

SECTION 11F: DIGITAL METHODS OF TRANSMITTING TELEVISION INFORMATION

REPORT 629-4

DIGITAL CODING OF COLOUR TELEVISION SIGNALS

(Question 25/11, Study Programmes 18L/11, 25G/11, 25L/11 and 25M/11)

(1974-1978-1982-1986-1990)

1. Introduction

Study Group 11 has brought together, during the study period 1982-1986 and previously, a large amount of information concerning the coding, processing, transmission and recording of picture signals in digital component form in the studio. This work has resulted in Recommendation 601 concerning the encoding of the digital video signal for studio production, and Recommendation 656 concerning studio interfaces for the digital video signal.

Additionally, this work has been taken into account in the Recommendation for the digital recording format (Recommendation 657) and the studies by Study Group 11 on bit-rate reduction (Report 1089) and the CMTT studies concerning the transmission of picture signals.

This Report summarizes the work on coding methods for signals within the studio complex, derived from both analogue and digital sources, and provides the basis for Recommendation 601 concerning the encoding parameters of the digital television signal in the studio. This is complimented by Report 962 which concerns the filtering, sampling, and multiplexing of digital signals.

2. Basic principles**2.1 Studio digital encoding parameters for conventional television**

Two different approaches to the coding problem have been proposed:

- *component coding*: in this approach the luminance and colour difference signal components are digitally coded separately and transmitted as separate bit streams, time-multiplexed together. When the colour television signal exists in the composite NTSC, PAL or SECAM form, it will be necessary first to separate the signal into its luminance and colour difference components;
- *composite coding*: in this method the composite colour signal is coded in its composite form as a single bit stream.

The first method has advantages over the second because, in the future, it will be possible for the signal to be transmitted in digital form, from the source to the broadcasting transmitter. Only at the broadcasting transmitter will it be necessary to generate the composite signal. Thus, at least for transmission purposes, the differences between NTSC, PAL and SECAM would disappear with a consequent simplification of the problems of the international exchange of programmes [CCIR, 1974-78a], except when different scanning standards are involved. (International programme exchange refers to the provision of the interface required for video tape recording equipment and of the interface with transmission equipment.) The second method is claimed to have advantages when, as is likely to happen during the period in which digital techniques are being introduced into broadcasting, the complete chain contains several digital and analogue sections in cascade.

Most administrations now agree that there would be considerable advantages in using component coding for studio standards. The reasons for this are as follows:

- recent technological developments, particularly in the fields of semiconductor storage and magnetic recording have opened up new and attractive possibilities in electronic picture processing and special effects. Such facilities have only been available in the past using expensive film techniques [CCIR, 1978-82a];

- component coding offers a uniform world standard, with the exception of field rate. Such a standard has the greatest number of significant parameter values common to 525-line and 625-line systems. It allows equipment and operation to have the maximum number of common features, a situation which is not achievable with analogue or composite digital standards. Except for field rate (which could be switchable), studios throughout the world would use many items of common equipment and programme production and exchange would be much simplified.

In determining the bit rate reduction method that might be used at the studio, prior to interconnection to any long-distance transmission facilities, it is important to take account of the digital hierarchies being standardized by the CCITT [CCIR, 1974-78b].

In [CCIR, 1978-82b], the EBU has proposed that, to facilitate international exchange of programmes, a signal based upon the separate coding of luminance and colour-difference signals should be used. Studies conducted by the EBU have clearly demonstrated the value of digital coding in avoiding some of the limitations associated with PAL and SECAM systems and indicate the feasibility of a universally compatible digital standard [CCIR, 1978-82c]. Considerations such as this, combined with similar proposals from other administrations, resulted in Recommendation 601 which suggests that the use of component coding is to be preferred for all studio and international exchange purposes.

2.2 Studio digital encoding parameters for HDTV

This subject has been dealt with by IWP 11/7 as required by Decision 60, and results as of May 1989 were contributed to the Extraordinary Meeting of Study Group 11 for HDTV [CCIR, 1986-90a].

The contributions discuss several approaches to a digital HDTV studio standard based on the concepts of a common image format or a common data rate.

The subject is still under consideration by IWP 11/7 and particular areas of study for which IWP 11/7 is seeking contributions are:

- digital signal characteristics
 - (a) digital signal levels
 - (b) form of coding
 - (c) dynamic range
- digital interface requirements
 - (a) parallel and serial interfaces
 - (b) synchronising words, number of bits, etc.
- digital synchronizing signals
- digital test signals
- requirements for digital image processing
 - (a) requirements for horizontal and vertical blanking
 - (b) image size change allowable through editing processes etc.

3. Coding methods

The initial processes in all digital coding methods which are under study are sampling and quantizing.

3.1 Bandwidths and sampling

The sampling process is determined by three basic factors:

- the sampling structure, i.e. the relative position of the samples in space and time;
- the number of samples per line;
- the filtering process, which may be one-, two-, or three-dimensional.

The sampling structure mentioned above may, or may not, be repetitive with respect to the picture. Likewise, the number of samples per line may, or may not, be constant from line to line.

The classical theory requires the sampling frequency to be equal to or greater than, twice the highest signal frequency, i.e. Nyquist sampling. However, studies have shown that lower sampling frequencies (i.e. sub-Nyquist sampling) can be used in practice [Messerschmid, 1969].

3.1.1 For component signals

The EBU [CCIR, 1974-78c] has suggested that those countries digitally coding the separate components should use a sampling structure repetitive from picture to picture. This approach is supported by [CCIR, 1974-78d]. Repetitive sampling structures may be either orthogonal [CCIR, 1974-78e] or interleaved.

Report 962 describes in some detail the work leading to the choice of sampling parameters listed in Recommendation 601 as the basis for a studio code and so only a brief summary is required here.

A number of sampling frequencies for the luminance signal of the 4:2:2 level were studied by administrations, in particular 12 MHz, 12.5 MHz, 13 MHz, 13.5 MHz and 14.3 MHz. The factors studied, which would have a potential bearing on the choice of sampling frequency, included basic picture quality, picture quality after processing, cost-performance relations, potential capacity of digital VTRs, bit-rate reduction to transmission hierarchy levels and compatibility with composite signals and composite coding.

During the course of their studies, some administrations saw advantages in choosing a sampling frequency related to their composite signal colour sub-carrier frequency, because this could be advantageous in a mixed use of component and composite coding nationally. However, they considered that the benefits of a world-wide unification of sampling-frequency might alter the balance of advantages in favour of the agreed value.

A luminance sampling frequency of 13.5 MHz was adopted for a world-wide standard. It is a compromise between, on the one hand, the need to choose values which allow practically realizable and economic equipment and, on the other, the need to allow a sufficient degree of picture processing. Also, this frequency is the only one in the range of 12 to 14.3 MHz that permits an integer number of samples per lines for both the 525 and the 625 line systems [CCIR, 1978-82d, e, f, g, h, i and j]. The sampling frequency applied to the colour-difference signals was set at half that applied to the luminance signal after checking that this would allow adequate quality in chroma-key (colour matte) processing. The digital interface for studio equipment is discussed in Report 1088 entitled "Interfaces for digital video signals in 525-line and 625-line television systems".

It was anticipated that present and envisaged applications of television are unlikely to be covered by a single set of digital parameters. *An extensible family of compatible digital coding standards* corresponding to different applications was therefore proposed [CCIR, 1978-82k, l and m].

The members of the family are denoted by a sequence of integer numbers such as 4:2:2 or 4:4:4. These numbers represent the relation of the sampling frequency for the luminance signal (first number) to the sampling frequencies for the colour difference signals (subsequent numbers). The convention adopted is that the number 4 represents the main sampling rate of 13.5 MHz (nominal). Thus, for example, the 4:2:2 member of the family is characterized by 13.5 and 6.75 MHz sampling frequencies for the luminance and the colour difference signals respectively as defined in Recommendation 601.

One possible set of such standards is considered in [CCIR, 1978-82m] as corresponding to the following levels:

- a studio standard;
- a lower standard using the same scanning parameters but resulting in lower bit rates and costs, suitable for lower quality applications;
- a higher quality standard having a capability beyond that provided by present scanning standards.

In [CCIR, 1978-82n] it is suggested that an internationally compatible digital code would be a component code incorporating line-locked (orthogonal) sampling, an identical number of samples per line for both the 525- and 625-line systems and membership in an extensible family of compatible digital codes having simply related sampling frequencies. The definition of preferred sampling frequencies should be the subject of further studies.

Subjective assessments of an extensible family of component coded digital television systems were performed during 1980 and 1981 by the EBU [CCIR, 1978-82d and f], the SMPTE [CCIR, 1978-82g], and by NHK in Japan [CCIR, 1978-82o; Nishizawa *et al.*, 1981]. The tests included the binary derived family members 4:4:4, 4:2:2 and 4:1:1 with luminance sampling frequencies ranging from 12 MHz to 14.3 MHz. The results of all these tests were consistent and tended to verify the 4:2:2 member as the preferred selection for the standard studio interface and verified the choice of a sampling frequency of 13.5 MHz as an appropriate compromise between acceptable picture quality after processing and bit-rate requirements. This is also supported by [CCIR, 1978-82e].

The possibility of using the 4:2:2 level of Recommendation 601 with pictures having a wider aspect ratio (16:9 instead of 4:3) is presented in [CCIR, 1986-90b], which points out that most studio equipment requires only minor modifications and the same interface as in Recommendation 656 can be used. However, in such applications it should be noted that wider aspect ratio signals should not be intermixed with conventional (4:3) aspect ratio signals.

[CCIR, 1978-82k] presents a description of an extensible family of compatible digital codes which is based upon a component code bearing the ratios of sampling rates of 4:1:1 (luminance to colour-difference). Such codes would be easily transcodable to an NTSC composite digital interface code and the family could be readily extensible upward to be suitable for higher definition television when advances in technology warrant it. Also, the family of codes is extensible downward to lower definition interface codes for special applications, e.g. electronic news gathering.

The 4:4:4 level described in the Annex to Recommendation 601 is under study by both the EBU and the SMPTE. The intended purpose of a 4:4:4 interface is for complex graphics and post-production. It is not the intent to replace the 4:2:2 interfaces already specified in Recommendation 656, as they are deemed more than adequate for normal studio operations. The 4:4:4 interface is expected to stipulate PCM coding with more than eight bits per sample. Agreement has been reached within the EBU and SMPTE to include consideration of the keying signal as part of the basic signal set. This level of Recommendation 601 is now referred to as 4:4:4:4 or 4x4. Work is concentrated on fitting the information within the current interface described in Recommendation 656. Amongst the issues still under investigation are the effects of various algorithms for dynamic rounding, to minimize the number of bits per sample, also the filtering characteristics and the requirements for keying signals. Dynamic rounding is a process which conceals the errors which arise when a sample is reduced in word-length, as from 10 bits to 8 bits.