Analysis of Optical Modulators over Free Space Optics

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Abstract- *Free Space Optics (FSO) is the recent technology in optical communication system. This requires some form of external optical modulator in the transmitter side to modulate the signal. The most commonly used optical modulators are Mach-Zehnder modulator (MZM) and Electro absorption modulator (EAM). In this paper, we compare the performance of both Mach-Zehnder modulator and Electro absorption modulator for Free Space Optical Communication systems and both areanalyzed in free space. We also discuss about the choice of optical modulator based on the intensity, Quality factor and eye-diagram of output light signal.*

Keywords- Mach-Zehnder Modulator, Electro-Absorption modulator, Free space optics, Modulator, Optical wireless communication

I. INTRODUCTION

Free Space Optics is a line of sight technology which involves the transfer of data from one point to another point using optical radiation in free space [2]. FSO provides the flexibility of wireless communication and the speed of fiber optic communication. The intensity and phase of the optical carrier signal can be modulated based on the message signal. An FSO system consists of optical transmitter with a laser transmitter and a receiver to provide full duplex connectivity. Each FSO unit uses a high power optical source like laser source and a lens that transmits the light through the atmosphere to another lens at the receiving end. Laser diodes operating wavelength centered at 1550 nm are generally preferred for FSO communication because of eye safety concern. The advantages of FSO are license free operation, high bit rate, ease of deployment, high transmission security, full duplex transmission and protocol transparency. Immunity towards electro-magnetic interference should also be mentioned as a significant advantage Free Space Optics (FSO) is the technology in which it is possible to transmit and receive multiple RF signals simultaneously over FSO links using wavelength division multiplexing technology. FSO is a line of sight technology that enables data transmission based on the propagation of light in free space. Compared to radio frequency (RF) communication systems, FSO provides high data rates, unregulated bandwidth, and low power. However, FSO have many challenges including atmospheric turbulence, weather dependent atmospheric attenuation and misalignment fading in this paper, we analyze the performance of optical modulators and their comparison based on power spectrum, BER, Q-Factor and Eye-Diagram.

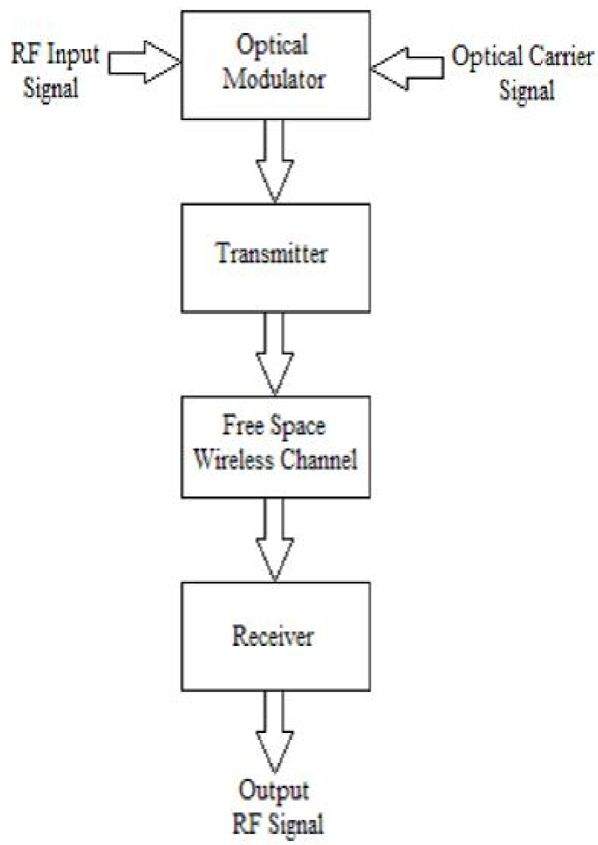

Fig.1 Basic model of optical wireless system

II. OPTICAL MODULATORS

As data rates in optical communication have been limited by the speed of available optoelectronics components. It is of much importance to consider practical aspects of modulation and detection hardware for designing optical modulation formats. Using the existing modulator structure in a new way has given birth to new optical modulation formats. The basic modulator technologies that are widely used are MZMs and EAMs.

A. Mach-Zehnder Modulator

MZM is an electro optic modulator (EOM) [4] which works on the basis of Pockel effect. In Mach-Zehnder modulator the incoming optical signal is sent to two different optical paths. Applying voltage to one of the optical path produces a refractive index variation in accordance with the applied voltage introduces a phase shift in the wave travelling path. The amount of electric voltage required to produce a phase shift of 180° is called half wave voltage. After a certain distance the two optical paths recombine, causing the optical waves interfere with each other. This type of arrangement is known as an interferometer. The individual signals interfere constructively or destructively depending on their relative phase differences which determine the amplitude of an output optical signal.

B. Electro-Absorption Modulator

Electro absorption modulators are based on electro-absorption effect, which is defined as the change of material absorption in the presence of an electric field. This modulator is used for modulating the intensity of laser beam via an electric voltage. The basic principle of EAM is Franz-Keldysh effect. It provides high data rate with low chirp.EAM have low driving voltage, large maximum extinction ratio a high figure of merit. The highest 3-dB bandwidth reported for EAM is 50 GHz. It can be monolithically integrated with driver circuitry and/or laser sources. These modulators have features such as low drive voltage (typically 2V) and are cost effective for large production. Today they are available up to 40 Gbps and researchers demonstrations up to 80 Gbps.

III. SIMULATION APPROACH

The general workflow for simulating an optical communication network is shown in fig. 2. There are basically four steps to set up for the simulation of an optical communication system. At first step, create the optsim project in which ever mode you want to make your project and set simulation parameters. After that In second step, draw the schematic diagram, set desired values of parameters of block models. In third step we simulate our project.nin last step we see the result like eye diagram, BER, power spectrum etc.

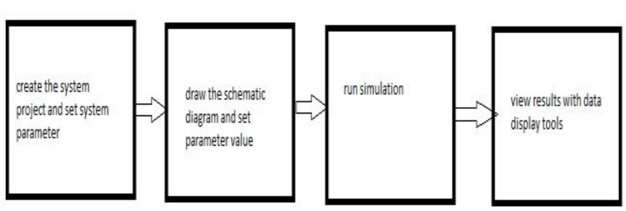

Fig.2 General Workflow for simulation

Table 1: Link parameters

Serial No.	Parameter	Value
1.	Bit-Rate	2.5 Gbps
2.	Transmitter power, P_{TX}	1.5dBm
3.	Beam divergence angle, θ	3 mrad
4.	Environment attenuation, α	-4.92 dB
5.	Standard deviation, σ	1.9 dB
6.	Receiver's detector aperture area, A	180 sq m

IV. SIMULATION RESULTS

This section presents simulated results for analyzing the performance of optical modulators in FSO based communication systems. Analysis is done at 2.5 Gbps for 1 km distance. Here a narrow bandwidth laser source is used to transmit the data. Free space is used as a channel for transmission. Parameters like eye-diagram, quality factor, BER, power are used for comparison of optical modulators. Here the basic networks which are used for simulation are shown below in fig. 3 and fig 4.

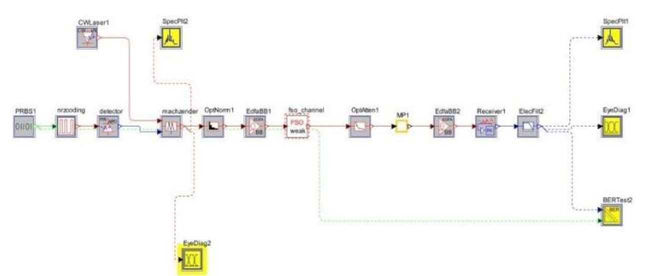

Fig.3 Simulation set-up for analysis of Mach-Zehnder Modulator

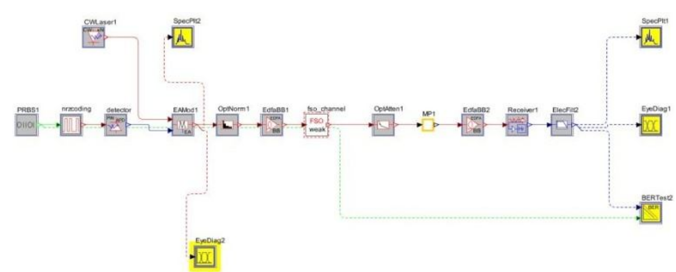

Fig.4 Simulation set up for analysis of Electro-Absorption Modulator

Here different electrical and optical scopes like eye-diagram analyzer, BER estimator, power spectrum analyzer etc are used to measure the various parameters. Results are shown in graphs as well as in tabular form. Output of both the modulators is passed through free space atmospheric channel and amplitudes of power are compared using power spectrum at the receiving end.

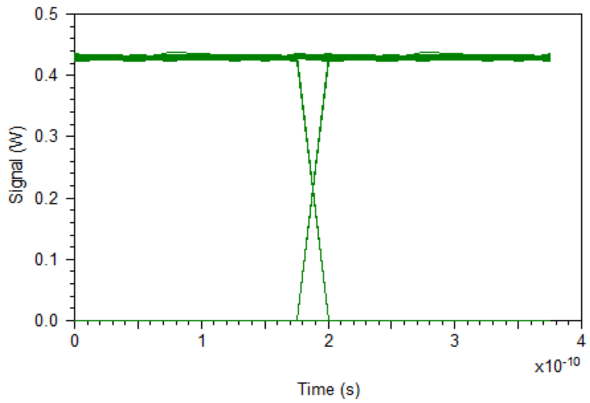

Fig.4 Eye-Diagram at the output of MZM

This is the power spectrum at the receiving end for Mach-Zehnder Modulator based free space communication system. From the power spectrum we can analyze power loss while transmission.

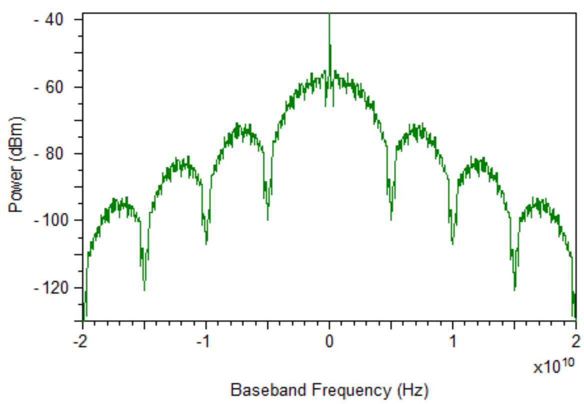

Fig 5 Power spectrum at the receiver end at 1 Km distance for MZM

This is the eye-diagram at receiver end at 1 km distance for MZM. Value of eye opening for MZM is 8×10^{-4}

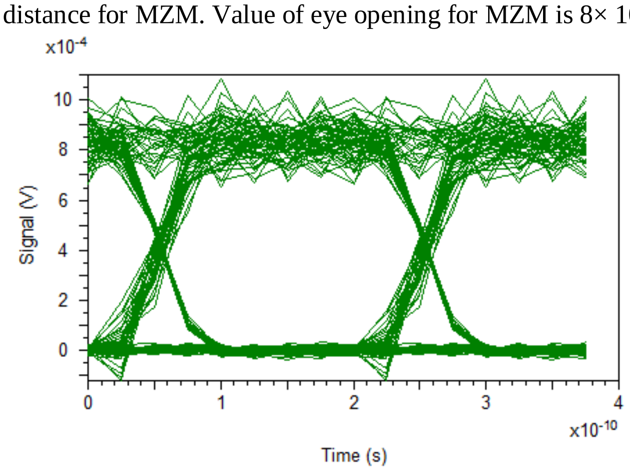

Fig 6 Eye-Diagram at receiver end at 1 Km distance for MZM

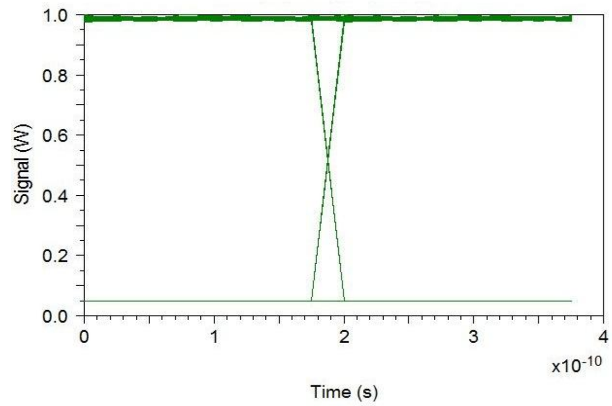

Fig 7 Eye-Diagram at the output of EAM

This is the power spectrum at the receiving end for Electro-Absorption Modulator based free space communication system. Power loss in EAM is less as compare to MZM.

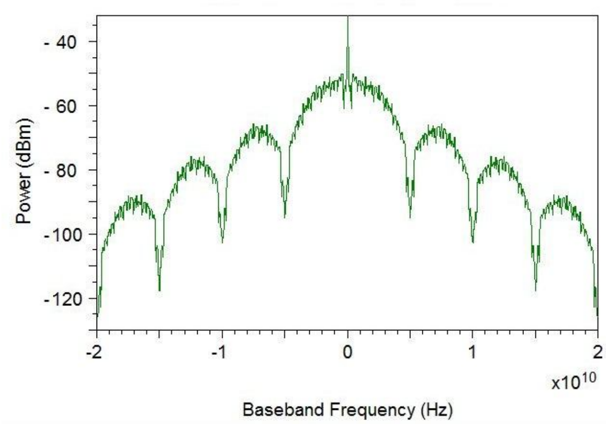

Fig 8 Power spectrum at the receiving end at 1 Km distance for EAM

Similarly eye-diagram at the output of EAM based network is shown in fig.9. Value of eye-opening for EAM is 2×10^{-3} which is higher than that of MZM.

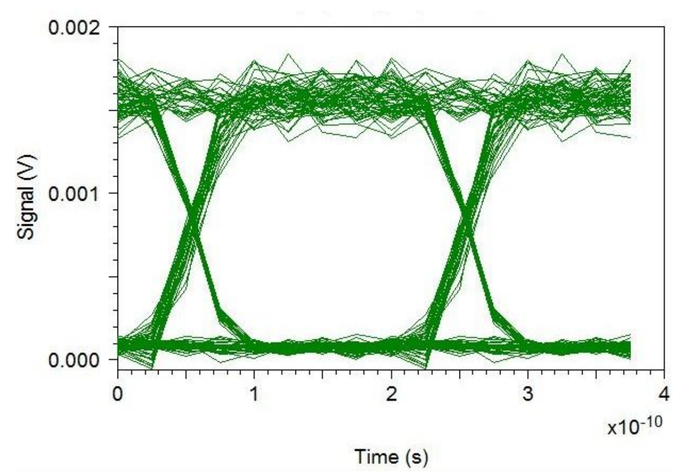

Fig 9 Eye-Diagram at the receiving end at 1 Km distance for EAM

As we know that higher the value of eye opening better will be our communication system. So performance of EAM modulator is better as compared to MZM modulator.

Table 2 Comparison of MZM and EAM for 1 km distance at 2.5 Gbps

Type of Modulator.	Power (dBm)	Bit Error Rate	Eye-Opening value	Quality factor
MZM	-38.86	21.22	0.0008	19.59
EAM	-32.47	32.44	0.002	21.54

From the comparison we conclude that EAM has lesser power loss as compared to Mach-Zehnder modulator. From the eye-diagram, it is clear that Eye opening is also better for Electro-Absorption modulator as compare to Mach-Zehnder modulator. Eye-diagram is distorted more in case of MZM.

V. CONCLUSION

The Mach-Zehnder modulator, Electro-Absorption modulators and wireless free space have been modeled and simulated for 1 km distance. A GHz signal was generated and it was modulated with the optical carrier signal using optical modulators. The modulated signal is applied to free space optical wireless channel. After transmission through the wireless channel, the output Power, BER, Eye-Diagram and Quality factor of both the modulators are compared. The numerical and graphical results shows that Electro-Absorption modulator provides comparatively higher output power, lesser bit error rate, more eye opening and higher quality factor.

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