Телевидение

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Some aspects of characterization the reference test signal for evaluation and correction linear distortion in TV channel

Вопросы оценки характеристик эталонного тест-сигнала для оценки и коррекции линейных искажений в ТВ тракте

Abstract. There are presented the results of analysis conducted as a continuation of published in [3] studies on problem of choice universal reference test signal for evaluation and correction linear distortion in TV channel.

Аннотация. Представляются результаты анализа, проведенного в продолжение исследования, опубликованного в работе [3], по проблеме выбора универсального эталонного тест-сигнала для оценки и коррекции линейных искажений в ТВ тракте.

GCR real-valued signal proposed in 1991 by D.Koo [1] is defined in Recommendation ITU-R BT.1124 [2] as C-system signal. This signal may be used for ghost cancellation as well as for correction of general type linear distortion in TV channel. Simultaneously it is possible to use this signal as test-signal for evaluation quality of TV programs transmission directly during transmission.

C-system GCR signal has some important merits in comparison with other signals [1]:

- high signal energy;
- a flat spectrum over the entire band of interest;
- a smooth phase characteristics over the entire band of interest;
- the auto-correlation function of the GCR is a windowed sinc(x)/(x);
- at a given high-energy level, the time duration of GCR seems as short as possible;
- the GCR's spectrum characteristics are practically not sensitive to different sampling frequencies and different data length;
- the GCR is real-valued for the save of hardware simplicity.

This signal is studied in [1,3]. In [1,2] GCR is represented by formula for Fourier-prototype of its spectrum which may be represented as:

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

where $$W(\omega) = \int_{-\frac{\pi}{c}}^{\frac{\pi}{c}} \left(\frac{1}{2\pi} \int_{-\Omega_1}^{\Omega_1} e^{i\gamma t} d\gamma \right)\left(\frac{1}{2} + \frac{1}{2}\cos(ct) \right) e^{-i\omega t} dt ,$$

A, b, Ω, c, Ω_1 - parameters which accept next values for 625-lines TV systems:

- ✔ $A = 3{,}185 \cdot 10^{-7}$ volts,
- ✔ $b = 0{,}2829 \cdot 10^{-12}$ sec^2/radian,
- ✔ $\Omega = 2\pi \cdot 5{,}5 \cdot 10^{6}$ radian/sec,
- ✔ $c = 0{,}9121 \cdot 10^{6}$ radian/sec,
- ✔ $\Omega_1 = 2\pi \cdot 5 \cdot 10^{6}$ radian/sec.

It is seen from this formula that amplitude frequency response of spectrum energy of GCR is defined by window function $W(\omega)$ and doesn't depend from b parameter in complex exponent signal $e^{i\,\mathrm{sign}(\omega)\,b\omega^2} = \cos(b\omega^2) \pm i\sin(b\omega^2)$. The question about influence of this parameter choice over metrological properties of GCR stays the problem to be solved.

It must be noted that GCR competes with complex signal for frequency response measurements in MAC TV chain defined by Recommendation ITU-T J.67 (ITU-R CMTT.722) [4] which are the same as of GCR.

Some analysis of these two signals was worked out in [3]. In particular, their analogue presentation in time domain and evaluation of some their characteristics were obtained.

$g(t)$ signal may be shown up to the constant precision as $g(t) = f(t) \otimes w(t)$,

where
$$f(t) = \frac{1}{2\sqrt{\pi b}}\left\{\cos\left[\omega(t)t - \frac{\pi}{4}\right] + \frac{1}{\pi}\sin\left[\omega(t)t + \frac{\pi}{4}\right] \otimes \frac{1}{t}\right\},$$
$$w(t) = q(t)s(t),\; q(t) = \cos^2\frac{\pi}{2}\frac{t}{mT},\; s(t) = \mathrm{sinc}\,\pi\frac{m-2}{m}\frac{t}{mT},$$
$$\Omega_1 = \Omega\frac{m}{m-2},\quad T = \frac{\pi}{\Omega},\quad m = \frac{\pi}{cT},\quad \omega(t) = \zeta t = \frac{t}{4b},$$
$$\xi = \frac{1}{4b},\qquad \mathrm{sinc}\,x = \frac{\sin x}{x},$$
$\otimes$ - designation of convolution.

With use of parameters defined in [1,2], there was shown in [3] that the law of frequency change of components of $g(t)$ signal inside time interval length of 24 µs corresponds to its maximum value $f_{\max} = 3{,}3755$ MHz.

C-system signal being optimal choice for linear distortion correction also may be used as universal signal for linear distortion evaluation with methods based on Fourier transform use. As we can see from formula for $f(t)$ signal, direct evaluation of frequency response distortion with the help of this signal is impossible.

There was proposed in [3] to make the waveform of GCR better by way of replacement window function for some from shown in table presented in [3] . As an example may be proposed optimized weight window function [5]:

$$W(t) = \frac{I_0\left[\alpha\sqrt{1-\left(\frac{t}{mT}\right)^2}\right]}{I_0(\alpha)}\;\mathrm{sinc}\left(\pi\frac{\mu-2}{\mu}\frac{t}{T}\right),$$

where $\mu = \frac{2m}{\sqrt{1+(\alpha/\pi)^2}}$, α=5,4414.

The signal $g(t)$ based on optimized weight function use, is compatible with signal defined in Recommendation ITU-R BT.1124 and has better metrological properties.

As already mentioned in [3], complex signal [4] may be applied for evaluation and correction of distortions in particular using simple methods as universal test-signal, formula for which may be written as

$$g_k = w_k e^{\frac{i\pi(k-256)^2}{512}};\; k \in \overline{0{:}512},$$

where
$$w_k = \begin{cases} 1 & \left(|k-256| \in \overline{0;\,203}\right), \\ \sin^2\frac{\pi}{2}\frac{|k-256|-203}{25} & \left(|k-256| \in \overline{203;\,228}\right), \\ 0 & \left(|k-256| \in \overline{228;\,256}\right). \end{cases}$$

Some inaccuracies in [3] must be corrected:

1) in reference at the table including window functions built by Kaizer window function modification (p.2, col.2) the formula for m must be excluded;
2) item (1) in Conclusion must be excluded;
3) item (2) in Conclusion must be replaced by following one: "Frequency duration interval of the sine and cosine components of both signals in less then needed for direct conclusion about frequency distortion in required bandwidth".

Further analysis of ITU-R and ITU-T test signals allows to make next conclusion on their comparison and evaluation:

1) ITU-R test signal is real valued and ITU-T signal is complex, both signals are equal from the point of view of evaluation and correction of linear distortion in TV channel based on modern computational methods using discrete Fourier transform. Considering wide spectrum of means and methods for measure and correction of distortions, it is desirable also to have possibility for evaluation of distortions with simple methods. In this case use of real valued signal doesn't permit to apply such methods as "method of four phases" [6], oriented for use of complex test signals.
2) Real-valued signal was proposed for the sake of hardware simplicity. At the same time it leads to economy of the place in field blanking interval.
3) Complex signal ITU-T is organized in such a manner, that it is transmitted in the only line in 4 subsequent realizations transmitted in 4 subsequent frames, i. e. in the frame it need the same place as real-valued signal.
4) Among other composite TV systems there is the most critical a problem of place for teletext and other additional information in SECAM system but considering the possible economy of the place in TV signal with simplifying the synchronization signals [7] this problem becomes not such actual.
5) Frequency duration interval of the sine and cosine components in both signals is less then needed for direct conclusion about frequency distortion in required bandwidth.
6) ITU-R signal energy is concentrated in interval $\overline{0, t_{\max}}$, ITU-T - in interval $\overline{-t_{\max}, t_{\max}}$; it means, that in case of ITU-R signal use for evaluation of distortion measuring error due time limitation at t = 0 would be greater though properties of this signal are such that this may be canceled. Lengths of two signals are approximately equal.
7) Metrological properties of both signals may be enchanced by replacement of window function with shown in table in [3], and enchanced signals may be compatible with defined in Recommendations ITU-R BT.1124 and ITU-T J.67.

Published considerations are actual in connection with general tendency of choice for standardization universal reference test signal, which may be chosen as only in the world.

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