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Research Paper

STUDY OF THE IMPACT OF RECEIVER APERTURE DIAMETER, LED ELECTRON CARRIER LIFE TIME AND RC TIME CONSTANT ON VISIBLE LIGHT COMMUNICATION USING OPTISYSTEM SIMULATION

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ABSTRACT

Optical wireless communication using white LEDs is the latest research field for next-generation communication. In this paper, we have studied the indoor visible light communication system with practically measured channel characteristics with the help of Optisystem simulation tool. The impact of LED's parameters such as Electron carrier lifetime, RC time constant and receiver aperture diameter for various bitrates and link distances on VLC system are also studied. The increase of receiver diameter from 1.5 cm to 5 cm and allowing the spatial diversity reception at receiver improve the Q factor above 6.5 and also extend link range from 3 meter to 3.8 meter. The optimum link distance of 3.8 meter is reached with Q value 5.8. The designed system can support upto 10 Gbps with in the 3 meter link range in the case of both Electron carrier life time and RC time constant of 0.001 sec.

KEY WORDS: White Light Emitting Diode (WLED), Visible Light Communication (VLC), Free Space optics (FSO), Electron carrier life time, RC time constant.

I. INTRODUCTION

Visible light communication (VLC) is the name given to an optical wireless communication system that carries information by modulating the light in the visible spectrum (400–700 nm) that is used for indoor lightings [1–3]. The required message signal is encoded on top of the light. Interest in VLC has grown rapidly with the growth of light emitting diodes (LEDs). The idea behind to use the light for communication is to save the energy and carry information at the same time. It is a technology that is "green" in comparison to radio frequency (RF) technology, using the existing infrastructure of the lighting system. The necessity to develop an additional wireless communication technology is the result of the almost exponential growth in the demand for high-speed wireless connectivity. Emerging applications which use VLC technology are, a) indoor communication where it augments WiFi and cellular wireless communications [4] which follow the smart city concept [5]; and b) communication wireless links for the internet of things (IOT) [6].

The initial VLC dates back to 1880s when Alexander Graham Bell invented the photophone, which transmitted speech on modulated sunlight over several hundred meters. In recent times, the commonly used light sources for VLC are fluorescent lamps and Light Emitting Diodes (LEDs) whose data transmission rates for the signals are 10 kb/s and up to 500 Mb/s [7] respectively. Usually p-i-n and avalanche photodiodes act as the detectors in optical communication but in VLC, bidirectional LEDs are used as a transceivers. A less complex, low-power system for low data rate applications can be constructed [8] by using these LEDs for bidirectional communication using On-Off Keying modulation. A LED-to-LED communication system for VLC has been demonstrated [9] in which the system modulates the light intensity with high frequencies and still the human eye is not affected by the light communication. An indoor wireless VLC with a panel of red, green, and blue LEDs was reported to achieve transmission rates of 19.2 kb/s [10]. The VLC standardization process is conducted within IEEE Wireless Personal Area Networks working group (802.15). In this paper, we propose the indoor short range communication with White LED and its performances are measured with the help of a numerical tool. Practically measured channel parameters are utilized for VLC system and analysis are carried out for various system conditions. Q factor values are measured in detected signal for the performance comparison. This paper is organized as follows. Section II, describes the experimental setup, Section III, discusses the results and finally the conclusion is given in the last section IV.

II. EXPERIMENTAL SETUP:

Fig.1 shows the experimental setup for the VLC system. The input data sequence is converted to NRZ electrical pulses and this signal directly drives the White LED. The White LED emits the modulated white light optical output with the optical output power of 7 W for the average luminance value of 358 lm. and this White LED establishes the connection with photo detector which located at few meter away from the transmitter through free space. The free space channel (air) characteristics are measured practically at room temperature environment (5x5x3) with the use of 2x2 Tekhol® White LED and HTC LUX meter. The typical parameter of the white LED and photodiode are in table 1. VLC system is designed with the help of *Optisystem 13.0.1*. The FSO (Free space optics) component is used for VLC channel and the channel parameters are measured practically. White LED has the luminescence of 120-160 lm, 600 mw/LED optical output power and the view angle of 120^{o}. For the measurement of channel parameters, Line of sight (LOS) model is taken i.e., without any diffusion from the side wall (LED is illuminated at room centre) and the measured FSO parameters are tabulated in table2. The measured parameters are utilized in Free Space Optics (FSO) component in Optisystem to realise the channel characteristics on simulation for our Visible light communication using White LED.

Table1. LED and Photo diode Specification detail:

LED specification	
Centre frequency	550 nm
Electron carrier life time	0.1 ns
RC time constant	0.1 ns
Quantum efficiency	65 %
Photodiode specification	
Responsivity type	Silicon
Dark current	10 nA
Shot noise distribution	Gaussian

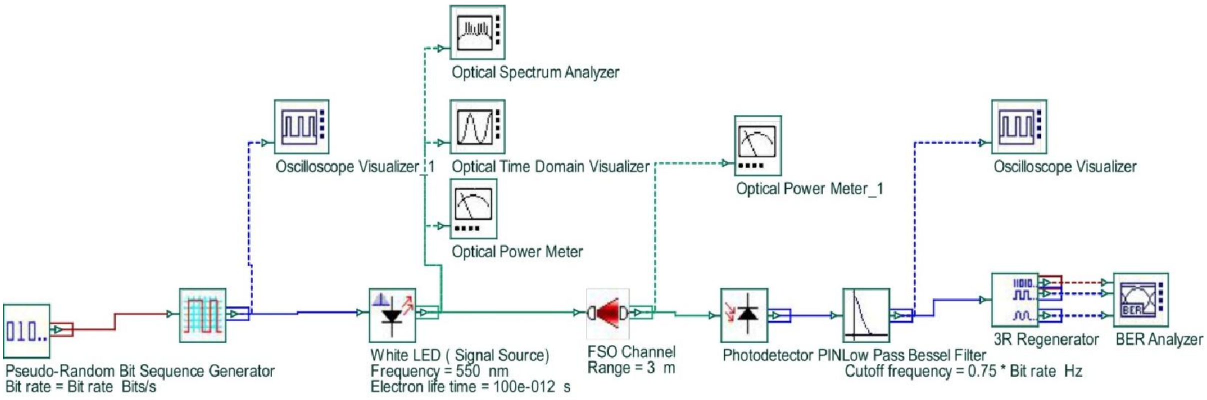

Fig.1 Experimental setup for the VLC System

Table2. Free space optics component parameter:

FSO specification	
Attenuation	8 dB/m
Beam divergence(FWHM)	63.5 °
Transmitter aperture dia	7 cm
Receiver aperture dia	1.5 cm

The received signal power is determined by both atmospheric and aperture loss [11]. And finally the detected electrical pulses from the photo diode are filtered with low pass Bessel filter and it is regenerated with the help of 3R regenerator to analyse the Bit error rate (BER) and Q factor in BER analyser.

III. RESULTS AND DISCUSSION:

The designed system is analysed for different receiver aperture size and different link range at bit rate of 2 Gbps. The aperture size of our Lux meter for the practical channel characterization is 1.5 cm, so here we directly use this aperture size in Optisystem for the FSO component. In general, a large receiver aperture size and small transmit divergences result in less geometric loss for a given range [11]. For the practical receiver aperture value of 1.5cm, the designed system can support 3m link range with 2 Gbps bitrate. As in Fig 2, if the receiver aperture diameter is higher than what we have used in practical case, then the received signal Quality factor and the link distance are improved to notable level for the bit rate of 2 Gbps. By increasing the receiver aperture diameter to 3 and 5 cm, it allows the spatial diversity reception and improves the received signal Q factor above 6.5 without so much tilt when compared to the 1.5 cm.

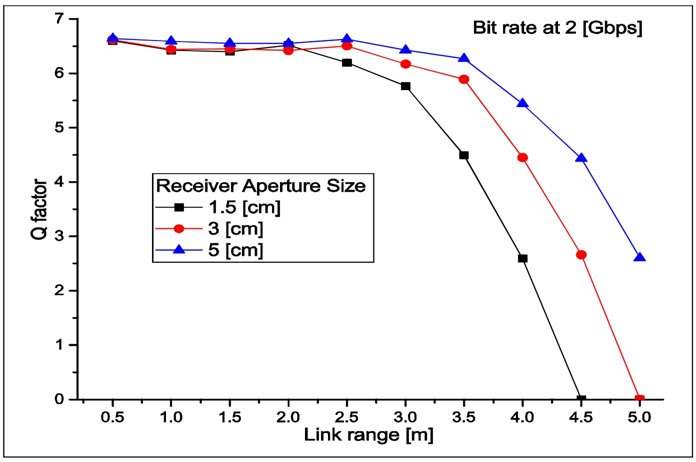

Fig 2. Q factor of the received signal for the different Receiver aperture size and link range at bit rate of 2 Gbps.

By the modification of receiver aperture diameter from the 1.5 cm to 5cm, Q factor of detected signal is improved and the link range is extended from 3 meter to 3.8 meter as in Fig 2. At link range of 3.8 meter th obtained Q factor is 5.8. The typical value of Electron carrier life time (τ_e) and RC time constant (τ_{RC}) taken for LED in simulation is 0.1ns. Both these parameters decide the modulation bandwidth of the white LED as in equation (1).

$$f_{3dB} = \sqrt{3} / 2\pi / (\tau_e + \tau_{Rc}) \qquad (1)$$

In future, any semicondutor material come with very low electron carrier life time along with very low value of RC time constant then the LED designed with that material can support higher bit rate also. Fig. 3 and 4 show the Q factor improvement by the modification of electron carrier life time and RC time constant in our simulated VLC system. As depicted in the figures, for the variation of electron carrier life time and RC time constant from 0.1 ns to 0.001 ns, the detected signal Q factor value gets improved to above 16. But still the link range is not improved and the maximum transferable link range is 3.5 m only. It implies that by reducing both electron carrier life time and RC time constant, we can only improve the modulation response of LED and respective received signals quality at higer bit rate not a link distance. Fig 5. also shows the received signal quality at higher bit rates for the value of both electron carrier life time and RC time constant are 0.001 ns. By this modification of LED parameters, modulation bandwidth is increased and the designed system can support up to 10 Gbps with promising Q factor value of about 6. Here also we can easily understand that higher bit rate supports with in the link range of 3 meter only even in the case of lower time constant value.

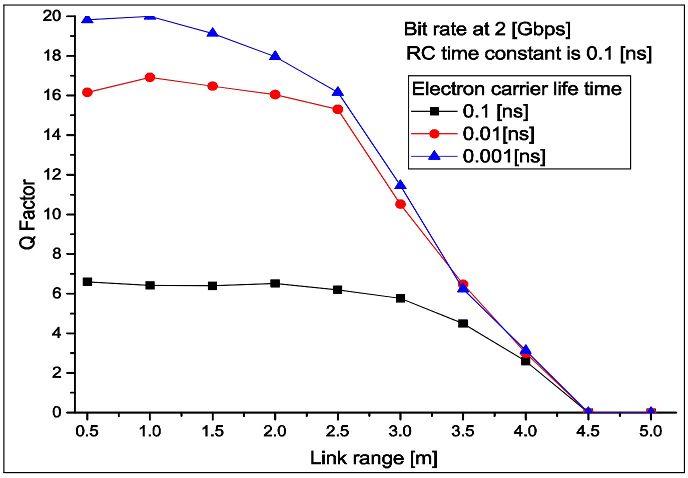

Fig 3. Q factor of the received signal for the different Electron carrier lifetime and link range at bit rate of 2 Gbps.

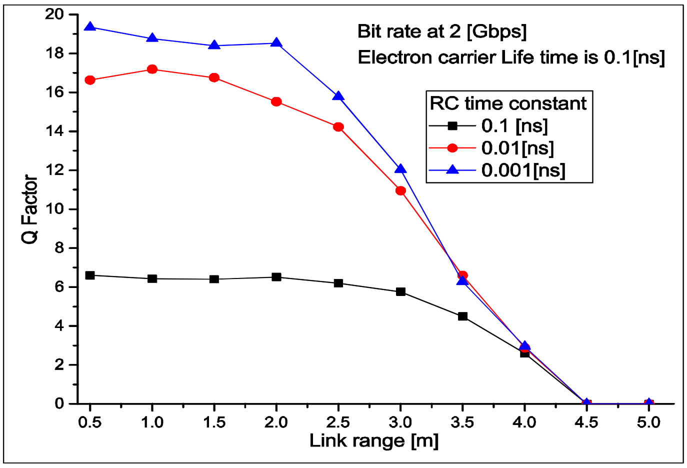

Fig 4. Q factor of the received signal for the different RC time constant and link range at bit rate of 2 Gbps.

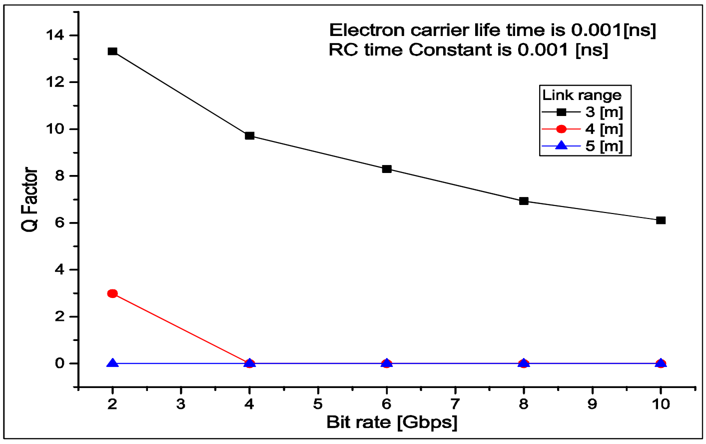

Fig 5. Q factor of the received signal for the different Bit rate and link range at both τ_e and τ_{RC} value is 0.001[ns]

IV. CONCLUSION:

We have proposed a study of Visible Light communication for white LED and practically measured channel characteristics using a numerical tool. The proposed system supports the maximum bit rate of 2 Gbps upto the link range of 3 meter with obtained Q factor value of 5.76. If the aperture diameter of receiver is incresed to 5cm then the Q factor value is improved to above 6.5 due to the nature of spacial diversity, and by this receiver aperture modification, the link range is extended to 3.8 meter even at bit rate of 2 Gbps. The LED electron carrier life time and RC time constant can improve the modulation response. The designed system can support upto 10 Gbps with in the 3 meter link range in case of both electron carrier life time and RC time constant is 0.001 ns. The proposed system and the study can support future VLC system for the better performance. This white LED based VLC system enables the higher data rates and broader bandwidths and it also tremendously saves the power loss by the existing wifi system.

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