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OFDM in Visible Light Communication through Organic LED to Increase Link Capacity

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Abstract—*Visible Light Communication (VLC) has been accepted as the alternate physical layer in the 5G networks. They offer high capacity communication links for extremely high mobile data traffic. Visible light communication is based on the fact that visible range of electromagnetic spectrum between 370nm-780nm can be utilized for the transmission of data. Light Emitting Diodes can be utilized for illumination and transmission of the data both .Organic LEDs are already attracting significant attention in these networks due various advantages like low cost, flexibility and low temperature of operation. This paper discusses the role of Visible Light communication in 5G network and utilization of Organic LEDs in VLC. Further, it will focus on the various modulation formats adopted to improve the bandwidth in OLED and utilization of the OFDM to increase the bandwidth in these systems.*

Keywords*: Visible Light Communication (VLC), Organic LED's, OFDM.*

1. INTRODUCTION

Mobile data traffic will increase at a compound annual growth rate of 57% in the period of 2014-2019 as per the latest projections.[1] It directly projects that overall mobile data traffic will reach upto 24EB/month in recent years. These increasing data rates will require the implementation of heterogeneous networks and Advanced radio access technologies to enable the high cell density and are expected to meet all the requirement in terms of Quality of Service. Basic requirement to provide this is efficient utilization of available frequency bands. 5G networks have the challenge to meet all the requirements to provide the better service and assure the utility of existing bands. However, it is still a challenge to accommodate the data greater than 30EB/month beyond 2020. [2] This data mainly consists of multimedia content.

Visible light Communication has proved to be a solution to fulfill ever increasing demand of data communications. Globally a large amount of research work is being done to develop the systems where illumination sources (LED) can be utilized for the data transmission as well. Main advantages of implementing such will be high security and immunity to electromagnetic interference, easy installation, license free zone as it includes the utilization of the visible spectrum of radiation. It can occur in various shapes and size with low cost and is also not a hazard to health. Extremely high speed data rates can be achieved with these systems.

Display devices such as LEDs and Organic LEDs both can be used for this purpose. To attain good speed of transmission, it is necessary that surface area of the illumination device should be high. In LED's, this is achieved by stacking of LEDs or using the array of multiple array so as to provide good illumination as it is the primary function of LED. Various techniques like spatial summing of LEDs etc are still in primary stage of research to provide the high transmission rate without ISI, major problem linked with VLC systems. Manufacturing process of LED's involves the epitaxial growth which in itself is an expensive process. In recent years , Organic LED's has attracted a significant attention as display devices. They are being used in high definition and high-end gadget television displays due the flexible surface. They are cost effective due to the easy manufacturing process. Material is highly soluble and they can be printed using inkjet printer that increases the range of the size of the device. [3] Another major advantage with OLED is color of the emitted light. They are source of variable wavelength, hence; do not require any filtering to achieve the required color of light. [4] This makes them more efficient than any other display devices. With the advancement in the technology Large area RGB OLED have become available for general illumination purposes. In this paper, general characteristics of OLEDs have been discussed. Trade-off between the size of OLED and its limitation with BW is discussed and various modulation techniques that are being employed to improve upon the BW. Role of OFDM in improving the system is discussed in detail that also leads to its implementation in MIMO systems.

2. ORGANIC LIGHT EMITTING DIODES

Organic Semiconductors provides several potential advantages to be ideally suited to act as fabrication material for the LED's for Visible Light Communication. They provide visible band gaps, short radioactive lifetime .In general; OLED is a three layers based structure. It has an Electron transport layer (ETL) and a Hole transport layer (HTL) as a replacement of conducting layer. When an electric field is applied, both, injected holes and electrons migrate towards the electrode of opposite charge. In this process, there is a probability that fraction of holes and electron localizes on the same molecule. If it occurs, then they form exciton , which is a bound state of electron and hole pair having a excited energy state. This process takes place in organic emissive layer of the LED. These excited electron-hole pairs , when return to their ground state releases the optical wavelengths. Many efforts are being taken to improve the frequency response of OLED for the transmission of the high data rates.

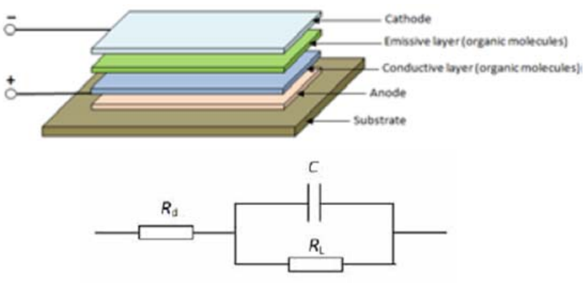

Fig. 1 : Structure of OLED and its equivalent circuit[1].

Emissive layer is made of organic material that is sandwiched between the anode and cathode of the LED, hence it behaves like a capacitor. Complete circuit behaves like a low pass filter where R is the effective resistance and C is the parallel plate capacitance.

$fc= 1/2\pi RC$

Effective capacitance of the OLED will be given as:

$C=A\varepsilon 0\ \varepsilon r/d$

A is the photoactive area of the diode and ε0 and εr are the relative permittivity of the free space and emissive layer respectively. d is thickness of the OLED , since thickness of the OLED is very small so it results in high value of capacitance. This causes the low available bandwidth usually in order of several kilohertz only. It is therefore required to adjust the values of resistance and capacitance through various pre and post equalization techniques to increase the modulation bandwidth. Switching capacity at high speed is the basic feature required by any source employed in VLC. Frequency response of the system can be improved by two methods: (i) to introduce various techniques to improve the frequency of the system so that , they can become more suitable to be used in communication purposes.(ii) to select such materials as organic layers that can provide better florescent lifetime of OLED's. [5] Florescent lifetime of any material depends upon the ability of high speed release of photon. If device can release photon faster, higher speed can be achieved. In presence of proper current mobility and temperature, high bias voltage also allows the faster mobility for better transmission speed.

But, it is evident from the above discussion that increasing the panel size will increase the capacitive effect between the anode and cathode causing to the decrease in modulation bandwidth. So, it becomes important to suggest trade –off between lighting performance of the devices and their bandwidth.

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3. MODULATION TECHNOQUES

OLED having a thickness in order of 1-200nm can provide the Bandwidth upto few Kilohertz only. This gives the possibility of ISI (Inter Symbol Interference). It means that the signal transient response is faster than system transient response and therefore, system cannot switch in required time. It leads to the interference between the symbols at sampling instant. To improve upon the system BW, some of the most useful techniques are on-off keying(OOK) and Pulse position Modulation(PPM). [6]

These modulation techniques are generally used for their unique features. OOK is efficient in Bandwidth whereas PPM is efficient for power requirement. Driving circuit has major impact on performance of any modulation scheme. Performance of any system is measured in terms of Bit Error Rate (BER). BER can be calculated either by Q factor or by comparing number of transmitted and received bits. However, for VLC systems, comparison of transmitted and received is most suitable as it contains AWGN (additive white Gaussian noise) and also limited Bandwidth. Fig. 2 depicts the comparison of the BER of the OOK system with 2- and 4-PPM. [7]. Achievable rates are varied as 250,150 and 50 kbps respectively.

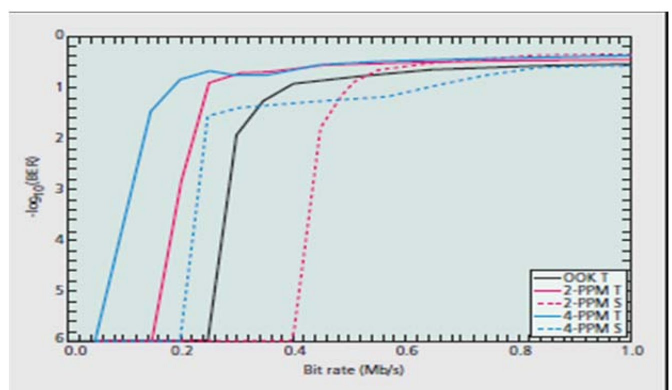

Fig. 2: Comparison of BER of OOK, 2-PPM and 4-PPM[7]

It is evident from figure that OOK outperforms 2 & 4 PPM due to its low bandwidth requirement. [8] Mathematics involved in calculation is beyond the scope of this paper. Still, achieved frequency response is lower than the required frequency response for any of above mentioned modulation schemes. To further improve the performance of systems, Equalizers are used .Various equalizers are employed to improve the system performance, they mainly consists ; non-neural and ANN equalizer's. Most popular equalizers being used are high pass filter resistor-capacitor equalization, Decision feedback equalizer (non-neural) and ANN (Artificial Neural Network). Filter resistor-capacitor works on the principles of electrical network where DFE and ANN equalizers require the training of network in terms of supervised and unsupervised learning. They have proved to be highly beneficial in terms of increased data rate that has reached upto 2.7, 2.2 and 1.25 Mbps for 4-PPM, 2-PPM and OOK respectively. It is observed that each of these data rates are very high when compared with un-equalized systems. Fig. 3 depicts data rates un-equalized, pre-equalized and post-equalized systems. Considerable amount of improvement is obtained in the BER of systems. [8]

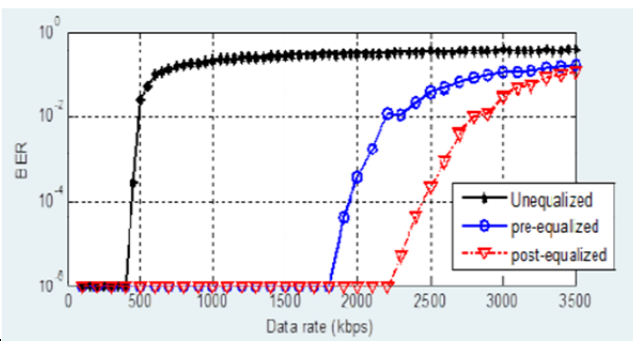

Fig. 3 Data rates before and after equalization[9].

4. OFDM IN OLED

Orthogonal Frequency Division Multiplexing is employed in OLED to utilize the limited bandwidth effectively. Illustrative

Study has been conducted by Z.Ghassemlooy which has shown considerable increase in data rates. Fig. 4 shows the block diagram OLED based communication system.

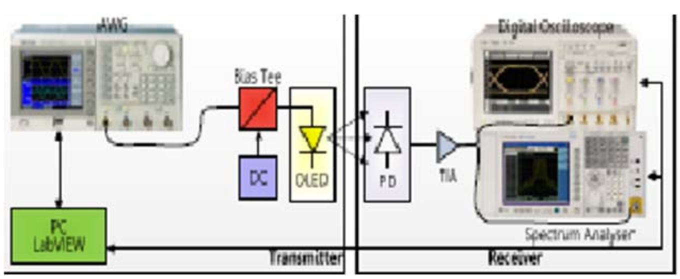

Fig. 4: Block diagram OLED based communication system.

In this arrangement, transmitter consists of LED –driver where OLED is directly modulated by output current, an arbitrary waveform generator (AWG) that generates OFDM signal. Inverse Fast Fourier transform is used to implement OFDM. Modulation bandwidth of this chosen to be 93 KHz. Cyclic prefix is added to protect the system. Process involves mapping of A PRBS data sequence into QAM constellation which is interleaved and converted into N parallel streams. Cyclic prefix protects the system from multipath effects and data is finally reshaped from all parallel streams into one serial data and then transmitted through OLED.

In this suggested experiment OFDM signal can find maximum possible data rate with a simple point to point link by employing 64 useful subcarriers .Intensity of the light obtained by OLED is approximately 440 lux. Received Data rate is 3Mbps with BER less than 10^{-4}. This arrangement is most suitable for office environment and that is why it can be successfully employed for Indoor communication applications. [11].

5. CONCLUSION

Visible Light Communication due to its potential advantage of unlimited spectrum over orthodox techniques is emerging as new light of communication. Unique feature of unlimited spectrum plays a vital role in its ever increasing popularity due to forever increasing demand of data transmission. LED's are presently being used to provide illumination and data transmission. OLED are still in development stage. This paper reviews how various modulation techniques like OOK, PPM are used with equalizers to enhance data rates and OFDM prove to be the best modulation technique till date.

REFERENCES

[1] Stanislav Zvanovec 1, Petr Chvojka 1, Paul Anthony Haigh 2, Zabih Ghassemlooy "Visible Light Communications Towards 5g" Radioengineering, VOL. 24, NO. 1, APRIL 2015.

[2] C. V. N. Index, *Global Mobile Data Traffic Forecast Update*, 2014-2019, White paper, ed. 2013

[3] C. Hung-Chi, L. Jiun-Haw, S. Chia-Chiang, Y. Chih-Chung, and K. Yean-Woei, "Electromagnetic modeling of organic light-emitting devices," *Lightwave Technology, Journal of*, vol. 24, pp. 2450-2457, 2006.

[4] Z. Ghassemlooy, H. Le Minh, P. A. Haigh and A. Burton "Development of Visible Light Communications: Emerging Technology and Integration Aspects" invited paper in Optics and Photonics Taiwan International Conference (OPTIC)2012

[5] Haigh, P. A., Bausi, F., Le Minh, H., Papakonstantinou,I., Popoola, W., Burton, A., et al. Wavelength-multiplexed polymer LEDs: Towards 55 Mb/s organic visible light communications. *IEEE Journal on Selected Areas in Communications.* Accepted, 2014.

[6] J. G. Proakis and M. Salehi, *Fundamentals of Communication Systems*, Pearson Prentice Hall, 2005.

[7] Paul Anthony Haigh and Zabih Ghassemlooy, Sujan Rajbhandari, Ioannis Papakonstantinou**,** **"**Visible Light Communications Using Organic Light Emitting Diodes"IEEE Communications Magazine (Volume:51 , Issue: 8)Page(s): 148 – 154 ISSN :0163-6804August 2013

[8] A. M. Street *et al.*, "Closed Form Expressions for Baseline Wander Effects in Wireless IR Applications," *Electronics Letters*, vol. 33, 1997, pp. 1060–62.

[9] Professor Z. Ghassemlooy” Visible Light Communications” lecture Series 11 May 2012.

[10] Z. Ghassemlooy” OLED-based Visible Light Communications” Published in: 2012 IEEE Photonics Society Summer Topical Meeting Series 9-11 July 2012 Page(s):102 – 104 ISSN :1099-4742

[11] H. Elgala, R. Mesleh, and H. Haas, "An LED Model for Intensity-Modulated Optical Communication Systems," Photonics Technology Letters, IEEE, vol. 22, pp. 835-837, 2010.