Performance Analysis of RoF link using Mach-Zehnder Modulator and its parameters

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ABSTRACT: In radio-over-fiber (ROF) systems, optical carrier is modulated by the electrical signal and thus, converts the electrical signal to optical domain. This leads to the generation of up-converted signal bands. Although modulation is a necessary process for the faithful transmission of a signal, but it also degrades the modulated signal by generating distorted sidebands which causes reduction in the dynamic range of the system. Dispersion originated from the transmission fiber and other optical devices also change the phase relationship between the optical carrier and the modulated sidebands. This causes degradation of the modulated signal due to power fading. Mach-Zehnder modulator (MZM) is the most preferred modulator used in RoF systems. The performance of RoF system depends upon various parameters of Mach-Zehnder modulator (MZM) like RF bias, bias voltage, extinction ratio and insertion loss. In this paper the behavior of Lithium Niobate (LiNbO3) MZM is studied on various bias and extinction ratio ranges and a particular bias and extinction ratio is fixed at which the proposed ROF system gives the optimum results.

KEYWORDS: RoF, RoFSO, MZM.

PACS: Optical fibers - 42.81.-I , fiber networks- 42.81.Uv, Optical modulators, 42.79.Hp,

42.79.Sz Optical communication systems, multiplexers, and demultiplexers (for fiber networks, 42.81.Uv),

42.79.Hp Optical processors, correlators, and modulators.

1 INTRODUCTION

Boost in mobile internet devices offering broadband wireless multimedia services has been continuously driving the communication technology to make continuous progress. To meet the vital demand of large bandwidth and high mobility, Radio over Fibre (RoF) and Radio over Free Space Optics (RoFSO) technologies were projected.[1] These technologies are assimilation of wireless and optical communications [2- 4]. The RoF and RoFSO systems when integrated with modern technologies, like WDM systems [5] and Radio access network of LTE systems provided better response, thus proved to be advantageous [6]. RoF systems operating at 60-GHz millimeter-wave (mmwave) is an effective technology used to increase the network capacity for the vast bandwidth over 7GHz unlicensed mm-wave band with spectral availability to achieve multi-gigabit data rate with very low power consumption [7].

Mach-Zehnder modulator (MZM) is the most preferred modulator generally termed as an electrical to optical (EO converter). Recent researches in the field of MZM reveal that, MZM can be used more than just an EO converter like to achieve linearization or for the compensation of dispersion introduced in the signal while travelling through an optical path. Specially designed MZM can resolve both the issues simultaneously. [8]

2 OPERATION OF DUAL-DRIVE-MZM

The most popular modulator in optical communication systems is the Lithium Niobate (LiNbO3) Mach Zehnder Modulator(MZM). There are two types of MZ Modulators: single drive Mach- Zehnder Modulator and dual-drive Mach- Zehnder Modulator. The optical wave enters from the input side and then splits equally into two arms. The structure of the dual-drive MZM has two arms and electrodes. Mach- Zehnder modulator is used to control the amplitude of an optical wave. Input waveguide splits into two waveguide interferometer arms and bias is applied to these arms. Due to the applied

voltage, phase shift is induced in the wave passing through that arm. At the output side, optical waves travelling through both the interferometer arms are recombined and the phase difference between the two waves is converted to an amplitude modulated signal. The RF signals are applied to the two arms of the interferometer with different phase shifts and the two arms are biased with different DC voltages. The optical phase in each arm can be controlled by changing the voltage applied on the electrode.[9-10] When Dual Drive - MZM is operated at suitable bias minimum value or null point, optical carrier-suppressed signal is received at the output port. When the DD-MZM is biased at quadrature point, optical carrier along with sidebands carrying information signal exits the output port as shown in figure 1.

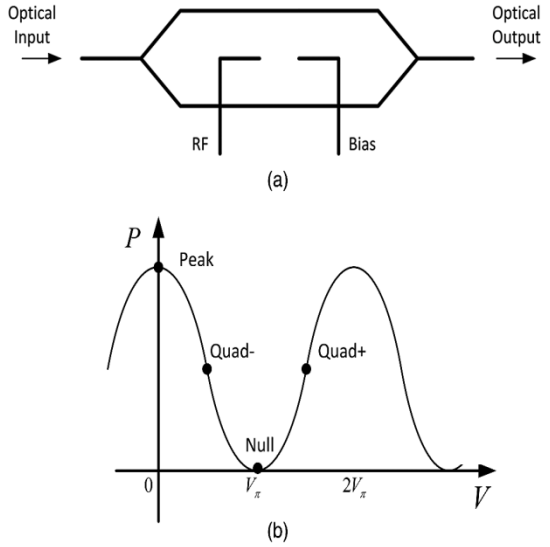

Figure 1. a) Layout of Mach Zehnder modulator

b) Output Power versus Bias characteristics

The DD-MZM suppresses undesired optical carrier power as well. The modulator is biased at the null point for the suppression of unwanted optical carrier power. Optical carrier power degrades the performance of RoF system in terms of link gain and noise figure (NF). Thus, undesired optical carrier power needs to be suppressed as shown in figure 1. b). For this, bias voltage at the null point is given to the modulator. This not only increases link gain but also reduces noise figure of the RoF network.

Extinction ratio is the another parameter which depicts the efficiency of the MZM. Extinction ratio is the ratio of two optical power levels of a digital signal generated by an optical source. It is given as:-

$$r_e = P_1 / P_0$$

where, P_1 is the output optical power level when the light source is ON, and P_0 is the output power level when the light source is OFF. The extinction ratio may be expressed in dB or as a percentage.[11]

Simultion Setup

The simulation is done in Optisystem where the proposed RoF link depicted in figure 2 was setup. In this link a narrow band continuous wave Laser signal of frequency 193.1 THz is modulated by a Lithium Niobate (LiNbO3) Mach-Zehnder modulator(MZM) to which another input is from local oscillator signal of the order of 10-GHz.Carrier signal is applied to MZM through a carrier generator and its frequency is 49.25 MHz having 78 channels each with frequency spacing of 6 MHz.

3 SIMULATION RESULTS AND FINDINGS

The proposed network was analysed for different values of bias and extinction ratio of Lithium Niobate (LiNbO3) Mach-Zehnder modulator(MZM) because these are the vital parameters on which the behavior of Mach-Zehnder modulator depends as discussed above and the following observations were made. The proposed RoF system being a

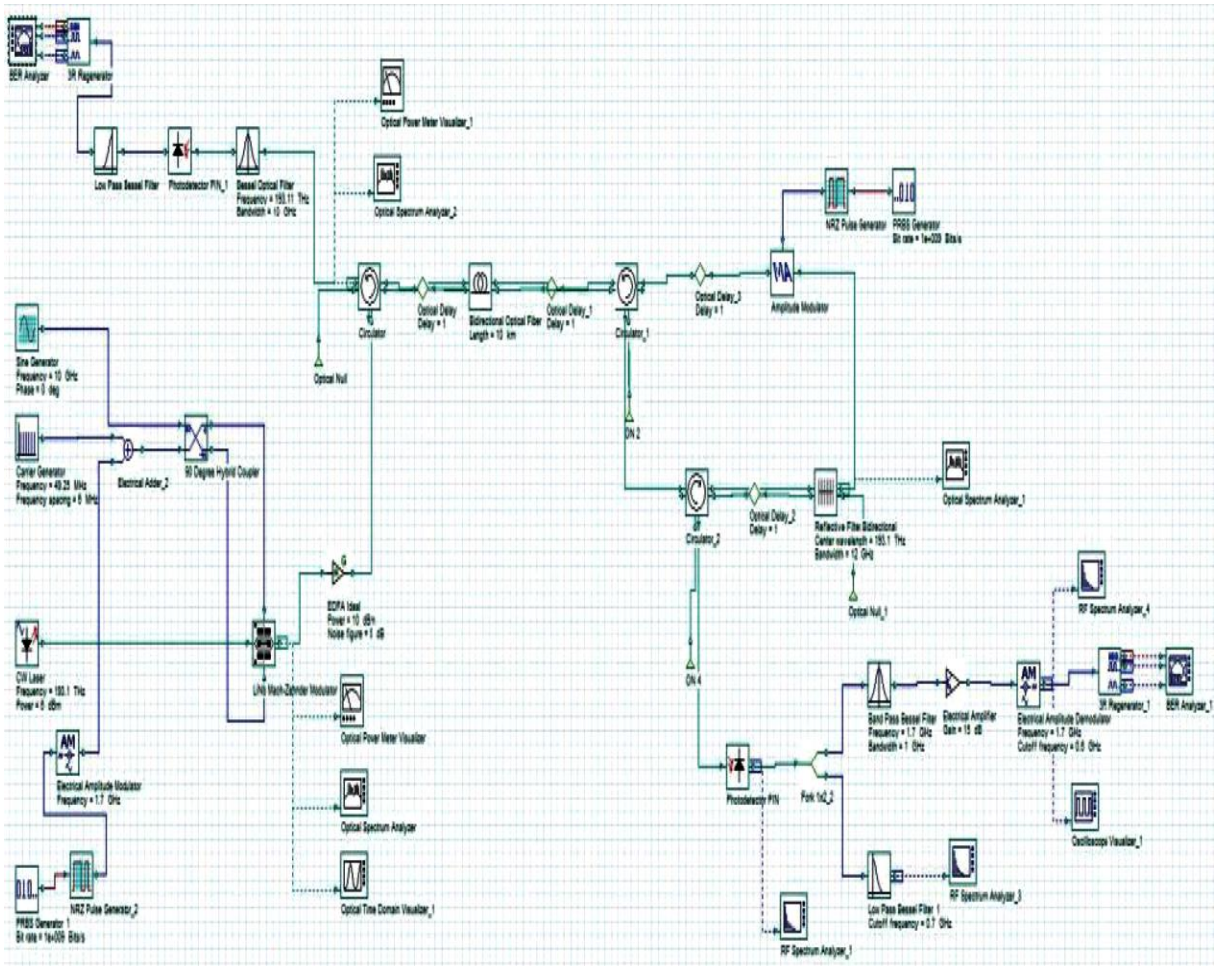

Figure 2. Radio Over Fiber link simulation setup

bidirectional setup consists of two BER Analyzers(BER Analyzer 1 and BER Analyzer) so as to test out the performance of uplink and downlink network.

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a) For Switching Bias Voltage

The proposed RoF system was tested for different switching voltage levels ranging between 1V - 7V and following results were achieved as shown in figure 3 and 5 in terms of Q-factor of the RoF system and in figure 4 and 6 in terms of Bit Error Rate. From figures 3,4,5 and 6 it can be concluded that the proposed system gives best results when the switching bias voltage given to Lithium Niobate (LiNbO3) Mach-Zehnder modulator(MZM) is 4V.

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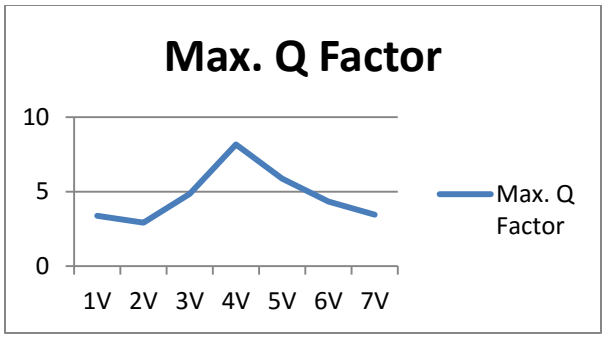

Figure 3. Q-factor versus Switching Bias voltage – BER analyzer 1.

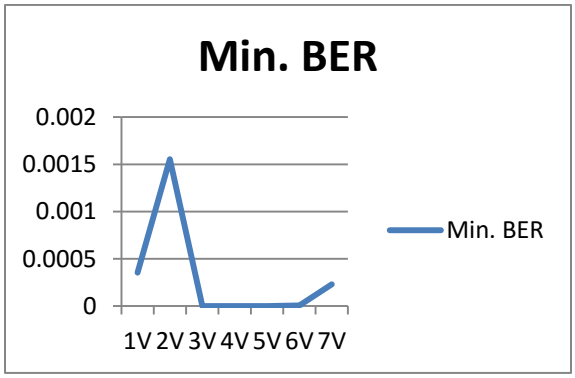

Figure 4. Bit Error Rate versus Bias voltage – BER Analyzer 1.

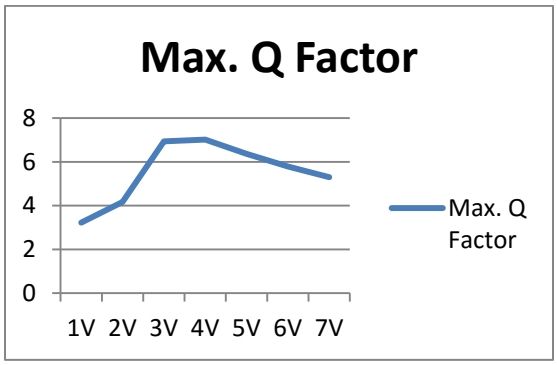

Figure 5. Q- Factor versus Switching bias voltage – BER Analyzer.

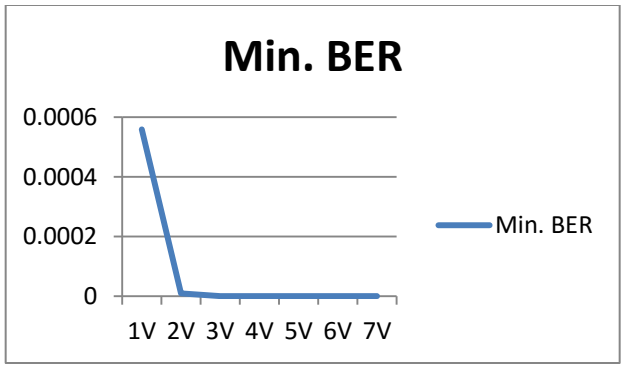

Figure 6. Bit Error Rate versus Bias voltage – BER Analyzer.

b) For Extinction Ratio

The proposed RoF system was tested for different Extinction ratios ranging from 5 dB to 60 dB and following observations were obtained, depicted in figures 8 and 10 in terms of Q-factor of the RoF system and in figure 7 and 9 in terms of Bit Error Rate. From these figures it is clear that the proposed system gives optimum results when the extinction ratio of Lithium Niobate (LiNbO3) Mach-Zehnder modulator(MZM) exceeds 30 dB as after 30 dB the results are constant for both Q-factor and BER. Therefore, 30 dB extinction ratio is an appropriate value for extinction ratio of MZM in the proposed system.

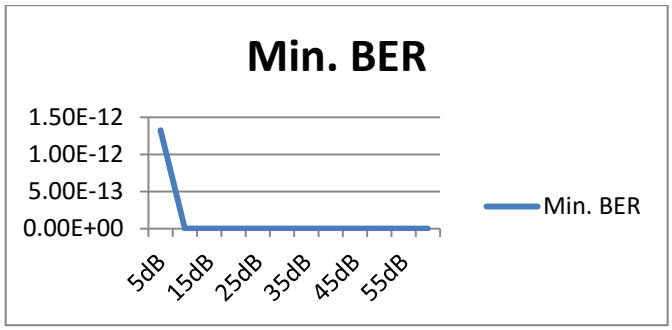

Figure 7. Bit Error Rate versus Extinction ratio – BER Analyzer 1.

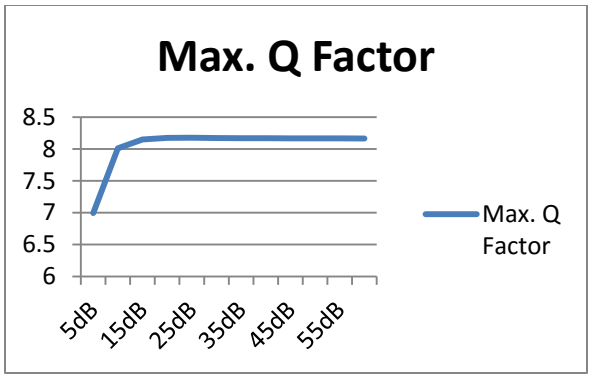

Figure 8. Q- Factor versus Extinction ratio – BER Analyzer 1.

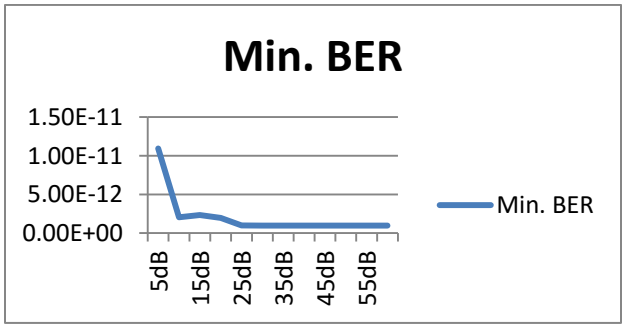

Figure 9. Error Rate versus Extinction ratio – BER Analyzer.

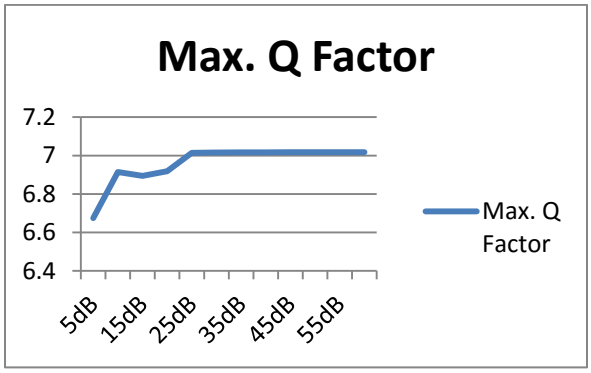

Figure 10. Q- Factor versus Extinction ratio – BER Analyzer.

From the above findings the performance of the proposed RoF system was tested particularly for 4V switching bias voltage and 30 dB extinction ratio of Lithium Niobate (LiNbO3) Mach-Zehnder modulator (MZM) and following eye patterns were obtained as shown in figure 11 and 12.

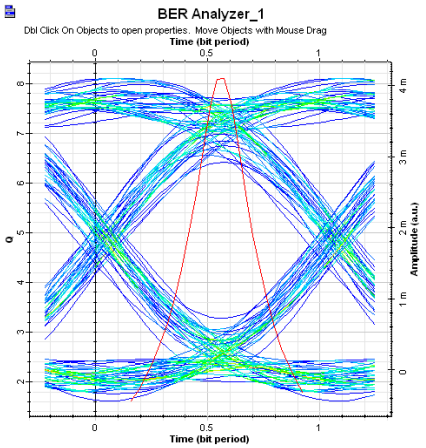

Figure 11. Eye pattern when Switching bias was fixed to 4V and Extinction ratio was fixed to 30 dB – BER Analyzer 1.

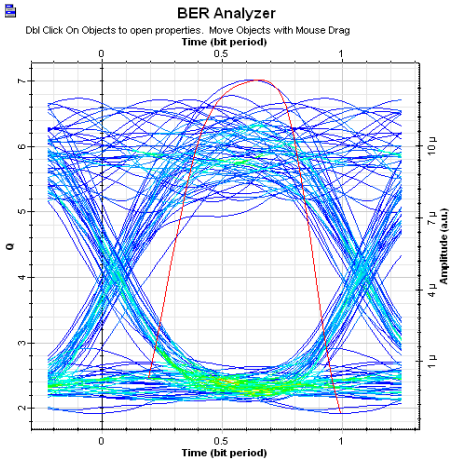

Figure 12. Eye pattern when Switching bias was fixed to 4V and Extinction ratio was fixed to 30 dB – BER Analyzer .

5 CONCLUSION

In order to overcome the dispersion losses and degradation of signal due to power fading which a signal experiences while travelling through an optical fiber, various optical devices, Mach Zehnder modulator is introduced in the Radio over Fiber system. The projected RoF system was analysed for switching bias voltage and extinction ratio of Lithium Niobate (LiNbO3) Mach-Zehnder

modulator(MZM) and from all the observations and findings it can be concluded that for the proposed system the appropriate switching bias voltage is 4V and the extinction ratio is 30 dB so as to achieve the optimum results that is maximum Q –Factor with minimum BER.

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