FPGA IMPLEMENTATION OF QAM

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Abstract—Field programmable gate array (FPGA) implementation of Quadrature Amplitude Modulation (QAM) is presented. The system implements 8 point QAM. The system is suitable for realization of the digital baseband-modulation part of software-defined radio systems. In addition, this kind of implementation can be used for educational purposes. Quadrature Amplitude Modulation (QAM) is widely used due to its spectrum efficiency. The proposed system accepts input message signal from the external user. Xilinx ISE 14.6 for the Verilog code simulation and hardware implementation is done on Spartan 3 XC3S400 FPGA board using Xilinx ISE 14.6 and iMPACT (manage configuration project process) software. The real time output is viewed on a digital storage oscilloscope.

Keywords—FPGA, QAM, Verilog, Digital Modulator and Demodulator.

I. INTRODUCTION

High performance of hardware systems and flexibility in design and implementation are required for the development of mobile and portable communications. In such situation, silicon technology is one of the best choices which allow us to produce high execution, high integrated density and dedicated purpose integrated circuit(IC). At present FGPA's and ASIC's are playing a vital role in designing, simulating, testing and implementing the new communication techniques. Moreover system level design and implementation is possible due to tools like system generator which facilitates testing algorithms, modifying designs as per the requirement very easily. Compared to ASIC, FPGA has simpler development cycle, low initial cost and are more flexible. The development in the modulation techniques had been witnessed since last two decades which demands reliable transmission of information with higher data rate. Due to high noise immunity, digital modulation techniques have created an interest. Modulation scheme such as QAM is one of the widely used modulation techniques in cellular communication because of its high efficiency in power and bandwidth. 8-QAM (Quadrature Amplitude Modulation) is a kind of digital modulation scheme which transmits 3 bits per symbol on two orthogonal carriers; one in phase and the other one in quadrature phase. Hence the data rate is increased. The hardware behaviour of modulator was described using Verilog which is simpler than VHDL. Verilog has structured top-down approach which is independent of device and technology. It has fast switch level simulation and is portable between different tools and platforms. The IMPACT software was used to program the FPGA using parallel port in Boundary Scan mode. The QAM modulator in FPGA was fed with input from the function generator. The modulator output was viewed in a DSO by interfacing DAC and demodulator output was directly fed to DSO.

II. THEORY

2.1 Quadrature Amplitude Modulation

Quadrature amplitude modulation (QAM) is a modulation technique which is widely used due to its spectrum efficiency in many digital data radio communications and data communications applications. A various forms of QAM are available which includes 16 QAM, 32 QAM, 64 QAM, 128 QAM, and 256 QAM. The numerical refer to the number of points on the constellation, that is the number of distinct states that can exist. Figure below shows the constellation diagram of a 8 point QAM. In a 2n-QAM scheme, the 2n-constellation points represent a series of n bits each, usually distributed in a square lattice. The lowest order QAM, 2-QAM, encodes just 1 bit per symbol. The amplitude is constant and there’s a phase difference of p between the two constellation points that correspond to 1 and 0. So 2-QAM is really the same scheme as BPSK. Similarly, the concept of 4-QAM may be different than QPSK, but the resulting constellation diagram is the same. Here as well, we have only one amplitude and the phase of the four constellation points differs by p 2. In 8-QAM, there are two possible amplitudes and four phases differing by p 2 that define the constellation points representing a series of 3 bits each.

![Figure 1: Constellation diagram](image)
The modulation and demodulation of QAM signals are more complex and in turn more expensive. On the other hand, the constellation points of higher order QAM lie further apart than in pure PSK schemes like BPSK. This makes them less susceptible to noise and distortions, which results in a lower BER. Thus QAM increases the efficiency of transmission for radio communications systems by utilising both amplitude and phase variations. QAM is used in many radio communications and data delivery applications. However some specific variants of QAM are used in some specific applications and standards. For domestic broadcast applications for example, 64 QAM and 256 QAM are often used in digital cable television and cable modem applications. In the UK, 16 QAM and 64 QAM are currently used for digital terrestrial television using DVB - Digital Video Broadcasting. In the US, 64 QAM and 256 QAM are the mandated modulation schemes for digital cable as standardized by the SCTE in the standard ANSI/SCTE 07 2000. In addition to this, variants of QAM are used for many wireless and cellular technology applications.

2.2. Field Programmable Gate Array

Field Programmable Gate Arrays (FPGAs) are semiconductor devices that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. In addition to the configurable logic blocks and its interconnections, most FPGAs also provide an infrastructure, which consists of one or more clock generators, I/O ports, and embedded memory cells. In contrast to other devices, such as read only memories and application-specific integrated circuits (ASICs), an FPGA is always configured at start up time. To this end, an on-board configuration device reads a device configuration file and configures all its internal logic elements, routing resources and registers accordingly. Thus, an FPGA can provide a different functionality any time it is re-programmed with a different configuration file.

The design has the following two main purposes:(1) it has to functionally design the desired system and (2) it has to map the basic logical functions onto the FPGAs logic elements. FPGA vendors provide the designer with several tools such that the design can be done on various abstraction levels, which require different levels of expertise.

On the most abstract level, the designer is provided with graphical tools with which a system can be composed out of basic modules. This applies not only to choosing the components but to their actual configuration, e.g., the number of a module's internal registers as well as their width. Afterwards, these tools do the transformation into an appropriate, low-level hardware description language. It might be interesting to note that the usage of these design tools is easy and straightforward. On the lower abstraction level, the designer is using a hardware description language, such as VHDL or Verilog, which provides the designer with the most possible design flexibility. Even though these languages are in design and usage quite similar to the C programming language, they require significant in-depth knowledge and thus require significant training.

III. BLOCK DIAGRAM

QAM (quadrature amplitude modulation) is a method of combining two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. QAM is used with pulse amplitude modulation (PAM) in digital systems, especially in wireless applications. In a QAM signal, there are two carriers, each having the same frequency but differing in phase by 90 degrees (one quarter of a cycle, from which the term quadrature arises). One signal is called the I signal, and the other is called the Q signal. Mathematically, one of the signals can be represented by a sine wave, and the other by a cosine wave. The two modulated carriers are combined at the source for transmission. But in this system a different algorithm is used in which the different carriers are stored in LUT and are multiplexed to output according to the message signal.

3.1 QAM Modulator

The external input is the message signal for the QAM modulator provided from a function generator. The external signal frequency has an upper limit depending on the number of points in the lookup table and the clock frequency.

The control block is used to synchronize the operation of the entire modulator section. The FPGA board has an inbuilt clock of 4.09 MHz and it is used as the control signal. The look up table (LUT) is used to store the sample points for the generation of carrier signals. The proposed system requires eight look up tables. Among these look up tables four of them consist of carrier signal of a particular amplitude in four different phases (45,135,225,315). Similarly, the rest consist of carrier signal of different amplitude.

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Figure 2: QAM Modulator
The carriers with different phases are obtained by changing the order in which the points are stored in the LUT. The sample points are calculated based on an equation and the number of sample points can be altered. As the number of sample points stored in the look up table increases the precision of the carrier wave generated increases. The frequency of the carrier signal generated will depend on the clock frequency and the number of sample points, i.e., the clock frequency divided by the number of sample points in the look up table. A 8:1 Multiplexer is used to facilitate the switching of the carrier signals to the output. The select line which controls the multiplexing action is the data input which is provided from a function generator. While performing offline modulation the output of a random sequence generator can be connected to the select line.

IV. SIMULATION RESULTS

For HDL (Hardware Description Language) simulation a PN sequence generator was used to provide the binary message and carrier signals were stored in the lookup table.

Figure 3: HDL simulation for QAM modulator

V. EXPERIMENTAL RESULTS

Real time implementation was done on Spartan 3 XC3S400 FPGA kit. The input signal was given as input message signal from a function generator. Internal clock frequency is 4.09MHz and hence carrier signal is 15kHz calculated by dividing 4.09MHz by 256 points of lookup table. BPSK modulator output was obtained on the DSO using DAC 0808 with amplitude 3.3Vpp and frequency 15kHz.

CONCLUSION

The QAM modulator was implemented in FPGA with user controllable input message signal. The system has relevance in the communication and embedded field. It provides opportunity to study outside the classroom on a real time processing software/hardware implementation of QAM modulation on popular programming platform-Field Programmable Gate Array (FPGA). It can be used in the implementation of software defined radios. Software defined radio (SDR) is a radio communication system where components that have been typically implemented in hardware are instead implemented by means of software on a personal computer or embedded system.

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REFERENCE


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