Spectrum Sensing In Cognitive Radio Using Matlab

Garima Nautiyal, Rajesh Kumar

Abstract-The radio frequency spectrum is a scarce natural resource and its efficient use is of the utmost importance. The spectrum bands are usually licensed to certain services, such as mobile fixed broadcast, and satellite, to avoid harmful interference between different networks. Most spectrum bands are allocated to certain services but worldwide spectrum occupancy measurements show that only portions of the spectrum band are fully used. Moreover, there are large temporal and spatial variations in the spectrum occupancy. In the development of future wireless system the spectrum utilization functionalities will play a key role due to the scarcity of unallocated spectrum. Moreover, the trend in wireless communication system is going from fully centralized system into the direction of self-organizing system where individual nodes can instantaneously establish ad hoc networks whose structure can change over time. Cognitive radio, with the capabilities to sense the operating environment, learn and adapt in real time according to environment creating a form of mesh network, are seen as a promising technology.

The paper presents an overview of cognitive radio, various spectrum sensing technique used in CR and also describe the state-of-the-art in cognitive radio standards and regulation. In this project we have implemented and analyzed the energy detection technique for spectrum sensing in CR.

Keywords: Cognitive Radio, Spectrum Sensing, Energy Detection, Primary user, Secondary user, Threshold, Probability of detection, Probability of false alarm.

I. INTRODUCTION & MOTIVATION

With the development of a host of new and ever expanding wireless applications and services, spectrum resources are facing huge demands. Currently, spectrum allotment is done by providing each new service with its own fixed frequency block. As day passes demand for spectrum are expected to increasing rapidly and it would get in future. As more and more technologies are moving towards fully wireless system, demand for spectrum is enhancing.

Most of the primary spectrum is already assigned, so it becomes very difficult to find spectrum for either new services or expanding existing services. At Present government policies do not allow the access of licensed spectrum by unlicensed users, consists them instead to use several heavily populated, interference-prone frequency bands. As the result there is huge spectrum scarcity problem in certain bands. In particular, if the radio spectrum is scanned, including the revenue-rich urban areas, it can be seen that some frequency bands in the spectrum are unoccupied for some of the time and many frequency band are only partially occupied, whereas the remaining frequency bands are heavily used [1].

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The radio spectrum is limited resource and is regulated by government agencies such as telecom Regulation Authority of India (TRAI) in India, Federal Communication Commission (FCC) in the United States. Cognitive radio is a novel technology which improves the spectrum utilization by allowing secondary user to borrow unused radio spectrum from primary licensed users or to share the spectrum with the primary users. As an intelligent wireless communication system, cognitive radio is aware of the radio frequency environment, selects the communication parameters (such as carrier frequency, modulation type, bandwidth and transmission power) to optimize the spectrum usage and adapts is transmission and reception accordingly [3]. By sensing and adapting to the environment, a cognitive radio is able to fill in the spectrum holes and serve its user without causing harmful interference to the licensed user. To do so, the cognitive radio must continuously sense the spectrum it is using in order to detect the re-appearance of the primary user. Once the primary is detected the cognitive radio should withdraw from the spectrum instantly so as to minimize the interference. This is very difficult task as the various primary users will be employed different modulation schemes, data rates and transmission powers in the presences of variable propagation environment and interference generated by other secondary users [1].

II. DEFINITIONS

After Mitola's coined the world "Cognitive Radio" its definition is also growing as research interest in CR in increasing. Regulatory bodies, prominent researchers and forums define in different ways.

According to Mitola's Cognitive radio can be said as next generation of software defined radio (SDR). They are flexible in terms of their transmission characteristics in terms of frequency, bandwidth, ISP which makes smart decisions to configure the SDR at any point in time to achieve a particular goal [7]. By combining these two technologies makes a radio intelligent and flexible and which helps to adapt it to the variations in the environment, user requirements as per the other radio users.

Adaptation to changes and requirements should lead to highly reliable communication whenever and wherever required, while making efficient use of spectrum. Good cognitive radio uses analysis done for long period to know about the environment and also his own behaviour.

Simon Haykin defines Cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment and uses the methodology of understanding by building to learn from the environment and adapt its internal states to statistical variations in the incoming radio frequency stimuli by making corresponding changes in certain operating parameters in real time, with two primary objectives in mind:

- highly reliable communications whenever and wherever needed
- efficient utilisation of radio spectrum

"Radio whose control processes permit the radio to leverage situational knowledge and intelligent processing to autonomously adapt towards some goal."

2.1. Cognitive Cycle:

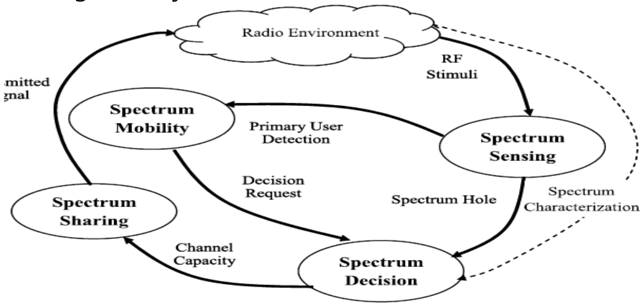

Figure No 2.1. Cognitive cycle

There are four main steps in Cognitive cycle [15]:

1. **Spectrum Sensing**: It refers to detect the unused spectrum and sharing it without harmful interference with other users. It is an important requirement of the Cognitive Radio network to sense spectrum holes, detecting primary users is the most efficient way to detect spectrum holes.
2. **Spectrum Management:** It is the task of capturing the best available spectrum to meet user communication requirements.
3. **Spectrum Mobility:** It is defined as the process where the cognitive user exchanges its frequency of operation
4. **Spectrum Sharing**: This refers to providing a fair spectrum scheduling method among the users. Sharing is the major challenge in the open spectrum usage.

III. SPECTRUM SENSING

3.1 Introduction

An important requirement of the CR is to sense the spectrum holes. It is designed to be aware of and sensitive to the changes it's surrounding. The spectrum sensing function enables the cognitive radio to adapt to its environment by detecting the primary users that are receiving data within the communication range of an CR user. In reality, however, it is difficult for a cognitive radio to have a direct measurement of a channel between a primary transmitter detection based on local observations of CR users [5]. In [1] the spectrum has been classified into three types by estimating the incoming RF stimuli, thus, black spaces, grey spaces and white spaces. Black spaces are occupied by high power local interferer some of the time and unlicensed users should avoid those spaces at that time. Grey spaces are partially occupied by low power interferers but they are still candidates for secondary use. White spaces are free RF interferers except for ambient noise made up of natural and artificial forms of noise e.g. thermal noise, transient reflection and impulsive noise. White spaces are obvious candidates for secondary use [1].

The goal of the spectrum sensing is to decide between the two hypotheses, namely

$$x(t) = n(t), H0$$

$$x(t) = hs(t) + n(t), H1$$

Where X(t) is the signal received by the CR user, s(t) is the transmitted signal of the primary user , n(t) is the AWGN band h is the amplitude gain of the channel. H0 is a null hypothesis, which states that there is no licensed user signal. Generally, the spectrum sensing techniques can be classified as transmitter detection, cooperative detection, and interference-based detection, as shown in Fig 4.1.

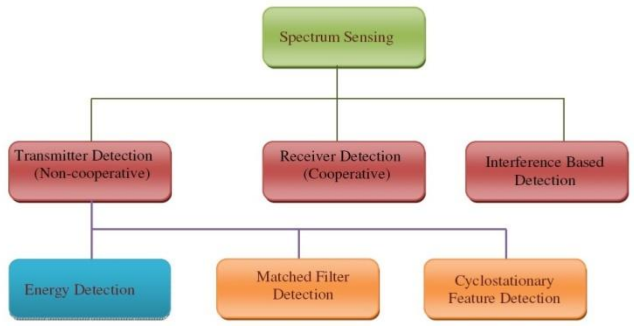

Figure No 3.1 Classification of Spectrum Sensing Techniques

3.2 Classification of Spectrum sensing techniques

- **Matched filter detection**
- **Energy detection**
- **Feature detection**
- **Cooperative detection**
- **Interference-based detection**

In this project we used energy detection technique.

3.3. Energy Detection

If the secondary user cannot gather sufficient information about the PU signal, the optimal detector is an energy detector, also called as a radiometer.

It is common method for detection of unknown signals. The block diagram of the energy detector is shown in Figure 4.2.

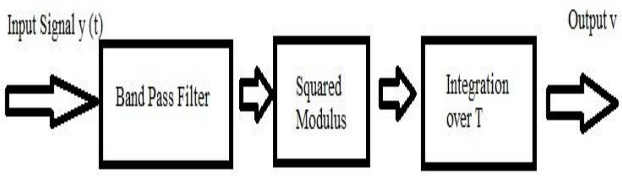

Figure No 3.2. Energy detection

First, the input signal y(t)is filtered with a band pass filter (BPF) in order to limit the noise and to select the bandwidth of interest. The noise in the output of the filter has a band-limited, flat spectral density. Next, in the figure there is the energy detector consisting of a squaring device and a finite time integrator.

The output signal V from the integrator is

$$\boldsymbol{V = 1/T \int_{t-T}^{t} |y(r)|^2 dr}$$

Finally, this output signal V is compared to the threshold n in order to decide whether a signal is present or not. The threshold is set according to statistical properties of the output V when only noise is present. The probability of detection Pd and false alarm Pf are given as follows.

$$\boldsymbol{pd = p\{y > \lambda \backslash H1\}}$$

$$\boldsymbol{pf = p\{y > \lambda \backslash Ho\}}$$

From the above functions, while a low Pd would result in missing the presence of the primary user with high probability which in turn increases the interference to the primary user, a high Pf would result in low spectrum utilization since false alarm increase the number of missed opportunities.

Since it is easy to implement, the recent work on detection of the primary user has generally adopted the energy detector. However, the performance of energy detector is susceptible to uncertainty in noise power. In order to solve this problem, a pilot tone from the primary transmitter is used to help improve the accuracy of the energy detector. The energy detector is prone to the false detection triggered by the unintended signals.

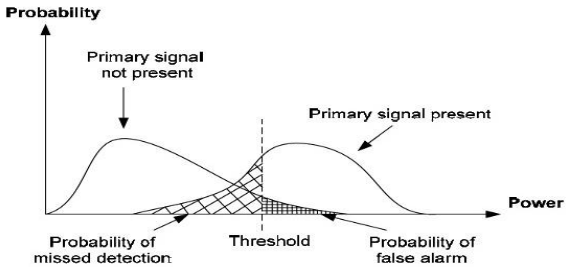

Figure No 3.3.Trade-off between missed detection and false alarm

A simple energy detector works poorly for frequency hopping spread spectrum signals. The channelized radiometer is multichannel receiver that has several energy detectors that integrate energy in many frequency bands simultaneously. It is especially useful detecting frequency hopping spread signals. An analysis of the effects of frequency sweeping on a channelized radiometer is presented in. It is assumed that the signal to be detected uses slow frequency hopping and that sweeping is faster than hop dwell time. In a practical signal detection system, the instantaneous bandwidth may be limited. In frequency sweeping, the centre frequency is changed as a function of time to cover a wider bandwidth. Numerical examples in demonstrate that if the number of hops observed per decision is small, sweeping can be necessary to get the desired performance. When the channel is fading, the best performance s obtained using fast sweeping. The drawback of channelized radiometer approach compared to a simple energy detector is the increased complexity.

IV. SIMULATION DIAGRAM OF COGNITIVE RADIO USING ENERGY DETECTION TECHNIQUE

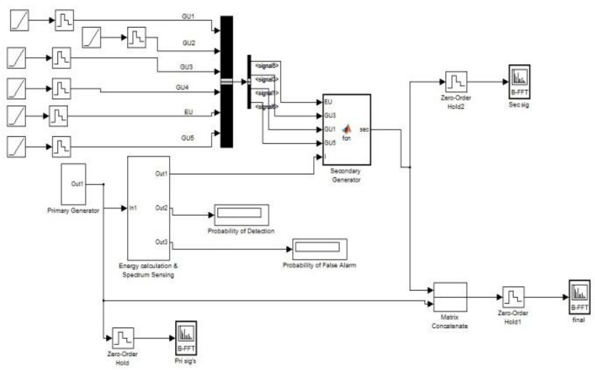

Figure No 4.1. Implementation block for energy detection

4.1. Primary Generator Block

The block representing the primary signal generation is shown in figure 4.2.

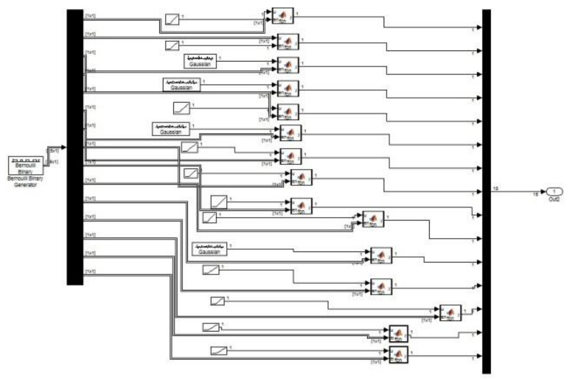

Figure No 4.2. Primary Generator block

4.2. Energy detection & Spectrum Sensing block

The block representing the Secondary signal generation is shown in figure 5.2.

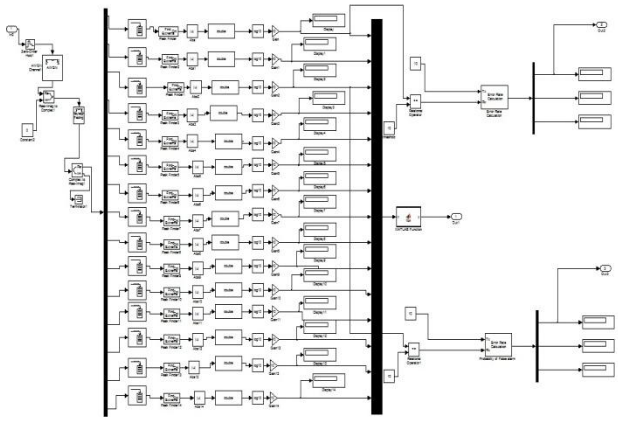

Figure No 4.3. Energy detection and spectrum sensing block

V. RESULTS & ANALYSIS

This chapter represents the plots obtained after analysis.

5.1. Scope Plots

The following figures represented the plots of “Primary signal scope”, “Secondary signal scope” and “primary and secondary signal scope” of the simulated model, respectively.

In figure 5.1, the peaks represented the generated primary signal and the lines represent the noise in the vacant frequency slots.

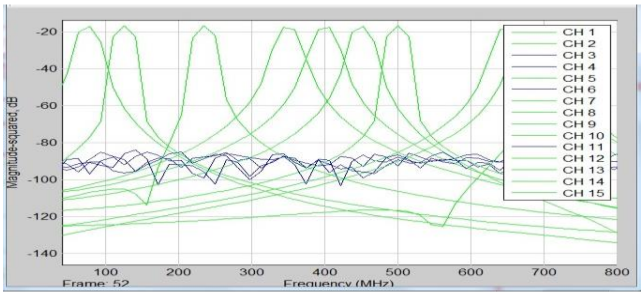

Figure No 5.1. Scope plot representing Primary signals

Figure 5.2, the secondary signal generated on the vacant frequency slots identified by energy detection, are shown.

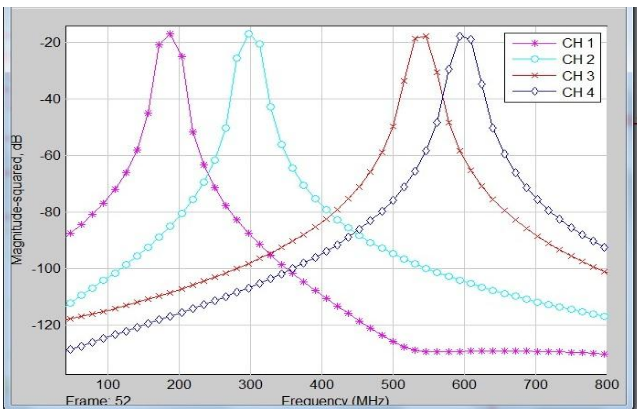

Figure No 5.2.Scope plot representing Secondary signals

In figure 5.3, all of the generated signals present in the spectrum band are represented with green peaks representing primary signals, colour peaks representing secondary signals and black lines representing noise signals.

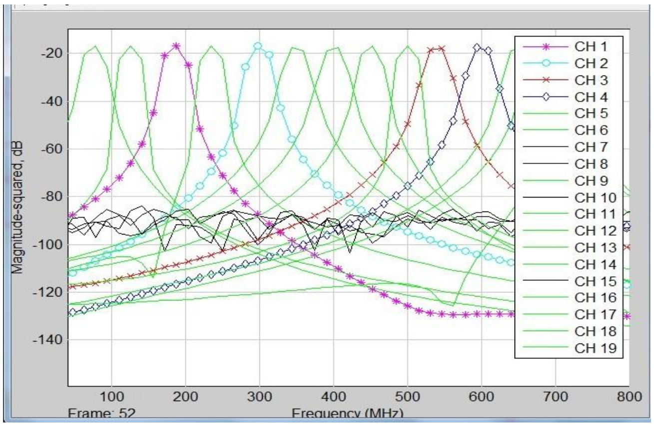

Figure No 5.3. Scope plot representing Primary & secondary signals

VI. CONCLUSION

This work presented here has been implemented and analyzed successfully.

- It can be seen from figure 5.1 that primary signals have been generated successfully.
- It can be seen from figure 5.2 that energy calculation and detection of generated primary user signal have been done & empty slots have been found successfully.
- It can be seen from figure 5.3 that secondary user signals have been generated on allocated vacant slots with priority consideration.

VII. ACKNOWLEDGMENT

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