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Performance Evaluation Comparison of Primary User Signal Detection Methods for Cognitive Radio System

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Abstract: Utilization of electromagnetic radiofrequency spectrum with efficient way, we required to check the spectrum to determine whether it is being used by primary user (PU) or not. 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 is the way to improve the efficiency of the radio spectrum utilization, which is achieved by CR, finds unused spectrum and allocate to secondary user without interfering to PU. The focus of this paper is on the comparative study of an important spectrum sensing detection methods. In this paper, we have considered four spectrum sensing techniques of transmitter detection: Matched filter detection, Energy detection, and Cyclostationary feature detection and Maximum eigenvalue to minimum eigenvalue ratio detector. Comparative analysis of the four techniques has been carried out in terms of probability of false alarm Pf, probability of detection alarm P_d, and probability of miss detection P_m. Finally by simulation result, the graphical comparison shows that at low signal to noise ratio (SNR), cyclostationary feature detection outperforms other two techniques, thus Cyclostationary have some difficulties like implementation is complex, long observation time, maximum eigenvalue to minimum eigenvalue ration detector methods overcome noise level variation difficulty, and also have the advantages of energy detection method

Keywords: Cognitive Radio System, PU, SNR, Cyclostationary, Detection Alarm, False Alarm.

I. INTRODUCTION

The available electromagnetic spectrum is becoming overcrowded day by day due to remarkable increment in wireless devices. It has also been notified that available spectrum is underutilized as shown in Fig.1, most of the time also that to operate in a specific frequency band each operator issued a license to operate in that particular band this the reason that approach to the spectrum management is very inflexible [1]. To overcome this problem The Federal Communications Commission (FCC) has been investigating new ways to manage RF resources. They provide a guarantee of minimum interference to those who is the primary license holder. The issue of spectrum underutilization wireless communication can be solved using Cognitive Radio (CR) technology. Cognitive Radios are designed to provide reliable communication for users and also effective utilization of radio spectrum. Cognitive Radio smartly senses and adapts with the changing environment by altering its transmitting parameters, such as modulation, frequency, frame format etc.

In the early days of communication there were fixed radios in which the transmitter parameters were fixed and set up by their operators. But now the things are different instead of fixed parameter it can be change like frequency range, modulation type or maximum radiated or conducted output power without any change in hardware as in Software Defined Radio (SDR). SDR is used to minimize hardware requirements; it gives user a cheaper and reliable solution.

But it will not take into account spectrum availability. Cognitive Radio is newer version of SDR in which all the transmitter parameters change like SDR but it will also change the parameters according to the spectrum availability.SDR gives a cheaper and reliable solution to the user; and is used to minimize the hardware requirements. But it will not change the parameters according to spectrum availability. On the other hand cognitive radio is newer version of SDR in which all the transmitter parameters change like SDR but it will also change the parameters according to the spectrum availability [2]. the Cognitive Radio technology will enable the user to determine which portion of the spectrum is available, detect the presence of primary user (spectrum sensing), select the best available channel (spectrum management), coordinates the access to the channel with other users (spectrum sharing) and migrate to some other channel whenever the primary user is detected (spectrum mobility) [3].

Cognitive Radio will enable the user to determine the presence of primary user, which portion of spectrum is available, in other words to detect the spectrum holes or white spaces and it is called spectrum sensing, select the best available channel or to predict that how long the white spaces are available to use for unlicensed users also called spectrum management, to distribute the spectrum holes among the other secondary users which is called spectrum sharing and switch to other channel whenever primary user is detected and this functionality of CR called spectrum mobility[4].Among these function Spectrum Sensing is considered to be the one of the most important critical task to establish Cognitive Radio Networks.

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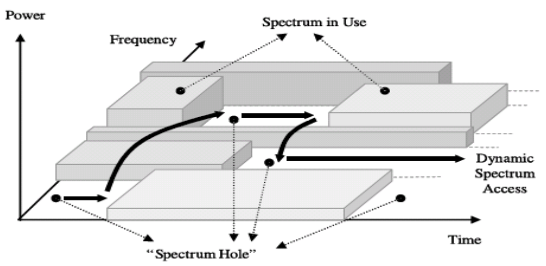

Fig.1 Illustration of spectrum hole

Cognitive Radio is characterized by the fact that it can adapt, according to the environment, by changing its transmitting parameters, such as modulation, frequency, frame format, etc. [4]. The main challenges with CRs or secondary users (SUs) 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 [5]. In this category, three major spectrums sensing. In this paper, we analysed the performance of spectrum sensing techniques, the spectrum sensing results are gathered in terms of probability of false alarm (P_f), probability of PU detection alarm (P_d), and probability of miss detection (P_m).Matched filter and cyclostationary feature techniques both require prior information of PU and implementation is complex, while energy detector does not require PU information, easy to implement, and speed of operation [6].

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 CR user,
w (n) =Additive white Gaussian noise,
s (n) =PU Signal,
h (n) =Channel gain

Here,H_0 and $H_1$are defined as the hypotheses of not having and having a signal from a licensed user in the target frequency band, respectively. In non-cooperative sensing generally three methods are used for sensing.

1. Energy Detection

Energy detection is a non-coherent detection method that is used to detect the primary signal. [3]. 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 of cooperative sensing in cognitive radio networks [2]-[3]. If the random Gaussian noise power is known, then energy detector is optimal choice. In energy detector as shown in Fig.2 the band pass filter selects the specific band of frequency to which user wants to sense. After the band pass filter there is a squaring device which is used to measure the received energy. The energy which is found by squaring device is then passed through integrator which determines the observation interval, T. Now the output of integrator, Y is compared with a value called threshold, λ and if the values are above the threshold it will be considered that primary user is present otherwise absent.

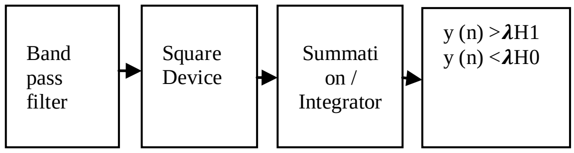

Fig. 2 Block Diagram of Energy Detector

Calculation of the energy of input received signal is done as follow

$$E = \sum_{n=1}^{N} | x(n) |^2 \quad (2)$$

Where,
x (n) = Received input signal.

E = Calculating the Energy of received input signal or some time denoted by y (n).
At the end of the above diagram the threshold decision block shown and its decision has been made on the base of two hypotheses are related to the detection of primary user signals, first one is null hypothesis H_0 and the alternative hypothesis H_1 . $H_0$is the case in which a primary user signal is not present in primary spectrum, and H1 describe the case in which a primary signal is available.

2. Matched Filter Detection

It is a known fact that the detector using a matched filter is able to perform efficiently and optimally when a user operate at secondary sensing node can perform a coherent detection of the primary signal [4]. However, within spectrum sensing to use the matched filter, the secondary sensing node must be synchronized to the primary system and it must be able to demodulate the primary signal.
Accordingly, the prior information about the primary system must be known to secondary sensing node such as the preamble signalling for synchronization, pilot patterns for channel estimation, and even modulation orders of the transmitted signal. The best way to detect signals with maximum SNR is to use a matched filter receiver. Its most important skill is the low execution time, but to know the signal proprieties is needed. This method includes the demodulation of the signal. This means that the receiver should agree with the source, estimate the channel conditions and to know the signal nature.

As shown in Fig. 3. Matched filter is a linear filter which works on phenomena of maximizing the output signal to noise ratio. Matched filter detection is then applied when the cognitive radio user having information about the type of primary signal. 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. The operation of matched filter detection is expressed as

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$$y(n) = \sum_{n=0}^{(N-1)} x(n) \times x_p^*(n) \quad (3)$$

Where,
x (n) = Input transmitted signal.
$x_P^*(n)$ = Conjugate of Known Pilot data.
y (n) = Received signal.

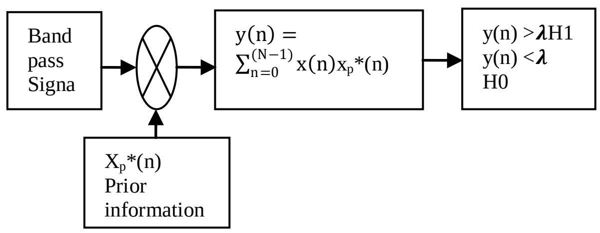

Fig.3 Block diagram of matched filter detector

Detection by using matched filter is useful only in cases where the information from the primary users is known to the cognitive users.

3. Cyclostationary Feature Detection

In cyclostationary feature detection technique [6], CR can distinguish between noise and user signal by analysing 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 [6]. 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. The block diagram for the cyclostationary feature detection is shown in Fig.4.
Here, input signal received by BPF and is used to measure the energy around the related band, and then output of BPF is fed to FFT. Now FFT is computed of the signal received and then correlation block correlate the signal and pass to integrator. The output from the Integrator block is then compared to a threshold [4]. This comparison is used to discover the presence or absence of the PU signal.

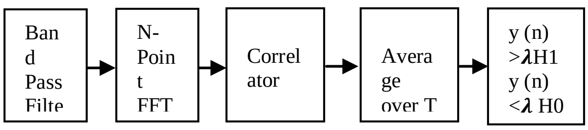

Fig.4 Cyclostationary Feature Detector

Now, considering a deterministic complex sine signal s (t) and passed it through an Additive white Gaussian noise (AWGN) channel which may be expressed as

$$s(t) = A\cos(2\pi f_o t + \theta), \quad (4)$$

Where,
A = Amplitude of input signal.
f_0 = Frequency,
θ = Initial Phase.
Transmission of s (t) through an AWGN, having zero mean, results to x (t) = s (t) + n (t). Thus, the Mean function of x (t) will be

$$Mx(t) = E[x(t), \quad (5)$$

$$Mx(t) = E[s(t + n(t)), \quad (6)$$

$$Mx(t) = E[s(t) \quad (7)$$

Where,
x (t) = Received signal.
s (t) = Transmitted Input signal.
E = Expectation operator.
M_x (t) = Mean function of x (t) and also a Periodic function with period T_0.
As discussed earlier, modulated signal x (t) is considered to be a periodic signal or a cyclostationary signal in wide sense if it's mean and autocorrelation exhibit periodicity as follows [1]

$$M_x(t) = M_x\, s(t + t_0) \quad (8)$$

Similarly, the auto-correlation function of x (t) is also periodic with period T_0

$$Rx(t,u) = R_x(t+T_0, u + T_0), \quad (9)$$

4. Maximum Eigenvalue to Minimum Eigenvalue Ratio Detector

It is shown that the ratio of the maximum eigenvalue to the minimum eigenvalue can be used to detect the signal existence. Based on some latest random matrix theories (RMT), we can quantize the ratio and find the threshold. The probability of false alarm is also found by using the RMT. The proposed method overcomes the noise uncertainty difficulty while keeps the advantages of the energy detection [9].
Let received signal x (n) is

$$x(n) = \sum_{j=1}^{P} \sum_{k=0}^{Nj} hj(k)sj(n-k) + \eta(n), \quad (10)$$

Where,
S_j (n) are P≥1 source signal,
H_{ij} (k) is channel response from source signal *j* to receiver *i*.
Ŋ (n) = noise sample
Considering L consecutive outputs and defining
We get

$$X(n) = H_s(n) + Ŋ(n), \quad (11)$$

Where H is ML*(N+PL) matrix
Let R (N_s) be the sample covariance matrix of the received signal, that is,

$$R(Ns) = 1/Ns \sum_{n=L}^{L-1+Ns} x(n) \quad (12)$$

Where Ns is the number of collected samples. If Ns are large, based on the assumption, we can verify that

$$RN(s) = HR_sH^+ + \sigma^2_Ŋ I_{ML}, \quad (13)$$

Where Rs is statically covariance matrix of the input signal, $\sigma^2_Ŋ$ is the variance of the noise, and I_{ML} is the identity matrix of order ML

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Let λ_{max} and λ_{min} be the maximum and minimum eigen values of R and ρ_{max} and ρ_{min} are the maximum and minimum eigen values of HR_sH^+. Then $\lambda_{max} = \rho_{max} + \sigma^2_{\eta}$ and $\lambda_{min} = \rho_{min} + \sigma^2_{\eta}$. , $\rho_{max} = \rho_{min}$ if and only if $HR_sH^+ = \delta\ I_{ML,}$ δ is positive number. In practice, when signal present, it is very unlikely that $HR_sH^+ = \delta\ I_{ML.}$ Hence if there is no signal $\lambda_{max} / \lambda_{min} = 1$; otherwise, $\lambda_{max} / \lambda_{min} > 1$. The ratio of $\lambda_{max} / \lambda_{min}$ can used to detect the presence of signal.

III. Simulation Results

Comparison of different spectrum sensing techniques on the basis of probability of detection, probability of false alarm, probability of miss detectionH_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.

- Declaring H_1 under H_0 hypothesis which leads to Probability of False Alarm (P_f).
$P_f = P_r\ (H1 / H_0)$
- Declaring H_1 under H_1 hypothesis which leads to Probability of Detection (P_d).
$P_d = P_r\ (H1 / H_1)$
- Declaring H_0 under H_1 hypothesis which leads to Probability of Missing (P_m).
$P_m = P_r\ (H0 / H_1)$

1. Probability of False Alarm

In Fig. 5, in terms of probability of false alarm detection, with respect to SNR the comparison of Energy detection, Matched filter detection, Cyclostationary detection, &Maximum eigenvalue to minimum eigenvalue ratio detector spectrum sensing techniques is done and plotted. The probability of false alarm should as minimum as possible. From Fig. it is shown that probability of false alarm for cyclostationary feature detection is better than other two techniques.

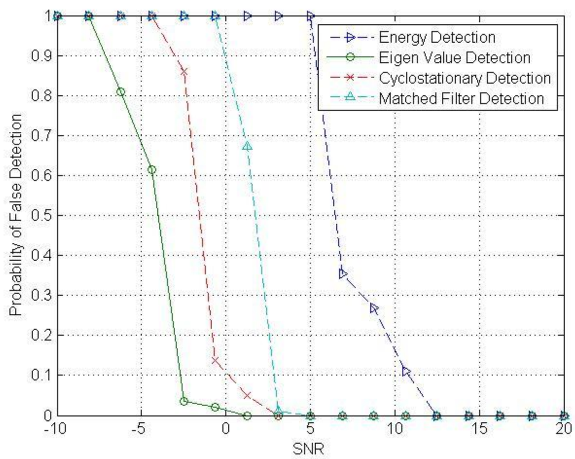

Fig. 5 Probability of false alarm vs SNR

2. Probability of Detection Alarm

Fig.6, in terms of probability of detection alarm detection, with respect to SNR the comparison of Energy detection, Matched filter detection, Cyclostationary detection & Maximum Eigenvalue to minimum eigenvalue ratio detector spectrum sensing techniques is done and plotted. The probability of detection alarm should as high as possible. From Fig. it is shown that probability of detection alarm for cyclostationary feature detection is detecting PU signal at low SNR as compare to other two techniques.

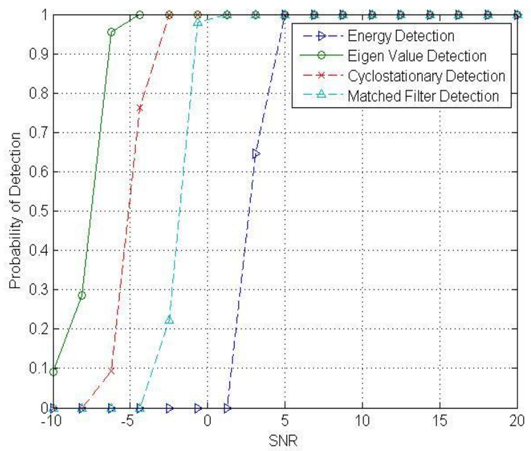

Fig. 6 Probability of detection alarm vs SNR

3. Probability of Miss Detection

In Fig.7, in terms of probability of miss detection, with respect to SNR the comparison of Energy detection, Matched filter detection, Cyclostationary detection and Maximum eigenvalue to minimum eigenvalue ratio detector spectrum sensing techniques is done and plotted. The probability of miss detection should as minimum as possible. From Fig. it is shown that probability of false alarm for cyclostationary feature detection is better than other two techniques.

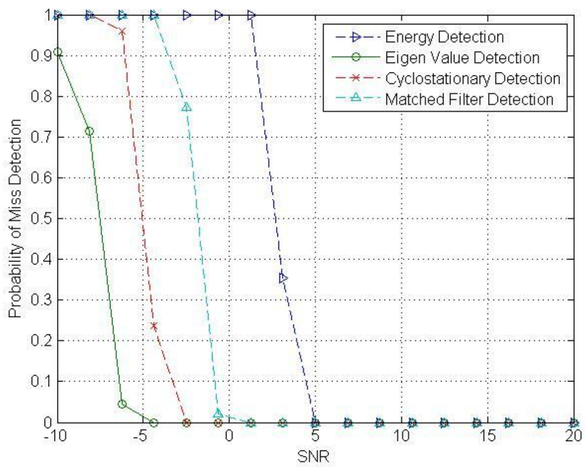

Fig. 7 Probability of miss detection vs SNR

As shown in table 1. Energy Detector requires a longer sensing time to achieve good results. It is unable to differentiate between sources of received energy i.e. it cannot distinguish between noise and primary.

Matched filter detection needs less detection time. 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 [2]the drawback of this technique is that Matched filter detection requires a prior knowledge of every primary signal. If the information is not accurate, MF performs poorly. Also the most significant disadvantage of MF is that a CR would need a dedicated receiver for every type of primary user. Matched filter detection needs less detection time .When the cognitive radio user having information about the type of primary signal, this type of detection works efficiently in stationary Gaussian noise. Matched filter detection works on a prior knowledge. If the information is not accurate, MF performs poorly. Also the most significant disadvantage of MF detection is that a matched filter detector needs receiver according to the primary user.

In cyclostationary detection ability to distinguish between noise and signal [6] makes it better than energy detection and matched filter detection. It performs very well for larger noise on channels. However, cyclostationary detection requires a large computational capacity and significantly long observation times, so difficult to implement. Further, it cannot detect the type of communication, so it reduces the flexibility of CR

IV. CONCLUSION

In this paper, we have compared of all four spectrum sensing techniques, namely energy detector, matched filter, and cyclostationary features based detection techniques in terms of P_f, P_d& P_m. 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.

TABLE-I
Comparative analysis of spectrum sensing technique

Parameter	Energy	Matched filter	Cyclostationary feature	Eigen value
Probability of False Alarm (P_f)	High	Moderate	low	Very low
Probability of Detection (P_d)	Moderate	low	High	Very high
Probability of Missing (P_m)	Moderate	High	Low	Very low
Prior information of input signal	Not necessary	Necessary	Not necessary	Not necessary
Implementation	Simple	Complex	More complex	Simple
Ability of distinguish Signal & interference	No	No	Yes	No
Detection time	Less	Less	Very Large	Moderate

However, its processing time is large and implementation is complex maximum eigenvalue to minimum eigenvalue ration detector methods overcome noise level variation difficulty, and also have the advantages of energy detection method Finally, comparative table showed that maximum eigenvalue to minimum eigenvalue ration detector better than other three techniques..

V. REFERENCES

[1] AshishBagwari, MIEEE, Brahmijit Singh "Comparative Performance evaluation of Spectrum Sensing Techniques for Cognitive Radio networks." 2012 4th international conference on computational Intelligence & communication network, 978-0-7695-4850-0 2012, IEEE (2012).

[2] Shahzad A. et. al. "Comparative Analysis of Primary Transmitter Detection Based Spectrum Sensing Techniques in Cognitive Radio Systems."Australian Journal of Basic and Applied Sciences, 4(9), pp. 4522-4531, INSInet Publication. (2010).

[3] I.F Akyildiz, W Lee, M.C Vuran, S Mohanty,"Next "Generation/ Dynamic spectrum access/cognitive radio wireless networks": A survey" Computer Networks 50(2006) 2127-2159, May 2006.

[4] Simon Haykin, David J. Thomson, and Jeffrey H. Reed (2009)."Spectrum Sensing for Cognitive Radio."IEEE Proceeding, Vol. 97, No.5, pp: 849-87. 2009.

[5] FCC, "FCC 03-322," [Online]. Available:http://hraunfoss.fcc.gov/docspublic/attachmatch/ FCC-03-322A1.pdf Dec.2003

[6] Federal Communications Commission. "Spectrum Policy Task Force." Rep. ET Docket no. 02-135, Nov. 2002.

[7] ParikshitKarnik and SagarDumbre, "Transmitter Detection Techniques for Spectrum Sensing in CR Networks."Department of Electrical and Computer Engineering Georgia Institute of Technology. 2004

[8] Lu, Xiangwei Zhou, UzomaOnunkwo and Geoffrey Ye Li."Ten years of research in spectrum sensing and sharing in cognitive radio." In EURAS Journal on Wireless Communications and Networking, pp. 1-16, Jan. 2012.

[9] Yonghong zeng and Ying-Chang Liang "Maximum-Minimum Eigenvalue Detection for Cognitive Radio." 18th Annual IEEE International Symposium on Personal, indoor and Mobile Radio Communication, 1-4244-1144-0/07, IEEE (2007

BIOGRAPHY

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