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Optimized BPSK and QAM Techniques for OFDM Systems

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ABSTRACT

A modulation is a process by which some characteristics of high frequency carrier signal is varied in accordance with the instantaneous value of another signal. In this paper presents the basic modulation and demodulation principle of Quadrature Amplitude Modulation (QAM) and Binary Phase-Shift Keying (BPSK). The QAM and BPSK modulation and demodulation algorithm is designed and implemented for OFDM system. QAM is widely used multi-level modulation technique, with a variety of application in data radio communication system. BPSK is a simple but significant carrier modulation scheme. The design of modulation and demodulation is done through Very Large Scale Integration (VLSI) system design environment.QAM and BPSK are the important modulation techniques for wireless communication system. These two modulations have different types of advantages in terms of less area, high speed and lower power consumption. QAM modulation has high speed to modulate the digital input whereas BPSK has low speed due to less angle coefficient. QAM and BPSK modulation and demodulation techniques are simulated by using ModelSim 6.3C and synthesized by Xilinx 12.4i.

Keywords: Quadrature Amplitude Modulation (QAM), Binary Phase-Shift keying (BPSK), Orthogonal Frequency Division Multiplication (OFDM), Very Large Scale Integration(VLSI).

1. INTRODUCTION

An OFDM system is a multi-carrier system which utilizes a similar processing technique permitting the simultaneous data transmission on many closely spaced, orthogonal sub-carriers. Quadrature Amplitude Modulation (QAM) is used in various communication protocols such as Digital Video Broadcasting (DVB) and Wi-Fi. The architecture of digital QAM modulator/demodulator is typically forced by several requirements. Such requirements are high immunity to noise, flexibility for various communication standards, throughput and low-on chip power. OFDM is a parallel digital modulation technology by extending the cycle of transmitting symbol to overcome multipath interference and it decomposes high speed serial data into multiple parallel low-speed data. Binary phase shift keying (BPSK) has high spectrum efficiency, good spectral characteristics, and strong anti-interference performance, faster transfer rates and other prominent features. So BPSK is one of the main modulation modes of OFDM system. With the rapid development of the integrated circuit manufacturing technology and OFDM technology, it will become the development trend of mobile communications to use the digital programmable devices to achieve the digital modem and baseband signal processing. Efficient modulation techniques are essential to modulate higher rate single data stream into different lower rate data streams. Different kinds of digital modulation such as Amplitude Modulation (Amplitude Shift keying (ASK) and Quadrature Amplitude Modulation (QAM)), Phase Shift Modulation(Binary-phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK)).

In this paper, QAM and BPSK modulation techniques are designed through Verilog Hardware Description Language (Verilog HDL). In these techniques are used to reduce the area, delay, power and also improves

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the speed and throughput. And also improves the performance of modulation and demodulation techniques. Further all techniques of OFDM like FFT, encoder and decoder are incorporated into OFDM system to execute the OFDM based communication system.

2. LITERATURE SURVEY

[Tan Mingxin, et al., 2009] explained the principle of 16QAM modulation and demodulation of BER and high data rate-to-bandwidth ratio in the transmission of 16QAM modulation, BPSK and QPSK modulation. BPSK modulation bandwidth utilization is $1^{bit/(s.Hz)}$, QPSK modulation bandwidth utilization is $2^{bit/(s.Hz)}$, and 16QAM modulation bandwidth utilization is $4^{bit/(s.Hz)}$. The communication system adopt 16QAM modulation can achieve the similar BER to QPSK and BPSK modulation, but utilization of bandwidth is better than BPSK and QPSK modulation.[Zhongjun Zhao, et al., 2011] described the design of BPSK based on software defined radio. The paper uses a Costas loop to achieve carrier synchronization when the BPSK demodulator is designed. The loops realize the purpose of phase detection using the more accurate and little hardware resources.

[J. Faezah, et al., 2009] described the adaptive modulation for OFDM System. The goal for the fourth generation (4G) of mobile communication system is to integrate a wide variety of services such as high speed data and multimedia traffic as well as voice signals. The OFDM system performance of uncoded modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK).[Lily Mishra, 2014] explained various adaptive modulation and coding techniques in wireless network. Power adaptation techniques are the optimal way of adaptation. In channel inversion the power is inefficient but it maintains a constant value of SNR at the receiver. In modern wireless communication technology, this is used to increase the spectrum efficiency by reducing the error rate.

[M.R. Dey, et al., 2012] explained performance analysis of PAPR reduction using forward error correcting code. Linear block coding based PAPR reduction technique is proposed for OFDM system which distributes input data to sub-block, uses the Hammimg code sequences, and changes the phase of the modulated output resulting in significant performance gain in terms of PAPR reduction. [Chuntao Man, et al., 2011] described the research of OFDM modulation and demodulation technology based on wavelet packet. It reduces the integrated interference rate of Inter-symbol Interference (ISI) and Inter-carrier Interference (ICI).

3. QUADRATURE AMPLITUDE MODULATION

Quadrature Amplitude Modulation is a form of modulation technique which is used for modulating the data signals onto a carrier used for radio communications. QAM is a signal in which two carriers are shifted by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. The analog versions of QAM are typically used to allow multiple analog signals to be carried on a single carrier. Digital formats of QAM are referred to as “Quantized QAM” and it is increasingly used for data communications. QAM involves transferring digital information by periodically adjusting the phase and amplitude of a sinusoidal wave. Each combination of phase and amplitude is called a symbol and represents a digital bit stream. In 16-state Quadrature Amplitude Modulation (16QAM), there are four I values and four Q values. It can transition from any state to any other state at every symbol time. Since, $16 = 2^4$, four bits per symbol can be sent. It consists of two bits for I and two bits for Q. The symbol rate is one fourth of the bit rate.

4. BINARY PHASE SHIFT KEYING (BPSK) MODULATION

BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are 0° and 180°. To generate a binary PSK signal, to represent the binary sequence in polar form with symbols 1 and 0 represented by constant amplitude levels of $+\sqrt{Eb}$ and $-\sqrt{Eb}$ respectively. The carrier and timing pulses used to

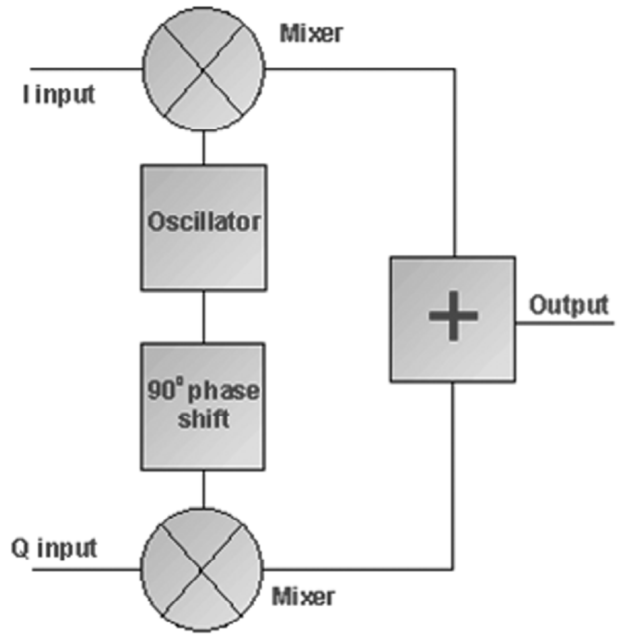

Figure 1: Block Diagram of QAM Modulation

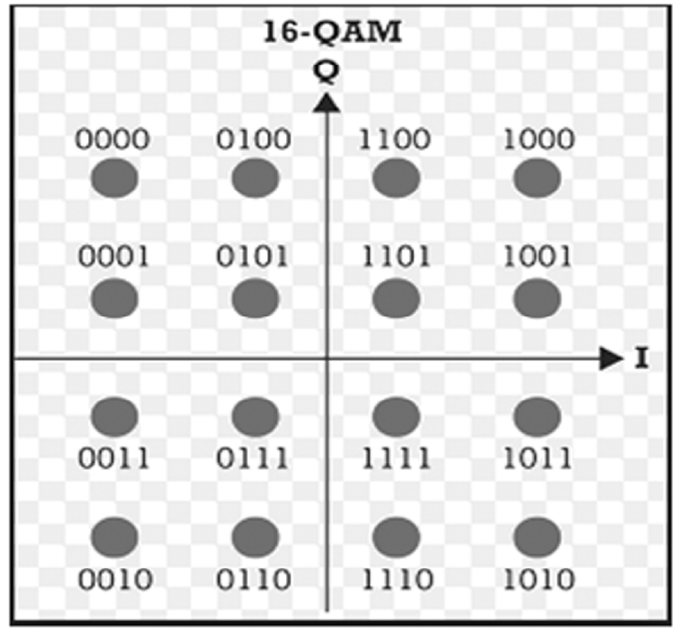

Figure 2: Constellation diagram of QAM modulation

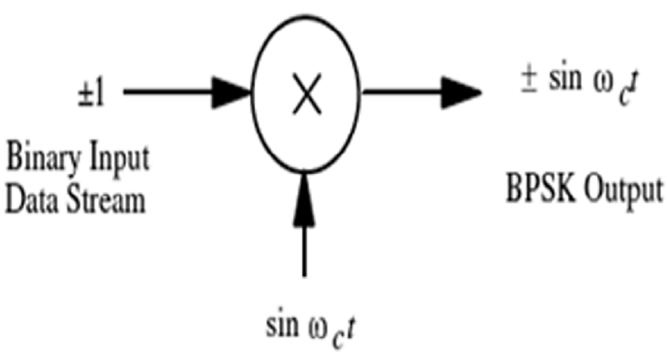

Figure 3: Block Diagram of BPSK modulation

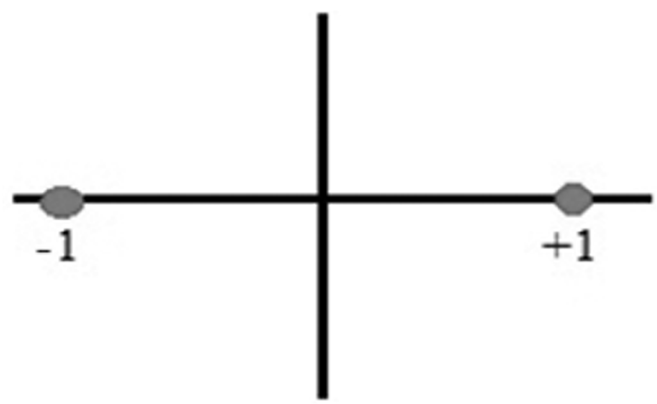

Figure 4: Constellation Diagram of BPSK modulation

generate the binary wave are usually extracted from a common master clock, the desired PSK wave is obtained at the modulator output.

$$S_1(t) = A \cos 2\Pi f_c t,\ 0\ \Pi\ t \leq" T, \text{ for } 1$$
$$S_2(t) = -A \cos 2\Pi f_c t,\ 0 \leq t \leq T, \text{ for } 0$$

5. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a parallel digital modulation technology by enlarging the cycle of transmitting symbol to overcome multipath interference and it degrades high speed serial data into multiple parallel low-speed data. It works on the principle of converting a serial data stream to a parallel data stream with each symbol from the parallel set modulating a separate carrier. The carrier spacing is 1/T where T is the duration of the OFDM symbols. The addition of orthogonal carriers modulated by parallel data streams is equivalent to taking the IFFT of the parallel symbol set. An OFDM carrier signal is the additional number of orthogonal sub-carriers, with base band data on each sub-carrier being independently modulated using QAM and PSK. The block diagram of OFDM transmitter and receiver is shown in fig. 5. The OFDM transmitter consists of Encoder, Modulation, Inverse Fast Fourier Transform (IFFT) and cyclic prefix. The OFDM receiver consists of removed cyclic prefix, Fast Fourier transform (FFT), demodulation and decoder.

Input signal is given to source encoder and it is used to convert analog to digital signal. Channel encoder and decoder, which is used to adding and removing the extra parity bits. The modulation, in which single higher rate data stream is divided into many lower rate data streams. Each lower rate data streams are shifted into IFFT block to convert frequency to time domain signal. In the receiver side, FFT block is used to convert the time to frequency domain signal. Cyclic prefix and Remove Cyclic prefix are the process of adding and removing some more additional bits in between the channel.

6. PROPOSED MODEL OF QAM AND BPSK MODULATION AND DEMODULATION FOR OFDM SYSTEM

In this paper, the proposed model of QAM and BPSK modulation and demodulation for OFDM system has been designed. QAM and BPSK modulation techniques provide different types of advantages in terms of silicon chip size requirement, delay and power consumption. The architecture of modulation and demodulation model is illustrated in fig. 6 and fig. 7. The proposed architecture consists of both modulation

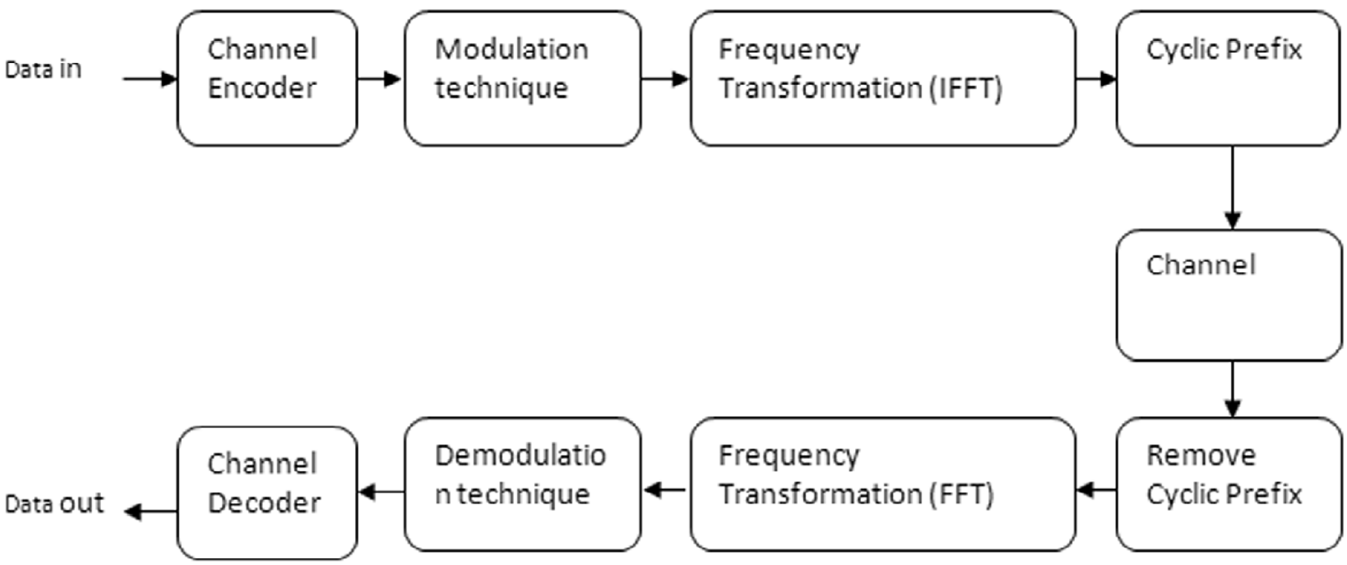

Figure 5: Block Diagram of OFDM System

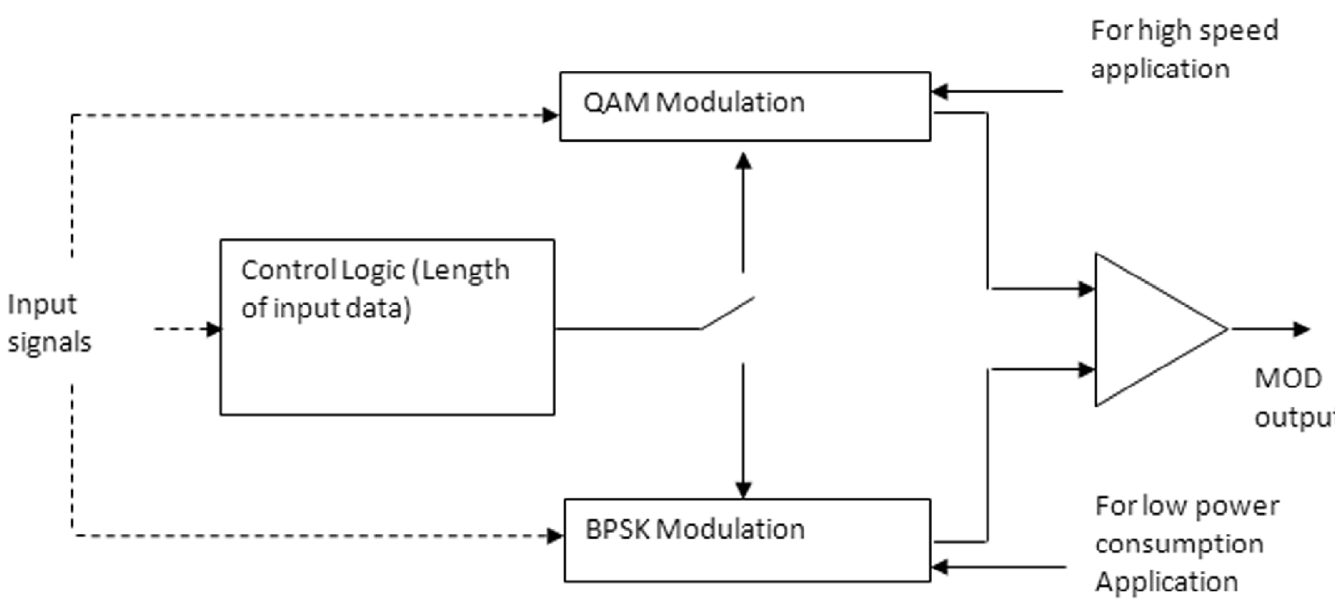

Figure 6: QAM and BPSK Modulation model for OFDM system

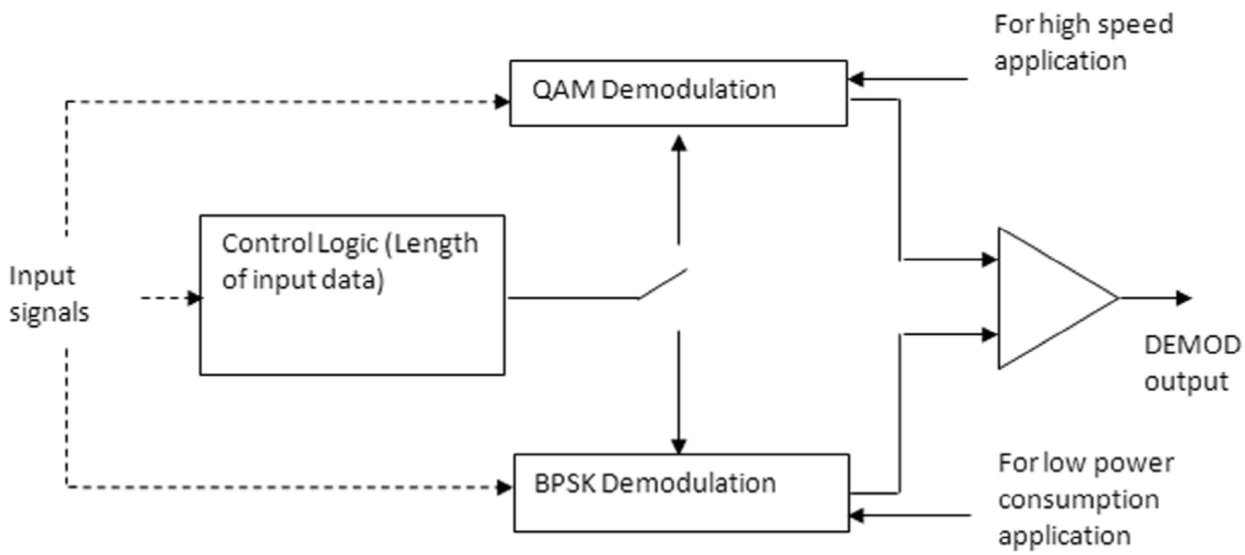

Figure 7: QAM and BPSK Demodulation model for OFDM system

and demodulation techniques such as QAM modulation, BPSK modulation, QAM demodulation and BPSK demodulation.

Control logic of proposed modulation is length of input data values. Based on this control signals, different kinds of modulation such as QAM and BPSK modulation are selected. For example, if the length of input data is in one bit, BPSK modulation is selected for lower power consumption application. If the length of input data is four bits, QAM modulation is selected for high speed applications. As in case of demodulation, ranging of FFT outputs are to be considered as control signals. Based on this control signals, different types of demodulation such as BPSK and QAM demodulations are selected. For example, if output of FFT values, BPSK demodulation is selected for lower power consumption applications. For any other selective ranges, QAM demodulation is selected for high speed applications.

7. RESULTS AND DISCUSSION

The proposed QAM and BPSK modulation and demodulation for OFDM has been designed by using ModelSim 6.3C and synthesis of QAM and BPSK modulation and demodulation has been validated by

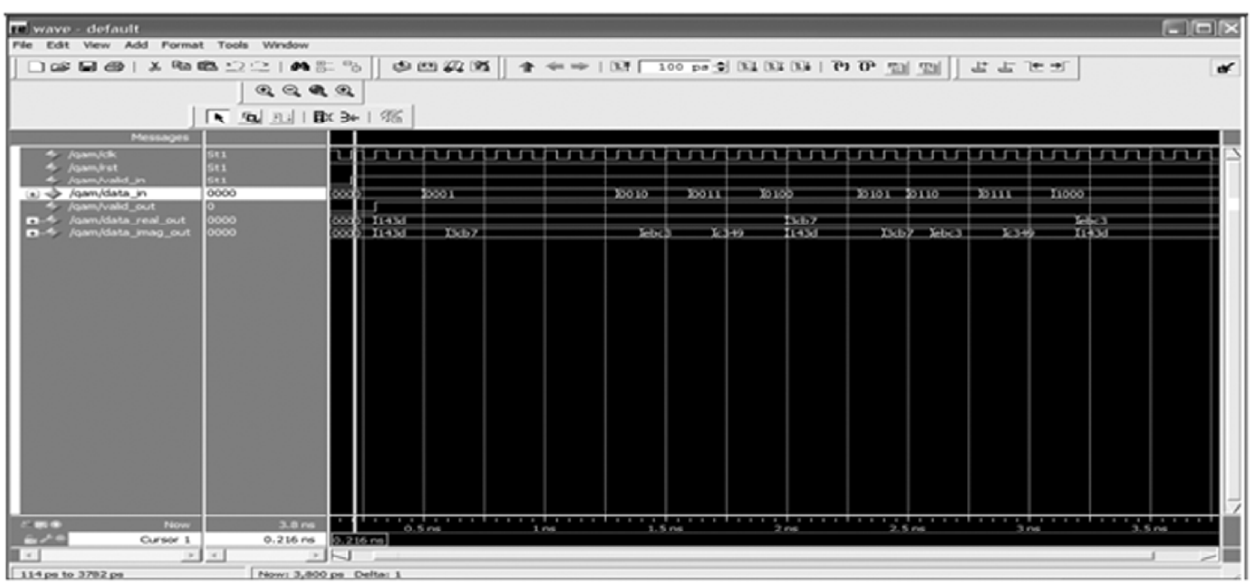

Figure 8: Simulation result of QAM modulation for OFDM system

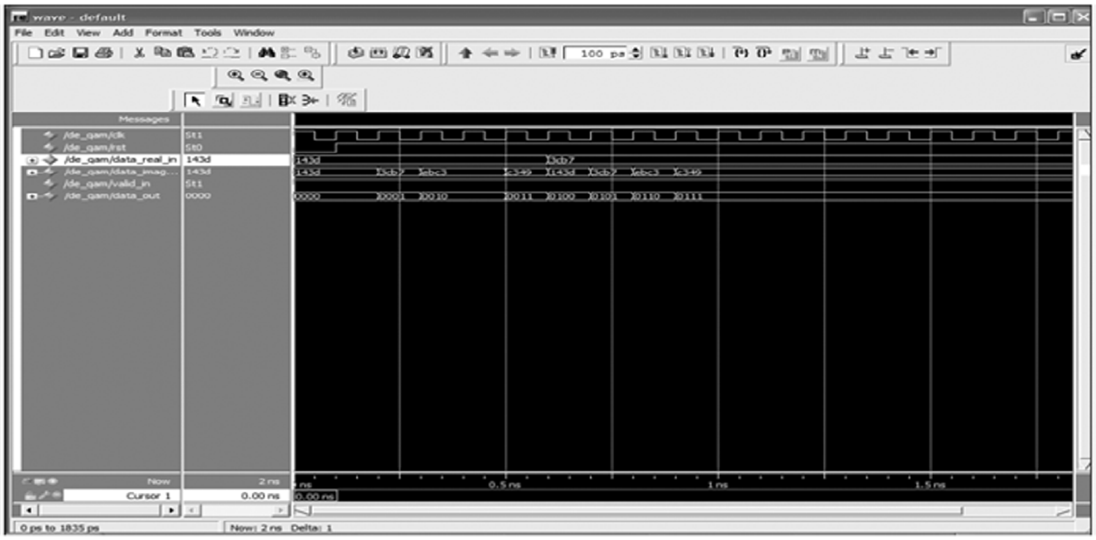

Figure 9: Simulation result of QAM demodulation for OFDM system

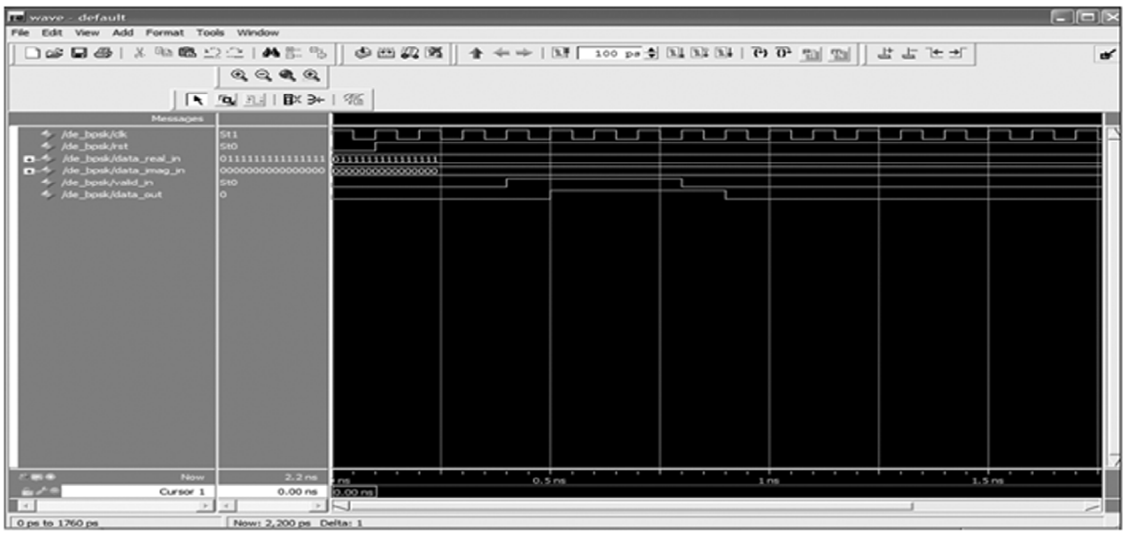

Figure 10: Simulation result of BPSK modulation for OFDM system

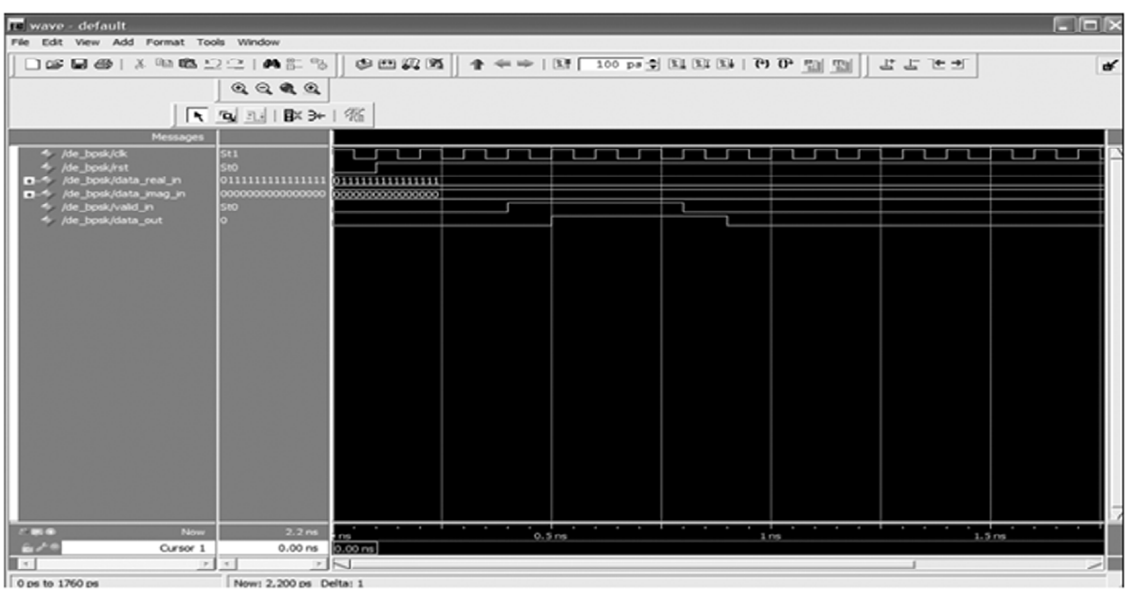

Figure 11: Simulation result of BPSK demodulation for OFDM system

Table 1
Comparison of QAM modulation and BPSK modulation for OFDM system

Types/Parameters	*Slices*	*LUTs*	*Delay (ns)*	*Power (W)*	*Application*
QAM Modulation	4	8	2.637	0.255	High speed application
BPSK Modulation	1	2	2.410	0.218	Low power consumption application

Table 2
Comparison of QAM modulation and BPSK modulation for OFDM system

Types/Parameters	*Slices*	*LUTs*	*Delay (ns)*	*Power (W)*	*Application*
QAM Demodulation	19	35	6.947	0.242	High speed application
BPSK Demodulation	3	5	3.193	0.187	Low power consumption application

using Xilinx 12.4i design tool. Simulation result of QAM modulation and demodulation for OFDM system is shown in fig.8 and fig.9.Simulation result of BPSK modulation and demodulation for OFDM system is shown in fig.10 and fig.11. In QAM modulation, four bits are required to modulate the digital inputs. Hence, sixteen combinations of phase angles are exhibited to get the modulation output. In BPSK modulation, only one bit is required to modulate the digital input. Hence, two combinations of phase angles are exhibited to get the modulation output. The comparison of QAM and BPSK modulation is shown in Table 1. and the comparison of QAM and BPSK demodulation is shown in Table 2.

In QAM modulation, Slices and LUTs are 4 and 8 which are reduced to 1and 2, delay is 2.637 which is reduced to 2.410 and the power is 0.255 W which is reduced to 0.218W, in case of BPSK modulation. In QAM demodulation, Slices and LUTs are 19 and 35 which are reduced to 3 and 5, delay is 6.947 which is reduced to 3.193 and the power is 0.242 W which is reduced to 0.187, in case of BPSK demodulation. Hence, QAM modulation and demodulation is suitable for high speed applications and the BPSK modulation and demodulation is suitable for low area and low power consumption.

8. CONCLUSION

In orthogonal frequency division multiplexing system, modulation and demodulation technique is the core content of OFDM technology. This paper presents a QAM and BPSK modulation and demodulation for OFDM system. This proposed method has been designed by using Verilog Hardware Description Language (Verilog HDL).QAM and BPSK modulation and demodulation are based on high speed and low power consumption requirement. In this proposed method, is used to reduce the area, delay and power. When compared to QAM modulation, BPSK modulation offers 75 % reduction in slices, 75 % reduction in LUTs, and 8.6 % reduction in delay and 14.5% reduction in power consumption. When compared to QAM demodulation, BPSK demodulation offers 84.2% reduction in slices, 85.7% reduction in LUTs, and 54% reduction in delay and 22.7% reduction in power consumption. For high speed requirement, QAM modulation and demodulation techniques are used. Hence, BPSK modulation and demodulation techniques are suitable for low power consumption requirement application. Finally, the modulation and demodulation techniques are incorporated into OFDM system.

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