Enhanced Spectrum Sensing with OFDM Technique in Cognitive Radio Networks

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Abstract
Cognitive radio network is a key to effectively utilize the underutilized radio spectrum. It works on the basis of Software Defined Radio. Spectrum sensing is the most important part of the cognitive radio system and it is used to detect the presence of signal in the air. There are many techniques to sense spectrum like Matched filter based detection, Energy detection and Cyclostationary detection. In the proposed work, Cyclostationary feature detection is chosen. A comparative analysis of Cyclostationary feature detection with and without OFDM is made. Orthogonal Frequency Division Multiplexing (OFDM) being a modulation technique uses multiple carriers for data transmission. And each of these carriers could be modulated using modulation techniques like BPSK or QAM. Thus implementation of OFDM scheme to these spectrum techniques leads to an enhanced spectrum sensing technique in Cognitive radio networks.

Keywords
Cognitive radio network, Software Defined Radio, Spectrum sensing, Energy detection, Matched filter detection, Cyclostationary feature detection, Orthogonal Frequency Division Multiplexing (OFDM).

I. Introduction

The cognitive radio is a wireless communication system that is aware of its surrounding environment and it is capable of using the current available spectrum without any interference. It is mainly used for measuring signal's presence in the frequency spectrum at a particular time and at particular locations.

This kind of awareness requires more amount of flexibility and this flexibility is provided by the radio architecture that is just a Software Defined Radio (SDR) which would be able to support the cognitive radio system. Cognitive Radio system rely on the SDR system model that introduces flexibility of operation to the radio system [1-2].

Hence, SDR is a radio architecture that shows some considerable grade of flexibility to the hardware radio system. This flexibility is achieved by changing radio configuration as needed. Further flexibility is attained by filtering process and by applying DSP technique.

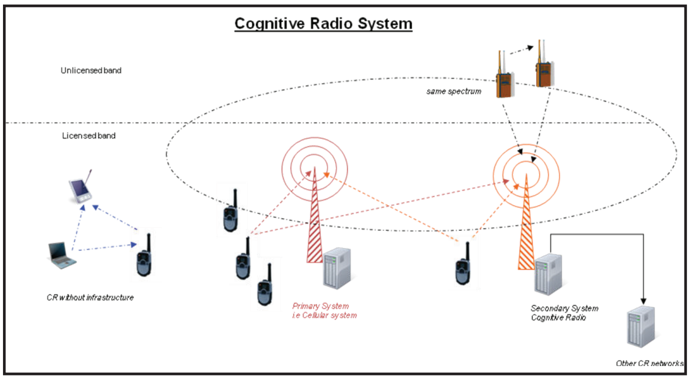

Fig. 1: Cognitive Radio System

II. Spectrum Sensing

Spectrum sensing is a technique which identifies the presence of signals in the spectrum. This sensing process requires in finding an empty spot as well as fast allocation of spectrum [3]. Irrespective of where the spectrum sensing device is located, the SDR should be capable of detecting the presence of signal over noise levels. The challenge in spectrum sensing is to perform the detection reliably and within a particular time period [7-8]. There are three methods to determine signal presence. They are energy detection, matched filtering and cyclostationary detection. Fig. 2 represents the frequency, time and power distribution of spectrum.

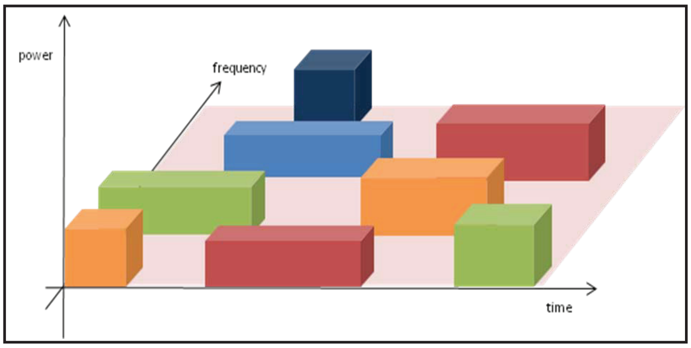

Fig. 2: Frequency, Power, Time representation

Energy detection is one way of spectrum sensing and there is no necessity of any knowledge about the primary user signals. The detected energy is compared with a threshold value. The detection is performed in time or in frequency domain [4]. Time domain implementation involves averaging the square of the signal. Frequency domain implementation involves FFT operation to be performed. But in both the cases the results are compared with the threshold.
The matched filter method gives the best Signal to Noise ratio as it matches the specific signal [5]. This method requires a thorough knowledge about the primary user signal. A coherent detection will be required as it is required to implement time and frequency synchronisation, knowledge about the modulation type, bandwidth requirement.
Any modulated signal will have some periodicity within them. For signalling and for synchronisation purpose preambles, pilots and cyclic prefix are added. Instead of using power spectral density, cyclic correlation function is used [6]. And the algorithms used here are able to differentiate noise from signals. Recent research efforts found that cyclostationary feature detection has been found to be superior to simple energy detection and matched filter [13] [14].

III. OFDM in Cognitive Radio System

OFDM is a modulation technique that has multiple carriers to transmit data .And these carriers could be modulated with modulation techniques such as BPSK and QAM. OFDM is also a frequency based modulation scheme, but it uses all the carriers to transmit data from a channel. The data are split and are transmitted over multiple lower rate channels which makes it more robust and thus higher data bits are transmitted. These

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schemes are improved by defining orthogonality between the carriers, allow them to be closer to each other and reduce the required bandwidth. The use of FFT makes OFDM to be easily implemented. The cognitive radio system is usually implemented by means of FFT. OFDM is also implemented using FFT, hence OFDM best fits into a cognitive radio system. The OFDM takes place in digital domain before the FFT operation, which allows manipulation of individual carriers to reduce the current bandwidth as needed. This also modifies the power on individual carriers, suppressing and shaping them. This system requires high synchronisation in both time and in frequency domain. Thus the inclusion of preambles, cyclic extension and pilots makes the receiver to achieve the requirements for synchronisation [17-18].

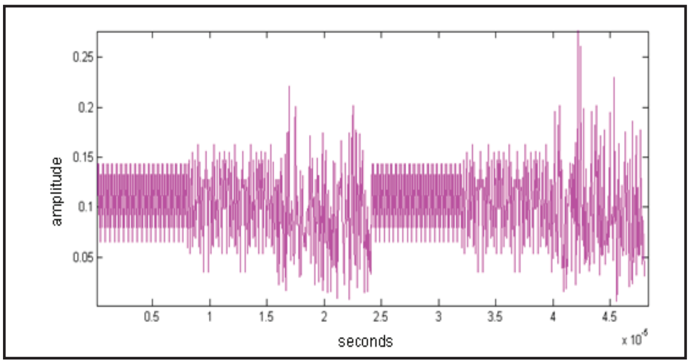

Fig. 3: Pilots Added in the OFDM Frame

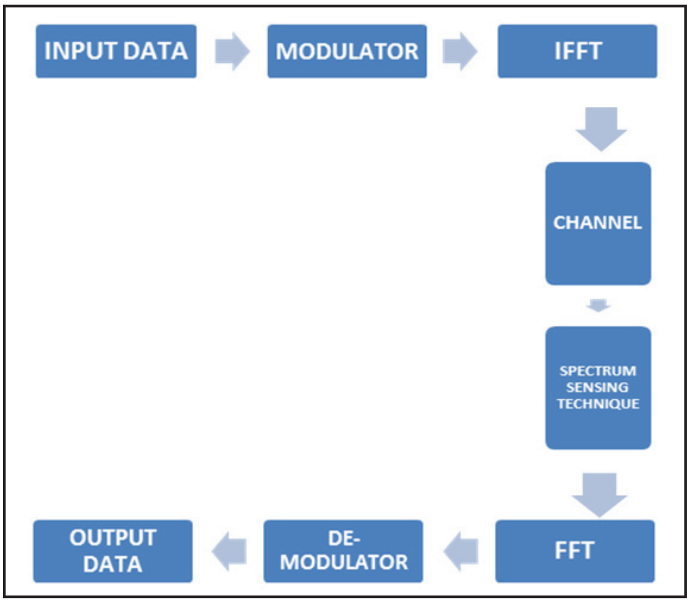

Fig. 4: OFDM Transmitter and Receiver

The OFDM system with transmitter and receiver is shown in the figure. It focuses on the current technology that makes more convenient to implement OFDM in the digital domain. The input bit stream is subjected to some pre-processing such as FEC encoder, interleaver and scrambler [20].

Usually the IFFT block is shared by the transmitter and FFT by the receiver [16]. The receiver front-end transforms the incoming analog signal to suitable levels to be applied to the ADC. Usually the ADC and the IQ detector are tuned to their respective frequency and phase of operation. This project focuses on implementing spectrum sensing in OFDM system. The transmitter produces the OFDM frames from the incoming data stream. The spectrum of this signal is used for detecting cyclic features by using cyclostationary feature detection [11] [15].

IV. Cyclic Feature Detection

Consider a modulated signal a (t),

$$a(t) = A(t)\cos(2\pi f_0 t) \quad (1)$$

The autocorrelation function of A(t) is given in Equ (2),

$$G_A = E\{A(t)a(t-\tau)*\} \quad (2)$$

A simple quadratic transformation followed by trigonometric identity of Equ (1) can be written as shown in Equ (3)

$$y(t) = \frac{1}{2}[b(t) + b(t)\cos(4\pi fo)\, t)] \quad (3)$$

Here b(t) is positive and it has spectral lines that appears together with the spectrum when f=0 on the Power Spectral Density(PSD). Likewise we can prove that the PSD as shown in Fig 5 of y(t) contains copies of b(t). And it is expressed in Equ 4

$$S_y(f) = \frac{1}{4}[K\delta(f) + S_b(f) + K\delta(f \pm 2fo) + \frac{1}{4}S_y(f \pm 2fo) \quad (4)$$

As the quadratic transformation is used, spectral lines starts to appear. But these transformation doesn't work in all the cases so, a delay has to be included. It is shown in the Equ (5) and Equ (6).

$$y(t) = a(t).a(t-\tau) \quad (5)$$

$$y\tau = a(t-\tau/2)a*(t+\tau/2) \quad (6)$$

Then conjugate is added to accommodate the complex values and it is shown in Equ 7.

$$N_X^\alpha = a\left(t-\frac{\tau}{2}\right)x*(t+\frac{\tau}{2})e^{-j2\pi\alpha t} \quad (7)$$

when α = 0,

$$G_X^0 = a\left(t-\frac{\tau}{2}\right)a*(t+\frac{\tau}{2}) \quad (8)$$

The above equation is re-named as cyclic autocorrelation function and it is given by the Equ (9),

$$G_X^0 = a\left(t-\frac{\tau}{2}\right)a*(t+\frac{\tau}{2})e^{-j2\pi\alpha t} \quad (9)$$

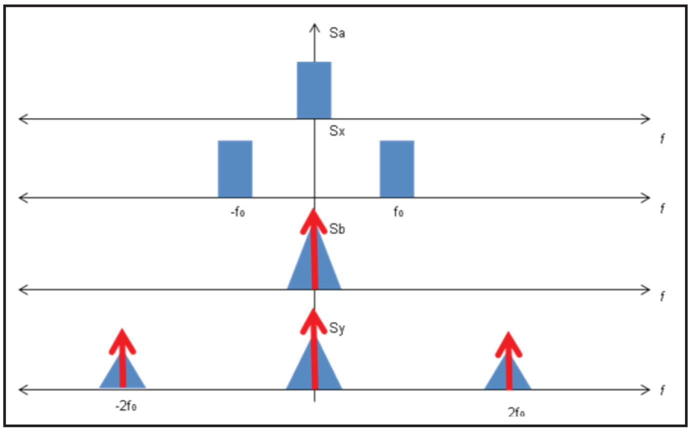

Fig. 5: Power Spectral Density

By rearranging, we can make it as,

$$G_x^\alpha(\tau) = \{\left[a\left(t-\frac{\tau}{2}\right)e^{+j2\pi\alpha\left(t-\frac{\tau}{2}\right)}\right]\left[a\left(t+\frac{\tau}{2}\right)e^{-j2\pi\alpha\left(t+\frac{\tau}{2}\right)}\right]\} \quad (10)$$

The spectral correlation function is derived from,

$$G_X = |a(t)|^2$$

For the shifted versions of v (t) and u (t),

$$G_X^\alpha(0) = u(t)v*(t) = |x(t)|^2 e^{-j2\pi\alpha t} \quad (11)$$

Equ 12 gives the PSD,

$$s_x(f) = \lim_{B\to 0} \left(\frac{1}{B}\right)^n (|h_B(t) * x(t)|^2) \quad (12)$$

And again for the shifted versions,

$$S_x(f) = \lim_{B=0} \frac{1}{B}\{|h_B(t) * u(t)||h_B(t) * v(t)| *\} \quad (13)$$

Equ (13) The above expression gives the Spectral Correlation Density Function (SCD).

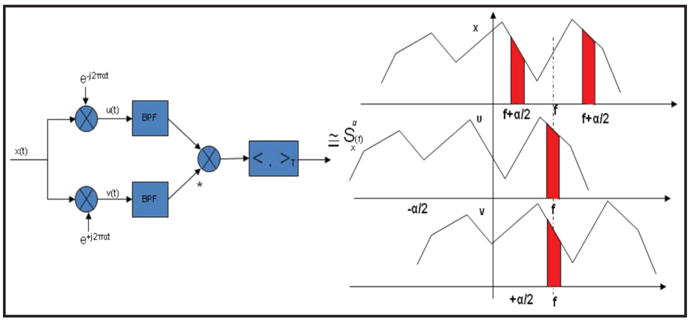

Fig. 6: The Spectral Correlation Function Procedure

V. Simulation Results

Based on the following inputs given in Table 1 the simulation for ROC curve and BER performance have been obtained with the help Matlab v2013b.

Table 1: Inputs

INPUT PARAMETERS	INPUTS
Subcarriers(N)	16
QAM order(Mo)	16
Cyclic Prefix(cp)	4
Sensing slot time(tau)	0.05 m sec
Sampling frequency(fs)	1500 Hz

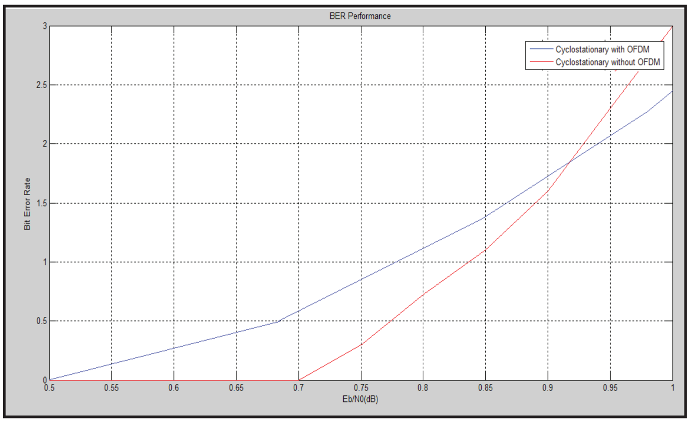

Fig. 7: BER Performance for Cyclostationary With and Without OFDM

Fig. 7 shows that, the bit error rate is lower for cyclostationary with OFDM technique when compared to cyclostationary without OFDM. This lower bit rate allows the receiver in easy synchronisation with the transmitter.

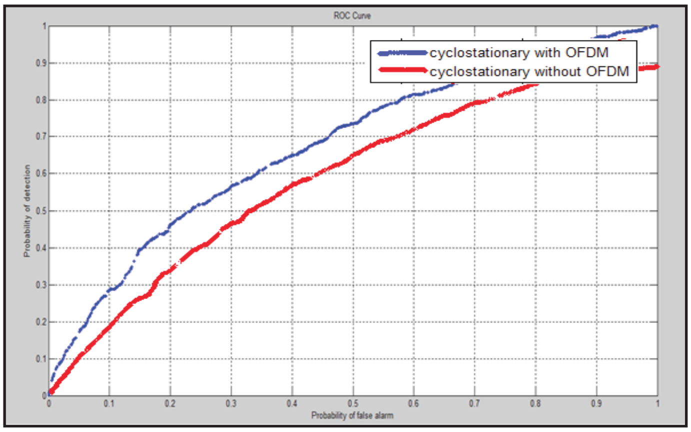

Fig. 8: ROC Curve for Cyclostationary With and Without OFDM

Fig. 8 shows the probability of detection for cyclostationary with OFDM is more efficient when compared to cyclostationary without OFDM.

VI. Conclusion

Thus in this work, the BER performance and ROC curve obtained with the help of Matlab simulations shows that the cyclostationary with OFDM is more efficient when compared to cyclostationary without OFDM. Thus an enhanced version of spectrum sensing is obtained when sensing is done with OFDM scheme.

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