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Analytical Investigation of 8-Channel Optical Wavelength Division Multiplexing Communication System

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Abstract

In this paper, the theoretical 8-channel Dense Wave Division Multiplexing (DWDM) telecommunication system is demonstrated. Laser Diode (LD) source was used for each channel, with external modulator, therefore making the system work at high bit rate. The analytical part was done using a software simulator. All the proposed system components were simulated using Optisystem software offered by Optiwave for testing a DWDM communication system. The 8-channel DWDM spectrum, attenuation, dispersion, and receiver performance was determined.

Keywords: Optical Fiber Communication, Wave Division Multiplexing, Modulation, Optical Amplifier.

الفحص التحليلي لنظام اتصالات متعدد دمج الأطوال الموجية الكثيف ذو ثمان قنوات

الخلاصة

في هذا البحث, وصفَ المبدأ النظري للمنظومة اتصالات من نوع متعدد دمج تقسيمات الأطوال الموجية الكثيف (DWDM) . أُستعملَ في العمل مصدر دايود ليزري لكل قناة مع مضمن خارجي وهذا يجعل المنظومة تعمل بمعدل بتات عالي. أما جزء التحليل قد تحقق بواسطة استخدام برنامج محاكاة خاص. كل أجزاء نظام الاتصالات المقترح, قد حللت وفحصت بواسطة برنامج محاكاة "Optisystem". حدد شكل الطيف و الخسائر والتشتت وأداء المستقبل الخاص بنظام متعدد دمج تقسيمات الأطوال الموجية الكثيف لثمان - قنوات(8-channel DWDM).

1. Introduction

A powerful aspect of an optical communication link is that many different wavelengths can be sent along a single fiber simultaneously in to 1300-to-1600-nm spectral band. The technology of combining a number of wavelengths onto the same fiber is known as wavelength-division multiplexing. Conceptually, the WDM scheme is the same as frequency–division multiplexing used in microwave radio and satellite system [1, 2].

The Dense Wave division multiplexing(DWDM) technology is widely used in today's telecommunication networks. However, the economical factor makes DWDM systems available only for application in long-haul systems with demand for high capacity [3]. Using such a system telecom operators would be able to multiplex various technologies /services via one fiber.

The simulation done by an advanced optical communication system simulation package designed for professional engineering called OptiSystem simulating software by

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optiwave. OptiSystem represents an optical communication system as an interconnected set of blocks. Each block is simulated independently using the parameters specified by the user for that block and the signal information passed into it from other blocks [4].

This paper discuses the DWDM telecommunication system. Section 2 gives overview n-channel DWDM communication system. Section 3 deals with simulation system and some results of the 8-channel DWDM system simulation. The summary of paper and present conclusions discuss in section 4.

2. DWDM System Design

Fig.(1) shows a schematic diagram of the n-channel DWDM system. The transmission side of DWDM system involves n-LD with internal modulation operating in the 1550nm region. This region was chosen to minimize influence of fiber loss and to have a potential opportunity to use EDFAs (Erbium Doped Fiber Amplifiers) for spans longer than 10 km.

The wavelengths may be combined in many ways; for example, a diffraction grating or prism may be used. Both of these components act as dispersive optical elements for the wavelengths of interest; they can separate or re-combine different wavelengths of light. The grating or prism can be quite small, and may be suitable for integration within a WDM transceiver package [5].

To find the optical bandwidth corresponding to a particular spectral width in this region, the relationship c = λν can be used, which relates the wavelength (λ) to the carrier frequency (ν). The change in frequency (Δν) becomes:

$$|Dn| = \frac{c}{l^2}|Dl|$$

The optical bandwidth is Δν=14THz for a usable spectral band from about 1370–1350 nm (the 1310nm window). Similarly, Δν=15THz for a usable spectral band from about 1480-1600 (the 1550nm window). This yields a total available fiber bandwidth of about 30THz in two low-loss windows.

The optical amplifiers like Erbium Doped Fiber Amplifiers (EDFA) work without having to convert optical signal into electrical from and back. This features leads to two great advantages. First, optical amplifiers support any bit rate and signal format because again they simply amplify the received signal. Thus optical amplifiers are transparent to any bit rate and signal format. Secondly, they support not just a single wavelength, as repeaters do, but the entire range of wavelengths. Due to the extremely desirable characteristics of the EDFA, most systems would use EDFAs. EDFA amplify only near 1.55µm, and therefore not use the dispersion-zero 1.3-µm band of the existing embedded conventional fiber base [6].

3. WDM System Simulation

The proposed 8-optical channel WDM system is shown in Fig.(2). On the transmission side of the system, the 8-laser diode operating in the 1550 nm region are plotted in one block. Each channel modulated with modulation rate to achieve data transfer rate of 10 Gbit/s. The type of modulation used was on-off keying (OOK) and NRZ (Non-Return to Zero) format was used for signal coding. The spectrum of modulated LD signal is shown in Fig.(3).

For multiplexing eight channels into a single fiber, the optical multiplexer with 20GHz channel bandwidth and 100GHz channel frequency spacing is used to reduce the crosstalk between adjacent channels. The system was designed so that to minimize noise from the adjacent channels. The spectrum of the 8-channel multiplexed signal at output of multiplexer is shown in Fig.(4).

Optical amplifiers EDFA work to amplifying the optical pulses signal. The gain is not uniform with wavelength, whereas the inter-amplifier losses are nearly wavelength independent. For a single amplifier, as shown in Fig.(2), the gain exhibits a peak at 1530 nm and a relatively flat region near 1555 nm[5]. The EDFA gain is 20dB and its Noise Figure (NF) is 4dB. The multiplexed signal spectrum after EDFA is shown in Fig.(5). It can be see from Fig.(5), the maximum signal becomes 0dBm for all channels while the input to the EDFA is equal -10dBm.

The multiplexed signal is tested by transmitting the signal over 20km, 50km and 80km of standard single mode fiber. The spectrum of multiplexed signal at end of fiber is shown in Fig.(6). Single mode fiber was chosen to minimize the influence of dispersion and the main limitation of the system as it is seen from the simulation. The demultiplexer has the same parameters as the multiplexer in terms of channel bandwidth and channel spacing.

On the receiver side of the system, the eight avalanche photodiodes (APDs) to detect signals and eight Bit Error Rate (BER) meters and eye-diagram analyzers to evaluate performance of each channel. Avalanche photodiodes were chosen because they have higher sensitivity than PIN photodiodes which is essential, because of high slicing losses.

The effect of attenuation only on the system is investigated by relationship between the BER and optical fiber length. This relation shown Fig.(7). Fig.(8) shows the influence of dispersion on BER for 10Gbit/s link. The major influence of dispersion on 10Gbit/s signal is limiting the fiber span from 67km to 37km in order to achieve BER< 10^{-9}.

The eye diagram of received signal is demonstrated in Fig.(9) for fiber length 20km, 50km, and 80km respectively. Fig.(9) show that the amplitude of received signal at fiber length of 20km is approximately ten times the amplitude at fiber length of 50km. It can see that the eye diagram of the received signal at 80km span is worse as shown in Fig.(9), the main reason for this being the influence of attenuation and dispersion.

4. Conclusion

This paper, reported and depicted the results of an investigation into the use of 8-channel Dense Wave Division Multiplexing (DWDM) telecommunication system in high bit rate optical transmission systems. The analytical investigation was employing standard optical fibers without and with dispersion. The dependence of the optical path loss, horizontal eye pattern opening on the fiber length and input impulse shape is found along the fiber by using computer simulation. In case of neglected the dispersion, the DWDM system has better parameters for transmission distances less than 67km. While testing the system with dispersion, make the distances become smaller and less than 37km.

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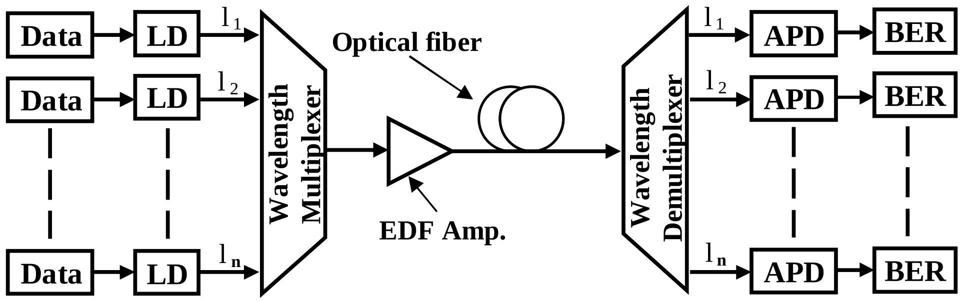

Figure (1) Schematic diagram of the n-channel WDM system.

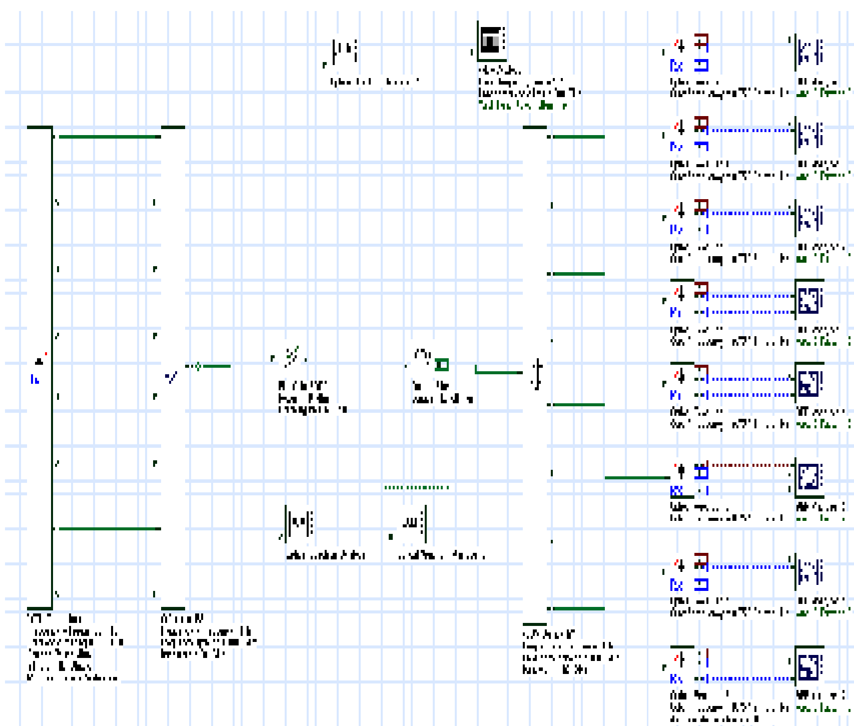

Figure (2) The proposed 8-optical channel WDM system

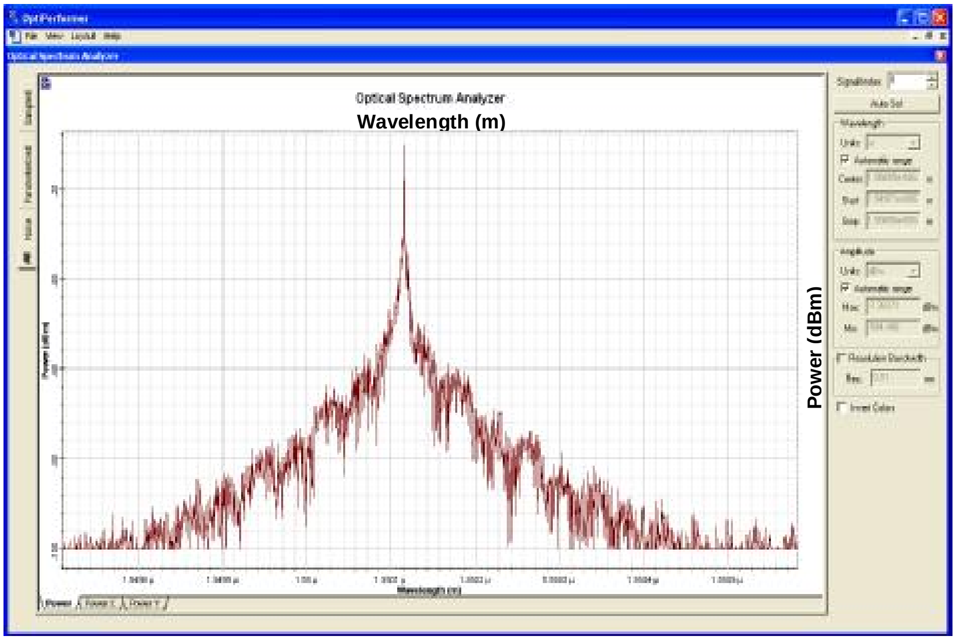

Figure (3) The spectrum of modulated LD signal

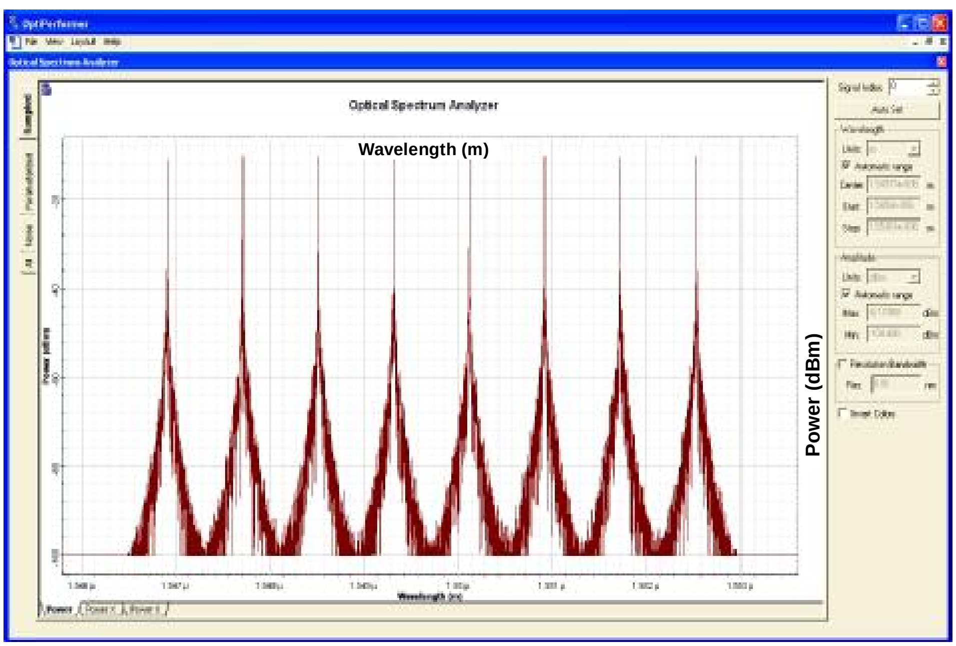

Figure (4) Spectrum of the 8-channel multiplexed signal at output of multiplexer

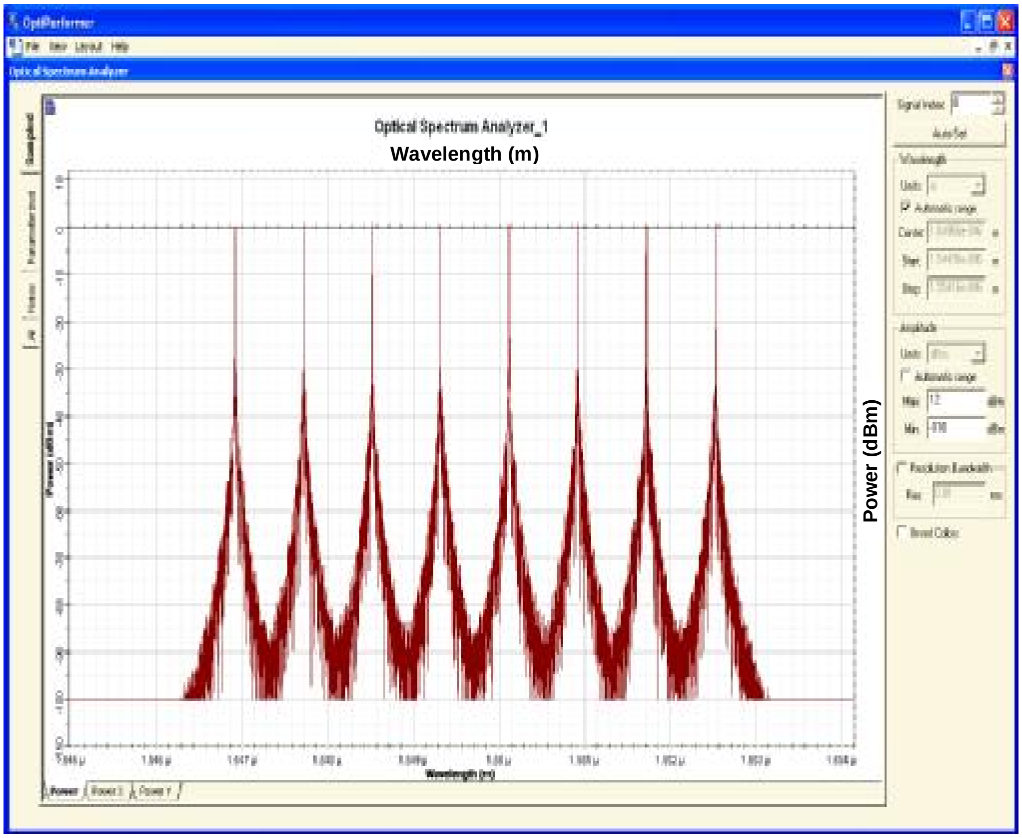

Figure (5) Spectrum of Output multiplexed signal of EDFA

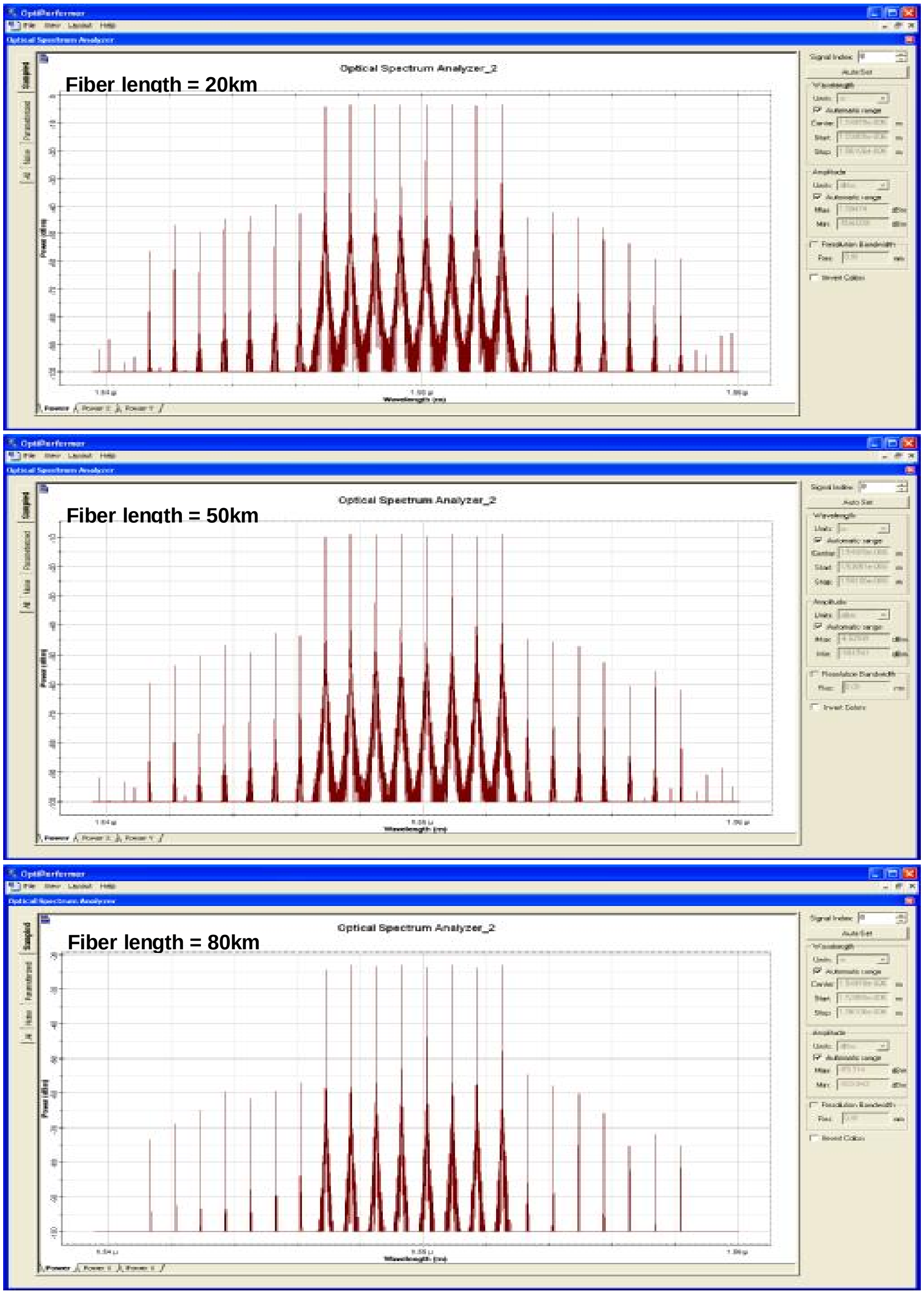

Figure (6) The spectrum of multiplexed signal at end of fiber

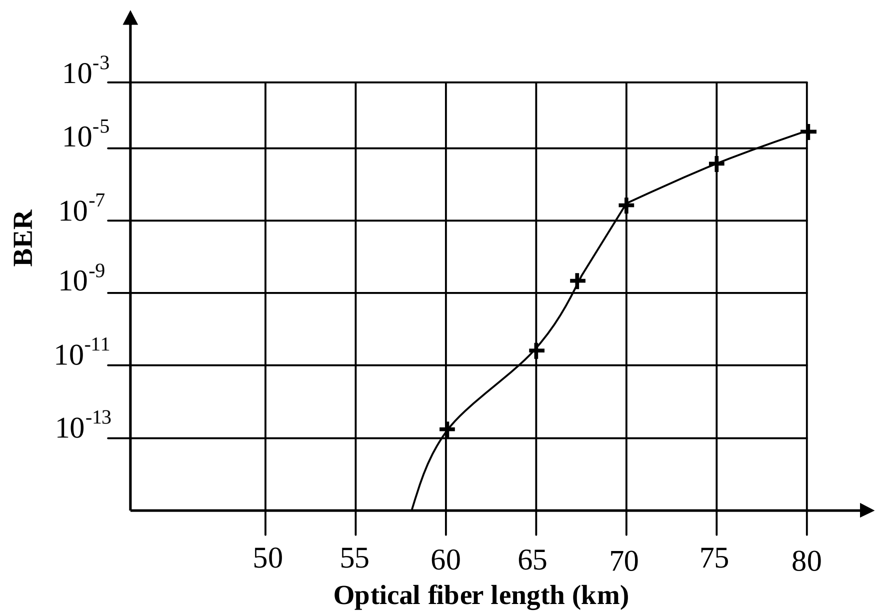

Figure (7) The influence of attenuation on BER

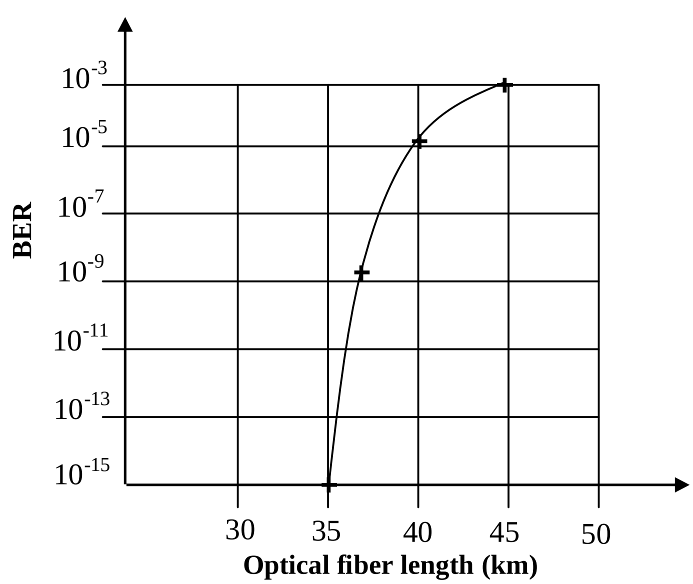

Figure (8) The influence of dispersion on BER

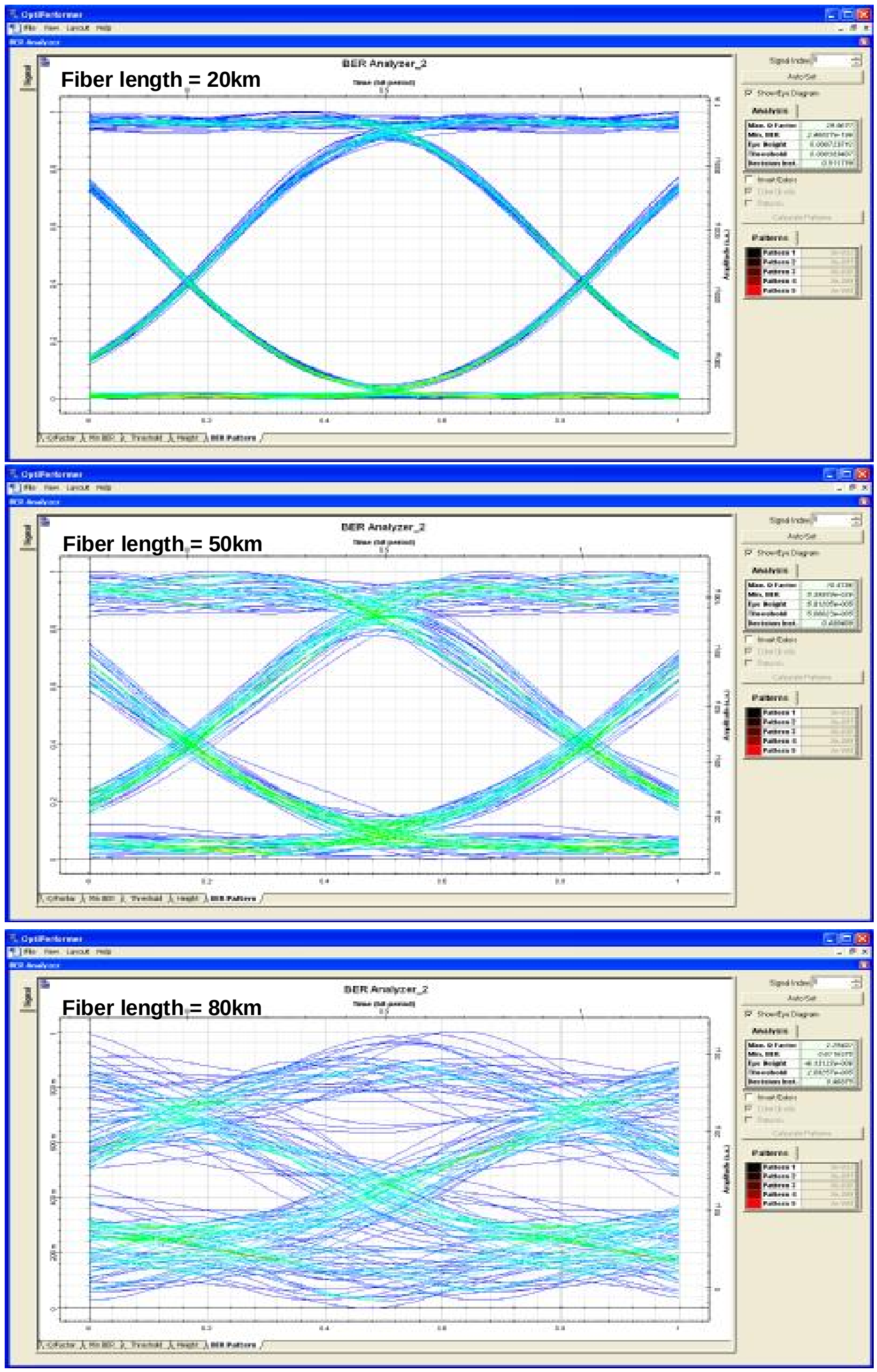

Figure (9) Eye diagram of received signal at various fiber length