Simulation and Performance Analysis of SMF and MMF with Varying Lengths and Different Modulation Patterns using Dispersion Compensation

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ABSTRACT
Fiber Optics has emerged as a major building block in terrestrial telecommunication industry. Optical networks are very high capacity networks, capable to transmit maximum number of bits/sec over maximum possible distance with fewest errors. Optical Fiber systems require hundreds of considerations regarding design such as the type of fiber, modulation scheme, source, type of filters, amplifiers etc. This paper studies and evaluates Single and Multimode fiber transmission with two different modulation schemes (RZ and NRZ). Here Q estimation is done to evaluate the quality of fiber under different conditions. Further to compensate dispersion; Bragg's dispersion grating is employed.

Keywords
Modulation Schemes, Attenuation, Eye Diagrams, Fiber Transmission, Multi Mode fiber, Pulse Dispersion, Eye Opening, Eye Closure

1. INTRODUCTION
The low attenuation and capability to fulfill ever increasing amount of bandwidth has made optical fiber systems advantageous over metallic based communication systems. The light weight and small diameter of optical fiber makes installation of newer ones within the existing ducts very easy and practical [1].The non conducting nature of Optical Fiber has emerged as it's another advantage. Hence its installation can be done in Electro Magnetic Interference (EMI) and Radio Frequency Interference (RFI) areas. Secure transmission over these cables makes them attractive for governmental bodies, banks and other applications which demand higher security. [2][3]

In this paper RZ and NRZ schemes have been considered to analyze the performance of system. As it is known that n addition to introducing loss, optical fiber distorts the signal. [4] It is discussed, how these formats deal with the impairments and whether the advantage of RZ format is maintained.

2. MODULATION SCHEMES
Whenever we are analyzing the performance of an optical system, signal format comes out to be an important issue, as it directly affects the detection of transmitted signal. Many coding schemes are available with digital communication systems each with its own pros and cons. The most common and simple ones are NRZ and RZ. [5]Also, NRZ has more energy content than RZ with no rest state. Further two propagating modes (SMF and MMF) have been discussed in this paper.

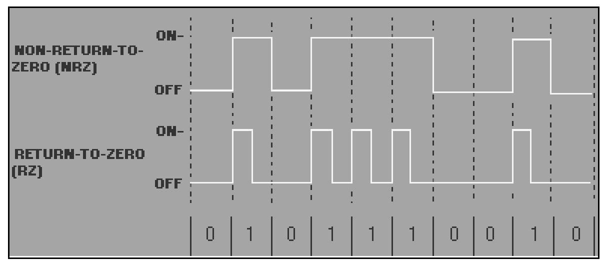

Fig. 1 RZ vs. NRZ Coding Scheme

Symbols per bit: NRZ: 01; RZ: 02
As fig.1 shows, NRZ requires one transition per symbol whereas RZ requires two. It directly implies that the require bandwidth for RZ is twice than NRZ and hence is more affected by dispersion and shot noise. In RZ, pulse is made to on for a portion of total period but in NRZ same is done for entire period. [6][7]

3. COMPARATIVE STUDY OF SMF AND MMF
In Single Mode Fibers (SMF), as only one mode propagates, it is free from Modal dispersion. Another merit is its ability to produce coherent light of one wavelength because of having laser as source. [8]

On the other hand Multi Mode Fibers (MMF) have higher numerical aperture and hence better at collecting light. Another benefit of MMF is its ability to allow the use of low cost source such as Light Emitting Diode (LEDs) and Vertical Cavity Surface Emitting Lasers (VCSELs). SMF operate at higher wavelengths (1550 nm) and require expensive Lasers.

The number of light reflections created in MMF is many due to large diametric core making it able to transmit more data in a given period. But the cons are high dispersion and attenuation rates which degrade the quality of signal over long distances.

The application area of MMF include data and audio/video transmission in LANs (short distance), whereas SMF are mostly used in high precision scientific research because of their easiness in focusing light. [9]

4. DISPERSION COMPENSATION (IDEAL FIBER BRAGG'S DIFFRACTION GRATING)

Diffraction is just a phenomenon of separating closely spaced wavelengths. Whenever any wave meets any obstacle, diffraction is said to occur. A Diffraction grating in its arrangement is equivalent to its action to a number of parallel slits placed and equidistance. The grating angle at which light is made to incident and the operating wavelength decides the direction of reflection of light. [10][11]This paper represents the effect of ideal Bragg's grating on the system.

5. OPTSIM SIMULATOR 5.1

Optsim is a CAD (Computer Aided Design) tool developed by RSoft. It provides an intuitive modeling and simulation environment which supports the designing and performance evaluation of transmission level of optical communication system. Optsim is ideally suited for optical networks i.e. analog/digital systems, optical LANs; DWDM/OTDM amplified systems etc.[12] In this paper I have discussed a communication system as a collection of interconnected icons to represent flow of signal from one component to another thus providing wide variety of measuring tools to analyze jitter, eye opening/ closure, electrical/optical spectra analysis and various other features for performance analysis such as Q Factor, BER, eye diagram etc.[13][14]

The new release Optsim 5.1 provides environment which is ideal for designing and simulating next generation systems such as burst mode data transmission and advanced electrical circuit modeling. It includes electrical and optical dispersion compensation, DSP based polarization recovery and direct error counting beyond a million bits.

6. TOPOLOGY and SIMULATION SC NARIOS

The optical transmission link with NRZ modulation scheme using SMF with CW Laser as source is shown in figure2.the various components needed to realize the optical system is divided into three parts: optical transmitter, transmission channel and optical receiver.

Optical transmitter consists of random data generator followed by recurrent NRZ scheme which encodes the train of electrical pulses defined by train of pulses at its input and then electrical Bessel filter to enhance signal quality. Sin 2 Sin amplitude modulator modulates the incoming signal with the help of carrier signal generated from CW Laser source. Before feeding this signal to the optical fiber, fixed output power optical amplifier (booster) is applied. Optical splitter is used whenever output is to be splitter into measuring as well as processing component.

Then comes transmission channel consisting of Optical Fiber .at the end comes optical receiver which combines fixed gain amplifier, raised cosine optical filter, attenuator, ideal grating, sensitivity receiver and output electrical Bessel filter. Fixed gain OA is employed with flat gain shape and gain of 25 db. Raised cosine Optical Fiber i.e. Notch Band pass is used with centre frequency 193.414 THz and centre wavelength of 1550nm.optical attenuator; effectively the opposite of amplifier, used to reduce the light power without appreciably distorting its shape. Benefit is to protect measuring device from signal levels that might damage it.

Ideal fiber grating is employed with reference frequency 193 THz and reference wavelength of 1550nm.sensitivity receiver consists of PIN photodiode which converts optical field into electrical signal. Photo detector is followed by electrical Bessel filter to again enhance signal quality.

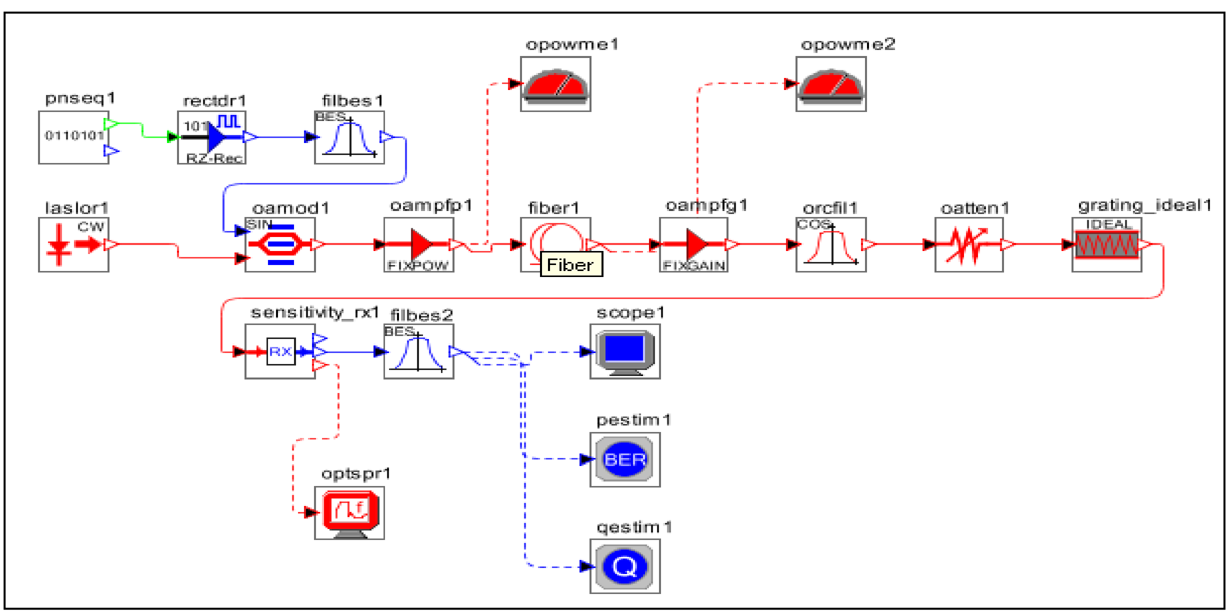

Fig. 2 Block Diagram of SMF Optical Fiber Link with NRZ Scheme

Main parameters regarding selection of filter are cut off frequency and its order. Received sensitivity is defined as the optical power received required to achieve certain BER. Photo diode is square law detector; hence the received electrical power is proportional to square of input optical power.

Further, measuring instruments employed are optical and electrical spectrum analyzers, Q estimator, optical power meters and oscilloscope. Figure2 shows RZ bit coding scheme implemented on MMF using VCSEL as Laser source.

Result 1
SMF vs. MMF

Here SMF and MMF are compared with a transmission distance of 10 km and data rate of 10 Gbps. Modulation scheme is Non Return to Zero in both the cases. Corresponding eye diagrams are shown in figure 3(a) and 3(b).

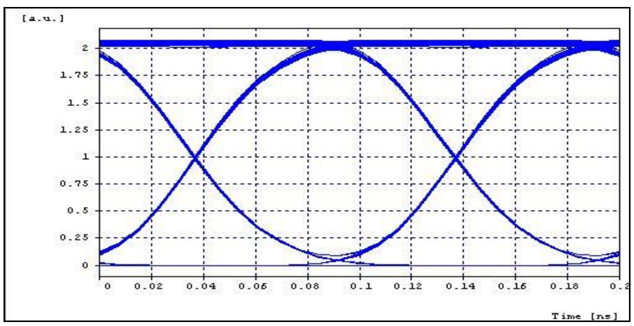

Fig. 3(a) Eye Diagram for 10 Km, SMF

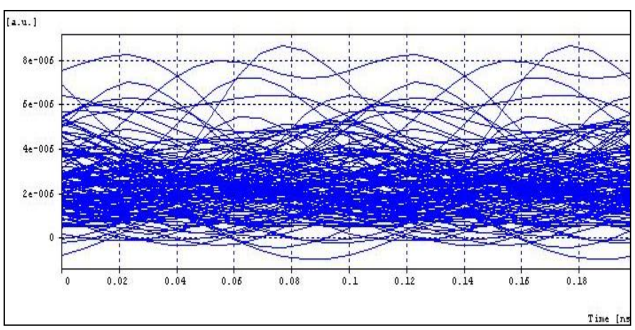

Fig. 3(b) Eye Diagram for 10 Km, MMF

Comparing the two plots it can be clearly seen that Q value has reduced from 32 db in SMF to 6 db in MMF. Simulations show that SMF is a better performer at larger distances. The larger eye openings in SMF show low attenuation whereas in MMF attenuation increases sharply with increase in length of fiber. Further SMF proves its merit through jitter analysis also which comes out to be 0.018 in SMF and 0.029 in MMF.

Result 2
NRZ vs. RZ

In this case RZ and NRZ coding schemes are compared with SMF of 60 km. Numerical analysis show that Q factor with NRZ and RZ comes out to be 21.72 db and 18.92 db respectively. Jitter observations in NRZ are 0.020 ns whereas same in RZ is calculated in 0.0262 ns. And if we look at BER, its 8.02e-035 in NRZ and 8.16e-018 in RZ.

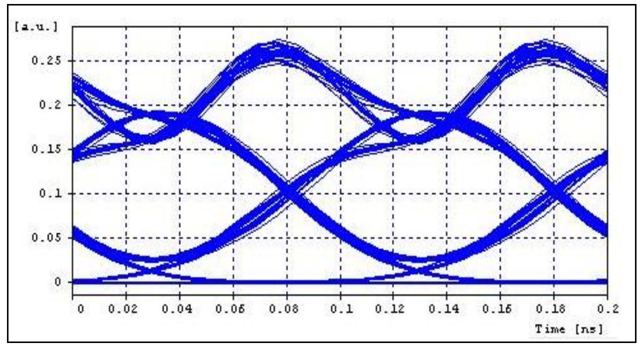

Fig. 4 (a) Eye Diagram for 60 Km, NRZ Coding

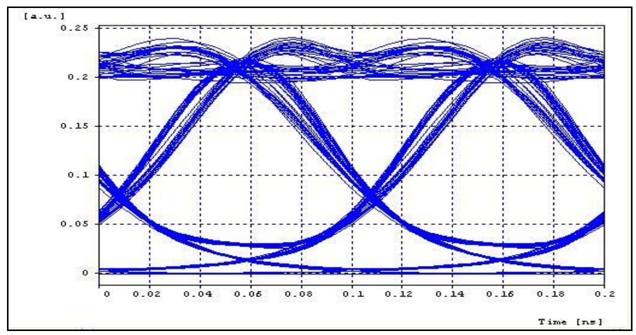

Fig. 4(b) Eye Diagram for 60 Km, RZ Coding

A conclusion can hence be drawn that Eye Closure Penalty (ECP) is more with RZ signal. Corresponding eye diagrams are shown in figure 4 (a) and 4(b). RZ gives small eye opening region and that too overlapped. Further as can be seen from figure 4(a) that bottom appears to have less amplitude variations than the top, indicating that the signal is carrying more 0's than 1's. The waveform is containing many rising and falling edges confirming the presence of deterministic jitter.

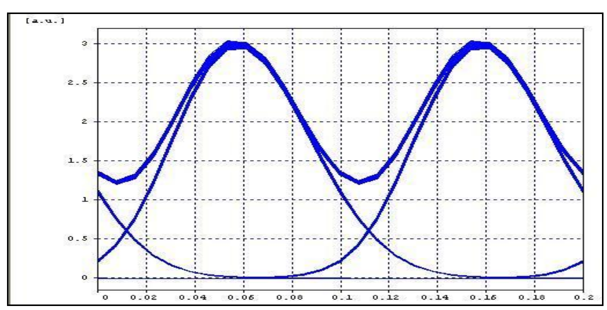

Fig. 4(c) Eye Diagram for 10 Km, RZ Coding

Also, Figure 4(c) demonstrates RZ coding scheme, with SMF performed on transmission length of 10 km. The same results can be drawn by comparing this plot with figure 3(a).Conclusion is that the appropriation of any code format depends upon the application area.

Result 3
Bandwidth Vs L

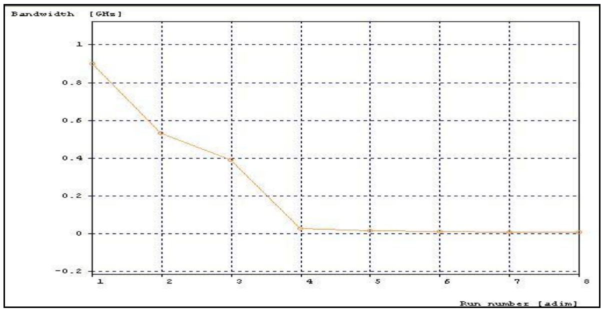

Fig. 5 Band Width Variation with Length of Fiber

Figure 5 indicates how BW varies with length of fiber. Fiber BW is one of the main elements that determine the performance of a data link. As the plot shows, BW decreases as L increases. But the impact decreases at larger distances, as noticed from run 5 to run 8.

This result is acquainted using NRZ modulation scheme on a multi mode fiber. This concludes that BW defoliates as communication distance increases.

Result 4
Eye Opening vs. L

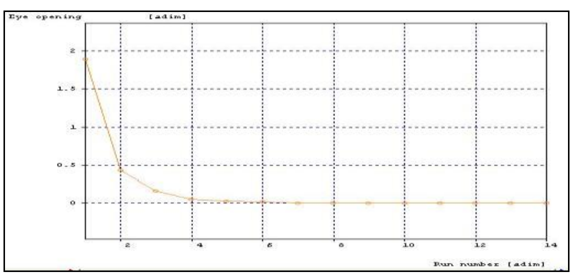

Fig. 6 Eye Opening Variation with Length of Fiber

Next result gives us a relation between eye opening and length of fiber, which increases as the number of runs increases. Graph clearly shows that eye opening varies inversely with L. Also attenuation increase can be seen in graph, which has greater impact when initially length varies from 10 to 60 km, and then decreases. Lesser impact can be seen from run 8 till the end. The main reasons for reduction in eye opening are scattering, absorption and bending losses occurring with in the fiber. These losses also increase as length of fiber increases.

Result 5
BER vs. L

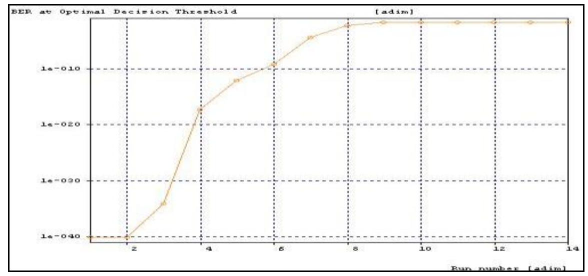

Fig.7 BER Variation with Length of Fiber

Figure 7 shows how BER changes with variation in the link distance. BER after a transmission distance of 10, 60, 90 km comes out to be 0.99e-40, 0.803e-34 and 0.963e-12 respectively. It clearly gives us the idea that BER is in direct relation with L.

Result 6
Eye Closure vs. L

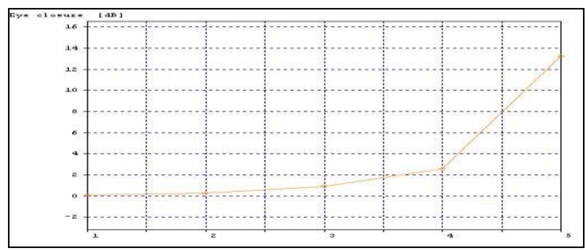

Fig. 8 Eye Closure Variation with Length of Fiber

These results are obtained with RZ modulation scheme, implemented on SMF. Figure 8 shows variation in eye closure with increasing L. Eye closure is in direct proportion with degradation of received signal. In contrast to the eye opening, its impact increases on larger distances. As can be seen, there is a sharp and linear increment in eye closure from run 4 to 5. Hence eye closure is in direct relation with the increase in transmission distance.

Result 7
Received Power vs. L

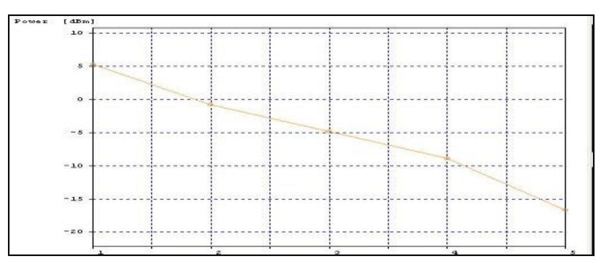

Fig. 9 Received Power Variations with Length of Fiber

Figure 9 shows hoe received power varies with L. Results are drawn when RZ coding scheme is implemented on SMF. When received power is subtracted from input power, it gives us the power down. And power down increases when received power decreases. The values of received power, comes out to be 5.287 dbm, -4.753 dbm and -16.680 dbm for L = 10, 60 and 120 km respectively.
This clearly demonstrates the inverse relation between output power and L. And the behavior of this numerical data agrees the corresponding eye plot.

Result 8

Q Value vs. L

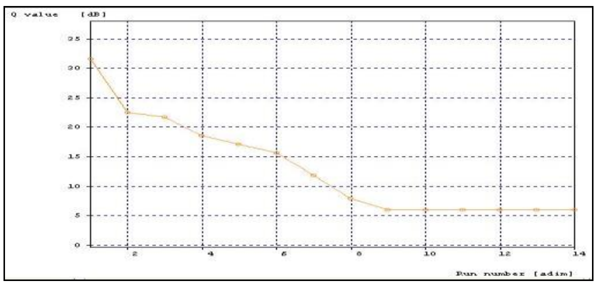

Fig. 10 Q Variation with Length of Fiber

Above figure shows a graph plotted between Q and the length of fiber. As is shown, Q varies in direct proportion with distance. This result is drawn for single mode fiber with non return to zero coding schemes. For length 10 km, 60 km and 100 km; Q comes out to be 31.6-1 db, 21.78 db and 15.69 db respectively. It clearly indicates performance degradation with increase in transmission distance.

7. CONCLUSION

In this paper, 10 Gbps topology has been built with Optsim 5.1.The link performance can then be recalculated at different operating points like, fiber length, modulating patterns, bit rate etc. Results are obtained which show the merits of using Optsim simulator for solving optic system design issues. Also the impact of parametric variations can be studied with cost, timing and manpower saving. In this paper, we studied that RZ pattern has better receiver sensitivity than NRZ. SMF and MMF are compared using eye diagrams and Q estimator with different parameters. In SMF, eye opening is direct proportion with fiber length. On the other hand, with MMF, eye opening is good with only small distances. Hence SMF perform better than MMF in terms of power down for long haul communications.

8. FUTURE SCOPE

Future developments of fiber optic system can be enriched using combination of DWDM with EDFA boosters. It will increase the distance and reliability of the system.
In WDM, information is sent using slightly different color of wavelength. Hence interference can be minimized many times with an increase in capacity. DWDM refers to sending many closely spaced color wavelengths through fiber at the same time.

The channel capacity depends upon the no. of channels transmitted which in turn depends upon channel spacing. It is implemented using couplers which are specifically designed to filter or mix the signals of varying wavelengths. Very closely spaced signals are separated by FBG in DWDM. DWDM + EDFA systems are still under scale to meet practical limitations in near future.

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