CHAPTER 1

INTRODUCTION

Recently, fibre optics has become the core of telecommunications and data networking infrastructures, replacing most wireless mediums. Multiplexing is a common technique used in optical communication systems for allowing multiple users to share the same bandwidth over a single fibre of the transmission medium. This makes a multi input system more economical than transmitting over multiple fibres. One of multiplexing technique is Wavelength Division Multiplexing (WDM) that offers great benefits to the optical fibre communication system. Another multiplexing technique that is used in communication systems is Optical Code Division Multiplexing (OCDM) in which each user's data is associated with a different code, which allows multiple users to efficiently share the bandwidth.

Multiplexing technique, dispersion management and modulation format are given much attention to achieve better transmission performance in long distance transmission. Meanwhile, dispersion management technique improves the performance for long haul optical fiber communication system to restore the distortion signal that is caused by fiber dispersion. Wavelength Division Multiplexing (WDM) is one of the multiplexing techniques used in long distance optical communication systems. Recently, the performance of Three Level Code Division Multiplexing (3LCDM) is investigated for the high speed optical fiber communication system. 3LCDM technique with dispersion management has advantages over Duty Cycle Division Multiplexing (DCDM) in order to support multiple users per channel in WDM system [1]. Three level code division multiplexing (3LCDM) is developed in this project which combines two data stream to double the bandwidth of WDM efficiency. 3LCDM has been developed in reference [2] which has advantage over RZ and NRZ line coding in doubling capacity at lower frequency and smaller bandwidth.

In research [1], 3LCDM has great benefits over NRZ system i.e., 3LCDM performs better in dispersion tolerance. It is also noticed that 3LCDM system can provide higher number of users using WDM technique. However, the potential of 3LCDM data to be carried over Wavelength Division Multiplexing (WDM) system has not yet been investigated. Meanwhile, WDM is the main multiplexing technique in optical fiber transmission. It uses optical fibers for long distance communication and known to suffer from losses due to dispersion and attenuation [3], [4]. The solution to reduce the loss of attenuation is by using optical amplifier [5]. In this project, the performance of dispersion compensation in 3LCDM over WDM system will be investigated. In order to compensate the dispersion in optical fiber, dispersion compensation fiber (DCF) is used [6]. The distance performance for the 3LCDM over WDM system will also be discussed and observed for long haul transmission system.

1.1 LITERATURE REVIEW

[1] 3LCDM over WDM system with dispersion management is investigated. The system is evaluated for two channels with aggregated bit rate of 10Gbps. By using optimum cut-off frequency of Gaussian low pass filter and Gaussian band pass filter at 18 GHz and 37 GHz, the performance of 3LCDM over WDM shows the best result. The input signal plays an important role to find the optimum received power of the system to achieve BER of 10^-9. With 142 km of distance of optical fiber communication, the 3LCDM over WDM system maintains a better performance for long haul transmission system.

[2] 3LCDM performance with two numbers of channels at aggregate bit rate of 40 Gbps is evaluated. At 40 Gbps, the results reveal a clear advantage of the proposed 3LCDM technique over NRZ-OOK in terms of the dispersion tolerance. Using the electrical multiplexing, demultiplexing technique can be carried over the same WDM channel. Consequently, the capacity utilization of the WDM channels can be increased tremendously as it can achieve better dispersion tolerance as compared with the conventional NRZ technique.

[3] The three-level code division scheme described has the potential to double bandwidth per wavelength. Code encryption is realised within the multiple level data transmitted rather than the wavelength bandwidth and avoids any multiple interference issues. The 195 Mbps data rate that is demonstrated in the laboratory experiment shows the suitability of the system in LAN’s.

[4] In 10 Gbps systems, it is necessary to include non-linear penalties for the performance analysis of TDM and WDM signals. The *Q* value for TDM signals is better than that for WDM in ultra-long haul and ultra-high capacity communications. When loss and dispersion are precisely compensated, SMFs are the appropriate media for 10 Gbps of TDM signal transmission. In SMFs, on employing FBGs instead of DCFs as the dispersion compensation devices, both TDM and WDM signals show better performance, whereas in NZDSFs, the reverse is true.

[5] The stabilizing effect of dispersion management due to various systems arises in applications. More precisely, we construct ground states in NLS with critical non linearities by introducing periodically varying dispersion.

[6] Design of set of parameters {xc, Anc} for ultra-wide space division multiplexing and ultra-wide wavelength division multiplexing to manage the chromatic dispersion, D, of single-mode binary glass fiber cables for any set of variables {T, D,} is carried out. A new mathematical model is employed to compute {&, Anc**}** within real technological limits 0.0 *5* x, 5 0.2, and 0.001 *5* Anc 5 0.01, in parallel form to achieve the given squeezed dispersion. Linear correlations in general are found and the 3-D displays integrate the general features of the present study. The present investigation is of deep impact in the design of optical fiber cables employed in high-speed optical communication systems.

[7] Two basic modulation formats RZ and NRZ are investigated in a repeated 10 Gbps dispersion managed system based on 120 km fiber spans. Dispersion Compensation schemes employed were pre and post dispersion compensation schemes. Input power levels of SMF and DCF are optimized. Existence of optimum transmission is clearly observed from contour plots. After optimizing pre and post dispersion compensation schemes, it is observed that RZ modulation format is better as compared to NRZ data modulation format. *Q* factor obtained in RZ transmission system is more as compared to NRZ transmission systems corresponding to two, five, ten and fifteen 120 km fiber spans.

[8] The principle of the DCDM technique and the proof of its viability are discussed. Data from different users (distinguished by different duty cycles) are carried over the same optical wavelength. Using the electrical multiplexing/de-multiplexing technique, more than two users can be accommodated over the same WDM channel. Therefore, the capacity utilization of channels gets increased and is achieved at a single user clock rate, lower spectrum bandwidth and better dispersion tolerance. As an example, a DCDM system with multiplexed 3-user is demonstrated showing that this system works well when tested up to 40 Gbps per user speed, which can offer an aggregated transmission rate of 120 Gbps per WDM channel.

[9] RZ pulse generator is used for simulation work. This work shows the quality factor of different pulses of RZ pulse generator. For better results, Gaussian pulse is used which performs better as compared to others then it is concluded that with increase in the power of

laser, we get better results. With 2 dbm laser power, better quality factor is obtained. It is observed that laser power is an important parameter in simulation work. According to OFC standards, the quality factor 5 and more than 5 is considered to be best quality factor. In this simulation work, quality factor of 11.84 is achieved at link length of 360 km and data rate of 40 Gbps.

[10] The effect of SPM on performance of 40 Gbps ODCDM is investigated using three symmetric dispersion compensation schemes over 400 kms. The results show that the combination of both dispersion post compensation and pre compensation is the best scheme to be used in this system. It is concluded from observations that by considering a correct dispersion compensation scheme with optimum parameters, ODCDM can be used in MAN and WAN applications with minimum deterioration from SPM effect for error free communication.

1.2 MOTIVATION

Fibre optics has become the core of telecommunications and data networking infrastructures, replacing most wireless mediums. With the exponential growth in transmission bandwidth usage, in particular (due to the rapid growth of Internet data traffic**),** there is a huge demand on transmission bandwidth. Fiber-optic communication is the best method to fulfil this broad bandwidth due to its following unique features:

1. Huge bandwidth due to extremely high carrier frequency
2. Very low loss
3. Light weight and compact size
4. Highly secure and immune to the external electromagnetic interference.

1.3 PROBLEM DEFINITION

Implementation of Three Level Code Division Multiplexing (3LCDM) over Wavelength Division Multiplexing (WDM) to achieve lower value of BER for high speed optical communication.

CHAPTER 2

THEORY AND CONCEPTS

2.1 TLCDM over WDM Theory

2.1.1 WDM

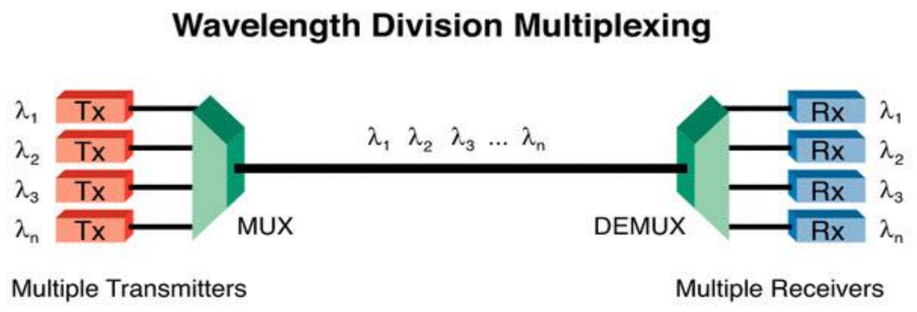


Fig 2.1.1: Wavelength division Multiplexing

WDM system is the main multiplexing technique in optical fiber transmission. It uses optical fibers for long distance communication and is known to suffer from losses due to dispersion and attenuation. The solution to reduce the loss of attenuation is by using optical amplifier. In order to compensate the dispersion in optical fiber, dispersion compensation fiber (DCF) is used.

Multiplexing technique, dispersion management and modulation format are given much attention to achieve better transmission performance in long distance transmission. Meanwhile, dispersion management technique improves the performance for long haul optical fiber communication system to restore the distortion signal that caused by fiber dispersion.

Wavelength Division Multiplexing (WDM) is one of the multiplexing techniques in long distance optical communication system nowadays.

Advantages:

1. It has greater transmission capacity.
2. Duplex transmission.
3. Simultaneous transmission of various signals.
4. Easy system expansion.
5. Lower cost and Faster access to new channels.

2.1.2 3LCDM

3LCDM technique with dispersion management has advantages over Duty Cycle Division Multiplexing (DCDM) as 3LCDM supports multiple users per channel in WDM system. Three Level Code Division Multiplexing (3LCDM) is developed in this paperwork, which combines two data stream to double the bandwidth of WDM efficiency. 3LCDM has been developed in reference that it has advantage over RZ and NRZ line coding in doubling capacity at lower frequency and smaller bandwidth.

3LCDM has great benefit over NRZ system since 3LCDM can perform better in dispersion tolerance. It is also noticed that 3LCDM system can provide higher number of users using WDM technique. However, the potential of 3LCDM data to be carried over Wavelength Division Multiplexing (WDM) system has not yet been investigated.

Although 3LCDM technique is quite similar to DCDM technique in the encoding process, it does have unique properties for its decoding part. In terms of capacity, 3LCDM is designed for two users per channel; on the other hand, DCDM can support more than two users per channel. Considering the performance of both systems for the same number of users (i.e. two users per channel), 3LCDM has a few advantages compared to DCDM. 3LCDM system uses only RZ and NRZ line coding whereas in DCDM technique, the usage of RZ at different percentage of duty cycles makes the system more complex. Using a guard band in the system's clock recovery is considered as another drawback of DCDM which requires more bandwidth in comparison with the 3LCDM clock recovery.

CHAPTER 3

PROJECT OBJECTIVES AND METHODOLOGY

3.1 OBJECTIVES

The following are the objectives of the proposed project work:

1. To study the basic concepts of NRZ and RZ coding techniques over WDM system.
2. To study the Three Level Code Division Multiplexing (3LCDM).
3. Analysis of the Component Libraries such as Transmitter library, Visualizer, Receiver library, WDM multiplexer etc. in OptiSystem.
4. Implementation of 3LCDM over WDM using OptiSystem.
5. Investigating the performance of 3LCDM over WDM.
6. Configuration of 3LCDM over WDM System and simulation.
7. Analysis of obtained simulation results.

3.2 METHODOLOGY

3.2.1 BLOCK DIAGRAM

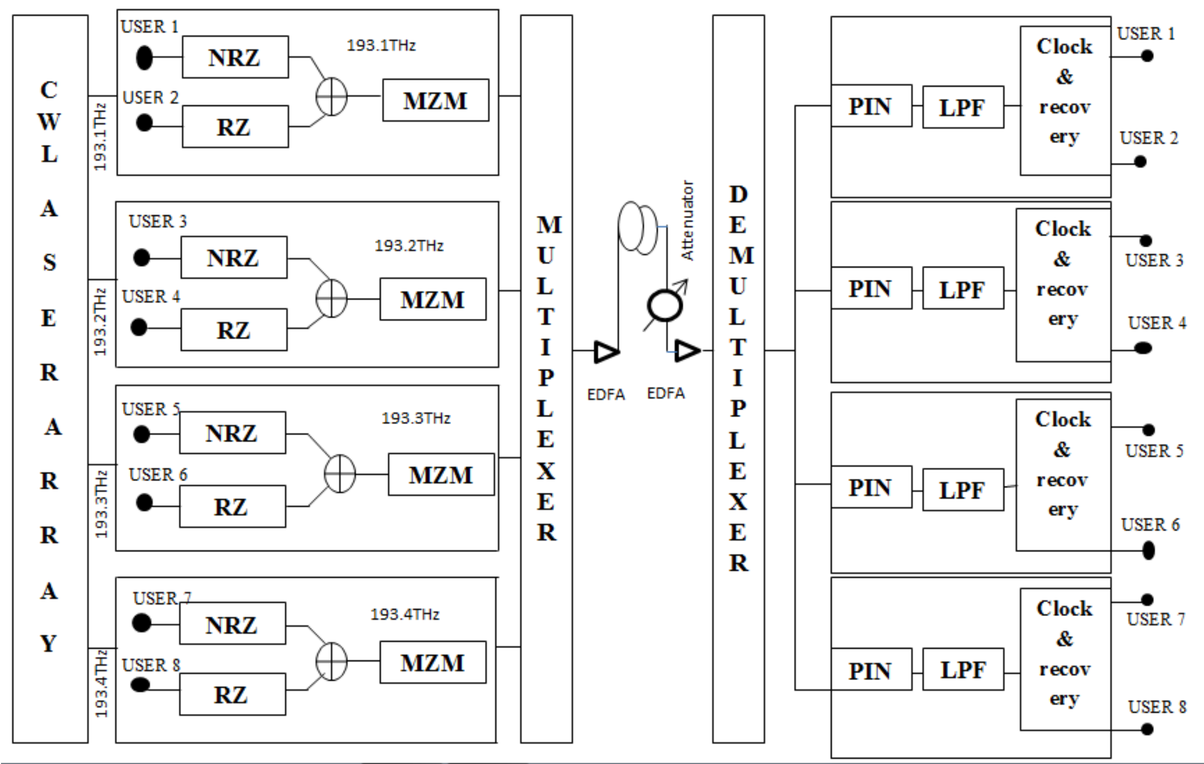


Fig 3.2.1: Block diagram of 3LCDM over WDM

Fig. 3 exhibits the simulation layout for 3LCDM over WDM system. The system is designed to support four channels of frequencies of 193.1 THz, 193.2 THz, 193.3 THz and 193.4 THz. The system is simulated using OptiSystem software for four channels at collective bit rate of 10Gbps.

At the transmitter end, the four channels at frequencies of 193.1 THz, 193.2 THz, 193.3 THz and 193.4 THz will have 2 information signals from each NRZ and RZ generator and each one is generated by a PRBS generator at bit rate of 5Gbps. The input data from each channel is aggregated using electrical adder to form 3 level signals. Later the signal is modulated using Continuous Wave (CW) laser at 0dBm of input signal power and a Mach-Zehnder Modulator (MZM).

The multiplexer is employed to multiplex four channels, so that all the four signals are transmitted through the optical fiber concurrently.

At the receiver end, a de-multiplexer is used that de-multiplexes the signals obtained from four channels. Later the optical signals coming from the de-multiplexer are filtered using band pass filter and detected by a PIN photo detector. Furthermore, the signal is passed through the electrical low pass filter. At last, clock and data recovery help de-multiplex the signal.

CHAPTER 4

EXPERIMENTAL WORK

Fig 4.1 exhibits the layout for 3LCDM over WDM system. The system is designed to support four channels of frequencies of 193.1 THz, 193.2 THz, 193.3 THz and 193.4 THz. The system is simulated using OptiSystem software for four channels at collective bit rate of 10 Gbps.

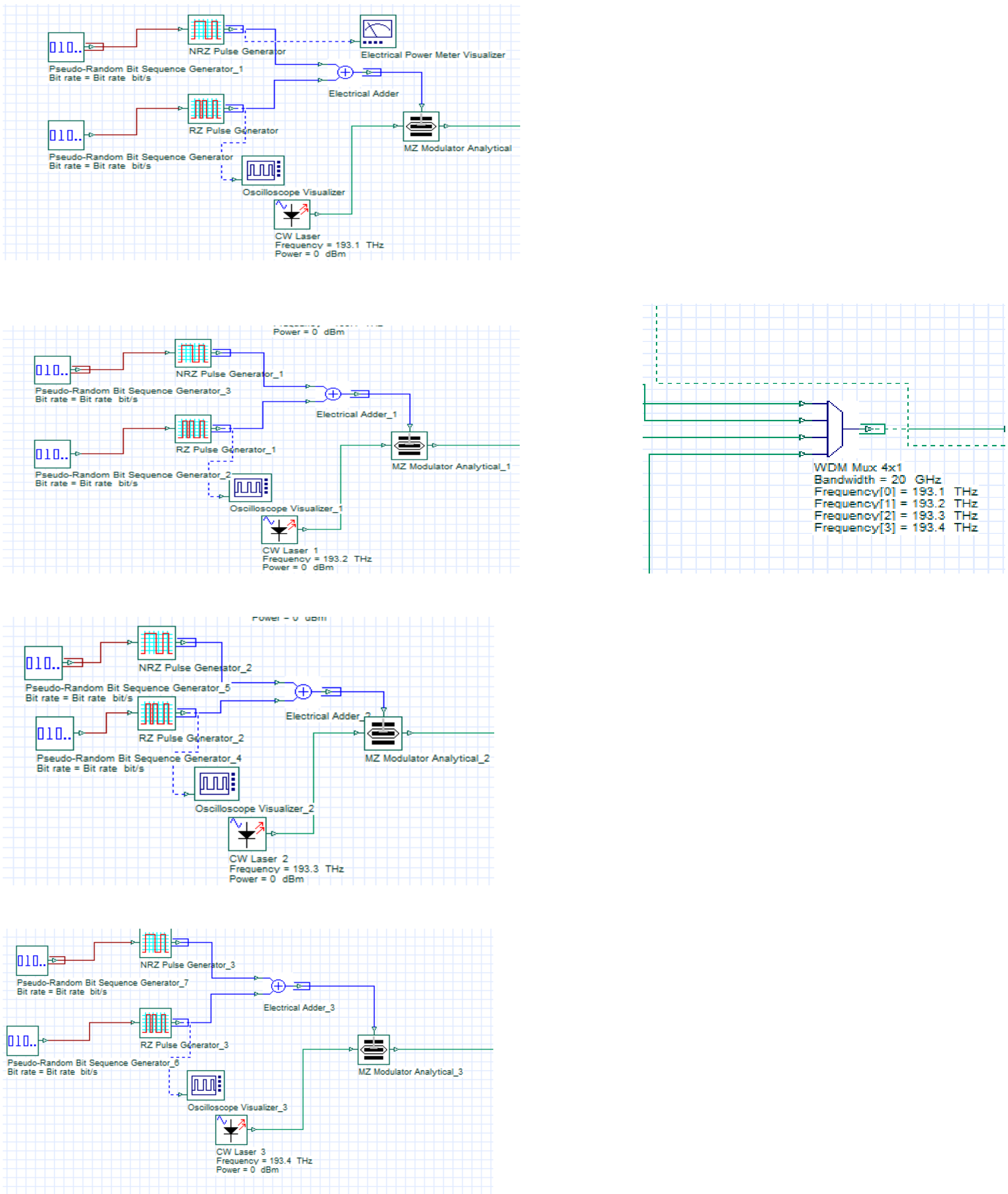


Fig 4.1: 3LCDM Transmitter End

- Input data from NRZ and RZ pulse generator will be combined using electrical adder to form three level signals.
- Then signal will be modulated using CW laser with input signal of 0dBm using single MZM.
- The multiplexer is used in the design to multiplex both channel so that multiple signals can be transmitted through the optical transmission simultaneously.
- WDM system is the main multiplexing technique in optical fiber transmission.

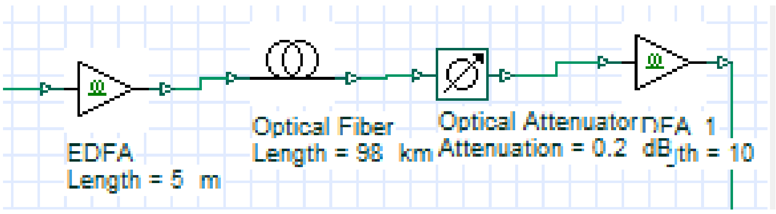


Fig 4.2 Optical Fiber Transmission Line

In Fig 4.2, Optical fiber transmission line is shown, whose components are :

- It uses optical fibers for long distance communication and known to suffer loss due to dispersion and attenuation.
- The solution to reduce the loss of attenuation is by using optical amplifier.
- In order to compensate the dispersion in optical fiber, dispersion compensation fiber (DCF) is used.

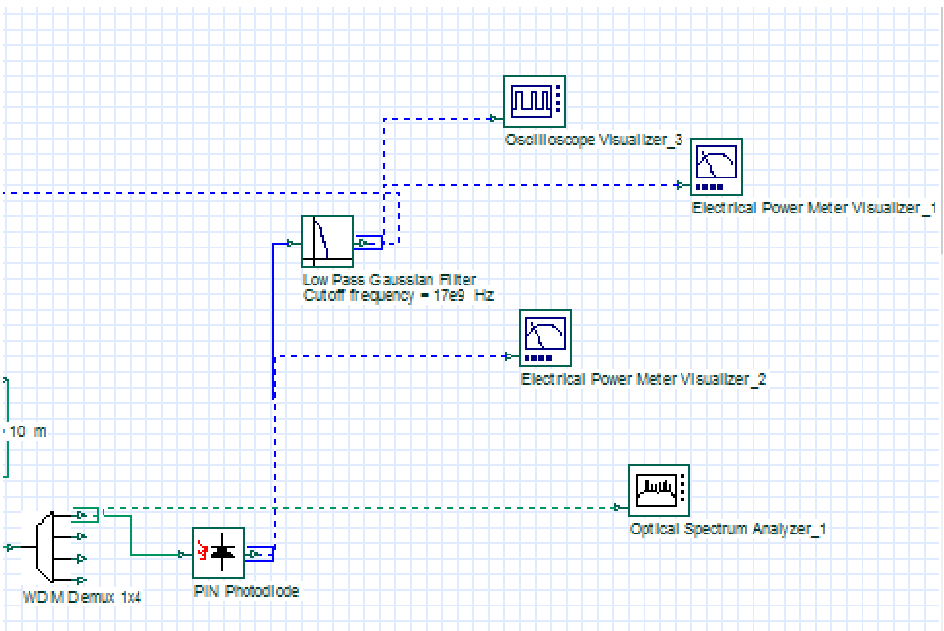


Fig 4.3: 3LCDM Receiver End

- In the receiver part of 3LCDM over WDM design as shown in Fig 4.3, demultiplexer will demultiplex the signals from both channels.
- Then the optical signal coming from demultiplexer is filtered by bandpass filter and the signal will be detected at PIN photodetector.
- After that, the signal will be passed through the electrical low pass filter.
- At last, clock and data recovery of 3LCDM over WDM design will demultiplex the signal.
- Finally, the system is simulated using OptiSystem software.

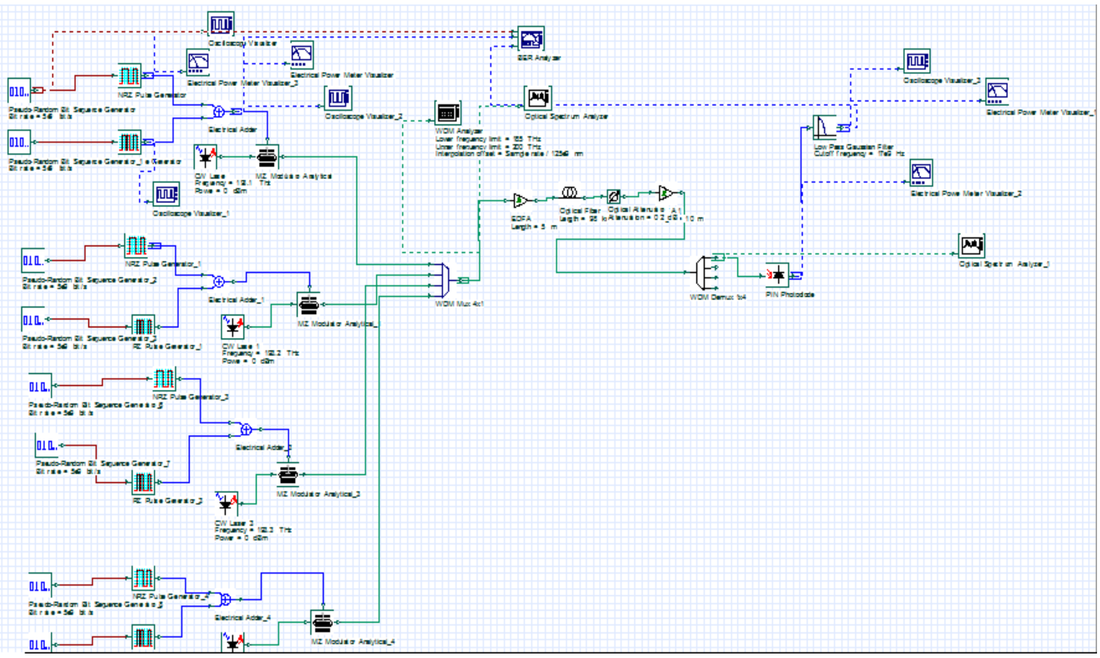


Fig 4.4: 3LCDM over WDM

CHAPTER 5

RESULTS

Fig 5.1 and 5.2 represent the transmitted optical signal's spectrum at a collective bit rate of 10Gbps of typical NRZ over WDM and 3LCDM over WDM system.

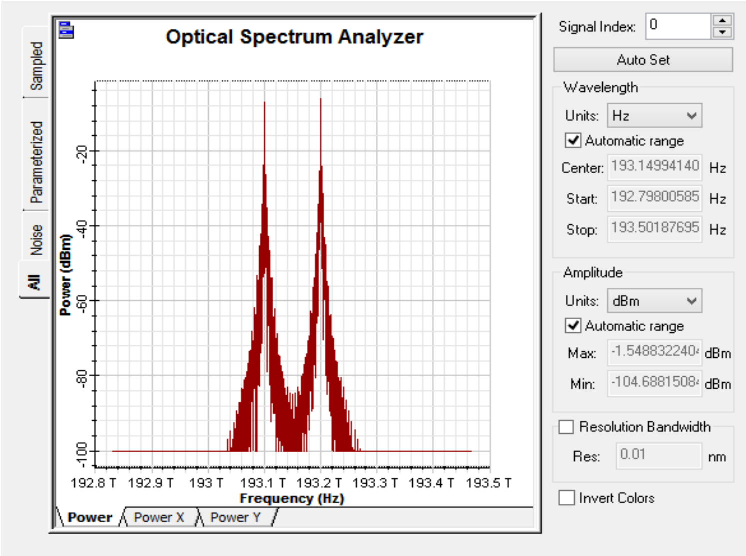


Fig 5.1: NRZ over WDM for 2 channels

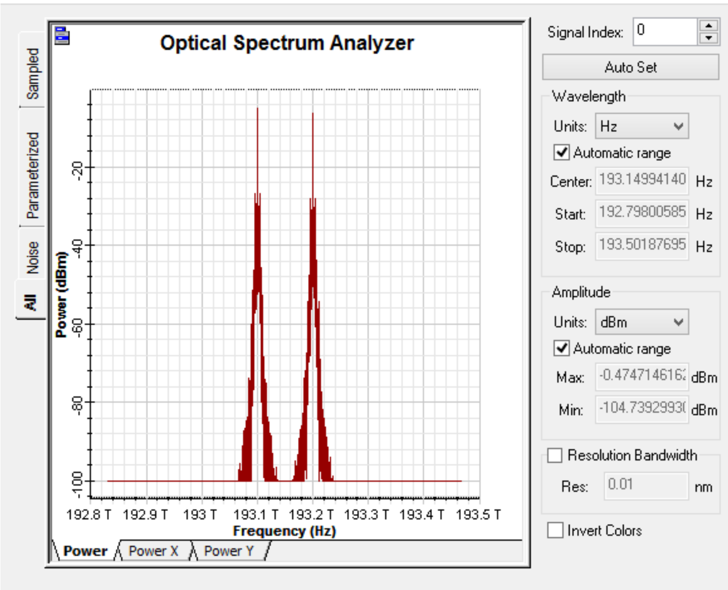


Fig 5.2: 3LCDM over WDM for 2 channels

The transmitted optical signal's spectrum of typical NRZ over WDM and TLCDM over WDM system are as shown in Fig 5.1 and 5.2 are compared.

It is evident from the simulation results that both the transmitted optical signal's spectrum has similar optical spectral width. Fig 5.1 depicts that the transmitted optical signal's spectrum obtained by convolving NRZ over WDM is noisier than 3LCDM over WDM system. Fig. 5.2 depicts that in 3LCDM over WDM system, the transmitted signal has akin broadening effect for all four channels at 193.1 THz, 193.2 THz, 193.3 THz and 193.4 THz. Therefore, it can be stated that the transmitted optical signal of 3LCDM over WDM system provides better noise performance compared to that of NRZ over WDM system and it is concluded that 3LCDM over WDM is far efficient for transmission over long distances.

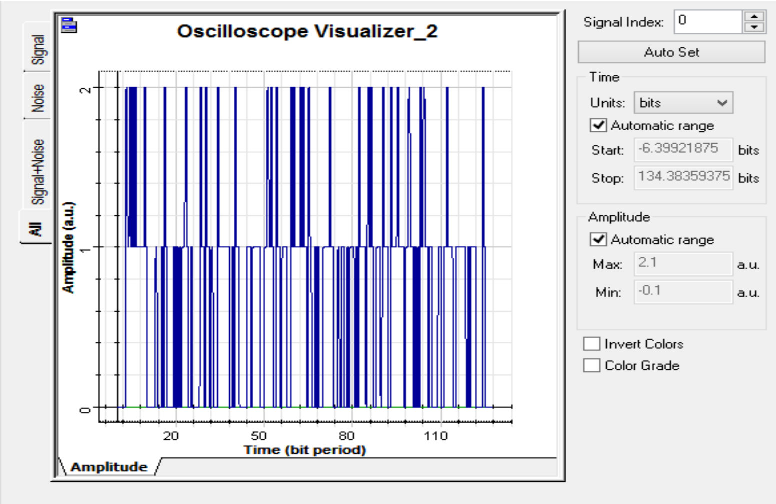


Fig 5.3: Transmitted signal

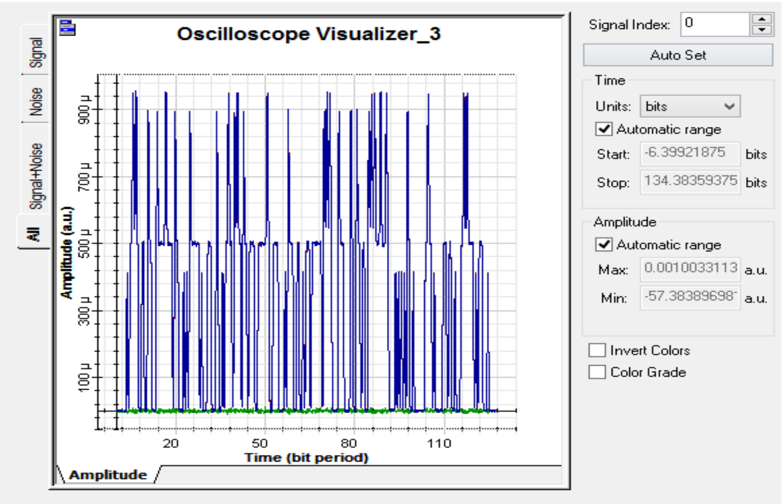


Fig 5.4: Received signal

The transmitted and the received signal of 3LCDM over WDM system at collective bit rate of 10Gbps are as shown in Fig. 5.3 and Fig. 5.4 where determination of signal and noise takes place.

The transmitter transmits the signal at bit rate of 5 Gbps and combines the data obtained from RZ and NRZ generator. The aggregated signal is analysed with the help of oscilloscope. It is evident from Fig 5.3 that the transmitted signal is a clean signal indicating that the transmitter part of system has zero noise. Later the signal is passed through the optical fiber transmission line [1]. It can be seen in Fig. 5.4 that the received signal has some fluctuation indicating the presence of noise. The losses in the fiber cause noise in the system and is is affected by optical amplifier, optical fiber and PIN photodetector. PIN photodetector detects the signal lost in the system [1]. Better noise performance can be achieved by using Avalanche Photodetector (APD) but at disadvantage of high cost. An alternative is to use SMF by decreasing its length.

5.1 RECEIVER SENSITIVITY PERFORMANCE

Table 1: Receiver sensitivity performance of 3LCDM over WDM

Received power (dBm)	**BER**
-10.610	10^{-5}
-8.982	$\mathbf{10^{-9}}$
-7.240	10^{-11}
-5.517	10^{-21}
-3.967	10^{-33}
-1.409	10^{-46}

Table 1 describes the receiver sensitivity of 2*5 Gbps for 3LCDM over WDM system is observed at channel 193.1 THz. By varying the input signal at -5 dBm, -4 dBm, -3 dBm, -2 dBm, -1 dBm and 0 dBm, it shows that input signal power is directly propotional to the received power in the system. The 3LCDM over WDM system needs received power around -8.982 dBm to get the ideal performance of BER less than 10^{-9}.

5.2 DISTANCE VS. BER

Table 2: Distance vs. BER of 3LCDM over WDM system

Distance(Km)	BER
20	10^{-55}
40	10^{-48}
60	10^{-42}
80	10^{-33}
100	10^{-25}
120	10^{-18}
140	$\mathbf{10^{-9}}$
160	10^{-5}
180	0
200	1

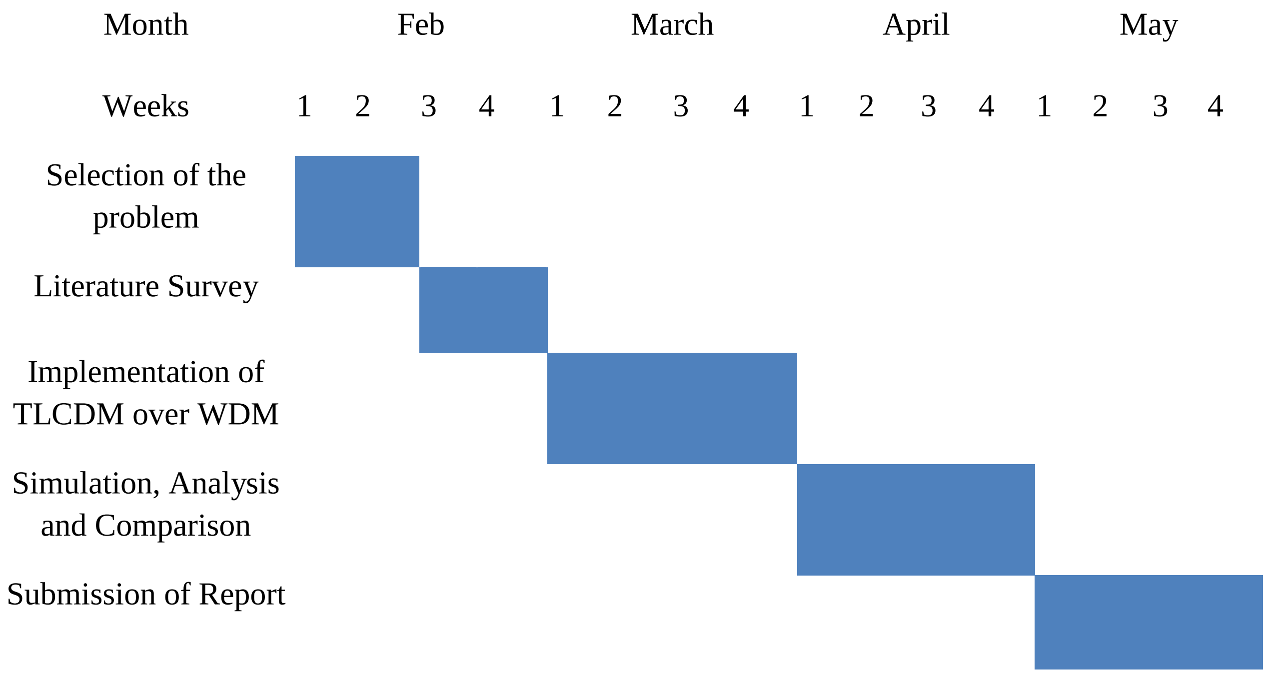
Table 2 represents the optimum distance for the system of 3LCDM over WDM at the collective bit rate of 10 Gbps. According to the Table 2, the optimum distance for 3LCDM over WDM system is around 142 km of transmission system. The result shows that 3LCDM over WDM system has better performance at long distance by using dispersion management technique. The deployment of pre- DCF and two stage EDFA in the design prove that it helps for better performance in long haul transmission system. The result verifies that the performance of 3LCDM over WDM is convenient for long haul transmission system.

CHAPTER 6

CONCLUSION

In this paperwork, 3LCDM over WDM system with dispersion compensation is examined with four channels at collective bit rate of 10 Gbps. Optimum cut-off frequency of Gaussian low pass filter at 18 GHz and Gaussian band pass filter at 40 GHz are used. By varying the input signal power, optimum received power of the system is determined that is required to achieve BER of 10-9. For optical communication of 142 kms, 3LCDM over WDM performs better compared to traditional technique of NRZ over WDM.

PROJECT SCHEDULE



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