



Science

RESEARCH EFFICIENCY OPTICAL TRANSPORT NETWORKS WITH USE TRANSFERRING AND RECEPTION OPTOELECTRONICS MODULE

Mehman H. Hasanov¹, Bayram G. Ibrahimov², Shalala F. Qodjaeva³
^{1,2,3} Azerbaijan Technical University, Baku, Azerbaijan

Abstract

The analyses qualities functioning optical transport communication networks on the basis technology spectral divisions of the channels using transferring and reception optoelectronics of the module. On a basis research the method improvement indicators fiber-optical systems transfer information is offered and key parameters efficiency and a noise stability optical transport networks are defined.

Keywords: Efficiency; Optical Fiber Communication Lines; Optical Terminal; Optical Signal; Optical Transport Network.

Cite This Article: Mehman H. Hasanov, Bayram G. Ibrahimov, and Shalala F. Qodjaeva. (2018). "RESEARCH EFFICIENCY OPTICAL TRANSPORT NETWORKS WITH USE TRANSFERRING AND RECEPTION OPTOELECTRONICS MODULE." *International Journal of Research - Granthaalayah*, 6(2), 324-330. <https://doi.org/10.5281/zenodo.1194756>.

1. Introduction

Currently, the development multiservice networks and communication systems, subject to intensive growth of the volume transmitted multimedia traffic, requires the creation effective and noise-immune transport fiber-optic communication lines (FOCL) using a terminal transmitting and receiving optoelectronic module.

Based on the research, it has been established [1, 2] that the performance of optical telecommunication systems depends significantly on fiber-optic transmission systems (VSPs), optical means and FOCL based on WDM & DWDM & HDWDM (Wavelength Division Multiplexing / Dense WDM & High Dense WDM) technology to transfer any types practical messages to any distances with the highest speeds. However, fiber-optic communication using the systems of spectral channel separation (SRC) for optical fiber multiplexing is one of the problems of the development of next-generation NGN (Next Generation Network) multiservice networks.

To solve such problems, great attention is paid to the creation efficient optical data transmission systems using WDM & DWDM & HDWDM technology for the organization of telecommunication optical local and transport media, which is great importance in telecommunication systems.

Thus, studies of methods for improving the efficiency and immunity of optical telecommunications networks using optical technology and analyzing the information efficiency of fiber-optic communication lines, providing QoS (Quality of Service) quality of optical traffic, which is the most relevant.

2. General Statement of the Problem

It is known [3, 4] that in order to improve the quality of fiber-optic transmission lines (FOTL) it is necessary to improve the efficiency of all hierarchical network levels, starting from the physical level of local networks to transport backbone networks.

The transport system for optical information transmission and its subsystems-FOTL, FOK, FOCL using the receiving and transmitting optical modules (ROM and TOM) operating in a mixed mode, operate under the ground-physical, channel, network and transport level of the reference model of interconnection of open systems.

In [4, 5], a common comparison is made between the structure of optical information transmission systems based on the qualitative and quantitative parameters of FOTL, but there was no detailed analysis of their performance quality on the achievable efficiency of transport optical networks using SRC-WDM & DWDM technology.

Taking into account the above mathematical formulation of the problem of the quality of functioning of transport optical networks using a terminal transmitting and receiving optoelectronic module based on WDM & DWDM technologies and can be represented by the following objective function [6]:

$$Q_{kf} = \arg \max_i [E_{i.ef}], \quad i = \overline{1, n} \quad (1)$$

Under the following restrictions

$$P_{BER.} \leq P_{BER.al}, \quad G_i \leq G_{i.al}, \quad C_{ap} \leq C_{ap.al} \quad (2)$$

where C_{ap} - the cost of optical information transmission lines and FOCL firmware based on optical subscriber terminals; G_i - is the gain of the optical signal, $i = \overline{1, n}$, where n is the number fiber-optic amplifiers in the fiber-optic link; $P_{BER.}$ - is the average probability of bit errors; $P_{BER.al.}$ - the mean bit error probability.

The methods improving the quality functioning transport optical networks using a transmitting and receiving optoelectronic module based on WDM & DWDM technologies are investigated.

3. Scheme Functioning of the Researched Link Optical Transport Networks

Based on the system-technical analysis [2, 3], it is established that for the construction of optical transport communication networks, the creation of FOCL with ROM and TOM is required, which allows to extract optical signals with certain wavelengths from a multichannel signal $\lambda_i = \lambda_1, \dots, \lambda_n$ and to introduce in their place others with the same wavelengths λ_i . All other transmitting signals come through these devices without any transformation.

Taking into account the above, the scheme of functioning of the investigated link optical transport networks is proposed, which is shown in fig. 1, which is a structural-functional FOTL scheme with spectral separation (WDM & DWDM) channels. From the diagram it follows that FOTL intended for one direction of information transmission over distances via fiber optic cables (FOK) optical signals, consists of the equipment forming a multichannel signal (EFMS), TOM and ROM, which provide the formation, processing and transmission of optical signals. Further, it consists of a device for spectral multiplexing (SDM), which carries out the input of various optical carriers into FOK and spectral demultiplexing devices (SDMD) of optical carriers.

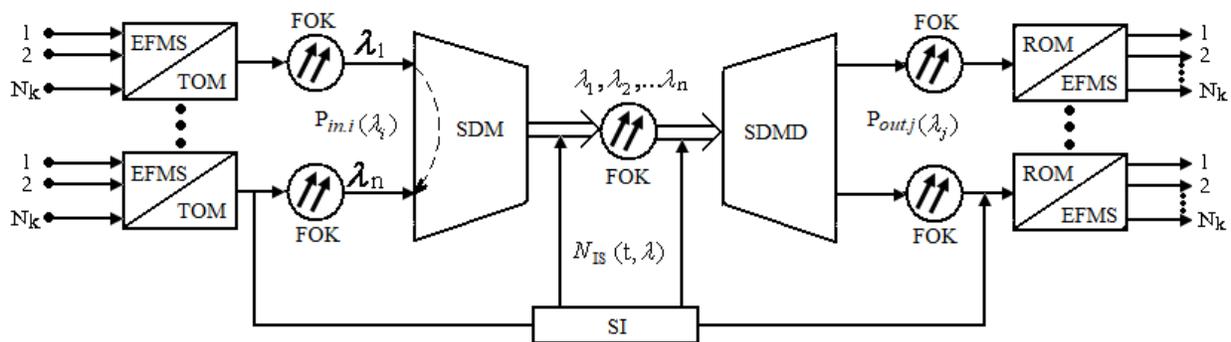


Figure 1: Structural-functional scheme of functioning of the researched link of optical transport networks using WDM and DWDM-technologies

FOCL are designed to transmit digital optical signals carrying information from the transmitting optical module to the receiving optical module via optoelectronic channels.

The algorithm of operation of the circuit of operation of the researched link of optical transport networks consists in that there is n-TOM at the transmitting station, i.e. optical transmitters emitting different optical carriers $\lambda_1, \lambda_2, \dots, \lambda_{n-1}, \lambda_n$.

With the help of SDM, the input is different in FOK and at the input SDMD looks like:

$$S(t, \lambda_i) = \sum_{j=-\infty}^{\infty} U[a_j \cdot U_m(t - j\Delta T)] + N_{SI}(t, \lambda), \quad (3)$$

Where a_j – is a coefficient equal to 0 when transmitting "0" or 1 when transmitting "1"; U_m – amplitude of the transmitted optical signal; $N_{SI}(t, \lambda)$ – source of interference at time t, is a narrow-band quasi-harmonic noise oscillations with random parameters.

4. Analysis Indicators FOCL

Preliminary studies helped to formulate a new approach to the solution of the above task: analysis of the quality of the functioning of the investigated link of optical transport networks. In this solution, a single-mode FOK and the FOCL based on them, using WDM & DWDM technologies with a wavelength $\lambda_i = (1.31-1.55)$ mkm are used to transmit optical signals.

The combination of FOTL and FOCL form a fiber-optic transmission line, which are the main subsystems of optical transport communication networks, providing control over the transmission and routing of optical information. Here, the important subsystems are SDM, i.e. a WDM & DWDM multiplexer that spatially combines the component signals into an aggregate signal [3-6].

The quality of the WDM & DWDM multiplexer in the creation spectral communication channels is characterized by transient attenuation at the near end of the $Z_{om}(\lambda_i)$, which estimates the transient effects occurring in Optical Add / Drop Multiplexer (OADM) and is determined by the relation:

$$A_{om}(\lambda_i, G_{yc}) = \min_{i \neq j} \{10 \lg [p_{out.j}(\lambda_j) / p_{in.i}(\lambda_i)]\}, i \neq j, i = \overline{1, n} \quad (4)$$

where $p_{in.i}(\lambda_i)$ – is the signal power with a wavelength λ_i at the input i – th of the optical port of the optical input multiplexer; $p_{out.j}(\lambda_j)$ – signal power with wavelength λ_j on the j – th output port of the optical input multiplexer, $i \neq j$; G_{yc} - the gain of a weak optical signal, where it is necessary in the wavelength division multiplexing subsystems (WDM & DWDM).

In modern WDM & DWDM systems, non-zero mixed dispersion (NZ-DSF) FOCs are used that meet ITU-T G.655 recommendations [5, 6]. In this case, the amplified emission power of the output signal $p_{out}(\lambda_i)$ SDM is given by

$$G_{yc}(\lambda_i) = \frac{\eta_{\kappa\omega}(\lambda_i)}{h \cdot \nu} \cdot p_{out}(\lambda_i) \cdot N_{sp}^{-1} + 1, \quad (5)$$

Where N_{sp} – is the coefficient of spontaneous emission; $\eta_{\kappa\omega}(\lambda_i)$ – the quantum efficiency of linear fiber-optic amplifiers and is expressed as follows:

$$\eta_{\kappa\omega}(\lambda_i) = p(\lambda_i) \cdot \frac{1,24 I_{ft}}{\lambda_i} < 1, \quad (6)$$

Where I_{ft} – the photocurrent of the optical multiplexer; $p_n(\lambda_i)$ – total optical power of radiation at wavelength λ_i .

5. Effective Use FOCL Bandwidth Using ROM Opto-electronic Communication Channel

From the circuit in fig. 1 it follows that with the help of SDM, the input of various carriers into FOK at the wavelength is made $\lambda_1, \lambda_2, \dots, \lambda_n$. On the receiving side in SDMD, optical carriers are separated and fed to optical receivers and then to EFMS. Thus, one FOK organizes n-spectrally separated optical channels.

Based on the WDM & DWDM technology organizing optical spectral channels, the FOTL throughput using the TOM and ROM of the optoelectronic channel is determined as follows [6]:

$$C_{\max}^{op}(\lambda_i) = \sum_{i=1}^n V_{i.nc}(\lambda_i) \cdot N_{i.k} \cdot L_{i.FO}(\lambda_i), \quad (7)$$

where $N_{i.k}$ – the limiting number of organized spectral optical channels; $L_{i.FO}(\lambda_i)$ – the number optical fibers in FOK, including the reserve ones on the length λ_i ; $V_{i.nc}(\lambda_i)$ – the limiting speed transmission optical signals at a specific L_{FOK} length of the regeneration portion that is determined by the type optical fiber and the characteristics of the ROM and TOM of the optoelectronic channel.

It is known [4, 5] that the efficient use FOCL throughput on the basis WDM & DWDM technologies is highly dependent on the optical signal-to-noise ratio ($OSNR_{out}$) and is determined by the expression:

$$OSNR_{out}(\lambda_i) = 0,5 p_{in.i}(\lambda_i) \cdot (h\nu \cdot \Delta f \cdot N_y \cdot N_{ns})^{-1} / G_{yc}(\lambda_i), \quad (8)$$

Expressions (7) and (8) are quantitative and qualitative characteristics of the investigated link of optical transport networks using WDM & DWDM technologies.

6. Analysis Communication Quality of Optical Transport Networks

The most important operational characteristic of the current optical transport information transmission system, which determines the quality of communication networks, is the average probability of bit errors [8, 9].

For practical cases of determining the probability of a ROM error, it is assumed that the noise at the input of the photodetector decision device has a normal distribution and is described by the following expression:

$$N(\lambda, i_n, t) = \frac{1}{\sigma_n(t)\sqrt{2\pi}} \cdot \exp\left[-\frac{i_n^2}{2\sigma_n^2(t)}\right], \quad (9)$$

where i_n and $\sigma_n(t)$ - both the instantaneous and rms values of the total interference current at time t, at the input of the threshold device ROM.

The passage of a digital optical signal through the optical transport path is accompanied by errors when "0" (absence of radiation) is fixed instead of "1" (the presence of optical radiation) and vice versa. The process of registering the symbols "1" or "0" of the information sequence $p(1)$ and $p(0)$ in the presence of interference is characterized by the average probability of bit errors P_{BER} and is determined by the sum:

$$P_{BER} = 0,5[p(0)p(0/1) + p(1)p(1/0)] \leq P_{BER.al}, \quad (10)$$

Where $p(0/1)$ – the probability of transformation is "0" under the influence of interference in "1"; $p(1/0)$ – probability transformation "1" under the influence of interference in "0".

Analysis of the quality of operation of the optical transport communication network has shown [4, 5] that an erroneous registration of the information sequence symbol is possible with certain ratios between the current values and the threshold current I_n of the ROM threshold device. Taking into account the recent assumptions, (9) and (10), the average probability of bit errors can be determined by the formula:

$$P_{BER} = \frac{1}{\sigma_n(t)\sqrt{2\pi}} \cdot \int_{I_n}^{\infty} \exp\left[-\frac{i_n^2}{2\sigma_n^2(t)}\right] di_n = 0,5 \operatorname{erfc}\left(\frac{I_n}{\sqrt{2}} \cdot \sigma_n^{-2}\right), \quad (11)$$

Where erfc – complementary error integral, the values of which are tabulated [6].

Expressions (10) and (11) define one of the important indicators of noise immunity of single-mode optical transport communication networks using a terminal transmitting and receiving optoelectronic module based on WDM & DWDM.

To evaluate the quality FOCL, analytical calculations were performed using the MATLAB 7.0 system and its Signal Processing Communications packages [7] and the following results were obtained: $\lambda_i = 1,31 \text{ mkm}$, $V_b \geq 622 \text{ Mбум/c}$, $L_{max} = (80 \div 160) \text{ km}$, $OSNR_{out}(\lambda_i) \geq (6, \dots, 6,48) \text{ dB}$, $C_{max}^{op}(\lambda_i) = 12,44 \text{ Hbit/s}$ и $P_{BER} \leq (10^{-9} \div 10^{-10}) \leq P_{BER.al}$.

It follows from numerical calculations that the obtained one meets the specified requirements of ITU-T, G.694 [5].

7. Conclusions

As a result, the study of the quality of optical information transmission systems proposed a method that takes into account the efficiency and noise immunity optical transport communication networks based on modern WDM & DWDM technologies.

On the basis of the proposed method, analytical expressions are obtained that allow to evaluate FOCL indicators based on WDM & DWDM technologies in the transmission various signals - telephony, television, telemetry, data transmission with different speeds and types of modulation, which provide the creation economic multifunctional telecommunication transport systems.

References

- [1] Agrawal G.P. Lightwave Technology Telecommunication Systems, Wiley, New Jersey, 2005, 449 p.
- [2] Greenfield D. Optical Networks. Kiev: LLC "TID" "DS", 2002, 256 p.
- [3] Ibrahimov B.G, Mamedov I.M. The Efficiency Fiber-Optic Communication Lines with Using WDM/DWDM Technologies//Proceedings of the Conference "Telecommunications and Computer Systems", Moscow, MTUCI, 2009, p.179-180.
- [4] Korneichuk V.I., Panfilov I.P. Fiber-Optic Transmission Systems. - Odessa. Publishing house "Friend", 2001, 436 p.
- [5] Listvin V.N., Treshchikov V.N. DWDM-Systems. M.: Technosphere, 2015, 256 p.
- [6] Ibrahimov B.G., Mammadov I.M. Researches Methods Noiseproof Reception Optical Signals at use WDM–Technology//Second International Conference «Problems of Cybernetics the and Informatics – PCI-12. Vol. I., Baku, Azerbaijan, 2012, p. 56-59.
- [7] Sergienko A.B. Digital Signal Processing. Textbook for high schools. 2 nd ed.-SPb.: Peter, 2007, 751 p.
- [8] Basharin G.P., Rusina N. Multirate Loss Model for Optical Network Unit in Passive Optical Networks//Distributed Computer and Communication Networks: Communications in Computer and Information Networks.-Cham.: Springer, 2014, pp. 219-228.
- [9] Zhou H., Mao S., Agrawal P. On relay selection and power allocation in cooperative free space optical networks//Photonics Network Communication. J.PNET, 29 (1), 2015, pp. 1-11.

Information about the Authors:



Associate professor Mehman Hasanov- Head of the department "Multichannel telecommunication systems" of the Azerbaijan Technical University.

Number of scientific publications: 66

Field of interest: Analysis of optical telecommunication systems.



Doctor of Technical Science, professor Bayram Ibrahimov- Department "Multichannel telecommunication systems" of the Azerbaijan Technical University.

Number of scientific publications: 250

Field of interest: The Fundamentals of the Theory Telecommunications and Development Next Generation Optical Telecommunication Systems.



Shalala Qodjaeva- Doctorant of the Department "Multichannel telecommunication systems" of the Azerbaijan Technical University.

Number of scientific publications: 3

Field of interest: Next Generation Optical Telecommunication Systems.