ANALYSIS OF HYBRID OPTICAL MODULATION TECHNIQUE WITH MULTICAST AND UNICAST SYSTEM

A Thesis submitted in partial fulfilment of the requirement for the Award of the Degree of

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Submitted By

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DECLARATION

I, **Akanksha Singh** hereby declare that the work presented in this thesis entitled "**Analysis of Hybrid optical modulation techniques with multicast and unicast system**" in partial fulfilment of the requirement for the award of degree of **Master of Engineering (ECE)** submitted at **Electronics and Communication,** Thapar Institute of Engineering &Technology (Deemed to be university), Patiala is an authentic record of work carried out under supervision of **Dr. R.S. Kaler** (Senior Professor, Department of Electronic and Communication Engineering, Thapar institute of engineering and Technology) from 3rd September, 2018 to 15th July, 2019. The matter presented in this thesis has not been submitted either in part or full to any other university or institute for the award of any other degree.

Date: 15/July/2019

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ABSTRACT

In past few years the optical fiber communication system is becoming the area of interest because of the several advantages provided due to which it is used in satellite communication, aircrafts and under water communication etc. During the transmission of a signal through channel the essential purpose of optical fiber communication system is to use minimum bandwidth and also to enlarge the spectral efficiency of the overall system. The spectral efficiency of the overall system can be enlarged by adopting the polarization multiplexing techniques together with Quadrature Amplitude Modulation (QAM) and Quadrature phase shift keying (QPSK). The system capacity can be upgraded by using orthogonal polarization between nearby WDM channel. However, the birefringence caused due to depolarization of the orthogonal states which may cause the signal to dissipate which in turn reduces the overall capacity of the and system bandwidth.

The intension of the thesis is to scrutinize the performance of hybrid optical modulation techniques with multicast system and unicast system and to achieve this target optisystem v15 simulation software is used which facilitates the user to design the different types of simulated models.

Firstly, to investigate the performance of hybrid modulation techniques in optical domain with multicast system and unicast system, we first need to study the different modulation techniques with their modulation and demodulation parts. When different modulation techniques are studied then the user needs to analyse their performance in terms of Bit Error Rate (BER), Power input and Q-factor etc. These modulation scheme are then combined to make one single technique, this is known as hybrid modulation technique. The advantage of hybrid technique is that it offers ease of security with high data rate transmission using minimum bandwidth so as to make a cost effective architecture.

The first model as depicted in chapter 3 is investigated using NRZ, DQPSK and PolSK as unicast data and DPSK as multicast data transmission. In this research work, the data rate of unicast is 1090Gbps, the length of the optical fiber used is 50Km and number of loops is 10 therefore, the overall fiber length is 500Km. The outstanding OSNR is observed for NRZ+DQPSK+PoLSK which are 26dBm at $7x10^{-4}$.

The second model is analysed by using DPSK multicast data and NRZ+DQPSK+DP-16QAM as unicast data. In this proposed work, the generated data rate of unicast data is 1690Gbps with 15GHz of channel spacing in every sub channel. The superlative OSNR is examined for unicast data (NRZ+DP-16QAM+DQPSK) which is 26dBm at a distance of $6.8x10^{-4}$. The optical fiber used is 50Km and loop control comprises of 8 loops therefore the total distance for the proposed work is 400Km.

The last model manifests the implementation of multicast and unicast system with Nyquist super channel. The modulation schemes used for unicast data transmission are Nyquist DP-16QAM

with PolSK providing data rate of 640Gbps and 40Gbps data rate for DPSK multicast data. The foremost OSNR is for unicast data (Nyquist DP-16QAM) which is 26dBm at $7x10^{-4}$.The length of the optical fiber used is 50Km and the number of N recirculating loops are 10threfrore the overall distance covered is 500Km.

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LIST OF ABBREVIATIONS

ASK	Amplitude Shift Keying
BER	Bit Error Rate
CD	Chromatic Dispersion
CW	Continuous Wave
DCF	Dispersion Compensating Fiber
DP	Dual Polarization
DPSK	Differential Phase Shift Keying
DQPSK	Differential Quadrature Phase Shift Keying
EDFA	Erbium Doped Fiber Amplifier
FWM	Four Wave Mixing
GVD	Group Velocity Dispersion
LO	Local Oscillator
MZM	Mach Zehnder Modulator
NRZ	Non Return to Zero
OSNR	Optical Signal to Noise Ratio
PBC	Polarization Beam Combiner
PBS	Polarization Beam Splitter
PMD	Polarization Mode Dispersion
PRBS	Pseudo Random Bit Sequence
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RZ	Return to Zero

SE	Spectral Efficiency
SNR	Signal to Noise Ratio
SOP	State of polarization
WDM	Wavelength Division Multiplexing
PolSK	Polarization shift keying
SMF	Single Mode Fiber
DWDM	Dense Wavelength Division Multiplexed
OCDMA	Optical Code Division Multiple Access
MAI	Multiple Access Interference
SAC	Spectral Amplitude Coding
SDD	Spectral Direct Decoding
FSO	Free Space Optics
WDM	Wavelength Division Multiplexing
TDM	Time Division Multiplexing
PON	Passive Optical Network
OLT	Optical Line Terminal
SCM	Subcarrier Multiplexing
SSMF	Standard Single Mode Fiber
PSCF	Pure Silica Core Fiber
LEAF	Large Effective Area Fiber
PM-QPSK	Polarization Multiplexed-Quadrature Phase Shift Keying
PM-16QAM	Polarization Multiplexed- Quadrature Amplitude Modulation
GE-PON	Gigabit Ethernet-Passive Optical Network
ONU	Optical Network Unit
SOA	Semiconductor Optical Amplifier

OPC	Optical Power Combiner
OXC	Optical Cross Coupler
PC	Polarization Controller
PM	Phase Modulator
HDTV	High-Definition Television
OTDM	Optical Time Division Multiplexing
HOA	Hybrid Optical Amplifier

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Communication is the process of conveying information from one place to another. A communication system is often required whenever information is to be passed at any considerable distance. Inside communication system, the information is transferred by overlaying the information signal on an electromagnetic wave known as carrier wave for message signal and transmitted to the destination side and received by the receiver and the original signal sent at transmitter side is demodulated in order to check the synchronization in the communication system.

1.1.1 Historical development

In optical fiber communication, the use of light waves has frequently used as a medium for communication. Elementary systems e.g., reflecting mirrors, signals fires and signalling lamps have provided the information but to a limited extend. Figure 1 represents the growth of optical fiber communication systems such 1974.

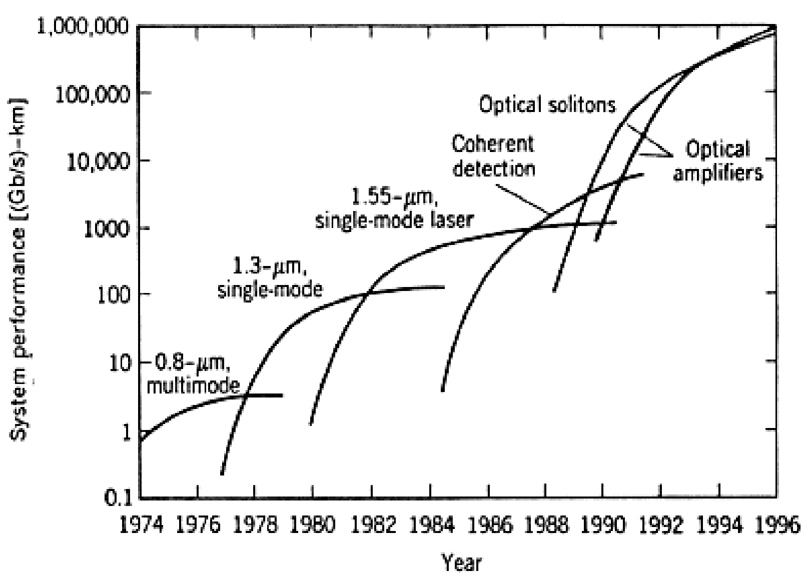

Figure 1: Diagram representing the development of optical fiber communication system.

In year 1880, a Scottish born scientist named Alexander Graham Bell described the communication of speech by employing beam of light as a medium to transmit it [1].In twentieth century, some investigation of optical fiber was under the process. However, the problem was its limited use in mobile and communication system of low capacity. Because of less shortage of availability of light sources, secondly when light used as a transmission media in climate, it was confined to the line of sight and badly overblown by atmospheric condition like thunder, fog and dust etc. Radio and microwave came with the concept of lower the frequency and higher the wavelength for higher data transmission at long distances but these waves were limited in information they convey in frequency. Lesser the information lesser is the bandwidth. Hence, information is directly proportional to the bandwidth of a communication system. So to send the larger amount of information at considerably higher wavelength Very High Frequency (VHF) and Ultra High Frequency (UHF) came where it lead to the introduction of higher frequencies and later on millimetre wave transmission.

1.1.2 About optical fiber

An optical fiber in structure is as thin as human hair and is an optical waveguide that operates on the principle of Total internal reflection.

As read earlier, the transmission of information at optical frequency gets increase by a factor of 10^4 it offers several advantages for which it is widely used and acts as a backbone for high bandwidth.

A) Huge bandwidth

   The range of optical carrier frequency is between 10^{13}Hz to 10^{14}Hz, which implies a greater transmission bandwidth than the existing metallic cable. The bandwidth of coaxial cable was typically around 20MHz of distance up to 10Km and the mm wave radio system has a bandwidth of 700MHz at a distance of negligible hundreds of meters. In year 2000, the normal product of bandwidth x length was around 5000GHz Km whereas the same product was around 1000GHz Km. So, the optical fiber has an improvement in terms of bandwidth by a factor of 50,000 as compared to the existing coaxial cable also providing high capacity information over long distance [2].

B) Miniature size and weight

The diameter of optical fiber is small as compared to the human hair. When optical fiber covered by the protective coatings the size and the weight is much lighter then copper cables. Therefore, the optical fiber is applicable in ships, satellites and in aircrafts.

C) Free from any conduction or current

When the optical fibres is designed with help, of electrical insulator such as Plastic polymer or glass, these fibres do not exhibit any earthing or current due to which they are feasible to use under water for under water communication.

D) Provide immunity against interference and cross talk

A dielectric waveguide formed by an optical fiber due to which these fibres are clear from electromagnetic interference (EMI) or Radio frequency interference (RFI). The processing of a signal in an optical fibre communication system remains unaffected by any noisy environment hence there is no requirement of shielding from EMI.

E) Ease of security

Light exhibited from optical fiber does not radiate appreciably due to which these fibres is used in banking, military and in computer networking because they provide high signal security.

F) Appropriate signal transmission with low loss

Over last 20 years, the development of optical fiber has produced the fibres with low attenuation, which copper cables could not accomplish. The minimum losses in the fibres is been fabricated with $0.5dBKm^{-1}$ which has become an attractive feature for optical fibre communication. With this advantage, it helps the communication link to use wide optical amplifiers or optical repeaters, which not only reduces the complexity of the system but also the cost as well.

G) Flexibility in usage

Due to its small size and weight, it can be inclined to negligible radii or can be warped without damaging the optical fiber. Because of this, the optical fibre can be storage, easily installed and easy to maintain.

H) Ensure reliability of the system and easy to maintain

As read earlier, maintain the signal strength with low loss in optical fibres facilitate the execution of communication link with large optical amplifiers which makes the system reliable. In addition, because the optical fibre is easy to install it makes the system easy to handle.

1.1.3 Modulation and need of modulation

In communication system, a message signal is the original signal, which needs to be transmitted at a considerable distance, but due to its low signal strength, it cannot travel long distance. The physical surroundings have the presence of noise, when added to the message signal, which in turn further reduces the strength of the signal. The above two mentioned scenario depicts that the message signal itself has low signal strength and the addition of noise will further reduce the strength of the signal. So, to send the signal at large distance, the strength of the signal needs to be increased. This can be accomplished by means of high frequency signal or in terms of energy; high-energy signal. The advantage of using this high frequency signal offers the signal to travel a long distance irrespective of external disturbances such as noise. This high frequency signal or high-energy signal is carrier signal. In order to transmit the original low strength signal, the high-energy signal called carrier mixed with the original low strength signal to produce a new signal of high frequency. This is obtained by changing the features or characteristics of carrier signal such as (amplitude, phase and frequency) according to message signal. This procedure of changing the features is modulation. Modulation means to change the characteristics of carrier signal. The original information is contained in the message signal whereas on the other hand, the carrier signal has no information. The purpose of using carrier signal is just to transmit the information contained in a message signal to a considerable long distance. At the destination side, where the information is obtained the message signal is achieved and the carrier signal is of no longer use. The characteristics of a message signal are never changed, while in the process of modulation the characteristic of carrier is changed. The idea behind changing the characteristics of carrier signal is that the carrier signal does not contain any information so even if the information is changed; there is no effect on message signal. However if the message signal containing information is changed the information will also change. Therefore, the carrier signal is only changed. Modulation defined as the process of changing the characteristics of carrier signal (Amplitude, phase and frequency) according to message signal and the device, which performs such operation, is modulator.

1.1.4 Need for modulation

The need for modulation is very important due to following reasons:

(i) To avoid combing of signals

(ii) To increase the range of communication at long distance

(iii) To promote need for wireless communication

(iv) To eliminate the noise effect

(v) To shorten the height of antenna

The communication is the major key for manhood thoughout its history. As a technology upgrades, communication is easy through copper wires, co-axial cables for long period of time. Now-a-days, communication through optical fiber is essential at long distance with high data rate. To improve the capacity of the system with efficient utilization of bandwidth different modulation techniques are required. Many researchers have proposed modulation techniques to increase the single channel capacity. Recently, many examiners have worked on combination of two or more modulation techniques known as hybrid modulation techniques (DPSK, DQPSK, POLSK and NRZ)[3][4] to increase the overall capacity of system to design a efficient utilization of bandwidth. The hybrid or multi-dimensional modulation techniques not only increase the speed of the channel but also increases the number of users[5]. While using the hybrid modulation technique, we also take care to enhance the capacity of each channel for multiple number of users. Now days, these benefits has been provided by multicast and unicast modulation techniques, in which Polarization and subcarrier modulation is used as a unicast and DPSK as a multicast[6]. In multicast task, the DPSK information has imposed on multiplexed unicast system. In my report work, the best hybrid modulation techniques has been studied and perceived to achieve noval security to avoid the eavesedropping [7] as well as for bandwidth efficient system. But hybrid modulation technique is limited for 105Gb/s for 35 channels[8]. So to enhance the system, these hybrid modualtion techniques are used with multicast and unicast system to improve capacity and data rate for multiple users. Multicast and unicast sytem with hybrid modulation techniques is less prone to chromatic dispersion (CD) and polarization mode dispersion (PMD) and also provide the high data rate of each channel with efficient utilization of bandwidth.

1.1.5 Modulation and modulation techniques:

In the area of electronics and telecommunication scenario, modulation is defined as the process of varying one or more than one properties of periodic waveform known as carrier waveform along with modulating signal which typically contains the information that needs to be transmitted. Overall, modulation is a process of carrying a message signal. There are three types of domain in communication,one is analog domain, second is digital domain and third one is optical domian. In analog domain, the analog baseband or low-pass signal is transmitted.Whereas in digital domain, a digital bit stream is transmitted over an analog communication channel. In optical domin, light is used as anlog/digtal signal for transmiting the signal. As compared to analog modulation, generally the prefered modulation is digital modulation due to high bandwidth, high noise immunity and permisisble power. In digital modulation, previously ASK(Amplitude Shift Keying), FSK(Frequency Shift Keying) and PSK (Phase Shift Keying) were used. In which carrier of the signal varies according to the amplitude, frequency and phase of the information signal. Afterthat, FSK and PSK is preferred over ASK due to constant amplitude of FSK and PSK and also have minimum inferences and non-linearities (such as dispersion, noise interference and FWM (four wave mixing)). Later on, PSK is better as compare to FSK because at the receiver end of FSK, the recovered carrier is unchanged even if the input signal has changed its sign. Therefore, it is not possible in FSK to determine whether the received signal is for positive one (+1) or negative one (-1). The distance between the signal points is also less in case of BFSK. Therefore, error rate of BFSK is more than BPSK. Hence, the user generally prefer BPSK over BFSK. Furter, researchers worked on DPSK (Differential Phase Shift keying), advanced version non-coherent PSK, in which input sequence of binary bits is modified such that next the next bit depends upon the previous bit also have no requirement of coherent carrier at the modulator. So the bandwidth requirement of DPSK is reduced as compared to BPSK. Last but no least, due to reason of probility of error is high as comapare to BPSK. So, Finally work started on BPSK with coherent receiver for synchronization. Afterthat, QPSK(Quadrature Phase Shift Keying) was used, in which two succesive bits in the data sequence were grouped together that reduces the bandwidth of the channel as compared to BPSK. Now days, DQPSK(Differential Quadrature Phase Shift Keying) is prefered over QPSK, in which phase as one symbol relative to previous symbol to convey the information and avoid the phase synchronization between transmitter and receiver because in DQPSK relative phaseis used instead of absolute phase.

1.1.6 Current hybrid modulation scheme**:**

Nowadays,many researchers are working on the combination of different modulation scheme such as NRZ,DQPSK and POLSK.These techniques are called hybrid modulation scheme.The advantage of adopting such technique is that it not only increases the speed of the overall system also increases the number of users at the same time.

*1.1.6.1 NRZ (Non-Return to Zero) transmitter***:**

Is a binary code where number of zeros present in a message signal are represented by negative voltage and number of ones represented by positive voltage. The design of NRZ transmitter in optisystem software is implemented with the help of 5 different components.The data source which comprises of Psuedo Random Bit Sequence (PRBS) generator and a NRZ generator connected to fork of 1x2 (one input and 2 output ports). PRBS is a binary sequence which will generate a random number of bits which is difficult to predict. A continous light wave beam from laser diode is fed to LiNb Mach-Zehnder Modulator which works in conventional modulator mode and modulated by data(with 25 Gbps data rate)in NRZ pattern. From fork, the two output ports are connected to Mach-Zehnder modulator to its upper and lower terminal while the input is provided from a continous wave laser(CW laser). From continous wave laser, an electrical signal is generated which is further modulated by LiNb Mach-Zehnder modulator.

The power of continous wave laser is 0 dBm while the frequency is 193.1THz. The NRZ generates a data rate of 25 Gbits/s.

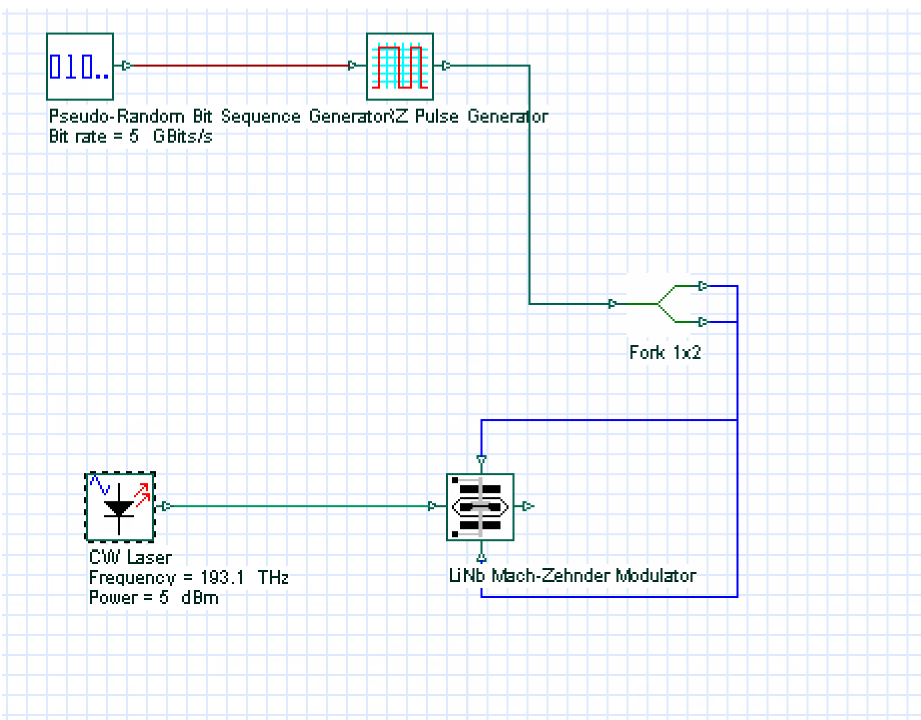

Figure 1.1.6.1(a) NRZ (Non-Return to Zero) transmitter

1.1.6.2 NRZ receiver:

The design of NRZ receiver is implemented with two different components.Its consist of a PIN photodetector with a Low pass bessel filter.The photodetector has a responsivity of 0.75A/W and dark current of 0.1 nA while the low pass bessel filter has frequency of 193.1THz with a bandwidth of 10 GHz.

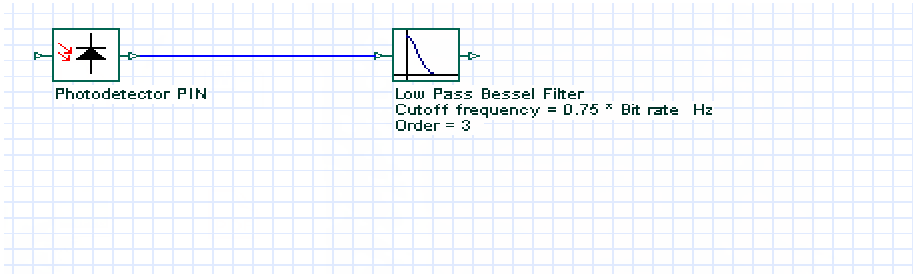

Figure 1.1.6.2 (b) Design of NRZ Receiver

*1.1.6.3 DQPSK(Differential Quadrature Phase Shift Keying) transmitter***:**

It conveys information by establishing a certain phase of one symbol relative to previous symbol.The design of DQPSK transmitter can be implemented by four different components. The first component is same as that of NRZ transmitter just the difference of RZ pulse generator. RZ pulse generator is used because DQPSK itself has very low losses in it but if the user wants to save power then the user can use NRZ pulse generator. The signal from the data source is splitted and given to two phase modulators which will modulate the phase of the incoming signal from data source. The first phase modulator modulate the signal at an angle of 180 degree whereas the second phase modulator modulates the signal at an angle of 90 degree.

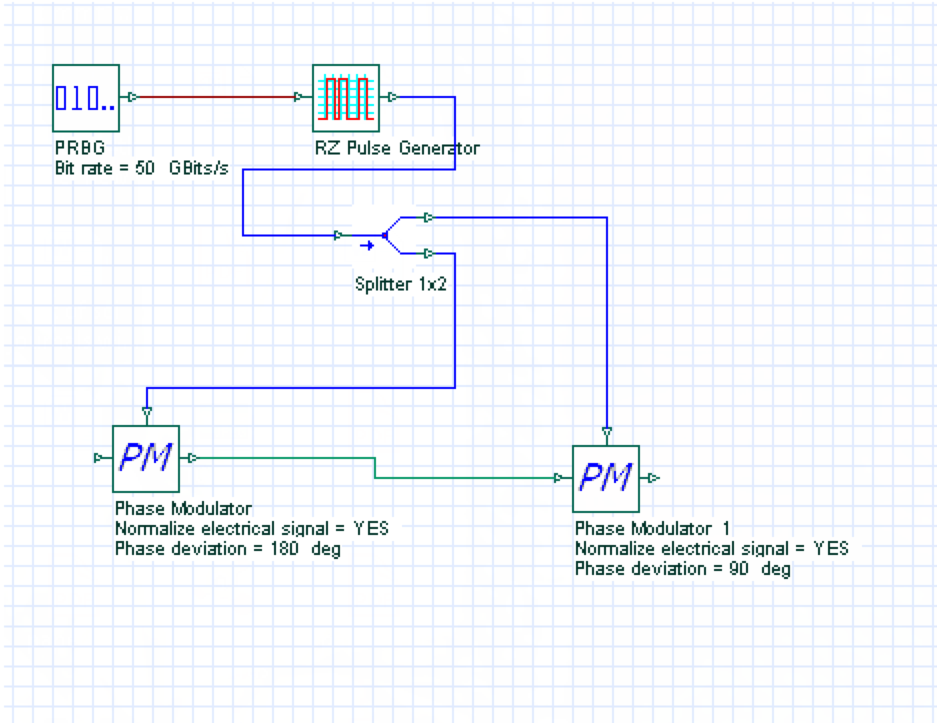

Figure 1.1.6.3(a) Design of DQPSK Transmitter

1.1.6.4 DQPSK receiver

From earlier knowledge, we know that DQPSK carriers information by establishing a phase of one symbol relative to previous one. A 3dB X coupler has four terminals comprising of two inputs and two outputs. The 3dB X coupler is a directional coupler in which both the two output ports have half input power. From the input side, at first terminal a linear polarizer is connected whereas at second input side a optical null is connected. Secodly, from output side, two forks are connected. Further these two forks are connected with two mach-zehnder inferometer. The mach-zehnder inferometer is a device that is used to determine the variations of relative phase shift between parallel rays derived from splitting of a light from a source or input. To combine these, mach-zehnder power combiner are used , passing the signal to a low pass bessel filter to avoid any high frequency component also to avoid any noise component. Finally, combining the signals from two low pass bessel filter to produce one single output.

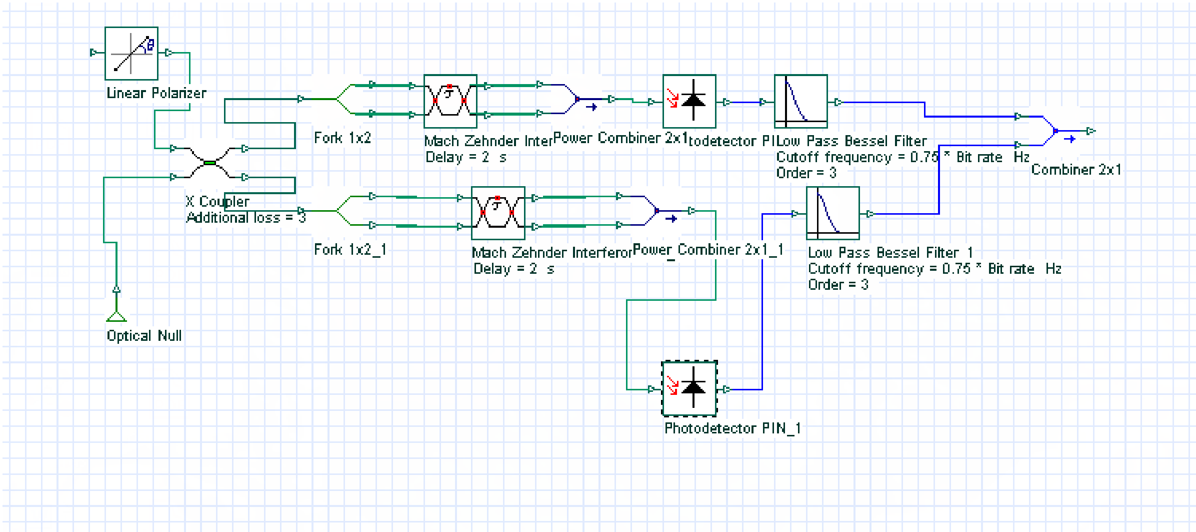

Figure 1.1.6.4(b) Design of DQPSK Receiver

1.1.6.5 PolSK (Polarization Shift Keying) transmitter:

In POLSK binary bits are encoded as orthoganal state of polarizartion at an angle of 45, in which bit 1 is represented by +45 linear polarized and 0 is -45 linear polarized. The implemetation of polarization shift keying transmitter comprises of Psuedo Random Bit sequence generator with RZ pulse generator.The output from RZ pulse generator is fed as an input to phase modulator.The phase modulator (PM) has two input ;one from RZ pulse generator and second from polarization splitter.The PM has a device angle of 45 degree further combining the signals from polarization splitter and the output from phase modulator. At the other end, a polarization controller is connected with polarization splitter which has two output ports.The polariation controller is an optical device which will allow only one polarization state of light to modify.The splitter will split the signals into two parts ,one is given to combiner while the other is fed to phase modulator of phase deviation 45 degree.The polarization combiner is a device which will combine two orthogonal polarization into a single fiber.

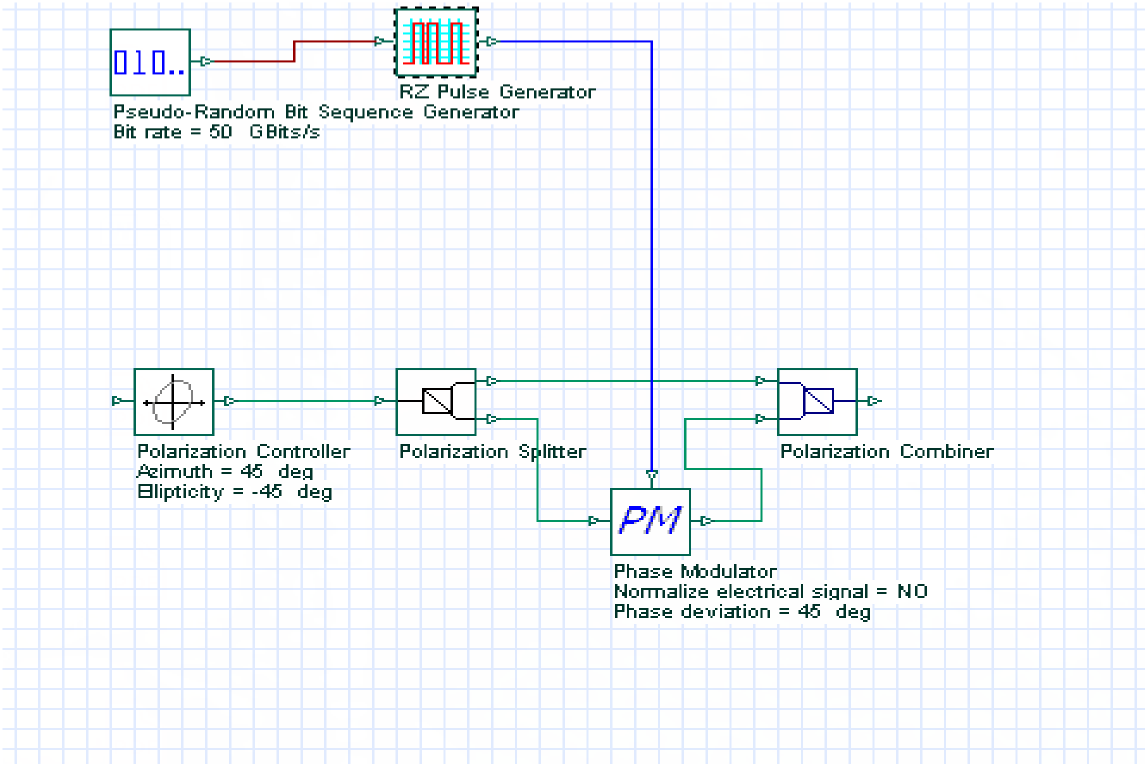

Figure 1.1.6.5(a) Design of POLSK Transmitter

1.1.6.6 PolSK (Polarization Shift Keying) receiver

POLSK receiver consist of polarization splitter which splits the signal into two parts. Before polarization splitter, a bessel optical filter and a polarization controller is connected where bessel optical filter has frequency of 193.1THz and bandwidth of 10GHz while the polarization controller has ellipticity of -45 degree. The first part and second part are given to photodetector PIN diode finally passing the signal to low pass bessel optical filter to pass only low pass bessel filter.The signals from low-pass bessel optical filter are then combined with a combiner of 2x1.The bessel optical filter has a frequencyof 193.1THz with a bandwidth of 10 GHz. The polarization controller has ellipticity of -45 and splitter has a device angle of 90 degree.

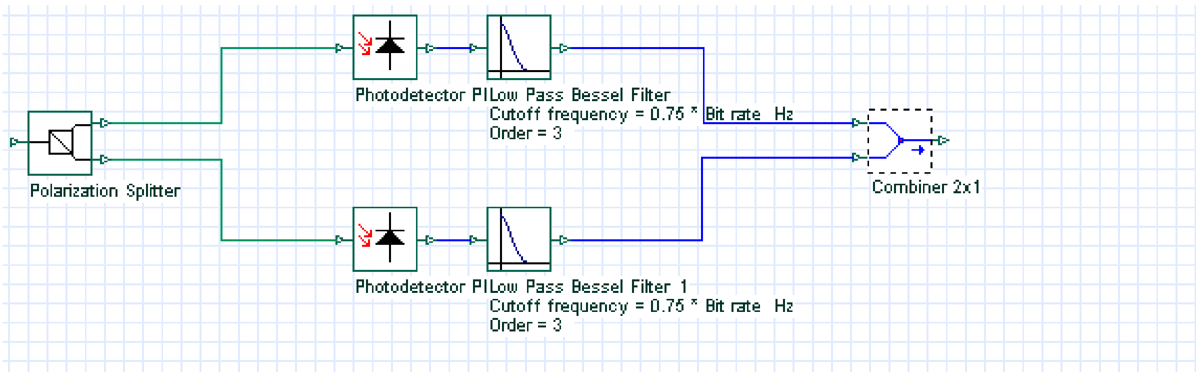

Figure 1.1.6.6 (b) Design of POLSK Receiver

1.1.6 *SCM* : SCM stands for subcarrier multiplexing. It is a method of combining several different /hybrid communication signals so as to transmit along a single optical fiber.The concept is different in case of SCM than WDM . In WDM , an optical carrier is modulated along with baseband signal with data rate of typically Mbit/s.Whereas in SCM, first baseband data is modulated on a GHz wide subcarrier that is modulated on optical carrier.

1.1.8 Hybrid modulation design

The following is the schematic diagram of hybrid modulation for one channel. The transmitter part consists of NRZ, DQPSK and POLSK modulator. The receiver and transmitter part are connected by a channel which consist of (i) single mode fiber (SMF) of length 40km attenuation 0.2dB/Km dispersion of 16.75ps/nm/Km where SMF is defined as the fiber which allow only one mode to propagate and dispersion slope of 0.075ps/nm^2/Km (ii) Erbium doped fiber amplifier (EDFA) of length 5Km, Erbium-doped fiber amplifiers (EDFA) are the most important amplifiers which are capable of amplifying light in the wavelength region of 1.5µm where telecom fibres have minimum losses (iii) Dispersion compensated fiber (DCF) of length 8Km, DCF is defined as the fiber which compensate or reduces the amount of dispersion in a fiber being carried out in an optical fiber system. The channel consists of hybrid amplifiers with DCF to strengthen the signal power [6]. The receiver part consists of NRZ receiver, DQPSK receiver and POLSK receiver. With the receiver part, three (3R) generator is connected with three BER analyser to observe the probability of errors in number of bits and optical to signal noise ratio. The 3R refers to three signal regeneration functions (Re-amplification, Re-shaping and Re-timing) of an optical repeater.

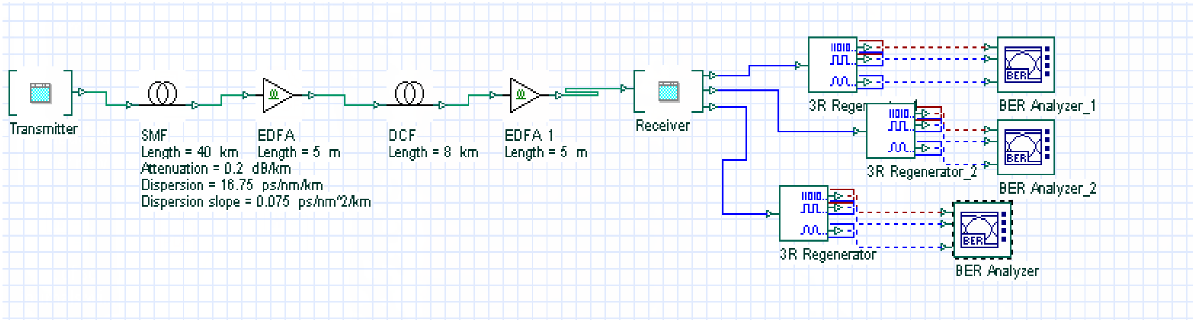

Figure 1.1.8(a): Design of Hybrid Modulation for one channel

1.1.8.1 Internal design of hybrid modulation at transmitter side:

The internal architecture of hybrid modulation at transmitter side consists of NRZ transmitter, DQPSK transmitter and finally with the POLSK transmitter. In the internal architecture of hybrid modulation,three modulation techniques (NRZ,DQPSK and POLSK) has been used and operates at a data rate of 25 Gbit/s, 40 Gbit/s, 40 Gbit/s respectively to make our system bandwidth efficient and secure against eavesdropping.

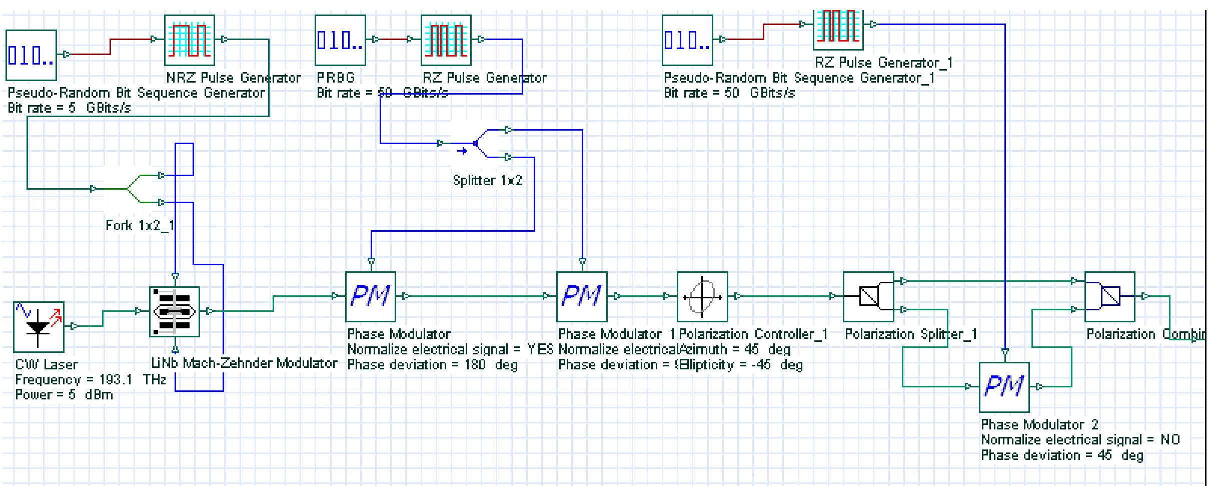

Figure 1.1.8.1(a) Design of Hybrid Modulation transmitter side

1.1.8.2 Internal design of hybrid modulation at receiver side:

The internal design of hybrid modulation at receiver side consist of NRZ receiver, DQPSK receiver and finally then POLSK receiver connected with X coupler. First X coupler is connected with polarization controller while the other terminal connected with

NRZ receiver.The polarization controller is further connected with second X coupler.This second X coupler is connected with POLSK receiver .With the remaining terminal of second X coupler, DQPSK receiver is connected.

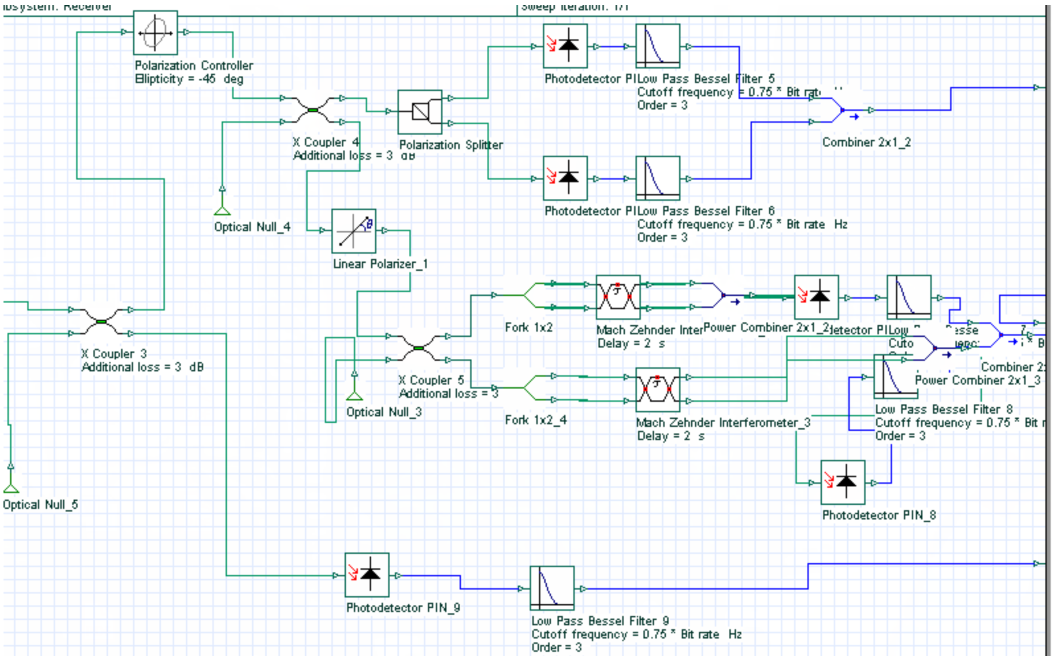

Figure 1.1.8.2(b) Design of Hybrid modulation at receiver side.

CHAPTER 2

LITERATURE REVIEW

Many papers related to Hybrid optical amplifiers (RAMAN, EDFA and HOA), Hybrid modulations (NRZ, Polarization shift keying, DQPSK and Dual polarization-M-QAM) and hybrid multiplexing (TDM/WDM/OCDMA) techniques with efficient utilization of bandwidth has been studied on different communication applications and their brief discussion are given below:

Singh and Kaler (2012) Performed hybrid optical amplifier (RAMAN/EDFA) for DWDM system with 10gbps data rate using NRZ and DPSK modulation [9]. This research has also compared with RZ modulations and different optical amplifiers (RAMAN and SOA) for reducing nonlinear effects.

In this paper, using hybrid optical amplifiers and hybrid modulations number of channels has improved up to 64 without any nonlinearity with good quality factor. From the results, it has also observed that RAMAN EDFA has better results in terms of acceptable output power and distance.

Singh and Kaler (2012) Investigated hybrid optical amplifier (RAMAN EDFA) with post pre and symmetrical power reparation methods to boost input signal power [10] .It has been observed that post power reparation is much better than pre and symmetrical power method. Further, In this design length of fiber has been varied with dispersion compensate fiber using RAMAN EDFA with post reparation method and achieved acceptable bit error rate, received power and eye closure penalty as compared to pre and symmetrical power reparation method.

Singh and Kaler (2013) Examined different hybrid optical amplifiers (RAMAN EDFA) for influence of word length input laser power PRBS (pseudo random bit sequence) on nonlinear cross talk and observed that cross talk is strongly effected on word length and subtle at channel spacing of 0.2nm and 0.4nm with relative input signals [11]. From this research RAMAN EDFA amplifier produced less cross talk in contrast to other existing hybrid optical amplifiers such as (RAMAN–EDFA-RAMAN, EDFA+RAMAN with EDFA) at 10Gbps data rate for 16 channels in DWDM systems. From the results it has been observed that acceptable quality factor with input signal power has been received with non-uniform cross talk.

Singh and Kaler (2014) Proposed hybrid optical amplifier for achieving multistage flattened gain at reduced channel spacing [12]. The performance has calculated in terms of gain flattened curve and noise figure using gain equalization technique for DWDM system. From the results, it has observed that gain-flattened curve has achieved at 25GHz channel spacing using hybrid optical amplifier for DWDM system and using equalization technique using HOA, acceptable OSNR and noise figure with gain flattened has verified.

Singh and Kaler (2013) Proposed a hybrid optical amplifier with distributed Raman amplifier (DRA) and erbium doped fiber amplifier (EDFA) for achieving flattened gain without the use of any gain equalizer or multiple pumping [13]. In this paper, a system has designed for 160 channels each at 10Gbit/s data rate using dense wavelength division multiplexing (DWDM) at 25GHz channel spacing. At different fiber i.e., single mode fiber (SMF) and dispersion compensated fiber (DCF), different dispersion has observed with pump frequency of 207THz and 201THz respectively. It has observed that, as input power increases, the gain variation over the bandwidth increases. With optimum input power of less than 8.9dBm, the achieved output power was 3mW with 12dB gain-flattened at 3.975GHz bandwidth.

Singh and Kaler (2014) Demonstrated hybrid optical amplifiers using hybrid/orthogonal modulation techniques at 100GHz channel spacing [14]. In this design, 8 DWDM channels has transmitted with NRZ and POLSK each at 10Gbps data rate with reduced channel spacing of 25GHz. From the results it has been observed that NRZ has larger eye opening and after POLSK modulation eye opening will be reduced due to addition of data bits from second data source It proposed NRZ and polarization shift keying modulation with Raman EDFA amplifier to get efficient bandwidth for DWDM system. From the results, this paper achieved acceptable quality factor and bit error rate across efficient bandwidth using hybrid modulation.

Singh and Kaur (2015) Proposed hybrid modulation technique with OCDMA (optical code division multiple access) for achieving novel security against eavesdropper with code switching technique [15]. In this technique for the observation of required result, firstly the illegal user have to check which spectral coding has been used and then the user has to check the data is approached on which axis. In this model, the spectral encoded signal has transferred using NRZ and DQPSK modulation at 25GHz channel spacing and compared with different code switching schemes. From the results, it has been observed 10Gbps data rate for each of modulation formats at 50 km distance with acceptable BER.

Singh (2017) Proposed a model of hybrid modulation technique at 3.5Tb/s data rate at minimum utilization of bandwidth. In this paper, three modulations named as NRZ (@25Gbps), DQPSK (@40Gbps) and POLSK (@40Gbps) has used for 35 channels each 105Gbps data rate for 50km distance [16]. From the results DWDM channels has successfully received with acceptable power and BER for high-speed data rate communication.

Sahbudin, Chun, Ahmad Anas, Hitam and Mokhtar (2015) Proposed/simulated SAC OCDMA over hybrid FTTX FSO link under different weather condition [17]. In this paper, SAC OCDMA has been based on K S Code that use spectral direct decoding technique (SDD); moreover this code eliminates multiple access interference (MAI) and supporting large number of users with simple code construction. The idea behind the OCDMA multiplexing technique that supports asynchronous as well as multiple user access to provide secure transmission of data. This paper simulates performance of downstream signals at a wavelength of 1550nm. From the result, acceptable BER has been observed with single mode fiber (SMF) for a distance of 20Km.The FSO supports the 1.25Gbps data rate for 1.48km distance during heavy rain.

Mandal, Patra (2017) Proposed a hybrid WDM/TDM PON with FTTH for triple play services that transmitting video, voice and data in single access subscription for128 optical network units [18]. In this paper, DPSK signal with a data rate of 10Gbps has been used to represent internet as well as voice component. Also, radio frequency and SCM scheme has been used to include analog video services. A single mode fiber is used of length 50km to transmit 10Gbps data rate. TDM PON has an attractive feature of low cost PON but at the same time it was unable to meet the future demands. So to overcome this problem WDM PON has been used with TDM PON, so it can provide individual wavelength at different time slots. From the results, acceptable optical power and BER has been received for a single mode fiber.

Xu and chow (2011) Proposed and demonstrated a bidirectional transmission, WDM PON with colourless transmission means no extra signal was required at OLT end [19]. It also provides the error free transmission using subcarrier modulation (SCM) techniques up to distance of 25km using standard single mode fiber (SSMF).

Kaler (2011) Demonstrated Giga Ethernet Passive Optical Network (GE-PON) architecture for optical communication system [20]. This design had simulated for different lengths starting from Central Office (CO) to the destination of RN remote node in terms of bit error rate. From the results, it has observed that the designed system can transmit the data at 10Gbps rate up to 15km distance.

Goyal and Kaler (2012) Simulated the performance and viability of a hybrid (WDM/TDM) PONs system with 128 optical network units (ONUs) for triple play services (voice, video and data) up to 28km distance [21]. It has also simulates the results on different modulation formats and achieved the acceptable BER with respect to best modulation technique.

Koacher and Randhawa (2013) Proposed a Fiber to the Home technique for Hybrid passive optical network and compare different PONs standards that has governed by ITU and IEEE [22]. They observed the results on different standards of hybrid passive optical network up to 50km transmission.

Goyal and Kaler (2016) Introduced a cost effective approach-using common carrier for optical networks for hybrid passive optical network [23]. This technique also demonstrated the non-linear impacts on passive optical network and diminishes it using common carrier that has received from optical line terminal.

Kaler and Singh (2009) Simulated the ten channels numerically at 10 Gb/s over 17,227 km using dense WDM transmission realistically with 70 km span of SSMF and DCF at 20GHz channel spacing [24]. For this design, they used inline semiconductor optical amplifiers (SOAs) and DPSK modulation format with minimum crosstalk and noise at 400mA bias current.

Kaler et al. (2006) Demonstrated first time road cast networks using wavelength converter at 40Gb/s with semiconductor optical amplifiers at low cost [25]. This technology has based on cross-phased modulation arranged by Mach- Zehnder interferometer to calculate the efficiency of wavelength conversion. They used return to zero line coding with 40 GB/s transmission rate.

Malhotra, Sharma and Kaler (2008) Allocated a unified investigation for wireless system above generalized fading channels which is modelled by two parameter gamma generalized model [26]. This model is flexible to illustrate short term fading such as Nakagami-m, weibull and shadowing. First the use of PA technique is evaluated to find easy way for the simplification for the compact rational expressions for MGF of output signal-to-noise ratio unlike earlier derived intricate expressions in the terms of fox's H and Meijer-G functions. With the help of these rational expressions the evaluation of performance of wireless receiver can be calculated under a range of channel fading conditions.

Wason and Kaler (2010) Proposed an efficient wavelength rerouting algorithm for dynamic provisioning of the light path [27]. In WDM networks, the rerouting of the light path can be used to enhance the throughput and to reduce the blocking probability. To achieve this objective an algorithm is proposed named as shortest path wavelength rerouting (SPWRR) for dynamic traffic in WDM optical networks. The results shown in this research represents that the SPWRR algorithm is helpful in enhancing the blocking performance of network. Also, the low complexity algorithm has also been developed which is used in the implementation of the blocking probability of network.

Wason and Kaler (2011) Demonstrated an efficient wavelength assignment algorithm for dynamic provisioning of the light path [28]. The proposed algorithm is based upon the frequently used wavelength assignment algorithm. A mathematical model is also suggested for minimization of blocking probability in the case of WDM networks. The results of the suggested model and the proposed model is compared with the existing conventional wavelength assignment algorithm such as first-fit ,best-fit , random and most used wavelength assignment algorithms. These proposed algorithms are effective for the elimination of blocking probability of optical WDM networks.

Kaur and Kaler (2012) Analysed an optical gate architecture using single SDA to implement AND, OR and NOT logic functions [29]. All simple reconfigurable optical logic functions are demonstrated using RZ where the modulated signals are at 40Gb/s of speed. The contrast ratio and the extinction ratio have also been analysed for all types of logic gates. The maximum extinction ratio and the contrast ratio obtained are 19dB and 17.2dB respectively.

Bhatia, Kamal and Kaler (2012) Investigated an adaptive filter based compensation scheme for coded direct detected optical OFDM system [30]. Different turbo codes are used for the subcarriers of different regions. For the subcarriers present in the low and high frequency regions a turbo code is used at lower rate. While, the remaining subcarriers are used at higher turbo code rate. Such kind of system design helps to provide receiver sensitivity and improved BER by more than 2dB.Nonlinear distortion and peak to average power ratio are also analysed.

Bhatia et al.(2013) Presented the concept of adding and dropping the signals by opting optical add drop multiplexers(OADMs) in an optical orthogonal frequency division multiplexing (OOFDM) system [31]. This research paper demonstrated the performance of transmission through simulation for optical OFDM system with OADM considering the nonlinearity effect and integrated Dense Wavelength Division Multiplexing. The results shown represent the system

Q is around 18dB for the proposed system when operating at a data rate of 9.953Gb/s in SSMF without dispersion up to a distance of 4500Km.The relative intensity to noise ratio is around -155dB/Hz.

Singh and Kaler(2013) Illustrated four modulation formats incorporating nonreturn -to-zero(NRZ), nonreturn -to-zero raised cosine(NRZ-RC), return-to-zero(RZ) and return-to-zero raised cosine(RZ-RC) in DWDM system with different hybrid optical amplifiers are established [32].The results shows that when Raman amplifier are used it degrades the performance of NRZ-DPSK and RZ-DPSK. The results obtained suggests that the RZ and RZ-RC DWDM system with Raman-EDFA provides good results and cover 1512 and 1260Km of distance with BER of $<10^{-9}$. Also, it is observed that the use of hybrid optical amplifiers is a best alternative to increase the distance of span.

Sharma, Kaler and Kamal (2002) Investigated pre, post and symmetrical compensation methods for 10 Gb/s NRZ links opting dispersion and standard compensated fibres through simulation to optimize high data rate optical transmission [33]. The effect of3 EDFA power and increased length of each fiber has been analysed. The results of all three compensation methods compared and it is observed that symmetrical compensation technique is superlative and the pre and post compensation technique.

Singh and Kaler (2008) Proposed placement of semiconductor optical amplifier for 10Gb/s NRZ to zero format in single mode and dispersion compensated fibre link [34]. The effect of increase in input power for a signal for three compensation methods is compared in terms of BER, eye diagram and eye closure penalty. It is observed that the post-power compensation method is superior to pre and symmetrical compensation techniques.

Singh and Kaler(2015) Since HOAs are very important for broadband band amplifiers and therefore are widely deployed in high capacity dense wavelength division multiplexed system [35]. A summarized theory is presented in state of-the-art in this growing field. Theoretical background and various inline configuration of optical amplifiers have also been presented. The results shows that the HOAs provide better gain flatness without using any expensive gain flattening technique.

CHAPTER 3

PERFORMANCE ANALYSIS OF NRZ, DQPSK AND PolSK AS UNICAST DATA AND DPSK AS MULTICAST DATA

3.1 INTRODUCTION

Communication is a procedure of conveying one's message to other person. By finding the right tool for communication, electronic communication is achieved. Earlier when there was no facility of internet, electronic communication was difficult to implement. A message or group of messages was exchanged with the help of writing letters to the destination place. When internet came to the world, it gave birth to electronic communication. Moving from paper work to electronic communication, this tool has made business connect easier, saving time as well as money. While transmitting a message, it was important to maintain its peak or signal strength. For long haul communication, when a signal sent it has less probability it may reach to receiver with similar transmit power at the transmitter side. Therefore, for long haul communication, modulation comes into picture. Many modulations techniques are there in present. These modulation techniques are divided into two broad categories namely, analog modulation and digital modulation. When two or more modulation techniques combined, this is hybrid modulation. Many researchers are working on a combination of different modulation techniques such as NRZ, DQPSK, POLSK, DP16QAM, DPSK etc. This hybrid modulation design not only increases the overall capacity of the system, but also enhances the efficient utilization of bandwidth in order to make a cost effective system.

In the proposed work, a model is investigated based on hybrid modulation. The modulation technique used is NRZ, DQPSK, and POLSK as unicast and DPSK as multicast data.

This model has suggested a new modern design of hybrid modulation along with multicast overlay system, which uses PolSK and hybrid modulation to convey 1090Gbps data rate and multicast (DPSK) to convey 40Gbps data rate. This research work investigates the design of 8.760Tb/s data rate by using unicast signal 8x1090Gbps and multicast signal 40Gbps using 0.015THz of bandwidth in every sub channel present in the hybrid modulation design

3.2 SYSTEM SETUP DESIGN

The proposed system setup as presented in figure 3.1 has six sub carrier channels starting from frequency range 193.1THz to 193.175THz, which are modulated by hybrid modulation providing data rate of 105Gbps with a delay of 1ns in every subcarrier at a channel spacing of 15GHz. In unicast modulation, the hybrid modulation used consists of NRZ modulation, DQPSK modulation and PolSK modulation generating a data rate of 25Gbps, 40Gbps and 40Gbps respectively. The present design of hybrid modulation has a laser diode, which will generate a continuous beam and is fed to LiNb Mach-Zehnder Modulator, which is modulated at 25Gbps NRZ modulation. The DQPSK modulator has two-phase modulator (PM) where the first PM modulates the phase of an optical signal at phase deviation of 180^0 while the other PM modulates the phase at 90^0. In case of PolSK modulation, the signal is further modulated at 45^0phase angle. The modulated signal from hybrid modulation generates a signal with 105Gbps data rate. From figure 3.1, it can be seen that the output of ten modulators which uses hybrid modulation(NRZ+PolSK+DQPSK) is conveyed to optical power combiner(OPC) where each modulator provides a data rate of 105Gbps with a delay of 1ns in each. Since there are ten transmitters of hybrid modulation and each generates 105Gbps so, for ten blocks, the overall data rate becomes 1050Gbps and superimposed on 40Gbps multicast DPSK modulator. After the DPSK multicast generator, the overall signal (UNICAST+MULTICAST) shifted to recirculating loops of ‘N’ and this N abide of EDFA, SSMF and DCF. The SSMF stands for Standard Single Mode Fiber which allows only mode to propagate and the advantage of using it is there is no degradation of signal and the amount of dispersion is low. To boost the strength of incoming signals, EDFA is used which acts as normal amplifier. The DCF stands for dispersion compensated fiber that compensates the dispersion present in fiber. To make practical system, the user may add white Gaussian noise to every channel. Now, the one block of unicast modulator has a combined block of hybrid modulation (NRZ+DPSK+PolSK). Likewise, these eight blocks of unicast data of 1090Gbps and multicast DPSK 40Gbps preceded to Demultiplexer and the receiver block will receive the signal at the right side of the schematic diagram as shown in figure 3.1. At receiver section, the optical 3dB cross coupler (OXC) will bifurcate both the unicast as well as the multicast data. By OXC2 and polarization controller 2 (PC2) the received version of unicast can be achieved and by Polarization controller1 (PC1) the received signal of multicast DPSK can be acknowledged. Looking at the receiver section of multicast DPSK generator producing data rate of 40Gbps has Mach-Zehnder interferometer with a delay of two seconds(2s) and consists of balanced detector to receive the transmitted signal of multicast DPSK signal. The state of polarization is changed at 45^0 when the unicast data of 40Gbps is transported to PC and is conveyed to PolSK modulator where the PM is driven at 40Gbps NRZ modulation and placed between PBS and PBC. The output from PolSK modulator 1090Gbps is achieved and passed to WDM Multiplexer. Furthermore, there are eight super channels, which are carried to WDM multiplexer where each super channel has 1090Gbps with frequency range 193.1THz to 193.8THz as presented in figure 3.2.To receive the unicast 105Gbps data, demodulators of hybrid modulation are connected. Before the process of demodulation takes place, the optical power splitter splits the six sub channels and wipe out the delays. To recover the transmitted signal of hybrid modulation (NRZ, DQPSK and PolSK) hybrid demodulators are used. After successful recovering unicast, PolSK and multicast DPSK data all three of them are associated with 3R analyser and BER analyser to detect the implementation of proposed system.

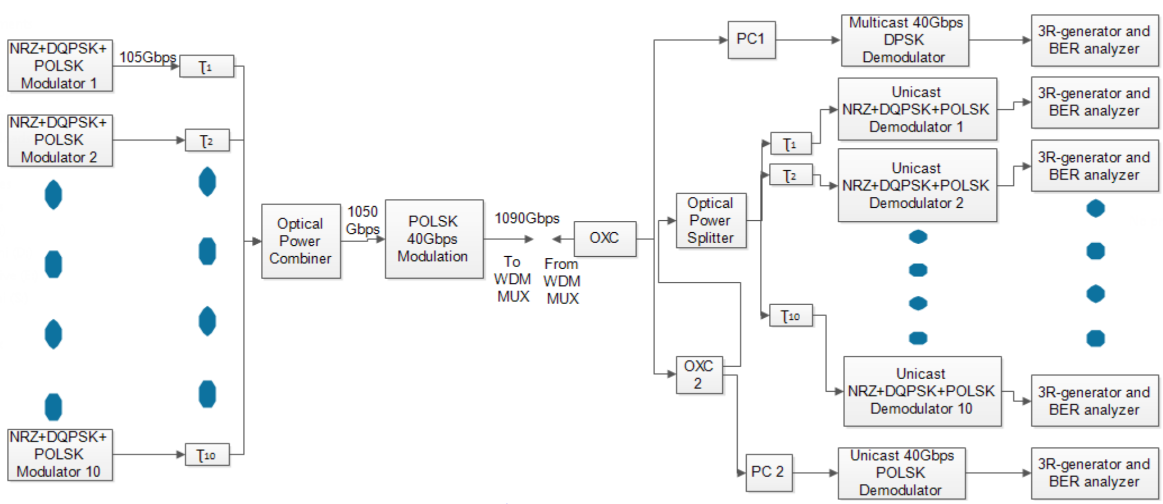

Figure 3.1: Block diagram of unicast and multicast system for single sub channel design.

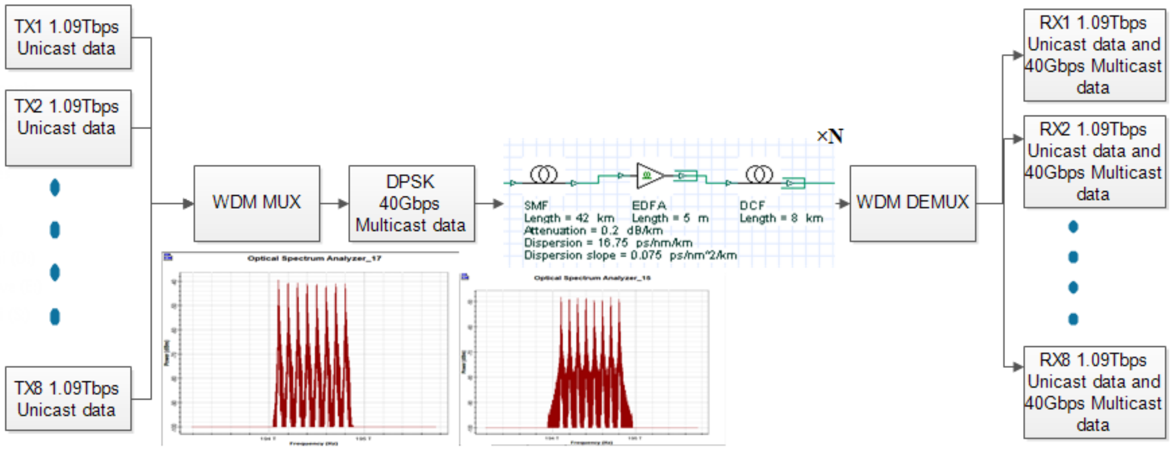

Figure 3.2: Block diagram representation of multicast overlay system for eight super channels.

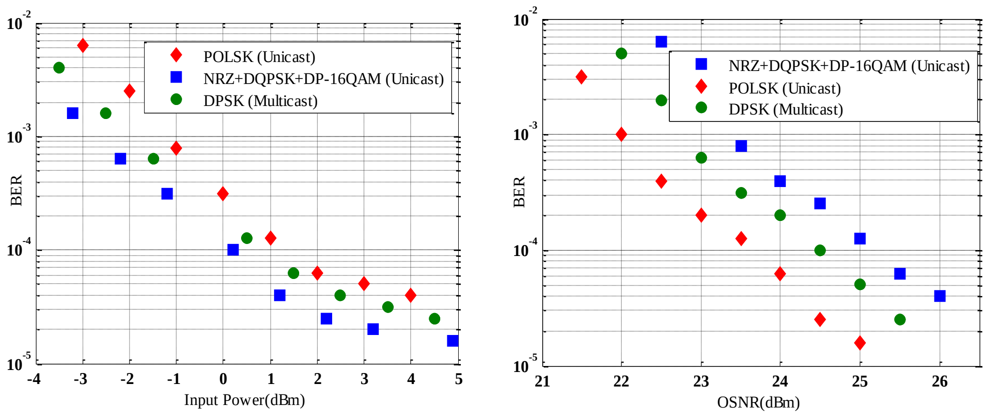

Figure 3.3: Simulation results of the proposed multicast overlay system (a) Input Power and BER (b) OSNR and BER

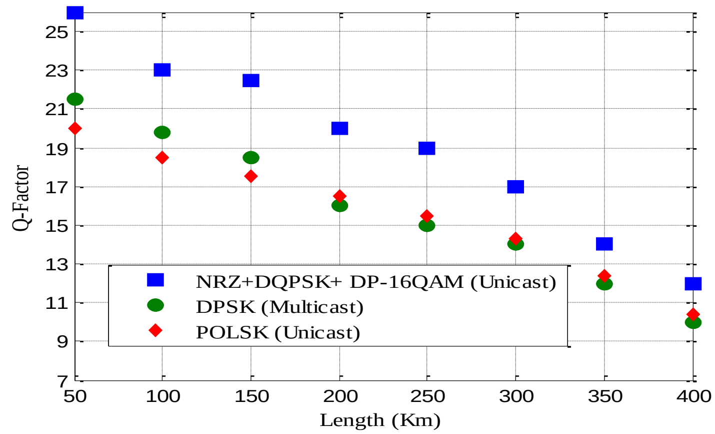

Figure 3.4: Length of the optical fiber vs. the Q-factor for unicast data (NRZ, DQPSK and PolSK) and multicast data (DPSK

3.3 SIMULATION RESULTS

The software used to observe the implementation of the proposed model is optisystem v15 simulation software, which is available online as a student trail version. The figure 3.3(a) represents the relation between BER and the Input power for the transmission of unicast and multicast data. In addition, it is recognized that for multicast overlay system the BER improves as the input power increases till 5dBm while on the other hand, power below 0dBm the BER deceases. The respectable BER is encountered for input power ranging from 0dBm to 5dBm for the proposed multicast overlay system. The figure 3.3(b) presents the graph of the OSNR vs. the BER for every channel in unicast data (NRZ+DQPSK+PolSK) and multicast data (DPSK) and it can observed that the leading BER is observed for unicast data transmission than that of multicast data transmission. In the case of unicast data (NRZ+DQPSK+PolSK) the perfect OSNR is observed as 26dBm at a distance of 7x10^-4. Figure 3.4 displays the length and the Quality factor for unicast data and DPSK multicast data also the quality factor decreases as distance increases because of multicast overlay system where the multicast is superimposed on unicast data and the nonlinearities present in fiber. The length of the fiber used in this research work is 50Km and Number of loops used in loop control is 10 therefore the total distance covered is 500Km. In this model, bandwidth efficient system is proposed using hybrid modulation along with multicast and unicast data with data rate of 8.760Tb/s. The modulation techniques used in unicast data are NRZ+DQPSK+PolSK, PolSK technique and DPSK as multicast data. The input power, supreme BER and Q-factor is observed from the simulation results for the multicast overlay system and this work proves to be much better than the previous work that has been carried out.

CHAPTER 4

PERFORMANCE ANALYSIS OF UNICAST DATA (NRZ, DQPSK&DP-16QAM) AND MULTICAST DATA (DPSK)

4.1 INTRODUCTION

From many years, the request for high data rate is expanding everyday with efficient employment of bandwidth [36].This huge demand for the data traffic can be achieve only if the optical fiber will grant the transmission of data at terabit speed. To accomplish this demand there is need for the different classification of optical techniques like WDM with OCDMA [39], WDM with OTDM [37-38],modulation techniques QPSK+RZ+PDM[41],WDM with Nyquist[40], DQSPK+NRZ+PolSK[42-43], PolSk+DQPSK+DRZ and multidimensional technique[44-45] and 3-Dimemmsional coding[46-47]. In different types of research methodologies, the various types of hybrid modulation schemes and hybrid multiplexing formats are calculated in past years. For cost effective architecture the minimum usage of bandwidth is required, the leading modulation techniques like PolSK+DQPSK+NRZ is needed to reach the purpose. S.Singh[43] analysed bandwidth efficient system by implementing modulation schemes like DQPSK+PolSK+NRZ with 0.85THz of channel spacing where individual format provides 105Gbps data rate for affluent communication for 35 channels. S.Singh [38] investigated multicast overlay system using WDM OTDM with data rate of 120Gbps at 0.1THz of channel spacing in every super channel and in every sub channel; channel spacing of 0.25THz was implemented. D.Sharma [42] proposed a system using Nyquist hybrid modulation format with WDM multiplexing for successful transmission of 9 channels with 1.55Tb/s data rate at 27.75GHz of channel spacing. The system model has been investigated in such a manner that will enlarge the complete capacity of the system within the unengaged bandwidth. In present system design a latest structure of hybrid modulation technique with multicast and unicast system is investigated. The unicast data consists of hybrid modulation techniques and PolSK technique to convey data rate of 1650Gbps as unicast data and Differential Phase Shift Keying of 40Gbps as multicast data. The paper layout is investigated to convey data rate of 13.56Tb/s by applying 8x1690Gbps as a unicast data and multicast at data rate of 40Gbps to deploy minimal bandwidth where in every sub channel the channel spacing is of 0.015THz.The model represents the unicast data (NRZ, DQPSK and DP 16QAM) and DPSK as multicast data. In this model, performance of unicast data, which employs 1650Gbps data rate for ten transmitter is investigated over SMF and DCF. The NRZ, DQPSK and DP 16QAM are used to obtain a data rate of 165Gbps as unicast and 40Gbps as multicast data. The Bit Error Rate (BER), quality factor, input power and frequency is analysed for both multicast and unicast data. The main layout comprises of unicast transmitter (NRZ, DQPSK and DP 16-QAM) section and receiver section comprising of (DPSK receiver, unicast receiver and POLSK receiver) connected with multicast DPSK transmitter and a channel between them. The structure is composed of ten transmitters and two receivers section.

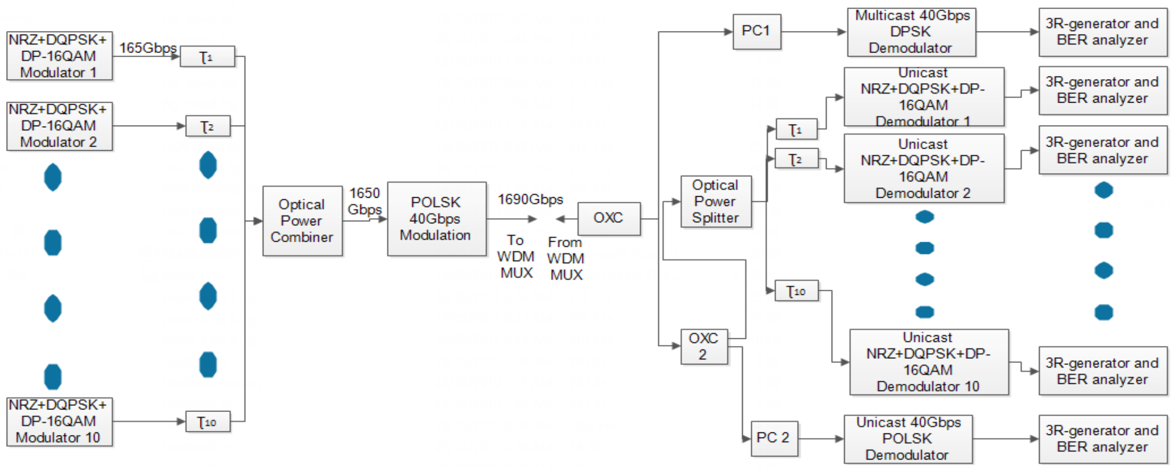

Figure 4.1: Block diagram of NRZ+DQPSK with DP-16QAM as unicast and DPSK as multicast data transmission.

4.2 SETUP THEORY

The setup comprises of hybrid modulation, which is further used as unicast and multicast data transmission. The hybrid modulation used to make one single technique consists of NRZ modulation, DQPSK modulation, DP-16QAM modulation and finally PolSK modulation scheme. The design is same as in the previous case. The diagram shows the three modulation design which are NRZ+DQPSK+DP-16QAM. Not all of three modulators can be connected in series so NRZ and DPQSK are connected in series whereas DP-16QAM is connected in parallel with two of them. As studied earlier, NRZ and DPQSK generates 25Gbps and 40Gbps of data rate respectively on the other hand, DP-16QAM generates 100Gbps of data rate. For ten modulators the total data rate becomes 1650Gbps or 1.65Tb/s. The range of frequency starts from 193.1THz to193.125THz with spacing of 15GHz. In NRZ modulation, a CW laser is used where it will generate a continuous beam of light whose output is electrical in nature. The output of CW laser is fed to LiNb Mach-Zehnder Modulator (MZM) which will produce 25Gbps of data rate. In DQPSK modulation case, there are two phase modulators (PM) used where the phase of optical signal will be modulated at a 180^0 phase deviation while the second PM will modulates the phase of an optical signal at 90^0 phase deviation. The delay in used after every hybrid modulation block is 1ns in each block. The delayed version of these techniques gets combined with optical power combiner (OPC) which will add all the power of delayed version of optical signals. After the signal passes from OPC, it gets added to PolSK modulator where it generates 40Gbps so the total data rate of speed of the signal comes out to be 1690Gbps or 1.69Tb/s. For the case of unicast data transmission, NRZ+DPQSK+DP-16QAM is now one single block for unicast data and these signals will be combined with WDM MUX. At the receiver section, from optical cross coupler, from third and fourth terminal there is polarization controller and again another cross coupler is connected. With polarization controller, Multicast DPSK generator and 3-R generator is connected to investigate the BER and quality factor of the input signal. From the X coupler, again polarization controller and PolSK with 3R generator is attached. The optical splitter will split the signal coming from X coupler into ten halves where these ten demodulators consists of NRZ, DQPSK and DP-16QAM receivers with the negative delay of the transmitter side. This completes the modulation part.

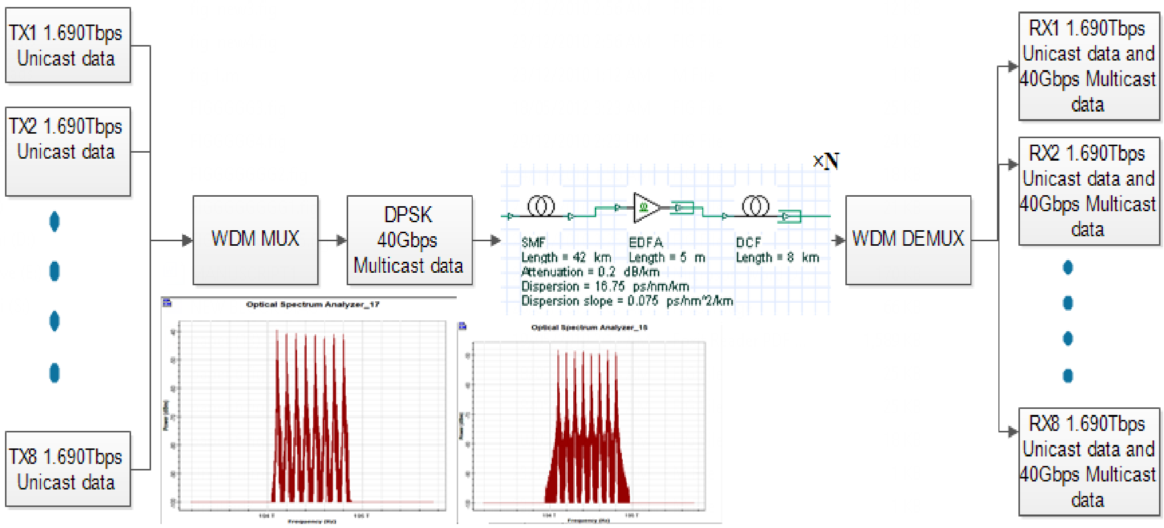

Figure 4.2: Schematic diagram of unicast (NRZ+DQPSK+DP-16QAM) and multicast data (DPSK)

The above diagram represents the multicast overlay system. The data rate provided by unicast data is 1.690Tb/s. These signals are combined with WDM MUX and passed to a multicast 40Gbps DPSK generator. The output is then passed to a channel where comprises of SMF, EDFA and DCF where each component will perform its individual function when a signal is entered. N represents the number of loops where N is 10.Therfore, the total distance covered is (42+8=50 & 50x10=500Km). The signal after channel is passed to WDM DEMUX where it will demodulate the signals into ten parts of the transmitted signals, which comprises of unicast (NRZ+DQPSK+DP-16QAM+POLSK) as well as multicast data (DPSK)

4.3 SIMULATION RESULTS

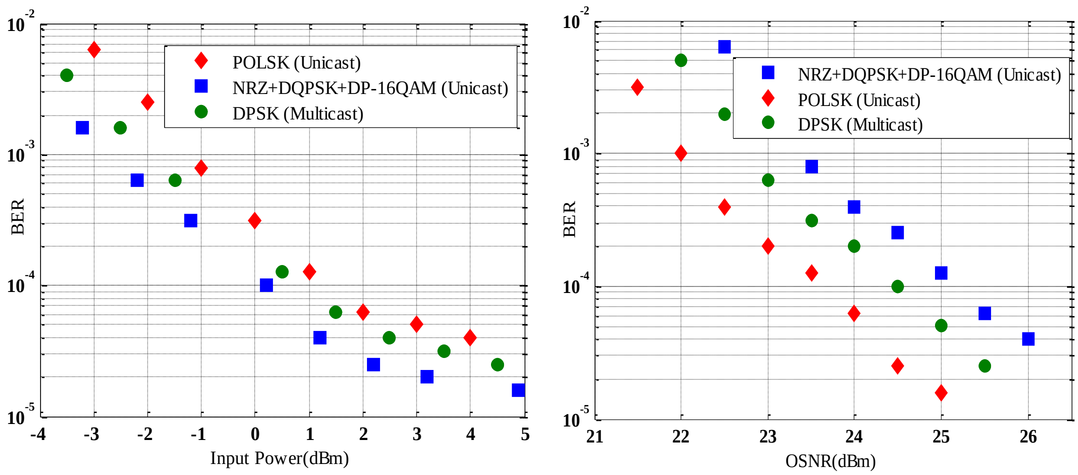

Figure 4.3: Observed results for unicast and multicast data (a) BER vs. input power for each modulation technique (b) OSNR vs. BER

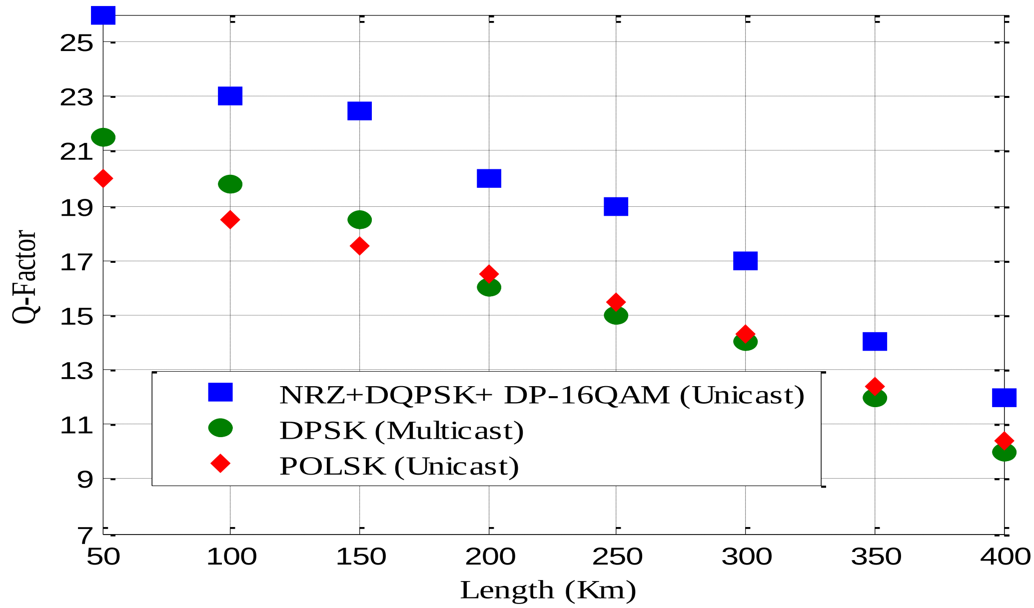

Figure 4.4: Optical fiber length versus the Q-factor for unicast modulation scheme (NRZ+DQPSK+DP-16QAM) with Multicast DPSK modulation technique

4.4 SIMULATION RESULTS THEORY

The arrangement of the proposed model is executed on the software Opti-System v15 simulation to analyse the implementation of hybrid modulation with unicast and multicast system. The figure 4.3(a) displays the relation between the Bit Error Rate (BER) and the input power. It is observed that the performance of multicast overlay system increases till 5dBm input power whereas below the input power of 0dBm, the BER goes on decreasing. The sustainable BER is detected from input power ranging from 0dBm to 5dBm for the proposed multicast overlay system. The arrangement of figure 4.3(b) displays the relation of BER and the OSNR for unicast data (PolSK), Hybrid modulation (NRZ+DQPSK+DP-16 QAM) and DPSK multicast data and it is studied that the unicast data provides the unbeatable BER than that of multicast DPSK data. The ultimate OSNR for the unicast data (NRZ+DQPSK+DP-16QAM) is 26dBm at a distance of $6.8x10^{-4}$. The figure 4.4 express the relation of length of the optical fiver and the Q-factor for unicast data (PolSK) and hybrid modulation (NRZ,DQPSK and DP-16QAM) and multicast (DPSK) data and it is perceived that as distance increases the Q-factor decreases due to multicast data is overlaid on unicast data and the fiber nonlinearities. The number of loops used in the proposed model is 8 and the length of the optical fiber used is 50Km.Therefore, the overall distance covered is 400Km. In the proposed setup, the performance of unicast data and multicast data is investigated with minimum utilization of bandwidth with a speed of 13.56Tb/s. The modulation techniques used for unicast data are NRZ+DQPSK+DP-16QAM and PolSK scheme. The unbeatable BER, Q-factor and input power is analysed from simulation results and from block diagram for the proposed model which is supreme than the previous research work.

CHAPTER 5

ANALYSIS OF PERFROMANCE OF MULTICAST AND UNICAST SYSTEM WITH NYQUIST SUPERCHANNEL

5.1 INTRODUCTION

In last few years, there has been large demand for the data traffic, which is increasing everyday with respect to cloud computing, HDTV and Video streaming. Also to operate at high data rate, it is mandatory for the data traffic to provide high bandwidth. This demand for the high transmission of data rate cam be fulfilled it the optical fiber would allow grant transmission of signal at terabit speed. Nevertheless, in order to accomplish this huge demand of data traffic it requires several types of optical techniques eg: Hybrid modulation techniques hybrid multiplexing techniques, multi-dimensional techniques, 3-dimensional techniques. It has also observed that as the order of modulation increases in hybrid modulation techniques the nonlinearities such as poor sensitivity, phase noise and high bandwidth requirement increases at the same time. In order to reduce or to eliminate these nonlinearities Nyquist WDM technique appears to solve these problems. Where the different sub channels are combined at considerably high data rate using the concept of spectral pre shaping filtering by which the bandwidth is equal to symbol rate. To achieve high transmission of data rate, hybrid techniques is encouraging technique in the case of multicast overlay system. In multicast overlay technique, unicast data as well as multicast data can be transmitted simultaneously. In this research work, for high transmission of data rate WDM OTDM multiplexing technique is used with Nyquist WDM multiplexing technique with the concept of efficient utilization of bandwidth. From literature survey, different work on hybrid modulation technique and hybrid multiplexing technique has been studied. These results increase the capacity of system within the available bandwidth. The proposed design is also paying attention to upgrade the capacity of the network within the available bandwidth and network administration. This paper design consists of multicast overlay system with Nyquist super channel which uses Nyquist(DP-16QAM) with PolSK to transmit signal at a speed of 640Gbps as a unicast data and 40Gbps as multicast data with channel spacing of 0.015THz in each sub channel in the case of Nyquist DP-16QAM .

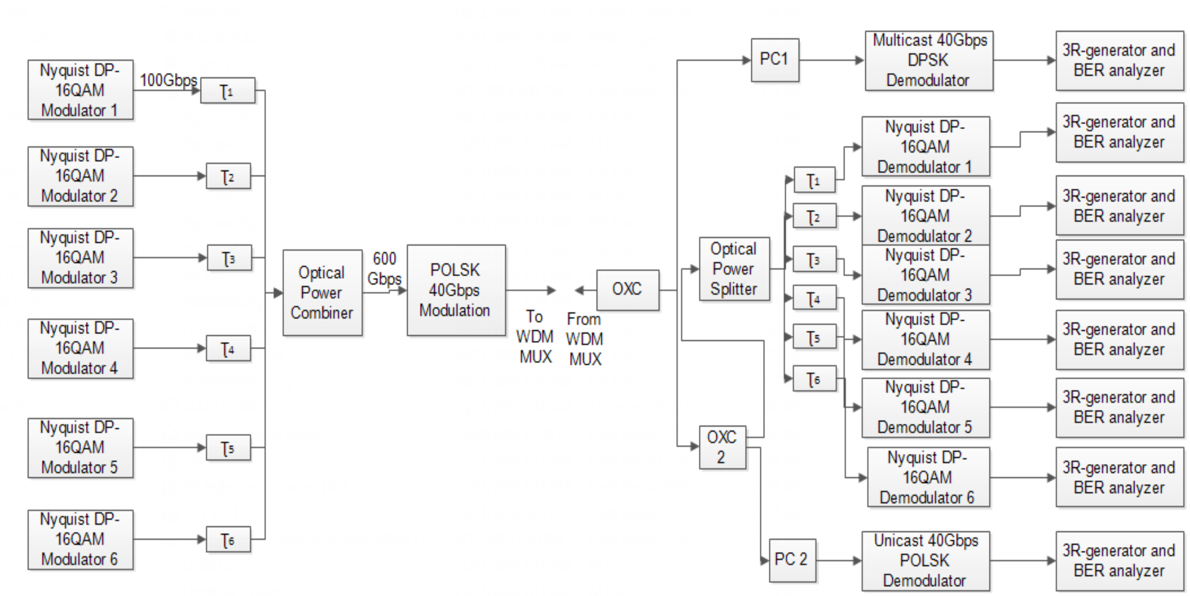

Figure 5.1: Representation of multicast and unicast data transmission and reception for single sub channel

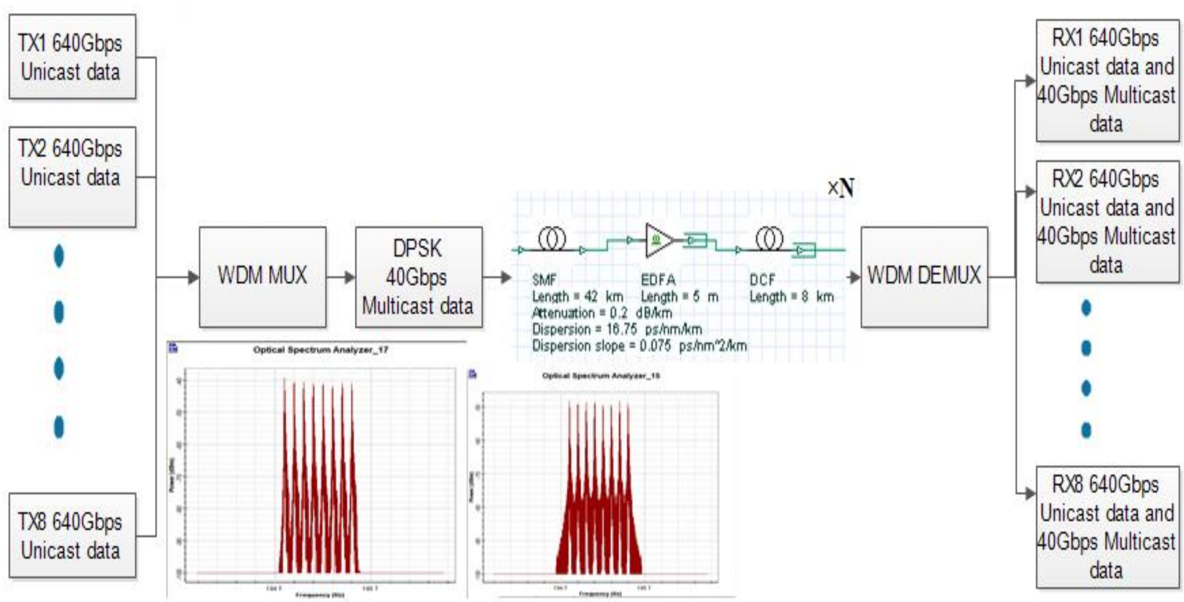

Figure 5.2: Illustration of multicast overlay system with unicast data (Nyquist DP-16QAM+PolSK) and multicast data (DPSK).

5.2 SYSTEM SETUP THEORY

As shown in figure1,the proposed design has six sub carrier channels starting from frequency range 193.1THz to193.175THz are being modulated with Nyquist DP-16QAM providing data rate of 100Gbps with channel spacing of 15GHz and a delay of 1ns in each sub channel. In this proposed design, the sub channel spacing is reduced for 15GHz to 27.75GHz[G] whereas using 27.75GHz of channel spacing reduces the spectral efficiency(SE) of the system and also dissipates the bandwidth. Therefore, an optimized value for sub channel is required and is proposed for Nyquist DP-16QAM modulation. Taking into account the case of DP-16QAM modulation, and M-ary Raised cosine filtering is used with the NRZ modulation, which utilizes the channel spacing efficiently also assure the Nyquist criterion. After the filtering of unwanted components or signals, a continuous beam of light from CW laser is passed to LiNb Mach-Zehnder Modulator at a data rate of 100Gbps and works on the principle of conventional mode. The output from six modulator of Nyquist DP-16QAM where each modulator is at 100Gbps is conveyed to optical power combiner (OPC) with a delay of 1ns. After the output from OPC the 100Gbps data rate from Nyquist DP-16QAM multiplexed signal is served to polarization controller (PC) where state of polarization (SOP) changes at an angle of 45^0 and is further passed to PolSK modulator where PM is being driven by NRZ data rate of 40Gbps NRZ modulator and is placed between polarization beam splitter (PBS) and polarization beam combiner (PBC). From the output of PolSK modulator, data rate of 640Gbps is now generated and is passed to WDM multiplexers. As shown in figure 5.2, likewise there are eight super channels where each super channel provides a data rate of 640Gbps starting from frequency range 193.1THz to 193.8THz is passed to WDM multiplexer. Now these eight super channels are superimposed on multicast 40Gbps DPSK generator. The integrated data of unicast data and multicast data is transported to recirculating N loops where this N comprises of an amplifier known as Erbium-doped Fiber Amplifier in short as EDFA, Standard Single Mode Fiber (SSMF) and to remove dispersion present in fiber, dispersion Compensated Fiber in short as DCF is used. In order to make the system more realistic, in each channel white Gaussian noise is added. Now, these eight unicast signals of 640Gbps and multicast data of 40Gbps is conveyed to WDM Demultiplexer where the receiver will receive these signal as represented in figure 5.1 at the right side of schematic diagram. Now towards the receiver side, the 3dB Optical Cross coupler (OXC) will separate both the multicast data as well as the unicast data where the 3dB optical Cross coupler2 (OXC2) and Polarization controller 2 (PC2) will provide the received signal of unicast data and Polarization controller1 (PC1) will provide the received signal of multicast data. To receive the transmitted multicast 40Gbps signal, the DPSK receiver comprises of Mach-Zehnder Interferometer (MZI) with a delay of 2s and also a balanced detector. The unicast PolSK 40Gbps has polarization beam splitter and a balanced photo detector to receive the transmitted data of unicast signal. From optical power splitter, six demodulators of Nyquist DP-16QAM are connected to receive the unicast data of data rate 600Gbps. The demodulator of Nyquist DP-16QAM consists of balanced detectors, phase shifters and polarization splitter to get back the transmitted Nyquist DP-16QAM signal. the After the signal is received from multicast DPSK generator, the unicast data (Nyquist DP-16QAM+PolSK) both are attached to 3-R analyser and a Bit Error Rate analyser(BER) to detect the implementation of multicast overlay system.

5.3 SIMULATION RESULTS:

The software optisystem v15 simulation is used to achieve the performance of Nyquist Super channel along with Multicast overlay system. The figure 5.3(a) demonstrates the relation between noise power vs. signal power for every individual channel for a set of different frequency. It is noticed that the signal power received has an admissible range from -20dBm to -26dBm while the noise power has -10dBm. The figure 5.3(b) represents the optical signal to noise ratio received at independent frequencies for each channel. For the proposed multicast overlay system, the admissible OSNR is obtained at 5.1Tb/s of data rate. The arrangement of figure4 presents the eye diagram of the proposed system where unicast data consists of Nyquist DP-16QAM, PolSK and multicast data as DPSK. The figure 5.3(a) depicts the graph of input power vs. BER for multicast overlay system also it is seen that as input power goes on increasing till 5dBm the BER also upgrades whereas the input power below 0dBm the BER decreases. For input power, ranging from 0dBm to 5dBm the tolerable BER has also been detected in the proposed model. The figure 5.3(b) presents the graph between OSNR and BER for multicast 40Gbps DPSK data and unicast 640Gbps Nyquist DP-16QAM +PolSK data also, it is noticed that the OSNR comes to be outstanding in the case of unicast data then that of multicast data. It has been observed that the finest acceptable OSNR is encountered for unicast data transmission in the case of Nyquist DP-16QAM modulation technique. Figure 5.6 displays the relation between the length of the fiber and the quality factor for individual channel for multicast data transmission (DPSK) and unicast data transmission (Nyquist DP-16QAM+PolSK) also it is realized that the distance and the quality factor are inversely proportional to each other reason being the nonlinearities present in the fiber. The length of the fiber used in the proposed system is 50Km and number of loops used is 10 therefore the overall distance explored is 500Km. In the proposed system, the Bandwidth efficient system is analysed using the concept of unicast and multicast system. The hybrid modulation techniques used for unicast are Nyquist DP-16QAM and PolSK modulation whereas in multicast DPSK modulation only one technique is used which is DPSK. The length of the fiber in the system is 50Km and number of loops are 10 so the overall distance becomes 500Km. The data rate provided by unicast data is 640Gbps and the data rate provided by multicast data is 40Gbps. The total speed of the system is 5.1Tb/s for the overall system. Results has been analysed for each channel for every modulation technique. The software used to achieve the speed of the system is Optisytsem v15 simulation software. Quality factor, BER, OSNR and noise power are also analysed in the results section.

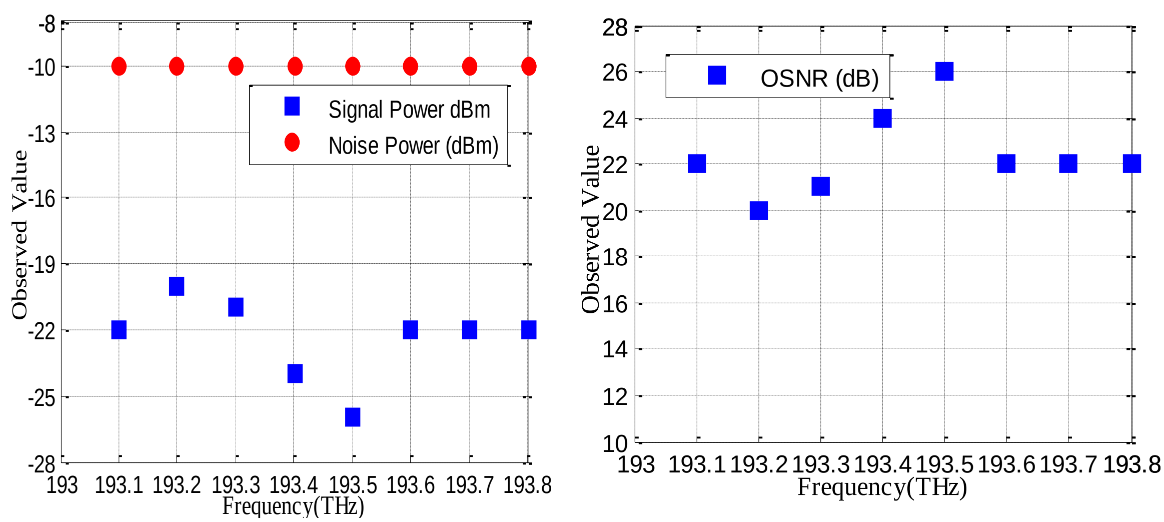

Figure 5.3(a) Noise power and received signal power (b) Frequency versus OSNR

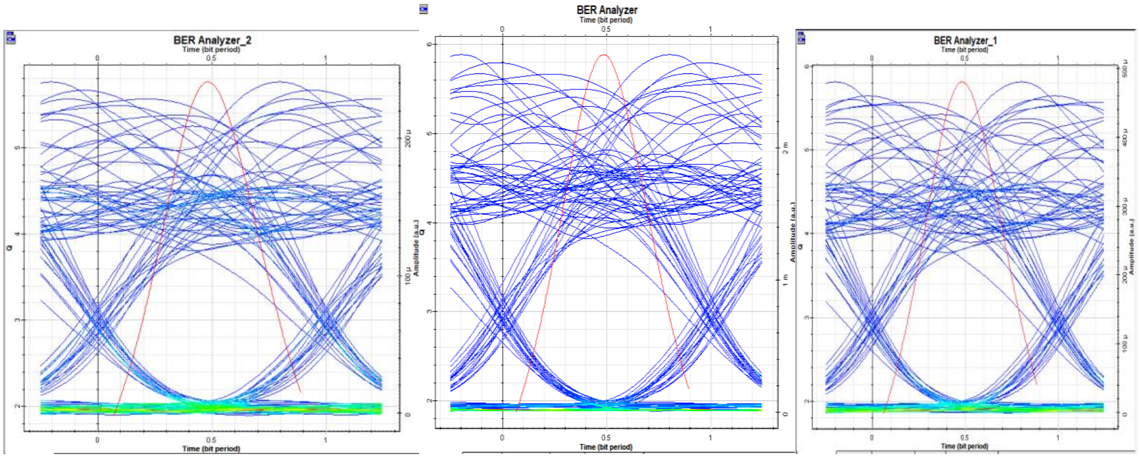

Figure 5.4: Eye diagrams of the proposed system (a) Unicast data (Nyquist DP-16QAM) (b) Unicast PolSK data (c) Multicast DPSK data

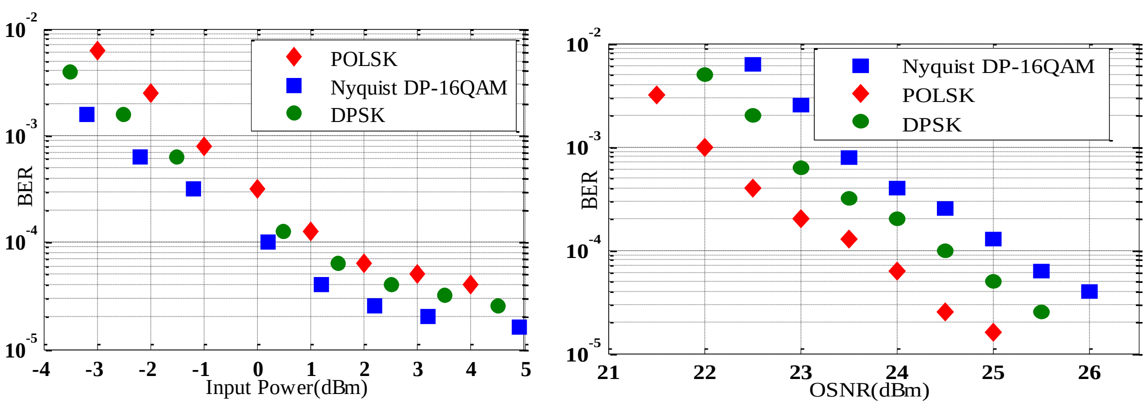

Figure 5.5: Examined results for each channel for proposed system (a) Input power vs. BER (b) OSNR vs. BER.

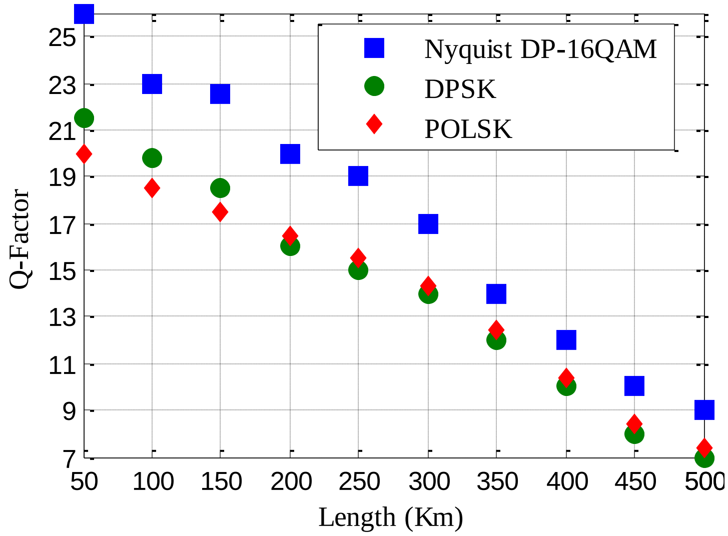

Figure 5.6: Length of the fiber vs. the quality factor for unicast data (Nyquist DP-16QAM, PolSK) and multicast data transmission (DPSK).

CHAPTER 6

STATEMENT OF PROBLEM BASED ON IDENTIFIED RESEARCH GAPS

This section lists the common limitations encountered while dealing with Hybrid modulation. This would realize the importance of the drawbacks and explicate the reasons for attempts to attain solutions to these problems. Based on literature review it is observed that there is a need of hybrid modulation reason being, it provides high speed also increase the number of users keeping in mind to avoid eavesdropping against novel security. More efficient and compact solutions has implemented by using multicast and unicast. There are attractive access networks solution with the advantage of low running cost and enormous bandwidth. A limited work has carried out for designing of architecture of hybrid modulation . It is preceived that number of users, type of modulation schemes used , data format , number of amplifiers and switching techniques directly decide the performance of system. The selection of appropiate modulation schemes of high data rate to have ability of high noise immunity and efficient utilization of bandwidth are some important factors in designing the hybrid modulation for improving efficiency of the overall network. The design and performance analysis to increase the number of users is not done in detail. For a total successful hybrid modulation development, the network system should have different modulation scheme of high data rate, robust, flexible, high-speed, efficient utilization of bandwidth, high noise immunity and cost effective. The nonlinearity has restricted by efficient designing of unique hybrid architectures to accommodate more number of users. Various amplifiers have also not properly investigated for achieving long reach networks. Proper amplification has needed to enlarge the distance so that the signals can reach to each user with high strength keeping in mind the peak-to-peak strength has maintained throughout in communication. Until now, investigation of hybrid system has carried out for lesser number of users at relatively low bit rate and wider channel spacing. Hence, there is a need to identify a hybrid modulation system with hybrid optical amplifier which can operate at higher data rate to facilitate different types if user data with acceptable bit error rate and reduced crosstalk [4]. The capacity of Hybrid modulation can be improved by using multicast and unicast topology to efficient utilize the bandwidth and to enlarge the distance for long haul communication. Hybrid optical amplifiers (RAMAN EDFA) had used with hybrid modulation schemes to increase the distance for efficient utilization of bandwidth [8]. To increase the data rate and to avoid interference hybrid multiplexing techniques (WDM/TDM) has used. In addition, to eliminate eavesdropping for secure system, multiplexing technique OCDMA has used with hybrid modulation technique.

6.1 RESEARCH METHODOLOGY

The research started with extensive literature survey to achieve the above research gaps. The implementation of the research gaps design by using simulation software named as Optisytem simulation software version 15.0, that are available online as a student trail version. The research carried out as:

- Different configurations of hybrid modulation designed and compared using Optisystem software 15.0 to minimize the interference.
- Different components including CW laser, NRZ pulse generator, PRBS, polarization controller, polarization splitter and polarization combiner etc. had investigated to design hybrid modulation using Optisystem software 15.0.
- The hybrid modulation schemes easily interfaced with popular simulation software VPI transmission and component maker to build the entire design. With the help of Optisystem software hybrid modulation, amplifier and multiplexing techniques further had studied to make the system bandwidth efficient.
- To make the system secure from any eavesdropping, Unicast and Multicast techniques had used with hybrid modulation techniques.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

From all the previous research, the following points are observed and concluded

1. A new hybrid modulation technique with hybrid optical amplifiers designed and analysed on Optisystem software 15.0.
2. Firstly Raman-EDFA HOA with hybrid modulation NRZ-POLSK modulation scheme is implemented to achieve a better amplified bandwidth in DWDM system for 8x20 Gbps system secondly, OCDMA multiplexing technique was studied to eliminate eavesdropping for secure system using hybrid modulation (NRZ and DQPSK) with BER of (<1x10^9). Last, a bandwidth efficient system was designed with hybrid modulation (NRZ, DQPSK and POLSK) to achieve data rate of 3.5Tb/S providing BER of 10^-9.
3. Hybrid modulation is designed using Optisystem software 15.0 with best parameters to enhance the bandwidth as well as to eliminate the eavesdropping for secure system.
4. Hybrid modulation (NRZ, DQPSK and POLSK) with hybrid optical amplifier (RAMAN EDFA) and Hybrid multiplexing (WDM/TDM) designed and compared with previous techniques.
5. To increase the more number of users, multicast and unicast techniques had used with hybrid modulation and hybrid optical amplifier (RAMAN EDFA).
6. To increase the distance, hybrid modulation and hybrid optical amplifier (RAMAN EDFA) had used with hybrid modulation so that it can provide data rate to each user. Also, as read earlier pre & post compensation technique is best technique to avoid dispersion.
7. Number of channels and received power with acceptable bit error rate had observed.
8. Using Hybrid modulation it has been observed that, it not only increase the speed but with multiplexing technique like OCDMA it prevents the system from eavesdropping so that the unauthorized user will come across such BER diagram which will be difficult to hack the information .

7.2 FUTURE SCOPE

The future scope of proposed Hybrid optical modulation techniques with hybrid amplifiers and multiplexing are:

1. Presented work enhanced by adding more number of channels and users to increase capacity of system using multi cast and unicast technique.
2. Security can be increased using Hybrid modulation technique, in which any eavesdropper cannot detect the signal on which axis, which modulation had used to receive the signal.
3. For high-speed applications, Hybrid modulation techniques with Hybrid amplifiers can be modified by Multicore-Multimode fiber instead of SMF.
4. To provide high data rate to N number of user which are at considerably large distance, multicast and unicast transmission method are capable of providing these benefits.

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LIST OF PUBLICATIONS

Akanksha Singh, Shivani Goyal and Rajinder Singh Kaler, ": Analysis of optical unicast design using 1.65Tb/s overlsy sytem with 40Gb/s multicast signal", Second International Conference on Applied Sciences and Engineering, Scopus Indexed, 2019 (**Accepted**)

Akanksha Singh, Shivani Goyal and Rajinder Singh Kaler, "Performance Analysis of Hybrid modulation with Multicast Overlay System, International Technical Conference of IEEE Region 10, (**Under Review**)

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Akanksha Singh

Thapar Institute of Engineering & Technology, Punjab, India

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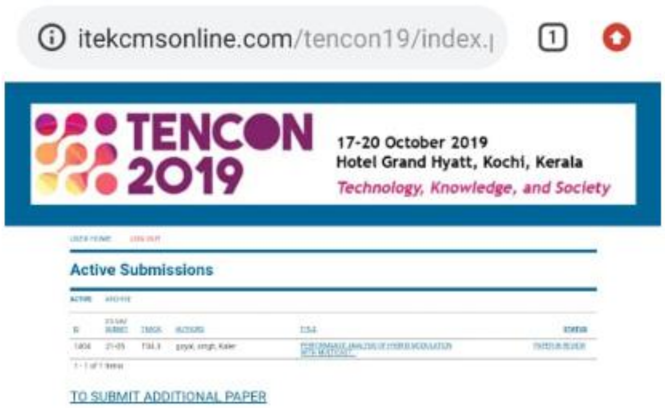
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