RECOMMENDATION 601-2

ENCODING PARAMETERS OF DIGITAL TELEVISION FOR STUDIOS *

(Question 25/11, Study Programmes 25G/11, 25H/11)

(1982–1986–1990)

The CCIR,

CONSIDERING

(a) that there are clear advantages for television broadcasters and programme producers in digital studio standards which have the greatest number of significant parameter values common to 525-line and 625-line systems;

(b) that a world-wide compatible digital approach will permit the development of equipment with many common features, permit operating economies and facilitate the international exchange of programmes:

(c) that an extensible family of compatible digital coding standards is desirable. Members of such a family could correspond to different quality levels, facilitate additional processing required by present production techniques, and cater for future needs;

(d) that a system based on the coding of components is able to meet some, and perhaps all, of these desirable objectives;

(e) that the co-siting of samples representing luminance and colour-difference signals (or, if used, the red, green and blue signals) facilitates the processing of digital component signals, required by present production techniques,

UNANIMOUSLY RECOMMENDS

that the following be used as a basis for digital coding standards for television studios in countries using the 525-line system as well as in those using the 625-line system:

1. Component coding

The digital coding should be based on the use of one luminance and two colour-difference signals (or, if used, the red, green and blue signals).

The spectral characteristics of the signals must be controlled to avoid aliasing whilst preserving the passband response. When using one luminance and two colour-difference signals as defined in Table I of RECOMMENDS 4, suitable filters are defined in Annex III, Figs. 1 and 2. When using the E'_R, E'_G, E'_B signals or luminance and colour-difference signals as defined in Table II of Annex I, a suitable filter characteristic is shown in Fig. 1 of Annex III.

* Main digital television terms used in the Recommendation are defined in Report 629.

2. Extensible family of compatible digital coding standards

The digital coding should allow the establishment and evolution of an extensible family of compatible digital coding standards.

It should be possible to interface simply between any two members of the family.

The member of the family to be used for the standard digital interface between main digital studio equipment, and for international programme exchange (i.e. for the interface with video recording equipment and for the interface with the transmission system) should be that in which the luminance and colour-difference sampling frequencies are related in the ratio 4 : 2 : 2.

In a possible higher member of the family the sampling frequencies of the luminance and colour-difference signals (or, if used, the red, green and blue signals) could be related by the ratio 4 : 4 : 4. Tentative specifications for the 4 : 4 : 4 member are included in Annex I (see Note).

Note – Administrations are urgently requested to conduct further studies in order to specify parameters of the digital standards for other members of the family. Priority should be accorded to the members of the family below 4 : 2 : 2. The number of additional standards specified should be kept to a minimum.

3. Specifications applicable to any member of the family

3.1 Sampling structures should be spatially static. This is the case, for example, for the orthogonal sampling structure specified in § 4 of the present Recommendation for the 4 : 2 : 2 member of the family.

3.2 If the samples represent luminance and two simultaneous colour-difference signals, each pair of colour-difference samples should be spatially co-sited. If samples representing red, green and blue signals are used they should be co-sited.

3.3 The digital standard adopted for each member of the family should permit world-wide acceptance and application in operation; one condition to achieve this goal is that, for each member of the family, the number of samples per line specified for 525-line and 625-line systems shall be compatible (preferably the same number of samples per line).

4. Encoding parameter values for the 4 : 2 : 2 member of the family

The following specification (Table I) applies to the 4 : 2 : 2 member of the family, to be used for the standard digital interface between main digital studio equipment and for international programme exchange.

TABLE I – *Encoding parameter values for the 4 : 2 : 2 member of the family*

Parameters	525-line, 60 field/s ([1]) systems	625-line, 50 field/s ([1]) systems
1. Coded signals: Y, C_R, C_B	These signals are obtained from gamma pre-corrected signals, namely: E'_Y, $E'_R - E'_Y$, $E'_B - E'_Y$ (Annex II, § 2 refers)	
2. Number of samples per total line: – luminance signal (Y) – each colour-difference signal (C_R, C_B)	 858 429	 864 432
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 – each colour-difference signal	 13.5 MHz ([2]) 6.75 MHz ([2]) The tolerance for the sampling frequencies should coincide with the tolerance for the line frequency of the relevant colour television standard	
5. Form of coding	Uniformly quantized PCM, 8 bits per sample, for the luminance signal and each colour-difference signal	
6. Number of samples per digital active line: – luminance signal – each colour-difference signal	 720 360	
7. Analogue-to-digital horizontal timing relationship: – from end of digital active line to 0_H	16 luminance clock periods	12 luminance clock periods
8. Correspondence between video signal levels and quantization levels: – scale – luminance signal – each colour-difference signal	 0 to 255 220 quantization levels with the black level corresponding to level 16 and the peak white level corresponding to level 235. The signal level may occasionally excurse beyond level 235 225 quantization levels in the centre part of the quantization scale with zero signal corresponding to level 128	
9. Code-word usage	Code-words corresponding to quantization levels 0 and 255 are used exclusively for synchronization. Levels 1 to 254 are available for video	

([1]) See Report 624, Table I.

([2]) The sampling frequencies of 13.5 MHz (luminance) and 6.75 MHz (colour-difference) are integer multiples of 2.25 MHz, the lowest common multiple of the line frequencies in 525/60 and 625/50 systems, resulting in a static orthogonal sampling pattern for both.

ANNEX I

TENTATIVE SPECIFICATION OF THE 4 : 4 : 4 MEMBER OF THE FAMILY

This Annex provides for information purposes a tentative specification for the 4 : 4 : 4 member of the family of digital coding standards.

The following specification could apply to the 4 : 4 : 4 member of the family suitable for television source equipment and high quality video signal processing applications.

TABLE II – *A tentative specification for the 4 : 4 : 4 member of the family*

Parameters	525-line, 60 field/s systems	625-line, 50 field/s systems
1. Coded signals: Y, C_R, C_B or R, G, B	These signals are obtained from gamma pre-corrected signals, namely: E'_Y, $E'_R - E'_Y$, $E'_B - E'_Y$ or E'_R, E'_G, E'_B	
2. Number of samples per total line for each signal	858	864
3. Sampling structure	Orthogonal, line, field and frame repetitive. The three sampling structures to be coincident and coincident also with the luminance sampling structure of the 4 : 2 : 2 member	
4. Sampling frequency for each signal	13.5 MHz	
5. Form of coding	Uniformly quantized PCM. At least 8 bits per sample	
6. Duration of the digital active line expressed in number of samples	At least 720	
7. Correspondence between video signal levels and the 8 most significant bits (MBS) of the quantization level for each sample:		
– scale	0 to 255	
– R, G, B or luminance signal (1)	220 quantization levels with the black level corresponding to level 16 and the peak with level corresponding to level 235. The signal level may occasionally excurse beyond level 235	
– each colour-difference signal (1)	225 quantization levels in the centre part of the quantization scale with zero signal corresponding to level 128	

(1) If used.

ANNEX II

DEFINITION OF SIGNALS USED IN THE DIGITAL CODING STANDARDS

1. Relationship of digital active line to analogue sync. reference

The relationship between 720 digital active line luminance samples and the analogue synchronizing references for 625-line and 525-line systems is shown below.

TABLE III

525-line, 60 field/s systems	122 T	720 T	16 T	
0_H (leading edge of line syncs., half-amplitude reference)		Digital active-line period	0_H	Next line
625-line, 50 field/s systems	132 T	720 T	12 T	

T: one luminance sampling clock period (74 ns nominal).

The respective numbers of colour-difference samples can be obtained by dividing the number of luminance samples by two. The (12, 132) and (16, 122) were chosen symmetrically to dispose the digital active line about the permitted variations. They do not form part of the digital line specification and relate only to the analogue interface.

2. Definition of the digital signals Y, C_R, C_B, from the primary (analogue) signals E'_R, E'_G and E'_B

This section describes, with a view to defining the signals Y, C_R, C_B, the rules for construction of these signals from the primary analogue signals E'_R, E'_G and E'_B. The signals are constructed by following the three stages described in § 2.1, 2.2 and 2.3 below. The method is given as an example, and in practice other methods of construction from these primary signals or other analogue or digital signals may produce identical results. An example is given in § 2.4.

2.1 *Construction of luminance (E'_Y) and colour-difference ($E'_R - E'_Y$) and ($E'_B - E'_Y$) signals*

The construction of luminance and colour-difference signals is as follows:

$$E'_Y = 0.299 E'_R + 0.587 E'_G + 0.114 E'_B \qquad \text{(See Note)}$$

whence:

$$\begin{aligned}(E'_R - E'_Y) &= E'_R - 0.299 E'_R - 0.587 E'_G - 0.114 E'_B \\ &= 0.701 E'_R - 0.587 E'_G - 0.114 E'_B\end{aligned}$$

and:

$$\begin{aligned}(E'_B - E'_Y) &= E'_B - 0.299 E'_R - 0.587 E'_G - 0.114 E'_B \\ &= -0.299 E'_R - 0.587 E'_G + 0.886 E'_B\end{aligned}$$

Note. – Report 624 Table II refers.

Taking the signal values as normalized to unity (e.g., 1.0 V maximum levels), the values obtained for white, black and the saturated primary and complementary colours are as follows:

TABLE IV

Condition	E'_R	E'_G	E'_B	E'_Y	$E'_R - E'_Y$	$E'_B - E'_Y$
White	1.0	1.0	1.0	1.0	0	0
Black	0	0	0	0	0	0
Red	1.0	0	0	0.299	0.701	−0.299
Green	0	1.0	0	0.587	−0.587	−0.587
Blue	0	0	1.0	0.114	−0.114	0.886
Yellow	1.0	1.0	0	0.886	0.114	−0.886
Cyan	0	1.0	1.0	0.701	−0.701	0.299
Magenta	1.0	0	1.0	0.413	0.587	0.587

2.2 *Construction of re-normalized colour-difference signals (E'_{C_R} and E'_{C_B})*

Whilst the values for E'_Y have a range of 1.0 to 0, those for $(E'_R - E'_Y)$ have a range of +0.701 to −0.701 and for $(E'_B - E'_Y)$ a range of +0.886 to −0.886. To restore the signal excursion of the colour-difference signals to unity (i.e. +0.5 to −0.5), coefficients can be calculated as follows:

$$K_R = \frac{0.5}{0.701} = 0.713; \; K_B = \frac{0.5}{0.886} = 0.564$$

Then:

$$E'_{C_R} = 0.713\,(E'_R - E'_Y) = 0.500\,E'_R - 0.419\,E'_G - 0.081\,E'_B$$

and:

$$E'_{C_B} = 0.564\,(E'_B - E'_Y) = -0.169\,E'_R - 0.331\,E'_G + 0.500\,E'_B$$

where E'_{C_R} and E'_{C_B} are the re-normalized red and blue colour-difference signals respectively (see Notes 1 and 2).

Note 1 – The symbols E'_{C_R} and E'_{C_B} will be used only to designate re-normalized colour-difference signals, i.e. having the same nominal peak-to-peak amplitude as the luminance signal E'_Y, thus selected as the reference amplitude.

Note 2 – In the circumstances when the component signals are not normalized to a range of 1 to 0, for example, when converting from analogue component signals with unequal luminance and colour-difference amplitudes, an additional gain factor will be necessary and the gain factors K_R, K_B should be modified accordingly.

2.3 *Quantization*

In the case of a uniformly-quantized 8-bit binary encoding, 2^8, i.e. 256, equally spaced quantization levels are specified, so that the range of the binary numbers available is from 0000 0000 to 1111 1111 (00 to FF in hexadecimal notation), the equivalent decimal numbers being 0 to 255, inclusive.

In the case of the 4 : 2 : 2 system described in this Recommendation, levels 0 and 255 are reserved for synchronization data, while levels 1 to 254 are available for video.

Given that the luminance signal is to occupy only 220 levels, to provide working margins, and that black is to be at level 16, the decimal value of the luminance signal, $\overline{Y}$, prior to quantization, is:

$$\overline{Y} = 219\,(E'_Y) + 16,$$

and the corresponding level number after quantization is the nearest integer value.

Similarly, given that the colour-difference signals are to occupy 225 levels and that the zero level is to be level 128, the decimal values of the colour-difference signals, $\overline{C}_R$ and $\overline{C}_B$, prior to quantization are:

$$\overline{C}_R = 224\,[0.713\,(E'_R - E'_Y)] + 128$$

and:

$$\overline{C}_B = 224\,[0.564\,(E'_B - E'_Y)] + 128$$

which simplify to the following:

$$\overline{C}_R = 160\,(E'_R - E'_Y)] + 128$$

and:

$$\overline{C}_B = 126\,(E'_S - E'_Y)] + 128$$

and the corresponding level number, after quantization, is the nearest integer value.

The digital equivalents are termed Y, C_R and C_B.

2.4 *Construction of Y, C_R, C_B via quantization of E'_R, E'_G, E'_B*

In the case where the components are derived directly from the gamma pre-corrected component signals E'_R, E'_G, E'_B, or directly generated in digital form, then the quantization and encoding shall be equivalent to:

$$E'_{R_D} \text{ (in digital form)} = \text{int}\,(219\;E'_R) + 16$$

$$E'_{G_D} \text{ (in digital form)} = \text{int}\,(219\;E'_G) + 16$$

$$E'_{B_D} \text{ (in digital form)} = \text{int}\,(219\;E'_B) + 16$$

Then:

$$Y = \frac{77}{256}\,E'_{R_D} + \frac{150}{256}\,E'_{G_D} + \frac{29}{256}\,E'_{B_D}$$

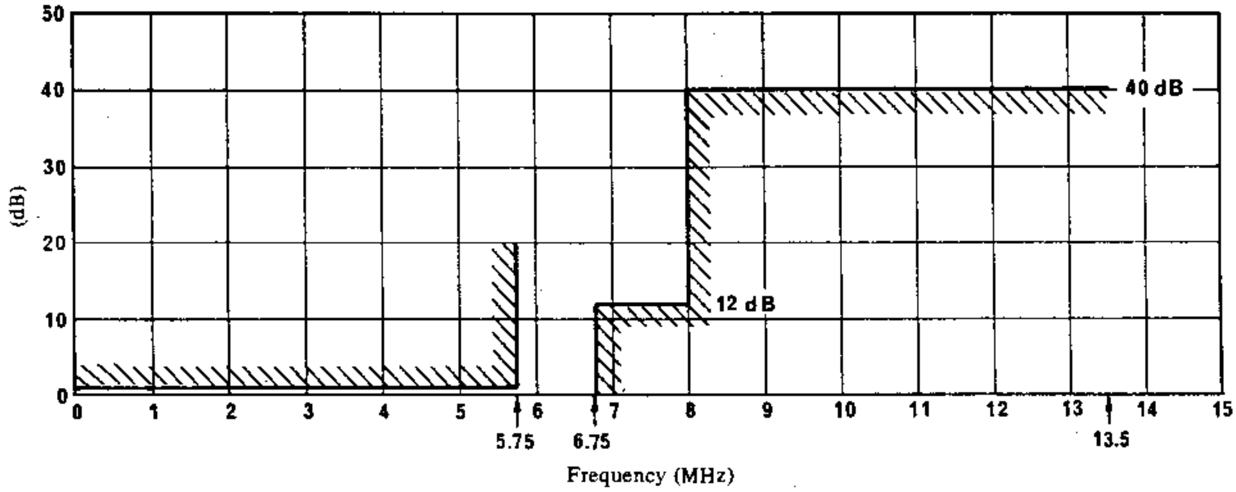
$$C_R = \frac{131}{256}\,E'_{R_D} - \frac{110}{256}\,E'_{G_D} - \frac{21}{256}\,E'_{B_D} + 128$$

$$C_B = -\frac{44}{256}\,E'_{R_D} - \frac{87}{256}\,E'_{G_D} + \frac{131}{256}\,E'_{B_D} + 128$$

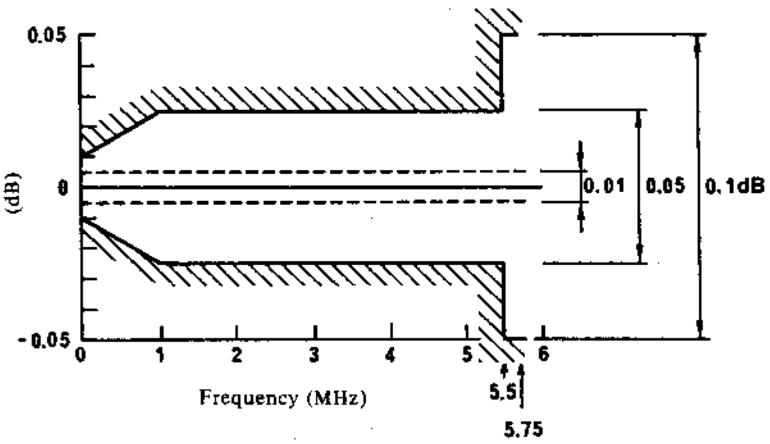
taking the nearest integer coefficients, base 256. To obtain the 4 : 2 : 2 components Y, C_R, C_B, low-pass filtering and sub-sampling must be performed on the 4 : 4 : 4 C_R, C_B signals described above. Note should be taken that slight differences could exist between C_R, C_B components derived in this way and those derived by analogue filtering prior to sampling.

ANNEX III

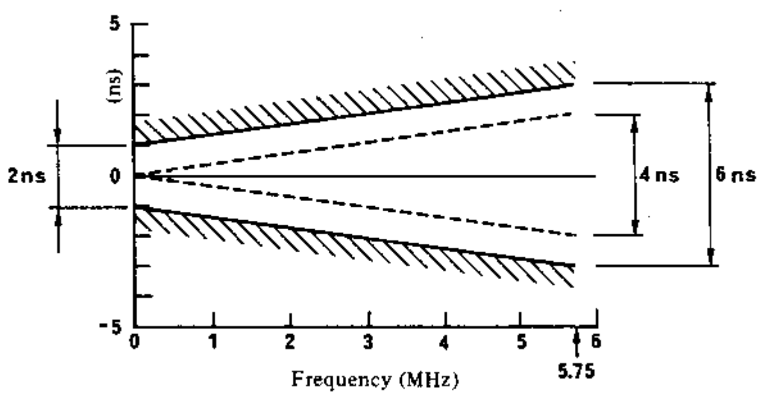
FILTERING CHARACTERISTICS



a) Template for insertion loss/frequency characteristic



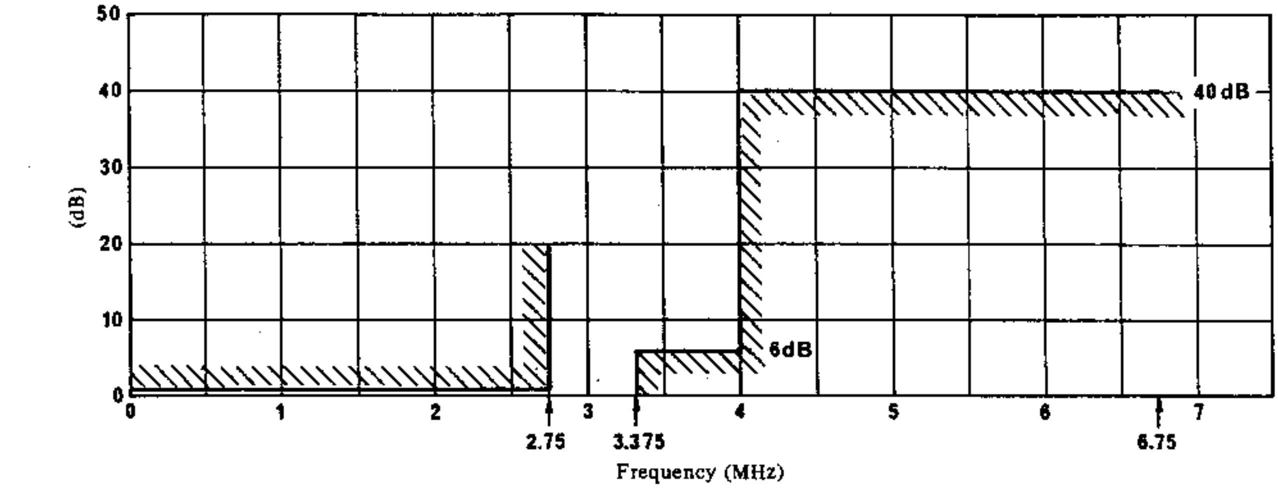
b) Passband ripple tolerance



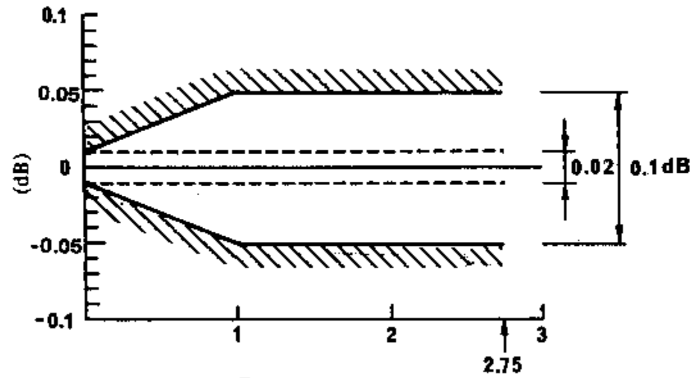
c) Passband group-delay tolerance

FIGURE 1 – *Specification for a luminance or RGB signal filter used when sampling at 13.5 MHz*

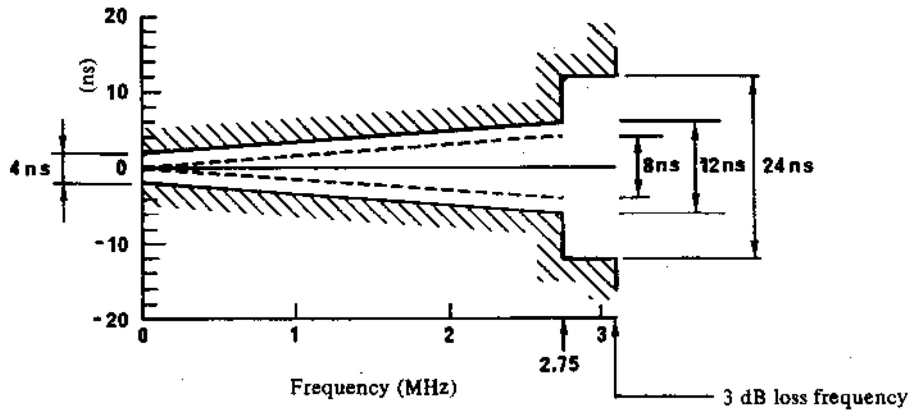
Note – The lowest indicated values in *b)* and *c)* are for 1 kHz (instead of 0 MHz).



a) Template for insertion loss/frequency characteristic



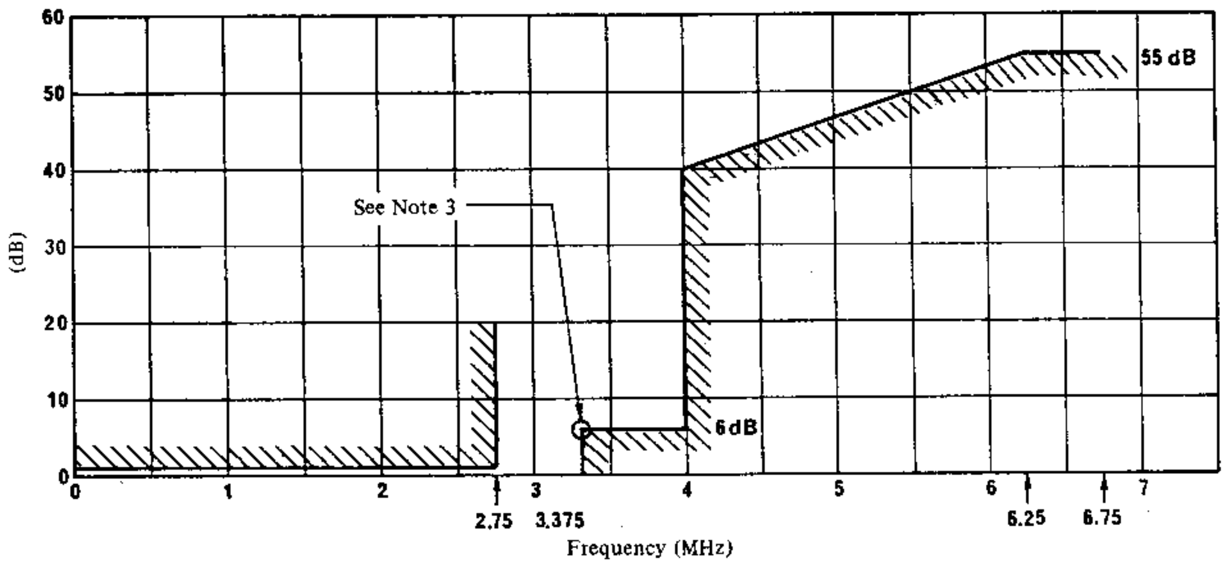
b) Passband ripple tolerance



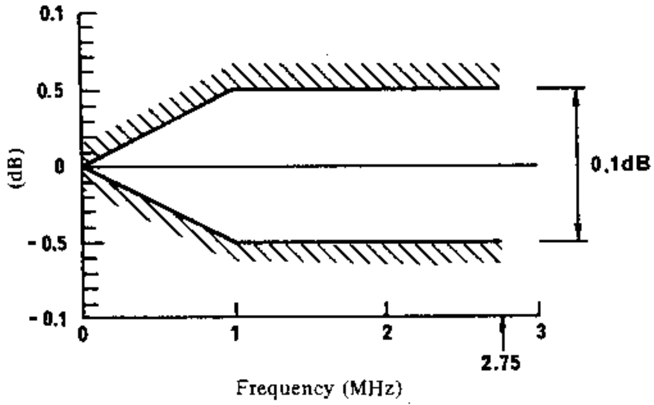
c) Passband group-delay tolerance

FIGURE 2 – *Specification for a colour-difference signal filter used when sampling at 6.75 MHz*

Note – The lowest indicated values in *b)* and *c)* are for 1 kHz (instead of 0 MHz).



a) Template for insertion loss/frequency characteristic



b) Passband ripple tolerance

FIGURE 3 – *Specification for a digital filter for sampling-rate conversion from 4 : 4 : 4 to 4 : 2 : 2 colour-difference signals*

Notes to Figs. 1, 2 and 3:

Note 1 – Ripple and group delay are specified relative to their values at 1 kHz. The full lines are practical limits and the dashed lines give suggested limits for the theoretical design.

Note 2 – In the digital filter, the practical and design limits are the same. The delay distortion is zero, by design.

Note 3 – In the digital filter (Fig. 3), the amplitude/frequency characteristic (on linear scales) should be skew-symmetrical about the half-amplitude point, which is indicated on the figure.

Note 4 – 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 of the sample-and-hold circuits is provided.