QAM MODULATION USING FPGA

Overview

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.

Significance of FPGA

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.

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)**.Quadrature amplitude modulation (QAM) technique is a widely used modulation scheme for digital communication

because of its **high bandwidth efficiency** . Re-configurability of FPGA provides better performance in satellite communication.

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.

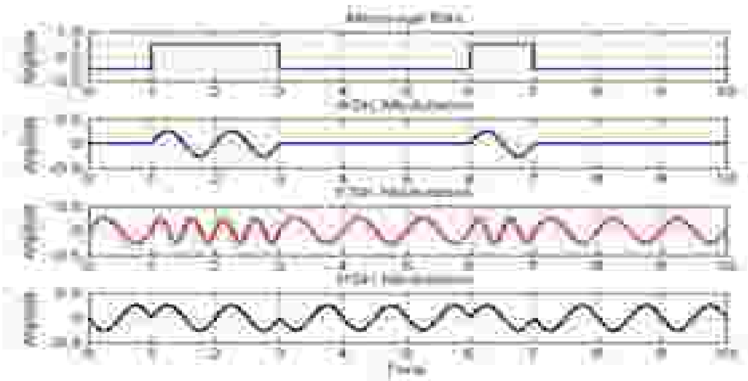


Fig. 1. Modulated signal waveforms of ASK, FSK and PSK [7]

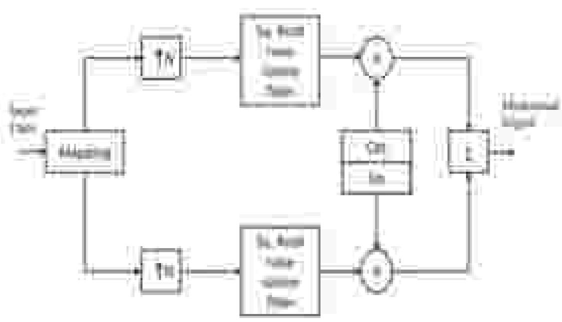
IV.QAM

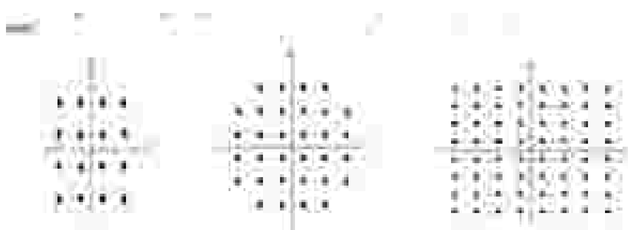
QAM is a modulation technique which uses both amplitude and phase modulation to transmit the information data.

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.

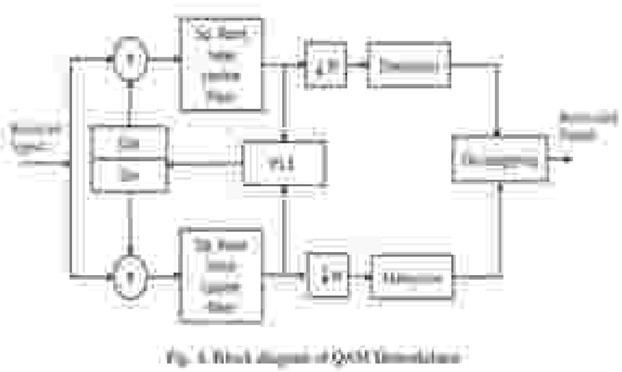




B. QAM Demodulator:

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 .

Fig. 4. Block diagram of QAM Demodulator



CONCLUSION

In this project, we successfully implemented QAM modulation using an FPGA, demonstrating its feasibility for high-speed digital communication. The FPGA efficiently handled the modulation process, ensuring real-time signal generation and transmission. The use of an FPGA with an inbuilt DAC enabled seamless conversion of digital signals into analog waveforms suitable for transmission.

This implementation highlights the advantages of FPGA-based QAM modulation, such as high processing speed, parallelism, and flexibility. The results confirm that FPGAs are well-suited for digital communication applications requiring high performance and adaptability.

Future improvements could include higher-order QAM implementations, error correction techniques, and adaptive modulation schemes to enhance performance and reliability. The project serves as a foundational step toward hardware-accelerated wireless communication systems, paving the way for further research and optimization.