International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 1(02), July 2022, pp. 9-14

Article Title: **Visible Light Communication - A Review**

Visible Light Communication - A Review

Benisha. R. B[1], G. Maria Kishoba[2]

[1]Associate professor, Department of Electronics and Communication Engineering, Rohini college of Engineering and Technology, Tamil Nadu, India.

[2] Department of Electronics and Communication Engineering, Rohini college of Engineering and Technology, Tamil Nadu, India.

ABSTRACT

The Visible light communication (VLC) is a novel topology seeks to improve the large, unused visible light spectrum of 400-800THz. The VLC technique employs a non-radio frequency, which is converted and restricted from telecommunications licenses, to meet an urgent need. Flicker is a serious issue because light is modulated at such a high rate, which can harm the human eye. Dimming is also a problem in indoor environments, in which an amount of light are required to be regulated according to the needs of the user. The rise time as well as non- linearity of LED creates problem in modulation. Hence, to overcome these issues, many modulation techniques has been employed in VLC. In this paper, a survey is carried out regarding the various modulation techniques used in VLC, in order to find the optimal one.

Keywords: VLC (Visible light communication), LED (Light emitting diode), Modulation techniques, transmitter and receiver.

1. Introduction

The increasing users for mobile communication and almost saturated spectrum of radio communication paved the necessity for the engineers around the world to come up with new technology which is an alternate to mobile communication. This is when the researchers in keio university, Japan came with an idea of using white LED in home for building an access network [1]. So basically VLC is a technology that utilizes an existing LED structure for both illumination and communication purposes. In VLC, light waves from visible spectrum with wavelengths between 380 and 750 nm are modulated for sending data. VLC refers to the method of information transmission that uses light waves that are visible to human sight. Data transport in VLC is imperceptible to the human eye.

Numerous nomenclatures have been developed for related technologies including OWC (Optical Wireless Communication) and Li-Fi (Light Fidelity) A widespread studies were done on radio waves for various works, since the commencement of nineteenth century, [1] which produce numerous discoveries concerning the characteristics of waves that bring an introduction of novel technologies into people day to day lives worldwide, including medical and military uses.

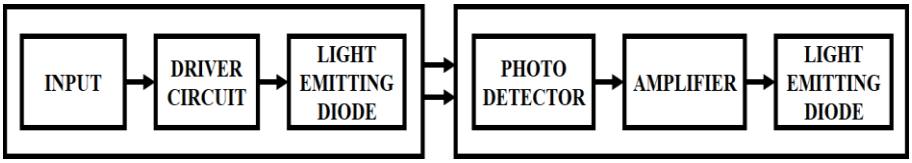

Figure 1: *Architecture of VLC*

The results of numerous studies in this area have increased the effectiveness of radio communications. For the past decade, academic institutions and industry have been attracted by the potential of visible light communication. [2]. As a result, LED light bulbs will eventually serve both the purposes of communication and lighting. VLC has recently been researched in major business and academic institutions, including NASA. [4], [5], Disney [6] and Philips [7]. Products and research in this area are also available from these industries. Figure 1 illustrates the general architecture of VLC. When compared to the electromagnetic spectrum's radio frequency spectrum, it is still underexplored even now. VLC is a potential area of research because it has the advantage of 1) using an unlicensed band 2) ensuring security with high transmission 3) use simple front end devices [2].VLC system architecture includes a transmitter and receiver. The transmitter is the LED luminaire .The information is modulated and sent through the LED bulb .The modulation is done in such a way that the variation in intensity can't be seen with naked eye. The modulated information is transmitted in air medium and is received by photo detector or imaging sensor which is a receiver, which decodes the information. In this paper, a general review is conducted amid the various modulation techniques used in VLC.

2. Review Of Different Modulation Techniques

Currently, almost all wireless communication systems rely on Radio Frequency (RF) spectrum and it creates high congestion along with strict guideline. For avoiding these issues, many new methods have been introduced in recent years. The VLC that employs broad, unregulated visible light spectrum, is among the alternatives (from 430 to 750 THz) and it complements the wide usage of LED technology for Solid State Lighting (SSL) applications with the aid of utilising LEDs' fast light modulation ability. For improving the performance of VLC, multiple modulation methods has been employed and some of them are explained below.

2.1 Feed Forward Pre-equalization with PAM modulation technique

A feed forward equalisation (FFE) at the transmitter (pre-equalization) in association with PAM modulation strategy, so as for attaining high data rates of > 1 Gb/s in LED relied VLC links has been introduced in this work. A pre equalization strategy is mainly presented for the free space VLC link using a PAM modulation strategy that possess increased spectral efficiency compared to NRZ modulation.

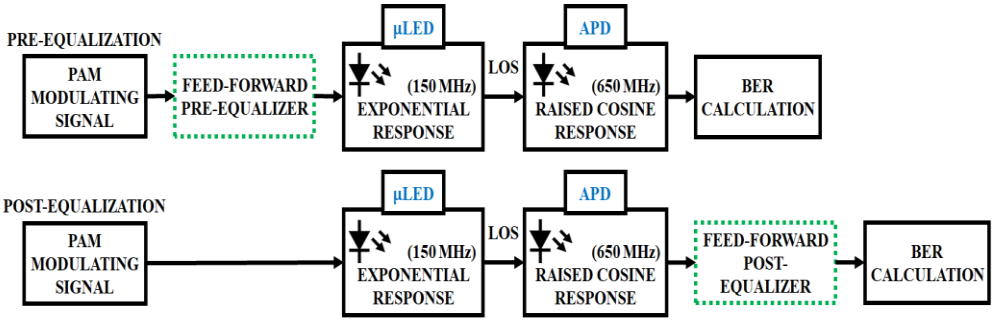

Figure 2: *Feed-Forward Pre-equalization with PAM modulation technique*

A defined technique is illustrated in Figure 2 and in this work, micro pixelated LEDs (LEDs) are employed as the transmitter, since they possess high modulation bandwidth than conventional large diameter LEDs. While at the receiver side, an avalanche photodiode (APD) is employed, so as to offer a higher link power budget. The resulting outputs denotes a possible advantages of pre equalisation in fast VLC systems. The defined technique provides an energy efficient, low cost and less complex technique, which further overcomes the bandwidth constraints. When the optimal power exceeds 12.2 dBm, however, error free transmission is not possible.

2.2 Enhanced sub band index carrier less amplitude and phase modulation (eSI-CAP) Method

To enhance VLC systems' multiband CAP (m-CAP) spectral efficiency, an enhanced sub band index carrier less amplitude as well as phase modulation (eSI-CAP) scheme is advanced. An eSI-CAP modulates symbols on the m-CAP sub bands utilising an indexing approach and a dual distinguished constellation to transfer information bits. Furthermore, it encrypts additional information bits on the sub band indices which are modulated by the dual constellation symbols. It allows for more flexible design while also improving power/spectral efficiency of traditional m CAP modulation method. The BER reduction rate must still be increased.

2.3 Out phasing technique

Based on the out phasing technique, related article advances a powerful LED driver for VLC that also serves as a transmitter. RF communications also employ the out phasing approach to increase amplifier effectiveness. The proposed transmitter consists of a DC/DC converter that biases the LEDs and two switching mode power amplifiers that duplicate the signals required for out phasing. The approach makes use of light, and signals are added in their light form rather than electrically, which simplifies the complexity of the design. Nonetheless, the electrical efficiency and overall efficiency are only 78 and 92 percent, respectively and must be improved in order to enhance system performance.

3. Comparative Review

Due to their high brightness, low power consumption, long lifespan, cost-effectiveness, and small size, white LEDs are anticipated to gradually replace incandescent and fluorescent bulbs for illumination in the majority of interior spaces. VLC based on LEDs is a promising complement to traditional radio frequency (RF) technologies. Table 1 provides a comparative survey corresponding to the different modulation techniques used in VLC.

Table 1: *Review of different Modulation techniques*

Sl. No	Author/ Publication Year	Modulation technique	Advantages	Disadvantages
1.	Kabiru O. Akande et al [2018].	The Carrier less amplitude and phase modulation (CAP) in LED based VLC systems, which especially suites for VLC applications is proposed in this work.	• Provides flexibility in the design. • Increased spectral efficiency.	• For further enhancements, theoretical evaluation of CAP has to be carried out.
2	Qian Gao et al [2016].	This paper introduces for single carrier and multi carrier VLC systems with signal-dependent shot noise, an effective modulation design method is available.	• Performs better than the square root and uniform signaling.	• Increased diminishing level leads to reduction in the SER performance.
3.	Chen Chen et al [2017].	In this paper, an NHS-OFDM (non-Hermitian symmetry OFDM) technique for MIMO-VLC systems is investigated.	• Enhances the communication coverage area. • High speed indoor wireless access.	• Needs enhancement in the receiver position offset.
4	Chen Chen et al [2017].	This work conducts a comprehensive analysis of the illumination and communication coverages of an indoor MIMO-VLC system.	• Very helpful in the formation of practical indoor MIMO-VLC systems.	• Realistic channel matrix has to be attained for different practical evaluations.
5	Antonio Costanzo et al [2021].	In this study, a system that ensures a feedback path through the usage of an uplink or channel has been proposed.	• Possess high dynamic environmental conditions.	• System has to synchronize with the uplink and downlink channel.

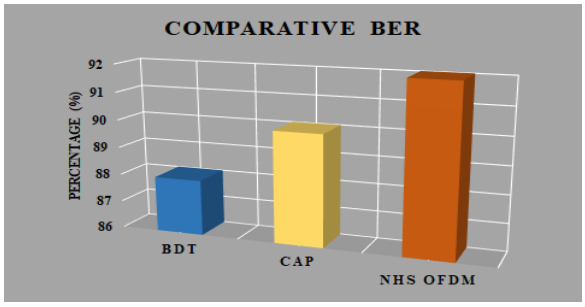

Figure 3: *Comparative BER*

Further, a comparative analysis is carried out amid the modulation techniques like CAP, NHS-OFDM and the B-dierectional modulation technique, with respect to BER reduction, which is depicted in Figure 3. It is identified that the NHS-OFDM perfomormes better in the BER reduction compared to other techniques.

4. Conclusion

The expanding research interest in VLC makes it a viable technology due to its numerous benefits and potential. VLC involves the use of LEDs that emit visibile light for wireless data communication. Although this method is inexpensive, the slow phosphorescent relaxation time significantly lowers the overall modulation bandwidth of PC-LEDs to a few MHz. For overcoming these issues, different modulation techniques has been employed and in this paper, a comparative analysis is carried out amid different modulation techniques, so as to identify the optimal technique. From the evaluation, the NHS-OFDM is considered to be significant compared to other techniques, in terms of BER reduction. In future, using improved modulation techniques, it is feasible to improve VLC's functionality..

References

1. Parth H Pathak; Xiaotao Feng; Pengfei Hu; and Prasant Mohapatra, Year: 2015, “Visible light communication, networking and sensing :A survey, potential and challenges”. IEEE communications surveys & tutorials, pp. 2047–2077.
2. Haoyue Li; Zhitong Huang; Yu Xiao; Shuang Zhan; Yuefeng Ji, Year: 2019, “A Power and Spectrum Efficient NOMA Scheme for VLC Network Based on Hierarchical Pre-Distorted LACO-OFDM”, Access IEEE, Vol. 7, pp. 48565-48571.
3. Luiz Eduardo Mendes Matheus (UFJF); Alex Borges Vieira (UFJF); Luiz F. M. Vieira (UFMG); Marcos A. M. Vieira (UFMG), Omprakash Gnawali (University of Houston), Year: 2019,“Visible Light Communication: Concepts, Applications and Challenges , IEEE Communications Surveys & Tutorials”, Vol: 21, no.4, 3204 – 3237.
4. Farshad Miramirkhani; Murat Uysal, Department of Electrical and Electronics Engineering, Ozyegin University, Istanbul, Turkey, Year: 2015, “Channel Modeling and Characterization for Visible Light Communications”, IEEE Photonics Journal, Vol.7, no.6.

5. E Luzhanskiy; B Edwards; D Israel; D Cornwell; J Staren; N Cummings; T Roberts; R Patschke, Year: 2016, “Overview and status of the laser communication relay demonstration”. In Free-Space Laser Communication and Atmospheric Propagation XXVIII, vol. 9739, pp. 100-113. SPIE.
6. Stefan Schmid; Giorgio Corbellini; Stefan Mangold; Thomas R Gross, Year: 2013, “LED-to-LED visible light communication networks, .In Proceedings of the fourteenth ACM international symposium on Mobile ad hoc networking and computing”, pp. 1–10.
7. Parth H Pathak; Xiaotao Feng; Pengfei Hu; Prasant Mohapatra Year: 2015, “Visible light communication, networking and sensing :A survey, potential and challenges”, IEEE communications surveys & tutorials, 2015, pp. 2047–2077.
8. K. O. Akande; P. A. Haigh; W. O. Popoola, Year: 2018, "On the Implementation of Carrierless Amplitude and Phase Modulation in Visible Light Communication," in IEEE Access, Vol. 6, pp. 60532-60546.
9. Q. Gao; S. Hu; C. Gong; Z. Xu, Year: 2016, "Modulation Designs for Visible Light Communications With Signal-Dependent Noise," in Journal of Lightwave Technology, Vol. 34, no. 23, pp. 5516-5525.
10. C. Chen; W. Zhong; D. Wu, Year: 2017, "Non-hermitian symmetry orthogonal frequency division multiplexing for multiple-input multiple-output visible light communications," in Journal of Optical Communications and Networking, Vol. 9, no. 1, pp. 36-44.
11. C. Chen; W. Zhong; D. Wu, Year: 2017, "On the coverage of multiple-input multiple-output visible light communications," in Journal of Optical Communications and Networking, Vol. 9, no. 9, pp. D31-D41.
12. X. Li et al., Year: 2016, "Wireless Visible Light Communications Employing Feed-Forward Pre-Equalization and PAM-4 Modulation," in Journal of Lightwave Technology, Vol. 34, no. 8, pp. 2049-2055.
13. K. O. Akande; W. O. Popoola, Year: 2019, "Enhanced Subband Index Carrierless Amplitude and Phase Modulation in Visible Light Communications," in Journal of Lightwave Technology, Vol. 37, no. 23, pp. 5867-5874.
14. D. G. Aller; D. G. Lamar; P. F. Miaja; J. Rodríguez; J. Sebastián, Year: 2021, "Taking Advantage of the Sum of the Light in Outphasing Technique for Visible Light Communication Transmitter," in IEEE Journal of Emerging and Selected Topics in Power Electronics, Vol. 9, no. 1, pp. 138-145.
15. A. Costanzo; V. Loscri; M. Biagi, Year: 2021, "Adaptive Modulation Control for Visible Light Communication Systems," in Journal of Lightwave Technology, Vol. 39, no. 9, pp. 2780-2789.