11/6 and 11/7) therefore must also be part of the methodological discussion.

An HDTV environment evaluation by Krivocheev, related in § 1 of Report 801-3 was used to delineate elements of the HDTV environment likely to be the subject of assessments.

2. Picture quality evaluations in an HDTV environment

2.1 Areas for picture quality evaluations

2.1.1 Evaluations of HDTV studio formats

There will be a need to evaluate:

- basic picture quality;
- picture quality after downstream processing such as colour-matte, slow-motion and picture manipulation, and possible conversion to other formats, including film.

2.1.2 Evaluations of conventional studio formats (and film) derived from HDTV studio sources

There will be a need to evaluate the adequacy, in terms of picture quality, of conventional studio formats and of film derived from HDTV studio sources.

2.1.3 Evaluations of HDTV emission formats

There will be a need to evaluate:

- basic picture quality;
- failure characteristics;
- echo behaviour; and
- susceptibility to interference.

2.1.4 Evaluations of conventional television pictures embedded in HDTV emissions

Some of the HDTV emission formats currently under consideration include an embedded conventional television format ("backwards compatibility"). Thus, there will be a need to evaluate, in terms of picture quality, the adequacy of conventional television pictures embedded in HDTV emissions.

2.2 Issues for picture quality evaluations

2.2.1 Evaluation methods

2.2.1.1 Evaluations of picture quality

The five-grade quality terms currently used in subjective assessments are not uniformly spaced conceptually and difficulties have been noted in comparing results obtained in different laboratories, particularly when language translation of terms is required [CCIR Report 1082 (MOD I)]. Further, due to the sensitivity of quality evaluations using conceptual quality terms to the range of conditions used in test, it is unwise to interpret terms in an absolute fashion or to compare results from tests conducted using different ranges of quality (e.g., HDTV and conventional television).

A seven-grade quality scale has been used successfully in [Fujio, et al., 1982] to establish the meaning of HDTV quality and such techniques may be useful in future. Further, alternatives to the five-grade quality methods are presented in § 4 of Recommendation 500-3 (MOD I) and in Report 1082 (MOD I). Nevertheless, on balance, IWP 11/4 suggests that the double-stimulus continuous quality method given in § 2 of Recommendation 500-3 (MOD I) generally be used for quality evaluations in an HDTV environment.

2.2.1.2 Evaluations of picture impairments

To an extent, the same problems have been noted for the five-grade impairment scale as for the five-grade quality scale. On balance, however, IWP 11/4 recommends that, when picture quality impairments are to be evaluated, the double-stimulus, impairment method given in § 3 of Recommendation 500-3 (MOD I) generally be used.

2.2.2 Viewing conditions for subjective evaluations in an HDTV environment

2.2.2.1 Evaluations of HDTV studio formats

Report 801-2 gives picture presentation objectives for HDTV studio formats.

2.2.2.2 Evaluations of conventional studio formats derived from HDTV studio sources

As these evaluations concern TV systems already considered in CCIR texts, evaluations of conventional studio formats should use the viewing conditions already agreed and presented in Recommendation 500-3 (MOD I).

2.2.2.3 Evaluations of HDTV emission formats

It is unclear how well the picture presentation objectives given in Report 801-2 for HDTV studio pictures relate to conditions likely in home viewing. However, subjective evaluations of HDTV emission formats should take account in some way of the higher performance objectives of the HDTV studio.

It is likely that, due to constraints on emission, HDTV emission formats will be unable to fully reproduce the level of picture quality possible in the HDTV studio. However, in recognition of the objective in emission formats to reproduce, as nearly as possible, the original studio image and in order to preserve consistency of subjective tests throughout the HDTV studio-emission chain, it is suggested that the viewing conditions given in draft Recommendation XB/11 be used equally for tests of HDTV emission formats, and for tests of HDTV studio formats.

2.2.2.4 Evaluations of conventional television pictures embedded in HDTV emissions

As these involve conventional television pictures, the viewing conditions given in Recommendation 500-3 (MOD I) apply.

3. Assessment of the picture quality of HDTV studio formats

3.1 Assessment of basic picture quality

At issue here is the picture quality of the HDTV studio format prior to downstream processing. Factors likely to affect basic picture quality include, but are not confined to, spatial resolution, temporal resolution, colour-gamut, and linearity characteristics. Annex I of this Report summarizes work on evaluation factors for assessing HDTV picture quality.

There is general agreement that an increase in colour-gamut and the inclusion of constant luminance coding are desirable goals for the HDTV studio system. However, these features carry with them the need for more complex signal processing at the camera and display, and it may become necessary to evaluate trade-offs between the benefits of these goals and the possible disadvantages due to the complex signal processing.

Evaluation of the value of increased colour-gamut and the impact of additional processing requires the availability of a display having a significantly larger gamut than current CRT displays and a source signal properly processed for that large gamut display. In addition, a current CRT-type display is required with the non-linear processing to transform the large gamut source signal into an appropriate signal for this smaller gamut display. Still pictures containing a range of normal colours plus a few colours that lie outside the smaller gamut should be evaluated by comparing the two displays. One source for high purity colours are balls of yarn containing saturated colours. Materials of this sort can provide very saturated colours that lie outside the gamut of current CRT displays and still lend themselves to reasonable scene composition. Subjective evaluation of such a scene on normal CRT displays and on high purity displays should provide an estimate of the quality gain.

The evaluation of constant-luminance coding methods in comparison to non-constant luminance coding methods should be carried out by comparing a full bandwidth RGB display to a display on which either constant-luminance or non-constant-luminance signals can be displayed. The scene subject matter should include detail in saturated colours along with normal scene elements. Shadows formed on balls of saturated red, green and blue yarns are one means for providing the detail in saturated colours [CCIR, 1986-90a].

The methods normally used to assess picture quality (i.e., double-stimulus methods) typically require a reference condition that provides quality superior to that of the system under test. The high quality of an HDTV studio system, however, makes it difficult to find appropriate reference conditions. For this reason, it may be appropriate to use directly-viewed scenes (still and moving) to provide the reference condition for assessments of HDTV studio systems [CCIR, 1986-90b].

3.1.1 Methodology

The double-stimulus, continuous-quality method could be used. The reference for picture quality assessments could be the scene viewed directly (subject to appropriate framing). The test could be the same scene viewed via the system under test. Methodological issues associated with the use of directly-viewed scenes as reference conditions are summarized in Document [CCIR, 1986-90b].

3.1.2 Viewing conditions

See draft Recommendation XB/11.

3.1.3 Assessment material

The test material could comprise a number of still pictures and moving sequences. Sources for the still pictures could be either transparencies (rear-illuminated) or photographic prints (directly illuminated). Sources for the moving sequences could be motion dioramas. The reference condition would be provided when a source is viewed directly, while the test condition would be provided when the same source is viewed via a camera and monitor. Identical framing for the two conditions could be maintained by reflecting the test materials for both onto the same 16:9 viewing mirror. Switching between conditions could be done by shutters in the optical paths. Switching is to be done under experimenter control.

The tests involve implied comparisons of test material from a video camera with the same material viewed directly. To minimize possible contamination of the results by differences implicit to television vs. the "real world", it will be necessary to control a number of factors. These include:

- parallax differences: while viewing, the observer should not be able to move appreciably as this would result in a degree of motion parallax in the directly viewed scene but not in the scene shown on the monitor;
- visible depth: the viewing mirror will display alternately the television image and the source scene. The composition and lighting of source scenes should be set to ensure that differences in depth between the television image and the directly viewed scene are minimized;
- scene lighting: the viewing mirror will display alternately the television image and the source scene. The lighting in the source scene will have to be adjusted when the display path is changed to hold intensity and colour temperature (D_{65}) constant in both of the images. The colour temperature may have to be set on scene-by-scene.

Document [CCIR, 1986-90a] provides a number of criteria for the composition of source scenes. These include:

- static spatial resolution;
- dynamic spatial resolution;
- luminance rendition;
- colour rendition; and
- motion rendition.

In addition, it might be useful to supplement these with other, special-purpose scenes. These might assess:

- apparent depth effects (e.g., in panoramic scenes);
- rendition of familiar tones (e.g., skin tones);
- feeling of presence (e.g., in a rapid pan); and
- flicker performance (e.g., with large, white sub-fields).

3.1.4 Interpretation of results

The system tested should approximate as closely as possible the level of quality provided by the directly-viewed reference. In considering the results, two issues should be kept in mind:

1. An HDTV studio system is likely to make compromises among the various features that relate to quality. In addition to considering quality averaged over the various pieces of test material, it would be wise to examine reactions to the individual source scenes in order to identify features that could be improved.

2. In interpreting results, it is necessary to identify and, to the extent possible, adjust for possible contamination of the results by technical maturity (state of implementation).

3.2 The assessment of HDTV picture quality following downstream processing

Two areas are considered: post-production processing and standards conversion.

3.2.1 Post-production processing

The major areas of post-production processing are colour-matte, slow-motion and picture manipulation. Assessments made at the time the Recommendation 601 4:2:2 standards were developed suggested that colour-matte is the most demanding post-production operation. For a given field-rate and scan system, this is likely to apply to HDTV.

3.2.1.1 Colour-matte assessments

a) Methodology

The double-stimulus impairment scale method should be used provided a full range of picture quality is available. The reference for colour-matte assessments could be a matted picture, using a full-bandwidth RGB signal as a foreground. The test could be a matted picture using the reduced colour-difference bandwidth signal as foreground. The matted test and reference pictures should be optimized for quality on a shot-by-shot basis, as this would be the situation in practice. The methodology appropriate, if a full range of picture quality cannot be provided, is still being considered.

b) Viewing conditions

See draft Recommendation XB/11.

c) Assessment material

The test material should be critical for the types of impairment likely for colour-matte processing. The material which is likely to be most demanding would contain moving fine detail. No specific test sequences for colour-matting in HDTV are known to be available, but moving combs, twisted ribbons, and glass (transparent) as in Report AG/11 may be appropriate for colour-matte evaluations. Colour-matte performance depends highly on scene lighting, and care must be taken to ensure this is optimized and consistent.

d) Interpretation of results

The test material should not be appreciably impaired relative to the reference material.

3.2.1.2 Slow-motion assessments and picture manipulation assessments

Methodology, viewing conditions, assessment material, interpretation of results

The assessments in this category pose problems in that a high quality reference signal is not likely to be available. It is the inclusion of a reference signal which gives the double-stimulus methods their properties. A ratio scaling method is being studied which may be adequately stable and reproducible without a reference. Alternatively, there may, in some cases, be a means of generating high quality reference sequences. For example, high quality slow motion may be possible by a separate shooting of the source sequence at a higher picture rate.

3.2.2 Picture quality following HDTV-to-HDTV standards conversion

a) Methodology

As noted in Decision 58-3, the declared objective of all administrations is to achieve a single world-wide HDTV studio standard, and one of the reasons is to permit international programme exchange without standards conversion. Situations, no doubt, will arise, however, where conversion from other HDTV formats or film will be required. In addition, similar conversions might be needed prior to the generation of an emission format with a different field-rate to the source. In such a case, an investigation of an emission format should consider this.

Field-rate standards conversion can give rise to transient temporal artifacts, and in order to provide a better overall system evaluation, a two-tier assessment method is proposed here.

Primary assessments

These are considered to be the main and most useful assessments. A double-stimulus continuous quality scale method should be used. The reference signal should ideally be the same picture or sequence used as an input to the standards converter, but shot using the scanning parameters of the converter output signal. If this is not possible, or if such tests were of interest for other reasons, the reference signal should be the input signal to the converter.

Auxiliary assessments

A number of expert viewers should be asked, using the single stimulus method (see Recommendation 500-3, § 4), to assign an overall quality grade to several representative converted programmes. It may also be possible to assess the frequency of detection of artifacts, but this requires further study.

b) Viewing conditions

As given in draft Recommendation XB/11.

c) Test material

Primary assessments

A relatively large number of still pictures and moving pictures should be used. A number of assessment sequences have been prepared in an 1125/60/2:1 format to evaluate the quality of HDTV-to-YUV/PAL conversion. They may also be candidates for HDTV-HDTV assessments in certain cases:

Drum
BBC disc*
Red car*
Merry-go-round*
Newbury racing
Rollers
NHK disc
Football
Pendulum*
Interview
White car*

A large transparency (10" x 8") of Kiel Harbour is available, and could be used to generate a test still picture.

It has been suggested that if test materials could be prepared and distributed in digital media (as is done with conventional pictures under Recommendation 657), the performance variations of analogue media could be eliminated. Digital recorders for HDTV are currently under development.

Auxiliary assessment

A number of expert viewers may be asked to scale the overall quality of several programmes of 5-20 minutes duration, which include examples of different types of movement and scenes with high detail. An example would be the "This is HDTV" programme by NHK.

Characteristics of test material

Critical test material for standards conversion is likely to include areas of high detail which have different movement speeds and directions.

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* These are probably the most critical for temporal processing systems.

d) Interpretation of results

Care must be taken in the interpretation of results, that any inherent quality differences in the two HDTV studio standards are not attributed to the conversion process. The use of reference sequences shot directly in the output standard would assist this.

According to Report 801-3, the subjective quality of the converted picture should be "virtually equivalent" to the input picture, unless it is limited by the parameters of either standard.

4. Assessments of the quality of conventional studio pictures derived from HDTV pictures in the studio environment

4.1 Areas for assessments

The interface between HDTV and conventional TV may imply conversions of line number, frame rate and aspect ratio, although cases without frame rate conversion are also possible. According to CCIR Report 801-3, the quality of the conventional picture should be the same as for direct production in the conventional standard.

4.2 Impairments by standards conversion

4.2.1 Impairments due to line number conversions

Conversions involving changes in the number of active lines may result in perceptible disturbances at edges moving vertically. These disturbances may be more pronounced for conversions which increase the number of lines than for those which decrease the number of lines.

4.2.2 Impairments due to frame rate conversions

Conversions involving changes in frame rate will introduce artifacts, such as judder, confined to the moving areas of the picture. The level of these impairments is related to the ratio of the frame rates involved and to the complexity of the conversion algorithm. Some techniques, such as motion adaptive compensation, can reduce these artifacts to very low levels.

4.2.3 Impairments due to aspect ratio conversions

Conversions from the wider aspect ratio of HDTV to the 4:3 aspect ratio of conventional formats may result in the loss of significant picture content or resolution. This is not an area, however, in which subjective evaluation is likely to provide useful guidance.

4.3 Assessment of the quality of conventional quality television derived from an HDTV signal

4.3.1 Methodology

It is evident that the performance of HDTV to conventional television converters can only be completely assessed with moving picture sequences. For the evaluation of the small impairments of the limited range to be expected, the use of the double-stimulus, continuous-quality-scale method is thought to be most useful. The assessors should be asked to view a pair of sequences, one direct in the conventional studio format and the other in the appropriate conventional format but derived from HDTV.

4.3.2 Viewing conditions

The viewing conditions should be as in Recommendation 500-3 (Mod I).

4.3.3 Assessment material

A wide range of relatively critical programme material should be used as assessment material. The following scenes were recommended by NHK and EBU experts for the assessment of the NHK converter:

Drum
BBC disc
Red car
Merry-go-round
Horse racing
Rolling captions
NHK disc
Football
Pendulum
Interview
White car

The test sequences could become even more revealing if some of these sequences were replaced by similar ones with higher maximum velocities.

Two other kinds of sequences, likely to be more critical, could be included as well:

- scenes with zoom motion;

- scenes with movements in contrary directions like a market place.

Tests should also be conducted with downstream processed material.

4.3.4 Interpretation

Ideally, an HDTV to conventional television interface should yield the same quality as conventional television direct. Because this demand will probably not be met completely for motion portrayal, the frequency of the assessed picture degradations in television programmes should be investigated. This may imply a two-tier approach as in HDTV-HDTV conversion.

5. Assessment of the quality of HDTV emission systems derived from an HDTV studio standard

5.1 Areas for assessment

The system characteristics which are of interest are as follows:

5.1.1 Basic quality: This is the picture quality under perfect reception conditions, i.e. when the SNR or CNR is high.

5.1.2 Failure characteristics: This is the relationship between picture quality and noise (which has a characteristic appropriate to the modulation system to be used). The range over which assessments should be made needs to be reviewed in the light of a preliminary run, and should be arranged to give 5-8 points covering the scale range. The range of interest for AM systems is usually a S/N of 25-55 dB, and for FM systems a C/N of 0-30 dB.

5.1.3 Echo behaviour: This is the relationship between picture quality and echo amplitude and delay. It is usually more relevant to AM systems. The range over which assessments need to be made should be reviewed in the light of preliminary runs, but a suitable approach might be to obtain information on three curves, having a delayed signal added to an undelayed signal with 150 ns, 1 μs, 5 μs delay respectively, and with echo amplitudes from -5 to -25 dB, compared to the wanted signal.

5.1.4 Interference behaviour: Co-channel and adjacent channel interference characteristics need to be assessed.

It may well be appropriate to assess items 2, 3 and 4 above both with and without scrambling.

5.2 Methodology

Basic quality

The basic design problem in HDTV emission is to meet, as nearly as possible, the visual requirements for HDTV within the bandwidth available. To do this, either or both of spatial and temporal subsampling may be used.

Such techniques may introduce detectable impairments, or losses in quality, beyond those attributable to the studio format. Spatial subsampling may result in detectable losses in one or more of horizontal, vertical or diagonal resolution. Temporal subsampling may result in detectable reductions in the quality of motion portrayal. Spatio-temporal subsampling may result in detectable losses in spatial resolution for moving picture sequences.

Clearly, high resolution pictures and moving picture sequences are needed to evaluate HDTV emission formats. However, in order to provide an adequate and representative overall evaluation, a two-tier assessment method is proposed here for basic quality.

- Primary assessments

These are considered to be the main and most useful assessments. A double-stimulus continuous-quality-scale method should be used. The reference should be the studio source signal and the test signal should be the emission signal.

- Auxiliary assessments

A number of expert viewers may be asked to scale the overall quality associated with several representative programmes in the emission format. It may also be possible to assess the frequency of detection of artifacts, but this requires further study.

Failure characteristics, echo behaviour and interference behaviour

A double-stimulus impairment scale method should be used following Recommendation 500-3 (MOD I) § 2.

Two approaches can be taken:

- cumulative failure characteristics - for these, the points at which objectionable losses occur relative to the unimpaired high-quality reference are considered;

- non-cumulative failure characteristics - for these, the points at which objectionable losses occur relative to the unimpaired emission format are considered.

5.3 Viewing conditions

See draft Recommendation XB/11.

5.4 Test material

Basic quality

The test material should be chosen from a range of high resolution still pictures and moving picture sequences which are critical but not unduly so.

A series of critical moving picture sequences is available on 1125/60/2:1 video tape, and these may be useful sequences for appropriate HDTV emission systems:

Drum
BBC disc
Red car
Merry-go-round
Newbury racing
Rollers
NHK disc
Football
Pendulum
Interview
White car

A large transparency (10" x 8") of Kiel Harbour is available and could be used to generate a still picture.

A possible source for the auxiliary assessments could be the NHK programme "This is HDTV". Certain sequences from this programme have detailed crowd scenes, and 10-20 s segments from this part may be useful for the primary assessments.

Material which is likely to be critical would require high detail with simultaneous movement at varying speeds and varying directions.

Failure characteristics, echo behaviour and interference behaviour

Adequate results should be achieved by using only a small range of still and moving pictures. The overall mean grade can usually meaningfully be calculated and used.

5.5 Interpretation of results

a) Basic quality

It seems reasonable to argue that to be effective, the quality of the HDTV emission signal must be closer to the HDTV studio quality than to the RGB quality of conventional television.

As a generality, and for most material, there must be sufficient additional quality, compared to a conventional television. Further, any temporal artifacts must be sufficiently unobtrusive not to detract from the HDTV quality.

b) Failure characteristics, echo behaviour and interference behaviour

(Subject to further study.)

6. Assessment of the quality of compatible pictures embedded in HDTV emission formats

6.1 Areas for assessment

Some HDTV emission systems are intended to allow simultaneous reception on HDTV and conventional receivers. Section 5 concerns the assessment of the HDTV emission quality itself. This section concerns the quality of the simultaneously received conventional signal.

In general, a design tradeoff must be made between the quality achieved on the HDTV display and the quality achieved on the conventional display, leading to a degree of compatibility based on the level of impairment introduced. This may imply an investigation of the same factors as are listed in section 5, but this time for the compatible picture.

The proposed HDTV emission systems involve temporal processing, and other mechanisms, which might cause impairments to the compatible pictures.

6.2 Methodology

For basic quality, the double-stimulus, continuous-quality method might be used with material prepared directly in the conventional emission format and/or material converted directly from the HDTV studio format as reference. For failure characteristics, echo behaviour, and interference, the double-stimulus, impairment method might be used, with material prepared directly in the conventional emission format (but not otherwise impaired) and/or material converted directly from the HDTV studio format (but not otherwise impaired) as reference. In all cases, the test signal should be the compatibly received picture.

6.3 Viewing conditions

As given in Recommendation 500-3 (MOD I) for conventional television.

6.4 Test material

A range of still and moving pictures should be used. For NTSC-compatible reception, the following 1125/60 sequences may be candidates:

Drum
BBC disc
Red car
Merry-go-round
Newbury racing
Rollers
NHK disc
Football
Pendulum
Interview
White car

Characteristics of test material should be generally as given for assessments in § 5 (i.e., critical, but not unduly so).

6.5 Interpretation of results

Interpreting what the quality of "compatible" pictures should be in quantitative terms presents problems, not least because of the non-interval nature of the scales.

Results for each test picture or sequence should be presented separately.

The quality of the embedded picture should, in principle, be "equivalent" to that of the reference signal. In practice, an agreed "degree of compatibility" must be achieved.

7. Assessment of the quality of motion-picture film derived from HDTV source material

(To be investigated.)

8. Comparisons of candidate HDTV formats

On occasions, it may be necessary to compare candidate HDTV formats for purposes of selection. It is the opinion of IWP 11/4 that such comparisons can be used most advantageously to identify the best features of the various formats under test.

8.1 Comparisons of HDTV studio systems

Three ways have been identified in which candidate studio formats can be compared:

- directly, by side-by-side comparison;

- indirectly, by implied comparisons to a common reference condition in a single experiment, and

- theoretically, by establishing relative placements in terms of psychophysically determined optima.

8.2 Direct comparisons ([CCIR, 1986-90a,c] discuss issues related to direct comparisons, further study is required)

8.3 Indirect comparisons

An indirect comparison requires a common reference condition with which each system under test is evaluated. The subjective methods normally used for indirect comparisons (i.e., the double-stimulus methods) use reference conditions that, typically, provide quality superior to that of any of the conditions under test.

However, the high quality of candidate HDTV studio systems makes it difficult to find such reference conditions. For this reason, it may be appropriate to use directly-viewed scenes to provide the reference condition.

For a valid indirect test, the directly-viewed reference must be held constant across all systems tested. For still pictures, of course, this can be accomplished by means of transparencies or photographs. For moving images, however, it is necessary to use fully reproducible motion sequences for the reference. This may be done using mechanically controlled scenes (e.g. dioramas).

It is equally important to ensure that, except for differences implicit to the formats themselves, the test materials are held constant across all systems under test. This would be accomplished if the video camera for the system-under-test is used to capture the reference still or sequence, as long as the reference is held constant.

It should be noted that all systems under consideration should be tested in a single experimental context (i.e. that viewers should see, over the course of the experiment, a random sequence of the systems under test). This may be done by alternating the cameras used to reflect the systems under test. The monitor which should be held constant, should be selected to be adequate for all system under test. It might not always be possible to extrapolate the general data applicable to the conditions set up by draft Recommendation XB/11 from the results obtained with the viewing conditions allowed by present equipment. Care should be taken in interpreting the results of the tests to distinguish system-standard-related values from those relevant to the practical implementation.

Directly-viewed scenes may provide a reference whose quality is considerably superior to that of the systems under test. This may lead to two issues:

1) differences in subjective reactions to the systems under test may be minimized artificially. When viewers judge, they tend to be influenced by the range and distribution of quality seen. When quality (including that shown by the reference) spans a wide range, cases somewhat similar in quality tend to be judged more similar than they would be if evaluated in a more constrained context or compared directly, and

2) the preferred test method may change. If conditions (including reference and test) cover a wide range of quality, the double-stimulus, impairment method may be used for indirect comparisons. However, if conditions span a smaller quality range, the double-stimulus,continuous-quality method is preferred.

Thus, depending upon the purpose of the test, two options arise. If tests are intended to place systems in relation to a "perfect" standard, they may use a superior reference and the double-stimulus, impairment method. In this case, however, fine differences among systems may not be detected. On the other hand, if tests are to make fine discriminations among systems, a superior reference should be avoided and the double-stimulus, continuous quality method used. In the latter case, it may be necessary to limit the quality of the directly-viewed scene by means of composition, lighting, optical filtering, etc.

8.3.1 Methodology

Depending upon the quality range involved in the test, either the double-stimulus,continuous-quality method or the double-stimulus, impairment method could be used.

If the double-stimulus, continuous-quality method is used, it may be appropriate to consider the variant of this method given in [CCIR, 1986-90d]. In this variant, relatively lengthy exposures are used to encourage the detection of subtle effects, particularly in moving sequences.

If the double-stimulus, continuous-quality method is used, each trial will involve multiple, alternating displays of the reference and test conditions. For half the trials (randomly determined), the reference condition is to be presented first; for the remaining trials, the test condition is to be presented first. If the double-stimulus, impairment method is used, each trial will involve a single alternation between reference and test, with the reference presented first.

The test material will comprise a number of still pictures and moving sequences. Sources for the still pictures could be either transparencies (rear-illuminated) or photographic prints (directly-illuminated). Sources for the moving sequences could be motion dioramas. The reference condition would be provided when a source is viewed directly, while the test condition would be provided when the same source is viewed via a camera and monitor. Identical framing for the two conditions could be maintained by reflecting the test materials for both on to the same 16:9 viewing mirror. Switching between conditions could be done by shutters in the optical paths. Switching is to be done under experimenter control.

Each viewer should see the viewing mirror through a viewing aperture that permits binocular viewing, but little or no head movement. Viewers can be run individually or in small groups. However, if more than one viewer is run at a time, the angle of view (to the scene) must be held constant for all viewers.

The tests involve implied comparisons of test material from a video camera with the same material viewed directly. To minimize possible contamination of the results by differences implicit to television vs. the "real-world", it will be necessary to control a number of factors. These include:

- parallax differences: while viewing, the observer should not be able to move appreciably as this would result in a degree of motion parallax in the directly viewed scene but not in the scene shown on the monitor;

- visible depth: the viewing mirror will display alternately the television image and the source scene. The composition and lighting of source scenes should be set to ensure that differences in depth between the television image and the directly viewed scene are minimized;

- scene lighting: the viewing mirror will display alternately the television image and the source scene. The lighting in the source scene will have to be adjusted when the display path is changed to hold intensity and colour temperature (D_{65}) constant for all the alternating displays. The colour temperature may have to be set on scene-by-scene.

As different linguistic groups are known to use quality and impairment scaling terms differently, all tests should be done in a single language with observers fluent in that language.

8.3.2 Viewing conditions

See draft Recommendation XB/11.

8.3.3 Assessment materials

See § 3.1.3.

8.3.4 Interpretation of results

Interpretation of results is made on the basis of relative placements of candidate systems relative to the common directly-viewed reference. The issues noted in § 3.1.4 should be kept in mind.

8.4 Theoretical comparisons

The basis of this approach is to consider, parameter-by-parameter, the placements of candidate systems in terms of the relevant psychophysical ideals. This approach is proposed in [CCIR, 1986-90c]; examples of its use (with generalizations) are given in Documents [CCIR, 1986-90e,f].

9. Comparisons of candidate HDTV emission formats

As with HDTV studio systems, comparisons may be direct, indirect, or theoretical. Here, only indirect comparisons are considered. Examples of this approach are given in [CCIR, 1986-90g].

9.1 Basic quality

This generally is as for HDTV studio formats (§ 8.3). Here the double-stimulus, continuous-quality method may be used with a single high-quality reference.

9.2 Failure characteristics

These tests generally are as given in § 5. However, the intent is to compare failure characteristics of all candidate systems.

10. Further issues

In [CCIR, 1986-90a] related issues are considered: evaluation methods for conversion from HDTV to 35 mm cine film, the use of the CCIR quality scale descriptors, interpretation of quality targets in terms of numerical results of assessment, subjective quality and signal-to-noise ratio characteristics of HDTV signals, relationships between picture and sound aspects of HDTV.

REFERENCES

FUJIO, T. et al. [June, 1982] High-definition television. NHK Technical Monograph No. 32.

CCIR Documents

[1986-90]: **a.** IWP 11/4-160 (IWP 11/4); **b.** IWP 11/4-171 (Canada); **c.** IWP 11/4-161 (France); **d.** IWP 11/7-189 (AHG-BCT); **e.** IWP 11/4-146 (France); **f.** IWP 11/4-172 (Canada); **g.** IWP 11/4-181 (Canada).

ANNEX I

EVALUATION FACTORS APPROPRIATE TO GLOBAL HDTV ASSESSMENT

In a recent large scale study in North America, viewers evaluated HDTV (MUSE-E via satellite) both in absolute terms and in comparison to studio quality NTSC [Lupker et al., 1988a and b; CCIR, 1986-90]. Evaluations considered both overall picture quality and specific evaluation factors, including image sharpness, colour quality, motion portrayal, depth portrayal, image brightness, screen size, and screen shape (aspect ratio). The results showed that:

1. Absolute judgments of HDTV alone concentrate at the end of the quality scale, suggesting possible problems if the results of separate tests with different HDTV systems were to be compared on the basis of absolute quality judgments.

2. Viewers were able to respond differentially to the different evaluation factors, suggesting that the specific factors approach may be useful in future evaluations.

3. Judgments of overall picture quality were strongly related to most, but not all, of the evaluation factors on which HDTV was perceived to differ from NTSC, suggesting that overall picture quality may fail to fully capture viewer reactions.

4. Judgments on specific factors were, to an extent, related, suggesting possible hierarchies amongst the factors used in the evaluations and the possible existence of lower order basic quality factors.

5. Judgments of overall picture quality were to an extent, affected by different evaluation factors, as a function of viewing distance, suggesting a need for careful consideration of the viewing distances to be used in evaluations.

REFERENCES

LUPKER, S., ALLEN, N. and HEARTY, P. [1988a] The North American High Definition Television Demonstrations to the Public: The Detailed Survey Results.

LUPKER, S., ALLEN, N. and HEARTY, P. [1988b] The North American Public Demonstrations of High Definition Television: An Overview of the Survey Results.

CCIR Documents

[1986-90]: IWP 11/4-144 (Canada).

DRAFT REPORT XG/11*

RECORDING OF HIGH-DEFINITION TELEVISION ON VIDEOTAPE AND DISK

(Question 18/11, Study Programme 18S/11)

1. Introduction

This topic is covered by Study Programme 18S/11 "Recording of high-definition television programmes". No CCIR Recommendation is yet available on this subject.

Experimental types of HDTV video tape recorders have been developed, based on analogue and digital techniques, and used for programme production trials by broadcasters. In addition, prototype disk recorders have been demonstrated which record short sequences and stills. The technologies used include optical, magneto-optical and electronic capacitance recording, with both analogue and digital modulation.

2. Analogue tape recording

Analogue HDTV recording techniques are similar to those used for conventional television, being based on FM modulation and high performance tapes. To accommodate the large bandwidth required, multiple channels combined with high writing-speed and narrow track-widths are used. A number of different approaches for dividing the baseband components of the HDTV signal between the channels have been demonstrated.

Examples highlighting this development are:

- a two-channel recorder with luminance (20 MHz) and line-sequential colour-difference (7 MHz) recorded on different channels, each of which is individually optimized. The signal-to-noise ratio obtainable with conventional (Co)α - Fe_2O_3 tape was 42 dB for the luminance component and 45 dB for the colour difference component [Shibaya et al., 1982];

- four channel recorders with 10 MHz bandwidth in each channel. Two channels are combined for carrying the luminance component (20 MHz) and one channel each for the two colour difference components (10 MHz). For that purpose, the luminance signal is bandsplit and 2:1 time-expanded prior to recording. Such recorders have been implemented using modified B-format (for 50 Hz systems) and C-format (for 60 Hz systems) transports achieving up to 75 minutes of programme duration using 14" reels. In the case of B-format, with the use of metal particle tapes, a signal-to-noise ratio of $\geq$ 40 dB for each component has been reported;

* This Report should be brought to the attention of the IEC.

- a cassette-based machine with time-division-multiplexed luminance (20 MHz) and line-sequential colour-difference (7 MHz), subsequently time-expanded and recorded on two channels. 1/2" metal-particle tape is to be used, resulting in a recording time of 63 minutes with a cassette similar in dimensions to those of a conventional VHS cassette. The signal-to-noise ratio obtained is quoted to be 41 dB and 45 dB for luminance and colour-difference respectively [CCIR, 1986-90a; Shibaya et al., 1988]. This recording format includes four channels of high quality digital audio (16 bit linear, 48 kHz) multiplexed with video.

3. Digital tape recording

Digital recording of HDTV has developed rapidly in response to the needs for greater transparency and operational flexibility and has resulted in a full performance recorder based on reel-to-reel techniques [CCIR, 1986-90b; Tanimura et al., 1987; Tsujikawa et al., 1988].

The machine characteristics are summarized in Table I.

[CCIR, 1986-90c] discusses some aspects of the modifications required to record HDTV signals complying with a 1375/50 standard on this machine.

The development of a cassette-based machine will require further study and will likely apply data compression techniques in the recording process [CCIR, 1986-90d].

4. Disc recording

Video discs are the appropriate mechanisms when random access to programme sequences is required. The technologies that have been explored for this application include optical recordings (write once, play only), magneto-optical recording (re-writable) and RAM based emulation of discs. For the case of FM-based component recording, maximum sequence length is limited to 15 min. In the case of digital recording, sequence length is reduced even further to 600 frames (for 30 Hz systems) [CCIR, 1986-90e]. Further development remains to be carried out to make disc recording practical for professional studio recording.

TABLE I

HDTV digital VTR characteristics

Video	Sampling frequency	Y	74.25MHz
		Ps, Pr	37.125MHz
	Form of coding		Uniformly quantized PCM 8 bits per sample
	Number of active lines per frame		1035
	Number of samples per digital active line	Y	1920
		Ps, Pr	960
	Number of user's area line per frame		More than 5
	Frequency response	Y	0 ~ 27MHz ± 0.5dB ~ 30MHz +0dB/-1.5dB
		Ps, Pr	0 ~ 13.5MHz ± 0.5dB ~ 15MHz +0dB/-1.5dB
	S/N	Y, Ps, Pr	More than 56dB
	Pulse response	2T Pulse	Less than 1%
		Tilt	Less than 1%
		Linearity	Less than 1%
	Error correction code		Reed Solomon product code structure
Audio	Sampling frequency		48kHz
	Form of coding		At least 16bits per sample Possible to record up to 20 bits
	Number of channels	Digital	8 channels
		Analog	1 channel
		Time code	1 channel
	Frequency response	Digital	20Hz ~ 20kHz +0.5dB/-1.0dB
Mechanism	Mechanical structure	Based on one inch Type C VTR	
	Maximum play time	96 minutes with 14 inches reel 63 minutes with 11.75 inches reel	
	Tape		Coated metal tape Coercivity (Hc): 1450 Oersted Retentivity (Br): 2450 Gauss
Tape speed		805.2mm/sec	
Video heads		Record : Sendust sputter (Tw=33u) Playback : Ferrite (Tw=40u)	
Scanner rotation speed		7200rpm	
Writing speed		51.5m/sec	
Minimum recording wavelength		0.69um	
Number of video channels		8CH	

REFERENCES

SHIBAYA, H. et al. [1982] Development of a VTR for high definition television. Tomorrow's Television SMPTE, 237-247.

SHIBAYA, H. et al. [October, 1988] An industrial application HI-vision VTR using the new 1/2-inch video cassette. 130th SMPTE Technical Conference.

TANIMURA, H. et al. [1987] HDTV digital tape recording. Montreux Symposium Records, 300-319.

TSUJIKAWA, K. et al. [1988] HDTV digital VTR. Synopses of papers, 130th SMPTE Technical Conference and Equipment Exhibit.

CCIR Documents

[1986-90]: **a.** 10-11/4-143 (Japan); **b.** 10-11/4-142 (Japan); **c.** 10-11/4-155 (USSR); **d.** 10-11/4-154 (Canada); **e.** 10-11/4-145 (Japan).

DRAFT

REPORT 294-6 (MOD Ex)*

STANDARDS FOR THE INTERNATIONAL EXCHANGE OF MONOCHROME AND COLOUR-TELEVISION PROGRAMMES ON FILM

(Questions 28/11, 40/11, 41/11, Study Programmes 28A/11, 40A/11, 41A/11 and 41B/11)

(1963-1966-1970-1974-1978-1982-1986)

1. Introduction

The several aspects of the international exchange of television programmes on film are covered in the following Questions and Study Programmes.

Question 41/11 "International exchange of television programmes on film"

Study Programme 41A/11: "Picture standards for the international exchange of television programmes on film"

Study Programme 41B/11: "Optical sound standards for the international exchange of television programmes on film"

Question 40/11 "Methods of synchronizing various recording and reproducing systems"

Study Programme 40A/11: "Recording of time and control code information on magnetic tapes for television"

Question 28/11 "International exchange of recorded television programmes. *Addition to television programmes (on film or magnetic materials) of data for controlling automatic equipment*"

Study Programme 28A/11: "International exchange of recorded television programmes. *Addition to television programmes (recorded on magnetic tape, film or other materials) of data for controlling automatic equipment*"

The present Report describes the state of progress of the studies listed in the mentioned Study Programmes.

2. Picture standards

2.1 Study Programme 41A/11, "Picture standards for the international exchange of television programmes on film", covers the technical characteristics and standards for the picture component of television programmes on film intended for international exchange.

Recommendation 265 describes such technical characteristics and standards; Recommendation 501 (with Annexes I and II) describes the methods for the subjective evaluation of the picture component of films for television presentation.

2.2 Recommendation 265, § 3.4, stipulates the maximum and minimum film densities for accurate picture reproduction in television.

[CCIR, 1978-82] reports that in the United Kingdom the maximum film density range employed for optimum colour reproduction has been extended to a range between 0.2 and 2.5. Further information on United Kingdom practice, including film transfer characteristics and some details of tests with a telecine is given in [CCIR, 1982-86a].

2.3 Study Programme 41A/11, seeks a definition of the telecine characteristics required to give optimum television reproduction of colour film. [CCIR, 1974-78a] points to a need to distinguish between two uses of film in television and hence a need for two modes of telecine utilization (see Recommendations 265 and 501).

The first category of film used in broadcasting involves theatrical, documentary, and current events films. These films come to the broadcasting organization with an artistic integrity that should not be altered. The characteristics of the telecine intended for this category of film should produce a television image that matches the projected film image under the conditions described in Recommendation 501.

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* The Director, CCIR, is requested to transmit this Report to the ISO, in accordance with Opinion 16.

The second category involves the use of film in television production. Here the film images may be intercut with material from television cameras and the artistic decisions are made within the television organization. The type of telecine intended for this category of film requires additional signal processing and controls to permit matching the images from film with those from the television cameras or the original scene.

It is believed that DECIDES 1 of Study Programme 41A/11 should involve a specification of only the first type of telecine use.

2.4 DECIDES 3 of Study Programme 41A/11 deals with specifications of standards, tolerances, and methods of measurement of colour balance for films intended for the international exchange of colour television programmes. [CCIR, 1974-78b] presents data showing that the differing spectral selectivity of neutral images on various film materials makes it impossible to specify a simple objective measurement of colour balance using standardized measuring equipment normally used in laboratory practice. Reliable, objective measurements can only be made with densitometers having a spectral response closely matched to that of the CIE standard observer.

2.5 The safe area for television titles and sub-titles on anamorphic films is specified in ISO Standard 1223-1981.

3. Sound standards

Study Programme 41B/11 "Optical sound standards for the international exchange of television pogrammes on film", covers the technical characteristics and standards for the sound component of television programmes on film, intended for international exchange.

Recommendation 265 describes such technical characteristics and standards.

4. Operating practices

Operating practices for the international exchange of television programmes on film are also described in Recommendation 265.

OIRT Recommendation 14/3 (1983) [CCIR, 1982-86b] specifies technical parameters by the OIRT for the international exchange of television programmes, which are essentially in agreement with Recommendation 265.

The matter of the information to be placed on the label of the film container is still of interest and some countries have been using, to their mutual advantage, a standard multi-lingual format for this label. Contributions on this topic are also requested.

Cueing leaders have been actively studied and are also a matter for ISO/TC 36. The EBU proposals [CCIR, 1970-74] are reproduced in Annex I to this Report. Further contributions are invited with the objective of agreement on a leader for use in television broadcasting which would also be acceptable for cinema use.

5. Data signals

Question 28/11, "International exchange of recorded television programmes. *Addition to television programmes (on film or magnetic materials) of data for controlling automatic equipment*", concerns the addition to recorded television programmes of data for controlling automatic television station equipment and contributions on this subject are requested. Study Programme 28A/11 considers this Question for both film and magnetic recording.

No Recommendation or Report is yet available on this topic.

6. Synchronization of picture and sound

Question 40/11, "Methods of synchronizing various recording and reproducing systems", and Report 468 of the same title, deal with the synchronization of pictures and sound. The Report takes into account IEC Publication 461 on time and control code for video tape recording. Annex I to Report 964 (EBU Technical Recommendation R25) covers the special case of international exchange of television programmes with two or more sound tracks on a separate support.

Further contributions are expected on the problems of synchronizing film pictures and film sound.

7. New developments

A feasibility study performed by the Society of Motion Picture and Television Engineers in the United States is reported in [CCIR, 1986-90a]. The report considers the use of a second frame-rate of 30 frames per second (fr/sec) for the production and distribution of motion picture films. The document reports the findings of the SMPTE when 30 fr/sec films are used for cinematographic projection.

(a) with regard to flicker, there is significantly greater perception at 24 fr/sec than at 30 fr/sec, with the perception being further increased at elevated screen luminances. (Normal optical projection practices, using a two-bladed shutter, were used);

(b) with regard to strobing effects in motion, a significant improvement in material shot and displayed at 30 fr/sec, compared to that at 24 fr/sec was noted;

(c) one unanticipated additional benefit of filming at 30 fr/sec was noted, being the reduction of granularity apparent on the screen. This improvement was observed to be even greater at elevated screen luminances.

The study also considered a possible change in film format from four perforations per frame to three perforations per frame for 35 mm film, to reduce film consumption. The combination of this change, with operation at 30 fr/sec would result in a net saving in excess of six per cent in print length.

The technical consequences of scanning such films in the TV environment are not yet clear. Contributions on this subject are invited.

8. Future improvements

A number of organizations have demonstrated that the accuracy of temporal image interpolation can be improved by motion detection and prediction. This processing may be used with a telecine to produce a much improved smoothness of movement, comparable to that of a normal television camera, rather than the jerky movement portrayal frequently associated with motion on film. Instead of deriving two or more successive video fields from the same film frame, the process permits successive video fields to be interpolated between the film frames when they do not coincide with the instants of the corresponding film frames, thereby more closely approximating the correct appearance of movement as sampled by the video field rate.

The complexity of this processing is significant, approaching in some ways that of a motion compensated standards converter, but the benefits are also significant. The complexity would be substantially independent of the film frame rate and of the television field frequency. The processing equipment may be assigned to a number of telecines.

It is expected that in the long term the cost and the size of these devices could be reduced, so that they could be incorporated in telecine themselves. As the trend is to install telecines in small numbers and in specialized installations that operate as a pool, the additional cost of motion detection and interpolation would be spread among the users [CCIR 1986-1990b].

A particular method of measuring the velocity of motion is described [CCIR, 1986-90c] which uses a technique of phase correlation.

An application of such methods of temporal image interpolation to an HDTV laser telecine has been implemented in Japan and is described in [CCIR, 1986-90d].

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CCIR Documents

[1970-74]: 11/257 (EBU).

[1974-78]: **a.** 11/71 (USA); **b.** 11/70 (USA).

[1978-82]: 11/284 (UK).

[1982-86]: **a.** 11/78 (United Kingdom); **b.** 11/103 (OIRT).

[1986-90]: a. 11/135 (CBS); b. JIWP 10-11/4-146 (CBS); c. JIWP 10-11/4-129 (BBC); d. JIWP 10-11/4-144 (Japan).

ANNEX I*

UNIVERSAL FILM LEADER FOR CINEMA AND TELEVISION

1. Introduction

Many different film leaders have been designed during the history of motion picture films. Basically, the leader is a length of film attached to the head of the programme film to assist in lacing the telecine machine or cinematograph projector. If, however, it is marked with suitable visual information it may be used to ensure that the correct amount of time is allowed for the machine to run up to speed and to arrive at the beginning of the programme information at a specific moment. It is also usual for the leader to bear marks which facilitate the synchronization of the reproduction of the sound record with that of the picture information. General advice on leaders is contained in Recommendation 265.

The reason for the existence of many different leaders lies in the fact that the visual requirements for cinema projection tend to be different from those for television use. There is the further complication that there are some systems using 24 frames per second and others using 25 frames per second. The latter is encountered where the field rate of the television system is 50 Hz.

It is very desirable that there should be a substantial reduction in the number of leaders encountered because operational errors arise from failure to recognise the significance of certain marks (particularly marks concerned with the synchronization of the sound) when an unfamiliar leader is used. There would also be an advantage in having a leader which is suitable for use in cinematograph projectors and in telecine machines: it should also permit the synchronization of all commonly-encountered separate sound systems and give a sufficiently accurate run-up timing when used in systems having either 24 or 25 frames per second.

This Annex describes a draft leader intended to fulfil these requirements.

The design incorporates a very small number of signs, and thus provides a basis for the possible development of more elaborate national leaders. The intention is that this structure should enable any operator in any country to deal with familiar images. The original leader can thus be retained with any film that is exchanged.

The draft was developed by Sub-group G3 of EBU Working Party G, who based its work on various national or international proposals for leaders in order to produce a leader suitable for the maximum number of users. Copies of the leader were made by Sveriges Radio, which used them experimentally for cinema projection and showing on television. These experiments have confirmed that this leader is suitable for both applications.

* This Annex is based on [CCIR, 1970-74].

2. Description of the leader

The general form of the proposal follows that of ISO Document ISO/TC 36 (October, 1968) entitled "Leaders and run-out trailers for 35 mm and 16 mm release prints". Other relevant documents are AFNOR Pr S 25-003, DIN 15 698, BSI 69/5182 and ASA PH22.55-1966. The changes incorporated in this draft are those considered necessary to provide a leader which is suitable for films used in television, as well as for presentation in motion picture theatres.

Leaders are normally divided into three sections:

- a protective section of blank film,
- an identification section,
- a synchronizing section.

Only the last two sections are represented in Fig. 1 (Universal film leader) of this Report and some details concerning the design are given below.

2.1 *Identification section*

The identification section will begin at frame No. 307 (marked HEAD) and will finish at frame No. 241. It will carry information in accordance with the provisions of Recommendation 265, § 3.9.

Frames Nos. 288 and 264 are allocated count numbers 12 and 11, respectively, and although they fall within the identification section, they are an extrapolation of the synchronizing section for use in certain dubbing operations where a very long run-up time is necessary.

2.2 *Synchronizing section*

2.2.1 *Projection speed*

The distances between the principal marker frames (Nos. 48, 72, 96, etc.) are 24 frames, conforming to normal cinema leader practice. Thus the "blinks" caused by the projection of the lower-density image in the marker frames will occur at intervals of one second, once the projector has run up to speed.

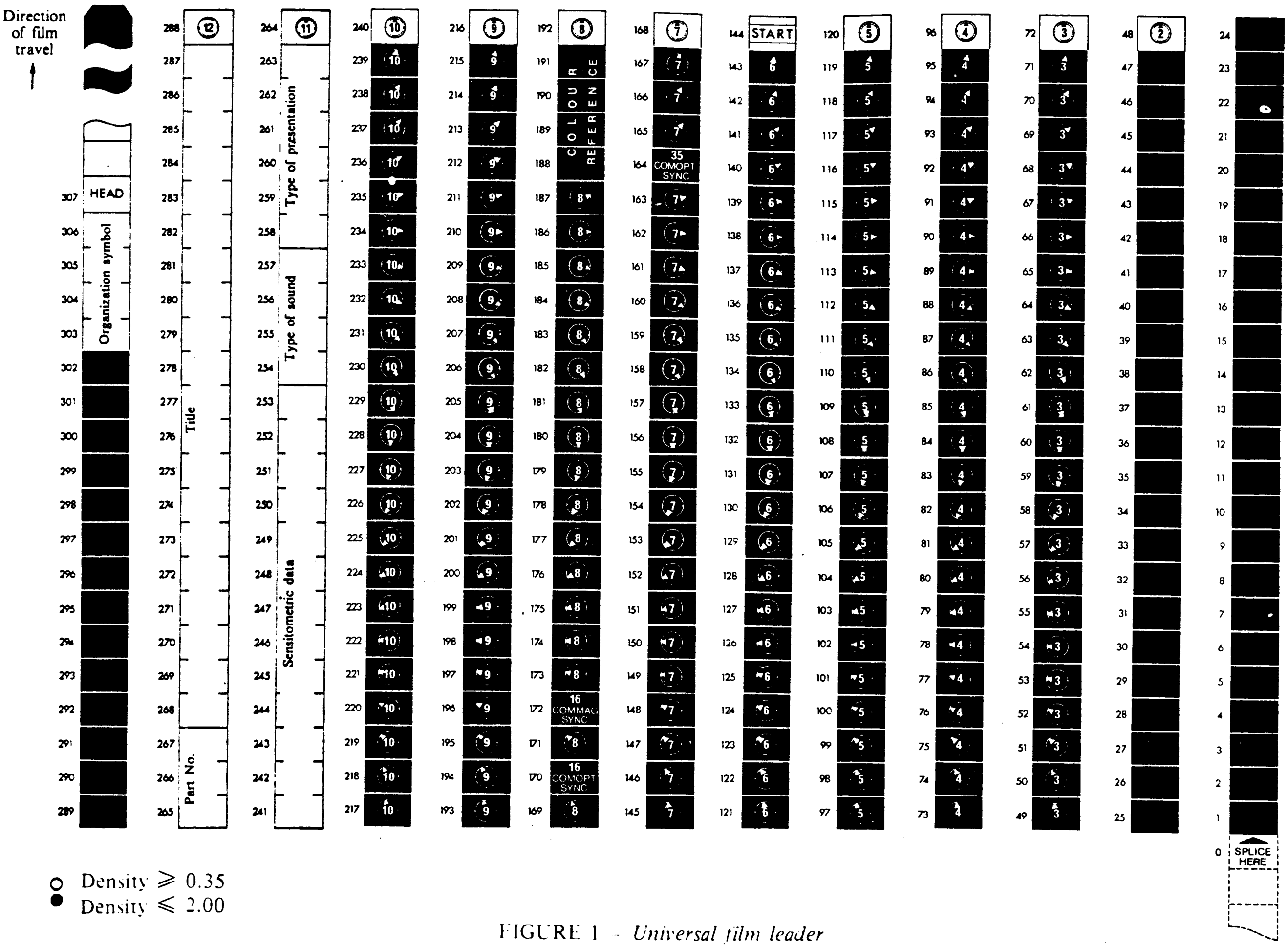

FIGURE 1 - *Universal film leader*

For part of the passage of the synchronizing section through the projector or telecine, the speed of the machine will be increasing from zero to the normal 24 or 25 frames per second and even when stability is reached, the importance of precise one-second measurements is not, as a rule, of great operational significance since the cue to start the machine must be made with a prior knowledge of its run-up characteristics.

For this reason, it is suggested that there is no substantial value in having leaders which are equally suitable for both 24 frames per second and 25 frames per second. The majority of systems function at 24 frames per second and, therefore, the leader should be based on this rate.

2.2.2 *Frame-by-frame details of the synchronizing section*

Frame 240 — The synchronizing section starts at frame 240 with the count number 10 surrounded by two circles with markings for every 15°. The number and the "clock" are in black-on-white, but the minimum density is controlled to prevent overload of telecines. A triangular black pointer marks 0°.

Frames 239 to 217 — Count number 10 is in white-on-black. The rate of 24 frames/s is indicated by a white pointer rotating around a centrepoint 15° for every frame.

Frame 216	Count number 9. Otherwise as for frame 240.
Frames 215 to 193	Count number 9. Otherwise as for frames 239 to 217.
Frame 192	Count number 8. Otherwise as for frame 240. This frame corresponds to START of the Academy Head Leader or PICTURE START of the SMPTE Universal leader.
Frames 191 to 188	Four black frames marked COLOUR REFERENCE (printed lengthwise with the film) and intended to be replaced by four frames of colour reference picture in the leader of all master material.
Frames 187 to 173	Count number 8. Pointer indications from 75° to 285°.
Frame 172	Indicator for position of sound reproducer for 16-mm film with magnetic stripe, 16 COMMAG SYNC, printed in white letters. (Correctly spaced with respect to frame 144.)
Frame 171	Count number 8. Pointer indication 315°.
Frame 170	Indicator for position of sound reproducer for 16-mm film with an optical track, 16 COMOPT SYNC (correctly spaced with respect to frame 144).
Frame 169	Count number 8. Pointer indication 345°.
Frame 168	Count number 7. Otherwise as for frame 240.
Frames 167 to 165	Count number 7. Pointer indications from 15° to 45°.
Frame 164	Indicator for position of sound reproducer for 35-mm film with an optical track: 35 COMOPT SYNC (correctly spaced with respect to frame 144).
Frames 163 to 145	Count number 7. Pointer indications from 75° to 345°.
Frame 144	START. The reference image for synchronization of all sound tracks.
Frames 143 to 121	Count number 6. Pointer indications from 15° to 345°.
Frame 120	Count number 5. Otherwise as for frame 240.
Frames 119 to 97	Count number 5. Pointer indications from 15° to 345°.
Frame 96	Count number 4. Otherwise as for frame 240.
Frames 95 to 73	Count number 4. Pointer indications from 15° to 345°.
Frame 72	Count number 3. Otherwise as for frame 240.
Frames 71 to 49	Count number 3. Pointer indications from 15° to 345°.
Frame 48	Count number 2. Otherwise as for frame 240.
Frames 47 to 1	Black.
Frame 0	White with black text "SPLICE HERE" with a pointer which marks the junction between leader and programme, namely, between frames 1 and 0.

2.2.3 *Technical design*

2.2.3.1 The following approximate densities are suggested:

white or low density $\geqslant$ 0.35
black or high density $\leqslant$ 2.00

2.2.3.2 The backgrounds shall be of 4 × 3 format with a white frame line between the frames.

2.2.3.3 The START-mark and the count numbers are confined to half picture-height to allow legibility when set up as a still frame in a flying-spot telecine.

2.2.4 *Separate sound recording*

In the case of the SEPMAG system, the sound film should have a very small perforation (approximately 1 mm square) at the point in the sound recording corresponding to the START reference point on the leader. So that the user may locate this point easily, a piece of adhesive tape may be attached to the sound film in advance.

Another method for ensuring that the picture and sound coincide at the start is to use the leader described above for the sound film.

DRAFT
REPORT XH/11

INTERNATIONAL EXCHANGE OF PROGRAMMES PRODUCED ELECTRONICALLY BY MEANS OF HIGH-DEFINITION TELEVISION

(Question 18/11)

1. Introduction

This Report concerns the international exchange of HDTV programmes on film and tape.

Such exchanges consist of the delivery of programmes available in HDTV to broadcasters who wish to use them for emission in HDTV or for emission in conventional television systems.

2. International exchanges

When the HDTV programmes are produced electronically and the broadcasters wish to use them for HDTV emission, the delivery could conceivably be effected:

- by means of a video representation such as a tape copy of the edited master videotape in HDTV followed by any required standards conversion, or,
- by means of 35 mm cinematographic film (24 or 25 frames/sec) transferred from the edited master videotape.

When the HDTV programmes are produced electronically and the broadcasters wish to use them for conventional television emission, the delivery could conceivably be effected:

- by means of a video representation such as a tape copy of the edited master videotape in HDTV made after the required standards conversion, or,
- by means of 35 mm cinematographic film (24 or 25 frames/sec) transferred from the edited HDTV master videotape.

For electronically produced programmes, tape distribution can be expected to provide better picture quality by avoiding the double transfer of the electronic source to and from film.

Reference can be made to CCIR Report AQ/11 for a description of two systems currently available to transfer HDTV programmes onto 35 mm film.

From the viewpoint of movement portrayal, the use of 35 mm film transfers at 24 or 25 frames/s for exchange of electronically generated HDTV programmes between broadcasters would cause a significant loss of temporal information on all programmes, even those that were shot with that constraint in mind. The result would be that programmes with fast movement, such as sports, could exhibit an annoying judder if exchanged by means of film transfers. By contrast, the use of tape recordings for programme exchange would not cause additional impairments to movement portrayal.

High definition television interchanged on videotape can provide excellent resolution of picture details. If the programme exchange does not require standard conversion, then a tape copy will deliver all the original picture resolution to the receiving organization. Even if standards conversion is required, spatial filtering in the conversion process will be optimized to deliver to the output the highest possible resolution compatible with the output television system.

By contrast, if 35 mm film is used as the exchange medium, the double passage from the electronic to the optical domain (in the film recorder) and back (in the telecine) is certainly bound to affect picture resolution to a certain degree.

Tape must be preferred to film as the exchange medium in this respect.

Similar considerations may apply, to a lesser degree of importance, when consideration is given to colour fidelity and gray scale linearity.

3. Conclusions

For international exchange of HDTV-produced programmes between broadcasters, technical considerations suggest that clear preference should be given to an all-electronic process, i.e. to the exchange of videotape copies of the HDTV edited master videotape, with or without standards conversion, as the circumstances may dictate (see draft new Recommendation XD/11).

An electronic solution remains the only possible one when live international exchange is required.

4. Future considerations

It has been demonstrated that the origination of major productions electronically produced in HDTV is suitable for application in cinemas using electronic displays.

Those programmes can also be distributed to conventional film cinemas using 35 mm prints obtained by transfer of HDTV video tape masters to film.

A study on the applications of these technologies will be appropriate; cooperation with other international bodies on this matter is desirable.

DRAFT
REPORT XJ/11*

SCANNED AREA OF 35 MM MOTION PICTURE FILM IN HDTV TELECINES

(Question 41/11, Study Programme 41A/11)

1. Introduction

The transfer of HDTV images to 35 mm motion picture film is considered in draft new Recommendation XC/11 which is based on ISO Standard 2906. The dimensions of the film area to be scanned are currently the subject of study due to the need to scan a variety of film formats and to take account of the special needs of television, such as motion compensation.

2. Proposal

In [CCIR 1986-90a], the EBU suggests that the scanned area in the telecine should be as shown in Table I, but notes also the need for all 35 mm film images to be scanned, even though they may be larger than those specified in the relevant standard. In practice this means that the telecine must be capable of scanning the full width of the film between the sprocket holes and a height equivalent to four sprocket hole pitches.

Document [1986-90b] gives further information on this matter.

TABLE I

	Width (mm)	Height (mm)
Scanned Image (normal)	21.11	11.87
Scanned Image (maximum)*	24.9	19.00

* This image does not result in an aspect ratio of 16:9.

REFERENCES

CCIR Documents

[1986-90]: **a.** IWP 10-11/4-149 (EBU); **b.** IWP 10-11/4-126 (CBS).

* This Report should be brought to the attention of the ISO.

DRAFT

REPORT AQ/11

RECORDING OF HIGH-DEFINITION TELEVISION PROGRAMMES ON CINEMATOGRAPHIC FILM

(Question 18/11, Study Programme 18T/11)

1. Introduction

The use of HDTV to produce films for the international exchange of television programmes and for other uses, such as direct projection in the cinema, is of increasing importance. The intrinsic high quality of the HDTV image, and the accompanying sound, allows film recordings of high quality for programme exchange. The development of the methods to perform this transfer with a low level of impairment is advancing rapidly. This equipment must include both image processing, to adapt the video signal to the film emulsion characteristics, and transformation from the HDTV scanning parameters to those of conventional 35 mm film. In particular, frame rate converters may be necessary, which require sophisticated processing. The equipment must also include high quality sound recording capability.

Two methods have been identified that offer the desired levels of image quality:

Laser beam recording

The colour film stock (positive or negative) is exposed directly by three modulated laser beams (corresponding to R,G,B) scanning the film frame. This method can operate in real-time and provides a resolution limited principally by the size of the focussed laser beams.

Electron beam recording

The HDTV image is separated into the three components (R,G,B) and a separate monochrome inter-negative film is made for each component by direct exposure to a modulated and scanned electron beam in a vacuum chamber. The deflection and modulation of the electron-beam is very similar to that occurring in a CRT. Subsequently, the processed inter-negative films are synchronized and printed through appropriate colour filters onto a colour film-stock in a conventional optical printer of high stability. The process is confined to non-real-time applications, generally operating in conjunction with an incremental HDTV reproducer and a frame memory.

In all such processes, high quality images can only be achieved by careful matching of the processed video to the colour and gamma characteristics of the colour film stock.

Note. - Report 469 concerns the recording of 525/625 television on cinematographic film.

Note from the Director, CCIR: This Report was not revised during the Extraordinary Meeting of Study Group 11.

2. Laser beam recording

[CCIR, 1986-90a] describes a 35 mm film recording system for high-definition television which has been developed in Japan using three laser beams of red, green and blue. Since substantially high outputs can easily be obtained with sharp beams from these lasers, films of fine grain, yet low sensitivity, can be used as recording media for real-time write-in. Thus high-resolution pictures can be obtained on colour films with low granular noise and high colour saturation. To obtain high-quality in moving areas of the image, the equipment uses motion-adaptive scan conversion techniques.

Colour films for the recording can be selected from various types such as negative, inter-negative, intermediate or positive (print film), and the loss of quality in an optical printing process can thereby be minimized.

The sound is also recorded by using a laser beam with a recording system of variable-area type. The equipment has been developed for this purpose. This system, as in the case of video recordings, utilizes the high intensity of laser which enable the use of low sensitivity high resolution film. The colour print film can be used as well as the ordinary 35 mm sound negative film, and an excellent sound quality can be obtained with good frequency response and good signal-to-noise ratio. This recording system, combined with a noise reduction system, provides suitable high quality sounds, well matched to the picture of HDTV.

3. Electron beam recording

[CCIR,1986-90b] describes an electron-beam recording (EBR) for transfer of high-definition television pictures onto 35 mm cinematographic film which has been developed in Japan. In this method, the electron beam stimulates the emulsion of the film directly. No optical system is needed. The depth of focus of the electron beam is large enough to allow the film plane to drift for as much as 3 mm without affecting focus. In addition, as the electron beam does not penetrate into the film base, there is no problem of halation. The electron beam is easily deflected electromagnetically to form a raster, thus a sharp and precise latent image is made on the film, although the recording must be performed in a vacuum. In order to make a sound track of better quality, electron beam recording for the sound tracks has also been developed. Electron beam recording improves transient characteristics and gives an overall distortion of less than 1% at 1 kHz, and frequency characteristics of -3 dB at 25 kHz.

Another advantage of EBR for sound is that a fine grain low sensitivity film such as Fuji 71337 can be used which improves the S/N ratio. Since the electron beam does not penetrate into the film base, there is no need to use the gray base to eliminate halation.

REFERENCES

CCIR Documents

[1986-1990]: a. 11/147 (Japan); b. 11/148 (Japan).

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DRAFT
REPORT XK/11

THE RELEASE OF PROGRAMMES IN A MULTIMEDIA ENVIRONMENT

(Study Programme 18D/11)

1. Introduction

The development of audio-visual media has progressed in a way that makes it more necessary than ever to harmonize the standardization that takes place in the CCIR, in the IEC, and in the ISO respectively.

The increasing integration of film and electronic methods in the production of programmes for both broadcasting and cinema release must be considered in the distribution of the work. Account must therefore be taken of the important work of the ISO regarding standards for the production and distribution of programmes on film.

The terms of cooperation among the CCIR, the ISO and the IEC are covered in Opinion 16.

2. The multimedia environment

It is recognized that the IEC has a wide field of action, extending well outside the broadcast equipment field, whilst the CCIR deals with broadcast systems only. Harmonization of efforts is needed in the common area of these fields of action, i.e., where the produced audio-visual message is transmitted and received.

The message itself may take several forms; it may be a television programme (entertainment, education, news, etc.), a recorded audio document, a teletext page, a movie, a computer output, etc.

The production of the message may use a variety of means and methods: normal television, high definition television, high quality audio recording, film, etc.

The fruition of the message may also happen in a variety of ways; on the home television display, by collective television or cinema displays, on computer displays and print-outs, etc.

The production installation can be seen as a production and postproduction facility that generates programmes for diversified outlets, e.g. in the case of television, terrestrial or satellite broadcasting, videodisc or video-cassette distribution facilities, cable systems, movie-theatre chains, etc.

The end-user installation may be seen, in the case of television, as a display (home or collective or professional), which is fed by a variety of consumer devices, e.g. terrestrial broadcasting tuner, satellite tuner, teletext decoder, video-cassette player, videodisc player, cable terminal, computer interface, etc.

In the case of an audio message, the same concepts apply; the end-user installation takes the form of audio amplifiers and loudspeaker units or headphones fed from a variety of consumer devices, e.g. terrestrial or satellite broadcast tuner, wire distribution tuner, cassette player, disc or CD player, etc.

Furthermore, an audio user installation may also represent the audio part of a television user installation and receive signals from some of the television devices exemplified above.

In addition, both the video and the audio installation may output programme signals to some peripheral equipment, such as a cassette recorder and there may also be cross ties, e.g. in the case of an audio user installation that receives a radiodata signal, decodes it and outputs the information in image form on the television display.

There is a need to ensure technical harmonization between message generation and message fruition from several viewpoints.

Specifically, the following aspects can be highlighted:

1. Production quality commensurate to the highest service intended

It is important that the sound and picture quality at generation be commensurate to the quality requirements of the most quality-demanding service among those for which the production is intended, if the production is generated for multimedia distribution. For instance, the picture quality capability for electronic distribution of movies to cinemas is obviously much greater than that required for normal television broadcasting to the home.

This aspect is of interest to broadcasters, since they often generate productions for multimedia distribution. It is also of interest to broadcasters when they broadcast productions generated elsewhere, since it is their role to define and protect the picture and sound quality of the broadcast service they operate.

2. Harmonized quality capability throughout a service chain

For any given service it is important that the sound and picture quality capability of the various elements in the total chain from production to fruition, be commensurate to the intended service. This quality requirement for sound and picture particularly applies to the recording process (and to the digital recording process) inserted in the chain; it applies as well to the quality capability of the picture display or listening unit used.

3. Harmonized standards and operating practices between broadcast and non-broadcast audio-visual applications

It would, of course, be highly desirable that harmonized technical standards and operating practices be applied, where appropriate, in consumer equipment intended for broadcast applications and for non-broadcast applications. This would ease the interconnection of the components of a unified consumer audio and video presentation system.

It would also be highly beneficial that harmonized technical standards and operating practices be applied, where possible and appropriate, in programme production facilities operated by broadcasters and in consumer equipment.

DRAFT
REPORT XL/11

HDTV RECORDING/REPRODUCTION EQUIPMENT FOR CONSUMER AND INDUSTRIAL USES

(Study Programme 18U/11)

1. Introduction

HDTV recording for professional broadcast use is described in Report XG/11.

For the semi-professional and consumer markets, the following progress has been reported to the CCIR.

2. HDTV video casette recorders

At the 130th SMPTE Technical Conference in October 1988 in New York, NHK (Japan Broadcasting Corporation) presented a paper about the first cassette type HDTV-VTR for industrial applications. Details are available in the literature [Shibaya et al., 1988].

A summary of the specification is listed in Table I:

A video cassette recorder from the Netherlands using a VHS transport was demonstrated in 1988 for the recording/replaying of an HD-MAC signal [Weissensteiner, 1988]. It achieved a bandwidth of about 12 MHz and an unweighted video signal-to-noise ratio of 42 dB by using four heads, two frequency-modulated recording channels and digital video and audio processing. A residual video timing error of < 15 ns was reported. It was able to record 80 min of HD-MAC (or MAC) signal on 1/2-inch metal particle tape. The processing included drop-out compensation. Options gave the facility of recording/replaying PAL, SECAM or NTSC signals.

3. HDTV disk systems

Various disk systems for moving and still pictures have been developed to serve as HDTV package media. The video disk offers a number of advantages over the VTR, in such capabilities as quick access and trick reproduction. A disadvantage of them has been a difficulty in user-recording. However, recently developed experimental disks can be used for the user-recording either once or repeatedly depending on the type of disk. At present, for the usage of playback only, the optical type is the major one, but others such as magneto-optic and electrostatic capacitance type have also been developed.

The development of the disk systems, both for moving and still pictures, has now reached a point where models for practical applications are being produced and some are now used in actual operations.

In step with the development of better disk materials, the introduction of a series of experimental systems is expected that can be used not only for reproducing but also for recording pictures with motion. Moreover, a semiconductor laser which can shorten the wavelength to half of that generated by conventional semiconductor lasers has also been developed. With these developments, further improvement will be made to increase the recording capacity and reproduction time of optical disks.

Table II shows characteristics of the major disk systems for moving pictures developed in Japan.

Table III shows characteristics of the major still picture disk systems developed in Japan.

In the Netherlands a video disc player was developed and demonstrated in 1988. It is based on existing optical laser and disk techniques [Horstman, 1988]. Its bandwidth was about 12 MHz with an unweighted signal-to-noise ratio of 32 dB and a residual timing error of < 7 ns. The playing time was 25 min per side of a 30 cm diameter disk.

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HORSTMAN, R.A. [1988] Videodisc and player for HD-MAC. IEE Conf. Publ. No. 293, 224-227. International Broadcasting Convention (IBC 88), Brighton, England.

SHIBAYA, H. et al. [October, 1988] An industrial application hi-vision VTR using the new 1/2-inch video cassette. 130th SMPTE Technical Conference.

WEISSENSTEINER, W. [1988] Concept of a consumer-type HD-MAC VCR. IEE Conf. Publl. No. 293, 228-230. International Broadcasting Convention (IBC 88), Brighton, England.

TABLE I

Characteristics of video cassette recorders

magnetic tape	1/2 inch, metal powder tape
cassette	new model, dimensions 121(W) x 205(L) x 25(H)mm
television standard	1125 lines, 60 fields/s
reproduced video modulation luminance bandwidth luminance S/N chrominance bandwidth chrominance S/N	 FM 20 MHz better than 41 dB 7 MHz better than 45 dB
reproduced audio modulation number of channels sampling frequency quantizing	 PCM 4 48 kHz 16 bits linear
recording time	63 mins

TABLE II

Characteristics of moving picture disks

Type		Optical				Electro-static capacitance
Pickup (Wavelength)		Semiconductor laser (780 nm)			(656 nm)	Capacitive pickup
Disk size		300 mm				260 mm
Recording time	CAV	14 min.	15 min.	-	-	40 min.
	CLV	30 min.	30 min.	20 min.	45 min.	-
Video signal		MUSE	MUSE	MUSE	MUSE	MUSE
Audio signal	No. of channels	2/4/6	2	-	-	2
	Modulation	TDM (3 levels)	TDM (4 levels)	-	TDM (3 levels)	RF-FM

TABLE III

Characteristics of still picture disks

Type		Optical	
Function		Playback only	Playback only
Disk size		300 mm	120 mm
Video signal		MUSE	MUSE
No. of frames		54,000 (CLV) 34,000 (CAV)	640
No. of picture elements or bytes per frame		-	540 Mbytes
Audio signal	No. of channels	4	2
	Sampling frequency and bits/sample	32 or 48 kHz/ 8 or 11 bits	32 kHz/ 8 bits

SECTION 11ExC - INFORMATION ON RESOLUTION COM5/3 (WARC ORB-88) RELEVANT TO THE PLENIPOTENTIARY CONFERENCE, NICE, 1989

Resolution COM5/3 of WARC ORB-88 recommended that the Plenipotentiary Conference, Nice, 1989, when establishing the post-1989 programme of conferences and meetings, should include provision for a world administrative radio conference competent to deal, inter alia, with matters relating to HDTV, which should be held sufficiently early to take due account of any period that may be needed to re-accommodate or adjust other services if necessary. The Sixth World Conference of Broadcasting Unions in its Washington meeting (March 1989), supported the need for such a conference.

The Resolution also invited the CCIR to undertake further studies of feeder links and down-links necessitated by this Resolution and to submit its report not later than one year before the WARC mentioned above. These studies are to include the following:

1. system parameters for HDTV transmissions by satellite, with emphasis on the effect of the choice of frequency,

2. propagation characteristics,

3. inter- and intra-service sharing and interference, interregional sharing.

The following paragraphs outline the status of studies on satellite HDTV emission to date. Also included is an estimate of the time by which further studies are expected to be completed.

The CCIR has been studying the subject of satellite HDTV emission for several years. It has concluded that it is technically feasible and that several techniques exist for the broadcasting by satellite of HDTV over a range of frequencies up to about 23 GHz. These techniques include bandwidth reduction, channel coding, multiplexing, modulation and reception. The technology for implementation of these techniques is available now, and technology for the implementation of satellite systems is either available now (as is the case for the 12 GHz band) or is expected to be available within the next ten years for the higher frequencies.

The CCIR is studying the suitability of the 11.7 - 12.7 GHz band for HDTV-BSS within the framework of the existing plans. Current highly band-compressed techniques would permit a limited amount of HDTV satellite broadcasting within the confines of the existing plans for the three ITU regions.

Therefore, for satellite broadcasting of wider RF-band HDTV service world-wide, potentially providing quality close to that of the studio/production standard, another frequency band will be required, and studies for all regions will be needed.

Since an operational service of wide RF/band HDTV by broadcasting satellite is likely to be introduced in some 10 to 15 years, it is desirable that a decision be made as soon as possible as to what frequency band will eventually be made available to wide RF-band HDTV BSS. A timely choice of frequency band will provide necessary planning time for future HDTV BSS operators, and provide a long enough time period for those countries which would have to re-accommodate services existing in the frequency band.

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