

# Study Performance of the Fiber Bragg Grating as a Dispersion Compensator an Optical Transmission System Using Optisystem Software

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## Abstract

This paper presents the design and simulation of an optical transmission system in optical fiber. Optical fiber is one of the most important communications media in communication system. Due to its versatile advantages and negligible transmission loss it is used in high speed data transmission. Although optical fiber communication has a lot of advantages, dispersion is the main performance limiting factor. There are various types of optical fiber, the Fiber Bragg Grating (FBG) is commonly chosen as important components to compensate the dispersion in optical communication system. Because the low cost of filter for wavelength selection and low insertion loss, it has also customized reflection spectrum and wide bandwidth. The simulation of transmission system will be analyzed based on different parameters by using OptiSystem simulator. By simulating a model of communication system and using the most suitable settings of the system which include input power (dBm), fiber cable length (km) and attenuation coefficient (dB/km) at cable section, there are three different parameters will be investigated, which are Signal power (dBm), Noise power (dBm), output power (Watt), at receiver.

**Keywords:** Optisystem simulator, parameters, Optical Transmission System Fiber Bragg Grating (FBG).

## دراسة وضائف FBG كمعوض للتشتت في نظام الاتصالات الضوئية باستخدام برنامج Optisystem

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### الخلاصة

تم في هذا البحث تصميم محاكاة لنظام البث البصري في الألياف البصرية . ان الألياف البصرية هي واحدة من وسائل الاتصال الأكثر أهمية في نظام الاتصالات. وذلك لامتلاك الألياف البصرية مزايا عديدة ومنها خسارة الإرسال ضئيلة لذلك يتم استخدامه في نقل البيانات عالية السرعة. ، والتشتت هو العامل الرئيسي الذي يحد الأداء. هناك أنواع مختلفة من الألياف البصرية، ومنها المشابك براج الألياف (FBG) يتم اختياره عادة لكونه احد العناصر المهمة لتعويض التشتت في نظام الاتصالات البصرية. واهم مزاياه لديه مرشح منخفض التكلفة لاختيار الطول الموجي وانخفاض خسارة الإدراج، وله طيف منعكس وعرض النطاق الترددي واسع وسوف يتم تحليل محاكاة لنظام الاتصالات استنادا إلى معايير مختلفة باستخدام Optisystem simulator. من خلال محاكاة نموذج لنظام الاتصالات البصرية وباستخدام الإعدادات الأنسب للنظام والتي تشمل مدخلات الطاقة (ديسيبل)، وطول الكيبل البصري (كم) ومعامل التوهين (ديسيبل / كم) الخاص بالليف البصري، وتم في هذا البحث حساب ثلاث معلمات مختلفة وتشمل كلا من طاقة الإشارة (ديسيبل)، طاقة الضوضاء (ديسيبل) والطاقة الخارجة (واط) عند المستلم.

## Introduction

Fiber optics is a medium for carrying information from one point to another in the form of light. Unlike, the copper form of transmission, fiber optics is not electrical in nature. A basic fiber optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fiber cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal [1]. Fiber Bragg Gratings (FBG) is added for the design of Optical Transmission System. Fiber Bragg gratings have many applications in fiber optical telecommunication systems such as dispersion compensation, gain flattening for EDFAs, Raman amplifiers and add/drop multiplexers and in fiber grating sensors and pulse shaping in fiber lasers. Combining, controlling and routing light are three main uses of FBGs in the optical communications [2]. They are also stimulating growth in fiber optic applications outside of telecommunications, such as nonlinear frequency conversion, spectroscopy, and remote sensing [3].

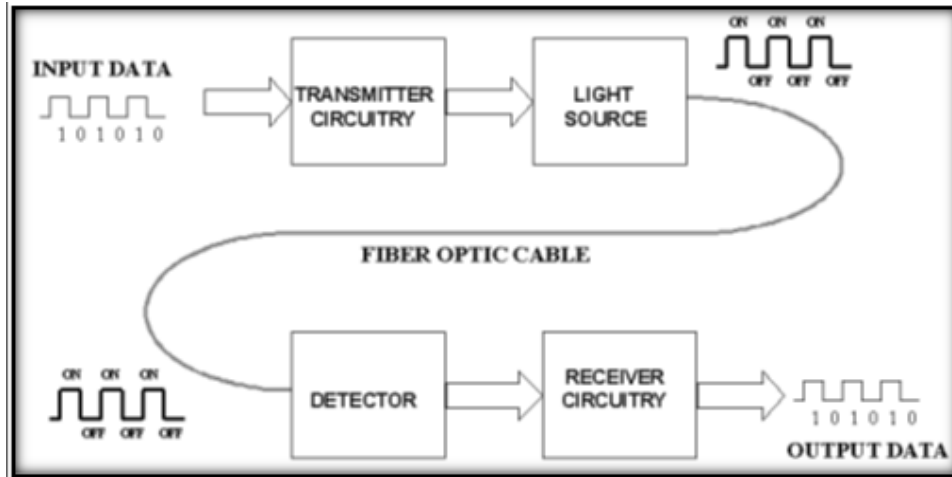
Optisystem is an innovative optical communication system simulation package that designs tests, and optimizes virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones. Optisystem is a stand-alone product that does not rely on other simulation frameworks. It is a system

level simulator based on the realistic modeling of fiber-optic communication systems. It possesses a powerful new simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be extended easily with the addition of user components, and can be seamlessly interfaced to a wide range of tools [4].

In this study, the simulation of the optical transmission system in optical fiber has been discussed by analyzing the effect of the components in data receiver by using different parameters setting. The value of parameters has been investigated such as Signal power (dBm), Noise power (dBm), output power (Watt), at receiver.

## Background theory

Fiber optics is a medium for carrying information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics is not electrical in nature. A basic fiber optic system consists of a transmitting device, which generates the light signal; an optical fiber cable, which carries the light; and a receiver, which accepts the light signal transmitted. The fiber itself is passive and does not contain any active, generative properties. This principle is shown in figure 1 [5].

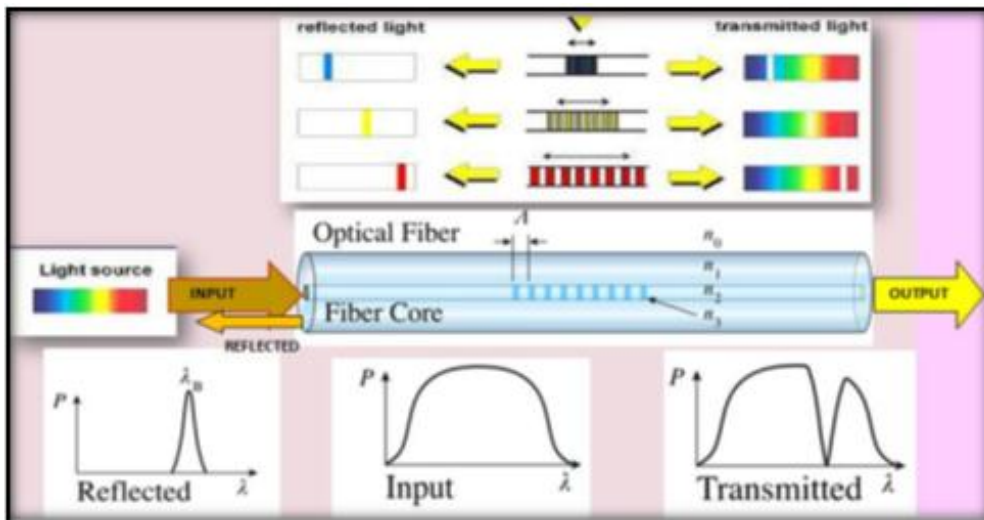


**Figure 1. Basic fiber optic communication system [1].**

### **A. Fiber Bragg Grating (FBG)**

Fiber Bragg Grating (FBG) has the advantages of a simple structure, low insertion loss, high wavelength selectivity, polarization insensitivity and full compatibility with general single mode communication optical fibers [6]. Fiber Bragg gratings reflect a narrow spectral part of light that is guided in the optical fiber core at the Bragg wavelength, which is dependent on the fiber grating period and the refractive index of the optical fiber. FBG is one mode that will be presented basic periodic pattern intense UV.

This leads to increased exposure of the refractive index, and thus the refractive index is increased permanently. Then the exposure pattern formation will be created called fixed index grating. When a light source is supplied to the FBG, only a narrow range of light wavelengths corresponding to the Bragg wavelength will be reflected, transmitting this spectral data to the attached FBG spectrum analyzer. All other wavelengths will partially reflect at tiny index variations and interfere destructively, causing those wavelengths to be transmitted. This principle is shown in figure 2 [7].



**Figure 2. The principle of Bragg's light.**

## B. Description of Components and consideration

The system is operated with the basic optical communication which consists of a transmitter, transmission link and a receiver. The system transmits information using optical carrier wave from transmitter to receiver via optical fiber.

Figure 3 shows the layout parameters. From Optisystem 7.0, the components used in it are shown in below.

1. Pseudo-Random Bit to generate sequence random bits (0 or 1).
2. NRZ pulse generator has an advantage on controlling bandwidth. This is due to the characteristic of the generator that the returning signals to zero between bits. Pseudo-random bit sequence generator

is used to scramble data signal in terms of bit rates [8].

3. Mach Zender- Modulator (MZ) has two inputs (optical signal and electrical signal) and one output (optical). Then the input signal is modulated with semiconductor laser that is represented by Continuous Wave (CW) laser through Mach-Zehnder modulator.
4. Continues laser diode (CW) to generate optical signals supplies input signal with 1550 nm wavelength and input power of 5dBm which is externally modulated at 10 Gbits/s. with a non-return-zero (NRZ) pseudorandom binary sequence in a Mach-Zehnder modulator with 30 dB of extinction ratio.
5. The optical fiber used is single mode fiber because single mode fiber has higher data rate, less dispersion therefore

operate in long haul distance, so it is suitable to be used as transmission link.

- The fiber Bragg grating which use as the dispersion compensator. The length grating that will be used is 6 mm since the most proper length for proposed model is equal to  $l = 6 \text{ mm}$  by try and error method [9].
- Fiber amplifier (EDFA). Optical amplification is required to overcome the fiber loss and also to amplify the signal before receive by Photo detector PIN at the receiver part.

- Photodetector Diode Positive Intrinsic Negative (PIN) to translate the optical signal into an electrical signal. One photon yields one electron [10].

- Optical Spectrum Analyzer (OSA), to monitoring output signals after each component.

The initial settings for the design are shown in Figure 3 order to operate as the optical transmission system: Input power 5dBm, frequency at transmitter 1550nm, fiber length 5km, Attenuation coefficient at cable section 0.2dB/km.

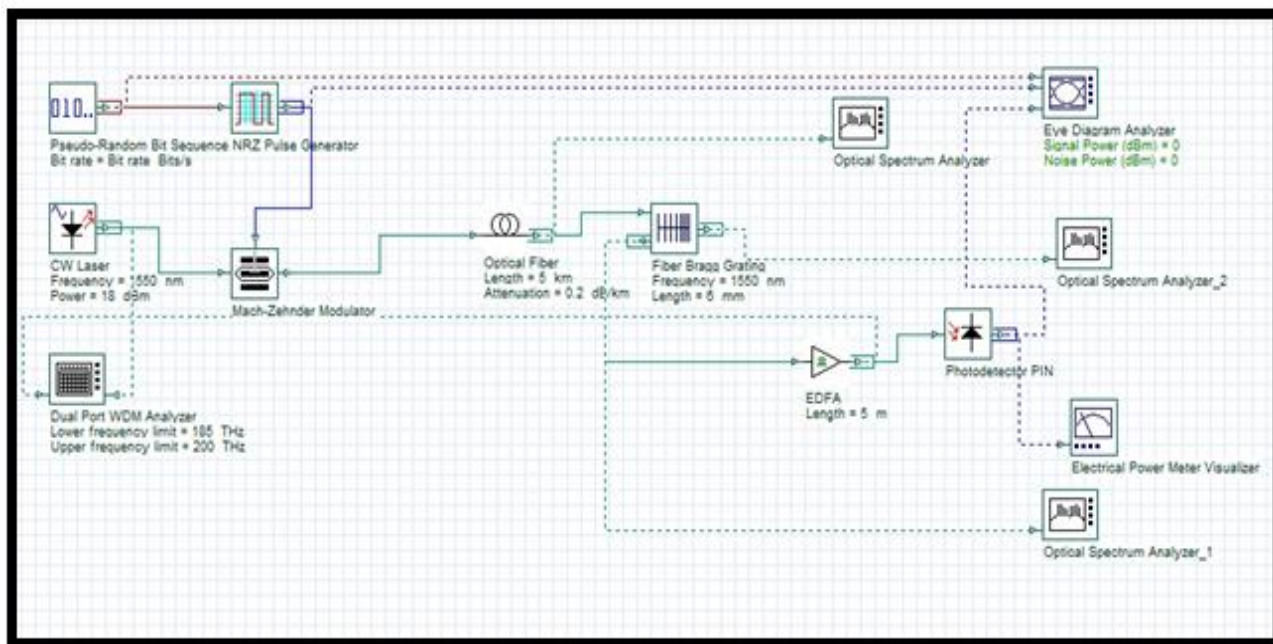


Figure 3. The designed model of simulated system with Optisystem software.

### Results and Discussion

The simulation and optimization of the design is done by Optisystem 7.0

simulation software. The eye diagrams and results of output power, Signal

power (dBm) at receiver, noise power are tabulated into figure 4 until figure 11 by using different values of input power (dBm), attenuation coefficient (dB/km),

and variable length of FBG (mm). The related graphs are also plotted as shown in figures 6, 9 and 11.

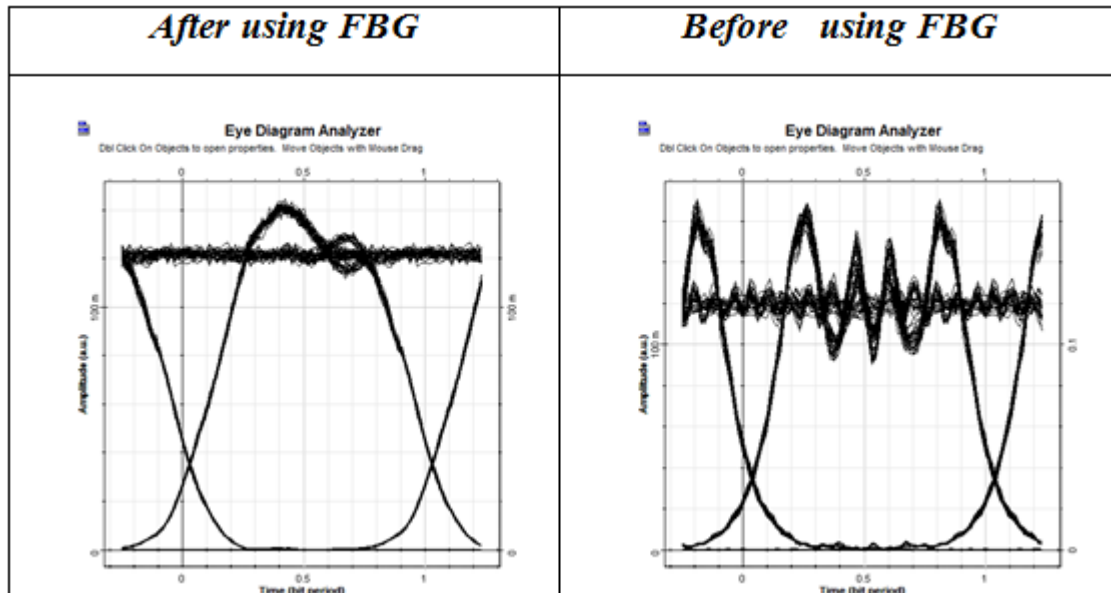


Figure 4. The differences of the eye diagram for the design with and without using Fiber Bragg Grating.

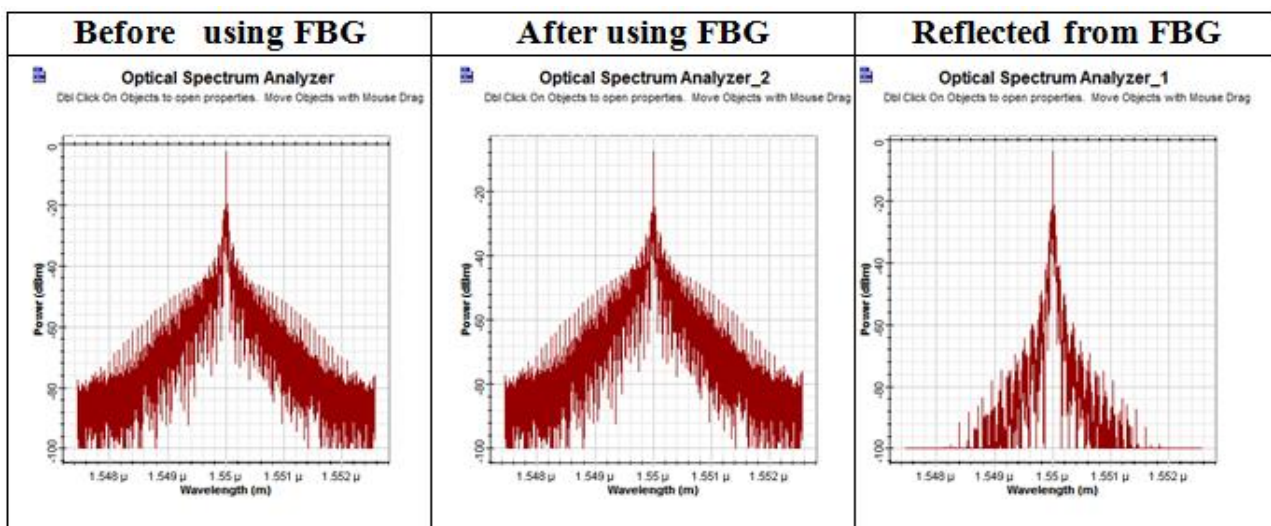
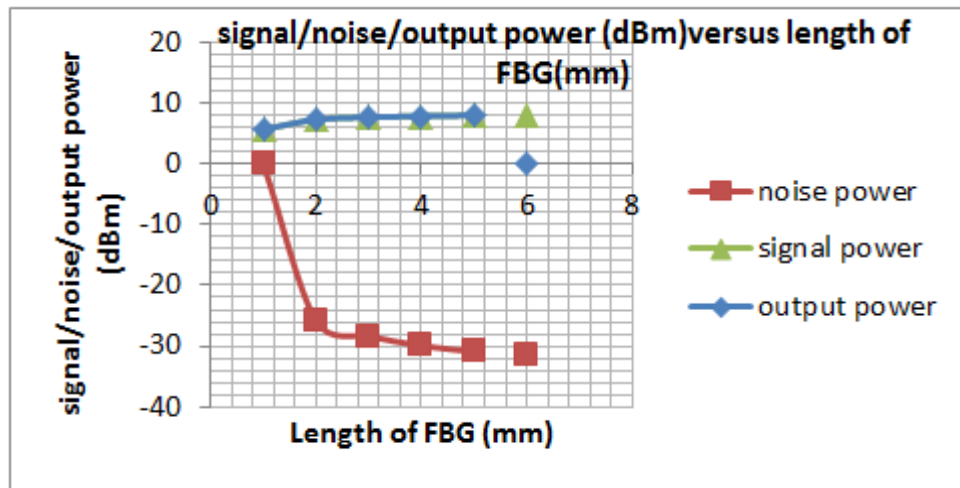


Figure 5. The output readings are measured by Optical power meter with(Transmitted and Reflected) and without using Fiber Bragg Grating.

**Table 1. The output readings are measured by varying the fiber bragg grating.**

Length (mm)	Signal Power (dBm)	Noise Power (dBm)	Output power (mw)
1	5.73945	-21.6174	3.775
2	7.35215	-25.8324	5.438
3	7.74958	-28.3721	5.957
4	7.93449	-29.9351	6.216
5	8.04336	-30.9361	6.374
6	8.11548	-31.5858	6.48



**Figure 6. Graph of Signal/noise/output power figure versus length of FBG.**

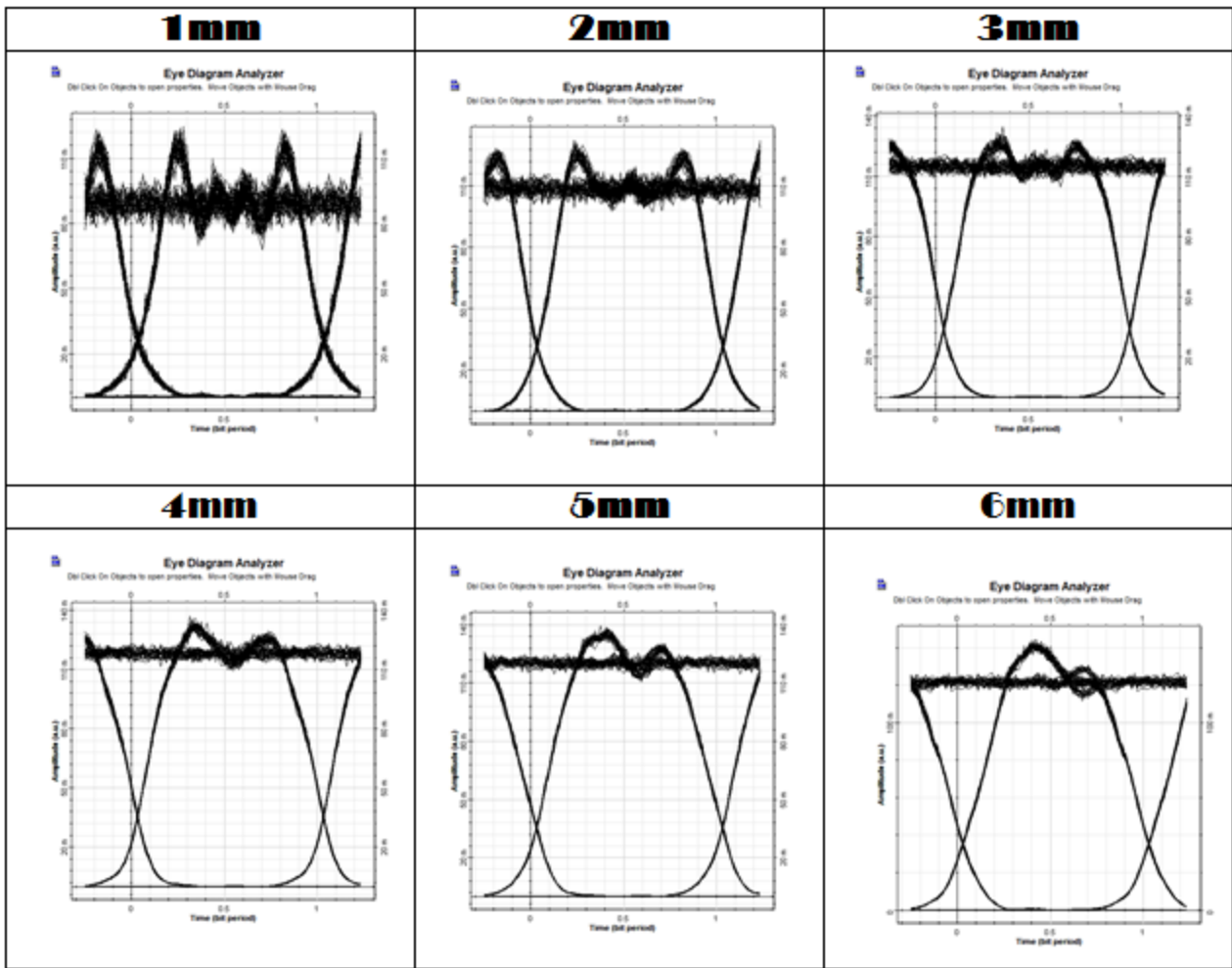


Figure 7. Eye diagrams are analyzed by using different values of fiber bragg grating.

Table 2: The output readings are tabulated by varying the input power.

Input Power (dBm)	Signal Power (dBm)	Noise Power (dBm)	Output power (mw)
1	7.7409	-28.123	5.945
5	8.11548	-31.5858	6.48
10	8.58785	-35.5157	7.224
15	9.48629	-38.3241	8.885
20	11.6114	-39.276	14.493

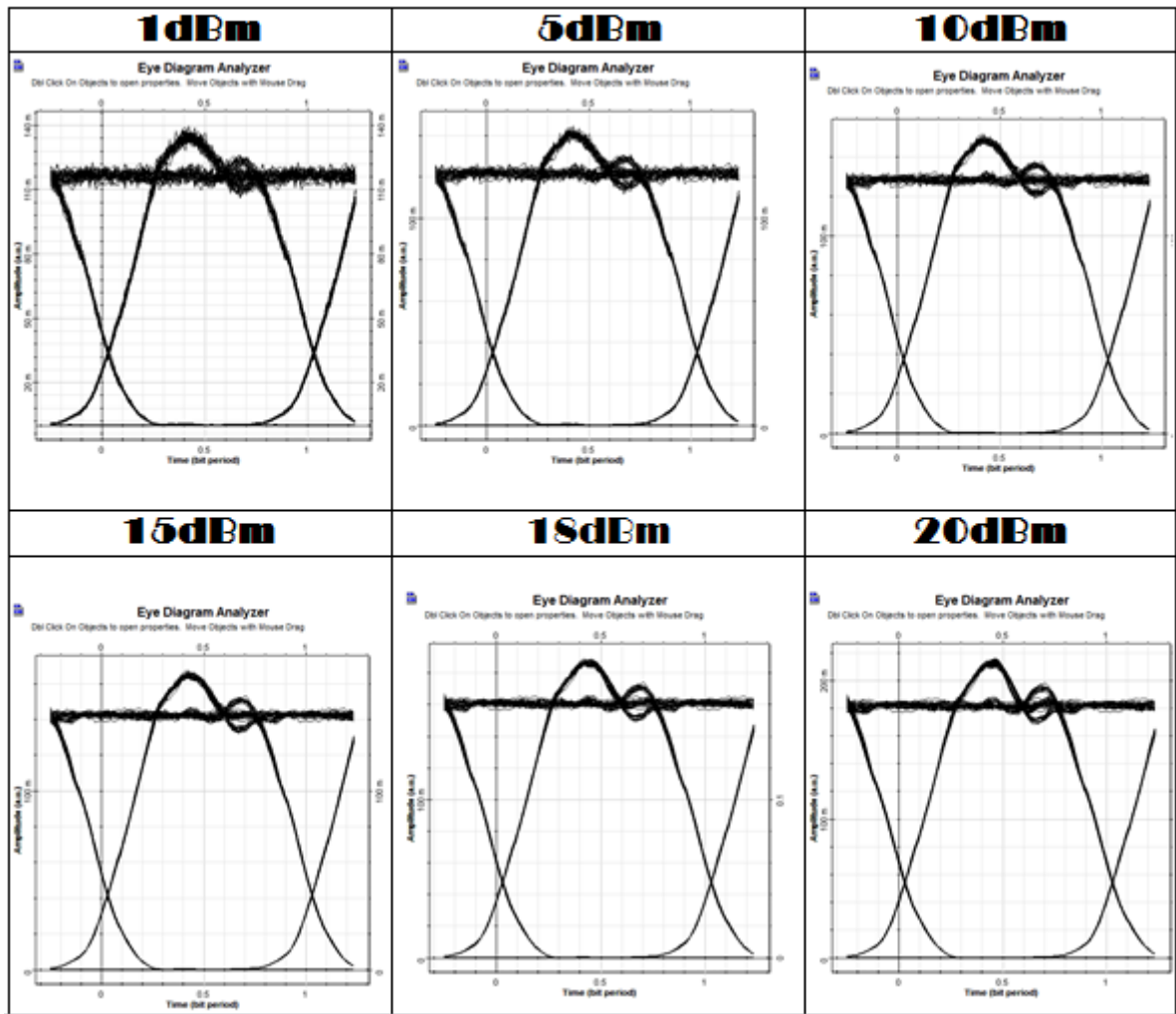


Figure 8. Eye diagrams are analyzed by using different values of input power.

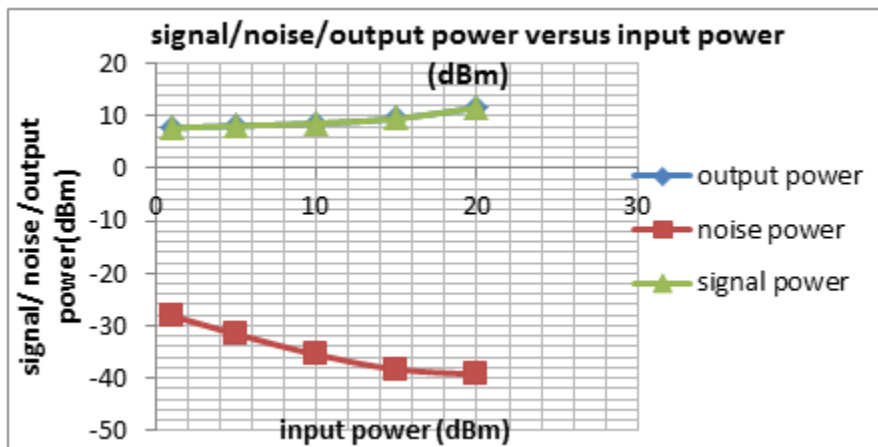


Figure 9. Graph of signal/noise and output power figure versus input power.

Table 3. The output readings are obtained by varying the attenuation coefficient at cable section.

Attenuation Coefficient (dB/Km)	Signal Power (dBm)	Noise Power (dBm)	Output power (mw)
1	7.74082	-28.1233	5.945
3	4.85972	-20.704	3.070
5	-6.5435	-21.1503	0.229
7	-24.987	-26.7976	0.00526

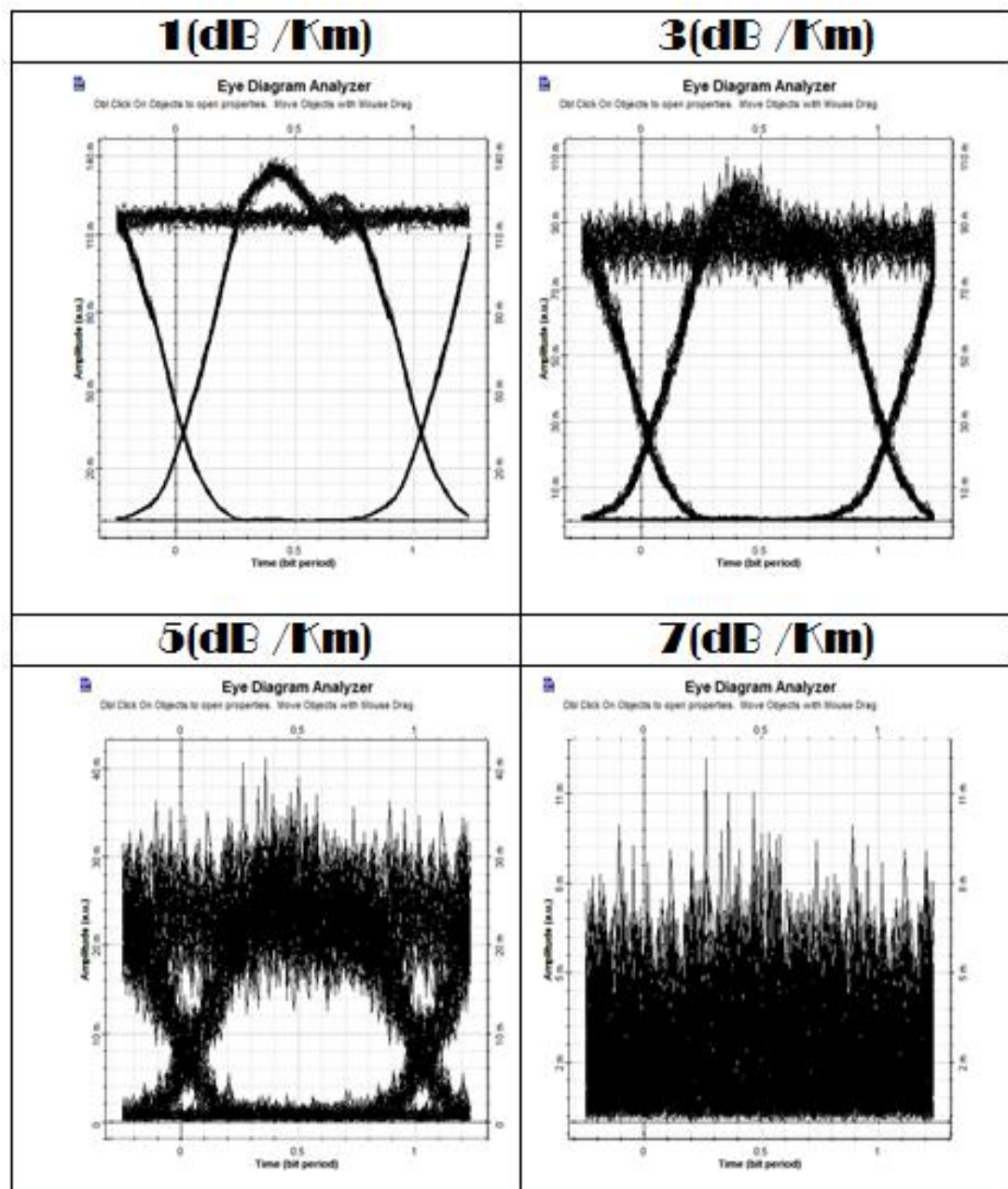


Figure 10. Eye diagrams are analyzed by using different values of attenuation coefficient at cable section.

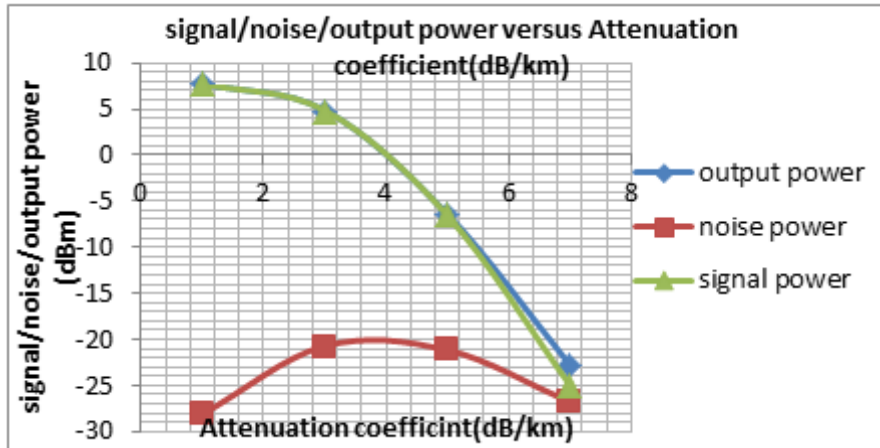


Figure 11. Signal/noise / output power versus attenuation coefficient

In this project, the transmission system has good performance and a characteristic is designed from the design, the optical fiber transmission system can be combined with the modulator which can modulate the output signals. Then, the transmission system consists of Fiber Bragg Grating (FBG) acts as to compensate the dispersion, optical amplifier which can be used to reduce the fiber loss and amplify the signal before being received by photo detector PIN at the receiver [7]. There are different parameters which include output power (mw), attenuation coefficient (dB/km) at cable section and Signal power (dBm) at receiver will be investigated to determine the most suitable setting for a high performance optical transmitter. By analyzing data on Table 1, it

shows that the length of fiber bragg grating is directly proportional to the value of noise signal. Figure 6 shows that with increasing FBG length, the Noise power decreases with further increasing length while the signal power and output power reading by electrical power meter increase linearly as increasing length.

Table 2 shows the varying of input power as verse as data of signal/noise and output power, figure versus input power is plotted in figure 9 showed when increasing of input power the noise was decreased with increasing input power, while the signal power and output power increase when the output power increase. Since EDFA is used as the optical amplifier, output power will

indicate that the optical amplifier will saturate or the gain has been compressed. The reason is that the power source of the amplifier.

Table 3 shows the output readings are obtained by varying the attenuation coefficient at cable section. From the table, it is obvious that when the attenuation coefficient is increased, the noise power will increase as well while the signal and output power is decreasing when the attenuation coefficient is increased.

## Conclusion

From the design and simulation of optical transmission system, the system will transmit information using optical carrier

wave from transmitter to receiver via optical fiber, the transmission system block diagram Figure1 has been designed which consists of laser light as the source, modulator, single mode optical fiber as the channel, fiber Bragg grating (FBG) as the dispersion compensator, optical amplifier and the photo detector as the light detector. The optical transmission system has been modeled by using Optisystem7.0 simulator as shown in Figure 3 in order to investigate different parameters of the system. From the simulation result, it can conclude that the fiber Bragg grating length and the input power are directly proportional to the signal power. While the noise is getting lower with the increasing length, on the other hand, the output power is decreased although the attenuation coefficient increased.

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