SPECTRUM SENSING TECHNIQUES AND ISSUES IN COGNITIVE RADIO

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ABSTRACT:

In present day communication wireless communication has become the most popular communication. Because of this growing demand on wireless applications has put a lot of constraints on the available radio spectrum which is limited and precious. In fixed spectrum assignments there are many frequencies that are not being properly used. So cognitive radio helps us to use these unused frequency bands which are also called as "White Spaces". This is a unique approach to improve utilization of radio electromagnetic spectrum. In establishing the cognitive radio there are 4 important methods. In this paper we are going to discuss about the first and most important method to implement cognitive radio i.e., "spectrum sensing". The challenges, issues and techniques that are involved in spectrum sensing will discussed in detail.

KEYWORDS: *Primary User, Secondary User, Spectrum Sensing, Signal Processing Techniques.*

I. INTRODUCTION

As the need of wireless communication applications are increasing the available Electromagnetic Spectrum band is getting crowded day by day. According to many researches it has been found that the allocated spectrum (licensed spectrum) is not utilized properly because of static allocation of spectrum. It has become most difficult to find vacant bands either to set up a new service or to enhance the existing one. In order to overcome these problems we are going for "Dynamic Spectrum Management" which improves the utilization of spectrum. Cognitive Radio works on this dynamic Spectrum Management principle which solves the issue of spectrum underutilization in wireless communication in a better way. This radio provides a highly reliable communication. In this the unlicensed systems (Secondary users) are allowed to use the unused spectrum of the licensed users (Primary users). Cognitive radio will change its transmission parameters like wave form, protocol, operating frequency, networking etc .based on the interaction with environment in which it operates. Figure 1 shows the Dynamic Spectrum Access in Cognitive Radio.

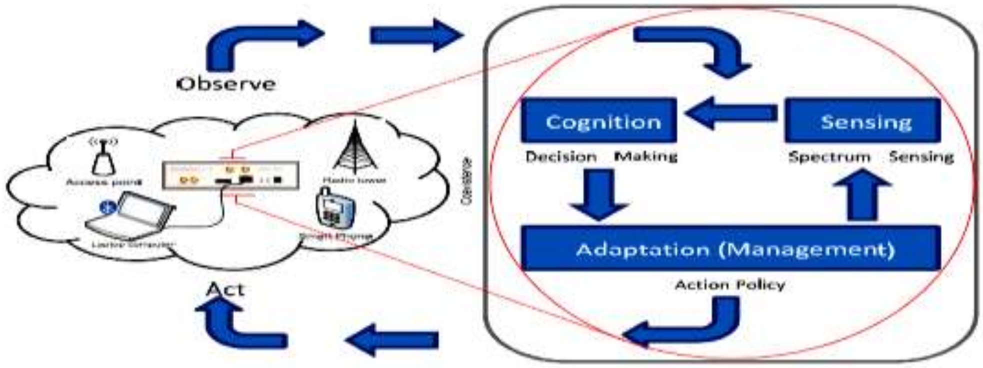

Fig. 1: Dynamic Spectrum Access

Cognitive radio has four major functions. They are Spectrum Sensing, Spectrum management, Spectrum Sharing and Spectrum Mobility. Spectrum Sensing is to identify the presence of licensed users and unused frequency bands i.e., white spaces in those licensed bands. Spectrum Management is to identify how long the secondary users can use those white spaces. Spectrum Sharing is to share the white spaces (spectrum hole) fairly among the secondary users. Spectrum Mobility is to maintain unbroken communication during the transition to better spectrum

In terms of occupancy, sub bands of the radio spectrum may be categorized as follows:

- White spaces: These are free of RF interferers, except for noise due to natural or artificial sources.
- Red spaces: These are partially occupied by interferers as well as noise.
- Blue spaces: The contents of which are completely full due to the combined presence ofcommunication and (possibly) interfering signals plus noise.

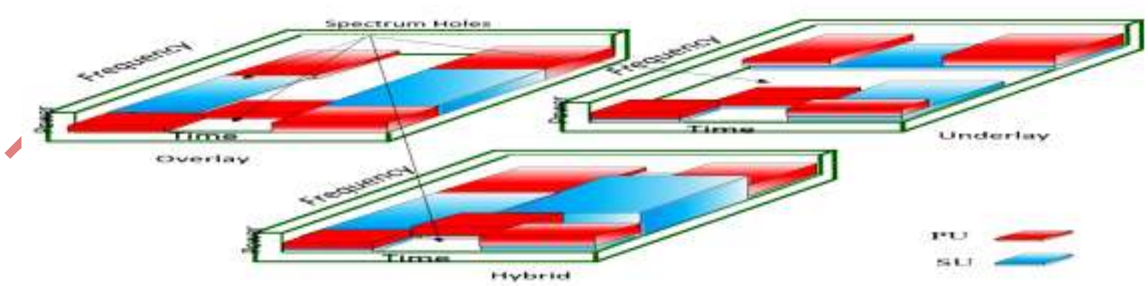

Figure 2: Illustration of spectrum holes utilization by SUs in cognitive radio system.

When compared to all other techniques, Spectrum Sensing is the most crucial task for the establishment of cognitive radio based communication mechanism.

II. SPECTRUM SENSING

The major challenge of the cognitive radio is that the secondary user needs to detect the presence of primary user and to quickly quit the frequency band if the corresponding primary radio emerges in order to avoid interference to primary users.

Spectrum sensing technique can be categorized into two types. They are: Direct and Indirect Techniques. Direct Technique is also called as frequency domain out in which estimation is carried out directly from signal approach. Where as in Indirect Technique (also called as time domain approach), in this technique estimation is performed using autocorrelation of the signal. Another way of classification depends on the need of spectrum sensing as stated below.

III. Spectrum Sensing for Spectrum opportunities:

1) **Primary transmitter detection:**Based on the received signal at CR users the detection of primary users is performed. This approach includes matched filter (MF) based detection, energy based detection, covariance based detection, waveform based detection, cyclostationary based detection, Primary Transmitter Detection.
2) **Cooperative and collaborative detection:**The primary signals for spectrum opportunities are detected reliably by interacting or cooperating with other users, and the method can be implemented as either centralized access to spectrum coordinated by a spectrum server or distributed approach implied by the spectrum load smoothing algorithm or external detection.

IV. CLASSIFICATION OF SPECTRUM SENSINGTECHNIQUES

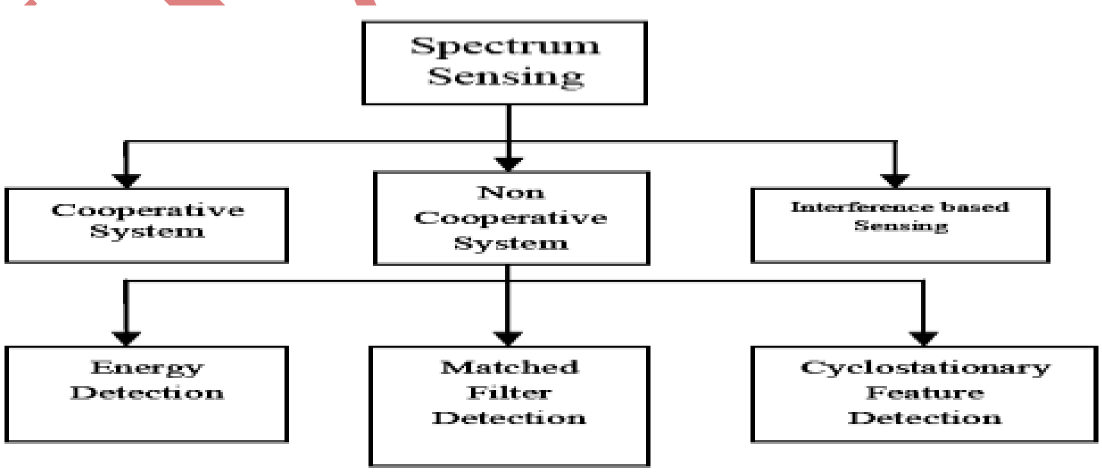

Fig. 3: Spectrum Sensing Techniques

V.Primary Transmitter Detection:

In this we are going to discuss about few primary transmitter detection techniques. We will be dealing primary transmitter based detection includes Matched Filter, Energy Detection &Cyclostationary spectrum sensing techniques**.** They are:

1. **Energy Detection:** In this technique there is no need of prior knowledge of Primary signal energy.

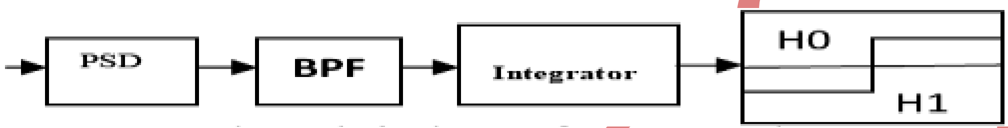

Fig. 4: Block Diagram of Energy Detection

Where, H0 = Absence of User, H1 = Presence of User.

The block diagram for the energy detection technique is shown in the Figure 4. In this method, signal is passed through band pass filter of the bandwidth W and is integrated over time interval. The output from the integrator block is then compared to a predefined threshold. This comparison is used to discover the existence of absence of the primary user. The threshold value can set to be fixed or variable based on the channel conditions.

y(k) = n(k)…………… H0

y(k) = h * s(k) + n(k)…… H1

Where y (k) is the sample to be analyzed at each instant k and n (k) is the noise of variance σ2. Let y(k) be a sequence of received samples kϵ{1, 2….N} at the signal detector, then adecision rule can be stated as,received samples kϵ{1, 2….N} at the signal detector, then adecision rule can be stated as,

H0…… if ε > v

H1…… if ε < v

Where ε = E |y(k)|2 the estimated energy of the received signal and v is chosen to be the noise variance σ2.

Limitations of Energy detector:

- The require time to achieve the desire probability of detection may be higher.
- The detection performance depends on the uncertainty of the noise.
- It is impossible to make distinguish between different primary users because energydetector is not able to differentiate between the sources of the received energy.
- It cannot be used for the detection of spread signals.
- The computation of the threshold value used for detection is highly susceptible for the variation of the noise levels which leads to a low SNR environment.

2. **Matched Filter:** A matched filter (MF) is a linear filter designed to maximize the output signal to noise ratio for a given input signal. The operation of matched filter detection is expressed as:

$$Y[n] = \Sigma\, h[n-k]\, x[k]$$

Fig. 5: Block Diagram of Matched Filter

Where, H0 = Absence of User, H1 = Presence of User.

When secondary user has a priori knowledge of primary user signal, matched filter detection is applied Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal.Where ‘x’ is the unknown signal (vector) and is convolved with the ‘h’, the impulse response of matched filter that is matched to the reference signal for maximizing the SNR. Detection by using matched filter is useful only in cases wherethe information from the primary users is known to the cognitive users.

Advantages: Matched filter detection needs less detection time because it requires only O (1/SNR) samples to meet a given probability of detection constraint. When the information of the primary user signal is known to the cognitive radio user, matched filter detection is optimal detection in stationary Gaussian noise.

Disadvantages: Matched filter detection requires a prior knowledge of every primary signal. If the information is not accurate, MF performs poorly. Also the most significant disadvantage of MF is that a CR would need a dedicated receiver for every type of primary user.

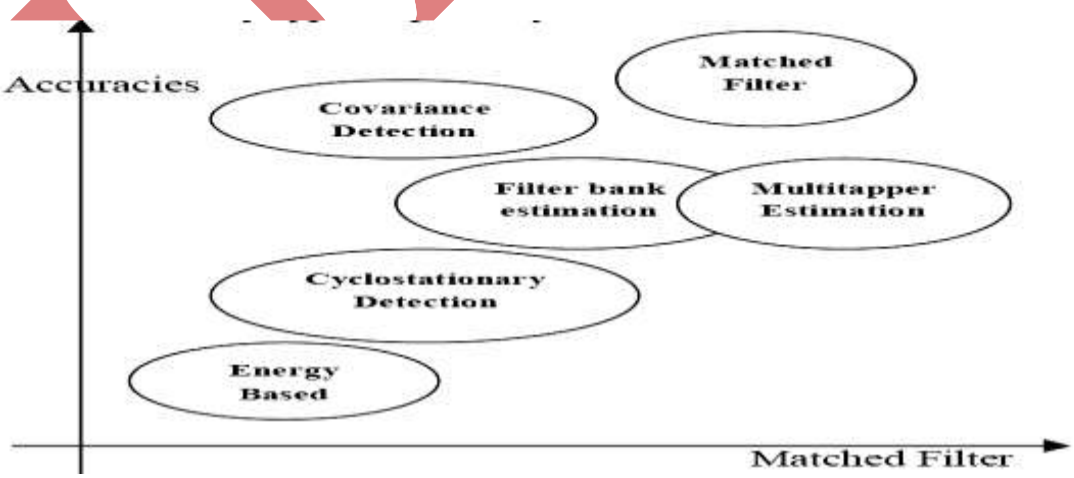

Fig. 6: Sensing accuracy and complexity of various sensing methods

3. **Cyclostationary Based Sensing:**The wireless communication device uses the Cyclostationary detection method to detect the existence of primary users in the feature detection approach.

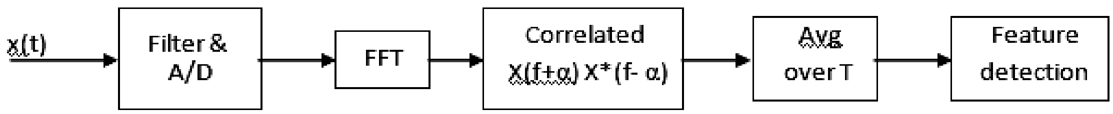

Fig 7: Implementation of Cyclostationary feature detection

A block diagram of Cyclostationary feature detection is shown in Fig 6. The feature detection can be implemented by applying the FFT cross products for all offsets with windowed averaging. The modulated signals carries hoping sequence, sine wave carriers, cyclic prefix or repeating, spreading and have the ability to extract those distinct modulated signals features. Two- dimensional spectral correlation is the way to detect these modulated features [6]. Although, these modulated signals are cyclostationary processes which has periodic autocorrelation function and is periodic in time. The cyclostationary signal is as shown in the Fig 8,

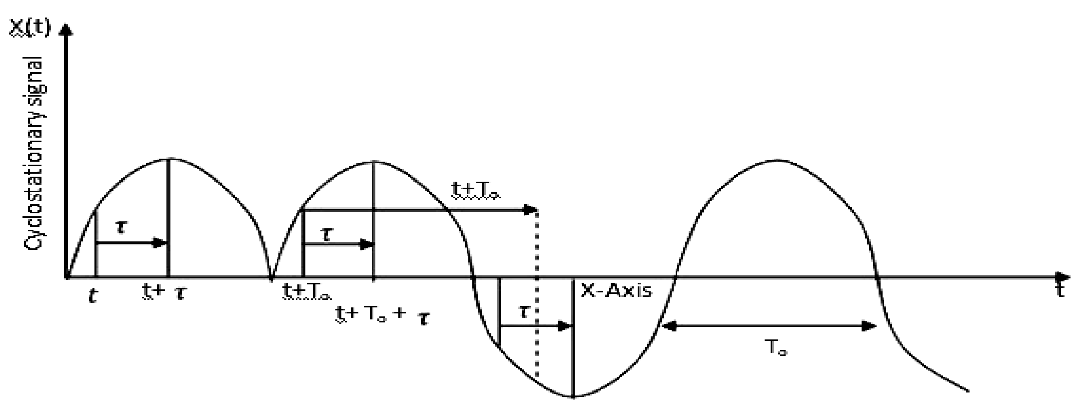

Fig 8: Modulated signals

Limitations of the Cyclostationary detection:

The CFD is more robust to uncertain levels of noise and gives much better performance in low SNR regions. However, this technique has its own limitations:

- High computational complexity
- Long sensing time

VI. Simulation Results

The cognitive radio spectrum sensing methods considered in the project are matched filtering technique, Energy detection method and Cyclostationary detection method. The sensing performance of each detection scheme is quantified by the receiver operating characteristic (ROC), such as *Pf* versus *Pd* and *Pm*. The simulation is carried out in the Matlab environment. Fig9 shows the relation between the probability ofdetection and probability of false alarm with various SNR values for matched filtering sensing method.Number of users are increased by 2 up to 10 in order to show how energy detection performs well in enhancing the detection when the users get increased.In fig.10-11, SNR=-12&-20 and Pfa from 0.01 to 1 by increasing 0.01 where 100 times are used. The probability of detection is estimated based on the different probability of false alarm and time bandwidth factors.

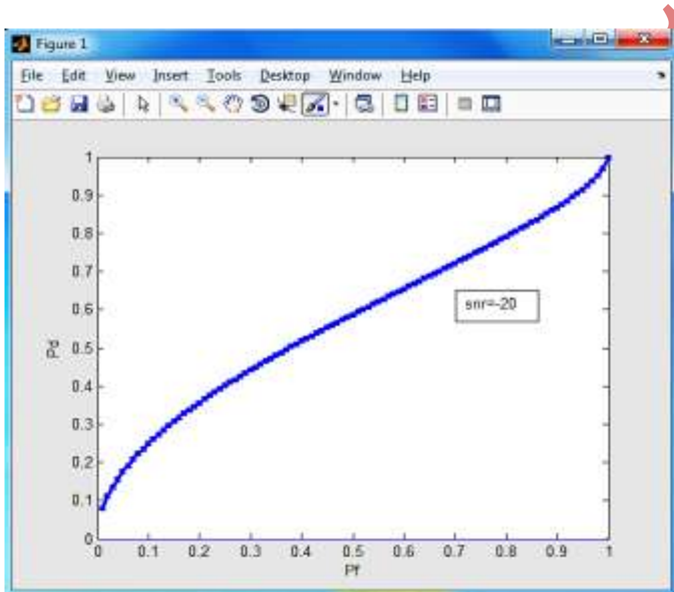

Fig 9: Pd Vs Pf

The detection probability varies based on the probability of false alarm and time bandwidth factor. When *L* is 100, then the detection probability is better than other used time bandwidth factor. When *L*is3500 is used, then the detection probability is worse than the other used bandwidth factor. When *L* is 2000 then, the detection probability is better than *L*=3500 and worse than *L*=1000. It shows that the probability of detection is increased when false alarm probability is increased and probability of detection is decreased when the time bandwidth factor is increased.

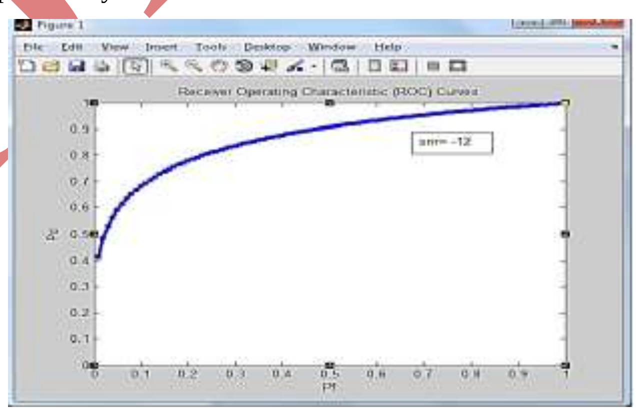

Fig 10: Pd Vs Pf

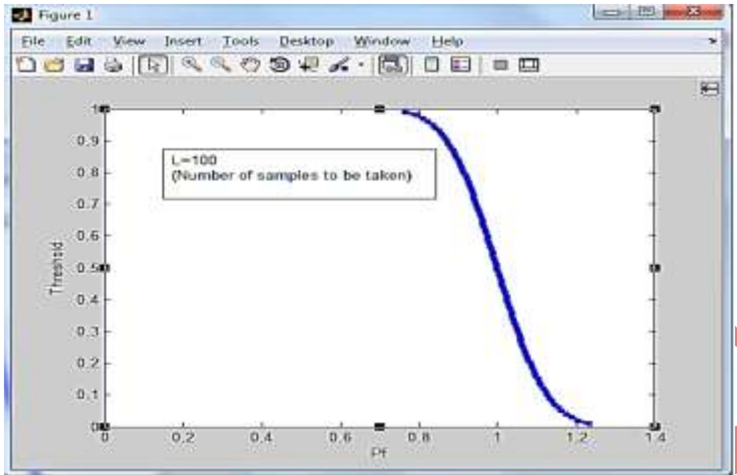

Fig 11:Threshold Vs Pf

The ROC of Energy detection under AWGN channel is plotted for probability of misdetection and probability of false alarm is as shown in the Fig 12,13.

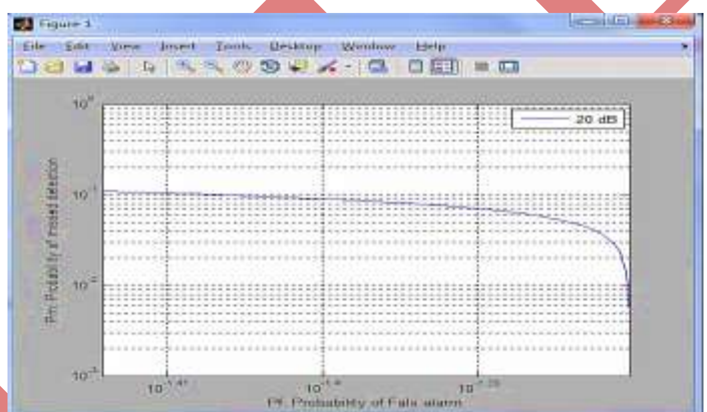

Fig 12: Pm Vs Pf(SNR=-20dB)

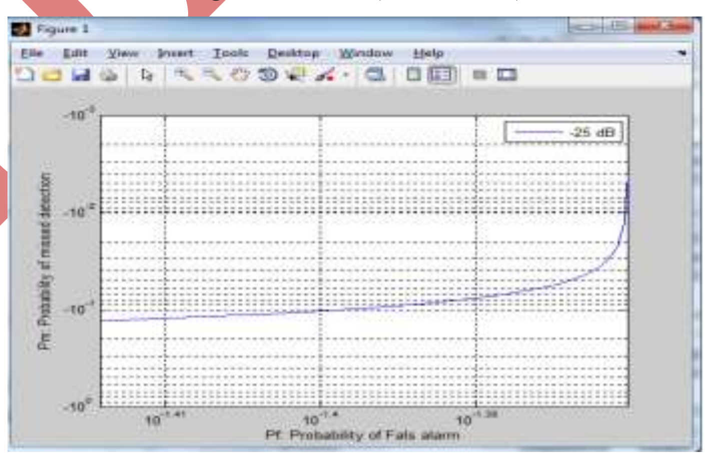

Fig 13: Pm Vs Pf(SNR= -25dB)

VII. Conclusion

The concept of using cognitive radio for air ground communication will be more beneficial to address the current spectrum scarcity problem. In the cognitive radio cycle, Spectrum sensing plays the most crucial role depending on which further steps are carried out. Here in this paper standard spectrum sensing techniques are analysed. Matched filtering performs well when SNR is high and perform worst in the case of low SNR. Energy detection performs well even in low SNR, but there are chances for misdetection. Cyclostationary method performs well but it has high complexity. By analysing these methods through simulation which is carried out in MATLAB environment, it is found that energy detection performs well and it is not so complex as cyclostationary method and does not performs as matched filter in low SNR environments. It is suggested that energy detection can be employed in air ground communication which performs well even in low SNR environment.

VIII. References

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