REPORT 1217

FUTURE DEVELOPMENT OF HDTV

(Question 27/11)

(1990)

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:

- approaches to a single world-wide HDTV studio standard;
- preliminary studies;
- 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 essentially defined in digital terms, with any required analogue definitions derived from the digital ones. The routes proposed 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.

Examples of this concept are found in discussions of the common image format and common data rate approaches below.

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.

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.

d) The concept of a convergent approach

This scenario relies on the adoption of common spatial characteristics of the active picture area for applications using current picture rates initially with ultimate convergence on a single picture rate in the course of time.

2.2 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 as routes towards a single world-wide standard.

[CCIR, 1986-90a] 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;
- the adoption of standards based on the "common image format" approach leading to the future adoption of a single standard;
- the adoption of standards based on the "common data rate" approach leading to the future adoption of a single standard.

Contributions have been received from a number of administrations further developing these concepts and the following explanations have been proposed to characterize and to distinguish between the "common image format" and "common data rate" concepts:

Common Image Format
The common image format (CIF) concept implies a commonality of spatial characteristics for the active picture area between implementations or applications with differing picture rates. These common characteristics include the picture aspect ratio, the number of samples per active line and the number of active lines, as exemplified in current proposals for HDTV. Other system characteristics may also be common whilst sampling frequency and data-rate may vary according to the picture rate.

Common Data-Rate
The common data-rate (CDR) concept implies a commonality of sampling frequency and data-rate (total and active) between implementations with differing picture rates. The picture aspect ratio and the number of samples per active line are also common, as exemplified in current proposals for HDTV. Other system characteristics may also be common whilst the number of active lines may vary according to the picture rate.
Proposals have also been made combining the features of a common image format approach with a common total data-rate.

Also the following definitions [CCIR, 1986-90b] are intended only for use in clarifying CCIR texts concerning HDTV.

A Sample, is the value of an image at a defined point in horizontal, vertical and temporal space.

A square sample distribution results when the sampling points are equispaced on an orthogonal horizontal-vertical lattice on a time-discrete image plane, assumed to be vertical for the purpose of this definition.

Pixel is the abbreviation of "picture element". It is the smallest area of the optical image that can be faithfully reproduced.

A square pixel has equal size in the horizontal and vertical directions.

With respect to the resolution actually achievable, the relation between samples and pixels is not necessarily identical in either or both the horizontal and vertical directions

2.2.1 A unique standard

All administrations have stated their preference for a single world-wide studio standard for HDTV. In [CCIR, 1986-90c] are summarized the essential reasons for the need for a world-wide unique studio standard for high definition television.

In [CCIR, 1986-90d] 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.

Based on analysis [CCIR, 1986-90e] and the information contained in Part 5 of Report 801-3 the United States concluded that a single world standard should be based on 1125/60 [CCIR, 1986-90f]. The United States now believes [CCIR, 1986-90g] 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.

In Document [CCIR, 1986-90h] the United States reaffirms its support for the adoption of a single world-wide HDTV standard for the studio and for international programme exchange as a very important CCIR goal.

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, 1986-90i].

Document [CCIR, 1986-90j] states that these European Administrations report that the administrations of the European Community fully supports the goal of a unique studio standard and considers that the 1250/50/1:1 system best meets this target. However, following agreement within the CCIR to study a two-step approach based on either a common image format or a common data rate, studies have been carried out into the relative merits of the two approaches and the results are analysed in the document.

Documents [CCIR, 1986-90k and l] argue that an HDTV standard that meets the needs expressed in CCIR documentation can most efficiently be implemented in the long-term with an image format of 1920 samples per line by 1080 active lines and a common frame rate.

2.2.2 A common image format approach

This approach, described by some administrations as a "unified" approach to a single standard is based on the fact that the development of a single standard is presently constrained by the desire for compatibility with the frame rates of existing television systems but that such constraint will likely be removed, in time, by developments in technology leading to the setting of a standard based on a higher frame rate for better motion rendition and easier conversion to all current frame rates. Initial studies [CCIR, 1986-90m] have indicated that frame rates higher than the ones presently in use will be needed in HDTV production if unimpaired motion portrayal is required. The common image format approach leads, in the interim, to a partial standard including only parameters for which single values are adopted on a world-wide basis. Adoption of common values for the basic parameters should lead to convergence towards a single world standard and avoid re-opening discussion on already agreed parameters during the later steps of the process. The partial standard

will allow different system implementations meeting the common agreed parameters and harmonized with the current television systems. The larger the number of parameters adopted at the beginning, the better it is to maximize homogeneity between the different system implementations, and the easier it will be to convert programmes produced through interim system implementations to the ultimate single standard.

In order to secure the convergence process toward a single standard, a number of basic parameters need to be identified for which single values have to be agreed upon early in the process. The multi-step"unified"approach is based on the concept of "common image format" to define the first step by allowing early agreement on image parameters leaving the frame rate, the scanning method and the related parameters for later discussions and agreement.

The concept of the Common Image Format is based on a broad view of image reproduction techniques including aspects from the fields of television, film, computer display and publishing. It consists of using common values for the parameters defining the active picture area in different HDTV system implementations. An image is a bounded, two-dimensional representation of a three-dimensional space which is defined by its spatial characteristics and its luminance and colour transfer functions. The image format is the specification of a virtual image defining the active picture area of the television frame. Figure 1 gives a pictorial representation of the concept of a common image format along with a possible set of parameter values.

The concept of a common image format applied in the context of the "unified" approach to a single HDTV standard implies a world-wide agreement on the following basic parameters of the active image area:

- aspect ratio of the image;
- aspect ratio of the picture element (pixel);
- number of samples in the horizontal direction;
- number of samples in the vertical direction (i.e. number of lines);
- sample arrangement;
- colorimetry - reference primaries, reference white;
- opto-electronic transfer characteristic at the camera; and
- electro-optic transfer characteristic at the display.

These correspond to the parameters in sections 1, 2 and 4 of the table in Recommendation 709. The definition of the common image format is exclusively confined to the samples and spatial domains of the active picture area and relates to its digital representation. The way this image is scanned for transmission, its repetition rate to reproduce motion, and its rendering on a physical display include temporal and subjective aspects that are beyond the definition of the image format. The concept leaves complete freedom as to the choice of scanning method, the frame rate and the size of the blanking intervals needed for synchronization and other purposes in the implementation of different HDTV distribution systems formats (see Fig.2) [CCIR, 1986-901].

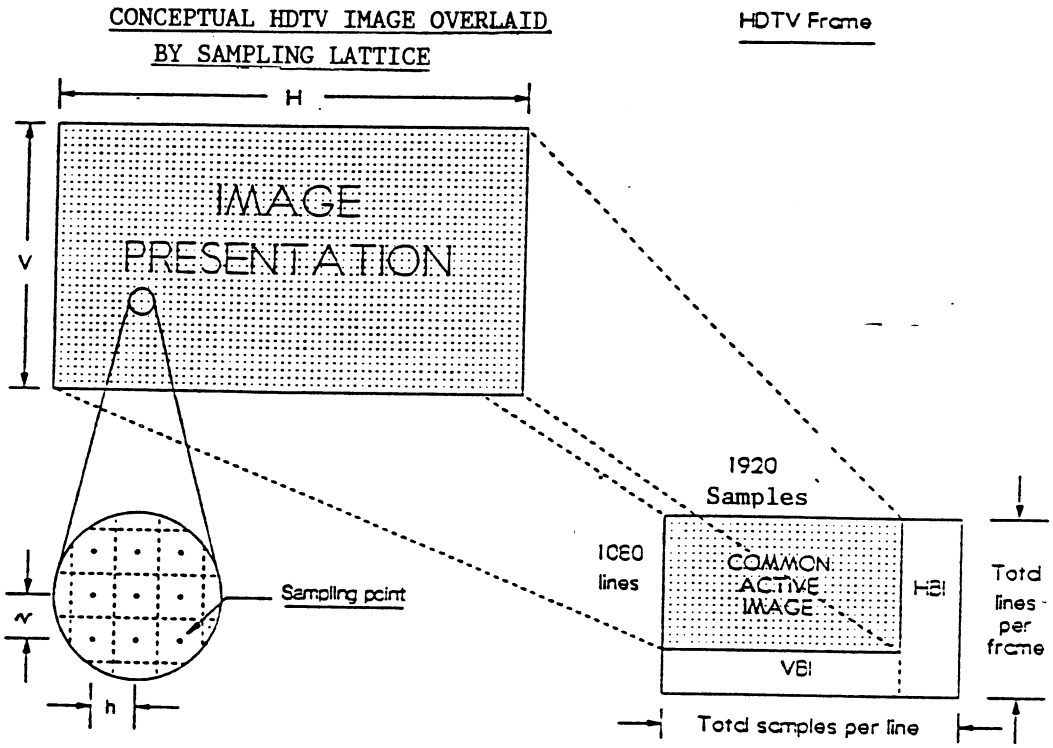
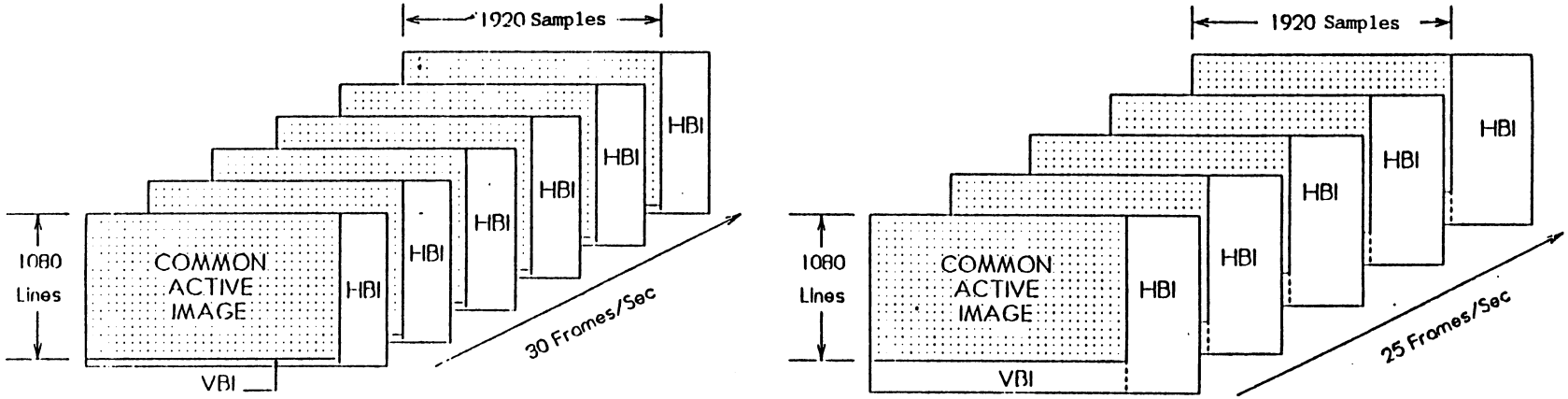


FIGURE 1

Common image format using a possible set of parameters



HBI: Horizontal blanking interval
VBI: Vertical blanking interval

FIGURE 2

Implementations of common image format at 30 and 25 frames per second using a possible set of parameters

[CCIR, 1986-90n] 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 aspect ratio 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 aspect ratio are interrelated by the formula:

$$\frac{\text{active horizontal pixels}}{\text{active vertical pixels}} = \frac{\text{aspect ratio}^*}{\text{pixel aspect ratio}^*}$$

[CCIR, 1986-90o] points to advantages for electronic image processing and for a wide variety of non-broadcast applications.

[CCIR, 1986-90p] claims 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". 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 can be seen as 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, 1986-90o].

[CCIR, 1986-90q] outlines two examples of common image format systems. The first uses 1152 active lines and 1200 total lines, and both interlaced 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.

In [CCIR, 1986-90g] the United States expressed 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. The United States has continued its studies [CCIR, 1986-90h] of the concept of common image format and common data rate and has concluded that the common image format, as an interim step, is the approach which is most likely to lead to the future single world-wide HDTV standard for the studio and for international programme exchange. The United States supports the common image format approach and could support the concept of common data rate if the principle of common image format is fully incorporated within it.

The ABU points out [CCIR, 1986-90r] that "all possible efforts should be made for the development of all parameter values which remain undefined in Recommendation 709 in the conclusions of the Extraordinary Meeting of Study Group 11. Should such objective not be achievable within the current study period, the ABU will support in this period the adoption of a common image format with 1920 x 1080 for the studio standard as a unified CCIR Recommendation, provided that there is a common agreement within the CCIR".

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* Picture and pixel aspect ratio are defined by width : height.

[CCIR, 1986-90s] 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.

It is shown in [CCIR, 1986-90t] 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.

2.2.3 A common data rate approach

In the first step of this approach, it is assumed that 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.

Central to any approach which commences with more than one picture rate is the need for high quality conversion as a gateway between the different HDTV standards during the first phase. Document [CCIR, 1986-90u] reports confidence in the likely availability of high quality converters demonstrating the viability of a common data rate approach as the first step towards a single HDTV standard.

In addition, Document [CCIR, 1986-90v] suggests that the advantages to manufacturers of having a single product which can be sold world-wide are significant, as are the advantages to the broadcaster who may at times wish to use his equipment on the alternative standard. The manufacturers' advantages of commonality can be easily eroded if significant changes need to occur within such equipments when switching between standards. Commonality advantages to the broadcaster can also diminish if changing standard means also changing an equipment's operating environment, perhaps because of different interfacing requirements. In this regard it is instructive to examine the commonalities which were considered important in the choice of parameters for Recommendation 601. Of great consequence however for HDTV sampling specification is also the ease of conversion to and from the parameters of Recommendation 601 itself. A simple relationship in terms of picture rate and line number between HDTV and current scanning standards is fundamental to the concept of practical compatible emission. This issue is being addressed in both 625- and 525-line countries.

Similarly there is a real practical need for the inclusion of picture material originated at 525/59.94 and 625/50 into HDTV productions and vice versa; Document [CCIR, 1986-90w] concludes that a similar simple relationship between each HDTV system and its respective present definition television system, as provided by CDR, should make these conversions more straightforward.

As a first step, the common data rate approach therefore chooses to retain, between two 16:9 ratio HDTV standards, the same features in common as the Recommendation 601 pair and a simple conversion to and from the respective member of the Recommendation 601 pair.

Figure 3 shows the concept of the HDTV future delivery environment in step 1. All items of studio equipment are switchable between 59.94 and 50 Hz field rates. The 59.94 and 50 Hz studios exchange programme material through a high quality HDTV-HDTV standards converter. For HDTV distribution in the local environment no field-rate or line-rate conversion is required. The converters required for 525- or 625-line distribution or enhanced 525- or 625-line broadcasting are relatively simple line-rate converters. Similarly the arrangements for 525- or 625-line contributions to the HDTV production centre are simple and of high quality.

Advances in digital technology should enable the second step to be taken where one of the two standards is adopted as the single production standard. For the other standard the consequence will be more complex standards conversion for distribution and enhance emission or for contributions from normal definition television standards. The timing of the second step will be determined by technology and by economic factors.

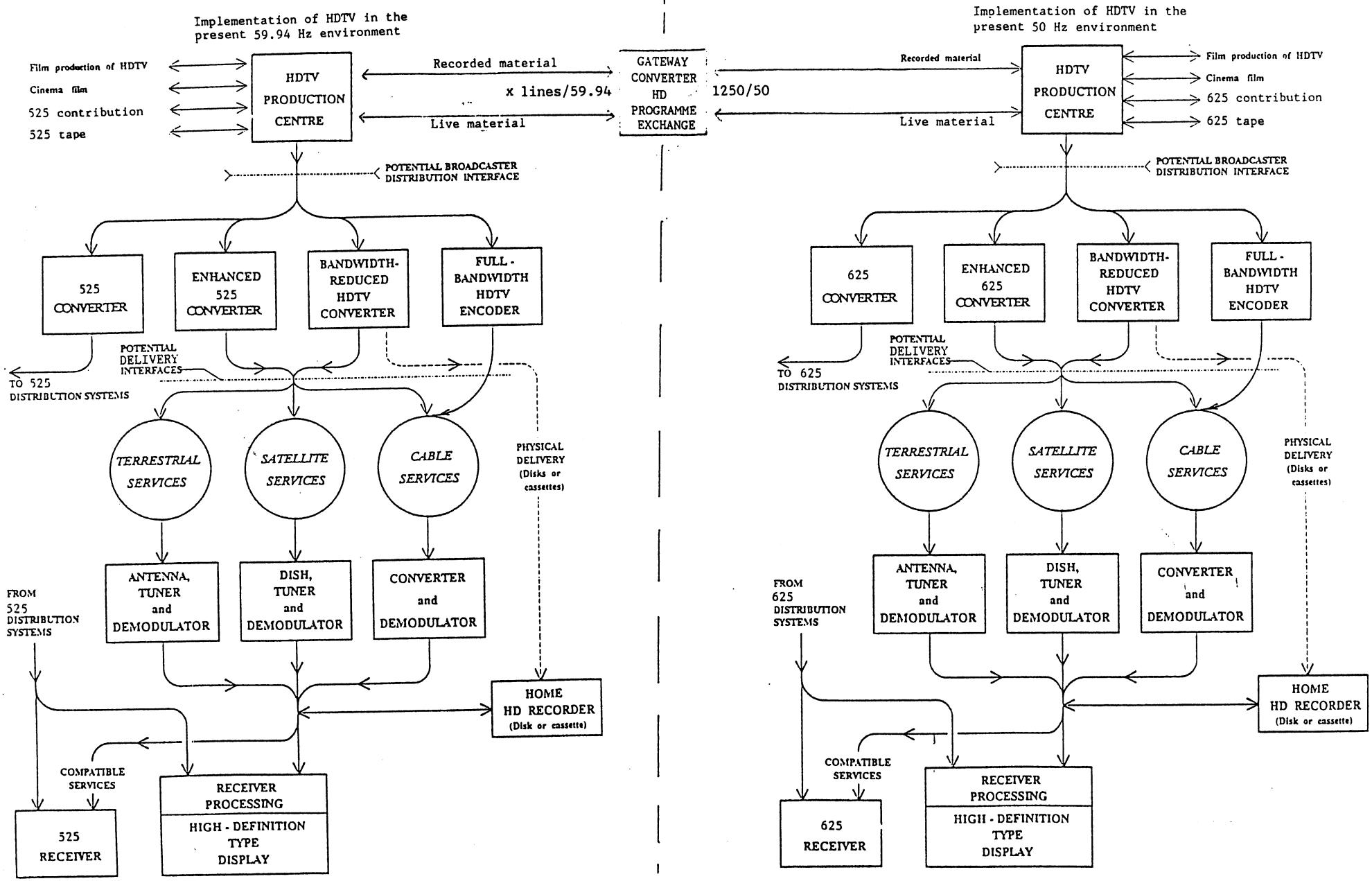

FIGURE 3

An example of the first step of the common data rate approach

In [CCIR, 1986-90x] 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, 1986-90v] 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, 1986-90q] 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, 1986-90y] 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.

[CCIR, 1986-90z] 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, 1986-90aa] gives an example of a common data rate system involving 1375/50 and 1155/59.94 partners. The number of active lines are respectively 1280 and 1080.

3. Preliminary studies

Preliminary studies of the relative merits of the common image format and common data rate approaches have not been conclusive. There are differences in the operational, technical and economic assumptions on which different administrations have based their tentative assessments. Further studies are necessary, however there is already a substantial amount of relevant documentation which is listed under the subject headings below.

3.1 Sources

CCIR 1986-90j, k, l, p, ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am.

3.2 Recording

CCIR 1986-90j, k, l, ad, ae, ah, al, an, ao, ap, aq, ar.

3.3 Displays

CCIR 1986-90j, l, ac, ah, al, am, as.

3.4 Production and post production

CCIR 1986-90j, l, ah, al, am, as.

3.5 Standards conversion

CCIR 1986-90j, k, l, u, w, z, al, am, at, au, av.

3.6 Transmission networks

CCIR 1986-90j, l, al.

3.7 Emission

CCIR 1986-90j, l, v, an, av, aw.

3.8 Other considerations

CCIR 1986-90j, k, p, v, ag, ai, aj, al, aq, ax, ay, az, ba, bb, bc.

4. Future activities to be undertaken

The CCIR considers it necessary to continue studies in the following areas:

i) the operational, technical and economic implications of the common image format and the common data rate approaches to the ultimate achievement of a single world-wide HDTV standard.

In making comparisons between both approaches, basic factors that may influence conclusions should be clearly stated. They should include:

- the assumptions made regarding the balance between equipment cost/complexity and the related operational benefits to the broadcasting or production organisations;
- the degree of commonality of components and subsystems between professional and consumer equipment;
- the strategy proposed to accommodate multiple frame rates. Studies should include both switchable and dedicated systems or equipment;
- the strategy to ensure the proposed scenarios are followed;
- the level of development maturity achieved;

ii) HDTV quality assessments and methods of measurement in the following areas:

- the subjective and objective effects of noise in HDTV pictures. Studies are to include both progressive and interlaced systems and comparisons between them;
- the quality of images after conversions between systems having different field rates;
- the quality of images after any conversion to emission systems.

iii) further compatible enhancements of the HDTV studio standard by the wider colour garment, improved luminance coding, and greater contrast ratio;

iv) temporal parameters of HDTV to achieve adequate motion portrayal, and to ease conversion to current television systems and interim HDTV implementations;

v) outstanding and additional parameters for inclusion in Recommendation 709;

vi) an analogue HDTV video tape studio recording format for programme exchange must be specified in the form of a Recommendation;

vii) similar work must also be done for a digital HDTV video tape recording format including studies on the implications of the possible use of bit rate reduction techniques;

viii) identification of appropriate locations and specifications of interfaces for different segments of the HDTV broadcast system;

ix) in consideration of the importance of multimedia release for HDTV productions, harmonization of HDTV standards; operating practices and interfaces for professional, non-broadcast and consumer applications must be pursued in cooperation with the IEC, ISO, CMTT AND CCITT;

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:

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

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

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

Additional studies are needed on terrestrial broadcast of HDTV. In particular it is necessary to study the relevant technical parameters including modulation, channel coding, spectrum utilization and protection ratios. Further, more measurements are required to determine the appropriate protection ratio between terrestrial and satellite HDTV systems.

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