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Multiple Spectrum Sensing Techniques for Cognitive Radio System

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Abstract- For efficient utilization of frequency spectrum, we need to sniff the spectrum to determine whether it is being used by primary user or not. Recent research shows that the available spectrum is not utilized efficiently. The term cognitive radio (CR) refers to the adoption of radio parameters using the sensed information of the spectrum. Cognitive Radio smartly senses and adapts with the changing environment by altering its transmitting parameters, such as modulation, frequency, frame format etc. The focus of this paper is on the comparative study of an important class of non cooperative spectrum sensing detection methods. In this paper, we consider four basic spectrum sensing techniques of transmitter detection: Matched filter detection, Energy detection, Cyclostationary feature detection and eigenvalue based detection.

Keywords- Cognitive Radio System, Cyclo-stationary, eigen values, eigen functions.

I. INTRODUCTION

In wireless communication, frequency spectrum is a limited resource. Moreover, due to fixed spectrum allocation scheme its utilization is poor making the scarcity more severe. In accordance to a report by Spectrum Policy Task Force of FCC, the spectrum is under or scarcely utilized and this situation is due to the static allocation of the spectrum [1-3]. Thus, to overcome the spectrum deficiencies and the inefficient utilization of the allocated frequencies [4], it is necessary to introduce new communication models through which frequency spectrum can be utilized, whenever the white space hole is available. This dynamic technique for spectrum access is known as CRs [6, 7]. The term cognitive radio (CR) finds unused spectrum and allocate to secondary user without interfering to PU. For a given purpose, CR arises as a tempting solution to the spectral congestion problem by introducing opportunistic usage of the frequency bands that are not fully occupied by licensed users.
Cognitive Radio is characterized by the fact that it can adapt, according to the environment, by changing its transmitting parameters, such as frequency, modulation, frame format, etc. [8]. The main challenges with CRs are that it should sense the PU signal without any interference. This work focuses on the spectrum sensing techniques that are based on primary transmitter detection [9]. In this category, four major spectrum sensing techniques named as Matched filter detection, Energy detection, cyclostationary feature detection and eigen value based detection.

II. SPECTRUM SENSING TECHNIQUES

In non-cooperative sensing we have to find the primary transmitters that are transmitting at any given time by using local measurements and local observations. The hypothesis for signal detection at time t can be described as [1]

$$x(n) = \begin{cases} w(n), & H_0 \\ s(n) + h(n) + w(n), & H_1 \end{cases} \quad (1)$$

Where, $x(n)$ = Signal received by the CR user,
$w(n)$ = Additive white Gaussian Noise,
$s(n)$ = PU signal,
$h(n)$ = Channel gain.

The terms H_0 and H_1 are the sensing states for absence and presence of signal respectively. H_0 is the null hypothesis which indicates that PU has not occupied channel and H_1 is the alternative hypothesis. It can define in following cases for the detected signal.
Now, working and implementation of four primary transmitter detection techniques are briefly described.

A. Matched filter Detection:
It is widely known that the detector using a matched filter is able to achieve the optimum performance when a secondary sensing node can perform a coherent detection of the primary signal which is helpful to maximize the SNR. However, in order to use the matched filter within spectrum sensing, the secondary sensing node must be synchronized to the primary system and must even be able to demodulate the primary signal. Accordingly, the secondary sensing node has to have prior information about the primary system such as the preamble, signaling for synchronization, pilot patterns for channel estimation, and even modulation orders of the transmitted signal.
Detection by matched filter is useful only in cases where the information from the PUs is known to the CRs. Block Diagram of the technique is shown in the Figure 1.

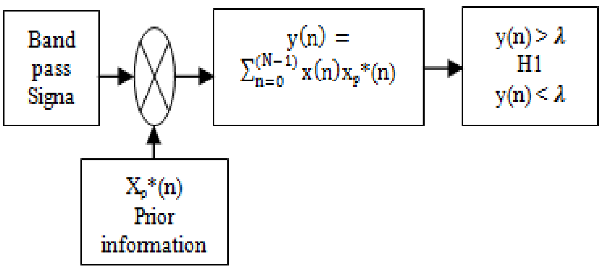

Figure 1. Matched Filter Detector

B. Energy Detection:
For the detection of unknown deterministic signals corrupted by the additive white Gaussian noise, an energy detector is derived. It is a simple method in which it is not required a priori knowledge of primary user signal, it is one of popular and easiest sensing technique, If the random Gaussian noise power is known, then energy detector is optimal choice. Calculating the energy of received signal, received signal can detect easily . The block diagram for energy detection technique is shown in the Figure 2.

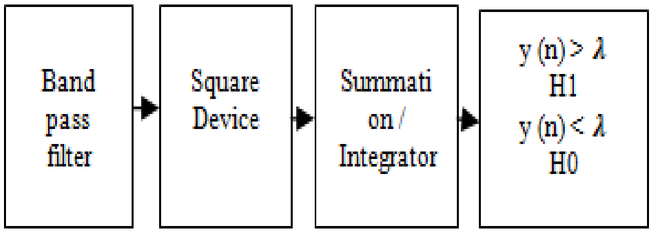

Figure 2. Energy Detector

C. Cyclostationary feature Detection:

In cyclostationary feature detection technique, CR can distinguish between noise and user signal by analyzing its periodicity. Cyclostationary feature detection is a much optimized technique that can easily isolate the noise from the user signal. In Cyclostationary feature detection, modulated signals (transmitted signal) are coupled with sine wave carriers, repeating spreading code sequences, or cyclic prefixes, all of which have a built-in periodicity, their mean and autocorrelation exhibit periodicity which is characterized as being cyclostationary. Noise, on the other hand, is a wide-sense stationary signal with no correlation. Using a spectral correlation function, it is possible to differentiate noise energy from modulated signal energy and thereby detect if PU is present. Ability to distinguish between noise and signal makes it better than energy detection and matched filter detection. It performs very well for larger noise on channels. The block diagram for the cyclostationary feature detection is shown in Figure 3.

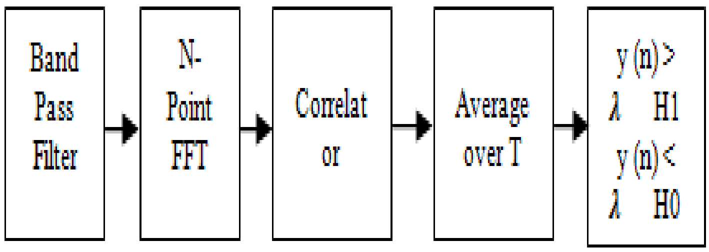

Figure 3. Cyclostationary Feature Detector

D. Eigen Value Based Detection:

To overcome the shortcomings of energy detection, we use new methods based on the eigenvalues of the covariance matrix of the received signal [8]. It is shown that the ratio of the maximum or average eigenvalue to the minimum eigenvalue can be used to detect the presence of the signal. Based on some latest random matrix theories (RMT) [9], we quantify the distributions of these ratios and find the detection thresholds for the detection algorithms. The probability of false alarm and probability of detection are also derived by using the RMT. The methods overcome the noise uncertainty problem and can even perform better than energy detection when the signals to be detected are highly correlated. The methods can be used for various signal detection applications with-out knowledge of the signal, the channel and noise power. Furthermore, different from matched filtering, the methods do not require accurate synchronization. The method overcomes the noise uncertainty difficulty while keeps the advantages of the energy detection.

III. SIMULATION RESULTS

A. Probability of Detection Alarm -

Figure 4 shows the probability of PU detection alarm (Pd) with respect to SNR for the four cases. The probability of detection alarm should be as much as possible with respect to SNR. Figure 4 shows that eigenvalue detection is detecting PU signal at low SNR as compare to other three detection techniques.

B. Probability of Miss Detection -

Figure 5 depicts the probability of miss detection (Pm) with respect SNR for the all cases. Probability of miss detection should be as small as possible with respect to SNR. Figure 5 shows eigenvalue detection is superior to other techniques.

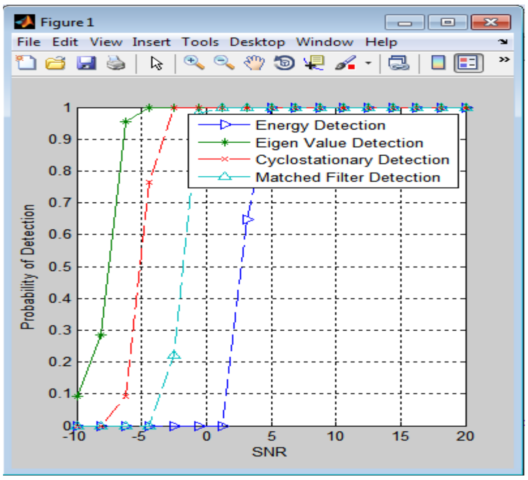

Figure4: Probability of Detection vs SNR for all Detection Methods.

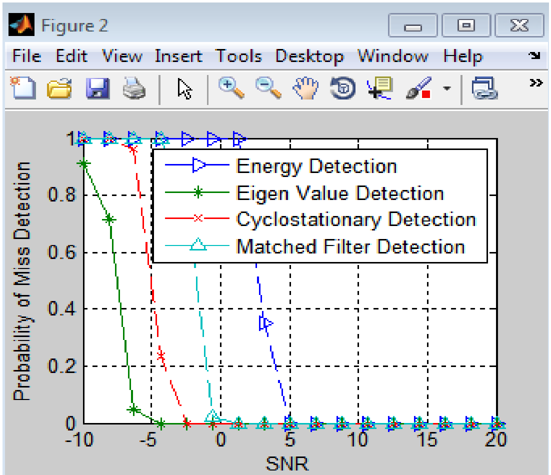

Figure 5: Probability of Miss Detection vs. SNR for all Detection Methods

C. Probability of False Alarm -

In Figure 6 the comparison of four mentioned spectrum sensing techniques in terms of the probability of false alarm detection (Pf) with respect to SNR is done and plotted. The probability of false alarm should as minimum as possible with respect to SNR. It is observed that probability of false alarm for eigenvalue detection is better than remaining three techniques.

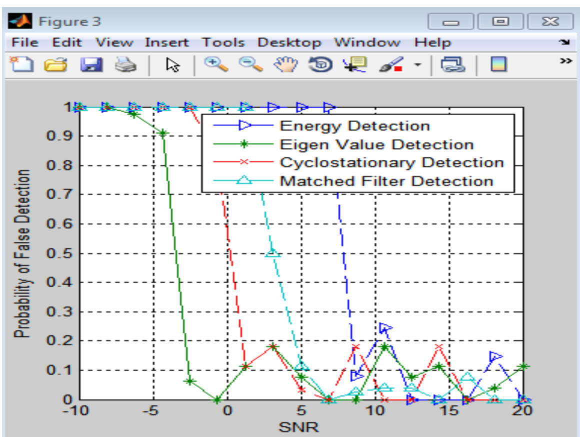

Figure 6: Probability of False Detection vs. SNR for all Detection Methods

IV. CONCLUSION

In this paper, we have discussed four spectrum sensing techniques, namely energy detector, matched filter, cyclostationary features , and eigenvalue based detection techniques in terms of Pf, Pd & Pm for given SNR. Each sensing technique had its own advantages and disadvantages. As, Matched filter detection improved SNR, but required the prior information of PU for better detection. Energy detection had the advantage that no prior information about the PU was required. But did not perform well at low SNR, there was a minimum SNR required after which it started working. Cyclostationary feature detection performed better than both, matched filter detection and energy detection. Finally, all graphs result showed that cyclostationary feature detection outperformed other two techniques. However, its processing time very large and implementation was complex. Maximum eigenvalue to Minimum eigenvalue ratio detector methods overcome noise level variation difficulty, and also have the advantages of energy detection method. The Maximum eigenvalue to Minimum eigenvalue ratio detector method perform better for Probability of detection, but its performance is poor for probability of false detection, and this is biggest limitation of Maximum eigenvalue to Minimum eigenvalue ratio detector because due to false detection the interference may be occurs between primary user and secondary user.

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