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Simulation of Carrierless Amplitude and Phase Modulation Techniques Based OFDM For Li-Fi System

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Abstract: In recent times, Carrierless Amplitude and Phase (CAP) Modulation has been used in wide range of industrial applications because of its simplicity and bandwidth efficiency. In this paper, a novel CAP modulation technique has been proposed for OFDM based Li-Fi in wireless communication system. Generally, reducing the spectrum efficiency losses and increasing the speed of the data transmission are the important requirements of the wireless communication systems. In Existing technologies transmitter takes long time to modulate and encode the signal, the time delay occurred during the conversion is affects the total Li-Fi networks. Same drawbacks are in the receiver side also to demodulate and decode the signal. In order to reduce this problem, novel modulation techniques have been proposed such as Carrier less amplitude and phase modulation (CAP) and Quadrature Phase Shift Keying (QPSK) Modulation .Carrier less amplitude and phase modulation(CAP) and Quadrature Phase Shift Keying (QPSK) have different advantages in terms of ADP(Area-Delay Product). The design simulation is carried out in ModelSim XE III 6.3C and Synthesized in Xilinx ISE 10.1 by using Verilog HDL Language.

Keywords: *Light Fidelity (Li-Fi), Carrier less amplitude and phase modulation (CAP), Bit Error rate (BER), Verilog Hardware description language (HDL), Area-Delay-Product(ADP), Modelsim, Xilinx.*

1. INTRODUCTION

Data transmission from one place into another place is one of the most effective tasks in wireless communications. In wireless networks, fixed bandwidth is assigned for multiple users. For multi user environment, the present wireless networks provide slow internet activity. Light Fidelity (Li-Fi) can be observed as light based Wi-Fi. Wi-Fi handles 2.4 -5 GHz RF for wireless internet access and bandwidth limitation is 50-100 Mbps. In place of Wi-Fi, the Li-Fi would be used for data transmission. Instead of radio waves, the light intensity from Light emitting diode (LED) is used for transmit the data. By using light intensity, Li-Fi can be used in applications which are interfered with radio waves and undersea where Wi-Fi cannot reach. Li-Fi used in various applications such as Military, Aircrafts, Hospitals. Li-Fi provides better authentication, mobility, efficiency than Wi-Fi.

Light fidelity (Li-Fi) is a visible light communication (VLC) technology with transfer the data through illumination of light intensity through LED bulb. These LED changes in the light intensity faster than a human eye. For data transmission and illumination, the VLC technology uses visible light between 400 THz and 800 THz. LED bulbs have capable to ON or OFF. Digital data 1 and 0 is transmitted based on light LED light conditions

Li-Fi performs multiple access points making a wireless network of minor optical atom cells with seamless handover to allow entire user mobility. Li-Fi forms a new layer within the existing heterogeneous wireless networks. In general, light sources described as only intensity modulation (IM) and direct detection (DD) system. For intensity modulation (IM) and direct detection (DD) system, the standard modulation technique is to be used. Such as Pulse amplitude modulation (PAM), Pulse position modulation (PPM), Binary phase shift keying (BPSK), Quadrature phase shift keying (QPSK).These standard existing modulation techniques not suitable for high speed data transmission because of Inter symbol interference (ISI). Orthogonal frequency division multiple access (OFDM) is used for fourth generation (4G) Mobile Communication systems. To generate high speed data transmission for Li-Fi systems with less number of ISI, the Carrier less amplitude and phase (CAP) digital modulation is proposed in this research work.

2. RELATED WORKS

Li-Fi system used Visible light communication to understand the wireless systems. These technologies are suitable for higher frequency in electromagnetic spectrum. Harald Haas [1] explained the difference between the visible light communication (VLC) and Light Fidelity (Li-Fi). Various digital modulation techniques is used to establish the Li-Fi system such as single carrier modulation, Multi carries modulation and Li-Fi specific modulation. Transmitter chip and receiver chip are the components of Li-Fi.

These models can be integrated into mobile terminals and to provide the required connectivity to realize IoT. OFDM based Li-Fi is used to enlarging the data rates and reduces the transmission delay. Li-Fi is capable to increase the transmission capacity in indoor area so its applicable for indoor applications. Walid Abdallsah et al. [2] presented OFDM based Li-Fi technology for 5G wireless access. Better transmission rate (3 Gbit/s) is achieved on visible light communication (VLC) based OFDM approach.Light Fidelity is not suitable for multi user environment.

Proposed encoding technique is used to generate higher transmission capacity between access points and gate way.PWM is used for transmitter section to modulate the signal. These signal is transmitted through Light emitting diode (LED) in the form of light signal . Abdelmoujoud Assabir et al. [3] presented Li-Fi data transmission based Pulse Width Modulation(PWM) signal. Photo diode is used for receiver section to transforms the light signal into electrical signal. Low pass filter(LPF) to detect the original signal.

Light emitting diodes is can be ON or OFF based of the PWM signal states (Low or High).Li-Fi design consists transmitter and receiver. In transmitter section, the Light emitting diode (LED) is used to transmit the data , Photo diode is used for receiver section. LED devices that varied the intensity of light very faster than human eyes. M. Samuel Lazar et al. [4] described high speed data transmission based Light Fidelity (Li-Fi). Data transmission consists of Li-Fi data transmission, LED driver circuit, Photo diode receiver circuit and UART. Li-Fi data transmission is allowing radio frequency bandwidth to resolve the issues with direct line of sight (LOS).

Various digital modulation techniques with all fading channels such as Rayleigh, Rician, Nakagami and Lognormal Shadowing Channels to achieve the efficient bit error rate and also for SNR for wireless communication systems. Then, modulation is done using digital modulation Techniques such as BPSK, QPSK, and QAM. Mranali Joshi et al. [5] stated the Analysing Various Fading Channels Using Different Modulation Techniques under IEEE 802.16 Standard. The output of this technique is real and imaginary value.

We have analyzed that the Rician channel performs better by using BPSK for 3 dB and 6 dB SNR. But, Nakagami Channel performs better at 9 dB SNR and provides lowest value (0.0020) of BER. The Nakagami channel is also performing better at SNR at 6dB and 9dB by Using 4-QAM and QPSK. These modulation techniques to obtain the positive and real valued signals for optical wireless communication (OWC) system. Power efficiency is improved by using DC biased OFDM. Yichen Li et al. [6] described optical spatial modulation based orthogonal frequency division multiplexing (OFDM).

Optical spatial modulations provide better spectral and power efficiency than the unipolar scheme. DC biased OFDM provide 5dB to 9dB energy efficiency. These systems provide power efficiency than the conventional unipolar OFDM and it remove the requirement for DC bias. Performance evaluation between the BPSK and QPSK modulation with interleaving process is calculated to determine the efficient Bit Error Rate (BER).

Swati Dutta et al. [7] explained the comparisions of BPSK and QPSK modulation scheme is performed with coding and interleaving. OFDM system based MIMO systems are analyzed by using BPSK and QPSK Modulation with efficient BER. Here Convolutional codes are used as FEC codes.Bit Error Rate of convolutional codes for BPSK and QPSK modulation schemes and compare them with OSTBC code. Results show that BER performance is improved when OSTBC coder is used. Also BER performance is further enhanced when interleaving is performed for both the modulation techniques .

3. DIGITAL MODULATION

In a digital communication system, the discrete in both time and amplitude input signal is transmitted. These digital signals are converted to an analog signal for transmission. For receiver operation, the analog signals are converted back to the digital form before received to the end user. These conversion processes at the transmitter is known as modulation, the receiver end process is known as demodulation.

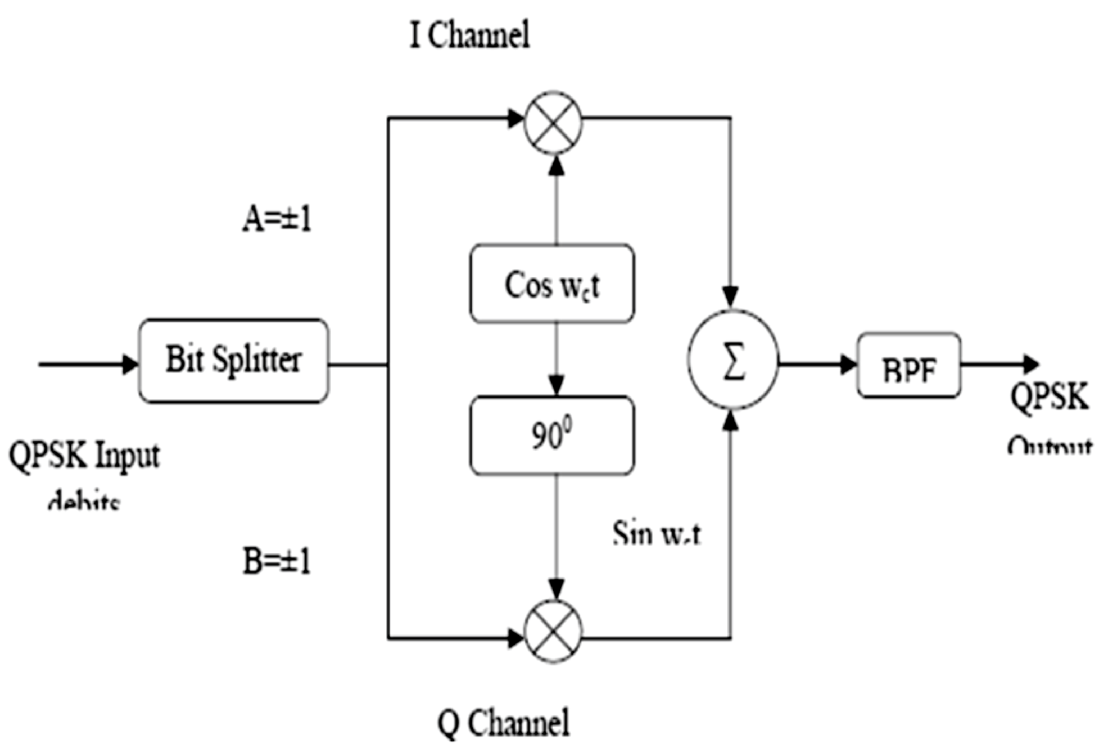


Figure 1: Block Diagram for QPSK

The input modulating signal is defined as pulses or symbols, where each pulses has m finite states. The digital modulations have several advantages over analog such as, greater noise immunity, robustness, easier multiplexing of various signals like audio, video. In wireless communication system, modulation is the process of initialing the transmitted signal on the radio carrier. Digital signal with limited spectrum is available mostly in wireless communication system. Possible of least spectrum is one of the main considerations in digital modulation techniques. The measurement unit is bits per second per Hertz (b/s/Hz). In general, the input signal is represented as a low pass signal. These low pass signal is necessary to move to the high frequency signal with f_c, called carrier frequency. That, carrier frequency(f_c) is removed to recover the input signal in receiver section.

3.1. Quadrature phase shift keying (QPSK) Modulation

Quadrature phase shift keying (QPSK) is most general form of phase shift keying and widely used in cellular and MODEM applications. In QPSK technique, two bits of carrier pulse are transmitted by using various phase shifts. NRZ Symbol sequence is used to modulate the each orthogonal carrier signal.

The input binary data is received at data rate R_b. By using serial to parallel converter, the R_b is divided to two data streams, one including even bits(b_{2n}) and another including even bits(b_{2n+1}). That odd and even bits are encoded into polar transmission symbols a_{2n} and a_{2n+1} by QPSK Modulator.

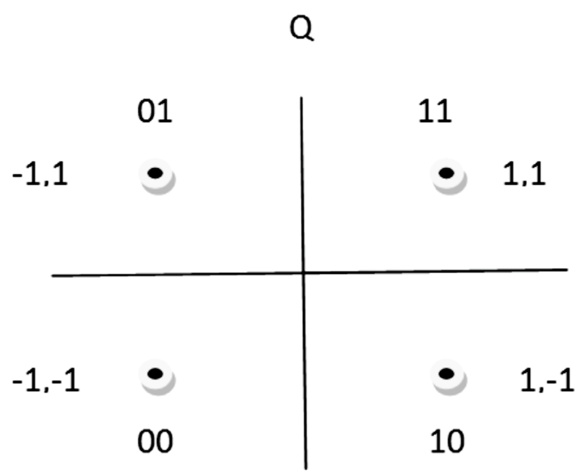


Figure 2: Constellation diagram for QPSK Modulation

In QPSK modulation, the phase shift of the carrier signal is not related to the reference signal but related to the previous signals phase shifts. For reconstruction, the two signals is only compared, it doesn't require reference signals. The angle of the signal is always related to the reference signal. Inter Channel Interference (ICI) is one of the main issue in this modulation scheme so the amplitude and phase of QPSK is varied due to the reduction of the ICI. QPSK technique is more sensitive for phase variations.

3.2. Carrierless Amplitude and Phase (CAP) Modulation

Both performance and complexity of the system, the length of the filter is a integral factor to achieve After the filtering operation, the data streams are added and transmitted to the channel. At the receiver end, the transmitted signals from channel is separated into the I & Q signal and given to the down sampling performance. Then the data stream is demodulated into the QAM Demodulation. In base band, the down conversion is not performed so the QAM demodulation process is perform in pass band. In carrier less amplitude and phase (CAP), there are two filters are used that is I and Q. Both are time and invariant filters. I and Q filters have 90 degrees difference in phase. Whenever the carrier frequency is not high then the practical distribution of the carrier less amplitude and phase modulations are applicable.

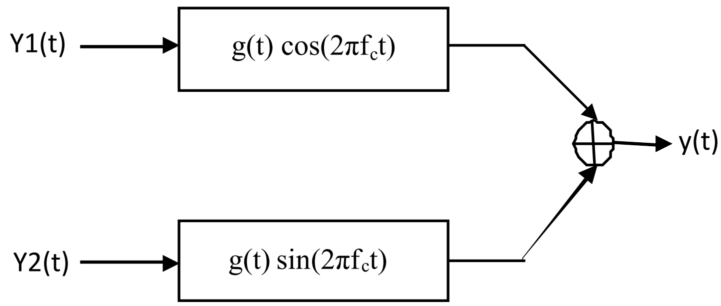


Figure 3: Block Diagram of the Carrier-less Amplitude and Phase (CAP)

$$Ya\,(t) = Yi(t) + Yiq(t) \quad (1)$$

$$Ya(t) = \sum_k Ak\, hi(t-kT) + \sum_k Bk\, hiq(t-kT) \quad (2)$$

Where, $$hi(t) = g(t)\cos(\omega c\, t) * f(t)\ \cos(\omega c\, t) \quad (2a)$$

$$hiq(t) = g(t)\cos(\omega c\, t) * f(t)\cos(\omega c\ \mathrm{t}) \quad (2b)$$

In $hiq(t)$, the zero interference at the sampling rate (Kt),

$$hiq(t) = \int_{-\infty}^{\infty} g(t)\cos(\omega c\, \tau).\, f(t-\tau)\sin \omega c(t-\tau)d\tau \quad (3)$$

$$hiq(t) = \sin(\omega c\, t)h(t) \quad (4)$$

In which, $h(t)$ can be defined as, $$h(t) = 0.5\,[\,g(t) * f(t)] \quad (5)$$

Similarly, $$hi(t) \cong \cos(\omega c\, t)\, h(t) \quad (6)$$

When the interference is zero between the I and Q corresponding paths, then the value of $hiq(t)$ is zero. For the requirement of the other sampling rates, Nyquist rate is used for the zero ISI (Inter Symbol Interference) . In case of this ISI Property, the adaptive equalizers and detectors is used to detect the ISI in PAM Systems.

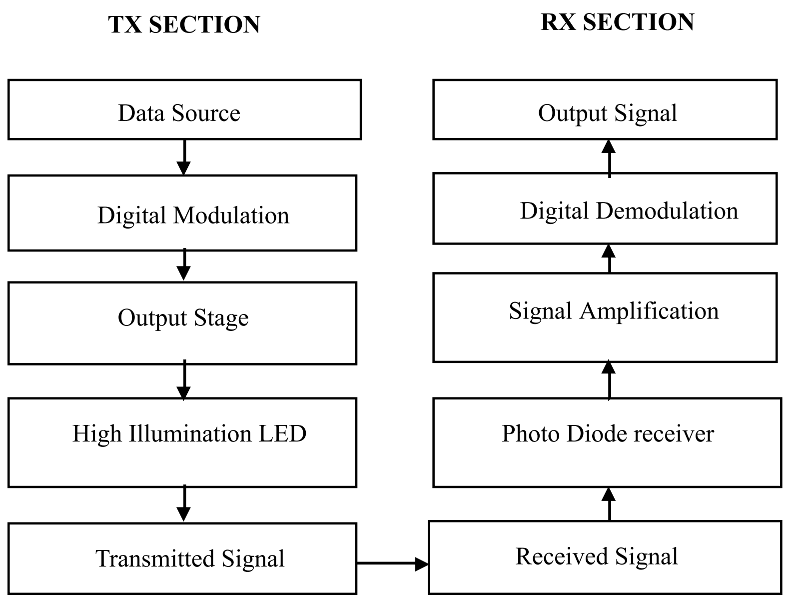
$$\sin(\omega\, c\, k\mathrm{T}) = 0; \quad (7)$$

This condition is practical , when the filters have excess bandwidth without any condition.

4. PROPOSED CARRIERLESS AMPLITUDE AND PHASE (CAP) DIGITAL MODULATION TECHNIQUE BASED OFDM FOR LI-FI SYSTEM

Light Fidelity (Li-Fi)is one of the best solutions to increase the transmission range in the indoor. It is purely based on Light Emitting diodes (LEDs) to achieve a high speed communication. Li-Fi communication network contains Transmitter and Receiver. Data communication between the transmitter and receiver is done by light. Because light provide the transmission rate up to 2Gbps. Transmitter contains Modulator, Encoder, Error detector and photo diode. Digital data is transferred from sender after the modulation and encoding process, the modified data is converted into light signal by using photo diode. In transmitter section, the input data is given as binary form to the digital modulation section. In order to transmit the data through LED is necessary to modulate those into a carrier signal. These basically depend on the chosen modulation techniques. Then, the modulation signal is forward to output stage. Photo diode is used in receiver section to receive the original signal and amplified by the inverting amplifier. The original given information is received by demodulation process.

In digital communication system, the carrier less amplitude and phase modulation (CAP) is one of the digital modulation method to be considered the band pass Pulse amplitude modulation (PAM). This digital modulation is observed at the change of QAM (Quadrature amplitude modulation) beyond the modulation and demodulation blocks. CAP is the multidimensional and multilevel digital modulation methodology to transmit the two bits of data in parallel, not depend on the carrier signal. In CAP modulation, the filter is used with orthogonal waveforms to separate the different stream of data's. This makes to achieve the same spectral efficiency and bandwidth than QAM. For low power consumption, the CAP signal is generated by using the analog filters to achieve efficient data rate(100Gb/s). To modulate the data in two dimensions, there are two orthogonal signature wave form is used to generate the orthogonal components instead of sinusoidal carrier signal. In CAP receiver, filter is used to restore the signal from other component. Due to high spectral efficiency, the narrow channel spacing is allowed to access the short range links.



Figire 4: Li-Fi Transmitter and Receiver System Model

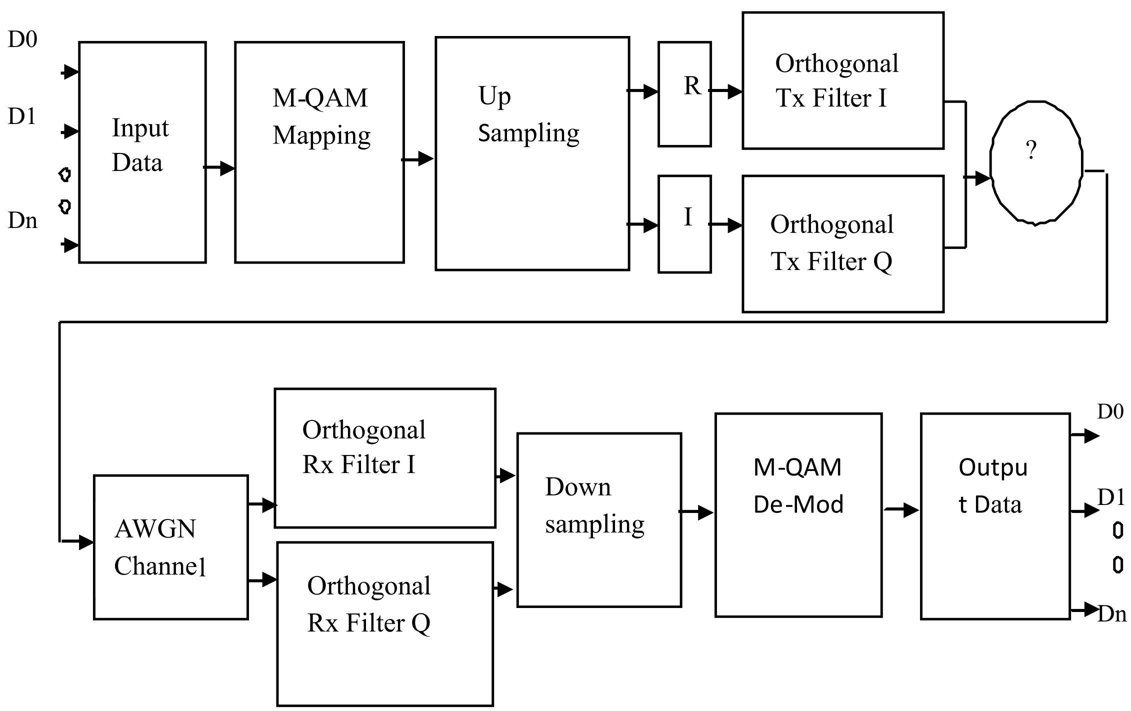


Figure 5: Block diagram of the proposed carrier less amplitude modulation

In order to attain 100 Gb/s by using this CAP Modulation, the input data stream is generated from pseudo-random bit sequence(PRBS) , which is copied eight times to reach 2^{14} bits. By using gray coding, that data stream is encoded into QAM Constellation. Ratio between the sampling frequency and symbol is generated by the number of samples per symbol. For sampling process, there are three samples per symbol are needed to for carrier less amplitude phase modulation (CAP). That is, the data stream necessary to have the sampling frequency 75GSa/s for a 25Gbaud signal. Then, the binary data stream is mapped into the QAM Constellations. In-Phase (I) & Quadrature (Q) Components can be separated to real and imaginary parts of the data streams. Orthogonal filtering is the next process to perform. There are two filtering is used to transmit the both real and imaginary data streams. Cosine frequency, roll of factor and filter length is the parameters of the filter characteristics. The frequency band of the transmitted data stream is generated by the sine and cosine frequency.

5. SIMULATION DIAGRAM AND ANALYSIS

The design of carrier less amplitude and phase (CAP) Modulation technique for Li-Fi system has been constructed by using Verilog Hardware Description Language (HDL). By using Modelsim XE III 6.3C, the results of QPSK Modulator & Demodulator, Proposed Carrier less amplitude and phase(CAP) digital modulation technique has been evaluated and the Proposed modulation synthesis results has been estimated by using Xilinx ISE 10.1 Carrier less amplitude and phase (CAP) modulation technique is provides high speed high reliable data transmission for communication systems, this transceiver is shown in Fig. 6 and 7 respectively. The simulation result of QPSK modulation and demodulation techniques are shown in Fig .8 and 9 .

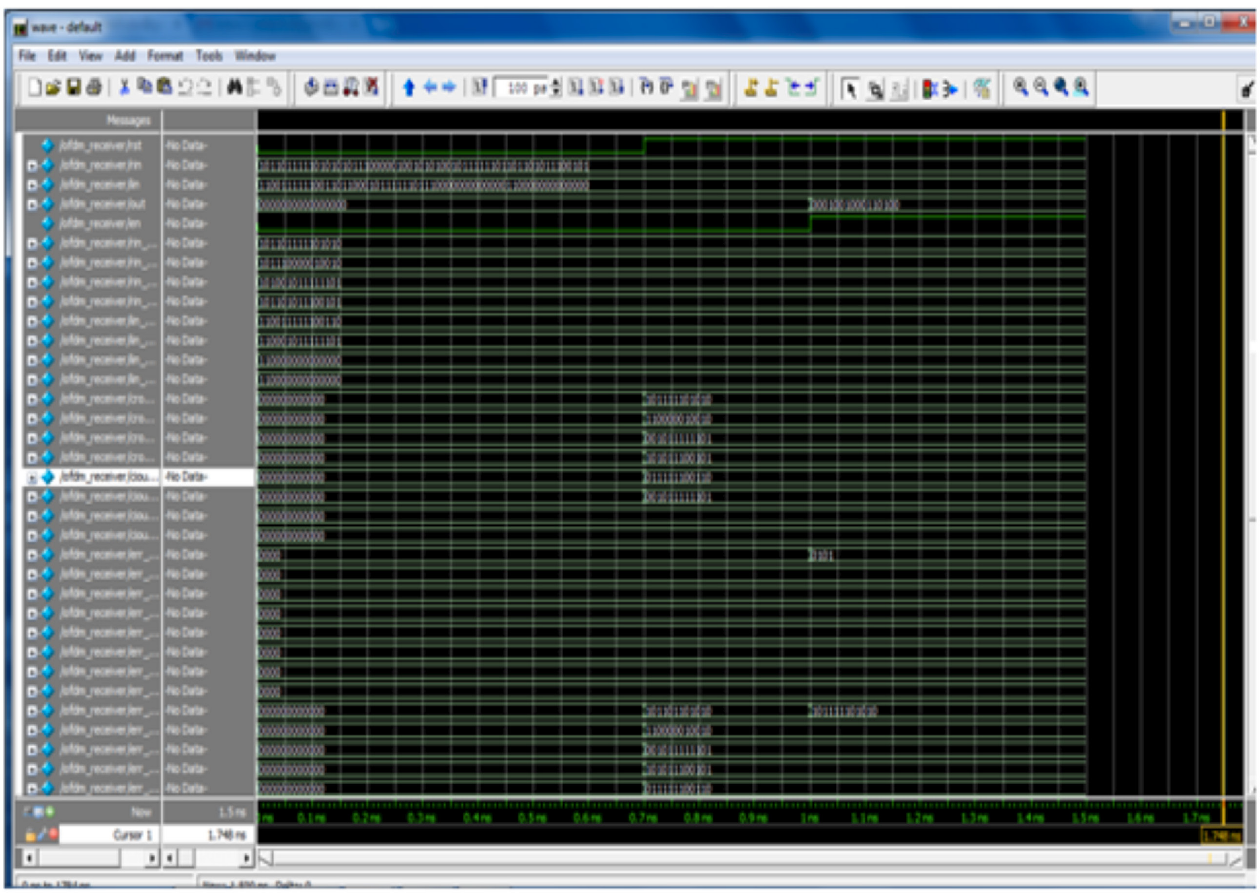


Figure 6: Simulation result for Carrier less amplitude and phase (CAP) Modulation

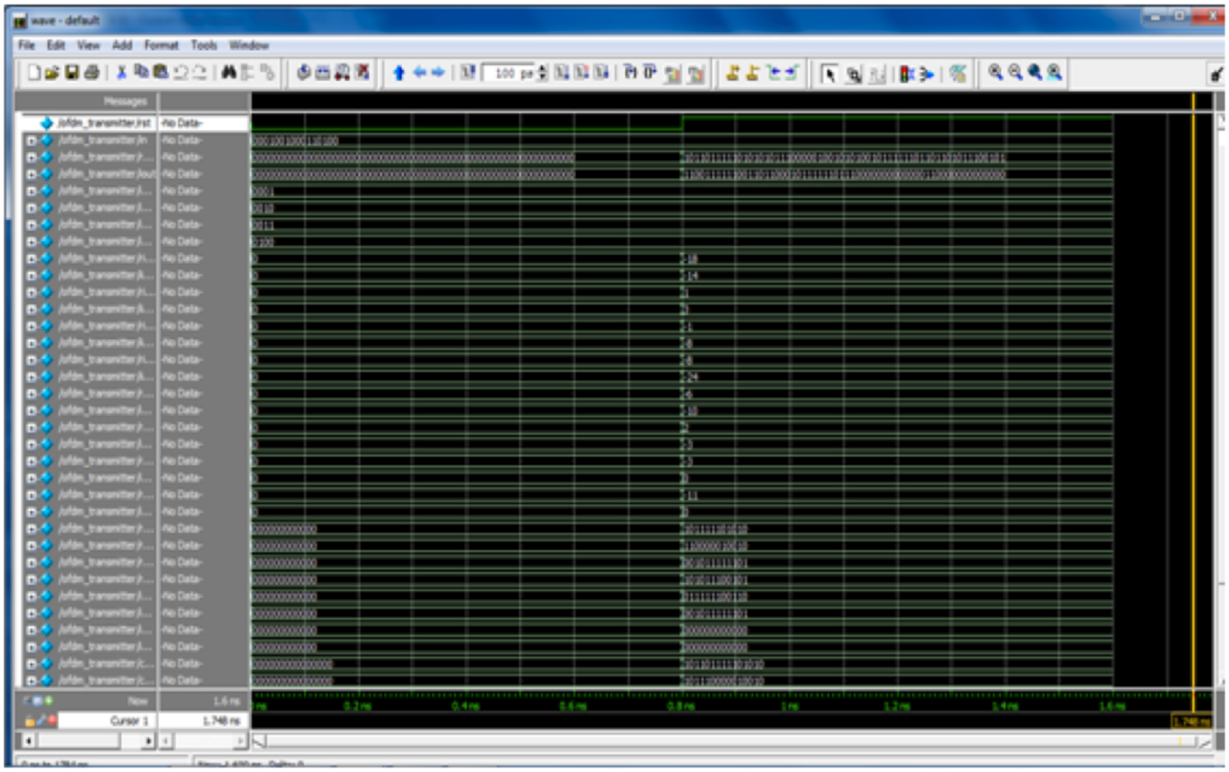


Figure 7: Simulation result for Carrier less amplitude and phase (CAP) Demodulation

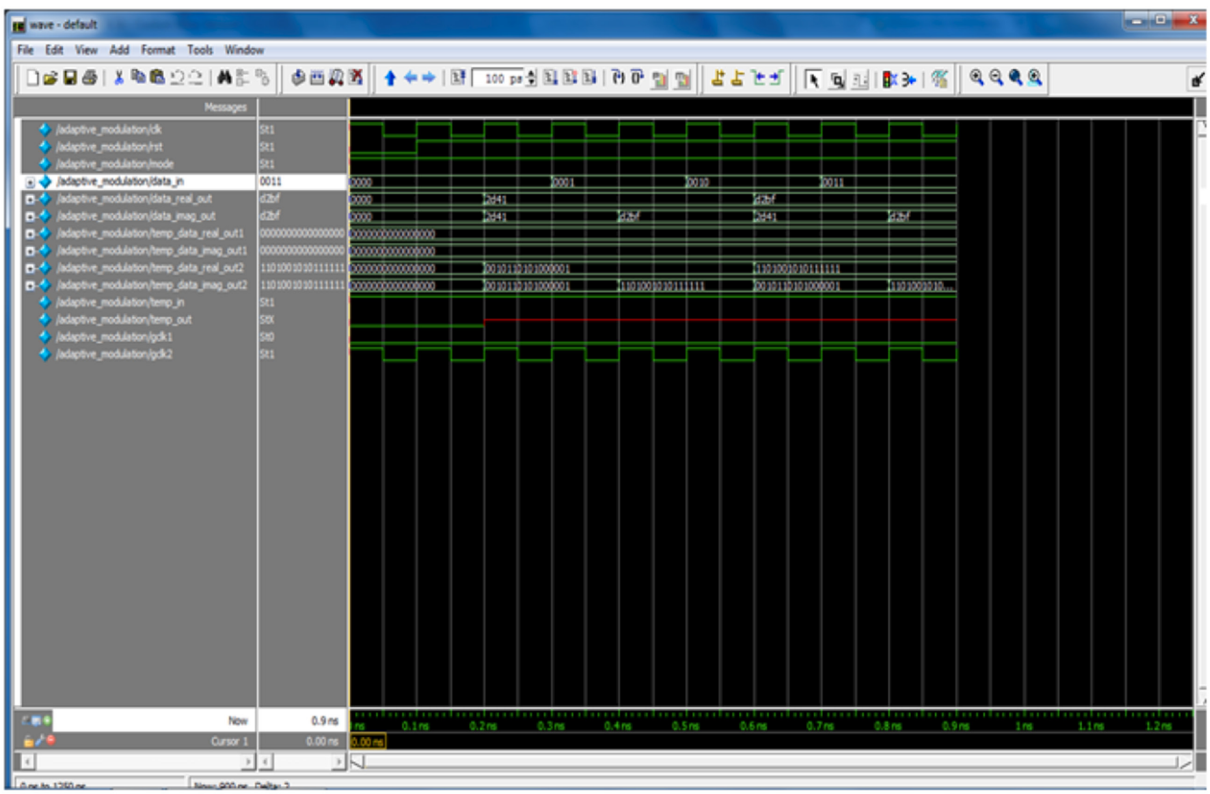


Figure 8: Simulation result for Quadrature phase shift keying (QPSK) Modulation

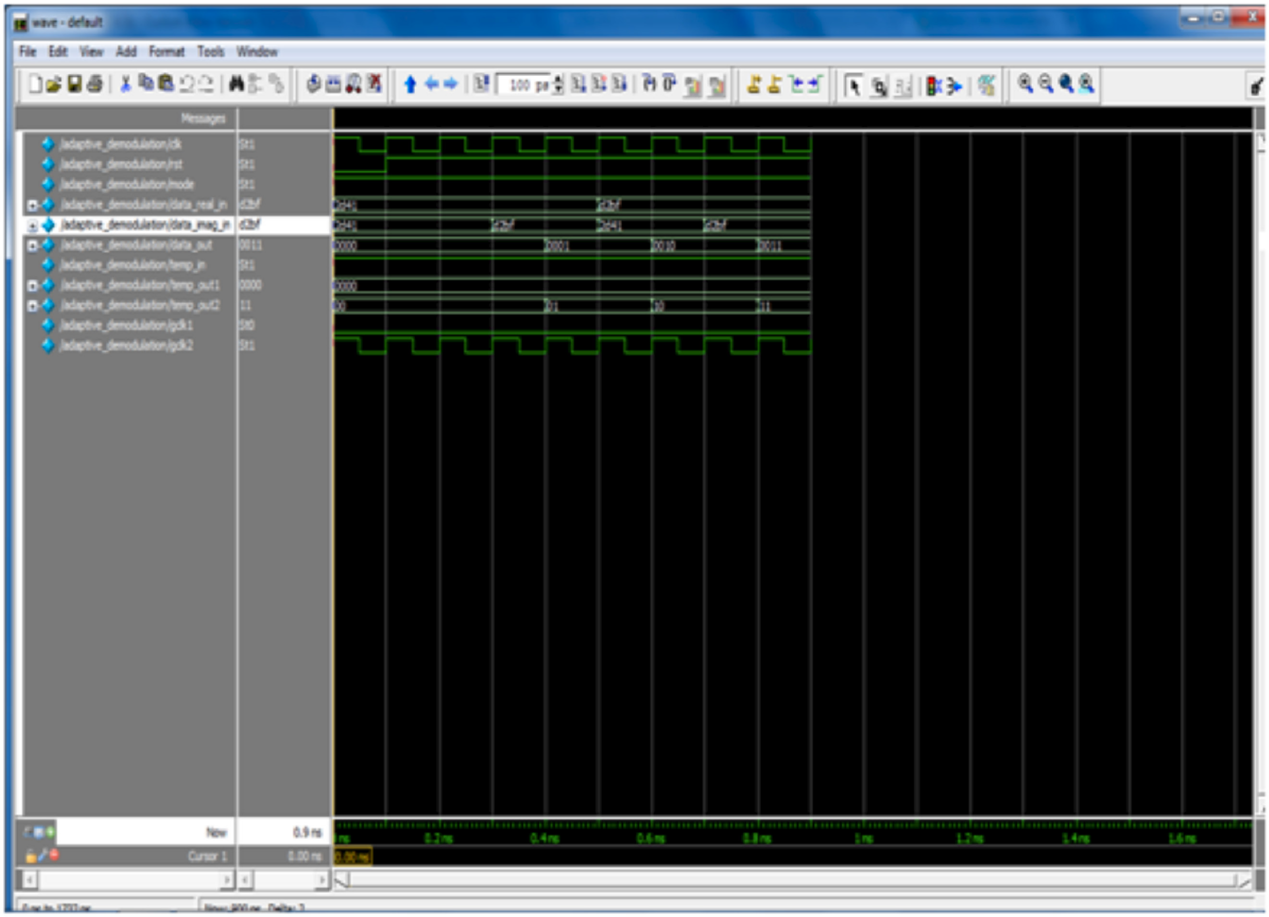


Figure 9: Simulation result for Quadrature phase shift keying (QPSK) Demodulation

Table 1
Comparison result of CAP and QPSK demodulation technique

Type	*Slices*	*LUT*	*Delay(ns)*	*Power(W)*
CAP Demodulation	19	35	6.141	0.024
QPSK Demodulation	12	22	6.216	0.030

6. CONCLUSION

In this paper, we have presented a novel carrier less amplitude and phase (CAP) digital modulation technique for Li-Fi systems. The CAP Digital modulation technique demonstrates the Power efficiency and Area-Delay Product (ADP) improvement for high speed data transmission. For the same spectral range, it provides higher bit error rate than existing digital modulation methods. When compared to the other digital modulation methods, this method used filtering for demodulation process to eliminate the requirement of the carrier recovery, Adaptive equalization or Frames. Hence, the Carrier less amplitude and phase modulation (CAP) is the finest resolution for high speed data transmission for communication systems. Simulations of the carrier less amplitude and phase modulation (CAP) with transmitter and receiver are analyzed.

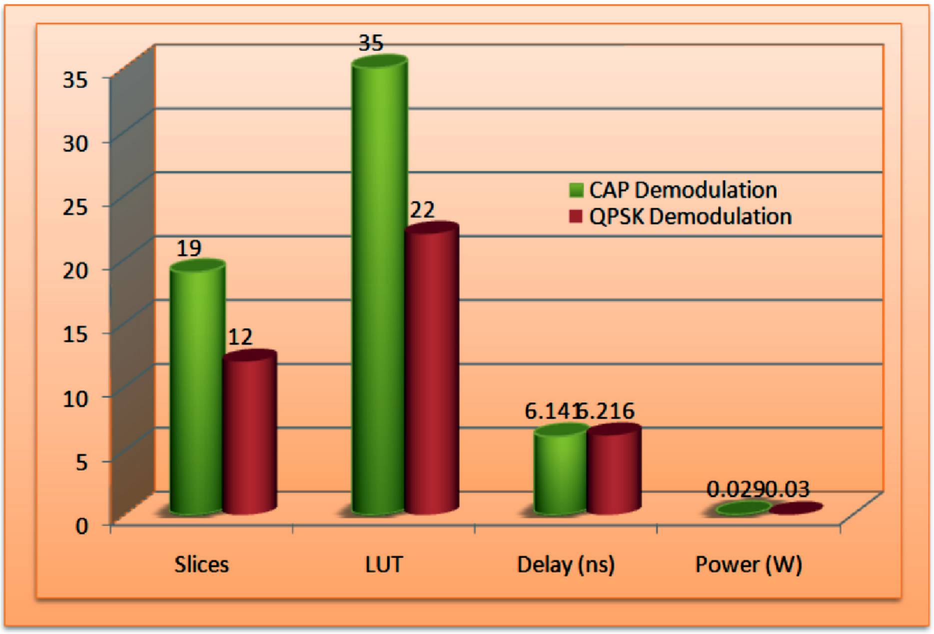


Figure 10: Performances of both CAP demodulation and QPSK demodulation in graphical view

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