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Spectrum Sensing methods for Cognitive Radio

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Abstract

Cognitive Radio (CR) is an interesting area of research in recent years. There are wide ranges of applications which can make efficient utilization of white spaces of TV that provides interoperability between various large communications systems. Many research activities have also targeted the utilization of cognition in Warfield, public safety and in disaster management environment. The advancement in the area of software defined radio leads to dynamic access of spectrum that creates intelligent system which can automatically detect available channels in wireless spectrum. It is focused that how cognitive radio can be used in the air ground communication in order to help the soldiers in battle field and to sort out the lack of communication during disaster environment, to address public safety, to use in automation and transportation to benefit the society. A Comparative study of standard spectrum sensing techniques has been carried out and simulations shown in this paper demonstrate the efficient spectrum sensing technique for air ground communication.

Keywords

Cognitive radio, spectrum sensing, Spectrum Hole

1. Introduction

Spectrum opportunities cannot be created commonly. In a heavily used spectrum environment, the availability of unutilized and access to white space spectrum is difficult. Cognitive radios [2] must find the gray and white spectrum to provide a solution to the spectrum issues. Several techniques allow cognitive radios to familiarize themselves with an unknown spectrum environment, recognizing specific moderately utilized spectrum bands that present an opportunity to be exploited using learning-enhanced dynamic spectrum access (DSA) techniques.

Much has been made of the potential for cognitive radios to operate in white spaces, in which secondary users (SUs) avoid interference with incumbents by utilizing portions of the spectrum that remain unoccupied for fairly significant periods of time. However, there is also a great potential for cognitive radios to operate in gray spaces which may be intermittently occupied or occupied by low-power interferers, requiring a degree of interference tolerance. Such spectrum opportunities, which can be exploited by cognitive radios, will not be uniform and far from it [7]. When a spectrum opportunity arises in a band that is occupied by other users whether the users are licensed or not, the behaviour of the users' networks determine what, if any, spectrum will be cognitive radio can learn how the other users are exploiting the spectrum, then it can make a more informed attempt to exploit the opportunity. The first step of cognitive cycle is spectrum sensing which a key to any application [1]. Cognitive Radio system will not cause any undue interference which relies totally on the spectrum sensing elements of the system. For the overall system to increase spectrum efficiency, the Cognitive Radio spectrum sensing system must be able to effectively detect if any other any other transmissions are there or not and also to identify what they are and inform the central processing unit within the Cognitive Radio so that the required action can be taken. The cognitive radio functions are as follows: Spectrum sensing, Spectrum management, Spectrum mobility, Spectrum sharing.

2. Spectrum Sensing In Cognitive Radio

Cognitive radio system can coexist with other radio systems, using the same spectrum but without causing any interference. While sensing the spectrum the cognitive radio system should consider various factors as shown here[4]. Continuous Spectrum sensing is a must for the cognitive radio system to continuously sense the spectrum. It is necessary that CR system should indicate the return of primary user to its own spectrum. Monitoring for other empty spectrum is necessary. In case the primary user returns to the spectrum being used, the CR must have another spectrum available to which it can switch to continue the communication. Monitoring Type of transmission is essential for the cognitive radio to detect the type of transmission being received. It will be beneficial to avoid the spurious transmissions and interference made by CR itself. Cognitive radio provides number of ways to perform spectrum sensing. Mainly it is categorized into two as follows: Non cooperative spectrum sensing in which cognitive radio works on its own then it will be utilizing this type of non cooperative spectrum sensing. It will automatically configure itself according to the signals it can detect the information with which it is previously loaded. Another category is Cooperative spectrum sensing in which number of different CRs with CR network [3]. Typically a central station called as fusion centre will receive reports of signals from various radios in the network and make the adjustment that suits the overall cognitive radio network. The demand of transferring with a higher data rate is increasing but current static frequency allocation cannot fulfil this requirement because of frequency spectrum limitation. Cognitive radio can be an attractive solution for this kind of problem by utilizing unused frequency bands [8]. In the case of intelligent wireless communication systems, cognitive radio is able to sense and be aware of its surroundings which make spectrum sensing an ideal requirement to realize. In wireless communications, radio spectrum is referred to as lifeblood. The unlicensed user, with the help of spectrum sensing can sense the environment to detect unused spectrum without

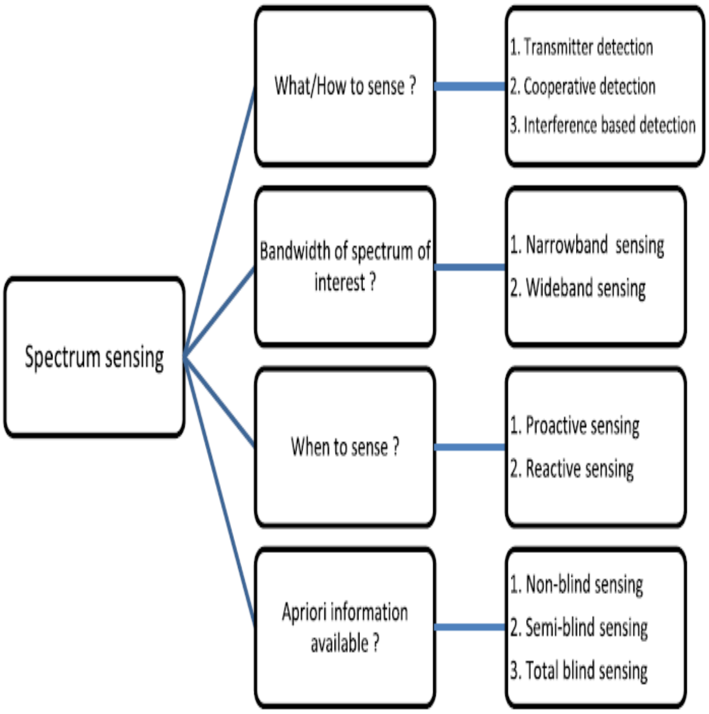

Fig 1 : Information gathering of spectrum sensing

Spectrum sensing is in need of various information before a decision is taken, which involves which part of spectrum it should sense & how, its bandwidth of spectrum of interest, when to sense and to see any priori information is available or not. It involves various steps which finally help in making a decision of the presence of primary user. The various steps involved in information gathering is as shown in the Fig 1. In order to obtain spectrum occupancy knowledge, the following details must be known.

1. Using Geo-location and database
2. By listening to Cognitive pilot channel or PU beacons.

Based on transmitter detection method, the spectrum sensing can be divided into Matched filter detection, Energy detection, Cyclostationary base detection. Here all the three standard sensing method are analyzed.

2.1 Match Filter Detection

A match filter is the optimal detection of primary users when the information of a transmitted signal is known and can maximize the received signal-to-noise ratio (SNR). An important drawback of matched filter detection is that each primary user of cognitive radio would need a dedicated receiver [5]. So cognitive radio needs a perfect knowledge of the primary users signal modulation type and order bandwidth, operation frequency, pulse shaping, packet format, etc. Another drawback of the match filter is that different receiver algorithms require performing for detection in case of larger power consumption. However on the other hand, the main advantage of the match filter is that it can achieve a high processing gain (probability of false alarm or probability of miss detection) in short time since only O(1/SNR) samples are required. Moreover, since cognitive radio needs receivers for all signal types, the implementation complexity of sensing unit is impractically large.

2.2 Energy Detection

When the secondary receiver is unable to locate the primary user (PU) signal with unknown signal strength and location, energy detection assists as the optimal detector if the detector is recognizable with receiver signal power of random Gaussian noise.

Energy detection is also known as radiometry or periodogram and is the classical method for identifying an unknown signal that quantifies the received signal energy over an observation time window. Fig 2a & 2b shows the block diagram of energy detection.

It can perform both in time and frequency domain. At first, in the case of time domain, a band pass filter is passed through a target signal in order to measure the strength of a signal in time domain.

Assumed that the input signal y(t) is real. This signal is transformed into digital form using an analogue-to-digital converter (ADC). After that, the received signal is squared and averaged, and then the output is compared with a threshold, λ, to decide if the primary user exists or not.

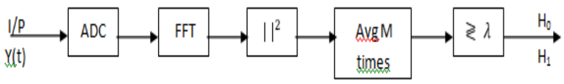

Fig 2a: Block diagram of energy detection

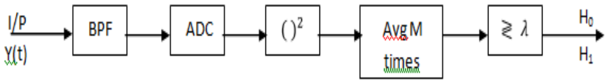

Fig 2b: Block diagram of energy detection in frequency domain

The decision is made by two binary hypotheses:

$$y(n) = \begin{cases} w(n), & Ho(\text{signal absent}) \\ x(n) + w(n), & H1(\text{signal present}) \end{cases}$$

n = 1…….., N, where N is the length of available know where, x(n) is the primary users signal to be detected, w(n) is the Additive White Gaussian Noise (AWGN) with zero mean and variance.The probability of false alarm (P_F) is the probability of declaring a channel occupied when it is vacant, i.e. the decision that is based on some statistics transcends the threshold when only noise is present. Normally, the probability of false alarm is limited so that it does not transcend the desired value; otherwise performance will be poor. The probability of detection (P_D) is the probability of declaring the channel occupied when it is really occupied. Energy Detection based approach is the most common way of spectrum sensing because of it slow computational and implementation complexities. When primary user signal is unknown or the receiver cannot collect sufficient information about the primary signal. The energy detection method is used. About Primary user signal, the energy detection is used. This method is optimal for detecting any unknown zero mean constellation signals and can be applied to cognitive radio[4]. Energy detection has some major problems with regards to noise uncertainty that causes difficulties to obtain accurate noise power.

2.3 Cyclostationary-Based Sensing

The wireless communication device uses the Cyclostationary detection method to detect the existence of primary users in the feature detection approach.

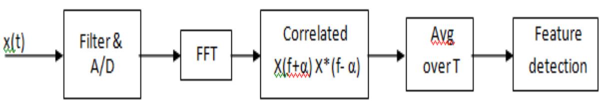

Fig 3: Implementation of Cyclostationary feature detection

A block diagram of Cyclostationary feature detection is shown in Fig 3. 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 4.

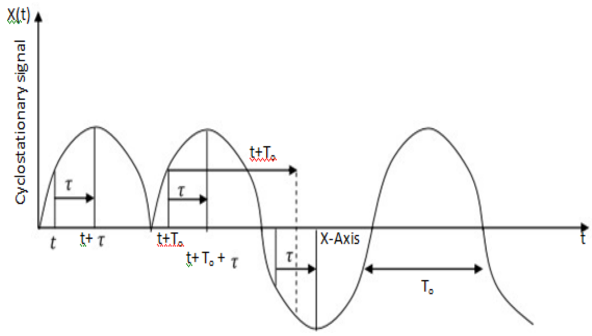

Fig 4: Modulated signals

3. 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. Fig 5 shows the relation between the probability of detection and probability of false alarm with various SNR values for matched filtering sensing method.

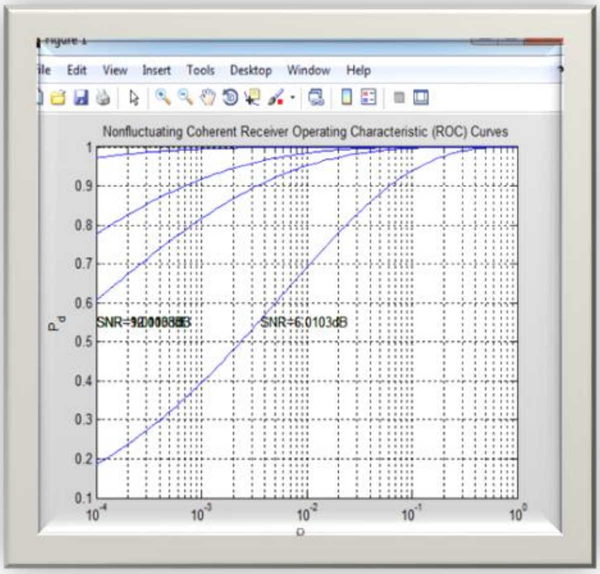

Fig 5 : Pd Vs Pf

When number of users increase in the network it worth to adapt energy detection sensing method in which the probability of detection gets enhanced. The 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. It is shown in the Fig 6.

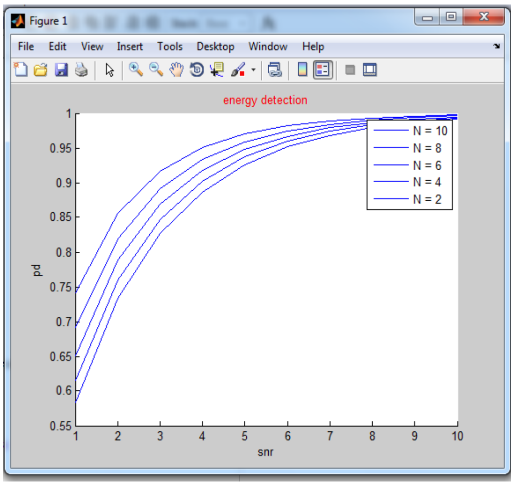

Figure 6: P_d Vs SNR

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 7.

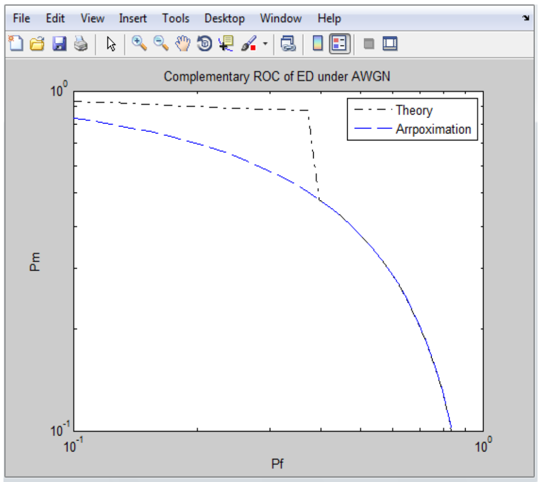

Fig 7: P_m Vs P_f

4. 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.

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