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VLSI Based Adaptive Modulation and Adaptive OFDM

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Abstract:-

In this paper, adaptive modulation technique is presented for Orthogonal Frequency Division Multiplexing (OFDM) based wireless communication system. The design of adaptive modulation is done through Very Large Scale Integration (VLSI) System design environment. In general, reducing the hardware complexity and increasing the speed of processors are the important requirements of VLSI System design environment. Quadrature Phase Shift Keying (QPSK) modulation and Quadrature Amplitude Modulation (QAM) 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 QPSK modulation has low speed due to less angle coefficient. Similarly, QPSK modulation utilizes less hardware and lower power consumption than QAM modulation to design the modulation technique. In addition to adaptive modulation, adaptive decoder, adaptive frequency transformation techniques such as Fast Fourier Transformations (FFT) are incorporated in OFDM System to improve the performance of OFDM based communication System. Hence, proposed OFDM System technically referred as "Adaptive OFDM".

Keywords: - Orthogonal Frequency Division Multiplexing (OFDM), Quadrature Amplitude Modulation (QAM), Quadrature Phase Shift Keying (QPSK) modulation, Adaptive Modulation, Adaptive Decoder, Adaptive Encoder, Adaptive Fast Fourier Transformation (Adaptive FFT), Very Large Scale Integration System (VLSI).

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transformation technique in which high rate data stream is divided into different sub-carriers of lower rate data streams. Hence, OFDM System is also referred to as modulation technique. Efficient modulation techniques are essential to modulate higher rate single data stream into different lower rate data streams. Large endeavours have been suggested the different types of digital modulation such as Amplitude Modulation (Amplitude Shift Keying (ASK) and Quadrature Amplitude Modulation (QAM)), Phase Shift Modulation (Phase Shift Keying (PSK), Binary Phase Shift Keying (BPSK), and Quadrature Phase Shift Keying (QPSK)). In general, phase shift modulation provides better performances in terms of VLSI concerns than amplitude modulation, because in phase shift modulation, different number of phase shift helps to easily modulate the inputs. However, the speed of amplitude modulation increased than phase shift based modulation. One of the promising techniques to achieve the integration of wide variety of communications system is OFDM. In fixed

OFDM has more complexity to in data flow path. Also, speed of fixed OFDM requires constant hardware complexity for any types of information. To overcome this disadvantage, Adaptive OFDM (AOFDM) is introduced in [2]. In [2] improvements of AOFDM System can be measured in terms of Bit Error Rate (BER) and throughput. Spectral efficiency of the input signals is to be considered to increase the performances of BER. In [3] and [4], the procedure for increasing the spectral efficiency and is briefly described with the help of adaptive modulation and coding rate techniques. The main aim of those works is reducing the BER rate for OFDM based communication system. Based on Signal to Noise Ratio (SNR) value, the adaptive modulation technique is proposed in [1]. Adaptive Modulation and Coding (AMC) helps to improve the efficiency of Channel State Information (CSI) and maximize the throughput with better spectral efficiency [9] and [5]. For the application of cognitive radio system, spread spectrum (SS) and Multi-carrier Spread Spectrum (MSC) are recognized as a high potential. Hence, therefore adaptive modulation is essential to improve the spectral characteristics of cognitive radio system. In [7], adaptive modulation technique is considered for visible light communication. Further, adaptive modulation based OFDM system can be extended for Multi-In-Multi-Out (MIMO) OFDM application. In this paper, adaptive modulation technique is designed through Verilog Hardware Description Language (Verilog HDL). Further all adaptive techniques of OFDM like adaptive frequency transformation (adaptive FFT), adaptive encoder and adaptive decoder are incorporated into OFDM System to exhibit the adaptive OFDM based communication system.

2. ARCHITECTURE OF OFDM

Block diagram of transmitter and receiver structure of OFDM System is illustrated in fig. 1. Transmitter part of OFDM System consists of Modulation, Encoder, Frequency transformation (Inverse Fast Fourier Transformation (IFFT)) and cyclic prefix. Similarly, receiver part of OFDM System consists of Removed cyclic prefix, Frequency transformation (FFT), Demodulation and Decoder. Input signal of OFDM System is transmitted into source encoder to convert the any type's information into digital information. Channel encoder and decoder produce the mechanism of adding parity bits (extra bits) and removing the parity bits respectively. This will helps to proper communication. Multi-carrier transmission scheme is exploited in modulation part of OFDM System, in which single higher rate data stream is divided into many lower rate data streams. Each lower rate data streams are shifted into Frequency Transformation (IFFT) block to convert the frequency domain of signal into time domain signal. At the same time, FFT is used in receiver side to convert the time domain signal into frequency domain signal. Cyclic prefix and Remove Cyclic Prefix are the process of adding and removing some more additional bits respectively in between channel. This process is used to remove the noise or distorted signal in transmission of information.

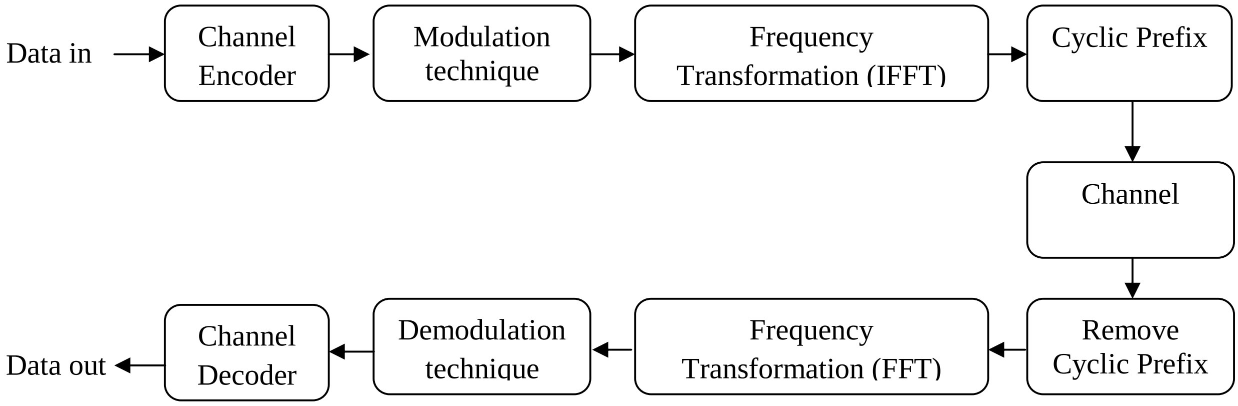

Figure 1: Block diagram of transmitter and receiver structure of OFDM System

3. QPSK MODULATION

Quadrature Phase Shift Keying (QPSK) modulation is a type of digital modulation coming under Phase Shift Keying (PSK) modulation. In Binary Phase Shift Keying (BPSK) modulation, phase of information signal can be changes every steps based on a single bit digital signal. But, in case of QPSK modulation, two bits (called as debits) are to be considered to change the phase of information signal. QPSK modulation is bandwidth efficient, because each signal point represented as two bits. Hence, reconstruction of original signal using QPSK demodulation is also provides more accuracy than BPSK modulation. The block diagram of QPSK modulation is illustrated in fig. 2. Based on debits, the frequency of inputs can be divided into two parts known as in phase and Quadrature phase represented in fig. 2 as I Channel and Q Channel respectively. The constellation diagram for QPSK modulation is illustrated in fig. 3. It has four common debits like 00, 01, 10 and 11 to modulate the digital input. However, one of the most disadvantages of QPSK modulation is delay consumption. QPSK modulation has been consumed more delay to perform the modulation. Instead it consumes less hardware complexity and lower power consumption than Quadrature Amplitude Modulation (QAM).

4. QAM MODULATION

Digital amplitude modulation is an alternative principle to digital phase modulation. In digital phase modulation, amplitude of signals kept no changes and varies the phase of the signals in every step. But, in case of Quadrature Amplitude Modulation (QAM), both amplitude and phase of the signals varies based on input bits. In QPSK modulation, two bits (debits) are to be considered to perform modulation. But, in case of QAM modulation four bits are to be considered to perform modulation. Like QPSK modulation, QAM modulation also has in phase and Quadrature channel. The advantage of using QAM is that able to carry more bits of information per symbol. The block diagram of QAM is similar to fig. 2, but difference is the input bits are four in case of QAM modulation whereas input bits of QPSK is two. Hence, QAM modulation is bandwidth efficient than QPSK modulation. The constellation diagram of QAM modulation is illustrated in fig. 4.

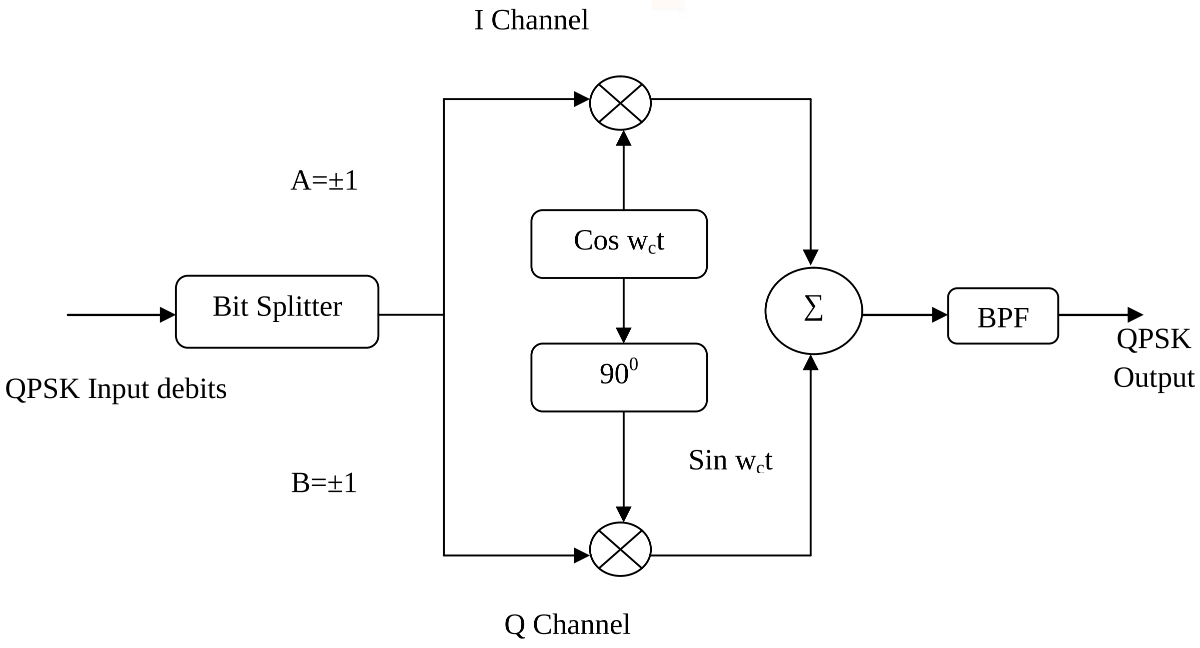

Figure 2: Block diagram of QPSK modulation

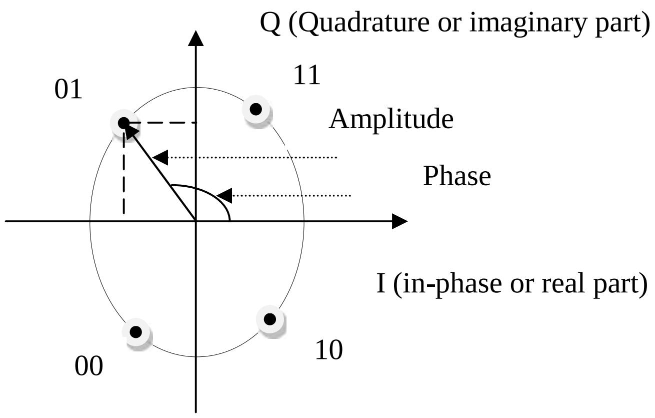

Figure 3: Constellation diagram of QPSK modulation

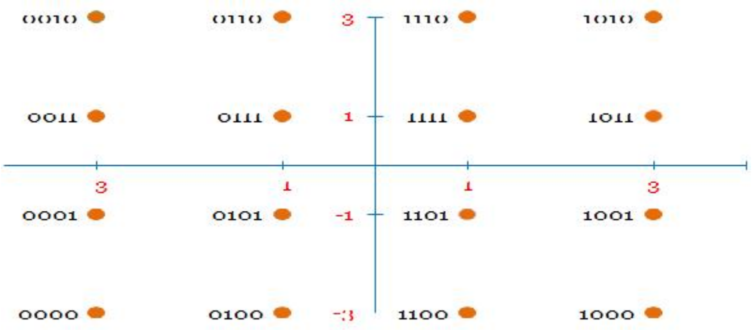

Figure 4: Constellation diagram of QAM modulation

It has sixteen combinations of input bits shown in fig. 4 to modulate the digital input. Hence, it utilize more hardware complexity to design, but instead the speed of QAM modulation is high than QPSK modulation. In addition, accuracy of QAM modulation and demodulation is high than QAM modulation due to considering four bits for each input (more combination of input data). Demodulation of QAM gives high level of interpolation than QPSK modulation.

5. PROPOSED MODEL OF ADAPTIVE MODULATION AND ADAPTIVE OFDM

Both QPSK and QAM modulation techniques provide different types of advantages in terms of silicon chip size requirement, delay and power consumption. With the help of those different advantages, we design the adaptive modulation model, which helps in different types of applications like infra-structure less network, Mobile Tele-communication networking System and Mobile Ad-hoc Network (MANET). The structure of adaptive modulation and adaptive de-modulation model is illustrated in fig. 5 and fig. 6 respectively. It consists of both types of modulation and demodulation techniques such as QPSK modulation, QAM modulation, QPSK demodulation and QAM demodulation.

Control logic of proposed adaptive modulation is length of input data values. Based on this control signals, different types of modulation such as QPSK and QAM modulations are adaptively selected. For instance, if input data is in two bits, QPSK modulation is adaptively selected for lower power consumption applications. Similarly, if the length of input data is four bits, QAM modulation is adaptively selected for high speed applications.

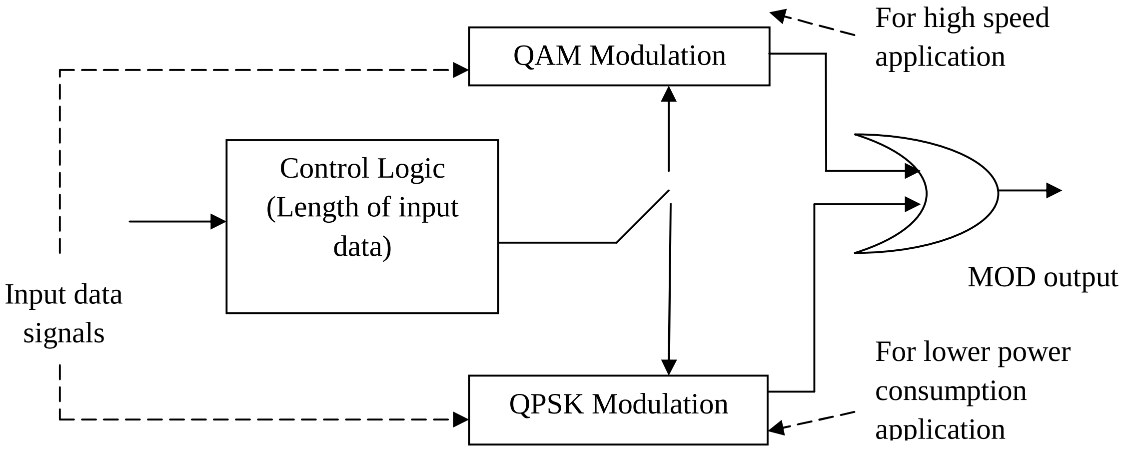

Figure 5: Adaptive Modulation Model for OFDM System

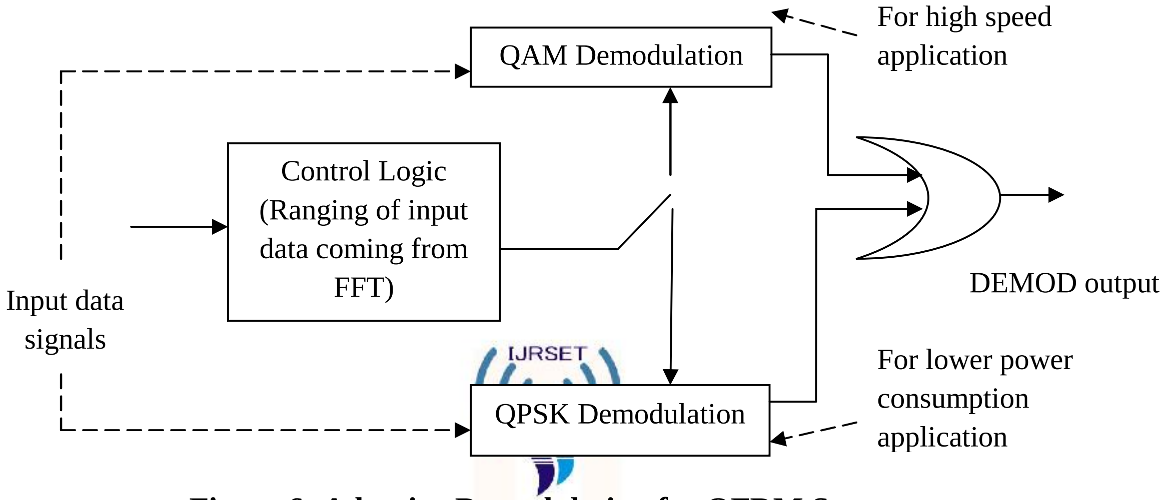

Figure 6: Adaptive Demodulation for OFDM System

As in case of adaptive demodulation, ranging of FFT outputs are to be considered as control signals. Based on this control signals, different types of demodulation such as QPSK and QAM demodulations are adaptively selected. For instance, if output of FFT is in ranging from 2D00to D2FF, QPSK demodulation is adaptively selected for lower power consumption applications. For any other selective ranges, QAM demodulation is adaptively selected for high speed applications. In addition to adaptive modulation and adaptive demodulation, other adaptive techniques like adaptive FFT, adaptive encoder and adaptive decoder models are incorporated into OFDM System. When incorporating this all adaptive techniques into OFDM System, Slices can be increased due to handling different types of modulations, encoders, decoders and frequency transformation techniques. But the advantage of proposed System is fulfilling the different types of applications requirement (lower power consumption and high speed). Transmitter and receiver part of adaptive OFDM is shown in fig. 7. For high speed application, QAM modulation is activated to modulate the input with multiple carrier signals. In addition, Hamming encoder block can be selected based on low SNR values of modulation technique. For lower power applications, QPSK modulation is activated to modulate the input with multiple carrier signals. In addition, Convolutional encoder block can be selected based on high SNR values of modulation process.

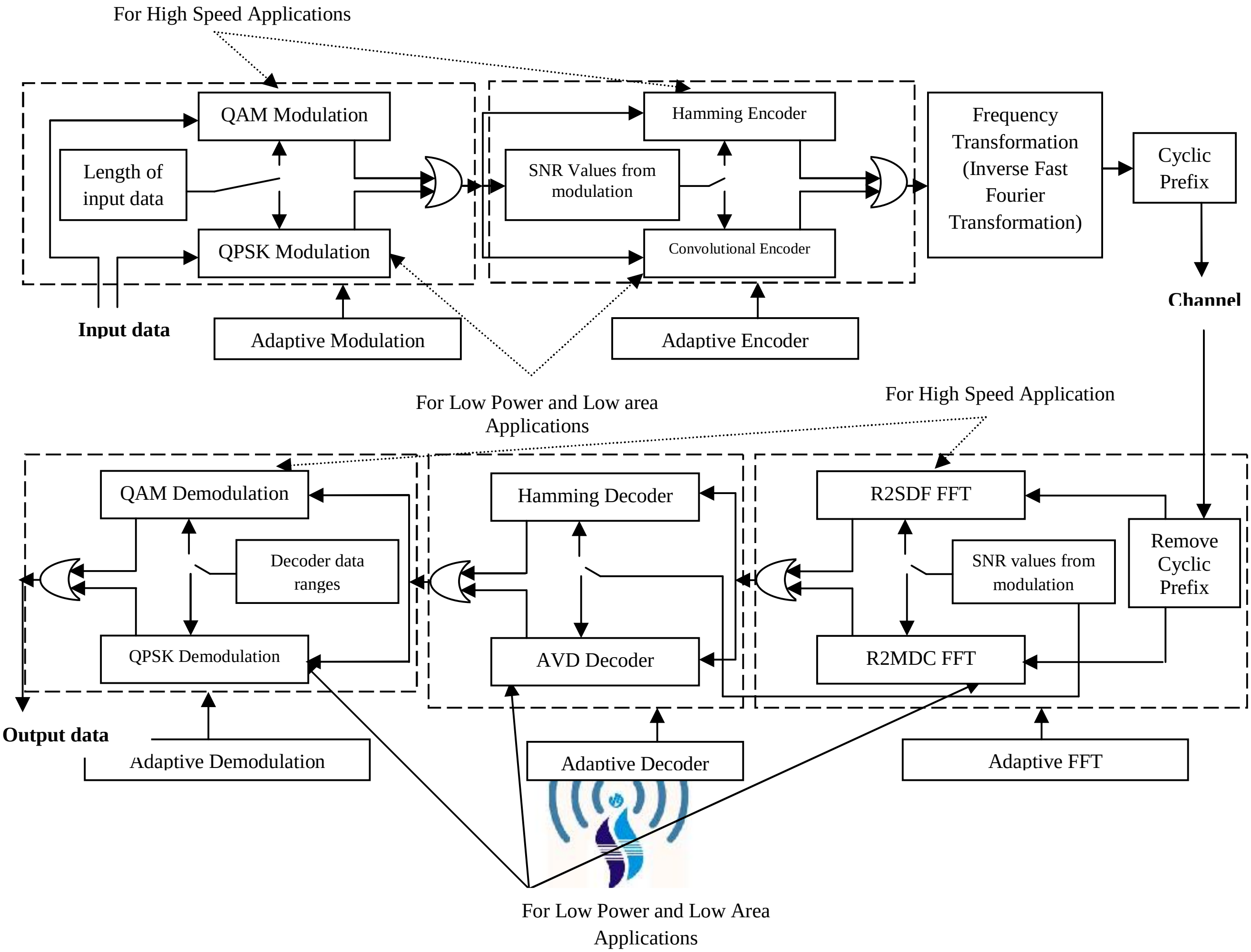

Figure 7: Transmitter and Receiver part of Adaptive OFDM System

Receiver part of OFDM also has adaptive technique such as adaptive FFT model, adaptive decoder and adaptive demodulation System. For high speed application, Radix-2 Single-path Delay Feedback (R2SDF) FFT, Hamming decoder and QAM demodulation are selected adaptively based on SNR values of modulation signal. Similarly, for low area and lower power consumption application, Radi-2 Multi-path Delay Commutator (R2MDC) FFT, Adaptive Viterbi Decoder (AVD) and QPSK demodulation are selected adaptively.

6. RESULTS AND DISCUSSION

The Results of proposed adaptive modulation, adaptive demodulation and adaptive OFDM are validated by using ModelSim 6.3C and synthesis results for QAM modulation and demodulation as well as QPSK modulation and demodulation are evaluated by using Xilinx 12.4i design tool. The simulation results of adaptive modulation and adaptive demodulation for high speed requirement is illustrated in fig. 8 and fig. 9 respectively. 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. These combinations are shown in fig. 8 and fig. 9 respectively in hexadecimal format. Similarly, the simulation results of adaptive modulation and adaptive demodulation for lower power consumption requirement is illustrated in fig. 10 and fig. 11 respectively. In QPSK modulation, only two bits are required to modulate the digital input. Hence, four combinations of phase angles are exhibited to get the modulation output. These combinations are shown in fig. 10 and fig. 11 respectively in hexadecimal format.

Figure 8: Simulation result of adaptive modulation for high speed requirement

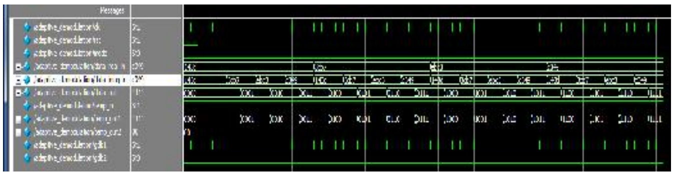

Figure 9: Simulation result of adaptive demodulation for high speed requirement

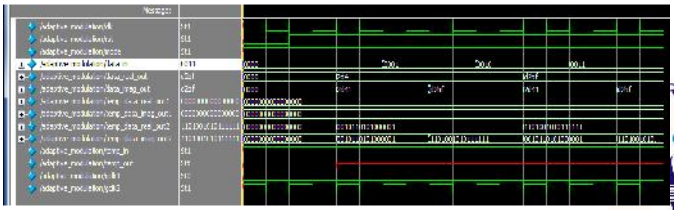

Figure 10: Simulation result of adaptive modulation for lower power consumption requirement

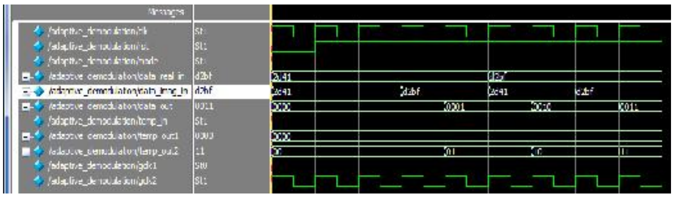

Figure 11: Simulation result of adaptive demodulation for lower power consumption requirement

In addition to adaptive modulation and adaptive demodulation, adaptive OFDM has been designed in this work with the help of adaptive encoder, adaptive decoder and adaptive frequency transformation techniques. Fig. 12 and fig. 13 illustrates the adaptive encoder and adaptive decoder model for high speed requirement OFDM applications respectively. Similarly, fig. 14 and fig. 15 illustrates the adaptive encoder and adaptive decoder model for low power requirement OFDM applications respectively.

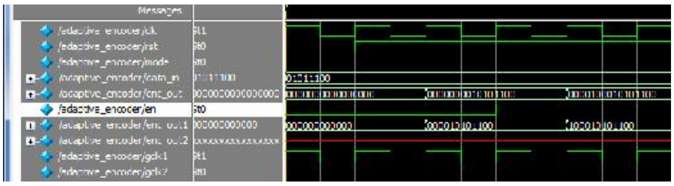

Figure 12: Simulation result of adaptive encoder for high speed requirement

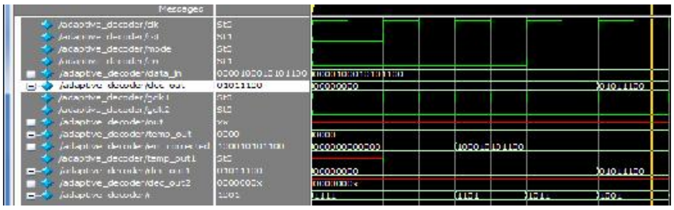

Figure 13: Simulation result of adaptive decoder for high speed requirement

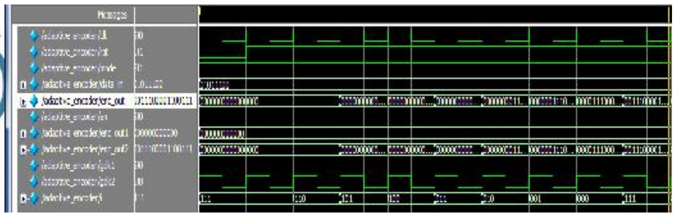

Figure 14: Simulation result of adaptive encoder for low power requirement

Figure 15: Simulation result of adaptive decoder for low power requirement

Similarly, simulation results for adaptive FFT for both high speed and low power requirement application is illustrated in fig. 16 and fig. 17 respectively. Synthesis results for proposed adaptive demodulation is evaluated and compared in table 1.

Figure 16: Simulation result of adaptive FFT for high speed requirement

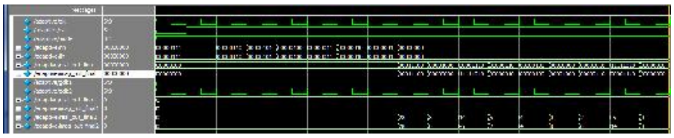

Figure 17: Simulation result of adaptive FFT for low power requirement

Type	Slices	LUT	Delay(ns)	Power(mW)	Application
QAM Demodulation	19	35	6.141	242	**High Speed Application**
QPSK Demodulation	12	22	6.216	197	**Low Power and Low area Application**

Table 1: Comparison of QAM and QPSK demodulation

Table 1 illustrates the performance of both QAM and QPSK demodulation. In QPSK demodulation, time required to perform the demodulation process is 6.216ns which is reduced to 6.141ns in case of QAM demodulation. Hence, QAM modulation and demodulation is absolutely suitable for high speed application. In QAM modulation, Slices and LUTs are required to design is 19 and 35 which are respectively reduced to 12 and 22 in case of QPSK demodulation. Hence, QPSK modulation and demodulation is absolutely suitable for low area and lower power consumption applications.

CONCLUSION

In this paper, adaptive modulation and adaptive demodulation are designed by using Verilog Hardware Description Language (Verilog HDL) for OFDM application. In addition to adaptive modulation and adaptive demodulation, adaptive OFDM is designed in this paper with the help of other adaptive techniques such as adaptive encoder, adaptive decoder and adaptive frequency transformation (adaptive Fast Fourier Transformation). QAM and QPSK modulation techniques are involved in proposed adaptive modulation and adaptive demodulation model to adaptively select the types of modulation based on high speed and lower power consumption requirement. QAM demodulation offers 7.5 % reduction in delay when compared to the QPSK demodulation. Hence, QAM modulation and demodulation technique is the best solution for high speed requirement. QPSK demodulation offers 36.84% reduction of Slices and 37.14% reduction of LUTs when compared to QAM demodulation. Hence, QPSK modulation and demodulation technique is the best solution for lower power consumption requirement application. Finally, all adaptation techniques of OFDM like modulation, decoder and FFT are incorporated into OFDM System to exhibit the adaptive OFDM technique. Simulations of adaptive OFDM with different types of modulations, encoders, decoders and frequency transformation techniques are analyzed in VLSI System design environment.

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