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Improved novel statically based performance analysis approach for spectrum sensing approach for cognitive radio

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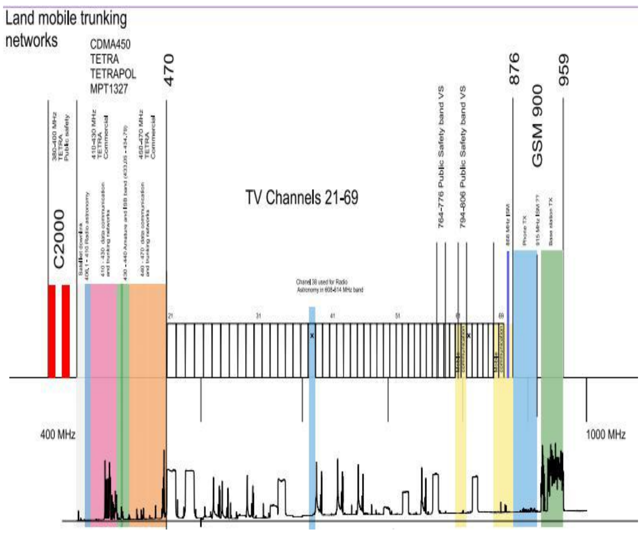
Abstract: *The current policies of spectrum allocation leads to inefficient use of spectrum making the spectrum a Scarce resource but the truth is, that spectrum is not scarce but is underutilized, there are many bandwidth that are not being properly used. So cognitive radio helps us to use these unused bands which are also called as "White Spaces". This unique approach to improve utilization of radio electromagnetic spectrum. In establishing the CRN there are 4 important methods. in current research paper we are going to discuss about the Cognitive radio characteristics and benefits. And in the later section of the paper we will implement two foremost using spectrum sensing technique namely energy based and cyclostationary based spectrum sensing, and ROC curve shows that cyclostationary based spectrum sensing technique performs better than energy based technique at low snr.*

Introduction

Cognitive Radio [2] 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 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 amethodology where 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.



Spectrum Utilization [2]

In order for the unlicensed or secondary users to use the licensed spectrum there are many things that should be taken care of in advance like

- Scanning the frequency spectrum for the discovery of different empty bands.
- Selecting the best available band. The selection can be done on the basis of the secondary user's application frequency requirement.
- Before transmitting on the selected band the power level should be maintained such that it provides minimal interference to other users. Also the power level can be so adjusted as to have maximum number of secondary users in the frequency band of interest.
- Depending on the distance and the error performance requirement the modulation scheme used can be varied.
- Spectrum sharing should be allowed so that other secondary users can also access the empty bands.
- Even after the beginning of the transmission, the bands must be continuously checked for any primary user entering to transmit in this range. If so then the secondary users should vacate the bands as quickly possible and go to some other empty frequency spectrum.

In terms of power spectra of incoming radio frequency (RF) is classifying the spectrum holes into three broadly defined types [8]

1. **Black spaces**:- which are dominated by high-power "local"interference some of the time.
2. **Grey spaces**:- which are partially dominated by low-power interference.
3. **White spaces: -**which are free of RF interference except for white Gaussian noise. Among these three, white spaces and grey spaces can be used by unlicensed operators if accurate sensing technique is designed, and Black spaces cannot be used because usage of this space will cause interference to the primary user (PU).
4. **Mohapatra,G.S et al., 2013[1]** investigated three techniques of spectrum sensing energy detection, matched filter, cyclostationary based detection in cognitive radio network environment were discussed along with their performance, applicability, effectiveness under different transmission conditions. They evaluated the performance of cognitive radio with energy based and cyclo-stationary based detection using different windowing techniques. Simulation results showed that the cyclostationary based approach gives better results under low SNR condition with some windows and with rest of windows performance is not satisfactory when SNR is in range of -20 dB.
5. **Lakshmi, M. et al., 2013[2]** carried out four different technique of spectrum sensing namely energy detection, matched filter, cyclostationary based detection ,multi resolution spectrum sensing were discussed. Out of these four main focus of this paper is on MRSS (multi resolution spectrum sensing) based on wavelet based transform for multi-resolution sensing feature. Simulations results showed MRSS examined wide spectrum with low power consumption, faster recognition,and high speed operation.
6. **Xushiynu, et al., 2008[3]** have discussed cyclostationary spectrum sensing technique .Authors proposed Combination detection method using multiple detection point for sensing. Simulations results showed that better detection performance were achieved using this method and some work were done on reducing complexity also.
7. **Mayank, et al., 2013[4]** proposed two techniques for Energy detection based onCooperative scheme named P out of I cooperative and Hybrid cluster approach were discussed on basis of parameter accuracy and speed. Simulations results showed this scheme had better detection for primary user than other previous scheme.
8. **KanthVU, et al., 2013[5]**discussed different spectrum sharing techniques in cognitive radio network for effectively utilizing the frequency spectrum. Spectrum sharing based on Architecture, Spectrum Allocation Behavior, Spectrum Access techniqueswere proposed. Conclusion showed spectrum sharing techniques utilize spectrum in more effective manner.
9. **Soudilya, et al., 2012[6]** suggested Combined Design (for channel access andspectrum sense) was discussed for secondary nodes to better access the channel and minimize the effects of channel sensing errors. Simulation results showed that there is considerable increase in secondary user access probabilities which increase Throughput and decrease Delay of both primary and secondary networks.
10. **Mounika, B et al., 2013[7]** investigated sensing techniques and Issues which lead to uncertainty in sensing were discussed. In this Interference based detection approach gave idea of ultra-wide band technology for cognitive radio to coexist and simultaneously transmit with primary user. Various issues which should be taken care into mind when dealing with CR approaches were helpful for successful detection.
11. **Zhang,S. et al., 2009[8]** proposed Energy detection based cooperative sensing scheme for the cognitive radio systems were proposed. This scheme greatly reduces the period overhead, sensing reporting overhead of the secondary systems and the power

scheduling algorithm dynamically allocate the transmission power of the cooperative sensor nodes. Simulations results showed that the false alarm and misdetection performance of this cooperative sensing scheme improved as there is in increase the number of cooperative sensor nodes.

12. **Anirudh et al., 2010[9]** derived Principal Component Analysis scheme for Energy detection spectrum sensing was discussed. Authors discovered correction factor to previous component analysis to equate signal to noise power of received signal to SNR of actual signal. Simulations results showed Modified Energy detection can sense spectrum hole in more accurate.

PROPOSED WORK

Problem formulation

In reference base paper (Mohaptra et al. (2013) authors have proposed window techniques for cyclostationary and compared cyclostationary technique with energy detection technique. But there are some points which require important consideration:

1)Authors have not mentioned clearly anything about probability of Detection (Pd),probability of False Alarm (Pf), probability of Miss Detection (Pm).

- **Probability of Detection (Pd):** probability of detection and the probability of false alarms were mainly evaluated for even degrees of freedom (6). Therefore, we provide an algorithm to compute the detection probability in the case of odd degrees of freedom based on the suboptimal energy detector. Moreover, as spectrum sensing must detect a very low signal-to-noise ratio (SNR), which in turn requires a high degree of precision, the previously derived expressions mainly depend on the number of terms in the summation to get highly accurate results.

- **Probability of False Alarm (Pf):** The analysis is referred to a detector using as test statistic the ratio between the largest and the smallest eigen value of the covariance matrix. Along with previous results on the probability of false alarm, this contribution completes the performance evaluation of this type of detector.

- **Probability of Miss Detection (Pm):** Is the theoretical analysis of this detection scheme by deriving a mathematical expression for the probability of missed detection as a function of the number of cooperating receivers, the number of samples and the signal-to-noise ratio of the primary user. The analysis is referred to a detector using as test statistic the ratio between the largest and the smallest eigen value of the covariance matrix. Along with previous results on the probability of false alarm, this contribution completes the performance evaluation of this type of detector.

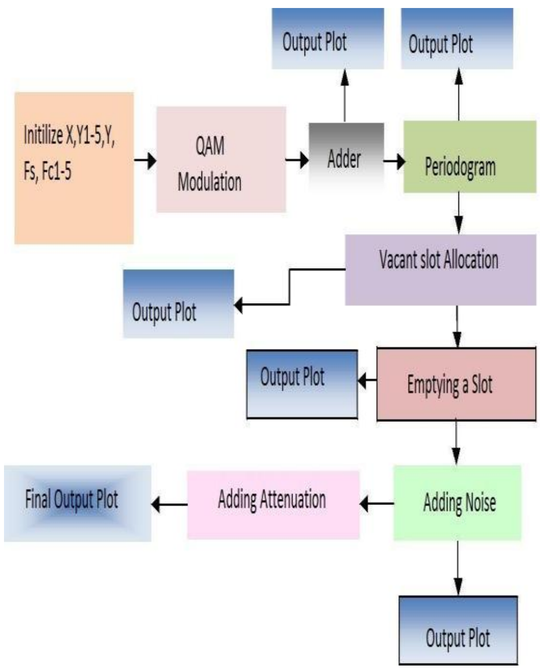
2) Failing to detect Signal at low SNR: Energy based detector failed to detect the signal at low SNR (signal to noise ratio).

The above mentioned considerations form the basis for this dissertation. As for as the literature survey is concerned some research gaps have been found in this field(spectrum sensing in cognitive radio). For the enhancement point of view these gaps which are mentioned above have to be fulfilled by certain parameters and to increase efficiency and performance of spectrum sensing techniques (energy detection and cyclostationary).

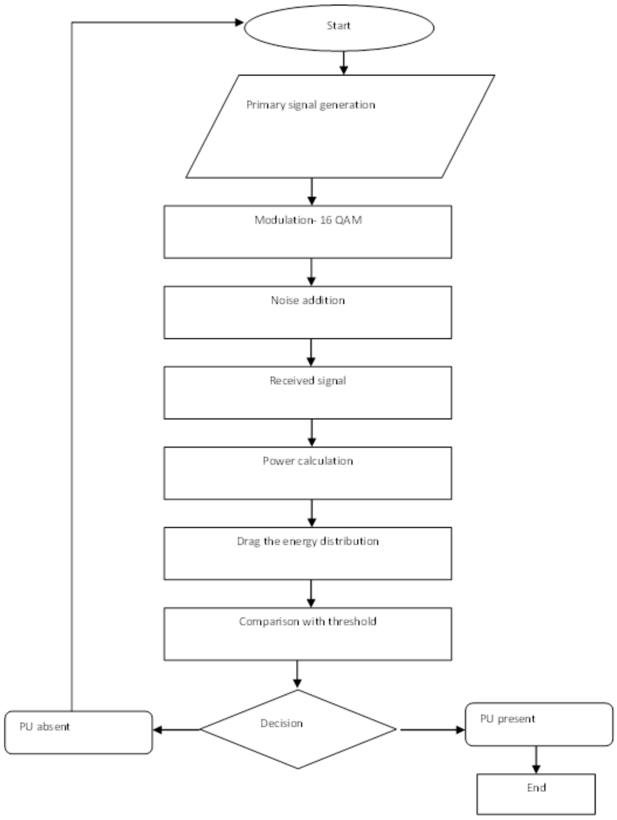
Problem Definition

It is proposed to simulate, evaluate and improve the performance of cyclostationary based and energy detection spectrum sensing technique on parameters like probability of detection, miss detection and false alarm and to compare the performance of both the techniques.

METHODOLOGY FOR COGNITIVE RADIO SYSTEM IMPLEMENTATION USING MATLAB



Block diagram of simulation set up methodology



Flow chat of Energy detection implementation

Steps to follow:-

1. Start
2. We can measure the energy of received signal by squaring the output of band pass filter.
3. Then integrated over the observation time.
4. Finally the output of the integrator Y is compared with threshold λ to decide whether primary user is present or not.
5. A Vacant slot is provided to secondary user.
6. In the proposed work, threshold used is Chi square distribution.
7. Stop.

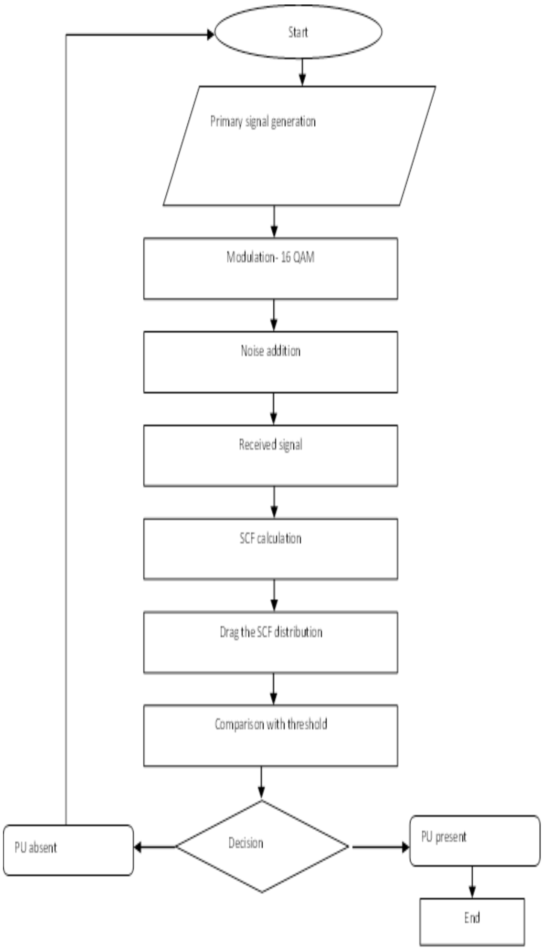


Figure 4.3 Flow chart of Cyclostationary detection implementation

Steps to follow:-

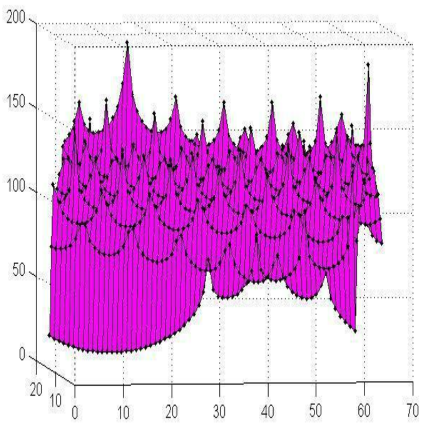
1. Start
2. Initially we go for a check to evaluate the occupancy of the channel.
3. User data is modulated to the carrier frequency
4. Modulated signals are added to construct carrier signal.
5. Periodogram is used for the estimation of power spectral density (PSD).
6. Initially we go for a check to evaluate the occupancy of the channel.
7. The first spectral hole is assigned to new secondary user.

RESULTS AND DISCUSSIONS

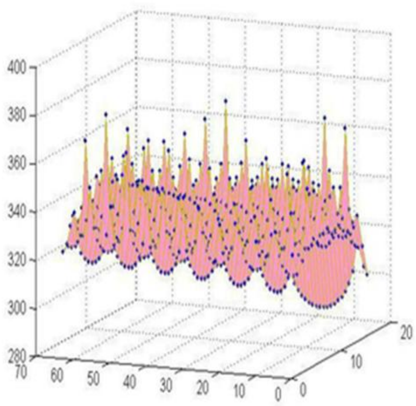
An extensive set of simulations have been conducted in MATLAB using the system model as described in the previous section. Research work of this paper is done in such a manner that outcome will be a selection of highly optimized parametric algorithm which would help to evaluate effective spectrum sensing technique.

Cyclostationary detection based on hann and KaiserWindow

The behaviour of the periodicity of signal is determined by SCF using different windows such as Hann Window, Kaiser Window, and Blackman Harris Window so as to detect primary user at low SNR. Peak in the graph shows the presence of primary user. In addition to this, the SCF can be used to find out the type of modulation scheme used by the primary user signal. This can be achieved by counting the number of secondary peaks at the double frequencies. If the modulation scheme involved is BPSK, there will be single secondary peaks at the double of operating frequency. Instead if the modulation scheme involved is QPSK, there will be two such secondary peaks at the double of operating frequency.

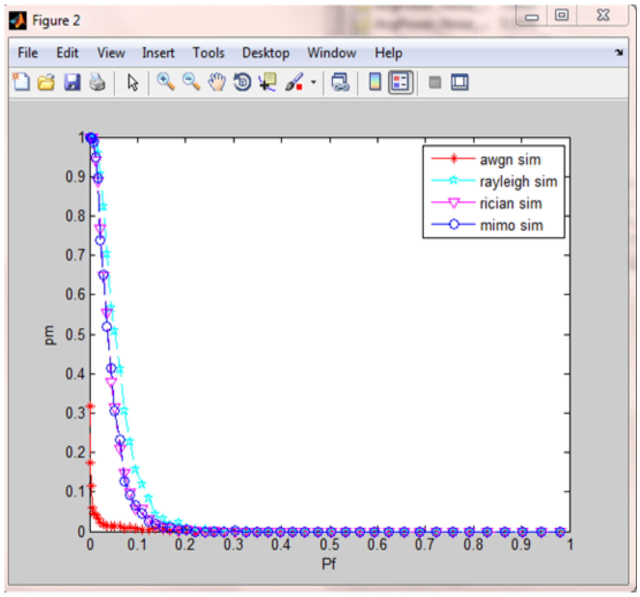


Detecting Primary user using Hanning window

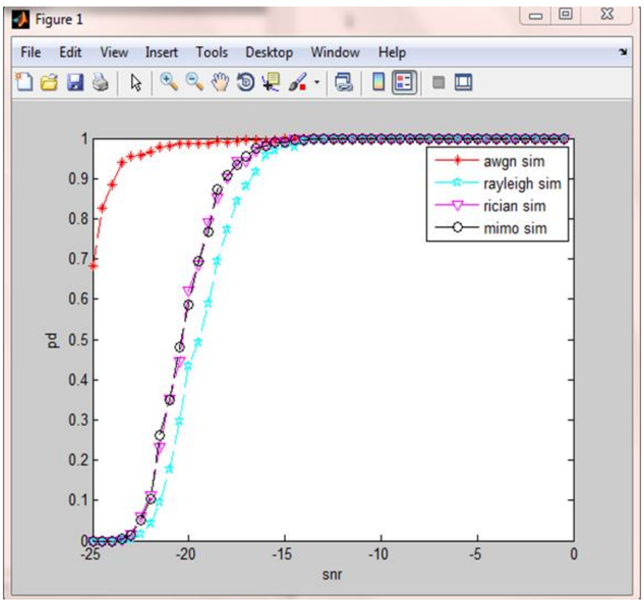


Detecting Primary user using Kaiser Window

The Energy Detector can be applied to different fading channel which includes Rayleigh fading channel, Rician fading channel and MIMO fading channel. We simulate Energy detector over MIMO fading because Bit error rate (BER) is significantly enhanced at low signal to noise ratio (SNR). That means as we increase the number of antennas at receiver end, the BER is decreased 2 times thus providing higher capacity, better transmission quality, increased coverage area, low probability of false alarm P_f and high probability of detection P_d. Moreover MIMO fading channel models other fading channels such as Rician and Rayleigh fading channel.



Representing different fading channels under pm, pf

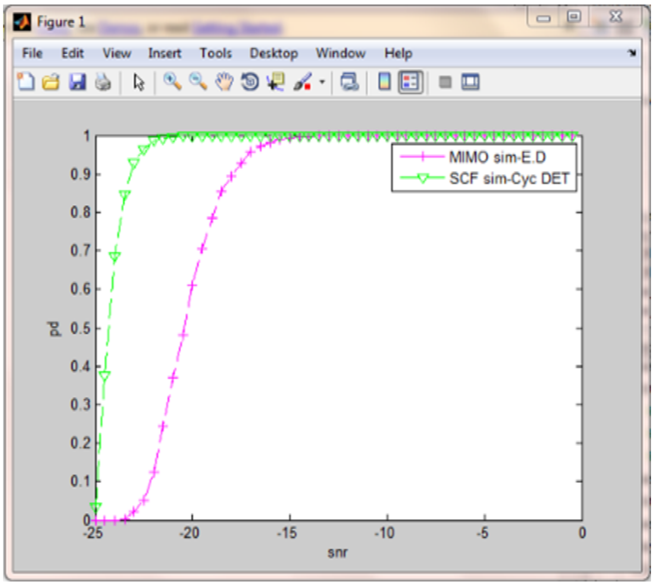


Representing different fading channels under pd , SNR

We simulate the Energy detector over MIMO fading channel as it models both Rician, Rayleigh fading channel. A graph is plotted for probability of detection over MIMO, Rician, Rayleigh fading channels shown in the figure. The graph shows that with increasing probability of detection, there is increase in the probability of false alarm. In this graph we determine pd with respect to pf.

Comparison between Energy detection and Cyclostationary Spectrum Sensing

Techniques-: Lastly the Statistical comparison is made between the two to evaluate theperformance in terms of SNR. This process basically depends on periodicity or statistics of mean or autocorrelation of the signal that vary periodically over time.



Comparison of energy based and cyclostationary based detection

This periodicity is used in received signal to represent the existence of the primary users. The cyclic correlation factor (SCF) is the key point for detecting the primary user signal. On the arrival of user data, it is modulated at the carrier frequency. Then all modulated signals are added to construct carrier signal. Periodogram is used for the estimation of power spectral density (PSD). Assignment of primary user with spectrum is done according to their data requirement. The first spectral hole is assigned to new secondary user. The particular slot is emptied if all the slots are filled. The effect of noise along with the attenuation is taken. To decide the behaviour of the signal whether it is periodic or aperiodic, spectral correlation function (SCF) along with different windows is used. Due to the periodicity of the baseband signal, SCF would be capable to detect the primary user signal at very low SNR because of its noise rejection capability. This is because noise is totally random and does not exhibit any periodicity. From the graph, it is evident that Cyclo stationary performs better than the Energy detector because of its detection capability.

Conclusion

This thesis takes the difficulty of ineffective use of spectrum given by FCC that spectrum is sufficient but is not properly utilized thus maximizing the utilization of the spectrum. In this dissertation, two Spectrum sensing techniques are successfully implemented. In Cyclostationary technique, the PSD is successfully introduced to check the proper allocation of the spectrum. Noise along with attenuation is considered on the signal efficiently. Spectral correlation function with different windows is used well to calculate the behaviour of the signal whether it is periodic or not. Based on periodicity of the baseband signal, primary user signal at low signal to noise ratio is computed successfully. Moreover Energy Detector over MIMO fading is developed positively that increases performance in terms of BER, capacity and provides better transmission quality. Finally the comparison between the two is made successfully to evaluate the performance in terms of SNR which shows that Cyclostationary detects well as.

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