PERFORMANCE ANALYSIS OF OPTICAL WIRELESS CHANNELS AT VARIOUS MODULATION TECHNIQUES

JavedAshraf

Deptt. of Electronics & Comm. Jamia Millia Islamia,New-Delhi-25,

ABSTRACT

There are many modulation techniques which are used for optical wireless communication. For getting high average-power-efficiency, OOK and PPM are implemented extensively in optical wireless communication. In optical wireless communication, DPPM, DPIM and DH-PIM are three new modulation techniques which may become the replacement of PPM because of their better results in bandwidth efficiency and power efficiency. In this paper, the bandwidth efficiency, transmission capacity, power efficiency and slot error rate of the typical modulation techniques such as OOK, PPM, DPPM, DPIM and DH-PIM are analyzed in combination of the features of the atmospheric optical wireless channel. Theoretical analysis and simulation results by matlab shows that DPPM, DPIM and DH-PIM are more applicable for the future optical wireless communication. When bit resolutions increases in OOK, PPM, DPPM, DPIM and DH-PIM modulation techniques, corresponding symbol length also increases. Hence the average optical power requirement decreases but the bandwidth requirement increases.

Keywords: DH-PIM, DPIM, OOK , Optical Wireless Communication, PPM, Slot Error Rate.

I. INTRODUCTION

Extension of network bandwidth resources and improvement of communication streams are the two important issues with the ever-increase of information communication. Currently, microwave and fiber are the main means of transmission of communication. In comparison with wire communication, microwave communication saves a lot of non-ferrous metals and complex topography can be crossed by using microwave. As a new communication technology, optical wireless communications have the advantages of optical fiber communication and mobile communications, with wide bandwidth and without the need for application of frequency. Therefore, in recent years, the research on wireless optical communication is getting more noticed. But the wireless optical communication leads to signal attenuation as it is influenced by atmospheric absorption, scattering and turbulence in the atmosphere. The average transmission power is limited owing to the requirements for safety of human eye [1],[2].Thus higher necessity of modulation is proposed.

II. CLASSIFICATION OF WIRELESS OPTICAL MODULATION

2.1 On-Off Keying Modulation

The On-Off Keying Modulation is based on intensity modulation with direct detection [3]. When sending information “1”, the light pulses are sent; when sending information “0”, the laser is shut down completely. In this way the optical pulses are generated by opening and breaking of lasers [4].

2.2 Single-Pulse Position Modulation (L-PPM)

Single-pulse position modulation at a particular time slot in time segment converts a binary M-bit data group to a single pulse signal. Time segments are composed by $L=2^M$ time slots and each time slot is called chip. Where L symbol length and M represent the bit resolution.

2.3 Differential Pulse Position Modulation (DPPM)

Differential Pulse Position Modulation improves the power and bandwidth efficiency as well as throughput also. In DPPM, modulation techniques removing all empty slots and follow a pulse in a PPM symbol [5,6]. Average number of slots per symbol in DPPM $\overline{L}_{DPPM} = \left(\frac{L+1}{2}\right)$ is approximately half of the PPM, which improves the bandwidth efficiency and possibility of the data throughput [5].Where L symbol length and $\overline{L}$ average number of slots per symbol. For the given channel and for any symbol length L, DPPM slightly requires higher power but a much lower bandwidth requirement as compare to PPM. Performance of DPPM, using a combination of Marker and Solomon coding, is used to correct insertion and deletion errors as shown in [7].

2.4 Digital Pulse Interval Modulation (DPIM)

The symbol length of DPIM can be divided into unprotected slots and protected slots as in DPPM. The symbol length is not fixed. For decreasing the impact of Inter-Symbol Interference (ISI) effectively, one protected slot is mostly adopted by protected DPIM modulation. The modulation symbols S_k (k is the decimal number expressed by the symbol) contain k+2 time slots; After each starting time slot L, the pulse adds a protected empty slot and k empty slots for expressing information. When demodulation in the receiver, after determining the pulse time slot, is received, it only needs to count the empty time slot and subtract one of them. Implementation of the system is efficiently simplified since DPIM only needs clock synchronization without symbol synchronization.

2.5 Double Header-Pulse Interval Modulation (DH-PIM)

DH-PIM is more complex as the symbol adopts two kinds of starting pulse. The time slot included by each symbol is also mutative. The symbol S_k is formed by a head slot and m empty time slots followed .The head time slot is included by α+1 time slots (α is integer). Considering two forms of head H_1 and H_2, the H1 initial pulse width is α/2 time slot, followed by (α /2) +1 protected time slots; H_2 pulse width is a time slots, followed by one time slot. When k<2M-1, the head time slot of symbol S_k is, otherwise it is H_2 .Where M I is the bit resolution.

III. COMPARISONS OF DIFFERENT MODULATION SCHEMES

Different modulation schemes are differentiated, with respect to power efficiency and bandwidth requirements. (Power requirement is defined as the average optical power required by an ideal system in the presence of AWGN channel to achieve error probability and a certain bit rate.)

3.1 Requirements of optical power and efficiency of different modulation schemes:

3.1.1Average power required for OOK system

The average power required for OOK system is

$$P_{avg\_OOK} = \sqrt{\frac{N_0 R_b}{2R^2}} Q^{-1}\left(P_{e\_bit\_OOK}\right) \ldots\ldots\ldots\ldots (1)$$

where

N_0 = Noise Spectral density

R_b = Bit Rate

R = Responsivity of the Photodetector

P_e = Probability of Error

3.1.2Average power required for PPM system

Average power required for PPM system is

$$P_{avg\_PPM} = \sqrt{\frac{2N_0 R_b}{R^2 L \log_2 L}} Q^{-1}\left(P_{sle\_PPM\_H}\right) \ldots\ldots (2)$$

P_{sle}_PPM_H= Probability of slot error for the hard decoding for PPM

where

L = Symbol Length

Hence the power efficiency of PPM is

$$\eta_{P-PPM} = \sqrt{\frac{4}{L \log_2 L}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

3.1.3Average power required for soft decision decoding PPM system:

Average power required for soft decision decoding PPM system is

$$\eta_{P-PPM} = \sqrt{\frac{2}{L\log_2 L}} \quad \text{.......................(4)}$$

3.1.4Average optical power and power efficiency requirements for DPIM system:

Average optical power and power efficiency requirements for DPIM system is

$$P_{avg\_DPIM} = \sqrt{\frac{2N_0R_b}{R^2\overline{L}_{DPIM\ \log_2} L}}Q^{-1}(P_{se\_DPIM}) \quad \text{....(5)}$$

where

$\overline{\mathrm{L}}$ = Average Symbol Length

$\mathrm{P_{se}}$ = Probability of slot error

$$\eta_{P-DPIM} = \sqrt{\frac{8}{(L+1)\log_2 L}} \quad \text{................(6)}$$

3.1.5 Average optical power and power efficiency requirements for DH-PIM system:

Average optical power and power efficiency requirements for DPIM system is

$$P_{avgDH-PIM} = \sqrt{\frac{9\alpha^2 2N_0R_b}{16R^2M\overline{L}_{DH-PIM}}}Q^{-1}(P_{seDH-PIM}) \quad \text{.........(7)}$$

where

M = Bit resolution

α = Integer

$$\eta_{p-DPIM} = \sqrt{\frac{9\alpha^2}{2M(2^{M-1}+2\alpha+1)}} \quad \text{...................(8)}$$

3.1.6 Requirements of bandwidth for different modulation schemes:

Bandwidth requirement of the baseband modulation schemes is defined by the minimum slot duration $\tau_{\min}$ given by the following relation.

$$B_{req} = \frac{1}{\tau_{\min}}$$

The bandwidth requirements for OOK, PPM, DPIM and DH-PIM are given as:

$$B_{req\_OOK} = R_b$$

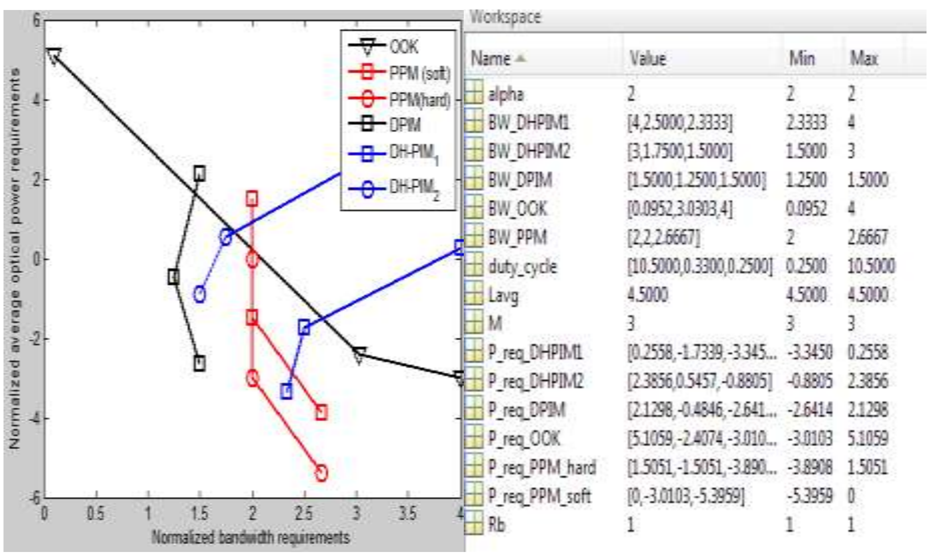
$$B_{req\_PPM} = \frac{L}{M} R_b$$

$$B_{req\_DPIM} = \frac{L+1}{2M} R_b$$

$$B_{req\_Dh\_PIM} = \frac{\left(2^{M-1} + 2\alpha + 1\right) R_b}{\alpha M} R_b$$

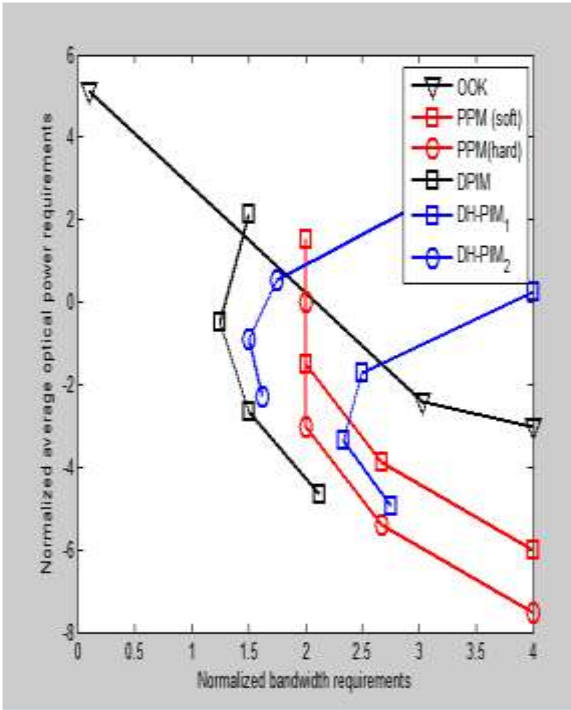
IV-EXPERIMENTAL RESULTS

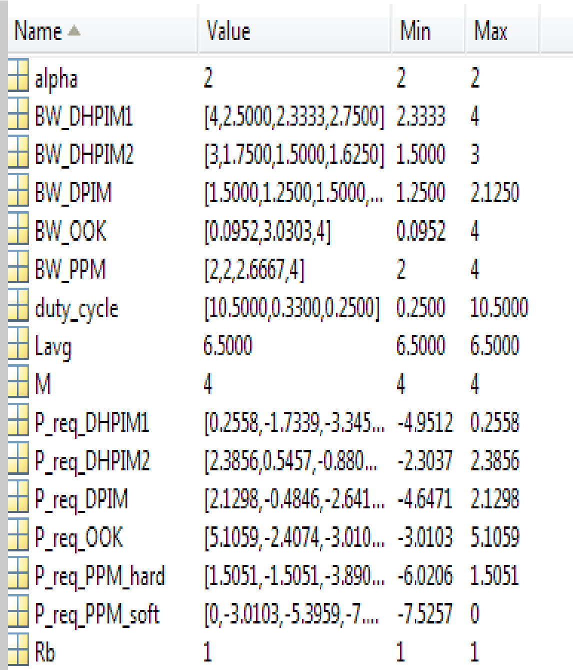
Simulated results clearly shows that when bit resolution increases, so corresponding symbol length also increases and the average optical power requirement decreases but the bandwidth requirements increases.



Name	Value	Min	Max
alpha	2	2	2
BW_DHPIM1	[4,2.5000,2.3333]	2.3333	4
BW_DHPIM2	[3,1.7500,1.5000]	1.5000	3
BW_DPIM	[1.5000,1.2500,1.5000]	1.2500	1.5000
BW_OOK	[0.0952,3.0303,4]	0.0952	4
BW_PPM	[2,2,2.6667]	2	2.6667
duty_cycle	[10.5000,0.3300,0.2500]	0.2500	10.5000
Lavg	4.5000	4.5000	4.5000
M	3	3	3
P_req_DHPIM1	[0.2558,-1.7339,-3.345...	-3.3450	0.2558
P_req_DHPIM2	[2.3856,0.5457,-0.8805]	-0.8805	2.3856
P_req_DPIM	[2.1298,-0.4846,-2.641...	-2.6414	2.1298
P_req_OOK	[5.1059,-2.4074,-3.010...	-3.0103	5.1059
P_req_PPM_hard	[1.5051,-1.5051,-3.890...	-3.8908	1.5051
P_req_PPM_soft	[0,-3.0103,-5.3959]	-5.3959	0
Rb	1	1	1

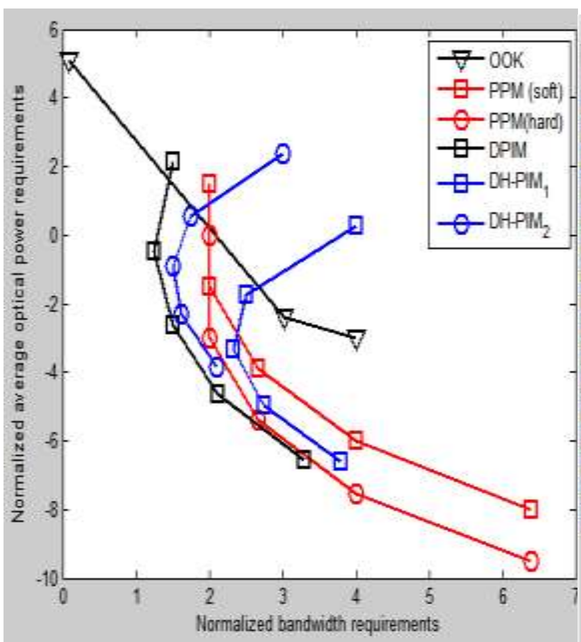
Performance of optical power and bandwidth requirements at bit resolution M=1:3

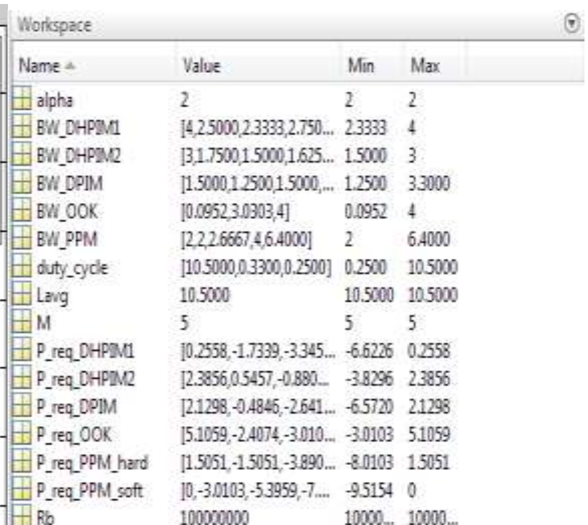




Name	Value	Min	Max
alpha	2	2	2
BW_DHPIM1	[4,2.5000,2.3333,2.7500]	2.3333	4
BW_DHPIM2	[3,1.7500,1.5000,1.6250]	1.5000	3
BW_DPIM	[1.5000,1.2500,1.5000,...	1.2500	2.1250
BW_OOK	[0.0952,3.0303,4]	0.0952	4
BW_PPM	[2,2,2.6667,4]	2	4
duty_cycle	[10.5000,0.3300,0.2500]	0.2500	10.5000
Lavg	6.5000	6.5000	6.5000
M	4	4	4
P_req_DHPIM1	[0.2558,-1.7339,-3.345...	-4.9512	0.2558
P_req_DHPIM2	[2.3856,0.5457,-0.880...	-2.3037	2.3856
P_req_DPIM	[2.1298,-0.4846,-2.641...	-4.6471	2.1298
P_req_OOK	[5.1059,-2.4074,-3.010...	-3.0103	5.1059
P_req_PPM_hard	[1.5051,-1.5051,-3.890...	-6.0206	1.5051
P_req_PPM_soft	[0,-3.0103,-5.3959,-7....	-7.5257	0
Rb	1	1	1

Performance of optical power and bandwidth requirements at bit resolution M=1:4





Workspace

Name	Value	Min	Max
alpha	2	2	2
BW_DHPIM1	[4,2.5000,2.3333,2.750...	2.3333	4
BW_DHPIM2	[3,1.7500,1.5000,1.625...	1.5000	3
BW_DPIM	[1.5000,1.2500,1.5000,...	1.2500	3.3000
BW_OOK	[0.0952,3.0303,4]	0.0952	4
BW_PPM	[2,2,2.6667,4,6.4000]	2	6.4000
duty_cycle	[10.5000,0.3300,0.2500]	0.2500	10.5000
Lavg	10.5000	10.5000	10.5000
M	5	5	5
P_req_DHPIM1	[0.2558,-1.7339,-3.345...	-6.6226	0.2558
P_req_DHPIM2	[2.3856,0.5457,-0.880...	-3.8296	2.3856
P_req_DPIM	[2.1298,-0.4846,-2.641...	-6.5720	2.1298
P_req_OOK	[5.1059,-2.4074,-3.010...	-3.0103	5.1059
P_req_PPM_hard	[1.5051,-1.5051,-3.890...	-8.0103	1.5051
P_req_PPM_soft	[0,-3.0103,-5.3959,-7....	-9.5154	0
Rb	100000000	10000...	10000...

Performance of optical power and bandwidth requirements at bit resolution M=1:5

V CONCLUSION

In this paper, we have compared the bandwidth requirement and the power requirement of different popular modulation techniques in optical wireless communication systems; OOK ,PPM, DPIM and DH-PIM in order to give a wide view about the modulation techniques that are suitable for optical wireless communication systems.

PPM is the most efficient technique in terms of power performance. But as both slot and symbol synchronizations are required at the receiver in PPM so it has a poor clock recovery and resynchronization characteristics. However, this would increase the power requirement by a factor of two. In DPIM, receiver structure is much simplified because each symbol is initiated with a pulse. Therefore, DPIM does not require symbol synchronization. Furthermore, DPIM removes all the unused time slots from within each symbol, thus giving a higher transmission capacity. It is concluded that the main advantages of DPIM, DH-PIM modulation techniques is the symbol synchronization ability and these are the most efficient techniques in terms of optical power and band width requirements. For OOK-RZ the power requirements decreases with duty cycle but the bandwidth increases accordingly. For PPM,DPIM and DH-PIM average optical power requirement decreases when the value of bit resolution M is increases because corresponding value of L increases; however the bandwidth requirements increases with M or the value of L increases.

REFERENCES

[1]Sun Yi, Wu Lei. Simulink Communication Simulation Development Manual [M]. Beijing: National Defence Industry Press, 2006.10.

[2]Hu Zongmin, Tang Junxiong. Atmospheric optical wireless communications systems in the digital pulse interval modulation [J]. Communications, 2005, 26 (3):75-79.

[3]Wang Hongxing, Zhang Tieying, Zhang Tieying, et al. Wireless Optical DH-PIM with DPIM modulation Performance Study [J]. Laser Technology, 2007, 31 (1):95-96.

[4]L. W. Couch, Digital and Analog Communication Systems, 6th ed. New Jersey: Prentice Hall, 200

[5]D. Shiu and J. M. Kahn, Differential pulse position modulation for power-efficient optical communication, IEEE Transactions on Communication, 47, 1201–1210, 1999.

[6]U. Sethakaset and T. A. Gulliver, MAP detectors for differential pulse-position modulation over indoor optical wireless communications, IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, E89-A, 3148–3151, 2006.

[7]U. Sethakaset and T. A. Gulliver, Performance of differential pulse-position modulation(DPPM) with concatenated coding over optical wireless communications, *IET Communications*, 2, 45–52, 2008.

[8] Ke Xizheng, Xi Xiaoli. The Survey of Wireless Laser. Communication [M]. Beijing: Beijing University of Posts and Telecommunications Press, 2004:148-157.

[9] Li jianxin, Liu naian. Analysis and Simulation of Modern Communication System [M]. Xian: Xi Dian University Press, 2004:48-58.

[10] Z. Ghassemlooy, W.Popoola, S. Rajbhandari- Optical Wireless Communications System and Channel Modelling with MATLAB.

[11] Mohamed D.A.Mohamed. Steve Hranilovic .”Optical Impulse Modulation for Indoor Diffuse Wireless Communication”. IEEE Transaction on Communications. Vol- 57,No.2,Februrary-2009.

[12] Xiaoming Jiang,Na Zhu.”Analysis of Power Request and Multiple-Site Techniques for Indoor Wireless Visible-Light Communication System Using LED Lights”978-1-4244-3709- 2/10/$25.00,2010 IEEE.

[13] Daniel J.F.Barros,Sarah K.Wilson,Joseph M. Kahn.”Comparison of Orthogonal Frequency- Division Multiplexing and Pulse-Amplitude Modulation In Indoor Optical Wireless Links”,0090-6778/11$26.00-2011 IEEE.