ISSN [Online]: 2583-2654

# Cognitive Radio Spectrum Sensing Using MATLAB Simulink

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Abstract— Cognitive Radio (CR) is an emerging intelligent wireless Communication Technology. It is a technique in which secondary user searches for a free band to operate in while primary user is not using its licensed band. Spectrum sensing that enables the cognitive radio to search for the free bands. It helps to detect the spectrum hole so that they can be used by secondary user. In this paper spectrum sensing detection methods like matched filter, and Energy Detection for CR is implemented using MATLAB Simulink software.
*Key words: Cognitive radio, FCC, QOS, Energy detection (ED), Spectrum sensing, primary Users, Secondary User (SU).*

## I INTRODUCTION

Spectrum sensing is a key function of cognitive radio to prevent the harmful interference with licensed users and identify the available spectrum for improving the spectrum utilization. The advent of increasing interests in wireless services resulted in dramatic increase in the demand for radio spectrum. With the increase in the trend for the emergence of new wireless technologies and applications there has been the compelled need for broadband wireless access and it has been continuously increasing since past decades. A number of different methods are proposed for identifying the presence of signal transmission, such as matched filter detection, energy detection, feature detection techniques.The spaces across frequency, time and space should be reliably identified. The secondary system monitors a licensed frequency band and opportunistically transmits when it doesn't detect any primary signal. Spectrum sensing has gathered more attention because of the fact that there is relatively low infrastructure cost and compatibility with legacy primary systems [1]. Recent study shows that some frequency bands in the spectrum are mainly unused most of the time and some

are less occupied. This leads to spectrum under utilization. Cognitive radio is one such technique to solve such spectrum problem. It helps to detect the spectrum hole so that they can be used by secondary user. In this paper a prototype system for designing and also explores Simulink based, matched filter detection, Energy. In this paper types of spectrum sensing techniques and cognitive radio functionality are dealt with. Simulation results for various parameter types of signals have been reported.

## II COGNITIVE CYCLE

The two important characteristics of cognitive radio are:

a) Cognitive capability: Cognitive capability refers to the ability of the cognitive radio technology to capture or sense the information from its radio environment.

b) Reconfigurability-CR: Reconfiguration enables the cognitive radio to be programmed dynamically according to the radio environment. Cognitive Radio mainly does four functions [2].

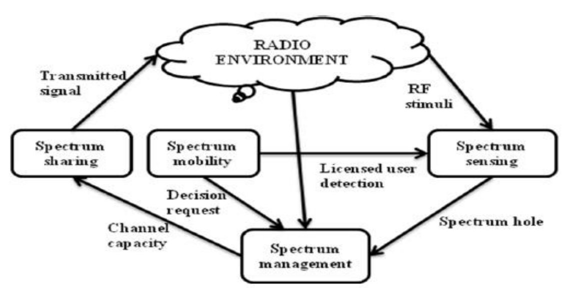



**Fig.1 Basic Cognitive Cycle**

**Spectrum Sensing:** Cognitive Radio continuously looks for the unused spectrum which is known as the spectrum hole. This property of cognitive radio is termed as spectrum sensing.

**Spectrum Management:** Once the spectrum holes found cognitive radio selects the available hole or channel. This property of cognitive radio is termed as spectrum management [3].

ISSN [Online]: 2583-2654

**Spectrum Sharing:** Cognitive Radio allocates the unused spectrum (spectrum hole) to the secondary (cognitive) user as long as primary user does not need it. This property of cognitive radio is termed as spectrum sharing [3].

### 2.1 Application of cognitive radio network

a) Military network
b) CR mesh network
c) Multimedia
d) Cellular network
e) Leased network
f) Emergency network

## III SPECTRUM SENSING TECHNIQUES

There are various spectrum sensing techniques which are employed for spectrum sensing such as

### Matched Filter Detection

The matched filter (also referred to as coherent detector), it can consider as a best sensing technique if CR has knowledge of PU. It is very accurate because it maximizes the received signal-to-noise ratio (SNR). Matched filter correlates the signal with time shifted version and compares between the final output of matched filter and predetermined threshold will determine the PU presence [4]. Hence, if this information is not accurate, then the matched filter operates weakly. A matched filter (MF) is a linear filter, designed to maximize the output signal to noise ratio for a given input signal. In matched filter detection of the secondary user has a prior knowledge of primary user signal is needed. Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal. It performs coherent detection. It acquires optimal solution to the signal detection but it requires preceding knowledge on the received signal.

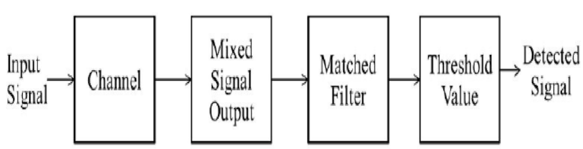



**Fig 2: Common Blocks for Matched Filter Detection**

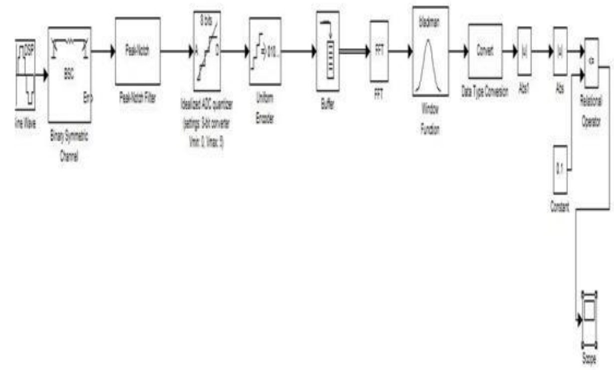
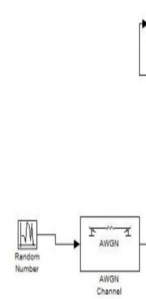


**Fig 3: Simulink Block**

**Parameters**

1. Sine wave has amplitude 1 V and frequency 100 Hz and sample mode discrete, phase off set 0, output complexity is real, computation method is trigonometric function, and sampling time is 1sec
2. Binary symmetric channel has error probability 0.01, Peak notch filter has order 6, and Quality Factor is 2.5.
3. Buffer has Output buffer size value 64.

Here the transmitted signal is passed through the channel where the additive white Gaussian noise is getting included to the signal and output is the mixed signal. This mixed signal is given as an input of the filter. Then the matched filter input is convolved with the impulse response of the matched filter and the matched filter output is then compared with the decision threshold for primary user detection. When the information of the primary user signal is known to the cognitive radio user, matched filter detection is optimal detection in stationary Gaussian noise. The disadvantage of Matched filter detection requires a prior knowledge of every primary signal. For Matched filter detection CR would need a dedicated receiver for every type of primary user.



### *Energy Detection*

Energy detector is the most popular way of spectrum sensing because of its low computational and implementation complexities. The receivers do not need any knowledge about the primary users. An energy detector (ED) simply treats the primary signal as noise and decides on the presence or absence of the primary signal based on the energy of the observed signal [5]. Digital

ISSN [Online]: 2583-2654

implementations using FFT-based spectral estimates Fig. 4

Shows the architecture for digital implementation of an energy detector.

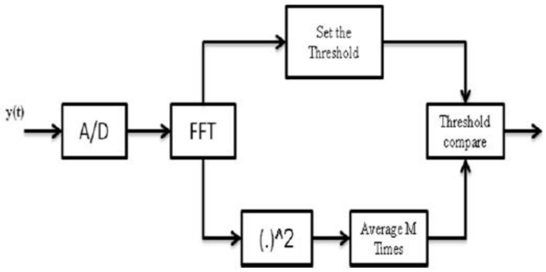



**Fig 4: Digital implementation of an energy detector**

The process flow of the energy detector is the received signal is passed through the ADC then calculates the FFT coefficient values then squared those values and average over the observation interval. Then the output of the detector is compared to a pre-defined threshold value to decide whether the primary user is present or not [6].

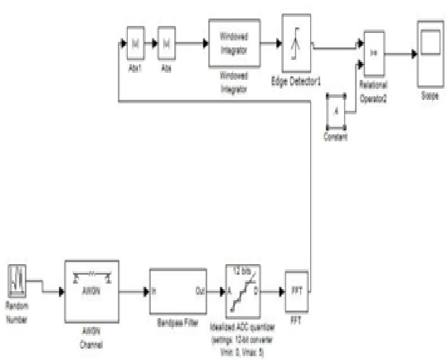



**Fig 5: Simulink model for Energy Detection**

***Parameters***

1) Uniform random number has maximum value 1 minimum value -1 and the sampling time is 1Sec
2) Windowed integrator has integration period (No. of samples) is 8.
3) Edge detector has rising edge.
4) Band pass filter has impulse response FIR and order mode is minimum filter type is single rate.

The input random signal is passed through a Band Pass Filter. Then Band Pass Filter passes selected range of frequencies and blocks other frequencies. The magnitude of received signal is squared using absolute math function. The Integrated signal undergoes rising edge detection and that Edge detector is used which can detect rising edge, falling edge. The relational operator is used to compare input signal and constant threshold signal [7].

Fig. 4. Gives the Simulink based model for energy detection using FFT. Here, the analog signal is first filtered through a band pass filter and then converted into a digital signal. A 12-bit ADC quantize (Vmin = 0V, $V_{max}$ = 5V) is used. This output is then passed through an FFT to get the corresponding coefficients. The signal is converted from time domain to the frequency domain by the FFT block. The magnitude of the received signal is then taken and it is squared.

## IV RESULTS

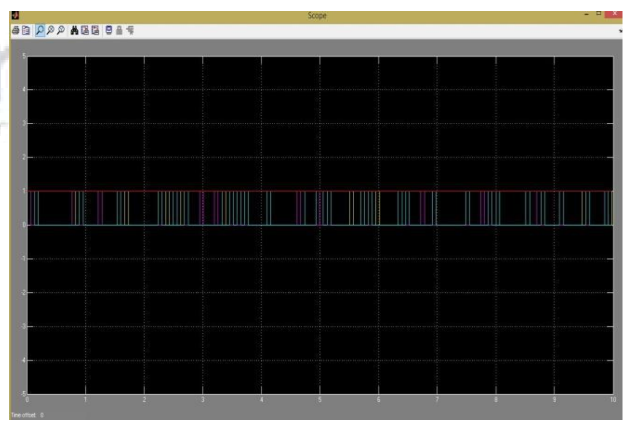


**Fig 6: Results for Matched Filter Detection**

If the value of the signal is greater than the threshold then the signal is present or else signal is absent. Fig 6 shows the output result of Energy Detection method. Threshold is set to 0.4 and if user will cross the threshold value then the user is present otherwise user will be idle and at that instant secondary user can occupy vacant space [8].

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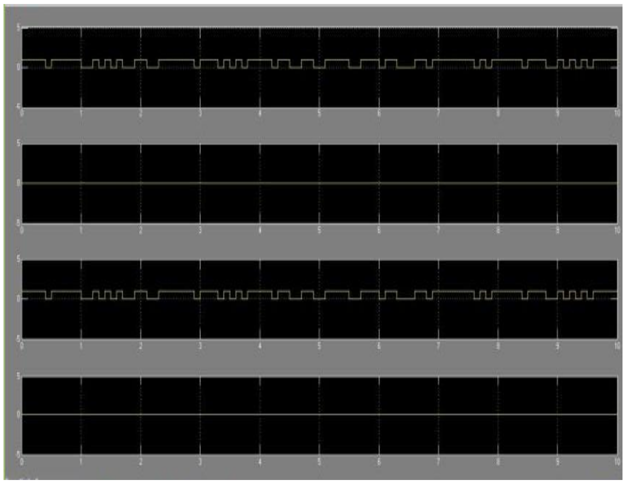

**Fig 7: Simulink output for Energy Detection**

In fig.7 it has been observed that threshold value is set at (0.7). Total number of users is 4. The user who will cross the threshold value is assumed to be present and who will not cross threshold value is assumed to be idle. As shown in graph that 1$^{st}$ and 3$^{rd}$ user cross the threshold value so they are assumed to be present. 2$^{nd}$ and 4$^{th}$ user does not cross the threshold value so they are assumed to be idle.



## V CONCLUSION

Different spectrum sensing algorithms respond differently at different SNR's. In the paper, Matlab based Simulink models for spectrum sensing algorithms i.e. Energy detection method and matched filter detection has executed in matched filter detection preceding information is required from primary user. Energy detection technique has better accuracy and overall performance expect for low SNR values. The energy detection (ED) method for spectrum sensing (SS) is carried out for four users. The appearance or nonappearance of the licensed user is selected based on the threshold value which is manually adjusted. The energy detection (ED) is better as com-pared to Matched filter detection

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