Australian Journal of Basic and Applied Sciences, 5(11): 1567-1572, 2011
ISSN 1991-8178

"Single Source Analytical Study on the Performance of Visible Light Communication"

Mohammad Syuhaimi Ab-Rahman, Luqman Al-Hakim Azizan, Mazen Radhe Hassan and Nurain Izzati Shuhaimi,

Spectrum Technology Research Group (Spectech) Dept., of Electrical, Electronics and System Engineering, Faculty of Engineering and Built Environmental Space Science Institute (ANGKASA) Universiti Kebangsaan Malaysia.

Abstract: Due to the rapidity of technological advances on optical communication, the wireless optical using visible light is being studied for indoor communication application. In this paper, the performance of single source white LED for communication is studied through analytical approach. Choosing on the On - Off Keying modulation, the value of Bit Error Rate (BER) and Received Power (Pr) are analysed with the specified distance and angle. The result showed that the value of BER, 10^-9 is achievable up to the distance of 3.4m with the acceptable value of Signal to Noise Ratio, about 15.7dB. At the same distance, the maximum angle of irradiance and incident angle is at 71.67° with the received power is - 19dBm which need an improvement. The performance of visible light system seems to be applicable for indoor communication system as it can provide an efficient communication medium in 3m distance.

Key words: Wireless Communication, White Led, Single Source, Snr, Ber, Received Power.

INTRODUCTION

The demand on large bandwidth for high speed communications force the researchers to explore the possibility of using the high frequency electromagnetic radiation for communication purpose. We cannot deny the use of the radio frequency in communication field plays a major role in human life since it is being introduced until today, and the presence is still valid. Relying on the radio frequency for communication is not promised for next generation as the radio communication systems have limited bandwidth. Moreover the communication systems today is not only used for connecting people but also being embedded with the source of information, that is known as information and communication technology (ICT). This technology is being widely used to connect people in any region of the world and at the same time sharing the information via the virtual system.

Recently the need to access wireless local area networks from mobile devices and portable personal computer grows exponentially as the number of users have been increased drastically over the span of last five years (Adiyta Goel, 2009; Ubolthip Sethakaset, 2005). The push of higher data rates of those networks due to the multimedia applications has motivated recent interest on optical communications (F.R. Gfeller and U.H Bapst, 1979; J.R. Barry, 1997). The technology of optical for communication application begin with the use of fibre optic cable instead of copper cable. Then the exploration of optical fiber for communications move a step to the introduction of using the the Polymer Optical Fiber (POF) which provide a faster data transmission. Nowadays, for short-range wireless communication an optical wireless communication using visible light radiation is being studied and developed. The visible light present a viable and promising supplemental technology to the current radio wireless in communication systems (Langer, K.D., 2008). The optical wireless communication has several advantages over the radio frequency for indoor application due to the immunity against the electromagnetic interference (EMI), providing high and unregulated bandwidth and also provide a secured network against eavesdropping as the light does not able to pass via the opaque-barriers (Kahn, J.M. and J.R. Barry, 1997). The advantages of optical wireless show the possibility of the implementation of this optical wireless system.

Basically in the optical wireless communication system there are two types of spectrum that are being studied i.e. that is infrared and the visible light. Even though the infrared spectrum has been studied for the last century but the implementation of infrared for local area networks is limited due to several reasons. The primary drawback of infrared radiation is potentially induced thermal damage to human eye and an international standard IEC 60825-1 is being introduced for laser safety (J.R. Barry, 1997; Kahn, J.M. and J.R. Barry, 1997). Besides, the Laser Diode (LDs) setup is very expensive than the Light Emitting Diodes (LEDs) and the spectral width of infrared is much smaller than the LEDs (Kahn, J.M. and J.R. Barry, 1997). With this reason the focus of optical wireless communication using infrared have been diverted to the new spectrum using LED that is known as the visible light.

Corresponding Author: Mohammad Syuhaimi Ab-Rahman, Spectrum Technology Research Group (Spectech) Dept., of Electrical, Electronics and System Engineering, Faculty of Engineering and Built Environmental Space Science Institute (ANGKASA) Universiti Kebangsaan Malaysia.
E-mail: syuhaimi@vlsi.eng.ukm.my

2.0 Indoor Optical Wireless Channel:

The most viable modulation scheme for free space optical is intensity modulation (IM) with the direct detection (DD) links. This such channel IM/DD could be modelled as the expression below, using the Additive White Gaussian Noise(AWGN) in the case that, there is no ambient light present (S. Karp, 1976; J.R Barry, 1997):

$$Y(t) := \rho \cdot X(t) \oplus h(t) + N(t) \tag{1}$$

Referring to the equation (1),Y(t) represent the received current at the photodetector, X(t) is the transmitted optical power, the impulse response represent with h(t), N(t) is the AWGN, ρ represent the photodetector efficiency converting an optical to electrical signal and the symbol ' ⊕ 'denotes convolution.

Single Source Received Power:

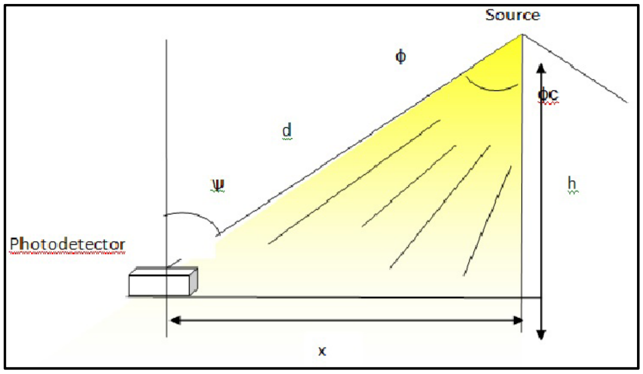

Fig. 1: The propagation model of direct links.

The Figure 1 shows the direct links of single source model using analytical method. The average transmitted power Pt is given as below (Kahn, J.M. and J.R. Barry, 1997),

$$Pt := \lim_{T \to \infty} \left[\frac{1}{2T} \left(\int_{-T}^{T} X(t)\, dt \right) \right] \tag{2}$$

and the average received power is given by (Kahn, J.M. and J.R. Barry, 1997),

$$Pr := H(0) \cdot Pt \tag{3}$$

where H(0) denotes the dc channel gain.

DC Channel Gain (Direct Links):

The DC channel gain of the direct detection(DD) links visible light communication is given as (Kahn, J.M. and J.R. Barry, 1997):

$$H(0) := \begin{cases} \dfrac{(m+1)\cdot A \cdot \cos(\phi)^{m} \cdot T \cdot g(\psi) \cdot \cos(\psi)}{2 \cdot \pi \cdot d^{2}} & \text{if } \psi c \geq (\psi) \geq 0 \\ (0,) \psi > \psi c \end{cases} \tag{4}$$

Where's p is referring to the order of lambertian emission, d is the distance between the receiver and transmitter, Ts(ψ) is the optical filter gain, g(ψ) is the gain of optical concentrator, □ is the irradiance angle, ψ is the angle of incidence and ψc is the field of view (FOV).

The gain of optical concentrator having refractive index, n depending on the concentrator field of view (FOV) is given as below (Kahn, J.M. and J.R. Barry, 1997).

$$g(\psi) := \begin{cases} \dfrac{n^2}{\sin(\psi c)^2} & \text{if } 0 < \psi < \psi c \\ 0, \psi > \psi c \end{cases} \tag{5}$$

The FOV is basically depending on the design of the receiver, usually ≤ 90degree. The narrower FOV will result a higher gain that is suitable for directed links.

The order of p, is related to the transmitter semi angle(at half power) Ǿ1/2 that is expressed as below (Kahn, J.M. and J.R. Barry, 1997):

$$p := \frac{-\ln(2)}{\ln(\cos(0.5\phi))} \tag{6}$$

In the optical wireless channel, the light wave becoming as the information carrier whose frequency is about 10^14Hz. This means that the multipath fading can be neglected. In fact, for optical wireless channel, spatial diversity is efficient as the detector dimensions are in the order of thousands of wavelength which prevent the multipath fading.

Performance of Single Source:

The output current of the optical wireless contain the Gaussian noise having a total variance V^2 that is the sum of shot and thermal noise (Kahn, J.M. and J.R. Barry, 1997),

$$V^2 := \sigma shot^2 + \sigma thermal^2 \tag{7}$$

The shot variance is given by (A.P.'Pang, 1996; T. Komine and M. Nakagawa, 2004):

$$\sigma shot^2 := 2q \cdot Ibg \cdot I2 \cdot B + Pt \cdot 2 \cdot q \cdot \gamma \cdot B \cdot H(0) \tag{8}$$

and the thermal variance is expressed as (A.P.'Pang, 1996; T. Komine and M. Nakagawa, 2004) :

$$\sigma thermal^2 := \frac{\left(8\pi \cdot k \cdot Tk \cdot \eta \cdot A \cdot I2 \cdot B^2\right)}{G} + \left[\frac{\left[16\pi^2 \cdot k \cdot Tk \cdot \Gamma \cdot (A)^2 \cdot \eta^2 \cdot I3 \cdot B^3\right]}{gm}\right] \tag{9}$$

In this study, the On Off Keying with Non-Return to Zero modulation scheme is applied due to its simple implementation, whereby the one bit is encoded if the light is transmitted and zero bit is encoded if there is no light transmitted.

From the equations above, the Signal to Noise Ratio(SNR) is given by (Kahn, J.M. and J.R. Barry, 1997),

$$SNR := \gamma^2 \cdot H(0)^2 Pt^2 \left[\frac{1}{\left(\sigma shot^2 + \sigma thermal^2\right)}\right]$$

and the BER can be expressed as (Kahn, J.M. and J.R. Barry, 1997):

$$BER := Q\left(\sqrt{SNR}\right)$$

SNR is used to evaluate the quality of communication while BER is used to estimate the current quality of the wireless link in term of data transition.

3.0 Analytical Simulation:

In this paper the value of distance is varied to identify the maximum length that is acceptable for communication applications of an area while the height is fixed about 1m. The angle of irradiance is considered the same value with the incident angle in the case where the horizontal plane, x is perpendicular with the vertical axis as shown in Figure 1. The value of angle is varied in conjunction with the value of x as the distance related with the angle. The table 1 below shows the value of parameters that are being used for the analytical modelling of visible light communication. The FOV of the receiver in this experiment is 90°, considering for wide input lights.

Table 1: The parameters for the above equation for simulation.

Pt	5W
n	1.5
Øc	60deg
Ts	1
A	5cm2
□	1.12u/m2
y	2m
B	100MHz
ρ	0.54A/W
Ibg	5100uA
G	10
□	1.5
gm	30mS
I2	0.562
I3	0.0868
Tk	300K
Γ	1.5
gm	30mS

RESULTS AND DISCUSSION

In this paper the value of Bit Error Rate (BER) is calculated to study the relation of distance with the signal quality by using single source. The value of BER present the number of bit errors that occur for a given number of bits transmitted (E. Louis, 2008). The acceptable value of BER for telecommunication is in the range of 10^-9 ("Fiber-Optics Info." 2011). The figure below shows the combination graph of BER and ψ versus distance. The value of BER is in term of log for easy observation.

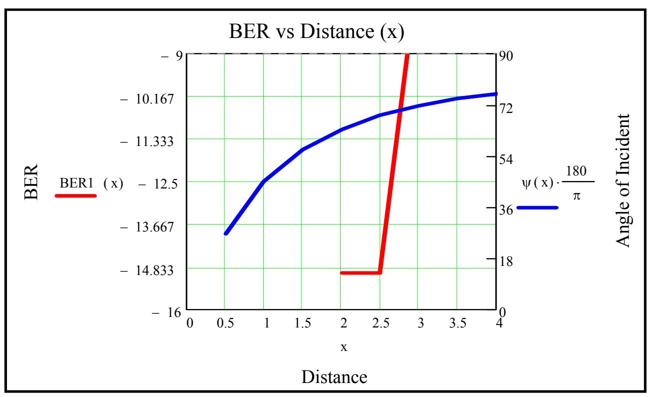

Fig. 2: The BER/Angle Of Incident (°) vs Distance (m).

The value of BER in the Figure 2 is in term of logarithm. By referring to the figure above, the value of BER for the distance of 0 to 2m is undefined, meaning that value of BER is too small. In this particular area the quality of communication is very high. In other words, this is area is known as direct detection links area. As stated above, the angle of incident varies with changes of distance(m). From the observation, the maximum distance that can provide a quality signal using visible light of single source is at the distance of 3.4meter length with the angle of incident and irridance 71.67°.

The next Figure 3 below, is the graph of BER and Signal to Noise Ratio(SNR) versus the distance. The SNR indicates the relative strength of signal and the noise in communication system and the minimum value of SNR for communication is 15dB ("Fiber-Optics Info." 2011).

The Figure 3 above shows the BER and SNR versus distance. In the wireless communication the acceptable value of SNR is 15dB evethough that is consider as the weak signal. This figure is to compare the appropriate value of BER and SNR for wireless communication at the maximum distance with high quality performance. The BER axis is giving the value beginning from ten to the power of minus 9 as that is the acceptable value for telecommunication. From the figure above, at the distance of 3.4m with BER value is 10^-9 and the SNR value is identified to be 15.7db which is still acceptable for communication. The highest SNR value which is directed detection link is 59dB.

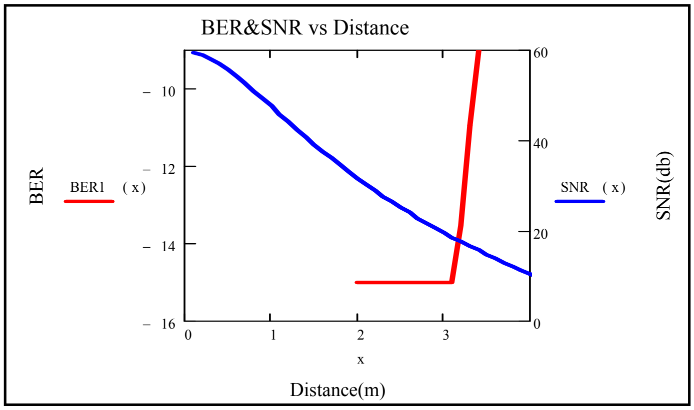

Fig. 3: SNR (db) & BER versus Distance (m).

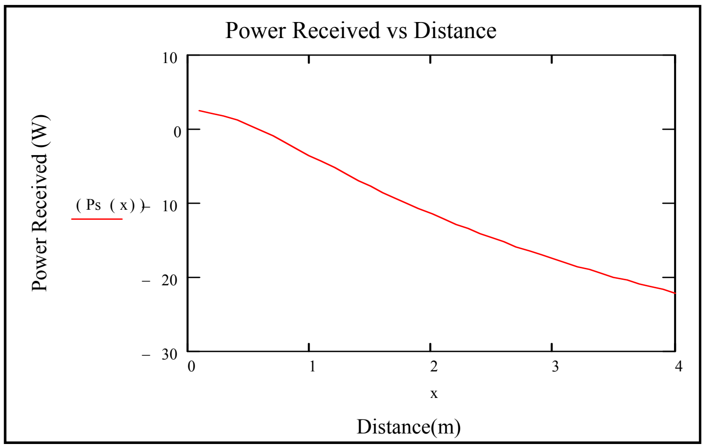

Fig. 4: The Received Power (W) versus Distance (m).

The Figure 4 shows the power received value in the term of dbm. Based on the observation of the graph above, distance(m) is reciprocal with the received power. The maximum received power is 2.43dbm while the received power at the distance of acceptable value of SNR and BER is -19dbm.

Conclusion:

As the conclusion of the results and discussion above, the single source of visible light using LED is applicable up to the distance of 3.4m for communication. This study will help a lot in the design of lighting using multisource for duo-function, lighting and communication. The improvement of the received power value is important for the real implementation. Based on the analytical approach, the visible light communication is possible for office application as the numbers of light is designed for high brightness purpose.

REFERENCE

Adiyta Goel, Er., K. Sethi, 2009. "Integrated Optical Wireless Network For Next Generation Wireless Systems " Signal Processing An International Journal (SPIJ)., 3(1).

Barry, J.R., 1997. " Wireless Communication Using Non-Directed Infrared Radiation,"Ph.D Dissertation, University of California at Berkeley.

Barry, J.R., J.M. Khan, 1997. " Wireless Home Link. Wireless Infrared Communications," 85(2): 265-298. 'Pang, A.P., J.M. Khan and K.P. Ho, 1996. "Wireless Infrared Communications Links Using Multi-Beam transmitters and Imaging Receivers,"Proc.IEEE Int. Conf. On Communication, Dallas, Tx June, 180-186.

bind.

Fiber-Optics Info." Retrieved 3 Oct, 2011, from http://www.fiber-optics.info/articles/fiber_wireless_and_free_space_optics_the_ties_that_

Gfeller, F.R. and U.H. Bapst, 1979. "Wireless In-House Data Communication via Diffuse Infrared Radiation, "Proceedings of the IEEE., 67(11): 1474-1486.

Kahn, J.M. and J.R. Barry, 1997. "Wireless infrared communications." Proceedings of the IEEE 85(2): 265-298.

Karp, S., R.M. Gagliardi, 1976. "Optical Communications. John Wiley&Sons, New York.

Komine, T. and M. Nakagawa, 2004. Fundamental Analysis for Visible Light Communication System Using LED Lights Febuary 2004 "IEEE Trans, on Consumer Electronics, 50(1): 100-107.

Langer, K.D., J. Grubor, *et al*., 2008. Optical wireless communications for broadband access in home area networks. Transparent Optical Networks. ICTON 2008. 10th Anniversary International Conference on.

Louis, E., Jr. Frenzel, 2008. "Principles of Electronic Communication Systems" 3rd Ed. Mc Graw Hill.

Ubolthip Sethakaset, T., Aaron Gulliver, 2005. "Differential Amplitude Pulse-Position Modulation for Indoor Wireless Optical Communications". EURASIP Journal On Wireless Communications and Networking, 3-11.