RECOMMENDATION ITU-R BT.1124-3

Reference signals for ghost cancelling in analogue television systems

(Question ITU-R 55/11)

(1994-1995-1998-2001)

The ITU Radiocommunication Assembly,

considering

a) that a ghost cancelling system using a ghost cancelling reference (GCR) signal is one of the most effective countermeasures for ghost images in individual and collective antenna reception of television signals;

b) that the system should be effective for cancelling multiple and long delayed ghost images as well as short delayed ghost images and it should be also effective for leading ghosts and waveform equalization of video signals;

c) that the GCR signals can be inserted into the lines in the vertical blanking intervals;

d) that for each television system an appropriate GCR signal can be defined;

e) that for each country the appropriate GCR signal can be used to suit the various propagation conditions and the types of transmission media;

f) that the ghost canceller using the GCR signals can be manufactured at a reasonable cost;

g) that the cost of ghost cancellers may be lower if there is widespread use of a common GCR signal,

recommends

1 that the GCR signal should be a dedicated reference signal optimized for ghost cancelling;

2 that the GCR signal should allow the rapid determination of the channel response even under poor signal-to-noise conditions;

3 that the GCR signal must be able to provide a flat amplitude and flat group delay response versus frequency over the entire passband of each system;

4 that the GCR signal should make efficient use of the vertical interval resources;

5 that for NTSC, PAL and SECAM television systems, a broadcaster wishing to integrate a GCR signal should use a GCR signal complying with the specifications given in Annex 1 for:

– GCR signal A,

– GCR signal B,

– GCR signal C;

6 that for new GCR applications for NTSC, PAL or SECAM, GCR signal C should preferable be used;

7 that for advanced analogue television systems, a broadcaster wishing to integrate a GCR signal should use a GCR signal complying with the specifications given in Annex 2 for a MUSE system.

ANNEX 1

GCR signal specifications for conventional TV systems

1 Introduction

GCR Signal A for use with the NTSC system, was recommended by ITU-R in 1994 and has been used extensively in Japan since 1989.

GCR Signal B was recommended by ITU-R in 1994 and has been used extensively with the NTSC system in Korea since 1993.

GCR Signal C for use with NTSC, PAL, and SECAM system is being adopted by broadcasters in many countries now introducing GCR signals.

1.1 GCR Signal A

Requirements for the GCR signal relevant to the NTSC system are specified in Tables 1 to 4 and Figs. 1 to 3.

TABLE 1

Specification of GCR waveform

	Value	**Remarks**
Amplitude	70 ± 2 IRE units	Difference between setup level and the centre point level of the GCR waveform
Setup	0 ± 2 IRE units	Difference between blanking level and pedestal level of the active line. Difference between line A and line B should be 0.5 IRE or less
Width	160 ± 1.0 sc(1) (44.7 ± 0.28 μs)	Measured at 50% value of the GCR amplitude
Start of GCR	60 ± 1.5 sc(2) (16.76 ± 0.42 μs)	GCR rising edge timing (50% point) with respect to leading edge of line sync
Rising edge	Integrated sin(*x*)/*x*	See equation (1)
Trailing edge	0.25 ± 0.05 μs (2T bar)	Interval between 10% point and 90% point of the GCR amplitude

(1) sc – Subcarrier cycles (one colour subcarrier cycle: 1/3.579545 μs).

(2) Specified at the output point of the GCR signal generator. Not specified at the output point of the GCR inserter unless necessary.

$$f(t) = \frac{1}{A} \int_{\infty}^{t} \frac{\sin(\omega x)}{\omega x} h(x) \, \mathrm{d}x \tag{1}$$

where A is a normalizing factor (A = $f(\infty)$), $\omega = 2\pi \times 4.177447 \times 10^6$, and $h(x)$ is a window function to give the signal spectrum as shown in Fig. 4, such as raised cosine having the half amplitude width of 10.5 µs.

FIGURE 1

GCR waveform for line A

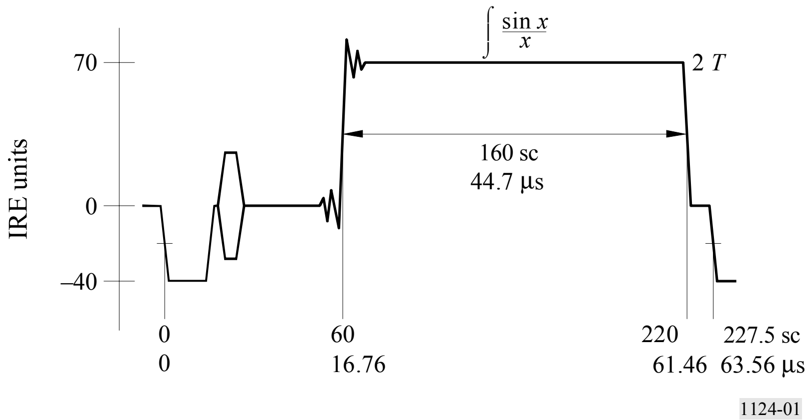


FIGURE 2

Zero-pedestal waveform for line B

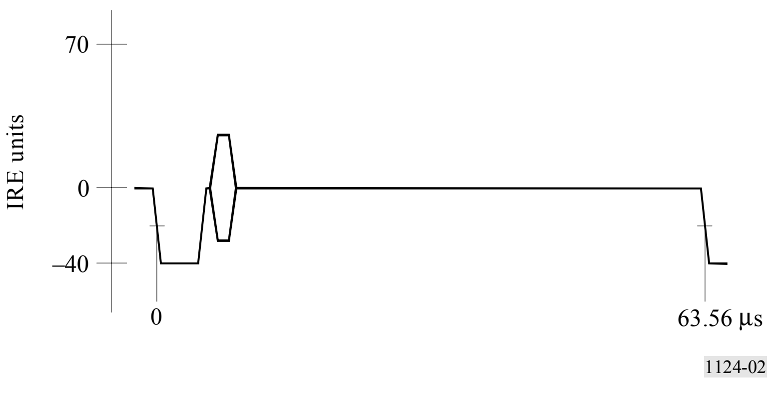
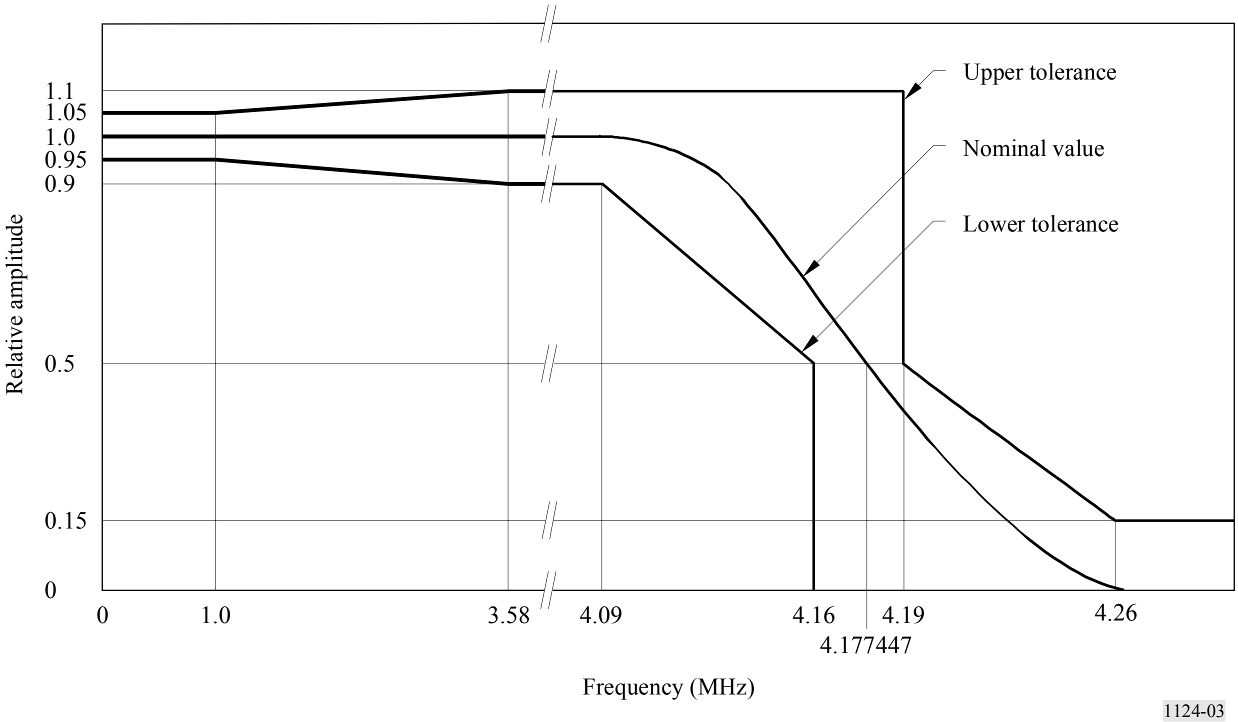


FIGURE 3

Frequency spectrum for reference pulse GCR signal



The characteristics are applied to the differential or one-sample difference of the GCR signal.

TABLE 2

GCR insertion line

Insertion line numbers	18 and 281

TABLE 3

Signal on the line immediately preceding the GCR line

Field numbers							
1	2	3	4	5	6	7	8
x_1	x_2	x_3	x_4	x_1	x_2	x_3	x_4

x_1, x_2, x_3 and x_4 should not contain time varying information.

TABLE 4

GCR transmission sequence

Field number	1	2	3	4	5	6	7	8
Waveform	Line A	Line B	Line A	Line B	Line B	Line A	Line B	Line A

1.2 GCR signal B

Requirements for the GRC signal relevant to the 525-line NTSC and 625-line PAL systems are specified in Tables 5 to 8 and Figs. 4 and 5.

TABLE 5

Ternary sequence of length 366

1	0	1	0	1	0	1	0	1	0	1	0	1	0	–1
0	–1	0	1	0	0	0	–1	0	–1	0	1	0	1	0
–1	0	1	0	1	0	1	0	–1	0	–1	0	–1	0	–1
0	1	0	1	0	1	0	1	0	–1	0	1	0	–1	0
1	0	–1	0	–1	0	0	0	1	0	1	0	–1	0	–1
0	1	0	1	0	–1	0	–1	0	1	0	0	0	1	0
–1	0	1	0	–1	0	–1	0	1	0	–1	0	1	0	1
0	1	0	–1	0	–1	0	1	0	1	0	–1	0	1	0
–1	0	0	0	–1	0	0	0	–1	0	1	0	–1	0	1
0	–1	0	–1	0	–1	0	–1	0	–1	0	1	0	–1	0
–1	0	1	0	–1	0	1	0	1	0	0	0	1	0	1
0	1	0	–1	0	–1	0	–1	0	0	0	1	0	1	0
–1	0	–1	0	–1	0	1	0	1	0	–1	0	1	0	1
0	–1	0	1	0	–1	0	–1	0	–1	0	–1	0	–1	0
–1	0	1	0	–1	0	1	0	0	0	–1	0	1	0	1
0	1	0	1	0	–1	0	1	0	1	0	–1	0	1	0
1	0	0	0	0	0	1	0	1	0	0	0	–1	0	1
0	1	0	1	0	0	0	1	0	–1	0	1	0	–1	0
1	0	0	0	–1	0	1	0	1	0	1	0	1	0	1
0	–1	0	1	0	–1	0	–1	0	1	0	1	0	–1	0
1	0	1	0	–1	0	–1	0	–1	0	1	0	–1	0	1
0	–1	0	–1	0	1	0	0	0	1	0	1	0	1	0
–1	0	–1	0	–1	0	–1	0	1	0	1	0	–1	0	–1
0	1	0	–1	0	1	0	–1	0	–1	0	–1	0	1	0
1	0	1	0	1	0									

TABLE 6

Specifications of GCR waveform

Television system	525-line	625-line	
		B, G	D, K
GCR signal frequency limit	4.18 MHz	5.0 MHz	6.0 MHz(1)
Pedestal height	30 IRE units	300 mV	
Start of pedestal(2)	8.75 µs	10.5 µs	
Finish of pedestal(2)	61.9 µs	62.5 µs	
Start of GCR(2)	11.5 µs	12.2 µs	
Duration of GCR	25.6 µs	20.6 µs	
Lowest level of GCR	–10 IRE units	0 mV	
Highest level of GCR	+70 IRE units	600 mV	
Clock frequency(3)	4 × 3.58 MHz	4 × 4.43 MHz	

(1) The 6 MHz option is not compatible with transmission of NICAM digital sound using a 5.85 MHz carrier.

(2) The start and finish times are defined at the half-amplitude points.

(3) This refers to the use of a clock at four times the colour subcarrier frequency of NTSC or PAL, as appropriate.

TABLE 7a

Transmission sequence of NTSC GCR signal

Field number	1	2	3	4
GCR signal polarity	+	–	+	–

TABLE 7b

Transmission sequence of PAL GCR signal*

Field number	2	4	6	8
GCR signal polarity	+	–	+	–

* There is no absolute relationship between the polarity of the GCR transmission sequence and the eight-field sequence of PAL.

TABLE 8

The frequency values in Fig. 4

TV system frequency	525-line	625-line	
		B, G	D, K
f1 (MHz)	1.00	1.00	1.00
f2 (MHz)	3.58	4.43	4.43
f3 (MHz)	4.09	4.80	5.80
f4 (MHz)	4.18	5.00	6.00
f5 (MHz)	4.25	5.20	6.20

FIGURE 4

Frequency characteristic of the lowpass filter

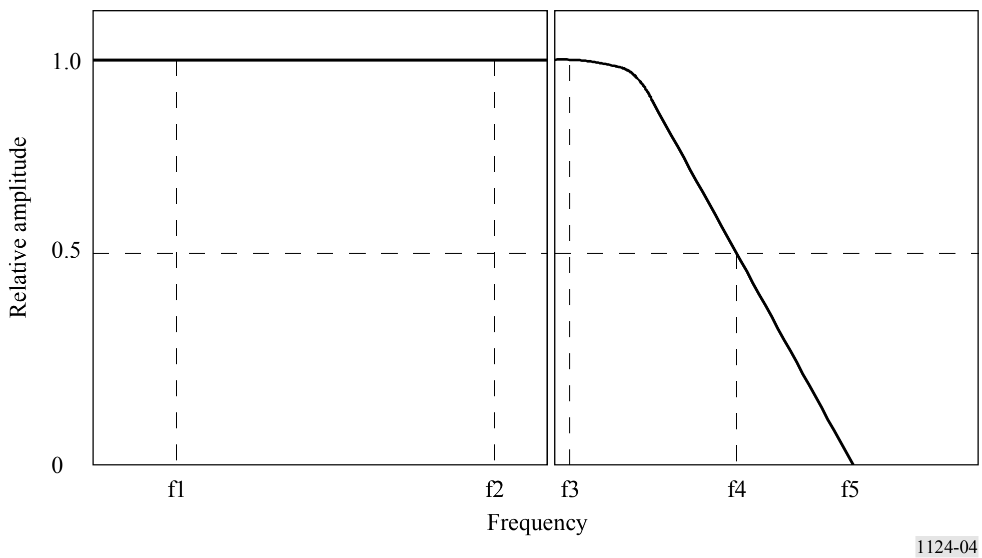


FIGURE 5a

Positive GCR signal for 525-line systems

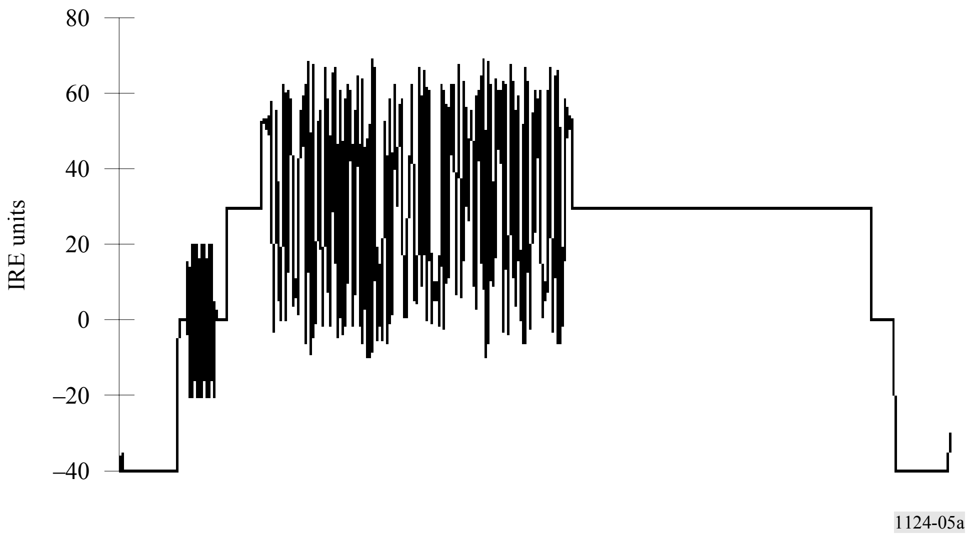


FIGURE 5b

Negative GCR signal for 525-line systems

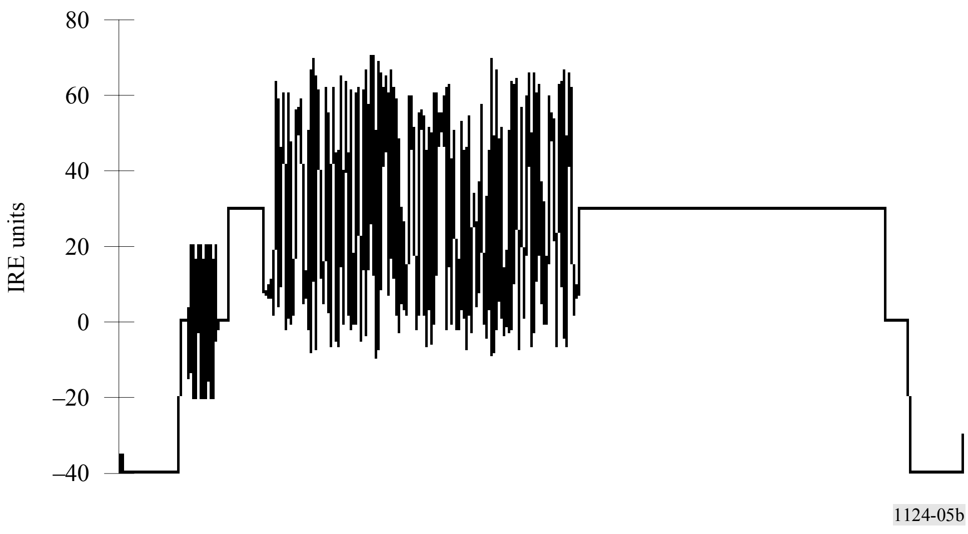


FIGURE 5c

Positive GCR signal for 625-line systems (5 MHz)

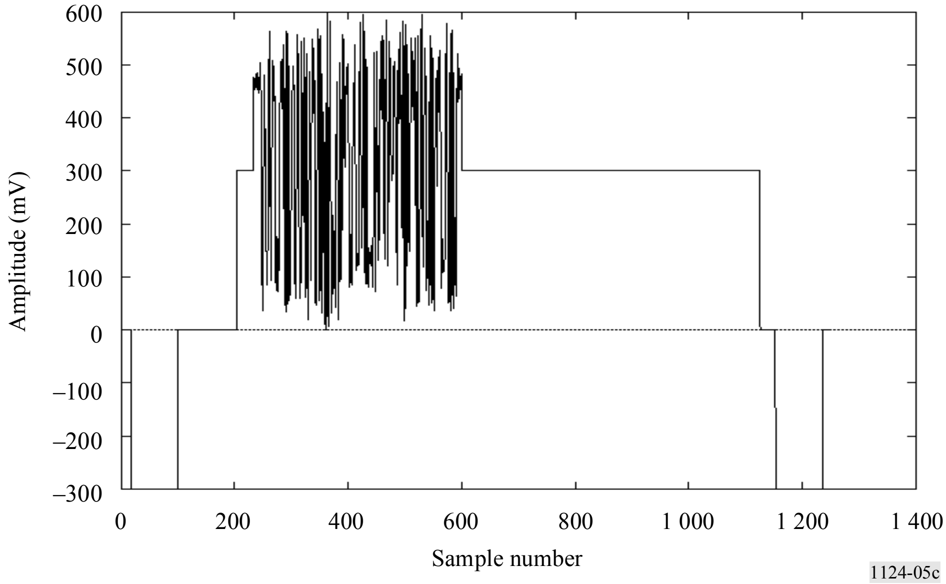


FIGURE 5d

Negative GCR signal for 625-line systems (5 MHz)

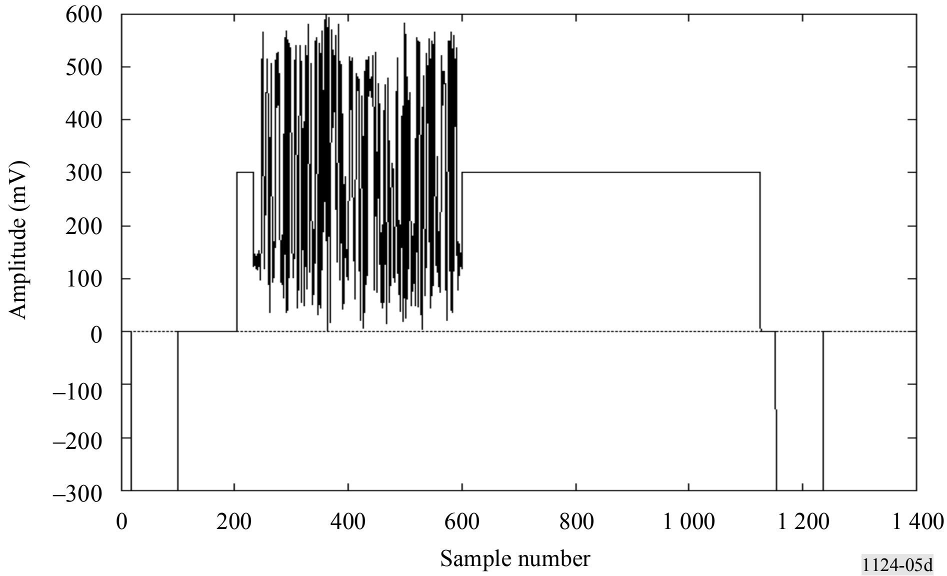


FIGURE 5e

Positive GCR signal for 625-line systems (6 MHz)

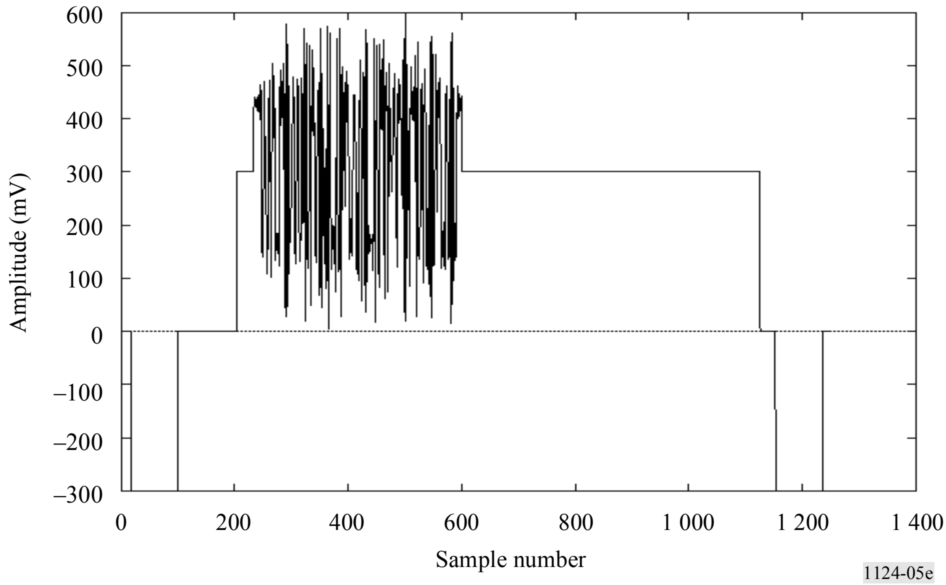
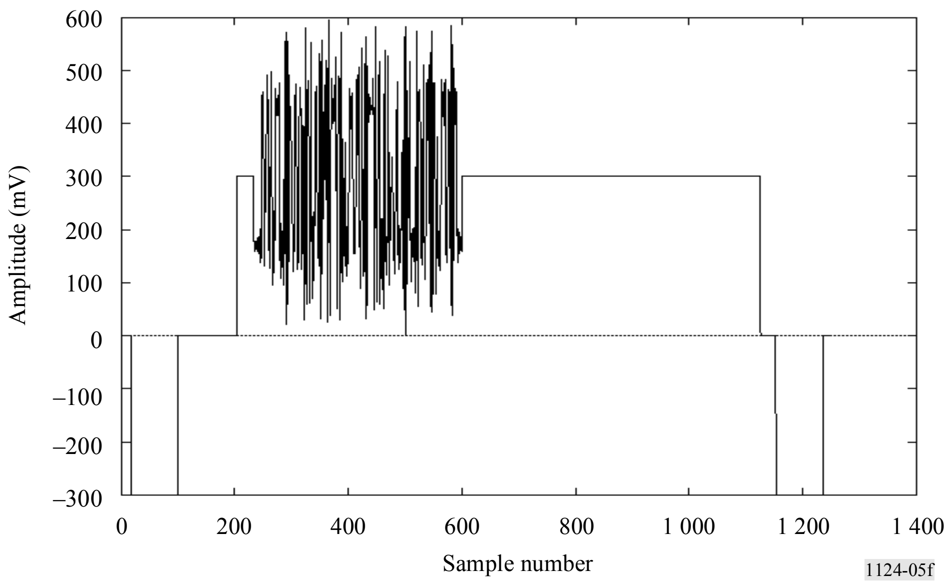


FIGURE 5f

Negative GCR signal for 625-line systems (6 MHz)



1.3 GCR signal C

Requirements for the GCR signal are described below. Specific parameters for 525- and 625-line NTSC, PAL and SECAM television systems (see Note 1) are set out in Table 9.

NOTE 1 – Correct operation of the motion adaptive colour plus (MACP) process used by the PALplus system relies on the fact that points separated by 312 lines within a frame have a precise phase relationship. In order to avoid disturbing this relationship, any changes to the equalization of the signal applied by a ghost canceller located in either the transmission or reception chain should preferably be made during the period of lines 624 to 22.

The GCR signal is placed on a single line in the vertical blanking interval, on one line per field in 525-line systems, and on one line per frame (two fields) in 625-line systems.

The GCR signal has a flat spectrum and high energy up to the frequency f1 and has low energy beyond the frequency f2. The values of f1 and f2 are shown in Table 9. Figure 6 shows the spectrum of the GCR signal. The normalized GCR signal as a function of time is shown in Fig. 7.

In 525-line systems, the GCR signal is placed on line 19 (and the corresponding line in the following field). In 625-line systems, the GCR signal is preferably placed on line 318, with the preceding line 317 containing no time-varying information. For both 625- and 525-line systems the line immediately preceding the GCR line should preferably not contain time varying information to avoid constraining the performance of ghost cancellers.

To provide efficient cancellation of 625-(525)-line systems requiring post ghost cancellation ranges greater than approximately 38 (31) μs, at least the following line should preferably not contain any time-varying information (e.g. if line 318 (19 and 282) is used for the GCR then line 319 (20 and 283) should not contain time varying information.

The GCR has nominally constant amplitude within the band of interest, and is placed on a pedestal of height V1. The rise and fall times of the pedestal are nominally 4 *T*, and the start and finish times to the half amplitude points, with respect to the leading edge of the horizontal sync are T1 and T2 respectively. The values of V1, T1 and T2 are given in Table 9.

The GCR signal has a duration of T3 (measured at 1% of the maximum value) and begins at time T4 after the leading edge of horizontal sync. The first peak (positive or negative) is T5 after the leading edge of horizontal sync. The GCR varies from V2 to V3. Note that the pedestal V1 is the mean of these extreme values. The values of T3, T4, T5, V2 and V3 are given in Table 9.

Waveforms of the GCR signal on the pedestal are shown in Figs. 8 and 9 represent line A and line B respectively. Line A and line B have the same pedestal height V1, but the GCR polarity is inverted from line A to line B.

TABLE 9

	Television system	525-line	625-line	
f1	GCR signal frequency limit	4.1 MHz	5.0 MHz(1)	6.0 MHz
f2	GCR signal frequency stop limit	4.3 MHz	5.2 MHz	6.2 MHz
V1	Pedestal height	30 IRE units	350 mV	
T1	Start of pedestal	9.5 µs	10.5 µs	
T2	Finish of pedestal	58.5 µs	62.5 µs	
T3	Duration of GCR	35.5 µs	23.2 µs	22.32 µs
T4	Start of GCR	12.0 µs	12.2 µs	12.6 µs
T5	First peak of GCR	16.7 µs	15.8 µs	15.7 µs
V2	Lowest level of GCR	–10 IRE units	0 mV	
V3	Highest level of GCR	+70 IRE units	700 mV	
GCR polarity:				
	Line A	Normal	Normal	
	Line B	Inverted	Inverted	
GCR transmission sequence(2):				
	Field 1	Line A	–(3)	
	Field 2	Line B	Line A	
	Field 3	Line A	–(3)	
	Field 4	Line B	Line B	
	Field 5	Line B	–(3)	
	Field 6	Line A	Line A	
	Field 7	Line B	–(3)	
	Field 8	Line A	Line A	

(1) For 625-line television system N, described in Recommendation ITU-R BT.470, the available vision bandwidth (4.2 MHz), is less than the bandwidth of the 625-line GCR (5.0 MHz). It is suggested that for television system N, the GCR signal for bandwidth 5 MHz described in this Recommendation for 625-line signals be used, but the band limited to the available vision bandwidth.

(2) There is no absolute relationship between the polarity of the GCR transmission sequence and the eight-field sequence of PAL.

(3) The use of a field mode GCR signal for 625-line systems, in conjunction with appropriate receiving equipment might offer improved performance in the case of moving ghost signals. Further studies need to be conducted to investigate this possibility.

Numerical values of the reference signal as a function of time can be calculated from equation (2):

$$f(t) = \frac{A}{2\pi}\left[\int_{0}^{\Omega}\left[\cos(b\,\omega^2) + \mathrm{j}\sin(b\,\omega^2)\right] W(\omega)\,\mathrm{e}^{\mathrm{j}\omega t}\,\mathrm{d}\omega + \int_{-\Omega}^{0}\left[\cos(b\,\omega^2) - \mathrm{j}\sin(b\,\omega^2)\right] W(\omega)\,\mathrm{e}^{\mathrm{j}\omega t}\,\mathrm{d}\omega\right] \qquad (2)$$

$W(\omega)$ is the window function (3):

$$W(\omega) = \int_{-\frac{\pi}{c}}^{\frac{\pi}{c}}\left[\left(\frac{1}{2} + \frac{1}{2}\cos(ct)\right)\left(\frac{1}{2\pi}\int_{-\Omega_1}^{\Omega_1}\mathrm{e}^{\mathrm{j}\gamma t}\,\mathrm{d}\gamma\right)\right]\mathrm{e}^{-\mathrm{j}\omega t}\,\mathrm{d}t \qquad (3)$$

where the constants: A, b, Ω, c and Ω_1 are given in Table 10. Alternative formulae for definition of this signal in real and in spectral spaces are presented in Appendix 1. They may be used for calculation numerical values of the reference signal instead of equations (2), (3) with the same result. They are presented for better understanding of the nature of GCR signal C. More detailed information on possibilities of this signal is published in Report ITU-R BT.2018.

Parameters for GCR formulae are given in Table 10.

TABLE 10

Parameters for GCR formulae

	NTSC (Normalized)(1)	**525-lines**	**625-lines (5 MHz)**	**625-lines (6 MHz)**	**Units**
A	9	3.592×10^{-7}	0.30358×10^{-6}	2.7×10^{-6}	V
b	110	0.53656×10^{-12}	0.2829×10^{-12}	0.23×10^{-12}	s^2/rad
Ω	$4.3\pi/7.16$	$2\pi \times 4.3 \times 10^6$	$2\pi \times 5.5 \times 10^6$	$2\pi \times 6.25 \times 10^6$	rad/s
c	$\pi/49$	0.917998×10^6	0.9121×10^6	0.9121×10^6	rad/s
Ω_1	$4.15\pi/7.16$	$2\pi \times 4.15 \times 10^6$	$2\pi \times 5.0 \times 10^6$	$2\pi \times 6.0 \times 10^6$	rad/s

(1) NTSC parameters normalized to 4 × 3.579545 MHz to 1 Hz and 1 V p-p.

FIGURE 6a

Magnitude of the spectrum of the GCR signal for 525-line systems

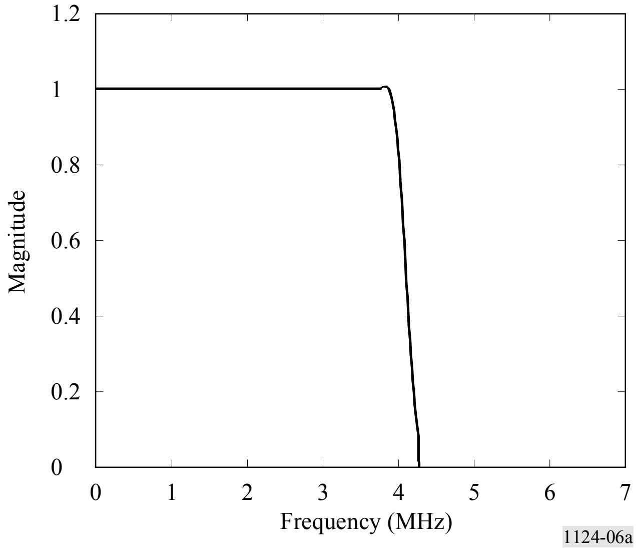


FIGURE 6b

Magnitude of the spectrum of the GCR signal for 625-line systems (5 MHz)

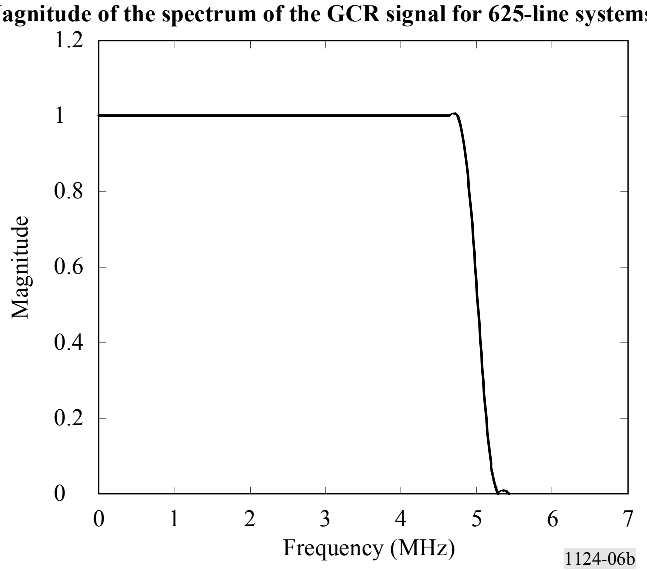


FIGURE 6c

Magnitude of the spectrum of the GCR signal for 625-line systems (6 MHz)

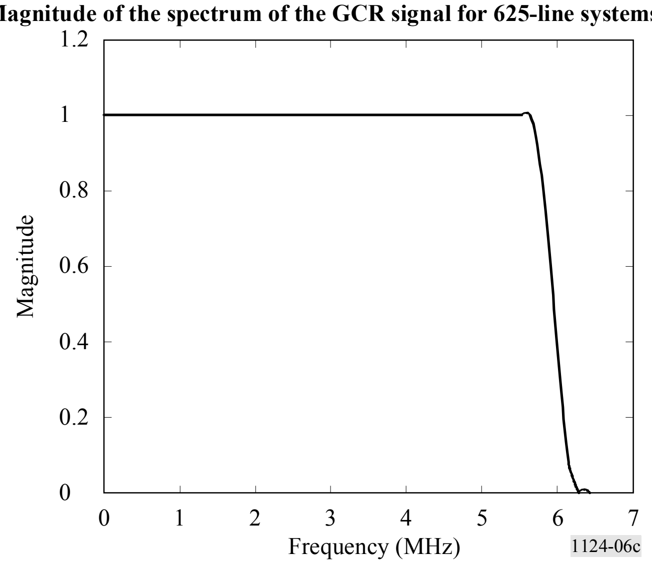


FIGURE 7

An example of a GCR signal as a function of time for 525-line systems

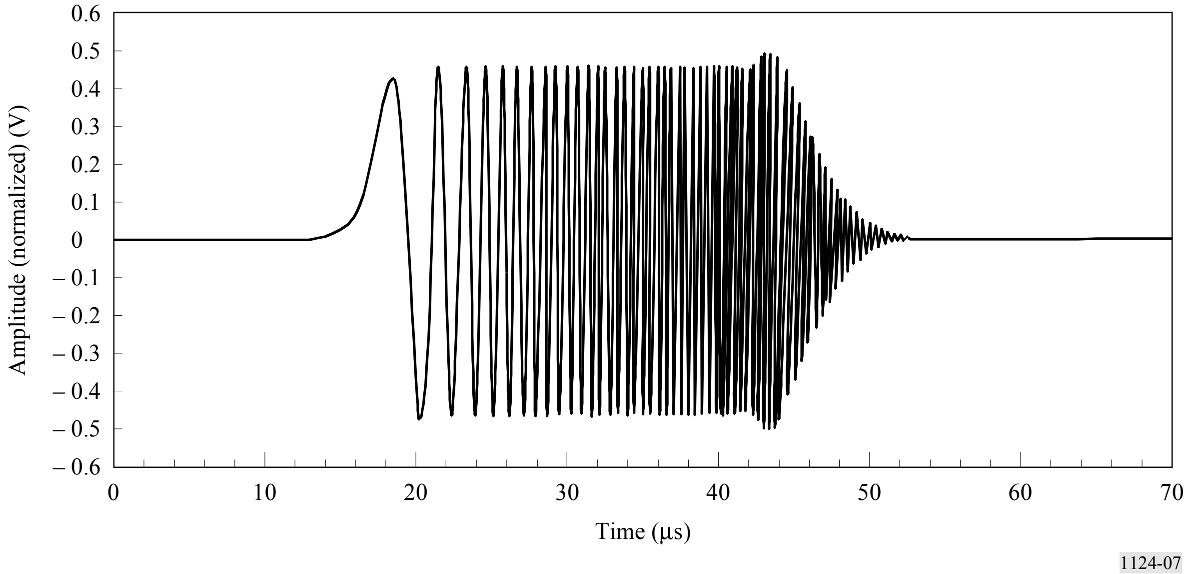


FIGURE 8a

GCR signal line A for 525-line systems

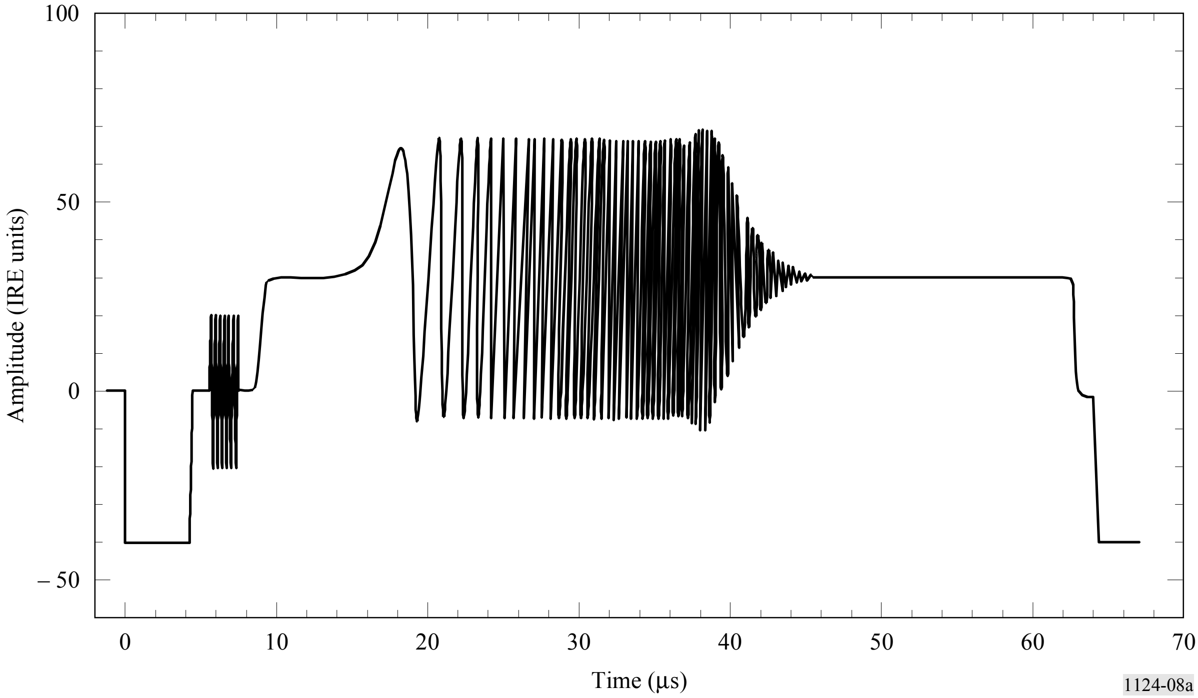


FIGURE 8b

GCR signal line A for 625-line systems (5 MHz)

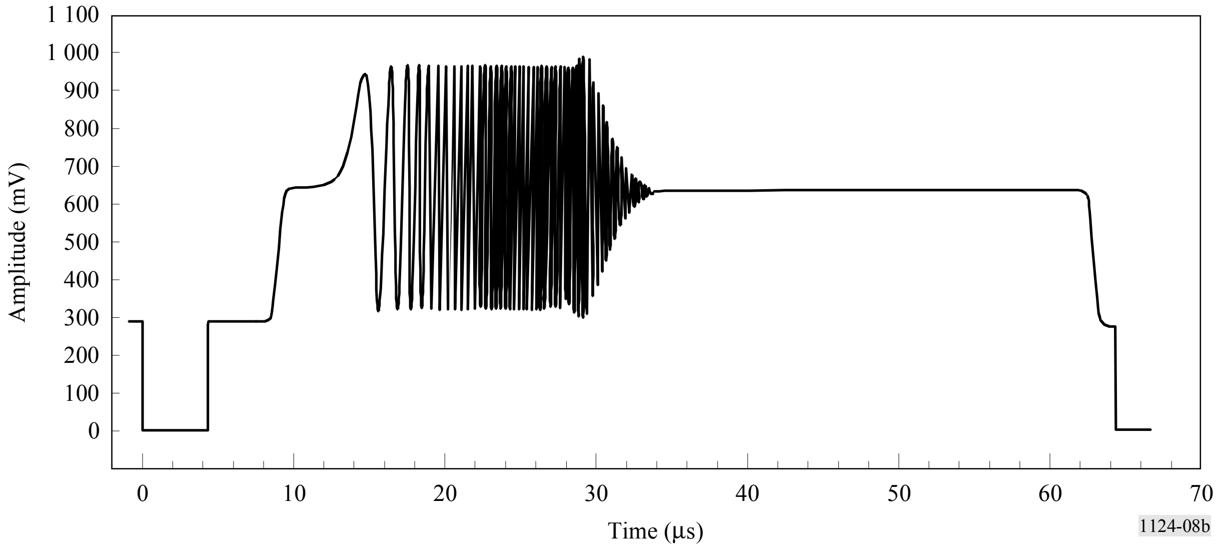


FIGURE 8c

GCR signal line A for 625-line systems (6 MHz)

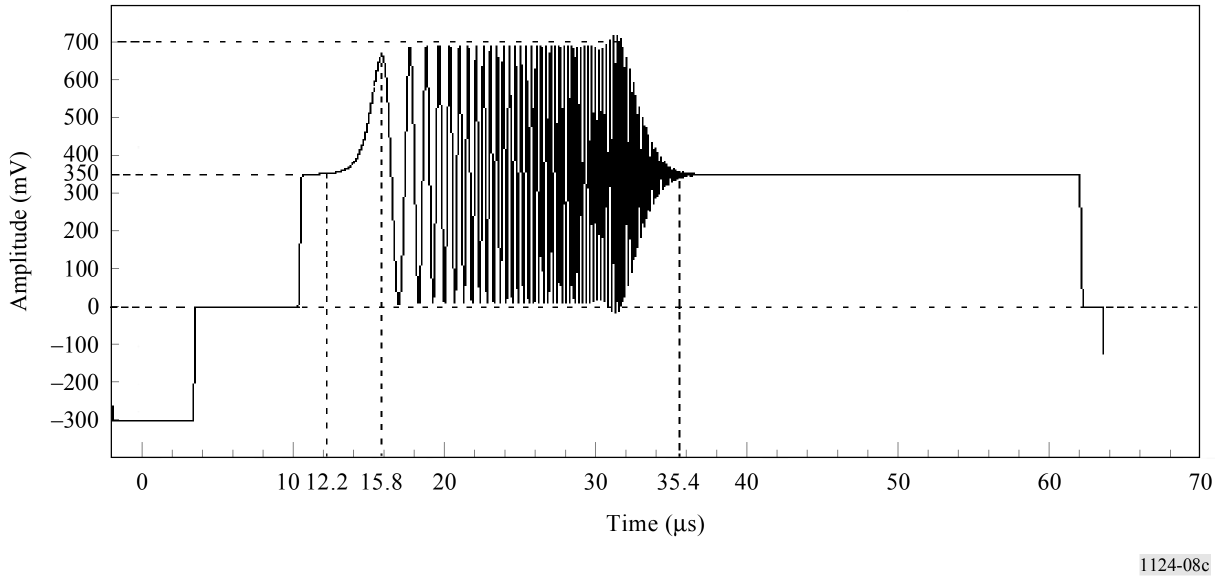


FIGURE 9a

GCR signal line B for 525-line systems

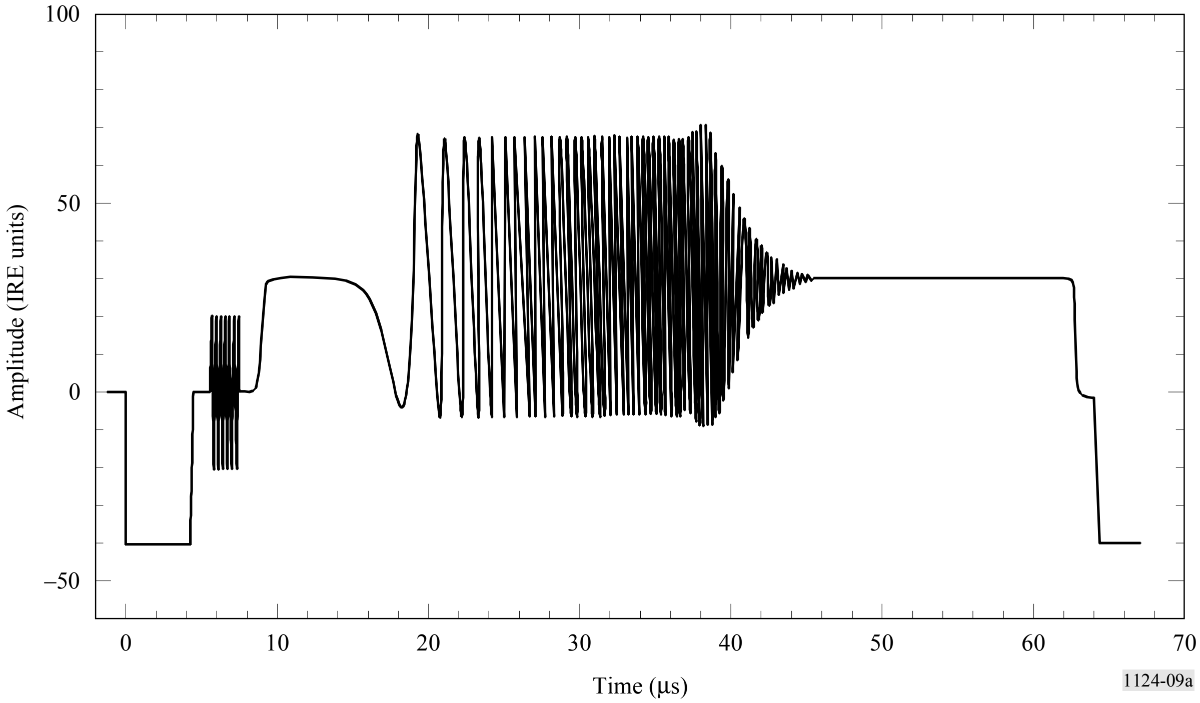


FIGURE 9b

GCR signal line B for 625-line systems (5 MHz)

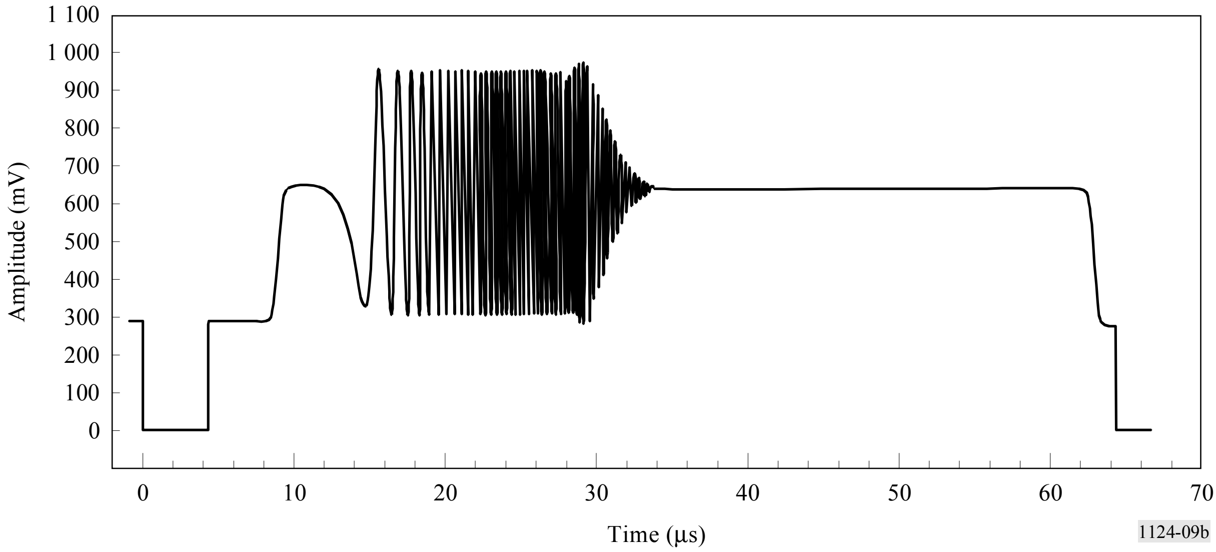
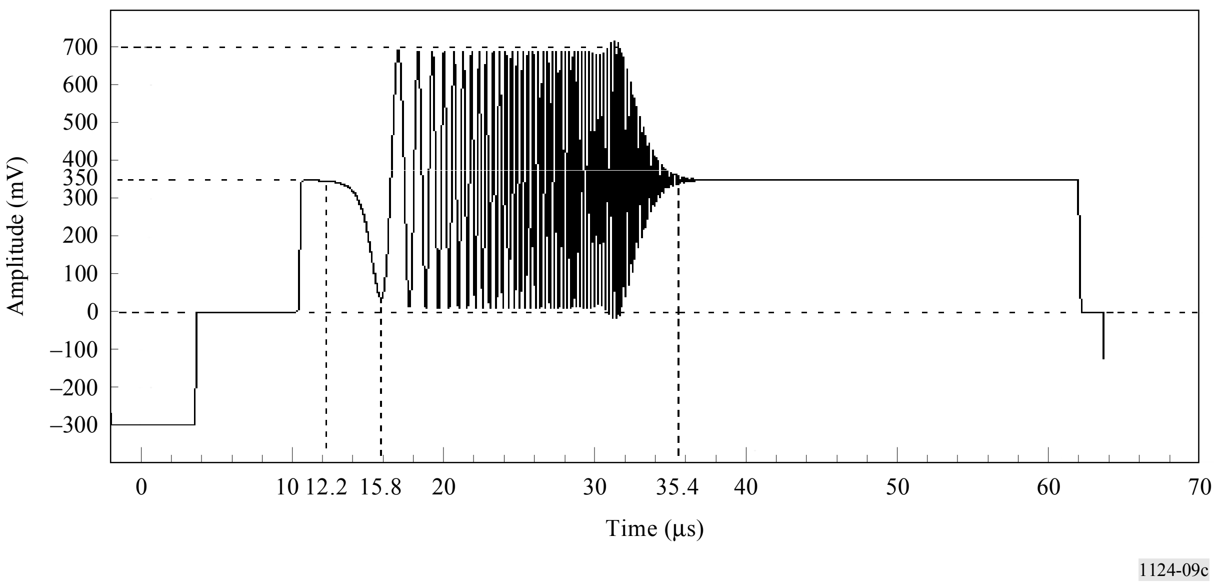


FIGURE 9c

GCR signal line B for 625-line systems (6 MHz)



APPENDIX 1

TO ANNEX 1

Possible alternative formulae for mathematical definition of GCR signal C

Equations (2) and (3) in § 1.3 of Annex 1, after corresponding transformations, may be also written in two presented below possible variants, which more clearly express the structure of the GCR signal. These variants use two window functions:

– $W(\omega)$ from equation (2) or its inverse Fourier transform, $w(t)$, and

– $P(\omega)$ or its inverse Fourier transform $p(t)$. It is a rectangular function limiting the interval of product $e^{j\,\mathrm{sign}(\omega)\,b\,\omega^2}\,W(\omega)$. This window function is not clearly seen from equation (4).

Variant 1

$$g(t) = \frac{A}{2\pi}\int_{-\Omega}^{\Omega} e^{j\,\mathrm{sign}(\omega)\,b\,\omega^2}\,W(\omega)\,e^{j\omega t}\,d\omega \qquad (4)$$

where:

$$W(\omega) = \int_{-mT}^{mT} w(t)\,e^{-j\omega t}\,dt, \qquad w(t) = q(t)\,s(t),$$

$$q(t) = \cos^2\frac{\pi}{2}\frac{t}{mT}, \qquad s(t) = \frac{m-2}{mT}\,\mathrm{sinc}\,\pi\,\frac{m-2\,t}{mT},$$

$$\mathrm{sign}(\omega) = \begin{cases} -1\,(\omega < 0), \\ 0\,(\omega = 0), \\ 1\,(\omega > 0), \end{cases} \qquad \mathrm{sinc}\,x = \frac{\sin x}{x},$$

$$T = \frac{m-2}{m}\,\frac{\pi}{\Omega_1}, \quad m = \frac{\Omega_1}{c} + 2$$

Values of T and m for GCR signal C parameters, given in Table 10 for 625-line 5 MHz system, are $T = 94.5$ ns, $m = 36.4439$.

Values of T and m for parameters, given for 6 MHz system, are $T = 79.487$ ns, $m = 43.332$.

Variant 2

$$g(t) = f(t) \otimes w(t) \otimes p(t) \tag{5}$$

where:

$$f(t) = \frac{1}{2\sqrt{\pi b}} \left\{ \cos\left[\omega(t)\, t - \frac{\pi}{4}\right] + \frac{1}{\pi} \sin\left[\omega(t)\, t - \frac{\pi}{4}\right] \otimes \frac{1}{t} \right\},$$

$$p(t) = \frac{\pi}{\Omega} \operatorname{sinc} \Omega t, \qquad \omega(t) = \frac{t}{4b}$$

$\omega(t)$: demonstrates the linear relationship between frequency change and time

$\otimes$: convolution sign.

ANNEX 2

GCR specifications for advanced TV systems

Test signals are necessary in order to control the quality of the channel. This monitoring must be done during live transmissions and the test signals are inserted in special lines of the vertical blanking interval.

MUSE contains a vertical interval test (VIT) signal for the use of waveform equalization. Figure 10 shows the MUSE signal format where the VIT signal is located in line Nos. 1 and 2 (see Recommendation ITU-R BO.786).

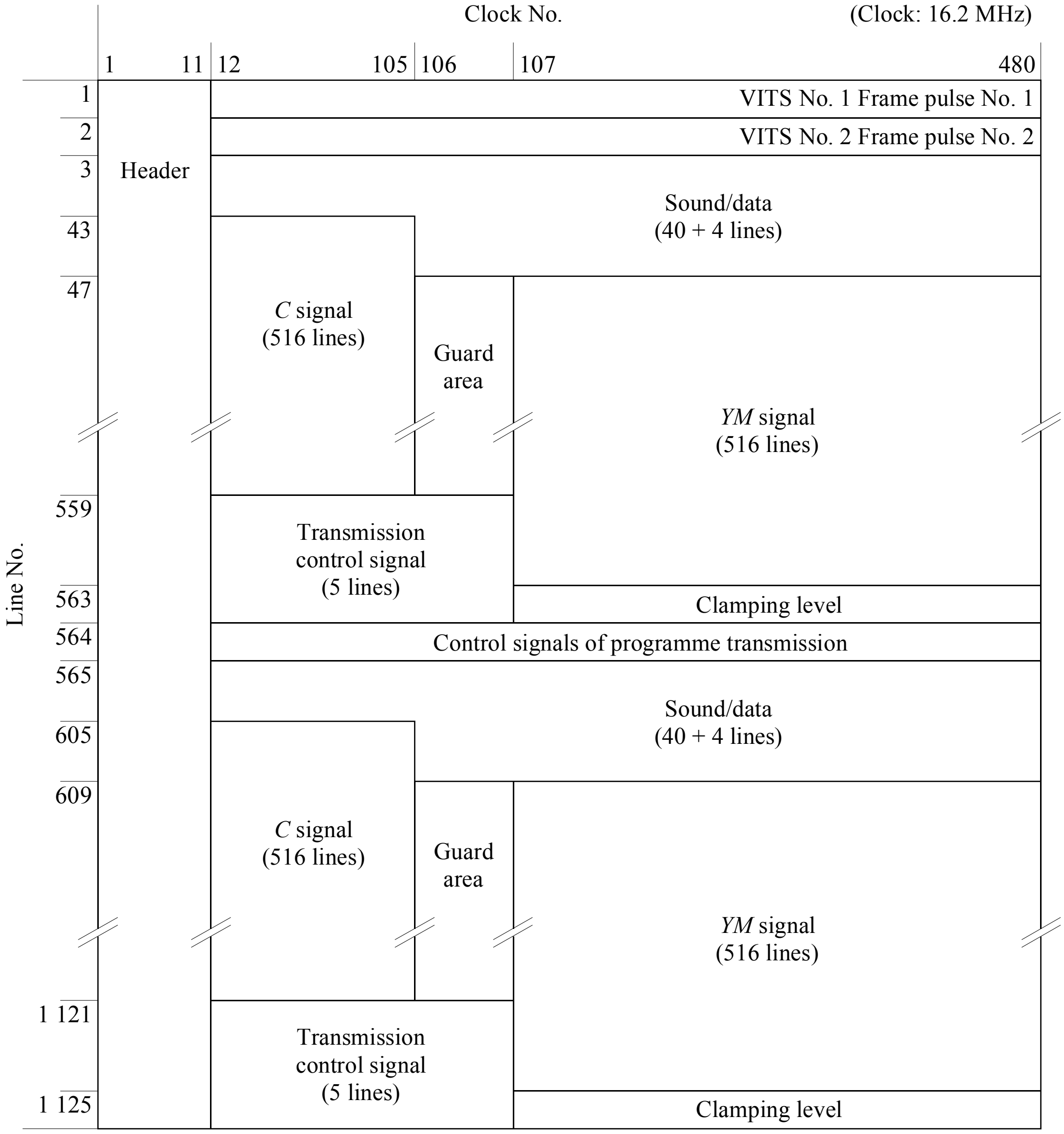
The VIT signal can also be used for a ghost cancelling reference. It consists of a set of positive and negative impulse signals which are bandwidth limited to 8.1 MHz (–3 dB). The waveform is shown in Fig. 11. The position of the impulse signal in the line is alternated by frame in such a way that in the first frame the peak point of the impulse signal co-sites with the sampling point (sampling frequency of 16.2 MHz), while in the second frame it is midway between the sampling points. This alternation enables the measuring of frequency characteristics of the transmission chain up to the sampling frequency, thus it is possible to equalize the waveform distortion over the necessary frequency range of MUSE transmission.

The top and bottom levels of the impulse signal before bandwidth limitation are equal to the white clip level and the black level respectively (239 and 16 in 8-bit representation).

In the case of FM transmission, the emphasis is not applied to the VIT signal.

FIGURE 10

MUSE signal format



Note 1 – The transmission control signal is valid for the next field following the field that contains it.

Note 2 – Line No. 564 is assigned to uses such as control signals of programme transmission by broadcasters.

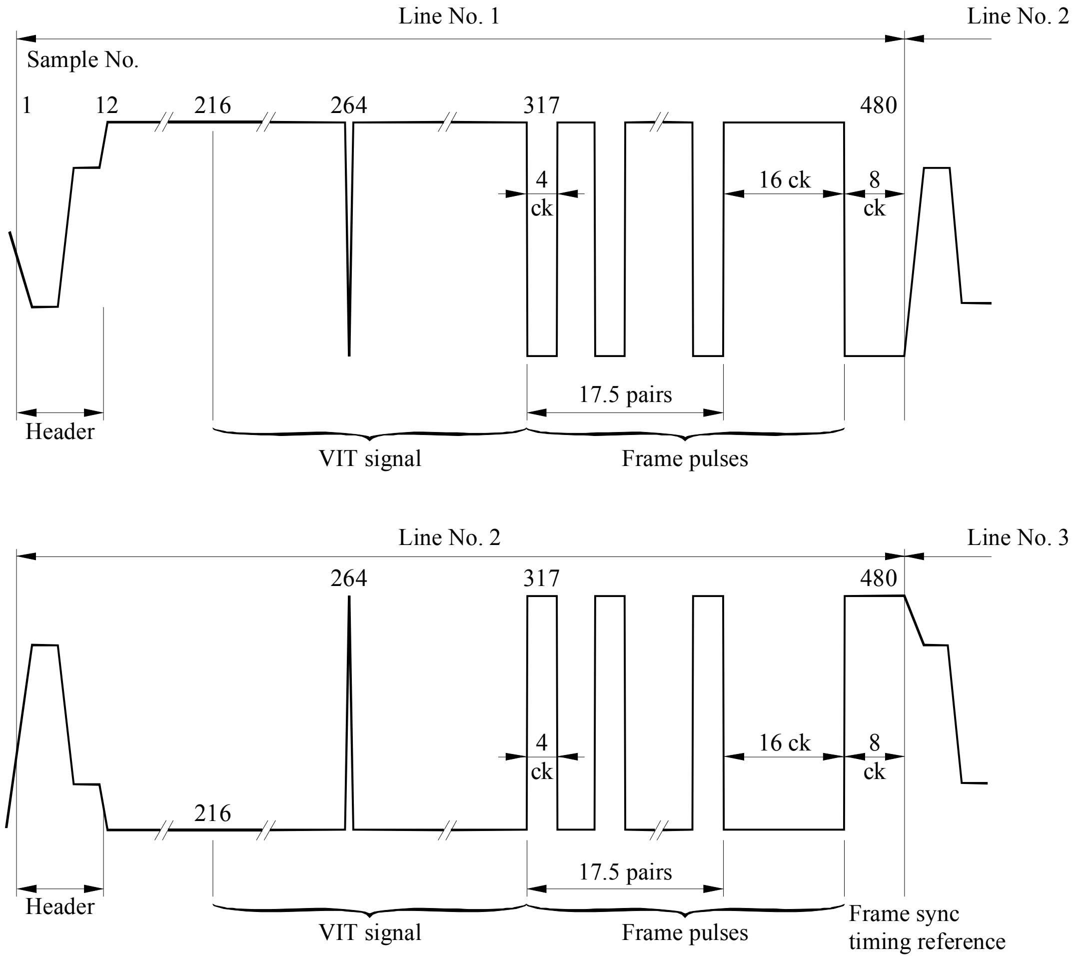
Note 3 – Timing relationship with the studio video signal is as follows:

C signal in line No. 43 and *YM* signal in line No. 47 correspond to the studio signals in line No. 42.

1124-10

FIGURE 11

VIT signal waveform



Note 1 – ck in the figure is indentical with one transmission clock duration (16.2 MHz).
Note 2 – The interval denoted by samples from No. 216 to No. 316 is used for VIT signals.

1124-14