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Practical Implementation of Cognitive Radio Using Cyclostationary Based Spectrum Sensing

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***Abstract*—The expansion within the wireless business the spectrum become valuable resource. The government agency allots the spectrum to the first user in a very static frequency allocation basis that causes spectrum underutilization. Dynamic Frequency Allocation for improve the spectrum utilization used by cognitive radio. Spectrum sensing is the main task in cognitive radio. Energy detection is a conventional spectrum sensing method used in the cognitive radio. It has less complexity but its performance degrade in low SNR region. Also a matched filter based spectrum sensing is used which require prior knowledge about the primary user signal of its detection. To overcome this we tend to use the Cyclostationary spectrum sensing technique. These techniques use the cyclic property of the first User signal for the user detection.**

***Index Terms*—Cyclostationary Detection, Spectral Correlation Function, Primary User, Secondary User.**

I. INTRODUCTION

The wireless communication technology has revolutionary changes in recent year. The amount of users and application of the wireless communication will increase so it demands the spectrum valuation. The matter in wireless communication is Static spectrum allocation that causes spectrum underutilization. To boost the spectrum utilization Cognitive feature radio is employed, that use the dynamic spectrum allocation [1]. The Cognitive feature radio includes Primary User and Secondary User. The first User could be an authorized user and also the secondary is unlicensed user. The secondary user uses the first user band once it's in idle state. The secondary users use only the unoccupied portion of the spectrum. So the secondary User search for the empty band is called as spectrum sensing. The main precaution in spectrum sensing is Secondary User does not create interference to the primary User and provide the quality of service for the secondary user.

There is Receiver and Transmitter discovering spectrum sensing techniques offered however rather than detection the state of the first User receiver it's simple to detect the first User Transmitter [8]. The standard spectrum sensing technique is energy detection however its performance degrades in low SNR. The second technique is Matched Filter detection that needs primary user info for user Detection. The Cyclostationary Detection is often working effectively in low SNR and doesn't need primary user info. The performance metrics of the spectrum sensing given by probability of Detection and False Alarm [9]. The probability that Secondary User make a call that presence of Primary User when it ON state is call detection probability. The probability of Miss-Detection declares about that secondary user make a call that primary user absent when it occupied band. The probability when secondary user makes a call that Primary User present when it idle state known as probability of false alarm. In a Cognitive radio the Probability of Detection should have High and Probability of Miss-Detection is its vice-versa. Selection of sensing parameters brings a couple of exchange between the speed (sensing time) and reliableness of sensing. The optimum worth depends on the capabilities of cognitive feature radio itself and also the temporal Characteristics of primary users within the environment [10].

This paper is organized as section two gives the detail work done on cognitive radio spectrum sensing, Different spectrum sensing methods with its advantage and Disadvantage. Section three deals with the native transmitter detection techniques such as Energy and Matched Filter Detection. Section four deals with the Cyclostationary spectrum sensing technique that is employed for implementation of Cognitive feature radio in MATLAB. Section five deals with the simulation results of Dynamic spectrum allocation in MATLAB. Section six declared the conclusion of the work.

II. RELATED STUDY

In the cognitive radio for the effective spectrum utilization the most critical task is that the spectrum sensing. Many articles are studied revealed on spectrum sensing up to now. In [1], gives the survey about local spectrum sensing methods. Problem associated with energy detection, matched filter. Also the hard and soft combination rules for the cooperative spectrum sensing are given. A hidden node problem and spectrum allocation and its sharing after its detection stated.

A Simulation and analysis of cognitive radio in MATLAB projected in [2]. During this the Energy detection method of spectrum sensing is used. The periodogram MATLAB functions used to compute the Energy of the received signal for its detection. In the low SNR the performance of the system degrades as the amplitude is does below threshold.

In [4, 5] use the Matched filter method for the spectrum detection. In which known primary signal is correlated with the data received at the secondary user. This method has

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drawback that it require primary user information for its detection. The primary User can't detected if its information not known.

In [3] projected the Cyclostationary methodology in the Simulink. The use the FFT and auto Correlation for the User detection and the computed sum of the Autocorrelation is compare with the constant for user detection. It does not have cyclic autocorrelation computation so the performance degrades in low SNR.

In [6] proposed comparison of the spectrum sensing methods with the performance matrix. The Probability of Detection is should be high for the good system performance and the probability of false alarm should be low. The Energy detection has low Probability of detection due to noise power consideration as compare to other methods.

In [7] proposed Cyclostationary Spectrum Sensing method. This method use the cyclic property of the received signal as all the First User signals are modulated by Carrier. The Mean and autocorrelation property are used for the User detection. Also the synchronization does not require which overcome match filter spectrum sensing drawback. Also this method correctly identify primary user signal due to the noise rejection ability.

III. SPECTRUM SENSING METHODS

Spectrum sensing is a key task in the cognitive cycle for user detection. The primary User transmitter sending data to the primary user receiver using the licenses band. But the secondary user intended to access the spectrum, so the spectrum sensing is used to protect primary user transmission from secondary user transmitter. There are two hypothesis H_0 and H_1 are used for user detection [7]. The Hypothesis H_0 is true if signal received at the secondary user is only noise so Primary User is absent. The signal received at the secondary user is a combination of the Primary User signal and other secondary user signal, so we consider them all together as a single signal received at secondary User as *q(t).*

$$q(t) = A_n(t) \qquad H_0 \; is \; True \quad (1)$$

And the Hypothesis H_1 is true if signal received at Secondary User is noise and Primary User signal so primary user present.

$$q(t) = P_s(t) + A_n(t) \qquad H_1 \; is \; True \quad (2)$$

Where q (t) is signal received at secondary user; $P_s(t)$ is primary User Signal; $A_n(t)$ Additive white Gaussian noise. The different Spectrum sensing methods show in tree diagram

A. *Energy Detection*

If the Primary User signal is unknown then the energy detection is used for user detection. The secondary Use calculate the energy of the received signal over the time duration given by equation

$$E = \frac{1}{M}\sum_{k=0}^{M-1}|q(t)|^2 \qquad (3)$$

Energy detection is generally used methodology for User Detection with low procedure quality [2]. The calculated Energy of the received signal is compare with Threshold for build a decision whether or not the first user present or absent. Energy Detection has an advantage that it does not require Primary User information for its detection. The performance of the energy detection degrades due to the uncertainty in noise power. The energy Detection does not separate signal and noise power so it causes false alarm in low SNR value.

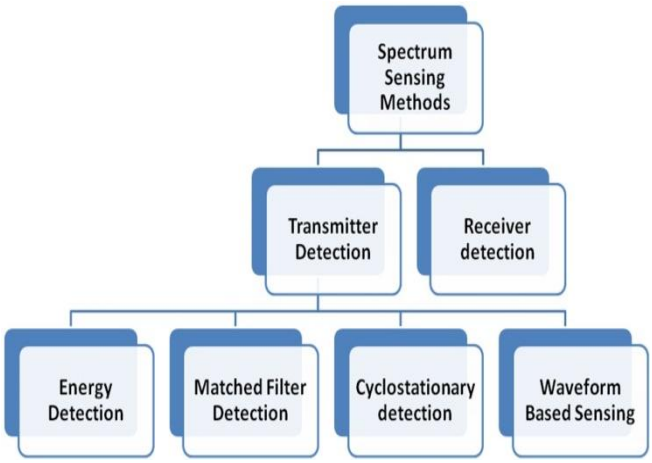

Fig.1. Spectrum Sensing Methods

B. *Matched Filter Detection*

The matched Filter spectrum sensing is used in the cognitive radio to maximize the receiver signal to noise ratio. A Matched Filter is a linear filter which convolves the received signal with the known pattern of the signal [4]. A signal received by the Secondary user is

$$r(t) = s(t) + n(t) \qquad (4)$$

Where (t) is AWGN noise, r (t) is convolves with known signal pattern which is given by Eqn.5.

$$h(t) = s\big(T - (t + \tau)\big) \qquad (5)$$

The matched filter method requires less sensing time for high processing gain signal [5]. Matched Filter method has limitation that it requires prior information about the user for its detection. So this technique is not applicable where Primary user does not share its information with secondary user. The Energy Detection have drawback that its performance is depend on the noise power in primary signal and Matched Filter require prior knowledge about the primary user signal but due to security issues Primary does not share its information so to overcome this problem we use Cyclostationary spectrum sensing method.

IV. CYCLOSTATIONARY SPECTRUM SENSING

Cyclostationary Spectrum sensing is additionally referred to as a spectral correlation methodology of the user detection because it use cyclic correlation perform. Cyclostationary method have the applied mathematics property like mean, autocorrelation are periodic in nature [7]. The entire

man-made modulated signals are Cyclostationary in nature because they are coupled with the sine-wave carrier. These are the second order Cyclostationary signal due to the periodic nature of mean and autocorrelation. If we consider that the signal received at the secondary user $m(t)$which is scalar in nature, then we can obtain the cyclic autocorrelation function by taking the correlation of the primary user signal and its frequency shifted version. A Primary User signal is modulated by the particular carrier therefore we tend to acquire the frequency shifted version by taking carrier as a cyclic frequency α.

$$R(\tau) = m(t).m^*(t)e^{-j2\pi\alpha t} \qquad (6)$$

Where (*) is the conjugate of $m(t)$, (.) is infinite time, α is cyclic frequency. Then the spectral correlation density can be obtained by taking the Fourier Transform of the cyclic autocorrelation function. This can be obtain as

$$R(f) = \int_{-\infty}^{\infty} R(\tau)\, e^{-2\pi f t}\, d\tau \qquad (7)$$

Finally for the mounted variety of sample (S) and time period (T) We will get Spectral correlation function R_{xx}^{α} by

$$R_{xx}^{\alpha}(f) = \frac{1}{S}\frac{1}{T}\sum_{f=0}^{S-1} R(f)\, R^*(f) \qquad (8)$$

When we plot the Spectral correlation Function it causes peak at the cyclic frequency. The block diagram of Cyclostationary detection is as shown in Fig.2.

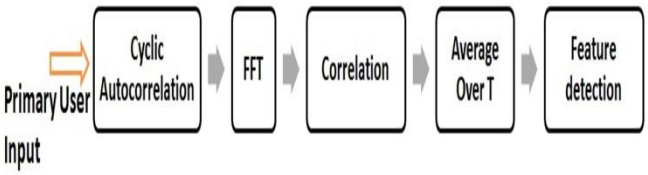

Fig.2. Block Diagram of Cyclostationary Detection

If the Maximum Value ofthe SCF at the cyclic frequency is greater than threshold then secondary user make call that Primary User present. If the Primary User absent it does not contain the peak at the carrier frequency as autocorrelation of the noise is zero. The Cyclostationary Detection is used in the low SNR region where Energy Detection is not applicable because of noise rejection ability. Noise is a random signal and it does not have any periodic behavior. Also Cyclostationary Detection does not require primary user information so it overcomes the drawback of matched filter spectrum sensing [7].

IV. SIMULATION RESULT

In this paper we have Practical Implementation of Cognitive Radio Using Cyclostationary Detection Technique in MATLAB (R2013a). For the simulation we assume 6 Primary User and 2 Secondary User. All the user benchmarking is shown in Table I.

TABLE I
Primary User Benchmarking

Signal	User	Carrier Frequency	Modulation Method	SNR in dB
A	PU1	10 KHz	AM	-20
B	PU1	20 KHz	AM	-15
C	PU1	30 KHz	AM	-10
D	PU1	40 KHz	AM	-5
E	PU1	50 KHz	AM	-10
F	PU1	60 KHz	AM	-15

For the simulation we assumed initially all primary user present as show in Fig.3. When the secondary user scan the entire frequency band as all the Primary User present then there is peak at the carrier frequency of each Primary user.

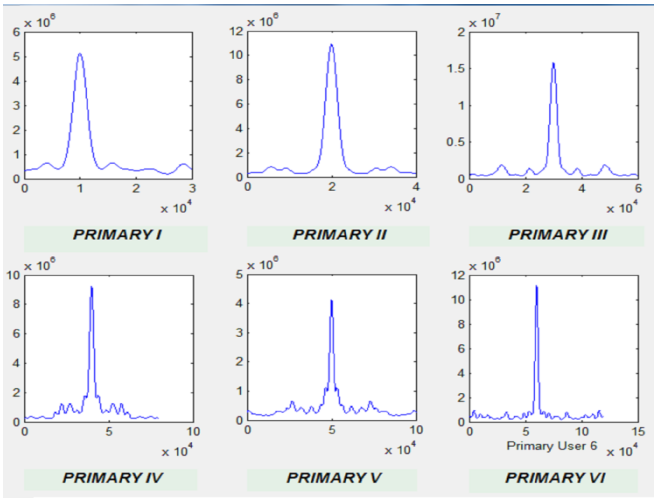

Fig.3. All Primary User present

Then we make some of Primary User OFF. In the simulation we make 2, 4, and 6 off. Now when the User is absent then only noise is received at the Secondary User so there is no peak at carrier Frequency i.e. at cyclic frequency. The secondary User make Decision that 2, 4, and 6 Band is empty as show in Fig.4.

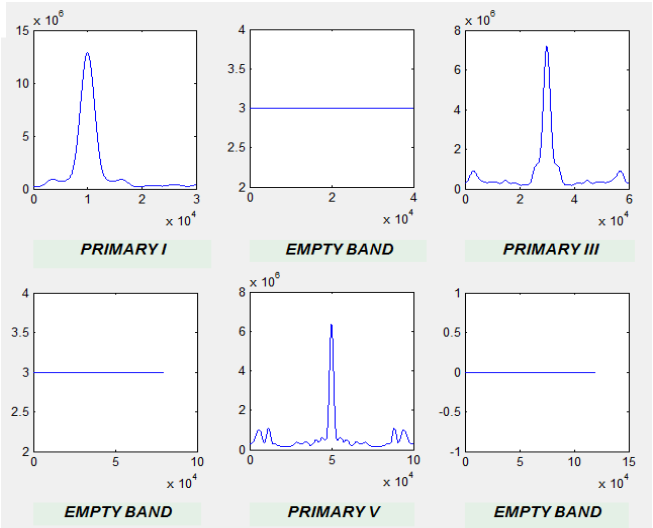

Fig.4. Empty Band Detection

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Now the Cognitive radio will insert the secondary user in the empty band location. If the empty band is satisfy the Secondary User requirement the band is used by secondary User. Here the 2 band satisfy First secondary user requirement as it occupied by secondary I as show Fig.5.

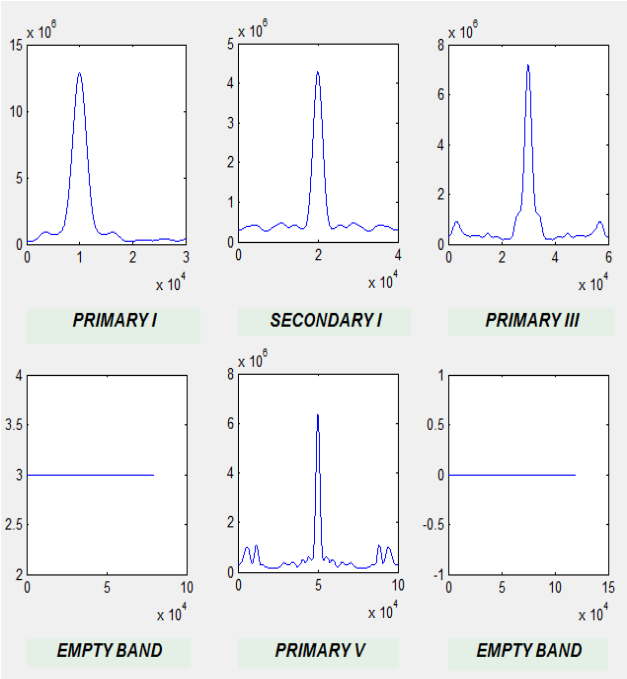

Fig.5. Insert a First Secondary User

After that we have to insert the second secondary user. So the Cognitive radio search for the empty band, the Primary User 4 is OFF and it satisfy the Secondary user requirement to Secondary II inserted on 4th band as show in below Fig.6.

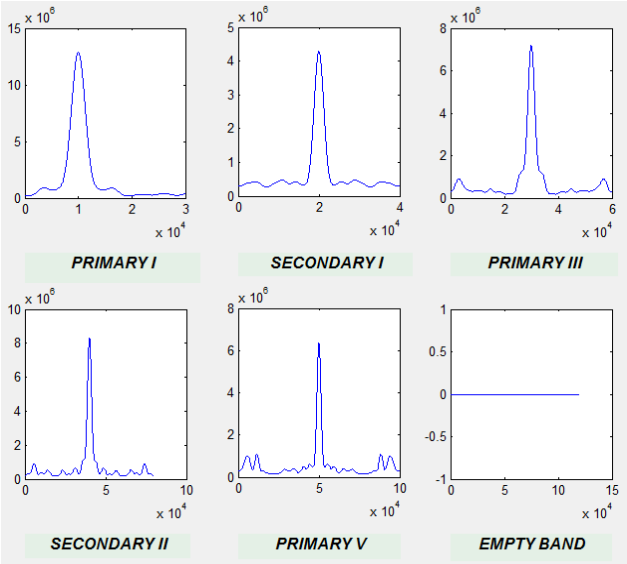

Fig.6. Insert Second Secondary User

In the Dynamic Spectrum Allocation spectrum secondary I use the Second Primary User band. If the Primary 2 wants to Use its band then the secondary 1 release Primary User Band, as show in Fig.7 And then secondary Search for empty band as the Primary User 6 is absent and it satisfy Secondary requirement so the secondary using its band. If there is no empty band the Secondary user keep searching for empty band.

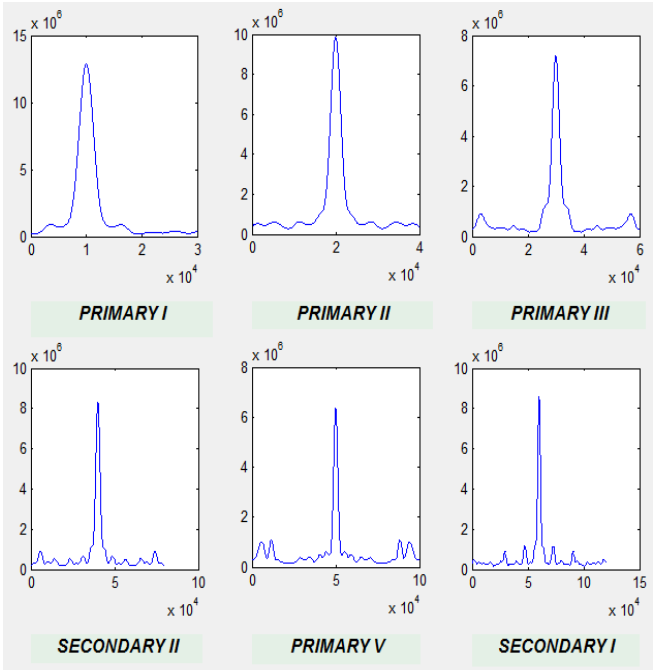

Fig.7. 2nd Primary User Want to Use

Secondary User 2 using 4th Primary User band as the PU4 want to use its band the secondary user stop its transmission without creating interference the Primary User. Secondary User search for empty band and Occupied it if empty band present. Here no empty band present so secondary II stop its transmission until it gets empty band detected.

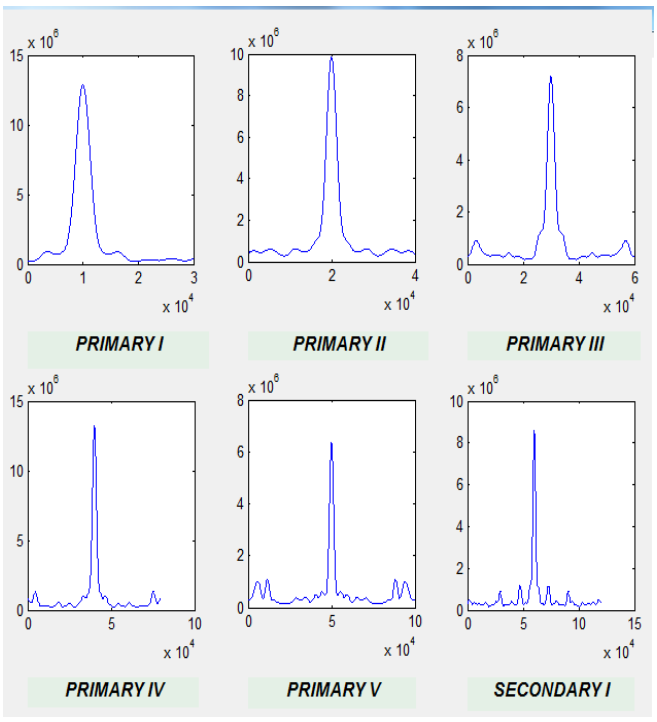

Fig.8. 4th Primary User Want to Use

VI. CONCLUSION

A sensible implementation of the cognitive feature radio by Cyclostationary methodology in MATLAB is done to improve the spectrum utilization. The Cyclostationary based user detection technique in low SNR is utilized, the Spectral correlation is employed for the approach to user detection. The spectrum gap is detected by the secondary user and uses the vacant spectrum as an unauthorized user by dynamic spectrum allocation while not making interference to the first user.

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