Reduction of Optical Background Noise in Light-Emitting Diode (LED) Optical Wireless Communication

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Abstract- *Background optical noises generated by the conventional tungsten filament sources, fluorescent light sources, or atmospheric attenuation can significantly affect the performance of the LASER optical wireless communication. These are major source of interference in LASER optical wireless communication systems, which affects the performance and produce the challenges to implementation. The paper presents the results of mitigation of optical background noises using NRZ coding and Manchester coding techniques. We demonstrate using NRZ coding for the LASER to mitigate the optical noise for high data rate. Here no adaptive monitoring, feedback, or optical filtering is required. Experimental result shows that NRZ coding can significantly eliminate optical noise generated by the atmospheric attenuation and fluorescent light.*

Keywords- NRZ coding, Optical communications, LASER, Manchester coding, Noise mitigation, Free-space optical communication.

I. INTRODUCTION

Nowadays, Light emitted by Stimulated (LASER) is used for wireless optical communication for its various advantages. Free Space Optical Communication (FSO) system uses Light Emitting Diodes (LEDs) to produce a signal in near infrared range, i.e., they are operating at 780–900 nm and 1500–1600 nm [1]. FSO communication is gaining acceptance these days owing to low power and mass requirements, high data rates and unlicensed spectrum. Laser diodes which have operating wavelength centered at 1550 nm are generally preferred for FSO communication because of eye safety concern. The allowable safe power emitted by laser is fifty times more than the power emitted by the 800nm window laser. The factor of fifty gives up to 17 dB extra margin and thus can propagate over longer distances with high data rates. Some of the laser diode used in FSO communication system are : Vertical Cavity Surface Emitting Laser (VCSEL) at 850 nm, Fabry Perotat 1550 nm, distributed feedback lasers (DFB) at 1550 nm and Nd-YAG at 1064 nm [2].

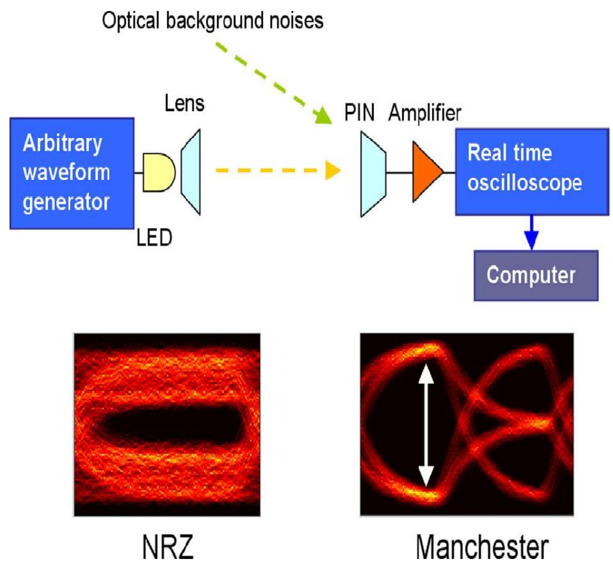

Fig.1- Basic Model of Optical wireless system

Figure shows the generation of optical background noises in LASER optical wireless communication system. In this block diagram an arbitrary waveform generator (AWG) generated a pseudorandom binary sequence (PRBS) of NRZ and Manchester electrical signals. These signals were then directly applied to a LASER light. The LASER has a 3-dB direct modulation bandwidth of about 1.25Gbps and 2.5Gbps. The white light was transmitted across free space via a pair of focusing lens and then received by a silicon based PIN diode. Then, the received electrical signal was amplified by an amplifier and recorded by a real-time oscilloscope. Manchester and NRZ coding can be used for the LASER to mitigate the optical noise. Another advantage of the Manchester coding is that it can provide signal synchronization and enhance the clock recovery. The experiment results show that the non-return-to-zero (NRZ) coding performs better than the Manchester coding. Manchester coding can mitigate the low-frequency background noises; although, it requires twice the modulation bandwidth of non return to- zero (NRZ) and limits the data rate of optical wireless system. Besides the Manchester coding, other forward error correction (FEC) techniques can also be used as the second layer of coding to further enhance the transmission performance.

II. PRINCIPLE

In Manchester-coded signal as shown in Fig. 2, the signal transition from low to high represents logic B1, while the signal transition from high to low represents logic B0. As shown in Fig.2, the Manchester signal can be generated by using exclusive-or (XOR) operation of the original NRZ data and the clock. This signal is applied to the LED source. At the receiver (Rx), the received Manchester signal will be power divided into two parts. One part will be half-bit delayed, as shown in Fig.2(c). The received Manchester signal will then subtract its half-bit delayed signal to obtain the output result.

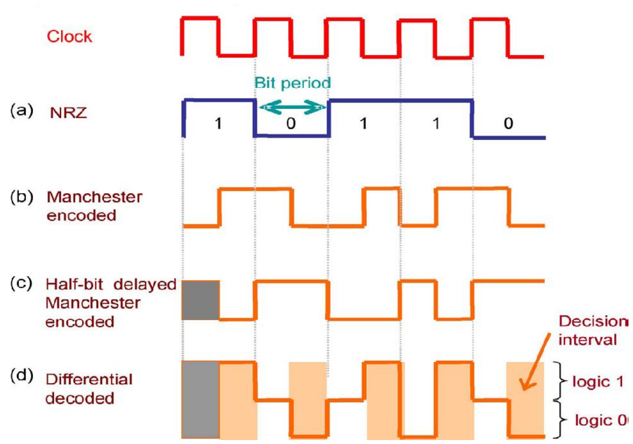

Fig.2. Coding Formats

III. FSO COMMUNICATION LINK DESIGN

FSO communication link design in Opt-Sim Weak turbulence based FSO channel compound component is shown in the Fig. 1(a). It consists of two blocks one is optical attenuator block that models additional and geometrical attenuation, and second is optical noise adder block that adds the background radiation to received signal. The FSO link consists of transmitter, channel and receiver and shown in Fig. 1(b). The transmitter consists of random binary bits sequence generator (PRBS), bits sequence to corresponding voltage signal generator (NRZ driver), and directly modulated LED. The transmitter's optical signal is the transmitted over FSO channel which has weak turbulence characteristics. The optical signal is then received by the receiver, which is a PIN photodiode and is followed by bit error rate (BER) tester. It also uses optical monitor for measuring received optical power (in dBm). Table 1 gives the various parameters with their values used in link design analysis.

Major challenges in FSO are absorption, scattering and turbulence. Out of these three, atmospheric turbulence plays a major role in degrading the quality of received signals. The turbulence in the atmosphere is caused by temperature gradient and wind velocities that create air pockets with rapidly varying densities and thus, changes the indices of optical refraction.

When optical beam propagates through such an un-homogeneous environment, it results in the intensities fluctuations of the received optical signal. This phenomenon is called scintillation. The fluctuations in optical signal caused by scintillation depend upon time of day and can vary during a hot day. It increases drastically with propagation distance and can affect the BER performance.

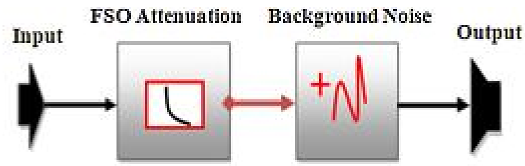

Fig.3 (a) FSO channel components with weak turbulence.

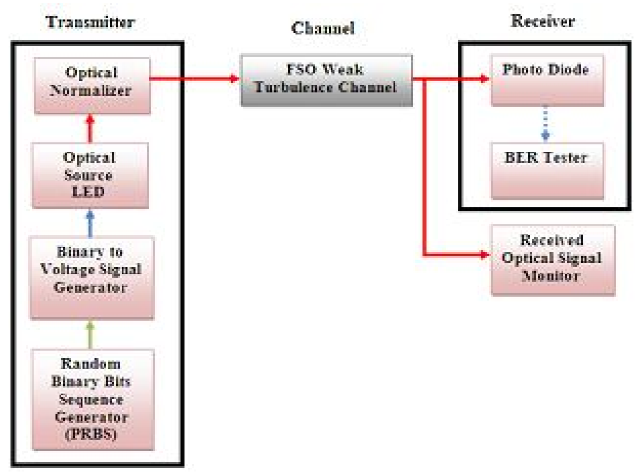

Fig.3 (b) FSO communication link block diagram.

Table1. Link parameters of FSO

S. no.	Parameter	Value
1.	Bit rate, f_b	1.25Gbps, 2.5Gbps
2.	Transmitter power, P_{TX}	3 dB m
3.	Distance, D	500 m
4.	Beam divergence angle, θ	3 mrad
5.	Environment attenuation, α	−4.92 dB
6.	Standard deviation, σ	1.9 dB
7.	Receiver's detector aperture area, A	180 sq cm

IV. SIMULATION RESULTS

This section presents various simulated results for analyzing the performance of FSO communication systems.

For 1000m distance, at two bit rates 1.25Gbps and 2.5Gbps, by using two coding NRZ and Manchester coding shows the comparative analysis has been shown.

Table2. BER of two codes at two data rates

S. No	ATTUN	BER Mancester 2.5 Gbps	BER NRZ 2.5 Gbps	BER Manchester 1.25 Gbps	BER NRZ 1.25 Gbps
1	0	2.05E-80	4.75E-113	1.35E-76	2.31E-113
2	-5	2.28E-28	2.95E-43	6.73E-40	1.24E-57
3	-10	1.38E-12	1.85E-16	4.67E-18	2.80E-23
4	-15	3.80E-05	2.38E-06	8.48E-07	4.13E-09
5	-20	1.43E-02	5.58E-03	2.63E-03	3.69E-04

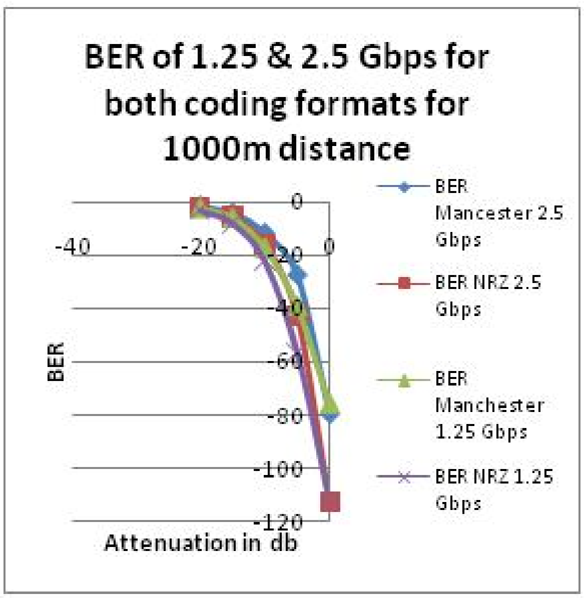

Fig.4. BER of 1.25 & 2.5Gbps for both coding formats for 1000m distance

Fig. 4 shows the BER performance versus environmental additional attenuation for different values of link distance (in meters). As the attenuation decreases, BER performance improves significantly. It can be seen from this figure, that BER of 10^{-10} can be achieved for distance for 500 m even at maximum attenuation (15 dB). But degradation in the BER performance is observed with increase in link distance. As the data rate increases the BER of Manchester raised stepper than NRZ.

Table3. Quality Factors measurement

S. no.	ATTEN.	Q M2.51000 m	Q M1.25, 1km	Q N2.5, 1km	Q N1.25, 1km	Direct
1	0	24.13	27.33	27.1	28.1	14.25
2	-5	20	20.82	22.76	25.2	9.8
3	-10	15.9	16.9	18.22	20.9	5.4
4	-15	10.95	11.95	13.2	16.2	2.12
5	-20	5.8	6.8	8.1	12.56	-2
6	-25	1.1	3	3.5	7.5	-9

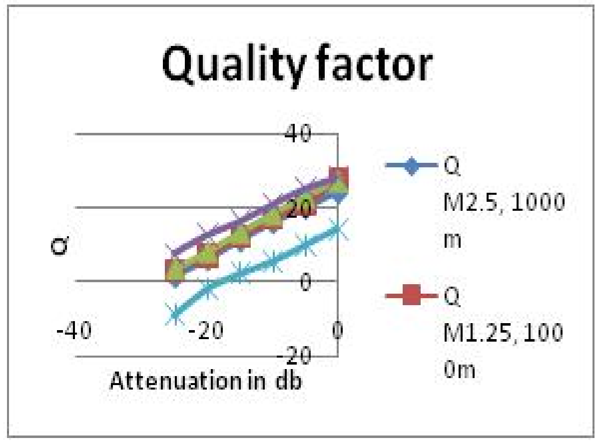

Fig. 5 Quality Factor at different values

Fig. 5 show that the quality factor have higher value for NRZ coding at 1.25Gbps for a distance of 1000m and it decreases with increase in data rate Manchester have comparatively low quality factor than NRZ and it also decreases with increase in data rate. Without any coding scheme power dissipation is much higher as compare to both the coding formats applying. NRZ with data rate at 1.25 Gbps shows the best case among all the combinations.

Table 4 Power dissipation.

attenu.	power 500m	power 1000m	power 1500m	power 2000m
0	-10.39	-22.74	-30.45	-33.36
-5	-20.72	-31.74	-38.9	-43.41
-10	-28.75	-41.74	-49.71	-54.51
-15	-40.09	-52.11	-58.29	-63.98
-20	-49.8	-62.74	-69.95	-74.8
-25	-60.36	-72.54	-78.58	-82.2

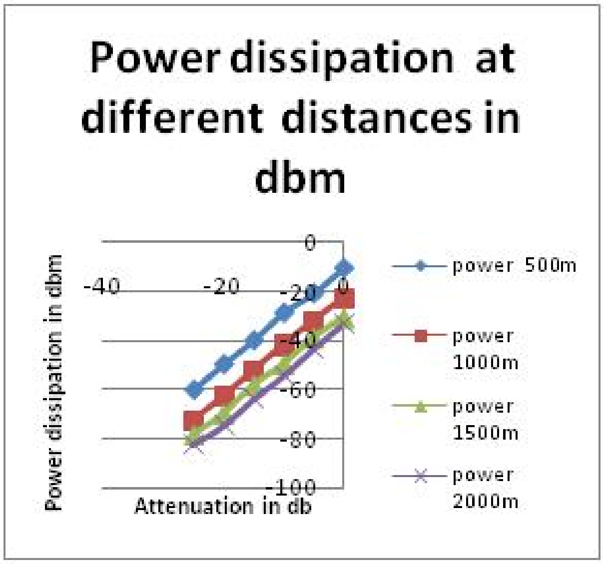

Fig. 6 Power dissipation at different distances.

Power dissipation neither depends on coding schemes nor depends on data rates. Power dissipation is proportional to the distance of transmission. The plot of received optical powers (in dBm) with varying environmental additional attenuation is given in Fig. 6. From this figure, it is seen that when attenuation has its maximum value, optical power received by the receiver circuitry is very less (below−28dBm). As attenuation tends to zero, optical received power also increase and has maximum value (−10.39dBm). These results show that as the distance increases power dissipation goes to increase.

Table5. BER at different distances

S. no.	attenu	ber 500m	ber 1000m	ber 1500m	ber 2000m
1	0	1.25E-250	1.35E-76	7.20E-70	1.10E-40
2	-5	9.58E-202	6.73E-40	4.78E-25	5.00E-14
3	-10	3.80E-63	4.67E-18	9.60E-09	1.50E-05
4	-15	2.58E-18	8.48E-07	7.78E-04	6.76E-03
5	-20	1.45E-07	2.63E-03	3.20E-02	7.60E-02
6	-25	1.27E-03	4.50E-02	1.60E-01	2.00E-01

It can be seen from the figure, that BER performance is better for lower data rates at lesser distances. For example, 1.25Gbps link can perform significantly well up till 1000 m giving a BER of 10−9at 1550 nm upto15db attenuation. Where, increase in value of BER is observed for higher data rates at same operating wavelength. BER increases logarithmically as the distance increases.

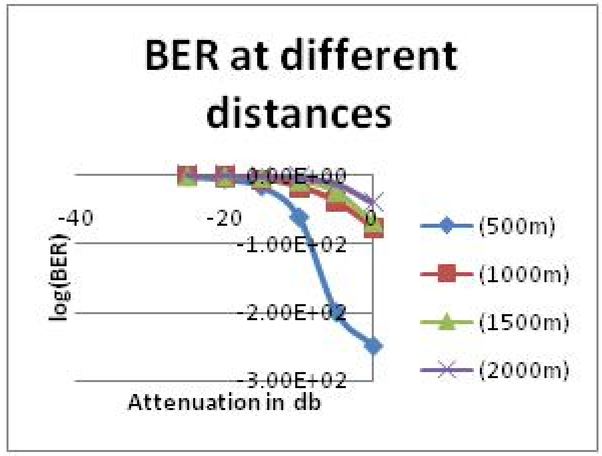

Fig.7. BER at different distances

V. CONCLUSION

In these papers, we studied the different techniques to reduce the noises in LED optical wireless communication. The analysis of proposed work & previous work, we conclude that if that for high data rate in laser sources NRZ coding effectively reduce the external noise and gives better result as compare to Manchester coding. As the attenuation is goes to increase due to external atmosphere the BER going to increase and the quality factor going to decrease. These two Factors also decreases if there is increment in any of the of factor like data rate or the distance.

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