Comparative Analysis of Single Span Long Haul Optical Fibre Link using Different Modulation Format

(OPTICAL FIBRE)

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In partial fulfilment of the Requirement for the
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By

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DECLARATION

I hereby declare that the dissertation proposal entitled Comparative Analysis of Single Span High Speed Long Haul Optical Link Using Different Modulation Formats submitted for the M.Tech Degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

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CERTIFICATE

This is to certify that SHITIZE TREHAN has completed M.Tech dissertation proposal titled Comparative Analysis of Single Span High Speed Long Haul Optical Link Using Different Modulation Format under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the dissertation proposal has ever been submitted for any other degree or diploma. The dissertation proposal is fit for the submission and the partial fulfillment of the conditions for the award of M.Tech in Electronics & Communication Engg.

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Signature of Advisor:
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Last but not the least, I would thank parents again and the God Almighty.

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ABSTRACT

In optical communication system with increase in the length of fibre the dispersion of the optical signal also increases. Due to dispersion it becomes very difficult to implement a long distance transmission system. In this research work to overcome dispersion such as chromatic dispersion, material dispersion and various nonlinear effects such as scattering effects and Kerr effect, dispersion compensating fibre (DCF) has been used with single mode fibre (SMF). Here in my base paper we are using various modulation formats like CSRZ, MDRZ, DPSK using three dispersion compensation schemes to find out which modulation technique is having less BER and high quality (Q) value. In which symmetric dispersion compensation scheme with DPSK modulation format comes out to be the best choice. Therefore DPSK in symmetric compensation scheme are mostly used for longer distance. Now further we are using DWDM DPSK to increase the no of channels and to increase the distance. DWDM (Dense wavelength division multiplexing) is a technology of optical fibre that can simultaneously transmit multiple information streams over the single fibre. This work is mainly focused to investigate the DPSK (Differential phase shift key) modulation scheme in high speed DWDM systems. In this paper 8 channels having capacity 40 Gb/s each are multiplexed with channel spacing of 25 GHz using polarization interleaving technique. In this work we are going to compare and investigate DPSK modulation technique by using different dispersion compensation schemes like pre, post, symmetrical compensation. The comparison of these schemes is observed in terms of Q value and eye opening by keeping BER in acceptable range with highest transmission distance. We are analysing that the symmetric schemes by using the DWDM DPSK is giving the best result in terms of longer distance than post and pre technique.

CONTENTS

CHAPTER 1

1.1 THE OPTICAL FIBRE 1

1.2 OPTICAL TRANSMITTER AND OPTICAL RECIEVER 7

1.3 TRANSMISSION IMPAIRMENTS IN OPTICAL FIBRE 9

1.3.1DISPERSION 9

1.3.1.1CHROMATIC DISPERSION 9

1.3.1.2MODAL DISPERSION 12

1.3.2NONLINEAR EFFECTS 13

1.3.2.1SCATERING EFFECT 14

1.3.2.2KERR EFFECT 15

1.4 MODULATION FORMATS 16

1.4.1CSRZ 16

1.4.2MDRZ 17

1.4.3DPSK 18

1.5WDM 19

CHAPTER 2

2.1 LITERATURE REVIEW 20

CHAPTER 3

3.1 PROBLEM FORMULATION 26

CHAPTER 4

4.1 OBJECTIVES AND RESEARCH METHODLOGIES 27

CHAPTER 5

5.1 SIMULATION SETUP 29

5.2 RESULT AND DISCUSSION 34

5.3 CONCLUSION AND FUTURE SCOPE 46

LIST OF FIGURES AND TABLES

FIGURE1: SAMPLE OPTICAL LINK 1

FIGURE2: TYPE OF OPTICAL FIBRE 2

FIGURE3: BLOCK DIAGRAM OF OFC 3

FIGURE4: COMMUNICATION SYSTEM AND OFC SYSTEM 5

FIGURE5: OPTICAL RECIEVER 8

FIGURE6: VARIOUS DISPERSION 9

FIGURE7: SINGLE MODE V/S DISPERSION MODE 11

FIGURE8: DISPERSION COMPENSATION SCEME 13

FIGURE9: SCATTERING EFFECT 14

FIGURE10: KERR EFFECT 15

FIGURE11: VARIOUS INTENSITY & PHASE MODULATION 16

FIGURE12: SCHEMATIC OF CS-RZ TRANSMITTER 17

FIGURE13: SCHEMATIC OF MDRZ TRANSMITTER 17

FIGURE14: WAVELENGTH DIVISION MULTIPLEXING 19

FIGURE15: BASIC MODEL SIMULATION OF DISPERSION SCHEMES 31

TABLE16: SIMULATION PARAMETERS 30

TABLE17: FIBER PARAMETERS 30

TABLE18: ANALYSIS OF BER AND Q FACTOR AT VARIOUS DISTANCES 34

CHAPTER – I: INTRODUCTION

Introduction of Optical Fibre System

Optical fibre technology is having the largest bandwidth capability in wired mode of communication system. In this chapter we analyse the optical technology for communication using single mode. The technology of fibre optics is very much based on the use of light to transmit the data. The youngest mode of communication is optical fibre technology. Over the past five years the growth of optic fibre industry has been explosive. For the transmission of data from one point location to another we use optical fibre technology (Figure 1). The major importance of optical technology is to lower the production cost and to point to point communication and for the security of transmission.

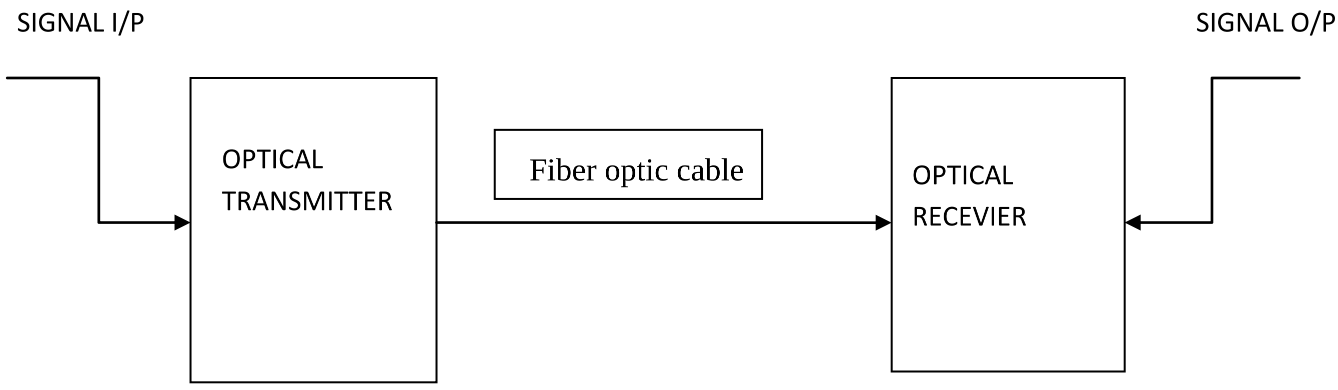


FIG 1: A SAMPLE OPTICAL LINK [1]

The main purpose of this chapter is to provide an overview of optical fibre, its construction, and its functionality. This link is basically the simplest fibre communication link. In the optical technology we use optical amplifier which help to transmit the signal for longer and optical filters that will help to discrete the signal from the noise which mainly exist due to the optical amplifier only. Before the fibre optic communication, the satellite -communication was the choice for long distance communication we use. The advanced modulation formats are the subject of the optical fibre that we will study. Optical fibres deal the study of propagation of light in different ways. Optical fibre communication system has emerged as the most important communication system as Compared to other systems.

1.1 THE OPTICAL FIBRE

The Optical fibre is basically thin glass fibre from which we can transmit the light. The optical fibre is thicker than human hair, flexible and transparent fibre which are made up of silica glass. According to the length the optical fibre will carry the light. The data transmission system of the optical fibre is done by turning the electrical signals into light. The Transmission For the optical fibre cable need repeaters at some distance intervals. Long-distance lines for most of the telephone company are basically made up of optical fibre. The Optical fibre used in optical fibre communications which are used for transmit data over long distance along with data rate needed to be high. According to the copper wire optical fibre carry more information.

Types of optical fibre:-

The basic 3 types of optical fibre cable are:

1] Step-index multimode.

2] Step-index single mode.

3] Graded-index.

The fibres which have many propagation modes are called to be Multi-mode fibres. While the fibres which has one or single mode of propagation are called to be Single-mode. So, generally the two types of fibres which are used for longer distances are called Single-mode fibre and which are used for the shorter distance are called Multi-mode fibres.

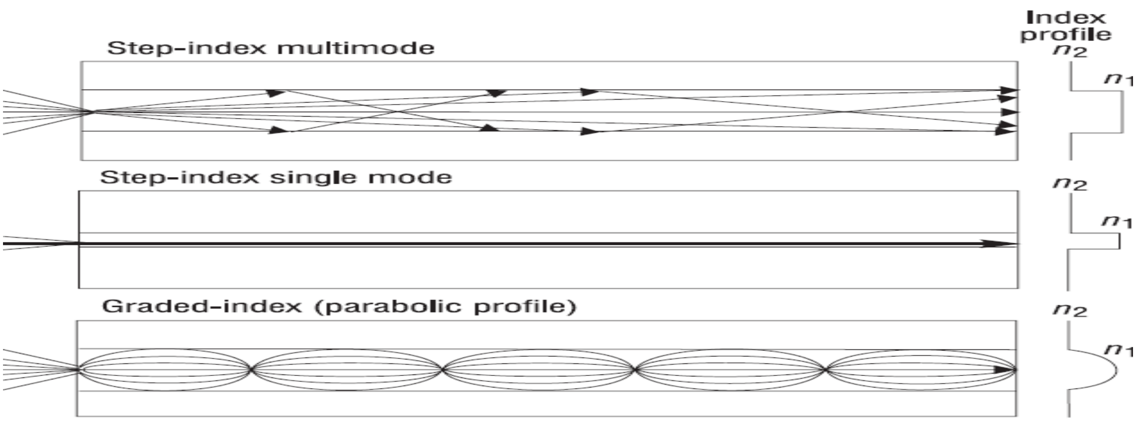


FIG 2: TYPES OF OPTICAL FIBRE CABLE [2]

Step – index multimode

- Easy coupling
- Lower data rates
- Modal dispersion
- Shorter distance

Step-index single mode

- Difficult coupling
- Higher data rates
- No modal dispersion
- Longer distance

OPTICAL FIBRE COMMUNICATION SYSTEM:

The optical fibre communication system block diagram made up of various blocks:

1] Transmitter.

2] Information channel.

3] Receiver.

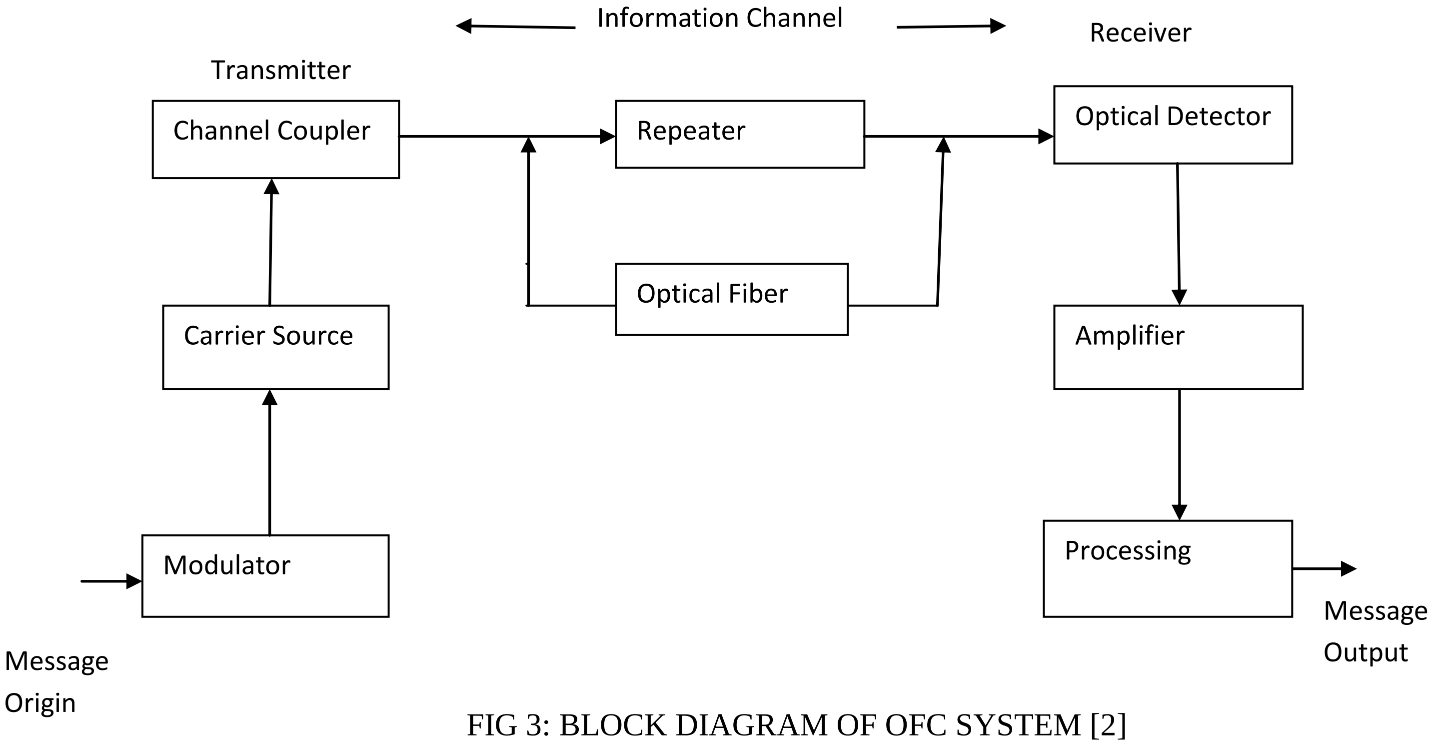


FIG 3: BLOCK DIAGRAM OF OFC SYSTEM [2]

- Message origin: Transducer is a device convert the non-electrical message into an electrical signal.
- Modulator: main two function of modulator are - 1] electrical message is converted into the proper format. 2] The wave is generated by the carrier source get impresses by the signal.
- Carrier source: The information is transmitted by the wave generated by carrier source. That wave to be called as the carrier. In optical fibre system we use optic oscillators which are light emitting diode (LED) and a laser diode (LD). They are very helpful in providing stable and single frequency waves mainly for long distance propagation with sufficient power.
- Channel coupler: In the information channel the power is feed by the coupler. In the optical fibre system the channel coupler is a lens which is used for directing the light toward the receiver by collimating the light emitted by the source. From the source to the optic fibre channel coupler help in efficiently transfer the modulated light beam.
- Information channel: The basic path between the transmitter and receiver is information channel. Glass or plastic fibre is the main channel in optical fibre. The main characteristic of the information channel is that it has low attenuation. Optical amplifiers boost the power levels of weak signals. The optical Amplifiers are required to provide sufficient power to the receiver for long links which will boost the power levels of weak signals.
- Optical detector: In the optical fibre system the photo detector convert the optic wave into an electric current which contain the transmitted information. The power in the incident optic wave is proportional to the current developed by the detector. The properties of photo detectors are economy, low power consumption, high sensitivity, size is small and life is long.
- Signal processing: Filtering and amplification is done in signal processing. In which to maximize the ratio of signal to unwanted power proper filtering is used. Decision circuit is an additional block in digital system. There should be very small bit error rate (BER) for good quality of communications.
- Message output: The messages which are in electrical form are converted into visual image or sound wave. Whenever the computers or other machines are mainly connected through optical fibre system we can use these signals directly.

So, these are the various blocks of the optical fibre Communication system in three main blocks that is transmitter, information channel and receiver. If we compare the general communication system and the general optical fibre communication system general communication system provide the information source which will pass through the transmitter (modulator).Proceed the information and the data to the transmission medium which is the centre hub of the general communication system. Then transmission medium will transmit the information and data to the receiver (demodulator). Receiver will receive the information and further transmit that information source to the destination. And in the case of general optical fibre communication system information source will transmit through the electrical transmitter and that will further transmit the information to the optical source. Then the optical source will be transmitted through the optical fibre cable to the optical detector which will detect the signal and transmit further. Then electrical receiver will receive the signal and send that to the destination. Generally the fibre optical communication is a method by sending pulses of light transmission of the information from one place to another. To carry the information electromagnetic carrier wave is modulated. The optical fibres are used for the fibre optic communication which is helpful for the transmission at higher BW for the long distance than any other communication forms.

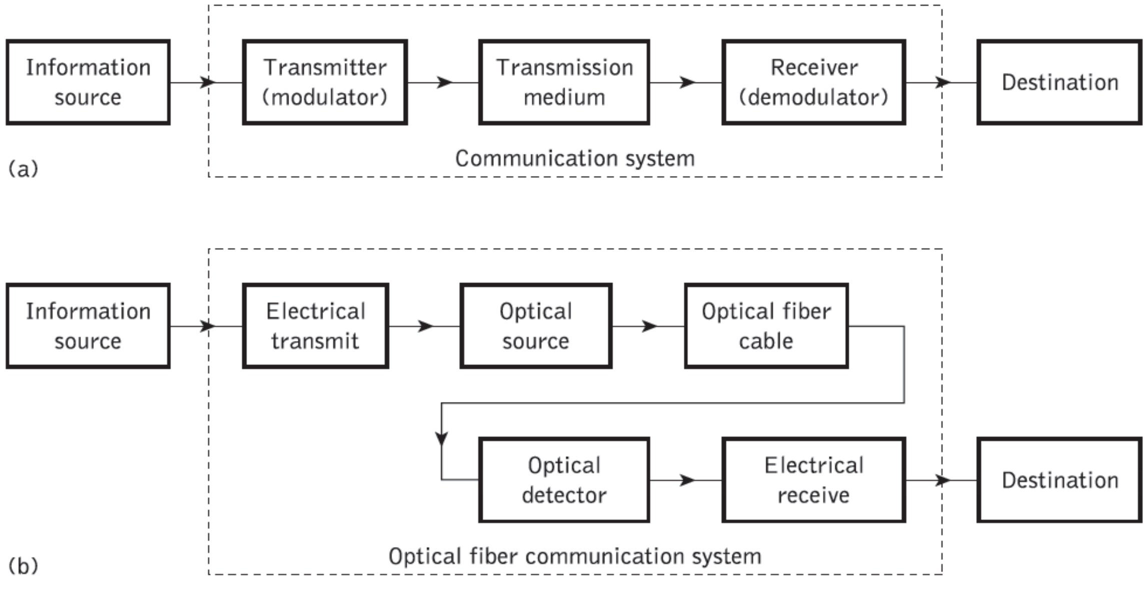


FIG 4: A) GENERAL COMMUNICATION SYSTEM &

B) GENERAL OPTICAL FIBRE COMMUNICATION [3]

ADVANTAGES OF OPTICAL FIBRE COMMUNICATION:

- Low cost: optical fibre is less expensive than copper and we know that optical cable prices are low as compare to others. As comparison to other system optical fibre cost is very less so the services of telecommunications with the smaller cost provide a good quality formation. With the less cost optical fibre cables last longer than copper cables.
- High bandwidth: Today every communication requires a large amount of bandwidth. The optical fibre communication has hundreds times more BW that of other cables. With the high BW transmission of data is done with the high speed which offers immediately transmission of data under the very high speed. Optical fibres have very small diameters near about a human hair.
- Long-distance signal transmission: Due to low attenuation of signal while transmit the weak signals can be strengthened very easily by amplifier. There is very less signal attenuation for longer distance offer by the optical fibre causes less loss.
- Light weight: The optical fibre cables are lighter than copper cables, aluminium cables or any other cables which are made of silica glass or plastic.
- Security: The optical fibres provide a high degree of signal security as the light does not radiate significantly. It is impossible to detect the signals which are being transmitted within the cable because of the dielectric nature of optical fibre this can be done by accessing the optical fibre. With the major security format optical fibre is used in governmental bodies, banks and many other areas.
- Environment immune: The optical Fibre cables are not affected by gases or corrosive liquids: The optical Fibre cables can handle the extremes temperature variations.
- Easy installation: The optical Fibre cables are easy to maintain and install. The small size and light weight of optical fibre make installation easier.
- Non conductivity: Dielectric nature is the one of the major advantage the optical fibre. The optical fibre can be installed in the areas or region with electromagnetic interference (EMI) and radio frequency interference (RFI). In the electrical and magnetic field the optic fibre cables are having high immunity.
- Less requirements of signal power/energy for transmit: In the way of transmission of data less consumption of energy and concerning the electric signal required.

APPLICATION OF THE OPTICAL FIBRE COMMUNICATION:

- The optical fibre is used in telephone network because they have high transmission bandwidth and low attenuation as compared to other cables.
- Broadband application.
- Medical application.
- Military application.
- Industrial application
- Mining application
- Railways and aircraft
- Telecommunication, data communications, video control and protection switching.
- SONAR application
- Used as light guide in medical and other buildings.
- Optical fibre sensors
- CCTV
- CABLE TV
- Local area networks.

1.2 OPTICAL TRANSMITTER AND OPTICAL RECEIVER

1] OPTICAL TRANSMITTER:

The major component in an optical transmitter is the optical source. The electrical input signal is converted into corresponding optical signal by the optical transmitter which is launched into the fibre. Light Emitting Diode (LED) and semiconductor Laser Diodes (LD) generally the optical transmitter. LED and LD are used because of high reliability, low cost, easy to manufacture, high optical power, can be used at high temperature, better modulation capability is there that's why LED and LD are generally used. High power is produced by the lasers. Powers can be produced in kilowatts by the lasers.

Various Characteristics of light source used for communication:

- Small emitting area should be there in optical fibre so that large amount of power coupled.
- Narrow output spectrum should be there in optical fibre link so that material dispersion can be reduced.
- Less cost and low weight.
- High coupling efficiency should be there with high optical output power.
- There should be low power requirement for its operation.
- For a long period of time it should be possible to operate the device at variety of temperature.
- There should be high optical output power.

2] OPTICAL RECEIVER:

The important parameter/characteristic we need to consider for optical receiver or detector are:

- How the signal is influenced into the low level signal when there is a noise present in the device.
- To understand the quick and sudden changes of the light in the device.
- Important parameter is efficiency of the device.
- Device operated by the range of wavelength.

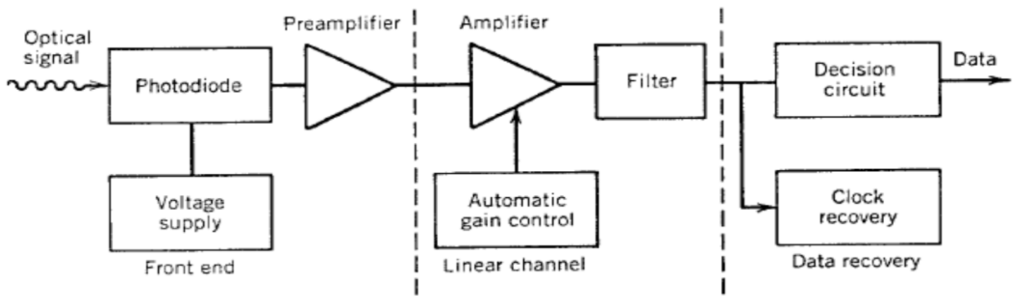


FIG 5: DIAGRAM OF OPTICAL RECIEVER [5]

Optical energy is converted into electrical signal by the optical receiver system. The optical receiver will amplify the signal. As given in fig (5) important block of the optical receiver are:

- Photo detector.
- Amplifier or Liner channel.
- Signal processing circuitry or Data recovery

TRANSMISSION IMPAIRMENTS IN OPTICAL FIBRE:

1.3.1DISPERSION:

Pulse spreading in an optical fibre is basically called as dispersion. Dispersion is expressed in term of the symbol Δt. The fibre elements such as core diameter, refractive index profile, wavelength, and numerical aperture propagates the pulse of light which make the pulse to be broaden. The dispersion will be as more as longer the fibre will be. Data rate-distance product is governed by the dispersion not the data rate.

We can determine Dispersion Δt: $\Delta t = (\Delta t_{out} - \Delta t_{in})1/2$ and,

Total dispersion per unit length: $\Delta t_{total} = L \times$ (Dispersion/km)

The overall effect of dispersion on the performance of a fibre optic system is known as Inter symbol interference. Dispersion is divided into different categories: chromatic dispersion, modal dispersion, polarization mode dispersion.

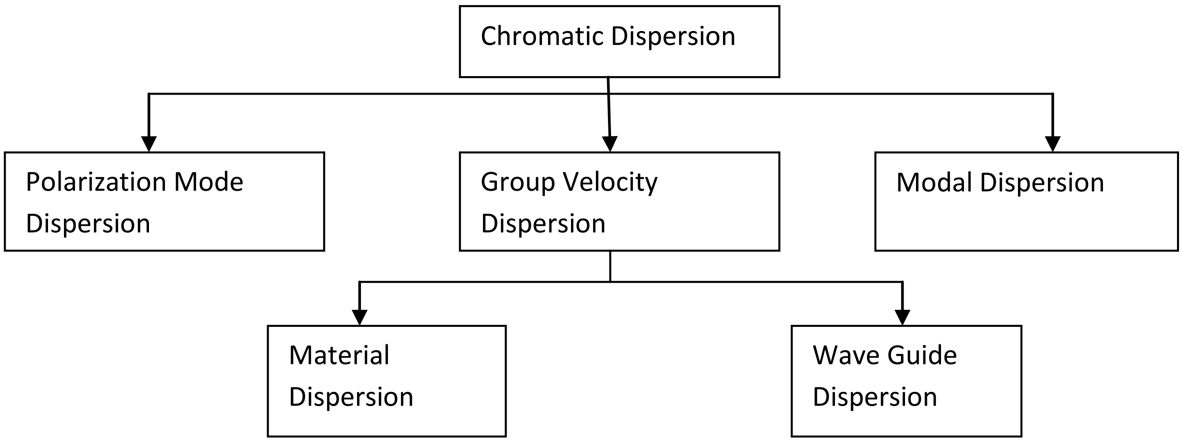


FIG [6]: VARIOUS DISPERSION [6]

A) CHROMATIC DISPERSION:

Among the degrading effects of fibre chromatic dispersion plays a very important role. Chromatic dispersion exists due to finite bandwidth of the signal. Chromatic dispersion is also known to be intra-modal dispersion which is present in single mode or in multimode. Different velocities through the fibre different wavelengths of light propagate which make chromatic dispersion as pulse spreading. The unit of chromatic dispersion is nanoseconds or picoseconds per (km-nm). Different wavelengths propagate at different velocities as the refraction index of glass fibre is a wavelength-dependent quantity.

The chromatic dispersion is divided into two parts: 1] material dispersion and 2] wave guide dispersion.

- Material dispersion:

Material dispersion exists due to intrinsic properties of the material, glass. The change in index of refraction for different wavelengths causes material dispersion. Pulse broadening is done from the different spectral component of different velocities launch from the optical fibre source due to material dispersion. Material dispersion causes the effect of pulse travel at different velocities comprising at different wavelength. The factor contributing to chromatic dispersion material dispersion is basically synonymous with spectral dispersion and intra-modal dispersion.

Material dispersion for unit length [L=1]:

$$D_{mat} = \frac{-\lambda}{c} X \frac{d_n^2}{d\lambda^2}$$

Where,
c = Light velocity
λ = wavelength

$\frac{d_n^2}{d\lambda^2}$ = Second derivative of index of refraction w.r.t wavelength

The upper sideband signal (lowest wavelength) indicates the negative sign which arrives before the lower sideband (highest wavelength).

- Wave guide dispersion:

Waveguide dispersion exists due dispersive nature of the bound medium. The velocity is a function of frequency in the optical fibre bound medium. Physical structure of the waveguide causes the waveguide dispersion. Only fibres which are carrying fewer than 5-10 modes make use of waveguide dispersion. The multimode optical fibres will not have waveguide dispersion as it carry hundreds of modes. Due to waveguide dispersion it arise the group delay (τwg). As we know that the combination of waveguide dispersion and material dispersion is known to be chromatic dispersion. These losses primarily concern with the correct choice of wavelength.
The waveguide dispersion is significant as the effect of the different dispersion mechanisms are not easy to separate within single mode fibre. Waveguide dispersion fully depends on the ratio of *a*/λ.
Fig [7] compares the material chromatic and fibre dispersion-shifted fibre and wavelength dispersions for single-mode:

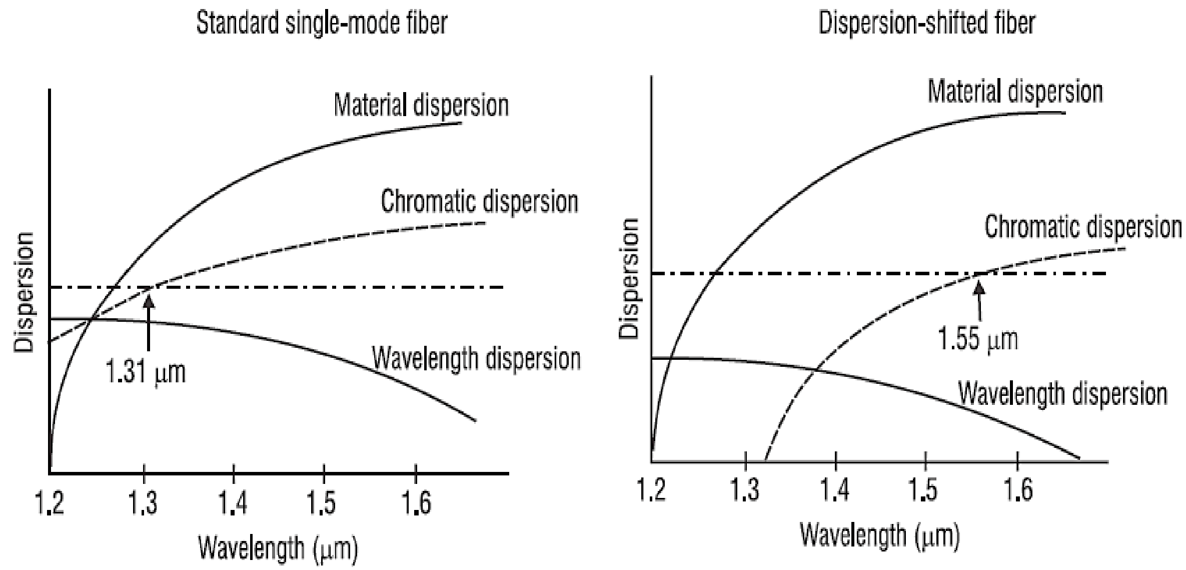


FIG [7]: Single-mode versus dispersion-mode versus dispersion-shifted fibre [3]

The modal dispersion and polarization mode dispersion are another dispersion which are to be discussed further after the chromatic dispersion.

B) MODAL DISPERSION:

The main thing about modal dispersion is that it takes place in multimode fibres. The modal dispersions are almost eliminated in single mode index fibre. Mostly in the graded Index fibres modal dispersion is present. Other names for this can be multimode dispersion, modal distortion or multimode distortion. Even with monochromatic light source modal dispersion is present. Modal dispersion has a very special case as polarization mode dispersion which associated with single mode fibres. The bandwidth of multimode fibre is limited by the modal dispersion.

Modal dispersion is given by:

$$\Delta t_{modal=\frac{n_1 z}{c}}\left(\frac{\Delta}{1-\Delta}\right)$$

Where,

Δt modal -Dispersion

n1 - Core refractive index

Z - Total fibre length

c - Velocity of light in air

Δ - Fractional refractive index

C) POLARIZATION MODE DISPERSION:

The limiting factor for optical communication system at high data rates is PMD [polarization mode dispersion] so that the effect of polarization mode dispersion must be compensated. The different polarization state [such as linear polarization and circular polarization] acquires by the different frequency component. Among all the different dispersion polarization mode dispersion is the most complex. Polarization mode dispersion very much attached to single mode fibres. Different velocities having different polarization mode travel with different propagation time between the two modes.

DISPERSION COMPENSATION SCHEME:

For the long distance transmission single mode fibre is upgraded to compensate the dispersion format. For that dispersion compensation scheme is applied to the system where we are using dispersion compensating fibre (DCF), single mode fibre (SMF) and EDFA. So the three dispersion compensation schemes are: pre, post and symmetric configuration.

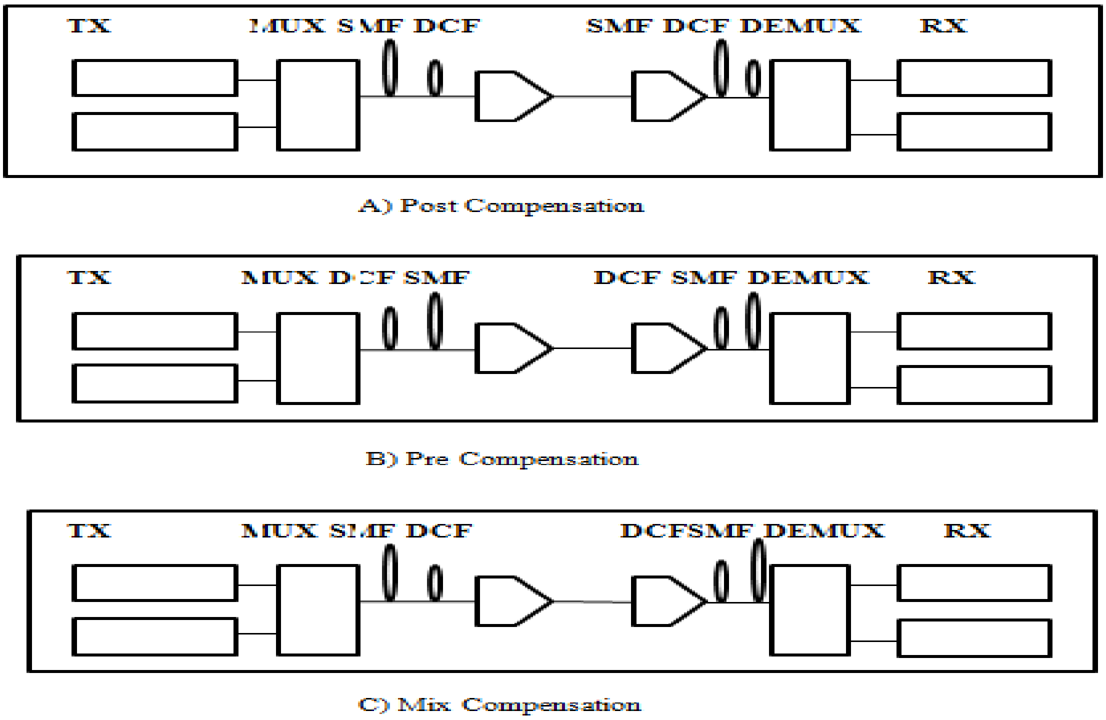


FIG [8]: DISPERSION COMPENSATION SCEMES [4]

1.3 .2 NONLINEAR EFFECTS:

The fibre refractive index will be modified when the optical intensity inside the optical fibre increases. Non linearity may occur due to the optical power of few tens of Mw in single mode optical fibre. The pulse propagation gets significantly modified when the optical fibre becomes non-linear which generates some new frequencies inside the optical fibre. The spectrum of the output signal is not similar to the input signal. Large optical power is required to observe the non-linearity in the bulk medium. Where as optical non-linearity can be easily observed with low optical power. The nonlinear effects are weak at low powers which can become stronger at high optical intensities.

To handle the signal propagation affected by non- linearity there is two approaches:

- By keeping low optical power levels we can avoid nonlinearity: Since the optical power has to be increased for long distance communication then the first option does not seem very feasible. Also in a multi-channel system like WDM, the total power of all channels together is large enough to drive the optical fibre into non-linear regime even if each channel has low power so this point to be considered.
- By Understanding the non-linear signal propagation and making the use of it for increasing the transmission capability of the fibre: The second option is more desirable. This option is challenging because the non-linear pulse propagation is a very complex phenomenon.

. The main two categories of nonlinear effects are:

1] Scattering effects.

2] Kerr effects.

1] SCATTERING EFFECTS:

Scattering take place when a single signal or wave strike the rough surface which leads to scattering of multiple signal. Optical wave in a fibre scattered the medium incident photons by producing a phonon emitted at various shifted frequencies. The energy difference with the scattered photon emerges at a frequency shifted below or above the incident photon frequency between the two photons being deposited or extracted from the scattering medium. Only if the material gives up quantum energy equal to the energy difference between the incident and scattered photon then only up shifted photon frequency is possible.

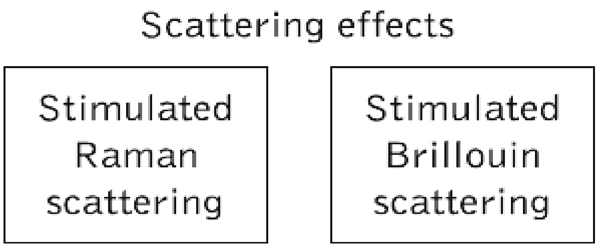


FIG [9]: SCATTERING EFFECT [3]

2] KERR EFFECT:

Kerr nonlinearities are the effects described by the intensity-dependent refractive index of the fibre. Kerr effect is also name as quadratic electro optic effect. Kerr effect causes a variation which is fully proportional to the local irradiance of light. To avoid the chromatic scattering at the time of transmission of light Kerr effect is used. Kerr nonlinear effects may be observed at higher optical intensities applied to field. Kerr effect is basically the production of double refraction by an electric field in a substance.

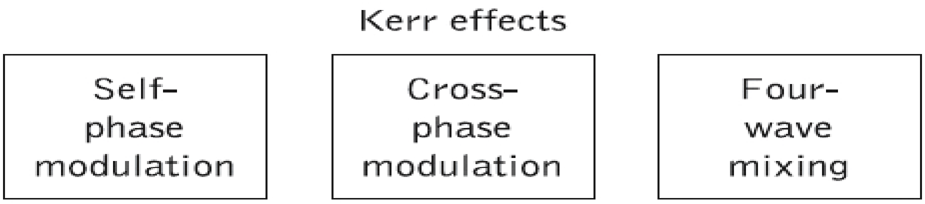


FIG [10]: KERR EFFECT [3]

The three process through which Kerr effect is produced are: self-phase modulation (SPM), cross-phase modulation (XPM) and four-wave mixing (FWM). The effect self-phase modulation (SPM) causes the modification to the pulse spectrum when the light pulse propagating in the fibre the leading and trailing pulse edges compared with different transmission phase for the peak. Depending on the fibre type and its chromatic dispersion the spectral broadening that is caused by SPM produces the dispersion effects which can limit the transmission rates for the long-haul optical communication systems. Cross-phase modulation (XPM) is very much similar effect to self-phase modulation (SPM) other than the overlapping of pulses possessing example as different wavelengths or polarizations involved in this. XPM is crosstalk mechanism between channels when either the intensity modulation is used in dispersive optical fibre transmission or, when the phase encoding is employed. Where as four-wave mixing (FWM) is termed as the generation of modulation sidebands at the new frequencies where the beating between the light at different frequencies or wavelengths in multichannel fibre transmission causes phase modulation of the channels.

1.4 MODULATION FORMATS:

The objective of this lesson is to demonstrate the ability to modulate optical signals in formats different of the common RZ and NRZ. In this our goal is to generate a optical signal in different modulation formats. To generate the optical signals we generally use a laser source, Mach-Zehnder modulators, NRZ pulse pattern generator and a sinusoidal electrical signal generator. The most important intensity and phase modulation format in optical fibre communication are:

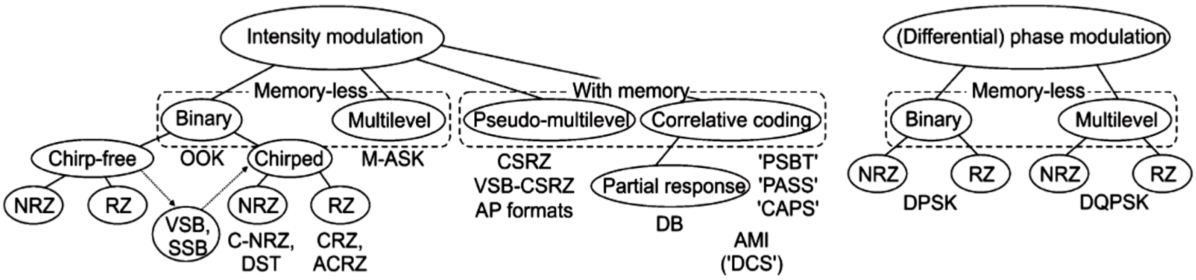


FIG [11]: VARIOUS INTENSITY AND PHASE MODULATION IN OPTICAL [1]

The modulation format we are using in this paper are:

1] Carrier-suppressed return to zero (CSRZ)

2] Modified duo binary return to zero (MDRZ)

3] Differential phase shift keying (DPSK).

1] CSRZ:

The CSRZ signal is generated in a similar way to the RZ format. Where the frequency of the sinusoidal electrical signal applied in the second MZM have half of the bit rate. Characteristic for CS-RZ is that there are two clock components of half data rate away from the carrier in its spectrum.

The mixed effect of the self phase modulation (SPM) and group velocity dispersion (GVD) has high tolerance for the CS-RZ format.

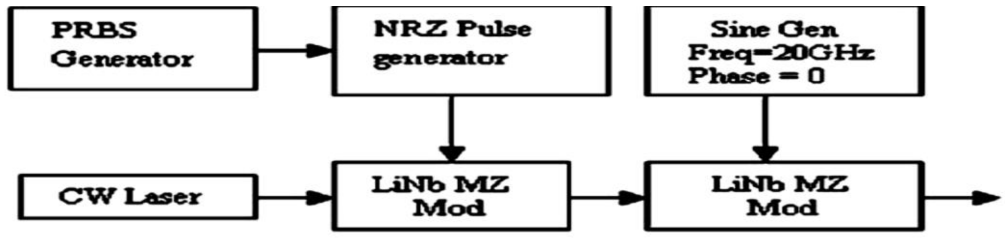


FIG [12]: SCHEMATIC OF CS-RZ TRANSMITTER [5]

The main reason for doing the CSRZ format is to suppress the central peak at the carrier frequency. In CSRZ modulation format firstly the NRZ signal is given to the Mach-Zehnder Modulator and then further given to the phase modulator.

2] MDRZ:

MDRZ is Modified duo-binary RZ. The MDRZ can be generated by first creating an NRZ dou-binary signal using an delay-and-subtract circuit that will drives the first MZM [1], and then concatenating this modulator with a second modulator which is driven by a sinusoidal electrical signal with the frequency of 40 GHz and -90° phase shift. The generation for MDRZ signal is almost identical to the DRZ signal. The schematic of the 40 Gb/s modified duo-binary transmitter which is also known to be carrier- suppressed duo-binary format figure for this is:

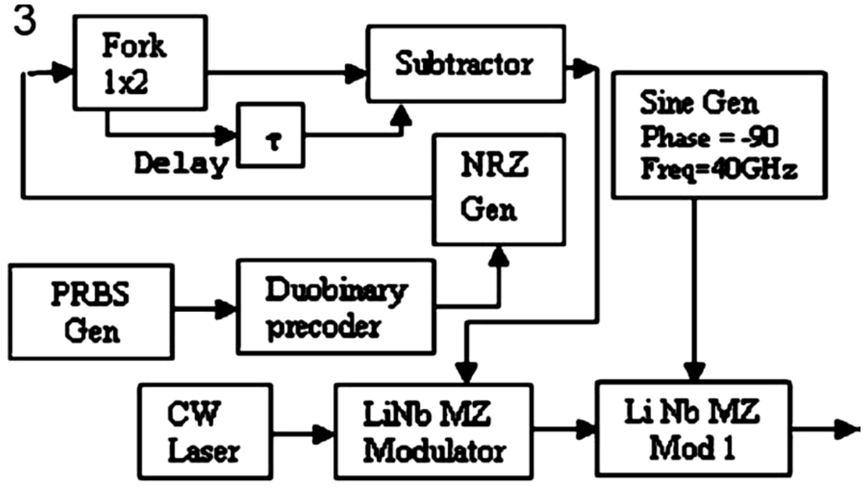


FIG [13]: SCHEMATIC OF MDRZ TRANSMMITER [5]

In the modified duobinary signal the phase alternate between the 0and p for the bits 1 but for the duobinary signals used before where the phase of bits ‘1’ are modified after bit ‘0’ where the phase of all ‘zero’ are kept constant and 180 degree phase variation between the consecutive ‘ones’ will be introduced.

3] DPSK:

For the DPSK signal generation, we will use two concatenated modulators. In DPSK format the phase modulation was generated by using a duo-binary the NRZ signal is firstly encoded that will drive the first MZM and modulates the phase of the CW signal. Then concatenate the first modulator with second modulator driven by a sinusoidal electrical signal with the frequency of 20 GHz. And then the encoding in the initial bit sequence will allow the demodulation of the transmitted signal at the receiver by using a Mach-Zehnder interferometer and balanced photodiodes. The various phases of the optical carrier are also used to represent the digital signal, which is OPSK (Optical Phase Shift Keying). The improvement of mono frequency laser sources with the active optical phase locking application makes the PSK very use full in all the formats. The DPSK modulation format is the most widely used among others. It will be recognized as "1" When there is a phase change between consecutive data bits in the carrier, and it will be considered as digital "0" when there is no phase change. The optical power remains always constant is the main aspect of NRZ DPSK signal. Here the DPSK modulation format comes to be the best format among MDRZ and CSRZ.

1.5 WDM

WDM is termed as wavelength division multiplexing. Wavelength division multiplexing is basically used to different optical signals at different wavelengths into one, so that it can be transmitted through single mode fibre. Wavelength division multiplexing (WDM) provides a convenient method for increasing the capacity of an optical system. Dispersion is the main factor for the utilization of WDM system. Main motto of wavelength division multiplexing [WDM] is to assign different wavelength to different channels, then multiplex them for carrying the information to the fibres and at last de multiplex them at receiver end. By using different wavelengths at the same channel will leads to increase the enormous bandwidth capacity. Most Wavelength division multiplexing (WDM) systems work in the c- band around 1550 nm. In practice standard channel separation grid from 191.1 THz to 192.5 THz separated by 100ghz, 50ghz, 25ghz. The channels are equispaced in frequency in Wavelength division multiplexing (WDM) not in wavelength. So the Wavelength division multiplexing (WDM) systems with the denser packing given above are called Dense Wavelength division multiplexing (DWDM). Each channel has a dedicated bandwidth since WDM carries each signal independently of other signal. In Wavelength division multiplexing (WDM) signal arrive at the destination at same time not in different time slots. WDM can support multiple protocols. Each signal can be carried at different bit rates. In Wavelength division multiplexing (WDM) technology the transmitters with stable tunable wavelengths are the laser source. Multiplexer will mix the wavelength before sending the signal through the link. DWDM is mainly consist of a transmitter and a receiver with a fibre link between them. These days DWDM are mainly used for long haul (thousands of km) with many component including amplifiers, DCF, wavelength converter etc.

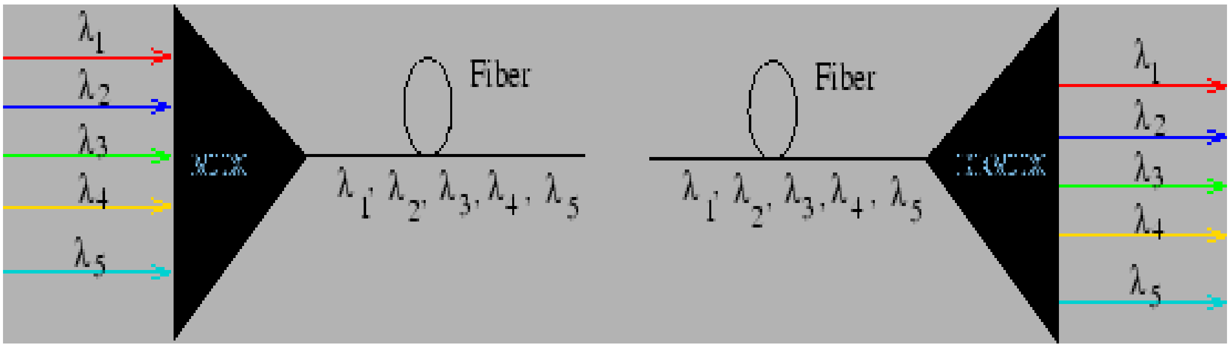


FIG [15]: Wavelength division multiplexing (WDM) [9]

CHAPTER 2

LITERATURE REVIEW

- **Ankit V. Patel**, **R.B Patel and Kinjal, A Mehta "Comparative Analysis of Single Span High Speed 40 Gbps Long Haul Optical Link Using Different Modulation Formats in the Presence of Kerr Nonlinearity" in 2014 [4]** : This paper proposes to examine long distance optical link by using various modulation format by using three dispersion compensation schemes in the presence of nonlinear effect. Here in this paper modulation formats like carrier-suppressed return to zero (CSRZ), modified duo binary return to zero (MDRZ), and differential phase shift keying (DPSK) are used. For this modulation format effect of change in the input power and transmission distance is observed in terms of Q value, BER and eye opening. For all three modulation formats the pre, post and symmetrical analysis is also carried out. We are simulating the single span optical link for long transmission distance. In all the three Pre, Post and Symmetrical Compensation schemes performance analysis is done for the three different modulation schemes used CSRZ, MDRZ and DPSK. Among the modulation formats DPSK with Symmetrical DCF compensation performance in terms of Q value, BER and eye opening is better than all.

- **Ajay K Sharma, A Shetaala and R.S Kaler, "Simulation of high capacity 40Gb/s long haul DWDM system using different modulation formats and dispersion compensation schemes in the presence of Kerr's effect" in 2008 [5]**: This paper proposes to examine simulative analysis for the long haul optical fibre DWDM system with the high capacity carried out for the modulation formats which are carrier-suppressed return-to-zero (CSRZ), duo binary return-to-zero (DRZ) and modified duo binary return-to-zero (MDRZ). For 16 channels The DWDM system has been analyse for the pre, post and symmetrical dispersion compensation schemes to find the optimum modulation format for high bit rate transmission. To find the effect of variation in input power and the distance of transmission is observed in terms of Q value and eye diagram for various modulation formats. It has been found that symmetrical compensation is better than pre and post dispersion compensation schemes.

- **R.S Kaler, Ajay K Sharma and T.S Kamala**, **"Comparison of pre-, post- and symmetrical-dispersion compensation schemes for 10 Gb/s NRZ links using standard and dispersion compensated fibers", in 2002 [6]**: This paper proposed to optimize the high data rate transmission, investigation is done for pre, post, symmetrical dispersion compensation methods for 10 Gb/s non-return to zero (NRZ). Bit error rate, eye diagrams and eye closure penalty characteristics performance at the output are studied by simulating the systems. Among the three compensation methods it is found that the symmetrical compensation method is superior to pre- and post-compensation methods. By simulating it has been found that there should be proper matching between the EDFA power and the length of fibre for good optical performance.

- **Gabriel Charlet** ***"Progress in optical modulation formats for high-bit rate WDM transmissions,"*** **in 2006 [7]**: This paper proposed by using wavelength division multiplexing (WDM), transmission is done for long distance by increasing the bit rates. The optical communication systems use WDM that is with several wavelengths which carry different information multiplexed into one single optical fibre and then transmitted. After the transmission from single optical fibre the optical signal will be de multiplexed. Then the optical signal is further detected by four receivers. We studied about different modulation format. We observe some trend towards modulation format. In which the first one towards modulation format for better sensitivity and non linear tolerance. And second is search for modulation formats compatible with high information spectral density in the system.

- **P K Raghav, M Sharma and A Sharma** ***"Analysis on Dispersion Compensation in WDM Optical Network using Pre, Post and Symmetrical DCF based on Optisystem"*** **in 2014 [8]:** This paper analyses the transmission performance influenced by the dispersion and to improve the overall system performance. The dispersion compensation scheme in the WDM system is used. Dispersion effect in optical transmission system is analysed. Three dispersion compensation schemes pre-compensation, post-compensation and symmetrical compensation with DCF are used. Based on these schemes simulation results such as Q factor, Min BER, Eye height, Threshold and OSNR are analysed and studied. After analysing above we find that Pre DCF technique is much better than post and symmetrical DCF techniques.

- **Saurabh Kumar, M Kumar and A.K Jaiswal** ***"Performance Analysis of Dispersion Compensation in Long Haul Optical Fiber with DCF"*** **in 2013 [9]:** This paper proposed to investigate post, pre and symmetrical/mix dispersion compensation methods for 40 Gb/s for non-return to zero link using dispersion compensated fibre to optimize high data rate optical transmission. By increases the power of CW laser evaluation is done for the performance of optical communication systems. The simulation is done for finding the Q factor and bit error rate (BER). Here we are using fibre brag gratings (FBG) are implemented instead of using dispersion compensated fibre (DCF) for dispersion compensation schemes. It is found that compensation schemes reduced the dispersion but the post compensation scheme reduced the chromatic dispersion to the maximum possible value. Bigger value of laser average power is favourable to the performance of the transmission system. So dispersion and loss are the major factor that that plays a role in affecting the fibre-optical communication. So here we are studying how to reduce the loss and dispersion by affecting the long haul optical fibre.

- **Sandeep Singh and V.B Tyagi** ***"Performance Analysis of WDM Link Using Different DCF Techniques"*** **in 2012 [10]:** In this paper the most commonly used technique is dispersion compensation fibre (DCF). Here we are studying the three compensation schemes pre-compensation, post compensation, symmetric – compensation which shows the symmetric is the best. Symmetric compensation generally reduces the influences of the fibre nonlinearity and also help full in increasing the transmission distance. Symmetric-compensation scheme reduce the fibre nonlinear effects better than other two.

- **M. I. Hayee and A.E Vilnerr** ***"Pre- and Post-Compensation of Dispersion and Nonlinearities in 10-Gb/s WDM Systems"*** **in 1999 [11]:** in this paper we are analysing 10-Gb/s non dispersion-managed and dispersion-managed. By using use pre-compensation, post-compensation, or symmetric-compensation technique. This compensation schemes technique is used to minimize the dispersion and non-linear effect. We will find that symmetric-compensation gives the best result which gives the minimal penalty for each channel in dispersion-managed WDM (wavelength division multiplex.

And further we will find the optimal amount of pre or post-compensation map used in the WDM system which will depends upon the specific dispersion. Finally in this we analyse the dual compensation of dispersion-managed systems for the three dispersion maps. And we find the best compensation scheme technique among all the three to be symmetric compensation technique.

- **Gaurang H Patel; Rohit B Patel and Sweta J Patel "A design and comparative analysis of 320 Gb/s DWDM optical network with CSRZ, DRZ, MDRZ modulation technique" in 2013 [12]:** In this paper we are analysing the design of DWDM optical network with various modulation formats which are MDRZ, CSRZ, DRZ using 8 channels with the frequency spacing of 100GHz. Here three dispersion compensation schemes are used pre, post, symmetric. And after simulated all the modulation formats with different compensation schemes we concluded that MDRZ modulation format give the best result among all the three modulation in symmetric compensation schemes. So MDRZ with symmetric compensation schemes is used for optical formation than other two modulations which are CSRZ and DRZ modulation format.

- **Urvashi Bansal and Kamaldeep Kaur " 1.6 Tbps high speed long reach DWDM system by incorporating modified duo binary modulation scheme" in 2014 [13]:** In this paper we are investigating modified duo binary modulation schemes in high speed DWDM system with 40 Gbps having 40 channels and channel spacing is of 50GHz. In this paper the role of laser line width is mainly used so that the non linear effect can be minimized. Here the analysis of modified duo binary modulation using DWDM with spacing 50GHz is done for the best results upto the distance 1800 km. here in this paper the investigation is done for 1 channel to 40 channels with 40Gbps data which clearly state that all the channels are transmitted upto 1800 km with acceptable SNR and BER given by ITU.

- **Sharanjeet kaur and Gurpreet bharti "Analysis of polarization interleaved WDM system with inline compensation" in 2014 [14]:** In this paper it is explained that polarization interleaving mean if there are 6 channels i.e. channel1, channel2, channel 3, channel4, channel5, channel6 are divided into odd and even channels and then multiplexed separately as odd channel for 0 degree and even channel for 90 degree. This paper investigate the performance of WDM system using polarization interleaving technique along with fibre Bragg Grating (FBG) inline compensation and investigation is done in terms of BER and Q factor using optisystem software. In this paper we are using different no of channels which are 6 channels and 12 channels and the channel spacing of 75Ghz and 100Ghz. We concluded that as the channel spacing increases from 75Ghz to 100Ghz the transmission distance increase and interchannel crosstalk get reduced.

- **Jyoti Choudhary; Lalit Singh Garia and Rajendra Singh Shahi "Comparative analysis of DWDM system using different modulation and dispersion compensation techniques at different bit rates" in 2014 [15]:** In this paper 16 channels DWDM system using different modulation techniques like NRZ, CSRZ, MDRZ and DRZ is used . here we are using different dispersion compensation schemes like pre, post and symmetric at various bit rates 10Gbps, 20Gbps and 40Gbps are used to find the difference in terms of BER and Q factor among them and we concluded that symmetric compensation gives the better result among pre and post compensation techniques at 40Gbps data rate with MDRZ (modified duo binary return to zero) modulation technique.

- **Lucky Sharan and V.K Chaubey " Design and simulation of long haul 32*40 Gb/s duobinary DWDM link in the presence of non-linearity with under-compensated dispersion " in 2012 [16]:** In this paper using DWDM (Dense wavelength division multiplexing) system with 32 channels comparing them with different modulation schemes that is pre, post, symmetric. The simulation is based on 40Gb/s long haul formation with 50Ghz channel spacing to all the 32 channels using DRZ (duo binary return to zero) modulation technique formation. The best result is shown upto the distance of 1000km with the accepted value of BER given by ITU. We have concluded that symmetric compensation scheme perform the best result among all three schemes the results have been concluded in terms of Q (Quality factor) and BER (Bit error rate) in eye diagrams formation.

CHAPTER 3

PROBLEM FORMULATION

A number of techniques are being found to increase speed and the length of fibre optic link. The research proved that the major issue which comes across while attaining high speed and long haul optical links is various types of noise like chromatic dispersion, PMD and non linear effect like kerr effect. Out of these noises, Chromatic dispersion significantly affects the system quality.

From literature survey, we concluded number of suggested ways but the issues is with implementation of these ways inspires us to look forward for solution which in itself should not be a problem to the kerr effect and chromatic dispersion noise issue.

Discussion of various problems identified:

1. In analysis of DPSK- DWDM at narrow channel spacing we will get the more dispersion as we will decrease the channel spacing

2. Signal power: To reduce the non linear effects power level should be low. But in long haul link high power is required so high power in long haul high speed link create problem.

3. Non symmetric DCF: Single configurations DCF are used in system to get best results. The fibre non-symmetric reduces the dispersion but not give best results.

So, by analysing the various issues in solutions of various reports in literature survey motivates us to find a promising way out to PMD, chromatic dispersion noise issue which can help us to enhance the high speed long haul systems in future and also to increase the speed of already existing systems by making minor possible changes into them.

CHAPTER 4
OBJECTIVE AND RESEARCH METHODOLOGY

OBJECTIVES:

The proposed is focused out to full fill following objectives:

1] To study fibre optical communication system.

2] To analyse the effect of pre, post and symmetric configuration of DCF on chromatic dispersion.

3] To study the performance of DWDM system using different dispersion compensation.

4] And main objective is to design and analysis DPSK- DWDM system at narrow channel spacing using different dispersion compensation schemes in terms of Q- factor and BER and increasing the distance for longer area.

RESEARCH METHODOLOGY:

Research Methodology that will be taken to complete the dissertation or project is described under: The first step will be simulation and designing of the High speed long haul optical fibre link using different modulation schemes. This will be done by using Optiwave's Optisystem software. Firstly the study about software will be done. The optisystem software is easy to use, flexible, powerful and fast than others. The optisystem enables users to plan, test and simulate the following:

1. WDM/TDM or CATV network design.
2. Estimation of BER and system penalties with different receiver models.
3. Transmitter, channel, amplifier and receiver design.
4. Dispersion map design.
5. SONET/SDH ring design.
6. Amplified system BER and link budget calculations.

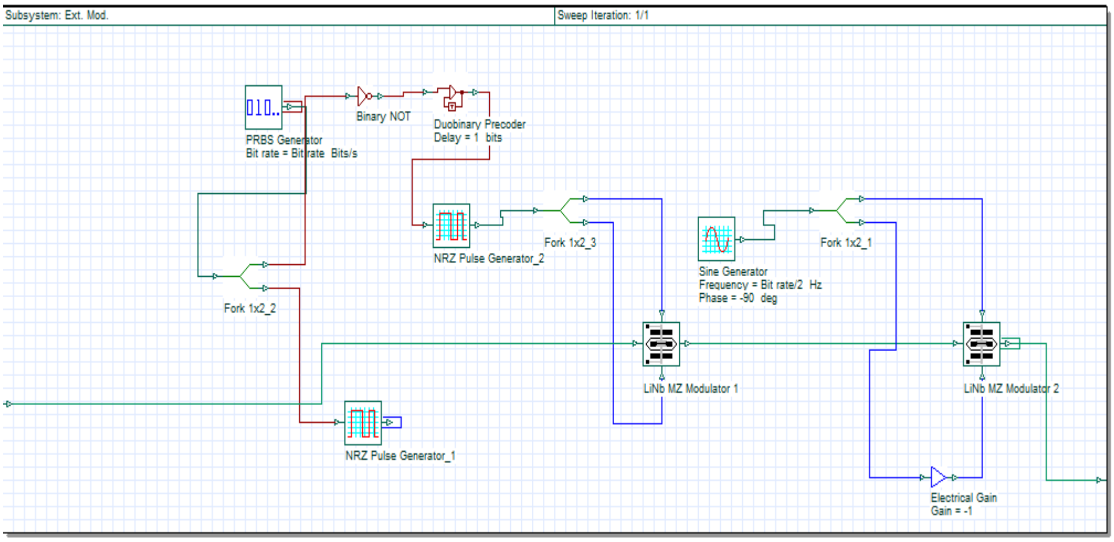
The optisystem components library includes hundreds of components that enable to enter parameters that can be measured from real devices. We can incorporate new components based on subsystems and user-defined libraries, or utilize co-simulation with a third party tool such as MATLAB or SPICE. In order to predict the system performance, optisystem calculates parameters such as BER and Q factor using numerical analysis or semi-analytical techniques for systems limited by Inter symbol Interference and noise Optisystem allow us to incorporate dispersion compensation technique by using different configuration. This allows to process data after simulation without recalculating. An arbitrary number of visualisers can be attached to the monitor at the same time.

By using model design of modulation technique such as DPSK using DWDM technique in optisystem software, the parameters such as Data rate, modulation schemes, signal power etc are varied and used to study system performance. The BER analyser visualiser will be used for analysis, where the system BER, Q-factor, and eye diagrams will be obtained. And the graphs between Q-factor, power, BER will be plotted.

CHAPTER 5
SIMULATION SETUP& RESULTS & CONCLUSION

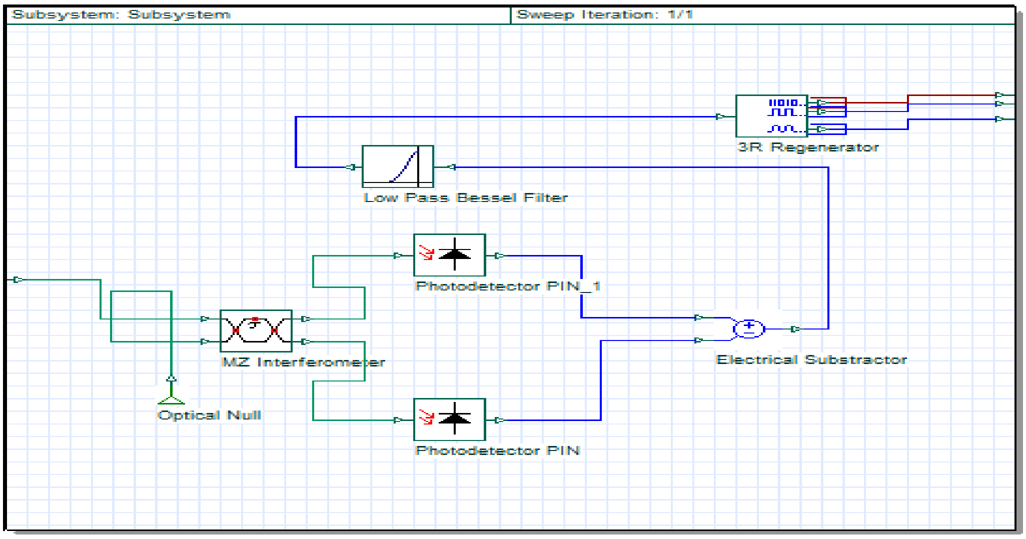
5.1 SIMULATION SETUP

In this research we are using DWDM (Dense wavelength division multiplexing) system with 8 channels with DPSK (Differential phase shift key) modulation technique so fig 1 shows the simulation setup for DPSK (Differential phase shift key) transmitter model inside look:



SIM FIG 1: DPSK transmitter model inside look

And now DPSK (Differential phase shift key) receiver model subsystem inside look in FIG 2:



SIM FIG 2: DPSK RECIEVER model inside look

So we came to know about the DPSK (Differential phase shift key) transmitter and receiver model inside look for the simulation setup for dispersion compensation schemes. Now TABLE 1 and TABLE 2 are used for showing the simulation parameters and the fibre parameters used in DWDM system are as follows:

Table 1: Simulation parameters

BIT RATE	40 GB/s
SEQUENCE LENGTH	128
SAMPLES PER BIT	64
BANDWIDTH	20
CENTRAL FREQUENCY OF 1^{ST} CHANNEL	193
CAPACITY	8*40GB/s

Table 2: Fibre parameters

PARAMETERS	SMF	DCF
ATTENUATION (dB/Km)	0.2	0.5
DISPERSION (ps/nm/Km)	17	-85
DISPERSION SLOP (ps/Km- nm^2)	0.075	-0.3
DIFFENTIAL GROUP DELAY (ps/km)	0.2	0.2
EFFECTIVE AREA	70	22

The simulation setup is composed of transmitter, receiver and fibre by analysing the formation simulation for DWDM (dense wavelength division multiplexing) by using DPSK (Differential phase shift key) in different dispersion compensation schemes and the models of dispersion compensation schemes for pre, post and symmetric simulation are shown in figures : FIG 3, FIG 4, FIG 5are as follows:

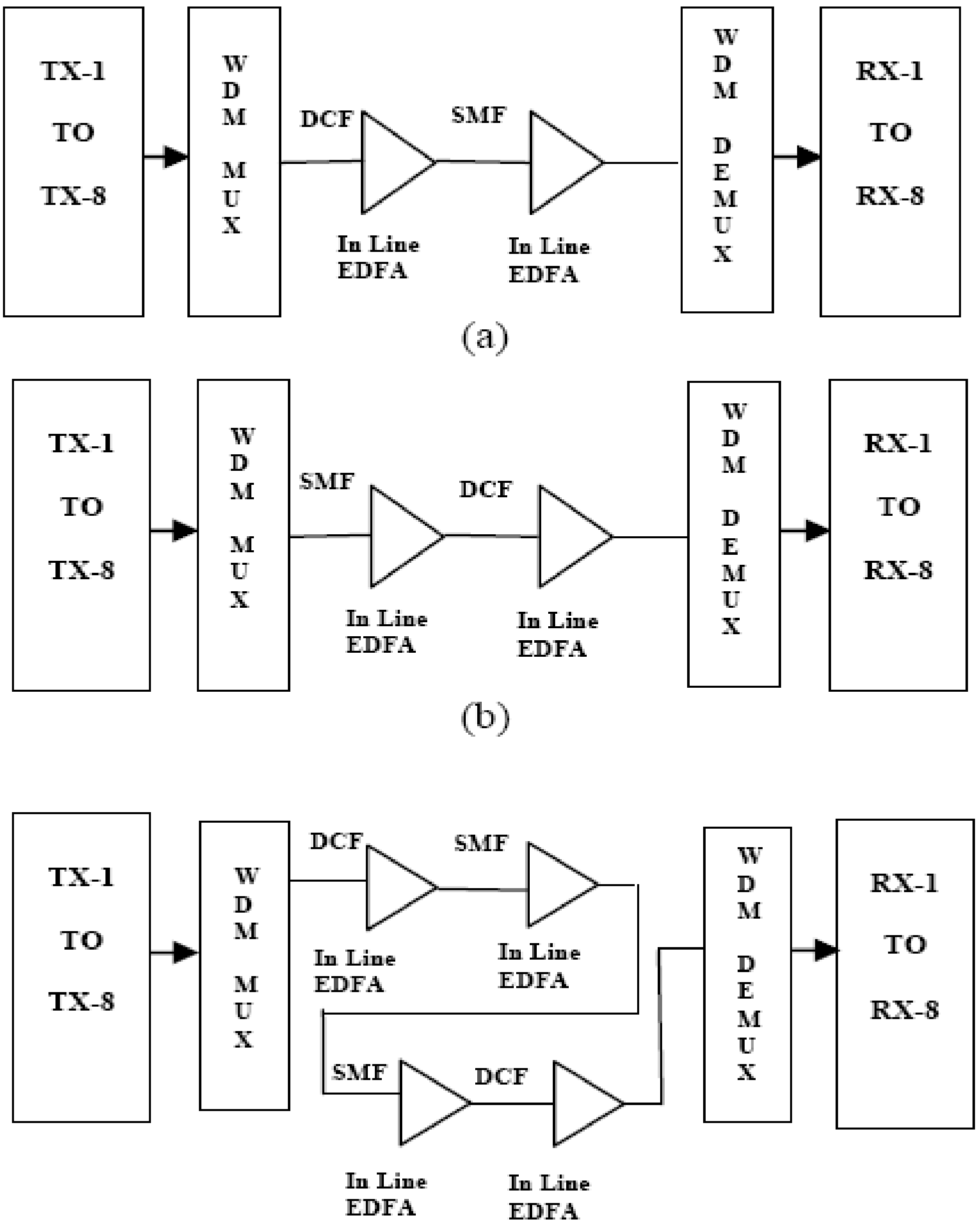
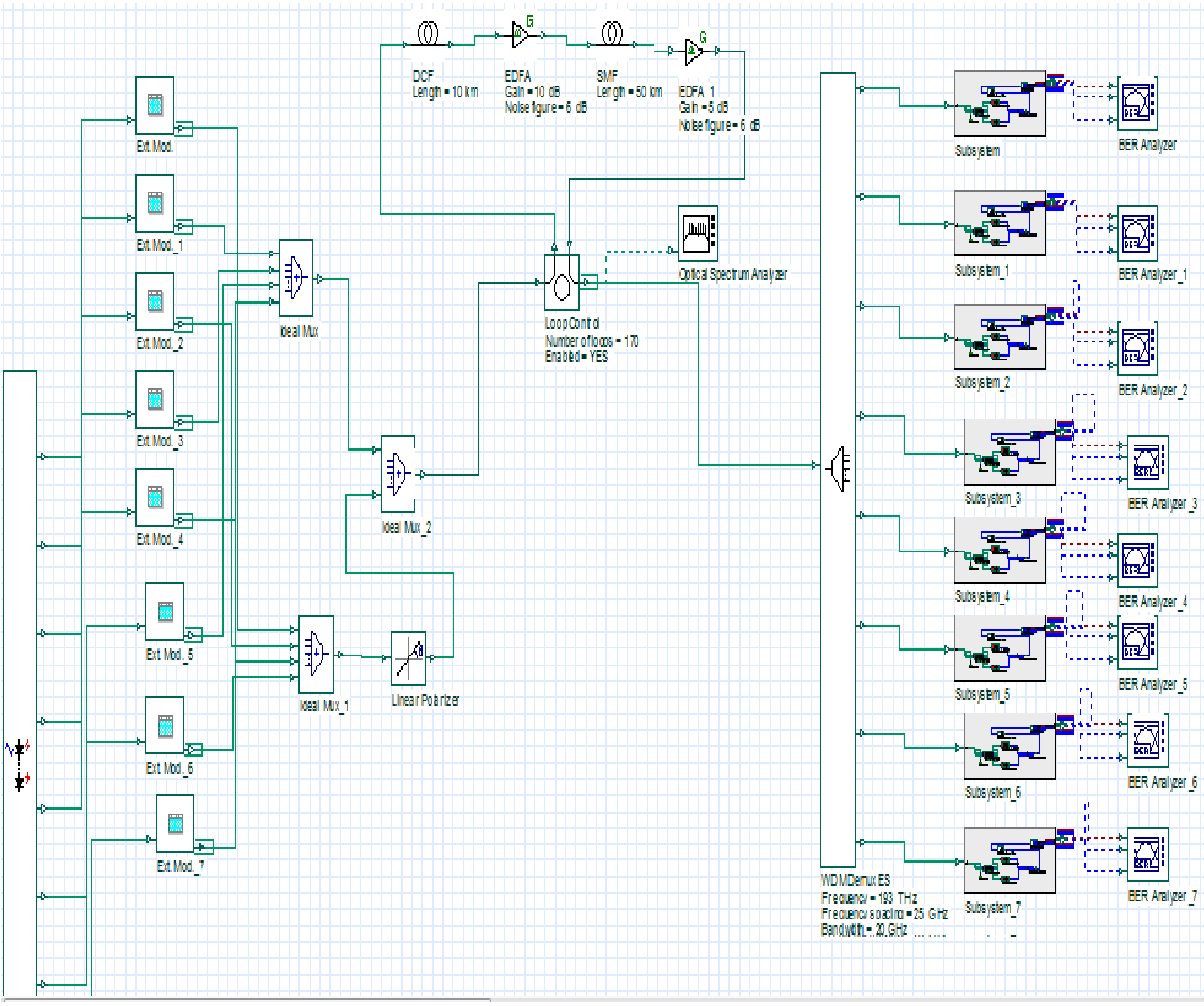


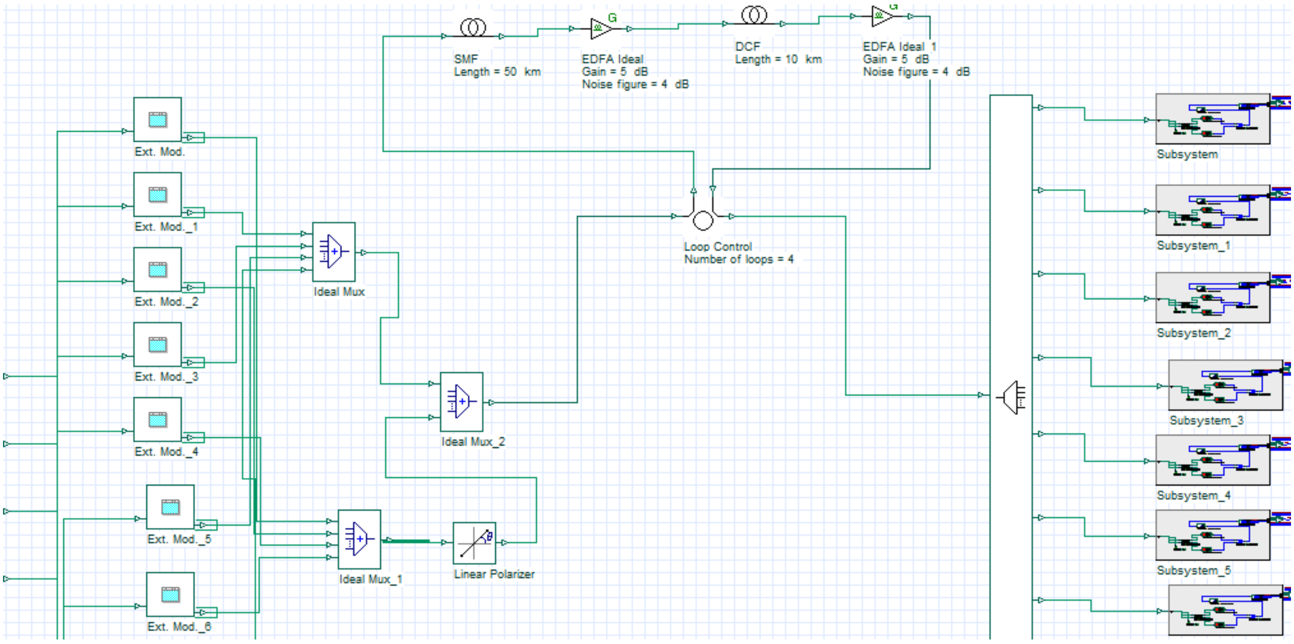
FIG [16]: Basic models of simulation for dispersion compensation schemes [9]

The simulation set up for DPSK (Differential phase shift key) DWDM (Dense wavelength division multiplexing) system using Pre dispersion compensation technique in FIG 3:



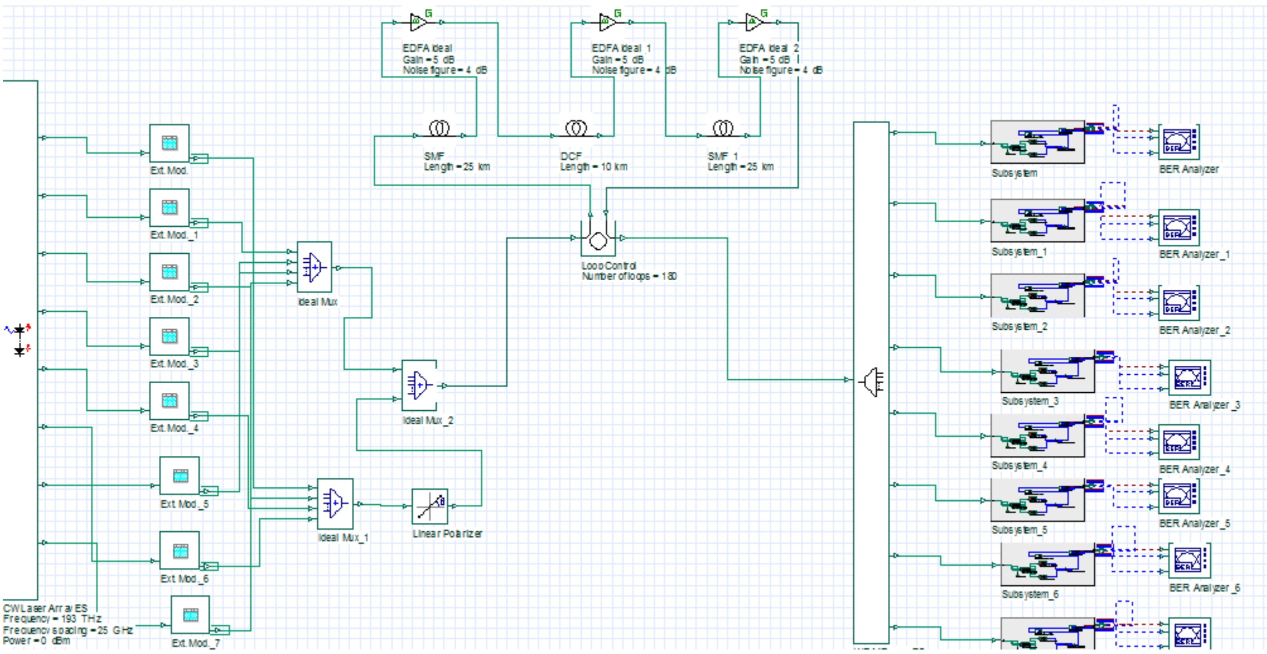
SIM FIG 3: DPSK DWDM SETUP FOR PRE DISPERSION SCHEMES

Now secondly the simulation set up for DPSK (Differential phase shift key) DWDM (Dense wavelength division multiplexing) system using Post dispersion compensation technique in FIG 4:



SIM FIG 4: DPSK DWDM SETUP FOR POST DISPERSION SCHEMES

At last the simulation set up for DPSK (Differential phase shift key) DWDM (Dense wavelength division multiplexing) system using symmetric dispersion compensation technique in FIG 5:



SIM FIG 5: DPSK DWDM SETUP FOR SYMMETRIC DISPERSION SCHEMES

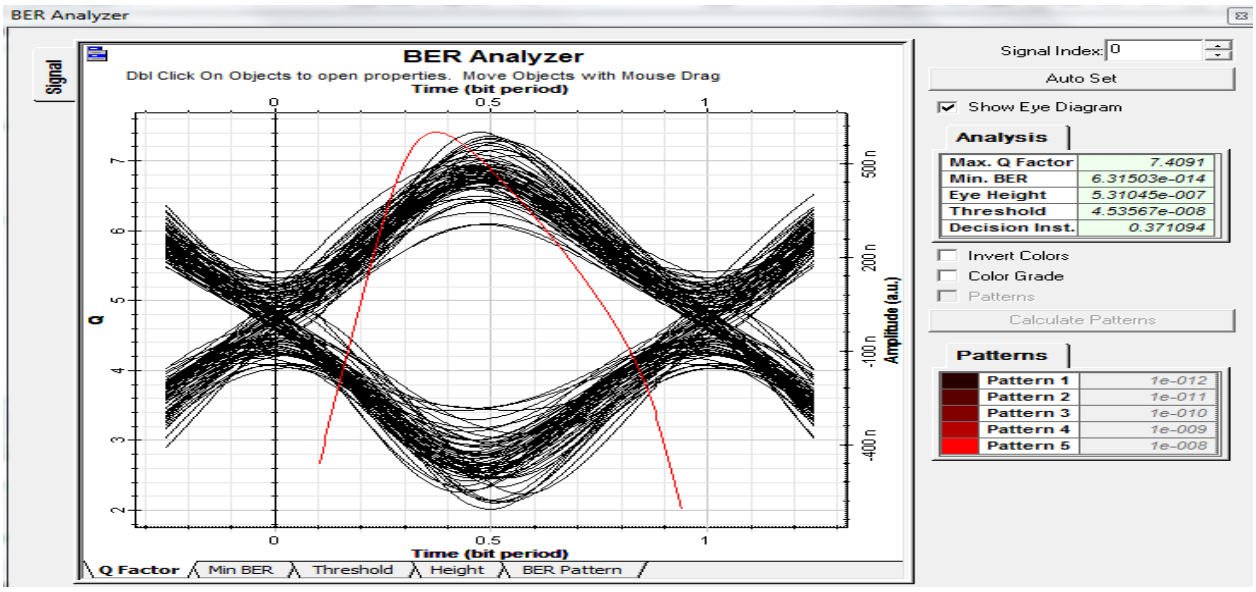
5.2 RESULTS AND ANALYSIS

The DPSK (Differential phase shift key) modulation format for different dispersion compensation schemes ie: pre, post and symmetric compensation schemes for 8 channels DWDM (Dense wavelength division multiplexing) system results are obtained in terms of Quality (Q) factor and BER (Bit error rate) by using eye diagram formation. To analyse the DPSK - DWDM system the results of first channel has been taken as it is a worst case format and the worst Q factor comes in 1^{st} and 8^{th} channel as they experience the most dispersion and nonlinear effects. The performance of pre, post and symmetric compensation has been analysed for various distance. The narrow channel spacing is done for 25 GHz form the central frequency of 1^{st} channel 193 THz to 193.2 THz of 8^{th} channel by using polarization interleaving technique.

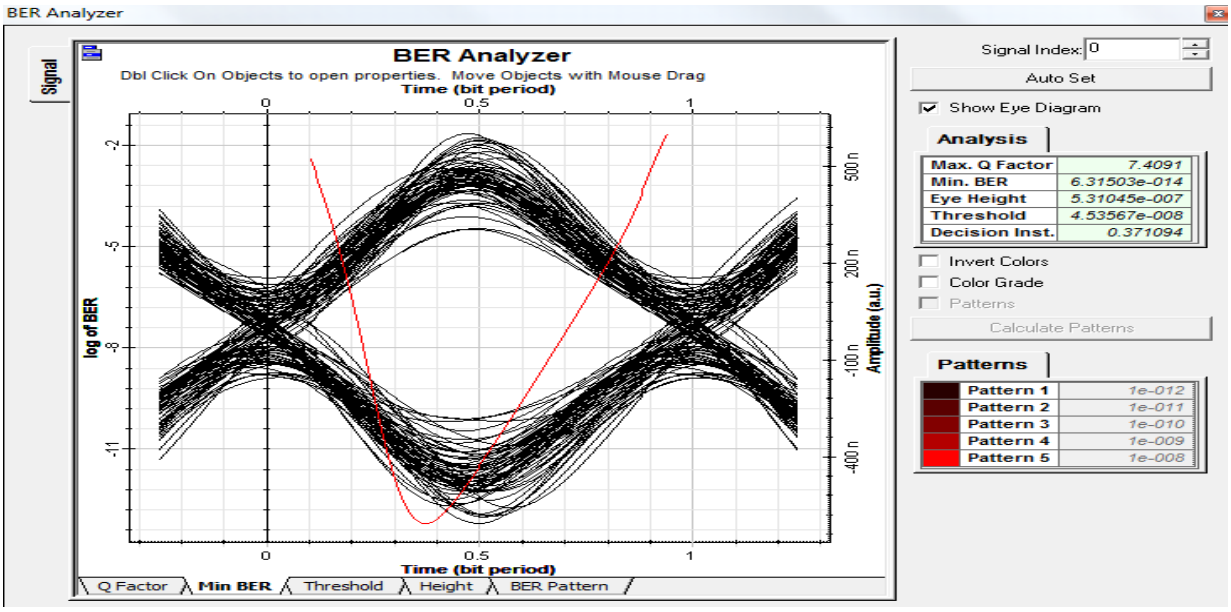
We have simulated the DPSK (Differential phase shift key) DWDM system in the optical link at 40 GB/s. By using all the three dispersion compensation schemes pre, post and symmetric we concluded that the result for post shows up to the distance of 200 km after that BER coming near 10^{-8}which is not excepted by ITU. For the pre compensation scheme we are getting the best result up to 8500 km after that same BER is not excepted. And at last the symmetric technique is used which gives the best rest in DPSK (Differential phase shift key) DWDM (Dense wavelength division multiplexing) system up to the largest distance that is 9000 km. and this symmetric compensation schemes comes out to be the best among all the three dispersion compensation techniques. So we mainly use symmetric compensation for DPSK (Differential phase shift key) modulation format.

Now the analysis and compare of the techniques used will be shown in term of eye diagrams and graphs for BER (Bit error rate) and Quality factor of pre, post and symmetric schemes for DPSK (Differential phase shift key) using DWDM system.

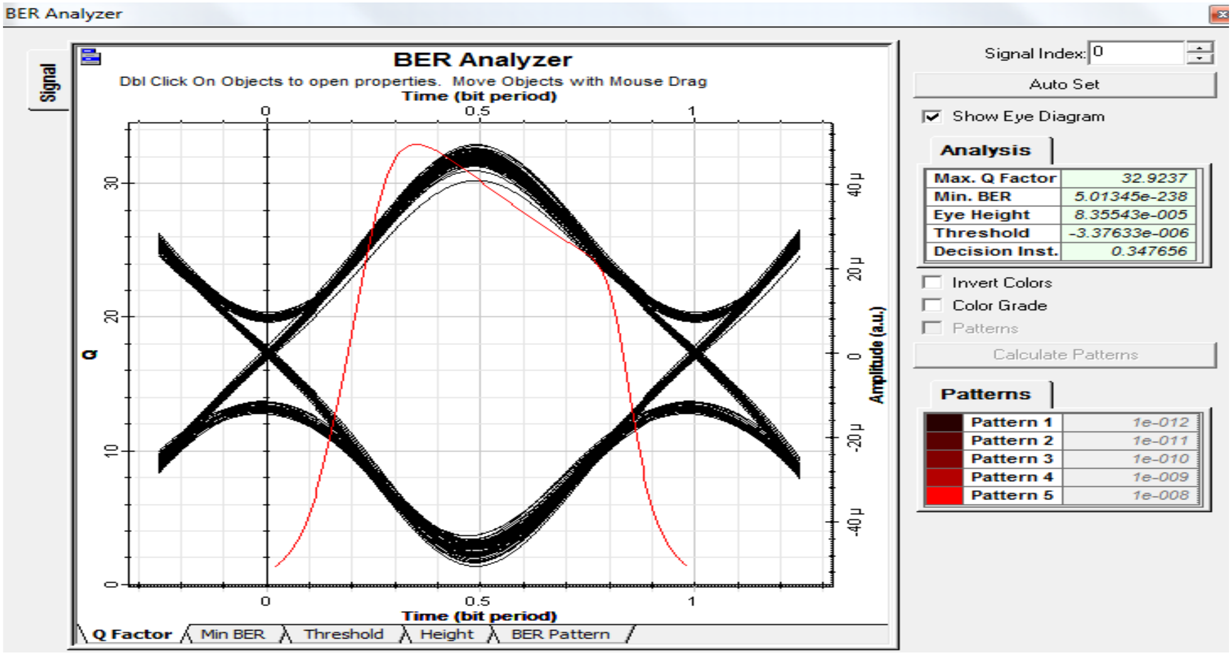
Firstly by taking the results at 200 km as post dispersion compensation technique shows the results up to 200 km as BER leads to more than 10^{-9} which is not except able by ITU. Now the BER and Q factor for all pre, post and symmetric is shown at SIM FIG 6 at 200 Km.



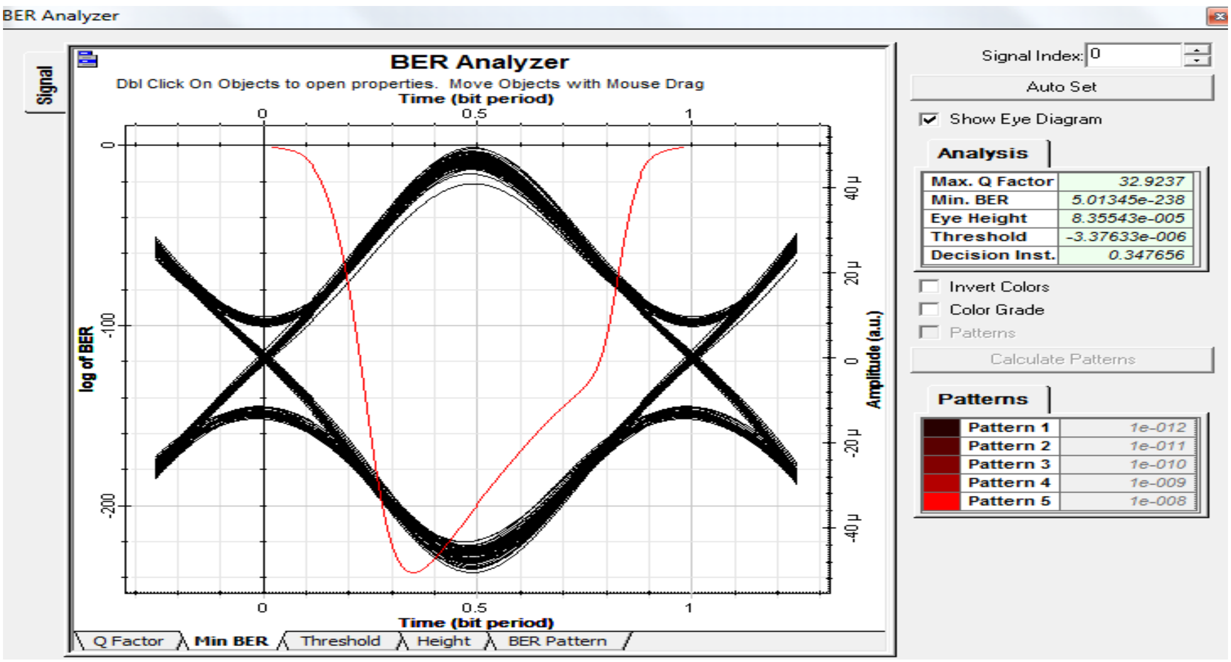
A) Post dispersion compensating Quality factor for 1st channel at 200 km.



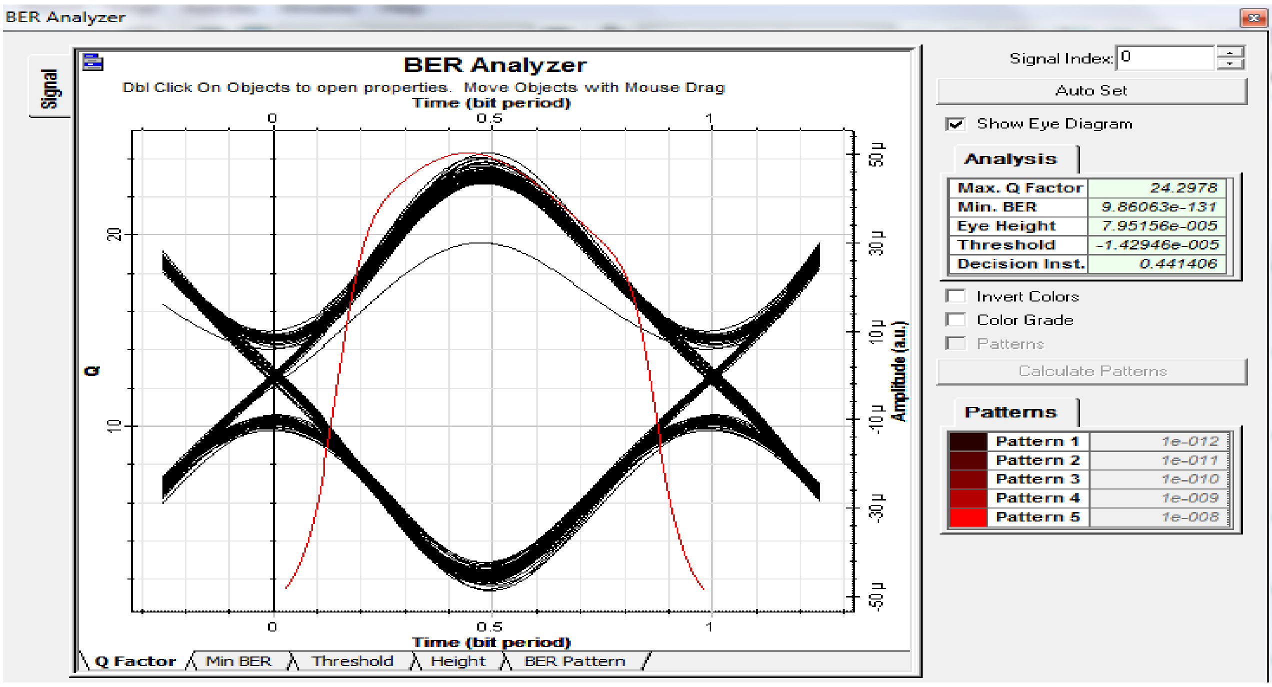
A) Post dispersion compensation BER for 1st channel at 200 km.



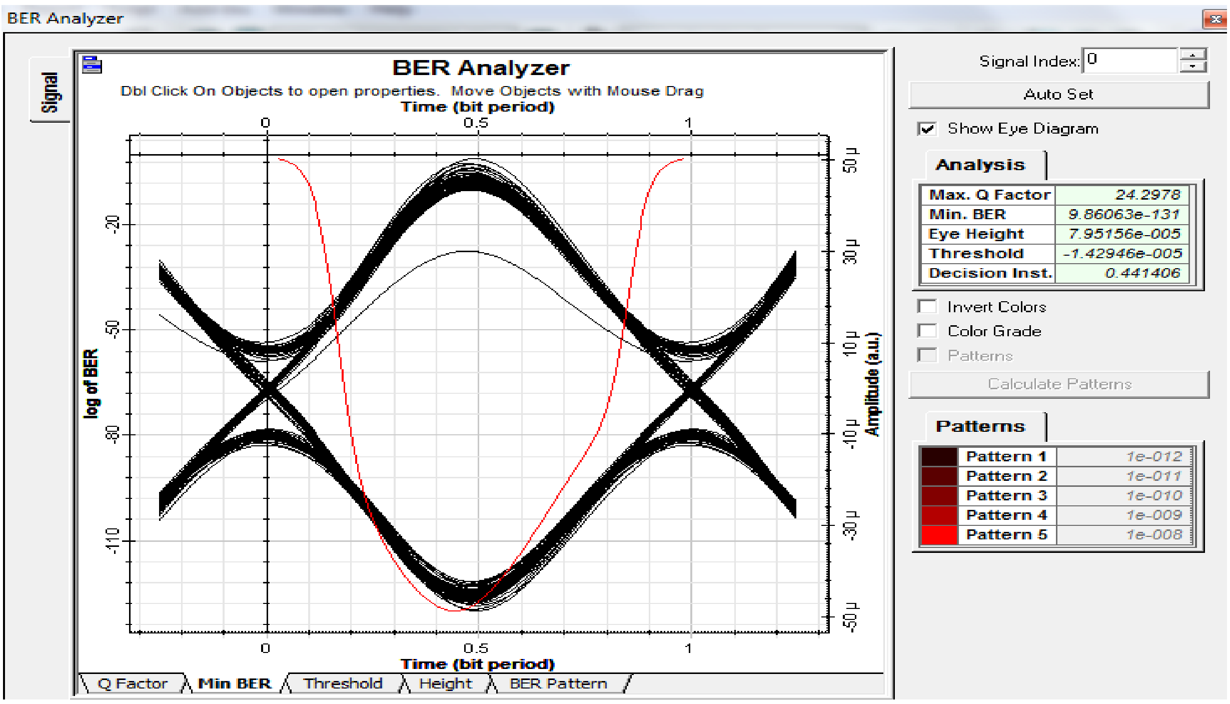
B) Pre dispersion compensation Quality factor for 1st channel at 200 km



B) Pre dispersion compensation BER for 1st channel at 200 km

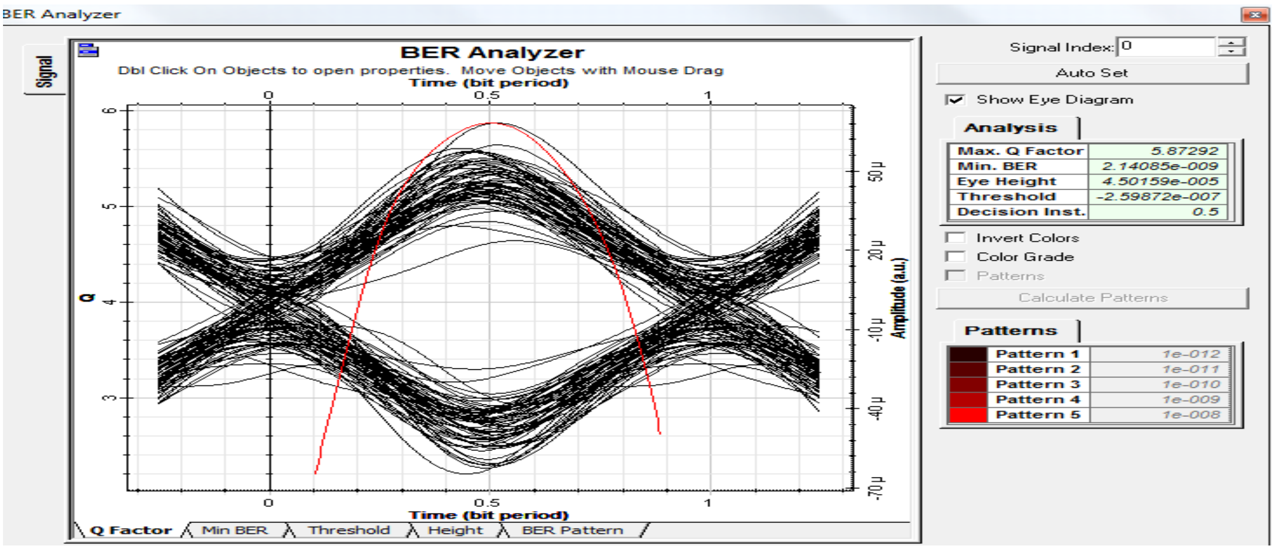


C) Symmetric dispersion compensation Quality factor for 1st channel at 200 km

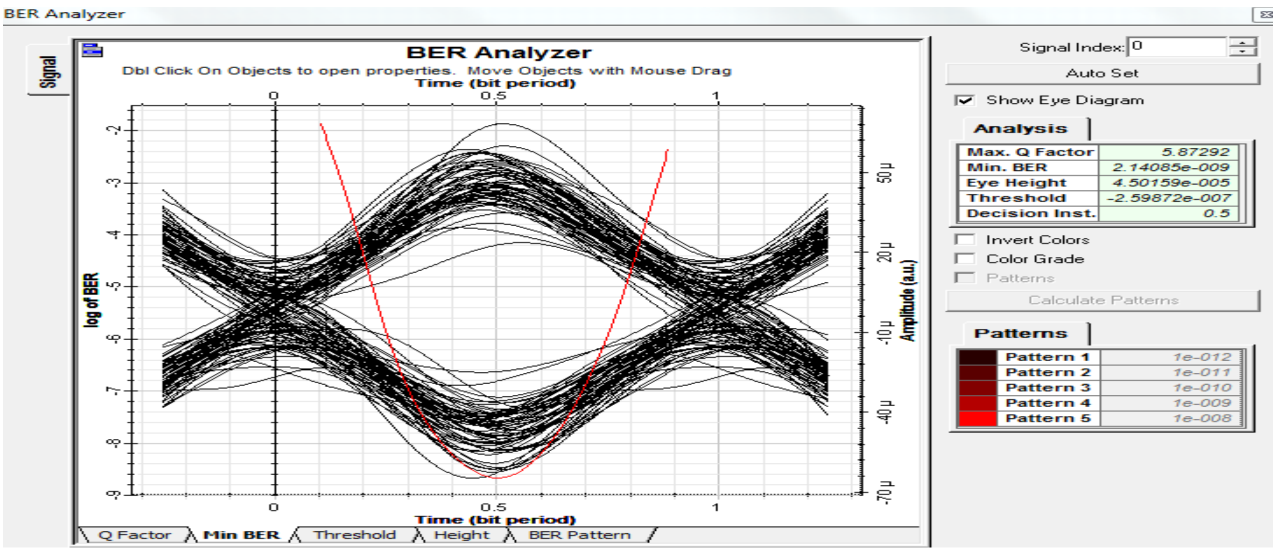


C) Symmetric dispersion compensation BER for 1st channel at 200 km
"SIM FIG 6"

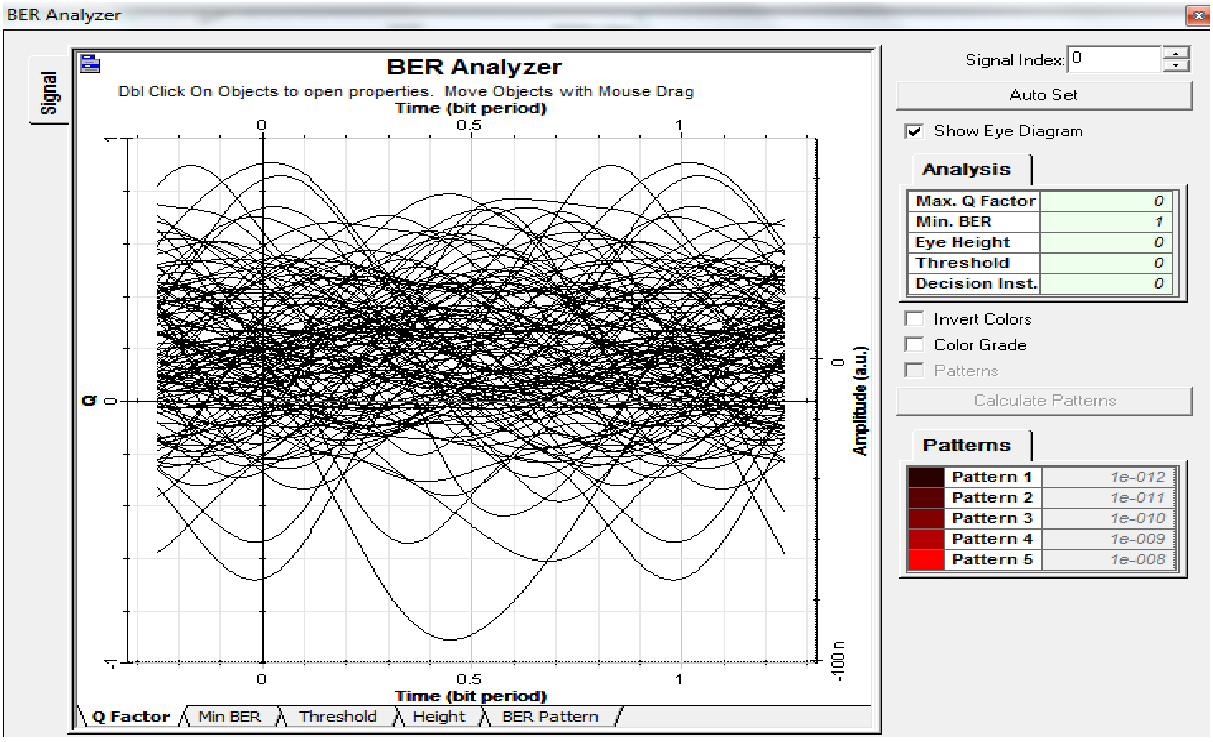
Now secondly by taking the results at 8500 Km as pre dispersion compensation technique shows the results up to 8500 km. As BER leads to more than 10^{-9} is not excepted by ITU. So the simulation is done up to 8500 km for pre compensating technique showing the best results for DPSK-DWDM system. Now the BER and Q factor for all pre, post and symmetric is compared and then shown at eye diagram figures comparing the pre and symmetric in SIM FIG 7:



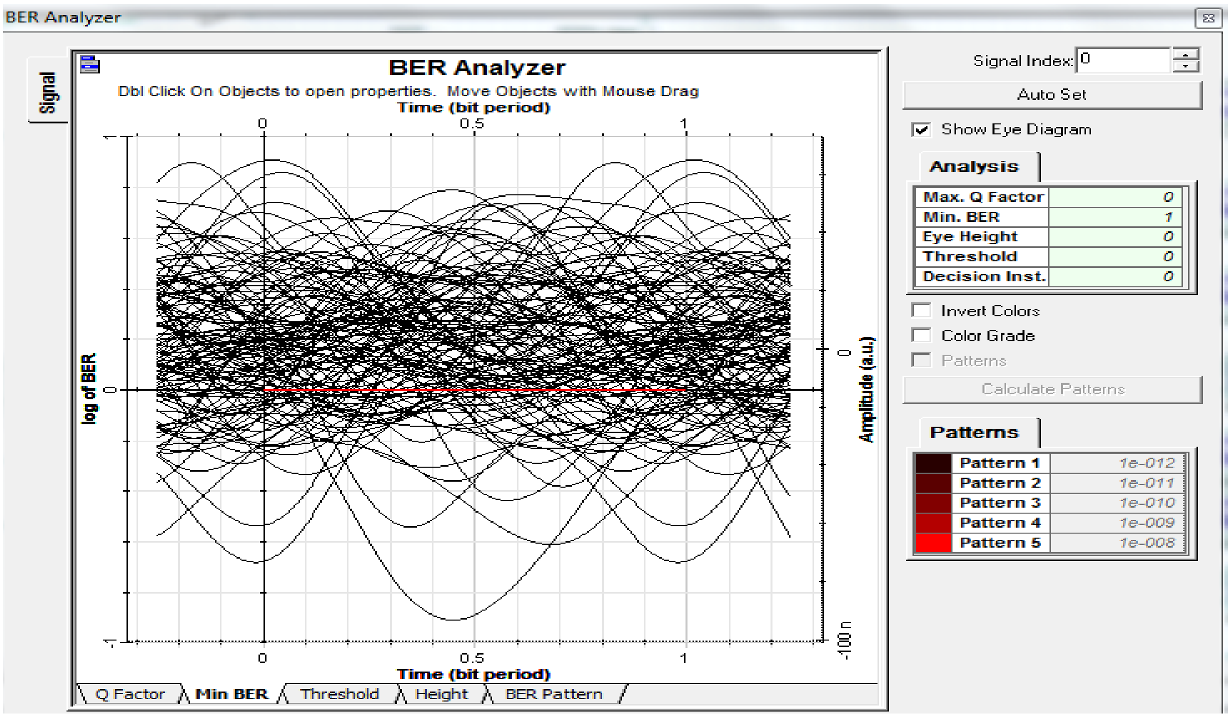
A) Pre dispersion compensation Quality factor for 1st channel at 8500 km.



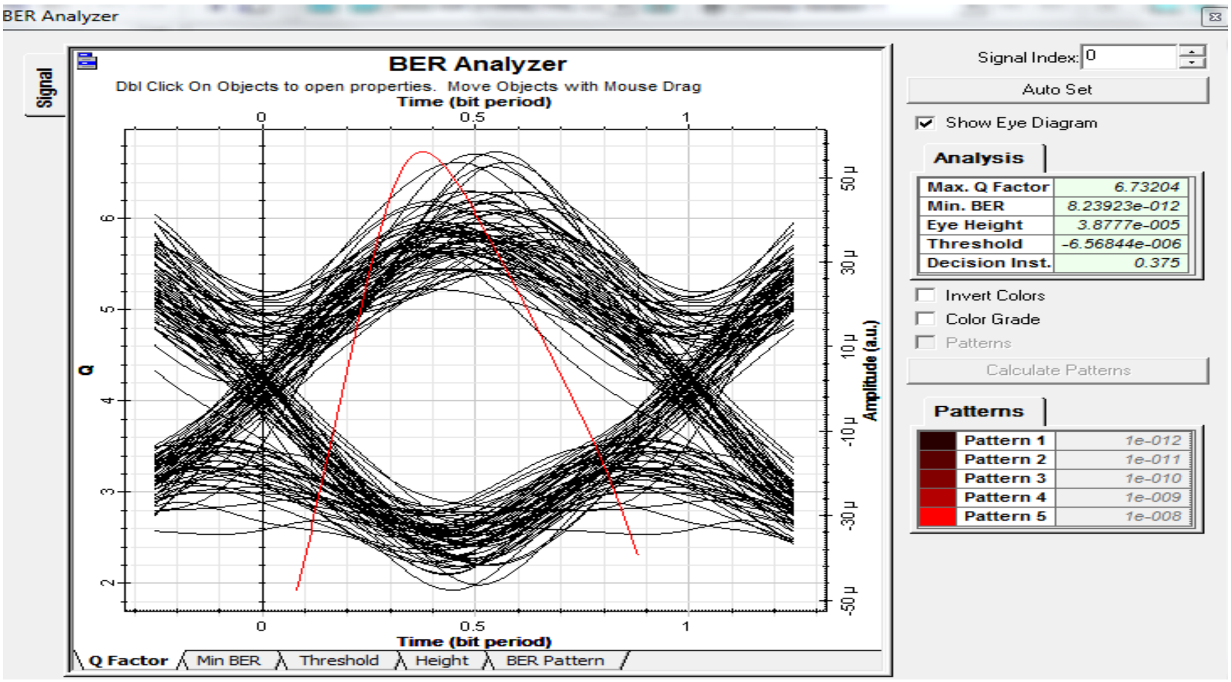
A) Pre dispersion compensation BER for 1st channel at 8500 km.



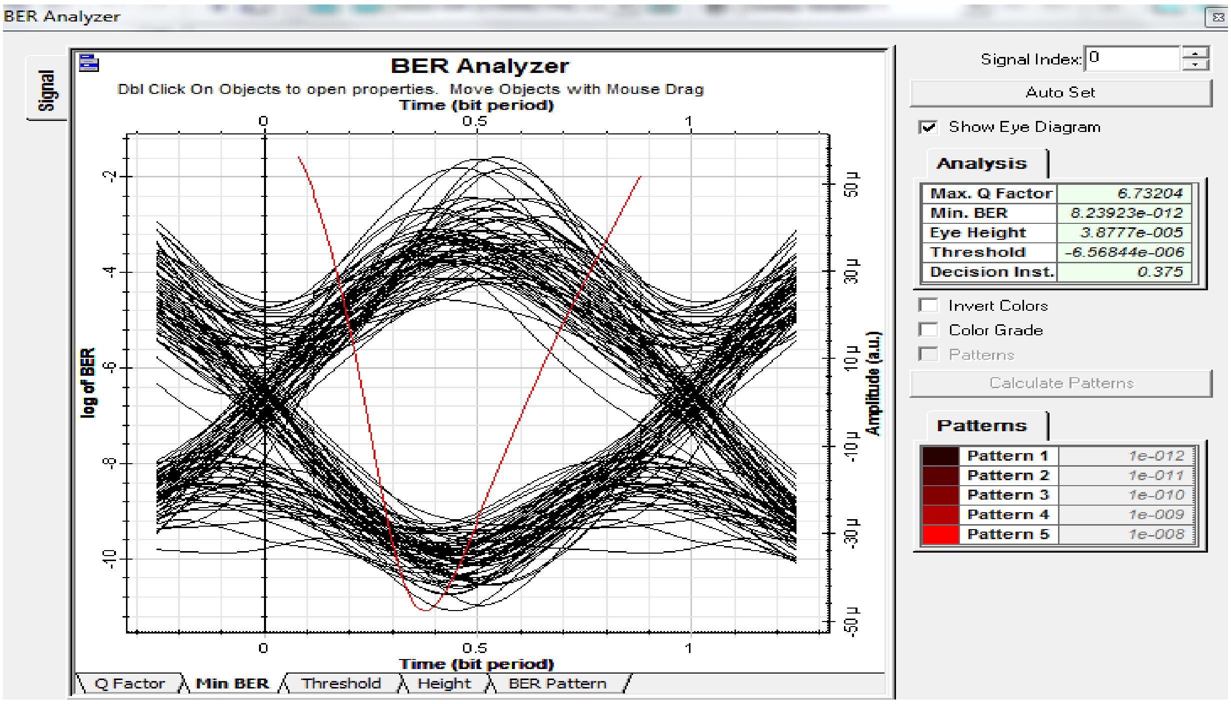
B) Post dispersion compensation Quality factor for 1st channel at 8500 km.



B) Post dispersion compensation BER for 1st channel at 8500 km

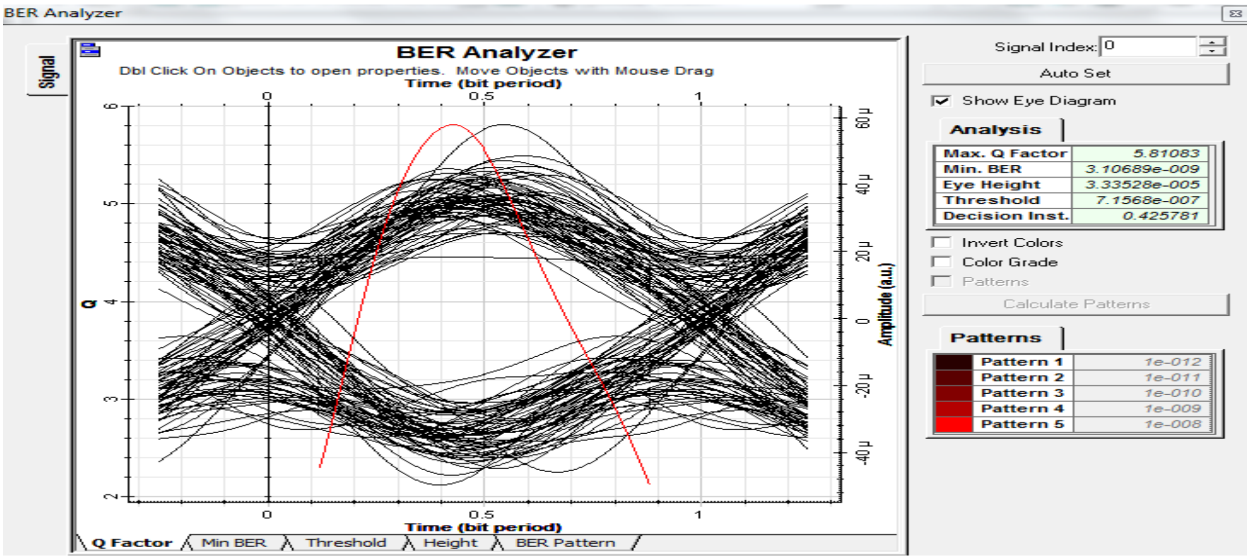


C) Symmetric dispersion compensation Quality factor for 1st channel at 8500 km.

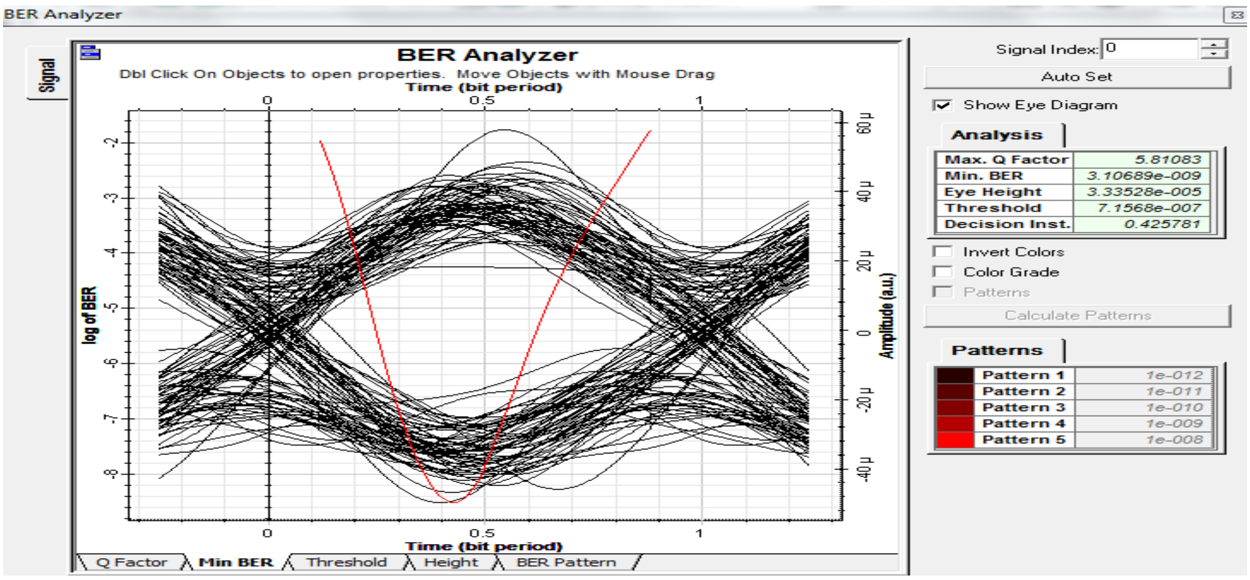


C) Symmetric dispersion compensation BER for 1st channel at 8500 km
“SIM FIG 7”

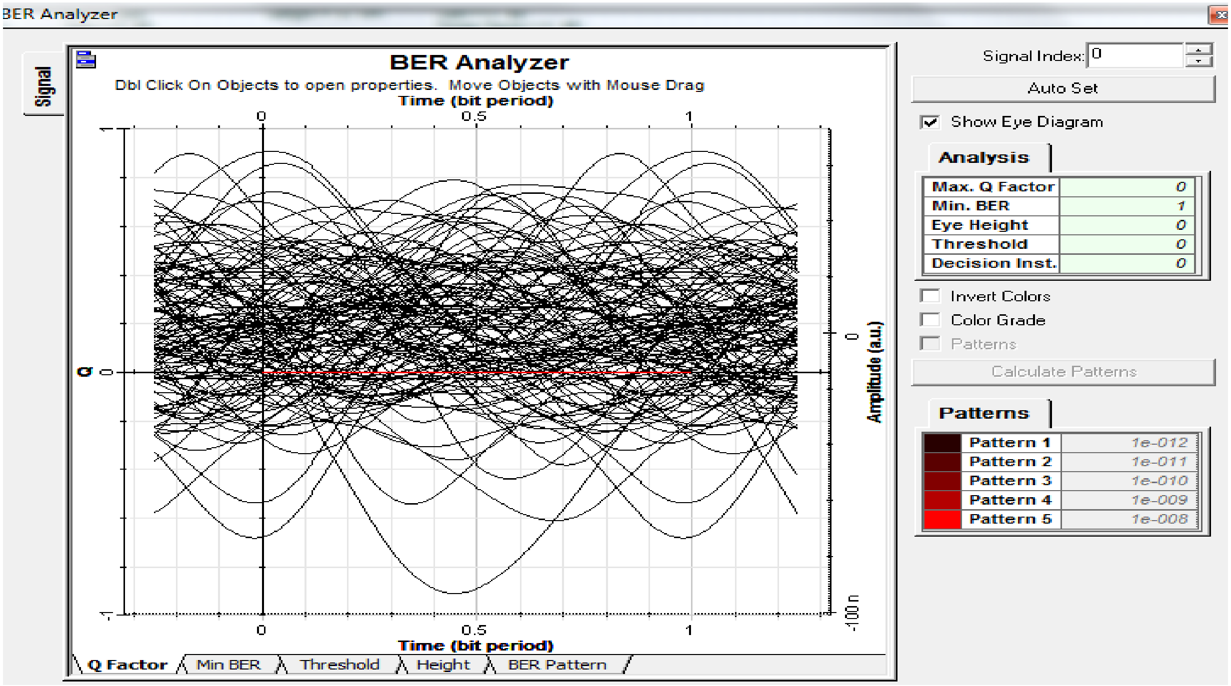
At last by taking the symmetric dispersion compensation schemes we are getting the best results up to 9000 km as pre dispersion compensation technique shows the results up to 8500 km, symmetric is showing up to 9000 km. which concluded that symmetric is showing the best results for larger distance as BER leads to more than 10^{-9} is not excepted by ITU. So the simulation is done up to 9000 km for symmetric compensating technique showing the best results for DPSK-DWDM system. Now the BER and Q factor for all pre, post and symmetric is compared and then shown at eye diagram figures comparing the pre and symmetric in SIM FIG 8:



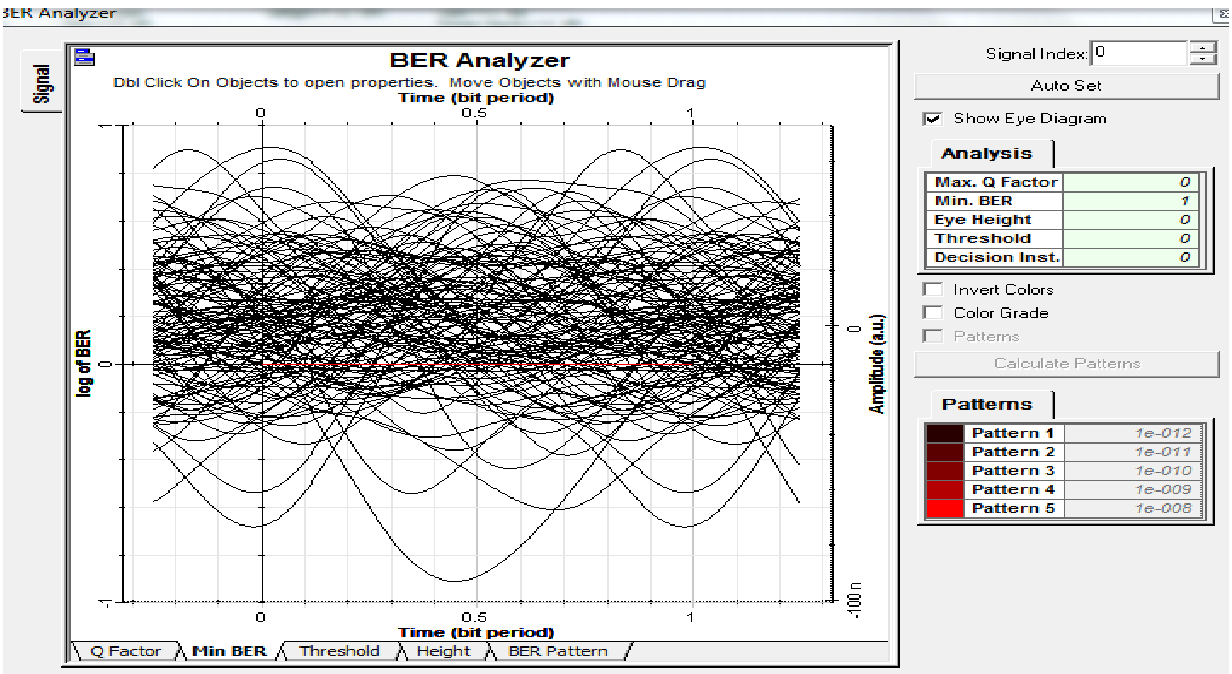
A) Symmetric dispersion compensation Quality factor for 1st channel at 9000 km



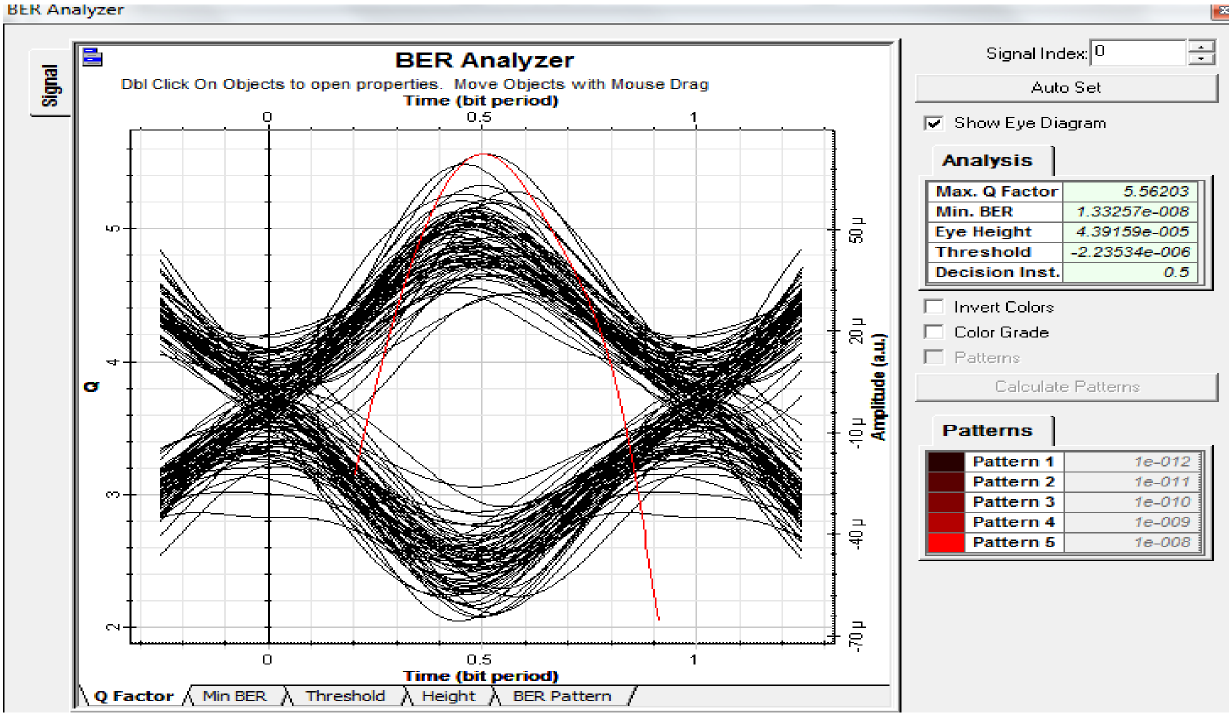
A) Symmetric dispersion compensation BER for 1st channel at 9000 km



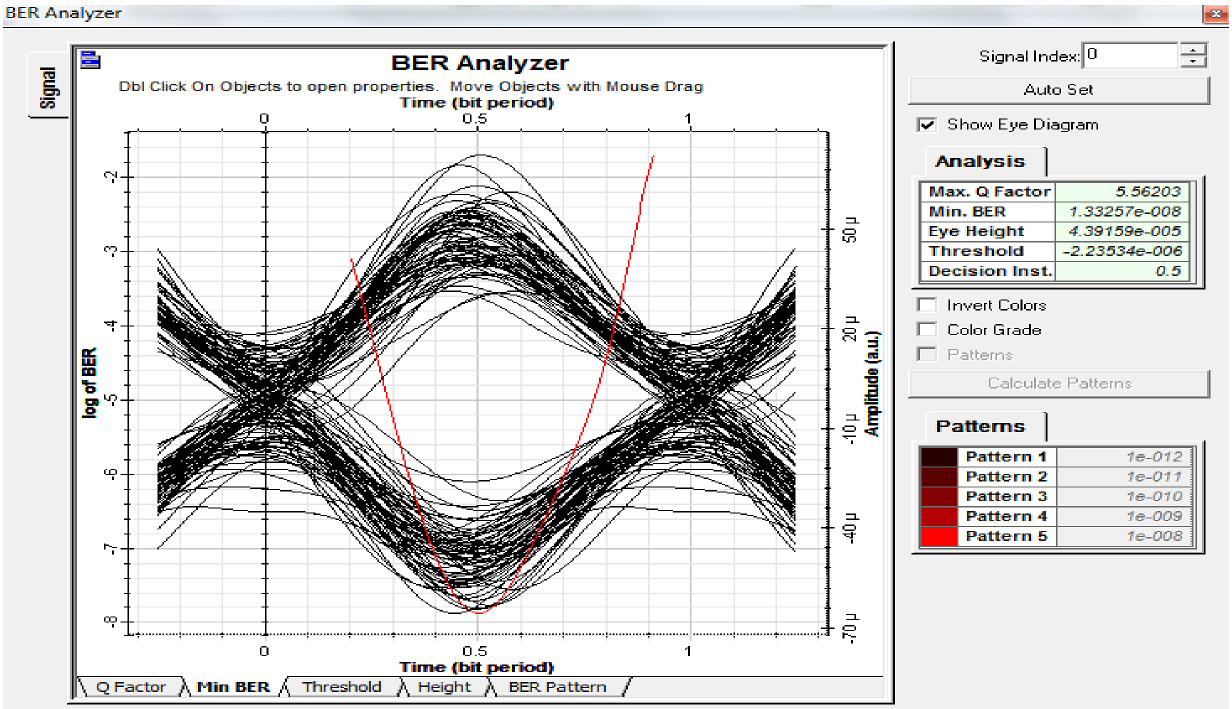
B) Post dispersion compensation Quality factor for 1st channel at 9000 km



B) Post dispersion compensation BER for 1st channel at 9000 km



C) Pre dispersion compensation Quality factor for 1st channel at 9000 km



C) Pre dispersion compensation BER for 1st channel at 9000 km
"SIM FIG 8"

We analysed and compare the DPSK (Differential phase shift key) DWDM system using different dispersion compensation schemes at 40 GB/s with narrow channel spacing of 25 GHz using 8 channels. And we found that the symmetric dispersion compensation scheme comes out to be the best among all the three techniques with the largest distance. So we prefer symmetric compensation technique among other two. As the figures shows clearly that at higher distance 9000 km post results are very weak and for pre we analysed and found that it shows the best result up to distance of 8500 after that BER is not excepted. So now the Table 3 will indicate us how the variation is coming in terms of BER and Q factor at various distance for pre, post and symmetric dispersion compensation techniques for channel 1.The table indicate the variation in terms of BER and Quality factor for various distances at 200KM, 500KM, 1000KM, 5000KM, 8500KM, 9000KM. The analysis of these techniques for BER and Quality factor variation is shown in graph and table.

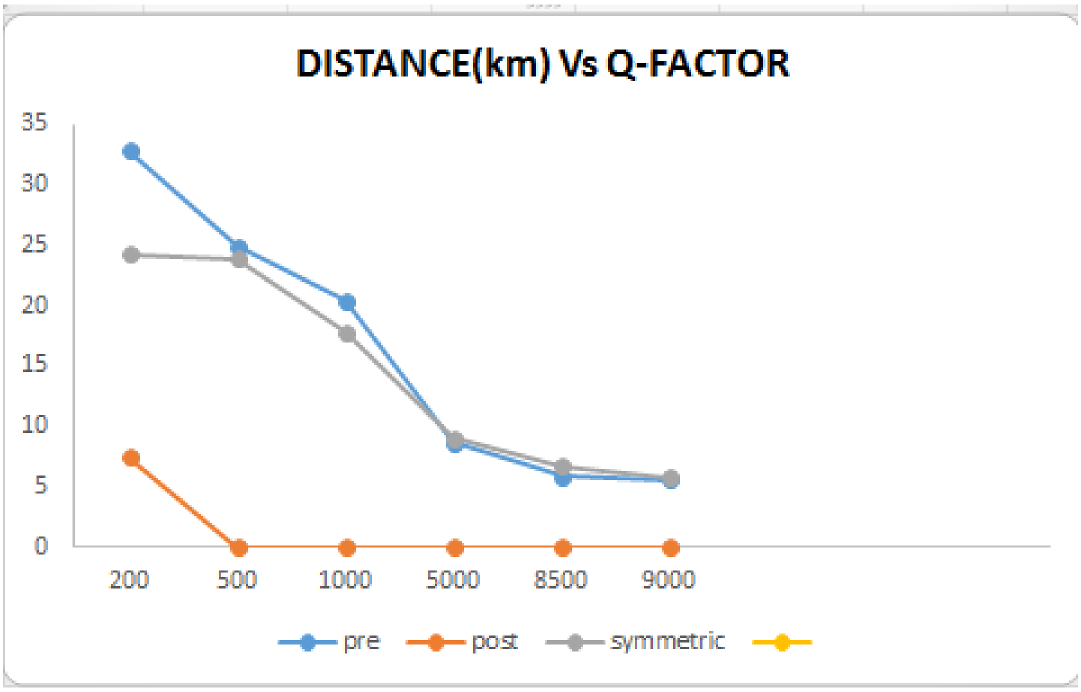
TABLE 3:

	COMPENSATION SCHEMES		DISTANCE					
			200KM	500KM	1000KM	5000KM	8500KM	9000KM
DPSK DWDM	PRE	Q	32.9237	24.9143	20.4499	8.68434	5.87292	5.56203
		BER	5.01345e-238	2.60208e-137	3.00836e-093	1.87499e-018	2.14085e-009	1.33257e-08
	POST	Q	7.4091	0	0	0	0	0
		BER	6.31503e-014	1	1	1	1	1
	SYMMETRIC	Q	24.2978	23.8872	17.8445	9.03349	6.73204	5.81083
		BER	9.86063e-13	12.04684e-126	1.55016e -071	8.29052e-20	8.23923e-012	3.10689e-09

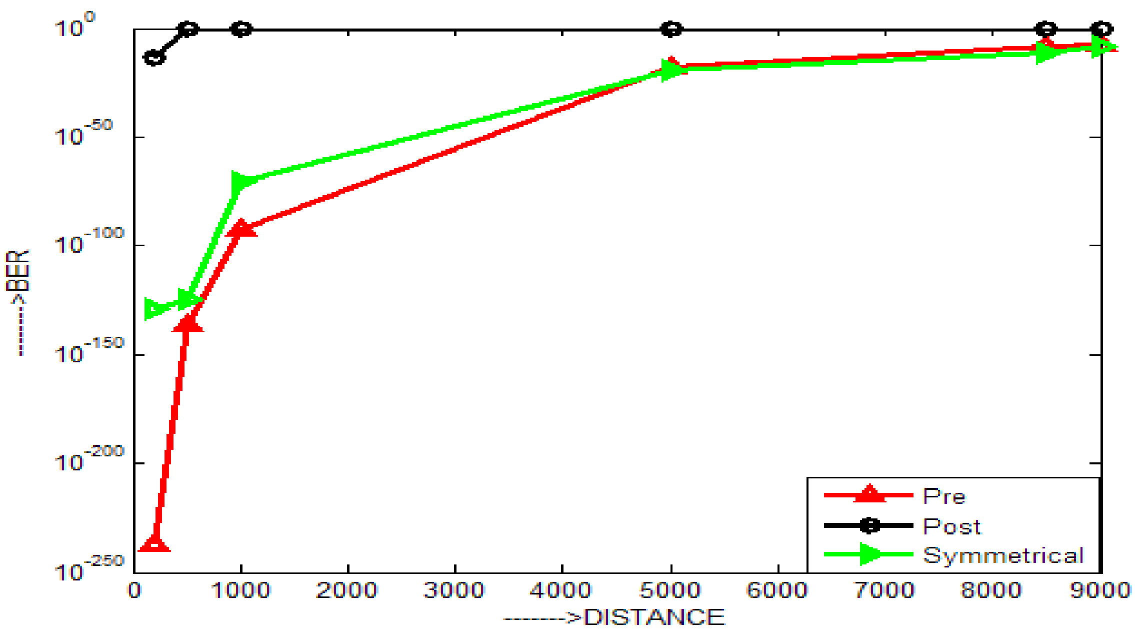
ANALYSIS OF Q VALUE AND BER FOR VARIOUS DISTANCES

.

Graph representation for pre, post, symmetric composition techniques by using different distance in DPSK (Differential phase shift key) DWDM system as follow:



A) DISTANCE (KM) VS Q- FACTOR



B) DISTANCE (KM) VS Q- FACTOR

5.3 CONCLUSION AND FUTURE SCOPE

This dissertation report gives a background of fundamental of optical fibre theory. Then in it I have discussed about the basic theory of optical fibre communication system, what are the problem arises in long haul single mode optical fibre which are dispersion and nonlinear effects and to analyse the effect of pre, post , symmetric dispersion compensation scheme by using modulation formats DPSK (Differential phase shift key) with DWDM system. Here the narrow channel spacing has been used with spacing 25 GHz to all the 8 channels by using polarization interleaving technique at 40 GP/s.

In next step I have investigated DPSK DWDM system on pre, post and symmetric configuration to find out whose performance is better in terms of Q value and BER. And we find that the DPSK modulation format with symmetrical DCF compensation shows the best performance with distance 9000 km whereas pre compensation leads up to 8500 km distance and post compensation schemes leads the lowest up to 200 km.

So by simulating these models in optisystem software we will find the best transmission format for long haul single mode optical fibre can be used for longer distance. The optisystem software is easy to use and faster than others which help in testing and simulating the transmitter, channel, amplifier and receiver design and estimation of BER. Lot of Future work is based on my work as we can increase the distance more by decreasing the dispersion and nonlinear effect. We can increase the no of channels to provide data to various users. In general if we say optical fibre is the future for whole world as it is the best wireless and wired communication format.

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