SIMULATION STUDY OF PARAMETERS AND CHARACTERISTICS OF OPTICAL COMMUNICATION LINE WITH SPECTRAL MULTIPLEXING

Stanimir Sadinov
Technical University of Gabrovo, Bulgaria

Abstract
The report presents the synthesis of a simulation model of an example optical communication line with spectral multiplexing. Results of parameters and characteristics of the optical signals are obtained from the graphic analyzers, which are visualized. Three separate examples with different input signal are used, and the presented tests contribute to the guaranteed efficient operation of the system by conducting a series of measurements to accurately determine all its main parameters with the aim of optimizing any of them.

Keywords: Simulation model, WDM, BER, P_{TX}, Q-factor, Mux, CW laser, EDFA, OSNR, OptiSys.

INTRODUCTION

The development of the telecommunications sector in Bulgaria is related to dynamic and continuous upgrading of optical communication networks. Operators strive to develop their infrastructure in order to increase the speed of data traffic and improve the quality of the services offered, which leads to the increase in requirements for the design of this type of communication networks. The advantages of transmission using optical signal amplification and wavelength division multiplexing (WDM) options have significantly changed the concept of building optical networks [1-4, 7, 8, 10, 12, 13, 14, 15]. In present days, optical fiber links are used on virtually any scale, from enterprise and access networks to backbone and transcontinental telecommunications link lines.

An analysis of the development of the lengths of the connection lines shows that, as a medium for transmitting information, optical fiber has no other alternative [5, 6, 9, 11]. This paper presents a part of the simulation results from an implemented model of an 8-channel WDM system for researching the parameters and characteristics of the transmitted optical signals and solving optimization tasks [13, 14, 15], with concrete examples from practice.

The model is simulated and explored by Optical Communication System Design Software [11] as a simulation environment.

EXPOSITION

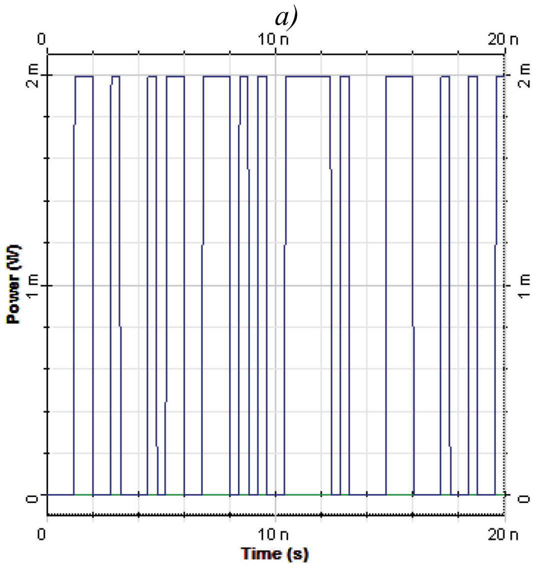
In previous reports, the exploration results of the optical 8-channel communication line with spectral multiplexing have been presented and similar results have been obtained and analyzed [13, 14, 15]. Here, the characteristics of the optical signals output by the used graphic analyzers of three cases are presented:

1) Optimum case at input signal power level PTX = 3 dBm with the following established parameters:
− Optical line length: L = 500 km;
− Amplification section length: l_{AS} = 100 km;
− Number of amplifying sections: N_{AS} = 5;

− Attenuation of optical fiber for kilometer distance: α= 0,2 dB/km;
− Optical transmitter power level set: PTX = 3 dBm;
− Gain of the optical amplifier: G = 20 dB;
− Optical amplifier noise figure: N_F = 6 dB;
− Sensitivity of the optical receiver: P_{RXsens} = –25dB;
− Measured power level at the input of the optical receiver: P_{RX} = –8,016 dBm;
− Measured quality factor for the optical line: Q = 19,76;
− Measured BER value at the output of the optical receiver: BER = $5{,}86.10^{-35}$;
− Measured signal / noise ratio of the spectral multiplexing optical signal at demultiplexer input: OSNR = 19,76 dB.

2) At the maximum power level of the input signal P_{TX} = 8 dBm with following parameters established:
− Measured power level at the input of the optical receiver: P_{RX} = –7,849 dBm;
− Measured quality factor of the optical line: Q = 10,97;
− Measured BER value at the output of the optical receiver: BER = $2{,}31.10^{-28}$;
− Measured signal / noise ratio of the spectral multiplexing optical signal at demultiplexer input: OSNR = 19,86 dB.

a)



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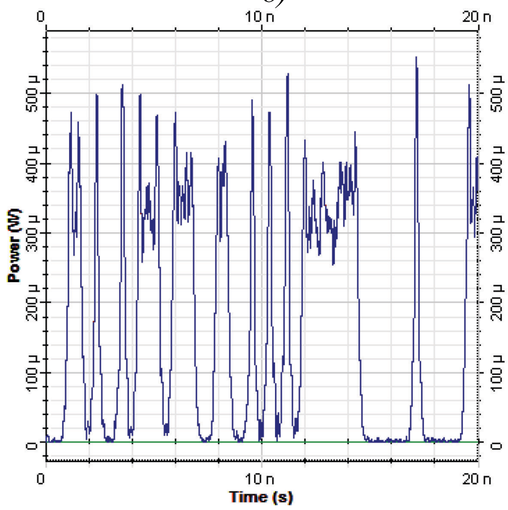
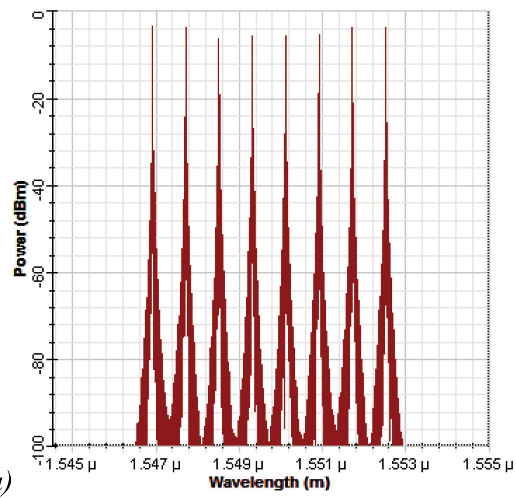
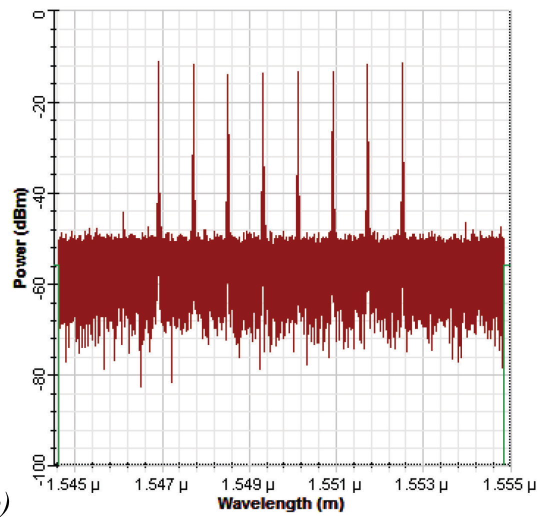


Fig. 1. *Timing diagrams of the optical signal at PTX = 3 dBm:*
a) at the output of the optical transmitter,
b) at the input of the optical receiver

3) At minimum power level of the input signal P_{TX} = –10 dBm with following parameters established:
− Measured power level at the input of the optical receiver: P_{RX} = –13,772 dBm;
- Measured quality factor of the optical line: Q = 6,72;
− Measured BER value at the output of the optical receiver: BER = $7{,}72.10^{-12}$;
- Measured signal / noise ratio of the spectral multiplexing optical signal at demultiplexer input: OSNR = 11,94 dB.



a)



b)

Fig. 2. *Spectral characteristics of 8-WDM optical signal at PTX = 3 dBm: a) at the output of the multiplexer, b) at the input of the demultiplexer*

After analyzing the measured PRX, Q, BER and OSNR, it can be seen at first glance that there are no deviations from the permissible values set as requirements.

Nevertheless, several problems will be located and analyzed in the figures below.

In fig. 1, there is a significant reduction in the amplitude of the optical signal at the input of the receiver compared to that at the output of the transmitter, which is the result of the attenuation along the optical fiber and the attenuation introduced by the multiplexer, amplifiers and demultiplexer.

The leading and trailing edges of the pulses are spread as a result of their propagation along the fiber, and individual pulses have different amplitudes as a result of different types of noise and the influence of dispersion.

From the spectra shown in Fig. 2, it can be seen that while the levels of the optical signal subcarriers are attenuated about 8 dB, as a result of the noise introduced by the individual optical components and their amplification by the optical amplifiers, the noise level in the signal spectrum has increased significantly - by more than 45dB.

Fig. 3 illustrates the resulting eye-diagram of the received signal, which graphically displays the digital parameters presented in the first case to this point.

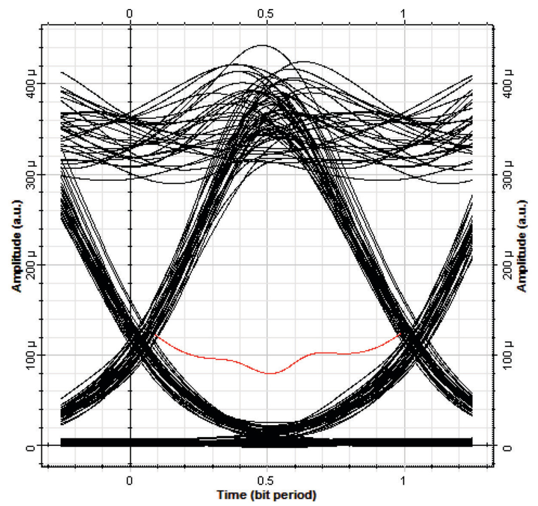
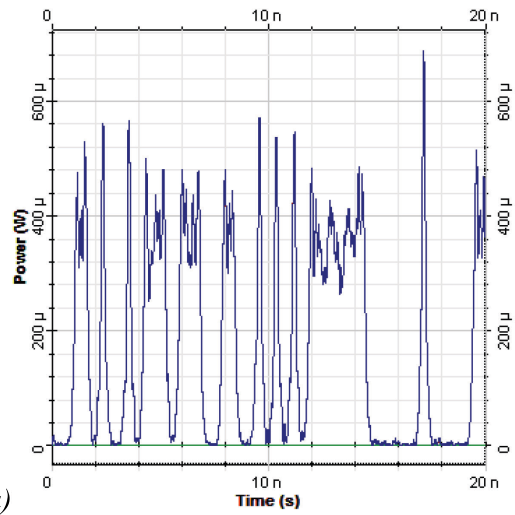


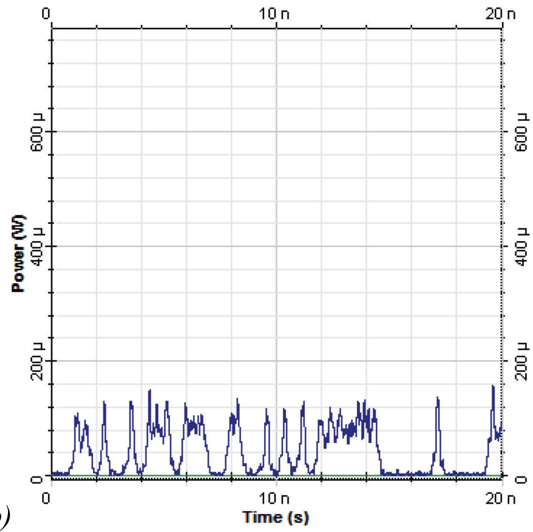
Fig. 3. *Eye-diagram and threshold level of the resolver in the receiver at PTX = 3dBm*

As already has been mentioned, both extreme cases are borderline, with the reported parameters falling within the acceptable limits for signal quality, but the difference is significant.

From the timing diagrams of Fig. 4, the significant lower level of signal amplitude and steeper slopes of the pulses in the case of the minimum value of the transmitter optical power can be noted. Of interest is the spectral characteristic at the maximum value of the optical power of the transmitter. As can be clearly seen from fig. 5 a), this gives rise to four-wave mixing of the signals, resulting in the appearance of combinational spurious wavelengths that are clearly visible outside the channel bandwidth (to the left and right of the 8 subcarriers of the WDM multiplexed signal).



a)

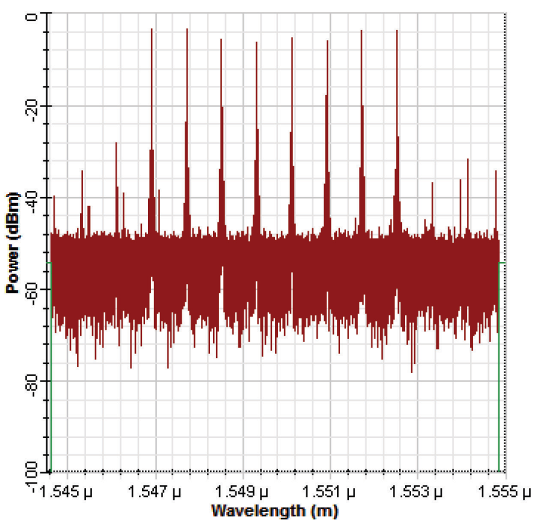


b)

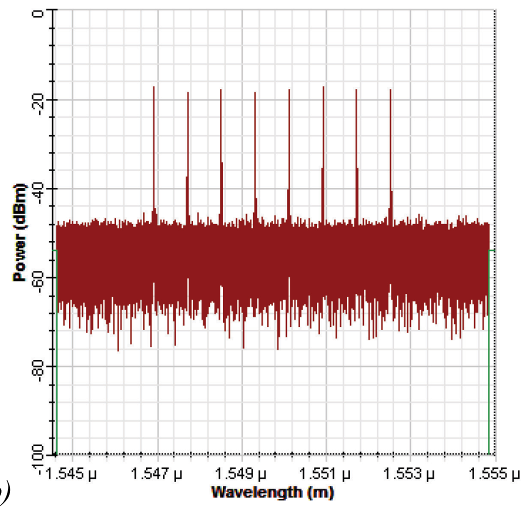
Fig. 4. *Timing diagrams of the optical signal at the input of the optical receiver at: a) PTX = 8 dBm, b) PTX = –10 dBm*

As can be seen from the spectral characteristic in Fig. 5 a), the amplitude of the composite parasitic wavelengths are not at all negligible – their maximum values are almost half of the amplitude of the subcarriers of the optical signal (they reach values from –27 dBm to –40 dBm).

As a result, if these spurious signals are not filtered out, they can cause errors in the solver. To this must be taken into account the fact that some of the parasitic wavelengths may coincide or be close to those of the subcarriers, which will lead to the appearance of intersymbol interference.



a)

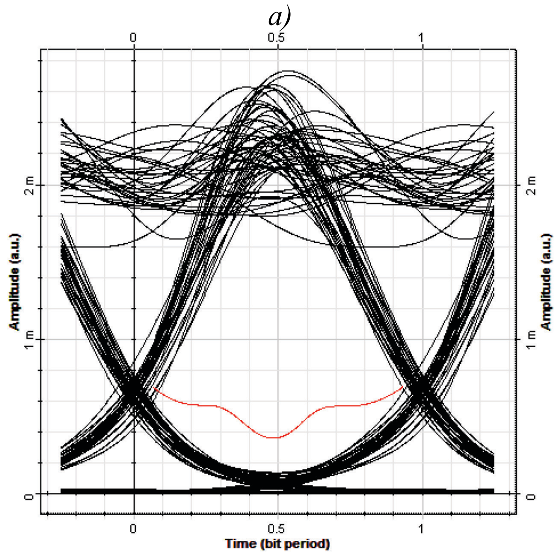


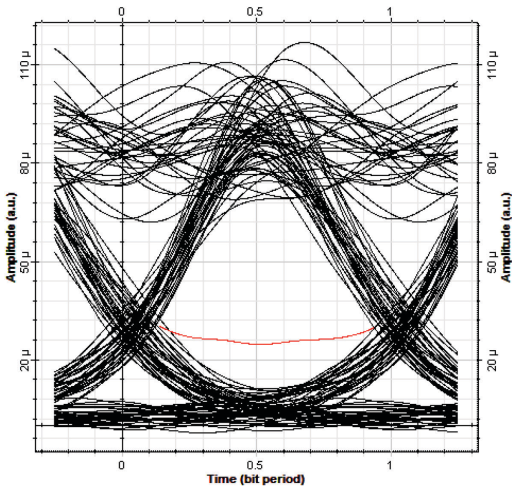
b)

Fig. 5. *Spectral characteristics of an 8-WDM optical signal at the input of the demultiplexer at: a) PTX = 8 dBm, b) PTX = –10 dBm*

Fig. 6 displays that as a result of a lower level of received optical power at the input of the optical receiver, the eye-diagram opening at PTX = –10 dBm will be significantly smaller, but sufficient for the correct operation of the resolver in the receiver (i.e. there is a correct decoding of log 1 and log 0). This evaluation is supported by the measured BER values, which is greater than the allowable (BER = 7.72.10–12 at PTX = –10 dBm).

a)





b)

Fig. 6. *Eye-diagram and threshold level of the resolver in the receiver at:*
a) PTX = 8 dBm, b) PTX = –10 dBm

CONCLUSION

After the simulation exploration, the following important inferences can be formulated:

- The need for periodic regeneration of the signal is causally related to the amplitude attenuation and the dispersion expansion of the code pulses.

− The negative effects of both processes, as well as other non-linear effects and disturbances, have quantitative expressions that increase with the length of the line.

- Nonlinear distortions in optical fibers are due to several phenomena that occur at unacceptably high levels of transmitted signals. They can be divided into two groups – nonlinearities related to optical power dissipation and nonlinearities related to the Kerr effect.

− Nonlinear effects related to phase self-modulation and four-wave mixing are extremely characteristic of WDM systems.

− Effects related to light scattering are characterized by a threshold level that is highly sensitive to the length of the amplifier section.

- The design itself does not ensure the effective functioning of the system - it is necessary to test it by conducting a series of measurements to accurately determine all its main parameters.

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