Performance Analysis Of Ambient Noise On Diffused Optical Wireless Communication Systems In Indoor Environments

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***Abstract* - The major interest of our project is analysis of the diffuse configuration when the communication is Non-directed for both the transmitter and the receiver. The IR wireless channel modelling is performed with multipath IR signals transmitted by the Transmitter and received by the receiver.Performance of Indoor wireless systems mainly depends on its channel impulse response. In this paper, we have estimated the channel impulse response, this estimated channel response is used to analyze the overall system performance by calculating the BER for ambient (natural and artificial) noise. Our study considered effect of sunlight, candescent light, flouroscent light and simple on-off Keying (OOK).**

***Keywords*— Infrared (IR), ambient noise, Short Range Wireless Communication , Diffused OWC**

1. INTRODUCTION

Diffuse indoor optical wireless systems have attracted attention in WLAN applications, because of high speed data transmission without electromagnetic interference [1-3]. Compared with radio wireless systems, Diffuse indoor optical wireless systems offer many advantages, such as higher bit rate, an enormous unregulated bandwidths, high security etc.A lot of research is going on in short range wireless communication in indoor environment which includes various mediums such as Visible light , Bluetooth , Infra red light etc. But it is essential that these systems are Fast, Secure and Reliable as there is tremendous scope for growth and various applications of these systems in residential and commercial complexes.

For fixed transmitter and receiver locations, multipath dispersion is completely characterized by an impulse response h(t), defined such that the intensity of the received optical signal is the convolution of h(t) with the intensity of the transmitted optical signal. In this paper, we present a method for calculating the impulse response of diffuse indoor optical wireless system with arbitrarily placed transmitters (multiple transmitters) and a single receiver. We used the calculated impulse response to analyze/simulate the effect of multipath Dispersion on indoor optical communication systems. In indoor environment both the transmitter and receiver are located inside the room hence there is every possibility of multiple reflections happening. This multiple reflections are likely to happen from the reflecting surfaces such as ceiling, walls, floor, glass windows etc.. The major interest of our project is analysis of the diffuse configuration when the communication is Non-directed for both the transmitter and the receiver. The IR wireless channel modelling is performed with multipath IR signals transmitted by the Transmitter and received by the receiver.

The performance of Infrared(IR) transmission systems is impaired by several aspects such as the speed limitations of the optoelectronic devices (LEDs and PIN photodiodes), the high path loss, the multipath dispersion, receiver noise, shot noise induced by the background ambient light and interference induced by artificial light sources. Out of these, multipath dispersion and the background ambient light are the most important sources of degradation. Both the shot noise and the interference produced by the ambient light have been characterized through experimental measurements [5]. It was found that the solar light is the most important source of shot noise and that the interference produced by artificial light has different characteristics, intensity and bandwidth, depending on the type of lamp that produces it. We have considered only the noise due to the ambient light because, the interference introduced by the artificial light sources.

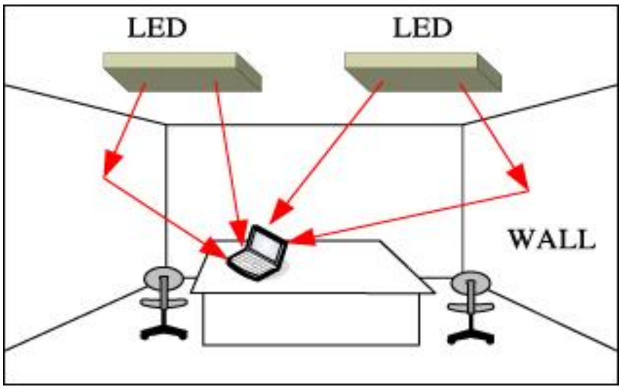


Fig (1) Multipath Data Transmission in Indoor Environment

Non-directed infrared communication systems are mainly based on the following two configurations: i) line-of-sight (LOS) and ii) diffuse. These two types of links are illustrated in figure 2. A LOS link requires an unobstructed path for reliable communication whereas a diffuse link relies on the existence of surfaces with good reflection characteristics. LOS links require less optical power than diffuse links, but as diffuse links are more robust to shadowing we will consider both inour work. In both the LOS and diffuse links, the optical signal emanates from the transmitter and impinges the receiver after multiple reflections from walls and other reflectors. The multipath propagation causes a spread of the transmitted pulse, which results in ISI.

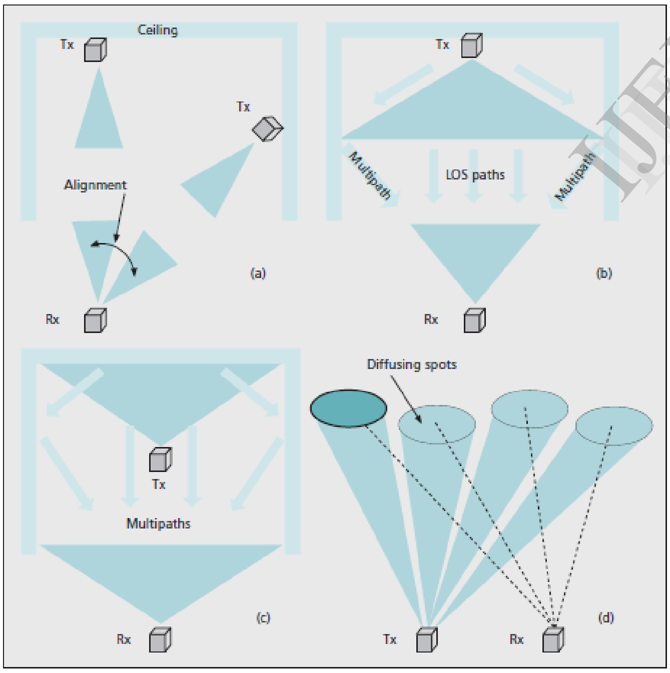


Fig (2) (a) LOS (b)Non directed LOC (cDiffuse (d)Quasi diffuse

The dominant source of noise in a non-directed link is background light, which is usually a combination of sunlight, incandescent and fluorescent light. The background light can be quite intense, especially near windows or under artificial light sources. The background light induces a high intensity shot-noise in the photo detector. Artificial light sources are also responsible for an interfering noise into the optical front-end. In a wireless infrared communication link, the existence of multiple paths between the transmitter and receiver ensures some resistance to shadowing of the receiver, which results from the multiple reflections of the optical signal on the walls, ceiling, floor and other objects. Multipath dispersion is the main bandwidth limitation of the communication.

	Link type		
	Point-to-point	**Diffuse**	**Multispot diffusing**
Link rate	High	Moderate	Moderate
Implementation complexity	Low	Low	High
Beam pointing	Required (exact)	Not-required	Required (partial)
Beam blocking	Yes	No	No
User mobility	Limited	High	High
Dispersion	None	High	Low
Path loss	Low	High	Moderate
Impact of ambient noise	Low	High	Low

1.2 TYPICAL INDOOR OW SYSTEM

A block diagram of a typical indoor OW system is illustrated in Fig.3 A basic OW system consists of a light source, free space as the propagation medium, and a light detector. Information, in the form of digital or analog signals, is input to electronic circuitry that modulates the light source. The source output passes through an optical system (to control the emitted radiation,e.g., to ensure that the transmitter is eye safe) into the free space. The received signal comes through an optical system passes along the detector, and the resulting photocurrent is amplified before the signal processing electronics. For most indoor applications, LEDs are the favored light sources due to the relaxed safety regulations, low cost, and high reliability compared to LDs. PIN PDs are commonly used due to their lower cost, tolerance to wide temperature fluctuations, and operation with an inexpensive low-bias voltage compared to avalanche photodiodes (APDs). Simple and low-cost optical carrier modulation and demodulation are usually achieved through intensity modulation with direct detection (IM/DD). The desired waveform is modulated onto the instantaneous power of the optical carrier, and the detector generates a current proportional to the received instantaneous power; that is, only the intensity of the optical wave is detected, and there is no frequency or phase information.

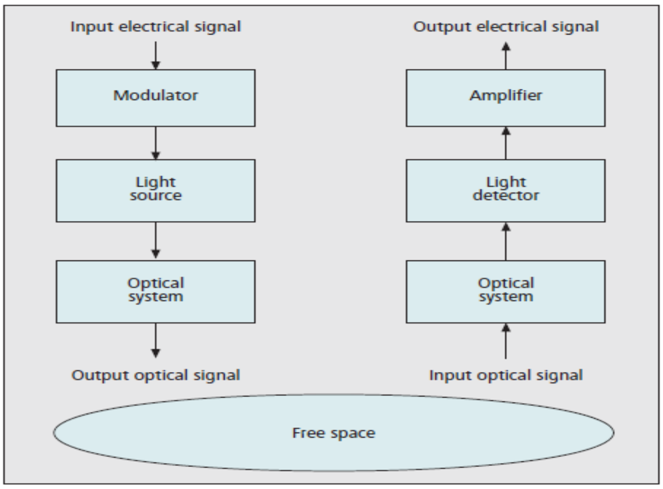


Fig (3) Block diagram of optical system

1.3 DIFFUSE INDOOR OW LINKS

Unlike point-to-point OW links, a diffuse OW link does not require the existence of a LOS to establish communications. It Employs wide beam transmitters and large FOV receivers to exploit diffuse reflections from the walls and objects inside the room and establish a communication link. the received signal is corrupted by multipath dispersion due to the large number of collected reflections at the receiver.The temporal spread of reflections results in inter-symbol interference at high data rates and limits the system bandwidth. Notice that although diffuse OW links suffer from multipath dispersion, they do not exhibit multipath fading as in RF links. The detector in diffuse OW links typically has a size of many thousands of wavelengths and the received optical intensity is integrated over the surface of the detector and provides an inherent degree of spatial diversity. Multipath dispersion severely limits the diffuse channel bandwidth and a vast array of modulation, coding and equalization techniques have been applied to combat this effect.

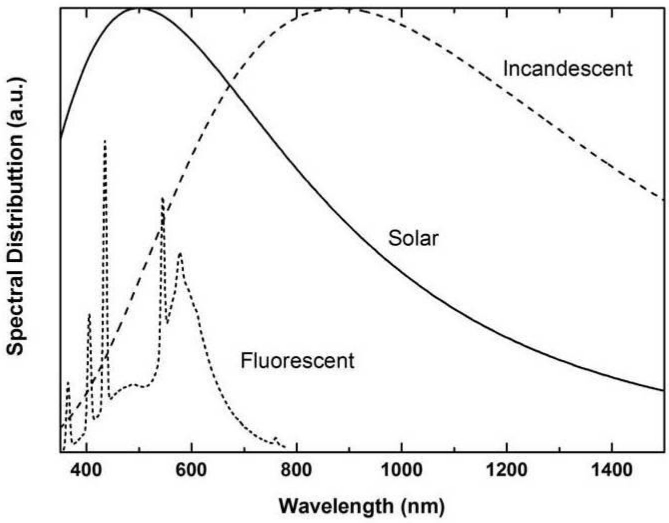


Fig.4 Spectral distribution of solar radiation and emissions from incandescent/fluorescent lamps in the visible and near-infrared wavelength range.

1.4 SYSTEM MODEL

The Block diagram for an optical wireless transmission system is shown in Fig.3. Information bits (a_k) are modulated into a symbol and transmitted to the channel. The channel input Xin(t) is then used to derive the optical source. At the receiver, the received signal Xout(t) which is transmitted signal plus noise, is filtered, detected and demodulated to produce an estimate bai of the original information bits.In this work, we assume that there is no bandwidth limitation imposed by the optical emitter on OOK modulated rectangular pulses which are transmitted through channel.

$$X_{in}(t) = \begin{cases} 2\ P_{avg} & 0 \le t < T_b \\ 0 & \text{otherwise} \end{cases}$$

where Pavg is the average transmitted optical power and Tb is the bit period. Tb = $1/R_b$, where R_b is the bit rate at which data is transmitted. As the transmitted signal propagates through the channel, it is attenuated and dispersion is introduced by the multiple reflections on the walls. As in linear electrical or radio channels with additive noise, the SNR is proportional to $|\text{Xin}(t)|^2$. However, infrared channels differ from conventional channels because the channel input $X_{in}(t)$ represents power. Thus, Xin(t) cannot be negative, and the average power is proportional to a time integral of Xin(t),

$$P_{avg} = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} X_{in}(t)\ dt$$

rather than the usual $|X_{in}(t)|^2$, which is appropriate when $X_{in}(t)$ represents amplitude At the receiver, the transmitted signal is added to the irradiance produced by the ambient light. The photodiode output current is given by,

$$X_{out}(t) = X_{in}(t) \otimes h(t) + I_B + n(t)$$

Where I_B is the DC photocurrent due to ambient light (natural and artificial) and n(t) is the shot noise produced at the photodiode. When there is no artificial light, the shot noise is a stationary process. Neglecting the photodetector dark current and assuming that I_B is much larger than the signal current $_{in}(t)$.The received signal waveform may be represented as,

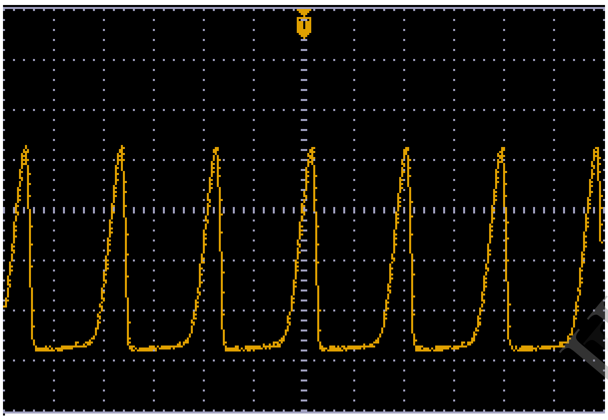
$$r(t) = \begin{cases} n(t) & \text{if a 0 is transmitted} \\ X(t) + n(t) & \text{if a 1 is transmitted} \end{cases}$$

The optimum receiver consists of a matched filter matched to X(t), whose output is sampled at t = T_b and followed by a detector that compares the sampled output to the threshold, denoted as A. If r >a ,1 is declared to have been transmitted; otherwise, it is a 0. The input to the detector may be expressed as

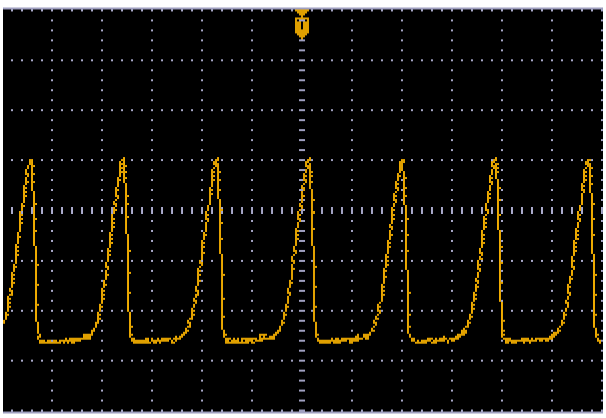
$$r(t) = \begin{cases} n & \text{if a 0 is transmitted} \\ E + n & \text{if a 1 is transmitted} \end{cases}$$

1.5 EFFECT OF AMBIENT LIGHT SOURCES

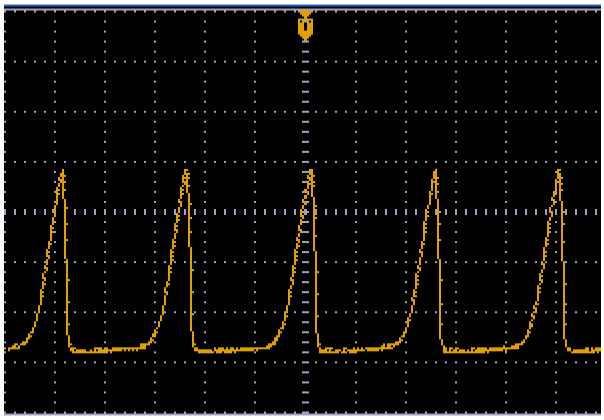
Artificial sources of ambient light introduce a periodic interference signal in optical wireless receivers which, if ignored, has the potential to degrade link performance. Consequently, knowledge of ambient light sources, both in terms of their optical power spectra and detected electrical spectra, is necessary in order to develop effective methods of mitigating the interference they produce. The three main sources of ambient light are sunlight, incandescent lamps and fluorescent lamps.



Fig(5) Incandescent Lamp Light + Natural Light effect



Fig(6) Fluorescent Lamp Light+ Natural Light effect



Fig(7) Sunlight effect

The optical power spectra of these ambient light sources are shown in Fig (8)

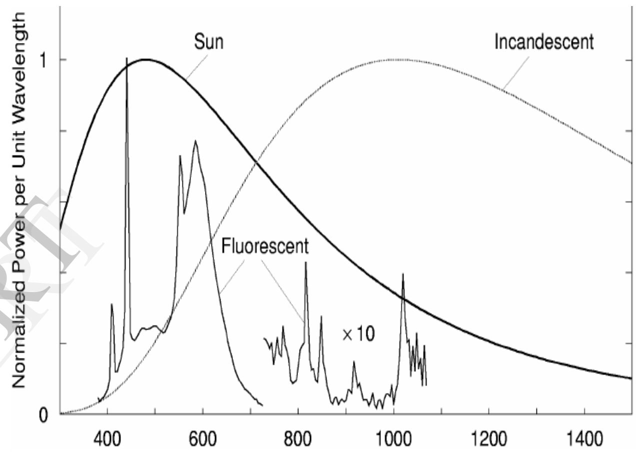


Fig (8) Optical power spectra of common ambient light sources

CONCLUSIONS

The performance of diffused indoor OWC system operating under ambient environment was evaluated. Study and the results for effect of different lights such as sunlight, Incandescent lamp light and Fluorescent lamp light on Indoor Optical Wireless communication system obtained. Its was found that these light significantly affect the performance of the system. Performance of the wireless system is highly dependent on channel characteristics, interference introduced by the artificial light source can be eliminated by using high pass filter at the receiver. It was found that the solar light is the most important source of shot noise and that the interference produced by artificial light has different Characteristics, intensity and bandwidth, depending on the type of lamp that produces it.

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