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A Review on Implementation of QAM on FPGA

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ABSTRACT: Quadrature Amplitude Modulation (QAM) is used in both analog and digital communication. In this technique, both amplitude and phase varies of carrier wave with respect to digital data or information. It provides high data rate for transmission. QAM is used in many application like color television, Wi-Max, OFDM (Orthogonal Frequency Division Multiplexing), and in digital satellite communication system. FPGAs (Field Programmable Gate Arrays) provide magnificent platform for implementation of many type of algorithms. The FPGA technology has been playing a vital role in portable and mobile communication due to the feature of configurability in designing and Implementation. This paper represents the review of implementation and optimization techniques of QAM on different FPGA development boards.

KEYWORDS: ASK, FSK, PSK, QAM, FPGA.

I. Introduction

Digital communication is widely used today. The development of digital communications requires not only high performance of hardware systems but also flexibility in design and implementation. FPGAs provide flexibility for implementing different communication techniques. In addition, area and power optimization can also be done by using HDL (Hardware Description Language). System-level design which has being developed recently, such as System Generator, makes design tasks much easier than it has ever been before. Designers can easily test algorithms, perform the whole system or modify and update diagram shortly [1, 2]. For this reason, system level design is playing a considerable role in implementing and optimizing.

Quadrature amplitude modulation (QAM) technique is a widely used modulation scheme for digital communication because of its high bandwidth efficiency [4]. Re-configurability of FPGA provides better performance in satellite communication.

II. Related work

Xuan-Thang Vu, Nguyen Anh Duc and Trinh Anh Vu (2010) proposed design for a 16-QAM transmitter and receiver based on the Virtex4 FPGA Kit [1]. They focused on carrier synchronization, time synchronization, and adaptive equalization. They designed a complete baseband IF 16-QAM system, in which the baseband signal is up-converted into IF frequency (up to 12MHz) at the transmitter and then is down-converted at the receiver. They implemented modulator and the demodulator in the two separated Kits. Both carrier synchronization and symbol synchronization were taken into account in their model using Coordinated Rotation Digital Computer (CORDIC) and Least Mean Square (LMS) algorithm.

Raghunandan Swain & Ajit Kumar Panda (2012) described 16-QAM model based on System Generator. They used two random integer generators for data source [2]. For up-conversion and filtering purpose they used MAC filter of 32-tap.Propsed system generator based model was contain many blocks. For simulation purpose, Simulink was used. They used Spartan 6 FPGA kit for implementation.

Faeza Abbas Abed (2013) proposed the design of 16-QAM transmitter for software defined radio (SDR) technology [3]. SDR is a multifunctional, programmable, and easy to upgrade radio that can support a variety of services and

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standards while at the same time provide a low-cost power-efficient solution. The SDR architecture is a flexible, versatile architecture that utilizes general-purpose hardware that can be programmed or configured in software. The advantage of SDR over traditional radio is its adaptability to its environment and the number of application that it can support. He designed it using MATLAB/SIMULINK and tested for 70MHz.

Arun Kumar K. A. (2013) described the design and implementation of 4/8/16/32/64 Quadrature Amplitude Modulation (QAM) and demodulation in FPGA using Partial Re-configuration [4]. Partial reconfiguration is a technique or the ability of a reconfigurable hardware to modify logic blocks dynamically without interrupting the system by downloading smaller bit files. Control register was introduced to switch between different QAM modulations. Virtex 6 was used to implement modem. In this paper, power optimization in implementation is not achieved.

III. MODULATION TECHNIQUES

Modulation is the process in which a property of one the carrier signal is varied in proportion to the message or information signal. Modulation is performed at the transmitter and demodulation at the receiver. There are different modulation techniques:

A. *Amplitude Shift Keying (ASK):*

Amplitude-shift keying (ASK) is a amplitude modulation in which digital data represented as variations in the amplitude of a carrier wave. In an ASK system, the binary symbol 1 is represented by transmitting a fixed-amplitude carrier wave and fixed frequency for a bit duration of T seconds. If the signal value is 1 then the carrier signal will be transmitted; otherwise, a signal value of 0 will be transmitted.

B. *Frequency Shift Keying (FSK):*

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through frequency changes of a carrier wave. The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary information.

C. *Phase Shift Keying (PSK):*

Phase-shift keying (PSK) is a digital modulation scheme that conveys digital information by changing the phase of the carrier wave. Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases; each assigned a unique pattern of binary digits. For example, 00 is assigned to 0^o, 01 to 90^o, 10 to 180^o, and 11 to 270^o. Figure 1 shows comparison between different keying techniques.

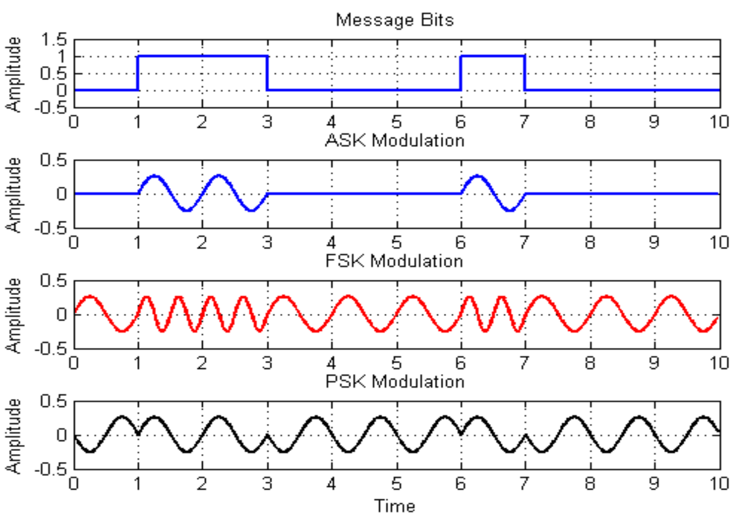

Fig. 1. Modulated signal waveforms of ASK, FSK and PSK [7].

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IV. QAM

QAM is a modulation technique which uses both amplitude and phase modulation to transmit the information data. If we want to transmit a symbol consisting of N bits that means 2^N = M different possible symbols. For example, if N = 2 then M = 4 and N = 4 then M = 16. The commonly used QAMs are 4-QAM, 8-QAM, 16-QAM, 32- QAM, and 64-QAM.

A. *QAM Modulator:*

QAM modulator block diagram is shown in figure 2. The mapping circuit decomposes input bit stream into In-phase (I) and Quadrature (Q) components according to the constellation assignment. Up-sampling produces the sequence that would have been obtained by sampling the signal at a higher rate. Square Root Raise Cosine (SRRC) filter is generally pulse-shaping filter in modulator which reduces Inter Symbol Interference (ISI). After multiplied by carrier signal, both in-phase and quadrature signals are combined at adder circuit to transmit over channel.

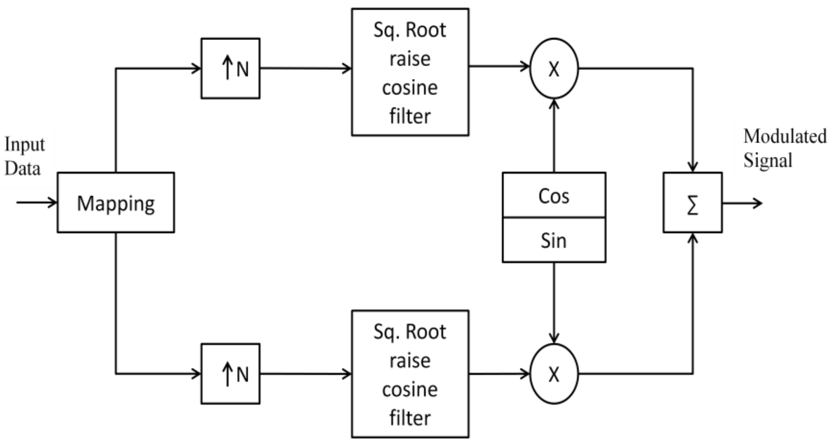

Fig. 2. Block diagram of QAM Modulator

Figure 3 shows the constellation diagram of 16, 32, 64 QAM respectively. As the number of symbols increases in constellation diagram, recovering of original information becomes complex and error probability increases but data rate increases.

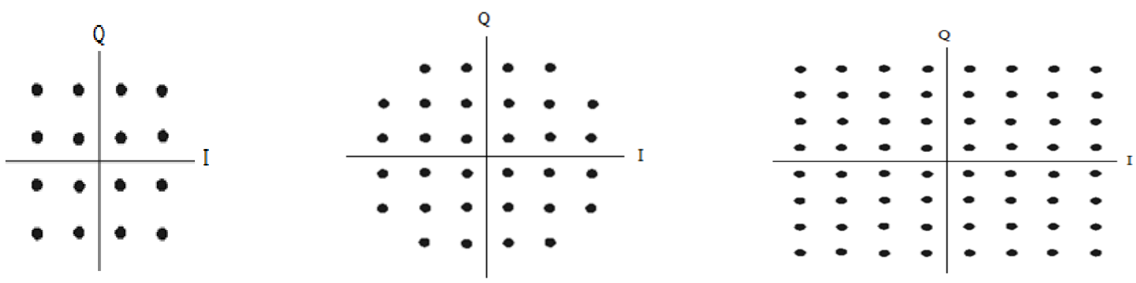

Fig. 3. Constellation diagrams of 16, 32, 64 QAM

The general form of a 16-QAM transmitted signal can be defined as:

$$S_i(t) = \sqrt{\frac{2E_{min}}{T_s}}\, a_i \cos 2\pi f_o(t) + \sqrt{\frac{2E_{min}}{T_s}}\, b_i \sin 2\pi f_o(t) \quad \ldots\ldots\ldots (1)$$

Where $0 < t < T_s$, i = 0,1,2,3…

Where E_{min} is the energy of the signal with the lowest amplitude, a_i and b_i are a pair of independent integers chosen according to the location of the particular signal point; f_o is the carrier frequency; T_s is the symbol period.

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B. *QAM Demodulator:*

QAM demodulator block diagram is shown in figure 4. A demodulation is an inverse process of modulation; it is used to recover the original information content from the modulated carrier wave. In demodulator matched filter is used. It is used to detect the transmitted pulses in the noisy received signal. Unlike the interleaving zeros between input samples, the matched filter cannot combine with the decimation factor because the Phase Locked Loop (PLL) requires all of its output for synchronization purpose. Phase Locked Loop is a key component in carrier and timing recovery. Phase detector, Loop filter and Numerically Controlled Oscillator (NCO) are elements of phase locked loop [6].

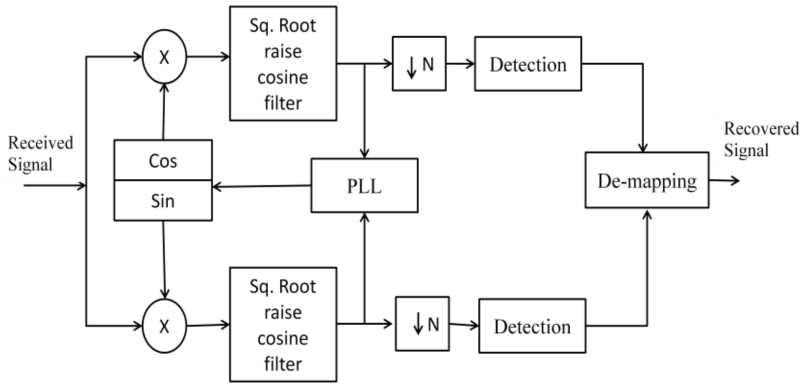

Fig. 4. Block diagram of QAM Demodulator

V. CONCLUSION

Here implementation and optimization of different modulation techniques are studied. A classification of modulation techniques is made in order to explain the different approaches presented in literature in the last years. For high data rate can be achieved by using QAM modulation. Still research needed to optimize area and power.

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