International Journal of Computer (IJC)

ISSN 2307-4523 (Print & Online)

http://ijcjournal.org/

To Improve the Probability of Detection in Spectrum Sensing by Using Equal Gain Combining Technique

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Abstract

Development of smart spectrum sensing techniques is the most important task in the design of a cognitive radio system, which uses the available spectrum efficiently. The Energy Detection (ED) and covariance absolute value (CAV) methods do not require any information about the signals, channel, and noise power. So these techniques are known as blind spectrum sensing techniques. This paper mainly focusing on equal gain combining technique. This technique was applied on both Energy Detection (ED) and covariance absolute value (CAV). By using this technique at low Signal to noise ratio (SNR) this system can improve the probability of detection.

Keywords: Cognitive radio; Spectrum sensing; Probability of detection; Equal gain combining; Energy detection; CAV.

1. Introduction

In present days, the use of radio spectrum has become crowded due to the increasing in the number of communication services [1]. By contrast, 90 percent of the existing licensed spectrum remains idle and the usage varies geographically and temporally as reported by the Federal communication commission (FCC) [2]. Permitting unlicensed user to access to the licensed spectrum can greatly increases spectrum utilization efficiency, but it is essential that the secondary users do not cause harmful interference to licensed users [3, 4]. A cognitive radio is required to achieve this, typically through spectrum sensing and interference management. The purpose of this cognitive communication changes is to investigate the spectrum utilization issues associated with primary and secondary user, sharing common spectrum based on throughput performances [5]. The overall goal is allow the unlicensed user to operate in the absence of the licensed users [6].

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Energy detection method is one of the simplest methods and it does not need any priori information to sense the presence or absence of primary user. It takes decision depends on threshold value [14].The main drawback for the energy detection is sensitivity to noise uncertainty. To overcome this problem, this system proposes new methods based on the statistical covariance or autocorrelations of the received signal. The statistical covariance matrices or autocorrelations of signal and noise are generally different. Thus, this difference is used in the proposed methods to differentiate the signal component from background noise. In practice, there are only a limited number of signal samples. Hence, the detection methods are based on the sample covariance matrix [14]. These methods do not need any information of the signal, channel, and noise power a priori. In addition, no synchronization is needed. In a wireless environment, the received signals undergo fading due to the presence of multipath signals. Spatial diversity is an adequate method of combating multi-path. This system can achieve diversity through the use of multiple antenna arrays. The multiple copies of signals received through different diversity paths are appropriately combined at the receiver. Diversity combining techniques are needed to combine the received signals into one. In this paper equal gain combining was studied and it was applied to the Energy detection and CAV. The comparative analysis is done for SNR vs. P_d [7]. The Rest of this paper is organized as follows. Section 2 briefly discuss on cognitive radio. Section 3 describes the System model. Section 4 describes Average probability of detection with diversity reception. Section 5 presents Simulation results. Section 6 concludes the paper.

2. Cognitive Radio

Opportunistic Spectrum access is performed by a device that acts as a radio with the ability to acquire, measure, sense, learn and be aware of its operating environment, which is termed as cognitive radio. Sensing techniques are based on the detection of primary user independently through continuous spectrum sensing. The presence or absence of primary user is identified periodically to locate the unused spectrum bands in targeted spectrum pool. There by, these bands can be used for secondary user transmission optimally without causing harmful interference to the licensed primary users.

3. System Model

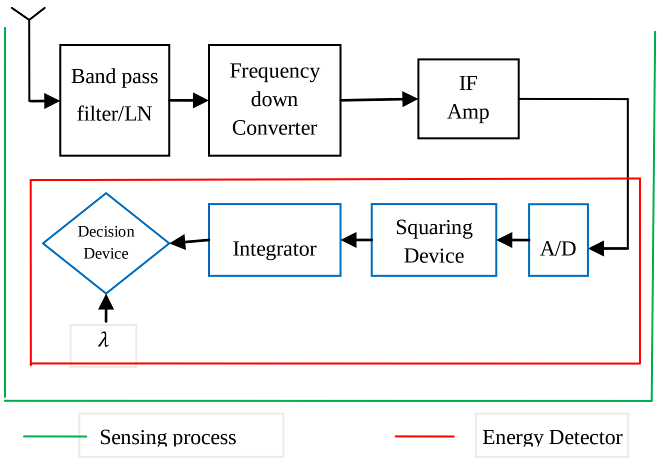

Figure1: Energy Detection Method

In this paper equal gain combining method is applied to energy detection and CAV. In figure 1, energy sensing method is explained. The energy sensing process has two steps [13] as shown in figure1. In the first step a filter is used to achieve the received signal x[n] in the desired bandwidth (B) so that the nearby signals and band noise may be rejected. After that an amplifier for low noise is used to down convert the frequency to an intermediate level. In the next step, sampling and quantization are done using an analog to digital converter [10]. Then, an integrator having Sensing time interval T and a square law device, measure the signal energy which is received. At last, the integrator's output, denoted by Y, is compared with a predefined threshold level¸ so that the absence (H_0) or existence (H_1) of a primary user may be determined.

The received signal X[t] can be defined as a binary hypothesis test as in equation (1)

$$X[t] = \begin{cases} n(t), & H_0 \\ h(t)S(t) + n(t), & H_1 \end{cases} \quad (1)$$

Where h(t) denotes the complex channel gain between Pus and CRs, s(t) denotes the transmitted signal from PUs, and n(t) is AWGN [14]. For the evaluation of the detection performance, the probabilities of detection P_d and false alarm P_f are defined as [12],

$$P_d = P\{decision = H_1 / H_1\} = P\{Y > \lambda / H_1\}$$

$$Pf = P\{decision = H_1 / H_0\} = P\{Y > \lambda / H_0\} \quad (2)$$

3.1. CAV Detection

Please Covariance-based blind detection is nothing but covariance absolute value (CAV), and it exploits the difference between the covariance matrices of primary signals and noise, and it has lower computational complexity compared with the Eigen value-based detection [16], [20].

Let us consider L consecutive samples and define the following vectors:

$$X(n) = [x(n) \;\; x(n-1) \;\; \dots \;\; x(n-L+1)]^T \quad (3)$$

$$s(n) = [s(n) \;\; s(n-1) \;\; \dots \;\; s(n-L+1)]^T \quad (4)$$

$$\eta(n) = [\eta(n) \;\; \eta(n-1) \;\; \dots \;\; \eta(n-L+1)]^T \quad (5)$$

Parameter L is called the smoothing factor in the following. Considering the statistical covariance matrices of the signal and noise defined as

$$R_x = E\,[X(n)\,X^T(n)] \quad (6)$$

$$R_s = E\,[S(n)\,S^T(n)] \quad (7)$$

Here verify that

$$R_x = R_s + \sigma_\eta^2 I_L \quad (8)$$

If signal s(n) is not present, $R_s = 0$. Hence, the off-diagonal elements of R_x are all zeros. If there is a signal and the signal samples are correlated, R_s is not a diagonal matrix. Hence, some of the off-diagonal elements of R_x should be non zeros. Denote r_{nm} as the element of matrix R_x at the n^{th} row and m^{th}column, and let

$$T_1 = \frac{1}{L} \sum_{n=1}^{L} \sum_{m=1}^{L} |r_{nm}| \quad (9)$$

$$T_2 = \frac{1}{L} \sum_{n=1}^{L} |r_{nm}| \quad (10)$$

Then, if there is no signal, T1/T2 = 1. If the signal is present, T1/T2 > 1. Hence, ratio T1/T2 can be used to detect the presence of the signal [11].

Statistical covariance matrix Rx can be approximated by the sample covariance matrix defined as

$$\tilde{R}_x(N_s) = \begin{bmatrix} \lambda(0) & \lambda(1) & \cdots & \lambda(L-1) \\ \lambda(1) & \lambda(0) & \dots & \lambda(L-2) \\ \vdots & \vdots & \ddots & \vdots \\ \lambda(L-1) & \lambda(L-2) & \cdots & \lambda(0) \end{bmatrix} \quad (11)$$

4. Average Probability of Detection with Diversity Reception

In case of more than one antenna used at receiver, diversity combining techniques are used. This section presents the probability of detection for Equal gain combining (EGC) in AWGN channel [7].

4.1. Equal Gain Combining

The Maximal Ratio combining technique provides the maximum performance relative to all other diversity combining techniques, but at the same time it provides the highest complexity of all the combining techniques because MRC requires knowledge of the fading amplitude in each signal branch. Whereas in equal gain combining complexity is very much reduced as it uses equal weights in each branch and so it does not require estimation of the channel (path) fading amplitudes. The total conditional SNR per symbol at the output is given by

$$\gamma_{EGC} = \frac{(\sum_{l=1}^{L} \alpha l)^2 E_s}{\sum_{l=1}^{L} Nl} \quad (12)$$

Where E_s is the energy (in joules) per symbol and N_l is the AWGN power spectral density on the l^{th} path. The probability of detection at the EGC output for AWGN channel can be calculated by

$$P_d = Q_{LN/2}(\sqrt{\gamma_{EGC})}\ , \sqrt{\lambda}) \quad (13)$$

5. Simulation Results

Here, this paper had shown the results for SNR (dB) vs. probability of detection for Equal Gain Combining (EGC) with ED and CAV. All simulations in this work are executed on MATLAB (Version R2017a). Monte Carlo (MC) method, which is a stochastic technique (based on the use of random numbers) forms the basis of these simulations.

5.1. Simulation results for ED and ED with equal gain

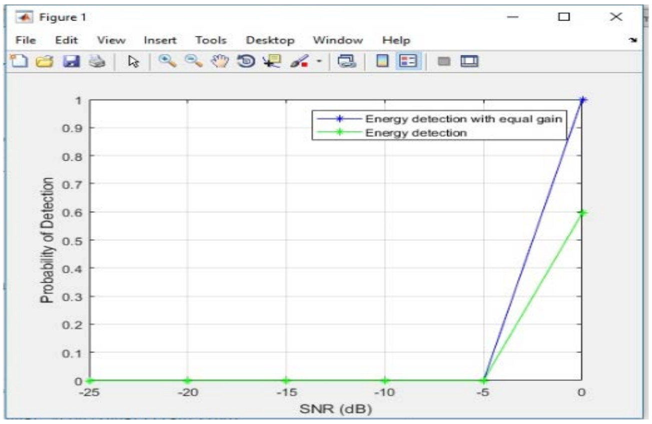

Figure 2: SNR (dB) vs. Pd for ED and ED with EGC

5.2. Simulation results for CAV and CAV with equal gain

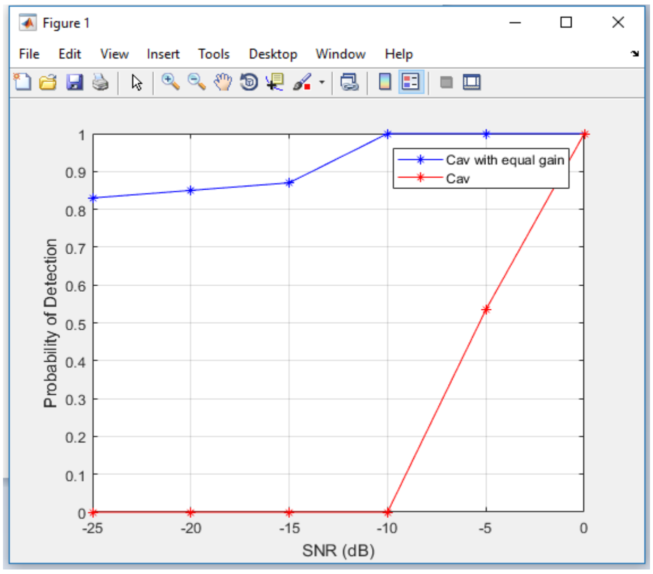

Figure 3: SNR (dB) vs. Pd for CAV and CAV with EGC

Table 1: Shows the simulation results of ED, ED with EGC, CAV, and CAV with EGC

SNR (db)	Probability of detection(pd)			
	ED	ED with EGC	CAV	CAV with EGC
-25	0	0	0	0.83
-10	0	0	0	1
-5	0	0	0.53	1
0	0.6	1	1	1

It can be seen from the Table.1. That performance is better in case of Equal Gain combining. So it can be concluded that the detection performance of energy detector and CAV can be enhanced by using equal gain combining technique.

6. Conclusion

In this paper, the results shows that the performance of spectrum sensing using energy detection and CAV under equal gain diversity reception scheme.

By using Equal gain combining technique there is noticeable improved the performance of the energy detector and CAV. EGC with CAV gives a better detection performance than ED and CAV.

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