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Method for Evaluating the Performance of Radio Paths

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Abstract: ***A communication link with retransmission is proposed for assessing the reliability of transmitted messages over composite (radio wired) communication lines. This solves the problem of the feasibility of using a communication repeater.***

Index Terms: ***Reliability of messages, efficiency of functioning, communication repeater, probability of error***

I. INTRODUCTION

A communication system as a basic element of a communication system for controlling stationary and mobile objects includes, as a rule, radio and wired channels organizing a composite communication network. When information passes through composite networks, its quality is determined by the characteristics of the channels that make up this network, their physical and operational characteristics. One of the important characteristics of the quality of functioning of communication networks is reliability, which characterizes the expected number of erroneously received message symbols.

II. THE QUANTITATIVE CHARACTERISTIC OF RELIABILITY

The quantitative characteristic of reliability is the probability of error, defined as the average value of the ratio of the number of incorrectly received pulses n sum to the total number N transmitted during a test session:

$$P = {}^{n_{sum}}/_{N}$$

So, for example, in wired communication channels the largest number of errors is caused by impulse noise, in radio channels - fluctuation noise [1]. In shortwave radio channels, the main amount of error occurs when the signal level changes due to the influence of fading [2].

At present, there are various approaches to the selection of indicators used to assess the performance of communication networks [7,8], while methods for evaluating composite communication lines are not sufficiently developed.

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To assess the reliability of the transmitted information of the composite communication network, the figure shows a model of wired communication lines. Any kind of communication network with different types of channels can be brought to this form by combining parallel and sequential branches (channels) in accordance with the laws adopted in the theory of communication.

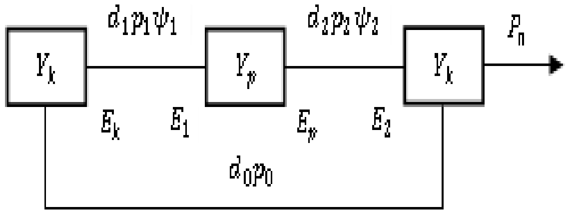

Figure 1 Wired Relay Link Mode

A. The most important component of the effectiveness of systems

The functioning of communication systems that determine the quality of the transmitted information is reliability. To assess the reliability of the transmitted information, the composite communication system in the figure shows a model of relay links:

$У_к$- radio correspondent node;

$У_r$ - node of the radio repeater;

$У_{pp}$ - node receiving radio information and transmitting it to the wired channel;

$d_0$is the length of a radio link without a$У_{pp}$ -$У_к$ repeater;

d_1Andd_2 - the length of the radio link between $У_к$, $У_r$and $У_r$,$У_{pp}$;

$\psi_1$andψ_2- the root means square value of the noise acting at the input of the receivers and$У_p$, $У_r$;

E_1 andE_2- the amplitude of the signal at the input of the receivers $У_p$and $У_r$;

$E_к$ andE_p- amplitude of the signal generated by radio transmitters $У_к$ and $У_r$;

P_1andP_2- probability of error in the radio lines $У_r - У_p$and $У_к - У_r$;

$P_p$is the error probability of the radio broadcasting radio link $У_к - У_r - У_p$;

P_n- the probability of error in the wired line (network) connection;

P_0- probability of error in the radio link without repeater $У_к - У_p$;

The presence of wired and radio interface junctions, radio signal transmission involves the use of signal regeneration at reception points, which increases the noise immunity of communications [5]. In the absence of a regenerator at the point of reception, it is necessary to ensure that the quality of communication on each of the spans is so that the temporal distortions, summing up, would not exceed the values of the correcting ability of the approximate terminal apparatus Therefore, the probability of an error at the input of a line without a generator increases by the magnitude of the probability that the distortion coincides at each of the spans. We assume the presence of regenerators in the terminal equipment of our relay link. In this case, the probability of an error in receiving one bit of information on the composite lines of k spans is determined as follows [4]:

$P_k = 1 - [(1 - P_1)(1 - P_2) \cdots (1 - P_k)]$ (1)

After simple transformations for the two-span track (k = 2), we obtain

$P_{1,2} = P_1 + P_2 - P_1 P_2$ (2)

for (k = 3)

$P_{13} = P_1 + P_2 + P_3 + P_1 P_2 P_3 - P_1 P_2 - P_1 P_3 - P_2 P_3$ (3)

Physically, this means that errors that occur during spans are summed, and if there are errors on each span, some errors that occurred during previous spans are “compensated” for different spans of the same binary sign. From expressions (2) and (3) it also follows that the noise immunity of the relay radio link is determined by the “worst” of the spans. Based on the above, in the proposed model, the overall probability of error will be

$P_{sum} = P_1 + P_2 + P_п + P_1 P_2 P_п - P_1 P_2 - P_1 P_п - P_2 P_п$

probability of error in the composite network system with

relay is equal to

$P_{sum} = P_p + P_n - P_p P_n$ (4)

where P_p error probabilities calculated for the broadcast link;

P_n- probability of error calculated for a wired communication network.

B. The most important component of the effectiveness of systems

Next, we determine the value of the error probability when transmitting messages over a radio relay link. We suggest that radio communication is carried out in the shortwave range, since so far this is the most common and widely used type of radio transmission. Then the probability of error P and HF channel is determined by the following expression [3]

$P = 1 - \Phi\left(\sqrt{\frac{\varepsilon}{2}}\right)$ (5)

$\varepsilon^2 = \frac{E^2}{\psi^2}$ −signal-to-noise ratio;

$\Phi(Z)$- integral function.

It is known from [2] that

$E = E_0 \exp(-\alpha d)$ (6)

where E_0 the average value of the field strength, which is created at a distance d with the radiated power N_0 excluding absorption in the ionosphere

$E_0 = A\frac{\sqrt{N_0}}{d}$;

α- absorption coefficient;

ψ -interference at the receiving point;

A - scale factor;

P_0 −radiation power;

Then in the proposed model we get

$E_1 = \frac{A\sqrt{N_к}}{d_1}\exp(-\alpha d_1) + \psi_1$ (7)

$E_2 = \frac{A\sqrt{N_p}}{d_2}\exp(-\alpha d_2) + \psi_2$ (8)

Now, taking into account (5), we can determine the probability of an error in the $У_к - У_г$ radio link

$P_1 = 1 - \Phi\left[\frac{A}{d_1\psi_1}\sqrt{\frac{N_к}{2}}\exp(-\alpha d_1) + \psi_1\right]$ (9)

Probability of an error in the radio link:

$P_2 = 1 - \Phi\left[\frac{A}{d_2\psi_2}\sqrt{\frac{N_P}{2}}\exp(-\alpha d_2) + \psi_2\right]$ (10)

Having determined the value of the error probabilities on each of the spans (9) and (10), we can find the resulting error probability in the radio relay link $У_к - У_г - У_р$ from expression (2).

Now we determine the probability of error in a wired communication network. As noted above, one of the main causes of errors in the transmission of messages over wired channels are pulsed interference. The accumulated static material describing the flow of impulse noise in the standard channels of the tonal frequency of wired communication lines reveals patterns that approximate the amplitude distribution of impulse noise. Thus, the distribution of the amplitudes of impulse noise with a sufficient degree of accuracy can be described by a hyperbolic law:

$P(U_n > U_c) = \frac{K}{U_n^m}$ (11)

where U_n is the interference amplitude: k, m - distribution parameters? In [6], a formula is given for the calculation of the probability of error arising under the action of impulse noise in wired channels of the tonal frequency, based on the law (11)

$P_{ош} = \frac{K}{U_c^m} \cdot h^m \cdot B\left(\frac{m-1}{2}, \frac{m+1}{2}\right) \cdot 2^{m-1}$ (12)

Where U_c is the amplitude of the signal; h_1- with phase modulation, h = 2 with amplitude modulation; B (x) - betta - function. In the case of the network

$P_n = \frac{\sum_{i=1}^{m} \alpha_i P_i^\gamma}{\lambda_{vx}}$ (13)

Where α_i is the number of messages passed by the γ_j route;

λ_{vx}-the total number of messages passed through the network;

P_i^γ is the probability of error on the γ_j- th route;

$$P_i^\gamma = 1 - \prod_{i \in \gamma_j}(1 - P_i)$$

P_i error probability on the i-th channel

Now, having determined the value of the error probability of the broadcasting lines and the average value of the error probability on the wired communication network, we can calculate the value of the total error probability using the expression (4) for the composite network by relaying. However, the following should be noted.

Given the characteristics of the shortwave radio network, where the quality of communication (probability of error) is significantly affected by factors such as radio wave propagation, ionosphere conditions, band occupancy and, to the greatest extent, the jamming environment at the receiving point and other factors information, we can conclude that the assessment of the effectiveness of a composite line of communication in terms of reliability may not be objective.

For example, with the averaged parameters of the communication line presented on the modem, theoretically the probability of an error in radio links with radio broadcasting, i.e. On the line$У_к - У_r - У_p$, it should be less than on the $У_к - У_p$radio line. However, in the case,when $\psi_1 \gg \psi_2$, this pattern is not observed, and in such a case, you can come to a false conclusion in evaluating the effectiveness of the adopted criterion of the communication network as a whole. Therefore, in order to eliminate such an error, it is necessary to carry out preliminary calculations of the possible gain in the signal-to-noise ratio at the points (nodes) of receiving messages during retransmission, i.e. determine the feasibility of using a communication repeater

To determine the possible gain in the signal-to-interference ratio when relaying in a radio network (radio link), we will proceed from the condition

$E_p = nE_1$ (14)

where n is the gain of the repeater, which shows how many times the radiation power d_2 should be greater than the received signal. Then from expression (8) with regard to (7), you can get an expression for calculating the amplitude of the transmitted signal at the receiving point $У_p$ during retransmission:

$$E_2 = \frac{nA^2\sqrt{N_k}\exp(-\alpha d_0)}{d_1 d_2} \quad (15)$$

where - $d_0 = d_1 + d_2$.

When calculating the level of interference at the point of receiving messages, it is necessary to take into account that interference with the relay also increases. Then, using (6), you can determine the total interference at the receiving point ψ_2':

$$\psi_2' = \frac{A\sqrt{\psi_2}}{d_2}\exp(-\alpha d_2) + \psi_2 \quad (16)$$

Determine the signal-to-noise ratio at the point of reception for a radio link with relays:

$$\varepsilon_P^2 = \frac{A^2 n^2 N_k \exp(-\alpha d_0)}{\left[\left[\frac{An\psi_2}{d_2}\exp(-\alpha d_2)+\psi_2\right]\right]^2 d_1 d_2} \quad (17)$$

The signal-to-noise ratio at the message point for a radio link without a repeater ($У_к - У_p$)taking into account (6), has the form

$$\varepsilon_0^2 = \frac{A^2 N_k}{d_0^2 \psi_2}\exp(-\alpha d_0) \quad (18)$$

And the win is equal to

$$\eta = \frac{\varepsilon_p^2}{\varepsilon_0^2} = \frac{n^2\psi_2 d_0^2}{\left[\frac{An\psi_2}{d_2}\exp(-\alpha d_2)+\psi_2\right]^2 d_1 d_2} \quad (19)$$

Thus, having determined the presence of a gain with respect to the signal / interference ratio, one can judge the expediency of transferring information from $У_к$ to $У_p$through $У_r$. If there is no signal / interference gain in the case of using an intermediate node (repeater) in the radio link, information is transmitted indirectly$У_к - У_p$. Then the probability of error in the composite communication system will be

$$P_{sum} = P_0 + P_n - P_0 P_n$$

III. CONCLUSIONS

It should be noted that, if there are multiple repeaters, using expression (19), you can choose the best direction of the radio transmission. In addition, using the above expressions, we can determine the probability of error on any part of the communication system.

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