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A Performance Analysis of Equal Gain Combining For Cooperative Spectrum Sensing in Cognitive Radio Networks

[1]Preeti Gadekar *(M.Tech Scholar)*, [2] Prof. Vinay Gupta *(Associate Professor)*
[1,2]Department of Electronics & Communication Engineering
[1,2]Bhopal Institute of Technology (BITS), Bhopal(M.P), INDIA
[1]gadekarpreeti@gmail.com , [2]Vinaygupta11121986@gmail.com

ABSTRACT – In this paper Cognitive Radio (CR) aims to access the wireless spectrum in an opportunistic manner while the licensed user is not using it. To accurately determine the licensed user's existence, spectrum sensing procedure is vital to CR system. Energy detection based spectrum sensing techniques is favourable due to its simplicity and low complexity. In addition, to improve the detection performance, cooperative spectrum sensing technique exploits multi-user diversity and mitigates detection uncertainty. In this thesis, we investigate several energy detection based cooperative spectrum sensing techniques. In this proposed work first, detect the energy of the signal for detection of the energy of the signal using square method. Further apply detected signal equal gain combining based Soft decision combining scheme, in which all CR users forward its observation to the fusion center, is derived. In order to reduce the communication overhead between cognitive radio users and the fusion center. Simulation of proposed method is created in MATLAB programming language to implement the proposed scheme and to analyze its simulation performance. The results of the simulation show that the proposed cooperative spectrum sensing and equal gain combining is appropriate for radio frequency sensor networks combination scheme is superior to the traditional hard combination schemes in terms of false alarm reduction. Probability of detection (Pd) v/s SNR (Different Values of Pf), Probability of Missed Detection (Pmd) v/s Probability of False Alarm (PFA), Probability of Detection (Pd) v/s Probability of False Alarm (SNR), Probability of detection (Pd) v/s SNR (Different values of time bandwidth factor) and Equal Gain Combining at ten user .

***Keywords*— Cognitive Radio Network (CRN), Equal Gain Combining (EGC), Square Law Method, Fusion Centre, Matrix laboratory (MATLAB)**

I. INTRODUCTION

Modern communication relies heavily on wireless technology. As a multitude of wireless technologies have been developed, and continuously increased capacity is being demanded, a severe problem has emerged. The electromagnetic spectrum is a fixed physical quantity, and only a certain part of it is suitable for radio communication. Available electromagnetic spectrum for wireless transmission has become a scarce and highly valuable resource.

The traditional way of governing this resource has been to administer licenses for portions of the spectrum, usually by a national agency such as Post og Teletilsynet (PT). Recent research published by the US Federal Communications Commission (FCC), see for instance or, shows that a large part of the spectrum is not being effectively utilized. A typical reason being the fact that system demand among licensed users varies significantly with time and location. Such research has spurred the development of a next generation wireless technology commonly referred to as cognitive radio. A device using cognitive radio technology will intelligently determine whether a certain part of the frequency spectrum is idle, or if it is being utilized. If the cognitive radio can successfully determine with a high degree of certainty that a specific part of the spectrum is being idle, it can then transmit on these frequencies without interfering with the licensed owner of the spectrum, thus achieving better spectral resource efficiency. The requirement of no interference is extremely rigid to avoid disturbing licensed users. It is thus key for the development of cognitive radio to invent fast and highly robust ways of determining whether a frequency band is available or being occupied. This is the area of spectrum sensing for cognitive radio

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B. Motivation

Reliable detection of the existence of primary users is a primary requirement for the minimization of interference to existing primary networks. In a real communication environment, the local sensing performance of individual users may severely degrade due to deep fading/shadowing. Therefore, individual spectrum sensing is unreliable and prone to errors. However, spectrum sensing can be significantly improved by allowing different users to share their local sensing observations and to cooperatively decide on the licensed spectrum occupancy.

By exploiting the diversity provided by associated radios, CSS improves the overall detection sensitivity without imposing higher sensitivity requirements on the individual CRs. A network of cooperative cognitive radios, which experience different channel fading conditions from the target, would have a better chance of detecting the primary radio if the individuals' local sensing is jointly combined at a base station.

Significant underutilization of the radio spectrum is the biggest motivation for the study of cognitive radio. Basically, Cognitive Radio solves the spectrum underutilization problem in a tightly inter-coupled pair of ways:

(i) Sense the radio environment to detect spectrum holes in terms of both time and location.

(ii) Control employment of the spectrum holes by secondary users efficiently, subject to the constraint.

II. COGNITIVE RADIO NETWORK

Radio communication has evolved around a rigid structure stringently defined by the choice of modulation, encoding and the type of hardware to implement these choices. However, the revolution in processor technology in the 1980's and 1990's gradually allowed more flexibility in the design of radio systems as a larger part of the necessary signal processing could be performed digitally. This flexibility created a developing field, researching highly dynamic and adaptive radio systems. These radio systems were defined in software but were implemented through reconfigurable hardware such as Field Programmable Gate Arrays (FPGAs). This branch of wireless technology was named Software Defined Radio (SDR). Cognitive radio, is an extension to SDR, where one allows the radio system to adapt to its environment through learning or artificial intelligence with the aim of increasing performance. An early paper introducing the concept of cognitive radio is.

Features

Cognitive Radio is a paradigm that has been proposed so that the frequency spectrum can be better utilized. The formal definition for Cognitive Radio is given as:

"Cognitive Radio is a radio for wireless communications in which either a network or a wireless node changes its transmission or reception parameters based on the interaction with the environment to communicate effectively without interfering with the licensed users."

If the frequency range from 40 MHz to 1000 MHz is carefully observed in figure 2-1 then this range can be classified into 3 sub-categories (i) Empty bands most of the time, (ii) Partially occupied bands, and (iii) Congested Bands. The main category of interest for the cognitive radio users is the first category in which the hardly used or empty bands are classified. In layman terms cognitive radio is nothing but a methodology wherein the first category of the frequency range is brought to the use for unlicensed users in such a way that interference to the licensed users is minimized.

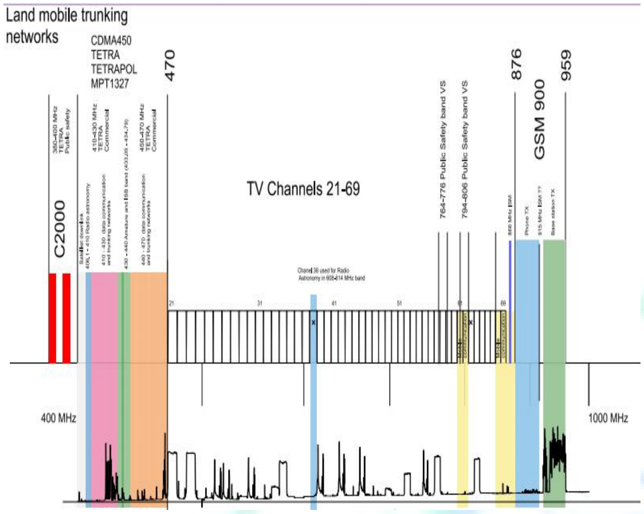

Figure 1: Spectrum Utilization

III. PROPOSED METHOD

In this chapter shows the proposed cognitive radio network (CRN). The proposed method contain different parts. In the first past detect the energy of signal (ES), after the detection of apply the spectrum sensing techniques. There are different spectrum sensing techniques are available. In the proposed work used square law device is used then apply equal gain combining (EGC) at the receiver end. At the receiver end there are multiple receivers available and they detect the probability of spectrum of the signal

A. Energy Detector –It is a simple detector which detects the total energy content of the received signal over specified time duration. It has the following components:

- Band-pass filter -- Limits the bandwidth of the received signal to the frequency band of interest.
- Square Law Device – Squares each term of the received signal.
- Summation Device – Add all the squared values to compute the energy.

A threshold value is required for comparison of the energy found by the detector. Energy greater than the threshold values indicates the presence of the primary user. The principle of energy detection is shown in figure 4.1. The energy is calculated as:

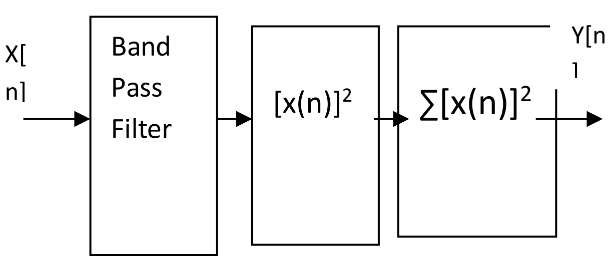

Figure 2: Principle of Energy Detection

Moreover, the ED does not involve complicated signal processing and has low complexity. In practice, energy detection is especially suitable for wide-band spectrum sensing. Energy detector is composed of four main blocks:

1) Noise Pre-filter.
2) A/D Converter (Analog to Digital Converter).
3) Squaring Device.
4) Integrator.

B. Matched Filter Technique

The Matched Filter Technique is very important in communication as it is an optimum filtering technique which maximizes the signal to noise ratio (SNR). It is a linear filter and prior knowledge of the primary user signal is very essential for its operation. The operation performed is equivalent to a correlation. The received signal is convolved with the filter response which is the mirrored and time shifted version of a reference signal. The figure 4.3 outlines the principle of its operation.

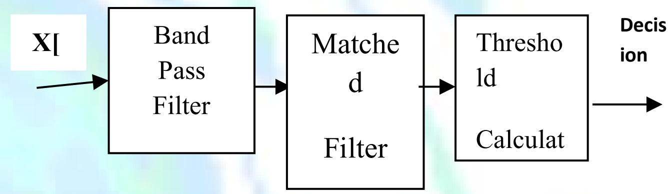

Figure 3: Principle of Matched Filter Operation

C. Combining Process – Equal-Gain Combining Diversity

Various techniques are known to combine the signals from multiple diversity branches. In Equal Gain Combining, each signal branch weighted with the same factor, irrespective of the signal amplitude. However, co-phasing of all signal is needed to avoid signal cancellation.

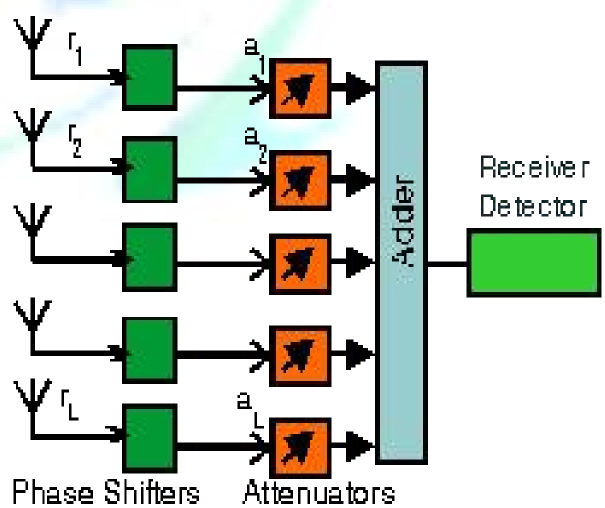

Figure 4.: *L*-branch antenna diversity receiver (*L* = 5)

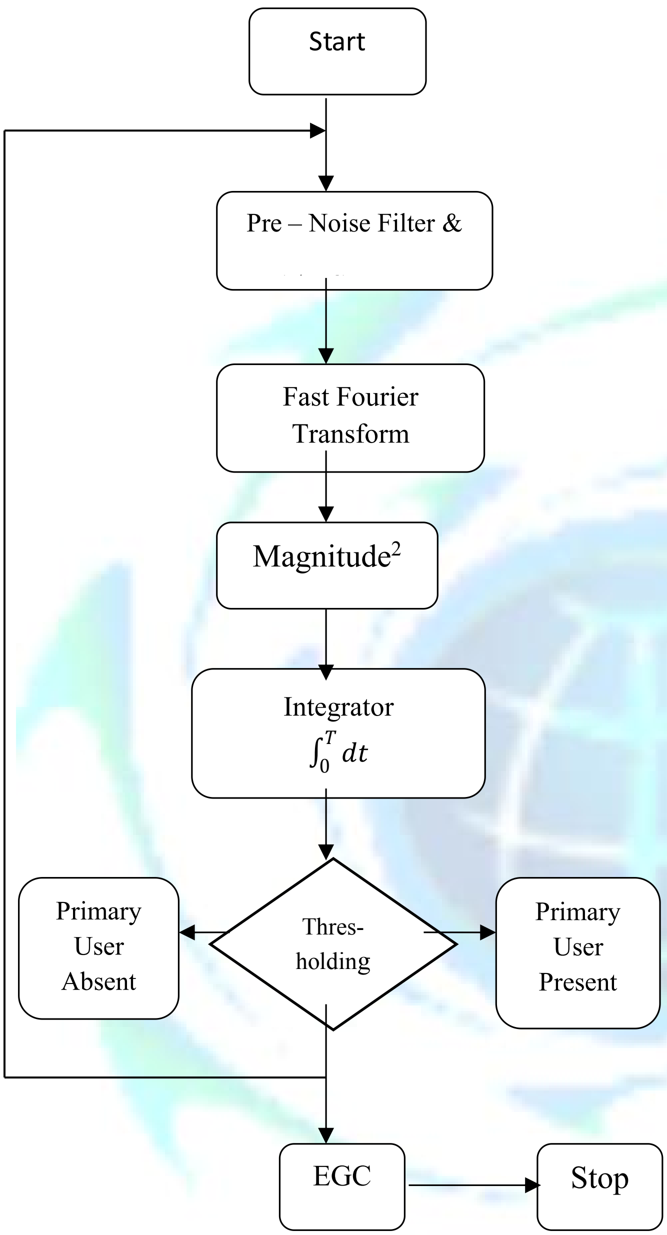

Figure 5: Flow Chart of Purposed Architecture

IV.SIMULATION AND RESULT

In this section, the results of proposed spectrum sensing that is based on square law (SL) based energy detection methods at different probability of detection and false alarm of non-fading AWGN Channel. After the energy detection apply equal gain combining (EGC) for combining the different sensing outputs. EGC is soft thresholding method used in the proposed work. In this proposed method calculate result on different parameters different values of time bandwidth factor (u) and changing different threshold conditions (λ) and also the results on the basis of probability of detection (Pd) and probability of false alarm (Pfa) are compared.

1. Probability of detection (Pd) v/s SNR (Different Values of Pf)
2. Probability of Missed Detection (Pmd) v/s Probability of False Alarm (PFA)
3. Probability of Detection (Pd) v/s Probability of False Alarm (SNR)
4. Probability of detection (Pd) v/s SNR (Different values of time bandwidth factor)
5. Equal Gain Combining at ten user

A. Result Calculation of Proposed Method –

In the first result calculate probability of detection (P_d) v/s SNR (Different Values of Pf). Figure 5.1 shows the probability of detection (P_d) of AWGN channel at different probability of false alarm rate (P_f=0.01, 0.05, 0.1 and 0.15). In this figure 5.1, X axis represents different SNR value and Y axis shows probability of detection. At P_f=0.15, probability of detection (P_d) is high (performance of AWGN channel is good at P_f=0.15). In below the figure 6 clearly see when increases the value of probability of false alarm (Pf) similarly probability of detection is also increases (Pd) with respect to the signal to noise ratio values (SNR).

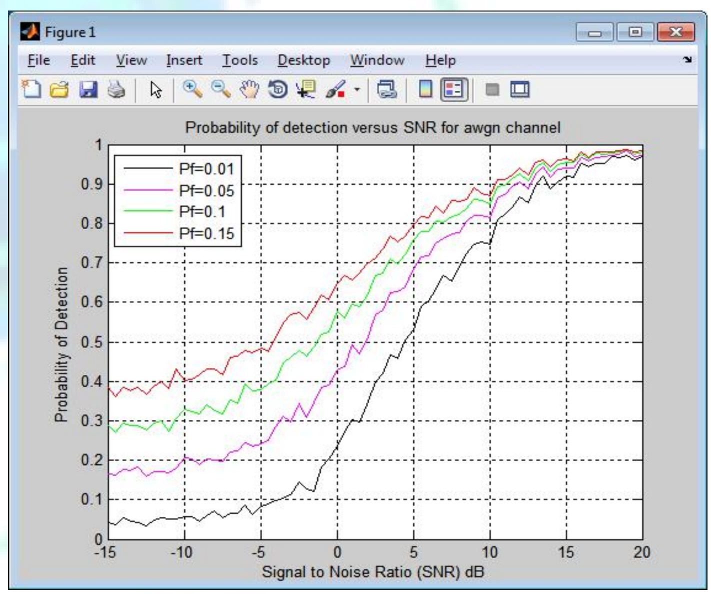

Fig. 6 Probability of detection (P_d) v/s SNR at different probability of false alarm (pf) (In AWGN channel)

Table 1 Probability of detection of AWGN channel at different Probability of False Alarm rate (Pfa)

Probability of detection (Pd) of AWGN channel				
Signal to Noise Ratio (SNR) v/s probability of detection (Pd)				
SNR	Pf =0.01	Pf = 0.05	Pf =0.1	Pf =0.15
-10	0.046	0.1853	0.35	0.402
-5	0.08	0.237	0.37	0.484
0	0.2287	0.413	0.55	0.648
5	0.5503	0.66	0.7683	0.797
10	0.7813	0.85	0.8727	0.87

B. Probability of Missed Detection (Pmd) v/s Probability of False Alarm (PFA) -

The below the figure 5 shows that the probability of missed detection v/s Probability of false alarm rate at different SNR values, Where X axis represents the probability of false alarm and Y axis represents that probability of missed detection. For compare the results of proposed method at different SNR value (5dB, 10dB and 15 dB) and evaluate the results,

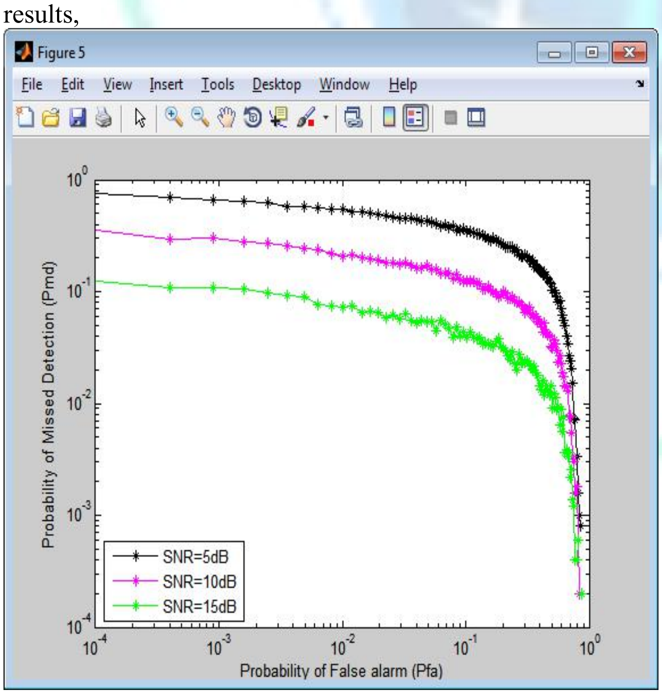

Fig. 7-Probability of Missed Detection (Pmd) v/s Probability of False Alarm (Pfa) (In AWGN channel)

Form a table which is shown in table 2. Performance of AWGN channel is good at SNR = 5dB.

Table .2-The Probability of False Alarm rate (Pfa) of AWGN channel at different SNR

ROC of AWGN channel			
Probability of false alarm (P fa) v/s probability of missed detection (P md)			
Pfa	SNR=5dB	SNR=10dB	SNR=15dB
0.0001	0.745	0.3576	0.1344
0.001	0.6616	0.2912	0.1046
0.01	0.5044	0.2126	0.0662
0.1	0.2932	0.1076	0.041
1	0.0002	0.0002	0.0002

The above table 2 is the tabular representation of the Probability of false alarm (pfa) v/s probability of missed detection (Pmd) at different SNR values (5, 10 and 15db). The above table shows the increases the SNR 5, 10 and 15 with respect to the (pfa) values proportional. Means that higher values of SNR shows the lower values of probability of false alarm rate.

C. Probability of Detection (Pd) v/s Probability of False Alarm (SNR) –

The below the figure 6 shows that the probability of detection (Pd) v/s Probability of false alarm (Pfa) rate at different SNR values, Where X axis represents the probability of false alarm and Y axis represents that probability of missed detection. For compare the results of proposed method at different SNR value (12dB, 14dB, 18dB and 20 dB) and evaluate the results. The below figure shows the relation between probability of detection (Pd) and probability of false alarm (Pfa). For better understanding this figure also compare the result in the tabular form that is also shown in the table 3

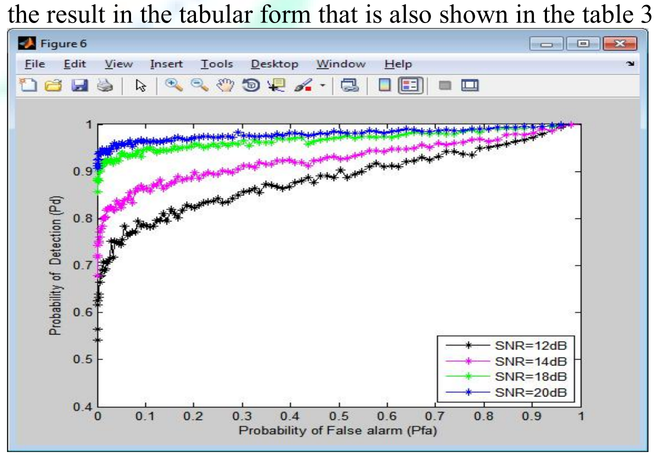

Fig. 8 Probability of detection (Pd) and Probability of False Alarm

Table .3 Probability of False Alarm (Pfa) of AWGN channel at different SNR (12 and 14)

SNR	Probability of False Alarm	Probability of Detection	SNR	Probability of False Alarm	Probability of Detection
12 dB	0.1	0.78	14 dB	0.1	0.85
	0.2	0.82		0.2	0.88
	0.3	0.85		0.3	0.91
	0.4	0.87		0.4	0.92
	0.5	0.9		0.5	0.93
	0.6	0.91		0.6	0.94
	0.7	0.93		0.7	0.96
	0.8	0.95		0.8	0.97
	0.9	0.97		0.9	0.98

The above the figure 6 shows that the probability of detection (Pd) v/s Probability of false alarm rate (pfa) at different SNR values, Where X axis represents the probability of false alarm and Y axis represents that probability of detection. For compare the results of proposed method at different SNR value (12dB, 14dB, 18 dB and 20dB) and evaluate the results.

V. CONCLUTION

In the proposed work, the spectrum sensing by proposed square law based equal gain combining methods are performed. The performance of proposed method based on spectrum sensing in AWGN channel is evaluated by deriving its detection probability (Pd) and probability of false alarm rate (Pf) and the performance of energy detection method is analyzed. Using this figure clearly seen that squaring method with equal gain combining shows better result as compare to the other different methods of spectrum detection.

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