Design of Quadrature Amplitude Modulation architecture using DPLL on FPGA

K. Sravanthi, V. Prakasam

Abstract— **DPLLs are used widely in communications systems like radio, telecommunications, computers and other electronic applications. Digital PLLs are a type of PLL used to synchronize digital signals. While DPLLs input and outputs are typically all digital, they do have internal functions which are dependent on analog signals. The FPGA technology has been playing a considerable role in portable and mobile communication. This is due to the features of flexibility, accuracy and configurability in designing and implementation [1].**

This project deals with the design of QAM architecture for carrier recovery using Digital Phase Locked Loop (DPLL).This paper presents a complete design for a 16-QAM transmitter and receiver based on VHDL. The implemented system can be used in typical Wimax system and any other QAM based communication systems.

The carrier synchronization and timing synchronization both issues are covered in the implementation. The transmitter of QAM consists of symbol mapper, NCO and modulator blocks. The NCO is used for carrier generation. The receiver of QAM consists of NCO, carrier synchronization block, time synchronization block, symbol demapper and clock managing unit. All blocks will be realized in VHDL and will be aimed to implement with generic feature so that the designs are scalable for different bit sizes.

Index Terms—**Xilinx, Modelsim, 16-QAM, DDS, WIMAX**

I. INTRODUCTION

Quadrature Amplitude Modulation or QAM is a type of modulation which is broadly utilized for modulating information signals onto a carrier utilized for radio communications. It is generally used because it offers advantages over different types of data modulation, for example, PSK, although many types of information modulation operate along side each other [2].

Quadrature Amplitude Modulation, QAM is a signal in which two carriers shifted in phase by 90 degrees are modulated and the resultant output comprises of both amplitude and phase variations. In perspective of the way that both amplitude and phase variations are available it might also be considered as a mixture of amplitude and phase modulation [3].

Quadrate amplitude modulation (QAM) may exist in what may be termed either analogue or digital formats. The analogue types of QAM are typically used to permit various analogue signals to be carried on a single carrier. For example it is used in PAL and NTSC television systems, where the distinctive channels provided by QAM enable it to carry the components of chroma or colour data. In radio applications a system known as C-QUAM is utilized for AM stereo radio. Here the distinctive channels enable the two channels needed for stereo to be carried on the single carrier [4].

Digital formats of QAM are often referred to as "Quantized QAM and they are being increasingly used for data communications often within radio communications systems.

QAM, Quadrature amplitude modulation is widely used in many digital data radio communications and data communications applications. QAM appears to increase the efficiency of transmission for radio communications systems by utilizing both amplitude and phase variations [5].

A. Constellation diagrams for QAM

Quadrature amplitude modulation, QAM, when used for digital transmission for radio communication applications is able to carry higher data rates than ordinary amplitude modulated schemes and phase modulated schemes [6].

As with Phase shift keying, etc, the number of points at which the signal can rest, i.e. the number of points on the constellation is indicated in the modulation format description, e.g. 16QAM uses a 16 point constellation [7].When using QAM, the constellation points are normally arranged in a square grid with equal vertical and horizontal spacing and as a result the most common forms of QAM use a constellation with the number of points equal to a power of 2 i.e. 2, 4, 8, 16 . . . .[8]

By using higher order modulation formats, i.e. more points on the constellation, it is possible to transmit more bits per symbol. However the points are closer together and they are therefore more susceptible to noise and data errors. To provide an example of how QAM operates the table below provides the bit sequences, and the associated amplitude and phase states. From this it can be seen that a continuous bit stream may be grouped into threes and represented as a sequence of eight permissible states [9].

II. IMPLEMENTATION

A. QAM transmitter

The transmitter of QAM is shown in the below figure 1. It consists of Signal source, symbol mapper, NCO, modulator blocks and adder. The NCO is used for carrier generation. Two four level random data sequences are generated corresponding to I and Q signal of 16-QAM at the rate of 4 clock periods. These signals then go to the mapping block. A symbol mapper takes symbols as inputs and maps them to appropriate constellation points as dictated by the modulation method specified. This process generates I and Q values.

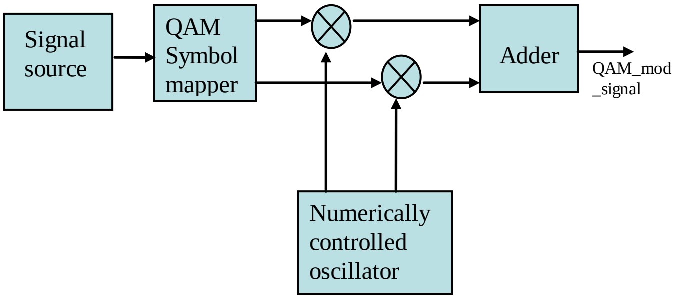

Fig. 1 Block diagram of QAM transmitter

The numerically controlled oscillator (NCO) accurately generates the in-phase and Quadrature carriers used by a QAM modulator. The carrier frequency of each sinusoid can be set to any precision by defining the phase increment input to the NCO. I and Q modulated signals are combined in the adder and produces the composite signal. This composite signal is transmitted to the receiver. Due to the digital nature of the modulator only at each clock tick the modulating signal value shall affect the resulting frequency. If the modulating signal is analog then an Analog Digital converter must be used to digitize the modulating signal which can be used in DDFS.

B. QAM receiver

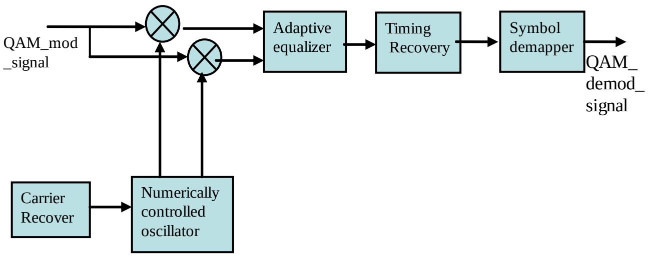

Fig. 2 Block diagram of QAM receiver

The receiver of QAM is shown in the figure 2. It consists of NCO, carrier synchronization block, time synchronization block, symbol demapper and clock managing unit. The numerically controlled oscillator (NCO) accurately generates the in-phase and Quadrature carriers. These carriers are multiplied with the received signal so as to separate I and Q modulated signals. An adaptive equalizer is an equalizer that automatically adapts to time-varying properties of the communication channel. It is frequently used with coherent

modulations such as phase shift keying, mitigating the effects of multipath propagation and Doppler spreading.

A symbol demapper performs the reverse operation of the mapper. It takes I and Q values and generates the corresponding data symbols. If the signal transmitted is the analog signal, we can use ADC to obtain the original transmitted signal. Carriers used at the receiver must be synchronized with the transmitter carriers. This synchronization is provided by the separate module called carrier recovery. The carrier recovery module is shown in the below figure 3.

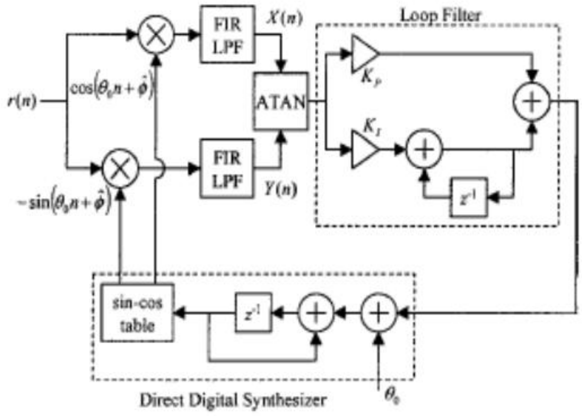

Fig. 3 Block diagram of Carrier recovery with DPLL

III. Simulation Results

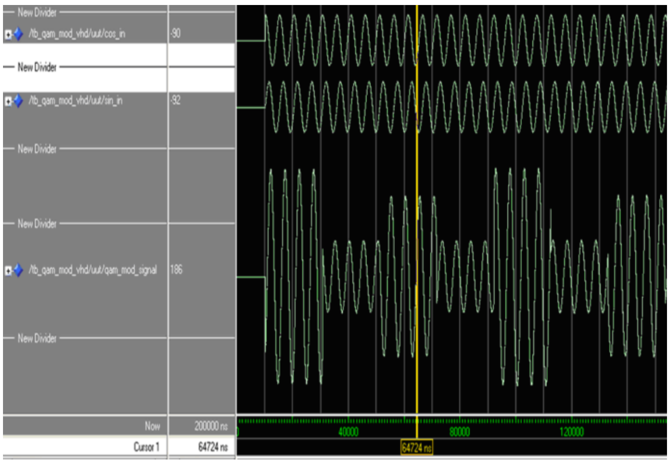

Fig. 4 QAM modulation simulation results

Input's of this module is sampled_4bit, cos_in and sin_in and output is Qam_mod_signal. Input sampled_4bit is split in to two those are i_bits and q_bits, these are used to produce cos_amp_factor and sin_amp_factor respectively. cos_amp_factor is multipled with cos_ in and generates temp_prod1, sin_amp_factor is multiplied with sin_in and generates temp_prod2. Temp_prod1 is added with temp_prod2 generates Qam_mod_signal. The output of the receiver is qam demodulated signal. The simulation results of QAM transmitter and receiver are shown in figure 4 and 5.

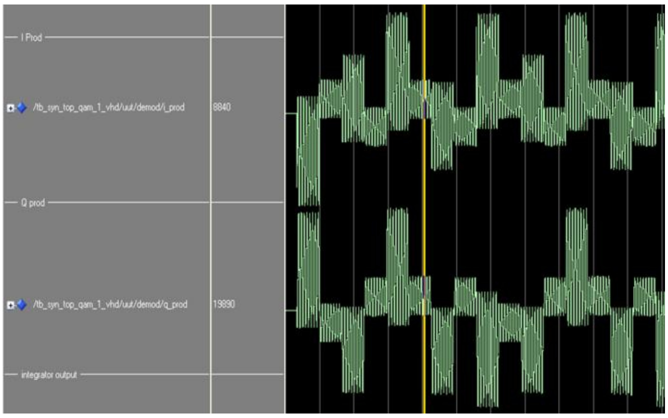

Fig. 5 QAM demodulation simulation results

IV. Chip Scope Results

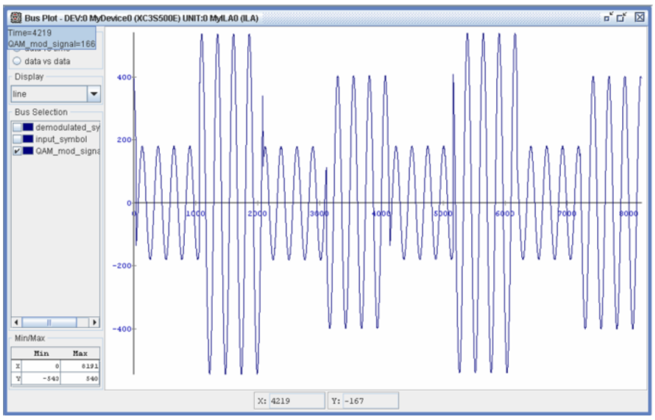

Fig. 6 QAM modulation Chipscope results

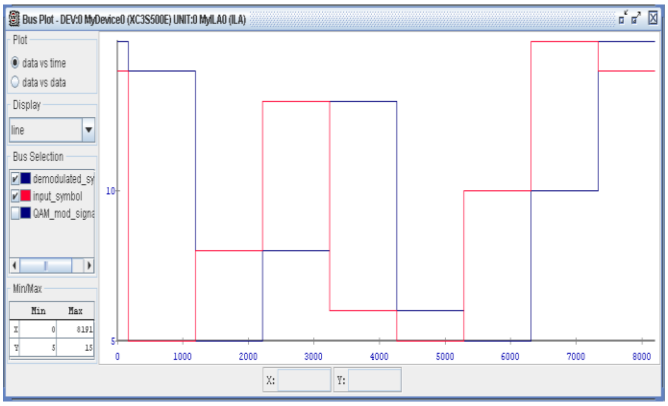

Fig. 7 QAM demodulation Chipscope results

V. Conclusion

In this paper, we Implemented Quadrature Amplitude Modulation architecture for carrier recovery using DPLL on SPARTAN 3E FPGA XC3S500E is done. Quadrature amplitude modulation is an important modulation scheme with many practical applications, including current and future wireless technologies. The implemented system can be used in typical Wimax system and any other QAM based communication systems.

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Authors:

K. Sravanthi is presently pursuing final semester M. Tech in VLSI system design at Vignan institute of technology and science.

V. Prakasam is presently working as Assistant Professor in the department of Electronics and Communication Engineering in Vignan institute of technology and science.

