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FPGA Implementation of PI/2 BPSK and PI/4 QPSK for IEEE 802.15.6 WBAN Standard.

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Abstract: *This paper presents FPGA based simulation results for digital modulation schemes PI/2 BPSK and PI/4QPSK. Digital modulation is less complex, more secure and more efficient in long distance transmission. The noise detection and correction in digital is more efficient than analog. So it has more importance in modern communication system[1].These modulations are particularly used for IEEE 802.15.6 WBAN Standard. The two modulations are realised using Direct digital Synthesizer(DDS). The Frequency control word of DDS is changed accordingly to obtain the required frequency for WBAN. In this paper, PI/2BPSK and PI/4QPSK modulation and demodulation techniques have been implemented on FPGA using VHDL on XILINX ISE 14.1, simulated with ModelSim6.3g and synthesized on sparten 3E FPGA*

Keywords: Digital Modulation Techniques, BPSK, QPSK, FPGA, VHDL

1. INTRODUCTION:

Digital techniques have low error rates and high reliability which is required in communication systems. The digital technique based communication systems are highly reconfigurable and programmable. The major advantage of using digital modulation technique is that the use of digital signals reduces hardware, noise and interference problems as compared to the analogue signal where large number of waveforms will be required resulting in a larger bandwidth for the symbol to be transmitted. BPSK and QPSK are easy to be realized, and also have excellent anti-interference ability and strong anti-fading performance. Therefore, they are widely used in short range wireless communication systems. Since BAN nodeshas to be small, intelligent, low in power consumption and so on, high-complexity techniques should be avoided in the realization. Since BPSK and QPSK has the problem of phase ambiguity, $\pi/2$- BPSK and $\pi/4$-shift QPSK are adopted in BAN standard, IEEE 802.15.6[11]. These modulations can be non coherently demodulated and thus have lessc omplexity.With the development of medical technology and with the growth of population, there will be tremendous growth in the healthcare monitoring markets, such as exercise monitor, health monitor for elderly people and remote patient monitoring. Patients and the aged will benefit from continuous monitoring of their diagnostic procedures. These applications can be integrated into wireless body area networks (WBANs) for health monitoring. WBAN appeals, particularly solutions to provide information about the health status of a patient in medical environments such as hospitals or medical centers.. The current IEEE 802.15.6 WBAN standard defines three PHY layers Narrowband (NB), Ultra wideband(UWB), and Human Body Communications(HBC) layers. In NB PHY, the standard uses Differential Binary Phase-shift Keying (DBPSK), Differential Quadrature Phase-shift Keying (DQPSK), and Differential 8Phase-shift Keying (D8PSK) modulation techniques except 420-450 MHz which uses a Gaussian minimum shift keying (GMSK) technique. The NB PHY layer has different frequency bands with different modulation requirements as mentioned any of above. This modulations can be tested for different frequency bands of IEEE 802.15.6 WBAN standard.

In this paper, the FPGA implementation of PI/2 BPSK and PI/4 QPSK modulator and demodulator is presented. Complete modulator and demodulator units are modeled using VHDL and functionality are verified using Modelsim simulation tools. The code is synthesized fully onto Xilinx FPGAs. The Modulator consists of various communication modules like Direct Digital Synthesizer(DDS), Phase shifter, Multiplexer, Demodulator. These digital modules are implemented as different modules and used as components in top level entities.

2. PI/2 BPSK:

In Binary Phase Shift Keying (BPSK), the phase of the sinusoidal carrier signal is varied in accordance with the value of the binary information data bit to be transmitted. The binary information is encoded in relative phase shift of 0 and 180 degrees. Whereas $\pi/2$, phase-shift keying ($\pi/2$-BPSK) is a modulation technique which encodes the binary information in relative phase shifts of $\pi/2$ and $-\pi/2$. It has as a result only two phases of the carrier, at the same frequency, but separated by 180°.The PI/2-BPSK signal can be represented as

$S(t)= A \sin(2\pi ft + 90^\circ)$ when data is 0

$A \sin(2\pi ft - 90^\circ)$ when data is 1

Where, $A \sin(2\pi ft)$ is a carrier signal with initial phase of 0°. When the input data changes between 0 and 1, the carrier signal shifts accordingly between relative $\pi/2$ and $-\pi/2$. A Direct digital Synthesizer is used to generate the carrier signal. DDS is used for modulation since it has multiplier less architecture, utilizes less resources on FPGA and in demodulation same architecture is used to obtain digital data back[3].Here the DDS uses lookup table to generate the sinusoids. A phase shifter is used to give a required phase shift of +90 and -90 degrees to the carrier signal. The multiplexer is used to transmit the corresponding phase shifted carrier signal depending upon the data. Figure 1 shows a simplified block diagram for PI/2 BPSK modulator.

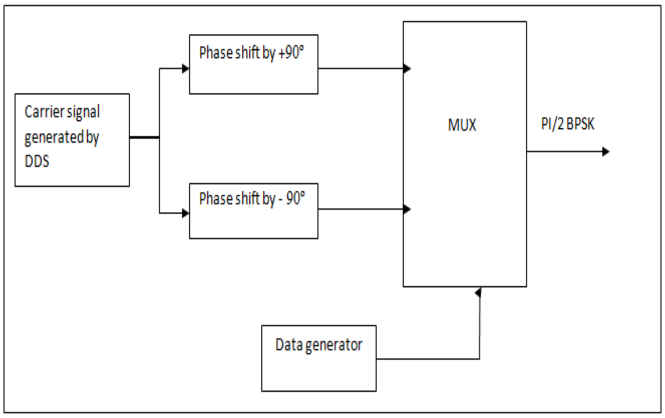

Figure 1, PI/2 BPSK Modulator

A demodulator is also employed for PI/2 BPSK. The modulated signal is received at the receiver side. This signal is compared with the threshold and the correct transmitted data is detected.

3. PI/4 QPSK :

The $\pi/4$ QPSK modulation scheme is a modulation scheme that has combined a conventional QPSK modulation scheme with an offset QPSK (OQPSK) scheme. In $\pi/4$-QPSK, we have 8 signals, every alternate symbol is transmitted using $\pi/4$ shifted pattern of the QPSK constellation. Symbol A uses a signal on path- A as shown below and the next symbol, B, even if it is exactly the same bit pattern uses a signal on path B .So, we always get a phase shift even when the adjacent symbols are exactly the same[2]. Although the symbols move around, they always convey just 2-bits/symbol[4]. Maximum phase transition of $\pi/4$- QPSK is limited to ±135 as compared to 180° for QPSK and 90° for OQPSK. Hence, the $\pi/4$- QPSK preserves the constant envelope property better than the band limited QPSK. In $\pi/4$-QPSK the set of constellation points are toggled each symbol, so transitions through zero cannot occur. This scheme produces the lowest envelope variations

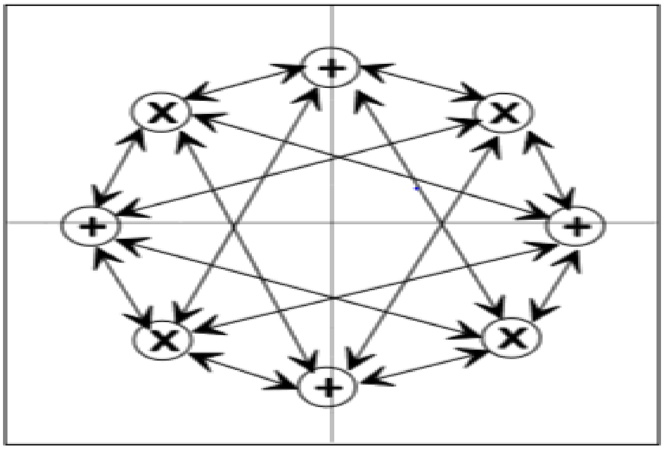

Figure 2. Constellation of PI/4 QPSK signal

The $\pi/4$ QPSK signal can be represented as

$S(t)= A \sin(2\pi ft)$ or $A \sin(2\pi ft+45)$ for 00

$S(t)=A \sin(2\pi ft+90)$ or $A \sin(2\pi ft+135)$ for 01

$S(t)=A \sin(2\pi ft+180)$ or $A \sin(2\pi ft+225)$ for 10

$S(t)=A \sin(2\pi ft+270)$ or $A \sin(2\pi ft+315)$ for 11

Where $A \sin(2\pi ft)$ is again a carrier signal to be modulated. When the input data changes, the carrier signal changes the phase accordingly.

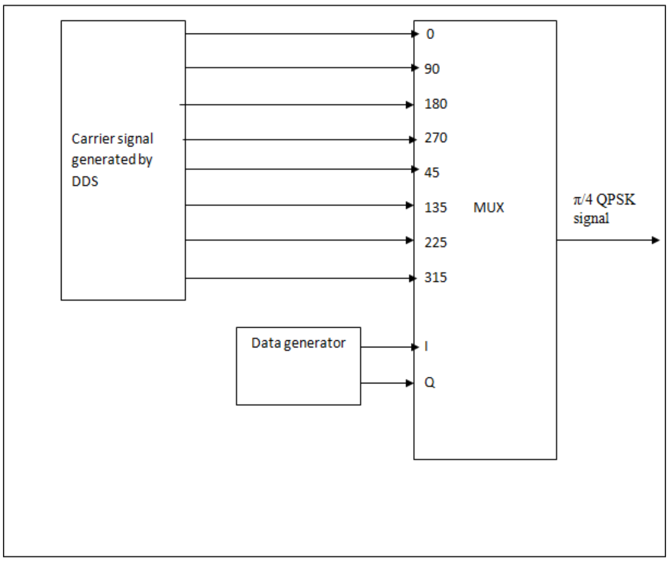

Figure 3: PI/4 QPSK Modulator

A phase shifter used generates different phases required. A multiplexer is used that selects corresponding phase shifted signal. Here, the multiplexer used is 8X1 mux where the two select lines are the dibit whereas the the third that is MSB select line always toggles as 0 or 1. When the data 00 is transmitted the carrier signal is modulated by a phase shift of 0 degrees but when the data 01 is transmitted, the phase shift from other constellation is selected. so every time the dibit is transmitted the carrier signal is phase shifted by the the phase from alternate constellation. A Demodulator is again implemented for PI/4 QPSK . The modulated signal is compared with the threshold and the corresponding transmitted data is detected at the receiver side.

These techniques compared to previously employed PI/2BPSK and PI/4 QPSK are relatively easy. The use of phase shifter to generate the different phase shifted signals instead of using different DDS reduces the complexity of the modulator and also the timing constraints. Also the use of DDS to generate the carrier signal gives the flexibility to perform the modulation at different frequencies. Since the IEEE 802.15.6 WBAN standard has different frequency bands DDS can be effectively used to perform the modulations in these frequency bands. The use of look up table for performing modulation may result in simpler architecture but it will be confined only to single frequency.

4 .SIMULATION RESULTS:

Figure 4 and 5 shows the simulation results for π/2BPSK and π/4QPSK modulator and demodulator respectively. We adopt the ModelSim 6.3g to carry out the algorithms in system level designing. The RTL level simulation is performed by the Xilinx ISE Design Suite 14.4 where we can verify the modulation and demodulation process and the result was correct. All the simulation waveforms are in standard expected form.

The modulations are verified for the different frequency band specified for IEEE 802.15.6 WBAN Standard.

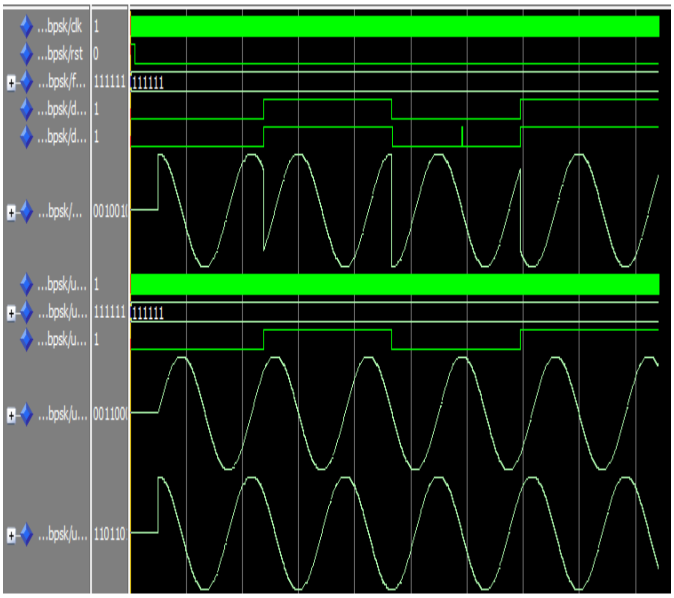

Figure 4. Simulation Results for PI?2BPSK

Figure 5. Simulation Results for PI?2BPS

5. CONCLUSION:

We proposed implementations for PI/2 BPSK and PI/4 QPSK .Both modulations and Demodulations are successfully verified.The algorithm developed for these modulations are unique. Also use of phase shifter for generating carrier signal with different phase shifts instead of using different DDS to generate the different carrier signals has reduced the complexity and the timing constraints. There is a large scope for this work as WBAN plays a key role in the future of e–Health

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