

STUDY OF THE SYSTEM C GHOST CANCELLING REFERENCE SIGNAL FOR THE EVALUATION AND CORRECTION OF LINEAR DISTORTION IN THE TELEVISION CHAIN

(Question ITU-R 55/11)

(1998)

Many countries are interested in improving the operational quality of existing television broadcasting networks.

The automatic correction in receivers of distortions that have accumulated in the TV chain is one of the most effective means of increasing the effective quality of the chain. For this purpose, Recommendation ITU-R BT.1124 defines ghost cancelling reference (GCR) signals for correction of linear distortions in receivers, which can also be used for the correction of distortions in individual sections of complex TV chains, and which can also serve for the evaluation of distortions.

At the present time, various enhancement modules are being implemented in existing TV services. The correction of linear distortion is considered to be one of the most important enhancement modules.

Some countries are currently using analogue systems with 6 MHz video bandwidth and intend in the future to use NICAM digital sound. So two bandwidths for the luminance signal are expected to be in use: 6 MHz (without digital sound) and 5 MHz (when digital sound is used). So the question of 5 MHz and 6 MHz GCR signals is of interest.

In 1996 (Doc. 11A/42) was published presenting some results of studies of the GCR system C signal.

This report brings together the results of further studies (Doc. 11A/80) on this subject.

1 Automatic correction of linear distortions as a part of the concept of enhanced analogue television

The concept of enhanced analogue TV assumes the use of the wide-screen picture aspect ratio of 16:9, digital sound, and improved image quality in comparison with conventional TV.

The realization of this concept is based on the use of digital signal processing.

Principles and some details of the construction of enhanced TV systems are described in ITU-R texts (Recommendation ITU-R BT.1118 – Enhanced compatible wide-screen television based on conventional television systems; Recommendation ITU-R BT.1197 – Enhanced wide-screen PAL TV transmission system (the PALplus system); Recommendation ITU-R BT.1298 – Enhanced wide-screen NTSC TV transmission system, and Doc. 11A/8).

One of the most significant characteristics of enhanced TV is the improvement of image quality. This is achieved by means of:

- use of high quality sources of signal (component digital studios);
- use of intra-frame signal pre-processing and post-processing, allowing more effective separation of luminance and chrominance signals in the decoding process;
- correction in the receiver of linear distortions accumulated in the TV path (referred to in the ITU-R texts as “ghost cancellation”).

The automatic correction of linear distortions has common importance both for conventional and enhanced TV. By including a device for ghost cancellation in the receiver, linear distortions that have accumulated in multi-chain TV paths are removed rapidly, with consequent improvements in displayed luminance and chrominance resolution and in the decoding of teletext.

2 The question of GCR test signal standardization

Recommendation ITU-R BT.1124 (Reference signals for ghost cancelling in analogue television systems) defines three GCR signal systems – A, B and C.

For Europe, and for many other countries, signal C is of interest. The direct purpose of this signal is concerned with the reduction of echo signals accumulated in the TV reception path. The GCR signal has wider application for the rapid estimation and correction of common linear distortions [Gofaizen, 1995a and b] and (Doc. 11A/42).

Correction of distortions is possible both in the television receiver, and at the input to each link in the distribution and transmission chain. Taking into account that linear distortions can result in nonlinear effects and in worsening noise characteristics of the image, the use of automatic correction of nonlinear distortions does not exclude the necessity of controlling these distortions in each link. Thus the estimation of linear distortions is possible on various criteria. Use of computer technologies allows these to be achieved by computing methods.

The studies in the Ukraine (Doc. 11A/80) took into account the following:

- The possible optimization of the system C GCR signal by the use of alternative window functions, suggested in work [O.V. Gofaizen, 1995a and b] and (Doc. 11A/42) with the objective of achieving an improvement in the accuracy of the estimation of distortions.
- Recognizing that the GCR signal is already standardized, any changes would need to be compatible with existing use of the signal in a number of countries; aspects of the compatibility of any modifications would need to be investigated.
- An optimized GCR signal should have higher noise immunity relating to interference from the adjacent channels than the standard GCR signal (noise immunity gain should be appreciated as the result of optimization).
- The introduction of an optimized GCR signal must not result in an increase in the cost of equipment.

Thus, during the course of choosing a GCR signal for some countries, various studies were felt to be appropriate in order to seek to provide the most effective solution bearing in mind these issues.

3 The mathematical description of the GCR signal and analysis of its basic properties

In Koo [1995] has described the properties of what has become known in the ITU-R as the system C GCR signal.

This analysis was continued and is complemented in works [Gofaizen, 1995a and b] and (Doc. 11A/42).

The following is a recent alternative description and analysis of the same system C signal, as derived during the course of latest studies:

In work (Doc. 11A/42) it is shown that the GCR signal may be represented by the formula:

$$g(t) = \frac{A}{2\pi} \int_{-\Omega}^{\Omega} e^{j \text{sign}(\omega) b \omega^2} W(\omega) e^{j\omega t} d\omega \quad (1)$$

where:

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

$$w(t) = q(t) s(t)$$

$$q(t) = \cos^2 \frac{\pi}{2} \frac{t}{mT}$$

$$s(t) = \frac{m-2}{mT} \text{sinc} \pi \frac{m-2}{m} \frac{t}{T}$$

$$\text{sign}(\omega) = \begin{cases} -1 & \text{for } \omega < 0 \\ 0 & \text{for } \omega = 0 \\ 1 & \text{for } \omega > 0 \end{cases}$$

$$\text{sinc } x = \frac{\sin x}{x}$$

The parameter values of this signal given in Recommendation ITU-R BT.1124 are:

$$A = 0.30358 \times 10^{-6} \text{ V}$$

$$b = 0.2829 \times 10^{-12} \text{ s}^2/\text{rad}$$

$$\Omega = 2\pi \times 5.5 \times 10^6 \text{ rad/s}$$

$$\Omega_1 = 2\pi \times 5 \times 10^6 \text{ rad/s}$$

$$c = 0.9121 \times 10^6 \text{ rad/s.}$$

The parameters T and m in equation(1) are:

$$T = \frac{m - 2}{m} \frac{\pi}{\Omega_1}$$

$$m = \frac{\Omega_1}{c} + 2$$

so that $T = 94.5 \text{ ns}$ and $m = 36.4439$.

In this signal there are two window functions:

- $W(\omega)$ in the frequency domain or its Fourier transform $w(t)$, presented in the formulae, and
- $P(\omega)$ in the frequency domain or its Fourier transform $p(t)$. This window function is not seen from the formulae. It is a rectangular function limiting the interval of product $e^{j \text{sign}(\omega)b\omega^2} W(\omega)$ when integrated by ω .

The structure of each of these window functions is shown in Figs. 1 and 2 respectively.

The equation for the GCR signal in the time domain may be represented as [Gofaizen, 1995a and b] and (Doc. 11A/42):

$$g(t) = f(t) \otimes w(t) \otimes p(t) \quad (2)$$

where:

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

$$p(t) = \frac{\pi}{\Omega} \text{sinc } \Omega t$$

$$\omega(t) = \frac{t}{4b}$$

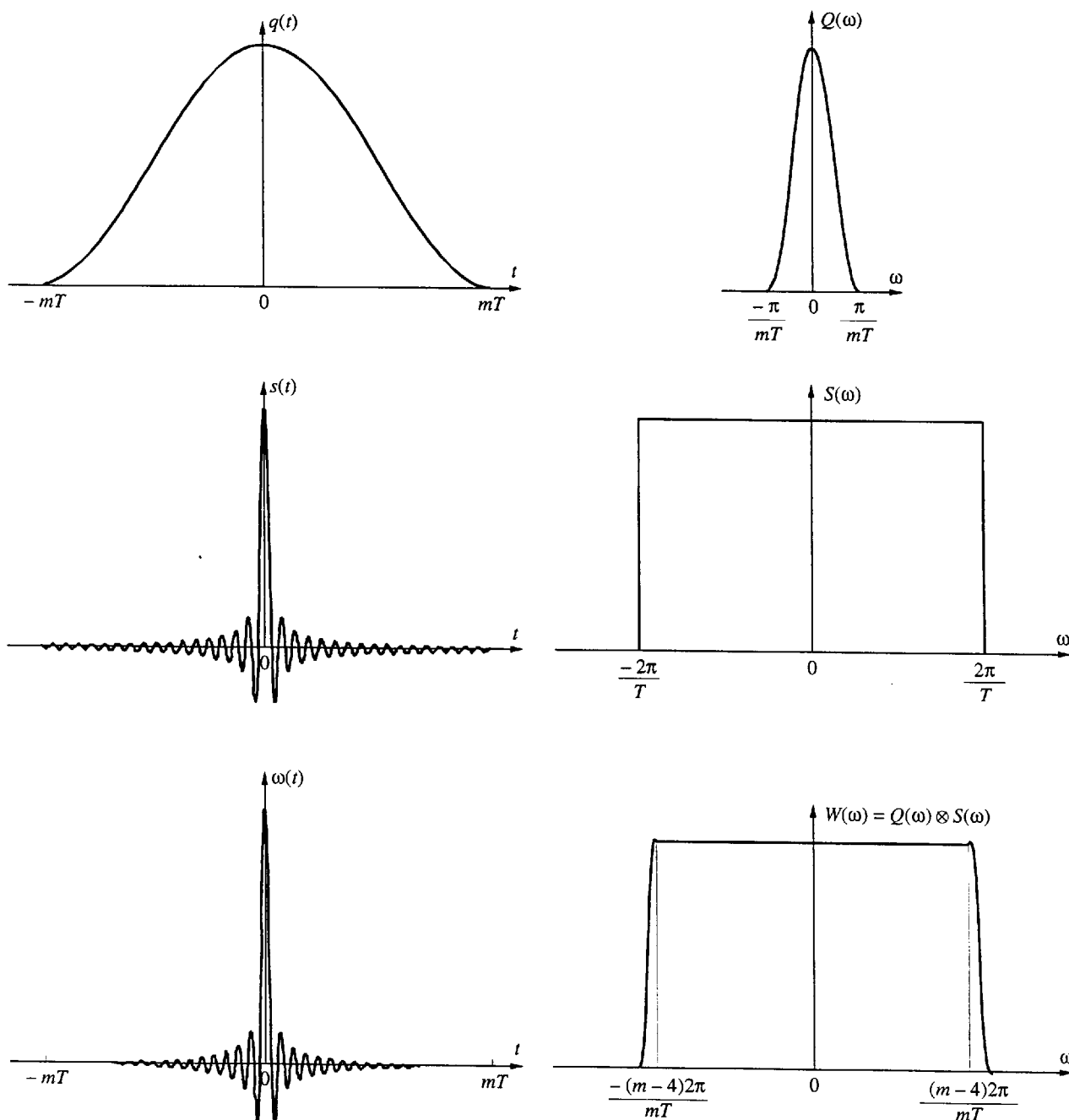
$\otimes$: convolution sign.

Here, function $\omega(t)$ demonstrates the linear relationship between frequency change and time.

The system C signal has the following inherent characteristics [Koo, 1995]:

- high energy,
- flat amplitude-frequency characteristic within the bandwidth of interest,
- smooth phase characteristic in the bandwidth of interest,
- GCR signal auto correlation characteristic is limited at the expense of convolution by function $\text{sinc } \Omega t$,
- at a given energy level the GCR signal duration is minimized,
- GCR signal spectral characteristic is not practically sensitive to change of sampling frequency and word length,
- GCR signal is real-valued, thereby simplifying the equipment needed for its use.

FIGURE 1
The structure of window function $W(\omega)$ in frequency domain and time domain

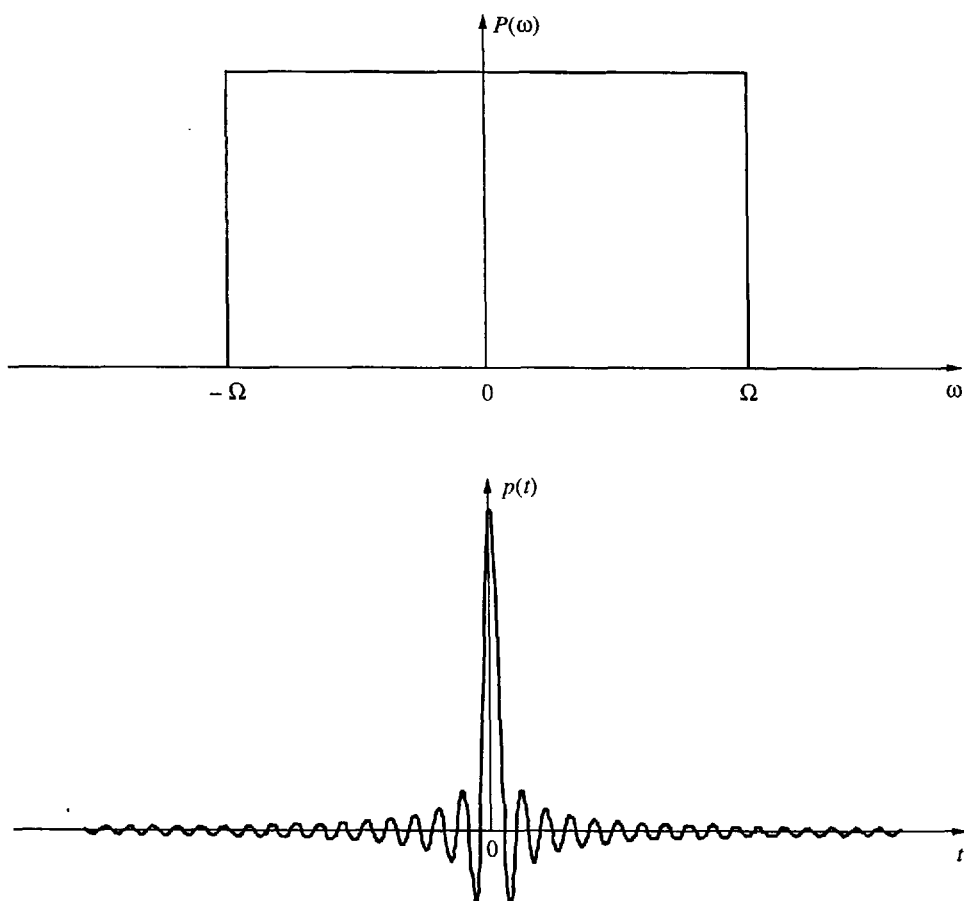


$Q(\omega)$, $S(\omega)$, $W(\omega)$: Fourier transform of $q(t)$, $s(t)$, $w(t)$

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FIGURE 2

The structure of window function $P(\omega)$ in frequency domain and time domain



$P(\omega)$: Fourier transform of $p(t)$

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4 Analysis of GCR signal parameters in the frequency and time domains

GCR signal characteristics, evaluated using such model, are presented below.

Figure 3 shows Fourier-prototype of window function $w(t)$.

Figures 4 and 5 describe window function $W(\omega)$ in linear and logarithmic scales. $W(\omega)$ decays to the following relative levels at the following frequencies:

-6 dB	at 5 MHz
< -60 dB	at 5.5 MHz
< -75 dB	at 6 MHz.

With further increase of frequency a rate of attenuation of about 20 dB/MHz is observed.

Figures 6 and 7 illustrate the two polarities of GCR signals, lines A and B.