International Journal of Combined Research & Development (IJCRD)
eISSN:2321-225X;pISSN:2321-2241 Volume: 4; Issue: 4; April -2015

Bandwidth and Power analysis of PADM

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Abstract—**In case of an optical communication, the loss of optical power is very high when the bandwidth is limited. The data rate is also poor. In this paper we are going to describe about the working of PADM (Pulse Amplitude Delay Modulation) and analyze its bandwidth requirements and efficiency as well as optical power. PADM is one of the latest modulation technique in which we modulate the signal with respect to amplitude as well as delay.**

Keywords- PADM, DH-PIM, Indoor VLC, FSO channel.

I. INTRODUCTION

While using indoor visible light communication system, the main issue is bandwidth limitation in uplink channel. This limitation depends upon many factors such as frequency of operation, type of link, communication medium, etc[1]. In order to maintain the efficiency high currently we are using different modulation schemes such as Differential Pulse Position Modulation (DPPM), Pulse Interval Modulation (DPIM) and Dual-Header Pulse Interval Modulation (DH-PIM), etc. Among these techniques the most efficient one is DH-PIM. But using DH-PIM we can maintain low power consumption but high speed communication is not possible[2][3]. In this technique (PADM) we can get high bandwidth efficiency and high speed communication.

II. INDOOR VISIBLE LIGHT COMMUNICATION SYSTEM

Wireless optical communication networks, when appropriately studied, developed, and optimized, could provide a reliable, high-security, interference-insensitive, and especially for elders and health-sensitive people, biologically friendly indoor communication and monitoring network. This network would allow the creation and expansion of seamless computing applications, telemetry, and medical sensor monitoring using large bandwidth high frequency pulsed light instead of RFs and microwaves. Any communication system has uplink and downlink. mostly infrared link is used in uplink. By using huge number of LEDs we can achieve large coverage area but speed of communication is still a challenge[4][7]. According to reference papers DH-PIM can achieve data rate=0.66* BW.

VLC is proposed to be used as the basic indoor access technique for next generation wireless communications[5][6].

III. PULSE AMPLITUDE AND DELAY MODULATION

Pulse Amplitude and Delay Modulation (PADM) is a combined technique in which both pulse amplitude and delay are varied to represent binary data. The length of the output signal varies according to the size of the input block size. In our case for each input block of size R an optical pulse of certain amplitude and delay will be generated. To find the PADM signal, first the input block is divided into two parts according to the value of α. As shown in figure the value of α tells about how much bits are going to be encoded as amplitude. The first part will be modulated according to amplitude and second part will be modulated according to delay. To avoid dispersion we add extra pulse of zero amplitude and Ts period between each encoded symbol. The general formula for PADM symbol is given by,

$$x(t) = \sum_{k=0}^{2^R-1} B_k.p[t-(k+1)T_s]$$

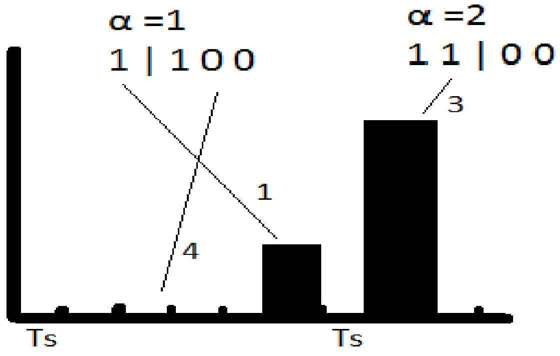


FIG. A

The above figure shows that, how the PADM sequence is generated for given Input binary Sequence

A. Table 1

PADM output for different input with input block size = 4

Binary Input	PADM for α=1	PADM for α=2
0000	00	00
0001	000	000
0011	00000	00000
0101	0000000	001
0111	000000000	00001
1000	01	02
1001	001	002
1111	000000001	00003

B. Bandwidth Requirements

- Average length of the PADM output symbol

Here the minimum length of the PADM output is 2 and the maximum length can be found using the following formula.

$$L_{min} = 2 \qquad L_{max} = 2^{(R-\alpha)} + 1$$

Therefore average symbol length is given by,

$$L_{avg} = \frac{2^{(R-\alpha)} + 3}{2}$$

- Time Slot Duration

Suppose the given data rate is Q. The length of the PADM pulse is Tb. Then Tb = 1/Q. From this we can find the time slot duration as,

$$T_s = \frac{RT_b}{L_{avg}}$$

- Required Bandwidth

$$B_{PADM} = \frac{1}{T_s} = \frac{L_{avg}}{RT_b} = \frac{2^{(R-\alpha)} + 3}{2RT_b}$$

From the above equation we can say that the required bandwidth of PADM depends upon the input block size, Data rate and the value of α.

C. Bandwidth Efficiency

Bandwidth utilization efficiency is determined by the amount of data (bits per second) that can be transmitted through 1 Hz of the link bandwidth using specified modulation technique. We can find the bandwidth efficiency using the following equation.

$$\eta_{PADM} = \frac{Q}{B} = \frac{2R}{2^{(R-\alpha)} + 3}$$

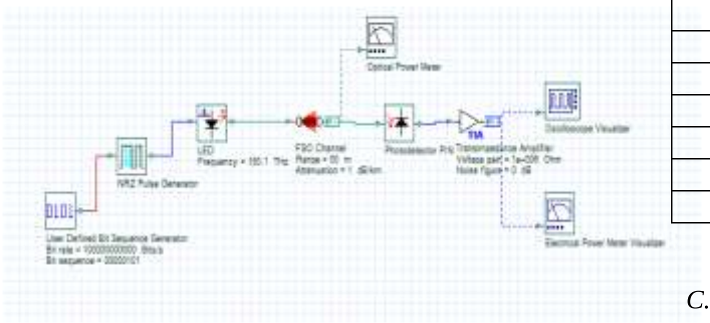
Using this equation, we found the required bandwidth for different values of α using MATLAB. Fig.1 shows the relation between Required bandwidth and total no. of input bits for different values of α varying from 2 to 6. Fig.2 shows relation between Bandwidth efficiency and Input block size.

Table 2 : Required BW for different Input Block Size (R)

Input Block Size	Min. Req. BW (10 bits)	Max. Req. BW (100 bits)
2	10 MHz	100 MHz
3	6.67 MHz	66.7 MHz
4	10 MHz	100 MHz
5	16 MHz	160 MHz
6	27 MHz	270 MHz
7	45.7 MHz	457 MHz

IV. RECEIVED POWER

We have generated the PADM sequence for the given input binary sequence using MATLAB and fed this sequence to the Bit sequence generator in Optisystem. We connected this sequence generator with NRZ Pulse Generator to get electrical signal. We generated optical signal by feeding this electrical signal to a LED. We used FSO as a communication channel and PIN-Photodiode as a detector at the receiver side. We used TIA (Trans Impedance Amplifier) to amplify the received signal. We measured the optical and electrical power for different distance, operating frequency, data rate.



A. Received Optical Power with Distance.

We calculated the Received optical power for different distance and plotted the graph between them. Fig.3 shows this relation. As we can see that received optical power decreases with increases in distance. So if we want to communicate for longer distances then we have to add repeaters which can retransmit our signal.

Table 3 : Received Optical Power with Distance

Distance (cm)	Optical Power (mW)	Optical Power (dBm)
1	158.626	22.004
2	158.499	22.000
5	158.118	21.990
10	157.487	21.972
20	156.236	21.938
50	152.571	21.835
100	146.742	21.666
200	136.043	21.337
500	110.118	20.419
1000	80.810	19.075
2000	48.773	16.882
5000	17.437	12.415

B. Received Electrical Power with Distance

The relation between Received electrical power and distance is shown in Fig.4. As we can see that received electrical power also decreases with increases in distance. So here also we need to add some amplifiers for long distance communication.

Table 4 : Received Electrical Power with Distance

Distance (cm)	Electrical Power (GW)	Electrical Power (dBm)
1	37.655	135.758
2	37.595	135.751
5	37.414	135.730
10	37.115	135.696
20	36.529	135.626
50	34.835	135.419
100	32.223	135.082
200	27.697	134.424
500	18.147	132.588
1000	9.773	129.900
2000	3.560	125.513
5000	0.455025	116.580

C. Received Optical Power with different Frequency and Data rate

Fig.5 shows the relation between optical power and data rate. As we can see that the received optical power increases with data rate up to some limit, after that the received optical power is constant. Fig.6 shows the relation between optical power and frequency of operation. The received optical power increases with increase in frequency. So if we want better power output we should use higher frequency of operation.

Table 5 : Received Optical Power with Data Rate

Data Rate (Gbps)	Optical Power (mW)	Optical Power (dBm)
1	5.588	7.473
2	11.050	10.433
3	14.626	11.645
5	15.400	11.875
10	16.404	12.165
20	17.012	12.308
50	17.336	12.388
100	17.437	12.415

Table 6 : Received Optical Power with Operating Frequency

Frequency (THz)	Optical Power (mW)	Optical Power (dBm)
180	16.254	12.110
185	16.706	12.228
190	17.157	12.345
193.1	17.437	12.415
195	17.609	12.457
200	18.060	12.567
205	18.512	12.675
210	18.963	12.778
215	19.414	12.881
220	19.866	12.981
230	20.770	13.174
240	21.672	13.359
245	22.123	13.449
250	22.575	13.536

ACKNOWLEDGMENT

I would like to thank Prof. Aarthi G for being a constant source of motivation and guidance throughout the whole project.

CONCLUSION

From the above results we came to know that in a Indoor Visible Light Communication System, if we use PADM modulation then the Bandwidth efficiency is increased compared to other modulation techniques. We also found that the received power decreases with distance. As we increase the data rate, the received power is increasing up to some limit, the it is constant. Received power varies linearly with change in operating frequency.

FIGURES

FIG.1: (the value above line represents α value)

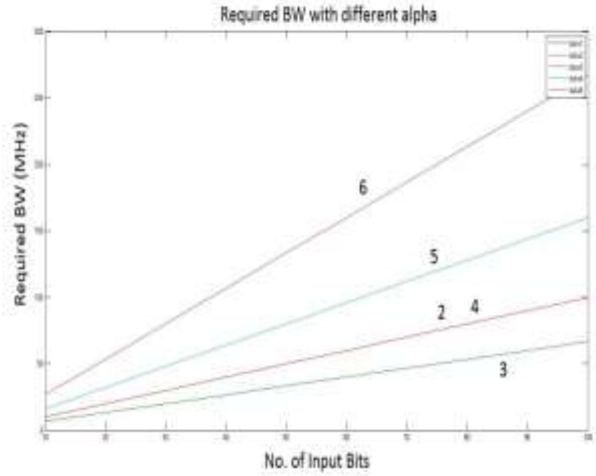


FIG.2

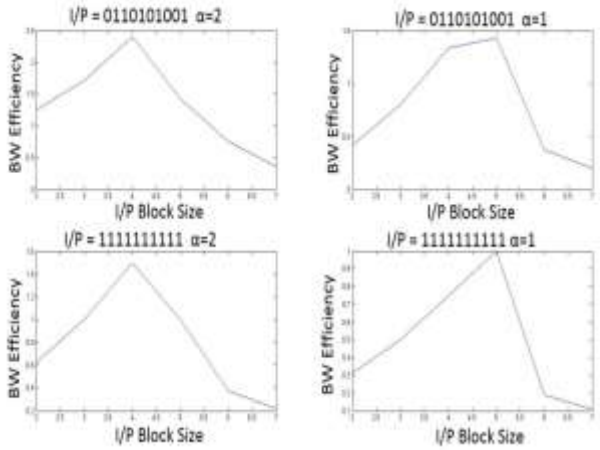


FIG.3

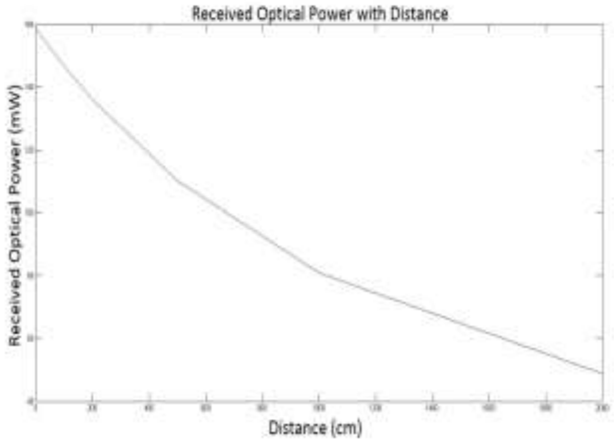


FIG.4

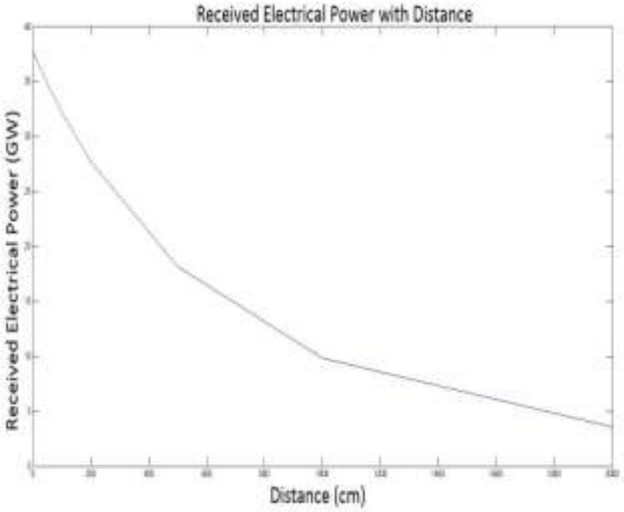


FIG.5

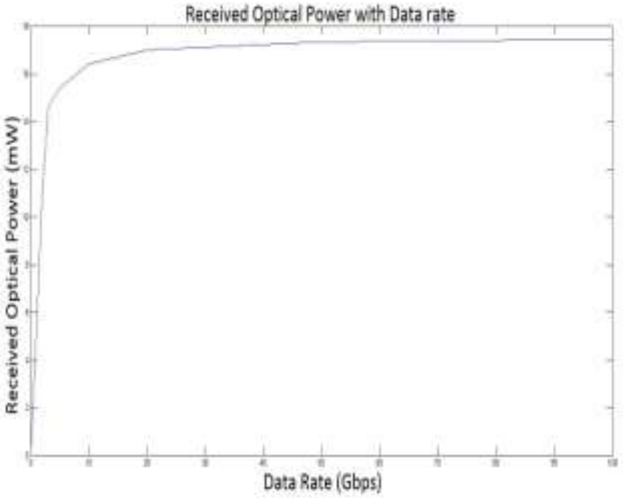
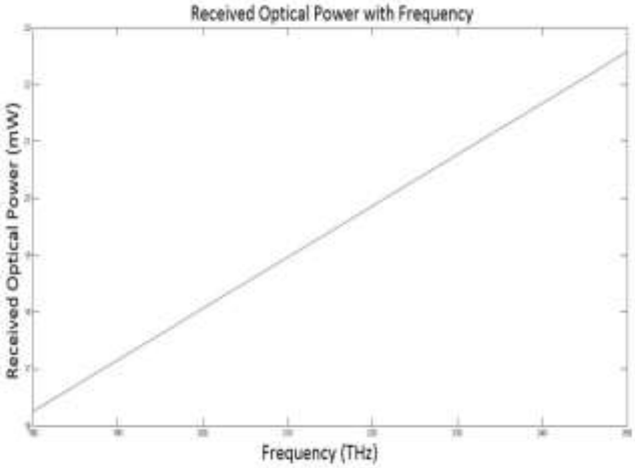


FIG.6



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