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ASSESSMENT OF THE QUALITY OF OPTICAL COMMUNICATION CHANNELS IN DWDM SYSTEMS

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Annotation. Research and the analysis of factors of the systems influencing quality with division according to wavelength and a choice of a method of an assessment of quality of optical channels are given in article.

Introduction. Fiber-optic communication systems with wavelength division multiplexing (FOCS-WDM) is fiber-optical technology, which offers very effective and inexpensive way of expansion of range of working frequencies of a network for the telecommunication industry. This technology allows telecommunication operators to satisfy constantly growing needs of customers for new look of services and provides big flexibility in the course of providing these services. Giving a chance to fiber-optical communication lines to transfer information on several channels at the same time, FOCS-WDM allow to use with the maximum advantage of available opportunities, with ease increasing the volume of transfer to more than 10 times in comparison with traditional systems of multiplexing on timing, and possess great potential opportunities. However design, installation and maintenance of FOCS-WDM demand closer attention to restriction of number of controlled parameters. Transition from systems with one wavelength to system with several length of waves leads to emergence of a number of problems which arise owing to nonlinear properties of fiber, insufficient suppression by the demultiplexer of signals of adjacent channels and dependences of losses of optical components on wavelength; monitoring of wavelength, power of the channel and the relation signal/noise for management of a network as FOCS-WDM - unlike single-wave systems in which for detection of failure only measurements of power in various points of a network are required — simple measurement of power isn't enough, and spectral measurements of each channel are necessary.

One of the main indicators of fiber-optical systems of transfer with wavelength division multiplexing (WDM) is quality of the transmitted data. Quality of transfer the information defines ability of the system to restore the transmitted signals with the set reliability.

The above shows relevance of a subject of this work.

Research methods. In this article the choice of a method of an assessment of quality of transfer in FOCS-WDM and calculation examples are considered.

For this purpose the following problems are solved.

1. The analysis and research of the major factors influencing to quality of transfer FOCS-WDM.

2. The analysis of methods of an assessment of quality of optical communication channels in WDM systems.

3. Examples of calculation of quality of transfer in FOCS-WDM, advantages of the chosen method of an assessment of quality of optical communication channels.

Research results and their discussion. Quality of FOCS-WDM is influenced especially by the nonlinear hindrances arising because of nonlinear effects in optical fiber and from nonlinearity of optical amplifiers. The optical amplifier not only strengthens a useful signal, but also strengthens noise.

Existence in FOCS-WDM of negatively influencing factors leads to a need of providing a stock on the power as in this case for maintenance of the demanded bit speed on the receiver has to arrive more powerful signal. It can be reached either directly increasing the power of a signal (in dB), or reducing the relation signal/noise. As the last more reflects considered problem, using of this is represented to the most expedient.

Especially quality of transfer of optical signals in systems of FOCS-WDM is influenced by nonlinear effects in optical fiber. They are caused by a nonlinear response optically of transparent substance on increase in intensity of the light stream having per unit area the cross section of a core of fiber. There are some types of nonlinear effects, each of them in different degree influences to distribution of signals by fiber. The most essential nonlinear effect is four-wave mixture (FWM).

Four-wave shift (FWM - Four Wave Mixing) leads to emergence of the disturbing harmonicas, the part of them gets to working channels of system and have the disturbing impact on transfer of the main signal.

FWM is sensitive to system characteristics: increasing the power in the channel, increasing a number of channels, reduction of a step between channels, also influences to level of hindrances and relation signal/noise.

Increasing a step between optical bearing and existence of chromatic dispersion reduce process of FWM, due to destruction of phase ratios between the interacting waves. For reduction of influence of nonlinear effects it is also possible to use an uneven step or the increased step between optical channels.

For normal functioning of FOCS-WDM characteristics of the optical fiber are more important. When studying FOCS-WDM considerably the bigger attention has to be paid to chromatic dispersion.

It is possible to reduce the FWM level by means of chromatic dispersion when using standard single-mode OF. The matter is that at the exit of lasers the coherent light radiation is formed in which signals are attached phase on the relation to each other. Therefore when signals extend along a fiber-optical cable that, interacting among themselves, eventually, form a new wave. This effect is counteracted substantially by the dispersion providing conditions under which coherence of phases of signals after passing of long distances by them is broken.

Characteristics of optical fiber have to be accepted surely in attention at design of fiber-optical communication systems and then have to be checked after their installation as FOCS-WDM are very sensitive to chromatic dispersion, small, but which carefully controlled part which necessary for elimination of such phenomenon as mixture of four waves.

Indicator of quality of digital channels and network paths (the Central Committee and R) and the requirements to them which entered the corresponding Recommendations of ITU-T G.821, G.826 and M.2100 [1, 2] are fuller, allowing to provide comprehensive quality check Central Committees and requirements.

Indicators of errors of digital channels and paths are statistical parameters, and norms are defined on them by the corresponding probability.

Quality of optical communication channels can be estimated by comparison of the accepted signal with initial or according to characteristics, characterizing a communication channel, for example on channel AFCh.

It is possible to determine accurately by the first method, how often there are mistakes:

$$K_{error} = N_{error} / N_{sim.},$$

where, N_{error} – number of the mistakes found for a certain period of time of control of T;

$N_{sim.}$ – number of the symbols transferred on a controlled site of a transmission line during time of control of T.

Or it is possible to determine by the following formula:

$$K_{error} = N_{error} / VT,$$

where V-speed of a digital data transmission.

At an assessment of quality of an optical signal on an entrance of a photo detector signal/noise (OSNR - Optical signal to Noise Ratio) or noise immunity is recommended to use such indicator as the optical relation:

$$A_{def} = 10\ lg \frac{P_{sig}}{P_{hindrance}} = p_{sig} - p_{hindrance}, \partial B, \quad (1)$$

where P_{sig} and $P_{hindrance}$ – respectively a power of a signal and power of hindrances;

p_{sig} and the $p_{hindrance}$ - respectively a level on the power of a group signal and hindrance.

Consecrate qualities of optical channels decreases depending on the following factors:

- with increase in power of a group signal;
- with increase in number of optical channels;
- with reduction of inter channel intervals.

For an assessment of influence of the specified factors on quality, we will execute calculation of a hindrance with a formula [2]

$$p_{FWM} \approx -57 + 10\lg(N/3) + 1200/\delta_f \ , \qquad (2)$$

level of hindrances and noise immunity with a formula (1) for various numbers of channels and channel intervals (tab. 1).

Results of calculation

Table 1

	N=8 δ_f=200 GHz (h=1,6 nm)	N=16 δ_f=100 GHz (h=0,8 nm)	N=64 δ_f=50 GHz (h=0,4 nm)	N=90 δ_f= 25 GHz (h=0,2 nm)	N=128 δ_f=25 GHz (h=0,2 nm)
P_{FWM}, *äB*	-46,7	-37,7	-19,7	5,8	7,3
$A_{def.}$, *äB*	63,7	54,7	36,7	11,2	9,7

From these tab. 1 it is visible that with increase the number of channels and with reduction of an inter channel interval increases influence of nonlinear effects of FWM and noise immunity decreases. For ensuring probability of mistakes 10^{-12} the noise immunity is limited to 24 dB, i.e. $A_{def} \geq 24$ dB. Results of calculation show that at increase in number inter channel intervals δf=50, 25 GHz aren't recommended for use.

Conclusion. For satisfaction of requirements for quality of transfer by optical communication channels in FOCS-WDM the following recommendations are offered:

- optimization of level of the transferred optical power by communication channels of systems with FOCS-WDM and justification of optical amplifiers;
- alignment of coefficient of strengthening of the optical amplifier;
- rational distribution of inter channel intervals, number of lengths of waves and stabilization of their level by the power (established in the Recommendation G.662) [4];
- influence of FWM sharply increases at reduction of a frequency interval to 50 GHz and at increase the optical power entered into optical fiber. For

neutralization of effect of FWM it is possible to use uneven intervals between channels in FOCS-WDM [5, 6].

The considered method of an assessment of quality of optical communication channels is recommended to use in FOCS-WDM.

The assessment of quality of transfer of optical communication channels in FOCS-WDM systems allows to solve a problem of evidence-based design, introduction and effective operation of perspective optical systems of transfer with wave division of channels.

List of sources used:

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