Indoor Non-directed Optical Wireless Communications -With Lambertian Order

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Abstract –

This paper analyzes the Lambertian order (LO) of light-emitting diodes (LEDs) for an indoor non-directed line of sight optical wireless communication (NLOS-OWC) system. Line of Sight systems employ high degree of directionality of the transmitter and receiver and uninterrupted LOS. LOS link design reduces multipath distortion and increases power efficiency. In this, we firstly derive an expression for the LO from a conventional Lambertian LED model. Then, we analyze the indoor cell NLOS-OWC channel characteristics which include the optical power distribution and the RMS delay spread of each LED used in system by adjusting FOV.

I. INTRODUCTION

In comparision to RF communications, indoor OWC systems promise a higher transmission bandwidth due to their inherent optical frequencie. This optical communication is also an alternative system that provides high security as it is very difficult for anyone to pick up the signal from outside the room as the optical signals do not penetrate through walls or other opaque objects. This improves the security of wireless communication. There are 3 types of indoor OWC systems which are:

1. Directed line-of-sight (LOS) indoor OWC system
2. Non-directed LOS indoor OWC system
3. Non-directed non-LOS (diffuse) indoor OWC system

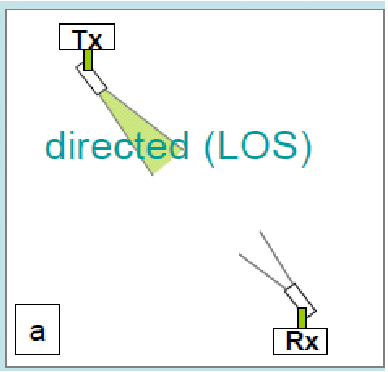


Fig. a: Directed line-of-sight (LOS)

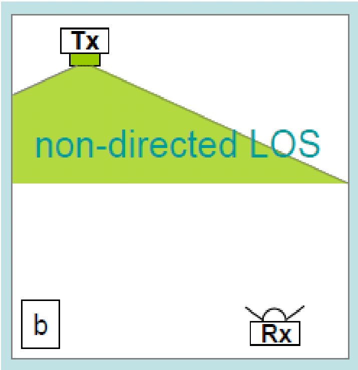


Fig. b: Non-directed LOS

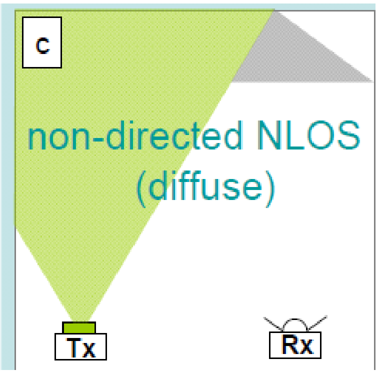


Fig. c: Non-directed non-LOS (diffuse)

With the increasing requirement of higher speed, higher power efficiency, lower path loss and lower multi-path distortion in future optical wireless local area network(WLAN), a directed line-of-sight (LOS) indoor OWC system, which has an extremely high bandwidth has attracted more attention in recent years[1,2]. Due to the small divergence angle of transmitter, the path loss is much lower and the multipath induced distortion is negligible. Moreover, a directed LOS link normally employing a photo detector (PD) with a smaller surface offers a large bandwidth and improved sensitivity[3]. Such links require a very precise alignment between the transmitter and receiver particularly when the user is mobile. Additionally, in directed LOS configurations the field of view (FOV) of the receiver is quite narrow to ensure reduced ambient light noise, but at the cost of increased transmission path blocking. On the other hand, diffuse configurations can provide a lager coverage area and an excellent mobility, but at a cost of low data rates, high path losses and multi-path induced inter-symbol interference (ISI)[4,5]. Compared with the LOS transmission, NLOS links offer a larger coverage area and an excellent mobility and without any need to precise alignment or a tracking mechanism. Compared with the common diffuse configurations, NLOSOWC links provide a lower path loss, lower ISI, and a higher transmission bandwidth. Therefore, NLOS-OWC links employing wide-angle transmitters and receivers are more convenient to use, particularly for mobile terminals.

LEDs are being widely used as sources in shortrange indoor OWC links for local area network (LAN)[7,8]. Due to the fast dynamic response of most currently available LEDs, they can be switched on and off at a much faster rates, thus enabling high speed data transmission[9] . With the increasing popularity of high definition television and video over the Internet, the indoor OWC access technology employing LEDs becomes a possible and economical solution to address the bandwidth congestion currently being experienced in most access networks[10,11].

II. SYSTEM DESCRIPTION

A. *System Configuration*

Suppose we have a room with dimension of *W* × *L* × *H* m3 (width, length, height). In this case the optical footprint has its maximum and minimum intensities at the center and the edge of the cell, respectively. The ceiling is divided into *n*-cell labelled as Ci and having identical footprints with a radius r (projecting onto the floor). A LED transmitter Tx is mounted at the centre of each cell, pointing downward to the floor plane. The divergence angles and the transmitted optical power of LEDs for all cells are assumed to be the same, so that each cell has a similar coverage area at the floor plane. At the floor plane, the optical receiver Rx has a dedicated FOV of φc and is oriented toward the ceiling to ensure seamless connectivity. As it is shown in Fig. 1, for each cell Ci, the received optical power at the receiver end consists of the power from both the LOS from C and multiple reflected paths from the neighboring cells.

B. *Channel Model with Lambertian Source*

The emission from a LED can be modeled using a generalized Lambertian radiant intensity [20]. In NLOS-OWC configurations, the transmitters, locatedat the ceiling, point downward to the floor and the receiver is pointed to the ceiling. The DC gain of the indoor LOS OWC channel is given by [20]:

$$H(0) = \left\{\frac{(m+1)A}{2\pi d^2}\right\} cos^{\mathrm{m}}(\phi) Ts(\theta) g(\theta) \cos(\theta) \text{ ,}0 \quad \leq \theta \leq \varphi c$$

$$=0 \qquad\qquad , \theta \geq \varphi c \qquad\qquad (1)$$

whereA is the photodetector surface area, ϕ is the irradianceangle, Θ is incidence angle, φc is the FOV (semiangle) of the receiver and *d* is the distance between transmitter and receiver. Also*Ts*(Θ) is the optical filter gain, and *g*(Θ) is the optical concentrator gain. m is the Lambertian radiant order relating to the transmitter semiangle φ*1/2*, (at half power), which is given by [20]:

$$m = -In2/In(cos\varphi 1/2) \quad (2)$$

The output power of a Lambertian radiant radiated into the solid angle dΩ based on the irradiance angle ϕ can be presented as [21]:

$$dPi = \frac{m+1}{2\pi} Pi \; cosm(\emptyset) d\Omega \quad (3)$$

$$PTx = \int Hemisphere \; dPi \quad (4)$$

Where , PTx is the total LED transmit optical power within C.

In practice, the semi-angle at half power of a Lambertian beam can be adjusted using some optics. Therefore m varies with the divergence angle of the Lambertian beam, which can be adapted for an indoor COWC link. For instance, a semi-angle at the half power down to ϕ1/2 ≅ 7opresents m≅ *110*. Assuming the optical receiver consists of a PD, for the multi-transmitter system, the received optical power of the LOS path is given by:

PRx LOS = PTxH(*0*)

where, PTx is the overall transmitted optical power of LEDs.

III. TABLE

SPECIFICATION FOR INDOOR NLOS OWC SYSTEMS

LED wavelength(λ)	(500-1000)nm
LED launched power	200mW
LED spacing	0.05m
Room(length,width,height)	$5*5*3m^3$
Active area of photodiode	$1cm^3$
Gain of optical filter	1.0
Refractive index of the lens at photodiode	1.5
Reflection coefficient (wall,ceiling,floor)	(0.8,0.8,0.3)
One cell configuration	
No. of LEDs per cell	144

III. NUMERICAL RESULTS AND DISCUSSION

Here, we present some numerical results to study the channel characteristics of multi-cell indoor NLOSOWC systems. The specifications and parameters are given in aboveTable. Two different configurations are considered and simulated.

A. *Optical Power Distribution and RMS Delay Spread*

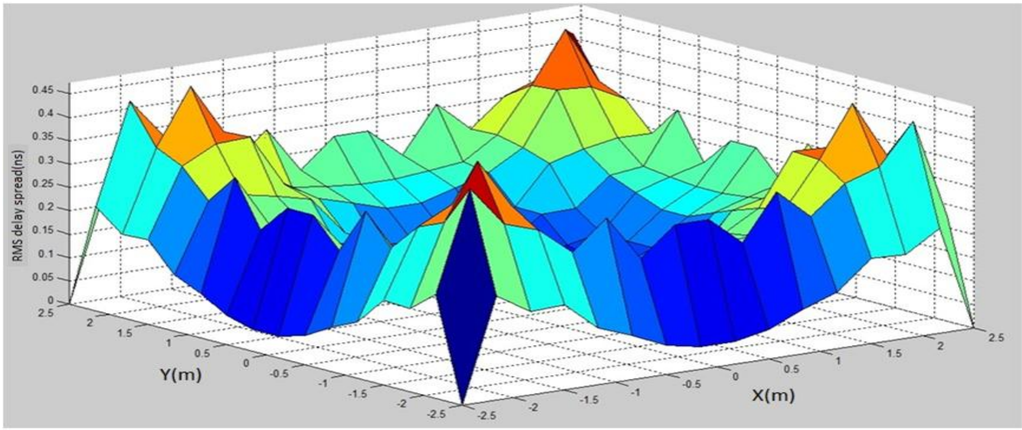
At the receiver the link performance could considerably be affected by the ISI. Here, we investigate the optical power distribution and channel delay dispersion for the proposed configuration. In this:

1) When FOV is 60^0, then recceived power varies between -1.07dbm to 2.50dbm and rms delay of each LED varies between 0 ns to 0.4727 ns.
2) When FOV is 70^0 , the received power is same ie. -1.07dbm to 2.50dbm but the rms delay of each LED increase and which varies between 0 ns to 0.6794 ns.
3) When FOV is 80^0 , the received power is same but rms delay further increase as FOV increase which varies between 0 ns to 0.7025 ns.
4) When FOV adjusted to 90^0 , the received power is same but rms delay further increase which varies between 0 ns to 0.7071 ns.

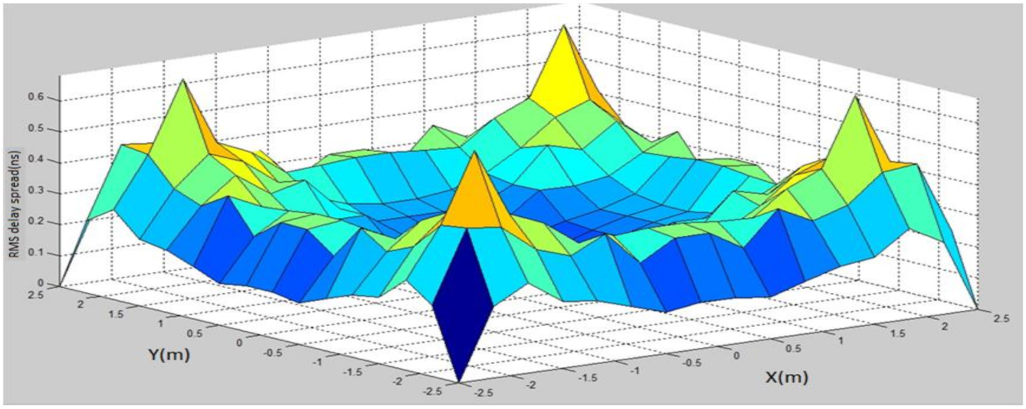
When FOV is further increased above 90^0, the RMS delay spread becomes constat.

B. *Figures*

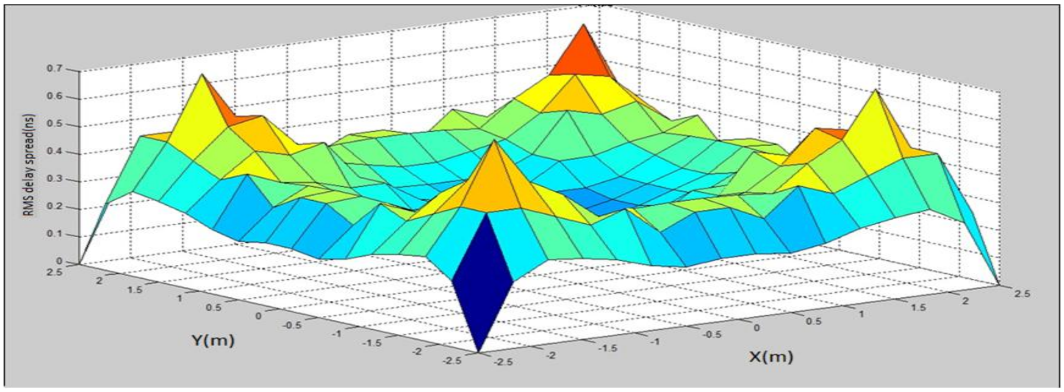
1. When FOV is 60^0



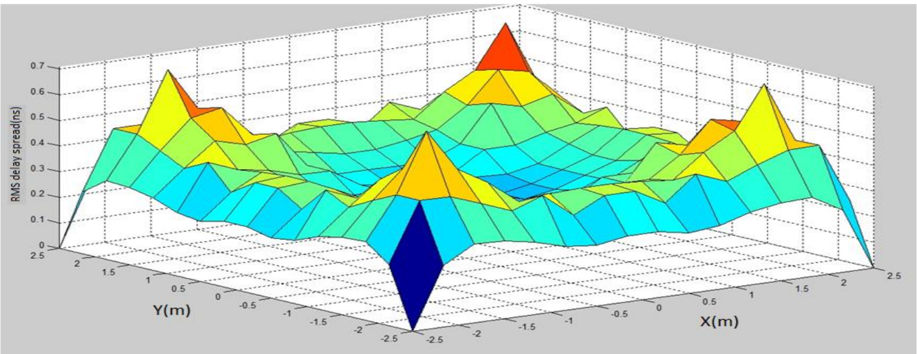
2. When FOV is 70^0



3. When FOV is 80^0



4. When FOV is 90^0



IV. CONCLUSION

In this paper, we have derived the LO for a particular indoor OWC configuration and in particular analyzed the performance for one-cell system using the Lambertian orders. The channel characteristics including optical received power distribution and RMS delay were also simulated and analyzed. From above discussion we conclude that as we increase the FOV angle the RMS delay increase. So we should use minimum FOV angle for reducing RMS delay. So the suitable FOV angle for getting minimum RMS delay is 60^0.

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