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Performance Analysis of 8-Channel Bidirectional Passive Optical Network using Optical Fiber at Various Power Levels and Distance and Channel spacing

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Abstract— From the past few years, demand of high bandwidth, high channel capacity increases rapidly. In order to meet these types of requirements we employ wavelength division multiplexing (WDM) over a bidirectional link. WDM performance mainly depends upon various performance metrics such as modulation formats, channel capacity, channel spacing, range etc. This paper shows the comparative analysis of various advanced modulation formats such as non return to zero (NRZ), return to zero (RZ), carrier-suppressed return to zero (CSRZ) and modified duo-binary return to zero (MDRZ). The designed system has achieved the best result at a distance of 120km over 4-channel bidirectional link (without using any amplifier or any dispersion compensating fiber). System performance has been evaluated in terms of BER, Q-factor and eye diagram on optisystem 14.1. From the results, it is found that MDRZ gives the dispersion less transmission and less BER for long distance transmission.

Keywords–*PON (Passive Optical Network), MZI (Mach-Zendher-Interferometer), OLT (Optical Line Terminal), ONU (Optical Network Unit, WDM (Wavelength Division Multiplexing, MMF (MultimodeFiber)*

I .INTRODUCTION

With the rapid population growth, there is a rising need of the computers in offices, educational systems, banks, shopping areas etc. Thus, there is a need of flexible inter cconnection through the distributed or centralized data communication systems. The conventional ways to fulfil thiss requirement is to form physical connection in between both ends to provide seamless connectivity. However, wired connections provides seamless connectivity in adverse weather conditions, provides higher security, strength and speed etc[1]. In wired communication, the data is transmitted through the medium such as twisted pair cable, coaxial cable and optical fiber cable. [2] Although it is relatively cheaper and is easier to install but electromagnetic interference has an adverse effect on them. Therefore, coaxial cable provides a better solution to this problem as it covers larger distance But it is difficult to install and is more costly as compared to twisted pair cable. So in order to overcome these problems, optical fiber cable is used as it offers a much more promising solution than the other two. It uses the principle of Total Internal Reflection and covers larger distance with larger bandwidth and high data rate [3].

Different types of fiber optical cables are used in optical networks i.e. single mode, multimode and graded index fiber cable. we define Optical networking as a kind of connection between more than two networking devices where fiber optical cables are used for the purpose of computer networking, and for other uses such as, file sharing technology, surfing internet, telecommunication and watching TV etc.PON stands for Passive optical network, a technology that modulates the light wave from optical line terminal (OLT) that locates at central office (CO) and transmits it through fiber to optical network units (ONUs) that locates at end user. It is designed to provide virtually unlimited bandwidth to the subscriber.

From literature review, we came across a number of suggested ways i.e. use of advanced modulation formats WDM-BPON at narrow channel spacing enhance the total system capacity. Also, there is a need for longer transmission length which can be solved by using Advanced Modulation Formats.

These formats not only increase the system length but also increase system security as the data is encrypted as they are modulated. Various Advanced Modulation Formats are NRZ (Non Return to Zero), RZ (Return to Zero), CSRZ (Carrier Suppressed Return to Zero), and MDRZ (Modified Duo binary Return to Zero).

Performance of WDM Passive Optical Networks on high data rates decrease with the increase in number of users. Today there is only one need that the rate of transmission of data will be increase with maximum link length and maximum number of users [5]. So to achieve this need we have designed and implement advanced optical modulation formats over 8-Channel Bidirectional Passive Optical Network.

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II. SIMULATION SETUP & PROCEDURE OF 8CHANNEL BIDIRECTIONAL WDMPON

Table1 represents the specifications of 8 channels Bidirectional WDM-PON System. In this Designed system consists of a laser wavelength of 1550nm, power varied from 0 dBm to 25dBm, channel spacing varied from 25 GHz to 200 GHz, attenuation factor of 0.2dB/km and beam divergence of 0.2 mrad. At input a laser array is used, this array consists of 4 distinct frequencies.

All channels are multiplexed by wavelength division multiplexing and every channel transferred its own information without interfering other channels. In this way it reduces the inter symbol interference effect. At transmitter side instead of simple modulator different advanced modulation formats are being used which also helps in reducing certain nonlinearities present in channel.

Best results have been achieved without using amplifiers and dispersion Compensation Fiber (DCF). Also, the fiber used is Bidirectional multimode fiber. When signal propagates from the channel then it is easily affected by the atmospheric effects so in order to remove high frequency components signal passes through the Bessel filter which remove non-linear and high frequency components along with certain harmonic components and at last signal is analyzed by the BER analyzer followed by 3R regenerator.

This 3R regenerator helps in providing the 3 inputs to BER analyzer as system contains subsystem at both the ends. The prototype model is analyzed by varying its power, distance and channel spacing.

Fig.1 represents the designed 8 channel Bidirectional WDM PON based system in which we use Advanced Modulation Formats. The data from this passed to the WDM mux, whose main purpose is to multiplex the signal and transmit over a bidirectional fiber with minimum intersymbol interference.

The use of bidirectional circulator is to provide isolation between the different signals at the input while at the output bidirectional splitter can act as Power splitter as well as Power combiner. The subsystem used at both the sides consists of advanced modulation formats as well as pulse generators etc.

In PON transmitter side is called OLT (Optical Line Terminal) while receiver is called ONU (Optical Network Unit). Due to the Bi-directionality of the system OLT can act as ONU and vice versa. After the signal transmitted through the transmission link, it is demultiplexed by device splitter. On the receiver side the signal is send to the Photo detector PIN, Bessel filter and then to BER analyzer. BER is used to analyze the received signal in terms of Q-factor, BER and eye height etc.

Table 1 Specifications of WDM PON System

Pulse generator	NRZ
LASER Wavelength	1550nm
Frequency Spacing	25GHz-300GHz
Power (in mw)	1dBm-25dBm
Attenuation	0.2 dB/km
Dark Current	10Na
Transmitter Aperture Diameter	50 mm
Distance	90km-120km
Multiplexing Technique	WDM
Number of users	8
Optical Fiber	Bidirectional MMF
Amplifier used	None
Dispersion compensation	None

In the block diagram of 10 Gbps, 8 channels Bidirectional WDM PON system is shown in Fig.1 The discussed transmission system consists of three parts: transmitter, fiber link and receiver. The transmitter and receiver part acts as transceivers as the system is bidirectional. The transmitter part consists of Laser source, modulators, bidirectional circulator and raised cosine filter. The receiver block consists of synchronization/timing extraction circuit, bidirectional splitter, and Bessel filter and 3R regenerator. At input a laser array issued, this array consists of 8 distinct frequencies.

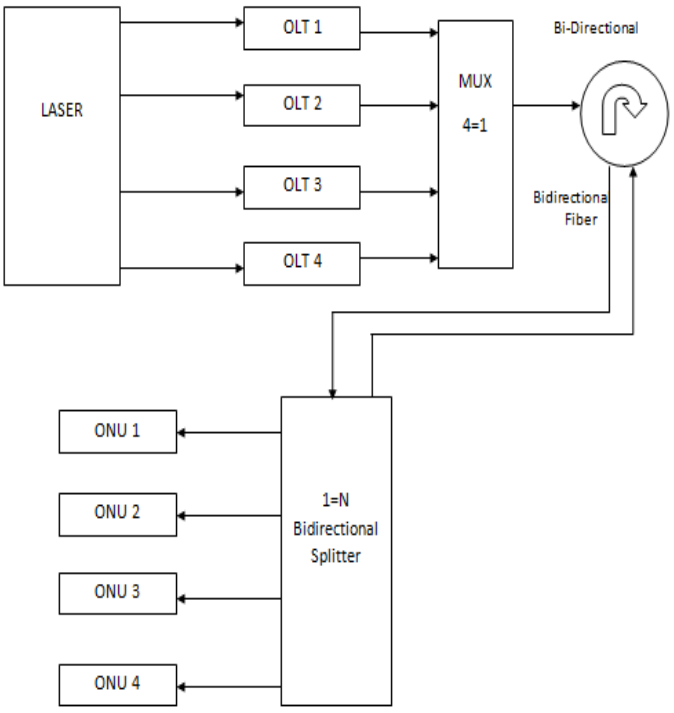

Figure 1: Simulation Setup of 8 channel Bidirectional WDM PON system

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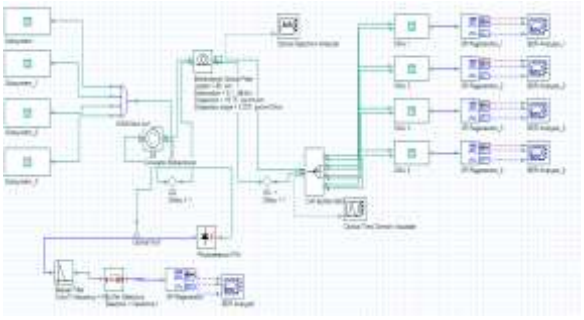

Figure 2: Simulation Setup of 8 channel Bidirectional WDM PON system

Figure 2 shows the implementation of 8 channels WDM PON over bidirectional link. The system consists of transceivers at both the ends. For transmitting part i.e. OLT, different modulation formats have been used like RZ, NRZ, CSRZ and MDRZ, which can also be called as RZ family. For receiving the signal at ONU, Photo Detectors (PD) has been used with filters for filtering the signal and 3R Regenerator, regenerating the electrical signal. In this system an OLT also acts as an ONU and vice versa. Also, the fiber used is Bidirectional multimode fiber. When signal propagates from the channel then it is easily affected by the atmospheric effects so in order to remove high frequency components signal passes through the Bessel filter which remove non-linear and high frequency components along with certain harmonic components and at last signal is analyzed by the BER analyzer followed by 3R regenerator. This 3R regenerator helps in providing the 3 inputs to BER analyzer as system contains subsystem at both the ends. The prototype model is analyzed by varying its power, distance and channel spacing.

III. TRANSMITTER

Various modulation formats acting as transmitter include various components like PRBS, MZI modulator etc. Various Advanced Modulation Formats prototype is shown under.

a) Design of NRZ Modulator

Fig. 3 shows the Non-Return-to-Zero (NRZ) is the simplest modulation format.. NRZ modulated optical signal converse 100% duty cycle. NRZ is widely used and has got a simplest configuration. In this an optical signal is generated by using a CW (Continuous Wave) laser which is then ON-OFF KEYED (OOK) by Mach–Zehnder Interferometer (MZI) modulator.

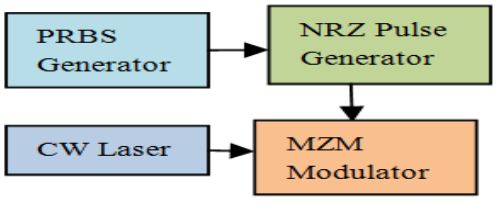

Figure 3: Block Diagram of NRZ modulator

b) Design of RZ Modulator

fig 4 shows return-to-zero format. In RZ, the width of the optical signal is smaller than its bit period. Usually a clock signal with the same data rate as an electrical signal is used to generate RZ shape of optical signals. Two different methods for generating optical RZ pulses. In first method, two modulators are used. The first modulator generates the NRZ pulses. The second modulator MZM transforms the NRZ to RZ format.

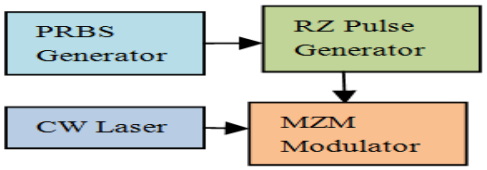

Figure 4: Block Diagram of RZ modulator

c) Design of CSRZ Modulator

Fig.5 shows the CSRZ havetwoMZI modulators. First MZI modulator generates chirp RZ signal and pie shift between adjacent bits is provided by second MZI modulator. Also it lacks DC component. This phase modulator is driven by sine wave. The frequency of the sine wave is half of the bit rate. The phase modulation stage introduce π phase shift between the two adjacent bits and the obtained modified spectrum has central peak carrier suppressed.

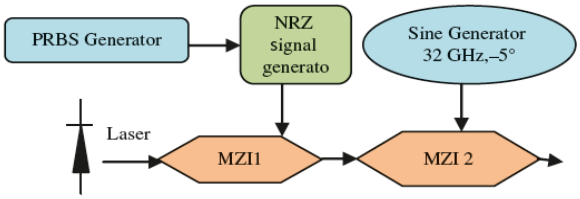

Figure 5: Block diagram of CSRZ modulator

d) Design of MDRZ Modulator

Fig. 6 shows the block diagram of MDRZ modulator is used to first create NRZ duo binary signal which drive 2 MZI modulators. Laser array is used which consists of laser's with various wavelength.

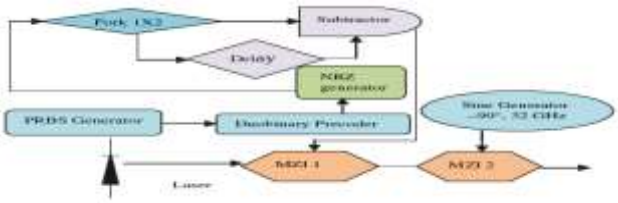

Figure 6: Block Diagram of MDRZ modulator

IV. RESULTS ANDDISCUSSION

Advanced Modulation Formats like NRZ (Non Return to Zero), RZ (Return to Zero), CSRZ (Carrier Suppressed Return to Zero), and MDRZ (Modified Duo binary Return to Zero) are compared by varying three parameters that are Power, Distance and Channel Spacing

1) **Analysis by varying Power:** Distance and channel spacing were kept constant at 90km and 200 GHz respectively

Table 2: comparative analysis of advanced modulation formats over varied power

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Q Factor								
POWER	NRZ		RZ		CSRZ		MDRZ	
dBm	Channel 2	Channel 4	Channel 2	Channel 4	Channel 2	Channel 4	Channel 2	Channel 4
0	8.96598	9.965854	7.98646	7.86947	8.14774	8.60508	10.9552	10.4083
5	27.4745	28.6941	22.6206	24.0248	27.6601	28.0262	32.8277	33.6501
15	218.26	203.774	191.055	186.662	193.007	216.701	105.385	106.815
25	8.62727	8.62214	1343.03	1458.66	1328.49	1283.54	45.120	49.568

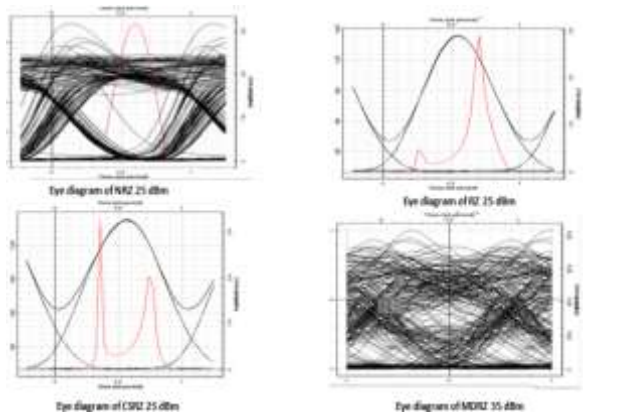

Figure 7: Eye diagrams over varied distance from 0 dBm to 25 dBm

The eye diagram as shown in fig.7 the system gives the best result when the opening of eye is maximum. But if we increase the power it produced the results with high intersysmbol interference.

2) Analysis by varying Distance: Power and channel spacing was kept constant at 25dBm and 200GHz respectively.

Table 3: comparative analysis of advanced modulation formats over varied Distance

Q Factor								
Distance	NRZ		RZ		CSRZ		MDRZ	
Km	Channel 2	Channel 4	Channel 2	Channel 4	Channel 2	Channel 4	Channel 2	Channel 4
90	9.76234	8.93602	9.75466	9.55962	9.91244	3.3824	14.0439	13.1242
100	7.58961	7.53851	7.90872	7.44583	8.67056	8.35078	14.3691	12.8743
110	6.04271	5.73422	6.00397	5.96754	7.9472	6.55817	14.0208	14.1454
120	4.81015	4.78544	4.91783	4.84445	5.34323	5.28504	13.1045	12.6574

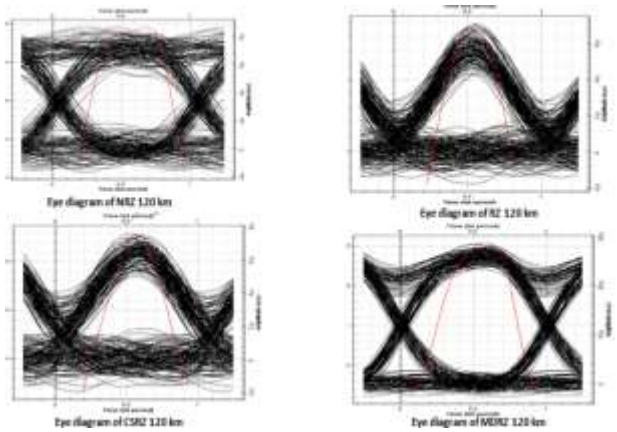

Figure 8: Eye diagrams over varied distance from 90km to 120 km

The eye diagram as shown in fig.8 if distance exceed beyond its limits then it creates the several problems.the system gives the best result when the opening of eye is maximum.

3) Analysis by varying Channel Spacing of MDRZ : Distance and power were kept constant at 90km and 25 dBm respectively

Table 4 comparative analysis of advanced modulation formats over varied channel spacing

Channel spacing (GHz)	MDRZ			
	Q-Factor		BER	
	Channel 2	Channel 4	Channel 2	Channel 4
25	10.2432	10.2102	$2.44113*10^{-40}$	$3.8095*10^{-40}$
75	12.5167	12.0483	$6.19145*10^{-45}$	$3.92441*10^{-43}$
125	13.4703	13.2717	$1.16533*10^{-41}$	$1.68434*10^{-40}$
200	14.2415	14.213	$2.49762*10^{-46}$	$3.8035*10^{-43}$
300	9.5641	9.4123	$4.5675*10^{-43}$	$4.1458*10^{-42}$

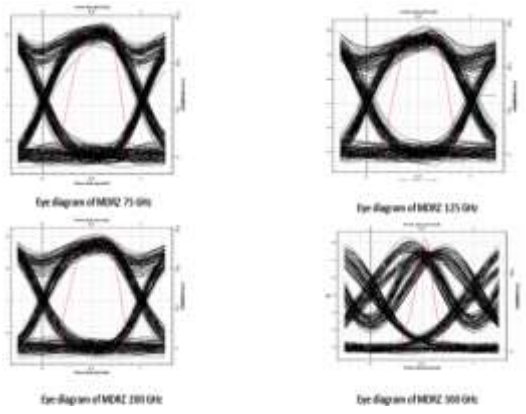

Figure 9: Eye diagrams over varied channel spacing from 25 GHz to 300 GHz

The eye diagram as shown in fig.9 Eye pattern has been analyzed the system gives the best result when the opening of eye is maximum.

V. CONCLUSION

In this research a Bidirectional WDM-PON system is designed, implemented having different advanced modulation formats and tested using optisystem 14.1. The results of designed system proved that Bidirectional 8 channel WDM-PON works best with MDRZ modulation format up to a distance of 120 km, power 1dBm and channel spacing 200 GHz, without using any amplifiers, DCF and repeaters.On the basis of analyses we conclude that with the increase in power laser intensity increases it cover more distance but at high power the non linear effects increases so we can increase the power up to particular level. On the other hand distance of 120 km and channel spacing 200 GHz becomes increase up to a particular level than system is affected by errors most of the part of light scattered in system and cause the noisy spectrum at the output.

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