International Journal of Research
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 08, August 2015
Available at http://internationaljournalofresearch.org

Indoor Channel Characteristics of Visible Light Communication

Tabassum Ara
M.Tech Scholar, AL-Falah University, Haryana, India
EMAIL: tabisiddiqui91@gmail.com[1], jashraf.jmi@gmail.com[2]
Assit. Prof. Javed Ashraf
AL-Falah University, Haryana, India
EMAIL: jashraf.jmi@gmail.com

Abstract

This article reviews the visible light communications (VLC), a technology in which the visible spectrum is modulated to transmit data. It presents the VLC communication system: the transmitter, the channel, and the receiver.In this paper, the optical power distribution is calculated at receiver plane in a LOS path (ignoring the reflection of walls) at different Field of View (FOV). It is observed that on decreasing the FOV, the concentrator gain and the maximum and minimum optical power distribution increases.

Key Words: VLC technology; modulation methods; Optical Wireless Communications; Light Emitting Diodes and Field of View

Introduction

The Visible Light Communication (VLC) refers to the communication technology that uses the air as a transmission medium, utilizes the visible light source as a signal transmitter, and the appropriate photodiode as a signal receiving component. In last few years, we have seen a growing research in Visible Light Communications (VLC), and the idea of using LEDs for both illumination and data communications. The VLC principle is a relatively new approach for optical free space applications. LEDs provide an almost ideal platform for VLC. An LED can emit and receive light at the same time using multiplexing technology.

Visible Light Communications (VLC) can provide free space communication at very high bit rates as high as 100Mbps. The major advantage of VLC is that it causes no interference to RF-based devices. This made wireless communication possible in hospitals and space station which are hazardous for RF communication. The other advantages of VLC are simple installation procedures safety, and band licensing-free. VLC uses white Light Emitting Diodes (LED), which send data by flashing light at speeds undetectable to the human eye. In this case, high speed data can be carried by the modulated light from the LED, which makes information transmission possible while lighting our life. When signals reach the receiver through the indoor wireless channel, the photodiode will convert the optical signals to electrical ones and the original information will be recovered. The

In last few years, luminous efficiency of LED has improved rapidly from less than 1.1lm/W to over 230lm/W and with a lifetime as high as 100,000 h . The organic LED (OLED) is another upcoming type of solid-state lighting source having relatively low luminous efficiency (measured value of 100lm/W and short life time compared with the LEDs. OLEDs may also be used as an alternative solution for large area lighting and communications.

The field of applications of LEDs is also expanding. In the automotive field except the main headlights, all lights now use LEDs. Traffic lights and signals now use solid-state lighting, as sources are reliable and compact. Architectural lighting using LEDs is also becoming common, as LEDs are reliable and are low temperature compared with incandescent lights and doesn't need frequent replacement.

The peak efficiency of white LEDs is more than 260lm/W whereas the luminous efficiency of fluorescent lamps is 90lm/W and that of the traditional incandescent is 52lm/W of . The VLC technology has a number of advantages such as :

- A higher humidity tolerance,
- A smaller and compact size,
- Low power consumption.
- Having minimum heat generation characteristics compared to all other lighting sources.
- Fast switching,
- A longer life expectation,
- Are mercury free,
- A much higher energy conversion efficiency

Due to these advantages, white LEDs are ideal sources for future indoor and outdoor applications for dual purpose lighting and data communications. LED contributes a lot in energy savings at a global level .White light LEDs typically use two methods to generate white light. Red, Green and Blue devices are combined in a single package and white light is generated by mixing them in appropriate proportion. This approach has the advantage of being able to tune the colour by altering the current to each device. Visible light sources have large emission characteristics and have high optical power output. Additionally, these devices have specific wireless channel impulse response, which is quite different from that of infrared wireless communication. For achieving higher data rates particularly from the phosphorescent white LEDs, advanced modulation schemes such as multilevel and multicarrier modulation techniques, and multi input/multi output technique could be readily used. Despite all the advantages offered by the white LEDs, there are a number of technical as well as non technical challenges that still need to be addressed. One such challenge is in the designing of low-cost devices with outstanding colour quality and high luminous efficiency.

OBJECTIVE

Indoor channel characteristics of Visible Light Communication.

RECENT WORKS

In future, LEDs are expected to replace all the incandescent and fluorescent lights. VLC technology focuses on utilizing the LEDs not only for lighting, but also for communication. Visible Light Communications (VLC) originated in Japan, with the Visible Light Communications Consortium (VLCC) playing a major role. There is now growing interest in Europe , and work to develop standards within the IEEE is also underway Many models have been proposed using LEDs as communications means in various applications, for example, traffic lights for signaling , accessing the Internet in a room and underwater communication using Remotely Operated Vehicles (ROVs)

If all the lights in our houses and offices are replaced by LEDs, free space optical communications can then be achieved. H. Elgala gives differences between Radio and Visible Light Communication and declares that Optical Wireless Communications has had a long history. HU Guo-yong†1, CHEN Chang-ying1,2, CHEN Zhen-qiang1 proposes the possibility of visible red light laser being used as signal light source for Free-Space Optical(FSO) communication.

VLC SYSTEM MODEL

The luminous intensity is used for expressing the

International Journal of Research
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 08, August 2015
Available at http://internationaljournalofresearch.org

brightness of an LED and the transmitted optical power indicates the total energy radiated from an LED. Luminous intensity is the luminous flux per solid angle and is given as :

$$I = \frac{d\phi}{d\Omega} \quad \ldots (1)$$

Here: Ω = Spatial Angle
ϕ = Luminous Flux

$$\phi = K_m \int_{400}^{700} V(\lambda)\phi_e(\lambda)d\lambda \quad \ldots (2)$$

Where
ϕ_e = Energy flux
$V(\lambda)$ = standard luminosity curve
K_m = Maximum visibility
Which is approximately 683lm/W at 555nm wavelength.

Transmitted optical power P_t is shown by

$$P_t = K_m \int_{\lambda min}^{\lambda max} \int_0^{2\pi} \phi_e \, d\theta \, d\lambda \quad \ldots (3)$$

Here
λ_{max} and λ_{min} calculated by photodiode sensitivity curve.
Radiation Intensity is given as:

$$I(\phi) = I(0)\cos^{m}(\phi) \quad \ldots (4)$$

Here I(0)=Centre Luminous intensity.
m = Lambertian Emission order
ϕ = Angle of Irradiance

Lambertian order $m = \frac{-l_n(2)}{l_n\left(\cos\phi_{1/2}\right)} \quad \ldots (5)$

Here $\phi_{1/2}$ = Semi angle at half illuminance
So that, Horizontal illuminance

$$I_{hor} = I(0)\cos^{m}(\phi) / d^2 \cdot \cos(\psi) \quad \ldots (6)$$

Where ψ = Angle of incidence
d = Distance between detector and the VLED.

Similarly,
Received power at the receiver

$$P_r = P_t \frac{(m+1)A}{2\pi d^2} \cos^{m}(\phi) T_s(\psi) g(\psi) \cos(\psi), \quad 0 \le \psi \le \Psi_{con} \quad \ldots (7)$$

Here Ψ_{con} = Field of View
$g(\psi)$ = Concentrator gain
$T_s(\psi)$ = Filter transmission

So the gain of optical concentrator at the receiver

$$g(\psi) = \begin{cases} \frac{n^2}{\sin^2\Psi_{con}}, & 0 \le \psi \le \Psi_{con} \\ 0, & \psi \ge \Psi_{con} \end{cases} \quad \ldots (8)$$

Here n= Refractive Index.

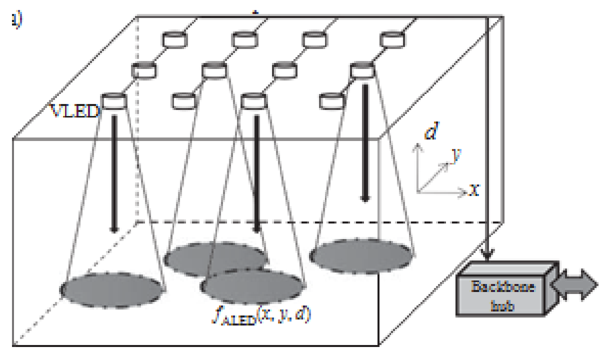

Fig.1: Schematic diagram of distributed LED array

Figure 1 shows a schematic diagram of distributed Light Emitting diode (LED) array for indoor application. Here, each single LED as a point light source. The radiation pattern of each LED can be observed as a function of the solid angle in the three-dimensional space with a well-defined radiation foot print. In basic illumination system all the LEDs are fully switched on, and they produced illumination distribution on the floor level, illumination pattern, defined in terms of the solid angle Θ as.

e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 08, August 2015
Available at http://internationaljournalofresearch.org

So the floor level of all the LED

$$f_{LED}(x,y,z) = \frac{I(\Theta)}{(x^2+y^2+z^2)} \quad \ldots (9)$$

VLC DATA TRANSMISSION

Transmitter: Fluorescent lights and LEDs can be used as transmitting device for VLC but incandescent lights are not recommended as VLC transmitters as they quickly break down when switched on and off frequently . VLC transmitters are usually also used for providing illumination of the rooms in which they are used. This makes fluorescent lights a better choice to use as a transmitter because they can sparkle quickly enough to transmit a meaningful amount of data and are already widely used for illumination purposes . LEDs are expected to replace fluorescent lights as illumination sources and VLC transmitters.

Receiver: The VLC receiver is composed of receiving optical elements including optical concentrator and optical filter, photodiode, amplifier, and signal recovery circuit. Basically, the VLC system is designed to employ direct detection at the photodiode.

The Silicon p-type-Insulator-n-type Photodiode (Si PIN-PD) and Silicon Avalanche Photodiode (Si APD can be used as photodiodes because they have good responsively to visible light.

There are several types of signal amplification circuits. The high impedance amplification is simple to implement. The series resistor is connected to the anode of the photodiode and the high input-impedance amplifier senses the voltage across the series resistor and amplifies it. The other one is trans-impedance amplifier that provides current-to-voltage conversion by using shunt feedback resistor around an inverting amplifier.

Generally, the noise in the VLC receiver is similar to the usual optical communication receiver, for example, the thermal noise from the load resistor and the photodiode, the shot noise in the photodiode, the excess noise from the amplifier. The main noise components are the sunlight and the other illumination light. Therefore, it is important to employ appropriate optical filter to reject unwanted DC noise components in the recovered data signal.

VLC systems use LEDs for transmission and photo-detectors for reception. The LED cannot be used as it is less sensitive than photo detector and this property negatively affects the achievable communication range. A second drawback is the resulting limited throughput due to the required multiplexing: Whereas, the transmission and reception can occur at the same time in parallel, with a single LED per VLC device. This LED can either only transmit or only receive but cannot do both at the same time. To use single LEDs as transceivers, the VLC device needs to alternate transmission and reception periods.

SIMULATION RESULTS

Simulation studies involves enhancement of the optical power distribution at receiver plane in a LOS path at different Field of View (FOV). Figure (1) . Shows a schematic diagram of distributed LED for indoor application where each single LED can be viewed as a point light source. Figure (2) shows a graph between FOV and Concentrator Gain (G_{con}). It is observed that Concentrator Gain (G_{con}) increases on decreasing the values of FOV. In Figure (3) a graph is drawn between minimum received power and the FOV. As shown the minimum received power is inversely proportional to the FOV, i.e. it increases on decreasing the value of FOV. Figure (4) shows a graph between a maximum received power and field of view. Maximum received power also increases on decreasing the FOV. Figure (5) shows the 3-D view of Optical power distribution of LOS link at a receiver plane using Matlab. Table 1 shows the assumed parameters of a typical room. Table2

International Journal of Research
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 08, August 2015
Available at http://internationaljournalofresearch.org

shows in tabulated form that the values of G_{con}, minimum and maximum received power increases on decreasing the angles of Field of View.

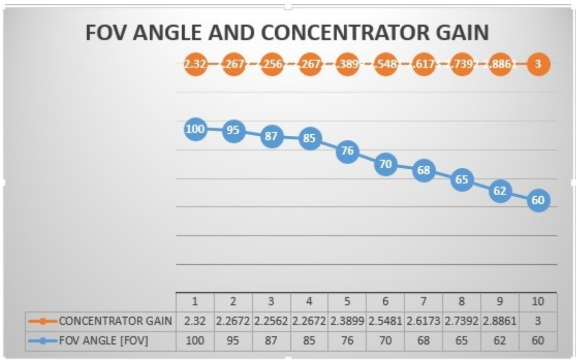

Fig. 2: Field of View and Concentrator Gain

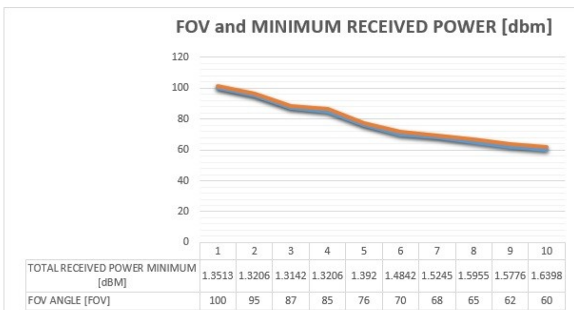

Fig. 3: Field of View and Minimum Received Power

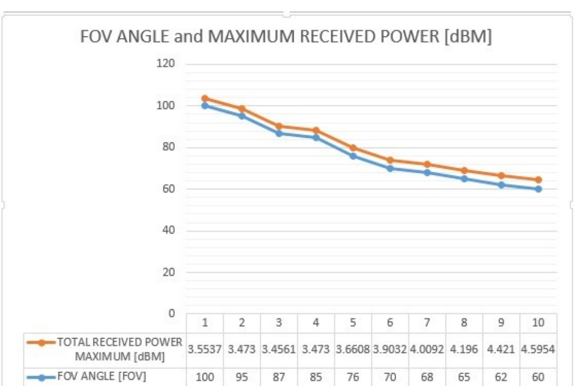

Fig. 4: Field of View and Maximum Received Power

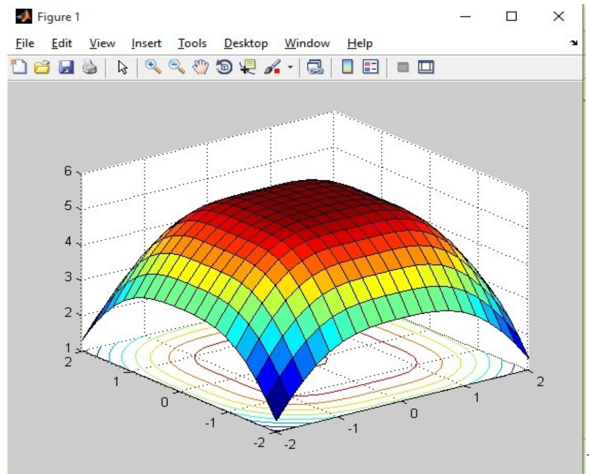

Fig. 5: Optical Power distribution of LOS link at 100^0 Field of View

Table 1: Assumed Parameters of a Typical Room

S. No.	Parameters	Values
1	Refractive Index	1.5
2	Room Size	(4×4×3)m
Receiver Parameter		
3	Distance between Source and Receiver Plane	2.00m
4	Active Area	$1cm^2$
5	FOV	(90,87,84,81,78,75,72,69,66,63,60)
Source Parameter		
6	Position of LED	(-1,1;-1,1),(-1,-1;1,1)
7	Position of one LED at the central of the	(0,0;0,0);(0,0;0,0)

International Journal of Research
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 08, August 2015
Available at http://internationaljournalofresearch.org

	Room	
8	Semi-angle at half power	70
9	Transmitted power (per LED)	25 mw
10	Number of LEDs per array	70×70

Table 2: Concentrator Gain, minimum and maximum received power at various Field of view

S. No.	FOV Angle (FOV)	Con. Gain (G_{con})	Total Received Power (dBm)	
			Minimum	Maximum
1	100	2.3200	1.3513	3.5517
2	95	2.2672	1.3206	3.4130
3	90	2.2500	1.3106	3.4466
4	87	2.2562	1.3142	3.4561
5	85	2.2672	1.3206	3.4730
6	76	2.3899	1.3920	3.6608
7	70	2.5481	1.4842	3.9032
8	68	2.6173	1.5245	4.0092
9	65	2.7392	1.5955	4.1960
10	62	2.8861	1.5776	4.4210
11	60	3.0000	1.6398	4.5954

CONCLUSION

In this paper, the key ideas on visible light communication (VLC) have been reviewed in relationship with optical wireless communication. The channel characteristics for VLC system were mentioned and the VLC transmitter and receiver are described including the basic characteristics of LEDs.

Based on the simulation result in this article following point wise conclusions can be drawn:

- The Line of sight links can be increased by reducing the Field of View (FOV).
- The minimum and maximum received powers are somehow inversely proportional to the Field of view, i.e., their value increases on decreasing the values of Field of view.
- The concentrator gain or channel gain is inversely proportional to the value of FOV, which is proved by simulated results.

REFERENCES

[1.] G. Corbellini, S. Schmid, S. Mangold, T. R. Gross, and A. Mkrtchyan, "LED-to LED Visible Light Communication for Mobile Applications," in Demo at ACM SIGGRAPH MOBILE 2012, August 2012.

[2.] N. O. Tippenhauer, D. Giustiniano, and S. Mangold, "Toys communicating with LEDs: Enabling Toy Cars Interaction," in Demo at Consumer Communications and Networking Conference, CCNC, IEEE, Jan. 2012.

[3.] O.Bouchet, M.ElTabach, M.Wolf, D.C. O'Brien, G.E.Faulkner, J.W.Walewski, S.Randeletal., Hybrid Wireless Optics (HWO):Building the next-generation home net-work, 6thInternational Symposium on Communication Systems, Networks and Digital Signal Processing, CNSDSP, Graz,, pp. 283–287. Austria, 2008

[4.] M.A.Naboulsi, H.Sizun and F.d.Fornel, Wave length selection for the free space optical telecommunication technology, SPIE, 5465, p.p168–179, 2004.

[5.] J.K.Kim and E.F.Schubert, Transcending the replacement paradigm of solid-state lighting, Optics Express, 16, 21835–21842, 2008.

[6.] W.Binbin,B. Marchant and M.Kavehrad, Dispersion analysis of 1.55μm free-space optical communications through a heavy fog medium, IEEE Global Telecommunications Conference, Washington, USA,, pp.527–531. 2007

[7.] V.Kvicera, M.Grabner and J.Vasicek, Assessing availability performances of free space optical links from airport visibility data, 7th International Symposium on Communication Systems Networks and Digital Signal Processing (CSNDSP), New castle upon Tyne, UK,,pp.562-565. 2010

[8.] G.J.Foschini, Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas, Bell Labs Technical Journal, 1, p.p41–59,1996.

[9.] T.Komine and M.Nakagawa, Fundamental analysis for visible-light communication system using LED lights, IEEE Transactions on Consumer Electronics, p.p50, 100-107,2004.

[10.] Vlcc: Visible Light Communications Consortium, www.vlcc.net, 2008

[11.] Forum, W.W.R.: Wireless World Research Forum, http://www.wireless-world-research.org/?id=92, 2008

[12.] IEEE 802.15 WPAN Visual Light Communication Interest roup (IGvlc) http://www.ieee802.org/15/pub/IGvlc.html, 2008

[13.] S. Iwasaki, C. Premachandra, T. Endo, T. Fujii, M.Tanimoto, and Y. Kimura. "Visible light road-to-vehicle communication using high- speed camera", in Proc. IEEE IVS', Eindhoven, Netherlands, pp. 13-18. 08, June 2008.

[14.] T. Komine and M. Nakagawa , " Fundamental Analysis for Visible-Light Communication System Using LED Lights ", IEEE Transactions on Consumer Electronics, Vol. 50, no. 1, pp. 100-107, February 2004.

[15.] J. Y. Joo, S. K. Lee, C. S. Kang and S. S. Park, "Design of an Ultra Thin Secondary Lens for Visible Light Communication Based on a White LED", in Proc. IEEE ISOT', Istanbul, Turkey. pp. 140-145. 09, Sept. 2009

[16.] H. Elgala, "A Study on the Impact of Nonlinear Characteristics of LEDs on Optical OFDM," PhD Thesis, 2010.

[17.] HU Guo-yong†1, CHEN Chang-ying1,2, CHEN Zhenqiang1"Free-Space Optical communication using visible light",2(1Institute of Optoelectronic Engineering, Jinan University, Guangzhou 510632, China) (2Department of Optoelectronic Engineering, Jinan University, Guangzhou 510632, China).

[18.] Z. Ghassemlooy, W.Popoola, S. Rajbhandari- Optical Wireless Communications System and Channel Modelling with MATLAB.

[19.] Kaiyun Cui, Gang Chen, "Line-of-sight Visible Light Communication System Design and Demonstration", CSNDSP, pp. 621-625, 2010.

[20.] T.Hara,S. Iwasaki, T. Yendo, T.Fujji, and M. Tanimoto, "A New Receiving System of Visible Light Communication for ITS", in Proc. IEEE IVS', Istanbul Turkey. pp. 474-479. 07,June 2007.-451.