

## RECOMMENDATION ITU-R BO.787\*

**MAC/packet based system for HDTV broadcasting-satellite services**

(Question ITU-R 100/11)

(1992)

The ITU Radiocommunication Assembly,

*considering*

- a) that many countries have established colour television broadcasting services based on a 625 line, 50 Hz field rate television system;
- b) that, for the establishment of a broadcasting-satellite service, the MAC/packet system has been proposed in Europe, as recommended in Recommendation ITU-R BO.650;
- c) that the introduction of an HDTV broadcasting service is greatly helped by downwards compatibility with an existing television service;
- d) that the HD-MAC system is specially designed to allow downwards compatibility with the MAC/packet system, fully retaining the MAC/packet capabilities, such as scrambling for conditional access and digital sound and data services;
- e) that there are proposals for HDTV studio standards which are very well coupled to the HD-MAC system, e.g. using 1 250 lines and a 50 Hz field or frame rate;
- f) that the HD-MAC signal is also used for subsequent distribution via cable networks;
- g) that the HD-MAC system has been tested and used in several major events, and some administrations may wish to receive these signals,

*recommends*

that, for an administration or organization wishing to initiate a MAC/packet 1 250 line, 50 Hz field rate based HDTV broadcasting-satellite service which is downwards compatible with the MAC/packet system, the signals should conform to the HD-MAC signal specification contained in Annex 1.

NOTE 1 – HD-MAC is currently the subject of a series of evaluations by the EBU.

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\* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44.

## ANNEX 1

**Signal specification of the HD-MAC/packet system****Introduction**

HD-MAC is designed to meet the highest quality criteria and to allow the introduction of HDTV services on existing MAC/packet services, or directly as new services.

Consequently, the specification in Europe of a high-definition television system (HDTV), studied in the context of the European EUREKA 95 project, is based, for its complete description, on the specification of the MAC/packet family which is presented in Recommendation ITU-R BO.650.

The following sections introduce the HD-MAC/packet specification. The section numbers correspond to the Part numbers of the MAC/packet specification contained in Chapter 3 of the ITU-R special publication "Specifications of Transmission Systems for the Broadcasting-Satellite Service".

For future generations of systems for broadcasting-satellite services, other transmission parameters are under consideration; for example, an increase in the frequency deviation sensitivity, the channel bandwidth and the peak-energy dispersal deviation. However, it is recognized that changes in such parameters should ensure compatibility with both the MAC/packet system and, where appropriate, Appendices 30 and 30A of the Radio Regulations.

**1 Time division multiplex and data transmission**

The time division multiplex is used for picture/sound/data multiplexing for HD-MAC transmissions which include two members of the MAC/packet family: D-HDMAC/packet and D2-HDMAC/packet systems. These two systems are suited for use in satellite broadcasting and any transmission medium which guarantees a baseband of about 11 MHz (see Table 1). In particular, they can be used with a VSB-AM modulated network with a channel spacing of 12 MHz.

**1.1 Structure of the multiplex**

The structure of the multiplex is based on a 40 ms digital frame which contains 625 lines of 64  $\mu$ s each. The multiplex is composed of three main components (see Fig. 1):

- the HD-MAC vision signal, which is described in § 2;
- the line blanking interval (LBI) data burst, which carries the sound/data multiplex;
- the field blanking interval (FBI) data burst, which carries the DATV/data multiplex (DATV: digitally assisted television).

The availability capacity in the LBI is nominally equivalent to four high-quality (or eight medium-quality) sound channels compatible with the D2-MAC/packet system and eight high-quality (or 16 medium-quality) sound channels compatible with the D-MAC/packet system.

TABLE 1

**General video characteristics of the HD-MAC vision signal**

Number of emitted lines per picture:	625
Number of fields per second:	50
Interlace ratio:	2:1
Analogue bandwidth:	11.14 MHz <sup>(1)</sup>
Aspect ratio:	16:9 (associated with panning information for compatible 4:3 displays)
Compression ratios	
luminance:	3:2
colour difference:	3:1
Sampling frequency:	20.25 MHz <sup>(2)</sup>
High definition reception	
Luminance resolution	
horizontal	
static and tracked motion:	620 c/apw <sup>(3)</sup>
untracked motion:	310 c/apw
vertical	
static:	400 c/aph <sup>(3)</sup>
motion:	200 c/aph
Compatible reception	
Samples per active lines	
luminance:	697
colour difference:	349

(1) Allowing for practicable 10% Nyquist filter.

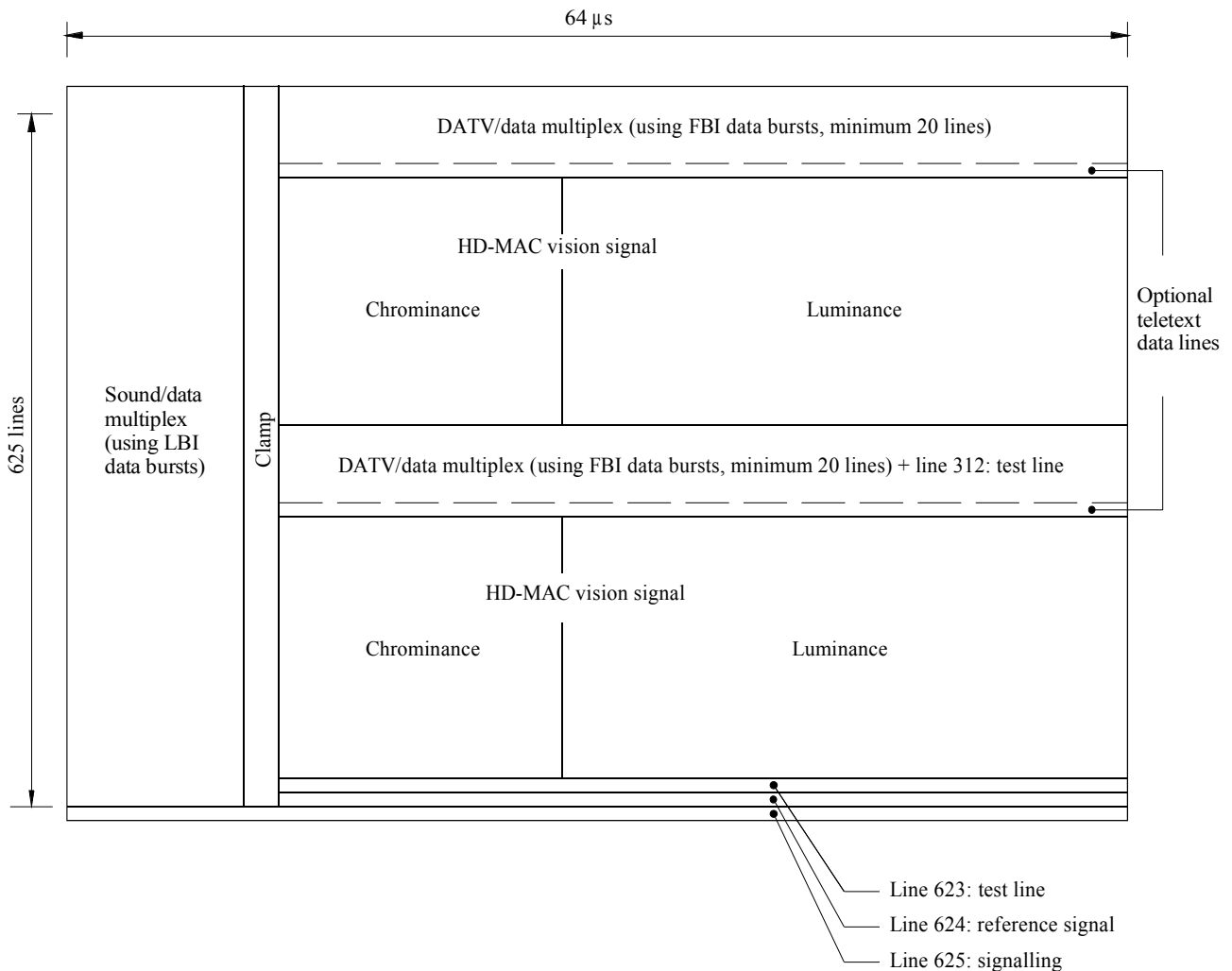
(2) Conventional MAC sampling frequency, with phase shift.

(3) Cycles per active picture width/height achievable in practical implementations.

Within the FBI, the DATV/data multiplex occupies 40 FBI data bursts per video frame, 20 per FBI chosen within lines Nos. 1 to 22 and lines Nos. 311 to 334 inclusive but excluding line No. 312. For the two systems, a capacity of about 1.1 Mbit/s is available in the field blanking interval. This capacity is primarily used for transmission of the DATV data (see § 2.4). The extra capacity is free for other applications such as Teletext or other data services.

FIGURE 1

General HD-MAC/packet TDM structure



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## 1.2 Synchronization and other signals

The synchronization is identical to MAC/packet system synchronization, i.e. provided by line synchronization words and a frame synchronization sequence. These two signals are designed to identify the frame parity. This frame parity is used to signal the HD-MAC coding period, the duration of which is 80 ms, with the following correspondence: the first field of the HD-MAC coding period is the first field of an odd frame, the fourth field of the HD-MAC coding period is the second field of an even frame (where the fields refer to a normal 625-line interlaced picture).

Lines No. 312 and No. 623 are reserved on a permanent basis within the field blanking interval for the emission of test signals. Those signals are compatible with the specifications of MAC/packet measuring equipment. In addition, the first part of line No. 312 is filled over two frames by a pseudo-random sequence of 512 bits, the first function of which is to help the equalizer process.

The other signals are the same as in the MAC/packet signal. A clamp period is provided on each line except line No. 625. Line No. 625 is used for signalling and carries in particular the description of the structure of the time division multiplex. A new parameter has been introduced to identify the DATV/data multiplex.

### **1.3 Data coding and multiplexing with the picture**

The data part is transmitted using duobinary coding as for the corresponding members of the MAC/packet family (see Recommendation ITU-R BO.650).

For the LBI data burst, the instantaneous bit rate is equal to 10.125 Mbit/s for the D2 system and to 20.25 Mbit/s for the D system. For the FBI data burst, the instantaneous bit rate is equal to 20.25 Mbit/s for both systems.

Data of the FBI and LBI multiplexes are transmitted in packets. The packet format is identical to the one which is defined for sound and other applications in the MAC/packet specification. A packet is a block of 751 bits divided in two parts: a packet header and a data area. The packet header carries a unique address code which is allocated to a particular service component such as one sound or the DATV data. The total length of the data area is 91 bytes, the first byte of which is generally used as a packet type byte which can be used to identify various packet usages.

Bit-interleaving is applied to all data transmitted in packet form in order to minimize the effect of multiple bit errors. After bit interleaving, energy dispersal is achieved by adding (modulo 2) a scrambling sequence to the data before D/A conversion. In addition, the useful data of packets may be scrambled by modulo 2 addition of a pseudo-random sequence. Such scrambling is used in the conditional access mode.

The multiplex is obtained by adding the analogue component to the duobinary data signal which is clamped to zero level during the period in which the digital component is not transmitted.

## **2 HD-MAC signal**

The HD-MAC BR coding scheme (BR stands for bandwidth reduction in general, except for the decoder where it stands for bandwidth restoration) is based on the use of the DATV concept (DATV stands for digitally assisted television). The resulting HD-MAC signal is therefore composed of the HD-MAC vision signal and the DATV data. The HD-MAC vision signal is the result of MAC compression of the bandwidth reduced signal. The specification has been established in order to ensure good compatibility with MAC receivers.

### **2.1 General video characteristics of the HD-MAC vision signal**

These are given in Table 1.

### **2.2 Bandwidth reduced vision signal**

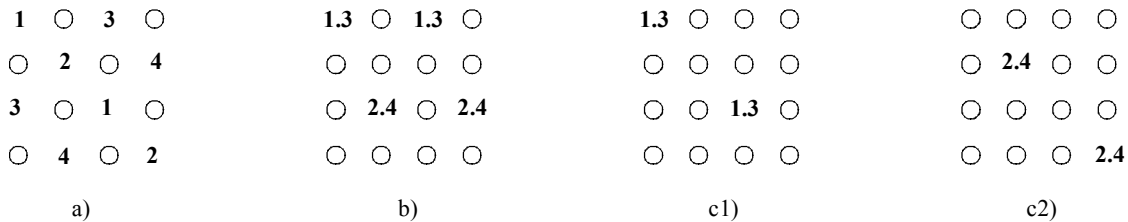
The HD-MAC BR coder uses three luminance coding branches, all with quincunx sub-sampling lattices (Fig. 2):

- an 80 ms branch with high-definition (HD) resolution for stationary areas;

- a 40 ms motion compensated branch for velocities up to 12 samples per 40 ms;
- a 20 ms branch for rapid motion and sudden picture changes, not active when in the 25 pictures/s film mode.

FIGURE 2

**Luminance sub-sampling patterns on 1 250/50/2 sampling grid with 54 MHz sampling frequency**



- a) 80 ms spatial-temporal sub-sampling pattern
- b) 40 ms spatial-temporal sub-sampling pattern
- c1) 20 ms spatial-temporal sub-sampling pattern for odd fields
- c2) 20 ms spatial-temporal sub-sampling pattern for even fields

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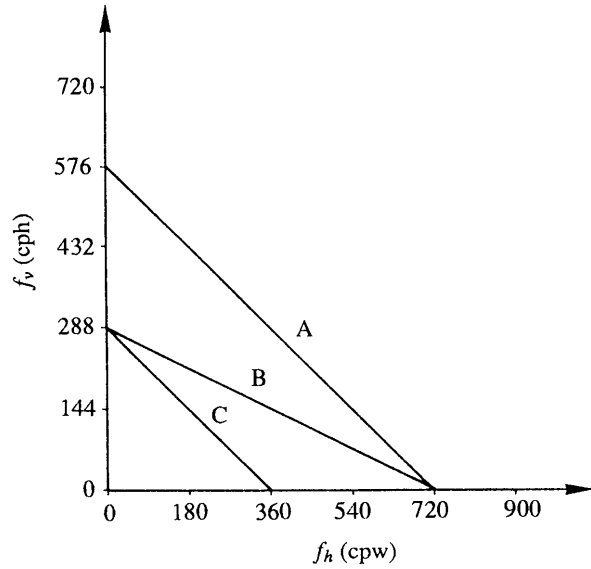
The transmissible range of spatial frequency is given in Fig. 3 for all the modes. To carry the information contained in a 1 250-line HD system through a 625-line MAC/packet channel, a process termed “shuffling” is used. For the 80 and 20 ms branches intrafield shuffling (or line shuffling) is used: the content of two intrafield source lines is transmitted as one MAC/packet line, by interleaving the HD samples. The properties of a MAC/packet transmission channel make it possible to separate these samples in the receiver. For the 40 ms branch interfield shuffling is used, the content of one source field is sent alternatively in the odd and even emission field (field skip).

The 40 ms branch is motion compensated. One motion vector is emitted for each block of 16 samples by 16 lines on the HD grid via the DATV data. The reconstruction of the missing fields is carried out by interpolating the available field according to the direction of local movement.

The HD-MAC bandwidth reduction coder uses three colour-difference coding branches, the first and third using a quincunx, the second an orthogonal sub-sampling lattice (Fig. 4):

- an 80 ms branch with HD resolution for stationary areas;
- a 40 ms branch for slow motion or picture changes, for velocities up to 6 samples/ms;
- a 20 ms branch for rapid motion and sudden picture changes, not active when in the 25 pictures/s film mode.

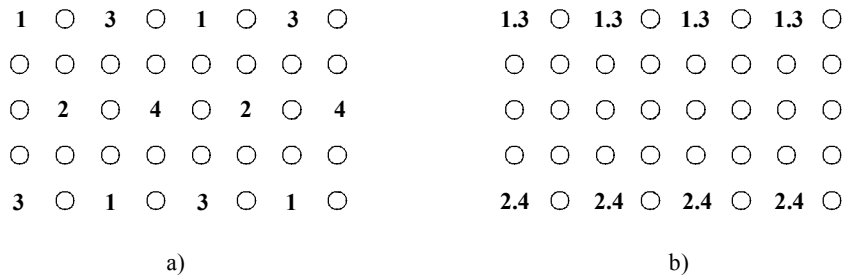
FIGURE 3  
 Transmissible range in spatial frequency domain  
 for the luminance sampling patterns described in Fig. 2



Curves A: 80 ms mode  
 B: 40 ms mode  
 C: 20 ms mode

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FIGURE 4  
 Colour difference sub-sampling patterns on 1 250/50/2 sampling  
 grid with 27 MHz sampling frequency

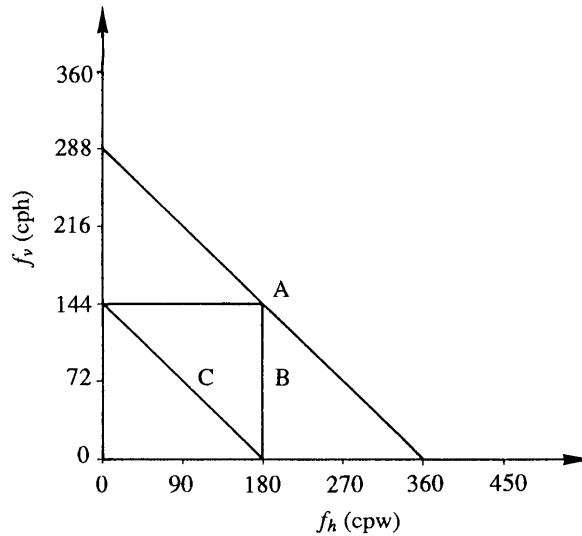


a) 80 and 20 ms spatial-temporal sub-sampling pattern  
 b) 40 ms spatial-temporal sub-sampling pattern

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The transmissible range of spatial frequency is given in Fig. 5 for all the modes. Intrafield shuffling is used for the 80 and 20 ms branches and interfield for the 40 ms branch. Motion compensation is not employed for the colour difference signal: for velocities between 7 and 12 samples per 40 ms, the luminance is processed through a 40 ms branch and the colour difference through a 20 ms branch.

FIGURE 5  
The transmissible range of the colour difference  
spatial frequency spectrum



Curves A: 80 ms mode  
B: 40 ms mode  
C: 20 ms mode

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Various countermeasure techniques are implemented before transmission in order to obtain a satisfactory compatible picture quality:

- an attenuation in the vertical direction for reducing spatial folding and interline twitter (VCI);
- a smoothing in the direction of the motion, for reducing the judder effect in picture areas processed in the 40 ms mode (MCCI);
- a frequency-dependent spatio-temporal attenuation in the temporal direction for reducing edge crawling in picture areas of low temporal activity (TCI).

Reciprocal processes are carried out in the HD-MAC decoder.



### 2.3 HD-MAC vision signal

The vision signal transmitted on each line contains the compressed luminance signal and one of the compressed colour difference signals (which alternate from line to line). The sample rate for emission is 20.25 MHz as for a MAC signal. However, to distinguish between the sub-Nyquist sampling phases, in every second and fourth field all the video samples are delayed by  $T/2 \approx 24.7$  ns. After MAC compression, a non-linear pre-emphasis followed by a Nyquist filtering (described in § 7) is performed around the Nyquist frequency of 10.125 MHz.

Scrambling of the HD-MAC vision, for conditional access, is possible conforming to the MAC/packet specification.

### 2.4 DATV data

Information for processing the picture is applied on a block basis. The block size is 16 samples by 16 lines on the HD grid and a complete picture is divided into 6480 blocks. For each block the basic information consists of a branch decision, BD (80, 40 or 20 ms process) and in case of a 40 ms mode decision, of a motion vector, MV.

This basic information is compressed for the transmission in the DATV channel as follows. Only five temporal routes are possible in a quantized 80 ms coding period and the branch decisions are constant during a frame period (40 ms), for coherence: four fields of 80, four fields of 40, two fields of 40 followed by two fields of 20, two fields of 20 followed by two fields of 40 and four fields of 20. The motion vectors of the 40 ms blocks, constant by definition over one frame, are coded over two frames. Absolute values are given in the first frame (range of  $\pm 6$  samples per 20 ms, horizontal and vertical: 169 values) and the best approximation is given by reference to the immediate neighbouring blocks of the previous frame in the second frame (only nine possibilities, eight when the block of the first frame is processed along a 20 ms mode; if none of these nine (eight) vectors fits, that means that there is a sudden local change which should be processed through the 20 ms branch).

As a result, DATV information that contains the branch switching signal and motion vector description allows for 1700 possibilities, coded in 11-bit-long codewords. The 6480 blocks by 80 ms coding period results in a bit rate of 891 kbit/s. The colour-difference switching information is derived from the luminance DATV data.

Extra information is added including a feature sequence, other processing information and error protection by a (90,82) Fire code. The result is transmitted by packets in the FBI DATV/data multiplex, using the packet format described in § 1.3. The maximum rate is 56 packets/frame equivalent to a net bit rate of 1.008 Mbit/s. All the DATV data concerning an 80 ms coding period is transmitted during the previous 80 ms period.

## 3 Sound

Currently, sound is coded according to the MAC/packet specification to ensure compatible reception. The main characteristics of this coding are:

- sampling frequency: 32 kHz for high quality, 16 kHz for medium quality;

- coding methods: linear 14 bit/sample or near instantaneous 10 bit/sample;
- error protection: first level by one parity bit/sample, second level by 5 bit Hamming code per sample.

Additional highly compressed sound coding methods will be available to provide an increased number of sound channels, including surround sound, required for the HDTV service, in the same compatible MAC/packet capacity.

#### **4 Teletext**

Teletext is coded according to the MAC/packet specification using either free lines in the FBI or capacity available in any packet multiplex.

#### **5 Service identification**

The service identification channel is coded according to the MAC/packet specification. A new parameter is introduced to describe the DATV data channel within the DATV/data multiplex.

#### **6 Conditional access**

All the access control methods provided for MAC/packet operation may be used for HD-MAC/packet.

#### **7 Modulation parameters**

##### **7.1 Baseband signal**

The coding of the HD-MAC vision signal, based on sub-sampling, implies that the overall transmission channel preserves the independence between consecutive samples, at 20.25 MHz. This condition is fulfilled if the equivalent baseband channel meets the first Nyquist criterion in the vicinity of 10.125 MHz.

One extra process is applied to the HD-MAC samples, namely non-linear pre-emphasis. The increase in baseband bandwidth to 11.14 MHz, on one hand, and the decrease in TV viewing distance, on the other, lead both to greater interference and noise sensitivities than for conventional MAC. The non-linear pre-emphasis is currently digitally implemented, as follows.

##### **7.1.1 Non-linear pre-emphasis network**

This specification is in accordance with the D-MAC/packet specification. The block diagram is shown in Fig. 6. The non-linear pre-emphasis (E7) is applied to vision samples only.

<i>High-pass filter</i>	F1: clock rate:	20.25 MHz
	Phase response:	linear

F1 is a 7-tap digital filter with the following coefficients:

$$\begin{aligned} C_0 &= 180/256 \\ C_1 &= C_{-1} = -58/256 \\ C_2 &= C_{-2} = -25/256 \\ C_3 &= C_{-3} = -7/256 \end{aligned}$$

These are scaled for a nominal AC gain of unity.

*Delay element T:* 3 clock periods

*Non-linear function N<sub>1</sub>* is defined by the relationship  $V_o = f(V_i) - V_i$

where:

$V_o$ : output from network

$V_i$ : input to network.

$f(V_i)$  is defined from the relationship  $V = f(V_i)$

where:

$$V_i = \frac{V}{C} + \frac{1}{B} \ln \left[ \frac{V + \sqrt{V^2 + (2AC)^2}}{2AC} \right]$$

with:

$$\begin{aligned} A &= 0.011 \\ B &= 19.8 \\ C &= 1.5225 \end{aligned}$$

*Non-linear function N<sub>2</sub>* is defined by the relationship:

$$V_o = V_i \left[ \frac{1-C}{C} \right] + \frac{1}{B} \ln \left[ \frac{V_i + \sqrt{V_i^2 + (2AC)^2}}{2AC} \right]$$

where:

$V_o$ : output from network

$V_i$ : input to network.

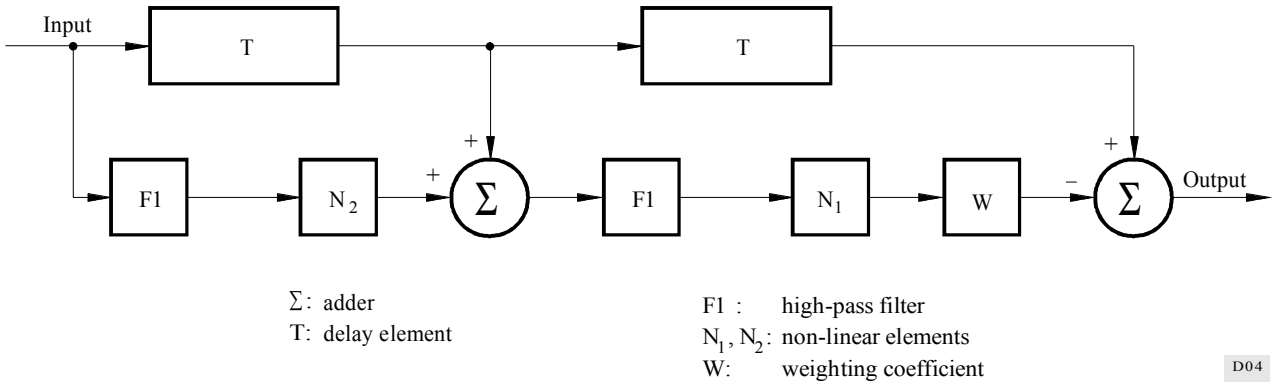
The non-linear functions  $N_1, N_2$  are illustrated in Figs. 7 and 8. Note that the input and output levels  $V_i, V_o$  are expressed as normalized values relative to the input range of the non-linear pre-emphasis network, in which the range  $(-0.5, 0.5)$  corresponds to the difference between constant black and white levels.

The pre-emphasis network is chosen to be complex in order to allow a simpler implementation of the de-emphasis network.

Pre-emphasis is applied only to active vision samples, and the transitions between E7 mode and non-E7 mode are controlled transitions. The weighting network is included as shown in Fig. 6.

FIGURE 6

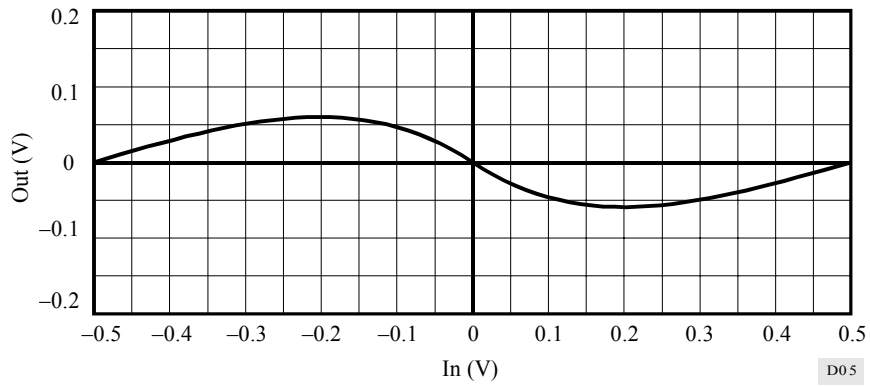
Non-linear pre-emphasis network



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FIGURE 7

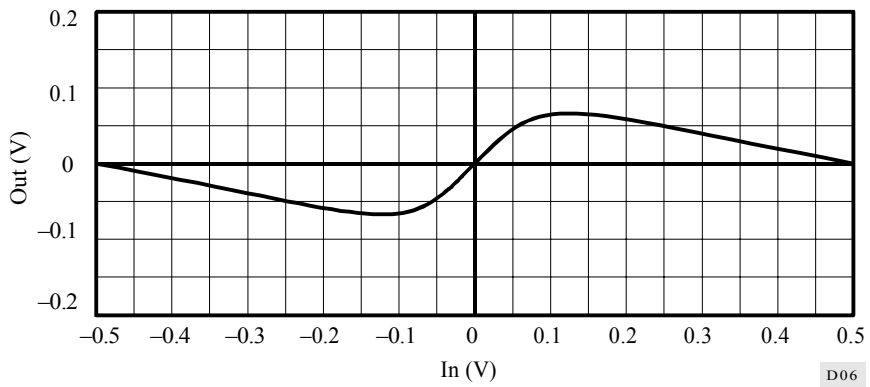
Non-linear function  $N_1$



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FIGURE 8

Non-linear function  $N_2$



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For active vision lines 23 to 310 and 335 to 622 inclusive, transition weights are as follows:

Transition weight	Sample Nos.	
	Scrambled MAC	Unscrambled MAC
0	1 to 225 inclusive	1 to 231 inclusive
1/8	226	232
1/2	227	233
7/8	228	234
1	229 to 1 287 inclusive	235 to 1 287 inclusive
7/8	1 288	1 288
1/2	1 289	1 289
1/8	1 290	1 290
0	1 291 to 1 296 inclusive	1 291 to 1 296 inclusive

### 7.1.2 Nyquist filtering

Nyquist filtering is applied after the above non-linear pre-emphasis.

The global 10% roll-off factor and the equal sharing of corresponding Nyquist filtering of only the HD-MAC vision signal between transmitter and receiver is identical for satellite broadcasting and cable distribution.

The half Nyquist filter has a theoretical transfer function defined by the following expression (see Fig. 9a):

$$\begin{aligned}
 H(f) &= 1 && \text{for } |f| < \frac{1}{2T}(1 + \alpha) \\
 H(f) &= \sqrt{\frac{1}{2} + \frac{1}{2} \sin \pi T \left( \frac{\frac{1}{2T} - |f|}{\alpha} \right)} && \text{for } \frac{1}{2T}(1 - \alpha) \leq |f| \leq \frac{1}{2T}(1 + \alpha) \\
 H(f) &= 0 && \text{for } |f| > \frac{1}{2T}(1 + \alpha)
 \end{aligned}$$

where:

$$1/T = 20.25 \text{ MHz and } \alpha = 0.1.$$

See Fig. 9b for the theoretical transfer function and the template to be used for the transfer function for a hardware implementation on the transmitter side.

The given parameters and filter specifications are subject to further confirmation.

FIGURE 9a  
Theoretical response of the 10% roll-off half-Nyquist filter

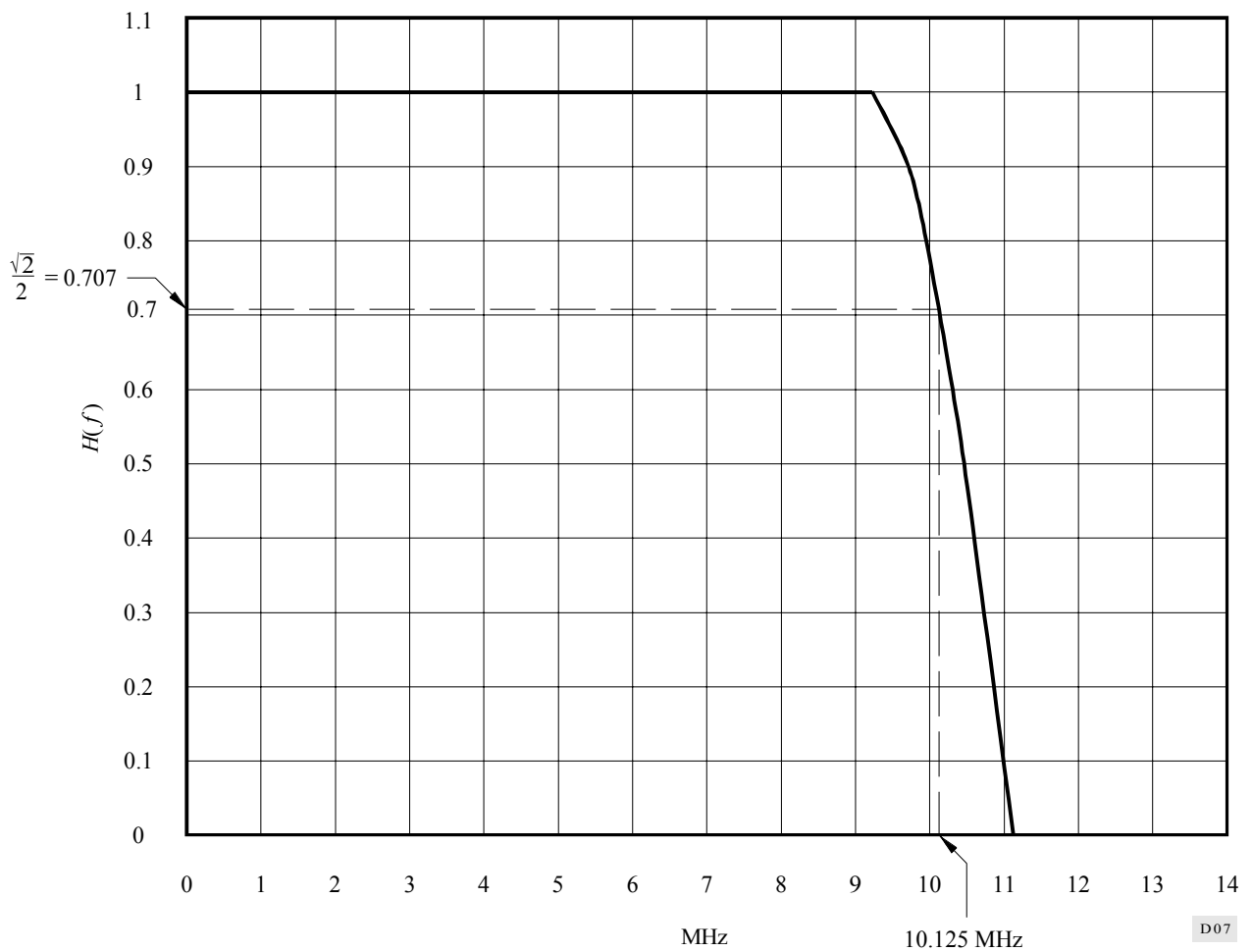
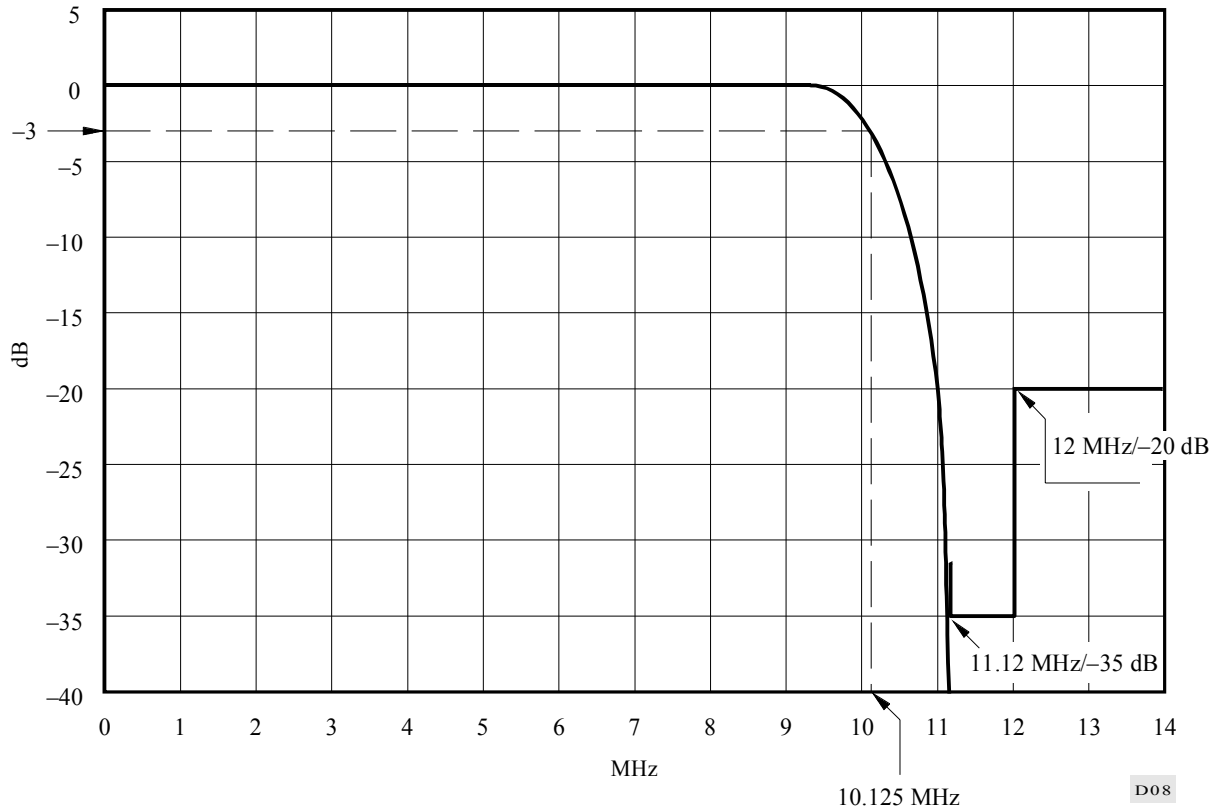


FIGURE 9b  
 Template for the transfer function of the transmitter half-Nyquist digital filter



**7.2 Modulation parameters for BSS**

These are summarized in Table 2.

TABLE 2

**Modulation parameters for the BSS**

Nominal vision signal bandwidth:	10.125 MHz at -3 dB
Nominal channel bandwidth:	27 MHz
Modulation:	FM
Polarity of frequency modulation:	positive
DC component:	preserved
Pre-emphasis characteristics:	non-linear process applied only to HD-MAC samples and linear applied to all the multiplex (same as for MAC)
Frequency deviation:	13.5 MHz at the cross-over frequency of the linear pre-emphasis network (1.37 MHz)
Energy dispersal:	triangular frame synchronous waveform (corresponding carrier deviation: 600 kHz peak-to-peak)

### 7.2.1 Modulation method

Frequency modulation is used for the whole baseband D- or D2-HD-MAC/packet signal. Linear pre-emphasis is applied to the whole baseband signal; energy dispersal is added, and the signal is used to frequency modulate a carrier.

A transition from black to white of the luminance signal corresponds to an increase in frequency at the receiver input.

### 7.2.2 Deviation sensitivity

The nominal frequency deviation sensitivity shall be 13.5 MHz/V at the transition frequency of the linear pre-emphasis network. Taking into account the effect of the linear pre-emphasis (see § 7.2.3), this corresponds to a deviation at low frequencies of 9.54 MHz for the vision signal (black to white transition of the luminance signal).

### 7.2.3 Linear pre-emphasis

The baseband signal of the D- or D2-HD-MAC/packet system will, before transmission, be pre-emphasized by means of a network whose transfer characteristic (as shown in Fig. 10) is defined by the expression:

$$H(f) = A \left( \frac{1 + j \left( \frac{f}{f_1} \right)}{1 + j \left( \frac{f}{f_2} \right)} \right)$$

The characteristics of the linear pre-emphasis network are given below:

$$A = 1/\sqrt{2}$$

$$f_1 = 0.84 \text{ MHz}$$

$$f_2 = 1.5 \text{ MHz}$$

### 7.2.4 Energy dispersal

An energy dispersal signal shall be added to the whole baseband signal (see Fig. 11). The dispersal signal shall consist of a frame synchronous 25 Hz triangular waveform with a deviation of 600 Hz peak-to-peak after modulation in the radio-frequency channel.

The dispersal deviation at the start of a line shall correspond to a 300 kHz reduction of carrier frequency.

### 7.2.5 DC restoration

DC restoration shall be applied to the whole baseband signal at the input of the frequency modulator. The carrier frequency corresponding to zero colour-difference is given by:  $f_0 + f_d$

where:

$f_0$ : channel centre frequency

$f_d$ : instantaneous frequency deviation produced by the energy dispersal signal.



FIGURE 10  
 Linear MAC pre-emphasis network

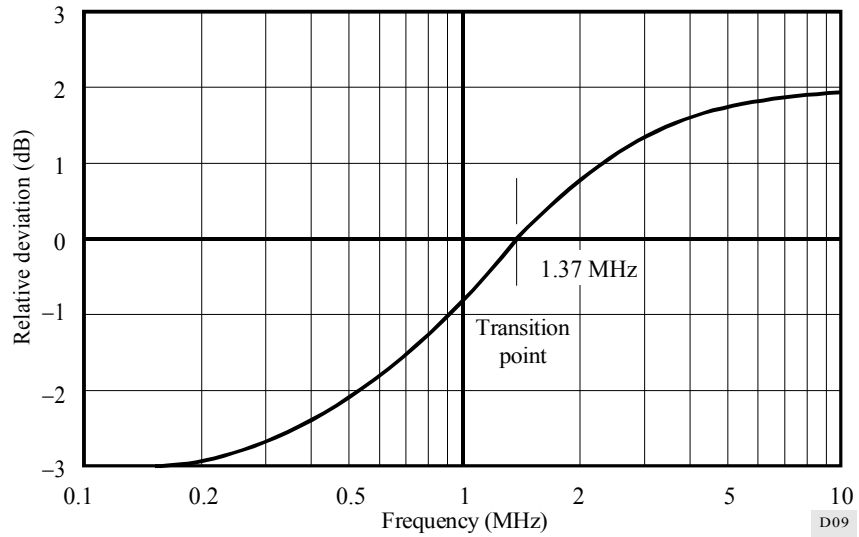
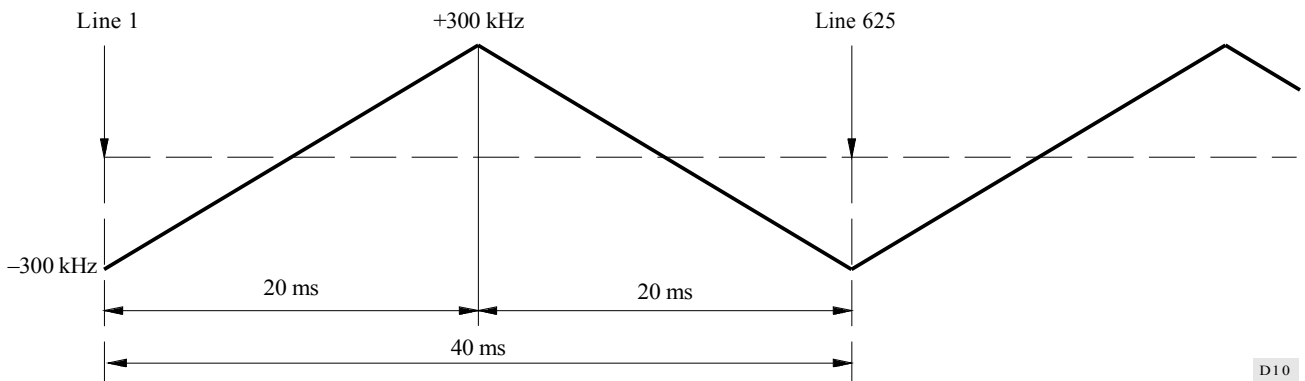
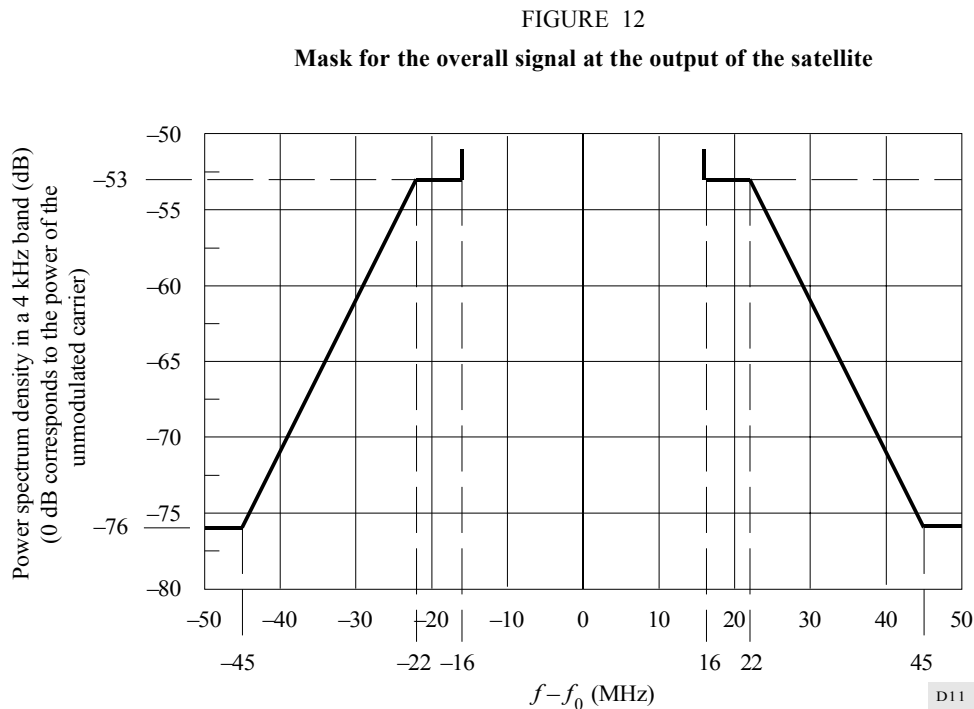


FIGURE 11  
 Energy dispersal waveform added to the baseband signal



### 7.2.6 Out-of-band radiation for the overall signal

Measured in a 4 kHz bandwidth, the radiated power flux-density must comply with the mask given in Fig. 12.



## 7.3 Modulation parameters for cable distribution

### 7.3.1 Modulation parameters

#### 7.3.1.1 Modulation method

VSB amplitude modulation shall be used for the time multiplex baseband signal.

#### 7.3.1.2 Sense of modulation

The sense of modulation shall be negative.

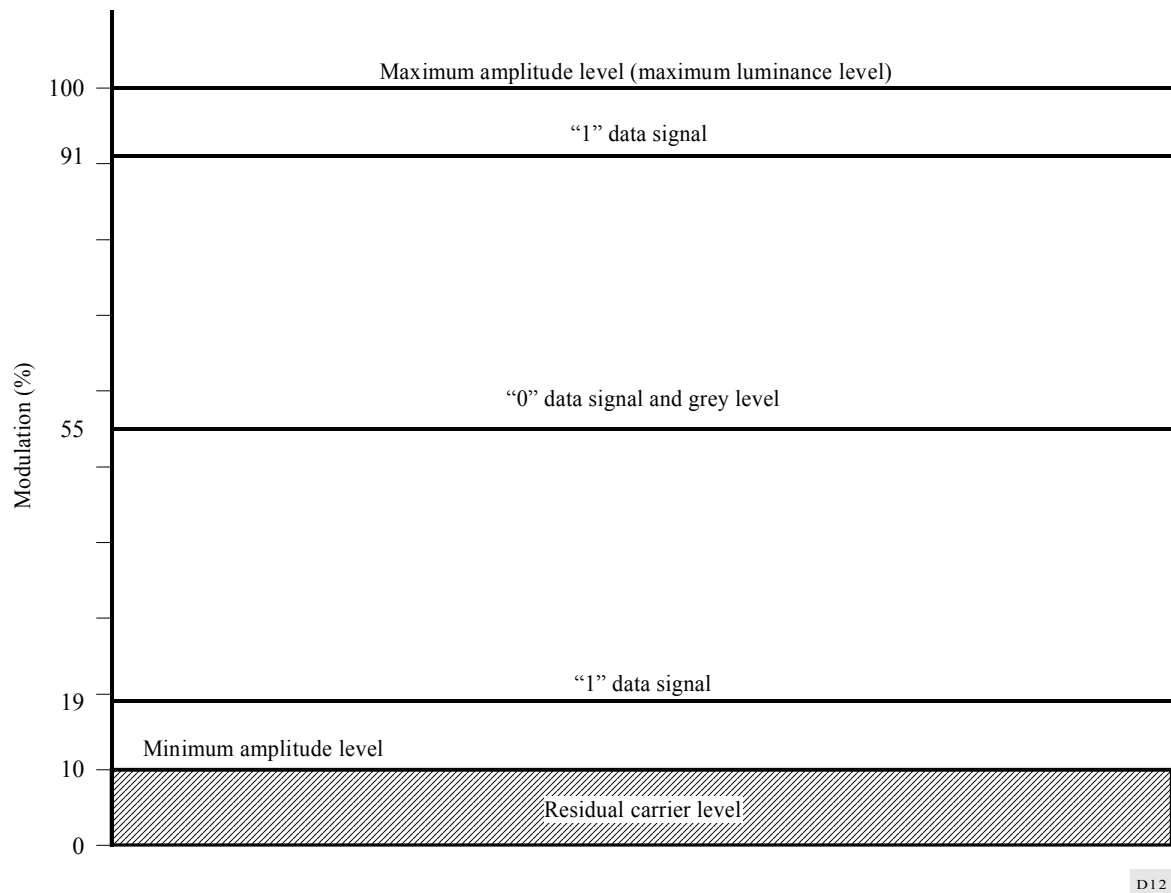
#### 7.3.1.3 Depth of modulation

Peak amplitude of the vision carrier is taken as 100%. The minimum level of the vision carrier will correspond to 10%. Under these conditions, level "1" in the data signal corresponds to 19% and 91% modulation, while level "0" corresponds to 55% modulation (see Fig. 13).

#### 7.3.1.4 Channel spacing

A channel spacing of 12 MHz is recommended as a common standard.

FIGURE 13  
Modulation levels (before transmission filtering)



### 7.3.2 IF filter specification

The Nyquist filtering at the vision carrier (carrier Nyquist) is completely done in the HD-MAC VSB/AM modulator.

The Nyquist filtering at the second Nyquist point at 10.125 MHz (HD Nyquist) is done at baseband level, equally split between transmitter (HD-MAC encoder) and receiver (HD-MAC front end) side.

#### 7.3.2.1 Modulator filtering

##### Nyquist filtering in the region of the vision carrier

The VSB will be filtered with a response which is skew-symmetric to the vision carrier frequency in a linear scale.

##### Amplitude characteristic

The recommended template of the amplitude characteristic of the transmitter IF filter is given in Fig. 14. The nominal value of the steepness of the Nyquist characteristic is  $\pm 500$  kHz (linear). For details see template.

##### Phase characteristic

The filter will be phase-linear.

The recommended template of the phase characteristic is given in Fig. 15.

FIGURE 14  
Modulator IF filter: amplitude response template

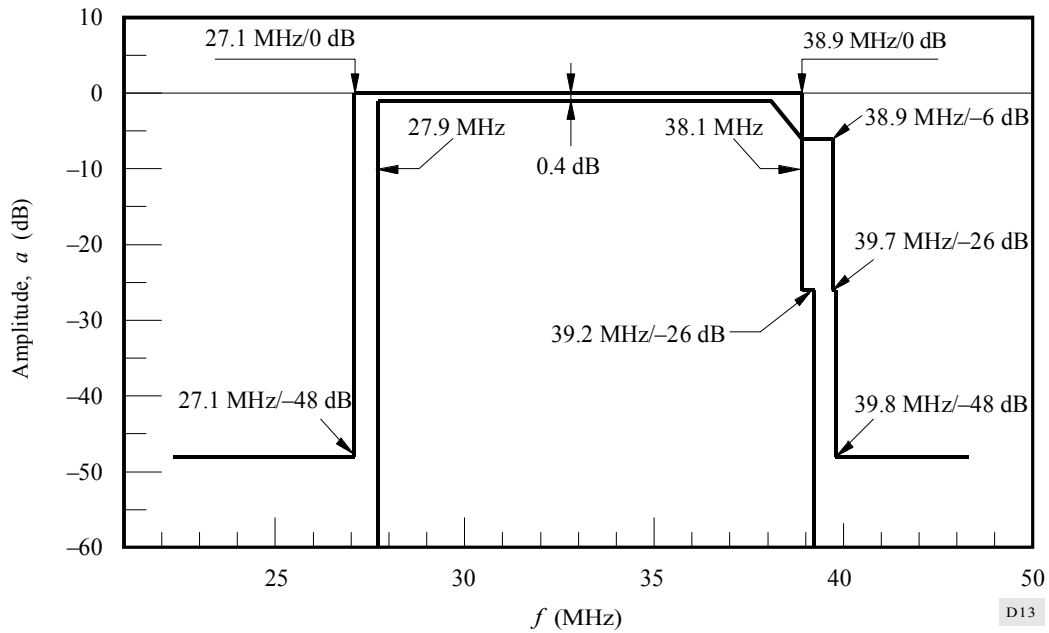
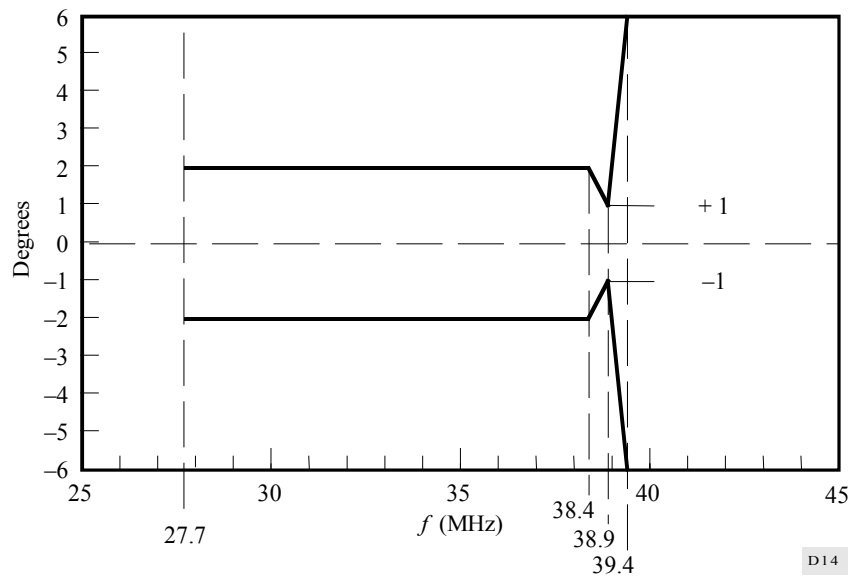


FIGURE 15  
Modulator IF filter: phase response template



7.3.2.2 Receiver filtering

Amplitude characteristic

The passband amplitude characteristic shall be essentially flat up to 11.14 MHz, i.e.,  $(1 + n/100)10.125$  MHz, in relation to the vision carrier frequency ( $n = 10\%$ , steepness of the Nyquist filter at the 10.125 MHz point).

The recommended template of the amplitude characteristic for an HD-MAC receiver IF filter is given in Fig. 16.

**Phase characteristic**

The filter will be phase-linear.

The recommended template of the phase characteristic is given in Fig.17.

FIGURE 16  
Receiver IF filter: amplitude response template

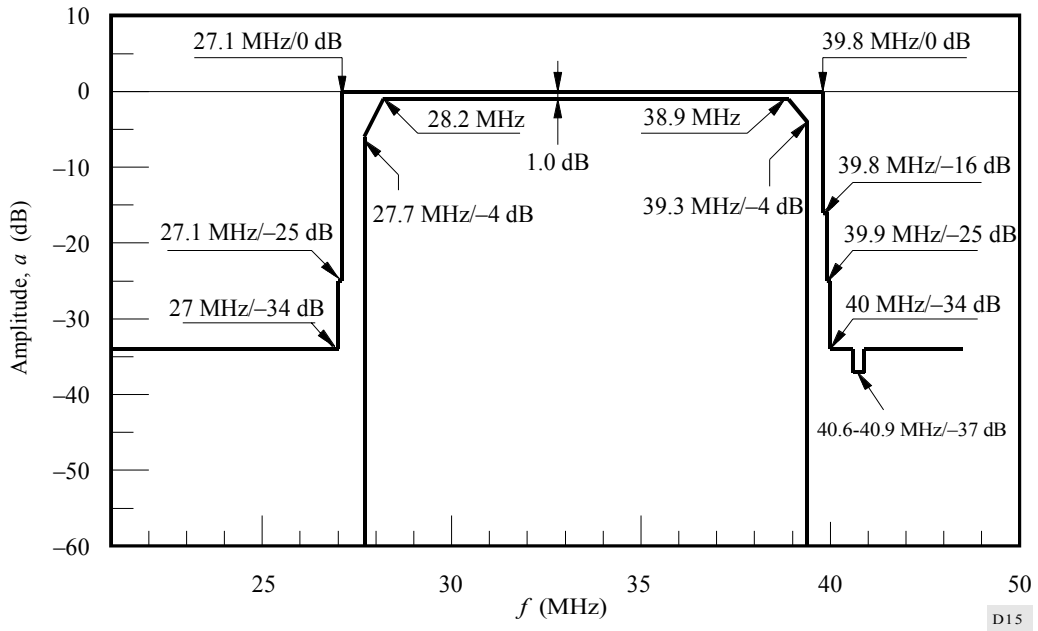


FIGURE 17  
Receiver IF filter: phase response template

