

International Telecommunication Union

ITU-R
Radiocommunication Sector of ITU

Report ITU-R BT.1088-2
(11/2009)

**Interfaces for digital video signals
in 525-line and 625-line
television systems**

BT Series
Broadcasting service
(television)



International
Telecommunication
Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

Note: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2010

© ITU 2010

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

REPORT ITU-R BT.1088-2

Interfaces for digital video signals in 525-line and 625-line television systems

(1986-1990-2009)

Preface**Introduction/purpose**

Readers of this Report should be aware that the text in this Report is the original text generated during the development of the SDTV digital interfaces. It has been retained as an historic record of the digital interface development. Many of the concepts and technical parameters developed during the 1982 to 1986 time-frame have changed, readers are advised to consult the latest ITU-R Recommendations before implementing digital interfaces.

Reference is made to the International Radio Consultative Committee (CCIR), the year 1920 saw the beginning of sound broadcasting at the improvised studios of the Marconi Company, and in 1927, the CCIR was established at a conference held in Washington D.C. The International Telephone Consultative Committee (CCIF, set up in 1924), the International Telegraph Consultative Committee (CCIT, set up in 1925) and the CCIR were made responsible for coordinating the technical studies, tests and measurements being carried out in the various fields of telecommunications, as well as for drawing up international standards. In 1989 the CCIR was reorganized into the International Telecommunication Union (ITU), over time, the Union was streamlined into three Sectors, corresponding to its three main areas of activity: Telecommunication Standardization (ITU-T), Radiocommunication (ITU-R) and Telecommunication Development (ITU-D).

Today the ITU-R has the responsibility for broadcasting services.

The broadcasting and related industries depend 100% on the interfaces and their derivatives that were proposed back pre-1986. In 1986 in Houston Texas the first digital serial interface as we know it today was demonstrated at a trade show, since that time the serial interface which originally ran at 270 Mbit/s (an interim interface ran at 243 Mbit/s, this interface had only very limited use) has been extended to 3 Gbit/s. The serial interface has also been adapted to carry almost any data signal in addition to the uncompressed video signals that was the original intent. Further treatment of the characteristics of the serial interfaces as implemented can be found in EBU Tech. 3283.

The following text is presented as an historic record of the digital interface development, along with a copy of the original Recommendations CCIR 601 and 656. The original Recommendation CCIR 656 was never implemented on a widespread basis as it was constrained to 8-bit operation. A later version, Recommendation ITU-R BT.656-2 replaced the 8/9 code mapping with scrambled NRZ coding. It is the scrambled NRZ version of the serial digital interface that found very widespread implementation. The original Recommendation CCIR 601 was originally called CCIR-AA/11 and was approved in 1982. The attached Recommendation CCIR 601-1 has been restored using the original text along with any errors that may have been in this text.

1 Introduction

Recommendation CCIR 656 specifies interfaces for digital studio equipment, in conformity with the basic parameter values contained in Recommendation CCIR 601.

This Report summarizes the contributions received on digital video interfaces which provided the basis for Recommendation CCIR 656, it includes supplementary information on the subject, and indicates areas in which further studies are required.

2 Definitions

Interface is a concept involving the specification of the interconnection between two items of equipment or systems. The specification includes the type, quantity and function of the interconnection circuits and the type and form of the signals to be interchanged by these circuits:

- a parallel interface is an interface in which the bits of a data word are sent simultaneously via separate channels;
- a serial interface is an interface in which the bits of a data word, and successive data words, are sent consecutively via a single channel. A parallel-serial (hybrid) interface is an interface in which portions of a data word are sent consecutively via separate channels.

3 Primary encoding format

There are features of the basic data organization which are common to the three types of interface defined above and which are the subject of Part I of Recommendation CCIR 656. They comprise: the organization of the video data into words and blocks; the timing reference codes providing video synchronization; ancillary data signal structure; data signals during blanking intervals; details of the multiplexing.

3.1 Blanking and synchronization considerations

[CCIR, 1982-86a, b, and c] agreed on the form and use of timing reference signals. Each timing reference signal consists of a four-word sequence. The first three words are a fixed preamble. The fourth word contains information defining:

- first or second field identification;
- state of field blanking;
- state of line blanking;
- error protection data.

[CCIR, 1982-86d] proposed that only one timing reference signal should be used, located at the end of each line-blanking period. This identification signal includes a clock burst (for a bit-serial interface), indication of the initial point of the data frame, field-blanking period and first and second field periods. End-of-line information will be obtained by counting clock pulses.

The EBU [CCIR, 1982-86e] suggested that additional codes be included in the data stream and that the beginning and end of the digital active line will be identified in the de-multiplexed Y , C_R , C_B data streams. It further proposed that these codes be included at the 4:4:4 level for both Y , C_R , C_B and R , G , B signals in digital form.

[CCIR, 1982-86f] stated that the timing reference (digital synchronization) codes inserted into the parallel code should be easily usable in a serial code.

Proposals for 525-line and 625-line differ in their definition of digital field-blanking intervals. [CCIR, 1982-86b, c, and d] stated that only 9 lines in both fields 1 and 2 belong to the field-blanking interval. [CCIR, 1982-86a and f] specify the digital field-blanking interval of 24 lines (field 1) and 25 lines (field 2). It may be advisable to shorten the digital field-blanking interval so as to allow for complex vertical filtering, though this problem needs further study.

Amongst other considerations [CCIR, 1982-86g] drew attention to the fact that “timing reference signals” should be referred to as “timing reference codes”.

In those data words occurring during digital blanking intervals that are otherwise unspecified, the OIRT [CCIR, 1982-86e] proposed that the digital codes equivalent to blanking level for Y , C_R , C_B be included in the appropriate locations in the multiplex.

3.2 Ancillary signals

Provision is made for ancillary data signals to be inserted synchronously into the video multiplex during both horizontal and vertical blanking intervals. It is noted that digital video tape recorders (see Recommendation CCIR 657) do not record any of the horizontal blanking intervals or some lines in the vertical blanking intervals. For that reason the EBU has allocated only four vertical blanking lines for ancillary signals. The unrecordable blanking periods can be used to transfer data between other studio equipment if required.

[CCIR, 1982-86 d and f] contain some details of the ancillary signals. [CCIR, 1982-86a, band c] propose the ancillary data signal format.

Time-code *is* an essential ancillary signal for control of post-production processes and the synchronization of video and audio. Four formats are currently recognised, IEC format [IEC Pub. 461] in the vertical interval and longitudinal forms, audio time code in accordance with Recommendation CCIR 647 and time code associated with the R-DAT audio recording format.

Ancillary data formats to include this information in the vertical interval are a current study in a number of Administrations and offer possibilities to maintain the synchronism of video and audio through various processes [CCIR, 1986-1990a).

Recommendation CCIR 656 specifies only a timing reference code ANC; the data field following the ANC is left unspecified. There have been discussions about various packet formats for the ancillary data.

Some information with higher priority and predetermined format might have a fixed data packet length and probably also a fixed time slot in the data stream. Less important ancillary data not having a predetermined format might have variable packet length.

[CCIR 1986-1990b] mentions digital line numbers as possibly useful information which should be considered as an ancillary signal. The document contains a proposal for two modes of digital line numbering. In addition one method for introduction of respective code words into the video data is proposed.

The study of the requirements for sound signals is included in Decision 60 to ensure that any possible effects upon the associated sound signals caused by the video interface parameters will be duly considered. Except for the need to control the relative delay between the video and the sound, no such effects have been identified.

4 Parallel interfaces

A number of proposals [CCIR, 1982-86a, b, c, d and f] suggested using eight conductor pairs, where each should carry, in NRZ format, a multiplex stream of bits (of the same significance) of each of the component signals, namely, Y , C_R , C_B . The eight' pairs should also carry timing reference information and may carry ancillary signals that are time-multiplexed into the data stream during video blanking intervals. A ninth pair would provide a synchronous clock at 27 MHz. These proposals, with [CCIR, 1982-86e], contributed to the preparation of Recommendation CCIR 656 (see also [EBU, 1983]).

The signals on the interface may be transmitted using balanced conductor pairs for a distance of up to 50 m without equalization and up to 200 m with appropriate equalization [CCIR, 1982-86a].

Appropriate coding of the clock signal, such as the use of an alternating parity (AP) coding, has been shown to extend this distance by reducing the effects of cable attenuation [CCIR, 1982-86h].

5 Serial interfaces

[CCIR, 1982-86d] gives an example of a data sequence using 216 Mbit/s multiplexing. Particular attention is paid to ease of clock extraction and word synchronization by the inclusion of words within the data stream which generate clock bursts.

[CCIR, 1982-86f] refers to channel coding and states that transmission should be effected via 75 Ω coaxial cables for distances up to 1 km.

[CCIR, 1982-86e] contains a detailed consideration of the special requirements for a serial interface and proposes in Annex I a draft Recommendation for a bit-serial interface for the 4:2:2 level of Recommendation CCIR 601. This contributed to the preparation of Recommendation CCIR 656 (see also [EBU, 1985]).

In [CCIR, 1982-86e] the transmission of signals is considered in both electrical form, using coaxial cable, and in optical form using an optical fibre. The special requirements for bit-serial signal transmission between studios, or between equipments in a studio are given as:

- low cost and low complexity coupled with high reliability;
- very low intrinsic error rate in the transmission due to the very short distances;
- multiple outputs for monitoring and distribution;
- rapid recovery from errors introduced by switching of the transmission path, the video source or signal interruptions;
- full compatibility with the format of the bit-parallel interface and signal code commonality of both electrical and optical implementations of the bit-serial interface;
- usable over a range of distances from zero to at least 500 m, with a minimum of adjustments and extremely low error rates;
- applicable to a range of cable types.

These requirements are confirmed in [CCIR, 1982-86i], which also points out that in the implementation of a digital video installation, preference would normally be given to the parallel interface for short connection lengths and that recourse would be made to the serial interface mainly in the case of long or complex connection paths, where the cost of the interface terminal equipment would not override the saving in the physical support of the connection itself. Coaxial cables would probably be preferred for connections of medium length, while preference would go to optical fibres for very long connection lengths.

This contribution also suggests that the code used should be structured so as to permit the redundant bits to be employed to implement a system for measuring the BER at the receiving end of the connection and thus automatically monitoring its performance.

It further suggests that in a fully integrated digital installation or system it may be useful for all interconnections to be transparent to any appropriate digital stream, irrespective of the message content. Thus, although the interface will be used to transmit a video signal, it should be “transparent” to the message content, i.e. it should not base its operation on the known structure of the message itself.

(CCIR, 1982-86e) reviews the characteristics of transmission media, including interference susceptibility and describes the proposals received for source encoding, channel encoding and error management.

Two methods of source encoding have been proposed. (CCIR, 1982-86j) suggests the use of a parallel scrambler with the addition of a parity bit for synchronization and limited error detection purposes. According to a preliminary investigation, it appears that the sending end, at least, of such an interface could be integrated in a single gate-array chip.

A second method (CCIR, 1982-86e) providing spectrum control, clock and word synchronization by an 8-bit to 9-bit adaptive mapped code, is adopted in Recommendation CCIR 656.

In relation to these methods of source encoding, two different approaches to channel encoding have been proposed. In the scrambled system the channel coding is the AMI (Alternate mark inversion) for coaxial cable, and NRZ for optical fibre. The AMI code restricts the required bandwidth. In the bit-mapped system the encoded bit-stream, in NRZ format, is suitable for feeding both transmission media.

The bit-parallel interface defined in Recommendation CCIR 656 includes the possible addition of two bits to each word, thus enhancing the accuracy of the sample from 8 bits to 10 bits. In some applications, such as computer graphics, this improvement has been found advantageous. In the case of the serial interface of Recommendation CCIR 656, this extension is not feasible, thus limiting the application of the serial interface in both its electrical and optical forms. Certain Administrations are studying methods to convey a 10-bit word length in the serial interface, based on scrambled NRZ coding techniques.

6 Parallel-serial (hybrid) interfaces

[CCIR, 1982-86d and f] also discuss an alternative solution in which signals are divided into multiple channels of 108 Mbit/s each in order to reduce the bit rate per channel. This method also enables various members of the extensible family of compatible coding standards to be accommodated within a multi-channel arrangement. However, as stated in (CCIR, 1982-86k], the main advantage advocated for the hybrid interface is that it reduces the bit rate sent on each of the parallel cables, but if 2 parallel cables are used, which is the most frequent proposal, then the bit rate is halved but the new bit rate is still too high to be implemented by means of much cheaper technologies.

On the other hand, the use of a hybrid interface involves complications at the sending and receiving ends, where circuits are needed to multiplex and demultiplex the bit stream, and also to phase the bit streams received on the cables.

These complications, and the cost of the additional cable (or cables) in the hybrid interface, appear overwhelmingly to militate in favour of a fully serial interface, rather than a hybrid interface, in those cases when the parallel interface cannot be used.

7 Optical interfaces

Work has been reported concerning the optimum characteristics of an optical fibre interface for use in the studio, [CCIR, 1986c, d, e]. The use of a single-mode fibre driven by a laser or LED at a wavelength of approximately 1300 nm is suggested. Appendix 1 contains a draft text, as yet incomplete, to form the content of § 7 of Recommendation CCIR 656. Administrations are invited to make studies and contributions to complete this section in the current study period.

[CCIR, 1986-90f] describes a new approach to the switching and routing of digital signals by optical means within a large studio centre. An arrangement is suggested in which the central routing switcher is eliminated by conveying all of the signals to every destination along a single optical fibre. The signals are assembled by a combination of time-division multiplexing (TDM) to a bit rate of the order of 2 Gbit/s, and optical wavelength-division multiplexing. The use of TDM means that the system is applicable to a wide range of bit rates including those required for digital HDTV. If this approach proves successful, appropriate interface specifications will be required. Document [CCIR, 1986-90g] described a method, applicable also to HDTV systems, for the transmission of three analogue wideband (up to 60 MHz) signals (R, G, B) through three optical fibres. The method used consists of the linearization of the characteristics of the optical device. The same document details the advantages of serial digital optical transmission at 1.15 Gbit/s for HDTV on a single fibre.

8 Practical implementation of interfaces

[Grimaldi *et al*, 1986] describes the all-digital studio in final implementation in France. Although some functions are still analogue (e.g. cameras) the system uses a large number of pieces of digital equipment, in particular a mixer/switcher, video tape recorders and miscellaneous other functions. This equipment is connected by coaxial cables using the serial interface of Recommendation CCIR 656, with some minor differences due to the early implementation. An optical link using the same signal format is operative over 6 km. A discussion of the solutions adopted is included.

[Baraclough *et al*, 1987] provides information on practical experience in the design, installation and operation of an experimental digital television production centre in the United Kingdom employing the parallel interface of Recommendation CCIR 656. The solutions adopted for problems encountered are given, including, for example, those associated with multiple equipment interconnections, synchronization and timing.

Further contributions on this subject are invited.

9 Interference with other services

Processing and transmission of digital data, such as digital video signals, at high data rates produces a wide spectrum of energy that has the potential to cause cross-talk or interference. In particular, attention is drawn in Recommendation CCIR 656 to the fact that the ninth and eighteenth harmonics of the 13.5 MHz sampling frequency (nominal value) specified in Recommendation CCIR 601 fall at the 121.5 and 243 MHz aeronautical emergency channels. Appropriate precautions must therefore be taken in the design and operation of interfaces to ensure that no interference is caused at these frequencies. Permitted maximum levels of radiated signals from digital data processing equipment are the subject of various national and international standards, and it should be noted that emission levels for such related equipment are given in CISPR Recommendation: "Information technology equipment -Limits of interference and measuring methods" Document CISPR/B (Central Office) 16.

In the case of the bit- parallel interface [CCIR, 1982-861] states that according to studies and experiments effected at the Canadian Broadcasting Corporation (CBC), with a correct shielding of the cables, no interference problem with other services is to be expected. This contribution recommends that radiation levels should comply with the limits given in Table I [CSA, 1983]. These limits are equivalent to those of the FCC in the United States of America.

TABLE 1

Limits of spurious emissions (CSA Class A)

Frequency (MHz)	Maximum field strength (dB(μV/m)) at 30 m
30-88	30
88-216	50
216-1 000	70

In relation to the bit serial interface [CCIR, 1982-86e] states that transmission by optical fibres eliminates radiation generated by the cable and also prevents conducted common-mode radiation, but the performance of coaxial cable can also be made near-perfect. It is believed that the major portion of any radiation would be from the processing logic and high-power drivers common to both methods. It adds that due to the wideband, random nature of the digital signal, little is gained by frequency optimization.

NOTE 1 – See Report ITU-R BT.1209.

10 Further studies

Further studies are required:

- on interfaces for the 4:4:4 level, and for lower members of the family of digital coding standards;
- to establish the types of ancillary signals to be carried, including their characterization and location in the data stream, and to propose international standards as necessary;
- to determine what special provisions may be necessary in relation to the associated sound channels, for example, to avoid excessive relative time delays;
- on the practical methods required to ensure acceptably low levels of radiated interference from the digital signals;
- on optical interfaces for bit-serial signals.

References

- BARACLOUGH, J.N., DALTON, C.J. and GREEN, N.W. [1987] Experience with an experimental digital production centre, IEE colloquium Digest 1987/11, p. 13/1-13/6.
- CSA [1983] Electromagnetic emissions from data processing equipment and electronic office machines: limits and methods C-108.8-M1983 - ISSN 0317-5669, Canadian Standards Association.
- EBU [1983] EBU parallel interface for 625-line digital video signals. Tech. Document 3246.
- EBU [1985] EBU serial interface for 625-line digital video signal. Tech. Document 3247.
- GRIMALDI, J.L., NASSE, D. and CAYET, A. [1986] An experimental all-digital television centre, J.S.M.P.T.E., Vol. 95 No. 1, Pt. 1, p. 13-19.

CCIR Documents

[1982.86]: a. 11/126 (EBU); b. 11/61 (United States of America); c. 11/94 (Canada); d. 11/24 (Japan); e. 11/291 (IWP11/7); f. 11/136 (OIRT); g. It/336 (Italy); h. 11/347 (Italy); i. 11/335 (Italy); j. 11/356 (Italy); k. 11/354 (Italy); l. 11/385 (Canada).

[1986-90]: a. IWP 11/7-257 (Australia); b. IWP 11/7-186 (OIRT); c. IWP 11/7-115 (United Kingdom); d. 11/112 (Canada); e. 11/124 (Canada); f. IWP 11/7-141 (United Kingdom); g. 11/28 (Thomson-CSF).

Bibliography

STICKLER, M.J., NASSE, D. and BRADSHAW, D. [August, 1984] The EBU bit-serial interface for 625-line digital video signals. *EBU Rev. Tech.*, 212, 181-187.

Appendix 1

Proposed draft additions to Recommendation CCIR 656 concerning an optical interface

7 Characteristics of the optical interface

7.1 Source characteristics

7.1.1 Output wavelength

1300 nm nominal

Maximum spectral line width 150 nm between half power points.

7.1.2 Output power

Maximum 0 dBm

Minimum -25 dBm

7.1.3 Logic convention

Maximum power output corresponds to the signalling of a logical 1.

7.1.4 Rise and fall times

To be decided.

7.1.5 Jitter

To be decided.

7.1.6 Isolation

Transmitter must withstand 10% of its output power returned by reflection.

7.2 Optical fibre link

FIBRE (compatible with optical fibre specified in CCITT Recommendation G.652)

Fibre type	–	single mode
Dimensions: mode field dia.	–	9-10 μm +1-10%
cladding	–	125 μm
Operating window	–	around 1 300 nm
Mode field concentricity	–	< 3 μm
Cladding non circularity	–	< 2%
Cut-off wave length	–	1 100-1 280 nm
Attenuation at 1 300 nm	–	< 1 dB/km
Max. dispersion (1 270-1 340 nm)	–	6 ps/nm.km
CONNECTOR		
Type	–	biconical

7.3 Destination characteristics

7.3.1 Sensitivity

Input power for a mean bit error rate of 1 in 10^9 –35 dBm.

Maximum input power –20 dBm.

7.3.2 Maximum input power

Receiver shall operate with a mean bit-error rate better than 1 in 10^9 up to a power level of –20 dBm.

Attachment 1

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

RECOMMENDATION 656

INTERFACES FOR DIGITAL COMPONENT VIDEO SIGNALS
IN 525-LINE AND 625-LINE TELEVISION SYSTEMS

(1986)

The CCIR,

CONSIDERING

- a. that there are clear advantages for television broadcasting organizations 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 to implement the above objectives, agreement has been reached on the fundamental encoding parameters of digital television for studios in the form of Recommendation 601;
- d. that the practical implementation of Recommendation 601 requires definition of details of interfaces and the data streams traversing them;
- e. that such interfaces should have a maximum of commonality between 525-line and 625-line versions;
- f. that in the practical implementation of Recommendation 601 it is desirable that interfaces be defined in both serial and parallel forms;
- g. that digital television signals produced by these interfaces may be a potential source of interference to other services, and due notice must be taken of No. 964 of the Radio Regulations,

UNANIMOUSLY RECOMMENDS

that where interfaces are required for component-coded digital video signals in television studios, the interfaces and the data streams that will traverse them should be in accordance with the following description, defining both bit-parallel and bit-serial implementations.

1. Introduction

This Recommendation describes the means of interconnecting digital television equipment operating on the 525-line or 625-line standards and complying with the 4 : 2 : 2 encoding parameters as defined in Recommendation 601.

Part I describes the signal format common to both interfaces.

Part II describes the particular characteristics of the bit-parallel interface.

Part III describes the particular characteristics of the bit-serial interface.

PART I

COMMON SIGNAL FORMAT OF THE INTERFACES

1. General description of the interfaces

The interfaces provide a unidirectional interconnection between a single source and a single destination.

A signal format common to both parallel and serial interfaces is described in § 2 below.

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

The data signal are in the form of binary information coded in 8-bit words. These signals are:

- video data;
- timing reference codes;
- ancillary data;
- identification codes.

2. Video data

2.1 Coding characteristics

The video data is in compliance with Recommendation 601, and with the field-blanking definition shown in Table 1.

TABLE I — Field interval definitions

		625	525
V-digital field blanking			
Field 1	Start (V = 1)	Line 624	Line 1
	Finish (V = 0)	Line 23	Line 10
Field 2	Start (V = 1)	Line 311	Line 264
	Finish (V = 0)	Line 336	Line 273
F-digital field identification			
Field 1	F = 0	Line 1	Line 4
Field 2	F = 1	Line 313	Line 266

Note 1 — Signals F and V change state synchronously with the end of active video timing reference code at the beginning of the digital line.

Note 2 — Definition of line numbers is to be found in Report 624. Note that digital line number changes state prior to 0_H as shown in Fig. 1.

2.2 Video data format

The data words 0 and 255 (00 and FF in hexadecimal notation) are reserved for data identification purposes and consequently only 254 of the possible 256 words may be used to express a signal value.

The video data words are conveyed as a 27 Mwords/s multiplex in the following order:

$$C_B, Y, C_R, Y, C_B, Y, C_R, \text{ etc.}$$

where the word sequence C_B, Y, C_R , refers to co-sited luminance and colour-difference samples and the following word, Y, corresponds to the next luminance sample.

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

2.3 Timing relationship between video data and the analogue synchronizing waveform

2.3.1 Line interval

The digital active line begins at 244 words (in the 525-line standard) or at 264 words (in the 625-line standard) after the leading edge of the analogue line synchronization pulse, this time being specified between half-amplitude points.

Figure 1 shows the timing relationship between video and the analogue line synchronization.

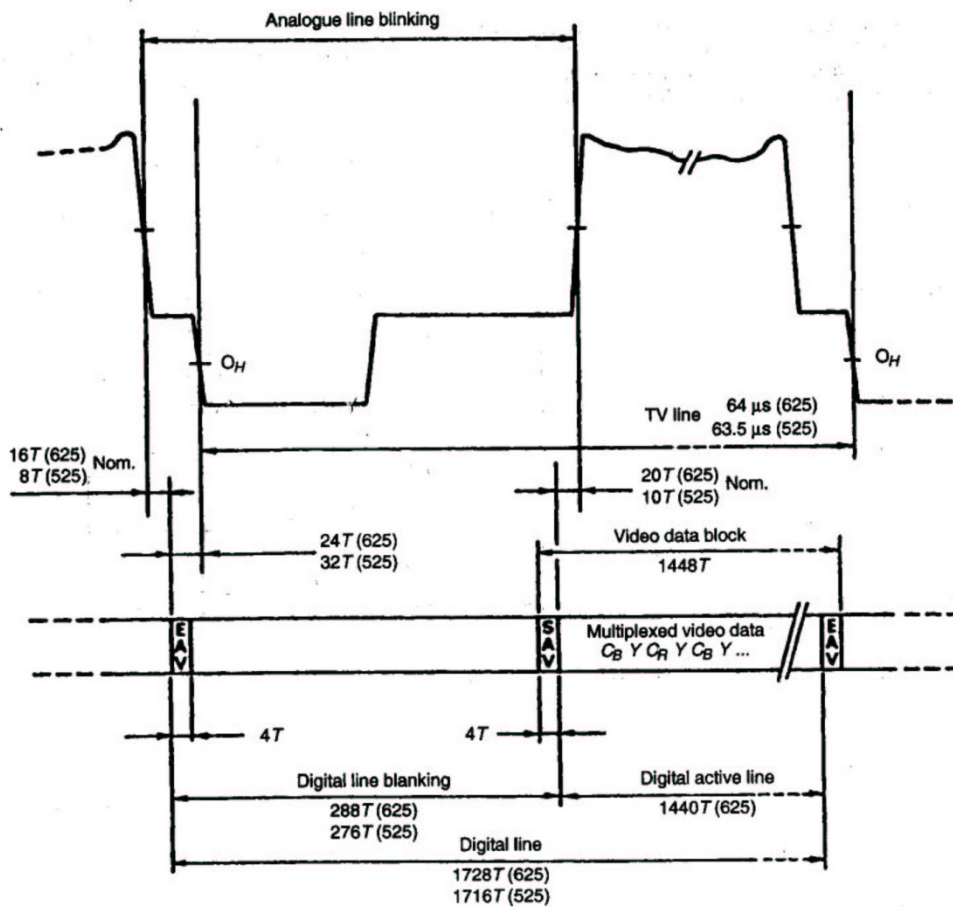


FIGURE 1 – Data format and timing relationship with the analogue video signal

T: clock period 37 ns nom.
 SAV: start of active video timing reference code
 EAV: end of active video timing reference code

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

2.3.2 *Field interval*

The start of the digital field is fixed by the position specified for the start of the digital line: the digital field starts 32 words (in the 525-line systems) and 24 words (in the 625-line systems) prior to the lines indicated in Table I.

2.4 *Video timing reference codes (SAV, EAV)*

There are two timing reference codes, one at the beginning of each video data block (Start of Active Video, SAV) and one at the end of each video data block (End of Active Video, EAV) as shown in Fig. 1.

Each timing reference code consists of a four word sequence in the following format: FF 00 00 XY. (Values are expressed in hexadecimal notation. Codes FF, 00 are reserved for use in timing reference codes.) The first three words are a fixed preamble. The fourth word contains information defining field 2 identification, the state of field blanking, and the state of line blanking. The assignment of bits within the timing reference code is shown below in Table II.

TABLE II — *Video timing reference codes*

Word	Bit No.							
	7 (MSB)	6	5	4	3	2	1	0 (MSB)
First	1	1	1	1	1	1	1	1
Second	0	0	0	0	0	0	0	0
Third	0	0	0	0	0	0	0	0
Fourth	1	F	V	H	P ₃	P ₂	P ₁	P ₀

F = 0 during field 1
1 during field 2

V = 0 elsewhere
1 during field blanking

H = 0 in SAV
1 in EAV

P₀, P₁, P₂, P₃: protection bits (see Table III).

MSB: most significant bit

LSB: least significant bit

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

Table I defines the state of the V and F bits.

Bits P_0 , P_1 , P_2 , P_3 , have states dependent on the states of the bits F, V and H as shown in Table III. At the receiver this arrangement permits one-bit errors to be corrected and two-bit errors to be detected.

TABLE III — Protection bits

Bit No.	7	6	5	4	3	2	1	0
Function	Fixed 1	F	V	H	P_3	P_2	P_1	P_0
0	1	0	0	0	0	0	0	0
1	1	0	0	1	1	1	0	1
2	1	0	1	0	1	0	1	1
3	1	0	1	1	0	1	1	0
4	1	1	0	0	0	1	1	1
5	1	1	0	1	1	0	1	0
6	1	1	1	0	1	1	0	0
7	1	1	1	1	0	0	0	1

2.5 Ancillary data

Provision is made for ancillary data to be inserted synchronously into the multiplex during the blanking intervals at a rate of 27 Mwords/s. Such data is conveyed by one or more 7-bit words, each with an additional parity bit (LSB) giving odd parity.

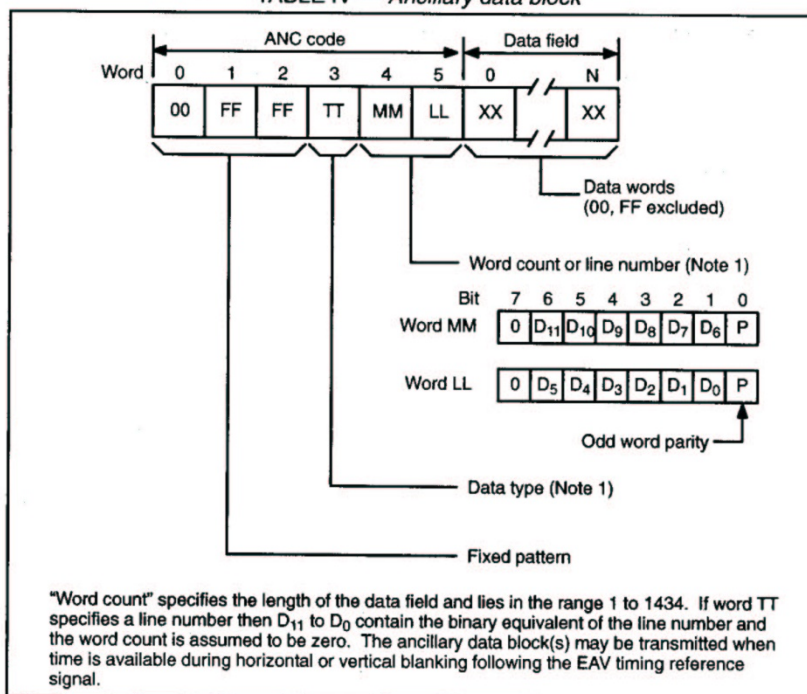
Each ancillary data block, when used, should be constructed as shown in Table IV from the timing reference code ANC and a data field.

2.6 Data words during blanking

The data words occurring during digital blanking intervals that are not used for the timing reference code ANC or for ancillary data are filled with the sequence 80, 10, 80, 10, etc. (values are expressed in hexadecimal notation) corresponding to the blanking level of the C_B , Y, C_R , Y signals respectively, appropriately placed in the multiplexed data.

Rec. 656

TABLE IV — Ancillary data block



Note 1 — The precise location of the ancillary data blocks and the coding of words 3, 4 and 5 require further study.

PART II

BIT-PARALLEL INTERFACE

1. General description of the interface

The bits of the digital code words that describe the video signal are transmitted in parallel by means of eight conductor pairs, where each carries a multiplexed stream of bits (of the same significance) of each of the component signals, C_B , Y , C_R , Y . The eight pairs also carry ancillary data that is time-multiplexed into the data stream during video blanking intervals. A ninth pair provides a synchronous clock at 27MHz.

The signals on the interface are transmitted using balanced conductor pairs. Cable lengths of up to 50 m (\approx 160 feet) without equalization and up to 200 m (\approx 650 feet) with appropriate equalization (see § 6) may be employed.

The interconnection employs a twenty-five pin D-subminiature connector equipped with a locking mechanism (see § 5).

For convenience, the eight bits of the data word are assigned the names DATA 0 to DATA 7. The entire word is designated as DATA (0-7). DATA 7 is the most significant bit.

Video data is transmitted in NRZ form in real time (unbuffered) in blocks, each comprising one active television line.

2. Data signal format

The interface carries data in the form of 8 parallel data bits and a separate synchronous clock. Data is coded in NRZ form. The recommended data format is described in Part I.

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

3. Clock signal**3.1 General**

The clock signal is a 27 MHz square wave where the 0-1 transition represents the data transfer time. This signal has the following characteristics:

Width: 18.5 ± 3 ns

Jitter: Less than 3 ns from the average period over one field.

3.2 Clock-to-data timing relationship

The positive transition of the clock signal shall occur midway between data transitions as shown in Fig. 2.

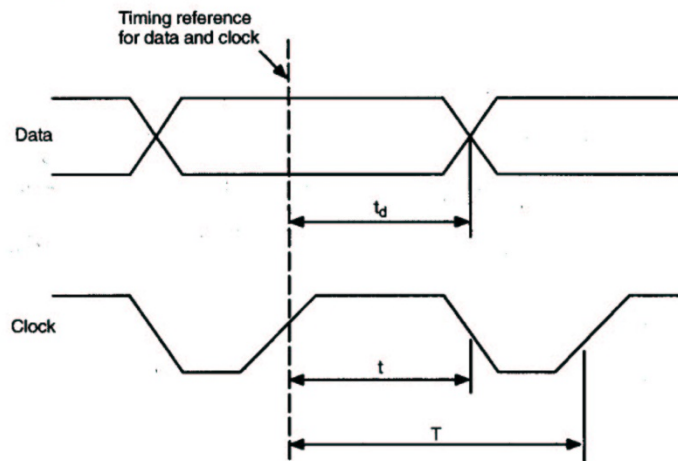


FIGURE 2 — Clock-to-data timing (at source)

Clock period (625):	$T = \frac{1}{1728 f_H} = 37ns$
Clock period (525):	$T = \frac{1}{1716 f_H} = 37ns$
Clock pulse width:	$t = 18.5 \pm 3ns$
Data timing - sending end:	$t_d = 18.5 \pm 3ns$
f_H : line frequency	

4. Electrical characteristics of the interface**4.1 General**

The interface employs nine line drivers and nine line receivers.

Each line driver (source) has a balanced output and the corresponding line receiver (destination) a balanced input (see Fig. 3).

Although the use of ECL technology is not specified, the line driver and receiver must be ECL-compatible, i.e. they must permit the use of ECL for either drivers or receivers.

All digital signal time intervals are measured between the half-amplitude points.

Rec. 656

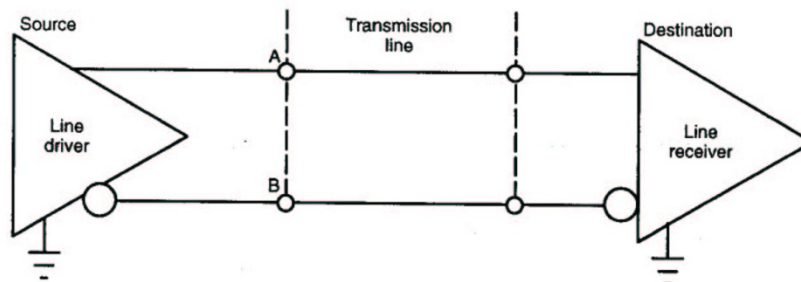


FIGURE 3 — Line driver and line receiver interconnection

4.2 Logic convention

The A terminal of the line driver is positive with respect to the B terminal for a binary 1 and a negative for a binary 0 (see Fig. 3).

4.3 Line driver characteristics (source)

4.3.1 *Output impedance:* 110 Ω maximum

4.3.2 *Common mode voltage:* $-1.29 \text{ V} \pm 15\%$ (both terminals relative to ground).

4.3.3 *Signal amplitude:* 0.8 to 2.0 V peak-to-peak, measured across a 110 Ω resistive load.

4.3.4 *Rise and fall times:* less than 5 ns, measured between the 30% and 80% amplitude points, with a 110 Ω resistive load. The difference between rise and fall times must not exceed 2 ns.

4.4 Line receiver characteristics

4.4.1 *Input impedance:* 110 $\Omega \pm 10 \Omega$.

4.4.2 *Maximum input signal:* 2.0 V peak-to-peak.

4.4.3 *Minimum input signal:* 185 mV peak-to-peak.

However, the line receiver must sense correctly the binary data when a random data signal produces the conditions represented by the eye diagram in Fig. 4 at the data detection point.

4.4.4 *Maximum common mode signal:* $\pm 0.5 \text{ V}$, comprising interference in the range 0 to 15 kHz (both terminals to ground).

4.4.5 *Differential delay:* Data must be correctly sensed when the clock-to-data differential delay is in the range between $\pm 11 \text{ ns}$ (see Fig. 4).

5. Mechanical details of the connector

The interface uses the 25 contact type D subminiature connector specified in ISO Document 2110-1980, with contact assignment shown in Table V.

Connectors are locked together by a one-piece slide lock on the cable connectors and locking posts on the equipment connectors. Connectors employ pin contacts and equipment connectors employ socket contacts. Shielding of the interconnecting cable and its connectors must be employed (see Note).

Note — It should be noted that the ninth and eighteenth harmonics of the 13.5 MHz sampling frequency (nominal value) specified in Recommendation 601 fall at the 121.5 and 243 MHz aeronautical emergency channels. Appropriate precautions must therefore be taken in the design and operation of interfaces to ensure that no interference is caused at these frequencies. Emission levels for related equipment are given in CISPR Recommendation: "Information technology equipment – limits of interference and measuring methods" Document CISPR/B (Central Office) 16. Nevertheless, No. 964 of the Radio Regulations prohibits any harmful interference on the emergency frequencies.

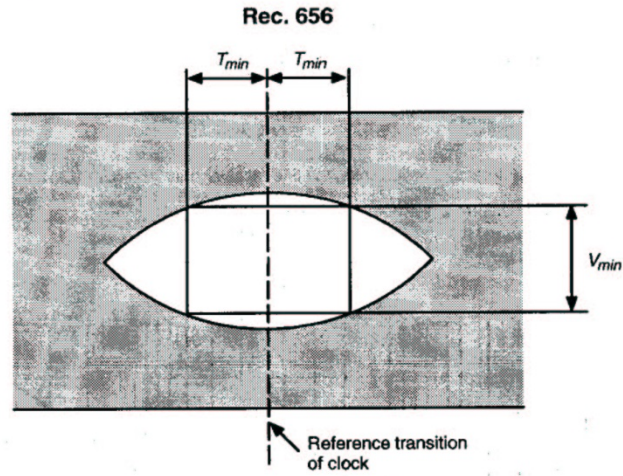


FIGURE 4 — Idealized eye diagram corresponding to the minimum input signal level

$$T_{min} = 11 \text{ ns}$$

$$V_{min} = 100 \text{ mV}$$

Note — The width of the window in the eye diagram, within which data must be correctly detected comprises ± 3 ns clock jitter, ± 3 ns data timing (see § 3.2), and ± 5 ns available for differences in delay between pairs of the cable.

TABLE V — Contact assignments

Contact	Signal line	Contact	Signal line
1	Clock A	14	Clock B
2	System ground	15	System ground
3	Data 7A (MSB)	16	Data 7B
4	Data 6A	17	Data 6B
5	Data 5A	18	Data 5B
6	Data 4A	19	Data 4B
7	Data 3A	20	Data 3B
8	Data 2A	21	Data 2B
9	Data 1A	22	Data 1B
10	Data 0A	23	Data 0B
11	Spare A-A	24	Spare A-B
12	Spare B-A	25	Spare B-B
13	Cable shield	—	—

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

Any spare pairs connected to contacts 11,24 or 12,25 are reserved for bits of lower significance than those carried on contacts 10,23.

6. Line receiver equalization

To permit correct operation with longer interconnection links, the line receiver may incorporate equalization.

When equalization is used, it should conform to the nominal characteristics of Fig. 5. This characteristic permits operation with a range of cable lengths down to zero. The line receiver must satisfy the maximum input signal condition of § 4.4

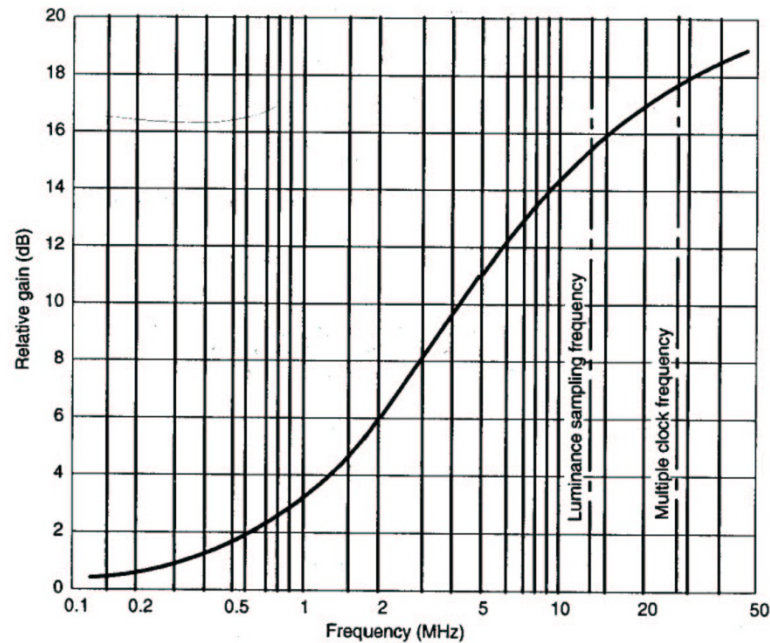


FIGURE 5 — Line receiver equalization characteristic for small signals

PART III

BIT-SERIAL INTERFACE

1. General description of the interface

The multiplexed data stream of 8-bit words (as described in Part I) is transmitted over a single channel in bit-serial form. Prior to transmission, additional coding takes place to provide spectral shaping, word synchronization and to facilitate clock recovery.

2. Coding

The 8-bit data words are encoded for transmission into 9-bit words as shown in Table VI.

For some 8-bit data words alternative 9-bit transmission words exist, as shown in columns 9B and $\bar{9}B$, each 9-bit word being the complement of the other. In such cases, the 9-bit word will be selected alternately from columns 9B and $\bar{9}B$ on each successive occasion that any such 8-bit word is conveyed. In the decoder, either word must be converted to the corresponding 8-bit data word.

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

TABLE VI — Encoding table

Input	Output		Input	Output		Input	Output		Input	Output		Input	Output		Input	Output	
8B	9B	9B	8B	9B	9B	8B	9B	9B	8B	9B	9B	8B	9B	9B	8B	9B	9B
00	0FE	101	2B	053		56	097		81	0AA		AC	12C		D7	0CC	
01	027		2C	1AC		57	168		82	055		AD	0D9		D8	139	
02	1D8		2D	057		58	099		83	1AA		AE	126		D9	0CE	
03	033		2E	1A8		59	166		84	0D5		AF	0E5		DA	133	
04	1CC		2F	059		5A	09B		85	12A		B0	11A		DB	0D8	
05	037		30	1A6		5B	164		86	095		B1	0E9		DC	131	
06	1CB		31	05B		5C	09D		87	16A		B2	116		DD	0DC	
07	039		32	05D		5D	162		88	0B5		B3	02E		DE	127	
08	1C6		33	1A4		5E	0A3		89	14A		B4	1D1		DF	0E2	
09	03B		34	065		5F	15C		8A	09A		B5	036		E0	123	
0A	1C4		35	19A		60	0A7		8B	165		B6	1C9		E1	0E4	
0B	03D		36	069		61	158		8C	0A6		B7	03A		E2	11D	
0C	1C2		37	196		62	025	1DA	8D	159		B8	1C5		E3	0E6	
0D	14D		38	026	1D9	63	0A1	15E	8E	0AC		B9	04E		E4	11B	
0E	0B4		39	08C	173	64	029	1D6	8F	153		BA	1B1		E5	0E8	
0F	14B		3A	02C	1D3	65	091	16E	90	0AE		BB	05C		E6	119	
10	1A2		3B	098	167	66	045	1BA	91	151		BC	1A3		E7	0EC	
11	0B6		3C	032	1CD	67	089	176	92	02A	1D5	BD	05E		E8	117	
12	149		3D	0BE	141	68	049	1B6	93	092	16D	BE	1A1		E9	0F2	
13	0BA		3E	034	1CB	69	085	17A	94	04A	1B5	BF	066		EA	113	
14	145		3F	0C2	13D	6A	051	1AE	95	094	16B	C0	199		EB	0F4	
15	0CA		40	046	1B9	6B	08A	175	96	0A8	157	C1	06C		EC	10D	
16	135		41	0C4	13B	6C	0A4	15B	97	0B7	148	C2	193		ED	076	
17	0D2		42	04C	1B3	6D	054	1AB	98	0F5	10A	C3	06E		EE	10B	
18	12D		43	0C8	137	6E	0A2	15D	99	0BB	144	C4	191		EF	0C7	
19	0D4		44	058	1A7	6F	052	1AD	9A	0ED	112	C5	072		F0	13C	
1A	129		45	0B1		70	056		9B	0BD	142	C6	18D		F1	047	
1B	0D6		46	14E		71	1A9		9C	0EB	114	C7	074		F2	1B8	
1C	125		47	0B3		72	05A		9D	0D7	128	C8	18B		F3	067	
1D	0DA		48	14C		73	1A5		9E	0DD	122	C9	07A		F4	19C	
1E	115		49	0B9		74	06A		9F	0DB	124	CA	189		F5	071	
1F	0EA		4A	06B		75	195		A0	146		CB	08E		F6	198	
20	0B2		4B	194		76	096		A1	0C5		CC	185		F7	073	
21	02B		4C	06D		77	169		A2	13A		CD	09C		F8	18E	
22	1D4		4D	192		78	0A9		A3	0C9		CE	171		F9	079	
23	02D		4E	075		79	156		A4	136		CF	09E		FA	18C	
24	1D2		4F	18A		7A	0AB		A5	0CB		D0	163		FB	087	
25	035		50	08B		7B	154		A6	134		D1	0B8		FC	186	
26	1CA		51	174		7C	0A5		A7	0CD		D2	161		FD	0C3	
27	04B		52	08D		7D	15A		A8	132		D3	0BC		FE	178	
28	1B4		53	172		7E	0AD		A9	0D1		D4	147		FF	062	19D
29	04D		54	093		7F	152		AA	12E		D5	0C6				
2A	1B2		55	16C		80	155		AB	0D3		D6	143				

RECOMMENDATIONS OF THE CCIR, 1990

CCIR 656

Rec. 656

3. Order of transmission

The least significant bit of each 9-bit word shall be transmitted first.

4. Logic convention

The signal is conveyed in NRZ form. The voltage at the output terminal of the line driver shall increase on a transition from 0 to 1 (positive logic).

5. Transmission medium

The bit-serial data stream can be conveyed using either a coaxial cable (§ 6) or fibre optic bearer (§ 7).

6. Characteristics of the electrical interface**6.1 Line driver characteristics (source)****6.1.1 Output impedance**

The line driver has an unbalanced output with a source impedance of 75 Ω and a return loss of at least 15 dB over a frequency range of 10 to 243 MHz.

6.1.2 Signal impedance

The peak-to-peak signal amplitude lies between 400 mV and 700 mV measured across a 75 Ω resistive load directly connected to the output terminals without any transmission line.

6.1.3 DC offset

The DC offset with reference to the mid amplitude point of the signal lies between +1.0V and -1.0 V.

6.1.4 Rise and fall times

The rise and fall times, determined between the 20% and 80% amplitude points and measured across a 75 Ω resistive load connected directly to the output terminals, shall lie between 0.75 and 1.5 ns and shall not differ by more than 0.40 ns.

6.1.5 Jitter

The timing of the rising edges of the data signal shall be within ± 0.10 ns of the average timing of rising edges, as determined over a period of one line.

6.2 Line receiver characteristics (destination)**6.2.1 Terminating impedance**

The cable is terminated by 75 Ω with a return loss of at least 15 dB over a frequency range of 10 to 243 MHz.

6.2.2 Receiver sensitivity

The line receiver must sense correctly random binary data either when connected directly to a line driver operating at the extreme voltage limits permitted by § 6.1.2, or when connected via a cable having loss of 40 dB at 243 MHz and a loss characteristic of $1/\sqrt{f}$.

Over the range 0 to 12 dB no equalization adjustment is required; beyond this range adjustment is permitted.

6.2.3 Interference rejection

When connected directly to a line driver operating at the lower limit specified in § 6.1.2, the line receiver must correctly sense the binary data in the presence of a superimposed interfering signal at the following levels:

d.c.	± 2.5 V
Below 1 kHz:	2.5 V peak-to-peak
1 kHz to 5 MHz:	100 mV peak-to-peak
Above 5 MHz:	40 mV peak-to-peak

RECOMMENDATIONS OF THE CCIR, 1990**CCIR 656**

Rec. 656**6 Cables and connectors****6.3.1 Cable**

It is recommended that the cable chosen should meet any relevant national standards on electro-magnetic radiation.

Note — It should be noted that the ninth and eighteenth harmonics of the 13.5 MHz sampling frequency (nominal value) specified in Recommendation 601 fall at the 121.5 and 243 MHz aeronautical emergency channels. Appropriate precautions must therefore be taken in the design and operation of interfaces to ensure that no interference is caused at these frequencies. Emission levels for related equipment are given in CISPR Recommendation: "Information technology equipment – limits of interference and measuring methods" (Document CISPR/B (Central Office) 16). Nevertheless, No. 964 of the Radio Regulations prohibits any harmful interference on the emergency frequencies.

6.3.2 Characteristic impedance

The cable used shall have a nominal characteristic impedance of 75 Ω .

6.3.3 Connector characteristics

The connector shall have mechanical characteristics conforming to the standard BNC type (IEC Publication 169-8), and its electrical characteristics should permit it to be used at frequencies up to 500 MHz in 75 Ω circuits.

7. Characteristics

To be defined.

Attachment 2

Rec. 601 -1

SECTION 11F : DIGITAL METHODS OF TRANSMITTING TELEVISION INFORMATION

Recommendations and Reports

RECOMMENDATION 601-1

ENCODING PARAMETERS OF DIGITAL TELEVISION FOR STUDIOS*¹

(Question 25/11, Study Programmes 25G/11, 25H/1 1)

(1982-1986)

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 restricted to eliminate aliasing. When using one luminance and two colour-difference signals as defined in Table I, this can be achieved by using filters as defined in Annex 111, Figs. 1 and 2. When using E'_R , E'_G , E'_B signals or luminance and colour-difference signals as defined in Table II of Annex I, the characteristics defined by Fig. 1 of Annex III will apply.

Note. — The values shown for the luminance filter, used when sampling at 13.5 MHz, given

¹ Main digital television terms used in the Recommendation are defined in Report 629

in Fig. 1 of Annex III should be considered as provisional. Administrations are requested to perform urgent studies to confirm these values.

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 ⁽²⁾ systems	625-line, 50 field/s ⁽²⁾ 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 I1, § 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	<p style="text-align: center;">13.5 MHz ⁽³⁾</p> <p style="text-align: center;">6.75 MHz⁽³⁾</p> <p>The-tolerance for the sampling frequencies should coincide with the tolerance for the line frequency of the relevant colour television standard</p>	

² See Report 624, Table I.

³ 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.

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 <i>OH</i>	16 luminance clock periods	12 luminance clock periods
8. Correspondence between video signal levels and quantization levels: - scale - luminance signal - each colour-difference signal	<p>- 0 to 255</p> <p>- 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 excursion beyond level 235</p> <p>-225 quantization levels in the centre part of the quantization scale with zero signal corresponding to level 128</p>	
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	

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 11 — 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 — <i>R, G, B</i> or luminance signal (⁴) each colour-difference signal (⁴)	– 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 excursion beyond level 235 225 quantization levels in the centre part of the quantization scale with zero signal corresponding to level 128

⁴ If used

ANNEX II

DEFINITION OF SIGNALS USED IN THE DIGITAL CODING STANDARDS

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., period 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:

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

whence:

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

and:

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

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'_{CR} and E'_{CB})

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:

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

Then:

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

and:

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

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

Note 1. – The symbols E'_{CR} and E'_{CB} 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, Y , prior to quantization, is:

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

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, C_R and C_B , prior to quantization are:

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

and:

$$C_B = 224 [0.564 (E'_B - E'_Y)] + 128$$

which simplify to the following:

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

and:

$$\bar{C}_B = 126 (E'_B - E'_Y) + 128$$

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:

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

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

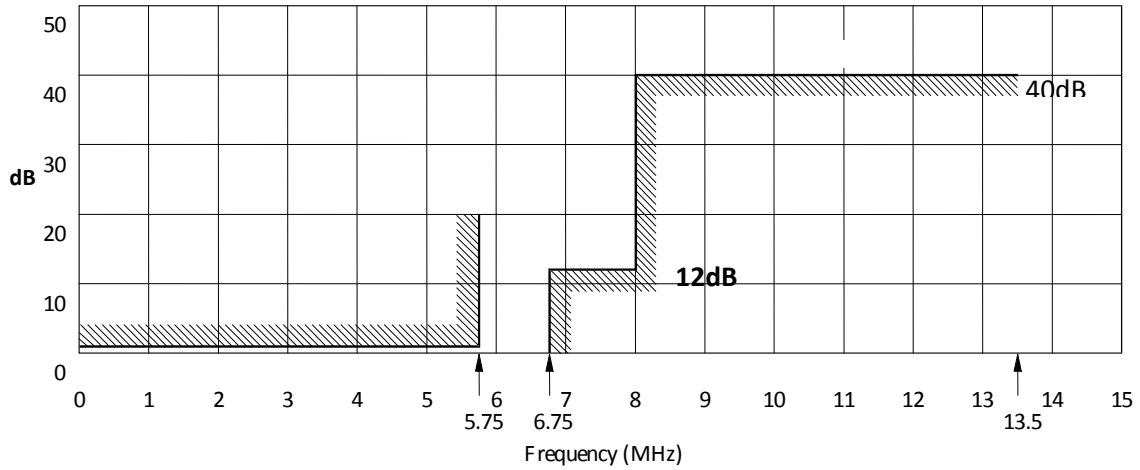
$$C_B = -\frac{44}{256} E'_{R_D} - \frac{87}{256} E'_{G_D} + \frac{131}{256} E'_{B_D} + 128$$

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.

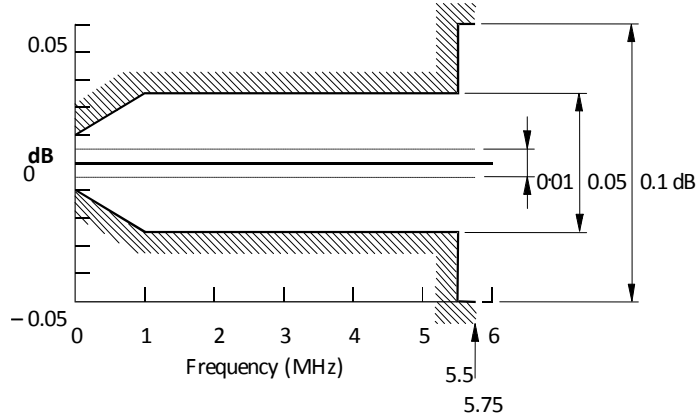
ANNEX III

Filtering Characteristics

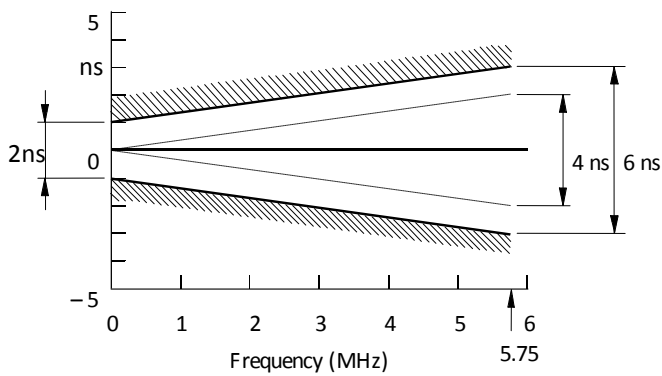
FIGURE 1
Specification for a luminance or RGB signal filter
used when sampling at 13.5 MHz



a) Template for insertion loss/frequency characteristic



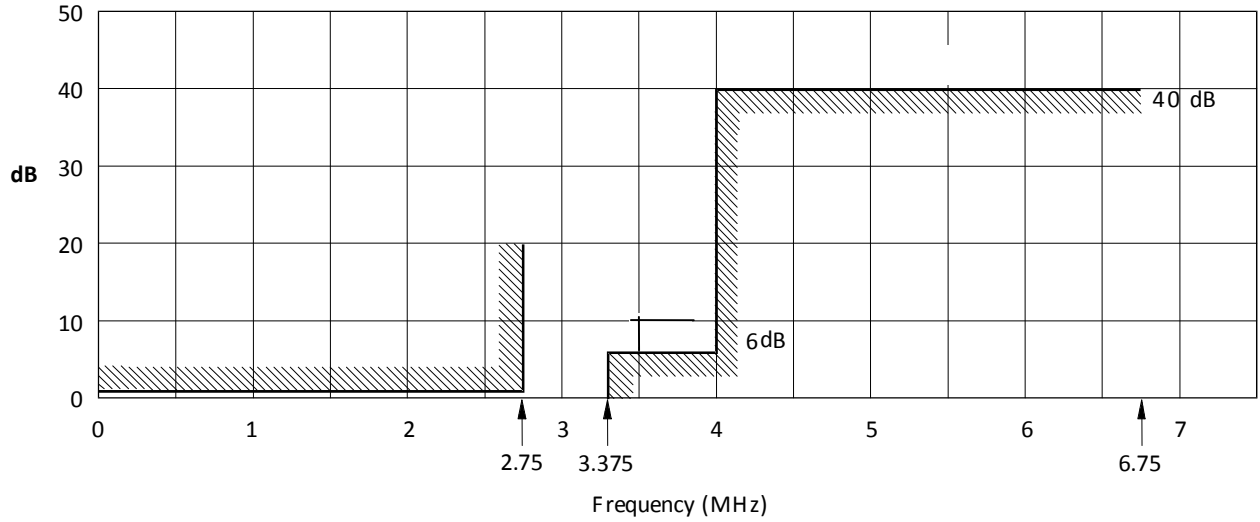
b) Passband ripple tolerance



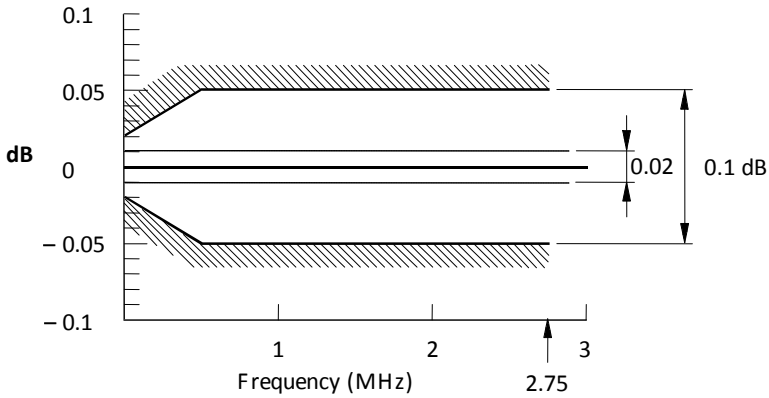
c) Passband group-delay tolerance

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

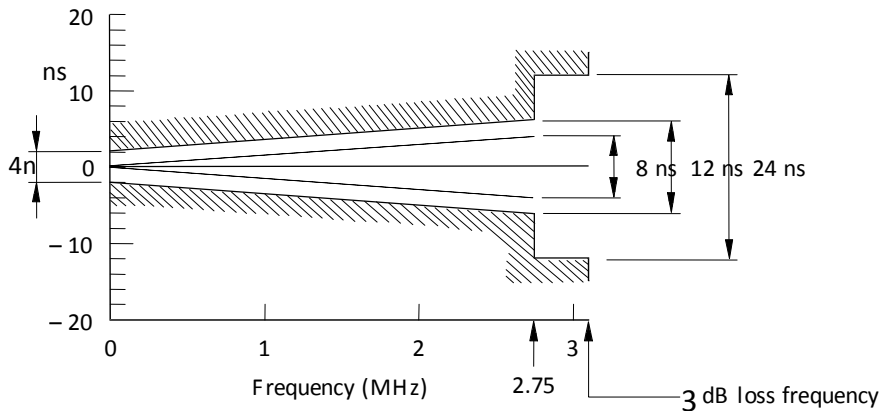
FIGURE 2
Specification for a colour-difference signal filter
used when sampling at 6.75 MHz



a) Template for insertion loss/frequency characteristic



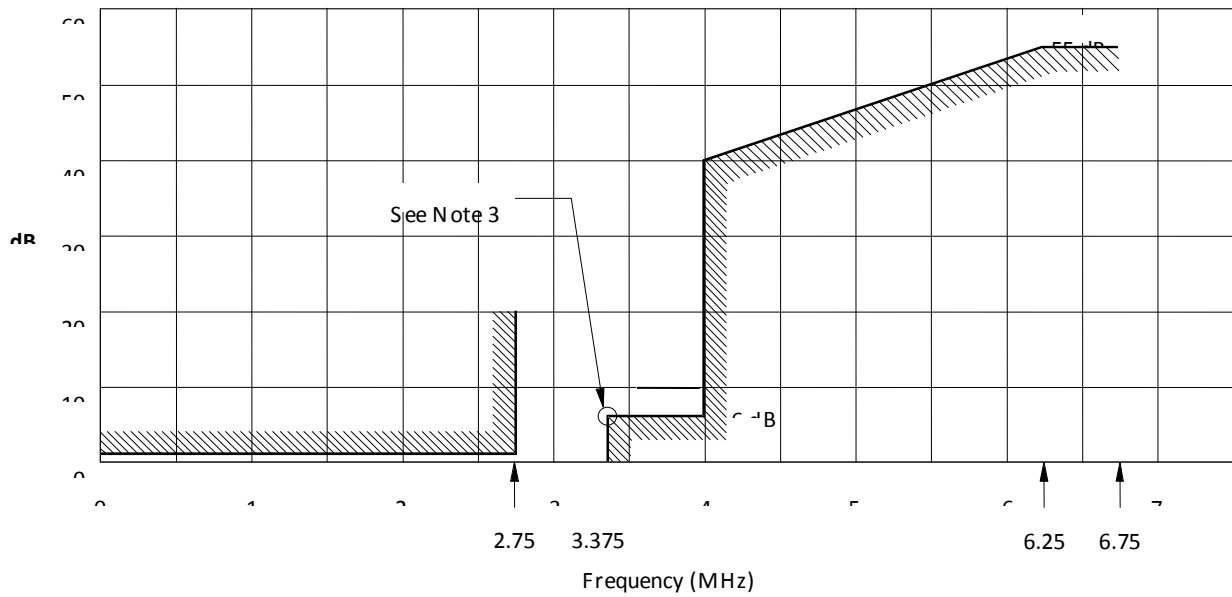
b) Passband ripple tolerance



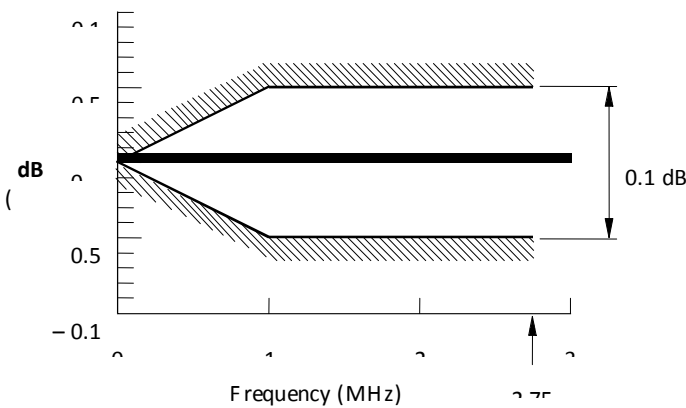
c) Passband group-delay tolerance

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

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



a) Template for insertion loss/frequency characteristic



b) Passband ripple tolerance

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.