Performance Analysis of ODSB-SC Ro-FSO System under Atmospheric Attenuation

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ABSTRACT
Radio over free space optics (Ro-FSO) technology provides a promising solution for future wireless network, offering high data transmission compared to RF technology. In this paper, performance of double sideband–suppressed carrier based Ro-FSO system under various weather conditions is investigated. It transmits two RF signals at 10 and 15 GHz over an optical wireless channel of 1 km. At transmitter Mach Zehnder modulator is used for both carrier suppression and signal modulation. At the receiver, delay interferometer is used for separation of RF signal having delay of 0.1ns.

Keywords
Radio over free space optics (Ro-FSO), RoF, FSO, ODSB-SC, Wavelength interleaving (WI).

1. INTRODUCTION
The increased bandwidth demand for future wireless network has led to the rise of optical wireless communication. Ro-FSO technology is the combination of radio over fiber (RoF) and free space optics (FSO) [1]. The main advantage of RoF is the ability to distribute the RF signal at large bandwidth using optical fiber at lower attenuation, immunity to RF interference and low power consumption. The FSO has similar working principles as optical fiber communication [2] [3]. The only difference is that it utilizes atmosphere for transmission of the signal instead of optical fiber as a channel which help to reduce the cabling cost. FSO also provides highly secure license free operation and high data rate transmission, which makes it to be used in a wide range of wireless service and cellular architecture. The major challenge of free space optics is the atmospheric attenuation. In geographical areas like buildings, hilly terrains, underground, FSO cannot be used due to multipath fading. At such situation FSO technology can be integrated with radio technology to get an uninterruptable wireless service.

In this paper wavelength interleaving (WI) technique has been used for channel spacing of RF signals. WI technique helps to improve the spectral efficiency [4]. The system employing WI technique reduces the channel spacing to the value less than twice the highest modulation frequency. The system having channel spacing smaller than the RF carrier frequency provides better spectral efficiency. At the receiver side interferometer has been used for separating the WI signals. It is found that interferometer with time delay 0.1ns provides better performance [5].In this paper, externally modulated two RF signals transmitted at 10 and 15 GHz frequency. In section 2, simulations setup of RoF-FSO system is discussed .In section 3, the result has been reported .Finally, in section 4, conclusions are made.

2. SYSTEM DESCRIPTION
The schematic diagram of proposed Ro-FSO transmission system is shown in fig. 1. The system consists of two RF signals of 10GHz and 15GHz.These signals are combined using electrical multiplier and combiner. The RF signals are then passed through Mach-Zehnder modulator which is used for both optical carrier suppression and signal modulation. The continuous wave laser is used at 193.1 THz and power of 20dBm. The optical signal then transmitted over 1km. through optical wireless channel at reference wavelength of 1550nm. At the receiver end signal is then passed through an interferometer which separate the RF signal with time delay of 0.1ns. Each receiver section has a Bessel filter of 193.1 THz with 40 GHz bandwidth. Optical amplifier has been used having gain of 15dB. PIN diode is used as a photo detector. The signal is demodulated using AM demodulator with cutoff frequency 1GHz having bandwidth of 20GHz and 30GHz for 10 and 15 GHz wavelength interleaved signals.

The Link Equation of the free space optics is given by [6][7]

$$P_{Received} = P_{Transmitted} \frac{d_R^2}{(d_T + \theta R)^2} 10^{-\alpha R/10}$$

Where d_R defines receiver antenna aperture diameter and d_T is the transmitter antenna aperture diameter. The θ defines the beam divergence. R is the range and α is the atmospheric attenuation.

3. ATMOSPHERIC ATTENUATION
3.1 ATTENUATION DUE TO FOG
The attenuation due to foggy weather is given by Kim's model [8], which is found very accurate for the wavelength range of 750-1550 nm.

$$\alpha_{Fog} = \frac{3.91}{V} (\frac{\lambda}{550})^{-q}$$

Where V is the visibility, λ is the operating wavelength and q is the parameter related to the size of the droplet.

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$$q = \begin{cases} 1.6 & if\ V > 50\ km; \\ 1.3 & if\ 6km < V < 50km; \\ 0.16V + 1.34 & if\ 1km < V < 6km; \\ V - 0.5 & if\ 0.5km < V < 1km; \\ 0 & if\ V < 0.5km. \end{cases}$$

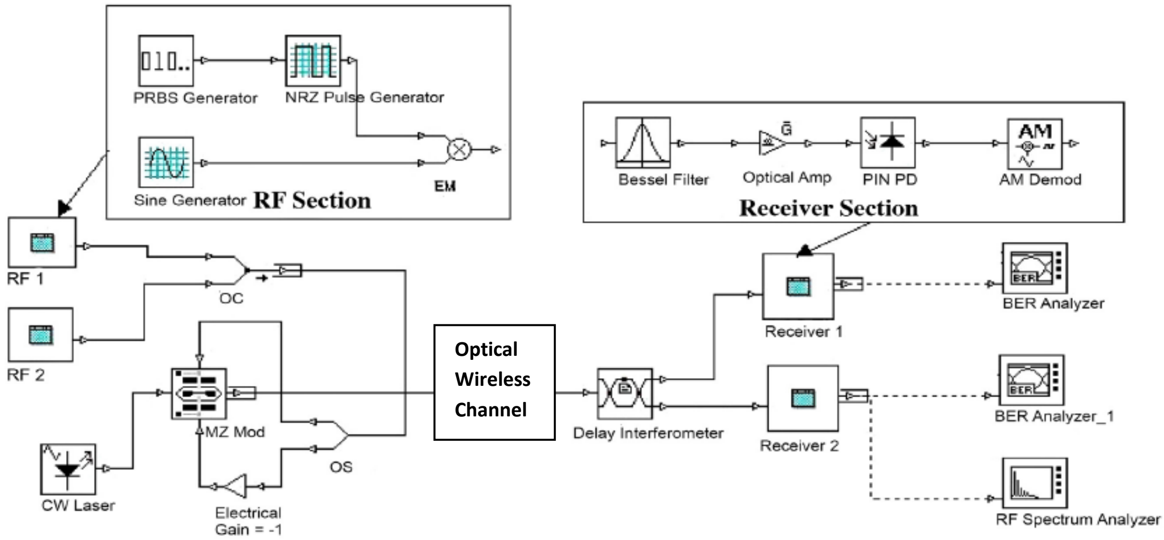

Fig.1. Schematic diagram of ODSB-SC Ro-FSO system

3.2 ATTENUATION DUE TO RAIN

In case of rain, the loss in optical power does not depend upon the wavelength. For rain empirical model is based upon the visibility range [9].

$$\alpha_{Rain} = \frac{2.9}{V}$$

4. RESULT AND DISCUSSION

For different visibility condition of Fog and Rain the performance of ODSB-SC RoF system is analyzed. Table 1 shows max Q factor at different Fog visibility condition and Figure 2.1, 2.2 , 2.3 & 2.4 shows the Eye Diagram for the 10 GHz receiver under different visibility condition of 500 m , 400 m , 300 m & 200 m.

Table 1. Max. Q factor at different Fog visibility

Visibility (meter)	Max Q factor
500	17.38
400	11.19
300	4.32
200	0

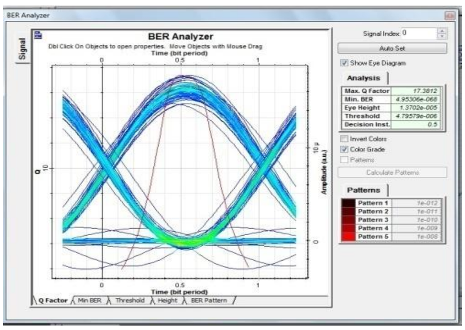

Fig.2.1 EYE Diagram at 500m Fog Visibility

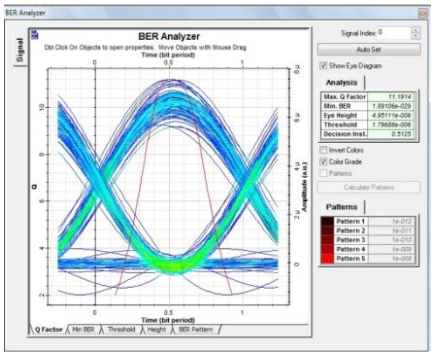

Fig.2.2 EYE Diagram at 400m Fog Visibility

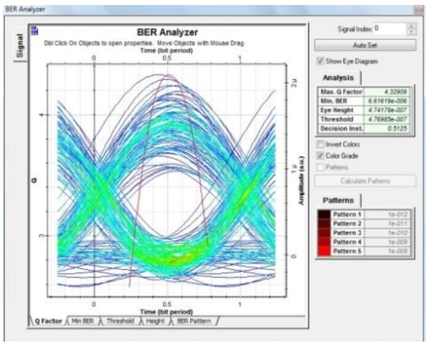

Fig.2.3 EYE Diagram at 300m Fog Visibility

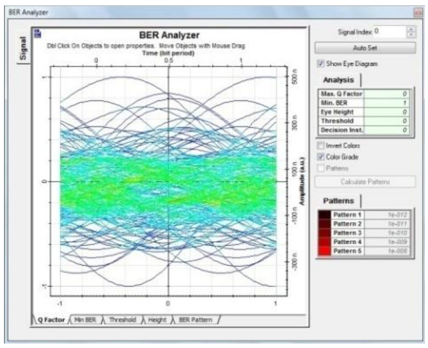

Fig.2.4 EYE Diagram at 200m Fog Visibility

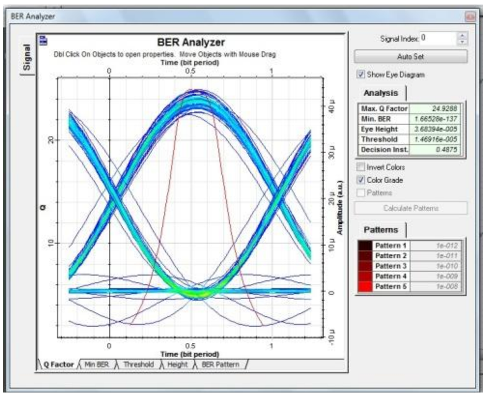

Fig.3.1 EYE Diagram at 500m Rain Visibility

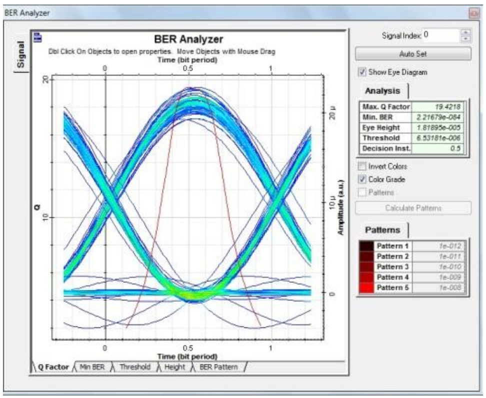

Fig.3.2 EYE Diagram at 400m Rain Visibility

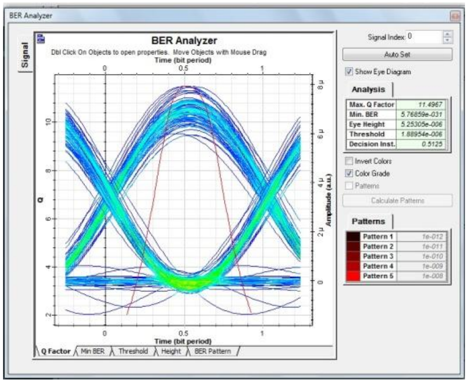

Fig.3.3 EYE Diagram at 300m Rain Visibility

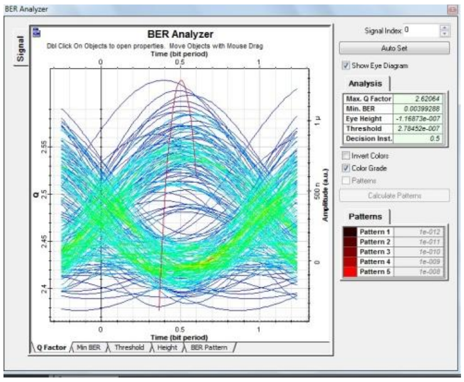

Fig.3.4 EYE Diagram at 200m Rain Visibility

In case of Rain attenuation also optical signal is analyzed at its different visibility. Table 2 shows max Q factor at different Rain visibility condition and Figure 2.1, 2.2 , 2.3 & 2.4 shows the Eye Diagram for the 10 GHz receiver under different visibility condition of 500 m , 400 m , 300 m & 200 m.

Table 2. Max. Q factor at different Rain visibility

Visibility (meter)	Max Q factor
500	24.92
400	19.42
300	11.49
200	2.64

5. CONCLUSION

In this paper simulation of 1Gbps data transmission is shown. It is found that due to Rain and Fog attenuation, signal in optical wireless channel highly attenuated. Attenuation of optical beam due to the rain is found low compared to the fog. It is also found that as the distance between transmitter and receiver increases the atmospheric effect over the link also increases.

The future work is to reduce the effect of atmospheric attenuation and to increase its range to get a high data rate Ro-FSO network.

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