University of Huddersfield Repository

Buhafa, Adel M, Al-Nedawe, Basman, Sibley, Martin J.N. and Mather, Peter

MATLAB Simulation for DiPPM over Diffuse Optical Wireless Communications

Original Citation

Buhafa, Adel M, Al-Nedawe, Basman, Sibley, Martin J.N. and Mather, Peter (2013) MATLAB Simulation for DiPPM over Diffuse Optical Wireless Communications. In: Proceedings of Computing and Engineering Annual Researchers' Conference 2013 : CEARC'13. University of Huddersfield, Huddersfield, pp. 127-132. ISBN 9781862181212

MATLAB Simulation for DiPPM over Diffuse Optical Wireless Communications

Adel M. Buhafa, Basman M. Al-Nedawe, Martin J. N. Sibley, and Peter J. Mather
University of Huddersfield, Queensgate, Huddersfield HD1 3DH, UK

ABSTRACT

In this paper computer simulation is presented for dicode pulse position modulation (DiPPM). DiPPM system offers good performance and operates at only twice the original PCM, thus it is very simple to implement in comparison to other PPM modulations. This makes DiPPM an extremely attractive modulation scheme for indoor optical wireless applications. MATLAB/Simulink has become the universal mathematical and modelling tool in most universities and research laboratories around the world. Studying complex models in optical link communications may be simplified by using simulation models so that real and industrial applications can be approached.

The DiPPM is implemented over a diffuse optical wireless link using an LED at a wavelength of 1550nm and data rate of 1Gb/s. The data sequence, coded by using DiPPM coder, is convolved with the diffuse optical link then received and decoded by DiPPM coder to get the original data signal. The indoor diffuse channel model which considers additive white Gaussian noise (AWGN) model as more appropriate for significant background light has been simulated and bit error rate (BER) has been calculated.

Keywords: DiPPM, Simulink, Optical System, BER.

INTRODUCTION

The requirement of using wireless local area networks (LANs), with high capacity backbone and short range communication links, for accessing portable computers and telecommunication devices has rapidly grown in offices, medical facilities, manufacturing plants, business establishments, shopping areas and houses. In these arenas, mobile users need to access to similar high speed network modules that supported wired services.

Designing LANs with high data rates needs a large bandwidth. Radio systems can give a reasonably high data rate, but can only support limited bandwidths, due to spectrum limitation and interference. Optical fibre cable offers an attractive alternative to these requirements, but with some inherent problems in setting up and in its expansion. Alternatively, optical wireless systems have been widely investigated and seem to be ideal for future wireless communications [1-3]. Practically, optical wireless systems (indoor or outdoor) offer all the advantages of optical fibre links with fast installation and low cost, and have more advantages than radio systems as a medium for indoor wireless communications. Many types of modulation schemes have been investigated for optical communication systems each with its particular advantages and disadvantages. Theoretical modeling of the optical systems can be difficult because it requires knowledge of optical dispersion, as well as optical sources and photodetector translation models. Therefore, computer simulation plays an important role in for design, implementing, and system optimization. MATLAB software and integrated Simulink can be used as real time simulation. Simulink blocks are designed for operators to implement and develop mathematical and algorithms structures [4, 5].

In this paper, simulation modelling of DiPPM scheme is applied to the diffuse indoor optical wireless link based on the impulse response of the ceiling bounce model. The simulation results show that the DiPPM modulation technique can be implemented on a diffused channel transmission. In the second section of the paper the DiPPM transmitter is described with the binary sequence coded by DiPPM coder being used as the input to the optical source. In the third section, the output of the transmitting section is propagated in a diffuse mode. The simulation displays the convolution processing between the LED pulses and the ceiling bounce impulse response. In the fourth section, at the receiver side, the simulation results show how the optical signal is received by the photodetector and regenerated by the DiPPM decoder to get the original data sequences. The Bit Error Rate (BER) is calculated in fifth section. The conclusion about using MATLAB/Simulink for implantation of DiPPM is presented in the last section.

MODELLING AND SIMULATION OF DiPPM SYSTEM

The basic block diagram of the optical wireless link using DiPPM coding system is shown in figure 1. It consists of an optical transmitter, optical source (LED), optical link, photodetector, and optical receiver. On the transmitting side, the optical transmitter converts the input signal into a current used to modulate the optical source. The optical output propagates through a wireless indoor link. The reflected optical signal is collected by a photodetector. The optical receiver uses the photodetector to convert the optical signal into an electrical signal and amplifies it to be treated as a digital signal. The model of the transmitter involves a signal generator that generates pseudorandom data binary values 0 and 1 which is used as the input to the optical source LED. The input data to the LED is coded by leading coding based on DiPPM technique. The transmission bit rate and signal level are defined using Matlab/Simulink. The transmitter does not need to be aimed at the receiver since the radiant optical power is assumed to reflect from the surfaces of the room [6-10].

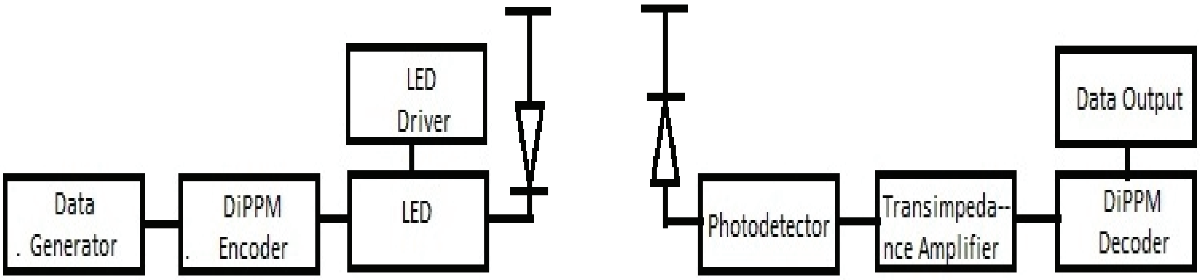

Fig.1 Block Diagram of the Optical Wireless Diffuse Link

The SIMULINK SIMULATOR

This section outlines a number of models which can be used to simulate the transmission of optical signals over a diffuse wireless transmission link. This simulator prototype is completed using MATLAB/SIMULINK. The first prototype that was designed in MATLAB/SIMULINK is the DiPPM transmitter. The first stage of that design is signal modulation, where the signal is modulated with a random binary generator. The second stage involved in import of the DiPPM coder to the Simulink prototype by using DSP builder HDL (Hardware Description Language). Import tools which used to convert HDL RTL (Register Transfer Level) files into DSP Builder models. The HDL files can be VHDL, Verilog or Quartus II project files, the last is implemented in the existing simulator. The DiPPM coding instruction has been written by VHDL language and the overall project files is created by Quartus II software [11, 12].

The next stage is the optical diffuse propagation model which is designed using the convolution of the infrared signal (LED Simulink block) and the channel impulse response of the ceiling bounce. This propagation model is fitted into this MATLAB/SIMULINK model. The model for diffuse indoor optical wireless link adopted here is proposed by Carruthers & Kahn [13]. This method is based on the ceiling bounce functional model to obtain the channel impulse response. The impulse response based on ceiling bounce model is given by

$$D_T = \frac{D_{rms}}{T_s} \tag{1}$$

where T_s is the pulse time slot.

For the simple base model, the transmitter and the receiver have the same separation distance from the ceiling, and so are co-located, hence the impulse response $h_c(t)$ is

$$h_c(t) = \frac{6a^6}{(t+a)^7}u(t) \tag{2}$$

where, u(t) is the unit-step function and **a** is a constant depends on the room height, transmitter and receiver positions. The parameter *a* is related to the D_{rms} by

$$D_{rms} = \frac{a}{12}\sqrt{\frac{13}{11}} \tag{3}$$

The last stage is the optical receiver, where the signal is received by photodetctor and passed through trans-impedance amplifier, both involved in one Simulink block. The final Simulink block is the DiPPM decoder that imported by using DSP builder HDL, also it has been written by VHDL language.

DiPPM Transmitter

DiPPM coding is a new technique proposed by M. J. N. Sibley [6], The DiPPM technique is illustrated in Fig.2. Two signals SET and RESET are converted into two pulse positions in data frames. If no data transition is present, there is no pulse, while if transitions occur from zero to one or one to zero there are SET(S) and RESET(R) pulses, respectively. If the PCM data is constant, no signal is transmitted. This modulation formats the output data on an optical carrier by switching the light signal on or off depended on the coding value 0 or 1.

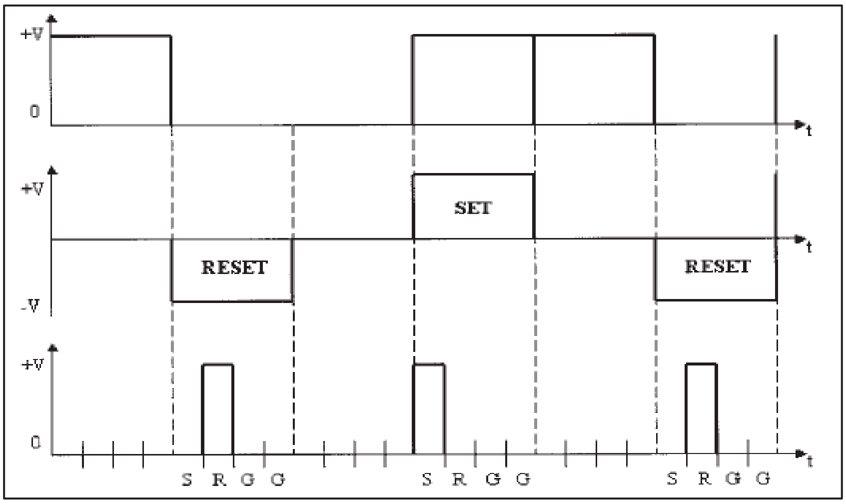

Fig.2 Conversion of PCM data (top trace) into dicode (middle trace) and DiPPM (bottom)

Figure 3 shows the block diagram of DiPPM coding and LED in Simulink models. The binary codes generated by random signal generator and then coded by DiPPM coder, this sequence is injected to the LED optical source. The simulation results in figure 4 show how the response of the LED which will be propagated and reflected after convolution process with the impulse response of the ceiling bounce reflector, which plotted in next section.

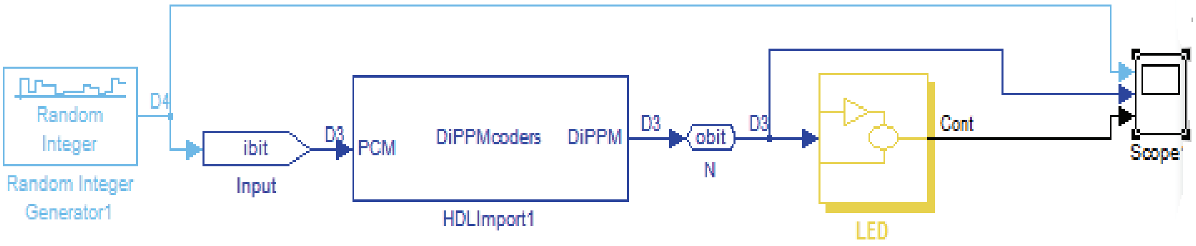

Fig.3 Block Diagram of DiPPM Coding and LED Response

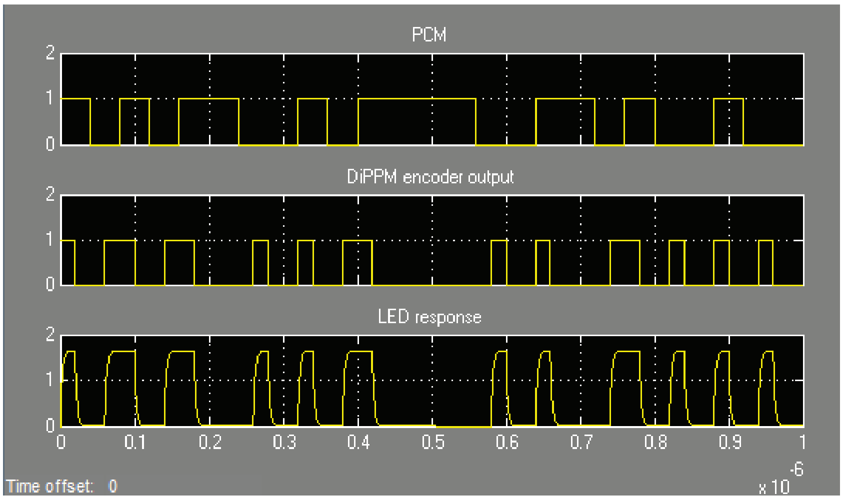

Fig.4 Simulation Results of DiPPM Coder and LED Response

Convolution Process

The impulse response based on the ceiling bounce model in equation (2) is written in MATLAB m.file, as it is complicated to transfer it to s-domain. In figure 5 below the file is imported to the Simulink prototype using (From Workspace) block. The (From Workspace) block reads data from a workspace and outputs the data as a signal. The signal output is convolved, by using Simulink Convolution block, with the diffuse propagated signal from LED output. Figure 6 shows the simulation results of the convolution process, the outputs are assumed to be received by the photodetector at the receiver side.

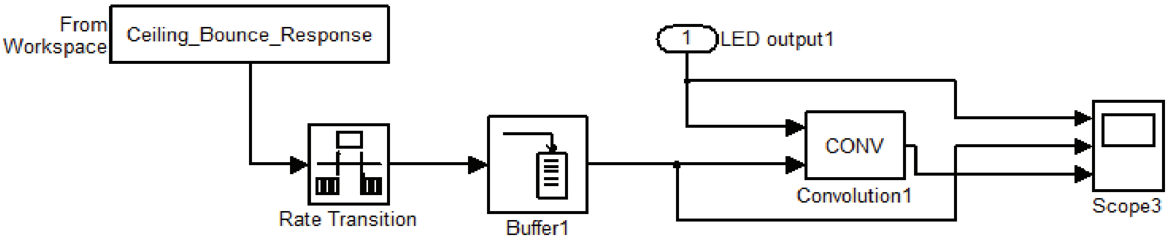

Fig.5 Simulink Block for Convolution Process

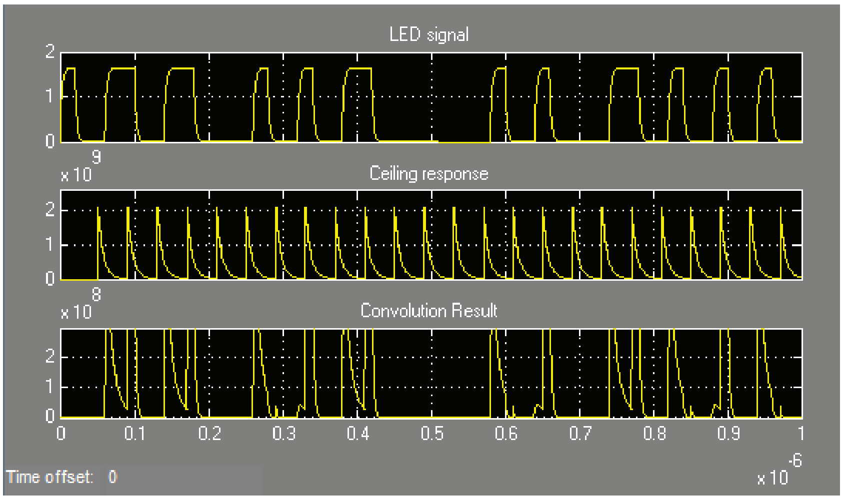

Fig. 6 Simulation Results of the Convolution Process

DiPPM Receiver

The overall receiver model is shown in Figure 7. The input current to the receiver, generated by the photodiode, is extremely small thus a pre-amplifier is needed to amplify this signal. The preamplifier has a simple first-order frequency response. This typology is referred to as a trans-impedance amplifier. The Simulink model is designed according to these requirements. The received pulses from the output of the convolution processor are matched to the photodiode by using Smulink-PS Converter, which converts the Simulink output to a physical signal, and at the input of the DiPPM decoder the physical signal converted into Simulink output signal [11]. Figure 8 shows the simulation results of the optical signals received by photodetector and decoded by DiPPM decoder

In this case we assume that the channel is non-dispersive. The received pulses of the wireless diffuse link are produced from the convolution of optical transmitted pulses and the impulse response of the ceiling bounce model. There are some errors due to signals interferences. The main source of interference is the signals received from the other users that are transmitting simultaneously, which produced from optical multiple access interference. Interference due to fluorescent light is assumed to be negligible compared with the optical multiple access interference. Therefore, Bit Error Rate (BER) will be calculated, next, according to Additive White Gaussian Noise (AWGN) [14, 15].

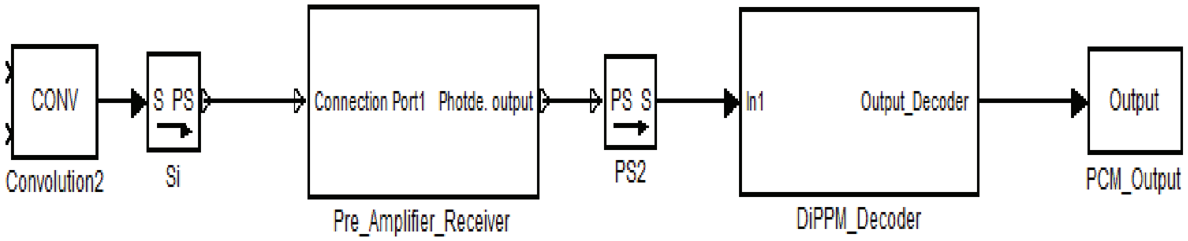

Fig.7 Simulink Model of Optical Receiver

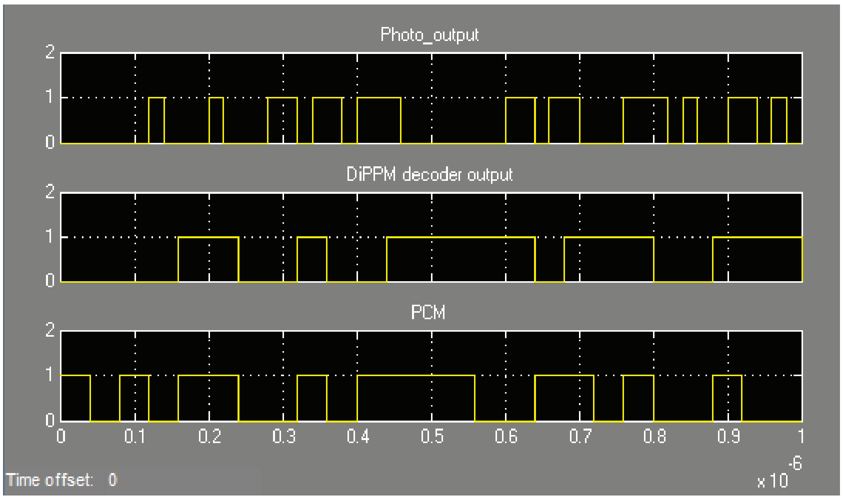

Fig.8 Simulation Result of the Optical Signals at the Receiver

BER Calculation

A necessary parameter in evaluating the system performance of any optical transmission system is the receiver sensitivity, which defined as the minimum average optical power for a given Bit Error Rate (BER). A good receiver means a receiver with high sensitivity, it is important to study the different parameters that have significant effects on overall receiver sensitivity. In other words for any communications system the better the receiver sensitivity the better the system performance [16].

The higher the data rate the less receiver sensitivity will be because at the receiver more power is required to support the higher data rate. Optical power is limited by eye and skin regulations, thus high sensitivity is required. To achieve the best optical sensitivity, it is important to maximize the signal before data decision. In optical system and for a given delay spread increasing the data rate leads to shorter pulses, increasing the effect of ISI and degrading the system performance. The degradation of system performance due to unwanted high ISI will reach a point where the BER is irreducible at any rate of transmission power [17].

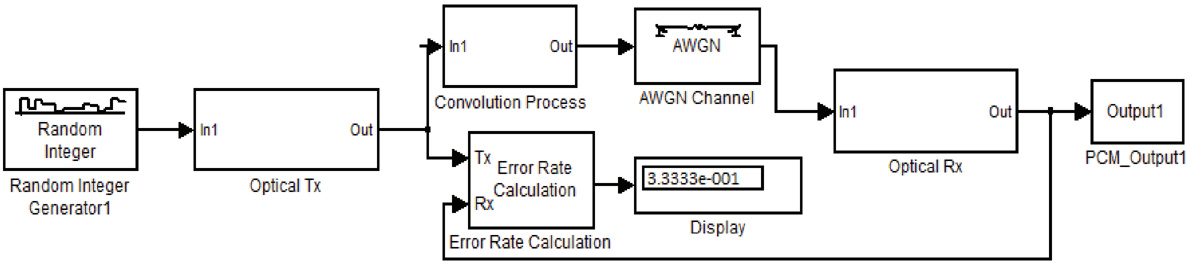

Fig. 9 Simulink Model of BER Calculation

Practically, improved receiver sensitivity offers more freedom to system designer to make trade-offs between system performance and economics. Increasing a data rate with significant receiver sensitivity is achieved by using suitable modulation techniques. Monitoring of data received that the output of the receiver is required to obtain the data for evaluation of the BER [17, 18]. The Simulink models, in figure 9, show how to calculate the BER performance in presence of Additive White Gaussian Noise (AWGN) that involved due to channel distortion. Tx and Rx outputs are connected to error rate calculation model. The numerical simulation shows the error rate is 3.333e-1 at data rate of 1Gb/s, which means a bad connection link. There are many types of error correction techniques can be used, such as Maximum likelihood and Reed Solomon code.

CONCLUSIONS

The design of a high performance indoor optical diffuse wireless link with a high bit rate is dependent on the channel propagation and the impulse response of the reflecting surfaces. Using MATLAB/Simulink, a simulation of dicode pulse position modulation (DiPPM) over an indoor diffuse optical wireless system has been done. The simulation results show the response of the LED to the DiPPM coding. They also show how the LED output is convolved with the impulse response of the ceiling bounce reflector. As the AWGN is introduced into the Simulink model, the BER is calculated for system performance at 1Gb/s. Error correction of any modulation technique is required for system performance improvements.

REFERENCES

[1]J.M.Kahn and J.R.Barry, “Wireless Infrared Communications,” Proceedings of the IEEE, vol. 85, no. 2, February 1997, pp. 265-298.

[2] J.R.Barry et al. “High speed-Non-Directive Optical Communication for Wireless Network,” IEEE Network, vol. 5, no. 6, Nov.1991, pp. 44-54.

[3] A.Moreira, R.Valadas, and A.Duarte, “Performance of Infrared Transmission Systems Under Ambient Light Interference,” IEE Proc. Optoelecronics, vol. 143, no. 6, Dec. 1996, pp. 339–346

[4] Elrefaie, A.F., J.K. Townsend, M.B. Romeiser and K.S. Shanmugan, 1988. Computer simulation of digital lightwave links, IEEE J. Selected areas in Communicat., 6 (1): 94-105.

[5]. Pires, V.F., J. Fernando and A. Silvia, 2002.Teaching Nonlinear Modeling, Simulation and control of electronic power converters using Matlab/Simulink, IEEE Transaction Educat., 45 (3): 253.

[6] SIBLEY, M.J.N.: “Dicode pulse-position modulation: a novel coding scheme for optical-fiber communications”, IEE Proc. Optoelectronics, vol.150, no.2, pp.125-132, April 2003.

[7] SIBLEY, M.J.N.: “Analysis of dicode pulse-position modulation system using a PINFET receiver and a slightly/highly dispersive optical channels”, IEE Proc. Optoelectronics, vol.150, no.3, pp.205-209, 2003.

[8] SIBLEY, M.J.N.: “Analysis of multiple pulse position modulation when operating over graded-index, plastic optical fibre”, IEE Proc.-Optoelectron., vol.151, no.6, December 2004.

[9] SIBLEY, M.J.N.: “Performance analysis of a dicode PPM system, operating over plastic optical fibre, using maximum likelihood sequence detection.”, IEE Proc. Optoelectronics, vol.152, no.6, pp.337-343, December 2005.

[10] M. Menon and R. A. Cryan , “ Optical Wireless Communications Utilizing a Dicode PPM PIN-BJT Receiver”, Microwave and Optical Technology Letters, vol. 45, No. 4, May 20 2005.

[11] R.A. Charitopoulos, M.J.N. Sibley: ‘Dicode Pulse Position Modulation Coder Simulation’, School of computing and Engineering Researchers’ Conference, University of Huddersfield, Dec 2007.

[12] R.A. Charitopoulos, M.J.N. Sibley: ‘EXPERIMENTAL CODER/DECODER OF DICODE PULSE POSITION MODULATION’, submitted for publication at IEE Proc.-Optoelectron.

[13] J. B. Carruthers and J. M. Kahn, “Modeling of non-directed wireless infrared channels,” IEEE Trans. Commun., vol. 45, no. 10, pp. 1260–1268, 1997.

[14] W. O. Popoola, Z. Ghassemlooy, and E. Leitgeb, "BER performance of DPSK subcarrier modulated free space optics in fully developed speckle," in 6th International Symposium on Communication Systems, Networks and Digital Signal Processing, (CNSDSP), Graz, Austria, pp. 273-277, 2008.

[15] R. K. Tyson, " Bit-error rate for free-space adaptive optics laser communications " Optical Society of America Journal, vol. 19, pp. 753-758 2002.

[16]R.A. Cryanand M.J.N Sibley,“Minimising intersymbol interference in optical-fibre DiPPM system”, IEE Proceedings Optoelectronics, vol.153, Iss.3, pp.93-99, 2006.

[17] R.A. Chaitopoulosand M.J.N. Sibley, “Dicode pulse position modulation coder simulation”, school of computing and engineering researcher. Conf. University of Huddersfield, December 2007.

[18] Z. Ghassemlooy, A. R. Hayes, and N. L. Seed, "The effect of multipath propagation on the performance of DPIM on diffuse Optical wireless communications," in Proceedings of the IASTED International conference on wireless and optical communications Canada, 2001, pp. 166-172.