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INVESTIGATION OF VARIOUS MODULATION TECHNIQUES FOR UNDER-WATER COMM.

[1]Ms. Bhawna Gupta, [2]Ms. Swati Gaur, [3]Mr. Kartik Gupta

[1] Research Scholar Department of Electronics & Communication Engineering in Delhi College of Technology& Management

[2] Assistant Professor in Delhi College of Technology & Management

Email: bhawnagupta72@gmail.com

Email: kartik.gupta90@gmail.com

Abstract:
Underwater laser communication is a very attractive and efficient way to communicate in ocean environment without disturbing the marine life. Though acoustic communication is very popular in this kind of communication system, the laser communication would be the best way for transmitting and receiving signal or data in deep oceanic environment due to higher bandwidth and security. This system would be suitable to transfer intelligence, surveillance and reconnaissance (ISR) data between ships and from ship to shore, and could be used by the Navy and the US Marine Corps. In this paper, we investigate the transmission efficiency, channel capacity, peak to average power ratio and bandwidth of various modulation techniques like OOK, PPM, DPPM, and DPIM. Experimental results, based on Lab VIEW and MATLAB simulation.

Key Word: *Pulse Time Modulation, on-Off keying, Pulse Position Modulation, Digital PPM, Digital Pulse Interval Modulation*

I. Introduction

Underwater wireless communications has been proposed for submarine communications due to the flexibility and scalability. In recent years, underwater wireless optical communications (UWOC) has attracted considerable attentions as an alternative to traditional acoustic approach. As a special typeof free space optical (FSO) communications, UWOC systems employ the blue/green region of visible light spectrum to realize data transmission since this region of light suffers lowest attenuation in natural water [1]. Compared with acoustic communications, UWOC systems can provide high security, low time delay and a much higher data rate up to hundreds of Mbps [3] in relatively short ranges (typically shorter than
100meters). Due to these advantages, UWOC has numerous applications such as real-time video communications, remote sensing and navigation, imaging as well as high throughput sensor network.

Laser communications provides wide bandwidth and high security capabilities to Unmanned Aircraft Systems, the transition to laser communications for Unmanned Aerial Vehicle (UAV) and Unmanned Underwater Vehicles (UUV) can begin in earnest optical communication has received a great attention since a few years and has been considered as an attractive transmission technique for under water wireless sensor networks (UWSN) due to its cost effectiveness and power efficiency.

Optical propagation in water is subject to high absorption and scattering leading to strong light intensity attenuation. Fortunately, in most practical situations, high data-rate communication over medium transmission ranges is possible without suffering from any inter-symbol-interference (ISI) [1], [2].Energy efficiency, in turn, depends on the optical modulation scheme as well as on the receiver detection and signal processing parts among other factors. We would like in this work to compare the performance of different modulation techniques from the point of view of energy efficiency while taking into account other important factor such as bandwidth (BW) efficiency and the receiver implementation complexity. We focus on intensity modulation and direct detection (IM/DD) techniques due to the transceiver cost and implementation complexity concerns. More specifically, we study the four modulation techniques of ON-OFF keying (OOK), pulse position modulation (PPM), pulse width modulation (PWM), and digital pulse interval modulation (DPIM). Compare the demodulation schemes from the point of view of maximum achievable transmission range conditioned to a target bit error-rate (BER) performance.

II. MODULATION TECHNIQUES

Higher average power efficiency can be achieved by employing pulse modulation schemes in which a range of time dependent features of a pulse carrier may be used to convey information. This classification is based on the

Corresponding author: Bhawna Gupta

spectral behavior and whether the scheme discontinuous or discrete. Discrete (digital) pulse time modulation (PTM) techniques fall into two categories, namely isochronous and an isochronous. Isochronous schemes encode data by varying the position or width of a pulse, but the overall symbol structure remains constant. In contrast, isochronous schemes have no fixed symbol structure [3].

A. On-Off Keying

Among all modulation techniques based on intensity modulation with direct detection, on-off keying (OOK) is the most used scheme used in fiber and free space optical communication due to its simplicity [3]. We consider the non-return-to-zero OK modulation and denote the symbol duration by TOOK.

The transmitter emits a rectangular pulse of duration 1/*R*b (*R*b = bit rate) and intensity 2*P* (*P*: transmission power) to signify a "one" bit and no pulse to signify a "zero" bit. The bandwidth required by OOK is roughly *R*b = 1/*T*, the inverse of the pulse width [1, 12]. The transmit optical power per ON slot is PON = 2Pav and the required BW B is equal to Rb.

B.PPM (Pulse position Modulation)

For a direct-detection optical link, under peak and average power constraints, a slotted binary modulation like PPM can nearly achieve the channel capacity [3]. When performing hard signal detection at the receiver, PPM has the advantage that, in contrary to OOK, it does not require dynamic shareholding for optimal detection. Consider the classical L-ary PPM where a symbol corresponds to M = $\log_2$L bits. Also, let T_{PPM} and Ts denote the symbol and slot durations, respectively, where Ts = T_{PPM} /L. We have T_{PPM} = Took ($\log_2$L) and $\mathrm{P_{ON}}$ = L P_{av}. The important advantage of PPM over OOK is that it is more average-energy efficient. However, this comes at the expense of lower BW efficiency; The required BW for L-PPM is B = LR_b/($\log_2$L) which increases with L. Although a large BW is usually available in optical communication, a larger L results in a higher peak-to-average power ratio (PAPR), necessitates a higher switching speed for the electronic circuits, and also makes the receiver slot synchronization more difficult.

C. DPPM (Digital Pulse Position Modulation)

Digital information may be transmitted using PPM by dividing each data frame into *K* possible time slots and allowing the location of a pulse in just one of these time slots per frame to indicate the data. *K* = 8 = 23, the maximum information rate for this system is 3 bits per frame. Clearly, the more time slots we allocate per frame, the higher the information rate we can achieve for a given frame rate. On the other hand, as we increase the number of time slots, synchronization becomes more critical: correct decoding of the data requires us to recover, from the incoming signal, timing information relating to frame boundaries and time-slot locations. In addition, we must be able to determine within which of the *K* possible time slots a given pulse is located. This latter consideration suggests that a wide channel bandwidth providing for narrow, well defined received pulses is desirable.

D. DPIM (Digital Pulse Interval Modulation):

The DPIM is closely related to pulse interval modulation (PIM), a continuous PTM scheme, in that it employs the time interval between adjacent pulses to represent sampled data. But in DPIM these time intervals are made discrete. The DPIM is an isochronous PTM technique in which each successive frame length is different and determined by the value of the data being sampled, not by a predetermined clock period. It is well suited to the free-space optical links by virtue of its simplicity, increased transmission capacity and the absence of receiver synchronization.

By DPIM, for each symbol, an ON slot of duration $\mathrm{T}_S^{\prime}$is sent followed by a number of OFF slots depending onthe M input bits. An additional guard slot (GS)is also added, in general, to avoid sending consecutive ON pulses. Due to this reason, it is sometimes called 1 GS DPIM. We have $\mathrm{P_{ON}}$ = (L + 3) P_{av}/2. Also, the averagesymbol duration for DPIM is T_{DPIM} = (L + 3)$\mathrm{T}_S^{\prime}$ /2 and the required average BW is B = (L + 3) Rb/(2 $\log_2$L) PPM and PWM are usually called *isochronous* and *synchronous* modulations because they map the input bitson a symbol of fixed duration. Both schemes require slot and symbol-level synchronization. In contrast, DPIM is an isochronous and *asynchronous* time modulation scheme with variable symbol length, and does not require symbol synchronization [7]. In addition, it is more BW efficient than PPM and PWM, because we should not wait the end of a fixed symbol period before sending the next symbol. The main potential problem with DPIM is the error propagation in signal demodulation at the receiver [2].

III COMPARISION

A. Transmission Efficiency/ Capacity

PPM has the same transmission capacity as OOK, but PPM is more power efficient. For DPIM, it can offer more transmission capacity. Assume the transmission capacity of OOK is M bit symbol; the symbol time is *Tsoo*and the transmission capacity of DPIM will be

$$C_{DPIM}=\frac{2\left(2^M+1\right)}{2^M+3}M\ .$$

So, for DPIM the information capacity, normalized to OOK/PPM, will increase as M increase. When M is large enough, the information capacity of DPIM will approaches 2M, twice that of OOK/PPM, as expected, since on average a DPIM symbol with no guard slot will be only half the length of an OOK or PPM symbol.

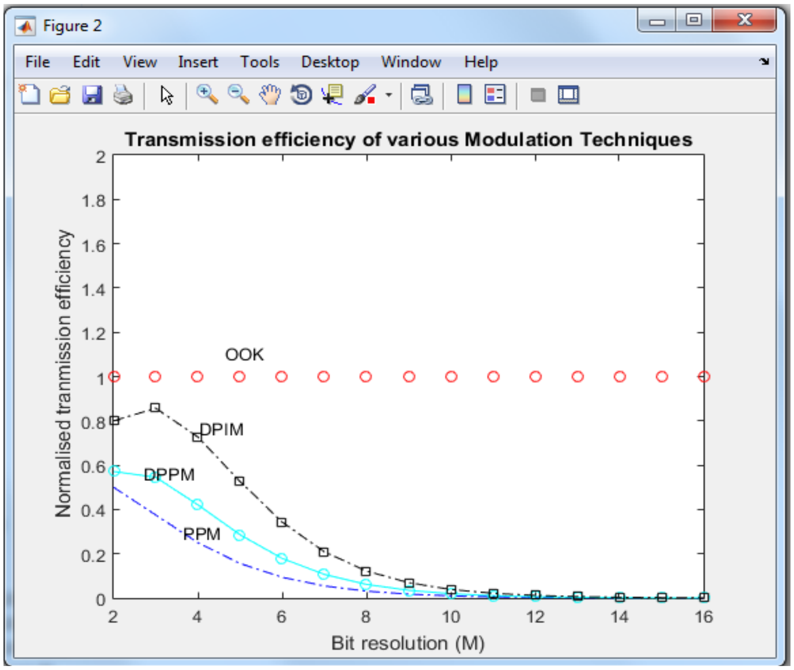

Figure 1: Transmission efficiency/capacity of OOK, PPM, DPPM and DPIM

B. Bandwidth requirement

We suppose that transmitter information bit rate is R_b bit/s each nodulation symbol has M bits. Thus, for OOK, the bandwidth requirement is roughly equal to R_b, denotesB_{OOK}=R_b, the inverse of the pulse width. For PPM the bandwidth requirement is approximately the inverse of one slot duration, i.e. $B_{PPM} = (2^M/M)\, B_{OOK}$

Table1: Bandwidth Requirement similarly for the other modulation schemes, bandwidth requirement can be derived according to the average slot widthvarious modulation techniques

Modulation Schemes	Bandwidth
OOK	$B_{OOK} = R_b$,
PPM	$B_{PPM} = (2^M/M)\, B_{OOK}$
DPPM	$B_{DPPM} = ((\frac{2^M}{M}+1)/2M)B_{OOK}$
DPIM	$B_{DPIM} = ((\frac{2^M}{M}+3)/2M)B_{OOK}$

C. Peak to Average power ratio

Correspondingly, assumes that optical pulse amplitude is constant in different modulation schemes, in this case, the pulse amplitude can be assigned to 1, then the transmission power only correlate with the optical pulse width. That is to say, the transmitted optical power is also varied, but the average transmitted optical power could be calculated according to the mean slot length which be occupied by optical pulse. In OOK, the probability of 0 and 1 is equal in block of *M* bits binary data, the average power require is

P_{OOK}= $(M/R_b)*(1/2) = M(2R_b)$

Table2: Average Power of various modulation techniques

Modulation Schemes	Average Power
OOK	$P_{ook} = M/(2R_b)$
PPM	$P_{PPM} = (2/2^M)P_{ook}$
DPPM	$P_{DPPM} = (4/(2^M + 1))P_{ook}$
DPIM	$P_{DPPM} = (4/(2^M + 3))P_{ook}$

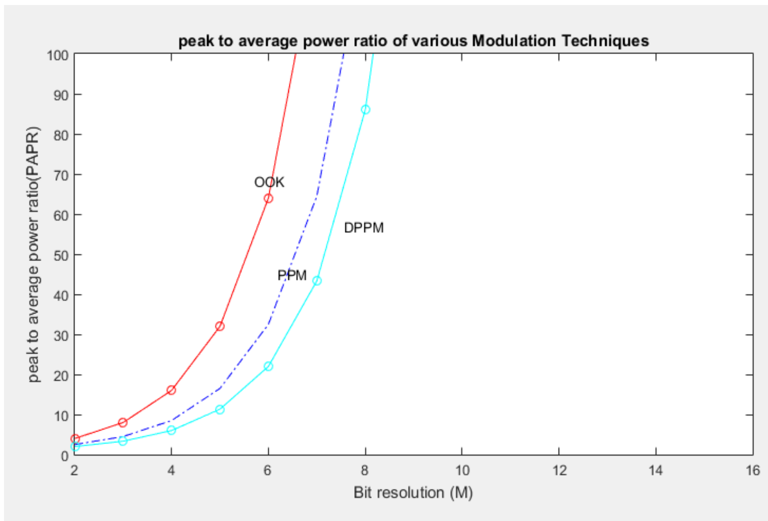

Figure 3: PAPR of OOK, PPM, DPPM

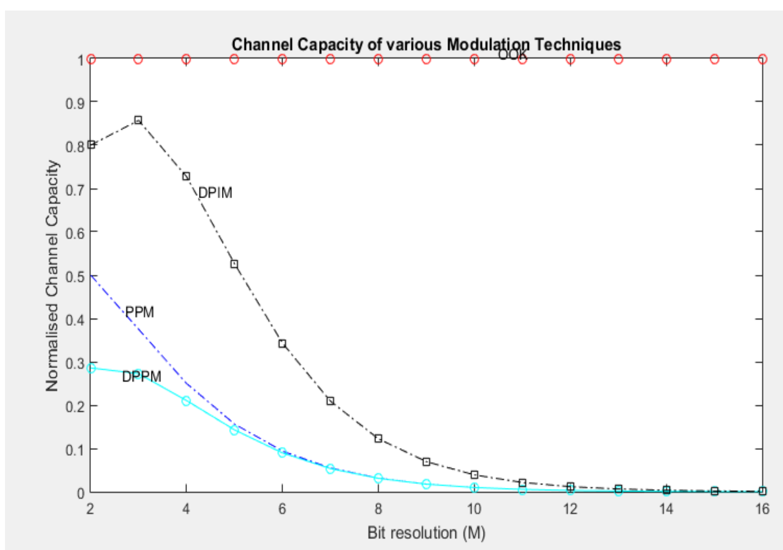

Figure 4: Channel capcity of OOK, PPM, DPPM and DPIM

IV. CONCLUSION

In the highly challenging underwater environment, the power resources are limited and their optimization is primordial. In this paper we discussed the various modulation techniques that are suitable for optical wireless communication systems for under water comm., which include OOK, PPM, DPIM, and DPPM. We have compared the bandwidth, peak to average power ratio, transmission efficiency and channel capacity for OOK, PPM, DPPM, and DPIM. The results show that the PPM in compare with OOK requires less optical power as *M* increases but its bandwidth increases as well. The channel capacity of DPPM is better than other modulation techniques. Unlike PPM, DPIM requires no symbol synchronization, thus resulting in a much simplified receiver structure. DPIM can offer some improvement in transmission power but lost some of bandwidth efficiency compared to OOK. DPIM offers higher transmission capacity compared to OOK/PPM, which can be employed to improve either the bandwidth efficiency or power efficiency of the system. Therefore, DPIM is the most efficient scheme in terms of transmission capacity and bandwidth requirements. When it comes to power and error performance, PPM is the best among the these techniques. The better BW efficiency and PAPR of DPIM, as compared to PPM, are obtained at the expense of more computationally complex demodulation, however.

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