

# PSO Algorithm Based Resource Allocation for OFDM Cognitive Radio

Kokil Tyagi<sup>1</sup>, Er. Bhawna Sharma<sup>2</sup>

<sup>1</sup>M.Tech Student, Yamuna Institute of Engineering & Technology, Yamuna Nagar, India

<sup>2</sup>Asst. professor, Electronics & Communication Engineering Department, Yamuna Institute of Engineering & Technology, Yamuna Nagar, India

*kokiltyagi1@gmail.com*

**Abstract:-** With the development of remote correspondences, the issue of data transmission lack has turned out to be more conspicuous. Then again, to sense the presence of authorized clients, range detecting procedures are utilized. Vitality recognition, Matched channel identification and Cyclo-stationary component location are the three ordinary techniques utilized for range detecting. However there are a few downsides of these strategies. The execution of vitality indicator is helpless to instability in noise power. Coordinated channel range detecting strategies require a devoted collector for each essential client. Cyclo-stationary element Detection requires parcel of calculation exertion and long perception time. This proposition talks about the routine vitality location strategy and proposed enhanced vitality identification technique utilizing cubing operation. Additionally, cyclic prefix based range detecting is talked about in this theory. Scientific Description of vitality location and cyclic prefix based range detecting strategies is likewise delineated for fading channels.

**Keywords:** Cognitive Radio, Energy Detection, Match Filter

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## I. INTRODUCTION

With the development of wireless devices and technology, new frequency bands are being used in the radio spectrum. Due to increase in the wireless device count, the radio spectrum is becoming increasingly congested. Also, the augmentation in the new wireless devices with the development in technology has promised more and more frequency band to be utilized. This may result in the high level of interference among the frequency bands which are being operated adjacent to each other. Again, it depends on the time and place of use. However, if trend continues in the future, all the remaining frequency bands will be utilized and the devices need to face heavy interference thus restricting the performance.

This may lead to deciding of the upper limit to the wireless device count. Measurements and statistics show that a broad range of the spectrum is not being used all the time, depending on the geographical region, whereas the other ranges are used heavily. Thus, the radio spectrum is being underutilized depending on the place and time of the day. This results in the inefficient use of the spectrum. Generally, the frequency bands which are licensed operate at fixed time and remaining time they are free. These free or unused bands of the spectrum cannot be used by conventional wireless systems because these are licensed and can be used only by the respected owners of that band. So, to use those bands which are unused by the licensed user during certain time, we need a device which can automatically change the operating parameters whenever it senses the unused band.

Cognitive Radio also known as smart radio is an intelligent radio technology which can learn its radio environments and change its transmission parameters [3]. It was first proposed by Joseph Mitola in a seminar at KTH, The Royal Institute of Technology, in 1998. So, Cognitive Radio is sometimes referred to as Mitola Radio. It can adapt itself to decide the future actions dynamically to improve the communication quality and meet the overall requirements of the users. The main feature of CR system is that it is autonomous and is

software controlled. It can change its characteristics dynamically without the intervention of the user. This involves the sensing of the free spectrum and then deciding the radio resources such as bandwidth, symbol rate, power, number of subcarriers etc. to a group of secondary (or CR) users based on the behavior of the users to whom the frequency band is licensed (primary users). These processes are all controlled by software and are fully dynamic in nature.

The main functions of Cognitive Radio are to sense the environment, to manage the environment for data transfer, to look for any disturbances in the environment and if so, then re-sense the environment for nominal disturbances. It operates in a cycle fashion such that it begins sensing the environment unless it is not favorable for data transmission. Here, sensing the environment means sensing the free and unused band of frequency.

The spectrum sensing involves the detection of unused spectrum from the wireless band which results in minimal interference with other users. The free frequency bands are known as spectrum holes. There are various techniques by which the spectrum holes can be detected such as Transmitter detection, Matched Filter detection, Energy detection, etc. After the proper frequency has been sensed, the problem of spectrum management

## II. OFDM FOR COGNITIVE RADIO

OFDM stands for Orthogonal Frequency Division Multiplexing. It is the multi-carrier modulation technique in which data is split up into chunks and every chunk are modulated using closely spaced orthogonal subcarriers. The orthogonal subcarriers have the property that they do not have any mutual interference between them. So, this scheme is very useful for high bit-rate data communication. One of the serious problems of high data rate transmission is time dispersion of pulses resulting in Inter-symbol Interference (ISI). In OFDM, the data is split into several low-rate data chunks and are modulated in overlapping orthogonal subcarriers. These

splitting increases the symbol duration by the number of subcarriers used, thus reducing the ISI due to multipath. OFDM is adapted as the best transmission scheme for Cognitive Radio systems [1]. The features and the ability of the OFDM system makes it fit for the CR based transmission system. OFDM provides spectral efficiency, which is most required for CR system. This is because the subcarriers are very closely spaced and are overlapping, with no interference.

Another advantage of OFDM is that it is very flexible and adaptive. The subcarriers can be turned on and off according to the environment and can assist CR system dynamically. OFDM can be easily implemented using the Fast Fourier Transform (FFT), which can be done by digital signal processing using software.

### III. LITERATURE REVIEW

It requires the allocation of various parameters on which data transmission takes place. It includes allocation of proper subcarriers; transmit power, number of bits per symbol, all within the interference level of the adjacent band of another user and proper quality of service. If the operating channel meets with the interference level above threshold, then the frequency of operation needs to be changed in a smooth manner, not disrupting the existing data exchange.

(i) Parametric Problems: during this variety of problems, parameters area unit the choice variables to be optimized. These optimisation issues are often more categorised into strained and at liberty issues. The matter constraints may be style conditions, initial boundaries or quality demands.

(ii) Combinatorial problems: Combinatorial optimisation problems will either be relative or absolute and area unit characterised by a finite set of possible solutions. Typical example of combinatorial issues is sort of a salesperson United Nations agency travels between cities and at the top of his travel returns to the initial town he started thereby covering the shortest distance. it's quite common to resolve such drawback through the utilization of a heuristic search rule like Genetic Algorithm (GA).

### IV. OVERVIEW OF PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM

Swarm Intelligence are associate optimisation procedure supported biological activities of flocking of birds, schools of fish also because the social activities of living beings. PSO is one in these entire population primarily based algorithmic program that is applied to seek out solutions to optimisation issues. The PSO is the additionally acknowledge for its quick convergence once applied to hunt out the solutions in comparison to alternative optimum techniques like Genetic Algorithms that involutes mutations, crossovers and chromosomes imitating biologically the natural process theorized by Darwin.

Particle Swarm Optimization (PSO) is an iterative technique whereby it represents a particular drawback as some extent or surface in associate n-dimensional area, and with the trouble of cooperation through the 3 socio-cognitive principles explicit by Kennedy [6] it retrieves the specified solution:

- [1] Evaluate
- [2] Compare
- [3] Imitate

The problem is assessed with the help of particles that are seeded with initial positions and velocities that move through the outlined area. Whether or not the particles are willy-nilly seeded or it is not decided by the lookers of the algorithmic program and its supposed application. Memory is additionally at play here since each particle is needed to notice down the last result obtained and also the level of success it had. So the primary in try in achieving or near one would be an optimum location for the opposite "flocks" to get "food". The algorithmic program which can wrestle many various ways to achieving the goal, the final plan is to judge the native neighbours encompassing that particles and compare, then imitate on as to if an answer could also be obtained from constant or close locations.

The general strategy is coordinated in line with sure criteria apart from the fitness perform that takes under consideration the native best worth also because the world best worth obtained, so avoiding confining itself to any native minima or maxima, that be deluded from the particular optimum answer if such a happening happened.

The main plan of the initial PSO algorithmic program is taken by the social behaviour of the animals, specially the power of teams of some animals to figure as an entire in inform fascinating positions during a given space, e.g. birds flocking to a food supply. This seeking behaviour was co-related thereupon of associate optimisation look for the solutions during a search area. The scientists wish to grasp thirstily that however giant number of birds synchronously typically changes direction, scattering and re-grouping that is later to be found depends chiefly upon the birds efforts to take care of the minimum distance between them. The foremost common implementation of PSO includes within which the particles move through the search area mistreatment associate amalgam of associate attraction to the most effective answer that they singly have found, associated an attraction to the most effective answer that any particle in their neighbourhood has found. In PSO, a neighbourhood is outlined as that for each particle the encompassing particle through that they will communicate simply. Every particle in PSO is appraised as some extent during a D-dimensional search area. The amount of the particle within the search area is delineated as and also the best position of that ordinal particle is delineated by!, rate by "!" And the index of that particle is delineated by Gbest.

Since 1995, many several makes an attempt are created to boost the performance of the PSO, wherever it is not a world improvement algorithmic program, has been verified by E van den Bergh [5]. Therefore, a replacement PSO algorithms program planned by researchers to boost the performance of PSO algorithm, as an example, a replacement PSO algorithm offered by Jun Sun [6], [7] referred to as quantum-behaved PSO (QPSO) will solve this downside, however it see because the substitute PSO algorithms that have the matter of the irritation Of spatiality, that in explicit that their performance deteriorates at the spatiality of the search area will increase.

Additionally, a replacement PSO algorithmic program referred to as Cooperative QPSO (CQPSO) bestowed by [5] that adopt the advantage of cooperative technique to unravel the matter of the high-dimensions curse of QPSO essentially.

## V. PARTICLE SWARM OPTIMIZATION (PSO)

The Particle Swarm Optimization (PSO) is a swarm intelligence-based evolutionary algorithm. It is a biologically inspired algorithm motivated by social analogy. Its aim is to obtain the global optimum of a real-valued function defined in a given space [3]. It was inspired by the behavior of the swarm to look for food. This was introduced first by Kennedy and Eberhart in the year 1995. Kennedy was an American psychologist and Eberhart was an electrical engineer. This algorithm makes use of social behavior and movement dynamics of insects, birds and fish. Let us take example of the fish food searching behavior. The searching space of the fish can be considered as the search space and the fish in the shoal can be considered as small particles denoting solutions in the search space. The process of searching the food can be viewed as an optimization process. In the process, the members of the shoal compete among themselves and share the information with the partners to find the best solution of the problem altogether.

The research have shown that when birds or fishes search for food, they do it in groups (flocks or swarms) and not individually. The observation is based on the assumption that the information is shared inside the group among the individuals. The behavior of each individual is influenced by the behavior of the whole group. The PSO was developed through simulation of the simplified social system and has been found robust in solving nonlinear optimization problems [2]. The PSO algorithm can produce simplified and good solution with lesser calculations, shorter time and stable convergence than any other conventional methods.

The PSO is closely related to the Artificial Life and Evolutionary Algorithms. It uses a position-velocity model in a swarm based searching process. A swarm consists of a set of individuals or particles, each representing a potential "solution" of the problem being formulated. Each particle is characterized by its position and velocity in the searching space.

The position and velocity determine the searching region. The fitness value for each particle is evaluated by using the position and velocity to determine the solution performance using the avail or the fitness function.

There are various pros and cons of the PSO algorithm which makes it limited in use in certain areas only. It has very efficient global search algorithm and is easy to implement with less number of parameters to be determined. However, it has slow convergence in the refined search stage or has weak local search ability. But still it is simple to use and is immune to the changing the scale of the parameters.

The PSO algorithm is best suited to the continuous variable problems. It has been applied to a number of applications including the Artificial Neural Networks. It is used in the training of Neural Networks in areas like image processing and Fuzzy logic. It can be applied in electrical distribution field for

optimized power supply. Various other applications include system identification in biomechanics and biochemistry and in structural optimization of shape and size design.

Two basic types of PSO can be identified based on the processing of the algorithm, synchronous and asynchronous PSO. In synchronous PSO the particles are evaluated parallel first and then they are compared. Generally, a synchronous point is required for all the particles from where again the process can start for iteration. In asynchronous PSO, each particle is evaluated separately and then compared in every step. If a particle is already found to be fit, it need not be re-evaluated, thus saving the computation time.

### b) Parameters of PSO [2]

1. Initial Population: The population is the set of  $n$  particles, and is generated randomly.
2. Population Size: It refers to the number of particles in a swarm and should be set according to the problem (based on the tradeoff between accuracy and computation time).
3. Swarm: It is a set or group of the particles or population which move in random directions.
4. Search Space: It is the range in which the algorithm computes the solution. It is the set of solutions defined in a space.
5. Number of Iterations: It refers to the maximum number of steps required for the fitness value to converge to an optimal solution.
6. Inertia weight: The inertia weight controls the convergence of the algorithm and should be chosen very carefully. Too high or too low inertia weight can lead convergence to fail and no solution will be obtained.

The present of the primary signal in the cognitive radio can be defined using Binary hypothesis

Hypothesis 0 (H0): the primary signal is absent.

Hypothesis 1 (H1): the primary signal is present

Let the transmitted signal is denoted as  $S$ . complex signal which has real component  $S_r$  and imaginary component  $S_i$  then  $S = S_r + j S_i$  and the received signal  $y$  is sampled, the  $n$ th ( $n=1,2,3,\dots$ ) sample  $y(n)$  is given as :

$$y(n) = \begin{cases} x(n), & 0 \leq n \leq N-1 \text{ idle} \\ x(n) + n(n), & 0 \leq n \leq N-1 \text{ busy} \end{cases}$$

And  $x(n) = h s(n)$  where  $h$  is the channel gain and the complex noise  $n(n)$  can be expressed as  $n(n) = n_r(n) + j n_i(n)$  is the noise sample with zero mean

( $E\{w(n)\} = 0$ ) and variance  $2\sigma_w^2$  ( $\text{Var}[n(n)] = 2\sigma_w^2$ ) i.e  $gN(0, 2\sigma_w^2)$  equation 3.1 can be re write as :

$$y(n) = \theta x(n) + n(n)$$

Where ' $\theta$ '=0 for H0 and ' $\theta$ '=1 for H1 therefore the signal model H1 can be given as:

$$H1: y(n) = \begin{cases} x(n), & 1 \leq n \leq n_0-1 \\ x(n) + n(n), & n_0 \leq n \leq N \end{cases}$$

[1] Energy detector Test statistics

The purpose of this test statistics is to compare the threshold value with that of the received signal SNR value and decide the presence/absence of primary signal in CR system.

When Nyman-Person Criterion applied in the binary hypothesis model the probability density function of the given signal  $y$  can be expressed as  $H$  is  $f_{\lambda}(y)$   $H(x)$  where  $H \in \{H_0, H_1\}$

Therefore based on the above test statistics, the performance of energy detector is defined using the following metrics:

False alarm probability (P<sub>f</sub>): the probability of deciding the signal is present while H<sub>0</sub> is true, i.e.,  $P_f = Pr[\Lambda > \lambda | H_0]$  where  $\lambda$  is the detection threshold.

Missed detection probability (P<sub>m</sub>): the probability of deciding the signal is absent while H<sub>1</sub> is true, i.e.,  $P_m = Pr[\Lambda < \lambda | H_1]$ ,

Detection probability (P<sub>d</sub>): the probability of deciding the signal is present when H<sub>1</sub> is true, i.e.,  $P_d = Pr[\Lambda > \lambda | H_1]$  and thus,  $P_d = 1 - P_m$ .

The statistical properties of  $\Lambda$  are necessary to characterize the performance of an energy detector.

To get the statistical properties, signal and noise models are essential.

[2] Performance metric measurement

The performance of the spectrum sensing technique can be quantified by the performance metric values.

The following parameters are used to check the performance of energy detector:

- Probability of detection.
- Probability of false alarm.
- Probability of miss detection.

The receiver operating characteristics curve(ROC),

The performance matrices ROC curve measure the sensitivity of the detector and it can be used in binary hypothesis system.

The graphical plot of P<sub>d</sub> (or P<sub>m</sub>) versus P<sub>f</sub> as the threshold varies in the ROC curve

[3] Derivations of P<sub>d</sub> and P<sub>f</sub> for Different Channel Models

Let's consider that the noise  $n(t)$  is a band pass signal hence the low pass signal representation of the noise is :

$$n(t) = n_i(t) \cos 2\pi f t - n_q(t) \sin 2\pi f t$$

Where  $n(t)$  is the noise signal having power spectral density  $N_0$  with band width  $BW$ ,  $n_i$  and  $n_q$  are the in phase and the quadrature component of the noise of low pass signal representation of the noise signal  $n(t)$ , having bandwidth

$BW/2$  and the power spectral density for low pass signal is  $2N_0$  the energy of the noise for period of  $T$  is

$$E = \int_0^T n(t)^2 dt$$

$$E = \int_0^T n(t)^2 dt = \frac{1}{2} \int_0^T [n_i(t)^2 + n_q(t)^2] dt$$

[4] Probability of detection and probability of false alarm detection for AWGN

$P_d$  is the probability that H<sub>1</sub> is selected when the primary signal is present and

$P_{fa}$  is probability of false alarm when H<sub>0</sub> selected.

We also assume that the threshold value of  $\kappa$  is selected hence the  $P_d$  and  $P_{fa}$  can be defined as:

We also assume that the threshold value of  $\kappa$  is selected hence the  $P_d$  and  $P_{fa}$  can be defined as:

$$P_d = P(Y > \kappa | H_1)$$

$$P_{fa} = P(Y > \kappa | H_0)$$

Then from their PDF it is possible to express  $P_{fa}$  as:

$$P_{fa} = \int_{\kappa}^{\infty} f_Y(y) dy$$

VI. RESULT SIMULATION

To simulate the effect of SNR on detection of the above equations using Matlab: for single user detection in AWGN model:

Case 1 Set  $P_{fa} = 0.01$ ;  $d=1$ ;  $N = \text{number of Monte Carlo samples} = 1000$

Vary the SNR and find the corresponding probability of detection value and plot the result graph  $P_d$  vs SNR the resulting graph will be

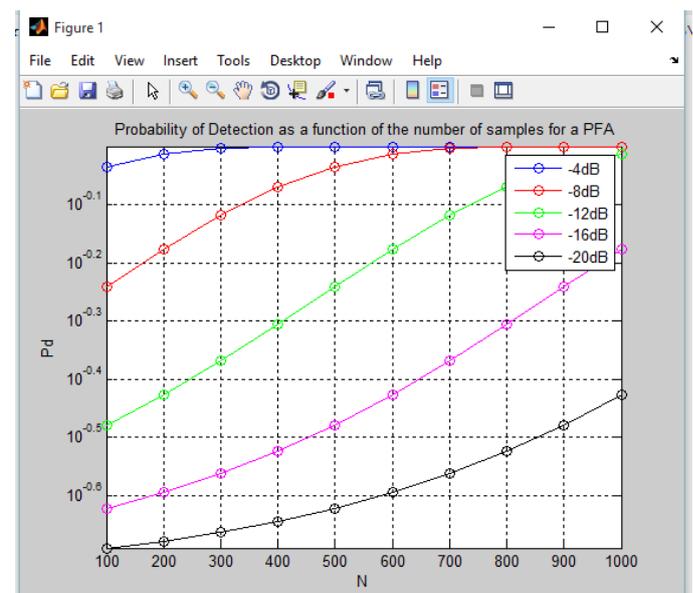


Figure 1.1: Probability of detection as a function of the number of samples for a PFA.

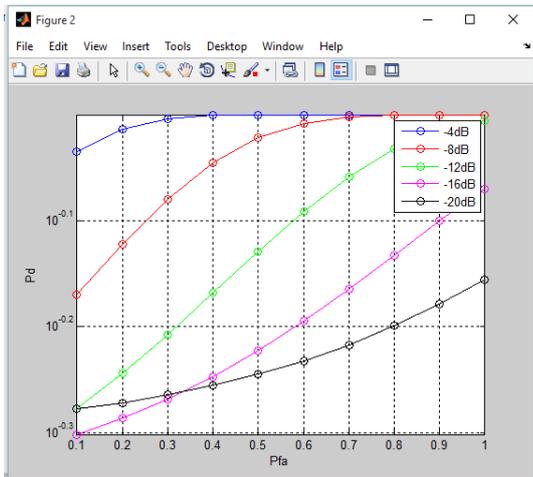


Figure 1.2: Probability of detection as a function of a PFA.

Case 3 complementary ROC curve for energy detector for AWGN this graph shows the relation between Probability of miss detection and false alarm probability for different value of SNR value 0 to -15dB  
 Set SNR value =0dB,-5dB,-10dB-15dB  
 Time bandwidth product  $d=4$ ; sample size  $N=1000$  and probability of miss detection is found  $P_m=1-P_d$  and the expected graph is like:

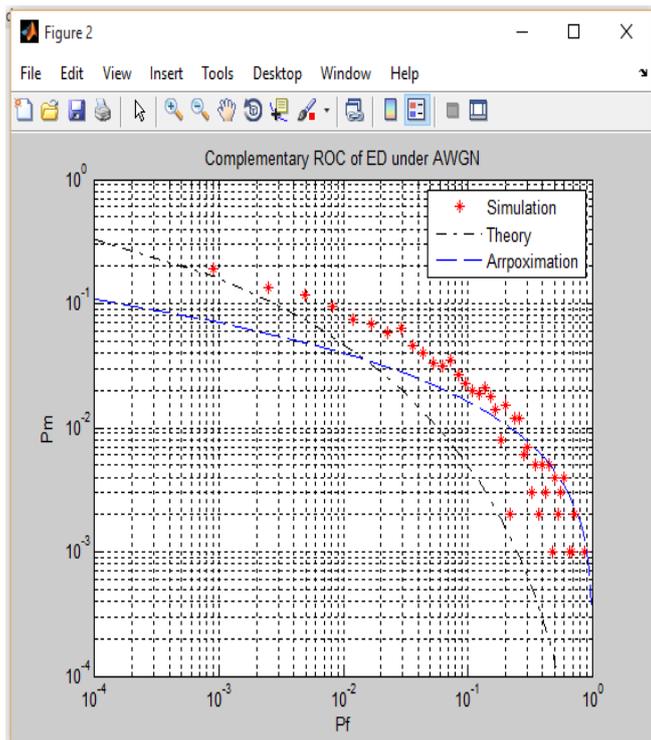


Figure 1.3: complementary ROC curve for energy detector for AWGN.

The received signal at the base station is as given below

$$Y = h_k^r x_k + n_r$$

In this equation  $h_k^r$  shows the channel coefficient of reporting link while  $x_k$  is transmitted signal at k sensor node while  $n_r$  represents additive white Gaussian noise.

This equation implementation shows these results

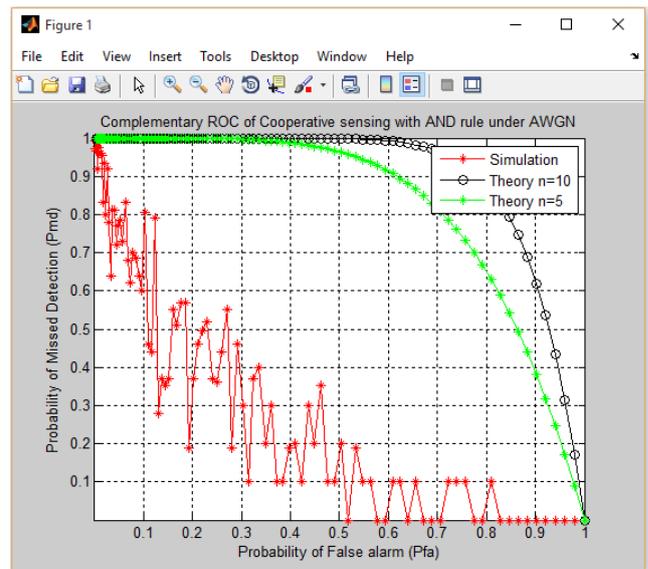


Figure 1.4: complementary ROC of Cooperative sensing with AND rule under AWGN.

Above figure shows result of direct path, indirect path result which is also the combined result.

Diversity added by passing same signal through different propagation paths combined result gives lesser BER that means diversity has improved the reliability of signal by reducing error rate.

This chapter proves in its last diagram the two objective of this research that were

- To minimize bit error rate using diversity.
- To increase reliability of signal.

Error rate achieved after implementation of thesis proved that reliability of signal that has minimum error rate is more, such signal generates more accurate result than one having huge bit error rate. Diversity using multi radio improves signal trustworthiness as well.

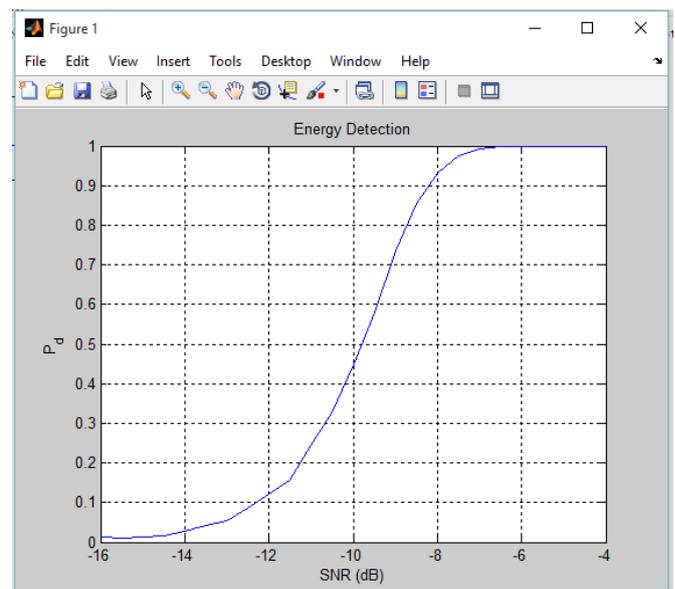


Figure 1.5: Energy detection using wiener filter.

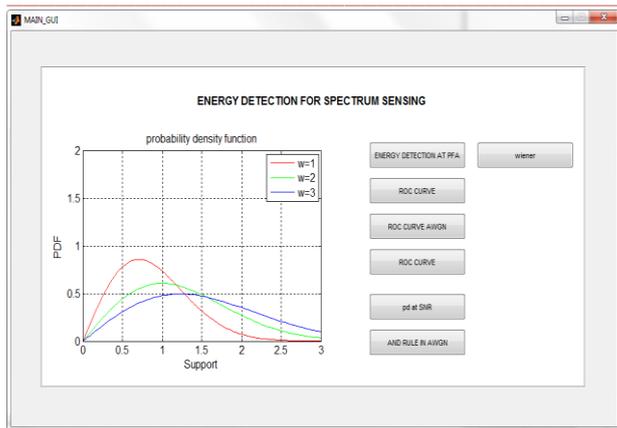


Figure 5.6: Graphical User Interface for energy detection for spectrum sensing.

## VI. CONCLUSION

Here, two spectrum sensing techniques (Cyclic-Prefix Based Spectrum Sensing and Energy detection Based Spectrum Sensing) have been discussed. Two operations have been used to implement Energy Detection method. The Performance of Spectrum Sensing techniques have been evaluated using ROC (Receiver Operating Characteristics) curves and Probability of detection versus SNR plots. The cyclic-prefix based spectrum sensing method has been shown to be the best method for spectrum sensing as it performs well in the fading channels and under low SNR conditions.

The proposed operation helps to improve the performance of conventional energy detector. An improvement of up to 0.6 times for AWGN Channel and up to 0.4 times for Rayleigh channel has been achieved, as the operation is changed in an energy detector.

With increase in SNR, the performance of spectrum sensing method improves. It has been found that with 5 dB increase in SNR, the probability of detection increases up to 0.8 times for AWGN Channel; and up to 0.7 times for Rayleigh Channel, in case of squaring operation based energy detection method. While this improvement is up to 0.4 times for AWGN Channel and up to 0.3 times for Rayleigh Channel; in energy detector.

It has also been observed that increase in probability of false alarm, improves the probability of detection of a particular spectrum sensing method. 5% increase in probability of false alarm; increases the probability of detection up to 1.8 times for AWGN Channel and 0.8 times for Rayleigh Channel in case of conventional energy detection method.

The cyclic prefix based spectrum sensing method provides an improvement of up to 1.48 times for AWGN Channel and 1.36 times for Rayleigh Channel with 5% increase in probability of false alarm.

Cognitive radio is known as new trend for wireless communication to manage the available spectrum. This research proved the spectrum detection procedure in cognitive radio and diversity effect upon signal when same signal passed through different propagation paths.

### • RESULTS OF THIS RESEARCH

The results achieved by this research implementation are

- Cognitive radio spectrum detection implementation using cooperative sensing scheme in cognitive radio networks.
- Multi antenna diversity to improve signal reliability.
- Multi antenna diversity to minimize bit error rate of combined signal result passed through different propagation paths.
- SUGGESTIONS AND FUTURE DIRECTIONS OF RESEARCH

This thesis leads towards these future directions for better wireless communication system, so it can be assured that all users and services can work properly and efficiently.

- In future, cognitive radio implementation should help to reduce burden upon links.
- Diversity usage in future should be implemented in all signals to generate accurate results.
- Wireless communication system should be more intelligent and secure by using cognitive radios.

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