METHODS AND ALGORITHM OF CONTROL OF OPTICAL COMMUNICATION NETWORKS

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Abstract. The main trends in the development of modern long-distance backbone optical systems are considered. This is, first of all, the complication of signal modulation formats, an increase in the symbol rate in the optical path, the use of superchannels and the formation of the signal spectrum, spectrum management (FlexGrid), the development of amplifiers in new spectral ranges, and the study of low-mode and multi-core optical fibers. It has been shown that existing technologies theoretically make it possible to achieve a throughput of about 100 Tbit/s over a single fiber. Further increases in capacity require the use of new spectral bands or spatial multiplexing using new types of optical fibers.

Keywords: DWDM, coherent reception, fiber optic communication network, modulation format, spectral efficiency, spectrum shaping, spectrum management, FlexGrid, symbol rate.

INTRODUCTION

The needs for traffic transmission are constantly growing, which creates a demand for increasing the performance of long-distance optical systems [1]. At the end of the 2000s, the first commercial coherent systems 40G and 100G were created; in 2013-2014, there was a large-scale transition of the world's largest telecom operators to coherent 100G channels as the main type of backbone channels (in Infinera terminology - optical reboot - optical reboot). A 100 Gbps channel in terrestrial DWDM systems is typically transmitted in the 50 GHz band (spectral efficiency SE = 100/50 = 2 bps/Hz).

In 2015, the first commercial optical units were created, providing 200 Gbit/s transmission over a single carrier in the 50 GHz band. By the beginning of 2016, all leading manufacturers had already presented such units, including Acacia, ClariPhy, NEL. The spectral efficiency of these types of optical units is 4 bit/s/Hz, which is twice as high as that of 100G systems. At the beginning of 2017, optical units with a speed of 400 Gbit/s over one carrier are expected to appear.

Thus, the capacity of existing DWDM communication systems over a single fiber is 9.6 Tbit/s in the C-band (96 100G channels), and 27 Tbit/s (270 100G channels) in the extended C+L-band. When moving to systems with SE = 4 bit/s/Hz, the maximum capacity increases accordingly to 19.2 or 54 Tbit/s. According to existing theoretical estimates, a 400G channel can also be transmitted in the 50 GHz band (SE = 8), which theoretically will allow achieving a capacity of 100 Tbit/s in a single fiber in the C+L-band (270 400G channels).

MATERIALS AND METHODS

In practice, the use of an extended spectral range (C+L), as well as an increase in spectral efficiency, requires solving a number of technological problems. In this regard, today there is active research into technologies that will increase the speed of long-distance optical systems. To continue the sustainable development of long-distance optical systems, it is vital not only to develop existing technologies and approaches, but also to search for new physical ideas and principles, with the use of which breakthrough technologies of the next generation will be created.

The main scientific and technological problems that scientists and engineers around the world are currently actively working on can be divided into four groups [2]:

1. Improving coherent communication systems:

– multi-level modulation formats;

– increasing the symbol rate of transmitters and receivers;

– superchannels and spectral engineering;

– use of photonic integrated circuits in transponders;

– software-reconfigurable networks.

2. Improving signal processing methods in coherent communication systems:

– compensation of distortions during digital signal processing;

– development of error correction algorithms.

3. Improving methods of amplification and regeneration of optical signals:

– the use of distributed amplifiers and amplifiers with remote pumping;

– use of currently unused spectral ranges;

– optical regeneration.

4. New infrastructure of fiber-optic communication networks:

– special fibers with reduced nonlinearity;

– fibers with low physical delay;

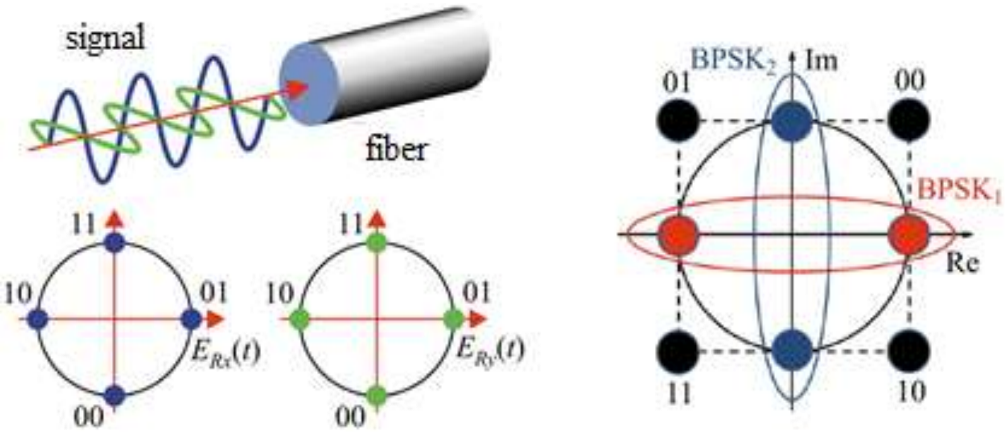
– spatial multiplexing methods: multi-core and few-mode fibers.

RESULTS AND DISCUSSION

Coherent communication systems allow the use of all four degrees of freedom of the electromagnetic field: amplitude and phase (or two quadratures) in each of the two polarizations. This allows, for example, in the DP-QPSK format (dual polarization – quater phase shift keying) to transmit 4 bits per symbol using only one power level. Accordingly, the transition to coherent detection makes it possible to increase the information transmission rate without increasing the symbol rate, i.e. without changing the currently accepted frequency grid (50 GHz) in wavelength multiplexing.

Thus, the transition from direct detection to coherent detection in the new generation of communication systems is natural. It allows you to increase the volume of transmitted information using spectral and polarization multiplexing of channels, as well as spectral-efficient modulation formats, in particular the DP-QPSK format. It is no coincidence that literally over the last few years, power modulation systems (PMS) operating at a repetition rate of 10 Gbit/s have been replaced by coherent modulation formats at repetition rates of 40 and 100 Gbit/s [2–4].

The structure of the optical signal in the DP-QPSK format is shown in Fig. 1. The signal contains two information components in the QPSK format on orthogonal polarizations. This means that polarization multiplexing is carried out (see Fig. 1, a), therefore, to denote this format, along with the abbreviation DP-QPSK, the abbreviation PM-QPSK is used, i.e. polarization multiplexed QPSK. In turn, each of two orthogonally polarized signals in the QPSK format can be represented as a combination of two binary phase BPSK signals, phase shifted by $\pi/2$ (see Fig. 1, b).



a *b*

Fig. 1. Optical signal structure in DP-QPSK format:

a – polarization multiplexing of two signals in QPSK format; b – QPSK signal structure

Multi-level modulation formats. Further development of fiber-optic communication systems, as can be seen from the trends of 2014–2015, will most likely be based on the use of more complex modulation formats (DP-16QAM, DP-64QAM, etc.) [5], which make it possible to significantly increase the spectral efficiency and, accordingly, the speed in the bandwidth familiar to the operator. However, the complication of the structure of the modulation format inevitably leads to a significant decrease in the transmission range.

CONCLUSION

In the coming years, progress in increasing the performance of communication systems will be based on the introduction and improvement of spectrally efficient modulation formats in combination with coherent detection and digital signal processing. In the future, apparently, the priority areas for the development of backbone communication systems will be the expansion of the used spectral range, the integration of photonics and electronics, the development of multimode and multi-core fibers and corresponding optical amplifiers.

REFERENCES

1. Promising DWDM communication systems with a speed of 20 Tbit/s per connection / A.G. Novikov, V.N. Treshchikov, S.O. Plaksin, A.Yu. Plotsky, O.E. Naniy // Photon-express. – 2022. – No. 3 (99). – pp. 34–38.

2. Treshchikov V.N. Development of a DWDM system with a capacity of 25 Tbit/s // Foton-express. – 2021. – No. 2 (106). – pp. 24–28.

3. Performance of coherent DWDM systems with a channel speed of 100 Gbit/s / N.V. Gurkin, O.E. Naniy, V.N. Treshchikov, R.R. Ubaydullaev // Communications Bulletin. – 2019. – No. 2. – P. 39–40.

4. Treshchikov V.N., Naniy O.E. New generation of communication systems // Foton-express. – 2018. – No. 4 (116). – pp. 18–20.

5. Makovey S., Korotkov N. Trends in the development of optical communication systems operating at speeds of more than 100 Gbit/s // Foton-express. – 2014. – No. 1 (113).