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Optimal Analysis of Hybrid Combining Mechanism using Cyclo-Stationary Feature Detection with MRC for CRNS

Ashish Kumar Sinha[1], Prof. Rajeev Thakur[2]
[1]Research Scholar, Department of Electronics & Communication Engineering
[2]Associate Professor, Department of Electronics & Communication Engineering
[1,2]NRI Institute of Information Science and Technology, Bhopal (M.P.)

Abstract
The study of present day, the spectrum usage reveals that nearly 70% of available spectrum is underutilized which is a serious concern as the available spectrum is the most precious resource for radio communication. The concept of cognitive radio emerged as a very strong solution that employs Dynamic Spectrum Access (DSA) in contrast to the present day situation employing Fixed Spectrum Allocation (FSA). To combat the difficulties of hidden user node problem, SNR degradation and issues related to difficulties in non-cooperative spectrum sensing, the cognitive radio networks were upgraded to the cooperative spectrum sensing. Cooperative sensing acquires information from multiple secondary users for primary user detection. By analyzing the conclusions drawn from this research, it is reconfirmed that the adopted enhanced energy detection provides a better sensing performance than the traditional energy detection described in literature and provides an enhancement of 20.25% in detection probability for the simulation done in this dissertation. The simulation done in this dissertation establishes that if the enhanced energy detection scheme is employed for local sensing instead of the traditional method, the performance of the traditional centralized combining hybrid spectrum sensing (employing Hard Combination at the Fusion Center) is improved for all the three rules viz. AND, OR, Majority rule. The increase in mean probability of detection is most significant for the Majority rule (which is 71.48%) and least significant for AND rule (which is 0.00256%), whereas it is 0.02% for OR rule, as concluded from the simulation proposed in this dissertation. Thus a centralized cooperative spectrum sensing network employing Hard Combination at the Fusion Center, can be optimized by using the Enhanced Energy Detection for local sensing.

Keyword- Dynamic Spectrum Access, MATLAB, Fixed Spectrum Allocation.

Introduction

Most of the available radio spectrum (ranging from 3Khz-300Ghz) has been already allocated to various sectors of service such as mobile communication, defence, microwave communication, television etc. Radio transmission starts at VLF (very low frequency) range extending to VHF (very high frequency) and UHF (ultra-high frequency) bands. Thus it is evident that different parts of the spectrum are used for different technologies and applications. The spectrum is composed of several frequency bands which are slotted into channels and each band is used for a special purpose. The radio spectrum is a very scarce and valuable asset for every radio engineer and so great emphasis has to be given on its optimum usage. The term 'radio' refers to the transmission and reception of electromagnetic waves that carry information such a speech or data while the term 'cognitive' refers to the processes related to acquisition and analysis of knowledge about something. Many revered institutions have put forward the definition of a cognitive radio. According to ITU, a cognitive radio is a system that is aware of its operational environment and senses it to dynamically change its transmission parameters while the FCC puts forward a simpler definition describing cognitive radio as a radio that can change its transmission parameters on the basis of its interaction with the environment. The transmitter and receiver detection techniques are single user techniques (non- cooperative), involving secondary user (SU) nodes that individually search for spectrum holes and transmit upon finding them. Cooperative detection on the other hand, is a multiuser approach in which the nodes first sense the spectrum individually (termed as local sensing) and the locally sensed information is amalgamated to form a single decision.

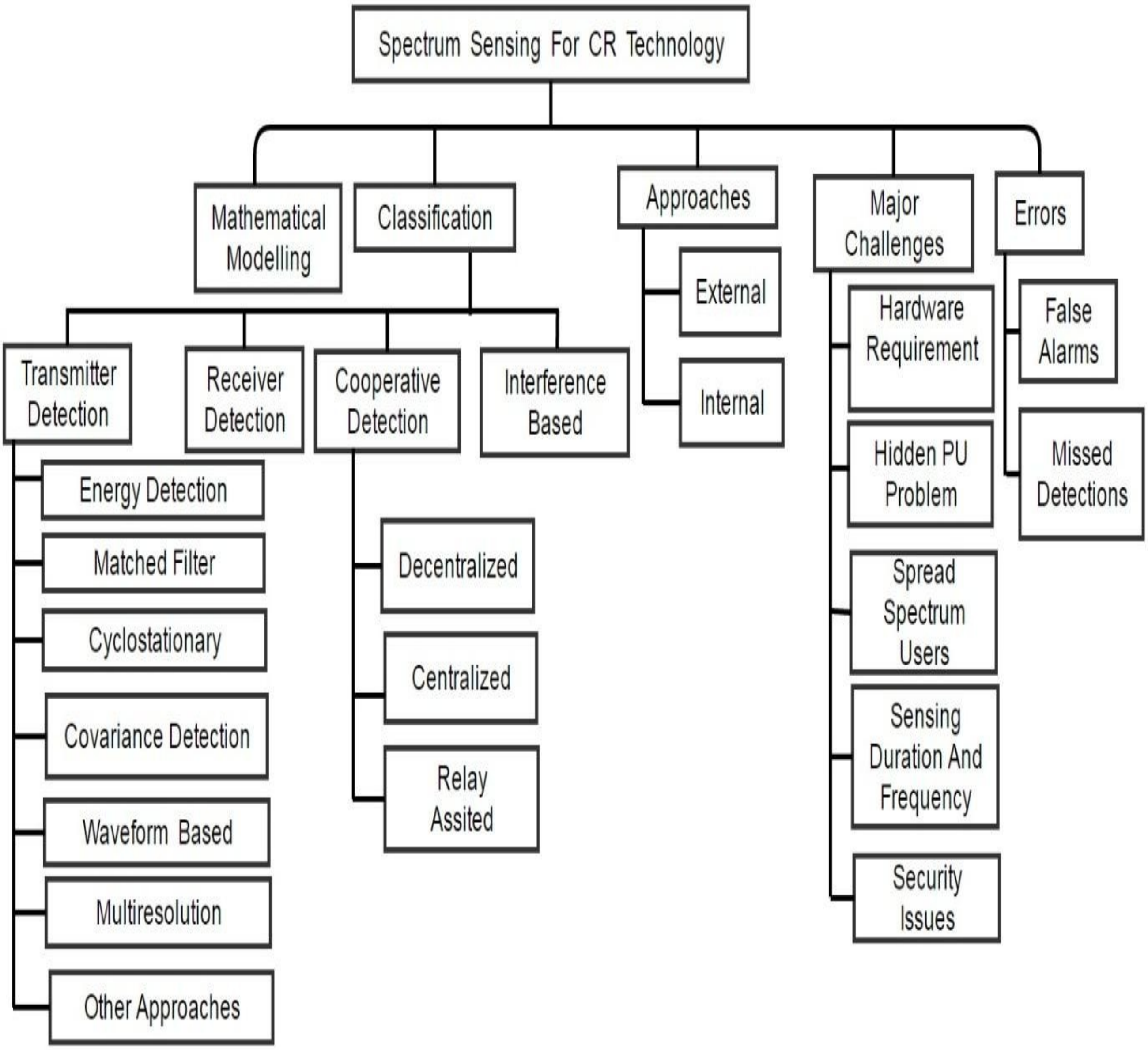

Figure 1: Spectrum Sensing For Cognitive Radio.

Objectives of the Research Work

In order to identify the possible ways for enhancing spectrum sensing, some objectives of research were setup. These objectives are:-

To review the existing methods of spectrum sensing, mainly focusing on transmitter detection techniques and cooperative spectrum sensing.

Identification of problem specification in context of cooperative sensing.

Identification of solution and mathematical modeling of spectrum sensing.

Simulation of solution in programming language and analysis of result.

2. Literature Review

Waleed Ejaz et al: This work puts forward the scenario of a CRN with heterogeneous sensing devices. Here, a CRN with sensing nodes employing different local sensing methodologies is described and a performance analysis of hard and soft combination for this network is proposed. It is concluded that if only a small number of SU nodes in a homogeneous network (employing a uniform local sensing method) are replaced by nodes employing improved sensing methodologies, a significant improvement in the detection performance can be obtained. The work also concludes that the soft fusion techniques outperform the hard fusion techniques for the heterogeneous CRNs which holds true for the homogeneous CRNs also.

Ting Peng et al: This work proposes a novel hard decision fusion algorithm designed to combat the effects of the spectrum sensing data falsification (SSDF) attacks. SSDF attacks mislead the FC to make incorrect decisions about spectrum availability. SSDF attacks are launched by malicious users (MUs) hidden within the primary network, mimicking a PU. The work describes the attack modes of hidden MUs as always busy attacks (AB), always free attacks (AF) and always opposite report attacks (AO).To mitigate these attacks, a reputation based mechanism is adopted in which the SU nodes are classified on the basis of reputation and MUs are screened . It is observed that OR fusion rule has strong robustness under AF attacks whereas for AB and AO rules, the proposed algorithm outperforms traditional hard decision fusion rules.

James D. Gadze et al: In this work the authors provide a detailed study of the energy detection(ED) technique. The study aims at assessing the performance of an energy detector for non-fading and fading channel scenarios. The authors suggest that ED performed over a Rayleigh channel exhibits a tough detection performance compared to that of AWGN channel. The concept of cooperative spectrum sensing is also studied and it is concluded that for both noon cooperative and cooperative scenarios, ED technique performs better in AWGN channel than in fading channels.

3. Problem Statement

Based on the literature review in the above sections, the researcher found the following research:

Most of the researchers working in the field of cooperative spectrum sensing (CSS) algorithms have shown interest in energy detection due to its simplicity. Hence this research focuses on improving energy detection scheme.

From the study done, it was observed that cooperative spectrum sensing has emerged as a strong concept to battle large number of issues. Hence this research work focuses on how cooperative spectrum sensing can be optimized further.

The appraisal of the diverse literature helped in the identification of the gap or problem in the selected area of interest. So, the problem statement has been formulated as: “Optimization of Centralized Combining Hybrid mechanism for Cognitive Radio Networks”.

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4. Proposed Methodology

The purpose of this research was primarily to find out a way that would optimize spectrum sensing in cognitive radio networks. A thorough analysis of existing research in the domain of spectrum sensing for cognitive radio puts forward the need of hybrid combining spectrum sensing to combat issues like multipath fading, receiver uncertainty etc. The factors that become crucial for this research are as follows:

1. To know the various schemes for optimizing combining sensing existing in literature and to study the effects of local sensing on the overall system performance.
2. Find an optimized energy detection scheme that performs better than the traditional energy detector.
3. Put forward more accurate cooperative spectrum sensing by implementing local sensing through the optimized energy detector.
4. Develop a unique learning approach that works well and stable under all conditions.

As we have discussed earlier, in the section of problem specification that there is a requirement of incorporating enhanced local sensing methods such as the enhanced energy detection scheme incorporated in this work that can enhance the cooperative gain of the network. Thus we wish to build a methodology using improved energy detection that amplifies the detection performance of a conventional cooperative sensing network. This methodology will be most suitable for implementation in cooperative cognitive radio networks for avoiding system failures caused due interference to the primary network , since it lowers the false alarm probability and also provides lesser missed detections

5. Terminology of Spectrum Sensing

It is possible that the prevalent environmental noise degrades the signal to be detected to such an extent where it is hardly recognizable. It is thus important that the sensing algorithm should be made as robust as possible. The performance of any cognitive radio (CR) system lies only on the sensing quality.
Spectrum sensing is analysed in terms of a probabilistic approach and the important probabilities determining the system performance are defined as follows:

1. Probability of False Alarm: probability of a CR user declaring the presence of a PU when it is actually absent.
2. Probability of Missed Detection: probability of a CR user declaring the absence of a PU when it is actually present.

Reality	Response of the CR detector	
	RESPONSE : "PU ABSENT"	RESPONSE: "PU PRESENT"
PU PRESENT	MISSED DETECTION	DETECTION
PU ABSENT	CORRECT REJECTION	FALSE ALARM

Table 1: Terminology Based on CR Response and the Real Situation.

a) Steps of Cooperation Between the Secondary Users Nodes

Cooperative spectrum sensing can be put forward as a simplified process comprising of the following three steps, each of them having equal significance:
Step 1: Local sensing
Step 2: Reporting / sharing

Step 3: Final decision as the result of information fusion
Local sensing is referred to as the sensing done by individual CR node within the periphery of its local environment. The locally sensed information is then reported to the fusion center (as in centralized approach) o with other CR nodes (as in decentralized approach). The local information collected is fused to form a unified/global decision which is broadcasted to all of the nodes belonging to the network.

6. Results

Any simulation remains incomplete without a proper outcome analysis and a comparison of the prevailing differences between the proposed and existing methodologies. In this subsection of the dissertation, emphasis is given to the analysis of result obtained and the inferences drawn from it. The result analysis put forward consists of determining the following points:

- Determination of the transmitted and received signal waveforms.
- Modeling of the transmitted Primary User (PU) signal, the signal received by the secondary user (SU) node and the channel noise.
- Understanding the structure of the coding indented for simulation.
- Developing an understanding of the ROC plots to interpret simulation results.

Constraint	Value
Transmitted PU signal	Gaussian Random variable
Channel type	AWGN
PU signal SNR	-14 dB
Length of Sensing interval	1000 samples
Simulation method	Monte Carlo
Number of Monte Carlo simulations	100
Probability of false alarm	0.01 to1 (100 values)

Table 2: Various Constraints for Proposed System Model.

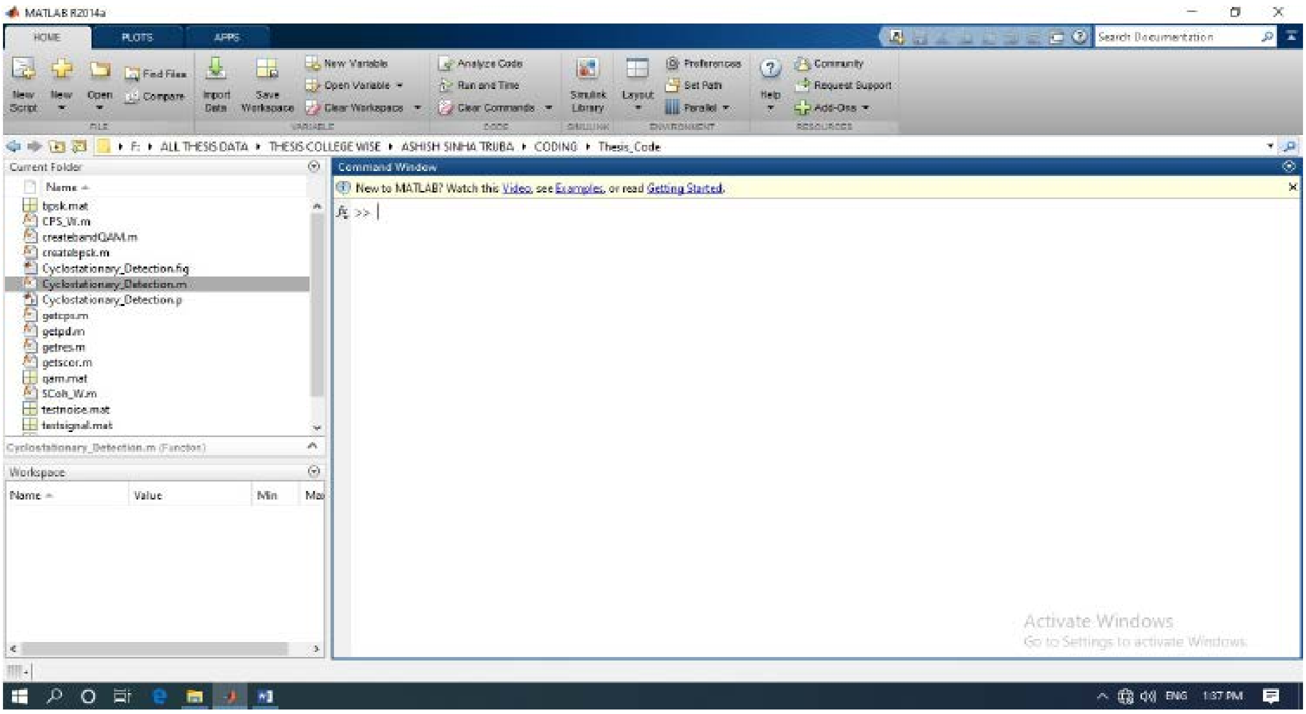

Figure 2: Shows that the initially empty window for implementation of centralized combining spectrum sensing mechanism.

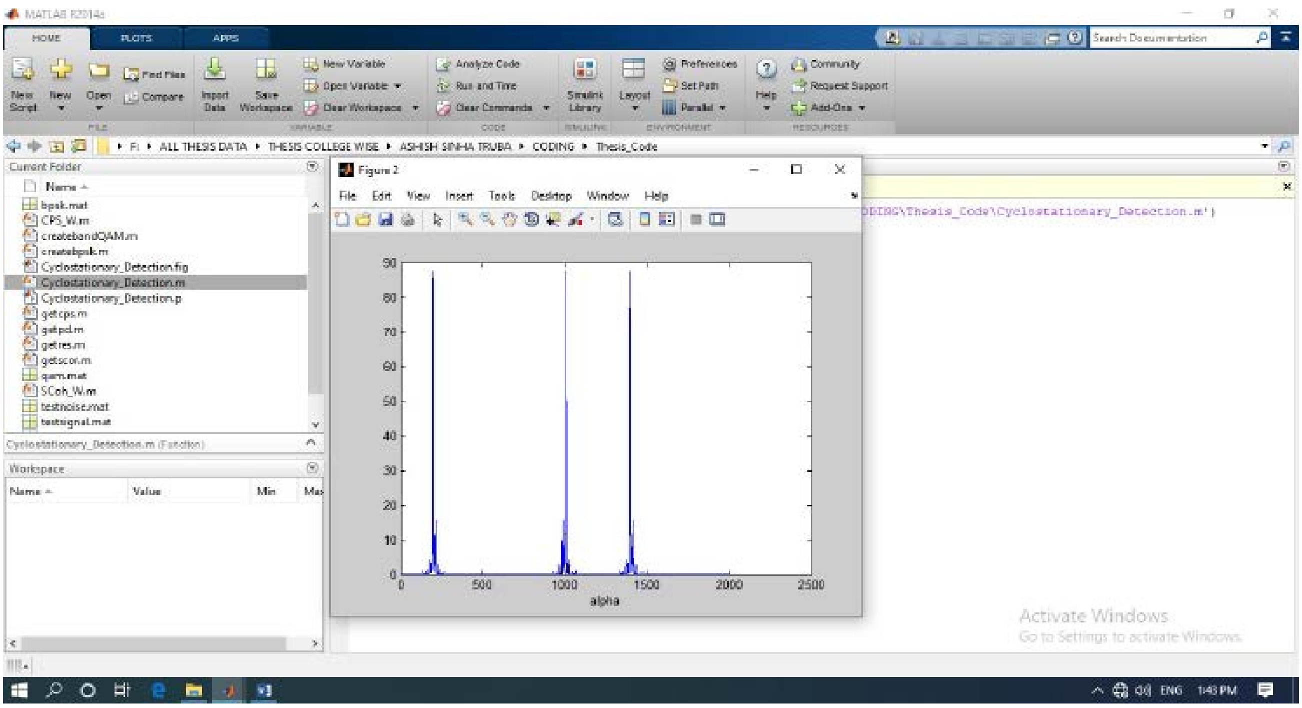

Figure 3: Shows the signals at different value of alpha.

As above depicted figure 3 shows that cyclic spectral density for signals that shows different value frequency and alpha signal. Figure shows the signal peak value of signal at different point.

SNR	Probability of Detection		
	Pfa = 0.01	Pfa = 0.05	Pfa = 0.1
-20	0.42	0.50	0.54
-15	0.46	0.60	0.62
-10	0.54	0.79	0.81
-5	0.75	0.85	0.90
0	0.86	0.88	0.91
5	0.88	0.90	0.96

Table 3: Pd with increase in Pf a using Improved Energy Detector Operation for AWGN Channel.

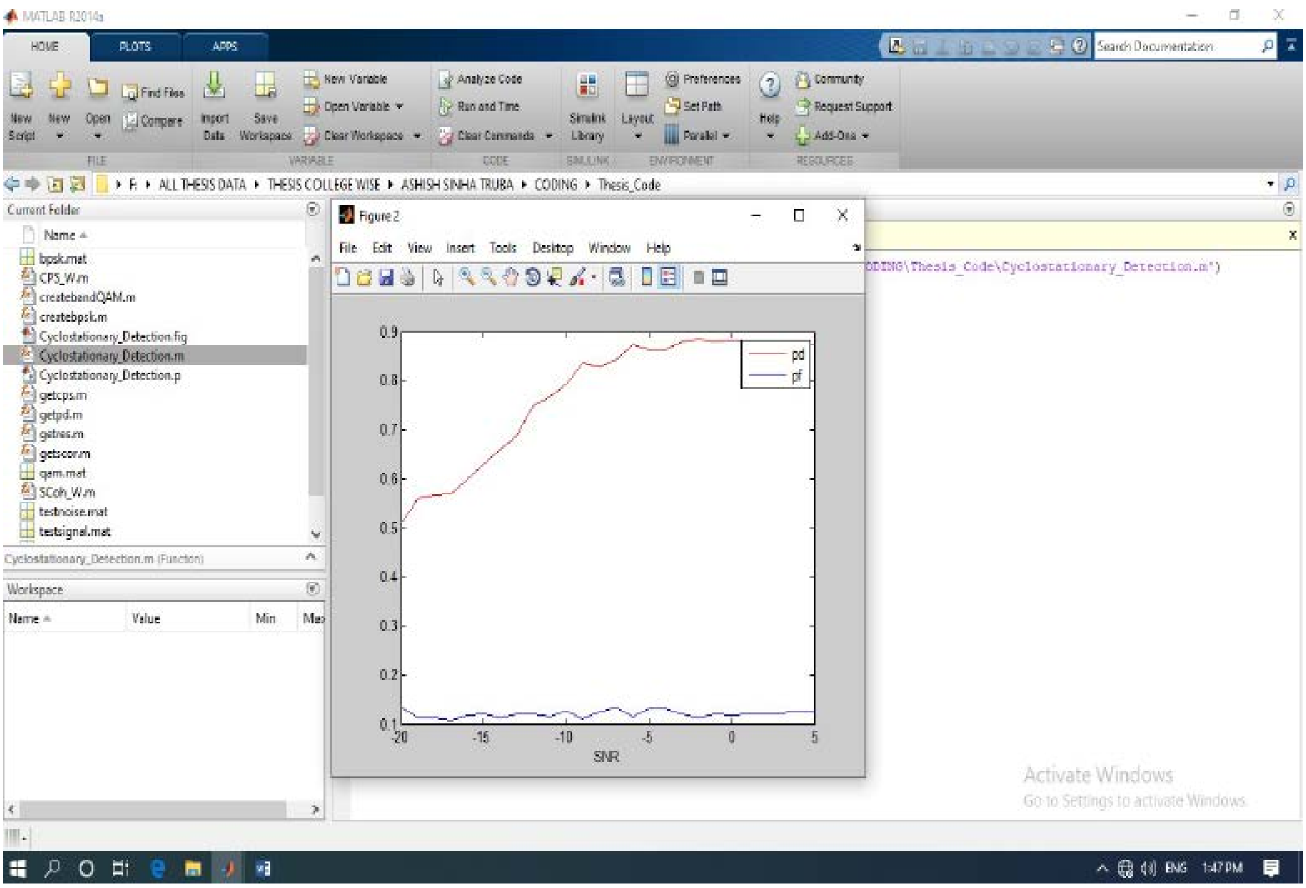

Figure 4: SNR Vs Pd and SNR Vs Pf Curve for Improved Energy Detector for AWGN Channel.

SNR	Probability of False alarm (Pfa)	Probability of Detection (Pd)
-20	0.10	0.50
-15	0.11	0.62
-10	0.12	0.79
-5	0.13	0.85
0	0.13	0.88
5	0.14	0.90

Table 4: Pf and Pd with increasing value of SNR for Improved Energy Detector for AWGN Channel.

As the above depicted table 4 shows that the value of probability of detection with increasing value of SNR and probability of false alarm also, in that see from the table the value of probability of detection increase with increase in SNR and increase value of Pfa also. As above values of probability of detection for improved energy detector operation over AWGN channel plotted in the figure 5 as depicted below.

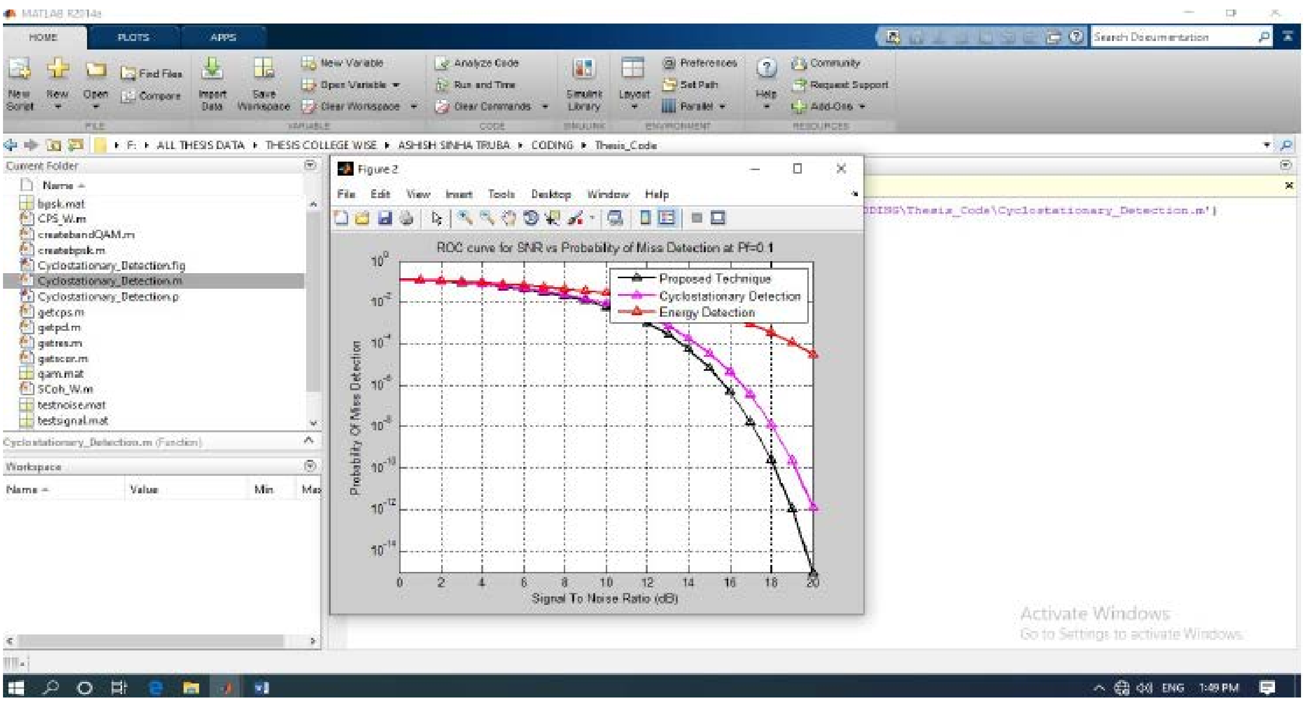

Figure 5: ROC Curve for SNR Vs Probability of Missed Detection at Pf = 0.1.

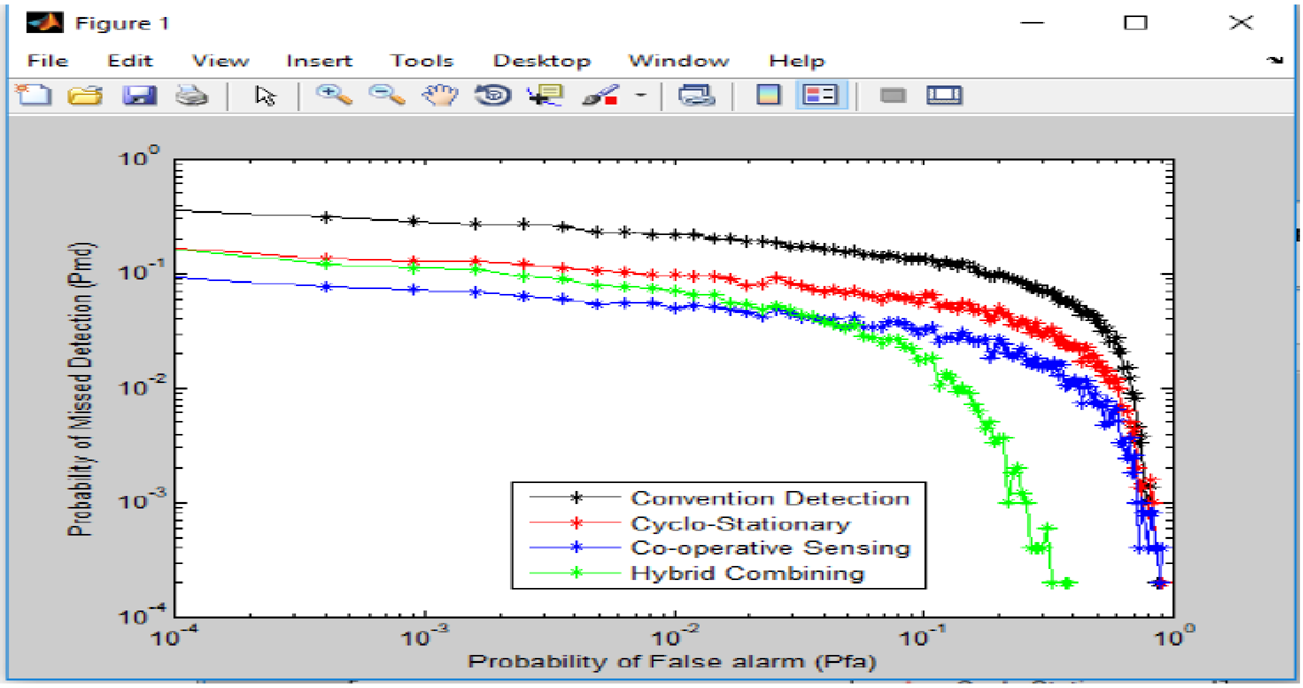

Figure 6: ROC Curve Pmd Vs Pfa for Different Mechanism of Energy Detector Operation over AWGN Channel.

Parameter	Previous Base Paper Work	Proposed Work
Algorithm Used	Group-based Multi-bit Cooperative Spectrum Sensing	Cyclo-Stationary Feature Detection with Maximum Ratio Combining
Compatibility	Good	Quite Better
Complexity	Quite High	Low
Performance	Good	Quite Better
Pd	0.94	0.96
Pmd	0.06	0.04
Pfa	0.1	0.05
BEP	0.16	0.09

Table 5: Results Comparison between Existing Mechanism and Proposed Mechanism.

7. Conclusion

This dissertation was undertaken with the aim of optimizing the traditional setup of cooperative sensing network (which uses traditional energy detection at every node for individual/ local sensing).

Although the research in this dissertation accomplished a promising result of "Optimal Analysis of Hybrid Combining Mechanism using Cyclo-Stationary Feature Detection with MRC for CRNs", there always exists a scope of improvement in every work which is also described in this chapter.

1. The enhanced energy detector (EED) provides a better detection probability in comparison with the tradition energy detector (TED), providing an enhancement of 20.25% in detection probability for the simulation proposed in this dissertation.
2. The enhanced energy detection scheme reduces the average probability of missed detection by 34.78%, for the simulation proposed in this dissertation.
3. The enhanced energy detector reduces the average bit error probability by 16.66%, for the simulation proposed in this dissertation.
4. The enhanced energy detection proves to be a better sensing algorithm as it provides an improvement of 12.20% in the test quality, for the simulation proposed in this dissertation.
5. The proposed optimized spectrum sensing provides higher mean probability of detection in comparison to the traditional cooperative spectrum sensing for all the hard combination rules. The increase in mean probability of detection (which is 71.48%) is most significant for the Majority rule and least significant for AND rule (which is 0.00256%) for the simulation proposed in this dissertation.
6. The OR rule outperforms the Majority and AND rule in terms of probability of detection, for the simulation proposed in this dissertation.
7. The Majority rule provides better detection probability for increasing values of SNR, for the simulation proposed in this dissertation.
8. The detection performance for Majority rule improves as the number of secondary user (SU) nodes increase, for the simulation proposed in this dissertation.

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