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FPGA IMPLEMENTATION OF DIGITAL MODULATION TECHNIQUES

(8-PSK and 16-PSK)

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Abstract— **This paper presents the review of the different digital modulation techniques and the various methods that are used to implement 8-PSK and 16-PSK on FPGA. Modern communication system makes use of the digital communication techniques mainly because of the development in the field of VLSI and DSP. Digital modulation is more secure and more efficient in long-distance transmission and noise detection and correction than its analog counterpart, it has an important place in modern communications.**

It includes an approach for the implementation of modulators 8-PSK and 16-PSK. The same modulators has been developed in MATLAB/SIMULINK environment with the help of XILINX system generator. Here it is focusing the constellation diagrams of these modulation techniques.

Index Terms*—*PSK, FPGA, system generator.

I. Introduction

Wireless communications is one of the most active areas of technology development of our time and has become an ever-more important and prominent part of everyday life. It is more cost effective and has Advantages like noise immunity, resistivity to the impairments of channels, error detection and correction, encryption, multiplexing of video, sound and data, security, source coding, equalization. The particular digital modulation techniques should provide low signal to noise ratio, low bit rate, occupy a minimum bandwidth, cost effective and easy to implement.

Modulation, by which data is transmitted by varying low-powered radio waves, plays a key role in wireless communication systems. The goal of a modulation technique is to provide high speed data transmission with good quality in the presence of mobile channel impairments while occupying minimum bandwidth and requiring the least amount of signal power.

II. FPGA IMPLEMENTATION OF DIGITAL TECHNIQUES

The FPGA and VHDL combination is a prevailing tool for realizing sophisticated systems and cost effective design schemes.

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FPGA is chosen to realize digital modulation techniques Traditionally gate arrays contained a number of building blocks or primitive cell. The FPGA is similar in structure to gate arrays the difference is that they have programmable elements. In case of Altera device the programmable cell is called Logic Element (LE) and in Xilinx devices it is Configurable Logic Block (CLB). VHDL and Verilog HDL are the hardware description language, which is a common language for designers. This is the high level language and simulation, synthesis tools are available. It allows adaptable reconfiguration and multiple level of abstraction. There has been lot of research on the use of reconfigurable computing based on Field Programmable Gate Arrays (FPGAs).

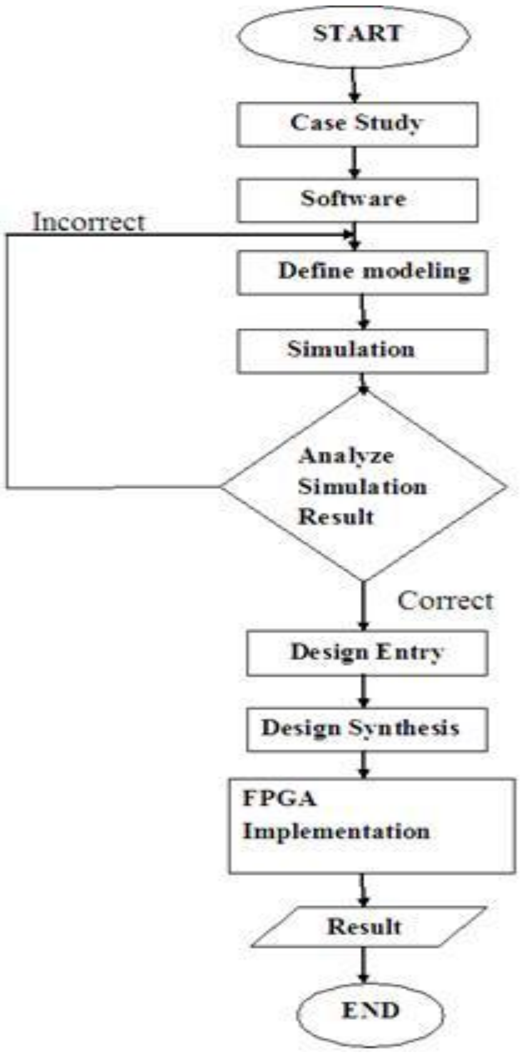

Fig1. Design implementation with FPGA.

Due to its reconfigurable ability and high throughput performance, Field Programmable Gate Array (FPGA) is widely used in embedded applications such as automotive, communication, industrial automation, motor control, and medical imaging.

The reported in this thesis evaluates the study of digital modulation techniques. Design and analyze in the MATLAB and Simulink environment using Xilinx system generator.

III. DIGITAL MODULATION

The move to digital modulation provides more information capacity, compatibility with digital data services, higher data security, better quality communications, and quicker system availability. Developers of communications systems face these constraints - -

- Available bandwidth
- Permissible power
- Inherent noise level of the system

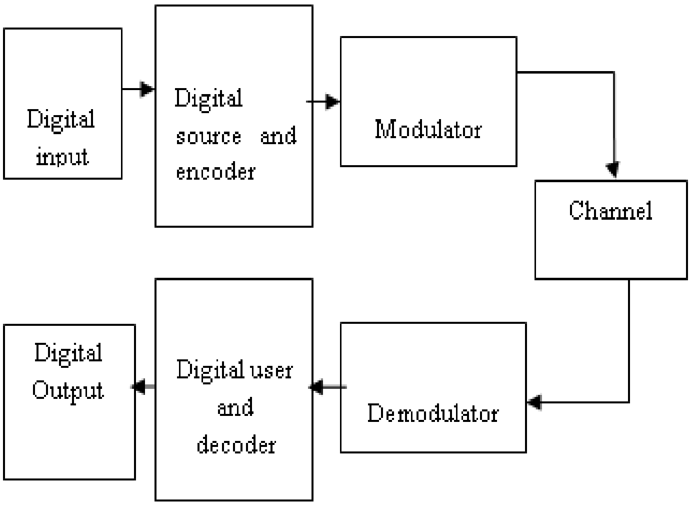

Fig2. Digital modulation system.

In electronics and telecommunications, **modulation** is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted.

In telecommunications, modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform transforms a baseband message signal into a passband signal.

A **modulator** is a device that performs modulation. A **demodulator** (sometimes detector or demod) is a device that performs demodulation, the inverse of modulation. A modem (from **mo**dulator–**dem**odulator) can perform both operations.

The aim of **analog modulation** is to transfer an analog baseband (or lowpass) signal, for example an audio signal or TV signal, over an analog bandpass channel at a different frequency, for example over a limited radio frequency band or a cable TV network channel.

The aim of **digital modulation** is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network (where a bandpass filter limits the frequency range to 300–3400 Hz) or over a limited radio frequency band.

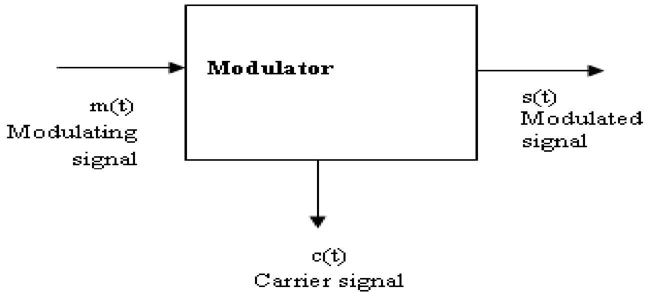

Fig3. Modulation process of signal.

Modulation Techniques can be broadly classified as follows:

1. Digital and Analog Modulation
2. Baseband and Bandpass (Passband) Modulation
3. Binary and M-ary Modulation
4. Memoryless Modulation and Modulation with memory
5. Linear and Nonlinear Modulation
6. Constant envelope and Non-constant envelope Modulation
7. Power efficient and Bandwidth efficient Modulation

IV. DIGITAL MODULATION TECHNIQUES

The most fundamental digital modulation techniques are based on keying:

- PSK (phase-shift keying): a finite number of phases are used.
- FSK (frequency-shift keying): a finite number of frequencies are used.
- ASK (amplitude-shift keying): a finite number of amplitudes are used.
- QAM (quadrature amplitude modulation): a finite number of at least two phases and at least two amplitudes are used.

The RF spectrum must be shared, yet every day there are more users for that spectrum as demand for communications services increases. Digital modulation schemes have greater capacity to convey large amounts of information than analog modulation schemes.

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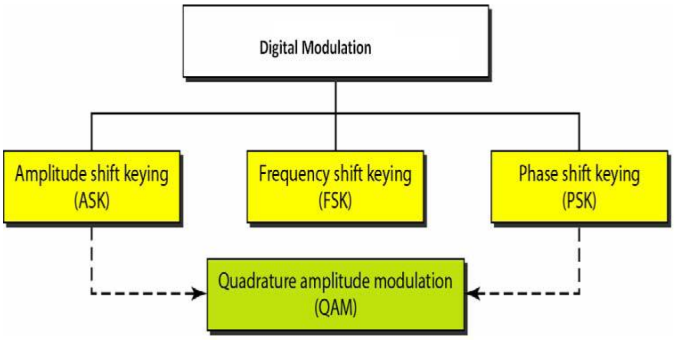

Fig4. Digital modulation techniques.

In the case of PSK, ASK or QAM, where the carrier frequency of the modulated signal is constant, the modulation alphabet is often conveniently represented on a constellation diagram, showing the amplitude of the I signal at the x-axis, and the amplitude of the Q signal at the y-axis, for each symbol.

I/Q Format:

Modulation in digital communication is depicted in terms of in-phase (I) and quadrature (Q) components. It maps data to a number of points in I/Q plane. These points are known as constellation points and are represented as (I, Q). In I/Q modulation it is simple to combine individual signal components into single mixed signal and can be easily separated into independent signal components.

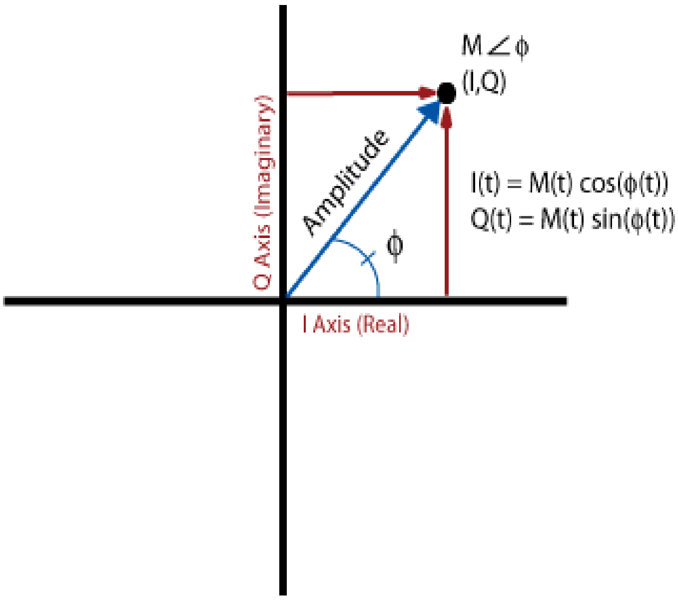

Fig5. I,Q format for constellation.

Figure shows rectangular form of polar diagram. I axis is along zero degree phase, i.e., in-phase and Q axis is along 90 degrees apart from zero degree phase, i.e., quadrature. Signal vector projections onto I-axis and Q-axis gives I and Q values and they represent the amplitudes of I and Q signals respectively. Angle made by the signal vector with I-axis is considered as phase (Φ) of the signal and its magnitude is represented as distance from the center.

In this paper aim is to implement only PSK techniques so all PSK techniques are discussed :

Phase shift keying (PSK):

Phase shift keying modulation technique transmits data by varying the phase of the carrier signal. It uses finite number of phases each assigned by unique pattern of binary digits to represent digital data. PSK schemes are simply represented on constellation diagram with points in complex plane. The real and imaginary axes correspond to in-phase and quadrature respectively. As the data to be conveyed is binary the number of constellation points being power of 2. In this way PSK can be expanded to M-ary type, employing multiple phases and amplitudes as different states.

Binary Phase shift keying (BPSK):

The simplest form of PSK is binary phase shift keying (BPSK), where N=1 and M = 2 where N represent number of bits and M represent number of levels. Therefore with BPSK, two phases (21 = 2) are possible for the carrier. One phase represents a logic 1, and the other phase represents a logic 0. As the input digital signal changes the state (i.e., from a1 to a 0 0r from a 0 to a 1), the phase of the output carrier shifts between two angles that are separated by 180°. Hence , other names for BPSK are phase reversal keying (PRK) and biphase modulation.

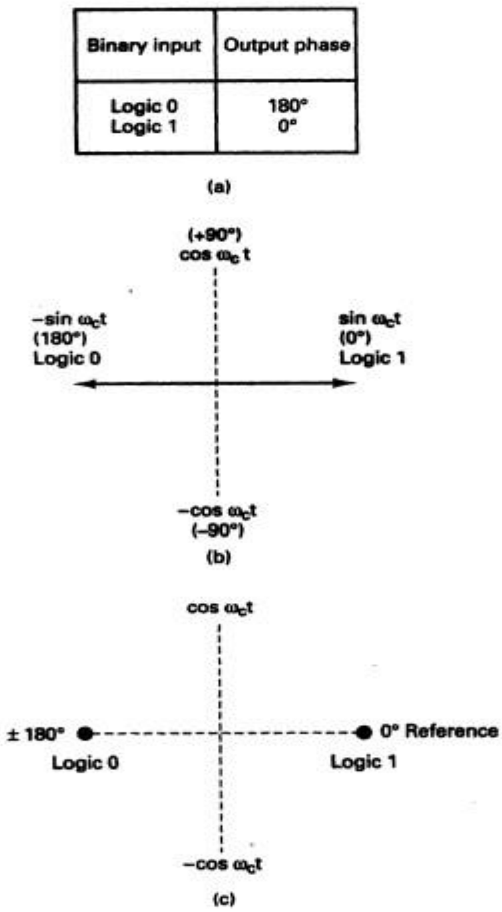

Fig6. BPSK modulator: (a) truth table (b) phasor diagram (c) constellation diagram.

Quadrature Phase shift keying (QPSK):

It is another form of angle-modulated, constant amplitude digital modulation. QPSK is an M-ary encoding scheme where N = 2 and M = 4. With QPSK four output phases are possible for a single carrier frequency. Because there are four output phases there must be four different input conditions. Because the digital to a QPSK modulator is binary signal to produce four different input combination, the modulator require more than a single input bit to determine the output condition. With two bits there are four possible conditions: 00, 01, 11, 10. Therefore with QPSK binary input data are combined into a group of bits called dibits. In the modulator each dibit code generate one of the four possible output phases (+45°, +135°, -45°, -135°).

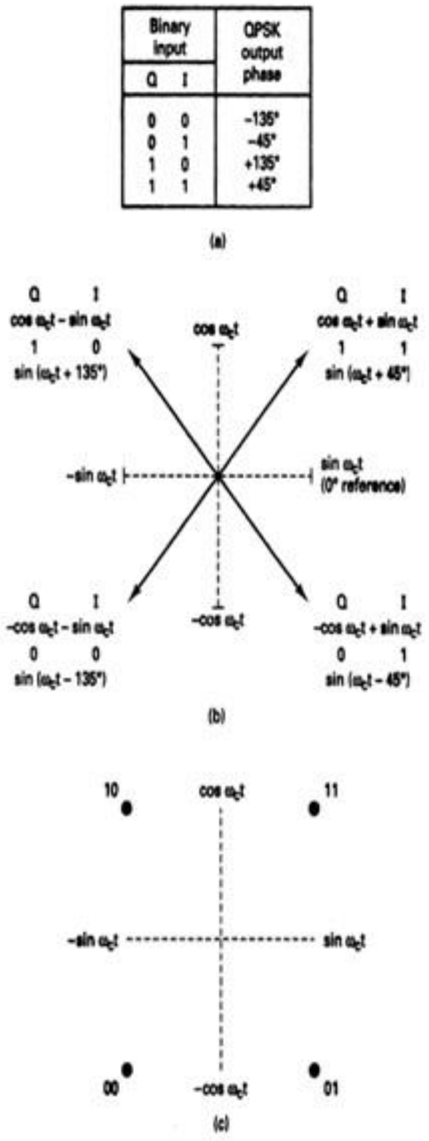

Fig7. QPSK modulator: (a) truth table (b) phasor diagram (c) constellation diagram.

8 - Phase shift keying (8-PSK):

With 8-PSK, three bits are encoded, forming tribits and producing 8 different output phases. In 8-PSK N = 3, M = 8, and are eight possible output phases. To encode the eight different phases, the incoming bits are encoded in group of three, called tribits ($2^3 = 8$).

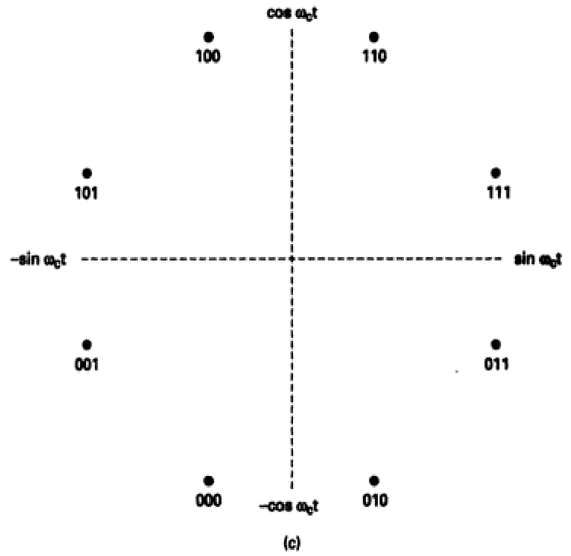

Fig7. Constellation diagram of 8-PSK.

16 - Phase shift keying (16-PSK):

16-PSK is an M-ary encoding technique where M = 16; there are 16 different Output phases are possible. With 16-PSK, four Bits are combined, producing 16 different output phases. With 16-PSK, N = 4 and M = 16; therefore minimum bandwidth and baud equal one- fourth the bit rate. With 16-PSK, the angular separation between the adjacent output phases is only 22.5°.

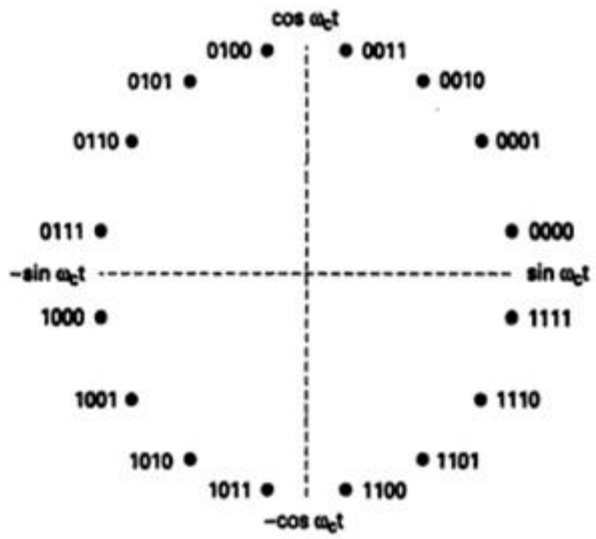

Fig8. Constellation diagram of 16-PSK.

V. WORK DONE PREVIOUSLY

Y. H. Chye1, M. F. Ain2, Norzihan M. Zawawi [12], designed and implemented BPSK transmitter using field programmable gate array (FPGA) for digital signal processing (DSP), and expansion P240 Analog Module for digital-to-analog (D/A) conversion. Thesoftware defined radio (SDR) provides a reconfigurable, high performance, and efficient platform to integrate all these individual functions of BPSK transmitter, which is different from the sophisticated implementation of binary phase shift keying (BPSK) transmitter where application specific integrated circuit (ASIC), mixer, and local oscillator (LO) for carrier signal were used. The period of carrier sinusoidal signal was designed as one cycle per bit for 5 Mbps input bit. The DSP-based BPSK transmitter was developed and compiled to Verilog HDL (Hardware Description Language) netlist. D/A converter (DAC) was interfaced with FPGA using a HDL module of configurations of P240 Analog Module and the HDL netlist is integrated with clock synthesizer of BPSK transmitter. The integrated design is implemented into Xilinx Virtex-4 FPGA MB development board with DAC.

Kangshun Li , Xiaoqiao Lu1, Wensheng Zhang, Feng Wang [13], proposed the design model of digital modulator by using the improved Direct Digital Synthesizer (DDS) technology through running the Matlab/DSP Builder environment. Using the improved DDS technology, helps in overcoming the shortcomings of the traditional method and also reduce a lot of errors and save a lot of hardware resources, which was further implemented and simulated in VHDL and Modelsim respectively. The correctness and validity of the model was verified in Field Programmable Gate Array (FPGA) chip.

C. Erdoğan, I. Myderrizi, and S. Minaei,[14], presented a Fieldprogrammable gate-array (FPGA) implementations of binary amplitude-shift keying (BASK), binary frequency shift keying (BFSK), and binary phase-shift keying (BPSK) digital modulators for educational purposes in a digital communication course. This architecture makes use of minimum number of blocks. And was compatible with the existing Altera Development and Education (DE2) FPGA board. The input carrier and the modulating signals are controllable for the frequencies of the signal. The digital modulators were designed in Verilog Hardware Description Language (HDL) netlist, and were later implemented into an Altera DE2 FPGA board.and was simulated using the Quartus II simulation software.

S.O. Popescu, A.S.Gontean and G.Budur also have purposed a BPSK system design which in terms of signal power the BPSK modulation and demodulation represents an important modulation technique. The BPSK system was simulated using Matlab/ Simulink environment and System Generator, a tool from Xilinx for FPGA design also it was implemented on two Spartan 3E Starter Kit boards one for the modulator other fo the demodulator.

Miss Faiza Quadri, Prof.ArunaD.Tete,[15] Modulated the output for ASK,PSK and FSK developed in Xilinx 13.1 and simulated using Modelsim by means of MATLAB/SIMULINK environment or system generator, and then it can be converted into VHDL or Verilog for the synthesis and ultimately implemented in FPGA.

VI. CONCLUSION

FPGA design is flexible to build digital communication systems. They provide a rapid prototyping platform, which can be reprogrammed for different hardware functions without incurring the non-recurring engineering costs typically associated with custom IC fabrication. The methods used for modulation can be reconfigurable which means that new designs can be implemented by simply downloading to the board. In this project 8-PSK and 16-PSK modulation schemes has been successfully designed in Xilinx system generator.

Digital Modulation provides more information capacity, compatibility with digital data services, higher data security, better quality communications, and quicker system availability.

Digital modulation schemes have greater capacity to convey large amounts of information than analog modulation schemes.

VII. REFERENCES

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