Review on Robust Estimator - Correlator for Spectrum Sensing in Cognitive Radio

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***Abstract*—** In communication, Cognitive radio (CR) plays important role for increasing the spectral efficiency in communication bands. Reason behind increasing efficiency of the spectrum usage is due to increasing demand for higher data rates, better Qos etc. Spectrum sensing is one of the most challenging issues in research area as the cognitive radio is concern. In this paper, we present various traditional techniques in order to detect presence of primary user but there are some limitations. Therefore, we introduces robust detection scheme, with respect to the uncertainty in the estimation of true covariance matrix. This paper provide idea behind the MIMO concept in cognitive radio where multiple nodes can be placed both on primary user and secondary user and results evaluate the better detection of primary user. This method implemented by using the Eigen value theory. In this paper, we are trying to improve the primary user detection in comparison with the traditional technologies.

Keywords- *Cognitive radio (CR), Spectrum sensing, multiple-input multiple-output (MIMO), RECD*

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I. INTRODUCTION

Amount of wireless communication network is rapidly increasing day by day, which require higher bandwidth for communications purpose. Therefore, it reduces the number of bands available for wireless network system. This is suffering from a lack of available bands, therefore cognitive radio (CR) is born. Cognitive radio (CR) systems [1] are useful for improving the efficiency of spectrum utilization by allowing a group of secondary users (SU) to access those vacant spectral bands also called as white space. In cognitive radio system band allotted to the primary user is enable to use the whole spectrum at particular instant of time that unused spectrum is further used by secondary user which avoid interference in the channel. Thus, it is responsible for weak primary user (PU) signal [2]. In this paper, we used definition adopted by Federal Communications Commission (FCC), which automatically sense and detect the presence of primary user and allow the secondary user to access that spectrum [3]. It also provides regulation for spectrum. Most important components of the cognitive radio are the ability to sense, share and do the management of the spectrum. In cognitive radio primary user have higher priority on the allotted part of the spectrum and secondary users that have lower priority. Cognitive radio accesses that spectrum in such a manner that they avoid interference between the primary and secondary users. Cognitive radio capabilities such as spectrum sensing are useful for secondary user to check the presence of primary user. If primary user does not use that spectrum then unlicensed user accesses that spectrum. By taking combination of cognitive radio and MIMO system, we can increase the spectral efficiency, avoid the channel interference and provide flexible spectrum management.

In fig.1 MIMO system, where multiple data can be transmitted and received simultaneously at the same instant, which increases the spectral efficiency.

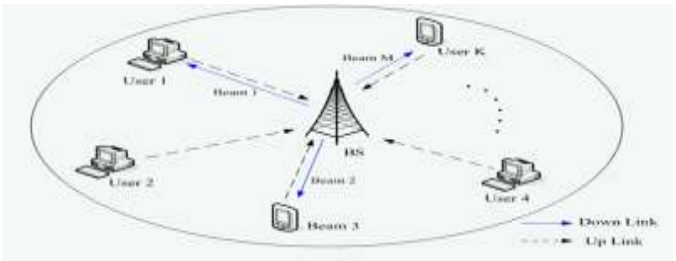

Fig. 1 MIMO System

II. SPECTRUM SENSING

There are four main tasks for cognitive radio: Spectrum sensing useful for determining the availability of spectrum and the presence of the licensed users. Spectrum management is nothing but the regulating process and provide spectrum to unlicensed user. In Spectrum sharing CR, distribute the spectrum holes among the secondary users equally. Spectrum

mobility is a process of changing frequency as per communication requirements and provides the spectrum dynamically. From all above task, we only focused on spectrum sensing techniques. For establishing of cognitive radio spectrum sensing is an useful component. It enables cognitive radio is capable for detecting spectrum holes present in the environment. Fig.2 shows the spectrum hole concept for cognitive radio. A spectrum hole also known as white space is nothing but a licensed frequency band, allotted to a primary user but for at a particular instant of time user does not utilize that particular band. If a primary user further wants to uses this unutilized band, the secondary user moves to another spectrum hole. There are several spectrum-sensing methods which are already proposed in literature [4] among these we will see few of them such as energy detector, matched filtering, cyclostationary feature detection method. In these methods, due to some limitation it is difficult to obtain presence of primary user. In this paper, we will discuss the problem of previous method and we tried to overcome those problems by proposing robust estimator correlator detector.

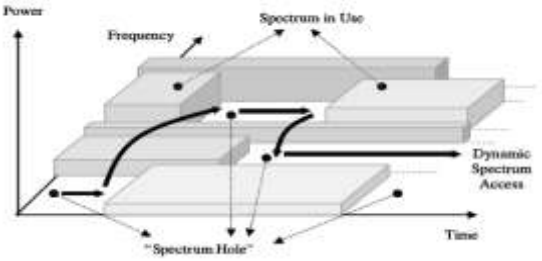

Fig 2 Spectrum hole Concept

III SPECTRUM SENSING METHODS

There are several number of different methods proposed for determining the presence of signal transmission. In some methods, characteristics of signal transmission are detected and it is beneficial for taking decision regarding signal transmission as well as finding the signal type. In this paper, some of the most common spectrum sensing techniques for cognitive radio is explain.

A. Energy Detector

Energy detector is simple in structure and most common way of spectrum sensing technique because of its low computational time and low implementation complexities [5]. Energy detector does not need any knowledge regarding primary user's signal structure. In this method, signals are detected by comparing the energy detector output with a threshold value. In energy detector, major problem is the selection of threshold value, which is essential for detecting primary channel user. Probability of detection (P_d) and probability of false alarm (P_f) are the main factors for providing the appropriate information of the availability of the spectrum. The block diagram of energy detector as shown in fig.3 the input is given to the band pass filter, with the center frequency fs and bandwidth W. A squaring device is used to measure the received energy, which is followed by the band pass filter after that integrator is used to determine the observation interval. Finally, the output of the integrator is compared with a threshold energy value to decide the presence of primary user.

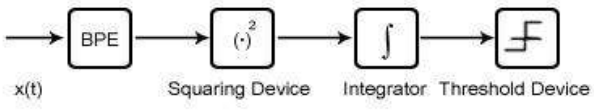

Fig. 3 Block diagram of energy detector

In a non fading environment where h is amplitude of the signal channel, probability of detection P_d and probability of false alarm P_f are given by following formulas

$$Pd = P(Y > \lambda / H1) = Qm(\sqrt{2\gamma}, \sqrt{\lambda})$$

$$Pf = P(Y > \lambda / H0) = \Gamma(m, \lambda/2)/\Gamma(m)$$

Where Y is the SNR, m = TW is the (observation/sensing) time bandwidth product Γ (.) and Γ (.,.) are complete and incomplete gamma functions, Qm ( ) is the generalized Marcum Q-function. In a fading environment h is the amplitude gain of the channel that varies due to fading effect, which makes the SNR variable. P_f is the same as that of non-fading case because P_f is independent of SNR. P_d gives the probability of detection for SNR. In this case, average probability of detection may be derived by averaging over fading statistics:

$$Pd = \int xQm(\sqrt{2\gamma}, \sqrt{\lambda}) f\gamma(x)dx$$

Where, f γ (x) is the probability distribution function of SNR under fading. A low value of P_d expresses an absence of primary user, it means that the CR user can access that spectrum. A high value of P_f express that there is no signal in the channel. It shows that in fading environment, where there is need to cooperate different CR users for detecting the presence of primary user. In such conditions a CR model helpful for relating different parameters such as detection probability, number and spatial distribution of spectrum sensors and more importantly propagation characteristics. Disadvantages of energy detection are that performance is sensitive to noise. In energy detector it is difficult to differentiate between signal power and noise power, it only gives the information related to the absence or presence of the primary user.

B. Matched Filter Detector

Matched filter is also called as optimum method for primary user detection when we transmit the known signal [6]. In matched filter detector, it requires prior knowledge of the signal transmitted by the primary user. The matched filter proceeds from threshold detector and used to detect the

presence of primary user. The matched filter is used for increasing the SNR ratio in the presence of additional white noise. This technique is possible only if number of users is very small. A matched filter detector is obtained by relating a known signal present in the channel, with noise present in environment for detecting the presence of the known signal in the channel, which is same as unknown signal with time of the signal. It perform two convolution function one function is to find out the level of similarity and another function is to find out the threshold value [7].

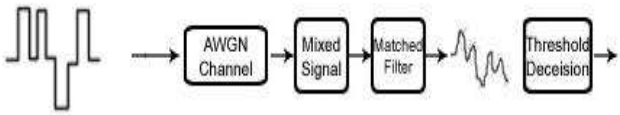

Fig. 4 Block diagram of matched filter

Advantage of matched filter is that it requires short time to achieve high processing gain due to channel detection. Disadvantage of matched filter is that it required a devoted sensing receiver for each primary user signal and requires the previous information of primary user signal, which is very difficult to obtain at the CRs.

C. Cyclostationary detector

In cyclostationary detector, signals are in general form such as sine wave, pulse trains, hopping sequences or cyclic prefixes, which results in regularity [8]. Even if the data is in random form, this signals are characterized as cyclostationary, hence their statistics, mean and autocorrelation exhibits periodicity. This method is achieved by comparing a spectral function. The periodicity is beneficial for signal format so that it is helpful for receiver for parameter estimation like pulse timing etc. This regularity is useful for the detection of random signals with the noise and other modulated signals.

From research, we found that cyclostationary feature detector method is better as compared with simple energy detection and match filtering. As we discussed, a matched filter detector requires previous knowledge about primary user while in energy detector as a non-coherent detection does not require any of prior knowledge about primary user's. Although energy detector is easy for implementation, it is highly susceptible to band interference and changing noise levels and it is difficult to differentiate between signal power and noise power.

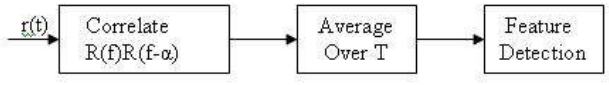

Fig. 5 Block Diagram of Cyclostationary Feature Detector

Implementation of cyclostationary feature detection is as shown in fig 5. Detected features are in the form of signals, presence of interferers. When the correlation factor is greater than the threshold then it means that there is a presence of primary user in radio environment. Although it performs better than energy detector and matched filter detector because it can differentiate between signal power and noise, as it is computationally very complex, therefore it requires long processing time, which generally reduces the performance of cognitive radio. Signal processing techniques motivate the need to study other feature detection techniques that can improve sensing detection and type of signals in low SNR.

IV. Robust Detection MIMO Techniques

To overcome all above problem we proposed robust detection for MIMO techniques in order to reduce the effect of uncertainty in the estimated signal covariance matrix. This method is based on the GLRT schemes, we formulate robust estimator-correlator detector (RECD), and robust test statistic detector (RTSD) based on Eigen theory for spectrum sensing for the estimation of true covariance matrix. In this method, we consider MIMO system where multiple data transmit simultaneously which increases spectral efficiency. Primary user detection problem can be formulated by taking hypothesis equation given as,

$$H0 : \mathbf{y}(k) = \boldsymbol{\eta}(k)$$
$$H1 : \mathbf{y}(k) = \mathbf{s}(k) + \boldsymbol{\eta}(k),$$

Where, H_0 denotes the absence of primary user whereas H_1 denotes the presence of primary user. Any spectrum-sensing scheme having two parameters: the probability of detection P_d i.e. the probability that H_1 is reported when the primary users are transmitting a signal and the probability of false detection P_f i.e the probability that H_1 is reported when actually the primary user is not present. Most of the schemes try to maximize the value of P_d for a given value of P_f, which is determined by the network designers according to how proactive they want the system. The performance of the detector is critically dependent on the accuracy of the covariance estimates. However, in practical wireless scenarios, it is challenging to obtain an exact estimate of the signal covariance matrix due to the limited resources and processing capabilities available at the secondary users coupled with the time varying nature of the fading wireless channel. Frequently, in such scenarios, it is only possible to obtain a nominal estimate of the true signal covariance matrix, which is unknown. SNR directly affects the performance of a wireless communication [9]. A higher SNR value means there is a better signal or meaningful information level than the noise level. A higher SNR value gives a higher data rates and fewer retransmissions therefore, it can offer a reliable transmission and vice-versa. A lower SNR value affects the transmission of

a wireless communication and gives a lower data rate, which decreases spectral efficiency.

RTSD is a GLRT based detector, signal transmitted by the primary user is received by the secondary user in the form of covariance matrix of the signal. Received signal, which are in the form of covariance matrix, is converted into its Eigenvalues, then this eigenvalues is compared with the threshold value and take the decision whether primary user is present or not. RTSD is formulate for spectrum sensing in MIMO cognitive radio is given as,

$$T_{RTSD} = \sum_{k=1}^{k} y^{H}(k) R_{\eta}^{-1} y(k) - f_{RTSD}^{*}$$

Similarly, RECD is the formulation of optimal detection rule for the primary user detection s given as,

$$T_{RECD} = \sum_{k=1}^{k} y^{H}(k) R_{\eta}^{-1} y(k) - f_{RECD}^{*}$$

Both the equations are derived from the result for the perturbation of eigenvalues in [10]. Robust detector that maximizes the probability of detection P_d for a given rate of false alarm P_f, and detect the presence of primary user.

V. CONCLUSION

In this paper, various methods are presented for primary user detection. Our proposed robust estimator-correlator detector method is advantageous for detection of primary user channel. For robust estimator-correlator detector multiple-input multiple-output (MIMO) fading channel is used for increasing spectral efficiency. In this method Eigen value theory is used which gives accurate covariance matrix for primary user channel detection. RECD detection method produces better sensing performance than the other detection methods. Traditional method like energy detector, matched filter detector and cyclostationary detector are described in detail each having their different advantages and disadvantages. After surveying different methods for primary user detection it is found that robust estimator-correlator method, mitigate the problem occur in traditional method and estimate the true covariance matrix which is important factor for the accurate detection of primary user.

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