International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 7 (2017) pp. 1401-1405


# The Performance of Varies Data Rate in Free Space Optical Communication System using Dual Diffuser Modulation

**M.F Talib, A.K Rahman, Anuar M.S, C.B.M.Rashidi, S.A Aljunid and Z. Ibrahim**

*School of Computer and Communication Engineering, Universiti Malaysia Perlis (UNIMAP), Perlis, Malaysia.*

**Abstract**

In this paper, we show the performance using varies data rate in free space optical communication system for a specific visual range and comparison between conventional technique and Dual Diffuser Modulation (DDM) technique to measuring bit-error-rates for free space optical communication system. The data rates used in this analysis are 155Mbps, 622Mbps, 2.5Gbps and 10Gbps. The effect of bit error rate in this varies data rate is depend on the range of FSO system. It shown that 155Mbps data rate is suitable used in FSO system for a long visual range. The comparison between technique shows that DDM technique can enhance the system performance in bit error rate and also improve the sensitivity of power received in the system.

**Keywords:** Free Space Optical;OOK Technique; DDM technique; Bit Rate; Power Received.

## INTRODUCTION

Free Space Optical (FSO) communication system is optical communication technologies that transmit data from point-to-point and multipoint using laser beam [1]. The latest technology in FSO which is design to deploy behind window has eliminating the need for costly rooftops rights. In terms of communication security, FSO provides far more secure than other wireless-based band transmission, such as uses narrow laser beam light making harder to intercept and crack [2].

The signal in FSO system are using a certain speed to make the data can transmit through the receiver. Synchronous Transport Module known as STM is the standard for transmitting signal over the optic network. STM-1 has a data rate of 155Mbps and these inputs are carried single mode optical signal. In STM-4, the input of the system use tributary unit for a future standalone data rate of 622Mbps. STM-16 using multiplexed signal to transmit and has data rate of 2.5Gbps and lastly STM-64 consist high speed processing part in optical transmission system and using 10Gbps data rate [3].

## BASIC DDM TECHNIQUE

Dual Diffuser Modulation (DDM) technique is upgraded based on conventional system of OOK technique. This technique operates using two transmitters. When first transmitter sends binary ‘1’, the second transmitter inverted the condition into binary ‘0’ in simultaneously and vice versa. The signal will through to the subtractor for differential detection process. When the system operates with ideal subtractor condition, no losses signal will occur. Therefore, the output signal detected ‘1’ when sending binary bit ‘1’ and become ‘-1’ when sending binary bit ‘0’. This modification technique particularly will improve the signal threshold detection and can reduce BER [4].

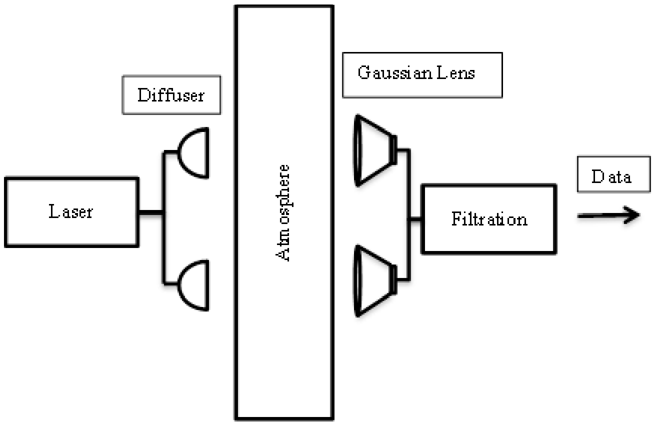



**Figure I:** DDM Block Diagram

## FSO SYSTEM PERFORMANCE

### *A. Performance Losses*

System performance of FSO can derived from the range equation which combines the attenuation and geometrical aspects to calculate the received power. The receiver’s sensitivity determines the amount of received optical power needed to achieve the required signal to noise ratio (SNR) for an expected communication performance. This parameter can be expressed as:

$$Received\ Signal, P_{Rec} = P_T G_T \tau_T \tau_{ATM} S G_R \tau_R \qquad (1)$$

$P_T$ = Total power

$G_T$ = Transmitter antenna gain

$\tau_T$ = Transmitter optical efficiency

$\tau_{ATM}$ = Atmospheric attenuation factor

S = Free space loss

$G_R$ = Receiver antenna gain

$\tau_R$ = Receiver optical efficiency

Where

The transmitter gain given by :

$$G_T = \frac{16}{\theta_T^2} \quad (2)$$

$\theta_T$ = Full transmitting divergence angle

Free space loss can be written as:

$$S = \left(\frac{\lambda}{4\pi L}\right)^2 \quad (3)$$

λ = Signal wavelength

L = Range

And Received antenna gain can described as:

$$G^R = \left(\frac{\pi D}{\lambda}\right)^2 \quad (4)$$

D = Receiver Diameter

In FSO system, the geometrical effect can reduce the optical power directly and make the laser beam spread from one end of the link into another. The geometrical effect can be calculated as [5]:

$$P_{Received} = P_{Transmitted} \frac{d_R^2}{(d_T + \theta R)^2} 10^{\frac{-\alpha R}{10}} \quad (5)$$

$d_R$= Receiver aperture diameter (m)

$d_T$ = Transmitter aperture diameter (m)

θ = Beam divergence (mrad)

R = Range (km)

α = Atmospheric attenuation (dB/km)

The bit error rate of the system depends on modulation format where the signal to noise ratio (SNR) contribution come from all possible sources which include signal shot noise, background noise and thermal noise in the photodetector. The SNR at the output of the photodetector is given by:

$$SNR_0 = \frac{2\Re^2\left(\left(\frac{\pi D^2}{4}\right)\left(\frac{P_o}{\pi W^2(L)}\right)\right)^2}{2e\Re B\left(\left(\frac{\pi D^2}{4}\right)\left(\frac{P_o}{\pi W^2(L)}\right)\right) + 2e\Re B\left(I_{sky} + I_{sun}\right) + \frac{4k_bT_nB}{R_L}} \quad (6)$$

D = Diameter receiver

W(L) = Beam spot size at receiver

$k_b$ = Bolztman's constant

$T_n$ = Temperature of receiver noise

B = Electrical equivalent noise bandwidth

$R_L$ = Load resistant

And

$$I_{sky} = \frac{N(\lambda)\Delta\lambda\pi\Omega_{FOV}^2}{4} \quad (7)$$

N(λ) = Spectral radiance of sky

$\Delta\lambda$ = Bandwidth of optical bandpass filter

$\Omega_{FOV}$ = Photocetector field of view angle

$$I_{sun} = W(\lambda)\Delta\lambda$$

W(λ) = Spectral radiant emittance of sun

The probability of error in FSO system can be denoted as:

$$BER_0 = \frac{1}{2}\left(\frac{SNR_0}{2\sqrt{2}}\right) \quad (8)$$

## FSO COMMUNICATION MODEL

Free Space Optical (FSO) communication system was modeled and simulated using OptiSystem software. This software can design and simulate every process of optical network. In this simulation test system, the following sources of system elements need to be state:

### *A. Optical Transmitter*

In subsystem of optical transmitter, there are four part that contain in this subsystem to transmit the signal. First is Pseudo-Random Binary Sequence (PRBS) generator. This subsystem operates using different modes. The sequence of the bit is designed to exact the characteristics of random data. The information or the data will represent in this subsystem. The output is binary pulse sequence of '1' (ON) and '0' (OFF). The second is Non-Return-to-Zero (NRZ) electrical pulse generator. The data from PRBS will encode in this subsystem using encoding technique and binary coding. The third subsystem is Continuous Wave (CW) Laser that generates a wave of optical signal. Last subsystem is Mach-Zehnder modulator. This subsystem using an analytical model and receive the light source from the laser and the pulse generator [6].

### *B. Channel*

Free Space Optical (FSO) channel is a tool using a principle of laser beam from transmitter through the atmosphere into receiver. This subsystem contains two telescopes and the free space channel between them.

### *C. Optical Receiver*

In optical receiver contain five part of subsystem. The first is Photodetector PIN. The incoming optical signal and noise bins are filtered in this subsystem. Second subsystem is Low Pass Bessel Filter. This subsystem filters the signal using a Bessel frequency transfer function. Third is 3R Regenerator that regenerates an electrical signal. It generates the original bit sequence and regulated electrical signal to be utilized for BER examination. The forth is BER Analyzer and its function are display the graph of optical signal. It can display the result of error rate signal and Q factor after simulation run. The last is Electrical Power Meter function to generates the power receive of the system.

## RESULT AND DISCUSSION

In this paper, the simulation of FSO system is designed to find the suitable data rate in a specific visual range of FSO to minimum the bit error rate. Table 1 shows the parameter that need to setup before simulate this analysis. Same parameters are setting for both techniques.

**Table I:** FSO PARAMETER

| ***Name*** | ***Value*** |
|---|---|
| Wavelength | 1550nm |
| Transmitter aperture diameter | 5cm |
| Receiver aperture diameter | 20cm |
| Beam Divergence | 2mrad |
| Power Transmit | 10dBm |

Figure II shows the optical spectrum analyzer of FSO system at wavelength 1550nm in a 155Mbps data rate with an acceptable BER of $10^{-9}$.

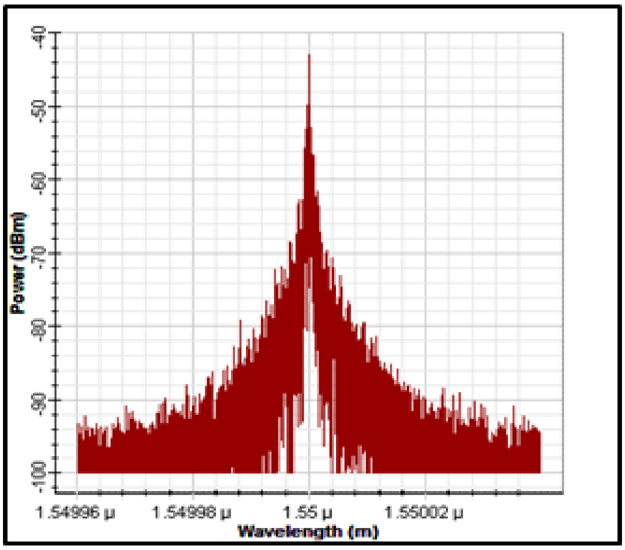
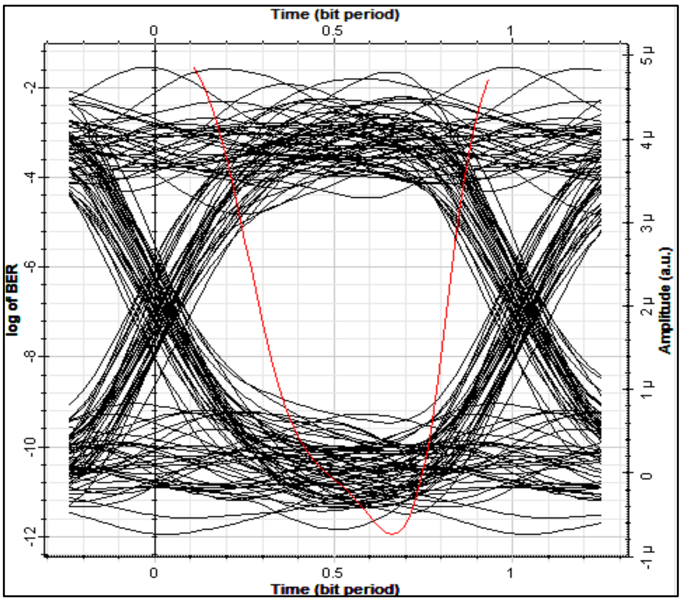
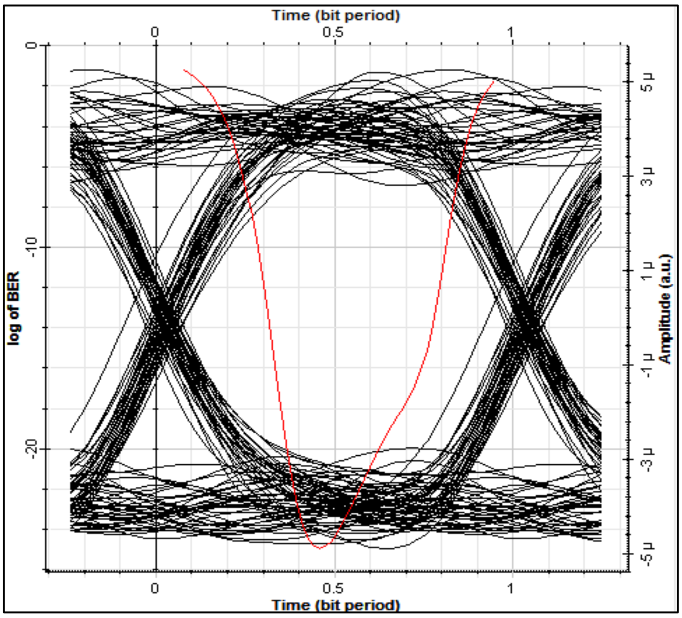



**Figure II:** Optical Spectrum Analyzer




(a)




(b)

**Figure III (a)** Eye Diagram Of Ook Technique
(B) Eye Diagram Of Ddm Technique

Figure III show the eye pattern in conventional technique of free space optical communication system that is OOK technique and purpose technique that is DDM technique. This pattern generates using a simulation analyzer and looks like a series of eyes between a pair of rails. By using the parameter of 5km range and 155Mbps data rate to trigger the process, we can see the opening eye that is from peak to peak in this OOK technique pattern is small and got many scattering noise in the signal compare to the pattern of DDM technique. The interference of noise in the signal is low and make the eye of the pattern in DDM technique bigger as well as make the signal transmit can transfer the data with a good bit error rate in the system performance.

Figure IV shows the comparison of oscilloscope signal visualizer between varies data rate in free space optical communication system. The visualizer display electrical signals in the time domain that can display the signal amplitude and autocorrelation. The visualizer represents the signal and noise by using parameter of 5km range and 1550nm wavelength. 155Mbps and 622Mbps data rate show that the noise is small and makes the signal can transfer the data with a little loss. When using high speed of data rate that is 2.5Gbps and 10Gbps, the signal can transfer the data with a faster speed but the noise in this system is high and makes the signal received with a high losses. It can disturb the operation of data transfer in the system.

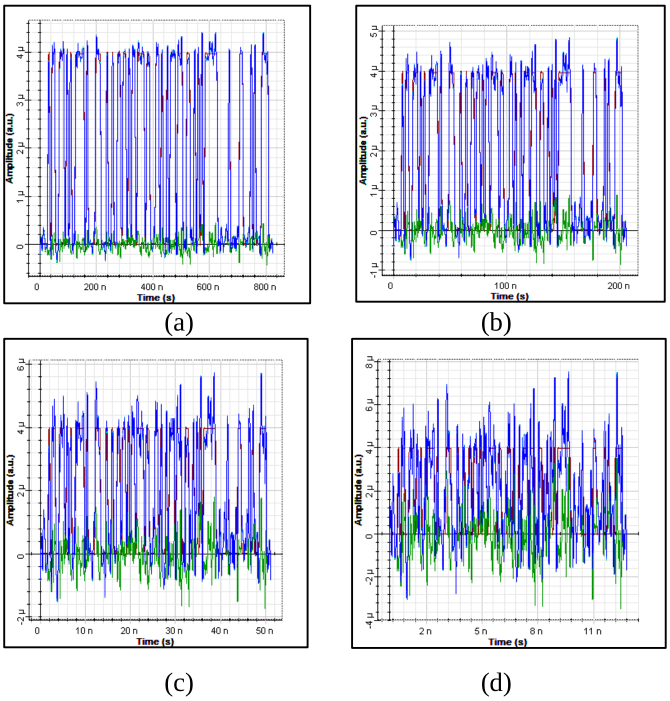



**Figure IV:** Signal Plus Noise of (a) 155Mbps (b) 622Mbps (c) 2.5Gbps and (d) 10Gbps

Figure V shows the comparison between varies data rate of 155Mbps, 622Mbps, 2.5Gbps and 10Gbps and different technique used that is conventional technique of OOK and propose technique is DDM in a free space optical communication system. The performance between this varies data rate and different technique was carried out to find the minimum bit error rate for a certain visual range. The minimum of BER in a free space optical communication system that can be accepted is $10^{-9}$. By using a constant power transmits of 10dBm, it shows that 155Mbps of data rate can achieve 7km visual range compare to 10Gbps of data rate only 2.2km. High speed of data rate transfer in the FSO system cannot transmit with a long distance due to the high data losses. This phenomenon occur when the sensitivity of bit signal in a high speed data transfer producing dispersion signal. For the comparison between techniques in a 155Mbps data rate, it shows that DDM technique makes an improvement of 28.5% in a magnitude of BER compare to the conventional technique OOK.

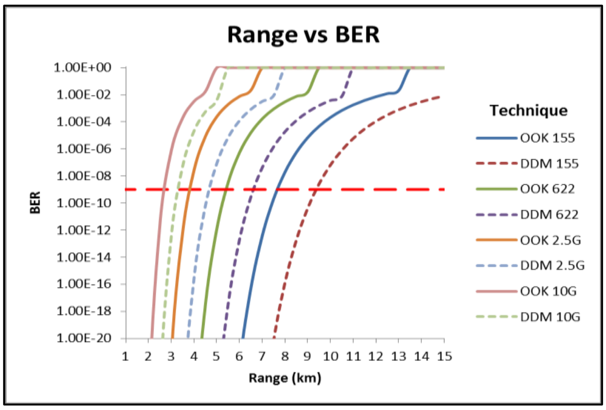



**Figure V:** BER against Range

Figure VI shows the comparison between effective power received for varies data rate and different technique in free space optical communication system.The wavelength for this analysis is 1550nm with a specific visual range same as figure V. In this figure, it shows that 155Mbps data rate is more sensitivity to detect a weak signal compare to 10Gbps data rate. The conventional technique for 155Mbps can achieve power received of -88.9dBm compare to 10Gbps data rate only -70.5dBm. For the comparison between technique, in 155Mbps data rate show that DDM technique make an improvement of 0.9% more to the OOK technique to detect the sensitivity of signal received in an acceptable condition of BER $10^{-9}$.

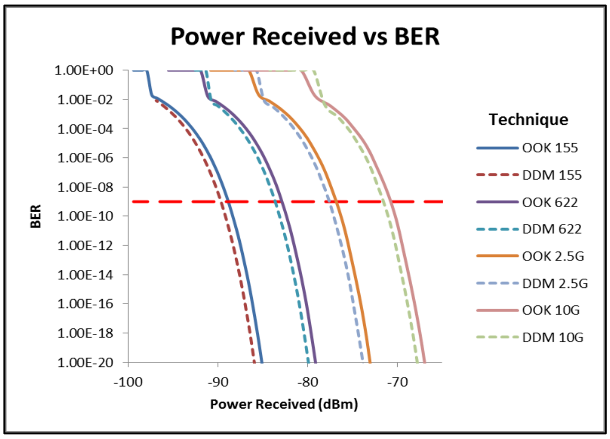



**Figure VI:** BER against Power Received

## CONCLUSION

In this analysis, the simulation results shows that 155Mbps data rate is suitable to use in a long range of free space optical communication system because of the visual range in a conventional technique can achieve 7km in acceptable of bit error rate $10^{-9}$. The high speed of data rate 10Gbps can be used for the low range of the system. 155Mbps data rate also more sensitive to detect the signal transmit in the system compare to the other data rate. Result shows that, the improvement of 20% magnitude of BER makes DDM technique can enhance the system performance in free space optical communication system compare to the conventional technique OOK.

## ACKNOWLEDGMENT

This works was support by the High Ministry of Education Malaysia under Fundamental Research Grant Scheme (FRGS) #9003-00556

## REFERENCES

[1] Al-gailani, S. A., Mohammad, A. B., & Shaddad, R. Q. (2012). Evaluation of a 1 Gb / s Free Space Optic System in Typical Malaysian Weather, (October), 1–3.

[2] Arun K. Majumdar and Jennifer C. Ricklin, Free Space Laser Communication, Springer, New York, USA (2008)

[3] Cho, J. I., Lee, T. H., & Lee, Y. K. (1997). A scheme of accommodating tributary signals in lOGbps transmission system, (September), 9–12.

[4] A. K Rahman, Anuar M.S., S. A Aljunid, M. N Ismail, B.S Naimullah,.Study of Rain Attenuation with Diversity

of Wavelengths Propagation Transmission in Tropical Rainforest Region, 2008 International Conference on Electronic Design, ICED (2008) 4786713.

[5] H.Weichel, Laser beam Propagation in the Atmosphere, SPIE, Bellingham, WA (1990).

[6] W. H., Flannery, B. P., Teukolsky, S. A., and W.T Vetterling, Numerical Recipes, C. Cambridge University Press, (1991).