Investigations On the Effect of Fiber Losses on The Performance of a Gigabit Ethernet Passive Optical Network (PON) Fiber to The Home (FTTH) Systems

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doi.org/10.64643/IJIRTV12I10-204472-459

***Abstract*—A new technology that has emerged in recent years is Passive Optical Networks. Fiber-to-the-home (FTTH) is experiencing great public acceptance throughout the world. Existing fiber-to-the-home (FTTH) access networks has to be upgraded, to satisfy future bandwidth demands. For meeting increasing bandwidth demands in optical networks Gigabit Ethernet passive optical network GEPON is becoming technology of choice. A network architecture based on FTTH systems with GEPON (Gigabit Ethernet Passive Optical Networks) access is investigated. FTTH provides long reach offering Triple play services (Data, Voice, Video) and also enormous bandwidth. Here a comparative investigation and study using different types of amplifiers are presented. Black box type of optical amplifier, EDFA and EY-CDFA are used for amplification. The study is done for various line coding formats. Investigation is done using OPTSIM 5.3.**

***Index Terms*—FTTH; PON; GEPON; Triple-play Services; BER.**

I. INTRODUCTION

To achieve larger transmission capacity and longer transmission distance optical communication technology has been developed rapidly. As long as data remains in optical domain higher data rates can be achieved. In order to satisfy the perceived need for future consumer applications, the vision of Fiber-to-the-Home (FTTH) has been developed. Optical fiber provides high bandwidth transport, remove “bottlenecks”, enable upgrades, and permit passive multiplexing which re-moves remote powering costs [1]. The consequent increase in the volume of generated traffic in our communication net-works and the steady increase in the demand for broadband services have motivated very much for the need to implement next generation networks. Thus, we can say that FTTH is the end game for many service providers. Passive Optical Net-work (PON) technology seems to be the best solution to alleviate the bandwidth bottleneck in the access network when compared to other broadband access technologies such as Digital Subscriber Line (DSL), and cable/modem. The first band-width breakthrough in the access network was the arrival of DSL and cable-based solutions. The complexity of the cable systems is expected to be higher than that of PONs since a coaxial cable has limited bandwidth. By applying different transmission techniques in the FTTH architecture more number of users can be accommodated. PON offers a better solution to increase the capacity of standard FTTH architectures. Although PON technology is mature for backbone networks, its user handling capacity and longer transmission distance has to be still considered for access networks. Hence, there is still a need to solutions for PON in FTTH access networks [2].

A passive optical network (PON) is also called as a fiber-optic access network architecture. This architecture using a point to multipoint scheme brings fiber cabling and signals to the home. In the architecture a single optical fiber is used to serve multiple premises typically 16-128. Optical splitters are used for this purpose.

Passive optical splitters, which are unpowered are used in this architecture. The use of such splitters reduces the cost of equipment when compared to point-to-point architectures. In such a PON architecture at the service provider's central office it consists of an optical line terminal (OLT) and at the near end users side a number of optical network units

(ONUs) are present.

When compared with point-to-point architectures a PON re-duces the amount of fiber and central office equipment re-quired. A PON is considered as a shared network, because the OLT sends a single stream of downstream traffic which can be seen by all ONUs. At the near end user side each ONU reads only the content of those packets that are addressed to it. Downstream signals are broadcasted to all premises sharing multiple users.

Upstream signals are combined using a multiple access proto-col, usually time division multiple access (TDMA).

II. FTTH USING GEPON

Here simulation of the FTTH using Gigabit Ethernet Passive Optical Network (GEPON) is done. In this FTTH, network between the OLT and the ONUs is passive, meaning that it has no power supply.

This reduces the operational cost and maintenance costs. The block for the section is shown in Figure 1.

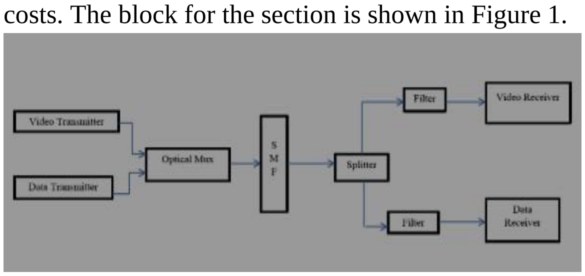

Figure 1. Schematic diagram of FTTH

The schematic diagram consists of a data transmitter of 1.25 Gb/sec and a video transmitter.

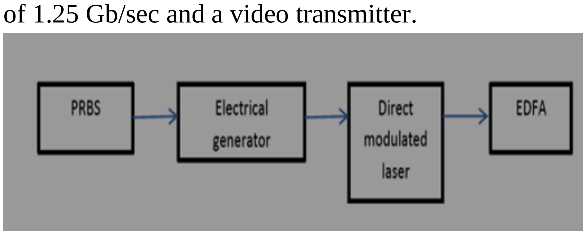

Figure 2. Schematic diagram of data transmitter

Figure 2 shows the schematic diagram of a data transmitter. The PRBS generator produced bit stream is directly fed to the NRZ electrical driver. The output from the electrical driver goes to the direct modulated laser. The output from direct modulated laser is an optical signal. The modulated light is-then amplified by the EDFA [3].

For video transmitter, there are two sine wave generator having different frequencies. The output from the sine generator goes to the input of the summer. Now the summer mixes both the frequencies and the output from summer goes to direct modulator and then the signal is amplified by amplifier. The block diagram for the video transmitter is shown in Figure 3.

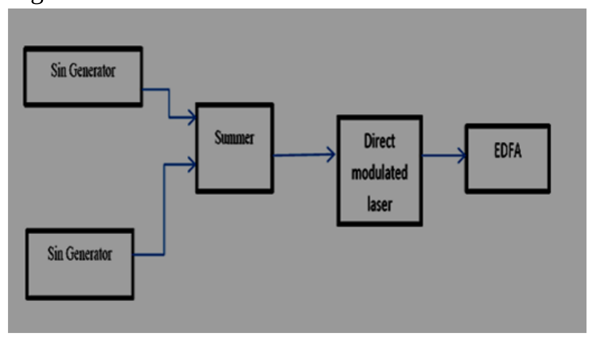

Figure 3. Schematic diagram of video transmitter

The outputs of both amplifiers are fed to multiplexer. Here both video and the voice/data combine and pass through the optical fiber. At the end of the receiver side, we have many ONU's, and every ONU has a particular receiver for both the reception of the video and the voice/data. A splitter has to be used to differentiate the particular user. From central office, after travelling through the fiber, optical signal arrives at optical network termination unit. At the subscriber, with the help of the optical filter, the signal demultiplexes into data/ voice and video components, and the data and video signal are fed to corresponding detectors. Then with help of a electrical filter both the sine waves are filtered out. Data/voice is transmitted at wavelength of 1490nm and video at 1550nm respectively. The data is transmitted at 1.25 Gb/s [4].

III. SIMULATION OF FTTH ARCHITECTURE

Here we use Optsim 5.3 to simulate the system setup of FTTH using GEPON architecture. In the simulation set up for the data transmitter section, the diagram consists of a PRBS generator which is producing 1.25 Gbits/s. The output from the PRBS is directly fed to the electrical driver. The output of the electrical driver goes to the direct modulated laser having a wavelength of 1490nm and the signal will be amplified using EDFA. Here in the present set up, black box type of optical amplifiers is used.

Now for the video transmitter section there are two sine wave generators, having two different frequencies of 55.2MHz and 547.2MHz. The output from the sine wave generators is fed as input to the summer. The summer mixes both the frequencies. The output from summer is fed to direct modulated laser of wavelength 1550nm.

Now both the data and video are multiplexed and transmitted over single mode optical fiber of length 5 to 20 Km [5].

Here we are using three simulation setups. We are using three types of optical amplifiers for amplifying the signal. The amplifiers used are black box optical amplifier, Erbium doped fiber amplifier (EDFA) and Erbium-ytterbium co-doped fiber amplifier (EYCDFA).

In the first simulation setup the output of the optical fiber is amplified using Black Box optical amplifier and fed to the input of the optical splitter which splits the input into the 1:16 outputs. In the second simulation set up output of the optical fiber is amplified using EDFA and fed to the input of the optical splitter which splits the input into the 1:16 outputs. In the third simulation setup output of the optical fiber is amplified using EYCDFA and fed to the input of the optical splitter which splits the input into the 1:16 outputs.

The splitter is used in order to differentiate the particular user. It works as a balanced splitter with the same attenuation on each output. Then the outputs are fed to the corresponding receivers. In the project, simulations are done by 1:16 splitters; which can be further expanded up to the 1:32 depending upon the capacity of the users. At the transmitter side both the voice as well as data is in the form of the electrical signal. This signal is converted to the light with the help of the laser which is then combined and transmitted through the fiber. At the receiver side the optical filters are used to separate the video and the data.

Now to convert the data and video has to be converted in to electrical form, corresponding detectors are used. Spectrum analyzers are used to measure the spectrum of the video and data. Since the data is transmitted as light pulses over the fiber, but due to Inter symbol Interference (ISI) dispersion occurs. So, to measure the error, BER Tester is used.

At the receiver side, every ONT has a particular detector for both the reception of the video and the data. APD is used as the detector [6–7]

Here in the first simulation setup a Black Box optical amplifier was used for amplification. Figure 4 shows the simulation setup of FTTH using GEPON with direct modulation and black box optical amplifier for amplification.

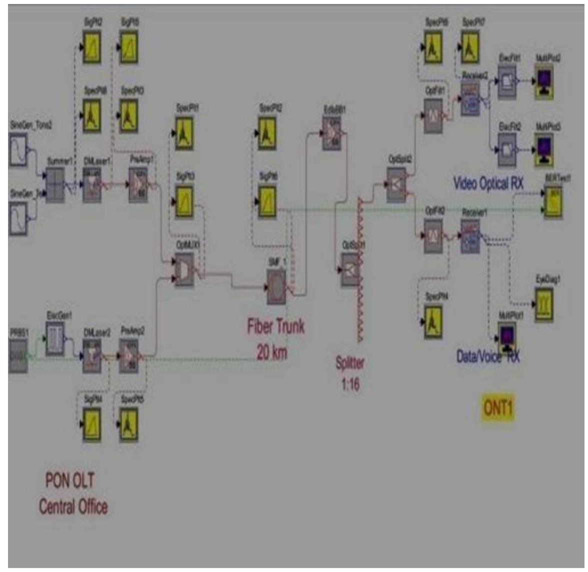

Figure 4. Simulation setup of FTTH using GEPON with direct modulation and black box optical amplifier for amplification.

Now the black box optical amplifier is replaced by EDFA. Figure 5 shows the simulation setup of FTTH using GEPON with direct modulation and EDFA for amplification. A CW laser is used as pump device. The pump wavelength is 980nm.

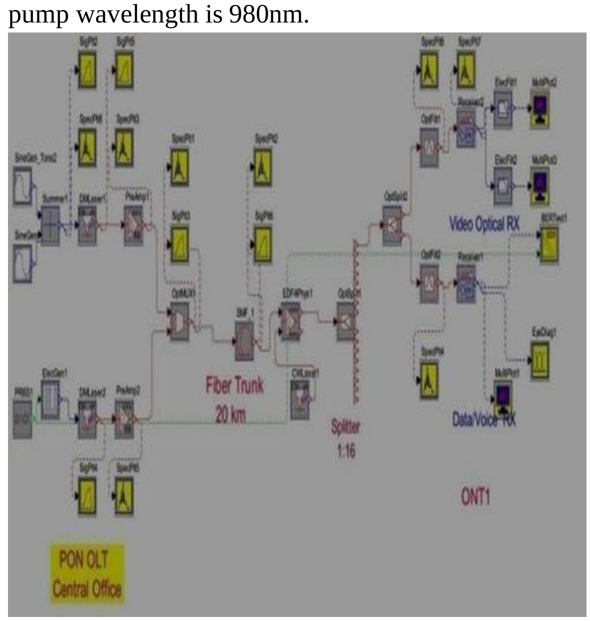

Figure 5. Simulation setup of FTTH using GEPON with direct modulation and EDFA for amplification.

Figure 6 shows the third simulation setup of FTTH using GE-PON with direct modulation and EYCDFA for amplification. Erbium-ytterbium co-doped fiber amplifier is used for ampli fictional CW laser is used as pump device. The pump wave-length is 976nm.

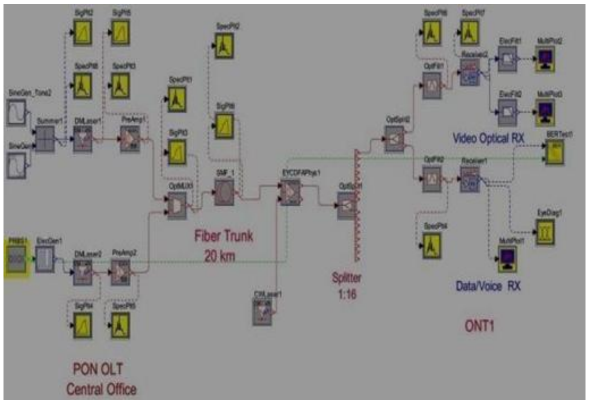

Figure 6. Simulation setup of FTTH using GEPON with direct modulation and EYCDFA for amplification.

Now in the next simulation setups show the variations in BER with fiber losses while using multi stage amplifiers are investigated. Figure 7 shows the simulation setup of FTTH using GEPON with direct modulation and multi- stage amplifier. The only difference in the setup when compared the setup in figure 4 is that two Black Box optical amplifiers were used for amplification and hence multi-stages of amplification is done. In between the two black box optical amplifiers a nonlinear fiber is there.

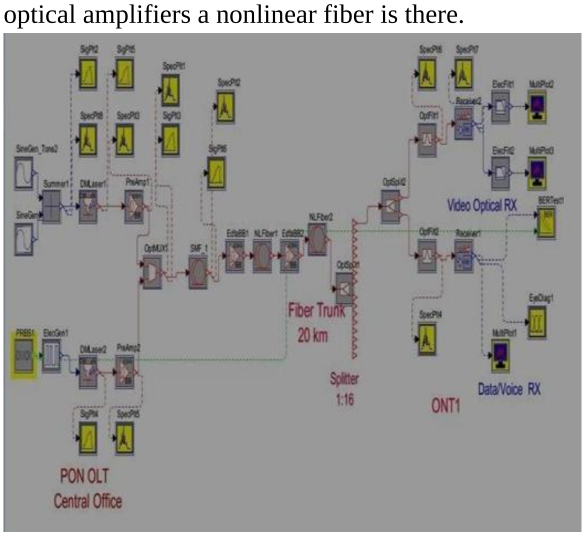

Figure 7simulation setup of FTTH using GEPON with direct modulation and multi- stage amplifier (black box optical amplifier).

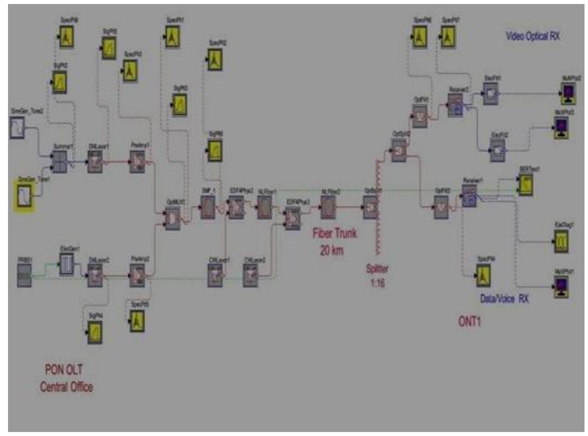

Figure 8. simulation setup of FTTH using GEPON with direct modulation and multi- stage amplifier (EDFA).

Figure 8 shows the simulation setup of FTTH using GEPON with direct modulation and multi- stage amplifier. The only difference in the setup when compared the setup in figure 5 is that, two EDFA were used for amplification and hence multi-stages of amplification is done. In between the EDFA a nonlinear fiber is there.

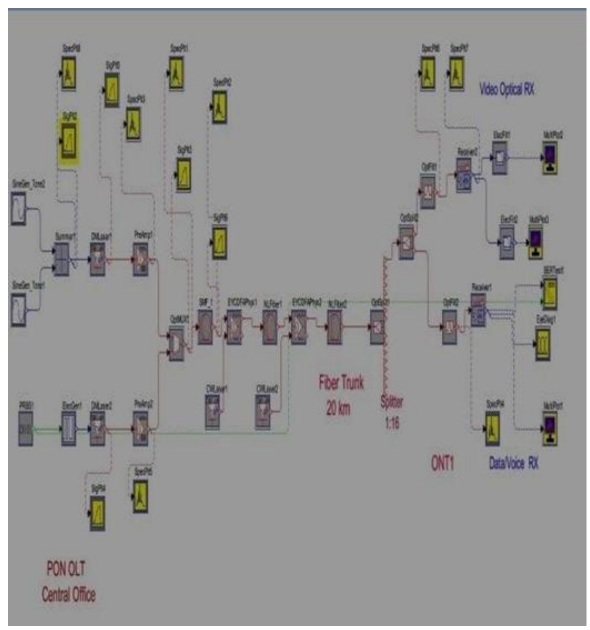

Figure 9. Simulation setup of FTTH using GEPON with direct modulation and multi- stage amplifier (EYCDFA).

Figure9 shows the simulation setup of FTTH using GEPON with direct modulation and multi- stage amplifier. The only difference in the setup when compared the setup in figure 6 is that, two EYCDFA were used for amplification and hence multi-stages of amplification is done. In between the EY-CDFA a nonlinear fiber is there.

IV RESULTS AND DISCUSSION

Optical loss is the primary performance parameter of most fiber optic components. For fiber, it is the loss per unit length or attenuation coefficient. Loss of a cable is the difference between the power coupled into the cable at the transmitter end and what comes out at the receiver end.

Attenuation is the reduction or loss of optical power as light travels through an optical fiber. The longer the fiber is and the farther the light has to travel, the more the optical signal is attenuated. Attenuation varies depending on the fiber type and the operating wavelength. Single mode fibers usually operate in the 1310 nm or 1550 nm regions where attenuation is low-est. This makes single mode fibers the best choice for long distance communication.

Fiber attenuation is caused by scattering, absorption, dispersion, bending and loses caused by splices and connectors.

Scattering (often referred to as Rayleigh scattering) is the re-flection of small amounts of light in all directions as it travels down the fiber. Some of the light escapes out of the core, while some travels back towards the source (back scattered light). Absorption occurs when impurities, such as metal particle or moisture, are trapped in the glass. These cause attenuation at specific wavelengths by absorbing the light at that wavelength and dissipating it in the form of heat energy. Moisture occurs more naturally in fiber and accounts for the rise in attenuation at the “water peak” found near 1385 nm. This is why fibers are traditionally not used in this wavelength region.

Bending occurs in two forms – micro-bending and macro-bending. Micro-bending’s are microscopic distortions along the length of a fiber, typically caused by pinching or squeezing the fiber. Macro-bending occurs when fiber is bent in a tight radius. The bend curvature creates an angle that is too sharp for light to be reflected back in the core and some of it escapes through the fiber cladding, causing attenuation.

Single mode fiber is affected by chromatic dispersion, where the boarder spectrum of certain transmitter types can result in varying travel times for different parts of a light pulse.

Optical losses of a fiber are usually expressed in decibels per kilometer (dB/km). The expression (equation 1) is called the fiber’s attenuation coefficient α and the expression is

$$\alpha = -\frac{10}{z[km]} \log \frac{P(z)}{P(o)} \qquad (1)$$

Where P(z) is the optical power at the position z from the origin, P(o) is the power at the origin. The addition of DFF (Dispersion Flattened Fiber), DCF (Dispersion Compensation Fiber) will introduce some losses in the system.

The study is based on the variation of BER with fiber loss. Here the observation is done for different types of line coding (NRZ, RZ, Manchester) formats. Bit rate and fiber length are kept constant as1.25 Gbits/s and 20km respectively. Now investigations are carried out for observing the BER with variation of fiber losses.

A. Graphical Results

1) Variation of bit error rate with variation in fiber-losses using one black box optical amplifier

Figure 10 shows the variation of bit error rate with variation in fiber losses using one black box optical amplifier. The gain of the black box amplifier was set to be 4.5 dB. It is found that the bit error rate is increasing exponentially with respect to fiber loss. The fiber loss is varied from 0.18 dB/km to 0.24 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.20 dB/km for NRZ line coding format.

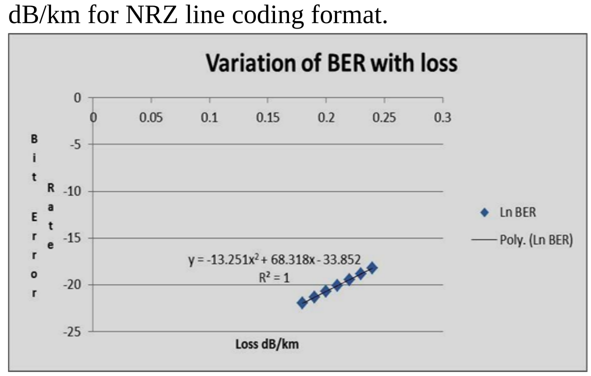

Figure10. Variation of bit error rate with variation in fiber-losses using one black box optical amplifier (NRZ line coding format)

For RZ line coding format as shown in figure 11it is found that the bit error rate is increasing exponentially with respect to fiber loss. But when the gain of the Blackbox optical amplifier was set to 4.5 dB (as set for NRZ line coding format), the standard BER of 10^{-9} was not obtained, and the value was much greater. Hence the gain of the amplifier was increased. The new gain value was set to be 6.5 db. The fiber loss is varied from 0.18 dB/km to 0.24 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.20 dB/km for RZ line coding format.

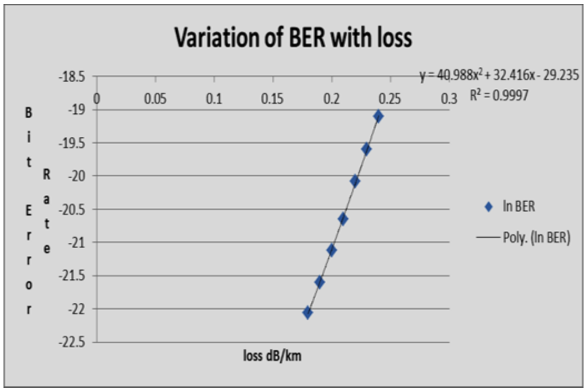

Figure11. Variation of bit error rate with variation in fiber-losses using one black box optical amplifier

2) Variation of bit error rate with variation in fiber-losses using EDFA.

Investigations have been carried out using the line coding formats (NRZ, RZ, Manchester).

Bit rate and fiber length are kept constant as1.25 Gbits/s and 20km respectively.

(A) EDFA with forward input loss of 0.1 dB

Figure 12. shows the variation of bit error rate with variation in fiber losses using EDFA (with forward input loss of 0.1 dB).

The forward input loss of the EDFA is set to be 0.1 dB. The fiber loss is varied from 0.18 dB/km to 0.24 dB/km. It is found that the bit error rate is increasing exponentially with respect to fiber loss. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.21 dB/km for NRZ line coding format and at a fiber loss of 0.18 dB/km for RZ line coding format respectively. For Manchester the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

Figure 12. Variation of bit error rate with variation in fiber-losses using EDFA (with forward input loss of o.1 dB)

(B) EDFA with forward input loss of 0.2 dB

Figure 13 shows the variation of bit error rate with variation in fiber losses using EDFA (with forward input loss of 0.2 dB)

The forward input loss of the EDFA is set to be 0.2 dB. The fiber loss is varied from 0.18 dB/km to 0.24 dB/km. It is found that the bit error rate is increasing exponentially with respect to fiber loss. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.20 dB/km for NRZ line coding format and at a fiber loss of 0.18 dB/km for RZ line coding format respectively. For Manchester the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

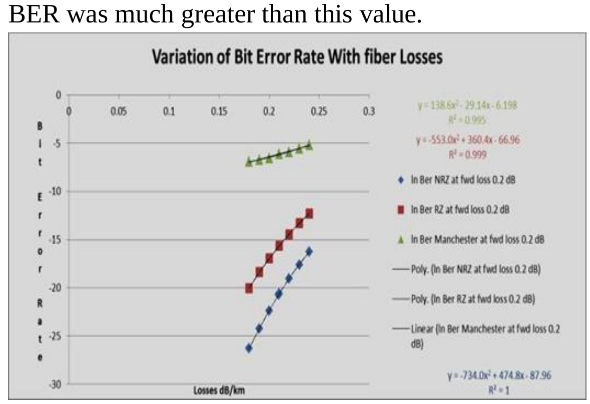

Figure 13. Variation of bit error rate with variation in fiber-losses using EDFA (with forward input loss of 0.2 dB)

3) Variation of bit error rate with variation in fiber losses using EYCDFA.

Investigations have been carried out using the line coding formats (NRZ, RZ, Manchester).

Bit rate and fiber length are kept constant as1.25 Gbits/s and 20km respectively.

A. EYCDFA with forward input loss of 0.1 dB

Figure14. shows the variation of bit error rate with variation in fiber losses using EYCDFA (with forward input loss of 0.1 dB).

The forward input loss of the EYCDFA is set to be 0.1 db. It is found that the bit error rate is increasing exponentially with respect to fiber loss. The fiber loss is varied from 0.18 dB/km to 0.21 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.21 dB/km for NRZ line coding format and at a fiber loss of 0.18 dB/km for RZ line coding format respectively. For Manches-ter the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

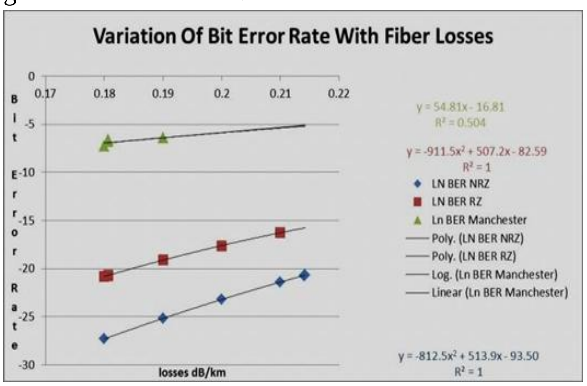

Figure 14. Variation of bit error rate with variation in fiber-losses using EYCDFA (with forward input loss of 0.1dB)

B. EYCDFA with forward input loss of 0.2 dB

Figure 15. shows the variation of bit error rate with variation in fiber losses using EYCDFA (with forward input loss of 0.2dB). It is found that the bit error rate is increasing exponentially with respect to fiber loss. The forward input loss of the EYCDFA is set to be 0.2 dB. The fiber loss is varied from 0.17 dB/km to 0.21 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber-loss of 0.20 dB/km for NRZ line coding format and at a fiber-loss of 0.17 dB/km for RZ line coding format respectively. For Manchester the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

Figure 15. Variation of bit error rate with variation in fiber-losses using EYCDFA (with forward input loss of 0.2dB)

4) Variation of bit error rate with variation in fiber losses using multi-stage Blackbox amplifier

Figure .16 shows the variation of bit error rate with variation in fiber losses using multi-stage Blackbox optical amplifier. It is found that the bit error rate is increasing exponentially with respect to fiber loss. The gain of black box amplifier is set to be 4.5 dB. The fiber loss is varied from 0.18 dB/km to 0.25 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.23 dB/km for NRZ line coding format and at a fiber loss of 0.19 dB/km for RZ line coding format respectively. For Manchester the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

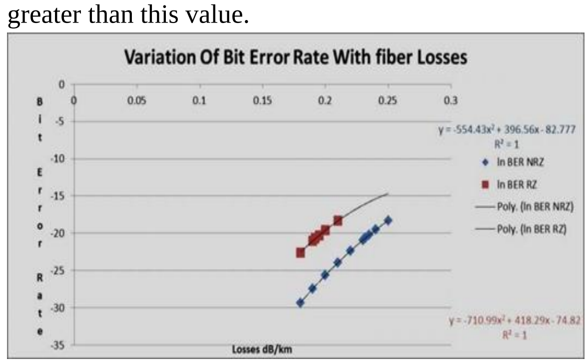

Figure .16 Variation of bit error rate with variation in fiber-losses using multi-stage Blackbox optical amplifier

5) Variation of bit error rate with variation in fiber losses using multi-stage EDFA

Figure .17 shows the variation of bit error rate with variation in fiber losses using multi-stage EDFA

The forward input loss of the EDFA is set to be 0.1 dB.

It is found that the bit error rate is increasing exponentially with respect to fiber loss. The fiber loss is varied from 0.18 dB/km to 0.24 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.23 dB/km for NRZ line coding format and at a fiber loss of 0.19 dB/km for RZ line coding format respectively. For Manchester the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

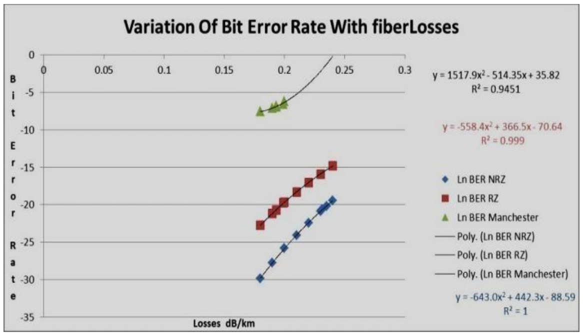

Figure .17 Variation of bit error rate with variation in fiber-losses using multi-stage EDFA

6) Variation of bit error rate with variation in fiber losses using multi-stage EYCDFA

Figure .18 shows the variation of bit error rate with variation in fiber losses using multi-stage EYCDFA

It is found that the bit error rate is increasing exponentially with respect to fiber loss. The forward input loss of the EDFA is set to be 0.1 dB. The fiber loss is varied from 0.18 dB/km to 0.23 dB/km. It can be noticed that the required standard Bit Error Rate (BER) of 10^{-9} is obtained at a fiber loss of 0.22 dB/km for NRZ line coding format and at a fiber loss of 0.19 dB/km for RZ line coding format respectively. For Manchester the required standard Bit Error Rate (BER) of 10^{-9} is not obtained, and the BER was much greater than this value.

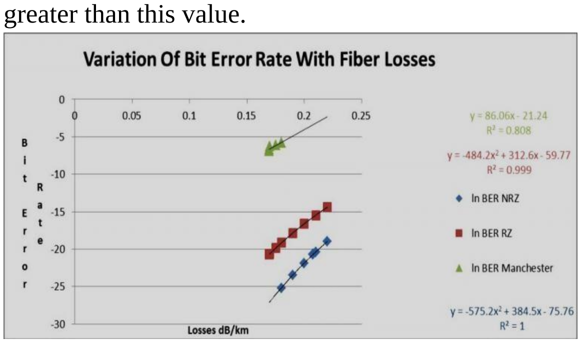

Figure .18 Variation of bit error rate with variation in fiber-losses using multi-stage EYCDFA

V. CONCLUSION

In this work, it is observed that the bit error rate (BER) is in-creasing exponentially with fiber losses. Fiber loss is caused by several factors. The main factors are absorption, scattering, bending losses etc. Here it is concluded that NRZ line coding format is better compared to RZ and Manchester line coding format. The fiber length enhanced when multi stage amplifiers are used. Also, it is observed that the performance was better while using EDFA when compared to EYCDFA and black box optical amplifier.

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