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INTERVAL SHIFT KEYING MODULATION FOR OPTICAL WIRELESS COMMUNICATION

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Abstract-* Optical wireless communication represents an emerging and dynamic research and development area that has generated a vast number of interesting solutions to very complicated communication challenges. For example, high data rate, high capacity and minimum interference links for short-range communication, inter-building communication or computer to computer network. In its many applications, optical wireless communication links have succeeded in becoming a part of everyday lives at homes and offices. Optical wireless products are already well familiar, ranging from visible-light communication (VLC), television remote control to infrared data association (IrDA) ports. Optical wireless is also widely available on personal computers, peripherals, embedded systems and devices of all types [1]. Obviously, the data rate, quality of service delivered, and transceiver technologies employed have improved greatly from those early optical wireless technologies, but light emitting diode which acts as optical wireless transmitter has raise fall period which restricts the data rate progress of optical wireless systems and bandwidth exploitation. In this paper, a proposed modulation scheme named interval shift key modulation (ISKM) is introduced to enhance the utilisation of huge bandwidth of optical wireless communication (OWC). MAT Lab is used to build a code to measure the data rate, spectral efficiency and bit error rate which directly related to the performance of OWC. Simulation results are obtained and found in a good agreement with those presented in state of arts.

Keywords - Wireless Communication, interval shift key, Quadrature amplitude modulation, Pulse Interval Modulation, Spectral Efficiency, Bit Error Rate (BER).

I. INTRODUCTION

Optical wireless communications (OWC) is an innovative technology that has been around for the last three decades and is gaining more attention as the demand for capacity continues to increase OWC is one of the most promising alternative technologies for indoor and outdoor applications. The rapid growth of portable devices and information terminals within indoor environment and the high bandwidth demand for each terminal has already enforced the deployment of advanced communication system using optical wavelength. It offers flexible networking solutions that provide cost effective, highly secure, high speed, and license free wireless broadband connectivity for a number of applications, including voice and data, video and entertainment, enterprise connectivity, disaster recovery, illumination and data communications, surveillance and many others. The radio frequency applications are limited due to the scarcity in available bandwidth as well as high licensing cost, whereas in optical domain the huge unlicensed bandwidth, in excess of 200 THz. Moreover, due to confinement of optical beam within close walls, the same wavelength or a rage of wave lengths could be used within the same room, neighboring rooms and the buildings without any inter-channel and adjacent channel interference. With optical spectrum is free from electromagnetic interference (EMI), the application of the OWC is more suitable for environment where sensitive equipments are needed to be protected from the IME. The visible and infrared (IR) spectrum has been proposed for OWC systems. The clear advantage of visible light communication (VLC) over IR communication is possibility of dual purposes for room lightening and communication. Due to the unique properties of the optical signal, one can precisely define a footprint and hence can accommodate a number of devices within a small periphery, thus offering a perfect OWC system. OWCs, also referred to as free space optical communication systems for outdoor applications, will play a significant role as a complementary technology to the RF systems in future information superhighways.

Most practical OWC systems being currently deployed employ the intensity modulation with direct detection (IM/DD) scheme for outdoor as well as indoor applications Atmospheric conditions, in particular heavy fog, is the major problem, as the intensity of light propagating through a thick fog is reduced considerably. Therefore, intuitively, it appears that the best solution to high attenuation would be to pump more optical power or concentrate and focus more power into smaller areas. However, the eye safety introduces a limitation on the amount of optical power being transmitted For indoor applications, the eye safety limit on transmit optical power is even more stringent. The optical channel differs significantly from the RF channels Unlike radio frequency (RF) systems where the amplitude, frequency and phase of the carrier signal are modulated, in optical systems, it is the intensity of the optical carrier that is modulated in most OWC systems. The use of photo-detectors with a surface area many times larger than the optical wavelength facilitates the averaging of thousands of wavelengths of the incident waves [1-3].

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Although the optical carrier can be theoretically considered as having an unlimited bandwidth, the other constituents (photo-detector area, channel capacity, LED bandwidth) in the system limit the amount of bandwidth that is practically available for a distortion-free communication system. Also, the ensuing multipath propagation in diffuse link/nondirected LOS limits the available channel bandwidth. This also makes the bandwidth efficiency a prime metric.

In fact, the constraints prohibits the use of a large number of band-limited pulse shapes, including the sinc pulses and root raised cosine pulses to name a few. The transmission power employed in OWC configurations (mainly indoors) is limited by numerous factors, including eye safety, physical device limitations and power consumption. In outdoor free space optical (FSO) systems, to overcome attenuation due to fog, one could employ lasers with higher powers, but this is also limited by the eye-safety standards.

Both quadrature amplitude modulation (QAM) on discrete multi-tones (DMT) and multilevel pulse amplitude modulation (PAM) are spectrally efficient modulation schemes suitable for LED-based communications, but are less power efficient. DMT is a baseband implementation of the more generalized orthogonal frequency division multiplexing (OFDM) and is the most useful for channels with interference or strong low-frequency noise due to the artificial ambient light sources(e g , fluorescent and incandescent). While L-PAM and L-QAM can provide higher bandwidth efficiency at the cost of reduced power efficiency, L-pulse time modulations (such as L-PPM and L-DPIM) can achieve higher power efficiency but at the expense of increased bandwidth requirement [1-3].

Limitations on the optical power favour modulation schemes with a high peak-to-mean optical power ratio (PMOPR) such as the pulse position modulation (PPM) and digital pulse internal modulation (DPIM). OOK (the most widely used scheme in FSO systems) offers similar power requirement to the 2-PPM, whereas pass-band modulation schemes such as binary phase shift key (BPSK) suffer from 1.8 dB power penalty. The bandwidth of high data rate systems is limited due to the capacitance constraints of large-area photodiodes and, therefore, a compromise between power and bandwidth requirements must be pursued. Selecting a modulation technique is one of the key technical decisions in the design of any communication system [1-3].

Several methods have been proposed and investigated to increase OWC system data rate such as equalization and optical blue filter, but the major player in OWC data rate is the modulation technique.

I. INTERVAL SHIFT KEY (ISK)

Interval shift key is a combination of pulse modulation and shift keying. The ISK frame based on pulse interval modulation frame (PIM), but header part represented with a QAM frame instead of a pulse.

ISK modulation deals with data as a group of bit.

ISK uses low bandwidth header to represent high data rate in intervals. Therefore ISK is a counter based system and the whole system data rate depends on how fast system processor can calculate interval between adjacent headers.

A. INTERVAL

The interval is a decimal composition of any number of bits

(M bits) symbol. It is encoded between two adjacent headers. It is empty time slots, where every single time slot duration depends on system clock speed.

If there is M bits symbol, it will be converted to its decimal equivalent and a counter will count intervals which equal to decimal value. If the most significant bit (MSB) of the symbol is 1, one’s complement of the symbol will be modulated to reduce intervals (as in dual header pulse interval modulation DH-PIM and header will indicate that change. Moreover, if the next MSB is 1 then, the one’s complement of the rest of the symbol (all bits except MSB) will be calculated [4].

In this paper M equals 8 bits will be used in simulation because the probability of finding small intervals is large. The probability will be less if M increased. If the counter frequency is 1GHz and header time equals 200ns. The ratio between header time and interval time obtained as follows:

(Header time/maximum interval time)

For M = 4: ratio is 200/3 = 66.6.

For M = 8: ratio is 200/36 = 5.6.

For M = 16: ratio is 200/16383 = 0.012

For M = 32: ratio is 200/1073741823 = 0

B. HEADER

The header is the part that carries the power of the signal. Actually it doesn’t carry any information but it represents how the interval was modulated. Moreover it keeps the synchronization of the frame. Headers carry 3 bits when each bit acts as a flag that represents the characteristics of the data as shown in Table 1.

Table I. header Values Representations (Where √ Symbol Means The Bits Satisfy The Item Above)

Header value	Signal end	1’st MSB=1	1’st MSB=0	Second MSB=1	Second MSB=0
000			√		√
001			√	√	
010		√			√
011		√		√	
100	√		√		√
101	√		√	√	
110	√	√			√
111	√	√		√	

C. HEADER MODULATION TECHNIQUE

Header was modulated using 8-QAM modulation, 8-QAM carries 3 bits in single symbol and less bit error rate (BER) than other modulation schemes that carry 3 bits like 8-PSK because of distance between constellation points in 8PSK modulation less than in 8-QAM as shown in Fig.1 [5].

I Q modulation was used to generate 8-QAM level values for header. {-1, -3, +1, +3} values used to represent real and imaginary signal amplitude as in Equation 1 [5].

The Header output signal (X) is given by

$$X = A\cos(\omega t + \theta) \qquad (1)$$

Where $A = \sqrt{(real)^2 + (imaginer}$

$w \equiv angulary\ frequency = 2$

$\theta = \tan^{-1}\frac{imagin}{real}$

II. PROPOSED INTERVAL SHIFT KEY (ISK) TECHNIQUE

The ISK system depends primary on the mathematical and the logical operations. So, the system processor speed is the major player in the data rate rather than LED bandwidth as in traditional modulation shames. Fig.2 shows the proposed ISK flowchart.

The system reads 8 serial bits symbol which represents the interval (I) from data source. If the MSB of I is 1, then I will equal the logical inversion of I and header data (H) will equal (010), otherwise I will still as it is and the header will equal (000). If the next MSB of I equals 1, then all bits of I except the first MSB will be inverted logical inversion and H will equal (011) or (001) depending on pervious state of I, otherwise I will still remains as it is and H will equal to (000) or (010) depending on pervious state of I. If the symbol is the last symbol in the data, then the H MSB will equal 1 to the

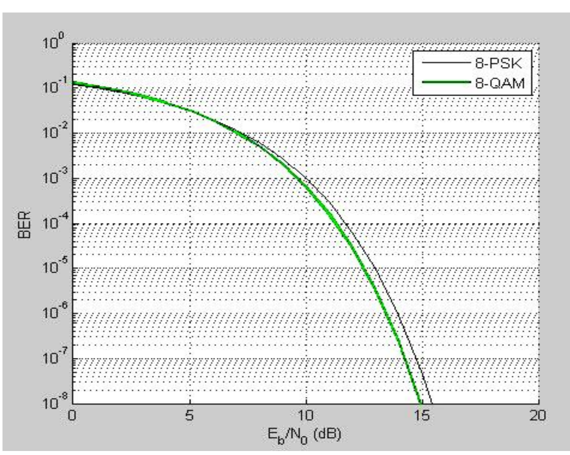

Fig. 1 Comparison between 8-PSK and 8-QAM BER in the presents of noise [6]

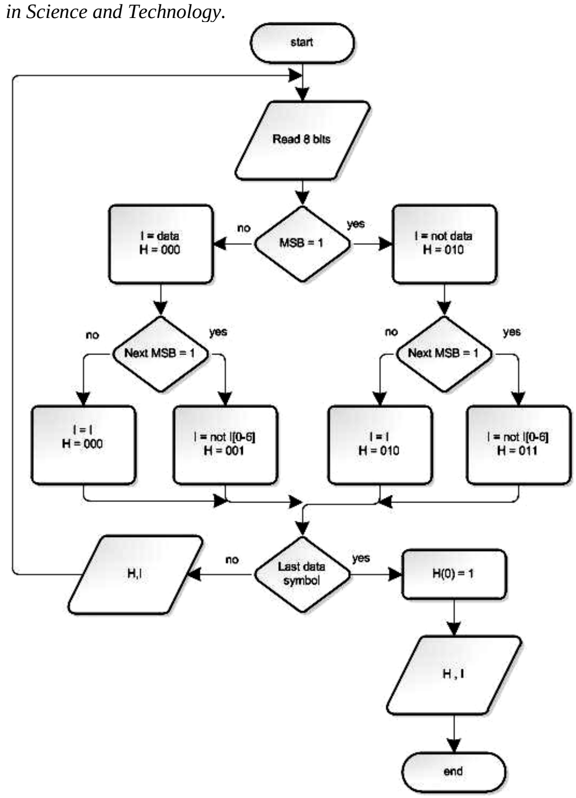

Fig. 2. The proposed mathematical and logical operations of ISK modulator Flow Chart.

Recognize the last frame otherwise it will equal 0. After that I value will be converted to its decimal equivalent and the counter will count empty interval slots which equals to the decimal value of I followed by 8-QAM frame loaded by H value.

In the demodulator part, the H value is used to determine whether I value is inverted or not and how many times it is inverted, this shown in Fig. 3. It also determines the end of the frame and keeps synchronization.

Firstly, the demodulator receives an ISK frame which consists of a header and an interval. After that the demodulator separates the header and the interval. If the header (H) equals (X1X) (X symbol means don't care) the interval (I) will be inverted logical inversion, and if H equals (X0X), then the interval will remain as it is.

After the previous stage the demodulator will test the next bit of H. If H equals (XX1) all bits of I will be inverted logical inversion except the MSB. If H equals (XX0), I will remain as it is. Then, I binary value will represent the received data. Fig. 3 shows the flow chart of the ISK demodulator.

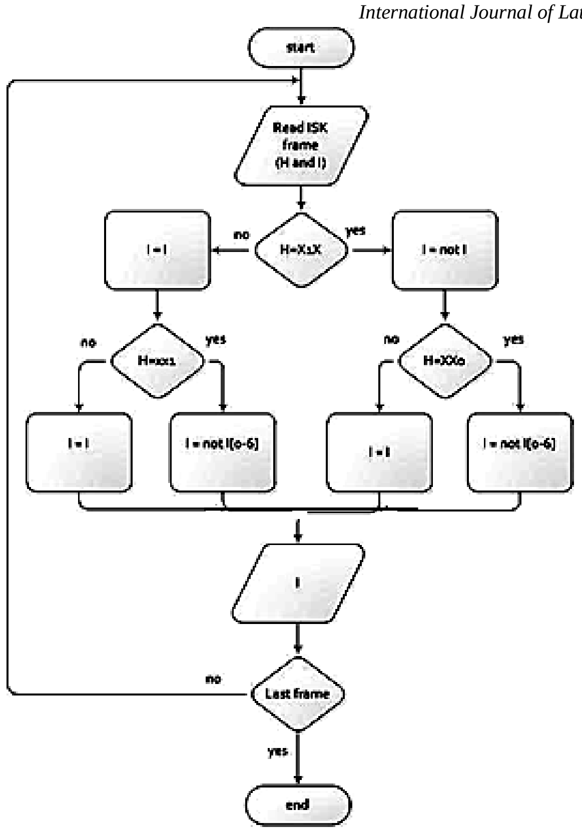

Fig. 3 Flow chart of ISK demodulator

III. RESULTS AND DISCUSSION

Mat lab 7.12.0 (R 2011a) program is used in the simulation. The Header (H) with the duration of 200ns and PC with processer counter frequency of 1GHz were selected in the simulation.

ISK based on 8-QAM modulation is found less sensitive to noise. Therefore it is expected to show bit error rate (BER) compared to other modulation techniques that carry 8 bits of data (for example 256-QAM). Fig. 4 shows the BER of ISK in the presence of Adaptive Gaussian White Noise (AGWN). The BER was also computed for 256-QAM under the same conditions and the results obtained is shown in Fig. 5.

It could be noticed that the BER distribution is not regular because if the header affected by noise, the interval also will be affected. The interval affection range depends on the value of the bits represented in the interval.

The ISK data rate affected by the decimal value of the data; therefore, the data rate is not a constant value. In the worst case (when I =00111111 or 63 in decimal) the frame time is 263ns. However; for the same working conditions the frame time for 16-QAM is 400 ns.

ISK modulation deals with data as a group of bits. The symbol M indicates the number of bits in every group. When M equals 4 that means there are 4 bits in every frame. The interval time is very short comparing with the header when time when M equals 4. H takes a lot of time because the capacitance of the LED. if a stream of data need to be modulated with M equals 4, the header will be repeated more times. It takes more time to modulate small amount of data.

If M equals 8 the interval time will increase and the number of frames will decrease which make the repetition of H is less. So it is better to modulate data stream with M equals 8.When M equals 16 the interval time will increase and the repetition of the frame will be decreased. But the interval time is very long when converting the data to the decimal equivalent which decrease the spectral efficiency.

If M equals 23 the decimal equivalent of the interval could be extremely large that will use almost the whole bandwidth. Therefore, M equals 8 bits makes the balance between the number of frames and the interval time and gives better to modulate date.

It is found that the ISK is more effective in improving the performance of optical wireless communication whenever the LED bandwidth reduced and the system counter frequency exceeded.

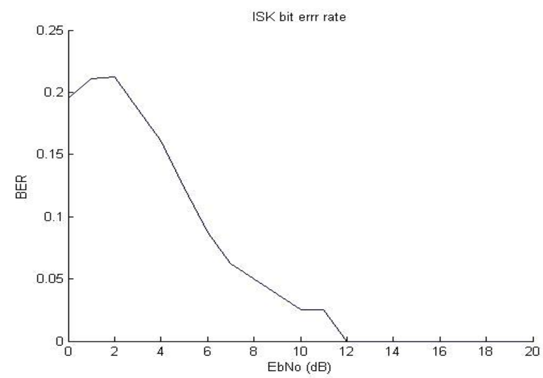

Fig. 4 the BER of ISK in a AGWN Channel.

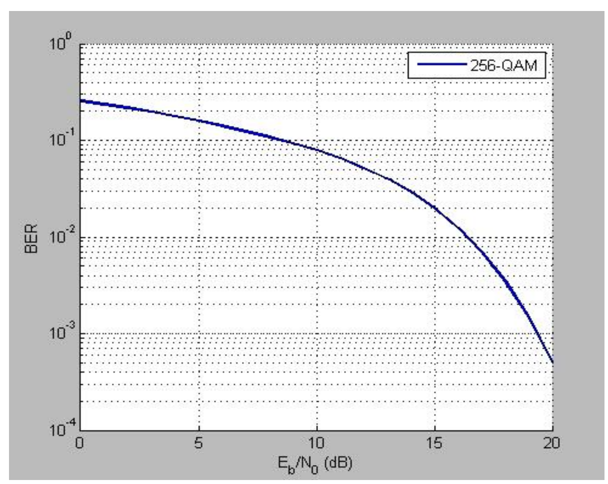

Fig. 5. The BER of 256-QAM in a AGWN channel [7].

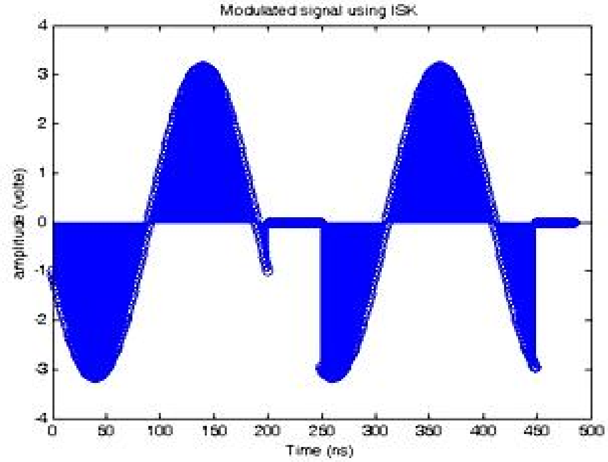

Fig.6. A sample of ISK signal of two successive frames that are carrying 16bits.

In the simulation of this study the LED bandwidth is chosen to be 5 MHz and processor counter frequency of is selected as 1GHz. The data rate value is found approximately, 40 Mbps data rate which leads to spectral efficiency of 8 bits/Hz. The results obtained are shown in Fig. 6.

The signal in the optical communication is always positive and therefore the DC bias is superimposed to ISK headers to avoid the presence of the negative signal. This is shown in Fig. 7 [4].

The ISK presents a high spectral efficiency which approximately 8 bit/Hz and this value is twice the spectral efficiency of the commonly used 16QAM.modulation. The simulation results also show the data rate of approximately 40 Mbps..Table 2 compares between of the ISK and different types of QAMs

Table2. Comparison between the BER and Spectral Efficiency of the ISK and QAMs

Modulation Type	**BER (Error Free at EbNo)**	**Spectral Efficiency** (Bit/Hz)
ISK	12	8
16 QAM	16	4
16 PSK	20	4
256 QAM	26	8

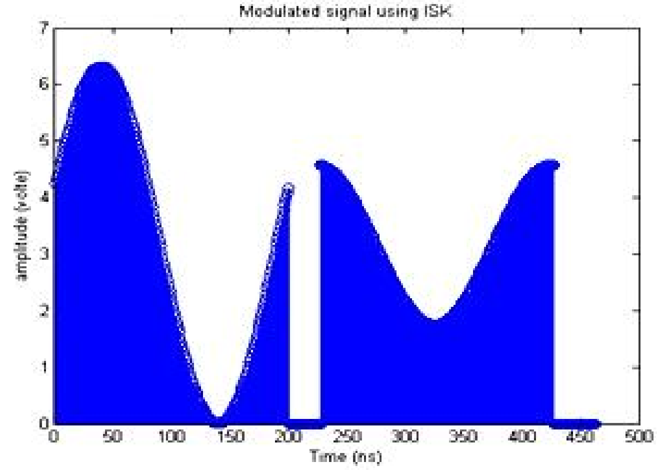

Fig. 7 ISK signal superimposed with DC bias.

IV. CONCOLUSION

This paper introduces the interval shift key modulation scheme for optical wireless communication. Mat lab is used to build a code to calculate the bit error rate, data rate and spectral efficiency for the proposed ISK system and compares the results with that of the other systems (QAMs). The simulation obtained for the proposed ISK are found in a good agreement with the results cited for the traditional modulation technique used in optical wireless communication.

ISK achieved spectral efficiency of approximately 8 bits/Hz which equals double spectral efficiency of common used modulation 16-QAM. In order to avoid inter symbol interference, an additional guard slot may be added to each symbol following the header.

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