Raised cosine/NRZ line coding techniques for upgrading free space optical communication systems through various levels of fog

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ABSTRACT

This study examines raised cosine/NRZ line coding techniques for upgrading free space optical (FSO) communication systems through various levels of fog. The max. Q factors are simulated and estimated for clear air, light fog, and moderate fog weather conditions at a data rate of 20 Gb/s. The optical signal to noise ratio is also measured for different weather conditions. The total power after both FSO channel and avalanche photodiode (APD) photo-detector receiver is estimated by an optical power meter for max. distances. The study shows that the max. propagation distance is extended to 50 km through clear air, 2.25 km through light fog, and 1.6 km through moderate fog with acceptable max. Q factor.

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1. INTRODUCTION

The demand for transmission bandwidth is increasing due to the increasing need to transfer data, especially high-definition video capture, which require a huge data size and high data rate to cover the live display, and on-air video conferencing and processing capabilities [1-4]. Expectations indicate that the demand for bandwidth will continue to increase. Now, the data is not just a matter of text chatting transfer or voice conversation [5-9], various types of data are transmitted with high data rate, size and resolution during applications and sites of social media, which are spreading day by day [10-13]. In order to support this mode of communication, a high bandwidth communication technology is needed [14-18].

The most important two methods to transfer data in free space are radio frequency (RF) and free space optical (FSO) communication. RF communication is used to fill the gap, but RF systems are hard pressed to meet the current bandwidth demands [19-26]. A best solution is free space optical communication, which relies on laser technology to provide fiber-like performance capabilities. Furthermore, free space optical communication offers other advantages such as immune to electromagnetic interference (EMI) and security. Nevertheless, it poses some shortfalls and limitations; these include susceptibility to varying weather conditions like heat from the ground and heavy fog or dust [27-33]. Many studies analyzed the attenuation of free space optical communication systems operating under different fog conditions and models were proposed for solution [34-37], this issue needs more studies.

2. RESEARCH METHOD

Figure 1 clarify the raised cosine/NRZ FSO channel model through various fog weather levels. User-defined generators generated stream sequences of bits and that were encoded by a raised cosine pulse generator within the electrical formation. The streams of bits were encoded through non–return to zero coding within the light formation. Laser rate equations generated the light signal. The electro-optic signals were injected into a dual-derive Mach Zehnder modulator and measured. The signal was modulated through electro-optic modulators. The modulated signal was amplified through erbium-doped fiber amplifiers (EDFA) amplifiers at a length of 5 m. The amplified signal was injected through a free space optics (FSO) optics communication channel at various weather conditions (clear air, light fog, moderate fog). The signal attenuation was 0.1 dB/km for clear air, 15.5 dB/km for light fog, and 25.5 dB/km for moderate fog.

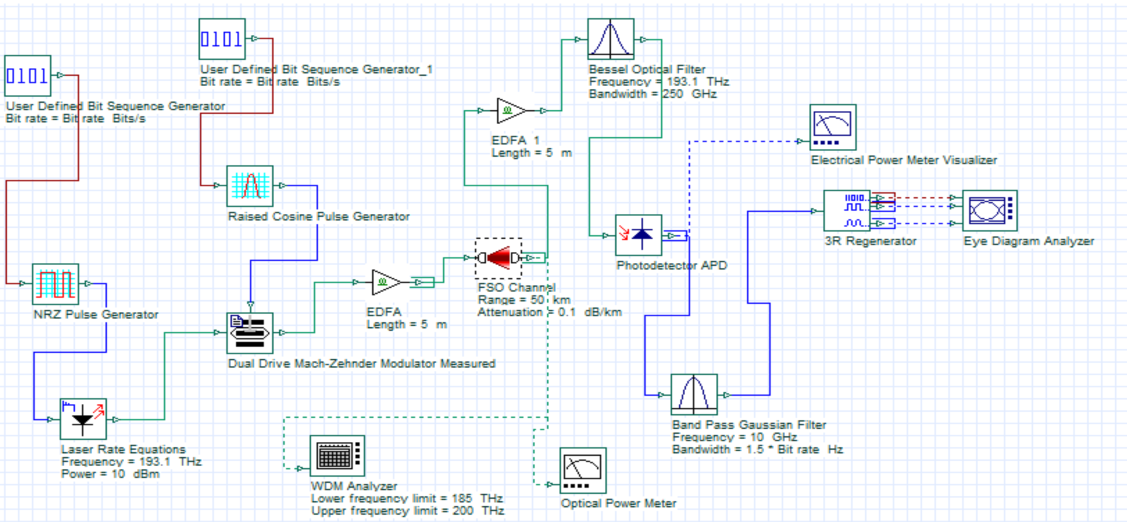

Figure. 1. Raised cosine/NRZ FSO channel model through various fog weather levels

The possible transmission distances were estimated for various weather conditions. The signal was treated through an optical Bessel filter. The light signal was converted to electrical signal form through avalanche photodiode (APD) light detectors. The electrical signal was treated through a band pass Gaussian filter whose operating frequency was 10 GHz. An optical power meter measured the light power through FSO channel. An electrical power meter measured the electrical signal after light receiver. Max. Q factor and min. BER could be measured at the receiver destination.

3. RESULTS AND ANALYSIS

All the simulation results are assured depending upon the parameters listed in Table 1. Figure 2 shows the max. Q factor variations versus FSO propagation distances through clear air weather conditions for the proposed and previous models. The max. Q factorswere 19.38 and 16 for the proposed and previous models, respectively, at a 10 km distance. At a distance of 30 km, the max. Q factors were12.43 and 9 for the proposed and previous models, respectively. The max. Q factorswere 2.81 and 1.65 for the proposed and previous models, respectively, at a 50 km distance.

Figure 3 shows the max. Q factor variations versus FSO propagation distances through light fog weather conditions. At 0.5 km, the max. Q factorswere 30.91 and 26.54 for the proposed and previous models, respectively. The max. Q factorswere 11 and 8.65 for the proposed and previous models, respectively, at 1.5 km. The max. Q factorswere 2.65 and 1.2 for the proposed and previous models, respectively, at 2.25 km.

Figure 4 indicates the max. Q actor variations versus FSO propagation distances through moderate fog weather conditions. At 0.2 km, the max. Q factorswere 29.58 and 27.65 for the proposed and previous models, respectively. The max. Q factorswere 18 and 12 for the proposed and previous models, respectively, at 0.8 km. At 1.6 km, the max. Q factorswere 1.23 and 0.954 for the proposed and previous models, respectively. Figure 5 shows the light signal/noise ratio with FSO propagation distance variations through various weather conditions for the proposed model. The light signal/noise ratioswere 33.5 dB, 15 dB, and 10 dB for clear air, light fog, and moderate fog, respectively, at 2 km. At 12 km, the light signal/noise ratioswere 15 dB, 7.5 dB, and 5 dB for clear air, light fog, and moderate fog, respectively. The light signal/noise ratioswere 3.32 dB, 1.5 dB, and 1 dB for clear air, light fog, and moderate fog, respectively, at 20 km.

Table 1. Parameters used in this proposed work

FSO Channel Specifications	
Frequency	1550 nm
Attenuation (Clear air)	0.1 dB/km
Attenuation (Light Fog)	15.5 dB/km
Attenuation (Moderate Fog)	25.5 dB/km
Tx. Aperture diameter	5 cm
Rx. Aperture diameter	20 cm
Beam divergence	2 mrad
Tx. /Rx. Pointing errors	0.1 µrad
Transmitter Specifications	
Frequency	193.1 THz
Power	10 dBm
Bias current	38 mA
Mod. Peak current	28 mA
Receiver specifications	
Gain	3
Responsitivity	1 A/W
Ionization ratio	0.9
Dark current	10 nA

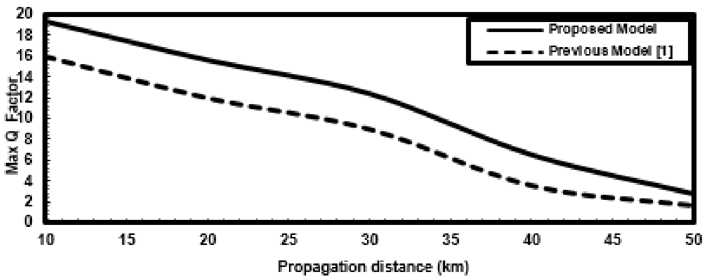

Figure 2. Max. Q Factor variations versus FSO propagation distances through clear air weather conditions for the proposed and previous models

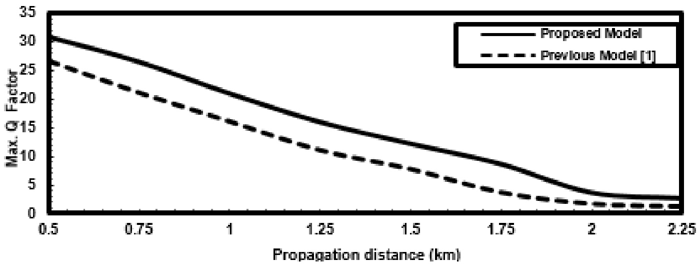

Figure 3. Max. Q Factor variations versus FSO propagation distances through light fog weather conditions for the proposed and previous models

Figures 6 and 7 show the total power in W and dBm after FSO channel/APD photo-detector receiver through clear air at a distance of 50 km. The total power was estimated to be 4.772 µW or -23.213 dBm through the FSO channel. The total power was estimated to be 3.069 mW or 4.870 dBm through the APD photo-detector receiver. Figures 8 and 9 indicate the total power in W and dBm after FSO channel/APD photo-detector receiver through light fog at a distance of 2.25 km. The total power was estimated to be 1.228 µW or -29.107 dBm through the FSO channel. The total power was estimated to be 301.86 µW or -5.201 dBm through the APD photo-detector receiver. Figures 10 and 11 show the total power in W and dBm after FSO channel/APD photo-detector receiver through moderate fog weather at a distance of 1.6 km. The total power was estimated to be 0.16649 µW or -37.786 dBm through the FSO channel. The total power was estimated to be 9.218 µW or -20.354 dBm through the APD photo-detector receiver.

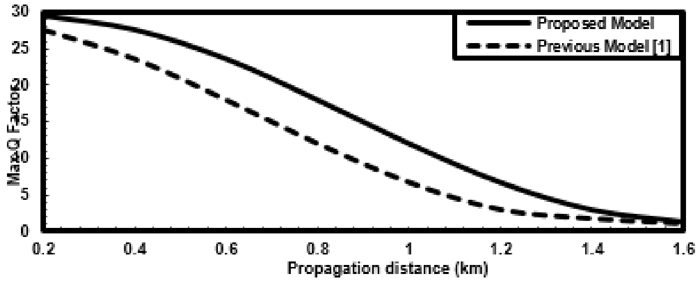

Figure 4. Max. Q Factor variations versus FSO propagation distances through moderate fog weather conditions for the proposed and previous models

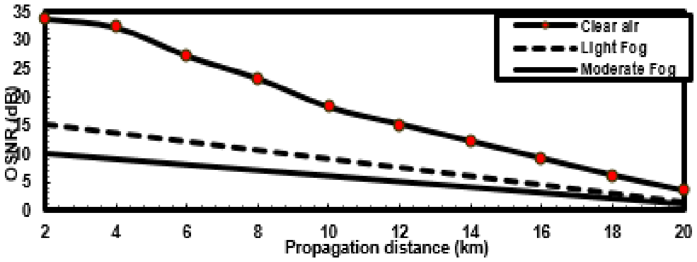

Figure 5. Optical signal to noise ratio with FSO propagation distances variations through various weather conditions for the proposed model

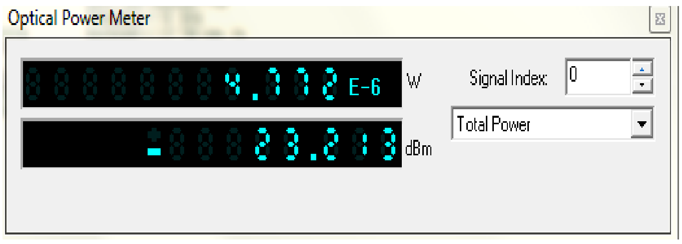

Figure 6. The total power in W and dBm after FSO channel through clear air weather at distance of 50 km

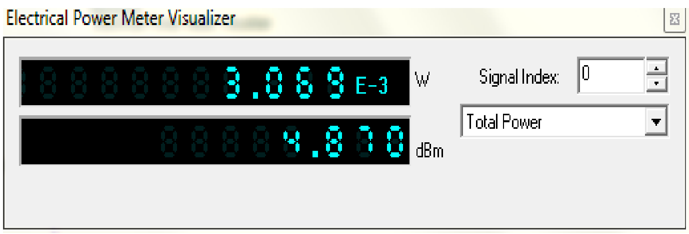

Figure 7. The total power in W and dBm after APD photo-detector through clear air weather at distance of 50 km

Figure 8. The total power in W and dBm after FSO channel through light fog weather at distance of 2.25 km

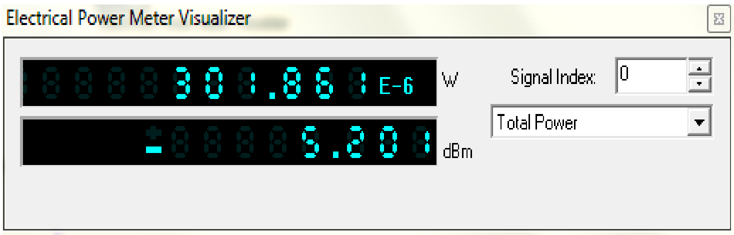

Figure 9. The total power in W and dBm after APD photo-detector through light fog weather at distance of 2.25 km

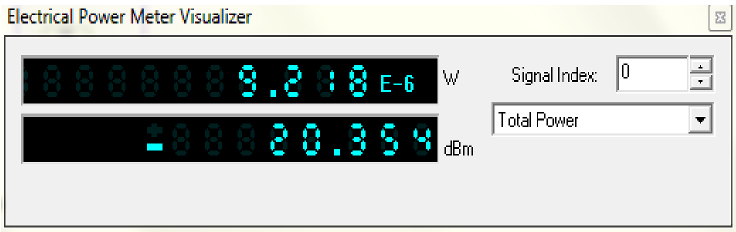

Figure 10. The total power in W and dBm after FSO channel through moderate fog weather at distance of 1.6 km

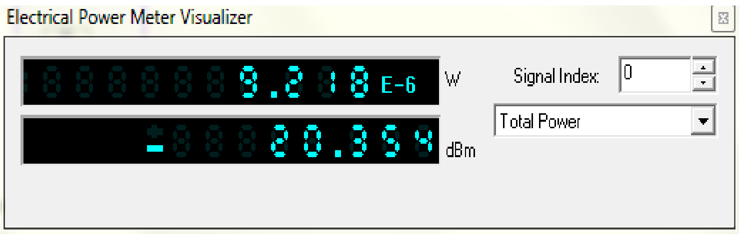

Figure 11. The total power in W and dBm after APD photo-detector through moderate fog weather at distance of 1.6 km

4. CONCLUSION

Raised cosine and NRZ line coding were employed in an FSO communication channel for the enhancement of optical transmission systems. The results show that the total power was 0.166 µW for the FSO channel and 9.218 µWfor the APD photodetector through moderate fog at a distance of 1.6 km. Through light fog at 2.25 km, the total power was 1.228 µWfor the FSO channel and 301.86 µW for the APD photodetector. The total power was 4.77 µW for the FSO channel and 3.069 mW for the APD photodetector through clear air at a distance of 50 km. The study found that the max. distances are 50 km, 2.25 km, and 0.6 km for clear air, light fog, and moderate fog, respectively, with acceptable max. Q factor.

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