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Digital Modulation Techniques for Performance Exploration of Optical Wireless Channels

Javed Ashraf [1], Prof. (Dr.) Anil Kumar [2], Prof. (Dr.) Mumtaz A. Khan[3]
[1]Deptt. of EE&CE Al-Falah University Faridabad (Haryana), India
[2]Vice Chancellor Al-Falah University Faridabad (Haryana), India
[3]Director Mewat Engineering College Palla, Nuh, Mewat, Haryana-122107

***Abstract:** There are many modulation techniques which are used for optical wireless communication. For getting high average-power-efficiency, On off Keying Modulation (* $M_{O.O.K}$ *) and Pulse position modulation (* $M_{P.P.M}$ *) are implemented extensively in optical wireless communication. In optical wireless communication Differential pulse position modulation (* $M_{D.P.P.M}$ *), Digital pulse interval modulation (* $M_{D.P.I.M}$ *) and Double header pulse interval modulation (* $M_{D.H.P.I.M}$ *) are three new modulation schemes which may become the replacement of* $M_{P.P.M}$ *because of their better results in power efficiency and bandwidth efficiency. In this research paper, the power efficiency and bandwidth of the typical modulation schemes such as* $M_{O.O.K}$ *,* $M_{P.P.M}$ *,* $M_{D.P.I.M}$ *and* $M_{D.H.P.I.M}$ *are analyzed by taking the combination of the features of the wireless optical channel. Simulation has been done using MATLAB software. Analysis and simulation shows that* $M_{D.P.I.M}$ *and* $M_{D.H.P.I.M}$ *are more applicable for the future of optical wireless communication. When bit resolutions increases in* $M_{D.H.P.I.M}$ *,* $M_{D.P.I.M}$ *,* $M_{O.O.K}$ *and* $M_{P.P.M}$ *modulation schemes, corresponding symbol length increases. Hence the bandwidth requirement increases but the average optical power requirement decreases.*

Keywords: $M_{D.H.P.I.M}$ *,* $M_{D.P.I.M}$ *,* $M_{O.O.K}$ *,* $M_{P.P.M}$ *, Optical wireless communication.*

I. INTRODUCTION

Optical wireless communications have the advantages of both optical fiber and mobile communication. It uses broad bandwidth. Therefore, the research work in the area of optical wireless communication in recent years is getting more optical range. The optical wireless communication leads to signal attenuation, the reason behind it being that it is impacted by scattering, turbulence and atmospheric absorption in the surroundings. The human eye safety limits the average transmission power in wireless optical communication [1], [2]. Thus, to overcome this problem an appropriate modulation technique is required [10], [11].

II. CLASSIFICATION OF OPTICAL WIRELESS MODULATION TECHNIQUES

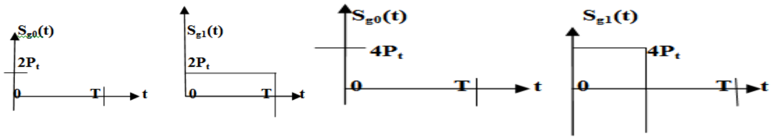
A. ON OFF KEYING DIGITAL PULSE TIME MODULATION TECHNIQUES $(M_{O.O.K})$

$(M_{O.O.K})$ is the elementary scheme that is implement in wireless infrared transmission, and due to its simplicity, it is the most commonly used modulation schemes for I.M/D.D in optical communication. In $M_{O.O.K}$ technique, the transmission of pulse is done when the code bit is binary '1' in a fixed time slot and when there is no pulse then the code bit is binary '0'. For getting a stream of pulses before transmitting the information, it is translated to a definite code for example Return to Zero $(M_{R.Z})$, Manchester, or Non Return to Zero $(M_{N.R.Z})$ codes. In an Additive White Gaussian Noise $(A_{A.W.G.N})$ channel, for achieving same level of bit error performance, $M_{O.O.K}$ with $M_{R.Z}$ signalling needs nearly 5logγ (dB) of optical power greater than that is required in $M_{O.O.K}$ with $M_{N.R.Z}$.

$P_{P.O.E}$ = Probability of Error, for $M_{N.R.Z}$ $M_{O.O.K}$, with no dispersion is given by [2]

$$P_{P.O.E\_OOK} = Q_{M.F}\left(\frac{R_{R.P.T}\overline{P}_{A.T.P}}{\sqrt{N_{N.S.D}R_{B.R}}}\right).....(1)$$

These pulses can have different duty cycle ($d_{D.C}$). When using a $d_{D.C}<1$, the desired bandwidth is raised by a factor of 1/duty cycle ($d_{D.C}$) whereas the average power need declines. This is the reason why in infrared systems, $M_{O.O.K}$ with $M_{R.Z}$ pulses is commonly used. Figure 1 shows the waveforms of $(M_{O.O.K})/M_{N.R.Z}$, and $(M_{O.O.K})/M_{R.Z}$ with $d_{D.C}=0.5$ [6]. $(M_{P.P.M})$scheme is more efficient for smaller $d_{D.C}$ [4].



(a)$(M_{O.O.K})/(M_{N.R.Z})$ (b) $(M_{O.O.K})/(M_{R.Z})$

Figure 1: waveforms of $(M_{O.O.K})/M_{N.R.Z}$, and $(M_{O.O.K})/M_{R.Z}$ with $d_{D.C}=0.5$.

There are different types of forward error control methods that are currently in use and are recommended for reducing the Bit Error Rates ($B_{B.E.R}$) [10]. In diffuse optical links, the achievable data rate is restricted by Multipath induced dispersion. For instance, with $M_{O.O.K}$, a data rate of up to 100 Mbs^{-1} is not practicable when signalling takes place inside a media which is having a normalized delay spread up to the value of 0.6 [10]. This is the reason of using, in half duplex communication, a paltry data rate of up to 1.150 Mbs^{-1} with a 25 percent $d_{D.C}$ in the serial physical layer standards by the IrDA [3], [4]. For $M_{O.O.K}$, the Maximum Likelihood Sequence Detector ($M_{M.L.S.D}$) should be adopted in a multipath channel for achieving optimal results. But the implementation of $M_{M.L.S.D}$ is impractical because of the prohibitive processing time and its complexity. Thus, a feasible aspect is utilization of an equalizer though it gives sub-optimal data rates. Using a Decision Feedback Equalizer ($D_{D.F.E}$) with the $M_{O.O.K}$, even in the most dispersive channel, makes the up till now unfeasible 100 Mbs^{-1} data rate a possibility [10] There are many other equalization techniques with their detailed analysis that have been proposed for $M_{O.O.K}$ scheme [1], [3] and [10].

B. Single Pulse Position Modulation Techniques (LPPM)

$M_{P.P.M}$ is an orthogonal modulation scheme for a wireless optical communications. When its comparison is done with all other remaining modulation schemes it is found that among them $M_{P.P.M}$ has the highest power efficiency. The aspect of having higher efficiency makes it applicable for handheld devices because one of the major factors in such type of devices is lower power consumption. It is commercially used in dedicated communication like laptop, palmtop, IrDA, etc. $M_{P.P.M}$ is defining to contain L slots in a particular symbol (mark) time. So in $M_{P.P.M}$, optical power transmission is constant within only one of chips and power in the remaining (L_{SL}-1) chips is zero. The un-coded 32- $M_{P.P.M}$ has smaller average power-efficiency than coded 16- $M_{P.P.M}$. Similarly, in $M_{P.P.M}$, un-coded 16- $M_{P.P.M}$ have lesser average power-efficiency than coded 8- $M_{P.P.M}$. $M_{P.P.M}$ pulse duration is shorter by a factor L_{SL}/B_{BRe} than the $M_{O.O.K}$ pulse duration for achieving the same throughput. It achieves higher power efficiency by a factor of L_{SL}/B_{BRe} but this is achieved by increasing the bandwidth requirement.

The Slot Error Rate $P_{S.E.R}$ of $M_{P.P.M}$ is given by [3] and [4]

$$P_{S.E.R\_PPM}=Q_{M.F}\left(\sqrt{\frac{1}{2}L_{S.L}.B_{BRe}}\,\frac{R_{R.P.T}\,\overline{P}_{A.T.P}}{\sqrt{N_{N.S.D}R_{B.R}}}\right)\ldots(2)$$

From the above equation it is clear that the average power required by the $M_{P.P.M}$ for achieving similar error performance, is lower by a factor of $(0.5\, L_{SL}.\, B_{BRe})^{1/2}$ than that required by $M_{O.O.K}$.

Another key advantage of $M_{P.P.M}$ is that if it is compared with $M_{O.O.K}$ it has a much lower DC component .This factor is beneficial for the $M_{P.P.M}$ to provide enhanced immunity against the noise produced by fluorescent lamps [1]

The two factors that limits the performance of the $M_{P.P.M}$ technique are the symbol and slot synchronization and the multipath induced Inter Symbol Interference ($I_{I.S.I}$). The acquired power penalty in diffuse infrared links due to $I_{I.S.I}$ is lesser in comparison of the $M_{O.O.K}$ modulation technique due to the existence of the L_{SL} -1 empty slot. A linear equalizer and decision feedback equalizer, both are used in [3] and [10] for minimizing the induced $I_{I.S.I}$ in diffused links.

C. Digital Pulse Interval Modulation ($M_{D.P.I.M}$)

$M_{D.P.I.M}$ is a modulation schemes that disposes of all the empty time slots presented by each symbol hence showing a higher transmission capacity. This technique does not need symbol synchronization given that every symbol starts with a pulse [12], [13]. The prearrangement of data is done among neighboring pulses as a number of discrete time intervals or slots. The average optical power of pre arranged pulse stream using $M_{D.P.I.M}$ is much better than a $M_{D.P.I.M}$ encoded pulse stream because of having a shorter symbol length ($L_{S.L.}$). The only thing it requires is clock synchronization without symbol synchronization [5]. The separation of symbol length ($L_{S.L.}$) of $M_{D.P.I.M}$ into protected and unprotected slots is possible in $M_{D.P.P.M}$.

For decreasing the impact of Inter Symbol Interference (ISI) successfully, one protected slot is mainly adopted with protected $M_{D.P.I.M}$ modulation schemes [7], [8]. The modulation marks, S_D, which is a decimal number and is communicated by the symbol, hold D+2 time slots. For communicating the information, the pulse adds a protected empty slot and D blank slots after each initial time slot L. The formatting of the pulse time slot is done for receiving the demodulation. Demodulation is done by only counting the empty time slot and subtracting one of them [6].

D. Double Header Pulse Interval Modulation ($M_{D.H.P.I.M}$)

Double header pulse interval modulation $M_{D.H.P.I.M}$ was at first initially proposed in 1999. It comprises of lesser transmission bandwidths in comparison to $M_{P.P.M}$ modulation scheme and thus providing higher bit rate. It moreover has incorporated frame synchronization facility [3], [5]. $M_{D.H.P.I.M}$ is further more troublesome as the symbol accepts two different sort of starting pulse The time slot incorporated each symbol is as well mutative. The symbol is made by a head slot in addition to empty time slots follow. Head time slot is built-in by β_I +1 time slots where β_I is an Integer. Two types of Headers are permitted, i.e. H_1 and where H1 is the preliminary pulse width with β_I/2 time slot, followed through (β_I /2) +1 confined time slots; pulse width is a time slot, followed via one time slot [5]. If k is less than 2^{M-1} after that head time slot of symbol S_D is H_1, or else it be H_2.

III. COMPARISONS OF VARIOUS MODULATION TECHNIQUES

Individual modulation schemes such as $M_{P.P.M}$, $M_{O.O.K}$, $M_{D.H.P.I.M}$ and $M_{D.P.I.M}$ are compared by differentiating with respect to power and bandwidth efficiency.

A. Power and Efficiency of distinct Modulation Techniques:

1) Provision of Bandwidth for distinct Modulation Techniques [9], [10]

Band width provision for $M_{D.H.P.I.M}$, $M_{D.P.I.M}$, $M_{P.P.M}$ and $M_{O.O.K}$ are given as:

$$B_{req\_D.H.P..I.M} = \frac{\left(2^{R_{B.R}-1} + 2\beta_I + 1\right)R_{B.R}}{\beta_I R_{B.Re}} R_{B.R} \;.....(3)$$

$$B_{req\_DPIM} = \frac{L_{SL} + 1}{2B_{B.Re}} R_{B.R} \;.....(4)$$

$$B_{req\_PPM} = \frac{L_{SL}}{B_{B.Re}} R_{B.R} \;.....(5)$$

$$B_{req\_OOK} = R_{B.R} \;.....(6)$$

2) POWER EFFICIENCY NEED FOR $M_{P.P.M}$ *[16]*

The power efficiency need for η_{PE_PPM} system is

$$\eta_{PE-PPM} = \sqrt{\frac{2}{(L_{SL})(L_{SL}\log_2)}} \text{......(7)}$$

3) POWER EFFICIENCY NEED FOR $M_{O.O.K}$ *SYSTEM [13], [14]*

Power efficiency need for $M_{O.O.K}$ system is

$$\eta_{PE\_OOK} = \sqrt{\frac{R_{B.R} N_{N.S.D}}{2R_{R.P.D}{}^2}} Q^{-1}\left(P_{P.O.E\_OOK}\right) \text{....(8)}$$

4) POWER EFFICIENCY AND AVERAGE OPTICAL POWER REQUIRED FOR $M_{D.H.P.I.M}$ SYSTEM [13], [14]

Power efficiency as well as average optical power for $M_{D.H.P.I.M}$ system is

$$\eta_{PE-DPIM} = \sqrt{\frac{9\beta_I{}^2}{\left(2^{B_{B.R}e^{-1}} + 2\beta_I + 1\right)\left(2B_{B.Re}\right)}} \text{.....(9)}$$

$$P_{avgDH-PIM} = \sqrt{\frac{9\beta_I{}^2 2N_{N.S.D} R_{B.Re}}{16R_{R.P.D}{}^2 M\overline{L}_{DH-PIM}}} Q^{-1}\left(P_{P.S.E\_DH-PIM}\right) \text{..(10)}$$

5) POWER EFFICIENCY AND AVERAGE OPTICAL POWER REQUIRED FOR $M_{P.P.M}$ *[13], [14]*

The power efficiency of $M_{P.P.M}$ is

$$\eta_{PE-PPM} = \sqrt{\frac{4}{(L_{SL})(\log_2 L_{SL})}} \text{....(11)}$$

Hence the average power need for $M_{P.P.M}$ is

$$P_{avg\_PPM} = \sqrt{\frac{2N_{N.S.D} R_{B.R}}{\left(R_{R.P.D}\right)^2 (L_{SL})\left(\mathrm{Log}_2 L_{SL}\right)}} Q^{-1}\left(P_{P.S.E\_PPM\_H}\right) \text{.....(12)}$$

6) POWER EFFICIENCY AND POWER OF A $M_{D.P.I.M}$ *SYSTEM [14], [15]*

Power efficiency and Power of an optical system for a $M_{D.P.I.M}$ is

$$\eta_{P-DPIM} = \sqrt{\frac{8}{(L_{SL})(L_{SL}+1)\log_2}} \text{.....(13)}$$

$$P_{avg\_DPIM} = \sqrt{\frac{2(N_{N.S.D})(R_{B.R})}{(R_{R.P.D})^2 (\overline{L}_{SL\ DPIM}) \log_2 (L_{SL})}} Q^{-1}\left(P_{P.S.E\_DPIM}\right) \text{.....(14)}$$

IV. SIMULATION RESULTS

The simulated results assuredly clarify that on incrementing bit resolution the average optical power requirement diminishes but the corresponding symbol length as well as the bandwidth requirements incrementing.

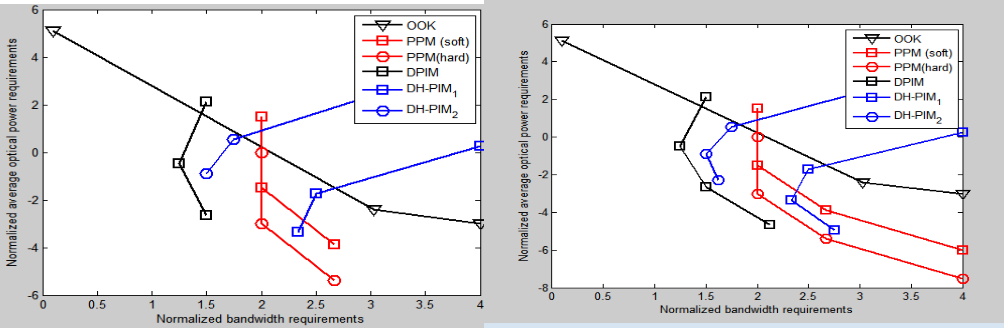


Figure 2 & 3 Normalized bandwidth and Normalized average optical power requirements at bit resolution =1:3 and 1:4

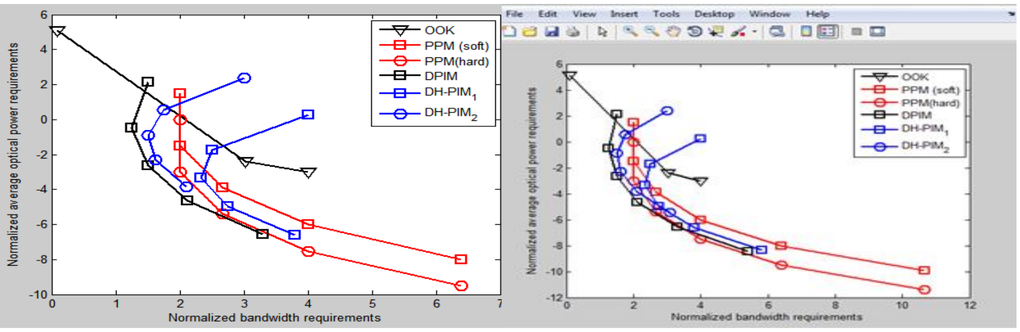


Figure: 4 & 5 Normalized bandwidth and Normalized average optical power requirements at bit resolution =1:5 and 1:6

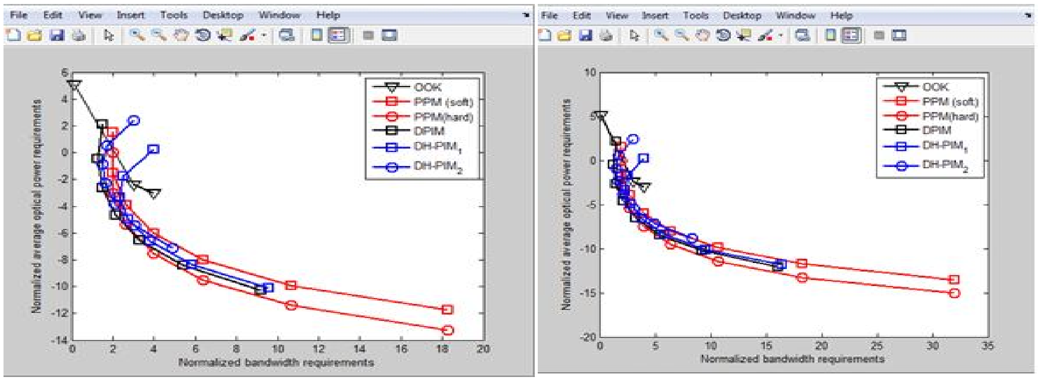


Figure: 6 & 7 Normalized bandwidth and Normalized average optical power requirements at bit resolution =1:7 and 1:8

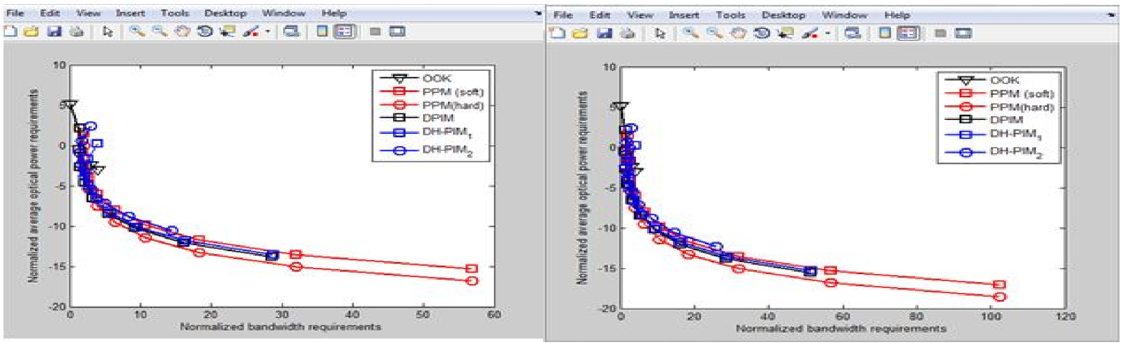


Figure: 8 & 9 Normalized bandwidth and Normalized average optical power requirements at bit resolution =1:9 and 1:10

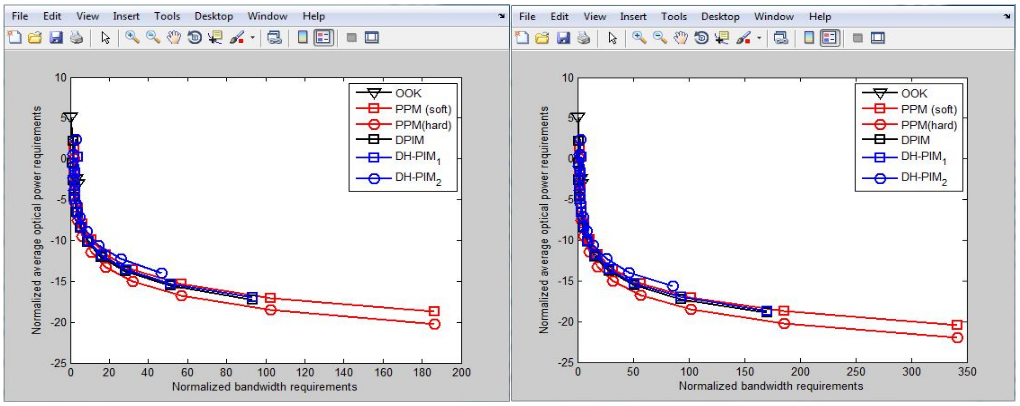


Figure: 10 & 11 Normalized bandwidth and Normalized average optical power requirements at bit resolution =1:11 and 1:12

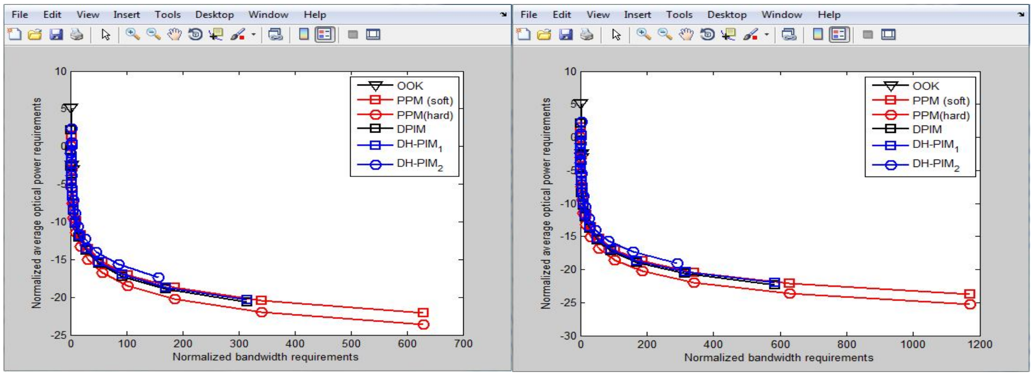


Figure 12 & 13 Normalized bandwidth and Normalized average optical power requirements at bit resolution =1:13 and 1:14

Table: 1 Comparative Statement of Required Power of distinct Modulation Techniques

S. NO	Bit Resolution $(B_{B.Re})$	Symbol Length $L_{S.L.}$	Requirements of Power $(M_{D.H.P.I.M0})$dBm	
			Mini	Maxi.
a	1:3	[2,4,8]	-3.35	0.256
b	1:4	[2,4,8,16]	-4.95	0.256
c	1:5	[2,4,8,16.32]	-6.63	0.256
d	1:6	[2,4,8,16.32,64]	-8.35	0.256
e	1:7	[2,4,8,16.32,64,128]	- 10.1	0.256
f	1:8	[2,4,8,16.32,64,128,256]	- 11.8	0.256
g	1:9	[2,4,8,16.32,64,128,256,512]	- 13.6	0.256
h	1:10	[2,4,8,16.32,64,128,256,512,1024]	- 15.3	0.256
i	1:11	[2,4,8,16.32,64,128,256,512,1024,2048]	-17.0	0.256
j	1:12	[2,4,8,16.32,64,128,256,512,1024,2048,4096]	-18.7	0.256
k	1:13	[2,4,8,16.32,64,128,256,512,1024,2048,4096,8192]	-20.4	0.256
l	1:14	[2,4,8,16.32,64,128,256,512,1024,2048,4096,8192,16384]	-22.0	0.256

Requirements of Power $\left(M_{D.H.P.I.M1}\right)$ (dBm)		Requirements of Power $\left(M_{D.P.I.M}\right)$ (dBm)		Requirements of Power $\left(M_{O.O.K}\right)$ (dBm)		Requirements of Power $\left(M_{P.P.M}\right)$ HARD(dBm)		Requirements of Power $\left(M_{P.P.M}\right)$ SOFT(dBm)	
Mini.	Maxi.	Mini.	Maxi.	Mini.	Maxi.	Mini.	Maxi.	Mini.	Maxi.
-.881	2.386	-2.64	2.130	-2.93	5.108	-3.90	1.505	-5.39	0
-2.31	2.386	-4.65	2.130	-2.93	5.108	-6.02	1.505	-7.53	0
-3.83	2.386	-6.57	2.130	-2.93	5.108	-8.01	1.505	-9.52	0
- 5.46	2.386	- 8.44	2.130	-2.93	5.108	- 9.91	1.505	- 11.41	0
- 7.14	2.386	- 10.3	2.130	-2.93	5.108	- 11.7	1.505	- 13.3	0
- 8.86	2.386	- 12.0	2.130	-2.93	5.108	-13.5	1.505	- 15.6	0
- 10.6	2.386	- 13.8	2.130	-2.93	5.108	- 15.3	1.505	- 16.8	0
- 12.3	2.386	- 15.5	2.130	-2.93	5.108	-17.0	1.505	- 18.5	0
-14.0	2.386	-17.2	2.130	-2.93	5.108	-18.8	1.505	-20.3	0
-15.7	2.386	-18.9	2.130	-2.93	5.108	-20.4	1.505	-22.0	0
-17.4	2.386	-20.6	2.130	-2.93	5.108	-22.1	1.505	-23.6	0
-19.0	2.386	-22.3	2.130	-2.93	5.108	-23.8	1.505	-25.3	0

Table: 2 Comparative statement of Required Normalized Band Width of distinct Modulation Techniques:

S. NO	Bit Resolution $\left(B_{B.Re}\right)$	Symbol Length $L_{S.L.}$	Requirements of Band Width For $\left(M_{D.H.P.I.M0}\right)$	
			Mini	Maxi
a	1:3	[2,4,8]	2.3333	4
b	1:4	[2,4,8,16]	2.3333	4
c	1:5	[2,4,8,16.32]	2.3333	4
d	1:6	[2,4,8,16.32,64]	2.3333	5.8333
e	1:7	[2,4,8,16.32,64,128]	2.3333	9.5714
f	1:8	[2,4,8,16.32,64,128,256]	2.3333	16.375
g	1:9	[2,4,8,16.32,64,128,256,512]	2.3333	28.778
h	1:10	[2,4,8,16.32,64,128,256,512,1024]	2.3333	51.500
i	1:11	[2,4,8,16.32,64,128,256,512,1024,2048]	2.3333	93.363
j	1:12	[2,4,8,16.32,64,128,256,512,1024,2048,4096]	2.3333	170.91
k	1:13	[2,4,8,16.32,64,128,256,512,1024,2048,4096,8192]	2.3333	315.30
l	1:14	[2,4,8,16.32,64,128,256,512,1024,2048,4096,8192,16384]	2.3333	585.35

Requirements of Band Width For $\left(M_{D.H.P.I.M1}\right)$		Requirements of Band Width For $\left(M_{D.P.I.M}\right)$		Requirements of Band Width For $\left(M_{O.O.K}\right)$		Requirements of Band Width For $\left(M_{P.P.M}\right)$	
Mini.	Maxi.	Mini.	Maxi.	Mini.	Maxi.	Mini.	Maxi.
1.500	3	1.2500	1.55	0.095	3.8460	2	2.667

1.500	3	1.2500	2.125	0.095	3.8460	2	4
1.500	3	1.2500	3.300	0.095	3.8460	2	6.400
1.500	3.0833	1.2500	5.4167	0.095	3.8460	2	10.667
1.500	4.9286	1.2500	9.2143	0.095	3.8460	2	18.286
1.500	8.3125	1.2500	16.063	0.095	3.8460	2	32
1.500	14.500	1.2500	28.500	0.095	3.8460	2	56.889
1.500	25.850	1.2500	51.250	0.095	3.8460	2	102.40
1.500	46.773	1.2500	93.136	0.095	3.8460	2	186.18
1.500	85.542	1.2500	170.70	0.095	3.8460	2	341.33
1.500	157.73	1.2500	315.11	0.095	3.8460	2	630.15
1.500	292.75	1.2500	585.17	0.095	3.8460	2	1.170

The Packet Transmission Rate, Average Symbol Length, Transmission Capacity and Bandwidth Requirement of $\left(M_{P.P.M}\right)$, ($M_{D.P.PM}$), $\left(M_{D.P.I.M}\right)$, ($M_{D.H.P.I.M}$),($M_{M.D.P.I.M}$) and ($M_{D.A.P.P.M}$) is discussed below in Table 3.

Table: 3

Modulation scheme	$M_{D.A.P.P.M}$	$M_{D.P.I.M} / M_{D.P.PM}$
Normalised Bandwidth Requirement to N.R.Z- $\left(M_{O.O.K}\right)$	$\dfrac{R_{B.R}\left(2^{B_{BRe}-1}+A_{PA}\right)}{2B_{BRe}A_{PA}}$	$\dfrac{R_{B.R}\left(2^{B_{BRe}}+3\right)}{2B_{BRe}}$
Packet transmission rate	$\dfrac{2B_{BRe}A_{PA}B_{req-DAPPM}}{N_{N.T.P}\left(2^{B_{BRe}-1}+A_{PA}\right)}$	$\dfrac{2B_{BRe}B_{req-P.P.M}}{N_{N.T.P}\left(2^{B_{BRe}}+3\right)}$
Average symbol length	$\dfrac{\left(2^{B_{BRe}-1}+A_{PA}\right)}{2A_{PA}}$	$\dfrac{\left(2^{B_{BRe}}+3\right)}{2}$
Transmission Capacity	$\dfrac{2B_{BRe}\,A_{PA}\,2^{B_{BRe}}}{2^{B_{BRe}}+A_{PA}}$	$\dfrac{4{B_{BRe}}^{2}\,B_{req}\left(2^{B_{BRe}}+1\right)}{\left(2^{B_{BRe}}+3\right)^{2}}$

Modulation scheme	$M_{M.D.P.I.M}$	$M_{P.P.M}$	$M_{D.H.P.I.M}$
Normalised Bandwidth requirement to N.R.Z $\left(M_{O.O.K}\right)$	$\dfrac{R_{B.R}\left(2^{B_{BRe}-1}+3\right)}{2B_{BRe}}$	$\dfrac{R_{B.R}2^{M}}{M}$	$\dfrac{R_{B.R}\left(2^{M-1}+2\beta_{I}+1\right)}{\beta_{I}M}$
Packet transmission rate	$\dfrac{2MB_{req}}{N_{P.K.T}\left(2^{M-1}+3\right)}$	$\dfrac{MB_{req-P.P.M}}{N_{P.K.T}2^{M}}$	$\dfrac{\beta_{I}MB_{req}}{N_{P.K.T}\left(2^{M-1}+2\beta_{I}+1\right)}$
Average symbol length	$\dfrac{\left(2^{M-1}+3\right)}{2}$	2^{M}	$\dfrac{\left(2^{M-1}+2\beta_{I}+1\right)}{2}$
Transmission Capacity	$\dfrac{4M^{2}B_{REQ}\left(2^{M-1}+1\right)}{(2^{M-1}+3)^{2}}$	$\dfrac{M^{2}B_{req}}{2^{M}}$	$\dfrac{2\beta_{I}\,M^{2}B_{REQ}\left(2^{M-1}+\beta_{I}\right)}{(2^{M-1}+2\beta_{I}+1)^{2}}$

V. CONCLUSION

In this research work, a vast view is represented of various modulation schemes that are compatible for wireless optical communication systems like $M_{O.O.K}$ $M_{P.P.M}$, $M_{D.P.I.M}$ and $M_{D.H.P.I.M}$. This has been achieved by comparing the power and bandwidth requirement of various prevalent modulation methods in optical wireless communication systems. In terms of power performance $M_{P.P.M}$ is the most proficient technique. It has a deprived clock recovery and resynchronization characteristics as both the symbol and slot synchronizations are needed at the receiver. More ever, this would increment the power requirement by a factor of two. Whereas in $M_{D.P.I.M}$, the receiver structure is much streamlined as each symbol starts with a pulse. Hence, symbol synchronization is not needed for $M_{D.P.I.M}$. Besides, $M_{D.P.I.M}$ extracts all the idle time slots from within each symbol, hence provides higher transmission capacity. It is concluded that the symbol synchronization capability is the main advantages of $M_{D.P.I.M}$ and $M_{D.H.P.I.M}$ modulation schemes and these are the most effective techniques in terms of band width and optical power necessities. The power necessity diminishes with duty cycle for $M_{O.O.K}$-RZ and on the other hand the bandwidth increments accordingly. Average optical power requirement diminishes for $M_{P.P.M}$, $M_{D.P.I.M}$ and $M_{D.H.P.I.M}$ on incrementing the value of bit resolution M due to the increase in the corresponding value of $L_{S.L.}$ Although the bandwidth requirements increases with increase in M or on increasing the value of $L_{S.L.}$.

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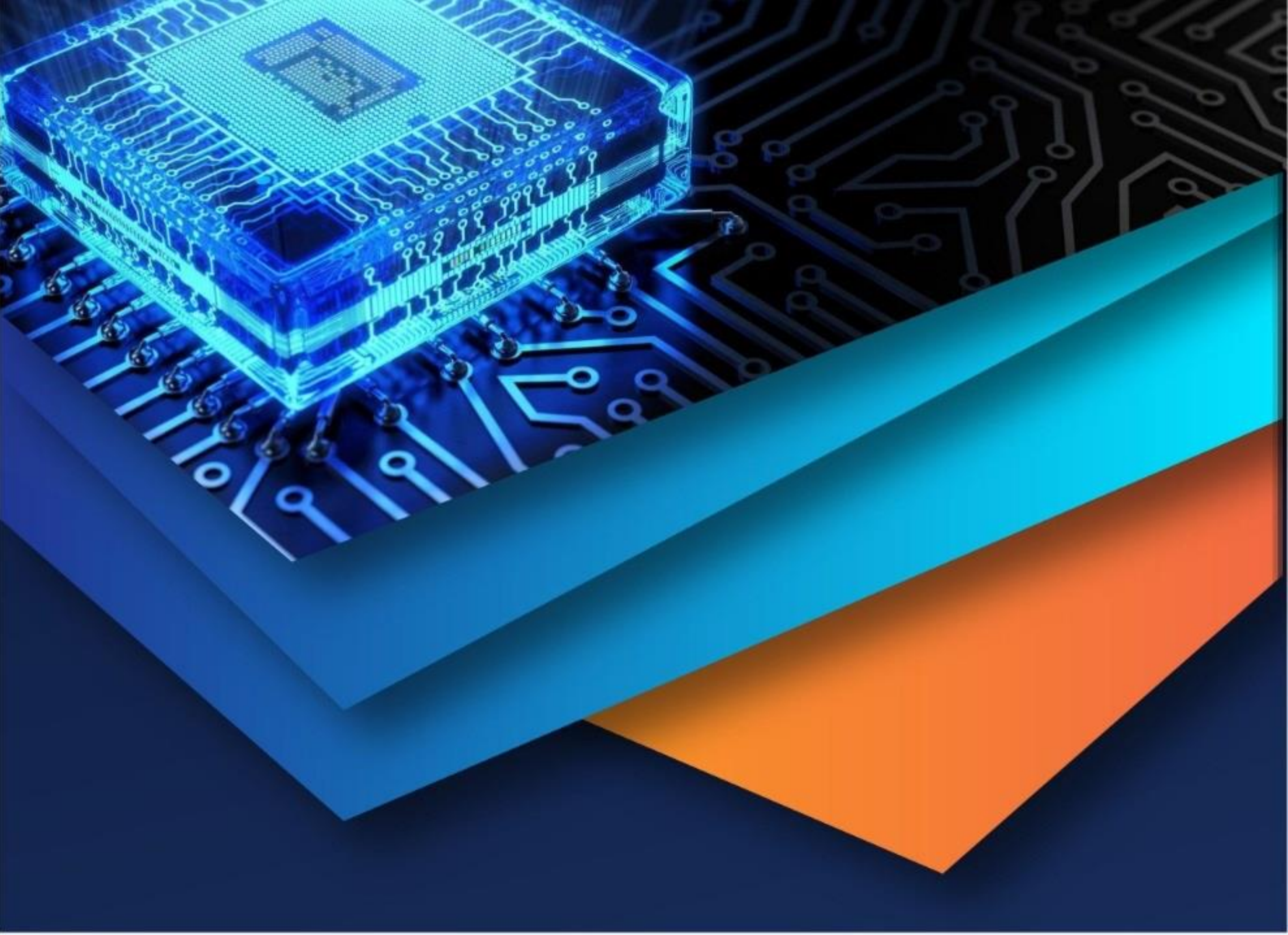

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