REPORT 962-2

THE FILTERING, SAMPLING AND MULTIPLEXING FOR DIGITAL ENCODING OF COLOUR TELEVISION SIGNALS

(Question 25/11, Study Programme 25H/11)

(1982-1986-1990)

1. Introduction

Report 629 provides a brief introduction to the subjects of bandwidth and sampling as relevant to the process of encoding component signals into digital form.

In order to ensure that the total bit rate of the digital signal is not excessive, it is clearly necessary to determine the bandwidths of the luminance and colour-difference signals which are adequate to provide high-quality broadcasting signals (which may be in the analogue composite form). Further, when considering the filtering and sampling of component signals, it is also necessary to bear in mind that proposals have been made to use such signals in digital form for purposes which could be more demanding than conventional broadcasting (see § 2.3). In particular, attention must be paid to the constraints imposed by modern programme production techniques, taking into account the quality margin required by the increasing demand for picture-processing operations [Akrich and Zaccarian, 1981].

In choosing the sampling parameters to be used for component signals, the sampling frequencies are, clearly, closely related to the bandwidths of the component signals, but other parameters are concerned with the picture sampling structure or structures (see § 3).

The number of bits necessary to describe each sample is discussed in § 4.

In order to handle a single byte stream in the studio when component coding is used, time-multiplexing of the three byte streams is required. Some possible arrangements are discussed in § 5.

2. Bandwidths

This section is divided in three sub-sections, the two following sub-sections outline the results of subjective tests aimed at establishing the overall luminance and colour-difference signal bandwidths, respectively. The third sub-section discusses the implications with regard to these bandwidths, taking into account the needs of studio signal-processing operations.

2.1 *Luminance-signal bandwidth*

[CCIR, 1978-82a and b] give the results of tests by members of the EBU, to determine the relationship between subjective quality and the bandwidth of the luminance component, using a 625-line system and monochrome display. The tests were carried out using a method described in Report 405, using the impairment scale and pictures slightly more critical than average, as required by Recommendation 500.

The main conclusion indicates that bandwidth-limiting to 4.5 MHz (at −3 dB) using sharp cut off low-pass filtering introduces an impairment which is imperceptible to 50% of the observers at a viewing distance of four times the picture height (see Fig. 1a). The results indicate that the effects of filtering on electronically-generated captions are less critical than those on the pictures. These studies did not show the expected advantage for the use of a comb filter (with sub-Nyquist-sampling) when compared with a low pass filter cutting off at half the sampling frequency.

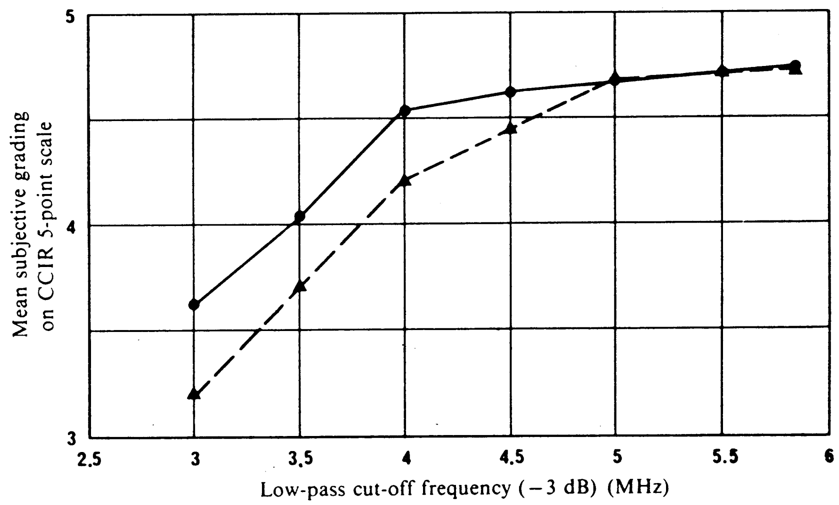

FIGURE 1 a – *Low-pass filtering.*
Mean values of the results obtained in seven laboratories, using 625-line test pictures

—●— viewers at a distance of six times picture height

—▲— viewers at a distance of four times picture height

The subjective test results obtained in these EBU tests have been analyzed in accordance with the method described in Annex III of Report 405 and this work is described in [CCIR, 1978-82c]. The result of the analysis is presented in Fig. 1(b). The same document discusses the substantial effect of the choice of picture material and the large spread of the results which can occur when Recommendation 500 is not followed. It also expresses the view that an impairment criterion of $I = 0.05$ (corresponding to grade 4.8 in a five grade scale) is appropriate and that consequently the minimum bandwidth of the luminance signal should be 5.8 MHz.

Tests carried out in Poland, and described in [CCIR, 1978-82d] also indicate that the luminance-signal bandwidth should not be less than 4.5 MHz for 625-line systems.

[CCIR, 1978-82e] describes work by the U.S.S.R. which concludes that the appropriate bandwidth for the luminance signal is 6.0 MHz.

The relationship between picture quality and luminance-signal bandwidth, for 525-line systems, has been investigated in Japan [CCIR, 1978-82f]. Separate tests were carried out, using colour pictures, for two different values of colour-difference signals bandwidth; the filters used in the luminance and colour-difference channels were of the Thomson type (i.e. relatively slow cut-off). The results of the tests indicate that a luminance-signal bandwidth of 5.6 MHz is suitable.

2.2 *Colour-difference signal bandwidth*

Tests in Poland [CCIR, 1978-82d] indicate that, for 625-line systems, the bandwidth of each colour-difference signal should be not less than 1.5 MHz, a result which agrees with that given in [CCIR, 1978-82e] from the U.S.S.R.

The work described in [CCIR, 1978-82f] also included tests to determine the colour-difference signal bandwidth appropriate to 525-line systems. The relationship between picture quality and colour-difference signal bandwidth was determined by separate tests, using colour pictures, in which two different values of luminance-signal bandwidth were involved. From the results it is concluded that the colour-difference signal bandwidth should have a value of approximately 2.8 MHz (Fig. 2).

Experiments conducted in France [Sabatier and Sallio, 1981; Sabatier and Chatel, 1981] show very similar results for 625-line systems.

Investigations to establish the optimum characteristic for limiting the bandwidth of colour-difference signals are outlined in [CCIR, 1978-82g]. These studies, carried out in the Federal Republic of Germany, were made assuming that the maximum bandwidth available (the Nyquist limit) was 2.0 MHz.

Studies involving subjective tests have been made to determine the optimum characteristics for a filter, also with a bandwidth of 2.0 MHz; these studies are described in [CCIR, 1978-82h].

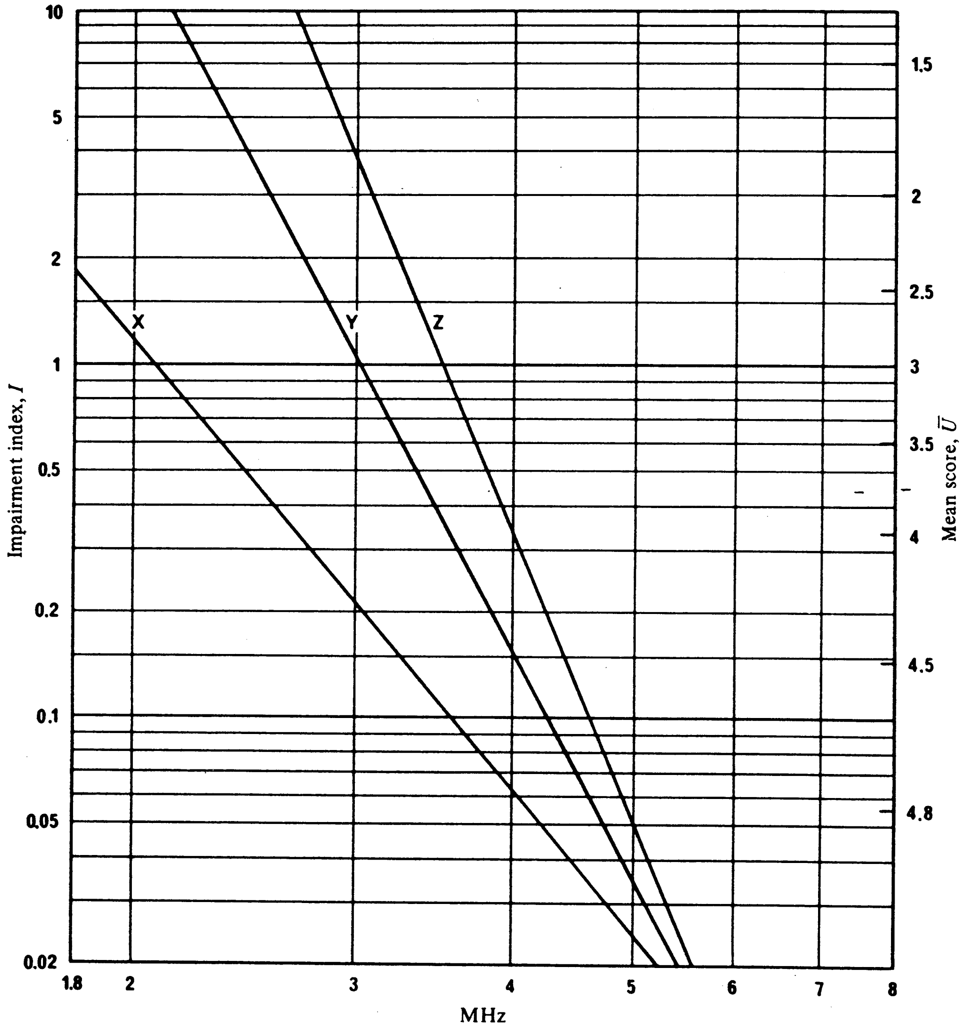

FIGURE 1b – *Impairment characteristics for bandwidth restriction, from EBU experiments: spread of results from different laboratories. Viewing distance is 4 times picture height*

Curves X: laboratory A (the least critical)
Y: average of results from 7 laboratories
Z: laboratory B (the most critical)

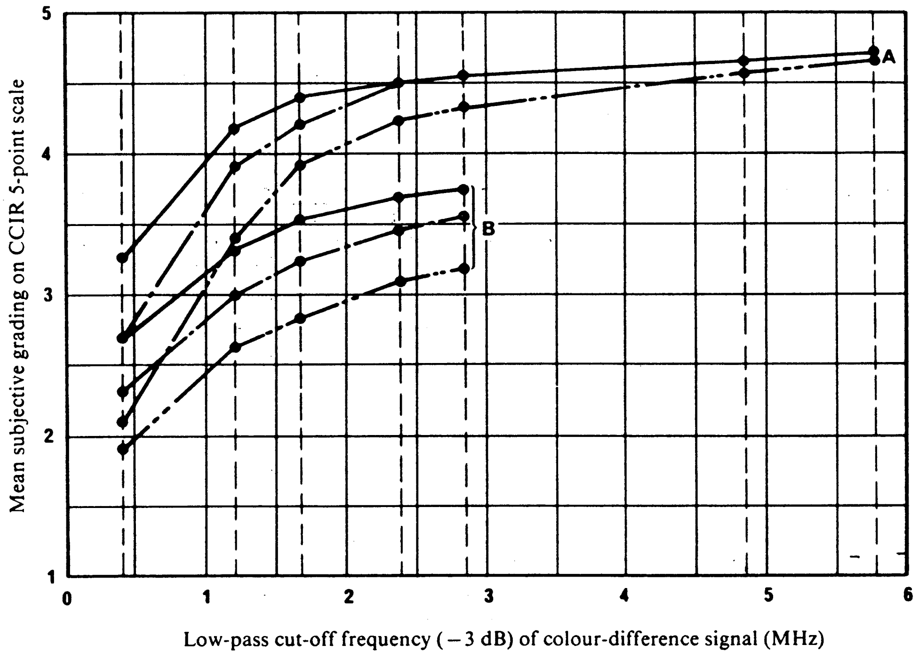

FIGURE 2 – *Relationship between colour-difference signal bandwidth and picture quality (525-line systems)*

Curves A: *Y* signal bandwidth 5.8 MHz (– 3 dB)
B: *Y* signal bandwidth 2.9 MHz (– 3 dB)

——— viewers at a distance of 6 times picture height
—·— viewers at a distance of 4 times picture height
—··— viewers at a distance of 2.5 times picture height

2.3 *Bandwidth requirements for studio signal-processing applications*

It must be borne in mind that the values of the luminance-signal bandwidth arrived at in § 2.1 and 2.2 are those regarded as desirable when considering the overall signal chain prior to the broadcast transmitter. [CCIR, 1978-82i] discusses the need for increased luminance and colour-difference signal bandwidths when considering signal processing in the studio. It is pointed out, first, that the luminance bandwidth must be adequate to permit a reasonable amount of picture recomposition, without causing a perceptible impairment of the output picture. Secondly, [CCIR, 1978-82i] argues that the bandwidths of the colour-difference signals must be sufficient to enable good results to be obtained with chroma-key (colour-matte). [CCIR, 1978-82h] also discusses colour-difference signal bandwidth requirements in the context of the chroma-key (colour-matte) process. It expresses the opinion that a colour-difference signal sampling frequency of 6 to 7 MHz (half that used for the luminance signal) is satisfactory with regard to both picture quality and chroma-key (colour-matte) requirements, provided that the filtering characteristic shows 12 dB attenuation at half the sampling frequency; further, the frequencies at which the attenuation values are 12 dB and 3 dB should be related by the ratio 1.25 : 1.

The general problem of the design of the band-limiting filters used in the digital coding of television signals has been studied in Italy [CCIR, 1978-82j]. Computer simulations were used to investigate the influence of several design parameters on the amplitude of overshoot and the amount of aliasing.

Experiments in the People's Republic of Poland are reported in [CCIR, 1982-86a] on the luminance filtering characteristics preferred for an environment where the luminance bandwidth of 6 MHz is used for conventional composite systems. A 6 MHz passband, insertion loss tolerance ± 0.05 dB, attenuation 15 dB at 6.75 MHz, and 40 dB at 7.5 MHz are suggested.

[CCIR, 1982-86b] reports studies in the USSR which, taking into account the circumstances above, and additional practical design considerations, propose a 5.75 MHz passband, insertion loss tolerance 0.1 dB, attenuation 20 dB at 6.75 MHz and 40 dB at 7.5 MHz for the luminance filter.

In Italy [CCIR, 1982-86c] a study was made using computer simulation of pre- and post-filter characteristics based on minimization of the weighted influence of over-shoots and aliasing. The study provided valuable preliminary data, which subsequently led to support for luminance and colour-difference filtering characteristics of the kind in [CCIR, 1982-86d].

A careful study of the performance of a cascaded chain of PCM codecs [CCIR, 1982-86e, f; Devereux, 1982] has shown that after minimizing the instrumental deficiencies of the codecs, the most important avoidable impairment which remains is due to the passband amplitude and phase responses of the analogue pre- and post-filters, and proposals for these characteristics are made in the above documents.

The OIRT [CCIR, 1982-86g] has studied the proposal to use a cut-off frequency of 5.75 MHz for the luminance signal in the digital 4 : 2 : 2 standard. This is nearer to the value of the 6 MHz cut-off frequency for the video signals specified by standards D, K, K1 and L (see Report 624). The value of 6 MHz for the band-limiting filter is also being studied.

Based on the results of the studies mentioned above, and an examination of the problems of the practical realization of efficient filters to meet the requirements of all administrations, the characteristics given in Fig. 1 of Annex III to Recommendation 601 were drawn up.

The study has been continued [CCIR, 1982-86d, f; Devereux, 1984] to determine specifications for filters for the colour-difference signals for the 4 : 2 : 2 coding standard of Recommendation 601. In these studies special attention has been given to:

(a) the need to maximize the usable bandwidths of both luminance and colour-difference signals;

(b) the need to ensure negligible impairments due to passband tolerances when a number of filter pairs are cascaded in a transmission chain;

(c) complementing (b) above, the need to avoid unnecessarily stringent values and tolerances;

(d) the need for the specifications of both analogue and digital filters to be capable of being met in production at reasonable cost.

Resulting from these studies, the specification for analogue filters for colour-difference signals sampled at 6.75 MHz are given in Fig. 2 of Annex III to Recommendation 601. The specification for a corresponding digital filter for sampling rate conversion between signals sampled at 13.5 MHz and signals sampled at 6.75 MHz is given in Fig. 3 of Annex III to Recommendation 601.

Some guidance on the practical implementation of the filters recommended in Annex III to Recommendation 601 is given in the following paragraphs.

In the proposals for the filters used in the encoding and decoding processes, it has been assumed that, in the post-filters which follow digital-to-analogue conversion, correction for the (sin x/x) characteristic is provided. The passband tolerances of the filter plus (sin x/x) corrector plus the theoretical (sin x/x) characteristic should be the same as given for the filters alone. This is most easily achieved if, in the design process, the filter, (sin x/x) corrector and delay equalizer are treated as a single unit.

The total delays due to filtering and encoding the luminance and colour-difference components should be the same. The delay in the colour-difference filter (Fig. 2 of Annex III to Recommendation 601) is double that of the luminance filter (Fig. 1 of Annex III to Recommendation 601). As it is difficult to equalize these delays using analogue delay networks without exceeding the passband tolerances, it is recommended that the bulk of the delay differences (in integral multiples of the sampling period) should be equalized in the digital domain. In correcting for any remainder, it should be noted that the sample-and-hold circuit in the decoder introduces a flat delay of one half a sampling period.

The passband tolerances for amplitude ripple and group delay are recognized to be very tight. Present studies indicate that it is necessary so that a significant number of coding and decoding operations in cascade may be carried out without sacrifice of the potentially high quality of the 4 : 2 : 2 coding standard. Due to limitations in the performance of currently available measuring equipment, manufacturers may have difficulty in economically verifying compliance with the tolerances of individual filters on a production basis. Nevertheless, it is possible to design filters so that the specified characteristics are met in practice, and manufacturers are required to make every effort in the production environment to align each filter to meet the given templates.

Subjective assessments of the visibility threshold for colour signal ringing were carried out in Japan. The results show that the visibility threshold is reached with 2.5% or less, for electronically generated patterns and characters, and with 5% or more, for general pictures. Based on the results of the assessments, a colour-signal shaping-filter was designed, for which the total disturbance due to ringing and aliasing was less than 2.5%. This characteristic can be realized by a digital transversal filter [CCIR, 1982-86h].

The specifications given in Annex III to Recommendation 601 were devised to preserve as far as possible the spectral content of the Y, C_R, C_B signals throughout the component signal chain. It is recognized, however, that the colour difference spectral characteristic must be shaped by a slow roll-off filter inserted at picture monitors, or at the end of the component signal chain.

2.4 Bandwidth and filtering for conversion between different sampling rates

[CCIR, 1986-1990a] considers the digital filtering and interpolation characteristics necessary to interface between the 4:2:2 signals of Recommendation 601 and signals conveyed using lower sampling frequencies, and gives examples of filters, designed to preserve the information content, of reasonable complexity. Only horizontal filtering is considered.

[CCIR, 1986-1990b] describes subjective tests carried out using the above characteristics implemented by computer simulation. It was found that for natural pictures, the effects of sub-sampling are more visible in coloured areas, but some impairment was introduced by sub-sampling the luminance component of electronically generated pictures. The former conclusion led to consideration of quincunx sub-sampling for chrominance signals.

3. Sampling parameters

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. In all the examples given below the sampling patterns were picture-locked.

A general theoretical survey is given in [Kretz and Sabatier, 1981].

Some comparisons between orthogonal and quincunx sampling patterns are given in [CCIR, 1978-82d]. These indicate that the orthogonal pattern has some advantages.

3.1 *Sampling rates*

The EBU has studied the problem of defining a standard set of essential coding parameters for television studio equipment. The work was carried out with four main objectives:

- to eliminate, in the production area, the differences between the existing 625-line systems;
- to ensure that the picture quality obtained is as high as, or higher than, that obtainable with good modern practice using analogue techniques;
- to ensure that the standard is suited to technology that is available at present, or is likely to be available in the near future;
- to arrive at parameter values which take into account the needs of picture processing in the studio.

In a first series of studies [CCIR, 1978-82k] orthogonal sampling was used with sampling rates of 768 f_H (line frequency) for the luminance signal and 256 f_H for the colour-difference signals; the colour-difference samples were co-sited and each pair of colour-difference samples was co-sited with a luminance sample.

These studies indicated that further work was necessary, with particular regard to the influence of picture-processing requirements on the choice of sampling rates.

The sampling parameters discussed in [CCIR, 1978-82k] are considered in [CCIR, 1978-82l] with regard to their suitability for digital-signal transmission at a rate of 140 Mbit/s. The view is expressed that signals based upon these sampling parameters would be of higher quality than those now provided by analogue transmissions.

The EBU has carried out a further series of studies relating to sampling rates. This work included experiments to assess the picture quality available using a number of parameter-set values within the range 12 : 4 : 4 to 14.3 : 7.15 : 7.15 where the numbers in these ratios correspond to the sampling frequencies (in MHz) used for the luminance signal and for the two colour-difference signals, respectively. Apart from the 12 : 4 : 4 set, all the parameter sets assessed had a ratio of 2 : 1 between the luminance and colour-difference sampling frequencies. [CCIR, 1978-82m; EBU, 1981] outlines these investigations and discuss the results obtained with each of the parameter-set values, with regard to a number of attributes.

First, concerning the picture quality obtained after one analogue *RGB* to digital *YUV* conversion, the results indicate, in broad terms, that the 12 : 6 : 6 parameter set gives a perceptibly better performance than the 12 : 4 : 4 set. However, they also indicate that the performance of the 14.3 : 7.15 : 7.15 set, in this regard, is not significantly better than that obtained using the 12 : 6 : 6 set.

Secondly, with regard to the quality of chroma-key (colour-matte) obtained, the results indicate that, while the 12 : 6 : 6 set clearly provides a better performance than the 12 : 4 : 4 set, a relatively steady improvement in performance can be noted as the luminance and colour-difference sampling frequencies are further increased to their maximum values, i.e. conforming to the 14.3 : 7.15 : 7.15 set.

Thirdly, it was found that, in tests involving a moderate amount of horizontal picture expansion, no aliasing could be observed, using natural (non-electronically generated) test pictures, for all luminance-signal sampling frequencies within the range 12 : 6 : 6 to 14.3 : 7.15 : 7.15. However, using an electronically generated horizontal-frequency sweep, aliasing decreased with increasing sampling frequency; the decrease was most noticeable in the range 12 to 13 MHz.

Finally, with regard to bit-rate reduction, the studies show that it is possible to reduce the bit-rate of a signal conforming to the 14.3 : 7.15 : 7.15 set so as not to exceed 140 Mbit/s, without affecting the picture quality or the potential capability for chroma-key (colour-matte) processing.

Some of the above-mentioned results were derived from work undertaken in the UK, which is described in detail in [CCIR, 1978-82n]. This work included tests on two parameter sub-sets, in order to investigate the properties of systems possibly qualifying as lower members of the family of compatible digital coding standards. In one of the sub-sets the luminance- and colour-difference signal sampling frequencies were related by the ratio 4 : 1.

The subjective tests involved in this work were carried out using the "double-stimulus" method described in the Appendix I of Recommendation 500 and reference pictures derived by digitally coding the input signals according to the 14.3 : 14.3 : 14.3 parameter set. The detailed subjective-test results obtained during the above-mentioned tests have been analysed by the method described in Annex III of Report 405, and the results of the analysis, described in [CCIR, 1978-82o], are given in terms of the impairment index I and the mean score $\overline{U}$. From the analysis it can be concluded that, with regard to basic picture quality the 13.5 : 6.75 : 6.75 parameter set is characterized by an impairment index I of 0.03 at 4 H (i.e. a mean score greater than 4.8) and that the corresponding results related to chroma-key (colour-matte) performance are I = 0.3 and $\overline{U}$ = 4.0.

In the USSR consideration has been given to the sampling parameters suitable for standards D and K. Early work included the study of a system in which the luminance signal was sampled orthogonally at a rate of 800 f_H (12.5 MHz), and each of the colour-difference signals were similarly sampled at 200 f_H (3.125 MHz); the investigation is outlined in [CCIR, 1978-82e]. In studies described in [CCIR, 1978-82p] the sampling parameters for digital TV studios were revised as it was found desirable to increase the sampling frequencies to about 13 to 13.5 MHz and 6.5 to 6.75 MHz for the luminance and colour-difference signals respectively.

[CCIR, 1978-82q] reports the results of comprehensive subjective tests which were carried out with the objective of determining the relationship between the reproduced colour-picture quality and the sampling frequencies and sampling structures used for the luminance and colour-difference signals.

A standard, designed to be a member of the family of digital coding standards below that recommended as the main studio standard is described in [CCIR, 1978-82r]. In this standard the luminance signal is sampled at 10.125 MHz and the useful bandwidth extends to 5 MHz. The colour-difference signals are sampled at a frequency equal to 3.375 MHz, and have a bandwidth of 1.5 MHz. Further studies are necessary to select the best sampling structure for this system. The system is known as a 3 : 1 system, owing to, first, the particular ratios used to calculate the sampling frequencies from the frequencies recommended for the main studio standard and, secondly, the use of line-sequential coding of the colour-difference signals. It is claimed that the picture quality obtained from this system is at least equal to that obtained using a conventional analogue PAL codec.

A system for coding a television signal at a bit rate of 70 Mbit/s using the DPCM method (folded quantization with 5 bit/sample) is described in [CCIR, 1982-86i; Wengenroth, 1982]. The sampling frequencies for luminance and colour-difference signals are derived from the studio standard by means of a digital filter which gives a conversion of the sampling frequency in the ratio 6 : 5. Line-sequential transmission is foreseen for the two colour difference signals.

Extensive subjective tests, using a method described in Report 405, Annex IV, were carried out in the USA using digitally coded component signals conforming to the 525-line standard; these are outlined in [CCIR, 1978-82s; SMPTE Journal, 1981]. The tests covered luminance-signal sampling rates corresponding to 768, 864 and 912 samples per total line and ratios of luminance-signal to colour-difference signal bandwidth of 4 : 4 : 4, 4 : 2 : 2, 4 : 1 : 1 and 2 : 1 : 1. Tests were carried out with regard to basic picture quality and on the properties of the various parameter sets with regard to production processes such as picture expansion, chroma-key (colour-matte), multi-generation digital recording and digital decoding from, and encoding into, analogue M/NTSC composite colour signals.

These tests confirm the selection of the 4 : 2 : 2 parameter set as the one preferred as a studio standard, and showed that a small but rising picture quality was obtained with increase of sampling rate.

Subjective tests with similar sampling parameters were carried out in Japan, and these are described in [CCIR, 1978-82t]. The tests included digital chroma-key (colour-matte) processing for parameter sets with luminance-signal sampling frequencies of 12.1, 13.6 and 14.3 MHz. The two main results can be summed up in the following way: first, the picture quality decreases gradually as the sampling frequency of the colour-difference signals decreases from a value equal to that used for the luminance signal, to a quarter of that value and, secondly, the picture quality obtained using the chroma-key (colour-matte) process decreases significantly as the sampling frequency used for the colour-difference signals is reduced; this decrease is more marked when the sampling frequency is reduced from half that used for the luminance signal to a quarter of that value.

[CCIR, 1982-86j; Khleborodov, 1983] contain a theoretical study of picture distortions in line-sequential transmission of colour-difference signals with a two-field cycle.

[CCIR, 1982-86k] describes results of subjective assessments of picture quality obtained with 4 : 1 : 1, 4 : 2 : 0, 2 : 1 : 1 and 3 : 1 : 0 coding, including the effects of line- and field-offset sub-sampling, and of line-sequential processing of the colour-difference signals; these tests used stationary test pictures. The results showed that the picture quality for 2 : 1 : 1 with field-offset sub-sampling was superior to that of the other members with a similar bit rate for most of the pictures tested.

[CCIR, 1982-86l] reports subjective tests on a 2 : 1 : 1 system employing field-offset sub-sampling which suggests that satisfactory portrayal of movement can be achieved.

3.2 *Changing the sampling rate*

Sampling rate changing is a process required in many picture processing operations. One example is that involved in converting the signals conforming to one member of the family of compatible coding standards to another. [CCIR, 1978-82u] describes a filtering process, based on comb filtering of the upper part of the signal spectrum, which enables signals to be converted easily between various members of a binary-related family (4 : 4 : 4; 4 : 2 : 2; 2 : 1 : 1). [CCIR, 1978-82t; Nishizawa *et al.*, 1981] include the description of a very sophisticated interpolation low-pass filter intended for the same purpose.

Change of sampling rate is also required when the family of compatible digital coding standards is not based upon binary ratios. [CCIR, 1978-82v] indicates that the design of the interpolating filter need not be unduly complicated, provided that the change of sample rate involves a ratio described by a rational number.

In [CCIR, 1982-86m] it is shown how various source coding procedures and bit-rate reduction techniques can be used to adapt the various members of the family of compatible digital coding standards to suitable levels of the transmission hierarchy based on 2048 kbit/s.

In order to avoid quality losses due to sampling frequency conversions and coding procedures in tandem and to eliminate the need for transcoding equipment to be set up at all transmission network nodes operating at different bit-rates, it is desirable to carry out bit-rate conversion at the television studio in accordance with the bit rate of the circuit section having the narrowest bandwidth.

Thus signals transmitted through a point-to-point link consisting of the tandem connection of sections of different capacity should be coded in conformity with the section having the smallest capacity, unless it is necessary for a signal of higher quality to be available at an intermediate point.

4. Uniformly quantized PCM

The basic form of digital coding is uniformly quantized PCM, where the value of each digital "word" represents the uniformly quantized amplitude of a sample of the baseband signal.

In all the examples given above, 8 bits per sample uniform quantizing is proposed for the luminance signal and for the colour-difference signals [CCIR, 1978-82e, k, l and w].

5. Multiplexing methods

The single-channel transmission of digitally encoded component signals requires that the three separately encoded signals, describing the luminance and two colour-difference signals, respectively, be combined together in time-multiplex form.

[CCIR, 1978-82x] compares two forms of multiplex. In the first, the three digital words describing each picture element are grouped together; in the second the words describing the luminance-signal values of all the picture elements in one line are grouped together, and this group of words is followed by two groups each describing the corresponding colour-difference signal values. The comparison concludes that the first arrangement is more economic but that the second is more advantageous with regard to monitoring.

[CCIR, 1978-82k] discusses a multiplexing structure identical to the first of those described above.

The work on the digital encoding of component signals carried out in the U.S.S.R. and described in [CCIR, 1978-82e], includes a multiplex arrangement in which the signals are transmitted in the order Y, D_R, Y, Y, D_B, Y, where Y represents a luminance signal value and D_R and D_B represent colour-difference signal values.

[CCIR, 1982-86n] describes a multiplexer which combines two signals, each having a bit rate of approximately 70 Mbit/s, to produce a signal at the fourth order of the hierarchical level, namely 139 264 kbit/s. Each 70 Mbit/s tributary may contain either one digital television signal or two signals of 34 368 kbit/s. The frame alignment signal and the net bit rate of the two tributaries are adjusted to the requirements of both telephony and television. Accordingly, it may be possible for digital television signals to be adapted to other hierarchical bit rates. The insertion of a frame alignment signal at the interface between the television studio and the transmission system would considerably facilitate the transmission of television signals in the integrated services digital network (ISDN).

[CCIR, 1982-86o] describes the results of studies on a bit-parallel transmission method which permits easy transcoding both to and from a bit-serial format having a bit rate of 108 Mbit/s using two channels, and also to and from a 216 Mbit/s single channel format. [CCIR, 1982-86p] gives some details on the 2 × 108 Mbit/s parallel-serial and 216 Mbit/s serial interfaces.

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CCIR Documents

[1978-1982]: **a.** 11/17 (EBU); **b.** 11/18 (EBU); **c.** 11/289 (United Kingdom); **d.** 11/89 (Poland (People's Republic of)); **e.** 11/128 (USSR); **f.** 11/305 (Japan); **g.** 11/113 (Germany (Federal Republic of)); **h.** 11/261 (France); **i.** 11/323 (Italy); **j.** 11/327 (Italy); **k.** 11/14 (EBU); **l.** 11/112 (Germany (Federal Republic of)); **m.** 11/330 (EBU); **n.** 11/285 (United Kingdom); **o.** 11/288 (United Kingdom); **p.** 11/328 (USSR); **q.** 11/302 (Poland (People's Republic of)); **r.** 11/278 (Germany (Federal Republic of)); **s.** 11/292 (USA); **t.** 11/343 (Japan); **u.** 11/294 (USA); **v.** 11/243 (Germany (Federal Republic of)); **w.** 11/31 (USA); **x.** 11/111 (Germany (Federal Republic of)).

[1982-86]: **a.** 11/393 (Poland (People's Republic of)); **b.** 11/327 (USSR); **c.** 11/348 (Italy); **d.** 11/292 (IWP 11/7); **e.** 11/65 (United Kingdom); **f.** 11/276 (United Kingdom); **g.** 11/424 (OIRT); **h.** 11/31 (Japan); **i.** 11/13 (Germany (Federal Republic of)); **j.** 11/90 (USSR); **k.** 11/22 (Japan); **l.** 11/415 (Japan); **m.** 11/14 (Germany (Federal Republic of)); **n.** 11/15 (Germany (Federal Republic of)); **o.** 11/24 (Japan); **p.** 11/136 (OIRT).

[1986-90]: a. IWP 11/7-138 (United Kingdom); b. IWP 11/7-159 (Italy).

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