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Comparison of NRZ and RZ data modulation formats in SAC-OCDMA system under introduced clock timing jitter of laser diode

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Abstract: In this paper, the implementation and performance analysis by using various optical fibers in the SAC-OCDMA system for different data modulation formats is presented. The optical fiber is used in communication systems because of its characteristics which include small size, low loss and low interference from outside environment. The various types of optical fibers used in SAC-OCDMA system such as Corning Submarine, Corning TITAN, Corning LEAF and Alcatel 6900 have been compared using different data formats NRZ and RZ formats. It is found that NRZ has the best performance for all the optical fibers used in the system. After that, these fibers have been compared in terms of BER and received optical power. The simulation results revealed that Corning Submarine can provide a better BER as compared to other fibers on varying the input laser power and it suggests that Corning Submarine may be used for OCDMA systems.

Keywords: Spectral amplitude coding-optical code division multiple access (SAC-OCDMA), Bit error rate (BER), Multiple access interference (MAI), Return to zero (RZ), Non return to zero (NRZ)

I. INTRODUCTION

The OCDMA inspired from radio frequency communications, is nowadays studied for application in optical networks such as local area networks (LANs) and optical wireless communications [1]. This technology is based on spread spectrum technique. In spread spectrum technology the bandwidth of the transmitting signal is much greater than the actual bandwidth required to transmit the data [3]. OCDMA allows several users or nodes to transmit simultaneously at the same time in the same frequency band. OCDMA is the multiple access technique in which each user is assigned a unique code sequence called code-words or spreading codes. .

As a core of an OCDMA system, various different types of optical codes have been proposed and studied for OCDMA technologies: one dimensional (1D) codes which spread in time [2] or in frequency [3] and two dimensional (2D) codes which spread in both time and wavelength [4]. Wavelength hopping time spreading (WHTS) system is a 2D coding approach that spreads the codes in both the time and wavelength domains simultaneously [5]. In 2D-OCDMA, all active users share the same wavelength and time domain space, providing a fair division of the bandwidth.

MAI is the major source of noise in OCDMA systems [6]. It results because of the interference resulting from the other users transmitting at the same time. The key to an effective OCDMA system is the choice of efficient address codes with good or almost zero correlation properties for encoding the source [7]. The ZCC codes have zero cross-correlation.

There are two possible modulation formats, non return to zero (NRZ) in which constant power is transmitted during the entire bit period and return to zero (RZ) in which power is transmitted only for a fraction of the bit period [8]. In case of NRZ format, the optical pulse representing each 1 bit occupies the entire bit slot and does not drop to zero between two or more successive 1 bits. In the RZ format, each optical pulse representing 1 bit is chosen to be shorter than the bit slot, and its amplitude returns to zero before the bit duration is over. The ratio of the pulse width to bit duration is referred to as the duty cycle of the RZ bit stream. The NRZ pulses have a narrow optical spectrum. The reduced spectrum width improves the dispersion tolerance but it is the effect of inter symbol interference (ISI) between the pulses. The narrow spectrum of NRZ pulses yields a better realization of dense channel spacing in DWDM system. The RZ pulse shape enables an increased robustness to fiber non-linear effects and to the effects of polarization mode dispersion [9].

The authors [8] proposed the design, implementation and performance analysis of various one dimensional codes in an OCDMA system for different data formats. A number of different codes, optical orthogonal codes (OCC), Walsh hadamard codes and zero cross correlation (ZCC) codes have been compared using different data formats, NRZ raised cosine, NRZ rectangular, RZ raised cosine and RZ

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rectangular. It is demonstrated that NRZ raised cosine has the best system performance for all the codes.

The authors [10] evaluated the performance of SAC-OCDMA system. A performance comparison has been made between various OCDMA signature sequences, random diagonal (RD), modified double weight (MDW) and modified quadratic congruence (MQC) codes. It is demonstrated that the system performance of the RD codes is better than the MDW and MQC codes in a local are network (LAN). In the above studies, the performance of OCDMA system is analysed using various codes only. The previous work is only limited to the implementation of codes and comparison of various codes in SAC-OCDMA system. But the performance analysis of the system under the effect of clock timing jitter is not studied. In this paper we have analysed the performance of the SAC-OCDMA system by introducing the clock timing jitter at the transmitter. The paper is organized as follows: Section I, presents brief introduction about OCDMA technique and SAC-OCDMA. Section II, introduces about clock timing jitter. Section III, describes the simulation set up for SAC-OCDMA system by introducing clock timing jitter in it. Section IV, includes the simulation results and section V, discusses the results. Section VI, concludes the results of work.

II. CLOCK TIMING JITTER

A Signal through the fiber as channel in the form of pulses, whatsoever shape may be, lose its identity at the farthest end over long distance of transmission. Periodically spaced amplifiers are added to the fiber line to boost the signal power and hence helping to preserve the information being carried. The optical system performance is affected by MAI, Kerr effect, PMD, Raman crosstalk, fiber birefringence, PIIN etc. Multiple access interference (MAI) is the main cause for the degradation of the system performance of OCDMA.

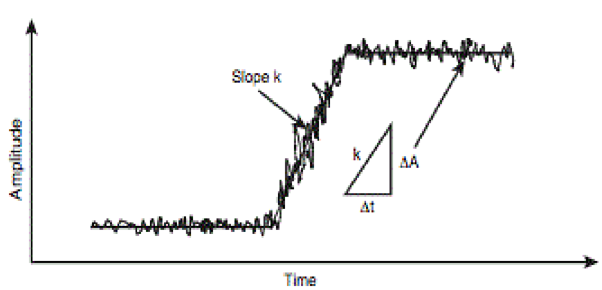

Fig 1: An ideal signal versus a noisy signal for a digital waveform

Noise is always added to the desired signal during its transmission over the channel. In the presence of noise, the received signal is the sum of ideal signal and the noise added to it. The received signal is deviated from the ideal signal due to the additive noise. The deviation of a noisy signal from its ideal can be viewed in two aspects: timing deviation and amplitude deviation. The deviation in the signal amplitude (ΔA) is known as the amplitude noise and the deviation in time (Δt) is known as timing jitter [11] as shown in figure 1.

III. SIMULATION SET UP

The block diagram of simulation set-up for OCDMA system for studying the effect of clock timing jitter on BER performance of the system consisting of three users is shown in figure 2.

IV. RESULTS

Using the simulation set-up as shown in figure 2 the value of BER, eye diagrams and optical power are measured. BER is measured at the receiver end by using the BER visualiser. The related graphs are also plotted as shown in figure 3 to figure 14. The results of output power, BER at receiver are tabulated into table 1 and table 2.

4.1. Alcatel 6900 optical fiber

Table 1 show the output BER readings for NRZ and RZ data modulation formats which are tabulated by varying the input laser power and figure 3 shows the graph for variation of BER Vs input laser power for NRZ and RZ data modulation formats using Alcatel 6900 fiber. It is observed that with increasing input laser power the BER value decreases and this shows the improvement in system performance. Most light wave systems specify a BER value of 10^{-9} as the operating requirement as shown by reference line in figure 3. For -130 dBm to -120 dBm input laser power there is a significant decrease in BER value but after -120 dBm input laser power, the BER remains almost constant for NRZ data modulation format.

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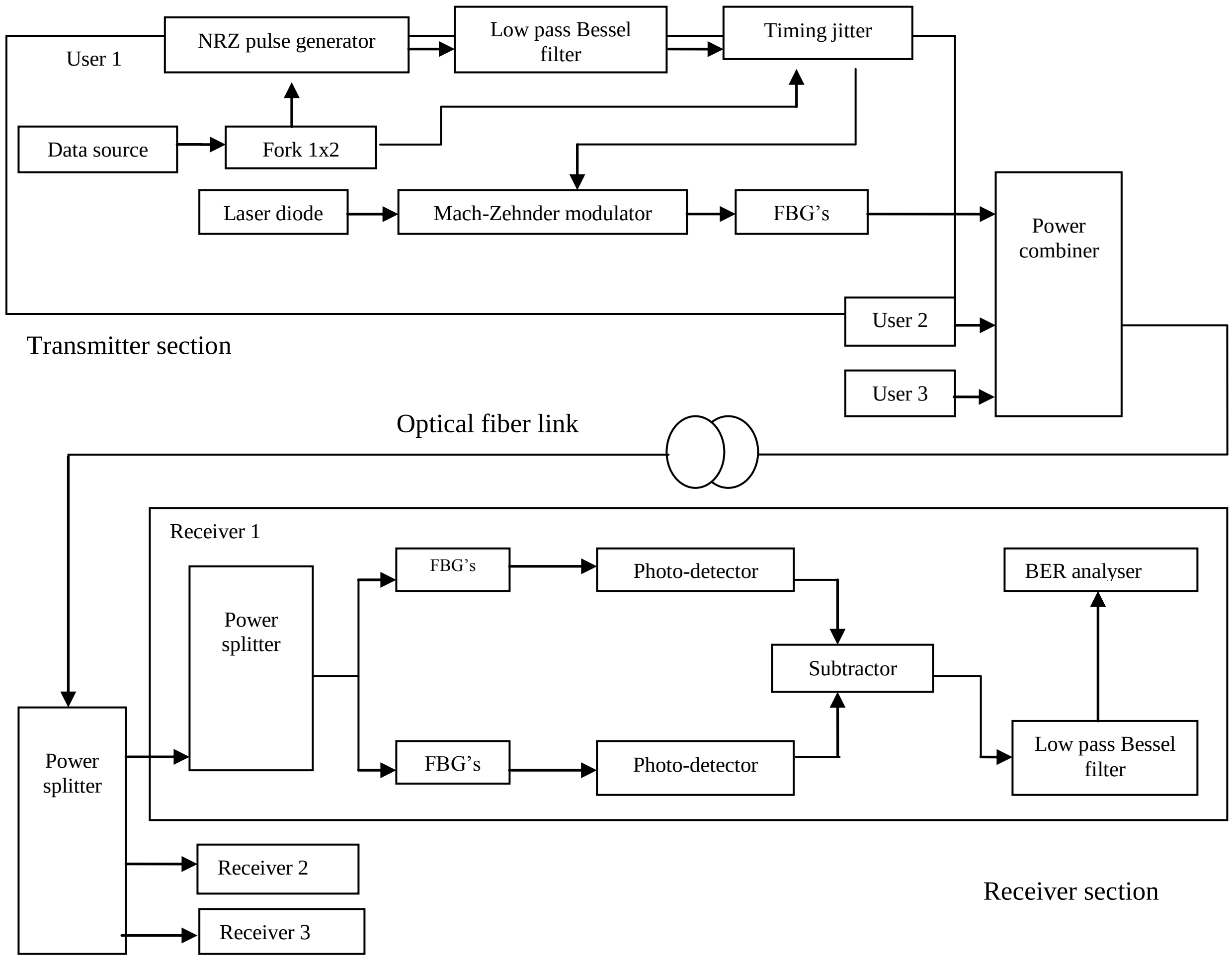

Fig 2: Block diagram for SAC-OCDMA system for 3 users.

TABLE 1: BER values for different fibers using NRZ and RZ data formats for various input laser powers.

Input laser power (dBm)	BER using NRZ modulation format				BER using RZ modulation format			
	Alcatel 6900	Corning Submarine	Corning LEAF	Corning TITAN	Alcatel 6900	Corning Submarine	Corning LEAF	Corning TITAN
-110	1.51E-16	4.42E-21	1.56E-18	7.80E-17	6.06E-11	8.37E-09	1.74E-09	2.96E-10
-114	8.60E-17	5.30E-20	1.81E-17	3.42E-17	6.49E-11	5.41E-09	1.82E-09	2.31E-10
-118	1.74E-16	3.06E-16	6.44E-14	3.27E-17	5.31E-09	2.13E-08	7.63E-09	5.74E-09
-122	2.89E-12	3.87E-09	1.93E-08	7.31E-13	1.43E-05	4.41E-07	6.43E-07	1.07E-06
-126	8.77E-05	6.06E-04	2.93E-04	2.51E-05	1.46E-02	3.74E-04	9.62E-04	3.20E-03
-130	2.36E-02	6.10E-02	5.75E-02	1.54E-02	1.00E+00	5.41E-02	7.26E-02	1.26E-01

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TABLE 2: Received power for different fibers using NRZ and RZ data formats for various input laser powers.

Input laser power (dBm)	Received power (dBm) using NRZ modulation format				Received power (dBm) using RZ modulation format			
	Alcatel 6900	Corning Submarine	Corning LEAF	Corning TITAN	Alcatel 6900	Corning Submarine	Corning LEAF	Corning TITAN
-98	-43.425	-41.773	-42.436	-44.457	-46.505	-44.871	-45.544	-47.521
-102	-51.425	-49.659	-50.435	-52.426	-54.501	-52.762	-53.531	-55.505
-106	-59.425	-57.644	-58.437	-60.424	-62.499	-60.739	-61.530	-63.494
-110	-67.425	-65.643	-66.438	-68.424	-70.495	-68.729	-69.529	-71.49
-114	-75.424	-73.642	-74.438	-76.422	-78.494	-76.73	-77.529	-78.989
-118	-83.418	-81.639	-82.434	-84.414	-86.48	-84.723	-85.521	-86.977

Therefore, in case of NRZ data format for Alcatel 6900 fiber, input laser power should be between -125 dBm to -120 dBm for optimum system performance. In case of RZ data format, there is rapid decrease in BER upto -115 dBm and after that BER remain constant. It can be seen that out of the two modulation formats used, NRZ has somewhat better BER with value of 1.51E-16 at -110 dBm input laser power.

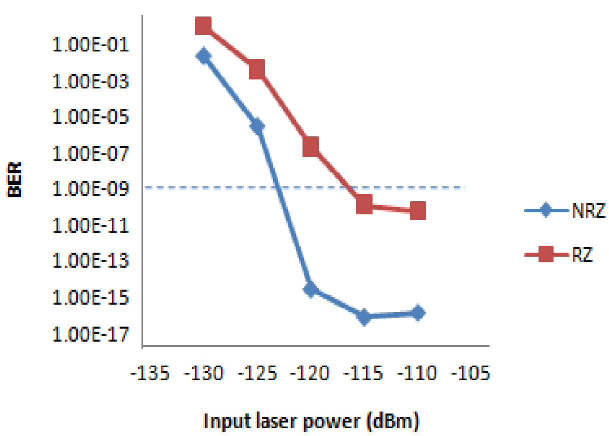

Fig 3: BER Vs input laser power for Alcatel 6900 fiber

Figure 4 shows the graph between optical received power and input laser power using Alcatel 6900 optical fiber for NRZ and RZ data modulation formats. It is seen that NRZ has more received power of -43.425 dBm than RZ data format when input laser power is -98 dBm.

4.2. Corning Submarine optical fiber

Figure 5 shows the variation of BER with input laser power for NRZ and RZ data modulation formats using Corning Submarine optical fiber in the system. It is clear from figure that BER value of 10^{-9} can be obtained with input laser

power of -122 dBm using NRZ data format whereas same performance can be achieved with input laser of power -115 dBm using RZ data format. Out of the two modulation formats, NRZ modulation formats give the best BER performance with value of 4.42E-21 at -110 dBm input laser power.

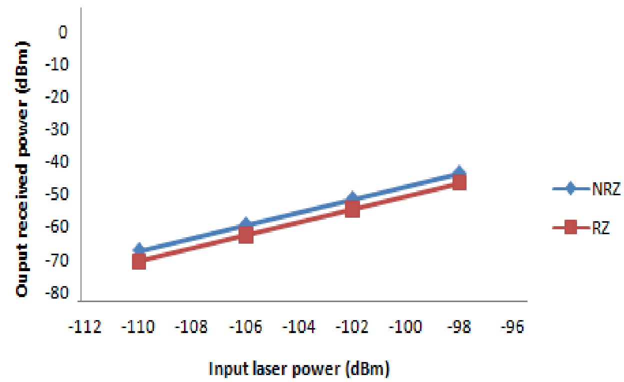

Fig 4: Received power Vs laser power for Alcatel 6900 fiber

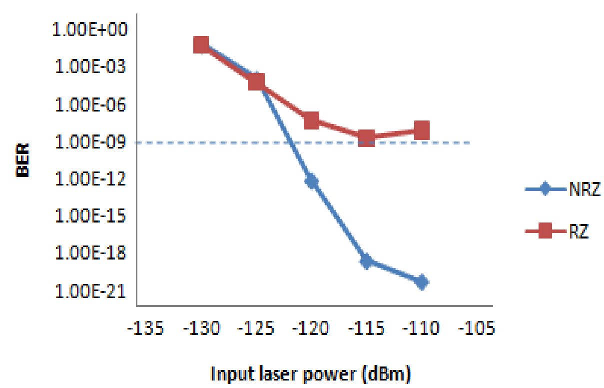

Fig 5: BER Vs input laser power for Corning Submarine fiber

Figure 6 shows the graph between optical received power and input laser power using Corning Submarine optical fiber for two data modulation formats. It is seen that NRZ has the large received power of -41.773 dBm as compared to RZ data format.

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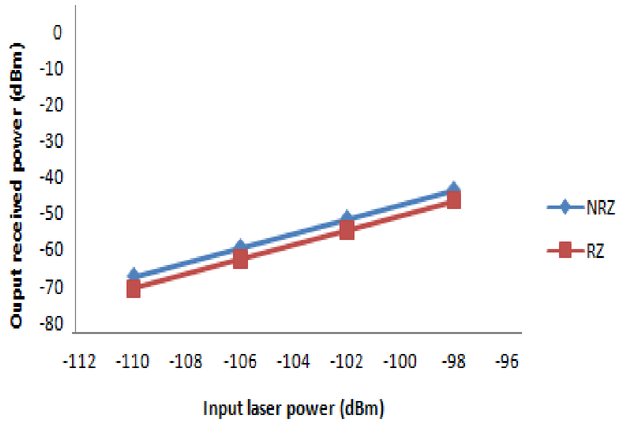

Fig 6: Received power Vs laser power for Corning Submarine fiber

4.3. Corning LEAF optical fiber

Figure 7 shows the variation of BER with input laser power for NRZ and RZ data modulation formats using Corning LEAF optical fiber in the system. From figure 7 it is seen that BER value reduces gradually from -130 dBm to -110 dBm input laser power and BER value of 10^{-9} is obtained by using -122 dBm input laser power for NRZ data format. In case of RZ same performance can be achieved by using -188 dBm input laser power. Out of the two modulation formats, an NRZ modulation format gives the best BER performance with value of 1.56E-18 at -110 dBm input laser power.

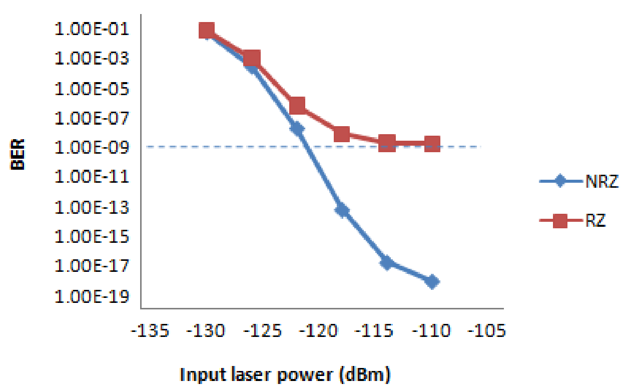

Fig 7: BER Vs input laser power for Corning LEAF fiber

Figure 8 shows the graph between optical received power and input laser power using Corning LEAF optical fiber for NRZ and RZ data modulation formats. It is seen that NRZ has more received power of -42.436 dBm than RZ data format.

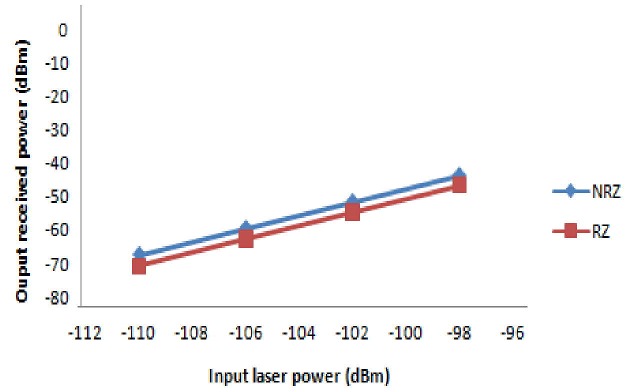

Fig 8: Received power Vs laser power for Corning LEAF fiber

4.4. Corning TITAN optical fiber

Figure 9 shows the variation of BER with input laser power for NRZ and RZ data modulation formats using Corning TITAN optical fiber in the system. It is clear from figure 9 that BER value of 10^{-9} in case of NRZ data formats can be obtained by using -125 dBm input laser power and in case of RZ data format it can be obtained by using -118 dBm input laser power. Out of the two modulation formats, NRZ modulation format gives the best BER performance with value of 7.80E-17 at -110 dBm input laser power. It is seen that upto -118 dBm input laser power the BER value decreases rapidly but after -118 dBm input laser power, BER becomes almost constant. Therefore, in graph the region of interest is only upto the input laser power of -118 dBm.

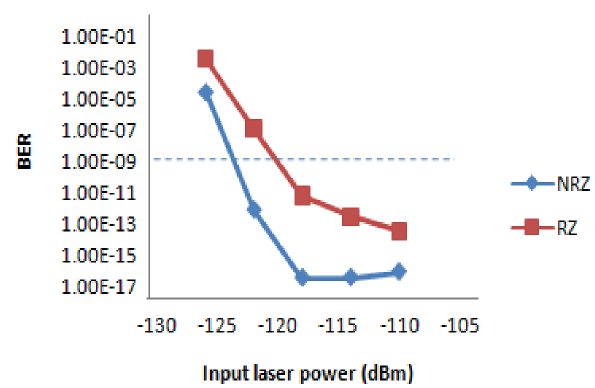

Fig 9: BER Vs input laser power for Corning TITAN fiber

Figure 10 shows the graph between optical received power and input laser power using Corning TITAN optical fiber for NRZ and RZ data modulation formats. It is seen that NRZ has the large received power of -44.457 dBm than RZ data format.

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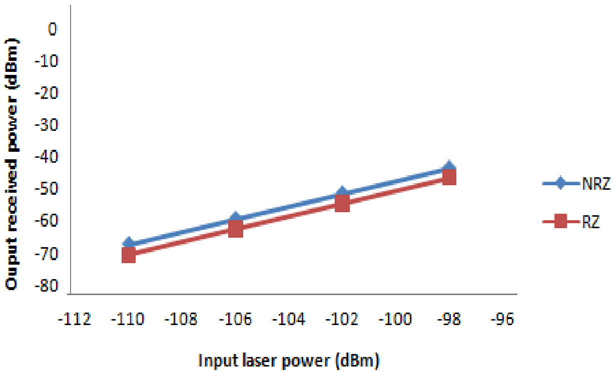

Fig 10: Received power Vs laser power for Corning TITAN fiber

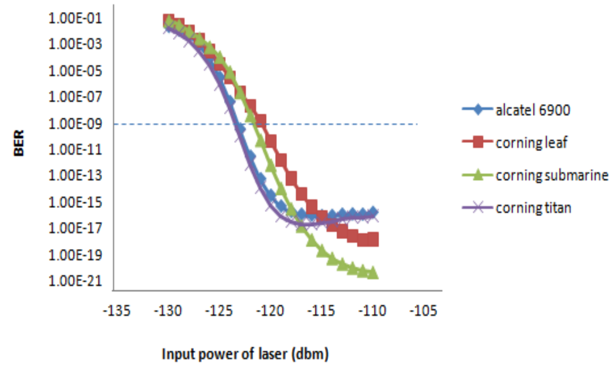

Fig 12: BER Vs input laser for four fibers using NRZ data format

4.5. Comparison of optical fibers

Figure 11 shows the comparison of four fibers in terms of BER using RZ data modulation format. It is seen that as input laser power varies from -130 dBm to -110 dBm, Alcatel 6900 and Corning TITAN optical fiber gives the lowest BER value of 10^{-9} at -118 dBm input laser power while next better performance is given by Corning Submarine fiber at -114 dBm input laser power.

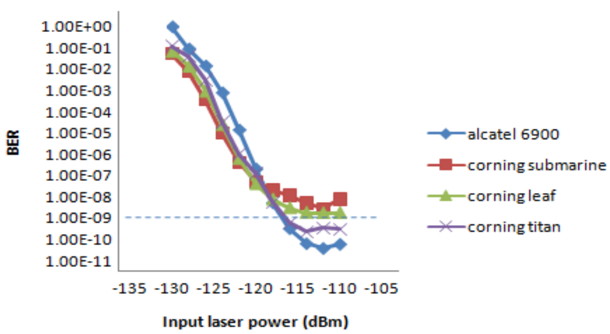

Fig 11: BER Vs input laser for four fibers using RZ data

Figure 12 shows the comparison of four fibers in terms of BER using NRZ data modulation format. It is seen that as the input laser power varies from -130 dBm to -110 dBm Corning TITAN and Alcatel 6900 give the best BER performance with BER value of 10^{-9} at -124 dBm input laser power. Next, better performance is shown by Corning Submarine as it gives same performance at -122 dBm of input laser power.

Figure 13 shows the comparison of four fibers in terms of received optical power using RZ data modulation format. It shows that Corning Submarine fiber has the largest received optical power as compared to other fibers, hence it gives the best system performance among all fibers.

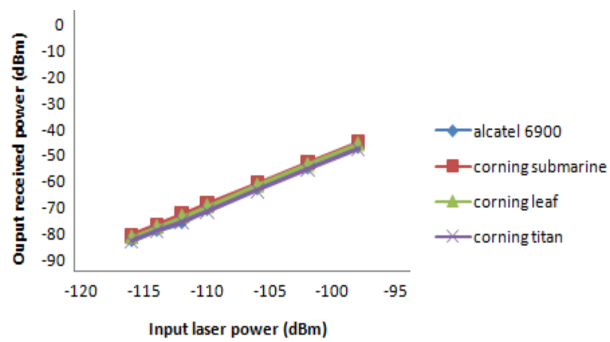

Fig 13: Received power Vs input laser for four fibers using RZ data format

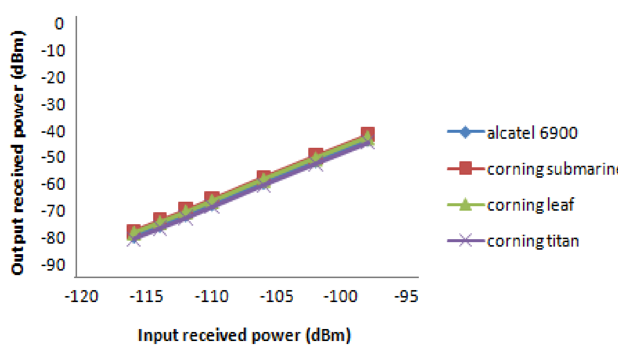

Fig 14: Received power Vs input laser for four fibers using NRZ data format

Figure 14 shows the comparison of four fibers in terms of received optical power using NRZ data modulation format. It shows that Corning Submarine fiber has the largest received optical power as compared to other fibers, hence it gives the best system performance.

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Figure 15 to figure 18 show the eye diagrams obtained using BER visualiser for Corning Submarine fiber. The eye diagrams are shown for varying input laser power of -120 dBm and -124 dBm for NRZ and RZ data formats respectively. For -120 dBm input laser power the BER performance of the system is analyzed to be optimum and eye opening is maximum with BER value of 10^{-9}. Hence, eye diagrams corresponding to -120 dBm input laser power are shown for both NRZ and RZ data modulation formats. The eye diagram is shown for -124 dBm input laser power for both NRZ and RZ data modulation formats to shown that how BER increases with the decrease in input laser power.

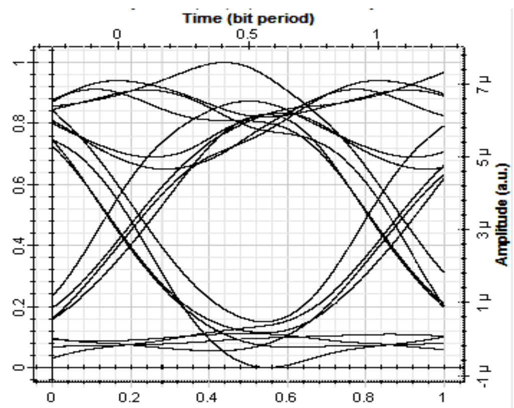

Fig 15: Eye diagram at -120 dBm input laser power for NRZ format

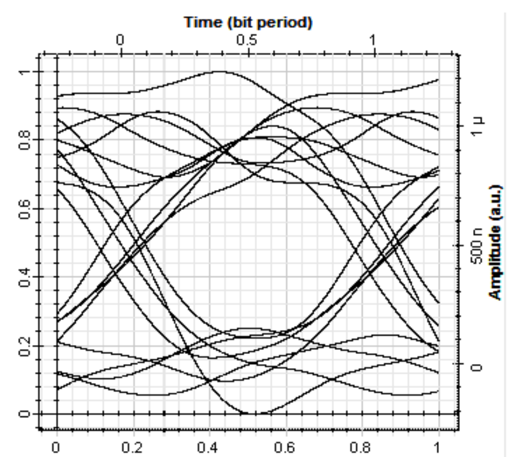

Fig 16: Eye diagram at -124 dBm input laser power for NRZ format

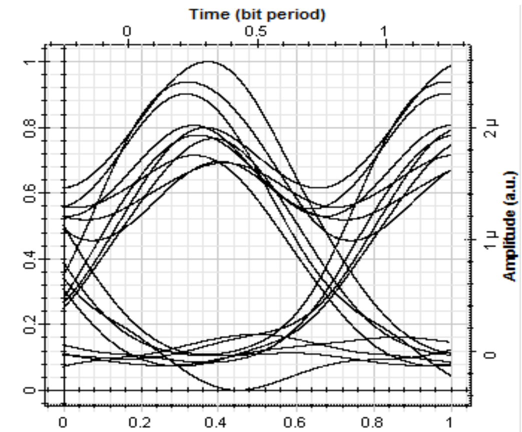

Fig 17: Eye diagram at -120 dBm input laser power for RZ format

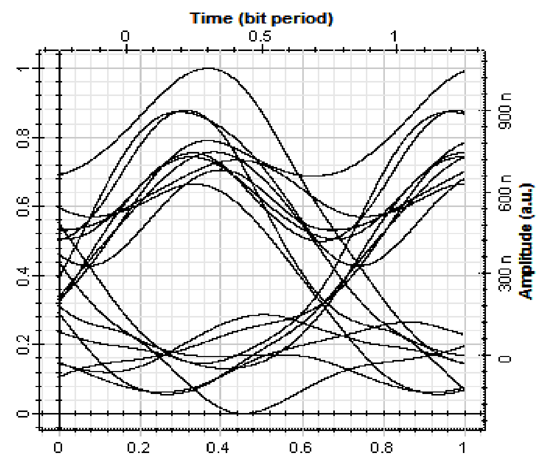

Fig 18: Eye diagram at -124 dBm input laser power for RZ format

The vertical distance between the top of the eye opening and maximum signal level gives the degree of distortion. The eye opening closes in the system because of the amplifier noise which gets added to the signal during its transmission over the channel and also the longer fiber length will present a larger dispersion and attenuation which increases the BER value. It is seen that with the decrease in input laser power, the eye opening also decreases which indicates the increase in BER value and thus degrades the system performance. The eye opening in figure 15 and figure 17 is more as compared to the eye opening in figure 16 and figure 18.

V. DISCUSSION

From the above results it is seen that NRZ data modulation format is better than RZ. This is because the NRZ pulses have a narrow optical spectrum and this reduced spectrum width improves the dispersion tolerance of the system. Also, with NRZ data format BER of 10^{-9} can be achieved by using less input laser power and on the other hand RZ data format require more laser power to achieve the same BER value.

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Therefore, NRZ gives more improved performance over RZ data format. An optical RZ pulse width with 50% duty cycle will have twice the peak power of an NRZ pulse. Also, an RZ has a wider optical bandwidth than on NRZ pulse. Also, it is more affected by dispersion. Finally, RZ pulses have larger peak power and as such are more susceptible to FWM (four wave mixing), SPM (self phase modulation) and XPM (cross phase modulation). From figure 3 to figure 10, it seems that the system which is used: NRZ is better than RZ in our model. This is because the signal bandwidth of NRZ is about 50% smaller than the RZ format. Finally, implementing the RZ modulation scheme requires a higher bandwidth driver on the transmitter end. The other reason for better performance of Corning Submarine as compared to other fibers as shown in figure 11 and figure 12 is due to its negative value of dispersion i.e -2.4 ps/nm/km and low attenuation value of 0.21 dB/km while the other fibers i.e Alcatel 6900, Corning LEAF, Corning TITAN have 0 ps/nm/km, 6 ps/nm/km and 0 ps/nm/km dispersion values and 0.3 dB/km, 0.25 dB/km and 0.35 dB/km attenuation values respectively.

VI. CONCLUSION

In this paper, the implementation and performance analysis of various optical fibers in OCDMA system by introducing clock timing jitter in transmitter, for different data formats are presented. The comparison of NRZ and RZ data modulation formats using Alcatel 6900, Corning Submarine, Corning LEAF, and Corning TITAN revealed that the NRZ data format has the edge over the RZ data format in OCDMA system. It is determined that NRZ has lowest BER value and hence better system performance. Therefore, NRZ format is suitable for local area networks using OCDMA systems. The comparison results revealed that Alcatel 6900 fiber gives better system performance with RZ data modulation format and Corning TITAN gives better system performance with NRZ data format. But overall, Corning Submarine shows superior performance. It can be seen from the values of BER, an eye opening and received power that Corning Submarine gives the better BER performance as compared to other fibers. Therefore, it is concluded that Corning Submarine fibers are most suitable to be employed in OCDMA systems using NRZ data format.

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The simulation is carried out by using optisystem ver. 7.0 software from optiwave.

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