Researches of Methods of Noiseproof Reception of Optical Signals at Use WDM-Technology

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Abstract— **Reception systems of optical communication networks on which basis the method for definition of indicators of a noise stability of the receiver of fiber-optical communication lines is offered at use of spectral multiplexing of a communication channel are investigated.**

Keywords— efficiency; optical fiber communication lines; optical terminals; optical signals; average probability bit mistakes reception of optical signals; optical transport networks

I. Introduction

Now the modern society worries a stage of rough information in spheres of the service which are based on broadband digital optical telecommunication communication networks. Fiber-optical communication lines (FOCL) with WDM-technology use (Wavelength Division Multiplexing) c the raised noise stability of system became the basic technology of these networks from the end of the last century.

The basic features of WDM-technology are in detail stated in a number of articles and books [1 - 4]. Its most typical feature - transfer possibility on one fiber optical (FO) several signals with use of various lengths of waves bearing λ_i . Thanks to the specified feature process of switching of optical signals of various lengths of waves in switching knots is possible.

Technology WDM represents optical systems on two optical channels with lengths of waves $\lambda_i = (0{,}850,...,1{,}310)mkm$ and $\lambda_i = (1{,}310,...,1{,}550)mkm$. The main advantage of WDM-technology consists that it allows to overcome restrictions on throughput of the channel and it is essential to increase speed of data transmission. Thanking WDM it is possible to organize bilateral multichannel transfer of the traffic on one fiber. In usual lines the pair of fibres - for transfer to direct and return directions is used.

The carried out theoretical researches show [1, 2], that frequency of a pass-band of optical signals $\Delta F_{dwm} = 60$ THs and therefore, potential throughput of fiber-optical communication lines` with WDM-technology use can make $C_{\max}^{düm}(\lambda_i) = 60\ T\ bit$ *per second.*

The basic channel organize the equipment for fiber-optical communication lines on base WDM - technologies are network terminals STM-16 (Synchronous Transport Mode) and STM-64 used for transfer of the non-uniform traffic: signals SONET&SDH (Synchronous Optical Network), cells ATM (Asynchronous Transfer Mode), packages IP (Internet Protocol), transfer and distribution of signals of digital TV.

However, despite, apparently, very big number of spectral channels, rapid growth of the long-distance and international traffic for last years has led to that already now on many highways fiber-optical communication lines the noise stability of reception of optical signals appears insufficient [2, 3].

II. The Basic Definitions and the General Statement of a Problem

On the basis of research it is established [1, 3, 4, 5], that for an estimation of noise stability FOCL, the new method estimating indicators of reception of optical signals is necessary. As the physical environment to transfer of optical signals it is applied one module fiber optical cable and created on their basis fiber-optical communication lines, using transmitters and receivers optical channel a communication channel with length of waves $\lambda_i = 1{,}55$ mkm. Taking into account the above-stated and on the basis of research [4, 5] it is established, that the method of increase of noise stability fiber-optical communication lines with reception optical module use can be presented as set of indicators of efficiency of each of subsystems:

$$D_{opt}(\lambda_{i`})=W\{\min[S_ч(\lambda_i),P_{ср.ош},C_{i.a}]\}, \qquad (1)$$

where $S_ч(\lambda_i)$ – sensitivity of optical receiver terminals; $P_{ср.ош}$ is average probability of bit errors (BER) reception of optical signals; $C_{i.a}$ is cost of equipment rooms and software of fiber-optical networks on ring topology.

In the present work the method of increase of a noise stability of the reception optical module of optical channel communications is investigated and indicators of receivers of optical signals are defined.

Estimation of Indicators of Optical Receivers

Passage of a digital optical signal on an optical linear path (OLP) is accompanied by occurrence of errors, when instead of «1» (presence of optical radiation) is fixed «0» (absence of radiation) and on the contrary.

It is a lot of reasons of occurrence of errors, but the cores from them are noise of the equipment of an optical linear path, the dispersive phenomena in fiber optical, intersymbolical hindrances, failures in work of devices of clock synchronization of linear and station regenerators, and also hindrances of transitions between spectral channels in fiber-optical communication lines with spectral division (technology WDM), Noise OLP develop of noise of sources of optical radiation of transferring optical modules , photo detectors, amplifiers, devices of correction and a filtration of reception optical modules, and also the noise caused by passage of signals of optical radiation on fiber optical.

For more detailed analysis to definition of probability of bit errors on fig. 1. Graphic dependence $w(i_ш) = E(i_ш, I_n)$ is shown.

Noise generate the errors which integrated estimation is the probability of an error. For practical cases of definition of probability of an error of a linear regenerator suppose, that noise on an input of the solving device a regenerator have normal distribution:

$$w(i_ш) = (\sigma_ш \cdot \sqrt{2\pi})^{-1} \exp[-(i_ш^2 / 2\sigma_ш^2)], \qquad (2)$$

where $i_ш$ и $\sigma_ш$ − instant and middle the quadratic values of a total noise current on an input of the threshold device of a regenerator.

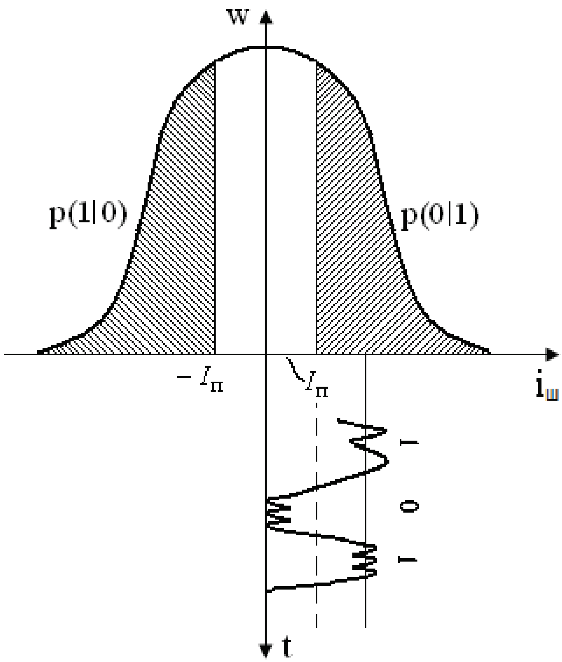

Figure 1. Realizations of noise, the sum of a pulse signal, noise and their functions of density of probability

Process of registration of symbols «1» or «0» information sequences in the presence of noise (hindrances) is characterised by error $P_{ош}$. Let the probability of occurrence «1» in information sequence is equal p_1, and the probability of transformation «1» under the influence of noise in «0» is equal $p(1/0)$. Здесь $p(1/0)$ - probability of interpretation 0 as 1.

On the basis of the formula (2) probability of interpretation 0 as 1, i.e. the probability of a false alarm is defined as follows:

$$P(1/0) = \int_{I_n}^{\infty} w_0(i_ш) di_ш = 1 - F(\frac{I_n}{\sigma_ш^2}), \qquad (3)$$

where $w_0(i_ш)$ − function to density of probability of a noise current and by means of distribution Hausas it is expressed by the following formula:

$$w_0(i_ш) = \frac{1}{\sigma_ш \sqrt{2\pi}} e^{-(i_ш / \sigma \sqrt{2})^2} \qquad (4)$$

Then by transfer «1» probability of an error is expressed as follows:

$$P_{ош}(1) = p_1 \cdot p(1/0) \qquad (5)$$

If similarly to accept, that the probability of transformation «0» under the influence of noise in «1» is equal $p(0/1)$, probability of an error by transfer «0»

$$P_{ош}(0) = p_0 \cdot p(0/1), \qquad (6)$$

where p_0, p_1 − aprioristic probabilities of signals 0 and 1 (I_0 and I_1) ; $p(0/1)$ − probability interpretations 1 as 0, i.e. the probability of the admission of optical signals will be defined by the following formula:

$$p(0/1) = \int_{-\infty}^{I_n} w_1(i_ш) di_ш, \qquad (7)$$

$w_1(i_ш)$ − function of density of probability of a mix of an optical signal with noise.

In work [2, 3, 5] it is defined, that $w_1(i_ш)$ − simply function of density of probability of noise $w_0(i_ш)$, shifted on amplitude of optical signal U_s and it is expressed as follows:

$$w_1(i_ш) = w(i_ш - U_s) \qquad (8)$$

On the basis of (4), expressions (7) will be assumed by the following air:

$$p(0/1) = \int_{-\infty}^{I_n} w_0(i_ш - U_s) di_ш = F[\frac{I_n - U_s}{\sigma_ш^2}],$$

$F(x)$ − function Laplase also is equal

$$F(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} \exp(-t^2/2)\, dt$$

Considering (5) and (6), the average probability of bit errors of reception of optical signals is defined by the sum

$$P_{cp.ош} = P_{ош}(1) + P_{ош}(0) \quad (9)$$

C the account of aprioristic probabilities of signals «0» and «1», accordingly p_0 and p_1, expression (9) will assume the following air:

$$P_{cp.ош} = p_0 \cdot \int_{I_n}^{\infty} w_o(i_ш)di_ш + p_1 \cdot \int_{-\infty}^{I_n} w_1(i_ш)di_ш \quad (10)$$

For an estimation of quality of reception of an optical signal we will accept, that function $w(\lambda_i, i_ш)$ shows even under condition of

$$p(1/0) = p(0/1) = 0{,}5 .$$

Then the average probability of bit errors of reception of optical signals is defined by expression

$$P_{cp.ош} = 1 - \frac{1}{2} erf\,[\frac{I_n}{\sigma_ш \sqrt{2}}], \quad (11)$$

where $erf(x)-$ function errors which is defined by expression:

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x \exp(-t^2)\,dt .$$

III. DEFINTIONS THROUGHPUT FIBER-OPTICAL COMMUNICATION LINES

Now we will consider limited on a strip of frequencies spectral channels $\Delta F(\lambda_i)$ additive white Houses noise. Formally, maximum throughput of such spectral channel in unit of time on the basis of their information characteristics is defined as follows [5]:

$$C_{\max}(\lambda_i) = \lim_{T\to\infty} \max T^{-1} \cdot I(X,Y), \quad (12)$$

where $I(X,Y)$ – average quantity of the information's.

From the above-stated, follows, that if we will accept signals $S_0(t,\lambda)$ and $S_1(t,\lambda)$ equiprobable the average probability of bit errors of reception is defined as follows:

$$P_{cp.ош} = 0{,}5[p(1/0) + p(0/1)] = Q[(2E_b / N_0)], \quad (13)$$

where E_b / N_0 – optical the relation signal-noise to rate (OSNR) on bit; E_b – energy an optical signal on bit; $Q(x)-$ is Q - function and it is defined by the following integral

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp(-0{,}5t^2)\,dt = 0{,}5\, erfc\,[x/\sqrt{2}],$$

$$x \geq 0 \quad (14)$$

Hence, cost of equipment rooms and software of fiber-optical networks $C_{i.a}$, taking into account cost D(λ_i) network and programming-means of the organization of transfer of the type information with the maximum throughput, is analytically expressed as follows:

$$C_{i.a} = \sum_{i=1}^{n} D(\lambda_i) \cdot C_{i.\max}(\lambda_i),\ i = 1, 2, \ldots, n \quad (15)$$

The received analytical expressions can be used for calculation of indicators of reliability of reception of optical signals by means of fiber-optical communication lines on the basis of WDM-system.

IV. CONCLUSIONS

As a result research it is offered methods of increase of reliability of transfer of an optical signal on which basis the analytical expressions estimating quantitative and qualitative indicators of the noiseproof receiver of fiber-optical communication lines at use of spectral multiplexing length of a wave are received.

REFERENCES

[1] Guljaev J.V., Nikitov S.A. Prospects of development of telecommunications //Nonlinear World. № 1 - 2, т.1, 2003. pp.7 – 15.

[2] Nany O. E. Bases digital fiber – optical communication systems // Lightwave Russian Edition, № 1, 2003. pp. 48-52.

[3] Proakis J.G. Digital communication. Mc Graw – Hill.New York. 2000. – 800 p.

[4] Agraval G.P. Fiber-optic communication systems. Second edition.John Wiley&Sons Inc.1997. -348 p.

[5] Mukherjee B. Optical Communication Networks. – Mc.Graw–Hill, 2001. – 576 p.