International Journal of Enhanced Research in Management & Computer Applications
ISSN: 2319-7471, Vol. 6 Issue 6, June-2017, Impact Factor: 1.544

Radio over Fiber Performance Analysis using Mach Zehnder Modulator

Rajbir Singh[1*], Deepak Sharma[2], Anjali[3]

[1,3]M. Tech. Student, (ECE) UIET MDU, Rohtak
[2]Research Scholar, (ECE) UIET MDU, Rohtak

ABSTRACT

Radio over Fiber (RoF) is used for wireless broadband Internet access in which radio signals are modulated on to light and transmitted over optical fiber cable. At the receiving end the optical signal is converted to an electrical signal and transmitted to the base station after amplification. In this paper we used MZM modulator and designed a two RF channel optical link, and the performance of designed link is analyzed by varying Extinction ratio and optical fiber length based upon variations in BER, Q factor and Eye Diagram analyzer using the Optisystem software.

Keywords: RoF, Radio Frequency (RF), Control Station (CS), Base Station (BS), Central Office (CO), MZM, Remote Anteena Unit (RAU)

I. INTRODUCTION

Optical Fiber communication technology is growing exponentially in the present time and has enabled long distance communications easily with lesser losses in transmission medium. Optical Fiber is capable of accommodating larger amount of data rates as compare to any other transmission medium used [1][2]. The design technologies in these communication systems are increasing rapidly and to meet these increasing consumer needs effectively and efficiently, the optical fiber communication is the most preferred way to enhance the transmission capacities of communication systems. Hence Optical Fiber communication is the best selection for large amount of data transmission.

II. RoF

The RoF is a latest technology used to share out RF signals over analog optical links. In RoF a light signal is modulated by a radio signal followed by transmission through optical fiber in order to support wireless applications effectively [4].

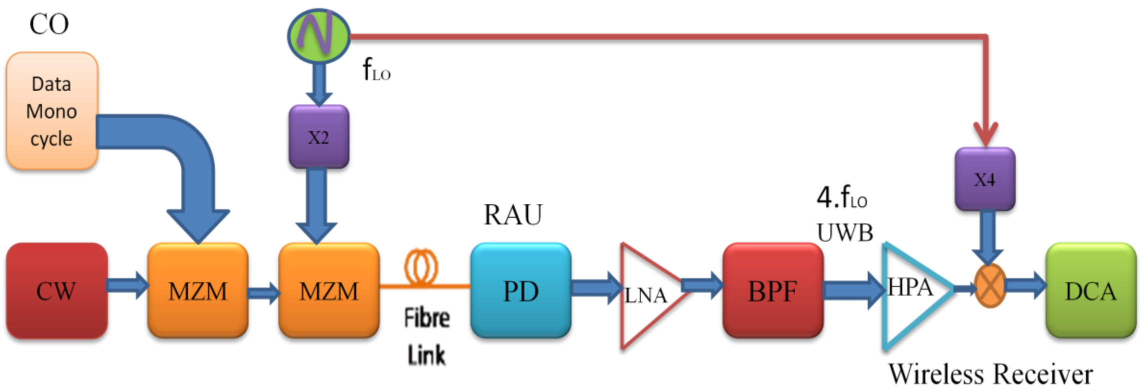


Fig. 1 Basic block diagram of RoF System

Figure 1 shows the block diagram of RoF techniques used for signal transmission. In this a CW laser carrier is modulated using a modulator (MZM) according to an input RF signal [11]. RoF is an analog transmission system because it involves sharing of radio signals, directly on radio carrier frequency which are transmitted between control unit and BS of communication system. At transmitter, the optical laser source is modulated by an electrical signal [12].

This modulated signal is in optical domain which is further transmitted through the optical fiber. At receiver, photo detector converts back the information signal into electrical form and we get output in form of electrical signal [3].

III. WORKING OF MZM

The most popular modulator in optical communication systems is the Lithium Niobate (LiNbO3) MZM. It is of two types, single drive MZM and dual-drive MZM [5]. The block diagram of MZM is shown in Figure 2. The optical wave enters from the input side and then splits equally into its two arms. The structure of the dual-drive MZM has two arms and electrodes [6].

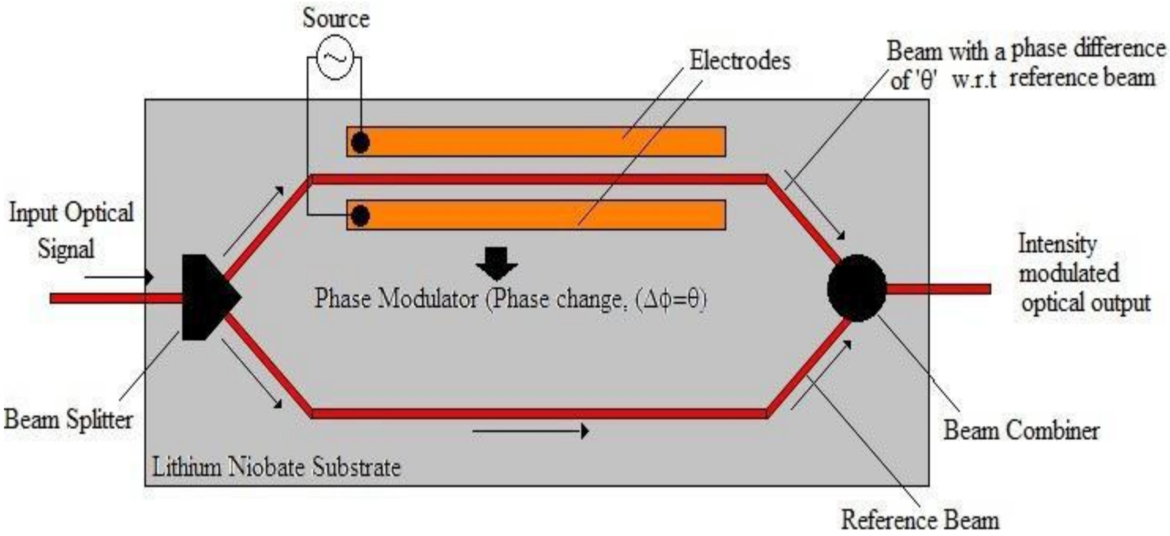


Fig. 2 Working diagram of Mach Zehnder modulator

MZM is used to control the phase and amplitude of an optical signal. The input waveguide splits into two waveguide arms and bias is applied to these arms which induces a phase shift during the passage of wave through these arms [13]. The optical signal travelling through both arms of the interferometer are recombined at the output of MZM and the phase difference between the two waves is converted into the Amplitude Modulated wave [14]. Phase shifted RF signals are applied to the two arms of the interferometer biased with different DC voltages. By changing the applied voltage on the electrode, the optical phase in each arm can be controlled [7]. Fig. 2 shows the principle of optical carrier modulation which is achieved by biasing a MZM. An optical carrier out of one arm of the MZM is expressed as:

$$E_{out}(t) = E_0 \cos[\pi V(t)/2V_\pi] \cos(\omega_c t) \quad \text{(i)}$$

Where, E_0 − Amplitude of the input optical carrier,
ω_c − Angular frequency of the input optical carrier,
V_π − Half-wave voltage of the MZM,
$V(t)$ − Applied driving voltage

$$V(t) = V_{bias} + V_m \cos(\omega_{RF} t) \quad \text{(ii)}$$

V_{bias} −dc biased voltage,
V_m −modulation voltage,
ω_{RF} − the angular frequency of electrical driving signal,

$$E_{out}(t) = E_0 \cos\left(\frac{\pi}{2}[V_{bias}/V_\pi + V_m/V_\pi \cos(\omega_{RF} t)] \cos(\omega_c t)\right)$$
$$= E_0\{\cos x . \cos[m \cos(\omega_{RF} t)] - \sin x . \sin[m \cos(\omega_{RF} t)]\} \cos(\omega_c t) \quad \text{(iii) [15].}$$

IV. PROPOSED BLOCK DIAGRAM OF SYSTEM

We have designed a RoF system in which MZM modulator is used for modulation of two combined RF channels as shown in Fig 3. The block diagram of proposed layout is shows Figure 3.

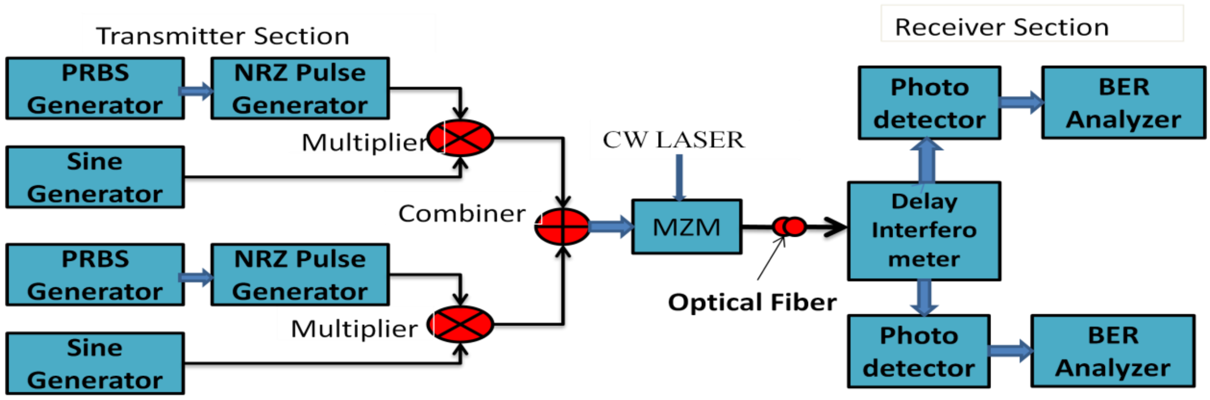


Fig. 3 Block diagram of proposed system [14]

V. SIMULATION SETUP

We have designed two RF channels optical link based on RoF system using OPTISYSTEM software. We have analyzed the performance of the system at various extinction ratios and at distances 10, 20, & 30 kms.

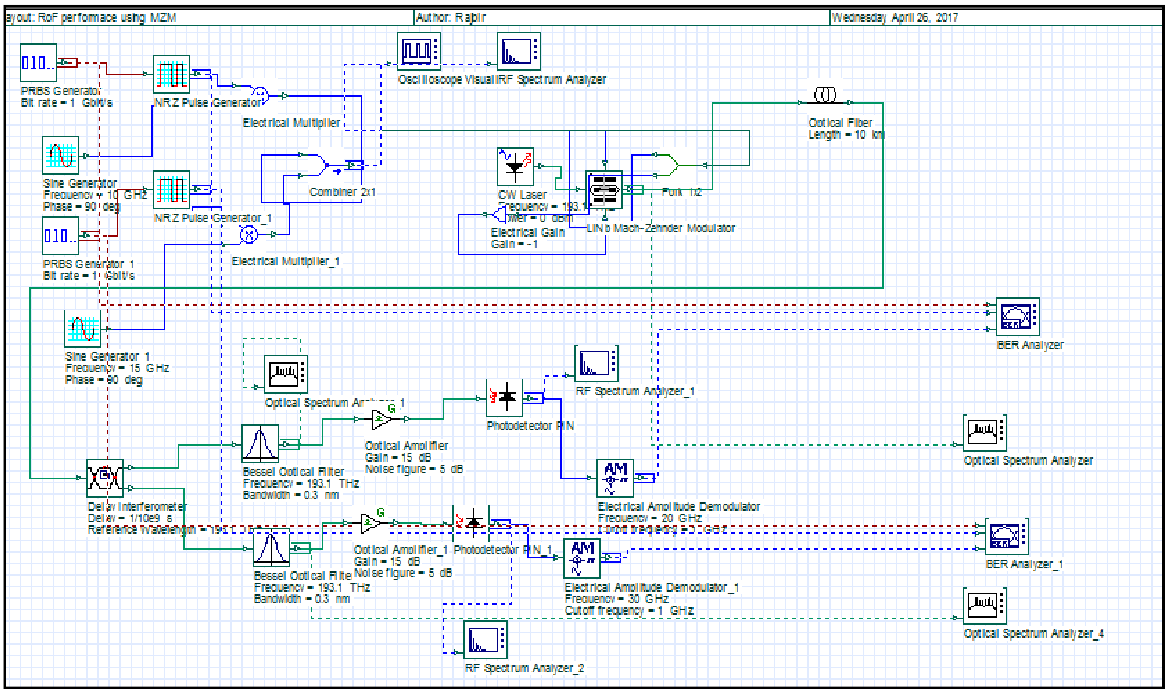


Fig. 4 Radio over Fiber link simulation setup using MZM [14]

VI. SIMULATION PARAMETERS

The analysis of designed optical link was performed using OPTISYSTEM simulator based upon several qualitative parameters such as Q-Factor and BER. The parameters used in simulations are shown in the table I given below:

Table I: Parameter values of Simulation Setup

Parameters	Values (units)
PRBS Generator Bit Rate	1 Gbit/s
Fiber Length	10, 20, 30km
Modulation Format	RZ,
MZM Extinction Ratio	10, 15, 20, 25, 30dB
MZM Insertion Loss	2dB
Optical Fiber Attenuation	2dBm
Electrical Amplitude Demodulator Frequency	20GHz

VII. RESULT AND DISCUSSION

We have performed the simulation using OPTISYSTEM based upon qualitative parameters such as Q-factor and BER. Q-Factor: Q-factor is a function of signal to noise ratio. It gives the performance of receiver qualitatively. It define the minimum signal to noise ratio require to acquire a specific BER for a given signal.

BER: In digital transmission the number of data bit received has been altered due to distortion, noise, interference, in bit or synchronization errors [10]. The bit error rate (BER) is the ratio of number of bit errors to the total number of transferred bits during a studied time interval [8].

Table: II Variation of BER and Q-factor with Extinction Ratio at 10km Fiber Length

Sr. No.	Extinction Ratio	Channel 1		Channel 2	
		Max. Q- factor	Min.BER	Max. Q- factor	Min.BER
1.	10 dB	16.8235	8.12531e-64	19.4102	3.13677e-84
2.	15 dB	17.6215	8.10521e-70	17.0531	1.49729e-65
3.	20 dB	20.6847	2.30146e-95	16.603	3.1247e-62
4.	25 dB	22.27	3.32408e-110	17.6365	6.01346e-70
5.	30 dB	21.6373	3.85601e-104	19.8642	3.03674e-88

The results obtained are given in the Table II III & IV. From table II, the values of Q-factor for channel 1 are 16.8235, 17.6215, 20.6847, 22.27, and 21.6373 at distance 10 kms for extinction ratio10, 15, 20, 25, & 30 dB respectively and it is 19.4102, 17.0531, 16.603, 17.6365, 19.8642 for channel 2.

Figure 5 shows the variation of Q-factor with increasing extinction ratio for channel 1 and channel 2. Q-factor increases as the extinction ratio increases.

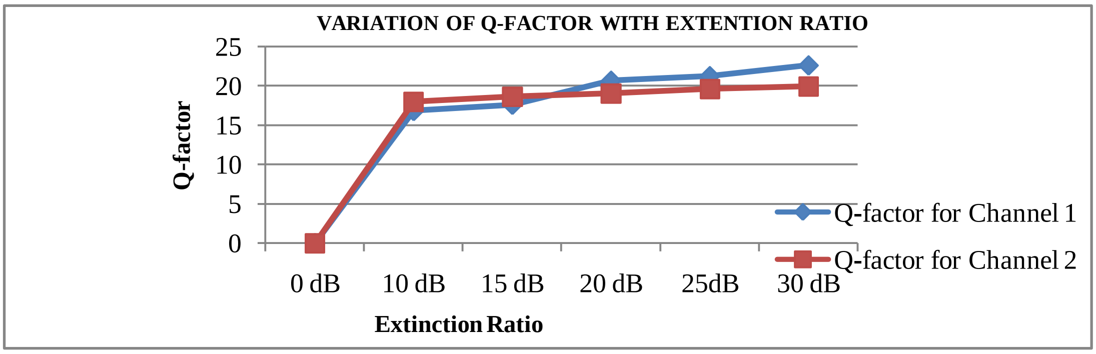
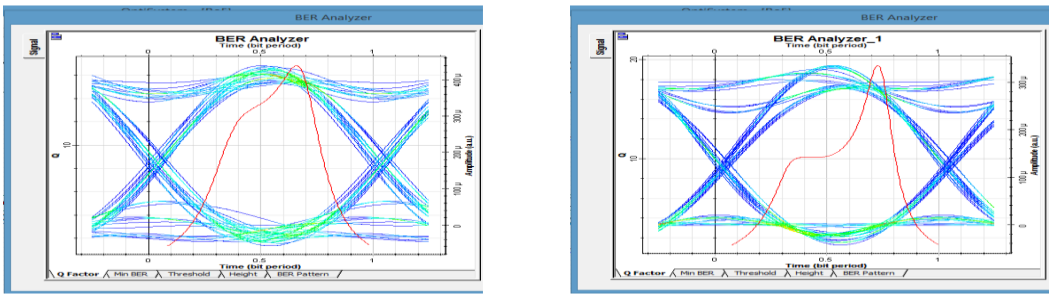


Fig. 5 Variation of Q-factor with Extinction Ratio at 10km Fiber Length

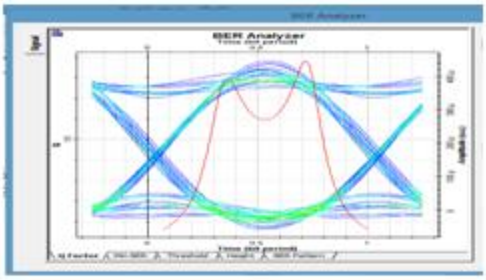
Eye Diagrams Analyzer: The Analyzer of OPTISYSTEM shows multiple paths of a modulated signal to produce an Eye diagram. The performance of the system was also analyzed using BER analyzer. The Eye pattern with MZM modulation gives a larger eye opening [9]. The figure 6 [(a) to (j)], 8 [(a) to (j)] and 10 [(a) to (j)] given below shows the Eye diagrams for various extinction ratios at 10, 20 and 30km fiber length.

Eye Diagrams Analyzer for 10km fiber length:

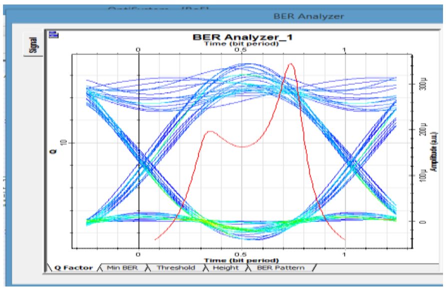


(a) (b)

Fig. 6 (a) & (b) Eye Diagram analyzer at Extinction Ratio 10 dB for channel 1 and 2 at Fiber Length 10 km

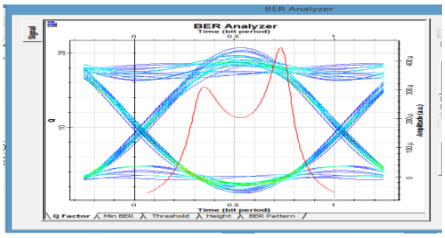


(c)

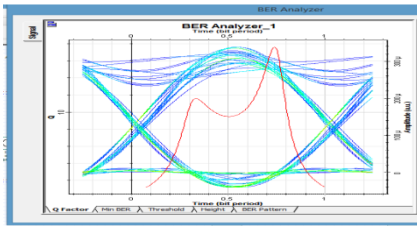


(d)

Fig.6 (c) & (d) Eye Diagram analyzer at Extinction Ratio 15 dB for channel 1 and 2 at Fiber Length10 km

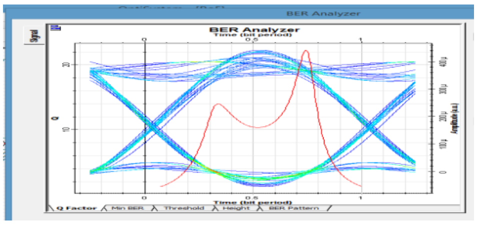


(e)

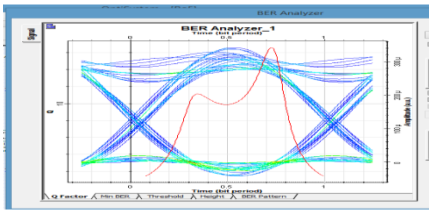


(f)

Fig.6 (e) & (f) Eye Diagram analyzer at Extinction Ratio 20 dB for channel 1 and l 2 at Fiber Length10 km

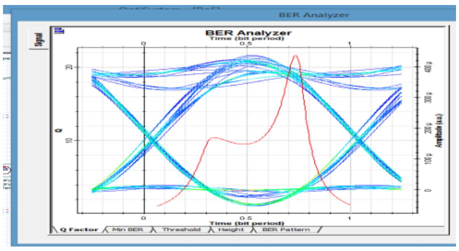


(g)

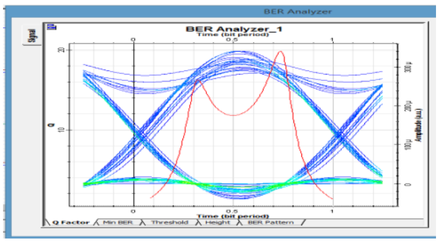


(h)

Fig. 6 (g) & (h) Eye Diagram analyzer at Extinction Ratio 25 dB for channel 1 and 2 at Fiber Length10 km



(i)



(j)

Fig. 6 (i) & (j) Eye Diagram analyzer at Extinction Ratio 30 dB for channel 1 and 2 at Fiber Length10 km

Table: III Variation of BER and Q-factor with Extinction Ratio at 20km Fiber Length

Sr. No.	Extinction Ratio	Channel 1		Channel 2	
		Max.Q-factor	Min.BER	Max. Q-factor	Min.BER
1.	10 dB	13.6628	8.46531e-43	15.9966	6.14191e-58
2.	15 dB	16.6026	3.09479e-62	18.9577	1.8287e-80
3.	20 dB	16.4052	8.68354e-61	18.9293	3.16113e-80
4.	25 dB	17.4336	2.1928e-68	17.7784	5.09888e-71
5.	30 dB	18.1683	4.19403e-74	18.6603	5.11242e-78

As given in table III the values of Q-factor for channel 1 are 13.6628, 16.6026, 16.4052, 18.1683 and 17.4336 for extinction ratio10, 15, 20, 25, & 30 dB respectively and it is 15.9966, 18.9577, 18.9293, 17.7784 and 18.6603 corresponds to extinction ratio10, 15, 20, 25, & 30 dB for channel 2 at distance 20 kms. , From these observations, it is evident that the designed optical link performs satisfactorily as Q-Factor for both channel 1 and channel 2 increases with increase in extinction ratio.

Figure 7 shows the variation of Q-factor with increasing extinction ratio for channel 1 and 2. Q-factor increases as the extinction ratio increases.

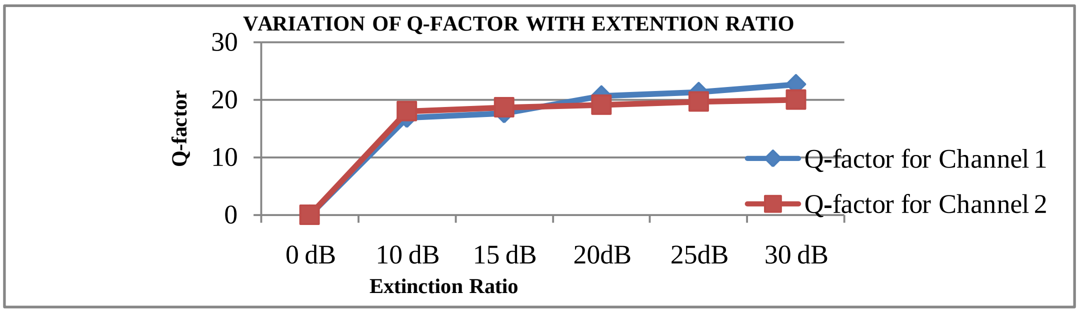
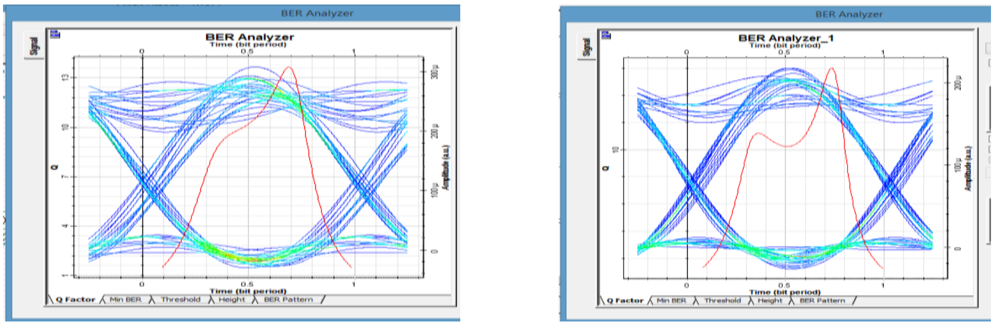


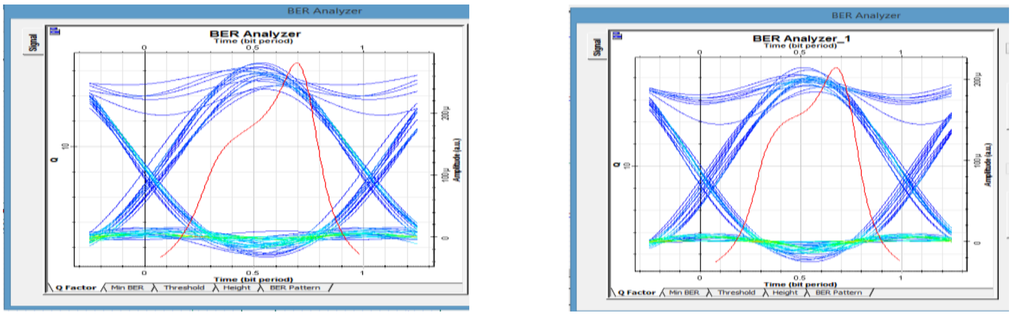
Fig. 7 Variation of Q-factor with Extinction Ratio at 20km Fiber Length

Eye Diagrams Analyzer for 20km fiber length:



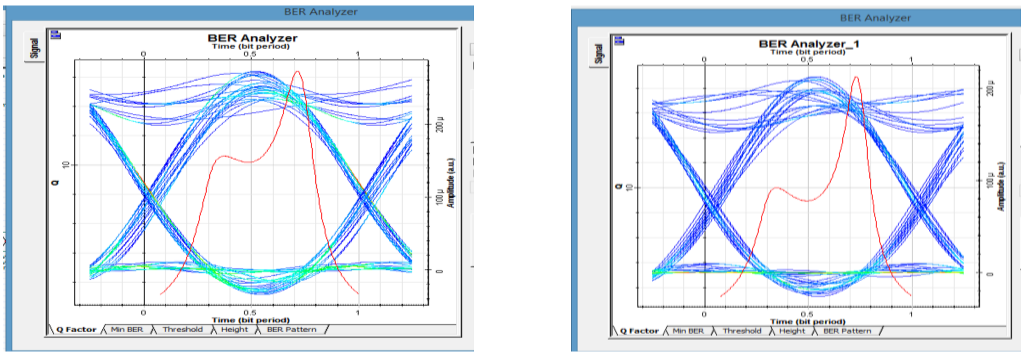
(a) (b)

Fig.8 (a) &(b) Eye Diagram analyzer at Extinction Ratio 10 dB for channel 1 and 2 at Fiber Length 20 km



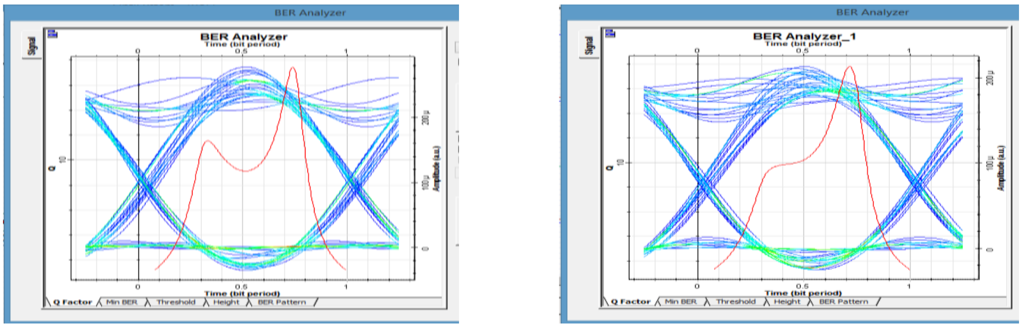
(c) (d)

Fig.8 (c) & (d) Eye Diagram analyzer at Extinction Ratio 15 dB for channel 1 and 2 at Fiber Length 20 km



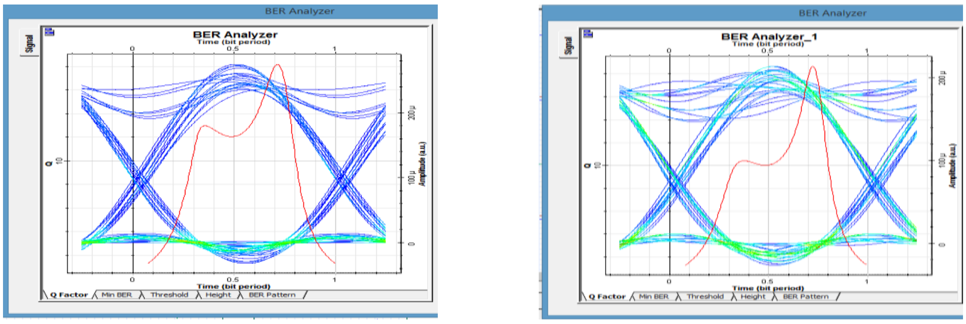
(e) (f)

Fig. 8 (e) & (f) Eye Diagram analyzer at Extinction Ratio 20 dB for channel 1 and 2 at Fiber Length 20 km



(g) **(h)**

Fig.8 (g) & (h) Eye Diagram analyzer at Extinction Ratio 25 dB for channel 1 and 2 at Fiber Length 20 km



(i) **(j)**

Fig.8 (i) & (j) Eye Diagram analyzer at Extinction Ratio 30 dB for channel 1 and 2 at Fiber Length 20 km

Table: VI Variation of BER and Q-factor with Extinction Ratio at 30km Fiber Length

Sr. No.	Extinction Ratio	Channel 1		Channel 2	
		Max. Q- factor	**Min.BER**	**Max. Q- factor**	**Min.BER**
1.	10 dB	10.7621	2.56124e-27	15.3417	1.9197e-53
2.	15 dB	12.3956	1.37999e-35	16.1067	3.09203e-62
3.	20 dB	13.7319	3.2049e-43	16.6323	2.32716e-53
4.	25 dB	16.2399	1.24011e-59	17.0332	1.87445e-49
5.	30 dB	17.2399	2.24011e-59	17.9332	1.87445e-49

As given in table IV, the values of Q-factor for channel 1 are 10.7621, 12.3956,13.7319, 17.2399 and 16.2399 for extinction ratio10, 15, 20, 25, & 30 dB respectively and it is 15.3417, 16.1067, 17.9332, 17.0332 and 16.6323 corresponds to extinction ratio10, 15, 20, 25, & 30 dB for channel 2 at distance 30 kms. From these observations, it is evident that the designed optical link performs satisfactorily as Q-Factor for both channel 1 and channel 2 increases with increase in extinction ratio.

Figure 9 shows the variation of Q-factor with increasing extinction ratio for channel 1 and channel 2. Q-factor increases with increasing extinction ratio.

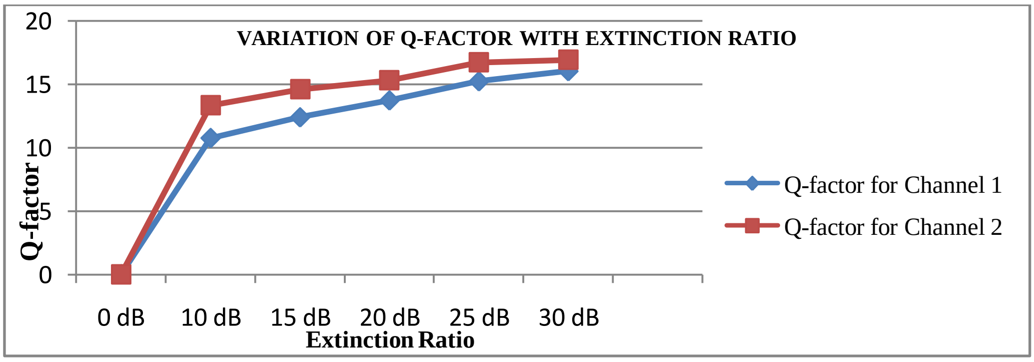
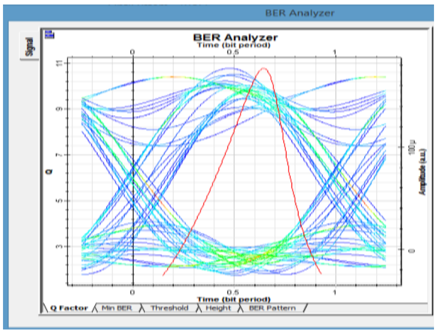
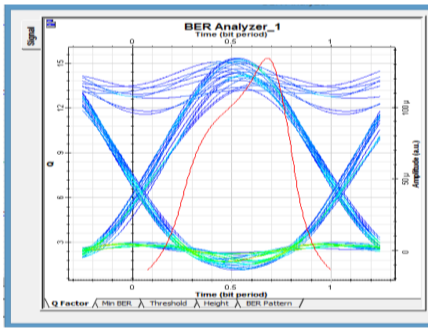


Fig. 9 Variation of Q-factor with Extinction Ratio at 30km Fiber Length

Eye Diagrams Analyzer for 30km fiber length:

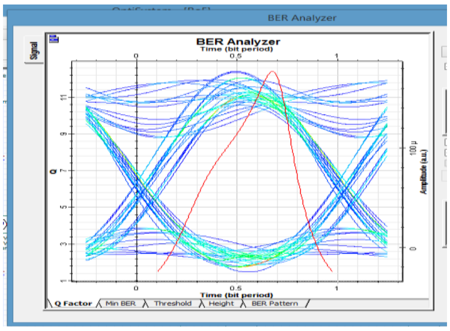


(a)

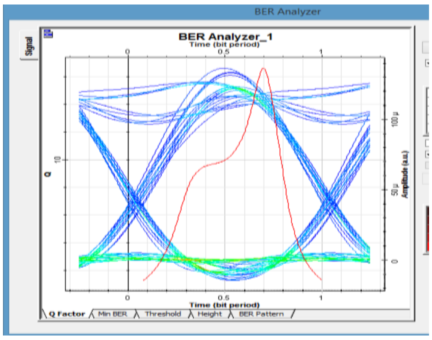


(b)

Fig.10 (a) & (b) Eye Diagram analyzer at Extinction Ratio 10 dB for channel 1 and 2 at Fiber Length 30 km

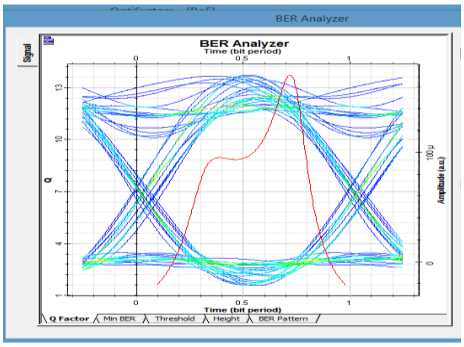


(c)

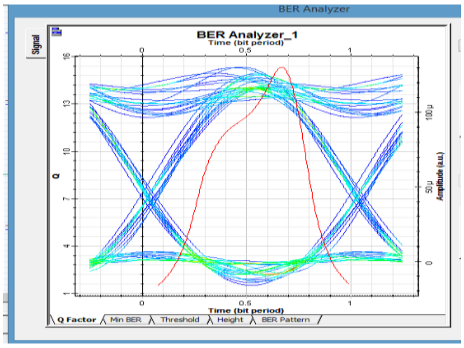


(d)

Fig.10 (c) & (d) Eye Diagram analyzer at Extinction Ratio 15 dB for channel 1 and 2 at Fiber Length 30 km

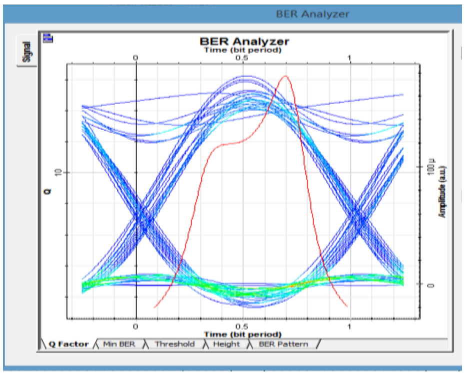


(e)

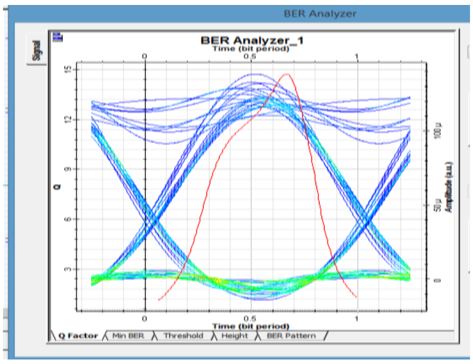


(f)

Fig.10 (e) & (f) Eye Diagram analyzer at Extinction Ratio 20 dB for channel 1 and 2 at Fiber Length 30 km



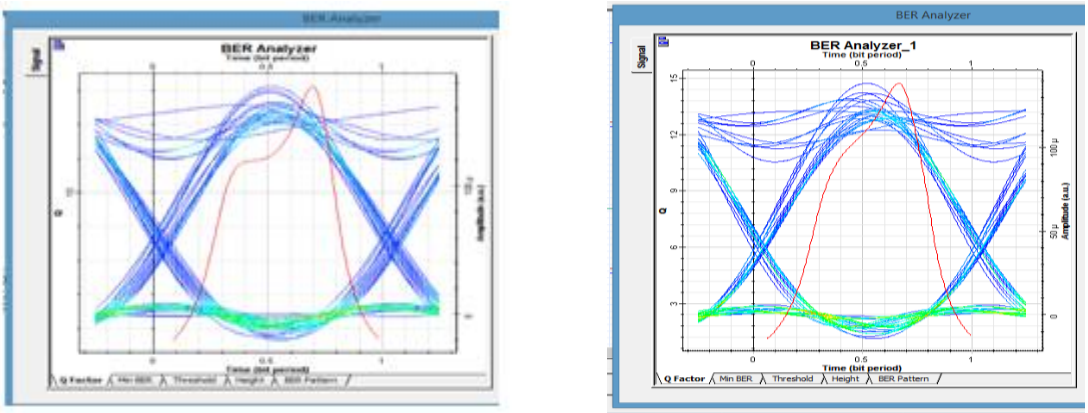
(g)



(h)

Fig.10 (g) & (h) Eye Diagram analyzer at Extinction Ratio 25 dB for channel 1 and 2 at Fiber Length 30 km

ISSN: 2319-7471, Vol. 6 Issue 6, June-2017, Impact Factor: 1.544



(i) (j)

Fig. 10 (i) & (j) Eye Diagram analyzer at Extinction Ratio 30 dB for channel 1 and 2 at Fiber Length 30 km

Figure 6 [(a) to (j)], 8 [(a) to (j)] and 10 [(a) to (j)], the Eye diagrams obtained for the extinction ratios 10, 15, 20, 25 and 30 dB at distance 10, 20 and 30 km respectively on BER analyzer are shown. These eye diagrams have a larger eye opening, greater eye height and width and there is less distortion among the various spectral components initially. But as the length of fiber increases, there is a slight distortion in the eye diagrams. With increase in length the fiber losses increases, that attenuates the signal and distortion decreases with increases Extinction ratio. And with increase in fiber length the dispersion also increases that led to spectral overlapping which distorts the signal.

CONCLUSION

In this proposed work we have successfully designed a RoF system link using MZM modulator and simulated using Optisystem software for parameters such as BER, Q-factor, for different Extinction ratios and at various fiber lengths. The values of Q-factor for channel 1 and channel 2 at Extinction ratios 10, 15, 20, 25, and 30 dB at fiber length 10, 20, and 30km are shown in tables II, III and IV respectively. From all the observations and findings it can be concluded that for the proposed RoF system the Q-factor decreases and BER increases with increase in optical fiber lengths, and Q-factor increases with increase in Extinction ratio and the designed system works optimally at extinction ratio of 30db.

REFERENCES

[1]. https://en.wikipedia.org/wiki/Radio_over_fiber

[2]. Kamaljit Singh Bhatiaa, Sandeep Singh "Performance Analysis of RoF link using Mach-Zehnder Modulator and its parameters," An International Journal of Engineering Sciences, Special Issue ICTMS-15, 29-30 December 2015 ISSN: 2229-6913 (Print), ISSN: 2320-0332

[3]. Fan Wei, Hanyi Zhang, and Bingkun Zhou Tsinghua, "Carrier Phase and Amplitude Manipulation for Linearization and Dispersion compensation in Radio-over-Fiber Systems Using Mach-Zehnder Modulator - Progress In Electromagnetic Research Symposium Abstracts,"Electromagnetics Research.

[4]. Pradeep R and Vijayakumar N, "Performance Analysis of RoF link using Mach-Zehnder Modulator in radio over fiber systems, " International Journal of Advanced Research in Engineering and Technology (IJARET).ISSN Print: 0976-6480 and ISSN Online: 0976-6499Volume 7, Issue 5, September-October 2016, pp. 45–52, Article ID: IJARET_07_05_006 ISSN Print: 0976-6480 and ISSN Online: 0976-6499© IAEME Publication.

[5]. Jincy John and Sreenesh Shashidharan,"Design and Simulation of a Radio over Fiber System and its Performance Analysis." Optical Networking Technologies and Data Security - OPNTDS 2012IEEE.

[6]. Kamal Moussati, and Jamal Zaidouni Ghoumid, Slimane Mekaoui, Ali El,"16-QAM Modulation Based on Quad-Parallel Mach-Zehnder Modulator Dedicated for Radio-over-Fiber System," International Journal of Information and Electronics Engineering, Vol. 3, No. 5, September 2013

[7]. M. Zhu, L. Zhang, J. Wang, L. Cheng, C. Liu, and C. Gee-Kung, "Radio-Over-Fiber access architecture for integrated broadband wireless services," J. Lightwave Technol. 31, 3614–3620 (2013).

[8]. Balinder Singh and Davender Singh, "A Review on Advantages and Applications of Radio over Fiber System,"

[9]. International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.

[10]. A. Bahrami, Student member, IEEE,T. Kanesan, W. P. Ng, Senior member, IEEE, Z. Ghassemlooy, Senior member, IEEE, A. Abd El Aziz, Student member, IEEE, S. Rajabhandari, Member, IEEE Optical, "Performance Evaluation of Radio-over-Fibre Systems Using Mach-ZehnderModulator"Researchgate.net/publication/231181708

[11]. Bhumika A. Patel, Prof. Ankit Patel , "Performance Analysis of Optical Link using EDFA, " IJSRD – International Journal for Scientific Research & Development| Vol. 3, Issue 03, 2015 | ISSN (online): 2321-0613.

[12]. Rajiv Chechi and Mukhwinder Kaur, "Radio over Fiber (RoF): A New Approach to High Speed Access Network", International Journal of Advanced Research in Computer Science (IJARCS). Volume 3, No. 6, Nov 2012 (Special Issue) ISSN No. 0976-5697.

[13]. Rajbir Singh, Manoj Ahlawat and Deepak Sharma "A Review on Radio over Fiber Communication System", International Journal of All Research Education and Scientific Methods (**IJARESM**) ISSN: 2455-6211, Volume 5, Issue 4, April 2017.

[14]. Rajbir Singh, Deepak Sharma and Manoj Ahlawat "Study and performance evaluation of Radio over Fiber using Mach Zehnder Modulator", International Journal of Advanced Research in Computer Science(**IJARCS**). Volume 8, No. 4, May-June 2017, ISSN No. 0976-5697.

[15]. Sai Naing Min Htet" Generation of Optical Carrier Suppressed Signal for Radio-over-Fiber (RoF) System Using Dual-Drive Mach-Zehnder Modulator ",International Journal of Scientific and Research Publications, Volume 4, Issue 9, September 2014 1 ISSN 2250-3153 www.ijsrp.org