APPLICATION OF THE THEORY OF INVARIANCE FOR NOISE-RESISTANCE ESTIMATION OF TRANSPORTATION INFORMATION SYSTEMS

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Abstract: *In the present paper is defined the functional stability of the communication systems for radio connection in the railway transport. It is associated with the possibilities for the realization of the principles of invariance within signal – noise environment altering itself.*

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1. Introduction in the problem

Information systems in some important production sectors, such as transport, production and distribution of electricity, etc., are crucial for their correct and reliable functioning. They required providing for the relevant security level and functional safety.

The traditional methods, based on multiple reservations, bringing into use systems for "built-in" control, and elements with enhanced security level, are insufficient.

For instance, the mobile systems for radio contact in the railway transport are distinguished on the one hand by functioning under extremely arduous and complex conditions with complex influence exerted by strong fluctuative, concentrated, impulse disturbances [4] in the grid – circuit as well as the operation of multiple devices while on the other hand by utilizing high level of reliability of the information being transferred which is related to the traffic safety. In relation to that, the development of approaches and methods capable of providing for reliability assigned in advance and guaranteed level of jamming resistance respectively is of exceptionally high interest and special actuality.

In the present paper, the mobile communication systems' capability of preserving characteristics' qualities of the jamming resistance property within certain bounds, while altering static characteristics of the random parameters, as well as varying both shape and parameters of the signal and the disturbances, is defined as functional stability [1,2,3].

It means that the given quantity of the system functioning is achieved thanks to the independency (partial or complete) of the perform-ance of the noise-resistance from reasons causing the non-stationary state of the channel of connection. This ability of the system to oppose resist against the disturbing actions is known as invariance [2,3].

In this paper the functional stability of the mobile systems for radio connection in the railway transport is associated with the possibilities for the realization of the principles of invariance within signal – noise environment altering itself.

2. Connection between functional stability of the communication system and theory of invariance

The problem of functional stability of the radio – communication systems for mobile radio connection establishment has been defined and given proof on in the [1,2]. Besides, as it has been mentioned in [1], the distinction between the problems of functional stability of the automatic control systems and suggested radio – communication systems must be emphasized in particular.

In the automatic control systems, both disturbances and control signals are spatially divided in main. This allows one to measure as well as estimate the disturbances regardless its random nature. Also, this allows one to utilize different compensational methods to realize their invariance regarding the disturbances distinguished by conditions and methods being employed in achieving the invariance [2].

In addition, it is also necessary to mention that the notion "invariance," being the main component and the goal the functionally stable control is to achieve, requires refinement in relation to which one of the control system's numerical characteristics is an invariant as well as which transformations or influences the system is invariant towards.

In case of radio – communication systems, the disturbances themselves in a broad sense play a certain part as disturbances: the different kind of noise, superposing the received signal, as well as random alterations of characteristics and parameters of both the communication channel and the signal influencing the jamming resistance. In that case, the system's characteristic that should be invariant to the disturbances is its jamming resistance being equalized quantitatively to the error probability during digital communications.

At the same time, it should be emphasized that in the communication systems, in contrast to the automatic control systems, the useful signal and the disturbance react upon the same point, i.e. the receiver input oftentimes, and could not be divided thoroughly. In the opposite case, it could be mentioned that the problem of struggling against the disturbances would not exist.

In the radio – communication systems, it is all about a composite between a signal and noise since the white noise is always available as additive. The parameters of the additive disturbance determine at first hand the jamming resistance of the communication system. If it were a non-stationary random process, the level of thrust-worthiness of the information transmitting process would be altered. For instance, if the disturbance power increased in time, the error probability of information transmitting would get increased as well. The non – additive disturbances lead to relevant alteration of the particular parameters of both signal and channel. Since the channel parameters alteration could be expressed through the relevant alteration of signal parameters, the non – additive disturbances exert influence on the jamming resistance while the receiving conditions are getting either deteriorated or improved, yet this alter the error probability.

This is why building functionally stable radio – communication systems with invariant, in relation to the disturbances complex influence, parameters and characteristics, requires for a variety of reasons another formulation and approach to be met as compared to the problem of functional stability of the automatic control systems.

Such a fundamental characteristic of the system for official radio contact with mobile objects, such as the jamming resistance, could not represent thoroughly the system's qualitative functioning. For this purpose, it is necessary to introduce indicators that would allow the system's ability to preserve characteristics' qualities of the jamming resistance within certain bounds, while altering the parameters of the signals and disturbances.

On the present level of growth of the mobile radio – communication systems, operating under conditions of complex influence exerted by disturbances, development of methods for increasing the jamming resistance is related to usage of signals with complex structure, channels with adjustable feedback, and synthesis of special algorithms [1,3], minimizing the influence exerted by disturbances on the jamming resistance. On these lines, looking into algorithms of information being transmitted through noise – like signals with optimized structure, permitting warranty related to the working capability of the system in a variety of situations rendering into account the static characteristics of the signal, the channel, and

the noise environment, is topical in particular. This approach is related to two – dimensional (frequency – temporal) coding of each signal parameter: by means of either forming pseudo – stable switching between the operative frequencies or usage of pseudo – random sequences manipulating the signal's phase [5,6]. Using either of the mentioned complex signals allow one to increase significantly both the jamming resistance of the radio systems, at the expense of introducing multiple frequency – temporal surplus within the signal, and the relevant complication arising during the signal's processing by the receiver.

Under conditions of work of businesses radio communication systems for transmitting information with security reliability in the railway transport, the decisive factor is the influence of the impulse disturbances during signals receiving [2,3]. This influence reveals itself during spontaneous alteration of the dispersion as well as failures of the adaptive devices of spatial – frequency – temporal signals' processing which signals are generated assuming that the received mixture is quasi – stationary and Gauss one (in common sense) [7].

As a result of that, the efficiency of the radio system is getting vastly deteriorated under the influence of these signals. It must be borne in mind that the indicators of the jamming resistance (the weighted error of the signal's reproduction and the probability of wrong decision to be taken by the demodulator regarding the discrete message being transmitted) are not completely adequate to the real conditions the connection is established under. In the non – stationary channels of the systems for mobile radio connection establishment, the relation "signal/noise" is altered during the system's functioning process. Therefore, the determined in this way reliability is also getting altered. If these alterations could be neglected within the time interval of message transmitting, the channel is considered as locally stationary one. In addition to either the weighted error or the probability of wrong estimation of the jamming resistance, it is necessary one to determine what the trust probability that the values of these variables will not exceed the limit is. During the effect of impulse disturbances, the constancy of the ratio "signal/noise" is violated by powerful momentary peaks within the electromagnetic field of the disturbances. These peaks dramatically change the ratio and evaluation of the acquired specific resistance (jamming resistance) traits.

In radio channels, intended to establish connection to mobile objects, the probability of error is variable quantity (heterogeneous channel with variable characteristics). In this case, even if securing the average probability of error less than assigned limit were successful, the probability of error could be set greater than permissible value. Furthermore, regarding all mobile channels, reducing the average probability of error does not show clearly improving the quality of the system's functioning. For example, if the percentage of cases of error probability were getting greater than admissible value, along with reducing the average probability of error allowance, the jamming resistance of the system would get decreased. It follows that, in particular, optimization of the radio system, in accordance with the widely used criterion for the minimum average probability of error, does not provide the best quality of operation of the real system in the radio channel with variable parameters. To ensure an acceptable quality of functioning of the real system in the radio channel with variable characteristics, it is necessary to maintain the probability of error at a level not exceeding a preset limit. In essence, this means that the specified quality of the system functioning is achieved due to error likelihood independence (partial or complete) of causes for non-stationary nature of the communication channel.

This standard, known as the invariance, is a property of the system to oppose the disturbing effects.

In the most general case, if the initial system coordinate *y(t)* for any point in time *t* does not depend on the disturbance *f(t)*, the system will be possessed by absolute invariance regarding *f(t)*, i.e:

$$y(t) = \text{invar}[f(t)]. \quad (1)$$

If this property is fulfilled roughly (in a certain sense) then the invariance will be accurate up to ε and the system will be relatively invariant, i.e:

$$y(t) = \text{invar}[f(\varepsilon)]. \quad (2)$$

The concepts of "invariance" and "functional stability" are interrelated. If one examined invariance of the jamming resistance characteristics, put in the form of functional dependence of the error probability of both the signal's and disturbances' parameters, in which case the system has characteristic of the jamming resistance being absolute invariance in relation to a definite class of disturbances, the study of functional stability would become futility. If the system has an invariant characteristic then the relative invariance and functional stability will be thought as concepts being largely equivalent.

3. Defining of conditions of invariance of the performance of noise-resistance

For a radio channel, the typical situation is the one where the performance of noise-resistance is determined by the presence of disturbances of several classes (fluctuating, spectrum-concentrated, impulse). The functional kind [3] 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 :

$$P = \left[\left\{\overline{h}_i^2\right\}, \left\{\overline{h}_\zeta^2\right\}, \overline{G}_{ij}^2\right], \quad (3)$$

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 *j-th* disturbance variant and the white noise spectral density.

The part of parameters of interaction between the signal and disturbances is played by set $\{\overline{G}_{ij}^2\}$, i=1÷n , j=1÷n_ζ , average statistical values of the coefficients of the reciprocal differences in the frequency-and-time area of their structures.

As the degree of the interaction between the useful signal and the 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 [3]:

$$\overline{G}_{ij}^2 = \left[\frac{K_0 K_\zeta}{2P_i T}\int_0^T \dot{S}_i(t)\Sigma^*_{\zeta_j}(t)dt\right]^2, \quad (4)$$

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 $\Sigma^*_{\zeta_j}(t)$ are the complex functions of the *i-th* signal and *j-th* disturbance,

$$P_i = \frac{K_0^2}{T}\int_0^T s_i^2(t)dt \quad (5)$$

is the average power of the *i-th* signal variant.

The conditions of the invariance of the connection system are expressed in relation to a certain class of disturbances and in dependence with the metrics selected on the signal space.

If *n(t)* and $\zeta(t)$ are random realizations of fluctuation noise {N} and quasi-determined interferences {Ξ} respectively, then the performance of noise-resistance is a function of both interferences:

$$P = P(N, \Xi,). \quad (6)$$

The system of connection is absolutely invariant to $\zeta(t)$, if :

$$P(n,\zeta) = P(n,0) = P(n) \quad (7)$$

is fulfilled.

When the noise-resistance characterization depends on interferences Ξ to a certain extent, e.g.:

$$\left|P(n,0) - P(n,\zeta)\right| \le \varepsilon, \quad (8)$$

then the system is relatively invariant (invariant to ε), where ε presents the given distance between $P(n,\zeta)$ and $P(n,0)$:

$$\varepsilon = \max_{\zeta}\left|P(n,\zeta) - P(n,0)\right| \quad . \quad (9)$$

4. Conclusion

The functional stability is a broader concept which is associated with the investigation of possibilities opened up by the development of modern element base for the realization of the principles of invariance within signal – noise environment altering itself

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