UDC 621.396.621 (045)

PERMISSION OF SIGNALS IN THE FIRST ORDER DISCRETE TRACING MEASURING DEVICES ACCORDING TO THE AREAS OF CAPTURE

A. Petrenko, PhD

National Aviation University

e-mail: pab.05@mail.ru

The detailed analysis of tasks «permission–capture» and «permission–tracing measuring» on the basis of calculation of capture area of nonlinear discrete tracing measuring device with the first order filter of evaluation with the method of differential-phase plan is offered.

Keywords: discrete tracing measuring device, permission of signals, capture area.

У роботі пропонується детальний аналіз задач «розрізнення–захоплення» та «розрізнення–слідкуюче вимірювання» на допомогою розрахунку області захоплення нелінійного дискретного стежного вимірювача з фільтром оцінювання першого порядку методом різницевої фазової площини.

Ключові слова: дискретній слідкуючий вимірювач, розрізнення сигналів, область захоплення.

Relevance of research

Along with such primary characteristics of radiosystems, determining quality of their work, as probability of signal detecting, its capturing on automatic tracing and accuracy of measuring of his parameters, for the wide class of the systems indexes, determining possibilities of the system to measure separately the parameters of signals the responses of which are closely located on the output of receiver, are important.

The modern discrete filters of evaluation of unpower parameters of radiosignals are intended for the tracing measuring of motion parameters of aircrafts and other mobile objects. Thus, the location observation of such aims are always provided on a background of mixture of parasite echo-signals, reflected from marine and earthly surfaces, different local objects, buildings, in a complicated obstacle environment.

All disturbing signals similar to useful signals and it is possible to select information, contained in the useful signals, only taking into account the differences in their parameters (direction of arrival of signals, time of their delay, Doppler shift of frequency and other).

Thus, permission of signals according to a parameter (in general case — vectorial) X supposes extraction of information from each of simultaneously observed signals of the same type, in the view of difference in their parameters. Thus procedure of «extraction of information» supposes finding out signals, capture and tracing measuring of parameters of radiosignals [1; 2].

It causes statistical interpretation of task of permission, which, at same time, is determined by procedure of processing of the received mixture (supervisions). And statistical interpretation allows the form task of permission in terms of discovery, distinction, capture and tracing measuring of parameters of signals.

Analysis of researches and publications

The task of permission (separate capture and measuring of parameters) of signals appears, for example, in a radio-location at the automatic tracing of two or a few closely located aims, or at affecting system of measuring by different obstacles [1;2].

Aim of article

Estimation of requirements of permission of signals in the nonlinear determined discrete tracing first order systems with the capture areas.

Model of nonlinear discrete tracing measuring device with the evaluation filter of the first order

The structural scheme of tracing measuring device is represented on fig. 1, it consists of: statistical equivalent of discriminator, which includes statistical description of discriminator (mean of voltage of evaluation error), fluctuation description of discriminator, which rations additive excitation of the system, impulsive element (IE) which fixes information and linear equivalent continuous part of the system instantly [3].

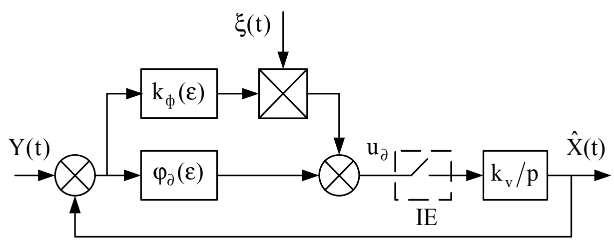


Fig. 1. Equivalent scheme of the nonlinear discrete system

Let suppose that an useful radio signal $s(t,X)=\mathrm{Re}\left[\dot{S}(t,X)\exp(j2\pi f_0 t)\right]$ operates at receiving part of nonlinear discrete system (fig. 1) with complex circumflex $\dot{S}(t,X)$, that contains the values of some unpower parameters, equal X. It is known that a obstacle in the form of white noise $\eta(t)$ and disturbing signal addicted to it accompanies the entrance signal of radio receiver (supervision). Under a disturbing signal similarity of useful signal

$$s(t,X_M)=\mathrm{Re}\left[\dot{A}_M\dot{S}(t,X_M)\exp(j2\pi f_0 t)\right],$$

at which complex amplitude is presented as $\dot{A}_M = A_M\exp(j\varphi_M)$ is understood, (A_M and φ_M — unknown amplitude and initial phase of mixing signal), and his unpower parameter is equal X_M.

Thus, a supervision operates on the entrance of receiving part of discrete tracing measuring device:

$$Y(t,X,X_M)=s(t,X)+s(t,X_M)+\eta(t), \quad (1)$$

where $X_M(t,t_M)$ — is a vector of state variables (phase coordinates) of strange (obstacle or mixing) «object» — sourse of disturbing signal which can appear after some time t_M after the beginning of evaluation of vector of phase coordinates of the object X.

Processing of entrance influences (supervisions) in receiver is carried out in accordance with expressions (2), where the formulas of coherent and non-coherent treatment are resulted:

$$\begin{cases} Y(t,X,X_M)=s(t,X)+s(t,X_M)+\eta(t); \\ S(t)=\int\limits_{-\infty}^{\infty}k(t-\tau)u_r^*(\tau,\hat{X})Y(\tau,X,X_M)\,d\tau; \\ Z=\sum\limits_j\left|S_j\right|^2; S_j=\sum\limits_l k\left[(j-l)T_s\right]Y_l. \end{cases} \quad (2)$$

Voltage of error signal in the optimum discriminator of tracing measuring device for the pair of entrance signals will correspond to following four items:

$$u_\partial(t,\varepsilon)=\frac{\partial\left|\left[S(t)+S_M(t)\right]\left[S^*(t)+S_M^*(t)\right]\right|^2}{\partial X}=$$
$$=\begin{bmatrix} S(t)S^*(t)+S_M(t)S^*(t)+ \\ +S(t)S_M^*(t)+S_M(t)S_M^*(t)\end{bmatrix}'= \quad (3)$$
$$=2\mathrm{Re}\left[S^*(t)S'(t)\right]+2\mathrm{Re}\left[S'(t)S_M^*(t)\right]+$$
$$+2\mathrm{Re}\left[S_M'(t)S^*(t)\right]+2\mathrm{Re}\left[S_M'(t)S_M^*(t)\right],$$

where $S'(t)=\left.\frac{dS(t,X)}{dX}\right|_{X=\hat{X}}$ — supporting signal, the vectorial parameter of which takes on a value, equal to the estimation of state vector of the set object (presently to time this estimation is produced by the filter of evaluation of tracing discrete measuring device); $S^*(t,X)$ — complex-attended value of amplitude of entrance useful signal; $S_M^*=(t,X_M)$ — complex-attended value of amplitude of disturbing (obstacle) entrance signal.

Before the moment of permission of two signals of the same type on a parameter in the filter of evaluation of tracing measuring device the estimation of state vector of object is produced and the estimations of vectorial parameter of disturbing signal absent for creation of two last elements of expression (3). And in default of estimation of vectorial parameter of disturbing signal it is impossible to define a disturbing supporting signal

$$S_M'(t)=\left.\frac{dS_M(t)}{dt}\right|_{X_M=\hat{X}_M}.$$

Hereupon, last two elements (3) can be not taken into account and it can be considered that the signal of unconcordances in a discriminator will be determined only the by first two constituents of right part of expression (3). These constituents causes the appearance of sum of two discriminatory descriptions: the first determines voltage of error at the estimation of state vecto of the set object without the account of disturbing signal, and second — at the account of influence of disturbing signal. Such description of discriminator is called the parametrical discriminatory description, it looks like:

$$\varphi_\partial(\varepsilon_n,r)=\varepsilon_n\exp\left(-\frac{b\varepsilon_n^2}{2}\right)+$$
$$+q(\varepsilon_n-r)\exp\left[-\frac{b(\varepsilon_n-r)^2}{2}\right], \quad (4)$$
$$n\in\overline{0,(N-1)}$$

where $\varepsilon=\hat{X}-X$ — error of evaluation of state vector of the set object; $\varepsilon-r=\hat{X}-X_M=\hat{X}-(X+r)$ — corrected error of evaluation of state vector of the set object taking into account influence of disturbing signal which differs the parameter $(X_M-X=r)$, equal $X_M=X+r$; $q=\frac{M\left[A_M^2(t)\right]}{\left|S(t)\right|^2}$ — relation of powers of disturbing and useful signals [3; 4].

Thus the mathematical model of the examined discrete measuring device will be determined by static description of discriminator:

$$\Delta\varepsilon_n = -\alpha\varphi_\partial\left(\varepsilon_{n-1}, r\right). \quad (5)$$

Positions of points of equilibrium of this system satisfy equality:

$$\varphi_\partial\left(\varepsilon, r\right) = 0. \quad (6)$$

Stochastic finite-difference equalization of the first orders looks like:

$$\begin{aligned}\Delta\varepsilon_n &= \Delta Y_n - \alpha\varphi_\partial\left(\varepsilon_{n-1}, r, q\right) - \\ &-\alpha k_\Phi\left(\varepsilon_{n-1}, r, q\right)\xi_{n-1},\end{aligned} \quad (7)$$

where $\varphi_\partial(\varepsilon_n, r, q)$ and $k_\Phi(\varepsilon_{n-1}, r, q)$ — parametrical discriminatory and fluctuation descriptions of the system [4,5].

Average equalizations in relation to moment functions in this case:

$$\begin{aligned}&\Delta m_{\varepsilon,n} = \Delta m_{Y,n} - \alpha k_0\left(m_{\varepsilon,(n-1)}, \theta_{\varepsilon,(n-1)}, r, q\right)m_{\varepsilon,(n-1)};\\ &\Delta\theta_{\varepsilon,n} = \Delta^2\theta_{Y,n} - \alpha\theta_{\varepsilon,(n-1)}k_1\left(m_{\varepsilon,(n-1)}, \theta_{\varepsilon,(n-1)}, r, q\right)\times\\ &\times\left[2 - \alpha k_1\left(m_{\varepsilon,(n-1)}, \theta_{\varepsilon,(n-1)}, r, q\right)\right] + \left(\alpha k_2\right)^2\frac{g_э^2}{2}.\end{aligned} \quad (8)$$

The parametrical statistical coefficients of linearizing of discriminatory description are used in equalizations (8):

$$\begin{aligned}&k_0\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}, r, q\right) = \left(1 + b\theta_{\varepsilon,n}\right)^{-\frac{3}{2}}\times\\ &\times\left\{\begin{aligned}&\exp\left[-\frac{bm_{\varepsilon,n}^2}{2\left(1 + b\theta_{\varepsilon,n}\right)}\right] +\\ &+q\frac{m_{\varepsilon,n} - r}{m_{\varepsilon,n}}\cdot\exp\left[-\frac{b\left(m_{\varepsilon,n} - r\right)^2}{2\left(1 + b\theta_{\varepsilon,n}\right)}\right]\end{aligned}\right\};\\ &k_1\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}, r, q\right) = \left(1 + b\theta_{\varepsilon,n}\right)^{-\frac{3}{2}}\times\\ &\times\left\{\begin{aligned}&\left(1 - \frac{bm_{\varepsilon,n}^2}{1 + b\theta_{\varepsilon,n}}\right)\exp\left[-\frac{bm_{\varepsilon,n}^2}{2\left(1 + b\theta_{\varepsilon,n}\right)}\right] +\\ &+q\left(1 - \frac{b\left(m_{\varepsilon,n} - r\right)^2}{1 + \theta_{\varepsilon,n}}\right)\cdot\exp\left[-\frac{b\left(m_{\varepsilon,n} - r\right)^2}{2\left(1 + b\theta_{\varepsilon,n}\right)}\right]\end{aligned}\right\}.\end{aligned} \quad (9)$$

From equalizations (8) and (9) evidently, that with the increase of dispersion of evaluation error in a tracing measuring device the coefficient of transformation of the system decreases in $\left(1 + b\theta_{\varepsilon,n}\right)^{-\frac{3}{2}}$ times and the aperture of the statistically linearized parametrical discriminator is increased due to a presence in the denominator of index of exponential functions of $\left(1 + b\theta_{\varepsilon,n}\right)$.

The coordinates of points of equilibrium of the system are determined with equalizations:

$$\begin{aligned}&F_1\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}, r, q\right) =\\ &= k_0\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}, r, q\right)\sqrt{b}m_{\varepsilon,n} = \frac{\sqrt{b}\left(\Delta m_{Y,n}\right)}{\alpha} = \mu;\\ &F_2\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}, r, q\right) =\\ &= k_1\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}, r, q\right)b\theta_{\varepsilon,n} = \frac{b}{2}\alpha k_2^2 g_э^2 = \lambda.\end{aligned} \quad (10)$$

Each of equalizations (10) can be solved, for example, by a graphic method.

At presence of random perturbation a diagram becomes dependent from dispersion error of evaluation. On a fig. 2 a diagram is presented for a few values $b\theta_{\varepsilon,n}$ and $q = 0{,}6$.

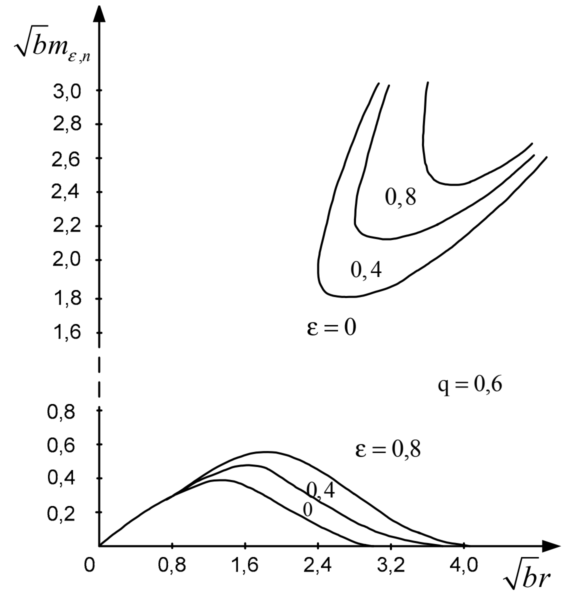


Fig. 2. Bifurcational diagram

At small bases r between the measureable parameters of signals in the discrete system there is one stable state of equilibrium and, consequently, these signals are not permitted. With an increase of r there is bifurcation of the states of equilibrium, and signals begin to be permitted. Influence of random perturbation is taken to that with growth of intensity of perturbation permission takes place in case of the large sizes of base r between the parameters of signals.

The limits of capture area of tracing measuring device in case of pair signal are calculated by the solution of the system of equalizations (8), in which it is necessary preliminary to turn direction time and to choose the coordinates of the states of unsteady equilibrium as initial conditions (in the nearest surroundings of these points) [6]. Lets consider the example of phase portrait of discrete tracing measuring device. As an a «phase» plane in relation to coordinates in form of moment functions $\left(m_{\varepsilon,n}, \theta_{\varepsilon,n}\right)$ for values $q = 0{,}6$ and $\sqrt{br} = 4{,}0$ is represented example on a fig. 3.

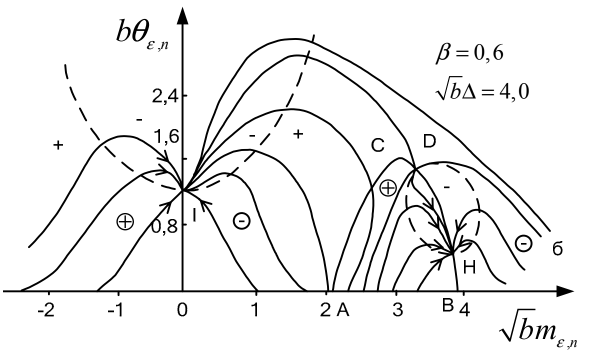


Fig. 3. Capture areas

Parametrical discriminatory description of the system is presented (fig. 3). The lines of *OI* and *BS* correspond to those branches of bifurcation diagram, which reflect the change of coordinates of points of steady equilibrium.

Line *AC* corresponds to the unsteady branch of diagram. It is possible to be convinced in that by considering distributing of signs (to polarity) of eventual differences (speeds) of change of $m_{\varepsilon,n}$ and $\theta_{\varepsilon,n}$. Signs in circles are for $m_{\varepsilon,n}$, and signs without circles — for $\theta_{\varepsilon,n}$. It is possible to define the motion of point on this phase plane, if inflict the points of the stable and unsteady states of equilibrium on the chart of discriminatory description, placed under phase plane of the system. As, all phase trajectories of the system cross curves, answering equalization $\Delta m_{\varepsilon,n} = 0$ with tangents, parallel to axis, then inclination of line *AC* on a phase plane (fig. 3) specifies the possibility of transition of depicting point from the area of branch *BH* on the area of *OI*. Possibilities of such transitions are eliminated if $q = 1{,}0$ and $\lambda = 0$, as a curve *AC* here — is a line, parallel to $0\theta_{\varepsilon,n}$.

On the basis of analysis of phase portrait, on a fig. 3 it is possible to represent the areas of capture for a pair signal with highquality, as it is represented on a fig. 4.

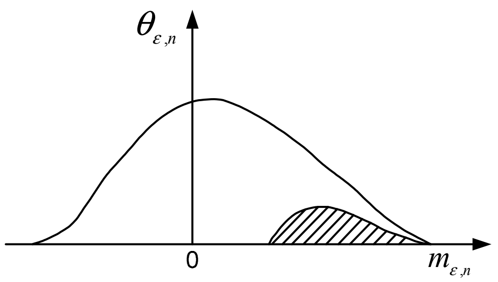


Fig. 4. Capture areas

The shaded area of capture corresponds to a signal with less power, and without shading — to the signal with greater power.

The small area of capture disappears at $r = r_p$ and appears at $r > r_p$, after bifurcation of steady equilibrium. Coordinates of points of equilibrium are found out with the solution of equalizations (9) which can be solved, for example, by a graphic method.

In determined case two signals in a discrete tracing measuring device was already permitted at these values of parameters. In stochastic case conditions of permission substantially depend on intensity of casual perturbation λ. Thus at $q = 0{,}6$ and $\lambda = 0{,}15$ two stable state take place in the system.

At $0{,}17 < \lambda < 0{,}32$ one stable state of equilibrium, corresponded to the first signal, appears in the system only (with greater power). At a further increase of λ there can be another (third) stable state of equilibrium in the system. It corresponds to a few large values of dispersion of evaluation error.

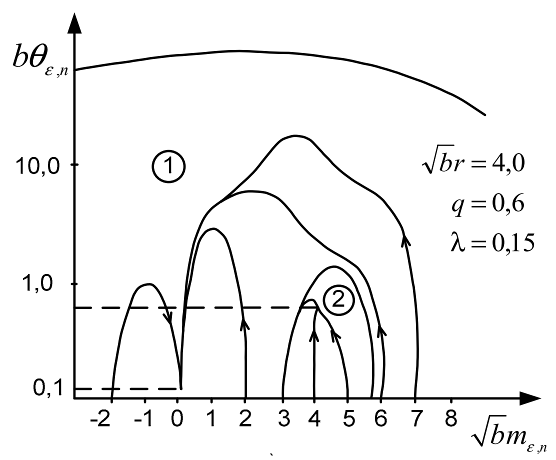
If $\theta_{\varepsilon,n} = 0$ in formulas (9), then it is possible to get a next formula for the expected value of evaluation error of vector of the state:

$$\sqrt{b}m_{\varepsilon,n} = \frac{q\sqrt{br}}{1+q}. \qquad (11)$$

It ensues from this formula, that position of points of steady equilibrium corresponds to the position of power center of two signals.

After calculating the coordinates of points of unsteady equilibrium and solving the system of equalizations (8) in the turned time, the capture areas for the case of pair signals are found. For parameters $\lambda = 0{,}15, 0{,}2$; $q = 1{,}0, 0{,}6$; the capture areas are presented on an im. 5 *a*, *b*.

An fig. 5 shows, that the capture areas depend on correlation of powers of signals q, base between the measureable parameters of signals r and from equivalent intensity of random perturbation λ.



a

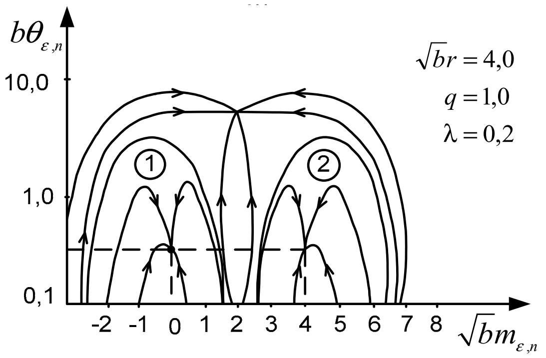


Fig. 5. Capture areas:
a — $\lambda = 0,15$; $q = 0,6$; b — $\lambda = 0,2$, $q = 1,0$
1 — capture area of the first signal;
2 — capture area of the second signal

Conclusions

Research of the mode of capturing is provided, here is two threshold values of intensity of random perturbation $\lambda_1^{пор}$ and $\lambda_2^{пор}$, at which resetting to zero of capture areas on each of signals is done.

Thus at $\lambda_2^{пор}$ = 0,4...0,18 there is localization of signal with less power into the area of capture, and at $\lambda_1^{пор} \cong$ 0,385 there is localization of signal with greater power into the area of capture. If intensity of perturba-tion $\lambda > \lambda_2^{пор}$, then the tracing measuring of parameters is possible only for a signal with greater power.

REFERENCES

1. *Radio* engineering systems: A Textbook for universities “Radio engineering” / Y. P. Grishin, V. P. Ipatov, Y. M. Kazarinovand oth., edited by Y. M. Kazarinova. — M. : HighSchool, 1990. — 496 s.
2. *Shmatok S. O.* Non linear stochastic dynamics of evaluation filter: the capture and distribution ofsignals / S. O. Shmatok, O. A. Baranov, I. P. Lisovy. — K. : Radio amateur, 2000. —217 s.
3. *Shmatok S. O.* Mathematical model of stochastic discrete on linear system of frequency measurement / S. O. Shmatok, O. S. Shmatok, A. B. Petrenko // Collection of scientific articles–Zhitomir : ZHVINAU, im. S. P. Korolova. — 2007. — № 12. — S. 18–26.
4. *Yudin O. K.* Combined of a phase-locked loop / O. K. Yudin, V. K. Steklov, A. A. Rudenko. — K. : Technology, 2004. — 328 s.
5. *Shmatok S. O.* Areas of capturing of discrete stochastic tracking measuring devices of non-energy parameters of radio signals / S. O. Shmatok, O. S. Shmatok, A. B Petrenko // Vistnyk NAU. — K. : — 2008. — № 3 (36). — S. 183–188.
6. *Shmatok S. O.* Distinguishing of signal subpar ammeter in discreet estimation filters / S. O. Shmatok, A. B. Petrenko // Proceedings ofZHVINAU. — 2008. № 1. — S. 34–44.

Article received 26.03.13.