International Journal of Scientific Research in Computer Science, Engineering and Information Technology
 | Volume 2 | Issue 1 | ISSN : 2456-3307

An Analysis of Spectrum Sensing Techniques for Cognitive Radio

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ABSTRACT

Spectrum is a very scarce and precious resource for a communication system. The entire spectrum will not be used all the time. Some part of the spectrum always remains unused. Also, the television transmission is shifting from analog to digital. Hence, the spectrum which was earlier intended for analog television has been rendered unused. Such unused frequencies are known as white spaces. Conventional systems employ static spectrum allocation, leading to inefficient utilization of spectrum. In order to utilize the spectrum in an efficient manner, spectrum allocation must be done in a dynamic way. Cognitive capability is the ability to sense the communication environment and adapt the parameters accordingly, so as to utilize the spectrum in an effective way. Spectrum sensing is the prime most step of cognitive radio. In this paper, several spectrum sensing techniques like energy based detection, matched filtering, cyclostationary have been analyzed and their simulation results are discussed.
Keywords: Cognitive Radio, Secondary User, White Spaces

I. INTRODUCTION

Cognitive radio mainly consists of three stages: Sensing the communication environment, taking the decision and allocation of spectrum. The user, to whom the spectrum was originally allocated is referred as a primary user. Upon sensing that the spectrum is not being used by the primary user, it will be allocated to another user known as secondary user [1]. Whenever the primary user requires the spectrum, reallocation of spectrum has to be done. Spectrum sensing forms an inevitable part of Cognitive radio [2]. Spectrum sensing techniques are broadly classified as non-cooperative, cooperative and interference based detection. In this paper, non-cooperative based detection is analyzed. Non-cooperative technique involves the detection of signal transmitted by the primary transmitter. There exists several methods under non-cooperative, namely: Energy based Detection, Matched filtering, Cyclostationary based detection [5].

II. METHODS AND MATERIAL

1. Energy Based Detection

The received signal is passed through a BPF (band Pass filter) and then the energy is calculated. The energy of a continuous time signal is calculated by finding the integral of the square of signal, whereas that of a discrete signal is obtained by finding the summation of square of each sample. Fig. 1 shows the block diagram for energy based detection. Fig. 2 shows the received signal.

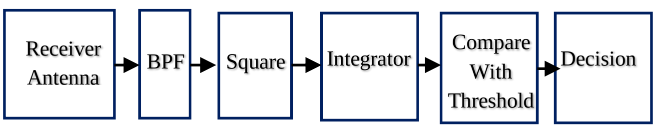

Figure 1. Energy Based Detection

The energy based detection simulation has been done to detect the presence of primary user in the frequency range of 1 Khz to 4KHz. Accordingly, a BPF has been designed with band pass of 1-4 KHz, to band limit the received signal. The frequency response of BPF is shown in the Fig. 3. The output of BPF is as shown in the Fig. 4.

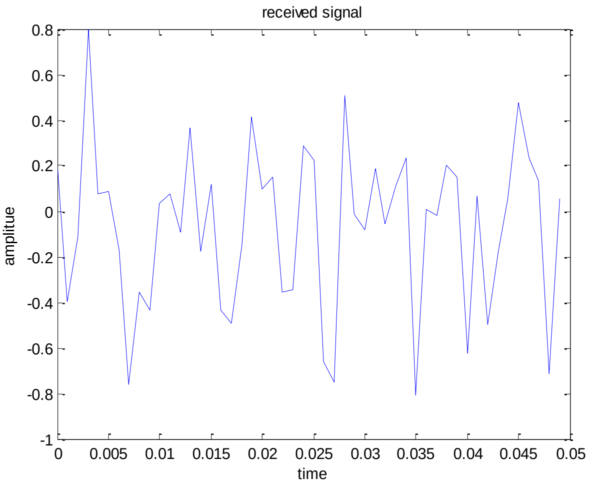

Figure 2. Received Signal

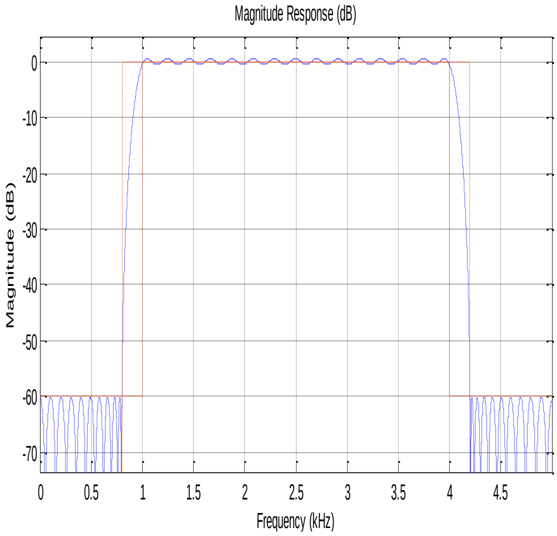

Figure 3. Frequency Response of BPF

The energy of the filtered signal is then compared with the threshold value [6]. If the energy is below the threshold, it indicates the absence of Primary user [7]. If the energy is above the threshold value, it indicates the presence of primary user, as shown in Fig. 5. If the noise content is more, then the threshold value has to be chosen a higher value.

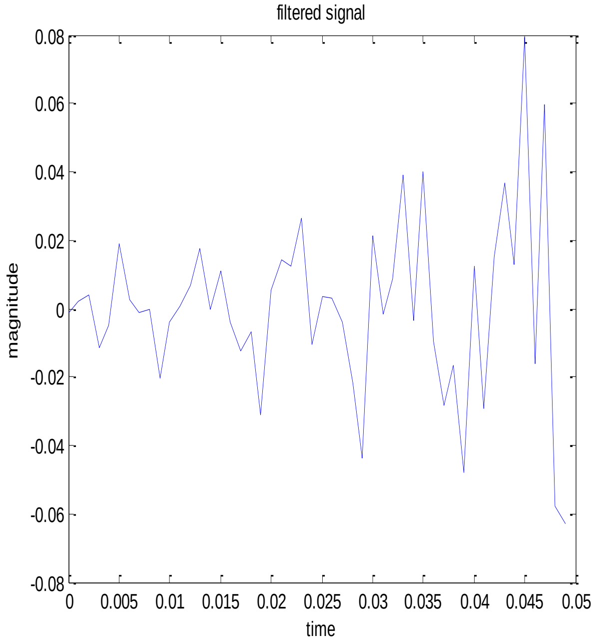

Figure 4. Output of BPF

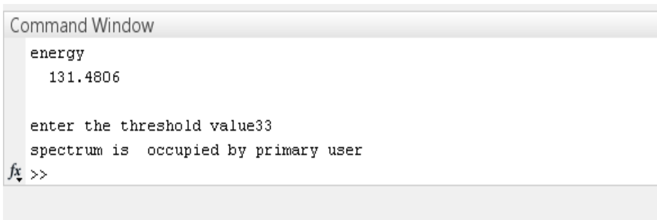

Figure 5. Energy of Received Signal

2. Matched Filtering

In order to perform matched filtering, the secondary user must have an accurate knowledge of the parameters associated with the primary users [3] [9]. Secondary users must know the frequencies associated with the primary signal. Once the secondary users acquires the knowledge of primary signal, corresponding matched filter can be designed to detect the presence or absence of the primary user. However, if the information pertaining to primary signal is not accurate, then matched filtering has a very poor performance [10]. The FFT of the primary signal to be detected is calculated, conjugate operation is applied. Then, IFFT is applied to derive the filter coefficients. The received signal is passed through the filter. Fig. 6 depicts the received signal. The output is obtained by convolving the received signal with the filter coefficients. If the primary signal is present, a peak will be obtained in the output at the middle of time range of input signal, as shown in the Fig. 7. If the received signal is different from that of primary signal, then the peak will not be obtained as shown in the Fig. 8.

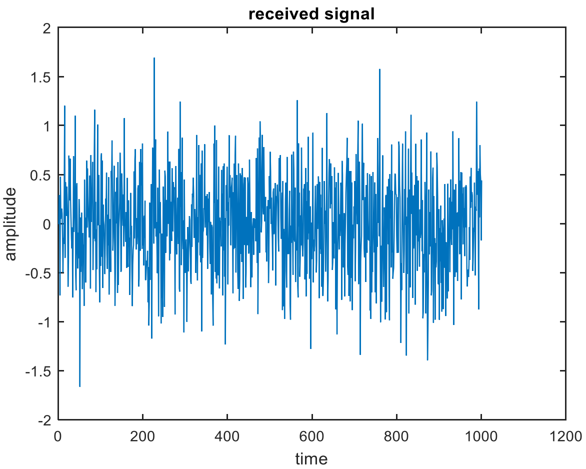

Figure 6. Input signal of matched filtering

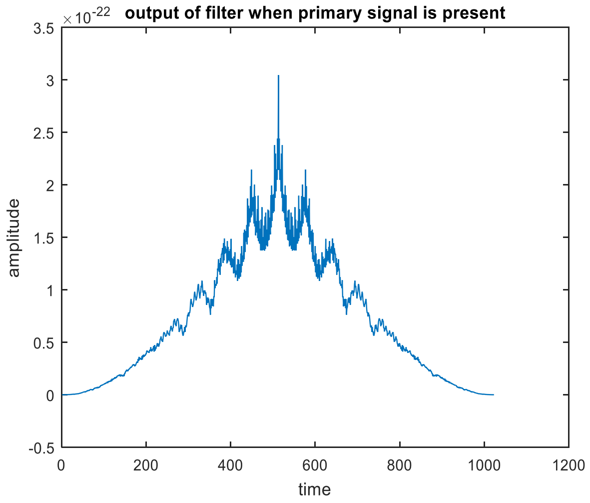

Figure 7. Output (when Primary User is Present)

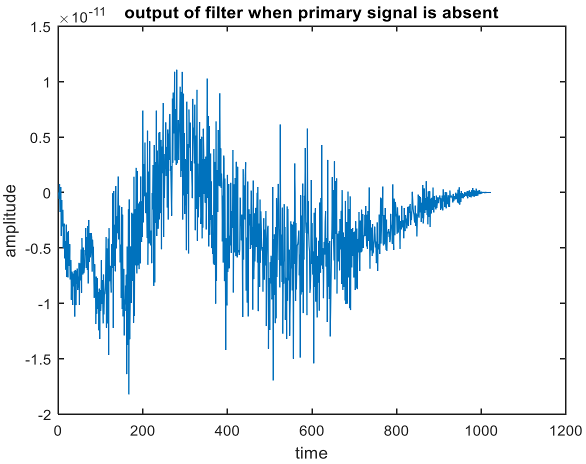

Figure 8. Output (when Primary User is Absent)

3. Cyclostationary

Sometimes the noise content is greater and hence its energy will be larger. It would lead to erroneous detection in case of energy based detection method. However, cyclostationary method is insensitive to noise and interference. Cyclostationary signals exhibit statistics that vary periodically over time. Noise and interference does not have statistics that vary periodically. Cyclostationary method is based on the statistics of the signal [8]. Hence, cyclostationary is more robust, when compared to energy detection. The probability of false detection of primary user will be lesser in cyclostationary method, when compared to that of energy based detection and matched filter detection. Fig. 9 shows the block diagram for cyclostationary based spectrum sensing. The input signal is frequency shifted, by multiplying with a complex exponential. The 'α' denotes the cyclic frequency. The cyclostationary method involves the calculation of spectral correlation. It is then averaged over the time interval.

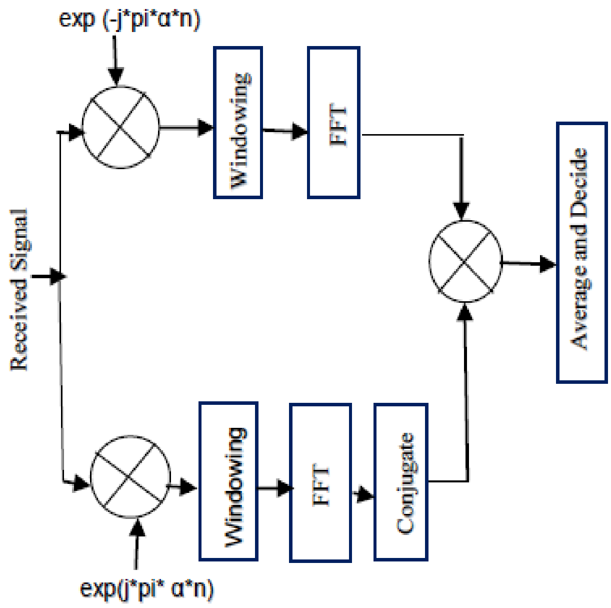

Figure 9. Cyclostationary Detection.

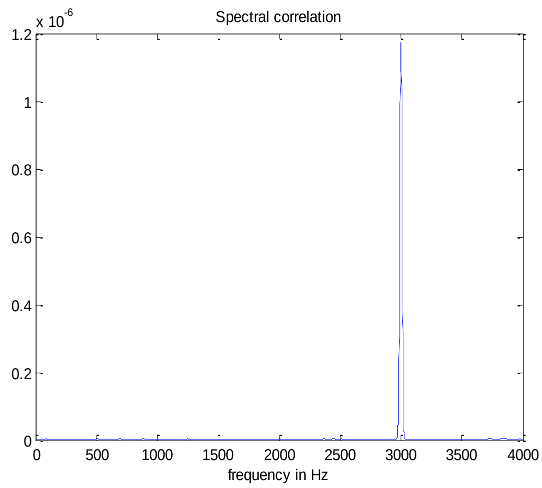

Figure 10. Result of Cyclostationary Based Detection

The result of cyclostationary based detection is as shown in the Fig. 10. The peak at 3 KHz frequency indicates the presence of primary user at 3 KHz frequency range.

III. RESULTS AND DISCUSSION

The table I shows the comparison of all three spectrum sensing techniques: Energy Based detection, Matched filtering based detection, cyclostationary based detection. Energy detection is the simplest of all the three sensing techniques [6]. The matched filter gives the most accurate results. Energy based detection does not require any knowledge of the primary signal to be detected, whereas the other two techniques require prior knowledge of primary signal [4].

Table I Comparison

Sensing Method	**Parameters**		
	Pre requisite	***Accuracy***	***Complexity***
Energy Based Detection	It does not require any information abour primary signal.	Very sensitive to noise, hence not accurate.	It is simplest sensing technique.
Cyclostatio nary	Primary signal characterist ics must be known.	More accurate than energy based detection.	Complex than energy based
Matched filter	Primary signal characterist ics must be known.	More accurate than cyclostatio nary.	Most complex.

IV. CONCLUSION

In this paper, we have discussed the different spectrum sensing techniques. The simulation results of energy based detection, cyclostationary based detection, and matched filtering based has been described. A comparison of spectrum sensing techniques has been done in terms of prerequisites, accuracy and complexity. The selection of sensing technique depends on the requirements of application.

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