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An Energy Detection Algorithm for Cognitive Radio Technique

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Abstract—The electromagnetic spectrum is a limited and natural resource. Being a limited resource it cannot accommodate rapid growing demand of new static channels allocation policies. This allocation tends to increase in spectrum scarcity problem. Cognitive radio (CR) technology is an enhanced wireless radio design which aims to increase spectrum utilization by identifying unused and under-utilized spectrum in dynamically and rapidly changing environments. The most important thing is to have a method of sensing primary user in licensed frequency band using dynamic spectrum allocation policies to utilize unused spectrum by cognitive radio

A simple spectrum technique is through energy detection, which does not require type of information present in signal of that frequency band but we need to improve the performance of the signal as in low signal to noise ratio (SNR) as performance is weak in this region the performance can be improved by signal processing algorithm. As energy detection is simply possible and is easy to implement in hardware, so it is preferred in emerging standard like IEEE 802.22, Wireless Region Area Network (WRAN), IEEE 802.11a, Wireless Local Area Network (WLAN) and 802.16, World Wide Interoperability Microwave Access (WiMAX).

1. INTRODUCTION

Wireless communication system usage is increasing day by day due to increasing demand of new communication devices and technology available in those compact devices. The mass useful spectrum is already allocated to several licensed users (e.g. mobile carriers, TV broadcasting companies) they generally that do not utilizes all the allocation spectrum band over the geographical locations all the time. The licensed users pay licensing fee to the government agencies like Telecom Regulatory Authority of India (TRAI) and Federal Communications Commission (FCC) in the United States. If this unused spectrum is allotted for unlicensed user (e.g. private users, short range networks) then some promising solution could be obtained for spectrum scarcity problem. Some of the examples are wireless toys, Wi-Fi and Bluetooth operate in unlicensed bands. These two standards share some part of undesirable spectrum with many other technologies [1, 2].

The whole requirement of this CR technique is that if the frequency of the channels goes to same value they mix and information which an individual channel is caring also mixes and no proper message reaches to the destination end. The best way to stop this mixing or inter channel distortion we have to allocate different frequencies channel to different information sources so definitely we need an organization which does this work so that no inter carrier distortion exists like TRAI and FCC.

Cognitive radio (CR) technology which enables a radio device to observe, sense, detect electromagnetic radio environment, synthesize and intelligently adapt its communications channel access in which device exists. CR devices after monitoring a radio spectrum and then modify their operational parameters such as phase, frequency, applied modulation schemes, and transmitting power, in order utilize available unused natural resources. A CR can improve and increase the spectrum efficiency which leads to higher bandwidth and reduce the load of centralized spectrum management by a particular spectrum distribution authority. The cognitive radio is an evolving technology in wireless communication.

Rising Cognitive Radio Cycle

Cognitive radios (CR), first proposed by Mitola. A cognitive radio system is self adaptive system network that can observe and sense the environment, learn from it, and adaptive to changing environment conditions this adaptive nature may be termed in a single word as smart. The SAN (software-adaptable network) is similar to that of software-defined radio (SDR) which is the hardware control of the system that provides the action space for the cognitive process. According to SAN cognitive radio is designed using OODA (Observe-Orient-Decide-Act) loop. The OODA loop is 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:

1. Observe: In this process the system senses the network environment and creates an working model of it. Information can be observed through sensor in SAN or can be extracted from previous taken decision or information stored from sensed results. The information which are directly observed include the presence of spectrum signal from primary and secondary users, received signal-to-interference and noise ratio (SINR), packet delays, selection of node parameters (location, channel selection, transmission power.

2. Orient: In this process preference is set according to sensed information. The cognitive radio elements must interact to sources of networks for effectiveness of cognitive radio to orient it. This step provides protocol for different cognitive radio elements that how to initiate or behave in the network.

3. 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.

4. Decide: Since the cognitive process has now observed the network environment and is oriented to he end-to-end objectives, it has to make a decision. The decision can be done on two step process

(i) A centralized mechanism could be developed can be called as decision-making unit whose work will be to gathers network state data and then distributes the state information to the connected nodes of the network, or

(ii) Another process where we distribute whole process into small units where all individual nodes have capacity to take decision by considering some certain conditions pre -programmed in them.

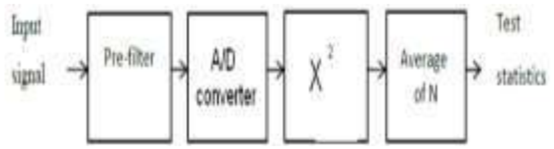
5. Act: Then Finally an appropriate action is taken and a message is send, reconfigure the system and then modify power level.

6. Learn: the system learning abilities enable the communication system to store and evaluate the quality of their past actions. The decision making system is a self learning system which learns from its past successes and failures to tune its parameters and its decision rules to its specific environment.

Energy Detection

It is a non cooperative detection technique. It is simple because it does not require prior information about structure of signal. Energy detection detects the spectrum by measuring the energy of the received signal in a certain frequency band; also called radiometry to acquire maximum strength of the received signal antenna arrays could be used. It is the most common detection method for spectrum sensing in cognitive radio networks.

The ED is said to be a eye less signal detector because it does not need to know the type and information in the signal the structure of the signal. It estimates the presence of a signal by using comparison technique by the energy received with a known threshold λ derived from the statistics of the noise.



The Figure 1.1 General Block Diagram of Energy Detection for Analog Input Signal

Let y(k) be a samples of received signal k =1, 2,...,N at the signal detector. Then, the decision statistics can be stated as

$$E(K) = \begin{cases} H0, \ if \ \ E < \lambda \\ H1, \ if \ E \geq \lambda \end{cases} \qquad (3.3)$$

Where E = E[| y(k) |2] is the estimated energy of the received signal λ is chosen to be the noise variance σ2 [12] In practical, one does not dispose of the actual received energy power E. The ED technique approximation, where

$$\hat{E} = \frac{1}{N}\sum_{1}^{N} |Y(k)|^2 \qquad (3.4)$$

As the number of samples N becomes large, by large number law, converges to E. Nevertheless, in spite of its simplicity, the ED is not a perfect solution. The approximation of signal energy E gets better as N increases. Thus, the performance of the ED is directly linked to the number of samples.

a) Advantages: Implementation simplicity and computational complexities low: an energy detector can be implementation is similar to that of a spectrum analyser which is done by averaging frequency bins of a FFT. Since it is easy to implement, the recent work on detection of the primary user has generally adopted the energy detector.

b) Disadvantages: The performance of the energy detector is highly susceptible to noise level uncertainty. The noise uncertainty causes problems especially in the case of a simple energy detector because it is difficult to set the threshold properly without the knowledge of the accurate noise level. Secondly, an energy detector can't differentiate between modulated signals, noise, and interference

Simulation Result for Binary Phase Shift Keying Result for BPSK Using AWGN Channel

With the binary hypothesis simulation was made. Input is taken as random bit sequences and the received signal at receiver is original signal with passes through AWGN [14]. The performance of signal can be studied by using ROC curve. The Roc curve is plotted between probability of detection (pd) and signal-to -noise ratio (SNR) in Figure 3-8. The detection performance can be performed finding the probability of detection by varying SNR from -25 dB to 10 dB using Monte Carlo simulation. The graph is plotted for SNR values on X-axis and probability of detection on Y-axis. Here we have taken different values of probability of false alarm i.e., 0.1, 0.05 and 0.01 and number of samples N. It is observed that performance is better at higher SNR values for a particular probability of false alarm with higher number of samples. And at high value of probability of false alarm signal detects faster compare to lower value of probability of false alarm for same number of samples.

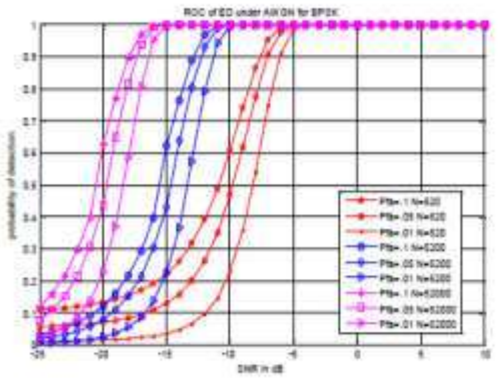


Figure 1.2 ROC for BPSK, Pfa=0.1, Pfa=0.01, Pfa=0.5

Again ROC curve is plotted between probability of false alarm on X-axis and probability of detection on Y-axis as shown in Figure 1.2. Here we have varied probability of false alarm from 0 to 1 with different number of samples and different SNR values. It is observed that detection performance increases with higher value of SNR with a fixed value of N.

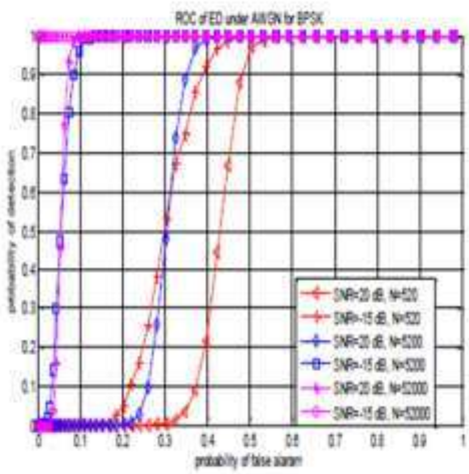


Figure 1.3 ROC for BPSK at different SNR

Architecture of Energy Detection Technique

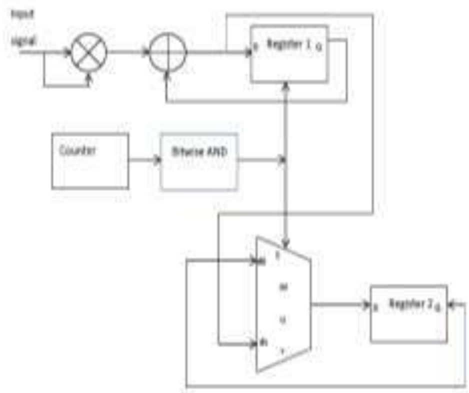


Figure 1.4 Architecture of Energy Detector

Architecture is proposed for ED technique in Figure 1.4 This ED model consists of multiplier, adder circuit, register, counter and multiplexer. The ED model is tested by providing different types of signal to input of ED [19].

The inputs samples are passed through the multiplier in order to get the square of the samples inputted to it. The resulted squared samples are added and then are accumulated using an adder-register arrangement, as shown in Figure 1.4. Here different numbers of samples is taken to have detected energy value However, the value N can be taken higher for better accurate result.

The counters initiates its count from 0 to total N number of samples continuously. For Example if total numbers of samples are taken 16 then, then counter counts from 0-15 and When 16 samples are reached, the content of the counter becomes 15; then, the output of bitwise AND becomes “1,” and Register1 is cleared or reset. The select Signal for multiplexer Mux now becomes “1,” and the energy value for 16 samples is fed to Register2, which forms the output. During the course of counting from 0 to 15, i.e., during the accumulation of 16 samples, the output of bitwise AND gate is “0;” hence, the Mux will select the output of Register2 itself, and hence, the output remains constant. As a result of this, irrespective of the time of duration of the input signal, the energy for 16 samples will be collected at the output. Initially pseudo-random code is used as input signal. The pseudo random generation block diagram is given in Figure 1.4

2. PSEUDO RANDOM GENERATOR

The sequence generated by PRSG. It is a shift register whose input is taken as random value. The only single bit is function of XOR logic. Here first input bit provided by taking linear XOR function of first and last bit. The other bits are depended on previous bit. The operation is deterministic to generate random bits. The sequence of bits are produced by shift registers and its current state completely determined by its previous state. The register has finite number of states and random sequence is repeated after some cycles. The PRSG can be well explained in Figure 1.5. It produces a sequence of bits which is random and generates a long cycle sequence. [20]

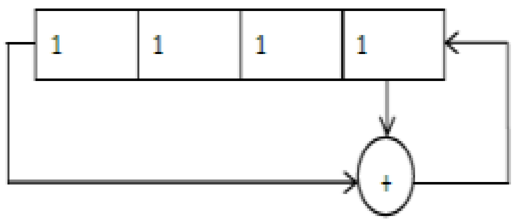


Figure 1.5 XOR operation of Pseudo Random sequence Generator

2.1 VHDL Implementation of BPSK for Energy Detection

Figure 2.1 Block Diagram of BPSK Modulator with Energy Detector Module.

In this chapter we are described designed of BPSK modulator and energy detected value from this BPSK modulator. The BPSK modulator is constituted by a random generated pseudo sequence and BPSK modulator itself. The BPSK modulator block diagram shown in Figure 2.1.The pseudo random data generator has two inputs (clk and rst) and one output (serial_data), BPSK modulator has three inputs (clk,reset,data), one output (BPSK_modulateddata) and energy detector has 3 inputs (clk, rst, Energy_data)and has one output(BPSK_ Energy output).

Data Generation Using Pseudo Random Sequence Generator

The random sequence generator has generated by using Pseudo-random-Sequence- Generator (PRSG). The PRSG is constituted from four registers and total number of sequence generated is=24-1. The detail about random sequence generator is explained in previous chapters. The generator of random sequence is little bit different than the previous sections. In this part random sequence is generated by XORing output of LSB and output of MSB. The block diagram is shown in Figure 4-5

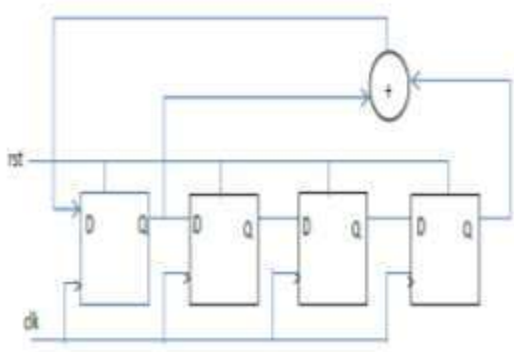


Figure 2.2 Block Diagram for Pseudo-random data generator for BPSK Modulator

The PRSG responds to positive edge triggered of clock signal and negative edge triggered reset signal which forces the register to logic 1 level. The rising edge of clock makes the data of DFF transferred to its output Q.

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.

A table is required to generate samples for sine wave. Thus, we created a package, where all the necessary functions are provided to define sine wave samples. The package name is “realbit”. It has two functions “trun” to generate samples of sine wave. The function “trun” is converted a real number to a binary number of nbits bits by two’s complement method (signed bit). Finally, we have defined a function called sin_table, which contains the sample values of the sine wave in an array of integers in M consecutive positions. The generated clock signal (clk) is the on-board 50 MHz clock oscillator. A sine_table that contains the samples of the sine wave are stored in an array of integers of M length. Given that the samples are sequentially positioned in the table, at positive edge of clock signal a new sample will be taken from the table along the time. Hence, after M jumps, the representation of the sine wave will be completed.

We have created the value from table in the form that if the data digit supplied by the data generator (serial_data) is “0” or this same value but negated if the data digit is “1”. This is generation of process of a BPSK modulation. After that, BPSK modulated data passed through Energy Detector Module and Energy output is found out.

3. CONCLUSION

This thesis provides some idea about cognitive radio technology, under its different classifications and different spectrum sensing techniques. The work of this thesis mainly focus toward energy detection technique in different wireless communication areas and finally energy detection technique implemented using VHDL code.

3.1. Contribution

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 being verified using Monte-Carlo simulation. The performance analysis is done by plotting ROC cure between probabilities of false alarm vs. probabilities of detection and signal to noise ratio 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 described 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.

3.2 Limitation

All the works in this thesis are based on MATLAB and VHDL simulation. The simulation results are taken for various different number of samples to study energy detection performances. The Monte -Carlo simulation done only for WLAN and WiMAX using OFDM. In this work simulation works are taken for digital input signal and output are also taken out inform of digital. In this thesis IFFT is implemented using radix-4 algorithm. The higher sample IFFT implementations are required to transmit higher samples of data in VHDL. This implementation can be done through floating point IFFT implementation using VHDL.

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