Evaluation of Frequency Hopping Spread Spectrum Signals Stability Against Impulse Disturbances

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***Abstract* - The paper presents a study on the stability of frequency hopping spread spectrum signals against impulse disturbances with coherent receiving. Expressions of quantity evaluation of the noise-resistant feature sensibility in the case examined have been introduced and the possibilities of its reduction by changing the signal phase structure have been investigated.**

***Keywords* - frequency hopping, spread spectrum signals.**

I. INTRODUCTION

One of the main characteristics determining the effectiveness of a radio communication system is the stability against disturbances [1,2]. It is characterized with the dependency of the fidelity of received communications on the line energy parameters, algorithms used to transmit information and statistical characteristics of [1,2]. With discrete systems of connections, the error probability of distinguishing signals is used for fidelity assessment [1]. What is defining under the performance conditions of a number of radio communication systems, it is the influence of impulse disturbances with signal receiving. This influence proves to be both in the direct change of disturbance disperse and the faults of adapting devices of signal frequency-and-time processing, as a result of which the radio system effectiveness has been deteriorating.

The paper presented is a study on the dependency of the noise-resistant characteristic of a frequency hopping spread spectrum signals (FHSSS) coherent receiver with the influence of impulse disturbances by signal and disturbance main parameters.

II. PRESENTATION

The mathematical model of impulse disturbances is the quasi-determined random process [2] that is described by the determinant function of the time of one or several random parameters:

$$\xi(t) = \cos[k\omega_0(t-t_0)+\psi_\zeta] \quad , \tag{1}$$

where: $t \in [t_0, t_0+\tau_\zeta]$, ψ_ζ and τ_ζ are the initial phases and duration of the impulse disturbance, t_0 is the moment when it is acting.

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The analytical expression that describes the i^{-th} signal element with FHSS [3] is:

$$s_i(t) = U_m \sum_{k=1}^{N} rect(t-(k-1)\tau_0) e^{j(\omega_{ki}t+\psi_{ki})} \quad , \tag{2}$$

where: $rect(t-(k-1)\tau_0) = \begin{cases} 1, & (k-1)\tau_0 \le t \le k\tau_0 \\ 0, & (k-1)\tau_0 > t > k\tau_0 \end{cases}$,

$\omega_{ki} = \omega_0 + d_{ki}\Delta\omega_0$, ω_0 - carrying frequency, τ_0 is the length of a signal element, N – number of signal elements,

$\Delta\omega_0 = \gamma \dfrac{2\pi}{\tau_0}$, $\gamma = 1,2...$,

$d_{ki} \in \{d_k\}$ is the spectrum-expanding code sequence determining the initial phases of primary signals $\psi_{ki} \in \{\psi_k\}$.

As the degree of the interaction between the useful signal and the impulse disturbance on the frequency-and-time plane is analogous to their mutual correlation function, it is suitable to assume the average statistical value of the mutual difference coefficient in the position of interaction between them. This value is expressed in the kind of:

$$\overline{G}_{il}^2 = \left[\frac{K_0 K_\xi}{2P_i T} \int_0^T \dot{S}_i(t) \Sigma_{\xi l}^*(t) dt \right]^2 , \tag{3}$$

where K_0, K_ζ, are the amplitude coefficients of the signal and disturbance, $T=\tau_0 N$ is the signal length, $\dot{S}_i(t)$ and $\Sigma_{\xi l}^*(t)$ are the complex functions of the i^{-th} signal and l^{-th} impulse disturbance, $P_i = \dfrac{K_0^2}{T}\int_0^T s_i^2(t)dt$ is the average power of the i^{-th} signal variant.

The functional kind of the expression of the error probability with receiving by elements depends on the sets of signal parameters, the disturbances and the interaction between them:

$$P = \left[\left\{ \overline{h}_i^2 \right\}, \left\{ \overline{h}_\zeta^2 \right\}, \overline{G}_{il}^2 \right] , \tag{4}$$

where $\overline{h}_i^2$ and $\overline{h}_\zeta^2$ express the mean statistical properties of the ratios between the energies of the i^{-th} signal variant and the l^{-th} disturbance variant and the white noise spectral density .

The conditions of optimal receiving are maximally satisfied with coherent formation of signals transmitted as the error probability is determined [4] by dependency:

$$P = \frac{1}{2}\left[1-\Phi\left(\sqrt{2}h_e\right)\right] \quad , \tag{5}$$

where $\Phi(.)=\sqrt{\frac{2}{\pi}}\int_0^t e^{-\frac{x^2}{2}}dx$ is the integral function of Cramp's distribution [1,4].

The ratio h_e depends substantially on the receiver type and the frequency-and-time properties of the signals processed and influencing disturbances. In references [2,3,4] there are different diagrams of coherent receivers that are examined as the receiver diagram has been optimized or made more complex according to the noise environment. Thus it has been adapted to influencing disturbances.

For a receiver that is optimal under the conditions of white noise and concentrated disturbances, with the influence of impulse disturbances h_e is expressed in the kind of :

$$h_e=\frac{a\bar{h}_i}{\sqrt{a+\frac{\bar{h}_\zeta^2}{FT}\frac{\tau_\zeta}{T}\left(1+D-2b\sqrt{D}\right)}}\quad, \tag{6}$$

where: F – signal frequency band , $a=1-\frac{1}{FT}$,

$$b=\cos\left(k\omega_0 t_0+\psi_{ki}\right)\quad, \tag{7}$$

$$D=\sum_{i=1}^{k}\cos\left[(i-k)\omega_0 t_0\right]\cos\psi_{ki}\quad. \tag{8}$$

It is evident that parameters D and b depend very much on the set of initial signal phases and moment t_0 of the impulse disturbance appearance.

Taking into account dependency (6), the noise-resistance characteristics is expressed in the kind of

$$P=\frac{1}{2}\left\{1-\Phi\left[a\sqrt{2}\frac{\bar{h}_i}{\sqrt{a+\frac{\bar{h}_\zeta^2}{FT}\frac{\tau_\zeta}{T}\left(1+D-2b\sqrt{D}\right)}}\right]\right\}. \tag{9}$$

The noise-resistance characteristic expressed by dependency (9) is a function of $\bar{h}_\zeta^2$ and depends on the signal phase structure expressed by the set of initial phases $\{\psi_k\}$.

III. PRACTICAL CONSIDERATION

The functional stability of the receiver examined is evaluated by the quantity expression of the noise-resistance characteristic (9) in respect to the variations of signal and disturbance parameters. In this sense, the sensitivity of error probability (9) has been determined towards the change of parameter b and the change of ratio $\bar{h}_\zeta^2$:

$$\left|Z_b\right|=\frac{\partial P}{\partial b}\frac{b}{P}, \tag{10}$$

$$\left|Z_{\bar{h}_\zeta^2}\right|=\frac{\partial P}{\partial \bar{h}_\zeta^2}\frac{\bar{h}_\zeta^2}{P}\quad. \tag{11}$$

The sensitivity of the error probability to the change of $\bar{h}_\zeta^2$ has been studied in two aspects: related to the decrease of parameter D by changing initial phases $\{\psi_k\}$ and to the increase of signal base (FT). The results of this study are given in Fig. 1.On the basis of the results obtained it follows that a weak change of the feature sensitivity to the variation of ratio $\bar{h}_\zeta^2$ has been accomplished by changing the signal phase structure. Fig.2 shows the study on the sensitivity dependency of error probability according to the change of parameter b with the fooling features of the signal and impulse $\bar{h}_\zeta^2=10^2$, $FT=10$, $\frac{\tau_\zeta}{T}$=0,05. It can be seen that the sensitivity of the noise resistance feature towards moment t_0 of the impulse disturbance action and the initial signal phases is considerable.

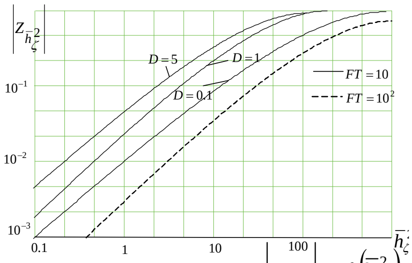

Fig.1. The dependency $\left|Z_{\bar{h}_\zeta^2}\right|=f\left(\bar{h}_\zeta^2\right)$

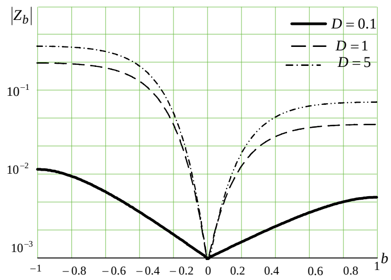

Fig.2. The dependency $\left|Z_b\right|=f(b)$

IV. CONCLUSIONS

The obtained dependencies of the noise-resistance characteristic sensitivity change on parameters depending on the set of initial signal phases $\{\psi_k\}$ have shown that the functional stability of the coherent receiver under examination with the influence of impulse disturbances can be improved by an appropriate choice of the signal phase structure. On the other side, it can be accomplished by a purposeful selection of a spectrum-expanding code sequence $\{d_k\}$ controlling $\{\psi_k\}$ that will result in minimal area of signal striking by the disturbances influencing in the channel.

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