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METHOD OF MULTICRITERIAL EVALUATION OF THE STATE OF THE SPECIAL PURPOSES OF RADIO COMMUNICATION SYSTEM CHANNELS

The issue of increasing the noise immunity of special purpose radio systems operating in a complex electronic environment is an urgent and unresolved problem in its entirety. One of the possible ways of increasing the noise immunity of special purpose radio communication systems is to increase the accuracy and speed of assessing the state of the communication channel in a dynamic signaling and interference situation. In this work, an analysis of existing methods for assessing the status was made, it was found that existing methods do not allow for multicriteria assessment of the quality of communication channels with acceptable computational complexity and reliability of decision-making. The methodology of multicriteria estimation of the quality of communication channels of special purpose radio communication systems, operating in a complex electronic environment, was developed. The article proposes to use a fuzzy logic device for conducting multicriteria assessment of the quality of communication channels due to deliberate interference and silence of the signal. The essence of the proposed methodology is to carry out an assessment of the state of communication channels of special purpose radio systems for each of the indicators of evaluation, after which a generalized assessment of the state of the communication channel is formed. Also, in the proposed method, the correction of the weight of expert rules is carried out, which allows to increase the speed and quality of the assessment of the state of the channels in a dynamic signaling and interference situation. The obtained results should be used in radio communication with programmable architecture, in order to increase the speed and accuracy of the assessment of the state of communication channels.

Keywords: *radiocommunication system, radiocommunication, radio-electronic suppression, intentional interference*.

Introdaction

In the projecting of adaptive radio communication systems, depending on their purpose, the problem of optimizing one of the efficiency indicators solved with the established limitations on others. In turn, the development and implementation of adaptive methods of information exchange require the creation of effective procedures for monitoring and forecasting the status of communication channels and the quality of information transfer. To solve this problem, it is necessary to involve methods of modern mathematical statistics, in particular, to check statistical hypotheses about parameter (group of parameters) that characterizes the state of the communication channel.

Different types of control can be classified by purpose, the time of connection of monitoring devices, the methods of obtaining and sources of information, the forms of presentation of the initial information, the relation to the process of information transfer, the ways of implementing the procedures.

Basic forms of presenting the initial information in radiocommunication systems: evaluation of the system function; value of the quality criterion, estimation of error distribution parameters, interference; evaluation of interference distribution functions; conclusion about efficiency; "coordinates" of failed elements and devices. Necessary form of output information is determined by the purpose of the control and is provided by the selected mathematical apparatus.

In most of the works [1–12] it is assumed that any object can be formally described in the form of a fairly simple mathematical model. In the general case, various differential, integral-differential, algebraic or transcendental equations used as such models, connecting individual parameters describing the structure of the object.

In practical problems of channel state estimation. For their application it is necessary to have priority information in the form of model channels, in which only certain parameters may be unknown. [1–12]: likelihood success method, least squares method, estimation method. Bayesian method, the Kalman filter method, and stochastic approximation method, etc.

As rule, evaluation of status of the communication channel is carried out using one single valuation indicator, namely [13–16]: the variance of the estimates of the amplitude components of the signals; Probability of bit error; Probability of a symbolic error; Power / signal ratio; variance of noise or interference; ratio of the bit energy to the spectral power density of the noise (Modulation Error Ratio) – the ratio of the average symbol power to the average error power; signal quality factor (Waveform Quality Factor) – the ratio of the average in the frame of the power of the original signal to the average received power; ratio of the symbol energy to the spectral power density of the noise.

Advantage of using the theory of fuzzy logic for estimating the quality of radiocommunication channels is related to the possibilities of constructing a system for estimating the quality of radiocommunication channels over a variety of different evaluation indicators.

Methods of fuzzy inference allow us to connect the functions of belonging to indicators and situations of the signal situation in the presence of the channel model in the form of "if-then" rules.

Therefore, **aim of this work** was to develop development of a methodology for multicriteria quality assessment of communication channels of special-purpose radio communication systems.

Exposition of the main material of the research

The essence of the methodology of multicriterial assessment of the quality of communication channels of special purpose radio communication systems is to evaluate the channel through using of fuzzy logic apparatus, through which the communication channel is represented in the form of a logical conclusion tree in which the root of the tree corresponds to the result of the estimation, and the vertices – channel quality score.

Setting objectives.

Given: a set of indicators for assessing the quality of the communication channel, namely: the presence of noise and fading signal, the probability of a bit error, the frequency response of the channel, pulse characteristics of the channel.

It is necessary: to maximize the quality of the assessment of the condition of the communication channel in the limitations on the time of evaluation with the given reliability of the decisions being taken.

Limitation: the state of the signal and interference is unchanged during the packet transmission.

The algorithm for implementing the method is shown in fig. 1.

There are many different approaches to estimating the parameters of radio link. Interest is represented by those of them that produce the estimation in the receiver. Estimation of parameters in algorithms using pilot signals based on the ability to accurately calculate the values of complex amplitudes at the instants of time where they are transmitted.

Thus, the result of estimating the quality of radio link can be represented [3–5] in the form:

$$y = f(x_1, x_2, ..., x_n), \tag{1}$$

where $x_1, x_2, ..., x_n$ – set of incoming channel quality metrics; y – channel quality assessment result.

Area of changing incoming quality indicators of the communication channel $x_i \in [\underline{x}, \overline{x}], i = \overline{1, n}$ and the initial

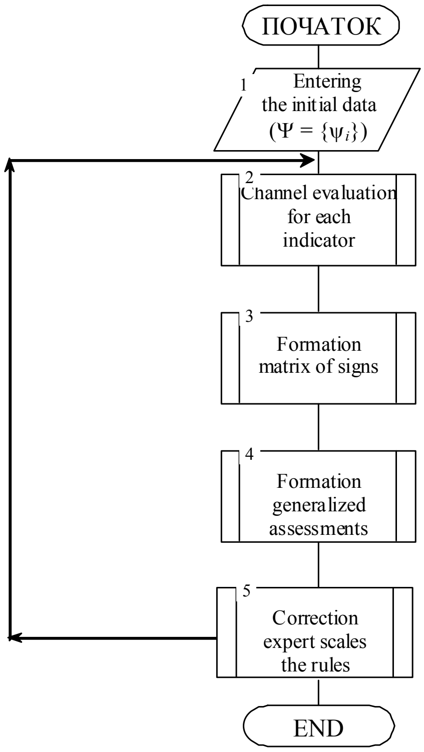

Fig. 1. Algorithm for implementing the method of multicriterial evaluation

values of the valuation indicators $y \in [\underline{y}, \overline{y}]$ are known. Here $\underline{x}_i \left(\overline{x}_i\right)$ – lower (upper) value of incoming indicators $x_i, i = \overline{1, n}$, $\underline{y}\left(\overline{y}\right)$ – lower (upper) value of evaluation results y.

Let it be: many solutions $D = \{d_j\}, \left(j = \overline{1, m}\right)$, which correspond to result of the estimation communication channel y; set of incoming indicators $X = \{x_i\}, \left(i = \overline{1, n}\right)$; ranges for the quantitative change of each incoming assessment indicator $x_i \in \left[\underline{x}_i, \overline{x}_i\right], i = \overline{1, n}$; membership functions that allow to present indicators $x_i, i = \overline{1, n}$. In the form of fuzzy sets (2–3); matrix of knowledge, which is defined by the rules (tabl. 1).

$$a_i^p = \int_{\underline{x}_i}^{\overline{x}_i} \mu^{a_i^p}(x_i) \Big/ x_i . \tag{2}$$

$$d_j = \int_{\underline{d}}^{\bar{d}} \mu^{d_j}(d) \Big/ d \,. \quad (3)$$

Graphically, the process of estimating the quality of communication channel, using fuzzy sets, can be represented in the form of fig. 2. Consider order of estimating the quality of communication channel using the proposed model. From the analysis of the functioning of the radiocommunication channel in different conditions of the signal environment, we determine the directions for estimating quality of the communication channel: the similarity of the indicators characterizing the quality of the communication channel and their changes during the course of the radio communication session until the decision on the quality of the communication channel was made.

Table 1

Fuzzy knowledge matrix

Number of input combination of values	Input variables				Output variables
	x_1	x_2	x_i	x_n	Y
11 12 … $1k_1$	a_1^{11} a_1^{12} … $a_1^{1k_1}$	a_2^{11} a_2^{12} … $a_2^{1k_1}$	… a_i^{11} … … a_i^{12} … … … $a_i^{1k_1}$ …	a_n^{11} a_n^{12} … $a_n^{1k_1}$	d_1
j1 j2 … jk_j	a_1^{j1} a_1^{j2} … $a_1^{jk_j}$	a_2^{j1} a_2^{j2} … $a_2^{jk_j}$	… a_i^{j1} … … a_i^{j2} … … … $a_i^{jk_j}$ …	a_n^{j1} a_n^{j2} … $a_n^{jk_j}$	d_i
...	…	…	…	…	…
m1 m2 … mk_m	a_1^{m1} a_1^{m2} … $a_1^{mk_m}$	a_2^{m1} a_2^{m2} … $a_2^{mk_m}$	… a_i^{m1} … … a_i^{m2} … … … $a_i^{mk_m}$ …	a_n^{m1} a_n^{m2} … $a_n^{mk_m}$	d_m

Channel quality estimation model is written as follows:

$$D(k) = f\begin{bmatrix} Y_1(k-1),...,Y_n(k-1), \\ Z_1(k-1),...,Z_n(k-1) \end{bmatrix},$$

where $Y_1(k-1)$ – vector, characterizing the first indicator of the quality of the channel at the k–1 step of modeling; $Y_n(k-1)$ – vector, charactezing n-th link quality estimate for the communication channel at the k-1 modeling step; $Z_1(k-1),...,Z_n(k-1)$ – vectors that characterize the generalized channel estimate for each of the link quality estimation indicators.

In turn, vectors for estimating the quality of the communication channel are determined by the following indicators:

$$Y_1,...,Y_n, Z_1,...,Z_n = \langle k_{11}(x),...,k_n(x) \rangle .$$

Possible states of the signal situation in the channel were given by the set $d \in \{d_1, d_2, d_3\}$, where d_1 – channel correspond to the norm (corresponds to the maximum frequency efficiency); d_2 – some of the channel quality indicators go beyond the limits of the norm and require an adjustment; d_3 – channel is not suitable for operation. Task of evaluation is to assign to each combination of indicators of the signal situation one of the solutions $d_i, i = \overline{1,3}$. Indicators $k_{11},...,k_{21},...,k_{141},...k_{145}$ will be treated as linguistic variables [3–5].

Structure of the channel quality estimation model can be represented as multi-level hierarchical tree of logical inference, which corresponds to the following states:

$$d = f_d(Z_1...Z_n), \quad (4)$$

$$Z = f_z(Y_1...Y_n), \quad (5)$$

$$Y_n = f_{y_n}\left(k_{n1}(x), k_{n2}(x), k_{n3}(x), k_{n4}(x), k_{n5}(x)\right). \quad (6)$$

For indicators that have quantitative dimension, the range of change is divided into four quanta. This enables the transformation of a continuous universal set $U = [\underline{u}, \bar{u}]$ into discrete five-element set [3]:

$U = \{u_1, u_2, ..., u_5\}$, where $u_1 = \underline{u}$, $u_2 = \underline{u} + \Delta_1$, $u_3 = u_2 + \Delta_2$, $u_4 = u_3 + \Delta_3$, $u_5 = u_4 + \Delta_4$, besides $\Delta_1 + \Delta_2 + \Delta_3 + \Delta_4 = \bar{u} - \underline{u}$, $\bar{u}(\underline{u})$ – upper (lower) border of the range of the indicator change. Then all matrices of pairwise congruences have dimension 5×5. Choosing of four quanta is determined by the possibility of approximating non-linear curves from five points [3–5].

To estimate the values of linguistic variables $k_{n1},...,k_{n1},...,k_{n1},...k_{n5}$ $\mathrm{k_{n1},...,k_{n1},...,k_{n1},...k_{n5}}$ we will use the scale of qualitative terms. To evaluate linguistic variables D, Z_n, Y_n. We use the following term sets:

$D, Z_1...Z_n, Y_1...Y_n$ = {channel parameters correspond to the norm, some parameters of the channel go beyond the limits of the norm and require correction, the channel is not suitable for operation}.

Each of the entered terms is fuzzy set, which is defined by the corresponding membership function. In general, the input variables $x_1, x_2,..., x_n$ can be given by number, linguistic term, or by the principle of a thermometer [3–5].

Evaluation of the communication channel occurs with using fuzzy logical equations [3–5], representing matrix of knowledge and system of logical utterances. These equalities make it possible to calculate the values of the membership functions of different evaluation results for fixed values of the incoming indicators. As a result of the assessment process, it is proposed to make a decision that has the greatest value of the membership function [3–5].

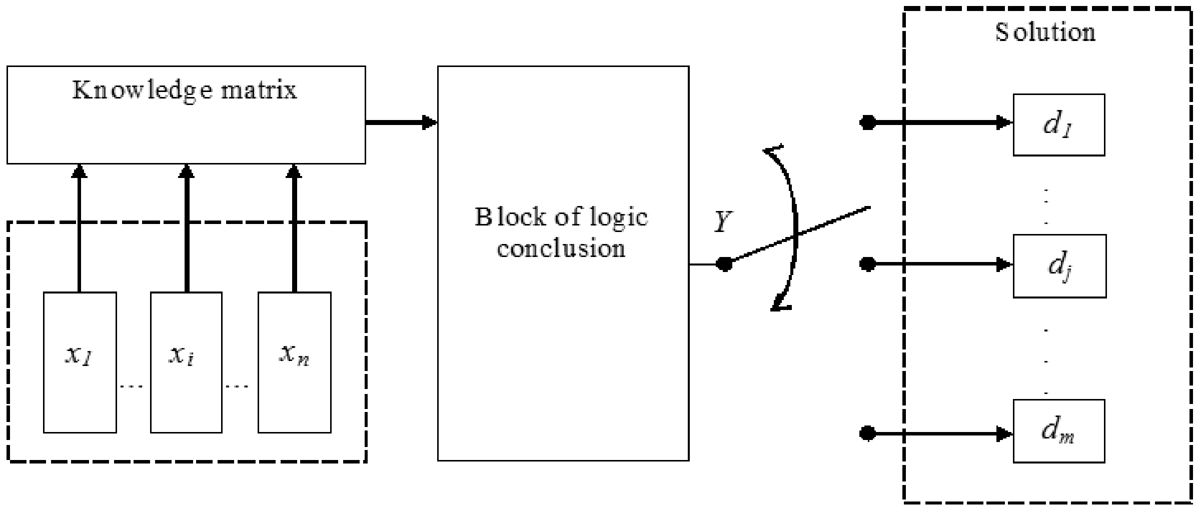

Fig. 2. Communication channel evaluation process model

Linguistic evaluation α_i^{jp} variables $x_1, x_2,..., x_n$, logical statements about solutions $d_j, j=\overline{1,m}$ (5–6), consider how fuzzy sets that are defined on universal sets $X_i = \left[\underline{x}_i, \overline{x}_i\right], i=\overline{1,n}$.

Let it be $\mu^{a_i^{jp}}(x_i)$ – membrship function $x_i \in \left[\underline{x}, \overline{x}\right]$ fuzzy term $\alpha_i^{jp}, i=\overline{1,n}, j=\overline{1,m}, p=\overline{1,l_i}$; $\mu^{d_j}(x_1, x_2,..., x_n)$ – function of the vector of input variables $X=(x_1, x_2,..., x_n)$ value of the output estimate $y=d_j, j=\overline{1,m}$. Relationship between these functions is determined by fuzzy knowledge base and can be represented in the form of the following logical equalities:

$$\mu^{d_j}(x_1, x_2,..., x_n) = \mu^{a_1^{j1}}(x_1) \wedge \mu^{a_2^{j1}}(x_2) \wedge ... \wedge \mu^{a_n^{j1}} \vee$$
$$\vee \mu^{a_1^{j2}}(x_1) \wedge \mu^{a_2^{j2}}(x_2) \wedge ... \wedge \mu^{a_n^{j2}}(x_n) ... \quad (7)$$
$$..\mu^{a_1^{jl_j}}(x_1) \wedge \mu^{a_2^{jl_j}}(x_2) \wedge ... \wedge \mu^{a_n^{jl_j}}(x_n), j=\overline{1,m}.$$

Equation data obtained from a fuzzy knowledge base by replacing variables (linguistic terms) with their membership function, and AND and OR operations on operation $\wedge$ and $\vee$.

We write the system (8) compactly as follows:

$$\mu^{d_j}(x_i) = \bigvee_{p=1}^{l_j}\left[\bigwedge_{i=1}^{n} \mu^{a_i^{jp}}(x_i)\right], j=\overline{1,m}. \quad (8)$$

Fuzzy logical equalities represent an analogue of Zade's procedure of fuzzy logic inference [1–7], which are performed with the help of operations "fuzzy (min-max) composition", in which operations $\wedge$ and $\vee$ correspond to the operation *min* and *max* [1–7], from (9) will get:

$$\mu^{d_j}(x_i) = \max_{p=\overline{1,l_j}}\left\{\min_{j=\overline{1,n}}\left[\mu^{a_i^{jp}}(x_i)\right]\right\}. \quad (9)$$

It can be seen from expression (9) that to calculate the membership function, it is necessary to have only the functions of the variables belonging to fuzzy terms. Consider the order of calculation of the membership function used in this procedure.

From the analysis of known methods for constructing the membership function [1–7] of the channel quality estimation indicators, it can be argued that it is inappropriate to apply direct methods for constructing the membership function based on specifying fixed graphs, analytic dependencies, and functions for solving this problem; Use of the quantified scale in the presence of a number of quantifiers in connection with the relative complexity of the choice of values of the membership function and large share of subjectivity.

When choosing indirect methods of constructing the membership function that convert expert information into form convenient for using in the interest of linkage estimation, it is necessary to take into account the computational complexity of their implementation. Thus, to construct the membership function on the basis of the pairwise comparison method, it is necessary to form matrix of paired comparisons and to solve the characteristic equation of the matrix of paired comparisons to determine its eigenvector. But this method has large computational complexity. Given the possibility of calculating the membership function using rank estimates, which are fairly easy to obtain in an expert survey, we use the paired comparison method to calculate the membership function.

Algorithm for calculating the channel quality membership function includes the following steps:

1. Quality indicator of the communication channel is selected, which must be estimated $x_j, j=\overline{1,m}$.

2. Defined set of fuzzy terms $\{u_1, u_2, ..., u_l\}$, used for estimating x.

3. For each term $u_i, i=\overline{1,l}$ forming matrix of paired comparisons:

$$T = \begin{vmatrix} 1 & \frac{r_2}{r_1} & \frac{r_3}{r_1} & \dots & \frac{r_n}{r_1} \\ \frac{r_1}{r_2} & 1 & \frac{r_3}{r_2} & \dots & \frac{r_n}{r_2} \\ \dots & \dots & \dots & \dots & \dots \\ \frac{r_1}{r_n} & \frac{r_2}{r_n} & \frac{r_3}{r_n} & \dots & 1 \end{vmatrix}, \qquad (10)$$

where $r_s(u_i)$ – rank of element $u_i \in U$, which characterizes the significance of this element in the formation of property described by some fuzzy term $\tilde{S}$.

Matrix (10) has the following properties:

elements of the main diagonal are 1 ($t_{ij}=1$, $i=\overline{1,n}$); relative to the main diagonal, the elements are connected by the expression $t_{ij}=1/t_{ji}$; satisfied transitivity condition: $t_{ik}t_{kj}=t_{ij}$, because the $\frac{r_i}{r_k}\frac{r_k}{r_j}=\frac{r_i}{r_j}$.

Thanks to these properties from the known elements of single row of the matrix T easy to find elements of other series. If you know the elements t_{kj}, $k, j=\overline{1,n}$ an arbitrary element t_{ij} like: $t_{ij}=t_{kj}/t_{ki}, i, j, k=\overline{1,n}$.

Since the matrix (11) can be interpreted as a matrix of paired comparisons of ranks, it is possible to use the twelve-point scale of Saati [1–7] for expert estimation of the elements of this matrix.

4. The membership functions are defined: 1) by absolute grades $r_i, i=\overline{1,n}$, which can be determined on a nine-point scale (1 – lowest rank, 12 – highest rank); 2) by relative estimates of ranks $r_i/r_j=t_{ij}, i, j=\overline{1,n}$, which are determined by the matrix of paired comparisons (11), membership function for each term is calculated. In this case, the normalization of the membership functions obtained is done by dividing to the highest degree of membership.

Thus, the main advantage of the proposed model for calculating the membership function of the communication channel quality indicators is that it does not require a solution of the characteristic equation in comparison with the known ones, which makes it fairly simple. Obtained relationships make it possible to calculate the membership function using rank estimates, which is fairly easy to obtain with the use of neural-fuzzy networks.

Using the knowledge matrix, known information about the quality of the communication channel can be specified in the form of system of fuzzy logical statements that relate the value of the incoming indicators x_i with one of the possible solutions $d_j, j=\overline{1,m}$.

$$\begin{gathered} \text{IF } \left(x_1=a_1^{11}\right) \text{ AND } \left(x_2=a_2^{11}\right) \text{ AND…AND} \\ \left(x_n=a_n^{11}\right) \text{ IF } \left(x_1=a_1^{12}\right) \text{ AND} \left(x_2=a_2^{12}\right) \\ \text{AND… AND } \left(x_n=a_n^{12}\right) \text{ OR…OR } \left(x_1=a_1^{1l_1}\right) \\ \text{AND } \left(x_2=a_2^{1l_1}\right) \text{ AND…AND } \left(x_n=a_n^{1l_1}\right) \\ \text{THEN } y=d_1, \ \ . \ . \ . \text{IF } \left(x_1=a_1^{m1}\right) \text{ AND} \\ \left(x_2=a_2^{m1}\right) \text{ AND…AND } \left(x_n=a_n^{m1}\right) \text{OR} \\ \left(x_1=a_1^{m2}\right) \text{ AND } \left(x_2=a_2^{m2}\right) \text{ AND…AND} \\ \left(x_n=a_n^{m2}\right) \text{ OR } \left(x_1=a_1^{ml_m}\right) \text{ AND} \\ \left(x_2=a_2^{ml_m}\right) \text{ AND…AND } \left(x_n=a_n^{ml_m}\right) \text{ THEN} \\ y=d_m, \end{gathered} \qquad (11)$$

where $d_j\left(j=\overline{1,m}\right)$ – linguistic evaluation of the outgoing variable y, which is defined from the term-set D; a_i^{jp} – linguistic evaluation of the incoming indicator x_i in p-th row j-th disjunction, which is chosen from the term set $A_i, \left(i=\overline{1,n}, j=\overline{1,m}, p=\overline{1,k_j}\right)$; k_j – number of rules that determine the value of the outgoing variable $y=d_j$.

Fuzzy logical equations (11), together with the fuzzy term membership function, allow us to estimate the quality of the communication channel using the following algorithm:

1. Values of the channel quality indicators were fixed according to predetermined criteria $X^*=\left(x_1^*, x_2^*, ..., x_T^*\right)$.

2. Using the algorithm for calculating the membership function, determine the membership function $\mu^j\left(x_i^*\right)$ for fixed values of indicators $x_i^*, i=\overline{1,m}$.

3. Using logical equalities (11), the membership function $\mu^{d_j}\left(x_1^*, x_2^*, ..., x_m^*\right)$ with the state vector $X^*=\left(x_1^*, x_2^*, ..., x_T^*\right)$ for all states $d_1, d_2, ..., d_n$. In this case, logical operations AND ($\wedge$) and OR ($\vee$)Over membership functions are replaced by operations *min* and *max* [1–7].

4. Determine the solution d_j^*, for which:

$$d_j = \arg \max_{j=\overline{1,m}} \left(\mu d_j\left(x_i\right)\right)..$$

These matrices form fuzzy knowledge base for estimating the quality of the communication channel [1–7].

Identification on the basis of fuzzy logical conclusion is carried out in accordance with the defined knowledge base (11) [20–26]:

$$\begin{aligned}
&\text{IF } (x_1 = a_{1,j1}) \text{ AND } (x_2 = a_{2,j1}) \text{ AND ... AND } (x_n = a_{n,j1}) \text{ with weight } w_{j1}, \text{ OR } (x_1 = a_{1,j2}) \\
&\quad \text{AND } (x_2 = a_{2,j2}) \text{ AND ... AND } (x_n = a_{n,j2}) \text{ with weight } w_{j2}, \\
&\quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
&\text{OR } (x_1 = a_{1,jk_j}) \text{ AND } (x_2 = a_{2,jk_j}) \text{ I ...I } (x_n = a_{n,jk_j}) \text{ with weight } w_{jk_j}, \text{ THEN} \\
&\quad y = d_j, j=\overline{1,m},
\end{aligned} \quad (12)$$

where $a_{i,jp}$ – fuzzy term for which the variable is evaluated x_i in the line with the number $jp(p=\overline{1,k_j})$, i.e. $a_{i,jp}=\int \mu_{jp}(x_i)/x_i$; k_j – the number of conjugate lines in which the output is evaluated by the value d_j; $w_{jp}\in[0,1]$ – weighting rule with a number jp.

Functions of the object matching $X^*=\left(x_1^*, x_2^*, ..., x_n^*\right)$ classes d_j are calculated so [20–26]:

$$\mu_{d_j}\left(X^*\right) = \underset{p=\overline{1,k_j}}{\vee} w_{jp} \cdot \underset{i=\overline{1,n}}{\wedge}\left(\mu_{jp}\left(x_i^*\right)\right), j=\overline{1,m}, \quad (13)$$

де $\mu_{jp}\left(x_i^*\right)$ – login matching function x_i^* fuzzy term $a_{i,jp}$; $\wedge(\vee)$ – s-norma (t-norma), which in the tasks of classification usually correspond to a maximum (minimum).

As a solution, a class with the maximum function of the correspondence of the calculated solution is selected $d_1...d_m$ [20–26]:

$$y^* = \underset{\{d_1,d_2,...,d_m\}}{\arg} \max\left(\mu_{d_1}\left(X^*\right), \mu_{d_2}\left(X^*\right), ..., \mu_{d_m}\left(X^*\right)\right).$$

Using the tables and the AND and OR operations, system of logical equations is recorded that links the membership functions of the channel quality assessment solutions to the functions of destabilizing factors.

Thus, knowing the value of the membership function of fuzzy terms, we can estimate the quality of the communication channel by solving the logical equations described above. Thus, the proposed method of the process of assessing the operational situation under conditions of uncertainty in the form of a hierarchical system of relationships makes it possible to evaluate the quality of the communication channel and to investigate its dependence on indicators based on the fuzzy logic rules "IF-TO."

Conclusion

1. In the article was developed the methodology of multicriteria estimation of the quality of the communication channel of special purpose radio communication systems.

The novelty of this methodology is to reduce the computational complexity of the process of assessing the quality of the communication channel due using of the fuzzy logic apparatus and the possibility of adjusting the weight of expert rules in the process of assessing the communication channel state.

Methodology is based on using of a structurally semantic model for estimating the link quality.

Structure of the generalized mathematical model is presented in the form of logical conclusion tree, which reflects the classification of parameters, the intermediate conclusions of the assessment. Root of the tree corresponds to the result of the estimate, and the vertices correspond to the quality of the communication channel. Output score and the link quality indicators are presented as linguistic variables that are estimated using fuzzy terms defined on the corresponding sets. Model for estimating the quality of communication channel based on fuzzy logic is carried out using the available information in the form of "IF-TO" rules that connect the fuzzy terms of the quality indicators of the communication channel and the result of evaluation.

This mathematical model has considerably less computational complexity in comparison with the known ones, since it is constructed using the fuzzy logic apparatus and does not require the solution of the characteristic equation.

The direction of further research is to development of techniques for assessing the quality of the link channel with less computational complexity.

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МЕТОДИКА БАГАТОКРИТЕРІАЛЬНОЇ ОЦІНКИ СТАНУ КАНАЛІВ ЗВ'ЯЗКУ СИСТЕМ РАДІОЗВ'ЯЗКУ СПЕЦІАЛЬНОГО ПРИЗНАЧЕННЯ

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Питання підвищення завадозахищеності систем радіозв'язку спеціального призначення, що функціонують в складній радіоелектронній обстановці, є актуальною та не вирішеною в повному обсязі проблемою. Одним з можливих напрямків підвищення завадозахищеності систем радіозв'язку спеціального призначення є підвищення точності та швидкості оцінювання стану каналу зв'язку в динамічній сигнальній та завадовій обстановці. В роботі проведений аналіз існуючих методів оцінювання стану, з'ясовано, що існуючі методи не дозволяють проводити багатокритеріальну оцінку якості каналів зв'язку з прийнятною обчислювальною складністю та достовірністю прийняття рішень. Проведено розробку методики багатокритеріальної оцінки якості каналів зв'язку систем радіозв'язку спеціального призначення, що функціонують в складній радіоелектронній обстановці. В статті запропоновано використовувати апарат нечіткої логіки для проведення багатокритеріальної оцінки якості каналів зв'язку при впливі навмисних завад та завмирань сигналу. Сутність запропонованої методики полягає у проведенні оцінки стану каналів зв'язку систем радіозв'язку спеціального призначення по кожному із показників оцінки, після чого формується узагальнена оцінка стану каналу зв'язку. Також в запропонованій методиці здійснюється корегування ваг експертних правил, що дозволяє підвищити швидкість та якість оцінювання стану каналів в динамічній сигнальній та завадовій обстановці. Отримані результати доцільно використовувати в засобах радіозв'язку з програмованою архітектурою,з метою підвищення швидкості та точності оцінювання стану каналів зв'язку.

Ключові слова: *системи радіозв'язку, радіозв'язок, радіоелектронне подавлення, завмирання сигналу, нечітка логіка.*

МЕТОДИКА МНОГОКРИТЕРИАЛЬНОЙ ОЦЕНКИ СОСТОЯНИЯ КАНАЛОВ СВЯЗИ СИСТЕМ РАДИОСВЯЗИ СПЕЦИАЛЬНОГО НАЗНАЧЕНИЯ

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Вопросы повышения помехозащищенности систем радиосвязи специального назначения, функционирующих в сложной радиоэлектронной обстановке, являются актуальной и не решенной в полном объеме проблемой. Одним из возможных направлений повышения помехозащищенности систем радиосвязи специального назначения является повышение точности и скорости оценивания канала связи в динамической сигнальной и помеховой обстановке. В работе проведен анализ существующих методов оценки состояния каналов связи, установлено, что существующие методы не позволяют проводить многокритериальную оценку качества каналов связи с приемлемой вычислительной сложности и достоверностью принятия решений. Проведена разработка методики многокритериальной оценки качества каналов связи систем радиосвязи специального назначения, функционирующих в сложной радиоэлектронной обстановке. В статье предложено использовать аппарат нечеткой логики для проведения многокритериальной оценки качества каналов связи при воздействии преднамеренных помех и замираний сигнала. Сущность предлагаемой методики заключается в проведении оценки состояния каналов связи систем радиосвязи специального назначения по каждому из показателей оценки, после чего формируется обобщенная оценка состояния канала связи. Также в предложенной методике осуществляется корректировка весов экспертных правил, что позволяет повысить скорость и качество оценки состояния каналов в динамической сигнальной и помеховой обстановке. Полученные результаты целесообразно использовать в средствах радиосвязи с программируемой архитектурой, с целью повышения скорости и точности оценки состояния каналов связи.

Ключевые слова: *системы радиосвязи, радиосвязь, радиоэлектронное подавление, замирание сигнала, нечёткая логика.*