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BPSK Modulation and Demodulation Scheme on Spartan-3 FPGA

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Abstract

The BPSK modulation and demodulation represents an important modulation technique in terms of signal power. The BPSK system is simulated using Matlab/Simulink environment and System Generator, a tool from Xilinx used for FPGA (Field-programmable gate-array) design as well as implemented on Spartan 3E Starter Kit boards. The implementation of BPSK modulator and demodulator has been implemented on FPGA using Xilinx ISE 12.1 Project Navigator. Both, the modulator and demodulator, have been designed and simulated and theirs performances were evaluated by measurements. The implementation of BPSK modulator and demodulator could have been implemented using Spartan-3 FPGA by using Xilinx ISE 12.1 Project Navigator, Modelsim 6.3, Matlab Simulink and Xilinx System generator.

Index terms: BPSK, Field Programmable Gate Array, Oscillator, Digital Modulator

I. INTRODUCTION

The aim of the paper is to create a BPSK (Binary Phase Shift Keying) system made of a modulator, a channel and a demodulator. The modulated signal was achieved in the first Spartan 3E board, passed through a channel and transmitted to the second board, which behaves as a demodulator. At the end of the demodulator, the modulating signal was obtained. The main difference is the System Generator block which makes possible the administration of the Xilinx components. Important studies were made in this field and were cited in this paper [1], [2], [3], [4], [5], [6], [7].

The resources used in generating the BPSK modulation and demodulation were a computer with the Xilinx Web Pack ISE on it, two Spartan 3E Starter Kit boards and a LeCroy WaveSurfer Xs Series Oscilloscope, a high performance digital oscilloscope.

The paper is organized into 6 sections. The paper begins with an introduction in section 1. Section 2 presents the theoretical backgrounds about the digital communication system and about the BPSK modulation and demodulation. After discussing in theory, implementation of the BPSK system in Matlab/ Simulink and System Generator are presented in section 3. Section 4 is dedicated to the implementation of the system: modulator and demodulator on the Spartan 3E Starter Kit boards. The results are discussed in section 5. The final section, 6, presents the conclusions.

II. THEORETICAL BACKGROUNDS

A. Digital Communication System

A typically digital communication system is presented in Fig.1.

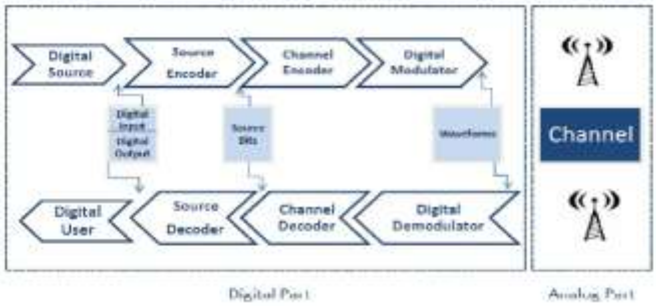

Figure 1. A Digital Communication System

The components of the digital communication system are both digital and analog parts. The digital part consists of digital source/user, source encoder/ decoder, channel encoder/ decoder and the digital modulator/ demodulator. The analog part is made of the transmitter, receiver, the channel models and noise models [8].

The message to be sent is from a digital source, in our case, from a computer. The source encoder accepts the digital data and prepares the source messages. The role of the channel encoder is to map the input symbol sequence into an output symbol sequence. The binary information obtained at the output of the channel encoder is than passed to a digital modulator which serves as interface with the communication channel. The main purpose of the modulator is to translate the discrete symbols into an analog waveform that can be transmitted over the channel [9], [10]. In the receiver, the reverse signal processing happens.
The role of a digital communication system is to transport digital data between the transmitter and receiver. As the signals propagate between the two nodes, they may be submitted to distortion due the channel imperfection. The digital data is transmitted between the transmitter and the receiver by varying a physical characteristic of a sinusoidal carrier, either the frequency or the phase or the amplitude. This operation is performed with a modulator at the transmitting end to impose the physical change to the carrier and a demodulator at the receiving end to detect the resultant
Modulation on reception [11].

B. BPSK Modulation and Demodulation

Digital modulation is the process by which digital symbols are transmitted into waveforms that are compatible with the characteristics of the channel. The modulation process converts the signal in order to be compatible with available transmission facilities. At the receiver end, demodulation must be accomplished by recognizing the signals. The modulation technique used in this work is BPSK (Binary Phase Shift Keying) and it is widely used in digital transmission. BPSK modulation is the simplest form and most robust of all the PSK modulation techniques. It is able to modulate at only 1bps and it is not suitable for high data-rate applications.

The BPSK modulator is quite simple and is illustrated in fig.1.1. The binary sequence m(t) or modulating signal is multiplied with a sinusoidal carrier and the BPSK modulated signal s(t) is obtained. The waveforms of the BPSK signal generated by the modulator are shown in fig1.2. To demodulate the signal, it is necessary to reconstitute the carrier. This process is made in the Carrier Recovery Circuit. Next, the BPSK modulated signal is multiplied with the carrier, pass through an integrator and a decision circuit to obtain in the end the modulating signal, which are shown in fig. 1.3.

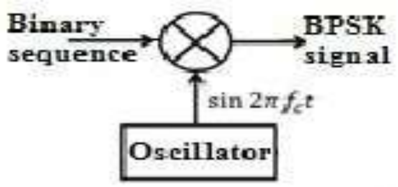

Figure 1.1 BPSK Modulator

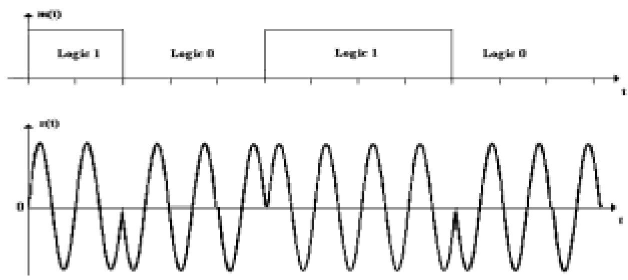

Figure1.2 BPSK Modulator Waveforms

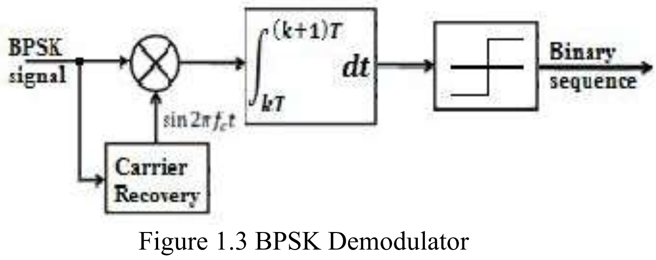

Figure 1.3 BPSK Demodulator

In all areas of satellite communications systems, cellular and wireless, A digital communication system is more reliable than an analog one thanks to the advanced signal processing algorithms used at the transmitter and the receiver ends. The aim of the propose work is to create a BPSK (Binary Phase Shift Keying) system made of a modulator, a channel and a demodulator. The modulated signal was achieved in the first Spartan 3E board, passed through a channel and transmitted to the second board, which behaves as a demodulator. At the end of the demodulator, the modulating signal was obtained.

III. BPSK SYSTEM

A. BPSK System in Simulink

In [4], a BPSK modulator and demodulator is implemented in the Simulink environment for a practical teaching course. Fig. 5 represents a communication system implemented in the Matlab/ Simulink environment that uses the BPSK modulation technique. The system is composed of the binary data source, a modulator, a channel and a demodulator. The binary data source is made of a random data source and a rounding function (fig.6). The corresponding signal is illustrated in fig.7c.

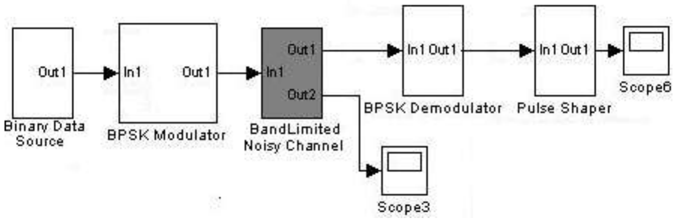

Figure 5. BPSK System.

The BPSK modulator (fig.6) is made of two sine carriers, the second one delayed with 180º and a switch which will choose between the first or third output depending on the value of the second input. If the second input is "1", the output value will be sine (fig.7a), but if the second input is "0", the output will be –sine (fig.7b).

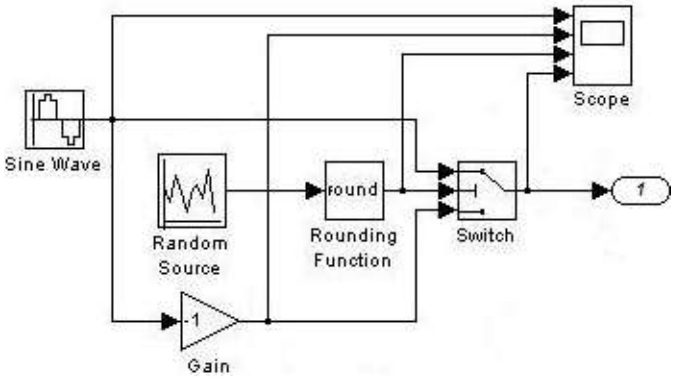

Figure 6. Binary data source and BPSK Modulator [15].

Figure 7. The waveforms on the scope [9]

Sine (b) –Sine (c) Modulating signal (d) Modulated Signal.

The modulated signal is then pass through a channel where noise is added. The channel also has a limited frequency bandwidth so that it can be viewed as a filter (fig.8). The corresponding signals are shown in fig.9.

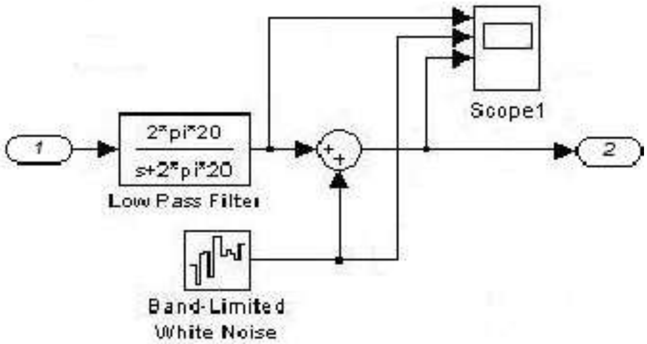

Figure 8. Band Limited Noisy Channel.

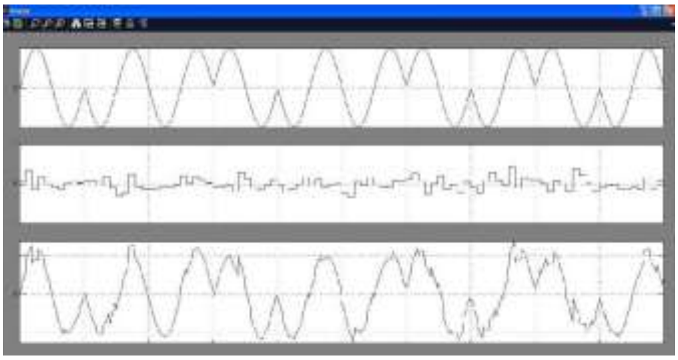
Figure 9. The waveforms shown on the scope
(a) The modulated signal (b) the noise(c) The noise added to the modulated signal.

The modulated signal added with noise arrives at the input of the demodulator. The first block in the demodulator is saturation (fig.10).

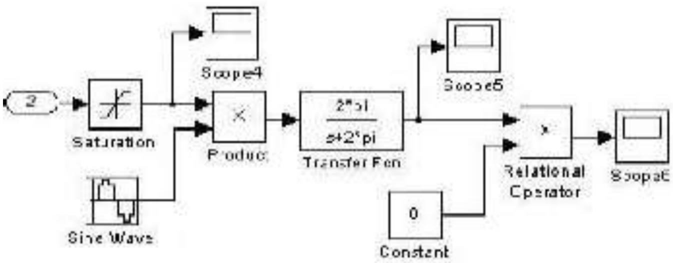

Figure 10. BPSK demodulator.

The saturation block [16] establishes upper and lower bounds for an input signal. If the input signal is within the limits of upper and lower bounds, the input signal passes through unchanged, otherwise the signal is clipped to the upper and/ or lower bounds (fig.11).

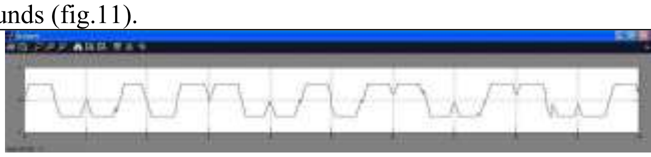
Figure 11. The signal at the output of the saturation block.

After limiting the signal to the upper and lower bounds, it is multiply by a sine waveform, which is the carrier obtained in theory from the carrier recovery circuit and then passed through the transfer function block which implements a transfer function between the input and the output. The signal obtained is illustrated in


Figure 12. The signal at the output of the transfer block.

The obtained signal enters the pulse shaper block and at its output the demodulated signal is found (fig.13).

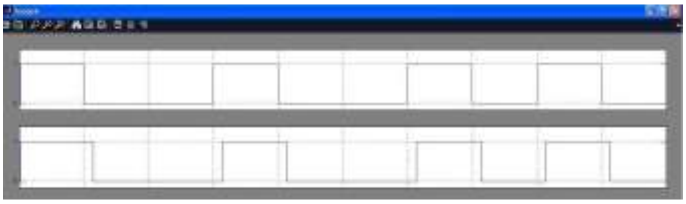

Figure 13. (a) The modulating signal (b) The demodulated signal

B. BPSK System in System Generator

System Generator is a digital signal processing design tool from Xilinx. Designs are made in the Simulink environment using a Xilinx specific blockset. All implementation steps, including synthesis, place and route are automatically performed to generate an FPGA programming file [17].

In [6] and [7] implementations of a BPSK system are presented. In [7], a hybrid DSP/FPGA architecture of a BPSK transceiver is discussed with implementation is System Generator. In [6], a method of designing BPSK modulator and demodulator is presented. The method uses a DDS (Direct Digital Synthesis), same as we used in our model implemented in System Generator.

Our BPSK system implemented in System Generator has the same block as in fig.5: data source, a modulator [15], a channel and a demodulator. The main difference is the System Generator block which makes possible the administration of the Xilinx components.

The modulating signal (fig.15c) is generated internal by a LFSR (Linear Feedback Shift Register) (fig.14). The carrier is generated internal by DDS blocks from System Generator (fig.14). The DDS Compiler Block is a direct digital synthesizer and it uses a lookup table scheme to generate sinusoids. A digital integrator generates a phase that is mapped by the lookup table into the output waveform [17]. The sine waveforms can be seen in fig.15 (a) and (b). The mux block implements a multiplexer. It has one select input and a configurable number of data inputs that can be defined by the user. The d0 and d1 inputs of mux represent the sine waves. The sel input of mux represents the modulating signal and selects between the d0 and d1 inputs. If LFSR is ‘1’, the modulated signal remained same as the carrier, but if ‘0’ was transmitted, the yielded carrier is transmitted.

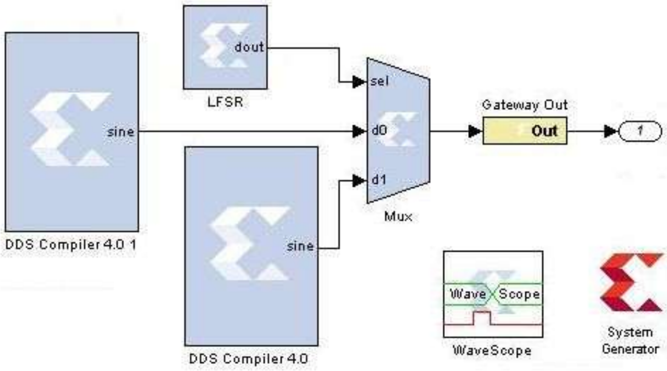

Figure 14. BPSK Modulator in System Generator.

With the System Generator WaveScope (fig.15), the user can view the waveforms generated in the design. It is well suited for analyzing and debugging System Generator designs [17].

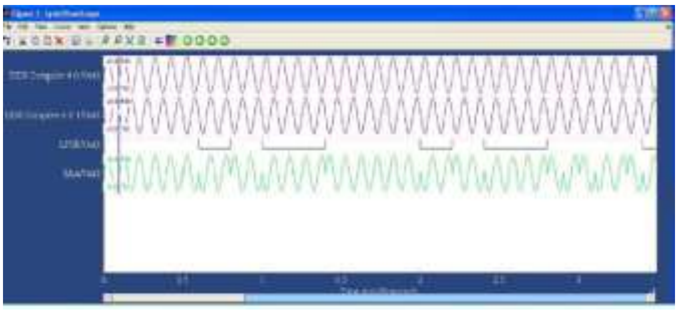

Figure 15. The waveforms: Sine (b) --Sine (c) The modulating signal (d) The modulated signal.

The modulated signal is then pass through the same channel where noise is added and arrives at the input of the demodulator. The carrier is recovered due to the DDS compiler and then multiplied with the modulated signal affected by noise. The obtained signal is then added with all the samples, multiplied, from a period. This operation takes place in the accumulator. Once we have a result, it is compared with a threshold. If the compared signal is positive, the demodulator take the decision that ‘1’ was transmitted, otherwise, ‘0’.

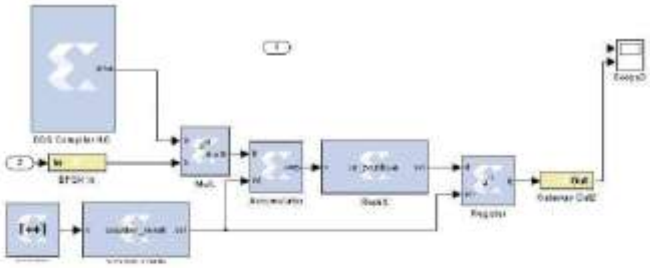

Figure 16. BPSK Demodulator in System Generator

Fig.17 illustrates the modulating signal generated in the modulator and the demodulated signal obtained after the demodulation operation.

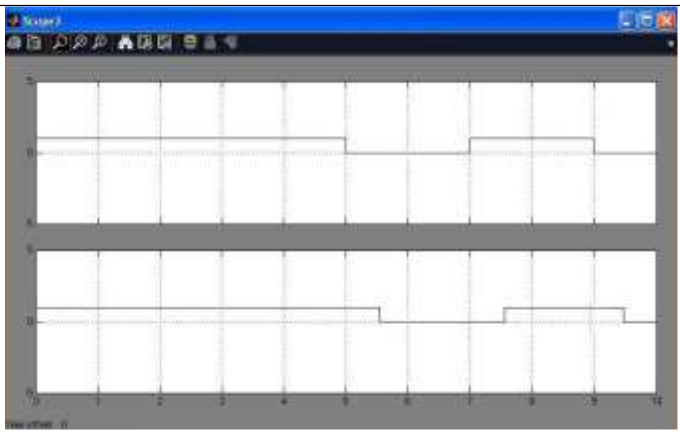

Figure 17. (a) The modulating signal (b) The demodulated signal

IV. BPSK SYSTEM ON THE SPARTAN 3E BOARD

The BPSK System (fig.19) = Modulator (fig.20) and Demodulator (fig.22) that we implemented on the Spartan 3E Starter Kit board [18] is, exactly, the implementation in System Generator. The carrier is generated internal, in a ROM.

The BPSK system (fig.18) consists of two Spartan 3E boards, first behaves as a modulator and the second one, as a demodulator. The connections between the two boards are made of three wires: first comports as a communication channel, the second as an asynchronous reset signal and the last one for the synchronization of the two boards.

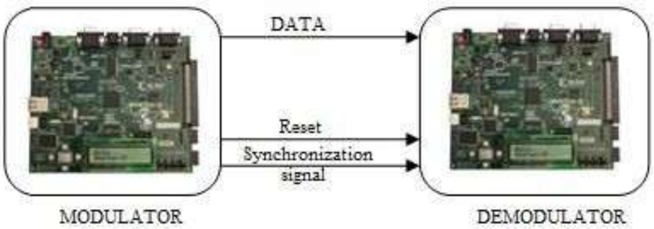

Figure 18. BPSK System.

The yellow cable represents the communication channel, the red one is the reset and the green one makes possible the synchronization between the two boards.

Figure 19. BPSK System – experimental setup.

V. CONCLUSION

Finally we proposed implementation of the BPSK System (Modulator and Demodulator) in the Matlab/Simulink environment. Then, we make a BPSK System in System Generator. Both, the modulating signal and the carrier are generated internal. The modulated signal is obtained at the output of a mux block and, then, passed through a communication channel where noise is added. In the demodulator, the carrier is recovered due to another DDS compiler and then multiplied with the modulated signal affected by noise. The obtained signal is then added with all the multiplied samples from the carrier in a period. The operation takes place in the

Accumulator. Once we have a result, it is compared with a decision threshold. If the compared signal is positive, the demodulator take the decision that '1' was transmitted, otherwise, '0'. The BPSK System implemented on the Spartan 3E Starter Kit board has the same principle as the implementation in System Generator. Although System Generator has an option to generate the VHDL code, for this design the code was made from the beginning because the generated code was hard to read. The only difference was that of the carrier which was indeed generated internal, in a ROM memory, but made of 16 different values. The yielded carrier with 180º phase shift was obtained by reading the ROM memory later with 8 samples. Comparing the design summary obtained with other works in this field [1] - [8], the logic utilization of the board was lower in terms of the slice flip-flops and LUTs used. All of these make the design suitable in terms of propagation, implementation and logic utilization of the Spartan 3E boards used in this work.

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