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163m/10Gbps 4QAM-OFDM visible light communication

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***Abstract*— A 4QAM-OFDM visible light communication (VLC) system employing 641 nm laser pointer (laser diode) with directly modulating data signals is proposed and simulated in software optisystem 10.0. With the assistance of PIN photodetector with ideal rectangular filter at the receiving sites, zero bit error rate (BER) at 163m/10Gbps operation is obtained. The use of class 3B laser and OFDM offer significant improvements for free space transmission performance. Improved performance of zero BER , as well as better and clear eye diagram were achieved in our proposed 4QAM-OFDM VLC systems. Laser pointer at visible frequency feature can be seen as a new category of data carrier which has the potential to achieve high-speed data rate, long transmission length, as well as easy handling and installation.**

***Index Terms*— VLC, OFDM, QAM**

I. INTRODUCTION

Visible light communications comprise a technology for transmission of information using light that is visible to the human eye. Visible light communication (VLC) systems are currently being evolved by researchers to create high-speed, highly secure, and friendly communication system using large bandwidth visible light instead of radio-frequency (RF) and microwave signals. VLC system has many attractive features, such as worldwide availability of unused, unlicensed bandwidth, non-interference with radio frequency bands, the potential to achieve very high data rates and highly secure communication system. Besides VLC systems can also provide many benefits, like: providing communication link in specific areas where RF communication is prohibited, such as in hospitals, in aircrafts and in some of defence application [1-6]

VLC systems uses modulated light spectrum that can be emitted and received by a variety of suitably adapted standard sources, such as indoor and outdoor illumination, digital camera, television, computer screen, and digital camera on mobile phone for communication purposes, With the rapid growth of VLC systems and semiconductor technology the increasing requirements raise the needs for high speed transmission. VLC systems using LEDs are recognized as promising means to the future generations of technology, where an LED light can be used for dual purpose like for illumination as well as for the purposes of high speed communication[7,8,9].VLC system using LED light also brings many challenges, including: (1) LEDs have limited modulation bandwidth. And (2) LED light can reach only up to a certain distance. However, the performances of the LED-VLC systems can be further improved by using laser pointer laser as the light source. The dual functions of LED-VLC, for lighting and communication, cannot be fulfilled by the laser VLC system, but higher speed at long distance transmission can be achieved by the laser as optical source. In this paper laser pointer is applied in the VLC system. A Laser pointer is a small portable device with a power source (usually a battery) and a laser emitting a very narrow coherent beam of visible light, intended to be used to for high speed transmission by modulating its light beam at very high speed. Laser pointer, with high optical power and light beam convergence characteristics, with QAM-OFDM modulation is expected to have good performances in VLC systems.

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II. INTRODUCTION TO OFDM

Orthogonal frequency-division multiplexing (OFDM) belongs to a broader class of multicarrier modulation (MCM) in which the data information is carried over many lower rate subcarriers. Two of the fundamental advantages of OFDM are its robustness against channel dispersion and its ease of phase and channel estimation in a time-varying environment. With the advancement of powerful silicon DSP technology, OFDM has triumphed in a broad range of applications in the RF domain from digital audio/video broadcasting (DAB/DVB) to wireless local area networks (LANs). However, OFDM also has intrinsic disadvantages, such as high peak-to-average power ratio (PAPR) and sensitivity to frequency and phase noise. [11]

In an OFDM system, a high data rate serial data stream is split up into a set of low rate sub-streams. The parallel data transmission offers possibilities for alleviating many of the problems encountered with serial transmission systems [12] such as intersymbol interference (ISI) and the need for complex equalisers. The total channel bandwidth is divided into a number of orthogonal frequency subchannels. Each low rate sub-stream is modulated on a separate subchannel. The orthogonality is achieved by selecting a special equidistant set of discrete carrier frequencies. It can be shown, that this operation is conveniently performed by the IFFT (inverse fast Fourier transform). At the receiver, the FFT (fast Fourier transform) is used to demultiplex the parallel data streams. In practical systems, channel distortions introduce ISI potentially violating the orthogonality. Therefore, a guard interval (GI) with a cyclic prefix is introduced to preserve the orthogonality between subchannels. An open issue is the high PAR (peak-to-average ratio) of the OFDM signal. This is a particular problem when used for wireless transmission.

Power amplifiers with a large linear range at reasonable costs are still an open issue. As a consequence, the power amplifiers have to be driven with a certain power back-off which compromises the signal coverage. OOK, PCM (pulse code modulation), PPM (pulse position modulation), and SC-BPSK (sub-carrier binary phase shift keying) are some of the more popular modulation schemes used in conjunction with LED wireless systems [13].We are using OFDM in combination with QAM. The use of OFDM was first discussed in [14]. The inherent robustness of OFDM against multipath effects, the possibility to combine it with any multiple access scheme such as TDMA (time division multiple access), FDMA and CDMA (code division multiple access), and the possibility to easily combine OFDM with any higher order modulation scheme makes it an excellent choice also for visible light communication. Moreover, the issue of high PAR in OFDM can be exploited constructively for visible light communication. Namely, the high signal variations of the time signal are utilised to intensity modulate the laser diode. The human eye would not be able to detect these variations.

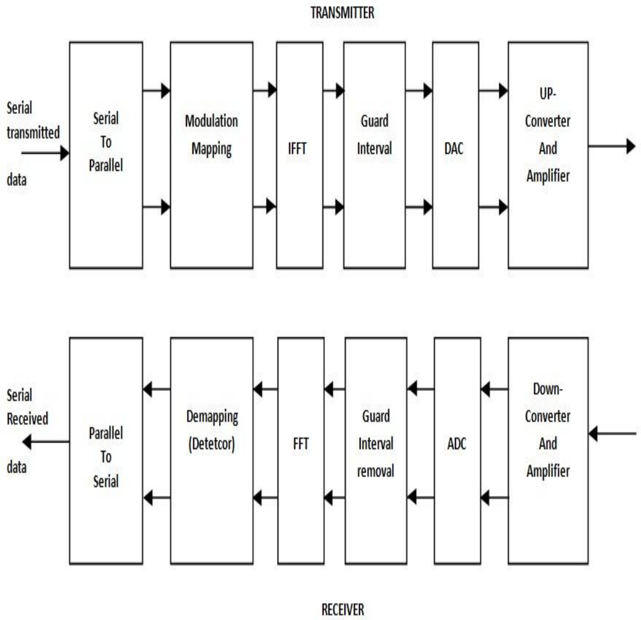

Figure 1: OFDM transmitter and receiver

III. Introduction to QAM

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (*modulating*) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components hence the name of the scheme. The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or (in the analog case) of phase modulation (PM) and amplitude modulation. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. PSK modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the modulated carrier signal is constant. QAM is used extensively as a modulation scheme for digital telecommunication systems. Arbitrarily high spectral efficiencies can be achieved with QAM by setting a suitable constellation size, limited only by the noise level and linearity of the communications channel.[15]

IV. Laser Diode

A laser diode, or LD, is an electrically pumped semiconductor laser in which the active medium is formed by a p-n junction of a semiconductor diode similar to that found in a light-emitting diode. A laser diode is electrically a P-i-n diode. The active region of the laser diode is in the intrinsic (I) region, and the carriers, electrons and holes, are pumped into it from the N and P regions respectively. While initial diode laser research was conducted on simple P-N diodes, all modern lasers use the double-heterostructure implementation, where the carriers and the photons are confined in order to maximize their chances for recombination and light generation. Unlike a regular diode used in electronics, the goal for a laser diode is that all carriers recombine in the I region, and produce light.

V. System Model

Figure2 below shows the Visible Light Communication System based on QAM-OFDM, which is made up of three stages transmitter stage, free space channel and the receiver stage. The transmitter stage is further divided into few stages bit sequence generator, QAM modulator, OFDM modulator and optical source. It starts with bit sequence generator which generates random bit sequence for transmission; these binary sequences are than modulated by QAM modulator which is an analog & digital amplitude modulation scheme, which modulates the amplitude of carrier signal in accordance to the bit sequence. Then QAM modulated carriers go through OFDM block, which is a multicarrier modulation scheme, in which information data is carried over many lower rate subcarriers. Now these OFDM modulated carriers are amplified and these electrical signals used to drive the optical source. It actually modulates the optical signal of the optical source. This optical signal travels through free space block where different factors were introduced to attenuate the optical signal.

At receiver side exact reverse methodology is used. The modulated and attenuated optical signal is detected by a photodiode; the photodiode is a device which generates electrical current in accordance to detected optical signal. These electrical signals are then gone through OFDM demodulator; it demodulates the electrical signals to QAM modulated carriers. And then QAM demodulator demodulates this signal into bit sequence.

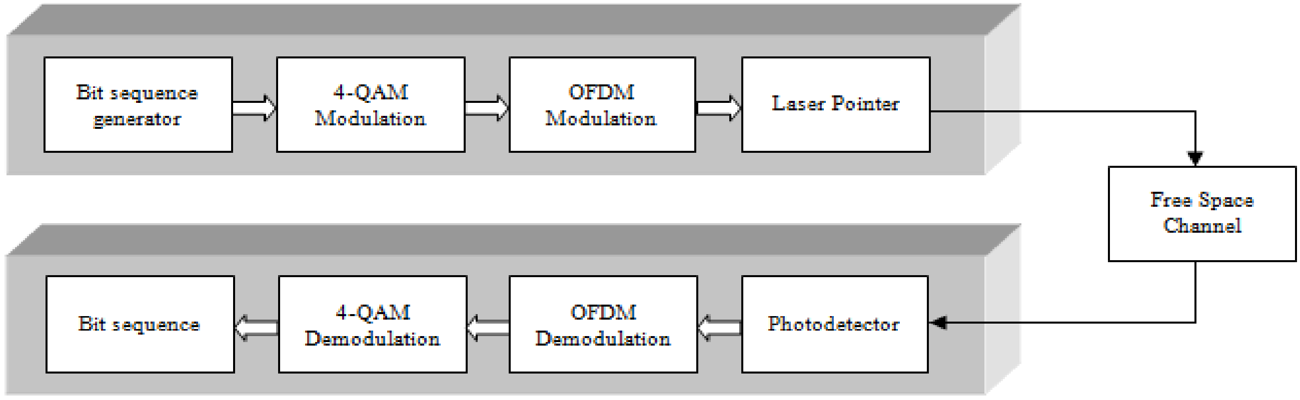

Figure 2: 4-QAM-OFDM VLC system model

VI. SIMULATION

Since the main concern in this system is to increase the transmission range and enhance the data rate along with minimum BER. Thus class 3B laser with optical power 28.30mW was chosen and the OFDM system was modeled in OptiSystem 10.0. Parameters such as bit rate, sample rate, sequence length, sample per bit, number of samples, optical transmitter and receiver operating wavelength, distance of the transmission links, and attenuation across distance were set. Parameters such as optical power of optical source, number of subcarriers in OFDM block, modulation frequency, cut of frequency of filter; transmission distance had been varied to obtain highest bit rate, longest transmission range and minimum bit error rate.

Parameters such as wavelength of Laser diode, photodiode responsivity, bit rate, bit sequence are set to be constant value throughout this simulation. System specifications which were set during the simulation are shown in Table 1.

Table 1: System specifications

Parameter	Value
Wavelength	671 nm
Output optical power	28.30 mW
Photo detector Sensitivity	0.65 mA/mW
Bit rate	10 Gbps
Time window	1.6384e-006 s
Sample rate	40 GHz
Sequence length	16384 bits
Sample per bit	4
Number of samples	65536
Number of subcarriers	512
Number of FFT points	1024

VII. SIMULATION RESULTS

A full system model was implemented and simulated in optisystem 10.0. A LOS (Line of Site) channel is considered as the base for the simulation. As the model is intended for short range data transmission applications, the results were obtained under the normal conditions.

Bit error rate with zero value was achieved at the distance of 163 meter with the speed of 10 Gbps in the simulation. In order to study the performance of the system transmitted and received data constellation diagram, BER graph and Eye diagram obtained from simulation are shown in figure 3.

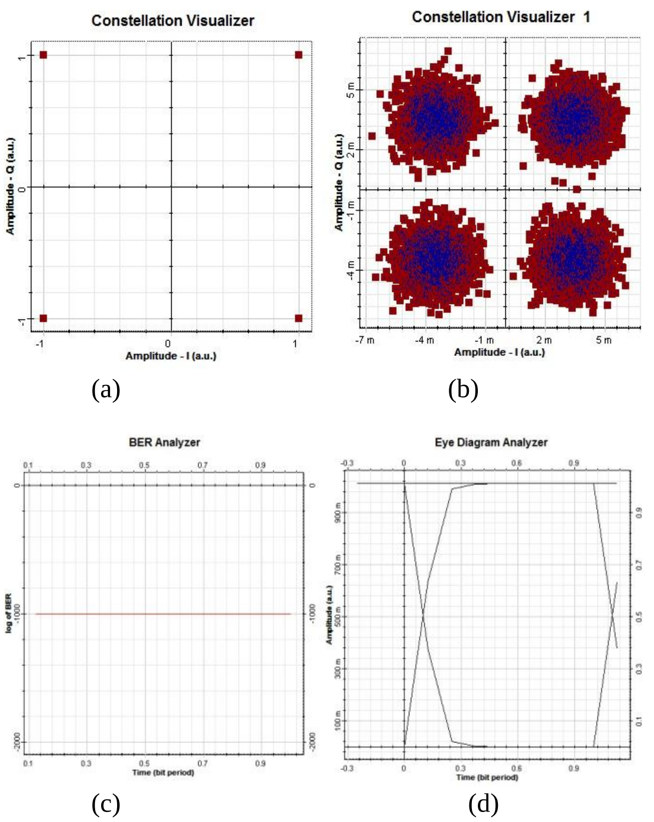

Figure 3: (a) Transmitted sequence constellation (b) Received sequence constellation (c) BER graph (d) Eye diagram

VIII. CONCLUSION

A visible light wireless communication model was developed and simulated in optisystem 10.0. The transmission is based on the assumptions of direct LOS and simplex channel conditions. It was demonstrated that the Laser diode (641 nm) based visible light data transmission system in combination with 4QAM-OFDM transmission is indeed theoretically feasible.

The following conclusions were made:

- laser diode can be modulated and used as signal light source in carrier space communications;
- The proposed system using a 28.30 mW power LD can theoretically achieve a maximum range of 163 m at data rate 10 Gbps;
- Link performance can be optimized by varying system parameters such as transmitter optical power, transmitter beam divergence and receiver diameter, etc.

References

[1] D. C. O'Brien, "Visible light communications: challenges and potential," IEEE *Photon. Conf.* 365–366 (2011).

[2] B. Bai, Z. Xu, and Y. Fan, "Joint LED dimming and high capacity visible light communication by overlapping PPM," *Wireless and Opt. Commun.* Conf. *(WOCC), 1–5* (2010).

[3] Y. H. Son, S. C. An, H. S. Kim, Y. Y. Won, and S. K. Han, "Visible light wireless transmission based on optical access network using white light-emitting diode and electroabsorption transceiver," Microw. Opt. Technol. Lett. **52**(4), 790–793 (2010).

[4] S. Okada, T. Yendo, T. Yamazato, T. Fujii, M. Tanimoto, and Y. Kimura, "On-vehicle receiver for distantvisible light road-to-vehicle communication," IEEE *Intelligent Vehicles Symposium, 1033–1038 (2009)*.

[5] H. Le Minh, D. O'Brien, G. Faulkner, L. Zeng, K. Lee, D. Jung, and Y. Oh, "High-speed visible lightcommunications using multiple-resonant equalization," IEEE Photon. Technol. Lett. **20**(14), 1243–1245 (2008).

[6] T. Komine and M. Nakagawa, "Fundamental analysis for visible-light communication system using LED lights,"IEEE Trans. Consum. Electron. **50**(1), 100–107 (2004).

[7] J. Vucic, C. Kottke, S. Nerreter, A. Buttner, K.-D. Langer, and J. W. Walewski, "White light wireless transmission at 200+ Mb/s net data rate by use of discrete-multitone modulation," IEEE Photon. Technol. Lett. **21**(20), 1511–1513 (2009).

[8] H. Le Minh, D. O'Brien, G. Faulkner, L. Zeng, K. Lee, D. Jung, Y. Oh, and E. T. Won, "100-Mb/s NRZ visible light communications using a postequalized white LED," IEEE Photon. Technol. Lett. **21**(15), 1063–1065 (2009).

[9] H.Elgala, R.Mesleh, H.Haas and V.Pericope "OFDM Visible Light Wireless communication based on White LEDs", proceedings of the IEEE 2007,pp.1550- 2252.

[10] J. Vucic, C. Kottke, S. Nerreter, K.-D. Langer, and J. W. Walewski, "513 Mbit/s visible light communications link based on DMT-modulation of a white LED," J. Lightwave Technol. **28**(24), 3512–3518 (2010).

[11] William Shieh, Ivan Djordjevic, ''OFDM for optical communication'' 2010 ELSEVIER Inc. ISBN: 978-0-12-374879-9

[12] W. Zou and Y. Wu, "COFDM–An Overview," *IEEE Tranaction on Broadcasting*, vol. 41, March 1995.

[13] T. Komine and M. Nakagawa, "Fundamental Analysis for Visible-Light Communication System using LED Lights," *IEEE Tranaction on Consumer Electronics*, vol. 50, pp. 100–107, February 2004.

[14] Y. Tanaka, T. Komin, S. Haruyamaand, and M. Nakagawa, "Indoor Visible Communcation Utilizing Plural White LEDs as Lighting," in *Proceedings of the 12th IEEE International Symposium on Personal, Indoorand Mobile Radio Communications (PIMRC 2001)*, San Diego,CA, September 2001, pp. F81–F85

[15] Online content: UAS UAV communications links, www.barnardmicrosystems.com/