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COMPENSATOR OF UNSTATIONARY TEMPORAL ERRORS OF THE WIDE BAR MEASURING CHANNELS WIDE BAR

The paper considers the question of an approach to determination of unstationary temporal errors, nature of their origin, the analysis of errors by an analytical method using the models of the measuring channels. There had been given the mathematical correlations which can be used for determination of the indicated errors, and also graphs which evidently demonstrate the conduct of such errors at the different values of parameters of channel and signal,. The algorithm of the signal processing is considered with the purpose of indemnification of unstationary temporal error in the measuring channels wide bar and realization of this algorithm in a vehicle kind.

Keywords*: unstationary temporal error (UTE), measuring channels wide bar, canceller UTE, algorithm of work of canceller UTE, structure of canceller UTE.*

Introduction

The problem of improvement of dynamic properties of measuring channels gets the special value at measuring of brief signals parameters, at research of unstationary processes, at the rapid change of the explored size. The estimation of dynamic properties of measuring channels can be conducted on the basis of research of their amplitude-frequency characteristics, phase-frequency characteristics or transitional characteristics at the input action of step or harmonious signals, as well as by determination of instantaneous difference of input signal value, calculated according to the initial signal of the measuring channel, to the value of nominal static description of channel and instantaneous value of input signal at the definite time period [1]. But such research does not allow to estimate the dynamic errors at measuring of phases changes, temporal intervals or group time delays based on determination of temporal changes of the signal characteristic points corresponding to its zero, maximal or minimum value, and to develop, the devices of dynamic properties improvement of such measuring channels on the basis of the research.

The purpose of the research is development of methods and facilities of indemnification of unstationary temporal error of measuring channels with the purpose of improvement of their dynamic properties.

1. Determination of unstationary temporal error

To evaluate the dynamic properties of the above measuring channels, the research of the reaction of measuring channel as for the single harmonious switching with further determination of displacement of temporal position of the signal characteristic points, later - absolute unstationary temporal error (AUTE) is appropriate [2].

The temporal position $t_{вих}$ of the signal characteristic points on the output of measuring channel at the action of the harmonious switching is determined as a sum of the following constituents:

$$t_{вих} = t_{вх} + \Delta t_{cm} + \Delta t_{нс}, \qquad (1)$$

where $t_{вх}$ - temporal position of characteristic points of input signal; Δt_{cm} – stationary constituent of temporal change, brought in a measuring channel in the stationary mode; $\Delta t_{нс}$ – AUTE.

The unstationary temporal error (RUTE) rationed to the period will be determined on the basis of the formula:

$$\gamma = \frac{\Delta t_{нс}}{T_0}, \qquad (2)$$

where T_0 – a period of signal of the harmonious switching.

AUTE is determined on the basis of the analysis of complex-considerable function argument $\dot{U}_{вих}(t)$ to the response of measuring channel on an input single harmonious act, the representation of which is determined by the formula:

$$U_{вих}(p) = K(p) \cdot U_{вх}(p), \tag{3}$$

where $K(p)$ - a transmission description of the proper measuring channel;

$U_{вх}(p) = U_m \cdot e^{j\varphi_0} / (p - j\omega_0)$ - representation of an input signal, U_m, ω_0, φ_0 - accordingly amplitude, frequency and initial phase of entrance signal, p – operator of transformation.

To conduct the necessary researches the model of the wide bar measuring channel with transmission description can be used:

$$K(p) = \frac{K_0}{1 + \tau \cdot p},$$

where K_0 - coefficient of the channel transmission at $\omega = 0$;

τ - time constant of the channel.

After the substitution of expression for $U_{вх}(p)$ in correlation (3) we get:

$$U_{вих}(p) = \frac{U_m \cdot e^{j\varphi_0} \cdot K(p)}{(p - j\omega_0)}. \tag{4}$$

Using the theorem of decomposition and taking into account the correlation $\Delta t = \frac{\Delta\varphi}{\omega_0}$, from (4) we get the expression AUTE for the indicated case

$$\Delta t_{нс} = \frac{1}{\omega_0}\left\{ arctg\left[\frac{B - A + C}{E - D}\right] - \omega_0 t - \varphi_0 + arctg[\omega_0 \tau] \right\}, \tag{5}$$

where A, B, C, D, E – coefficients that equal:

$A = \omega_0 \tau \cos(\omega_0 t + \varphi_0)$;

$B = \sin(\omega_0 t + \varphi_0)$;

$C = e^{-\frac{t}{\tau}} \cdot (\omega_0 \tau \cos\varphi_0 - \sin\varphi_0)$;

$D = e^{-\frac{t}{\tau}} \cdot (\cos\varphi_0 + \omega_0 \tau \sin\varphi_0)$;

$E = \cos(\omega_0 t + \varphi_0) + \omega_0 \tau \sin(\omega_0 t + \varphi_0)$.

The analysis of dependence of RUTE from time shows (fig.1), that RUTE in the moment of time $t = 0$ is $\gamma_{t1}^0 = \frac{\Delta t_{нс1}^0}{T_0}$=0,125, at $t = T_0/4$ is $\gamma_{t1}^{ext} = \frac{\Delta t_{нс1}^{ext}}{T_0}$=0,034, and in the time moment $t = T_0/2$ is $\gamma_{t2}^0 = \frac{\Delta t_{нс2}^0}{T_0}$=0,018 at the initial phase of input signal $\varphi_0 = 0$, where $\Delta t_{нс1}^0$, $\Delta t_{нс2}^0$, $\Delta t_{нс1}^{ext}$ - AUTE accordingly in the first and second intersections of a zero level of input signal and in the first point of maximum or minimum, fig.1(x).

The research is conducted for a case $\frac{f_в}{f_0} = 1$, where f_0 - frequency of input signal, $f_в = \frac{1}{2\pi\tau}$ - overhead frequency of bar of admission of channel (cut frequency).

With t growth RUTE changes under attenuation swaying law. An error achieves a maximum in points with a zero value of instantaneous amplitude of input signal, that is in points of zero transits and zero values, in points close to the extreme values of signal and depends on the initial phase of entrance signal. The dependence obtained allows defining temporal position of signal points, where RUTE achieves legitimate values.

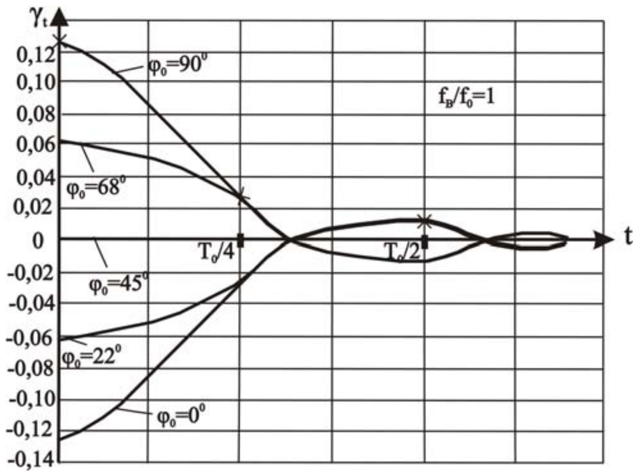

Fig. 1. Dependence of НЧП on time for
measuring channel wide bar

2. Compensator of unstationary temporal error

Indemnification of the unstationary temporal by error can be carried out by introduction of the compensation link to the measuring channel realized by the reverse operator of measuring channel $K^{-1}(p)$ in a vehicle or programmatic kind. At $K_0 = 1$ such transmission function in the case of measuring channel wide bar will look like:

$$K^{-1}(p) = 1 + p \cdot \tau ,$$

that corresponds to differential equalization

$$\tau \frac{dU_{вих}(t)}{dt} + U_{вих}(t) = U(t) .$$

For realization of compensator of unstationary temporal error (UTE) of measuring channel wide bar a device, represented on fig.2, is used [3].

Knots of compensator can be both analogs and digital, depending on the type of signals $U_{вих}(t)$ and $U(t)$.

Inserting the transmission function of measuring channel with compensator in expression (4)

$$K(p) = \frac{K_{01}}{1 + \tau_1 \cdot p} \cdot \frac{1 + \tau_2 \cdot p}{K_{02}} ,$$

where K_{01}, τ_1 - coefficient of transmission and time constant of measuring channel;

K_{02}, τ_2 - coefficient of transmission and time of compensator,

we'll get expression of AUTE for a measuring channel with compensator

$$\Delta t_{нсK} = \frac{1}{\omega_0} \left\{ arctg\left[\frac{D_K + E_K - F_K}{A_K - B_K - C_K} \right] - \omega_0 t - \varphi_0 - arctg\left[\frac{\omega_0 (\tau_2 - \tau_1)}{1 + \omega_0^2 \tau_1 \tau_2} \right] \right\} , \qquad (6)$$

where $A_K, B_K, C_K, D_K, E_K, F_K$ – coefficients that equal:

$$A_K = (1+\omega_0^2\tau_1\tau_2)\cdot\cos(\omega_0 t+\varphi_0);$$

$$B_K = \omega_0(\tau_2-\tau_1)\cdot\sin(\omega_0 t+\varphi_0);$$

$$C_K = e^{-\frac{t}{\tau_1}}\cdot\left(1-\frac{\tau_2}{\tau_1}\right)\cdot(\cos\varphi_0+\omega_0\tau_1\sin\varphi_0);$$

$$D_K = (1+\omega_0^2\tau_1\tau_2)\cdot\sin(\omega_0 t+\varphi_0);$$

$$E_K = \omega_0(\tau_2-\tau_1)\cdot\cos(\omega_0 t+\varphi_0);$$

$$F_K = e^{-\frac{t}{\tau_1}}\cdot\left(1-\frac{\tau_2}{\tau_1}\right)\cdot(\sin\varphi_0-\omega_0\tau_1\cos\varphi_0),$$

where $\Delta t_{нсK}$ - determined from expression (6).

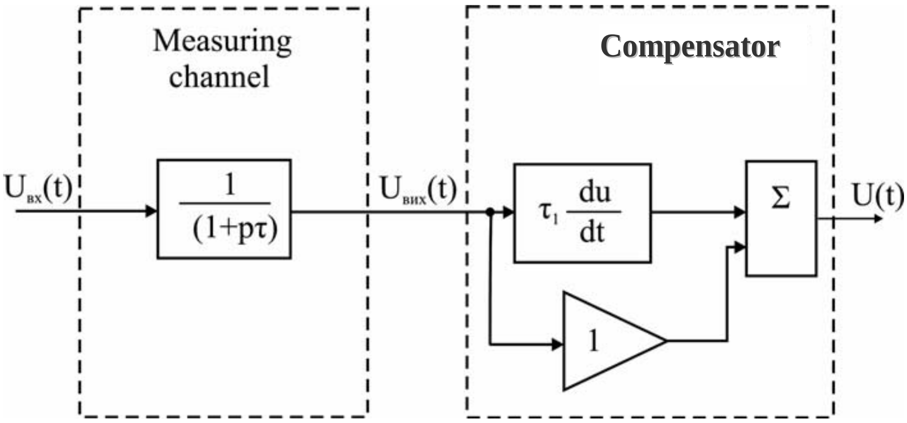

Fig. 2. Structure of compensator of UTE

The analysis of dependence of RUTE of measuring channel with compensate from correlation of time constant values of measuring channel τ_1 and compensator τ_2, fig.3, shows, that RUTE does not depend on the values of transmission coefficients of transmission. At $\frac{\tau_2}{\tau_1}=1$ an error equals zero.

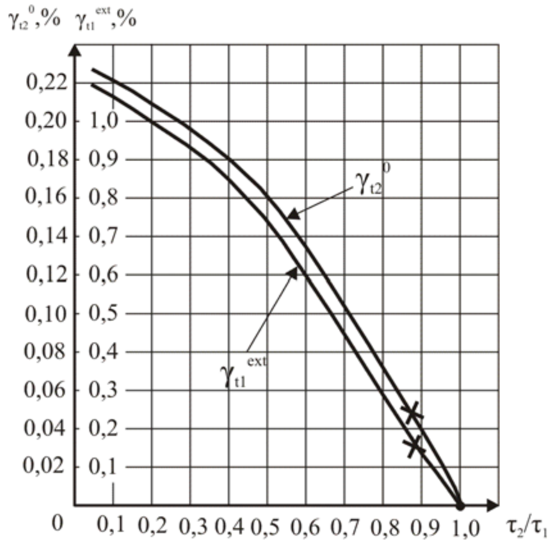

Fig. 3. Dependence of RUTE on correlation of time permanent of measuring channel and compensator

3. Results of experimental researches

In fig. 4 the general flow diagram of the device for experimental researches of AUTE in a measuring channel with compensator of error is shown.

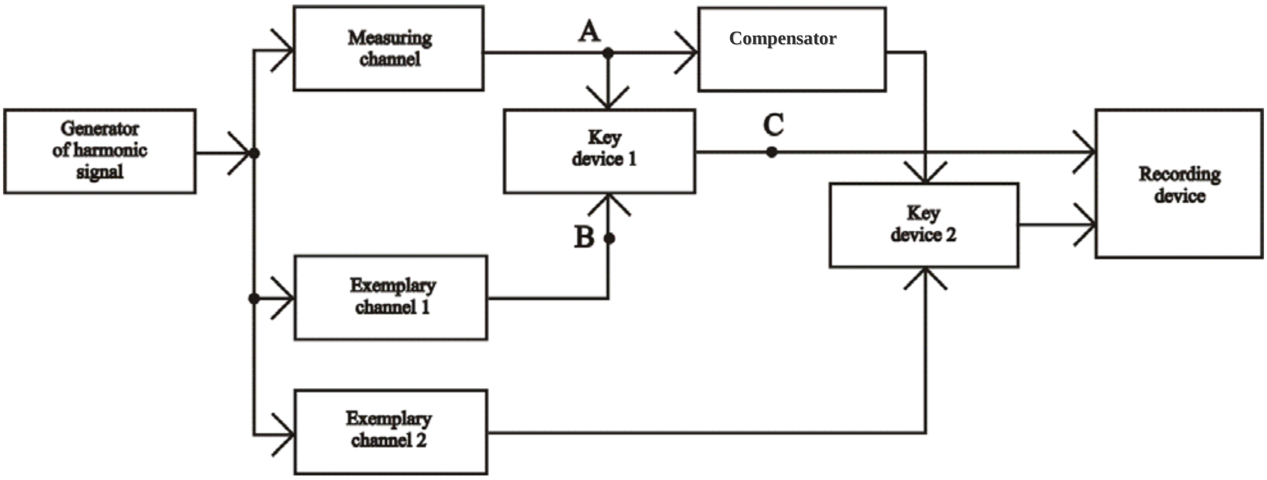

Fig. 4. Device for research of UTE compensator action

Such a device consists of generator of harmonic signal; two exemplary channels, compensate, two key devices which form rectangular impulses in the moments of transition of signals through zero or extreme values; recording device such as a two-ray oscillograph.

A temporal change between signals is determined by fixing of transit of initial signals of channels points through the set levels. In fig. 5 the forms of signals in the input (points A, B) of the first key device are shown. On the output of key device (point C) a signal will be as string of pulses, fig.6.

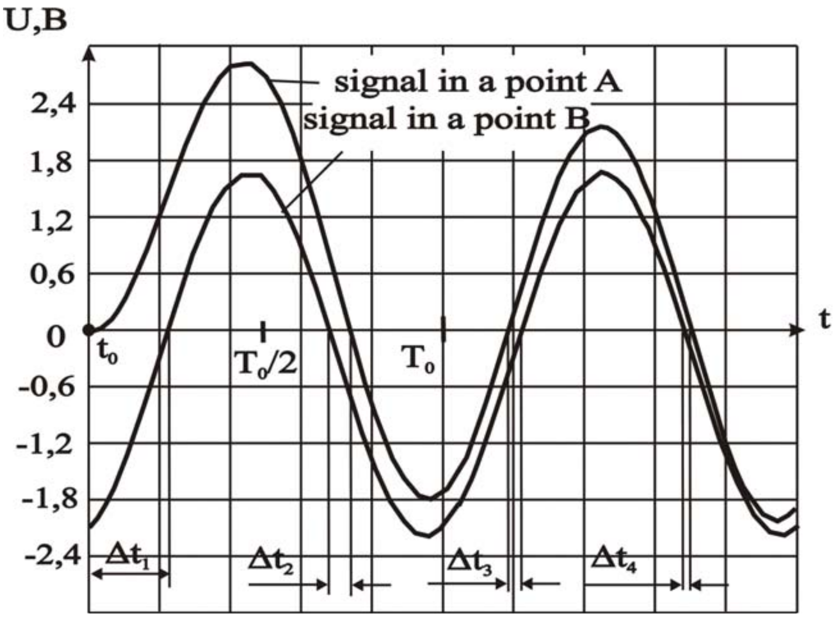

Fig. 5. Forms of signals in the input of key device

The duration of the impulses formed corresponds to AUTE of signal having got through the explored measuring channel, in relation to a supporting continuous signal in signal intersections of a zero level and in intersections of signal of extreme values.

The signals in input and output of the second key device are formed in the same way. In this case, duration of the impulses formed corresponds to the absolute value of signal UTE having got through the explored measuring channel with compensate.

As a measuring channel there have been investigated an amplifying device with cut frequency of $f_в$=1 MHz, what is the element of active matrix from m-inputs and n-outputs. The research has been conducted for a case $\frac{f_в}{f_0} = 1$, with an initial phase $\varphi_0 = 0$.

The analysis of impulses duration in the output of key device, fig. 6, shows that application of compensate allows to decrease the influence of unstationary temporal error. The benefit for an error $\gamma_{t1}^0 = \frac{\Delta t_{нс1}^0}{T_0}$ is 3,5 times, for an error $\gamma_{t1}^{ext} = \frac{\Delta t_{нс1}^{ext}}{T_0}$ – 22.6 times, and for an error $\gamma_{t2}^0 = \frac{\Delta t_{нс2}^0}{T_0}$ – 36 times, at frequency of input signal f_0=1 MHz and to the initial phase $\varphi_0 = 0$.

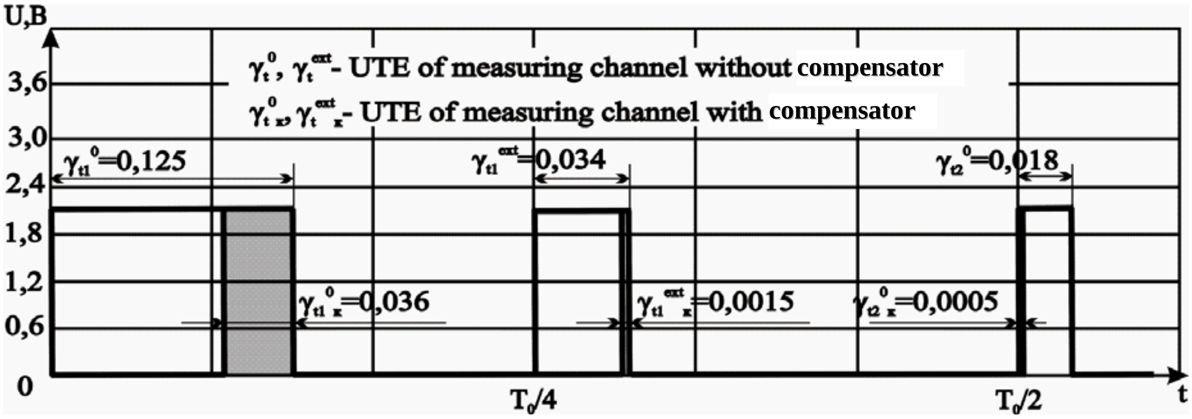

Fig. 6. Result of experimental researches

The comparative analysis of prognosis of compensate action is in a measuring channel, fig. 4, with the results of experimental researches, fig. 6, shows the practical coincidence of results of prognosis and experiment. The influence of spurious capacities, rejection of descriptions of active elements and variation of parameters of passive elements of measuring channel and compensate results in disagreement of permanent time τ_1 and τ_2. In the considered case the relation $\frac{\tau_2}{\tau_1}$ equals 0,87, fig. 3(x). More careful elements selection and tuning will allow improving the results got.

Conclusions

The rationed unstationary temporal error in the time moment of $t = 0$ is γ_{t1}^0=0,125, at $t = T_0/4$ is γ_{t1}^{ext}=0,034, and in the moment of time $t = T_0/2$ is γ_{t2}^0=0,018 at the initial phase of input signal $\varphi_0 = 0$.

The application of UTE compensate allows to decrease the unstationary temporal error and thus to improve the dynamic properties of measuring channel. The benefit for an error γ_{t1}^0 is 3,5 times, for an error γ_{t1}^{ext} is 22.6 times, for an error γ_{t2}^0 is 36 times at frequency of input signal f_0=1 MHz and to the initial phase of signal $\varphi_0 = 0$.

More careful selection of compensator elements and tuning will allow improving the results obtained.

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