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A Novel Study on an Optical Wireless Indoor System Based on Artificial Neural Network

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Abstract: Communication is one of the important aspects of life. High-speed wireless optical communication links have become more popular for personal mobile applications. Compared to the radio frequency domain, optical wireless communication offers much higher speeds and bit rates per unit power consumption. This work investigates the use of artificial intelligence and wavelet analysis as the main elements of indoor optical wireless communication receiver. The work uses the MATLAB tool for providing effects of Inter-symbol Interference and light interference on this receiver. This work presented focus mainly on the use of software based technique like continuous wavelet domain as an alternative for handling difficulties associated with these systems. In this, different modulation techniques like OOK and PPM are presented. The performance of this system will be analyzed based on BER value.

Keywords: Optical-Wireless, Wireless Communication, OOK, PPM etc.

I. INTRODUCTION

Communication is one of the important aspects of life. Previously various methods like sign languages were used for this purpose. With the advancement in age and its growing demands, there has been rapid growth in the field of communications. By the turn of 19^{th} century, a great leap in the field of communication was observed. Signals, which were initially sent in analog domain, are being sent more and more in digital domain now [1].

Today's society is becoming increasingly dependent on wireless connectivity with continuously converging technologies. The increasing demand for bandwidth had driven researchers to explore new technologies to accommodate more data throughput over the decades. Optical wireless communication attracted considerable attention from the academic community. Starting from short distances and low speed experimental links, the optical wireless communication domain became a viable addition to communication systems, and showed promising prospects.

Optical and wireless access networks were originally developed for different communication scenarios. Optical networks aim to provide long distance, high-bandwidth communications while wireless networks aim to provide ubiquitous, flexible communications mainly in community areas. Various kinds of optical and wireless access network architectures have been proposed and deployed as solutions for access networks separately. Optical wireless communication (OWC) is an alternative solution that provides safety for healthcare system. Optical wireless is safe for electro-medical devices and is proposed to be employed for healthcare services [3]. For wearable health monitoring, optical sensor technologies are being investigated. Furthermore, optical wireless communication provides some advantages such as high speed data rate, ease of instalment, low cost front-ends, license-free operation, and high security.

The free space optical wireless link mainly been applied in short range (less than 2 kilometres) and inter-building data connections complementary to existing RF networks. Although challenged by several competitive RF bands, including the industrial, scientific and medical (ISM) radio bands, and the local multipoint distribution service (LMDS) bands, optical wireless showed the promising features of higher data throughput and immunity to the interference usually suffered by RF systems.

The origin of optical wireless communication can be traced back to ancient times when fire beacons were used to transmit simple message over long distances. It was the pioneering research work done by F.R.Gfeller and U.Bapst in 1979 that inspired the technical community to explore further the potential of the indoor optical wireless communication. In comparison to RF, optical wireless communication enjoyed benefits such as: lower implementation cost, higher security, unregulated spectrum and operational safety. On the other hand, the channel can be severely interfered with by background noise: shot noise induced by the background ambient light (radiation from the sun if the system operated near a window or outside) and the interference induced by artificial light sources. IR systems can suffer from multipath distortion (in a diffuse system).

Despite of its good attributes that an optical wireless system has as one of the higher speed wireless system, although it is weather dependent as well. In temperate region fog and snow are the limiting factors in this regard. In tropical region, however, rain and haze are other factors limiting FOS performance. The multipath-induced inter-symbol interference (ISI) and fluorescent light interference (FLI) are the two most important system impairments that affect the performance of indoor optical wireless communication systems. The paper is ordered as follows. In section II, it represents related work with proposed system in optical wireless System. In Section III, It defines basics of proposed technique. In Section IV, It defines proposed System. Finally, conclusion is explained in Section V.

II. LITERATURE REVIEW

S.N.	Author's Name	Title	Conclusions
1.	Hao Du, Roger Green	Optical Wireless 2x2 Indoor MIMO System Based on OOK Modulation	• Provided the in-depth discussion and analysis on the design and performance of MIMO system based on a 2×2 infrared OOK modulation and regulated at 100 kHz, 1 MHz and 10 MHz bandwidth. • This described the advantages of an OOK based infrared MIMO system through evaluating the BER performance, and making comparisons of the SISO system, the diversity and multiplexing gain processes.
2.	Sujan Rajbhandari, Zabih Ghassemlooy	Wavelet—Artificial Neural Network Receiver for Indoor Optical Wireless Communications	• Presented the investigation of the DWT-ANN-based receiver for baseband modulation techniques including OOK, pulse position modulation, and digital pulse interval modulation. • The proposed system was implemented using digital signal processing board and results were verified by comparison with simulation data. • The multipath-induced inter-symbol interference (ISI) and fluorescent light interference (FLI) were the two most important system impairments that affected the performance of indoor optical wireless communication systems.
3.	Suriza Ahmad Zabidi, Islam Md Rafiqul	Rain Attenuation Prediction of Optical Wireless System in Tropical Region	• Main objective of this work was to predict and proposed specific rain attenuation parameter that best fit tropical region using measured data in tropical region for optical wireless system. • The effect of rain on optical wireless link was expressed in term of specific rain attenuation. Available specific rain attenuation parameter of optical wireless link was formulated from data measured in temperate regions.
4.	Wasinee NOONPAKDE E	Adaptive Wireless Optical Transmission Scheme for Health Monitoring System	• Presented an indoor optical wireless communications using adaptive wireless optical transmission scheme for health monitoring system. • In this scheme, optical wireless communication was proposed to transmit the obtained measurements from sensors to a central node and a medical centre using intensity modulation-direct detection (IM/DD) with on-off-keying (OOK) modulation. • The analytical results indicated that by employing the adaptive transmission scheme, the required SNR of 13.6 dB was achieved.
5.	Jiang LIU, Wasinee NOONPAKDE E, Hiroshi TAKANO	Evaluation of Reflected Light Effect for Indoor Wireless Optical CDMA System	• This was a study on the effect of reflected light on optical code-division multiple-access (CDMA) system over indoor optical wireless communication (OWC). • Bit error rate (BER) of this system was analyzed considering reflected light, background light, avalanche photo-diode (APD) noise, thermal noise, and multi-user interference. • The results proved that the BER of the system is influenced by the reflected light and the effect of reflected light was related to the room size and receiver position.

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III. INDOOR OPTICAL WIRELESS SYSTEM

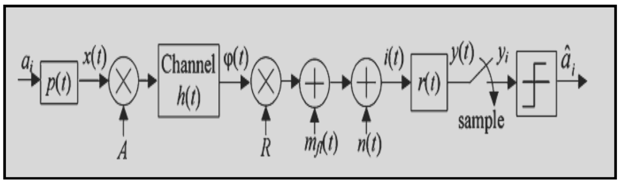

Figure 1: Block Diagram of the Unequalised OOK-NRZ system

Optical wireless communication systems consisted of a transmission unit and a receiving unit. In the transmission unit, a light emitting source (LED or LD) was modulated by a time-varying electrical current (EC) signals generated from the system input. In the receiving unit, photodiodes (PIN or APD) were used to generate EC signals according to the instantaneous optical power received from the EC signals of the transmission. Amplifier and filter modules were also used in both units to improve the system throughput and immunity to noise.

The induced inter-symbol interference (ISI) causes a significant optical power penalty (OPP), which increases exponentially with the data rate (or the delay spread). For example, the unequalized OOK modulation scheme incurs a large OPP (dB) at a normalized delay spread of. OPPs would be higher for other modulation schemes with narrower pulse duration such as PPM and DPIM; hence, unequalised reception is not feasible at high data rates for a dispersive channel.

Due to the physical properties of the link, most optical wireless systems employed intensity modulation and direct detection (IM/DD). Figure 2 showed a typical Infrared link using IM/DD. X(t) represents the instantaneous optical power from the emitter, Y(t) indicates the instantaneous current generated by the photo-detector. Since the surface of the photo-detector was millions of square wavelengths at the received optical signal wavelength, the optical link will not suffer from multipath fading effects that usually experienced by the RF system.

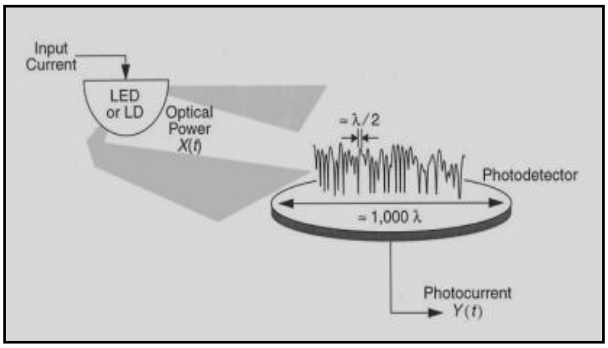

Figure 2: Transmission & Reception with IM/DD

According to transmitter and receiver calibration, the optical link can be classified as LOS or diffuse (non-LOS). In LOS links, the transmitter and receiver were aligned to give the maximum power efficiency. Compared to the diffuse system, LOS offered higher transmission speed due to the lower path loss and narrow field of view (FOV) of the optical receiver [10].

The LOS system can also be deployed in outdoor applications. The major drawback of LOS systems was that they were susceptible to physical blockage of the established links, and thus difficult to apply in mobility situations.

Nonreturn-to-zero (NRZ) OOK format is the most popular and widely utilized digital baseband modulation scheme for OWC systems in which binary "1" is represented by transmitting a pulse of duration Tb=1/Rb ,where Rb is data rate and binary "0" by an empty slot of duration Tb. The diffuse link, on the other hand, can provide more robustness for the optical channel at a cost of reduced power and bandwidth efficiency. The transmitter and receiver in a diffuse system established a connection by reflecting light from the ceiling or other diffusely reflecting surfaces. The users of a diffuse system need not consider the alignment between transmitter and receiver. A constant connection can be maintained, as long as the user was covered by the transmitter signals illumination.

IV. DESCRIPTION OF PROPOSED OPTICAL WIRELESS SYSTEM

The main interferences for Infrared communication channel including background noise and multipath inter symbol interferences (ISI). The multipath ISI was mainly limited by transmitter and receiver geometry. The ISI caused by multipath propagation and artificial light interference from fluorescent lamp driven by electronic blast are two major interferences, and these need to be taken into account when validating modulation schemes. The main challenge faced by this work is to seek the most optimized modulation scheme that can provide maximum system throughput while capable of withstanding most if not all of the intense channel interferences at a target BER requirement.

Bandwidth efficient schemes such as the OOK and PPM are prone to artificial lighting interferences. This led to a natural conclusion of a modulation scheme that can combine benefits from both above candidates and able to avoid the drawbacks of each individual scheme. So, in this work, ANN-based receiver for baseband modulation techniques including OOK, pulse position modulation (PPM) is proposed.

Modulation for Optical Wireless Communication

The optical channel is quite different from the conventional RF channel. This consequently resulted in a different approach when it came to the modulation design. Modulation schemes which fit well in electromagnetic channels were not necessarily perform well in the optical domain.

Modulation techniques remained an active topics amongst both academic researchers and industrial communication system engineers. Depending on the nature of the information source, modulation can be summarized as analogue or digital formats.

On-Off-Keying (OOK)

The OOK modulation scheme was one of the simplest modulation techniques. It was commonly used because of its easy implementation.

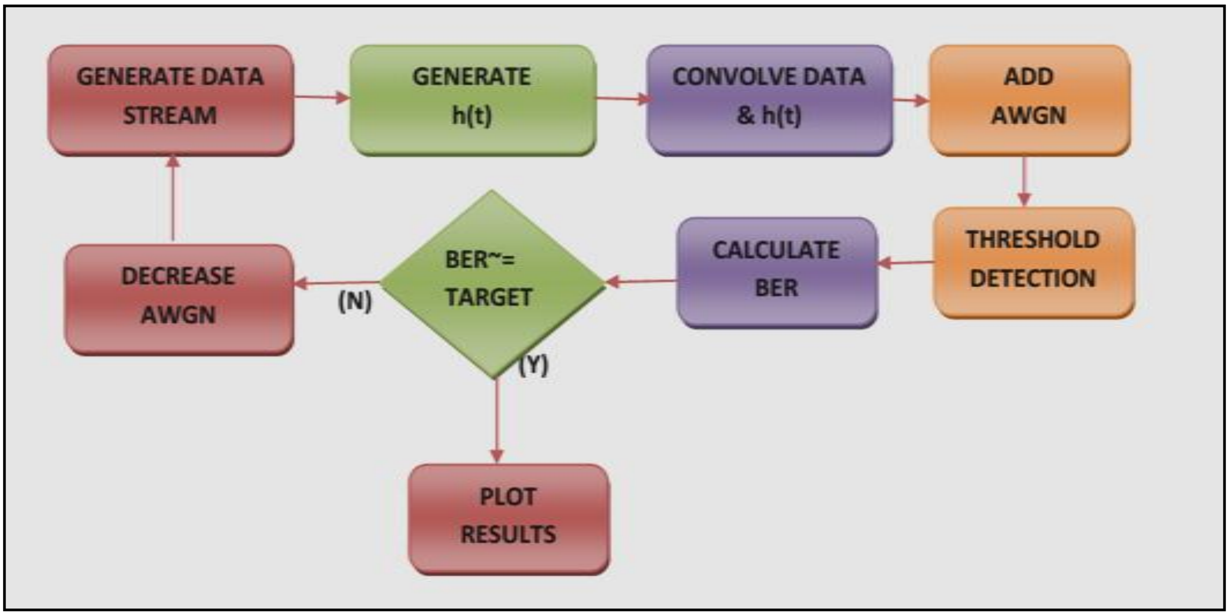

Figure 3: Proposed System Model

By default, the OOK modulation refers to the Non Return to Zero (NRZ) OOK, and this is different from the Return to Zero (RZ) OOK modulation by a fraction of γ, where $\gamma \in (0,1]$.

Pulse Position Modulation (PPM)

In PPM, transmitted optical signals were represented by the location of the pulse within a clock cycle. As a result, synchronization between transmitter and receiver was required or assumed when comparing PPM schemes with other schemes. In addition, the PPM modulation scheme was also regarded as particular version of an L-position PPM (L-PPM) system. For PPM with soft decision decoding, rather than considering individual slots, each symbol consisting of L consecutive slots must be considered as one.

The Infrared communication channel can be characterised by LOS and diffuse prorogation model. Channel noise mainly came from background noise and multipath ISI. The achievable data rate of a channel was restricted to the available bandwidth that a specific channel can provide. The impulse response of the channel was depended on transmitter, receiver location and orientation, dimension of the room where the system was deployed. Eye safety regulations defined the maximum allowed average and peak optical power that can be used in an optical wireless link.

V. CONCLUSION

The unique characteristics of the optical wireless channel exhibited challenges and opportunities. Constraints and interferences presented to the channel need to be taken into account when designing communication systems. In order to improve channel throughput, the first step was to set up the appropriate channel model. This work investigates the use of artificial intelligence and wavelet analysis as the main elements of indoor optical wireless communication receiver. The work uses the MATLAB tool for providing effects of Inter-symbol Interference and light interference on this receiver. This included fully understanding the mathematical model of the channel, noise sources and error performance under each or combined interferences. In this, different modulation techniques like OOK and PPM are presented. The performance of this system will be analyzed based on BER value.

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