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VLSI execution of Energy Detection Algorithm for WLAN and Worldwide Interoperability Microwave Applications

[1]Sunil Kumar, [2]Prof. Devendra Patle

[1]M.Tech Scholar VLSI , [2]Assistant Professor,

[1,2]Department of Electronics and Communication Engineering (ECE)

[1, 2]School of Engineering, SSSUTMS, Sehore M.P., India

Email id *sunilnitap@gmail.com*

***Abstract* — In this Research paper energy detection technique is applied for WLAN and WiMAX under BPSK modulation method and Monte-Carlo simulations are performed to test the performance of received signals in WLAN and WiMAX. Following to this work VLSI implementation of spectrum sensing using energy detection have been implemented for pseudo random sequence generated signal and BPSK modulates signal. OFDM is used as modulation standard and it is implemented in VLSI for WLAN and WiMAX. Energy detection is a simple spectrum sensing technique, which does not require prior information of signal which is present in the frequency band. But in low signal to noise ratio conditions, its performance is weak, which can be improved by signal processing algorithm. As energy detection is simple and easily implemented in hardware, so it is preferred in emerging standard like IEEE 802.22, Wireless Region Area Network , IEEE 802.11a, Wireless Local Area Network and, World Wide Interoperability Microwave Access.**

***Keywords*— Energy Detection, Spectrum Sensing, WLAN, Wi-MAX, BPSK.**

I. INTRODUCTION

Cognitive radio has become a promising technology that enables a radio device to monitor, sense, detect electromagnetic radio environment and intelligently adapt its communications channel access in which it exists. CR devices monitor a radio spectrum and modify their operational parameters such as frequency, different modulation schemes, and transmitting power, in order utilize available natural resources.

A CR can increase spectrum efficiency leading to higher bandwidth and reduce the burdens of centralized spectrum management by a particular spectrum distribution authority. The cognitive radio is an emerging technology in wireless communication. It is still too early to tell what a cognitive radio seems to be for different wireless applications due to complexity in implementation of cognitive radio in practical.

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A. Motivation and Objective

CR is an advanced technique which reduces the problem of spectrum scarcity in electromagnetic spectrum. Spectrum sensing is one of the method which checks the emptiness of primary user allocated to particular frequency spectrum. There are several methods for spectrum sensing for non-cooperative and cooperative CR users. Some of the techniques for spectrum sensing for non-cooperative CR users are energy detection, matched filter, cyclostationary feature detection. Matched filter and cyclostationary methods are complex techniques compared to energy detection technique. The energy detection technique dose not requires any information about signal structure present in the licensing band to detect the occupancy of user in that band. Energy detection works in high signal-to-ratio values compared to other methods.

B. Cognitive Radio

Cognitive radios "first proposed by Mitola have been chosen as an enabling platform in realizing such dynamic spectrum sharing due to their built-in cognition capabilities. A cognitive radio system is a 'smart' network that can observe the environment, learn from it, and adjust to changing environment conditions. The SAN (software-adaptable network) is analogous to the software-defined radio (SDR) which is the physical control ofthe system that provides the action space for the cognitive process.

According to SAN cognitive radio is designed using OODA loop.

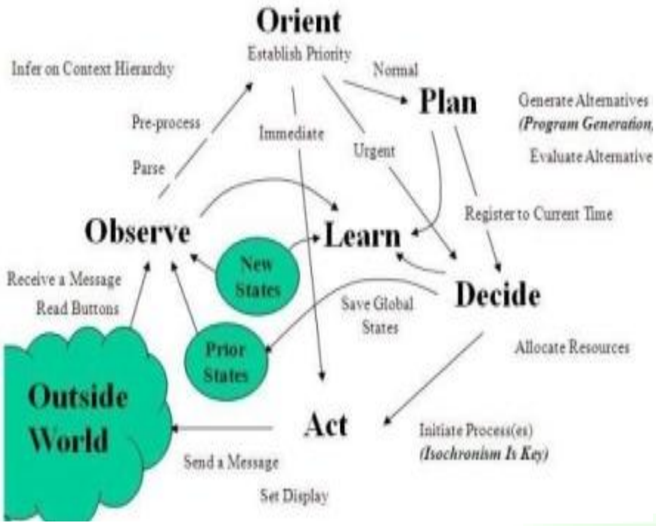

Figure: 1 Cognitive radio cycle

The OODA loopis first used for military officers, later on it was adopted for general decision making process. The loop consists of four main components with other two components. Cognitive radios first proposed by Mitola have been chosen as an enabling platform in realizing such dynamic spectrum sharing due to their built-in cognition capabilities. A cognitive radio system is a 'smart' network that can observe the environment, learn from it, and adjust to changing environment conditions. The SAN (software-adaptable network) is analogous to the software-defined radio (SDR) which is the physical control ofthe system that provides the action space for the cognitive process. According to SAN cognitive radio is designed using OODA loop. The OODA loopis first used for military officers, later on it was adopted for general decision making process. The loop consists of four main components with other two components:

- **Observe:** This process senses the network environment and creates an internal model of it. Information can be observed through sensor in SAN or extracted from previous decisions taken from sensed results. Possible information which are directly observed include the presence of spectrum signal from primary and secondary users, received signal-to-interference and noise ratio, packet delays, selection of node parameters location, channel selection ,transmission power.
- **Orient:** In this process priority are set according to observed information. The cognitive radio elements must interface to sources of networks for effectiveness of cognitive radio to orient it. This step provides guidelines to different cognitive radio elements that how to behave in the network.
- **Plan:** This schedule are planed according to the systems constraints. This step planned the procedure through which cognitive radio elements work. This process is not good choice.
- **Decide:** The cognitive process has observed the network environment and is oriented to the end-to-end objectives, it must make a decision. The decision making is a two- step process
    - A centralized decision-making unit that gathers network state data and distributes state information to the nodes of the network, or
    - A distributed process across the network nodes, with each node making decisions under some degree of autonomy.
- **Act:** Finally an appropriate action is taken during the act step in which message is send, reconfigure the system and then modify power level.
- **Learn:** learning abilities enable communication equipment to evaluate the quality of their past actions. The decision making engine learns from its past successes and failures to tune its parameters and its decision rules to its specific environment.

II. SPECTRUM SENSING USING ENERGY DETECTION TECHNIQUE

Spectrum Sensing from the Cognitive Radio Network Perspective

Signal detection is considered while spectrum sensing for cognitive radio. Spectrum sensing in cognitive radio perspective have some problems due to spectrum policies. There are some policies which have to follow by the CR users to operate in the licensed network. Some of these restrictions are provided below [5]:

No Prior Knowledge on the Signal Structure

There are portions of the spectrum where multiple technologies (using different protocols) share the spectrum. Cognitive radios networks must be able to deal with the existing multiple technologies, as well as new those technologies which are going to beappear in wireless network in future. These networks should be able to work properly in the medium irrespective of the technologies in use. Cognitive user must able to use spectrum without prior information about the signal structure.

Sensing Time,

The work of CR user is to detect the presence of primary user if that band is unused then that is used by secondary user. The secondary users must be designed to free the spectrum as soon as it senses that a primary user appear in the legacy network. These secondary networks sense available spectrum as fast as possible, in the minimum possible Number of received sample without interfering with the primary users. Cooperative spectrum sensing technique decreases the sensing time for the same level of accuracy.

Fading Channels

Spectrum sensing is particularly sensitive to fading environments. Spectrum-sensing devices must be able to detect in heavily faded channels. Several works have focused on sensing for the fading environment in the non cooperative environment, but it is cooperative sensing performs in a better way in fading channels.

III. VLSI Implementation of Energy Detector Technique

A. ***BPSK Modulator:* -** In this BPSK Modulator, the on-board clock frequency is 50 MHz. Therefore the modulator clock which controls the sine wave table has to oscillate at a frequency 32 times slower than that of the basis on-board clock. The data generated and provided to sine wave for modulation must be maintained unalterable during at least a complete cycle of the sine wave. It is constituted by M samples; hence the data clock has to oscillate at frequency M times slower than that of the table addressing generated for sine wave. BPSK modulator is designed using this clock frequency. A package constant is defined which is used during the design of BPSK modulator. In this package constant N is the length of data generator and constant M for the position s of a table which contain the values of sine waves. The number of bits of each word of table is (nbits) and number of bits used as decimals is ndec. All these bits are required to define a constant which used for modulation process of BPSK.

***B. VHDL implementation of OFDM for Energy Detection* -** The OFDM modulation is a multicarrier modulation. The single carrier modulation using VHDL is designed in previous section. The basic blocks to design OFDM is signal mapped to implement BPSK modulator, serial to parallel converter, IFFT block, parallel to serial converter and then energy detector. This chapter frame out the entire module to implement OFDM [21].

Serial to parallel converter (SIPO): In SIPO data are entered serially and comes out parallel manner. The operation is performed by shifting data from left to right hand direction one bit at each clock transition signal. The data entered to the shift register serially one after another from left hand side and after four clock transition the 4 bit register has four bit parallel output. The data are comes out in single clock signal. This register has four serial input and four parallel output. The circuit diagram of Serial to parallel converter circuit is shown in Figure 4-6.

IV. SIMULATION & RESULT FOR DIFFERENT BLOCKS OF OFDM

A. Simulation & Result for Different Blocks of OFDM

The OFDM consists of different blocks. These blocks are SIPO, PISO, and IFFT blocks. Figure 4-18 gives information that parallel output generated with positive clock and negative reset signal for serial input data. Figure 4-19 represents serial data output generated with positive clock and negative reset signal for parallel input data. The load and shift are act as control signal. When load is 1, all the parallel data are loaded and when load is 0, data are comes out serially.

B. Simulation result for SIPO

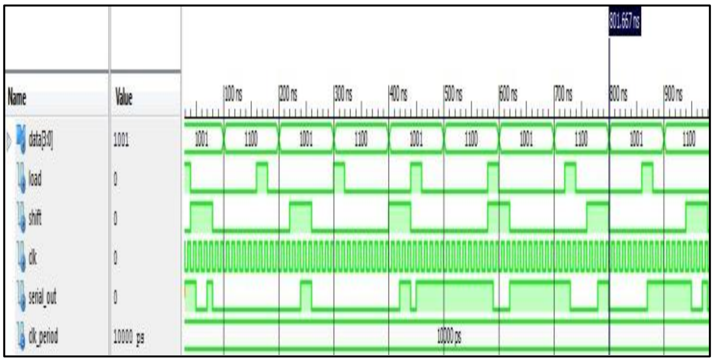

Figure:2 Simulation result for Serial in parallel out shift register

C. Simulation result for PISO

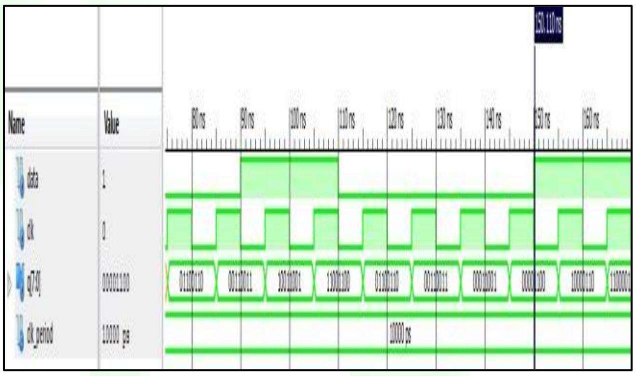

Figure: 3 Simulation result for parallel in serial out shift register

D. Simulation result for IFFT

In this section radix-4 is realized. OFDM requires IFFT for orthogonality. A single input is divided into two parts- real and imaginary part and generated output is also consistsof two parts real and imaginary part. Total four inputs are taken and total outputs are generated to implement radix-4 IFFT shown in figure 4.

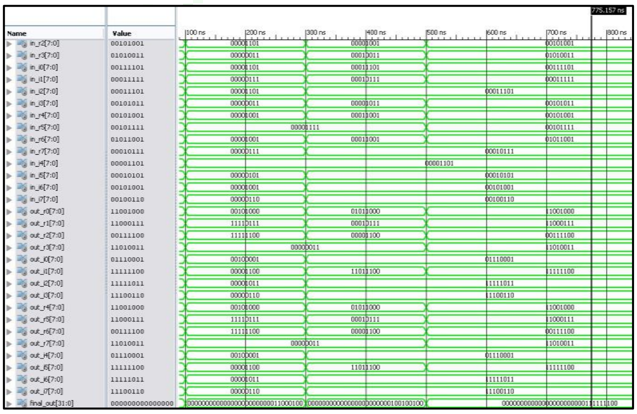

Figure: 4 Simulation result for radix-4 IFFT

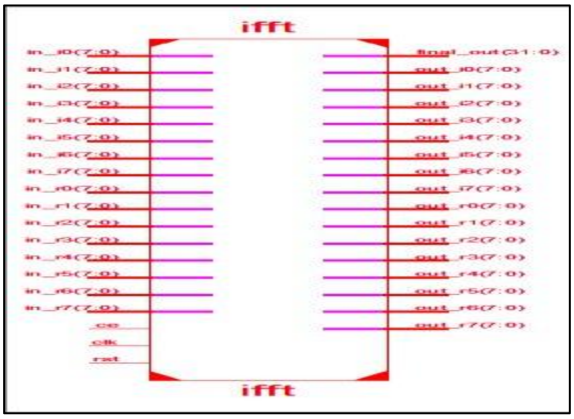

Figure 5: RTL for radix-4 IFFT

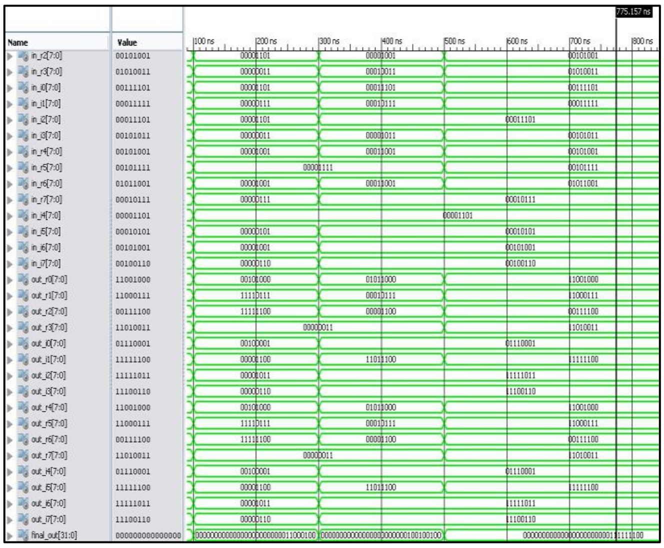

Figure 6: Simulation result for radix-4 IFFT

Table 1: Design summary for IFFT

Device Utilization Summary (estimated values)				% Logic
Utilization	Used	Available	Utilization	Number of
Slices	4		960	0% No. of
Slices Flip flop	8		1920	0% No. of
4 input LUTs	8		1920	0% No. of
Bonded IOBs	11		66	16% No. of
GCLK	1		24	4%

Table 2: Desing Statistics for 4 point radix-2 IFFT

Cell	Gate count
IOS	11
BELS	8
LUT2	1
LUT3	7
FD	8
Flip flops/latches	8
Clock Buffers	10
BUFGP	1
IBUF	9
0BUF	1

Speed- 485.909MHz
Power: 0.034W

E. Simulation result for IFFT for N=8

In this section radix-4 is realized. The radix-4 algorithm is used to found out IFFT of N =8 number of samples. Finally IFFT of eight samples are taken at output side and energy value is detected. Total eight inputs are taken and total eight outputs are generated using radix-4 IFFT shown in Figure 4-22. Figure 4-23 Shows RTL of BPSK and Table 4-5 presents design summary of BPSK modulator.

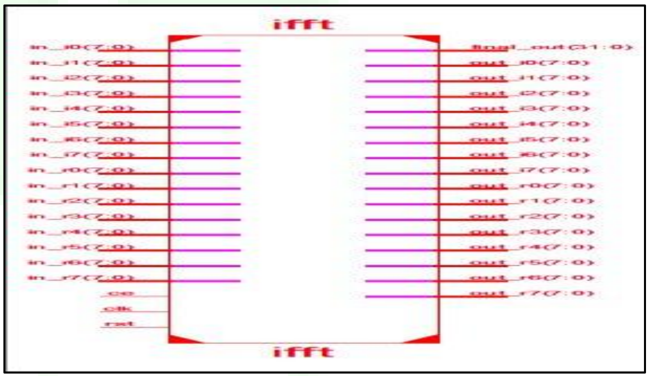

Figure 7: RTL for radix-4 IFFT

Table 3: Design Summary for radix 4 IFFT for N=8

Device Utilization summary (Estimated values)			%
Logic Utilization	Used	Available	Utilization
Number of Slice LUTs	395	28800	1%
Number of bonded IOBs	272	480	56%

Table 4: Design statistics for radix-4 IFFT for N=8

cell	Gate
IOs	291
LUT2	387
LUT3	4
LUT6	4
MUXCY	334
VCC	1
XORCY	392
IO Buffers	272

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IBUF	112
BEL	183
OBUF	160
GND	1

Hardware implementation of Energy detection for PRSG

The energy detector module is implemented using PRSG with Xilinx 10.1. The generated output is binary sequence .This energy detection for PRSG is dumped in Sparten- 3E. The resultant energy detected signal is viewed through chipscope pro shown in Figure 4-24. The result shows energy detected Figure 4-24 value for many samples. The behaviour of the PRSG is checked by using ISE Simulator. We use Xilinx 13.3 to write VHDL code for detected energy value for PRSG. The input to PRSG is clk, rst and output is energy detected values

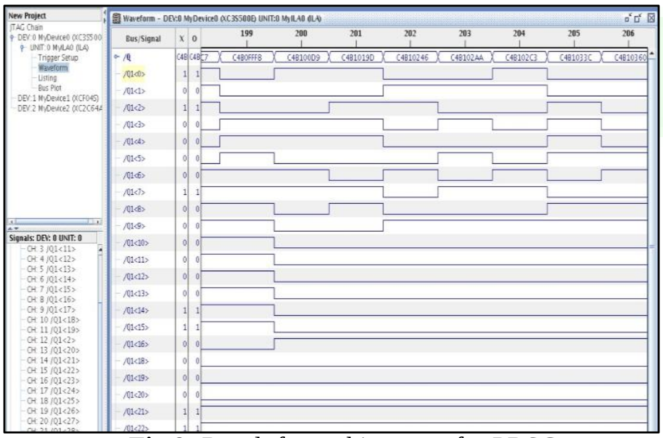

Fig 8: Result from chip scope for PRSG

V. CONCLUSION AND FUTURE SCOPE

The performances of spectrum sensing using energy detection technique are studied for single-carrier modulation and multicarrier modulation. The single carrier modulation and multicarrier modulation technique performances are verified using Monte-Carlo simulation. The performance analysis can be done by plotting ROC cure between probabilities of false alarm vs. probabilities of detection and signal to noise ration vs. probability of detection. This thesis presents performance of single carrier modulation for BPSK and multicarrier modulation for OFDM. In this thesis OFDM modulation is figured out in the field of WLAN and WiMAX standards. WLAN uses IEEE 802.11a standard and WiMAX uses IEEE 802.16 standard. The works are figured out using parameters based on IEEE standards for WLAN and WiMAX. The BPSK modulation and OFDM modulation performances are studied.

The VHDL implementation of energy detector module is provided in this thesis. The performance is figured out for energy detector module using input as pseudorandom sequence generation for different number of samples. The Energy detection is carried out for BPSK for different number of samples. The energy detector for OFDM is studied only for 8-point IFFT.

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