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VLSI Based FPGA Design of Digital Modulation Schemes BASK and BPSK

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***Abstract*— Modulation is the process of facilitating the transfer of information over a medium. Digital modulation is less complex, more secure and more efficient in long distance transmission. The noise detection and correction is more efficient in digital modulation than analog. So it has more importance in modern communication system. Digital modulation represents the transfer of the digital bit stream from the transmitter to the receiver via the analog channels. During the modulation process the information signal modifies one or more carrier parameters, leading to shift keying techniques. These shift keying techniques are Amplitude shift keying (ASK), Phase shift keying (PSK) and Frequency shift keying (FSK). All of these techniques vary a parameter of a sinusoid to represent the information which we wish to send. A sinusoid has three different parameters that can be varied. These are its amplitude, phase and frequency. These digital modulation techniques can be realized using FPGA (Field-programmable gate-array). Software-Defined Radio (SDR) transmitter employs the minimum number of blocks necessary for achieving BASK and BPSK modulation. The modulating and carrier signals can be user controlled and the modulators are developed and compiled to a Verilog Hardware Description Language (VHDL) net list. The functionality of these digital modulators are demonstrated through simulations using the Model Sim software and synthesis using Quartus-II software.**

***Keywords*— BASK, BPSK, digital modulator, FPGA, Verilog**

I. INTRODUCTION

Field-programmable gate arrays (FPGAs) are semiconductor devices containing programmable logic elements (LEs) and a hierarchy of reconfigurable interconnects to realize any complex combinational or sequential logic functions. Today's FPGAs consist of configurable embedded static random-access memories (SRAMs), high-speed transceivers, high-speed input/output (I/O) elements, network interfaces, and even hard-embedded processors [1]. A literature survey shows that FPGAs are widely used in different applications, such as motor controllers [2], neural network implementations [3-5], finite-impulse-response (FIR) filter realization [6,7], fuzzy-logic controllers [8], etc.

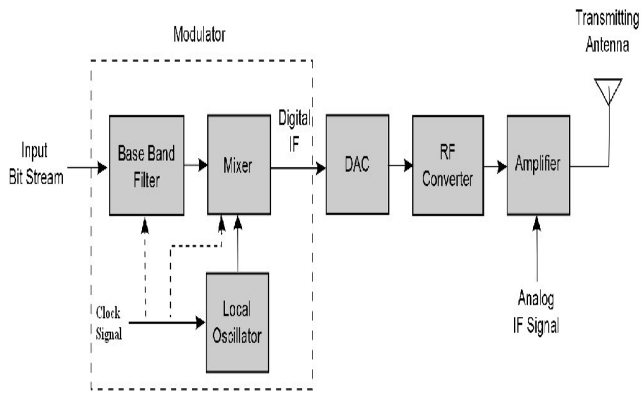

Fig. 1. Block Diagram of Software-Defined Radio Transmitter

The choice of digital modulation scheme will significantly affect the characteristics, performance and resulting physical realization of a communication system. Consideration must be given to the required data rate, acceptable level of latency, available bandwidth, anticipated link budget and target hardware cost, size and current consumption. The objective of a digital communication system is to transport digital data between two or more nodes. In radio communications this is usually achieved by adjusting a physical characteristic of a sinusoidal carrier, either the amplitude, phase and frequency or a combination thereof. This is performed in real systems with a modulator at the transmitting end to impose the physical change to the carrier [9].

The aim of this paper is to show the simulation results and synthesis of fully digital BASK and BPSK modulators that employ the minimum number of blocks suitable for software-defined-radio systems and are integrable with the Altera FPGAs. Furthermore, the implemented FPGA designs can be used in a digital communication system to demonstrate BASK and BPSK digital modulation techniques.

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II. DESIGN OF DIGITAL MODULATORS

A. BASK Modulator -

In a BASK (binary amplitude-shift keying) modulation process, the amplitude of the sinusoidal carrier signal is changed according to the message level ("0" or "1"), while keeping the frequency and phase constant. If transmitting data is 1, BASK modulated signal is carrier signal. But when transmitting data is 0, BASK modulated signal is 0. In modulation, data bits are multiplied with a carrier signal and then modulated signal is created.

$S(t) = A_c \,\mathrm{Sin}(2\pi f c t)$; if symbol = 1
$S(t) = 0$; if symbol =0 (1)

In Fig. 2, it is shown a block diagram of BASK modulator. The input signals provided are the modulating signal and carrier signal. The output will gives a BASK modulated signal. In Fig. 3, it is shown that BASK modulation [10].

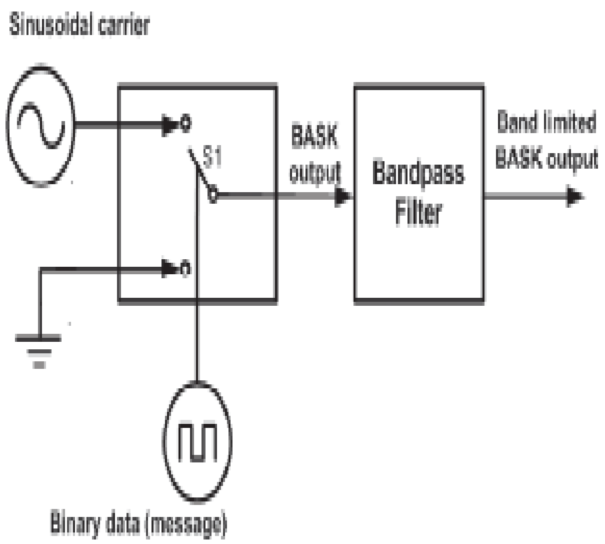

Fig. 2. A block diagram of BPSK modulation

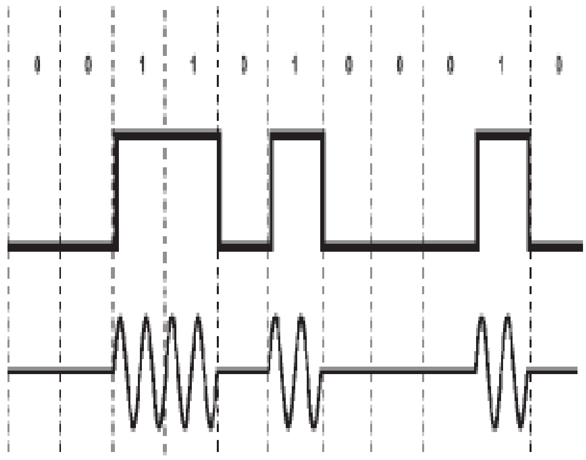

Fig. 3. The modulating-signal (message) and the BASK signal waveforms

B. BPSK Modulator –

In a BPSK (binary phase-shift keying) modulation process, the phase of the sinusoidal carrier signal is changed according to the message level ("0" or "1") while keeping the amplitude and frequency constant. Beginning of BPSK modulated signal's period is positive values, if transmitting symbol is 1. But if transmitting signal is 0, beginning of BPSK modulated signal's period is negative values. A block diagram of the BPSK modulation and its signal waveforms are shown in Fig. 4 and 5, respectively [10].

$S(t) = A_c \,\mathrm{Sin}(2\pi f c t)$; if symbol = 1
$S(t) = -A_c \,\mathrm{Sin}(2\pi f c t)$; if symbol = 0 (2)

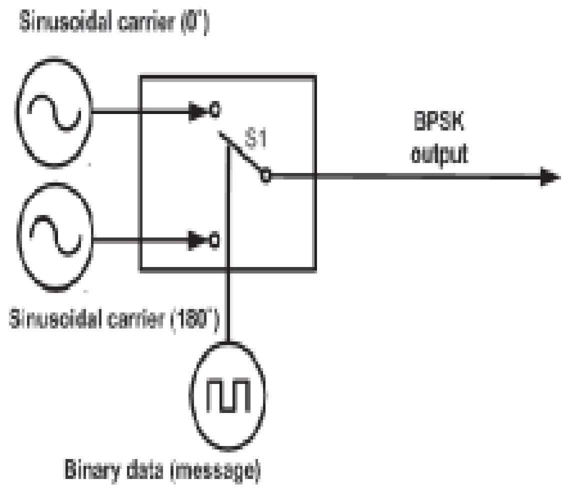

Fig. 4. A block diagram of BPSK modulation

In figure 4, it is shown the block diagram of BPSK modulator. The inputs are nothing but the modulating signal and carrier signal which provides the two carrier signals i.e. 0º and 180º for phase shifting. Thereby, BPSK modulated signal is created.

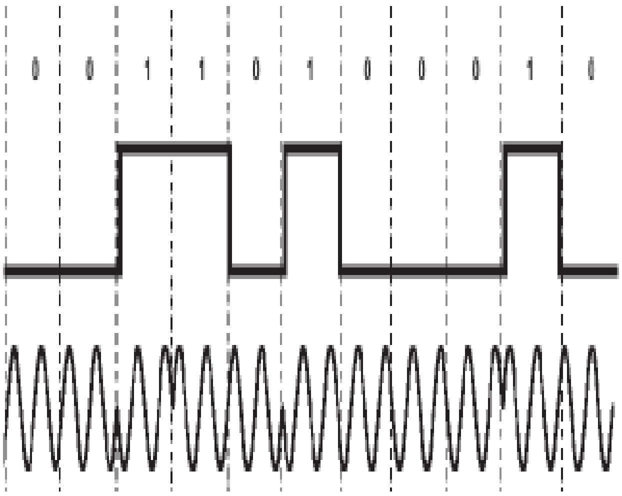

Fig. 5. The modulating-signal (message) and BPSK signal waveforms

III.SIMULATION RESULTS

Prior to the FPGA hardware implementation, the design of BASK and BPSK digital modulators are verified through simulations using the *Model-Sim* software.

1) BASK Simulation Result:

The simulation results for the BASK modulator are shown in Fig. 6. The input carrier signal is Sinusoidal (Modulating) Wave, the input modulating signal is Binary Sequence, and the output modulated signal is ASK Signal.

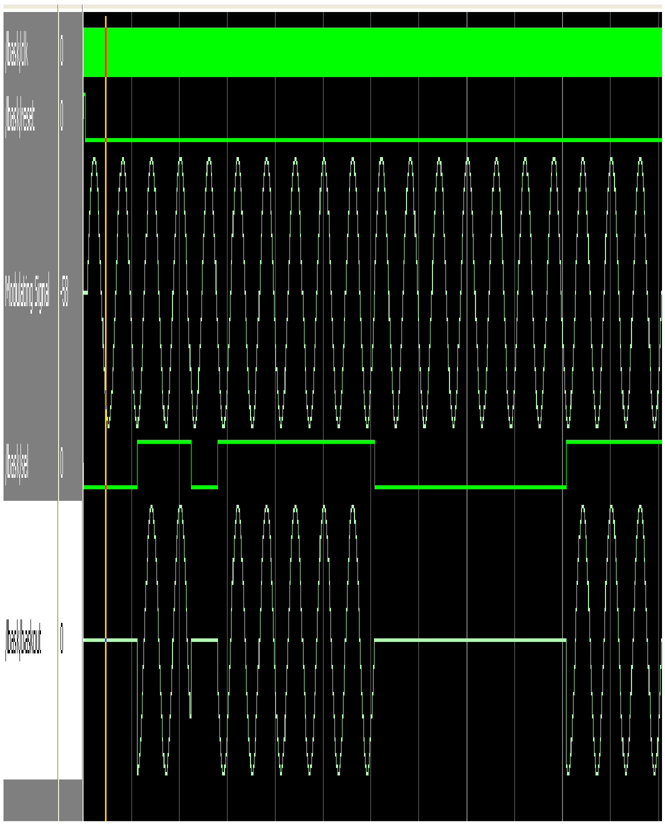

Fig. 6. BASK Simulation Result

2) BPSK Simulation Result:

The design parameters used for the simulations are a 16-bit phase accumulator that generated a 16-bit digital sine wave with a frequency of 1 kHz and phases of 0° and 180° (the complements of each other), and a 1010101...10 serial binary sequence (modulating signal).

The simulation results for the BPSK modulator are shown in Fig. 7. The input carrier signals are Sinusoidal Wave 1 and Sinusoidal Wave 2, the input modulating signal is Binary Sequence, and the output modulated signal is BPSK Signal.

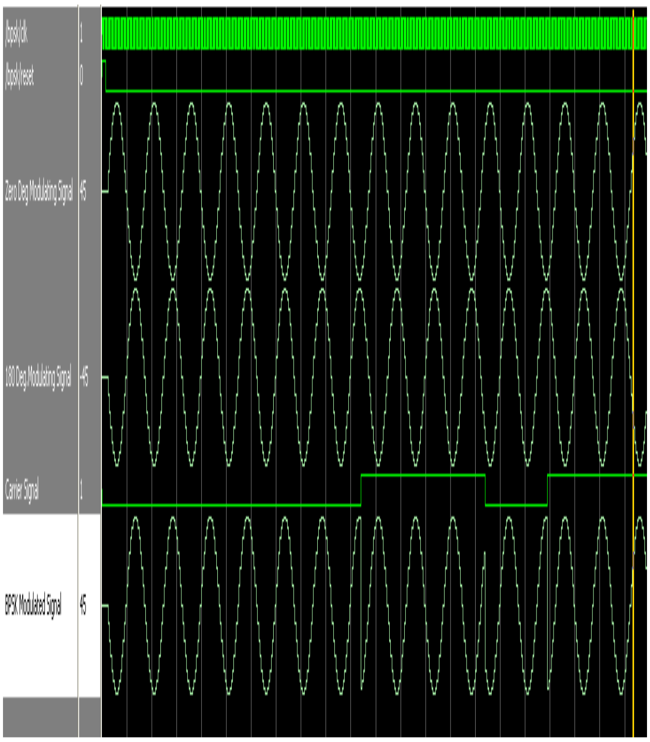

Fig. 7. BPSK Simulation Result

IV. SYNTHESIS OF MODULATORS IN QUARTUS-II

The synthesis of both the modulation schemes i.e. BASK and BPSK is done by using Quartus-II software. It uses Cyclone-II family of Altera FPGA. This gives the overall flow summary of the modulators which shows many parameters for the comparison and the system status of BAK and BPSK modulation techniques.

1) Synthesis of BASK Modulator-

Flow Summary

Flow Status	Successful - Sun Mar 17 19:13:40 2013
Quartus II Version	9.1 Build 350 03/24/2010 SP 2 SJ Web Edition
Revision Name	bask
Top-level Entity Name	bask
Family	Cyclone II
Device	EP2C20F484C7
Timing Models	Final
Met timing requirements	Yes
Total logic elements	34 / 18,752 (< 1 %)
Total combinational functions	34 / 18,752 (< 1 %)
Dedicated logic registers	13 / 18,752 (< 1 %)
Total registers	13
Total pins	11 / 315 (3 %)
Total virtual pins	0
Total memory bits	0 / 239,616 (0 %)
Embedded Multiplier 9-bit elements	0 / 52 (0 %)
Total PLLs	0 / 4 (0 %)

Fig. 8. Synthesis of BASK Modulator in Quartus-II

2) Synthesis of BPSK Modulator-

Flow Summary

Flow Status	Successful - Sun Mar 17 20:17:10 2013
Quartus II Version	9.1 Build 350 03/24/2010 SP 2 SJ Web Edition
Revision Name	bpsk
Top-level Entity Name	bpsk
Family	Cyclone II
Device	EP2C20F484C7
Timing Models	Final
Met timing requirements	Yes
Total logic elements	51 / 18,752 (< 1 %)
Total combinational functions	51 / 18,752 (< 1 %)
Dedicated logic registers	20 / 18,752 (< 1 %)
Total registers	20
Total pins	11 / 315 (3 %)
Total virtual pins	0
Total memory bits	0 / 239,616 (0 %)
Embedded Multiplier 9-bit elements	0 / 52 (0 %)
Total PLLs	0 / 4 (0 %)

Fig. 9. Synthesis of BPSK Modulator in Quartus-II

V. CONCLUSION

Implementation of BASK and BPSK digital modulators are demonstrated. The Simulation is done using Model-Sim software that shows the output waveforms for BASK and BPSK modulators. The main advantage of the implementation is the minimum numbers of digital blocks used for performing digital modulations, the ability to integrate with modules in FPGA boards, and the user controllability of the input signals' frequencies. The Synthesis results for both modulation techniques provides the detailed flow summary which shows and compare many parameters and its status. Also, comparison to performance of implemented modulation techniques will be analyzed. It is shown that modulation techniques (BASK and BPSK) have advantage and disadvantage in simulation and plotting results.

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