International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P) Volume-8, Issue-3, March 2018

Comparative Performance Analysis of Single Mode Fiber over Different Channels Using Matlab

Prabhat Gupta, Vaibhav Purwar

***Abstract*— Single mode optical fibers have already been one of the major transmission media for long distance telecommunication, with very low losses and high bandwidth. The most important properties that affect system performance are fiber attenuation and dispersion. Fiber optic cables are the medium of choice in telecommunications infrastructure, enabling the transmission of high-speed voice, video, and data traffic in enterprise and service provider networks. Depending on the type of application and the reach to be achieved, various types of fiber may be considered and deployed.**

In this paper a brief dispersion has been discussed & filtering concept is used so that a polarized signal could be transferred through a single mode fiber is analyzed using MATLAB & respective output graphs have been discussed.

***Index Terms*— SMF, Dispersion, Optical power signal, PMD, Filtering.**

I. INTRODUCTION

Optical Fiber is new medium, in which information (voice, Data or Video) is transmitted through a glass or plastic fiber, in the form of light. The field of applied science and engineering concerned with the design and application of optical fibers is known as fiber optics. Optical fibers are widely used in fiber optics, which permits transmission over longer distances and at higher bandwidth (data rates) than other forms of communication. Optical fibers may be connected to each other or can be terminated at the end by means of connectors or splicing techniques.

The optical fibre is treated as a cylindrical open waveguide structure. A model is shown in Figure 1, where we have assumed circular symmetry. Hence, we neglect imperfections such as longitudinally varying ellipticity or corrugation. Such imperfections will be accounted through a mode-coupling model. There, we will also address the influence of possible loss mechanisms, which are neglected elsewhere, by introducing a heuristic loss model. The shaded cross-sectional areas denote, from dark to light, the core, cladding and coating region(s). The coating may be surrounded by a jacket, although that is of no interest in our field analysis, as no power reaches this interface. Moreover, as long as sharp bends are absent in geometry of the fibre, we may omit the coating as well from our model for the same reason. Therefore, we shall assume that the cladding is homogeneous and of infinite extent.

Dispersion is a term which means broadening or degrading the signal. It may be like chirped signal or distorted one. [1] In single mode fiber (SMF) chromatic dispersion takes place.

Prabhat Gupta, Department of Electronics & Communication Engineering, M.Tech Scholar, Kanpur Institute of Technology, Kanpur, India

Vaibhav Purwar, Associate Professor, Department of Electronics & Communication Engineering, Kanpur Institute of Technology, Kanpur, India.

Also polar mode dispersion is observed and this dispersion is caused due to dependence of group index Ng to wavelength. Because of spreading of light pulse, two or more consecutive pulse signal may overlap each other which cause inter-symbol interference (ISI). Thus signals lose their original shape, size, amplitude & due to aliasing of signal receiver sometimes not able to identify that particular required signal & results in error in signal detection. Modal dispersion [8] may be defined as broadening of pulse due to time delay between lower – order modes
& higher order modes. Majorly it is difficult to tackle in multimode fiber. We know that index of refraction of glass fiber depends on wavelength therefore Chromatic dispersion is also broadening of pulse due to different velocities of waves that are of different wavelength. Waveguide dispersion is caused due to physical appearance and structure of waveguide. Fibers with complex index profiles faces major factor as waveguide dispersion.

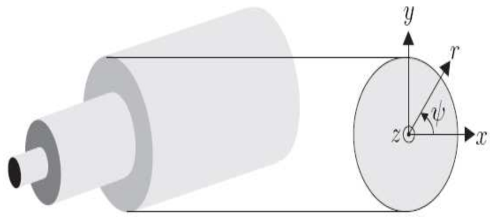

Figure 1: Model of the optical fiber

Polarization mode dispersion is also kind of a modal dispersion where due to the random imperfections, two different light waves travels at different speed, whereas normally they travel at same speed. Imperfections occur randomly in the path of light while travelling through an optical fiber. Due to these random imperfection and asymmetry the light travelling through optical fiber starts spreading which results in limited rate of data that is to be transmitted. There are some factors which matters a lot in transmission of a signal in context of polarized wave of light, it depends whether the case is of an ideal fiber or realistic optical fiber. Practically it is not possible to have perfectly symmetry & exact circular cross sections of optical fiber however in ideal optical fiber there is proper circular cross sectional of core is assumed due to which two orthogonal polarization of waves exits, whereas in realistic fiber imperfections are random so breaks the circular symmetry of fiber. This causes the two polarizations travel at different speed & thus slowly got separate further it results in pulse spreading. Transmission of a signal also depends on how much noisy channel it is crossing through various modulation techniques is responsible for it like DPSK modulation or DWDM modulation.

II. SINGLE-MODE FIBERS

Single-mode (or mono mode) fiber enjoys lower fiber attenuation than multimode fiber and retains better fidelity of each light pulse, as it exhibits no dispersion caused by multiple modes. Thus, information can be transmitted over longer distances. Like multimode fiber, early single-mode fiber was generally characterized as step-index fiber meaning the refractive index of the fiber core is a step above that of the cladding rather than graduated as it is in graded-index fiber. Modern single mode fibers have evolved into more complex designs such as matched clad, depressed clad, and other exotic structures.

Main Parameters of a Single-Mode Fiber Link Core Size and Numerical Aperture Single-mode fiber shrinks the core down so small that the light can only travel in one ray. The typical core size of a single-mode fiber is 9 microns. Since only one mode is allowed to travel down the fiber path, the total internal reflection phenomenon does not occur and the concept of numerical aperture is reduced to its definition (the same as for multimode fibers). It measures the core and cladding refractive indices difference but has little impact on the information propagation. The NA for a single-mode fiber is usually smaller than for a multimode fiber. Center Wavelength and Reach Single-mode fibers carry optical signals in the second and third telecom windows where attenuation is minimized. The center wavelength of the laser emitting into the fiber is approximately 1310 nm and 1550 nm, respectively. CWDM and DWDM channels operate over single-mode fibers in the third window with a wavelength drifting tolerance stricter than for non-WDM channels. Common lasers suitable for applications over single-mode fiber are Fabry-Perot and distributed feedback (DFB) lasers. As for multimode fibers, the reach is the minimum distance guaranteed for a type of laser, over a type of fiber at a certain data rate. The reach over a single-mode fiber is generally limited by accrued chromatic and polarization-mode dispersion, which are typically of greater impact as data rates are higher. Additionally, the reach can also be limited by the degradation of optical signal over noise ratio (OSNR) in the case of amplified links. Finally Fabry-Perot lasers are used for shorter-reach applications as their spectrum width is large and more subject to dispersion. DFB lasers are typically used for longer reaches as their spectrum width is narrow and therefore relatively less subject to dispersion. The attenuation of a single-mode fiber is of about 0.4 dB per km in the second window and 0.25 dB per km in the third window.

Dispersion affects single-mode fiber links and as for multimode fiber links, the consequence of the phenomenon is pulse spreading. In this case this is not due to the modal properties of the single mode fiber since it can only transport one and only one mode. Instead polarization-mode dispersion (PMD) and chromatic dispersion (CD) are responsible for pulse spreading. As for the case of multimode fibers, pulse spreading takes more importance with higher data rates as the pulse unit interval becomes smaller and risks of pulses overlapping are greater. Chromatic dispersion represents the fact that different colors or wavelengths travel at different speeds, even within the same mode. Indeed, a transmitted wavelength is not a perfect peak and instead displays a finite spectral width. Therefore it is a small wavelength range that is transmitted, and components within this range travel at slightly different speeds. This results in the spreading of pulses traveling over a significant distance. This distance varies depending on the fiber type, the laser type, and the data rate. Chromatic dispersion is the result of material dispersion and waveguide dispersion. Figure 2 shows chromatic dispersion along with key components waveguide dispersion and material dispersion.

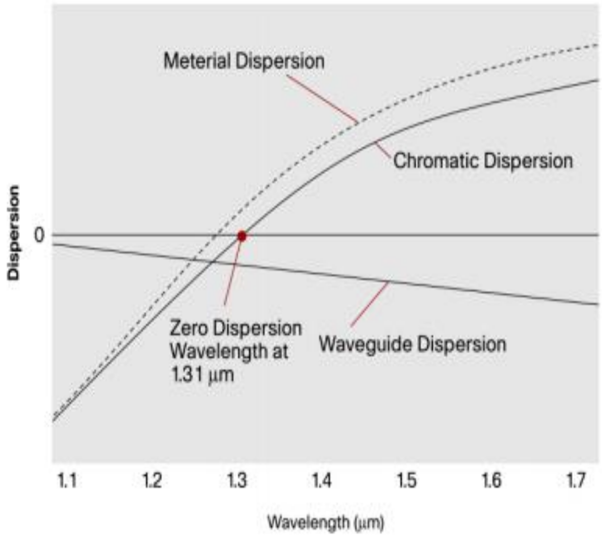

Figure 2: Chromatic Dispersion in a Standard Single-Mode Fiber

Dispersion is a function of the wavelength. Standard single-mode fibers have zero dispersion at 1310 nm. Therefore, 1310-nm transmitters are not subject to chromatic dispersion. Only 1550-nm, CWDM, and DWDM transmissions over standard single-mode fiber are affected by this phenomenon. However, the third telecom window is very advantageous and used more and more frequently because of lower fiber loss properties in this region and the ability to amplify optical signals with erbium-doped fiber amplifiers (EDFA). This implies the need for new fiber types or chromatic dispersion compensation techniques.

III. FIBER OPTICS

Optical Fiber is new medium, in which information (voice, Data or Video) is transmitted through a glass or plastic fiber, in the form of light, following the transmission sequence. Information is encoded into electrical signals. Electrical signals are converted into light signals. Light travels down the fiber. A detector changes the light signals into electrical signals. Electrical signals are decoded into information.

A. Advantages of Fiber Optics

Fiber Optics has the following advantages:

1. Optical Fibers are non-conductive (Dielectrics).
2. Electromagnetic Immunity:
3. Large Bandwidth (> 5.0 GHz for 1 km length)
4. Small, Lightweight cables.
5. Security

B. Principle of Operation - Theory

Total Internal Reflection - The Reflection that Occurs when a Light Ray Travelling in One Material Hits a Different Material and Reflects Back into the Original Material without any Loss of Light.

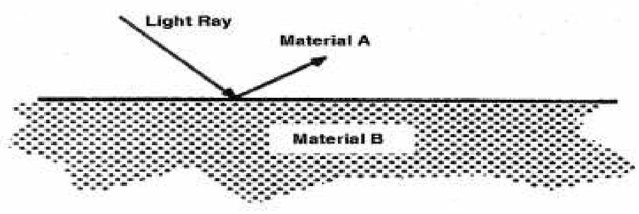

Figure 3: Total Internal Reflection

C. Theory and Principle of Fiber Optics

Speed of light is actually the velocity of electromagnetic energy in vacuum such as space. Light travels at slower velocities in other materials such as glass. Light travelling from one material to another changes speed, which results in light changing its direction of travel. This deflection of light is called Refraction. The amount that a ray of light passing from a lower refractive index to a higher one is bent towards the normal. But light going from a higher index to a lower one refracting away from the normal, as shown in the figures. As the angle of incidence increases, the angle of refraction approaches 90o to the normal. The angle of incidence that yields an angle of refraction of 90o is the critical angle. If the angle of incidence increases amore than the critical angle, the light is totally reflected back into the first material so that it does not enter the second material. The angle of incidence and reflection are equal and it is called Total Internal Reflection.

By Snell's law, $n1 \sin \varnothing_1 = n2 \sin \varnothing_2$
The critical angle of incidence $\varnothing_c$ where $\varnothing_2 = 90°$
Is $\varnothing_c = \arcsin (n_2 / n_1)$

At angle greater than reflected light means that n1 and n2 are equal (since they are in 2 are also equal. The angle of∅1 and ∅the same material), incidence and reflection are equal. These simple principles of refraction and reflection form the basis of light propagation through an optical fiber.

IV. POLARIZATION MODE DISPERSION (PMD)

Polarization mode dispersion (PMD) is a form of modal dispersion where two different polarizations of light in a waveguide, which normally travel at the same speed, travel at different speeds due to random imperfections and asymmetries, causing random spreading of optical pulses. Unless it is compensated, which is difficult, this ultimately limits the rate at which data can be transmitted over a fiber. In an ideal optical fiber, the core has a perfectly circular cross-section. In this case, the fundamental mode has two orthogonal polarizations (orientations of the electric field) that travel at the same speed. The signal that is transmitted over the fiber is randomly polarized, i.e. a random superposition of these two polarizations, but that would not matter in an ideal fiber because the two polarizations would propagate identically (are degenerate). In a realistic fiber, however, there are random imperfections that break the circular symmetry, causing the two polarizations to propagate with different speeds. In this case, the two polarization components of a signal will slowly separate, e.g. causing pulses to spread and overlap. Because the imperfections are random, the pulse spreading effects correspond to a random walk, and thus have a mean polarization-dependent time differential $\Delta\tau$ (also called the differential group delay, or DGD) proportional to the square root of propagation distance L:ΔT=DPMD√L DPMD is the PMD parameter of the fiber, typically measured in ps/√km, a measure of the strength and frequency of the imperfections. The symmetry-breaking random imperfections fall into several categories [7]. First, there is geometric asymmetry, e.g. slightly elliptical cores. Second, there is stress-induced material birefringence, in which the refractive index itself depends on the polarization. Both of these effects can stem from either imperfection in manufacturing (which is never perfect or stress-free) or from thermal and mechanical stresses imposed on the fiber in the field — moreover, the latter stresses generally vary over time.

V. RESULTS AND DISSCUSSION

In this research work we have use two type of channel one is AWGN Channel another is Rayleigh Channel. Now we simulate the dense wavelength separation multiplexing (DWDM) modulation technique with AWGN Channel and Dense wavelength separation multiplexing (DWDM) modulation technique with Rayleigh Channel. In this work we use DPSK Modulation techniques.

A. DWDM with AWGN channel

Figure 4 shows simulation of DWDM Spectrum corresponding to wavelength and Attenuation Dense wavelength separation multiplexing (DWDM) mentions primarily to optical signals multiplexed inside the 1550 nm group so as to impact the skills (and cost) of erbium doped fiber amplifiers (EDFAs) [19][20], that are competent for wavelengths amid concerning 1525–1565 nm (C band), or 1570–1610 nm (L band). EDFAs were primarily industrialized to substitute SONET/SDH optical-electrical optical (OEO) regenerators that they have made usefully obsolete [21]. EDFAs can amplify each optical gesture in their working scope, even though of the modulated bit rate. In words of multi-wavelength signals, so long as the EDFA has plenty impel power obtainable to it, it can amplify as countless optical signals as can be multiplexed into its amplification group (though gesture densities are manipulated by choice of modulation format).

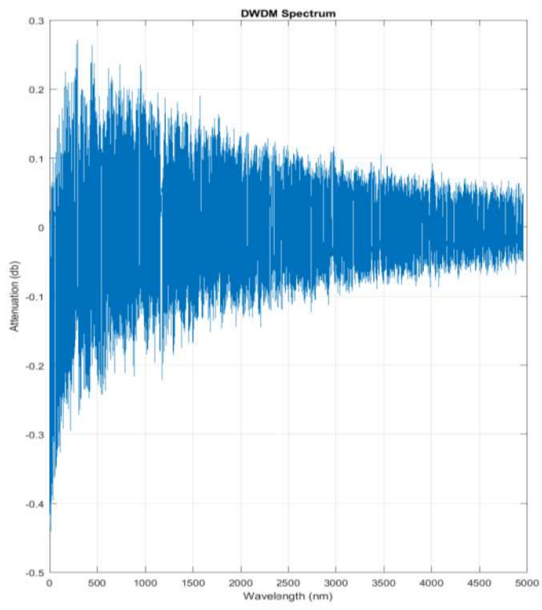

Figure 4: DWDM Spectrum with AWGN Channel

The main difference amid multi-mode and single-mode optical fiber is that the preceding has far larger core diameter, normally 50–100 micrometers; far larger than the wavelength of the light grasped in it. Because of the colossal core and additionally the potential of colossal numerical aperture, multi-mode fiber has higher "light-gathering" capacity than single-mode fiber. In useful words, the larger core size simplifies connections and additionally permits the use of lower-cost electronics such as light-emitting diodes (LEDs) and vertical-cavity surface-emitting lasers (VCSELs) that work at the 850 nm and 1300 nm wavelength (single-mode fibers utilized in telecommunications work at 1310 or 1550nm and need extra luxurious laser sources. Solitary mode fibers continue for nearly all visible wavelengths of light). Though, contrasted to single-mode fibers, the multi-mode fiber bandwidth–distance product check is lower. Because multi-mode fiber has a larger core size than single-mode fiber, it supports extra than one propagation mode; hence it is manipulated by modal dispersion, as solitary mode is not. The LED light origins from time to time utilized alongside multi-mode fiber produce a scope of wavelengths and these every single propagate at disparate speeds. This chromatic dispersion is one more check to the functional length for multi-mode fiber optic cable. In difference, the lasers utilized to drive single-mode fibers produce consistent light of a solitary wavelength. Due to the modal dispersion, multi-mode fiber has higher pulse spreading rates than solitary mode fiber, manipulating multi-mode fiber's data transmission capacity. Here disparate colors of light embody disparate wavelengths of light and their corresponding attenuation.

Figure 5 represents the single Vs multi Wavelengths through waveguide with AWGN Channel corresponding to wavelength and Attenuation.

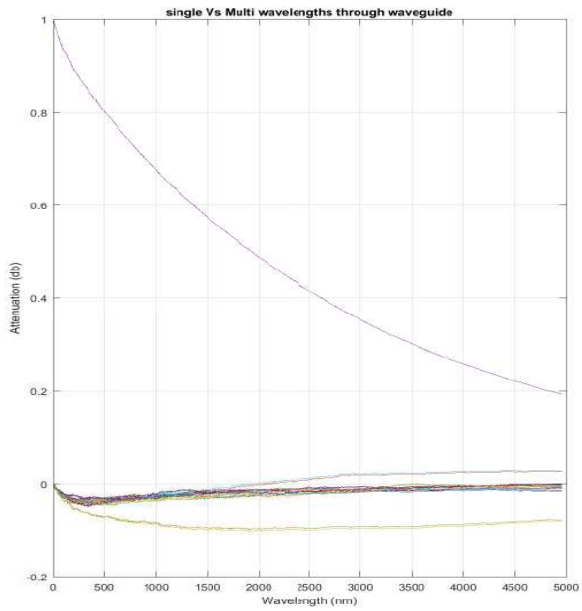

Figure 5: Single Vs Multi Wavelengths through waveguide with AWGN Channel

A dielectric waveguide employs a solid dielectric rod rather than a hollow pipe. An optical fiber is a dielectric guide designed to work at optical frequencies. Transmission lines such as micro strip, coplanar waveguide, strip line or coaxial may also be considered to be waveguides. The electromagnetic waves in (metal-pipe) waveguide may be imagined as travelling down the guide in a zig-zag path, being repeatedly reflected between opposite walls of the guide. For the particular case of rectangular waveguide, it is possible to base an exact analysis on this view. Propagation in dielectric waveguide may be viewed in the same way, with the waves confined to the dielectric by total internal reflection at its surface. Figure 6 represents the Waveguide without Dielectric Layer with AWGN Channel corresponding to wavelength and Attenuation.

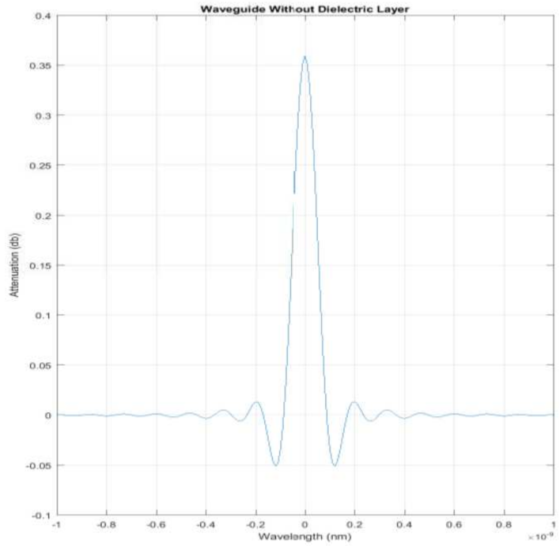

Figure 6: Waveguide without Dielectric Layer with AWGN Channel

Figure 7 represents the cosine corresponds to the amplitude spectrum with AWGN Channel corresponding to wavelength and Attenuation.

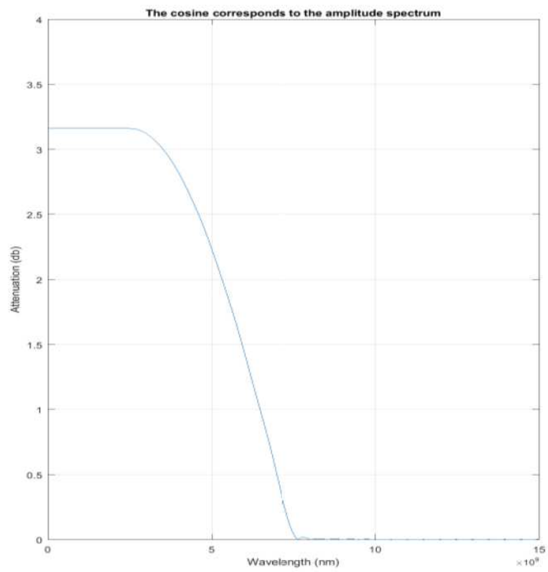

Figure 7: The cosine corresponds to the amplitude spectrum with AWGN Channel

Figure 8 represents the balanced output eye with AWGN Channel corresponding to wavelength and Attenuation. Here it could observed that a lot of zigzag signals are there along with the information signal, which needs to be rounded off or needs to make it more clear. Because jitter is a factor which is existing & need to reduce by equalizing or rounding off.

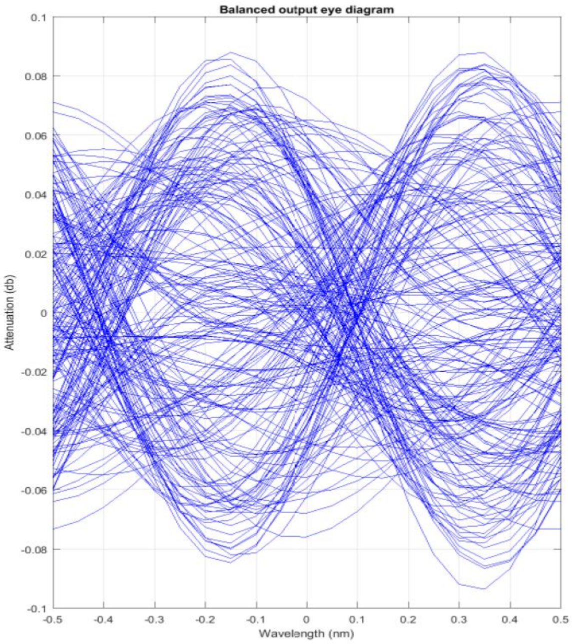

Figure8: Balanced output eye with AWGN Channel

Figure 9 represents the equalized Eye with AWGN Channel corresponding to wavelength and Attenuation. It clearly shows that the signal threads transmitted over a clear pattern without any noisy signal. There is less amount of jitter (more the eye is aliasing with the alternate eye, more jitter will be there which degrade the performance).

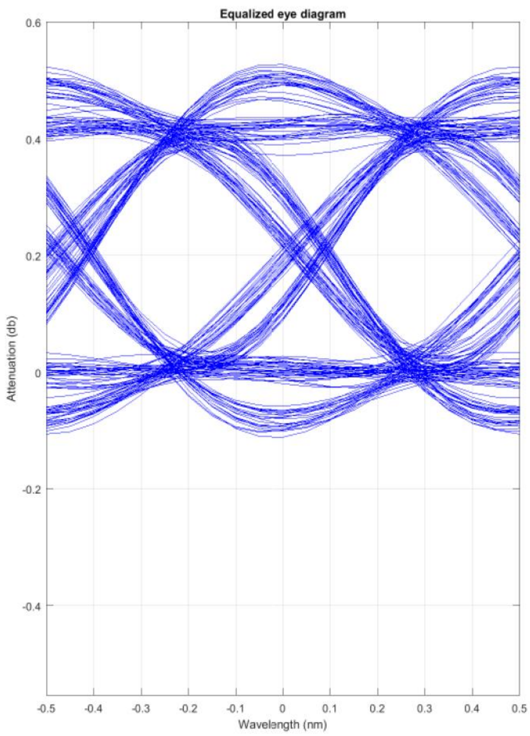

Figure 9: Equalized Eye with AWGN Channel

B. DWDM with Rayleigh channel

Figure 10 shows simulation of DWDM Spectrum corresponding to wavelength and Attenuation Dense wavelength separation multiplexing (DWDM) with Rayleigh channel.

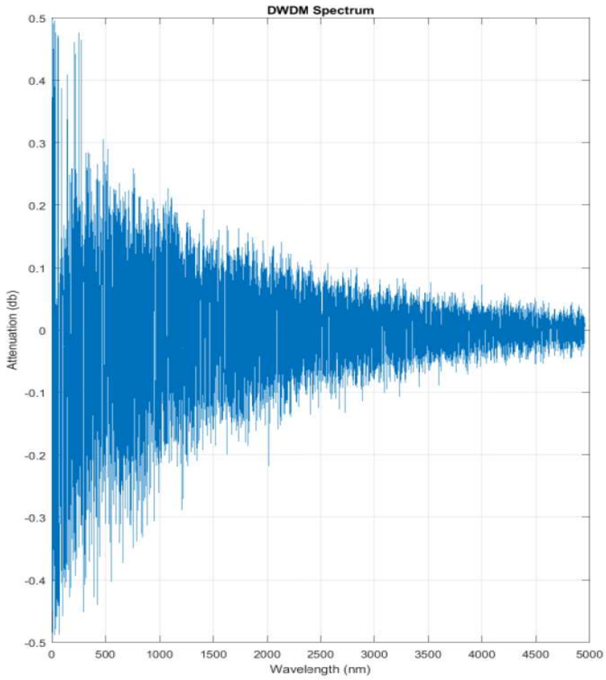

Figure 10: DWDM Spectrum with RAYLEIGH Channel

Figure 11 represents the single vs multi Wavelengths through waveguide with Rayleigh Channel corresponding to wavelength and Attenuation.

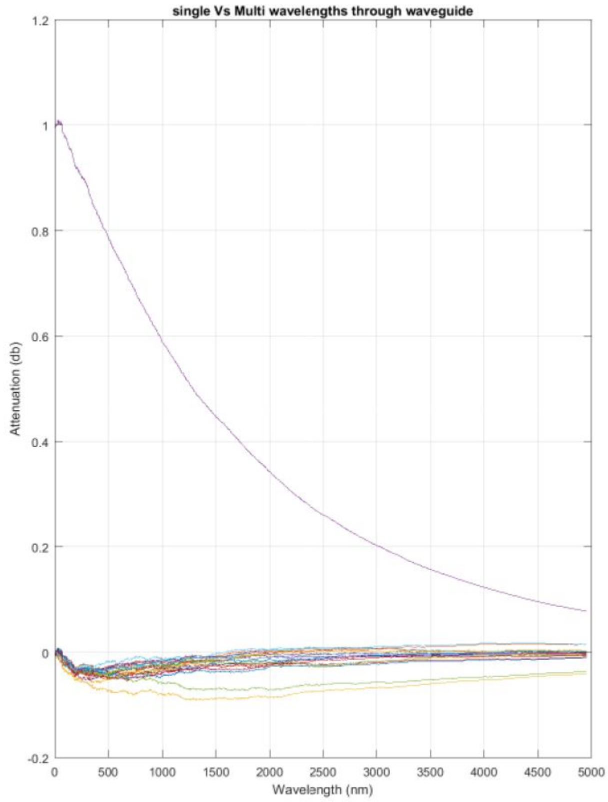

Figure 11: Single vs Multi Wavelengths through waveguide with RAYLEIGH Channel

Figure 12 represents the Waveguide without Dielectric Layer with Rayleigh Channel corresponding to wavelength and Attenuation.

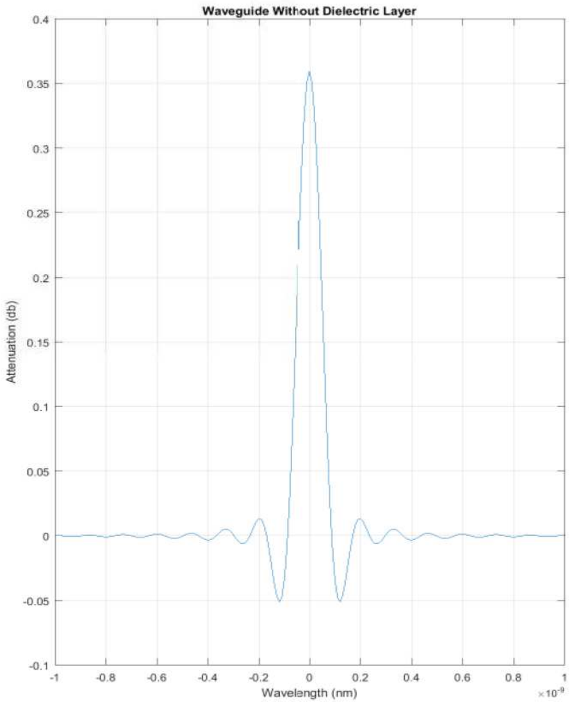

Figure 12: Waveguide without Dielectric Layer with RAYLEIGH Channel

Figure 13 represents the cosine corresponds to the amplitude spectrum with Rayleigh Channel corresponding to wavelength and Attenuation.

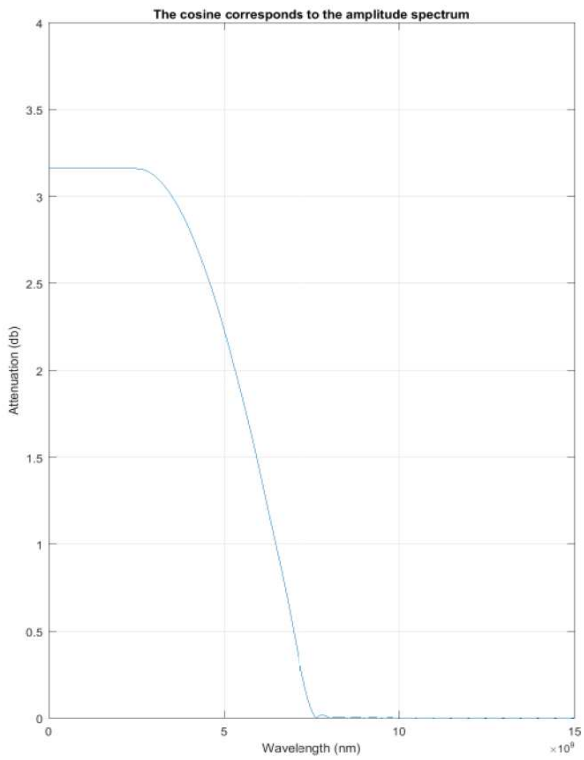

Figure 13: The cosine corresponds to the amplitude spectrum with RAYLEIGH Channel

Figure 14 represents the balanced output eye with Rayleigh Channel corresponding to wavelength and Attenuation. Here it could observed that a lot of zigzag signals are there along with the information signal, which needs to be rounded off or needs to make it more clear. Because jitter is a factor which is existing & need to reduce by equalizing or rounding off.

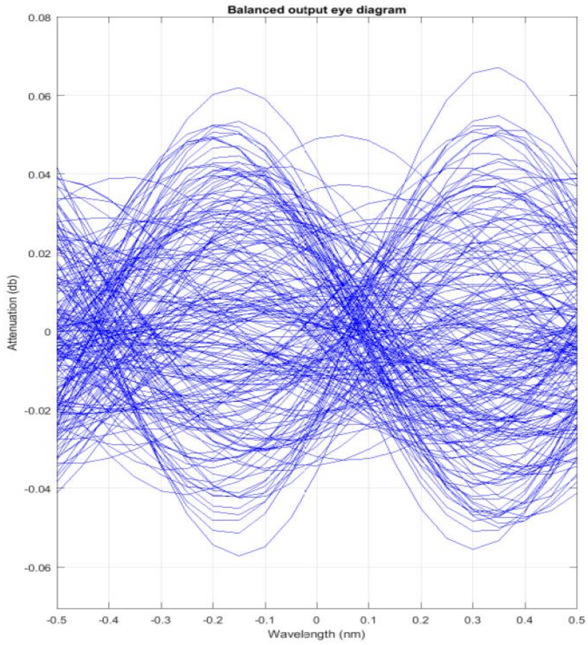

Figure 14: Balanced output eye with RAYLEIGH Channel

Figure 15 represents the equalized Eye with Rayleigh Channel corresponding to wavelength and Attenuation. It clearly shows that the signal threads transmitted over a clear pattern without any noisy signal. There is less amount of jitter (more the eye is aliasing with the alternate eye; more jitter will be there which degrade the performance).

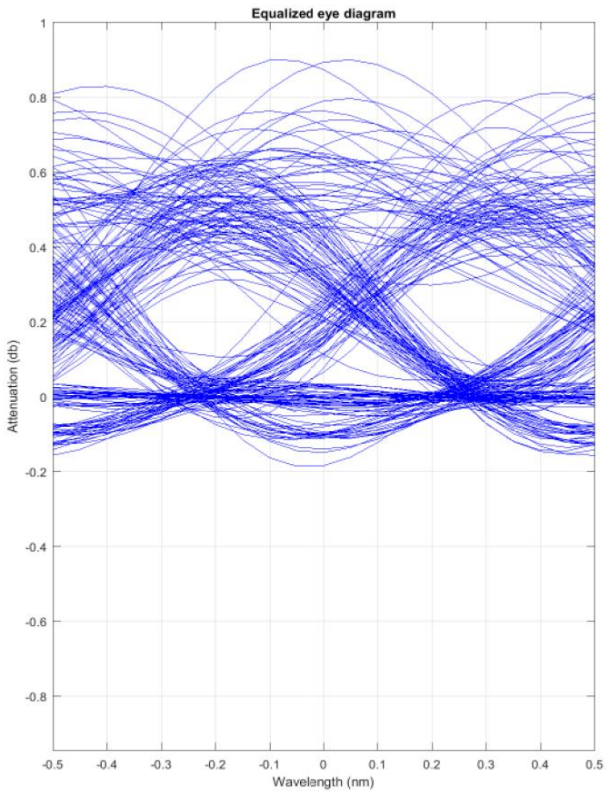

Figure15: Equalized Eye with RAYLEIGH Channel

C. DPSK Modulation Techniques

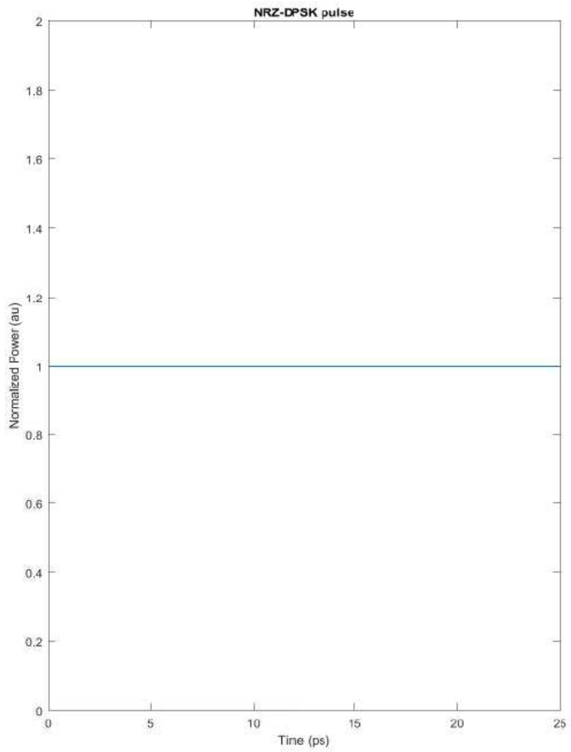

Figure 16: NRZ-DPSK pulse (0-2 au)

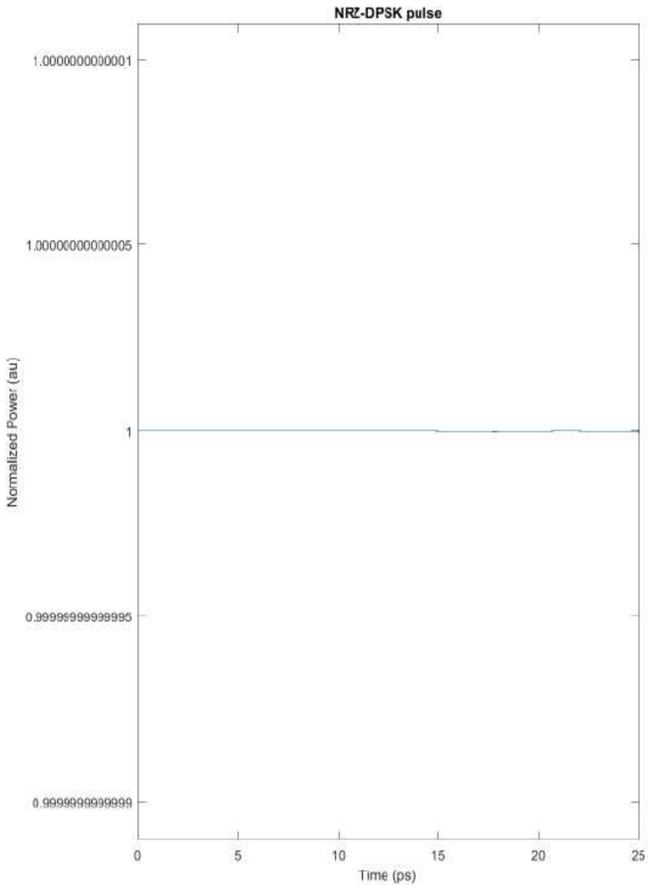

Figure 17: NRZ-DPSK pulse (0.9-1.01 au)

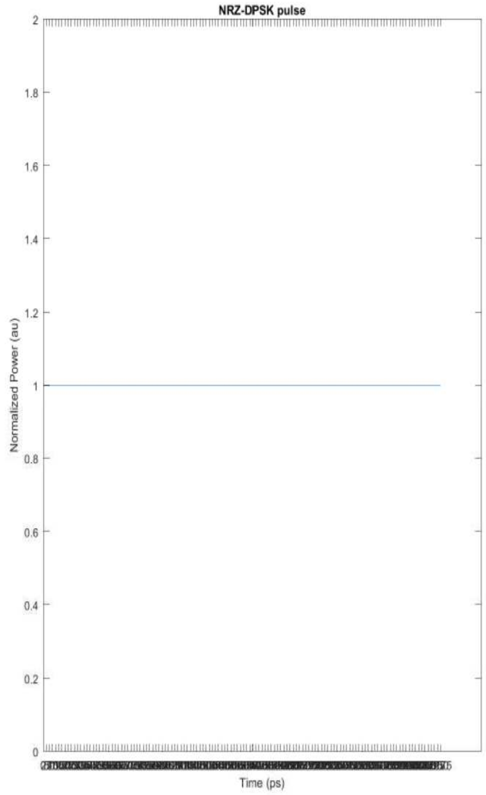

Figure 18: NRZ-DPSK pulse (0-2 au)

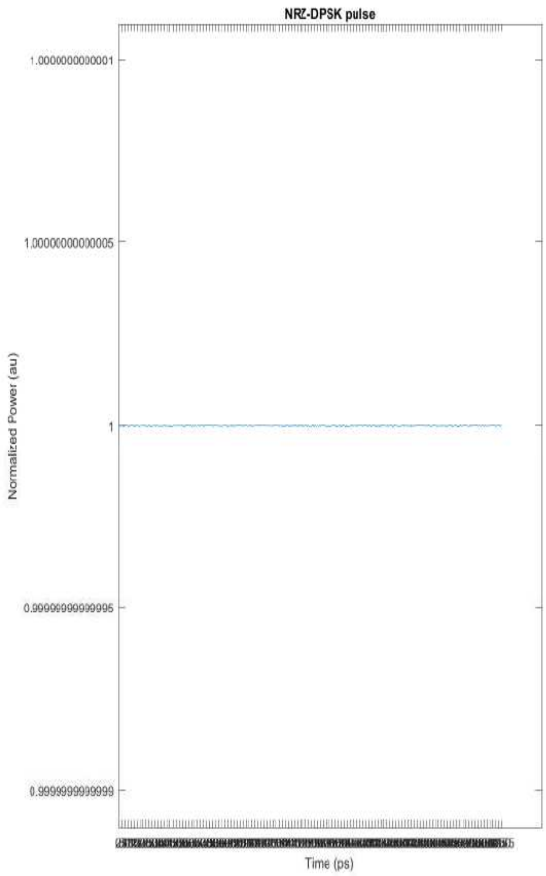

Figure 19: NRZ-DPSK pulse (0.9-1.01 au)

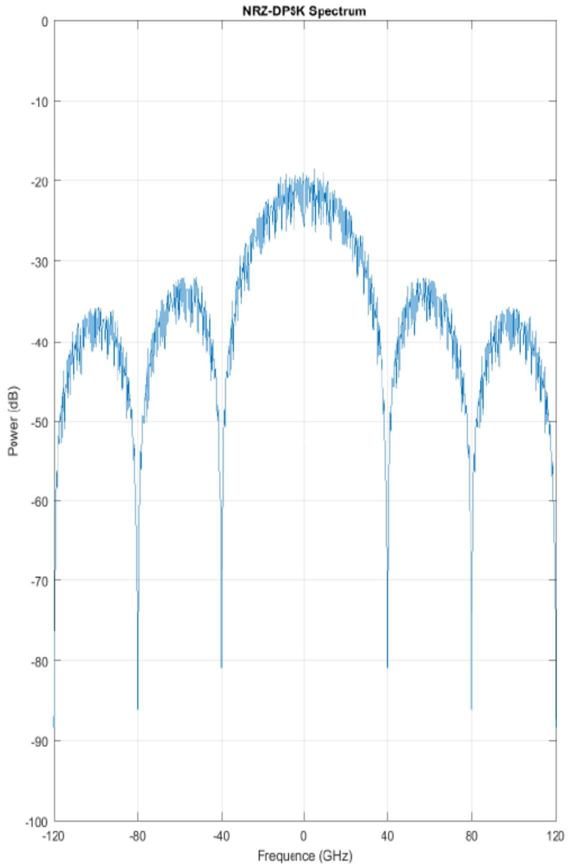

Figure 20: NRZ-DPSK Spectrum

VI. CONCLUSION

Researchers and scholars have made commendable research on fabricating perfect waveguide and there is a long list of various types of WG's. The groups participating in the race for the ultimate flexible, low-loss, high-power, and maximum reliability are in constant search for new combination of fabrication materials and methods. Although there are some types of WG's which found their way to the medical laser commercial market. The race is not yet over and there is still a lot to improve. The perfect WG is not yet introduced. so it's a long journey to establish a successful and commendable waveguide which can perform an invasive surgery with a stunningly low wavelength laser and waveguide which is of the order of mosquito needle, to facilitate painless and bloodless surgery. Though it's hypothetical in present scenario but a strong dedication and hard work of engineers will definitely make it possible one day.

REFERENCES

[1] Ling-Wei Guo, Ying-Wu Zhou, Zu-Jie Fang, "Pulse broadening in optical fiber with PMD", Optics communication, pp. 83-87, 2003.

[2] N. Gisin, J. P. Von Der Weid, J. P. Pellaux, "Polarization Mode Dispersion of short and long single mode fibers " IEEE Journal of Lightwave Technology, Vol. 9, No. 7, Jul. 1991, pp. 821- 827.

[3] H. Sunnerud, '' Polarization mode dispersion in optical fibers: characterization, transmission impairments and compensation '', PhD Thesis, Mar. 2001

[4] P. Hernday, "Dispersion measurements", Fiber optic test and measurement, Eds.D. Derickson, New Jersey: Prentice Hall PTR, 1998.

[5] F. Kapron, A. Dori, J. Peters, and H. Knehr, "Polarization-mode dispersion:should you be concerned?" NFOEC'96, Denver, pp. 757-768, 1996.

[6] G. P. Agrawal. Nonlinear Fiber Optics. Academic Press, Inc, 1989.

[7] Antonelli, Cristian, Antonio Mecozzi, Mark Shtaif, and Peter J. Winzer. "Stokes-space analysis of modal dispersion in fibers with multiple mode transmission." Optics express 20, no. 11 (2012): 11718-11733.

[8] Pallavi Gupta, Rahul Sharma, Manoj Kumar, LaviAgarwal ,IJSRET"Optical Fiber Communication:Optimization using Simulation"International Journal of Scientific Research Engineering & Technology,vol1, pp184-189, 2012.

[9] Gagandeep Singh, JyotiSaxena, GagandeepKaur"Dispersion Compensation using FBG & DCF IN 120Gbps WDM System, IJESIT,"International Journal of Engineering Science and Innovative Technology vol 3,2014.

[10] Er. Mamta Jangal and Er. Deepinder Singh Wadhwa, "Polarization Mode Dispersion System LMS Algorithm Based on Feed-Forward Compensation System Balance", International Journal of Engineering Research & Technology (IJERT) ,Issue 4,ISSN – 2278-0181,vol 4, 2015.

Prabhat Gupta, Department of Electronics & Communication Engineering, M.Tech Scholar, Kanpur Institute of Technology, Kanpur, India

Vaibhav Purwar, Associate Professor, Department of Electronics & Communication Engineering, Kanpur Institute of Technology, Kanpur, , India.