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Receiver Performance Improvement in Radio over Fiber Network Transmission

Lisawati Sainawi and Khadijah Ismail

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Abstract

Nowadays, wireless demand is raised rapidly since the number of mobile-cellular telephone and broadband internet are springing up. Thus, many base stations (BS) and a lot of money are needed to satisfy the demand. Radio over fiber (RoF) is the solution to this problem since it can operate a lot of BSs that connected to central station (CS) by using optical fiber, as well as offering cost-effective solution. Due to some factors, received signals of RoF tend to be in a low quality. Those factors will lead to some problems such as high value of bit error rate (BER), low value of Q factor, and the receiver could not operate in high data rate network. Wavelength division multiplexing (WDM) network can be one of the solutions of those problems where different signals are transmitted through a single-mode fiber. Bit error rate must be decreased to a certain value, and the Q factor should be increased. The design of RoF will be simulated by using Optisystem software. The performance of RoF's receiver is measured and analyzed based on the obtained BER, value of Q factor and height of opening of eye diagram.

Keywords: radio over fiber, performance, wavelength division multiplexing, receiver, bit error rate, Q factor, eye diagram, optical fiber, eye pattern

1. Introduction

Any form of telecommunication system that having light as the transmission medium is known as optical communication. Optical communication system consists of a transmitter, channel and a receiver. The transmitter will **encode** a message into an optical signal, the channel will carry the signal to its destination, and the receiver will reproduce the message from the received optical signal.

Radio over fiber (RoF) is a technology where RF signal modulates light and then transmitting it over an optical fiber link. Both wireless network and optical are supported by this technology. It is essential for communication system to have high capacity and subcarrier frequency since wireless signal sometimes intend to loss channel at the time of data transmission [1].

RoF is very convenient system since it is less costing and power consumption. This is because RoF lets the electrical signal modulates the optical source and after that the optical signal will travel along the optical fiber to the remote station. When the RF signal is modulated straight to the optical link, the power consumption drops while the antenna side has high frequency radio carriers. The reduction of cost in RoF technology can be explained in two ways. The first one is central station (CS), which provides resources that can be shared by variety of base stations (BS), and secondly, BS only executes simple function. Furthermore, the BS is in a small size and less cost consuming.

Basically, in this technology, central station (CS) is connected with many base stations (BS) by using optical fiber. BS only functions as a converter of optical signal into a wireless signal and vice versa, while at CS, all process involving modulation, demodulation, coding and routing are executed [2]. By using high linear optic link, RoF system distributes the RF signal between CS and BSs. **Figure 1** shows the basic construction of radio over fiber network transmission.

At the transmitter side, data or information from internet or other CS are fed onto modem in the CS during downlink process. Optical signal from the optical source is modulated by the RF signal. After that, the modulated signal will pass through optical fiber toward the BSs. As soon as the signal reaches the BS, photodetector (PD) will function as a detector to detect the modulated optical signal. The PD will also recover the signal before the signal is transmitted through antenna of the BS toward the mobile host. With the similar concept, reverse process is executed for uplink process between mobile host and CS. When the BS receives the signals, optical signal from the LD will be modulated to amplified and transmitted straight toward CS.

In order to determine either the receiver of the RoF in a good quality or not, we can measure and analyze the bit error rate (BER), Q factor value and the eye opening of the resulting result. Bit error rate is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference and distortion orbit synchronization errors. International Telecommunication Union (ITU) has stated that the minimum value of BER of RoF must be below than 10^{-9}. Basically, the value of BER is depending on the measurement time and factors lead to the error. The value of Q depends on the value of BER. There are several ways to determine either our obtained q factor is suitable for our BER value or not. The easiest way is to determine it from BER and Q factor graph. **Figure 2** shows the graph that indicates the relationship between the value of BER and Q factor.
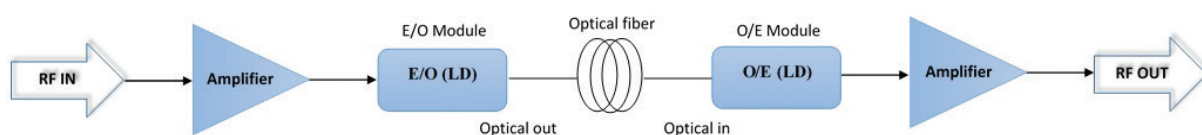

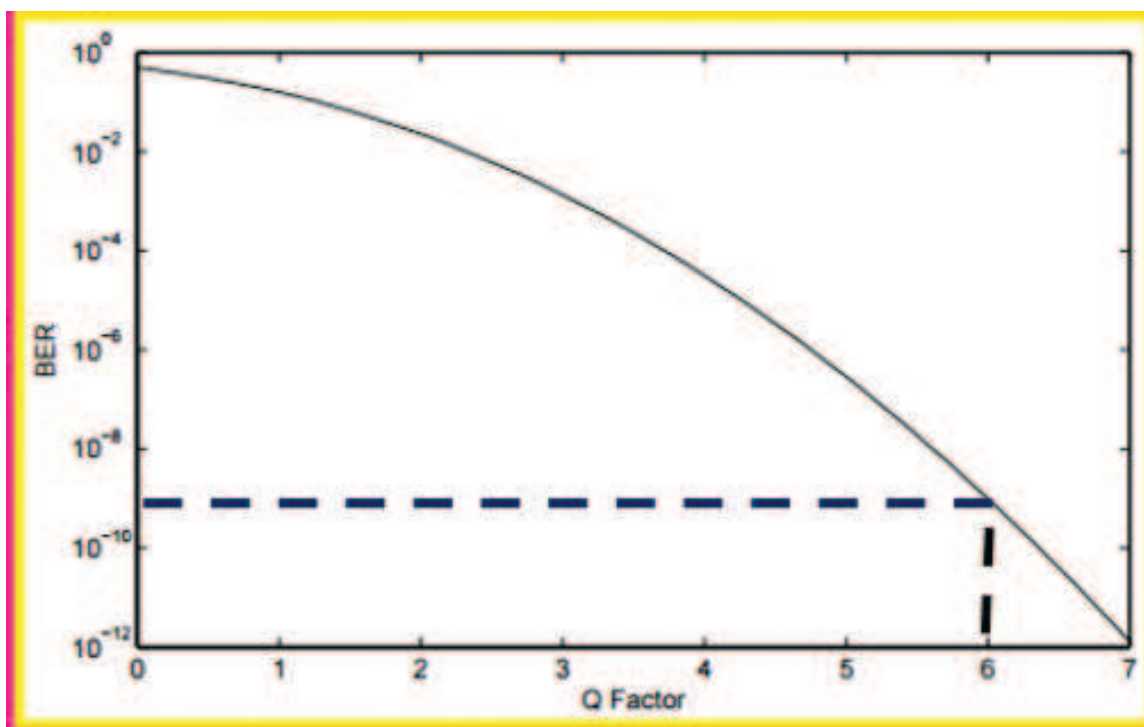**Figure 1.** Basic construction of radio over fiber.

Figure 2. BER versus Q factor.

From the graph, we can see that the value of Q factor increases when the BER decreases. From the graph also, we could see that the value of Q factor for 10^{-9} of BER is approximately 6. Thus, RoF system should have a value of Q factor more than 6 in order to obtain a very good performance of its receiver.

The receiver performance of RoF can also be measured by analyzing the eye diagram of the result after the design has been simulated. Eye diagram analyzer shows multiple traces of a modulated signal to produce eye diagram. This eye diagram is an oscilloscope display where the eye pattern diagram corresponds to minimal signal distortion due to intersymbol interference (ISI) and noise appear in the system [3]. The measurements of eye pattern are made based on time domain. The effect of waveform distortion will appear on the screen of regular BER test equipment. There are many information that could be obtained from eye pattern display. Time interval over which signal that has been reach at the receiver could be sampled without any error causes by ISI could be defined by the width of the eye opening. Noise margin can be determined by looking at the height of eye opening at specified sampling time.

2. Overview of radio over fiber

In 1990, RoF is firstly demonstrated for mobile telephone services or cordless. In this technology, highly linear optic fiber links are used to connect CS and BSs so that RF signal distribution between CS and BSs can be done. Processes involving modulation, demodulation,

coding and routing are executed mostly at CS. That means, the only processes occur in BSs only converting optical signal to electrical signal or vice versa. A lot of studies and research have been done just to investigate the limitation and generate new idea to increase the performance of RoF technologies.

Basic RoF consists of all hardware that enable to foist RF signal on an optical carrier at the transmitter side. It also needs fiber optic link to distribute the signal from CS to BSs. At the receiver side, RoF required all the hardware needed to recover the signal from the optical carrier.

2.1. Optical transmission link

2.1.1. Optical fiber

Optical fiber is a platform or a medium to carry information in the form of light from a point to another point. Functioning as a waveguide that will allow the propagation of light, a fiber is a thin filament of glass. One of the advantages of fiber is it provides a path for light with some losses due to the concept of total internal reflection.

In communication system, there are three types of optical fiber, which are step-index multimode, step-index single mode and graded index. Step-index multimode fiber is measured from cladding to the core to cladding as it serves an index of refraction profile that steps from low to high to low. For step index single mode, only one path is allowed for the light to travel in the fiber. Graded index provides large core diameter and higher bandwidth of single-mode fiber.

Optical fiber provides two regions that have low attenuation. First region is at approximately 1300 nm, which has attenuation less than 0.5 dB/km and bandwidth 25 THz. Second region is at approximately 1550 nm, which has attenuation less than 0.2 dB/km and also has bandwidth 25 THz [4]. This combination of two regions will make the total bandwidth as much as 50 THz. Due to the both low attenuation regions, signal loss in data transmission will be very small. Thus, we do not need a lot of amplifiers and repeaters.

2.1.2. Attenuation, dispersion and nonlinearities in fiber

In a fiber optic, attenuation can affect the signal power during the propagation of the signal through distances. Attenuation is a must aspect need to be considered in order to determine the longest distance that signal can go for a given sensitivity of the receiver and the power of the transmitter.

Widening of pulse duration when it propagates through a fiber is known as dispersion. When one pulse starts widening, the pulse is interfering with another pulse besides it. Thus, intersymbol interference (ISI) can happen. Because of this phenomenon, the pulse spacing and the maximum transmission will be limited. There are several types of dispersions and one of them is intermodal dispersion. Intermodal dispersion can happen when several modes of similar signal travels at different velocities through the fiber. Single-mode fiber would not have this kind of dispersion.

Chromatic dispersion is another type of dispersion. Most system will have this type of dispersion since there is no laser able to create a signal that having a single wavelength. Wavelength will be functioning as an index of refraction in dispersive medium. Certain wavelength will travel more fast than other wavelength if the signal that being transmitted has more than one wavelength [5]. Waveguide dispersion might be happen when the propagation of not similar wavelengths depends on characteristics of the waveguide such as indices and shape of fiber core and cladding. Chromatic dispersion is almost 0 in single-mode fiber at 1330 nm. About 1330 nm is also a low attenuation region, and thus, fibers with 0 dispersion can be achieved by using advance techniques such as dispersion shifting.

Nonlinearities may cause an attenuation, distortion and cross-channel interference. Its effect is able to affect the performance of wavelength division multiplexing (WDM) system. In WDM system, nonlinear effects can affect the spacing between similar wavelength channels, limit the maximum power of any channel and able to limit the maximum bit rate.

2.2. Optical transmitter

2.2.1. Optical sources

The most common of light sources used in fiber optic communications are laser diode and light-emitting diode (LED). The benefit of these devices is both have output power for wide range applications. The power also can be directly modulated where the input current is varied to the devices. The efficiency is also high, and they are compatible with the optical fiber.

The diffrence between LED and laser diode is that the laser diodes gives a coherent output where the optical energy is produced in an optical resonant cavity. **Figure 3** shows a basic structure of a laser.

Two mirrors in the laser will form a space between both of them called cavity, a lasing medium that occupied the cavity and a device for excitation. Lasing medium will receive current by the excitation devices and will produce a photon of light. The photon will reflect off the mirrors at both end of the cavity and will go through the medium again.
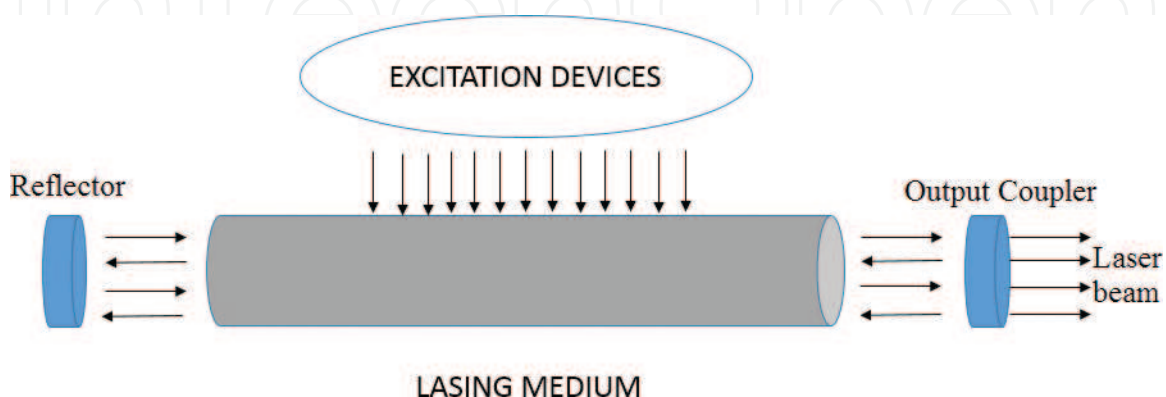

Figure 3. Laser structure.

2.2.2. Optical modulation and line coding

To transmit information across an optical fiber, the data are compulsory to be encoded or modulated onto a laser signal to allow the data being transported through the optical. There is variation of method for modulation. This is including an analog techniques such as frequency modulation (FM), phase modulation (PM) and amplitude modulation (AM). For digital signal, method of modulation includes amplitude shift keying (ASK), phase shift keying (PSK) and frequency shift keying. Among these techniques, binary ASK is the most preferable due to its simplicity. In the systems implementing ASK, the laser is switched on and of to achieved modulation techniques [6]. Current optical communication system also reported on the usage of on-off-Keying (OOK) and DPSK modulations.

To transport digitized information in a communication link, format of transmission the signal must be considered. The signal format is so important since the receiver needs to extract accurately the timing information from the incoming signal. Line coding has several principal functions and one of it is to minimize the errors which causes by noise or any interference effects in the bit stream. The easiest method for encoding data or information is unipolar return to zero (NRZ) code. Logic 1 is represented by a light source that fills the whole bit period, while logic 0 is represented by no pulse transmitted. The process turns the voltage on and off and that's why it is known as (ASK) or on-off keying (OOK). It is essential for NRZ to have a minimum bandwidth and NRZ must be simple to generate and decode.

2.3. Optical receiver

Optical receiver consists of signal processing circuitry, an amplifier and a photodetector [7]. The first thing receiver did when received a signal was converting the optical signal into an electrical signal. After that, the signal will be amplified to an optimum level so that the following process can be done. It is essential to determine and predict the performance of the system based on mathematical models of many receiver stages in order to design a receiver. Also, when designing a receiver, noises and distortions contributed by component in every stage must be considered. Plus, the receiver must have the ability in detecting weak or distorted signals, ability in making a decision on type of received signal and ability to reshaping the distortion signal. This is why it is more complicated compared to process of designing a transmitter. Bit error rate is the most important criteria in measuring RoF system. Other than that are Q factor and the opening of eye diagram.

The height of the eye diagram opening indicated the level of signal distortion. The upper level of the eye represents binary '1' and the bottom level represents binary '0'. Higher eye opening height is desirable, as this indicating that the binary '1' and '0' can be distinguished well. The height of eye opening at a specified time corresponds to the noise margin achieved.

2.3.1. Photodetector

It is compulsory for a receiver to have a device that can interpret the information in the optical signal. Photodetector is a device that can convert the incoming photonic stream into a

stream of electrons. When the optical signals reached the receiver, it is in weak and distort condition after undergoes the optical fiber. Thus, photodetector should be sensitive to the emission wavelength range of the optical sources being used. Photodetector also must have an addition of noise to the system, and most importantly, it has to response fast to handle the target data rate. Also, photodetector must be immune to the change of temperature and must be compatible with the physical dimensions of optical fiber. After the photodetector changes the optical signal into an electrical signal, the signal will be amplified and will undergo the threshold device. To determine either the bit is 0 or 1, the presence of light is referred to during the bit duration. It depends on either the electron stream is below or above a certain threshold.

PIN photodiode is the most usable semiconductor photodetector. The structure of this device as shown in **Figure 4** consists of p and n regions. Both regions are separated by intrinsic (i) region [8]. For normal operation, an optimum reverse-bias voltage is supplied across the photodiode to allow the intrinsic region completely depleted of carries. This will cause the n and p carrier concentrations that become less than impurity concentrations in the region. When a photon flux Φ penetrated into the device, the flux is absorbed.

In PIN photodetector, the light absorption causes the formation of electron-hole pairs. Then, the hole and electron are drifted to the opposite direction, causing the flow of current. More current flows as more light enter the photodetector, which giving rise to the number of electron-hole pairs.

When the energy of an incident photon is higher than or equal to the semiconductor's band-gap energy, the photon excite an electron from valence band to the conduction band by give up its energy. The absorption process will form an electron-hole pairs known as photo carriers. Normally, the photodetector is designed so that those carriers are mainly generated in the depleted intrinsic region. This region has the most absorption of incident light. The large amount of electric field will make the carriers separating between each other and will be collected across the reverse biased junction. Thus, current flow will increase in the external circuit where every carrier pair generated has one electron flowing.
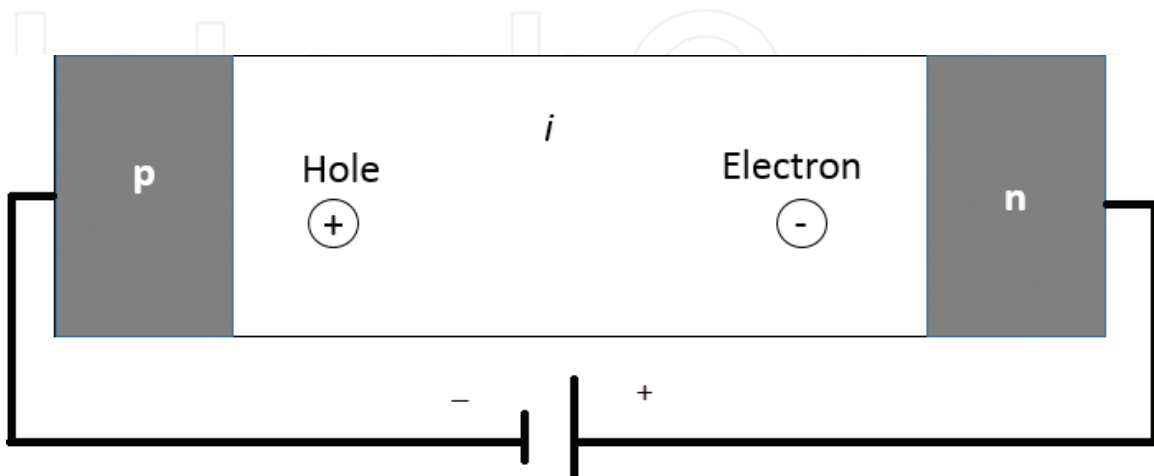

Figure 4. PIN photodiode structure.

2.3.2. Optical amplifier

Optical amplifiers can contribute a lot to long haul or local networks even optical signal still can transmit a long distance without amplifiers. There are several techniques of optical amplification. 1R (regeneration) techniques provide a booster to power up the signal. It does not restore the shape and the timing of signal. It also serves a total data transparency. 2R (regeneration & reshaping) amplification is a technique where the optical signal will be transformed into electrical signal before it directly used to modulate a laser.

3R (regeneration, reshaping, relocking) techniques change the data stream into electronic signal and after that retransmit the signal optically to amplifies the signal [9]. Noise can be eliminated much through the reshaping process where the signal produces back the original pulse shape of each bit. Mostly, reshaping works on digital signal but for some cases it may also works on analog signal but relocking does not work on analog modulated sign.

Basically, there are three main types of optical amplifiers. They are semiconductor optical amplifier (SOA), doped fiber amplifier (DFA) and Raman amplifier. The main function of all amplifiers is to boost the power level of incident light through optical power transfer process. Also, this process can be done through a stimulated emission. Using the concept of laser diode, the mechanism of SOA and DFA is creating the population inversion which is needed for simulated emission. Optical amplifier does not have the ability to generate coherent optical output since it does not have optical feedback which is compulsory for lasing. Thus, optical amplifier can only increase the signal levels.

The amplifier gained an energy from a pump, which is an external source as shown in **Figure 5**. Technically, the external sources are supplying an energy to the electrons in the active medium. This will cause the electrons increased and served a population inversion. The excited electrons will drop to lower level because the electrons are triggered by the incoming photon signal through the process of simulated emission. The output of the signal will be amplified since one incoming photon stimulates a cascaded effect in which way equal energy of photons is emitted by a lot of excited electrons when they hit the ground state.

Advantage of SOA is that this amplifier can be implemented if both signal processing and switching functions were call in optical networks. The drawbacks of SOA is it has rapid gain response that will cause the gain at specific wavelength fluctuate with signal rate for speed up
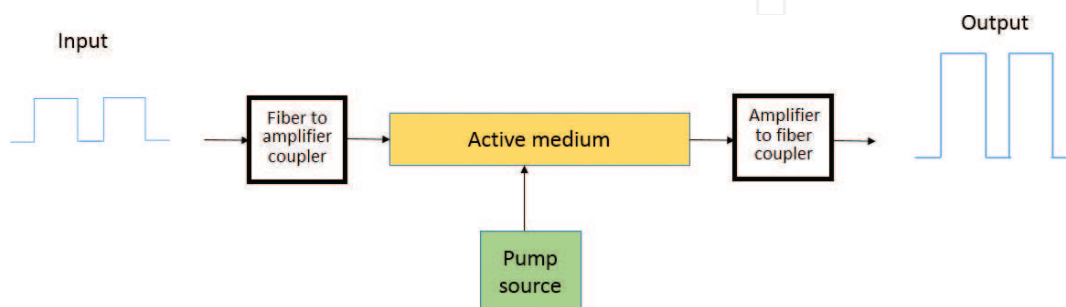

Figure 5. Signal amplification by an optical amplifier.

to some Gb/s. The overall gain also can be affected, and this will cause the signal gain of other wavelengths fluctuate. Thus, cross-talk effect can occur.

For DFA, the length of fiber will be doped with an element that able to amplify the light [10]. The most common element is erbium. The main advantage for this type of amplifier is it can pump the devices at some different wavelengths. DFA also has small coupling loss and low dependence of gain on light polarization. Plus, DFA is immune from interference effects since the gain responses are constant for signal modulations greater than few kilohertz.

Raman amplifier has a transfer of optical power form high power pump wavelength to light wave signals at longer wavelengths. Raman amplification does not need process of population inversion. It is based on stimulated Raman scattering (SRS) which is a nonlinear effect. This effect normally occurs in fibers at high optical powers. Raman gain mechanism was achieved through a discrete amplifier. This type of amplifier can be used in any wavelength band since the gain is based on SRS where the induced transfer of optical power from shorter pump wavelengths to longer signal wavelengths.

3. Overview of wavelength division multiplexing (WDM)

Various methods can be executed to gain full duplex transmission of RoF system and wavelength division multiplexing (WDM) is one of it. WDM has characteristic where the discrete wavelength will form an orthogonal set of carriers that can be separated, routed and switched without interfering with each other [11]. With WDM, many wavelengths are able to be transmitted over a large distance and the downlink and uplink data can be transmitted at the same time through single-mode fiber.

The design of WDM involves some requirements such as selecting various optical sources that has narrow spectral emissions bands. The most straightforward and simplest method can be done by choosing a series of individual lasers that emits at its own specific wavelength. The process of selecting optical sources requires small number of wavelength channel but can be cumbersome for links carrying many wavelengths. In order to implement WDM network, a combination of many passive and active component is need. The difference between passive and active components is passive components and is limited in their ability since passive components did not require an external control to operate, whereas active component can be controlled and has a wide network ability.

WDM contributes simplification to the network. With this method, different wavelengths are allocated toward individually BSs. Thus, the network will be simple and the service upgrades can be done easier. WDM multiplexes optical signals that came from multiple sources, and the signal will be amplified before it is transmitted through optical fiber to under goes demultiplexer so that it can be addressed to each BS as shown in **Figure 6**.

There are two types of WDM architecture: coarse wavelength division multiplexing (CWDM) [12] and dense wavelength division multiplexing (DWDM) [13]. Typically, CWDM systems provide eight wavelengths which separated by 20 nm, from 1470 to 1610 nm. To increase the
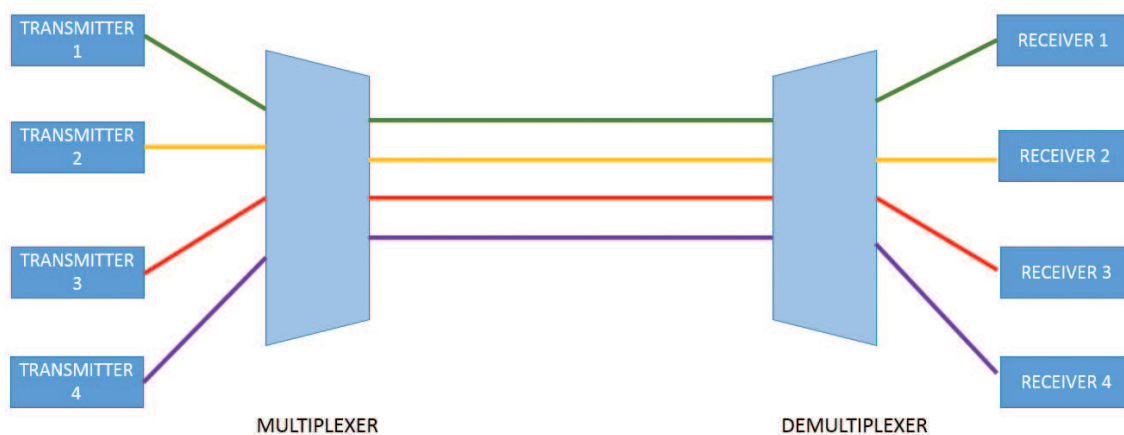
Figure 6. Wavelength division multiplexing.

channel of CWDM to 16, number of wavelength could be increased by using 1310 nm window. One of the advantages of CWDM is that the cost of the optics is 1/3 of the cost of same DWDM optic. This makes that the CDWM is preferable than DWDM. CWDM is able to match the basic capabilities of DWDM but with lower cost and capacity. Typically, CWDM is used for short-range communications. In addition, CWDM equipment is more compact and cost-effective if compared to DWDM designs.

DWDM network systems provide up to 96 wavelengths, which normally has less than 0.4 nm spacing. DWDM is used for long-haul transmission where wavelengths are compacted tightly together. Erbium-doped fiber amplifiers (EDFA) can help the system of DWDM to work over thousands of kilometers. CWDM is not implemented in long haul transmission, where the distance reaches up to thousands of kilometers, causing simpler overall sytem components requirement. This leads to lesser cost implementation, despite of having some limita-tions especially in propagation distance.

4. Methodology

The methodology used in designing RoF system consists of familiarization with Optisystem software, designing system, generate component and simulation object, running the simulation and analyze the data. Optisystem software is used to design, construct and simulate the RoF topology.

Optisystem software is a comprehensive software that provides a platform to plan, test, and simulate optical links in the transmission layer of modern optical networks. Optisystem is also an optical communication system simulation package for the design, testing, and optimization of 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.

A system level simulator based on the realistic modeling of fiber-optic communication systems, Optisystem, possesses a powerful simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be easily expanded with the addition of user components and seamless interfaces to a range of widely used tools. Optisystem is compatible with Optiwave's Optiamplifier and OptiBPM design tools. Optisystem serves a wide range of applications, from CATV/WDM network design and SONET/SDH ring design to map design and transmitter, channel, amplifier, and receiver design. Optisystem contains a MATLAB component that enables the user to call MATLAB within its environment to incorporate new components or models into the software. Optisystem uses the MATLAB.dll files to evaluate the MATLAB script in the component to perform the calculations.

Designing RoF system on Optisystem software includes generation of component, simulation object and makes connection between all of them. It is very important to design a very good topology so that the maximum performance of RoF's receiver can be achieved.

5. Simulation

5.1. System design

To send two signals, two continuous wave lasers are used in order to resonate 193.1 and 193.2 THz, respectively, as shown in **Figures 7** and **8**, respectively. To obtain an electrical network that simple and low in speed, a pulse generator is needed. A pseudo-random bit (PRBS) generator is used to operate a Gaussian pulse generator so that baseband signal can be generated. 1 Gbps was set as the bit rate. The PRBS generator indicates the random source of data. To simulate the signal, 1 Gbps per channel was set as the data rate for the simulation.

As the carrier frequency is 2.7 GHz for transmitter 1 and 1.7 GHz for transmitter 2, an amplitude modulator is operated by the 1 Gbps baseband signal. After that, the amplitude modulator will operate the LiNb Mach-Zehnder modulator (MZM)'s port 1. The main function of the amplitude modulator is to translate the baseband signal onto the RF clock. At a frequency of 49.25 MHz for both transmitter, the SCM carrier generator will mix with the RF signal. A 90° hybrid coupler is applied to the signal where it is utilized to separate that the input signal becomes 2 outputs that having 90° phase shift difference between each other. The separated signals are sent to the two arm of M-Z Modulator. At the both transmitter sides, to allow the signal being transmitted along the fiber, the signals change from digital to analog form.

Wavelength digital multiplexer (WDM) is used to multiplex all signals from the transmitter. The bandwidth of the multiplexer was set to 10 GHz. EDFA amplifier with power 10 dBm is used to boost up the power of the optical signal. Then, through an optical fiber, the signals are transmitted. This process can be seen in **Figure 9**.
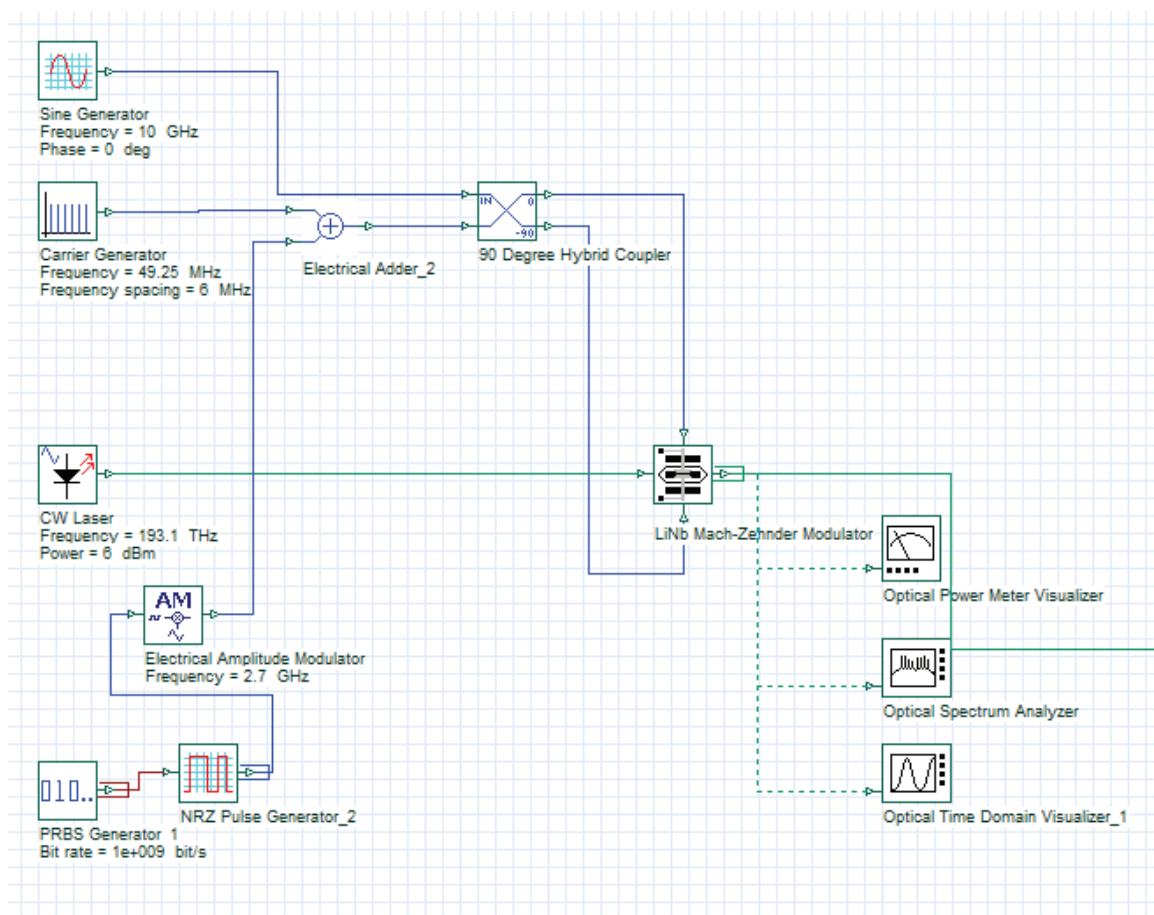
Figure 7. Transmitter 1.

As soon as the signal reaches the receiver side, demultiplexer is used to demultiplex the signals before the signals being distributed to its own receivers. 16 GHz is chosen as the bandwidth of the demultiplexer. At the receiver 1 as shown in **Figure 10**, the signal is once again amplified by using EDFA amplifier with power of 20 dBm. After that, photodetector is used to convert the optical signal into electrical form. Then, bandpass Bessel filter received the signal and filtered the signal. The received signal is amplified by using electrical amplifier with 15 dB gain before demodulated by using demodulator. 3R regenerator technique is applied to the signal before the BER analyzer analyses the received.

Same concept is applied at the second receiver. The EDFA amplifier is used to boost the power of the optical signal after the signal is demultiplexed. Photodetector will transform the signal into electrical form. The converted signal will be amplified by electrical amplifier, and the signal will be passed to the Bessel filter. After the signal has been filtered, demodulator is used to demodulate the signal before the 3R regenerator amplification is applied to the signal. Lastly, BER analyzer will analyze the signal. The configuration of the second receiver can be seen in **Figure 11**.
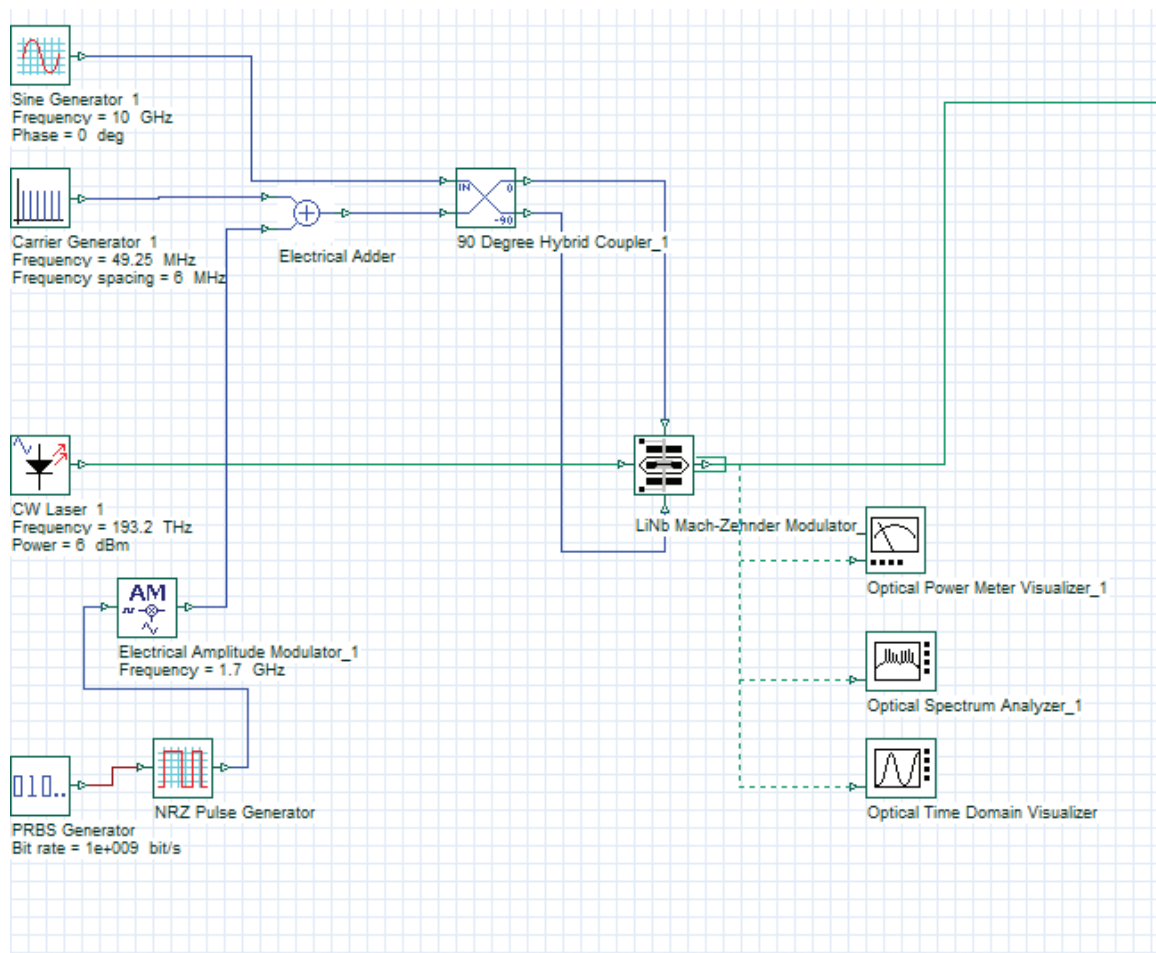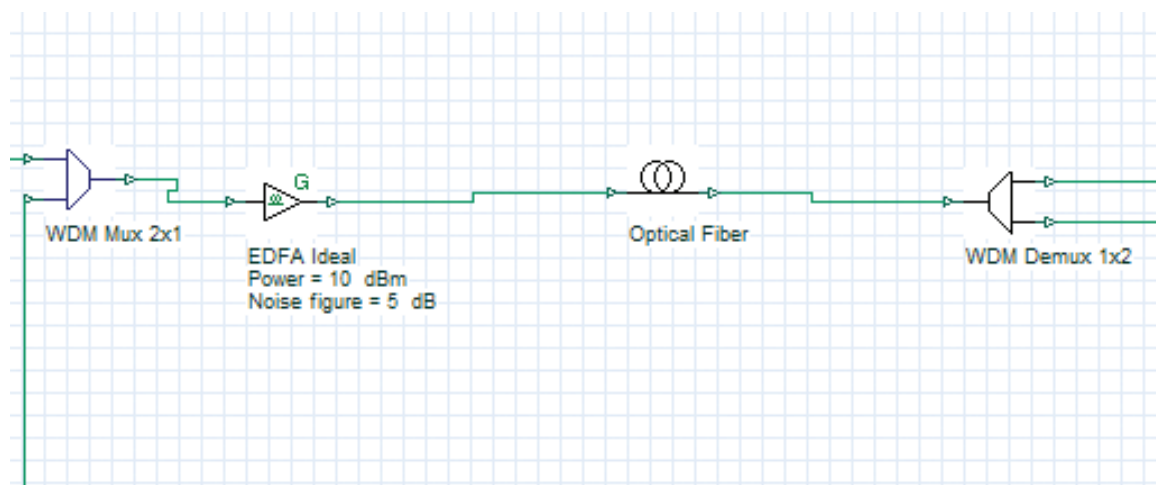
Figure 8. Transmitter 2.

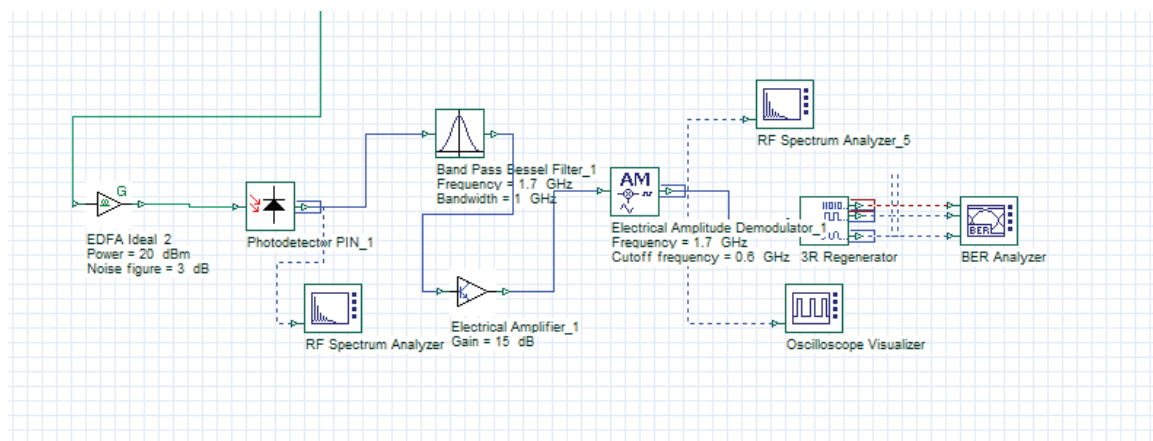**Figure 9.** Transmission of data through optical fiber.

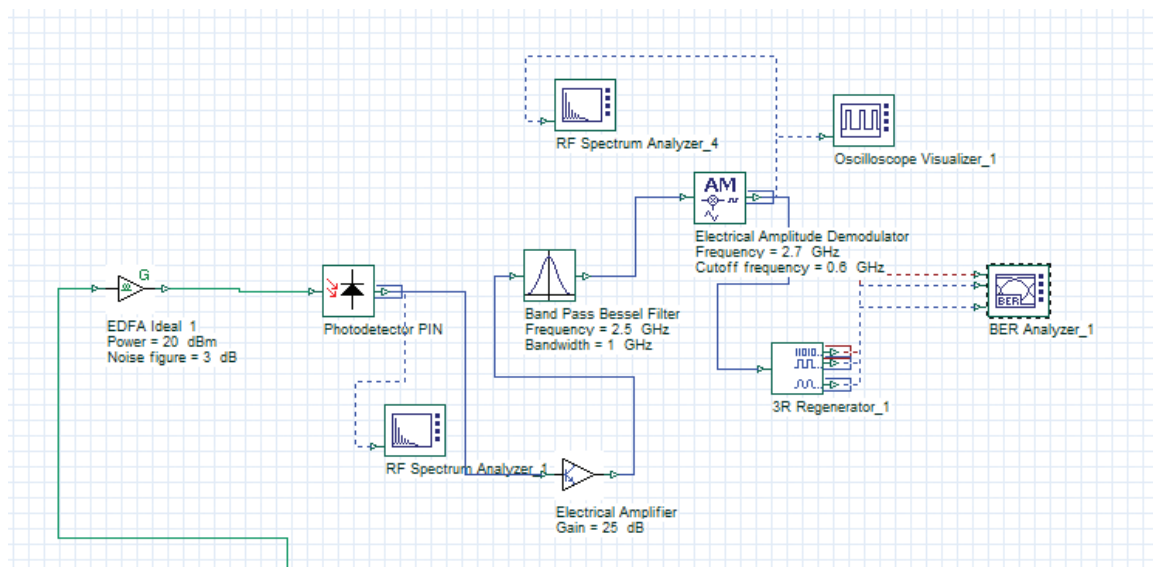**Figure 10.** Receiver 1.

Figure 11. Receiver 2.

5.2. Single parameter optimization (SPO)

SPO can benefit a lot in the simulation. It helps to optimize parameters so we could set a target for the simulation's result. With optimization tools, the software can optimize the fiber length of the EDFA so that a maximum gain could be obtained. It can also calculate the attenuation or the gain in order to get a desired Q factor and minimize the BER by optimizing the fiber length of the system.

After all components had been connected and SPO had been inserted to the topology, the simulation is run to see the result. After the run button is clicked, it will calculate all the calculation of the system. To measure the BER and the Q factor, just simply double click at the BER analyzer component. It will give an eye diagram showing eye opening, BER value and Q factor value. The example of the result is shown as in **Figure 12**.
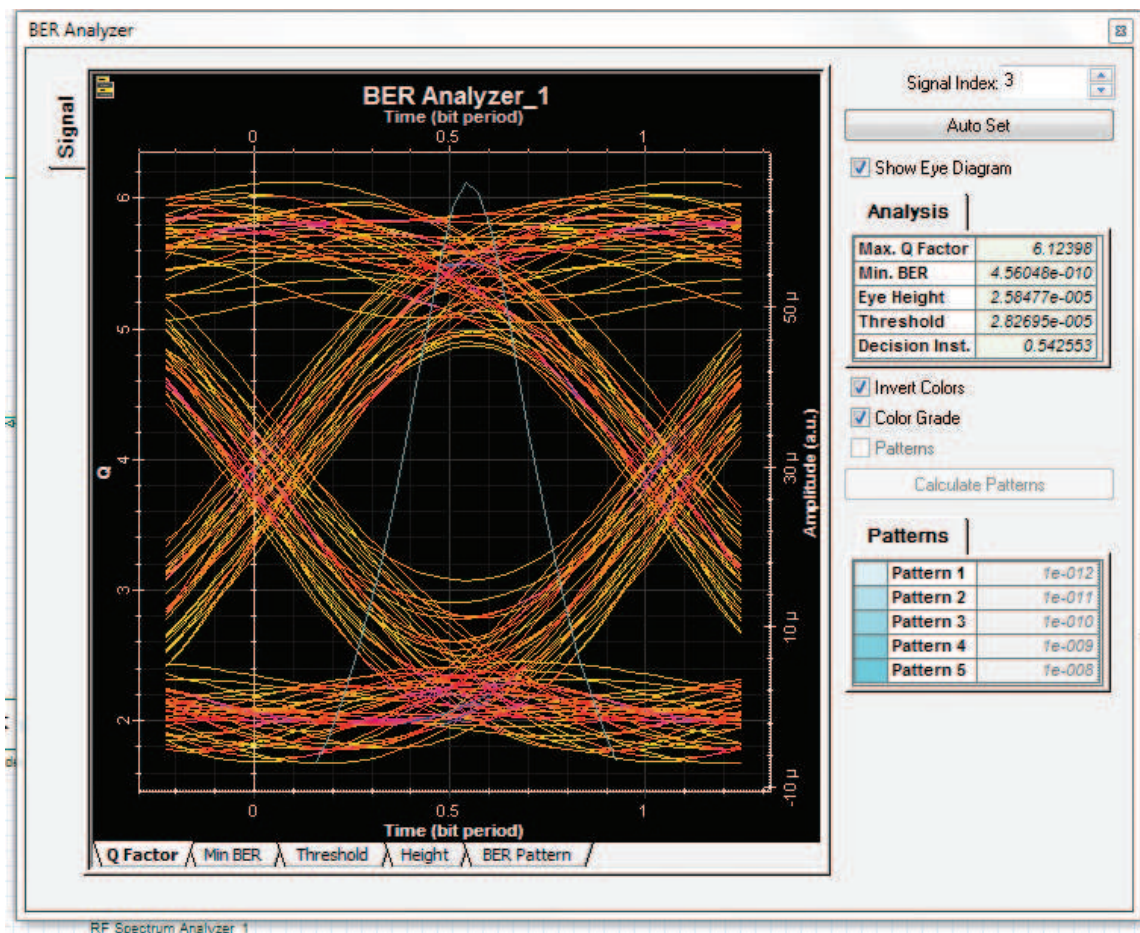
Figure 12. Example of BER analyzer's result.

As shown in the example above, the result tells us that the BER is 4.560^{-10} and the Q factor is 6.124. There is an eye opening in the result of the example which is 2.585^{-5}. The example is a quite good result since the BER is less than 10^{-9} and the Q factor is more than 6. If all the receivers receive an output just like the example above, all objectives had been achieved.

6. Results

After the simulation is done, the performance of the receiver is analyzed by referring the BER analyzer and the eye diagram at the two receivers. All the results can be seen in **Figures 13–16**.

For receiver 1, the BER analyzer shows that the BER for the received signal is 3.54×10^{-20}. The Q factor for this receiver is 9.13. This shows that this receiver has a very good performance since the number of BER is above 10^{-9} and the Q factor is more than 6.

As mentioned before, the height of the eye diagram defines the immunity of the received signal to the noise. The eye diagram for receiver 1 shows an eye opening of 0.0004.
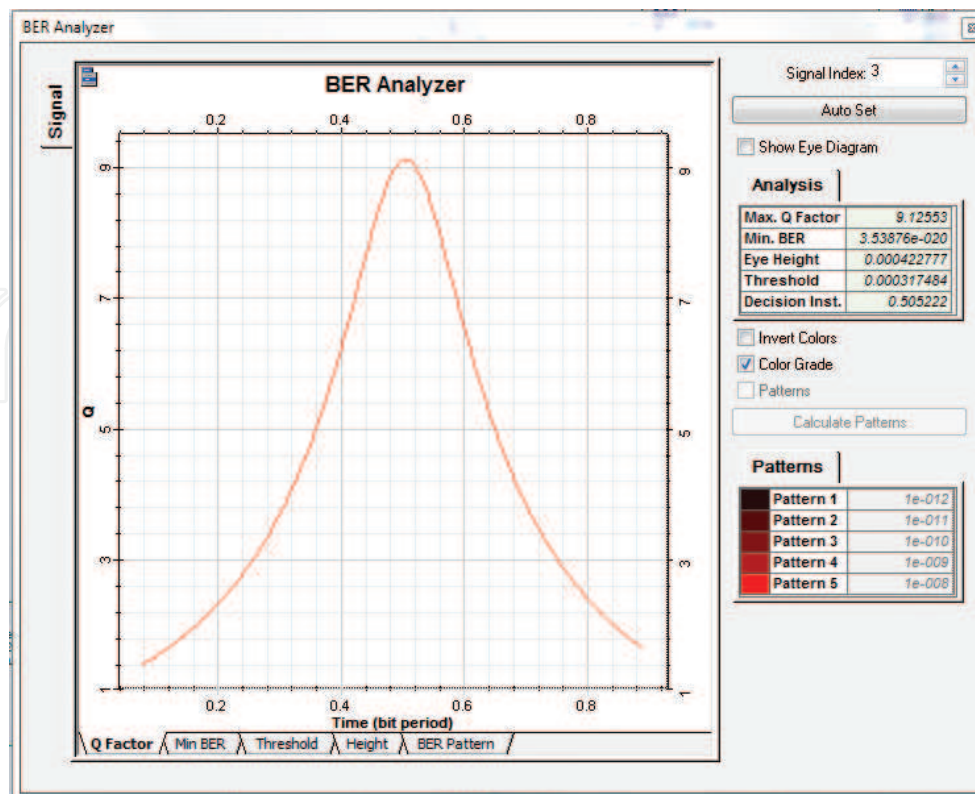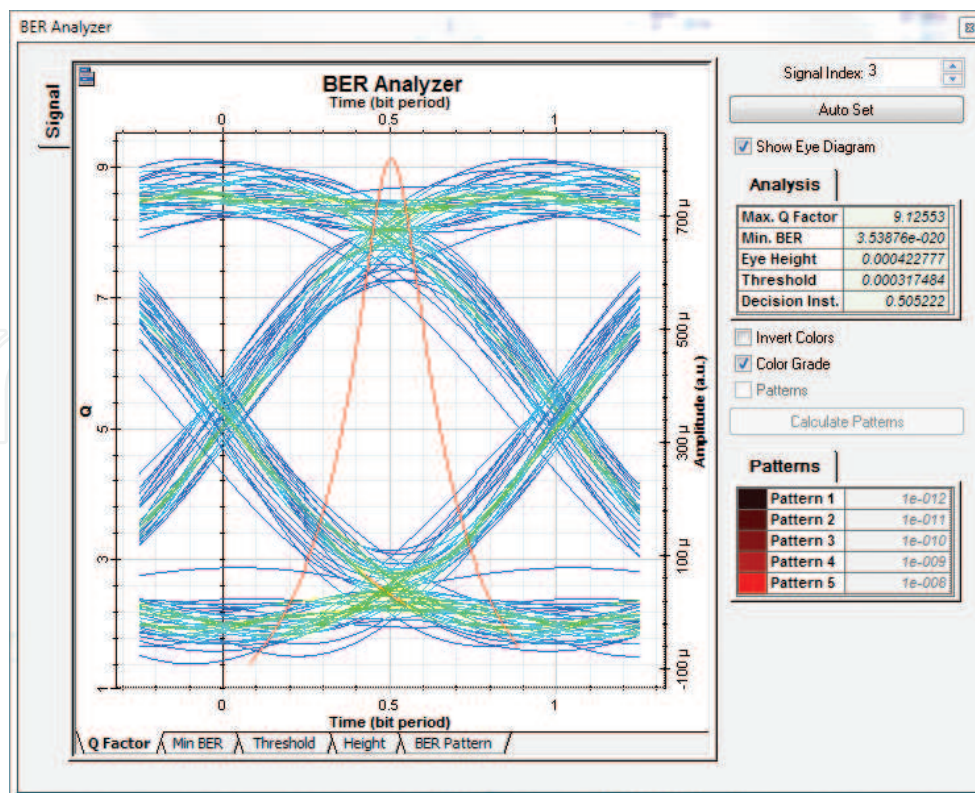
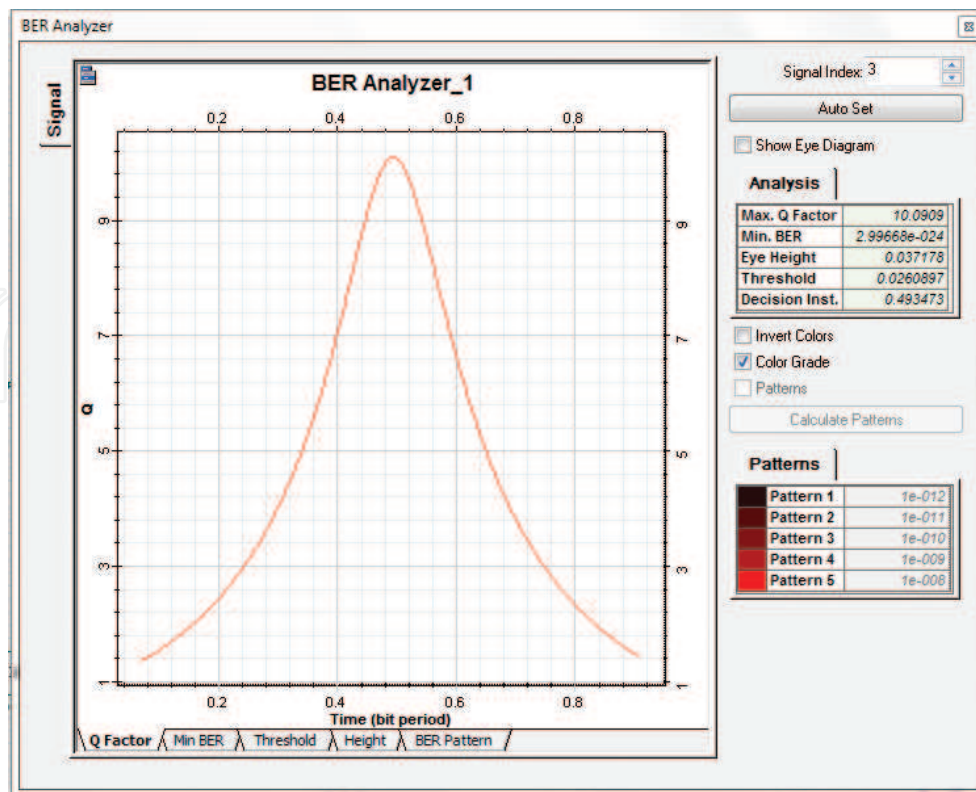**Figure 13.** BER result for receiver 1.

Figure 14. Eye diagram for receiver 1.
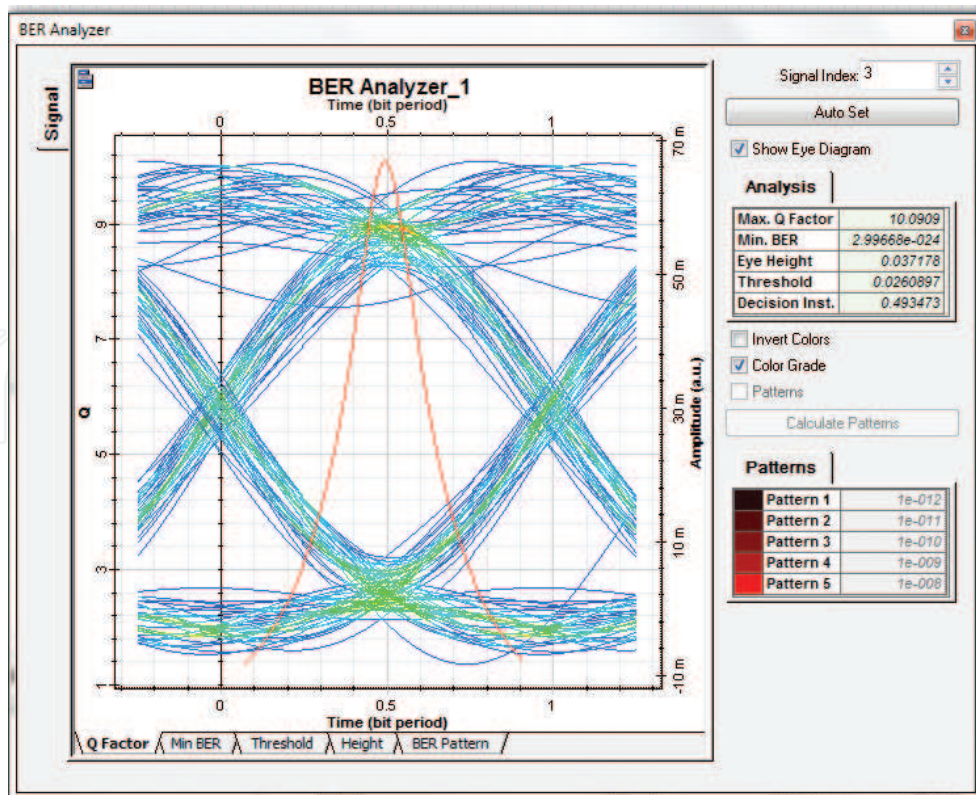
Figure 15. BER result for receiver 2.

Figure 16. Eye diagram for receiver 2.

For receiver 2, the received signal has BER of 3×10^{-24}. The Q factor for the received signal is 10.09. Thus, the BER analyser shows that this receiver also received a good quality of signal.

The eye opening of the eye diagram is 0.0371. It shows that received signal in receiver 2 has more immunity to noise compared to the received signal in receiver 1.

7. Conclusion

Basically, RoF is a transmission system of analog signal since it distributes a radio waveform from CS to BS direct at radio carrier frequency. A lot of way can be studied and developed to increase the performance of the RoF. This is why RoF is an ideal technology for the future generation. RoF also provides low attenuation and broad bandwidth. It is also immune to electromagnetic interference (EMI), which is a radio-frequency interference where disturbance generated by an external sources that affects an electric circuit by electromagnetic induction, coupling or conduction.

RoF system employing WDM technique is simulated using Optisystem 12.0. WDM is among the best method to be used in RoF. WDM enables transmission of multiple signals through a single fiber over large and can exploit the fiber network bandwidth. Various transmission formats can be supported by various optical channels. Plus, WDM enables the capacity of an optical fiber increase compared to simple point to point link that only enable to carry only single wavelength.

EDFA amplifier is used in this system because it has a lot of advantages. EDFA amplifier provides low noise figure. It also has an independent polarization. Thirdly, the dynamic range is large. The power transfer efficiency of EDFA amplifier is quite large. It also has relatively flat gain. Thus, it is very suitable for long-distance communication.

RoF is a technology that really cost-effective because in this technology, all of the expensive components can be shared by several BS. The installation and maintenance of RoF are easy since the concept of centralized configuration enables all sensitive components being located in safer surrounding. To modulate an optical sources, an electrical signal is used, and the modulated signal will be carried out through optical fiber to the receiver side. When the signal is directly modulated to the optical fiber, power consumption could be decreased, while the frequency of radio carriers is very high at the antenna side. Power consumption also can be decreased by having a simple radio station. All complex equipment and devices are kept at the CS.

RoF also provides operational benefits in terms of operational flexibility. Intensity modulation direct detection (IMDD) technique could be made in order to operate as a linear system. Low dispersion fiber (SMF) with combination with modulated RoF sub carriers (SCM) could be used to achieve linear system. The same radio over fiber network can be used to distribute multi-operator and multi-service traffic which results in huge economic savings.

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