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Spectrum Sensing Using OFDM Signal and Cyclostationary Detection Technique In Cognitive Radio

Mudasir Ah Wani[1], Gagandeep Singh[2]

[1]M.Tech Student, Department of ECE, Lovely Professional University, Punjab, India
[2]Assistant Professor, Department of EEE, Lovely Professional University, Punjab, India

ABSTRACT

Cognitive radio reduces the spectral inefficiency by sensing the under and over utilized parts of the spectrum and then redistributing the transmission to ensure that the spectrum is used efficiently. The awareness about spectrum usage is obtained by spectrum sensing. Cyclostationary feature detections one of the spectrum sensing techniques for cognitive radio. In this paper, we detect the presence and absence of an OFDM signal in the cognitive radio communication channel with the help of cyclostationary feature detection technique by using SCF.

Keywords: Cognitive radio, Cyclostationary feature detector, Cyclic frequency, Spectral correlation function, Spectrum sensing, Probability of detection, Probability of false alarm.

1. INTRODUCTION

The different parts of radio spectrum have been traditionally divided by different wireless technologies. The result is that today some frequency bands are crowded while others are hardly used at all that is called spectral inefficiency. Cognitive radio is an intelligent wireless technology based on the dynamic spectrum allocation (DSA) instead of fixed spectrum allocation. Using DSA, it is possible for the cognitive radio to conserve the resources and provide efficient utilization of spectrum. The primary users (PU) grant permission to secondary users (SU) to access the free part of the spectrum after it is confirmed that there is no interference in primary users' transmission. Therefore, the congestion arises by less availability of spectrum is solved by cognitive radio by introducing the opportunistic frequency band usage. Federal communications commission initiated the cognitive radio [1].

The unused spectrum is autonomously exploited to determine the new paths to the spectrum usage. In the terminology of cognitive radio, the PU is considered as the user who has the license for using spectrum. And, the SU is considered as the user whom the PU grants permission of using the spectrum but only in the absence of PU. However, if the PU is present then the SU's transmission gets shifted to another frequency in order to avoid interference with PU. Therefore, there is a great need for spectrum sensing for checking whether PU is using the spectrum or not.

The spectrum sensing in cognitive radio includes three digital signal processing techniques namely, Transmitter (Non-cooperative) technique, Receiver (Cooperative) technique and Interference-based technique [1]. The cyclostationary feature detection is a receiver based spectrum sensing technique. Within a specific modulation type, the cyclostationary feature detector is able to achieve the periodicity in the received signal to detect primary user signals as most signals vary with time periodically. A signal is called cyclostationary if the signal's statistics like mean and autocorrelation are periodic with time.

The use of OFDM scheme in present technologies is increasing day by day like Wi-Fi, WiMAX use OFDM scheme [2]. In OFDM the sub-carrier and symbol interval are orthogonal to each other. In this paper, during the transmission by primary user OFDM symbols are fed to a predetermined cyclostationary signature. This is done for reducing the data rate. The optimum statistics is calculated which include the spectral correlation function (SCF) of the signal. The calculation of optimum statistics is determined by power spectral density .Then, SCF is compared with the threshold, if it is greater, the OFDM signal is detected otherwise not. The steps of the signal detection are given in the Figure.1.

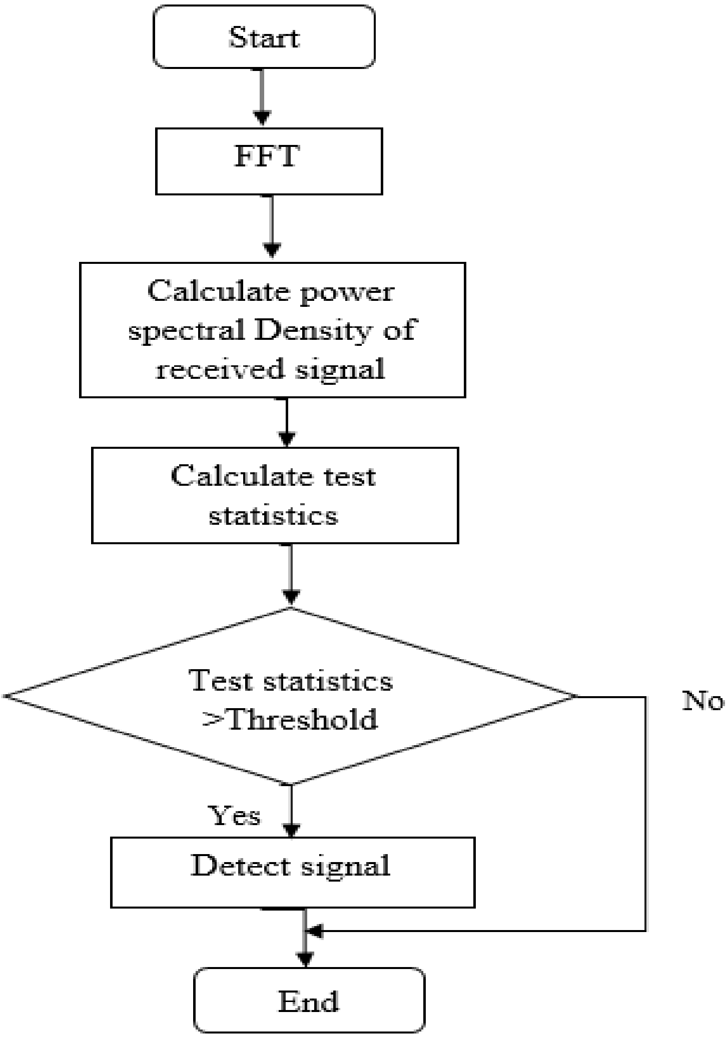

Figure.1: Flow diagram of an OFDM signal detection operation.

2. CYCLOSTATIONARY DETECTION

The problem of OFDM signal detection can be formulated as a binary hypothesis testing problem with the following hypothesis:

H_0: $y(t) = n(t)$

$$H_1: y(t) = h(t)\ conv\ x(t) + n(t) \qquad (1)$$

Where, $x(t)$ is the signal to be detected, $h(t)$ is the channel and $n(t)$ is the noiseH_0 and H_1 stand for the decision that the primary user (PU) is present or not.

When the product of two signals is cyclostationary, the correlation is given as equation (2).

$$R_X(\tau): \mathcal{E}\left[x\left(t+\frac{\tau}{2}\right) x*(t-\frac{\tau}{2})\right](2)$$

Where $R_X(\tau)$is the correlation, which is calculated by multiplying two signals by $\tau$and $\mathcal{E}$ is denotes average.
Power spectral density or spectral correlation function (SCF) of $x(t)$is achieved by Fourier transformof equation (2) [3], [4] as in equation (3).

$$S_X(f) = F[R_X(\tau)] = \int_{-\infty}^{\infty} R_X(\tau) e^{-i2\pi ft}\, dt(3)$$

Using (3), we get the test statistics by equation (4).

$$y_R(t) = \int_{-\infty}^{\infty} \frac{||H(f)|^2}{N_0} S_x(f) * S_{yt}\ (t,f) dt (4)$$

Where,$y_R(t)$ represents test statistics, $S_x(f)$ is CSF of original signal$x(t)$, $S_x(t,f)$ is CSF of received signal $y(t)$ and $H(f) = \int_{-\infty}^{\infty} h(t)e^{-i\omega t}\,) \,d\tau(5)$

In the form of preambles, cyclic prefixes and pilot carriers OFDM has an inbuilt periodicities. If the signal is cyclostationary, the correlation is determined by equation (6).

$$R_x(t+\tfrac{\tau}{2}, t-\tfrac{\tau}{2}) := \left[x\left(t+\tfrac{\tau}{2}\right) x*(t-\tfrac{\tau}{2})\right]$$
$$= R_x(t+\frac{\tau}{2}+T_0, t-\frac{\tau}{2}+T_0)$$
$$= \sum_\alpha R_x{}^\alpha(\tau)e^{-i2\pi\alpha t} \ (6)$$

Now, SCF of $x(t)$with respect to a cyclic frequency is determined by Fourier transform of $R_x{}^\alpha(\tau)$as in equation (7).

$$S_x{}^\alpha(f) = F[R_X(\tau)] = \int_{-\infty}^{\infty} R_x{}^\alpha(\tau)e^{-i2\pi f\tau}\, dt (7)$$

Where α is the cyclic frequency and is equal to $\frac{K}{T_s}$. K is an integer andT_0 is the multiple of T_s.
The test statistics $y_\alpha(t)$,which act as the basis for decision process is calculated by equation (8).

$$y_\alpha(t) = \int_{-\infty}^{\infty} \frac{H^*\left(f+\frac{\alpha}{2}\right)H\left(f-\frac{\alpha}{2}\right)S_x{}^\alpha(f^*)}{S_n{}^0(\left(f+\frac{\alpha}{2}\right)S_n{}^0\left(f-\frac{\alpha}{2}\right)} S_{yt}{}^\alpha(t,f)e^{-j2\pi\alpha t} df \ (8)$$

Where,$S_n{}^0(f)$ is SCF of noise when $\alpha = 0$ and $S_{yt}{}^\alpha(t,f)$ is SCF of current received signal i.e. $y(t)$.
The power spectral density of the received signal is given as equation (9).

$$S_y{}^\alpha(n,f) = \sum_{m=-\frac{p}{2}}^{\frac{p}{2}} Y_M\,(n,k+m)Y_M{}^*(n,l+m)(9)$$

Where the 'm' denotes a variable denotes a period and P is a large integer, The FFT signalY_M is provided to the correlator in the form of $Y_M(n,k+m)$and $Y_M{}^*(n,l+m)$.
The expression for cyclic frequency, $\alpha$and the typical frequency, f are given in equation (10).

$$\alpha = \frac{k-1}{M}$$
$$f = \frac{k+1}{M}(10)$$

Where k denotes a frequency, and M denotes a Fourier transform size.
Now, the test statistics $y_\alpha(t)$is compared with the threshold $\boldsymbol{\lambda}$ [3].

$y_\alpha(t) < \lambda$: PU is absent
$y_\alpha(t) > \lambda$: PU is present (11)

The terms that lead to complexity in computation are eliminated by normalization of SCF.

Therefore, spectral correlation method is best suited for signal detection. This method provides robustness against noise and interference. SCF is large when cyclic frequency value is equal to zero. So, cyclic frequency was utilized to determine the type of signal.

3. RESULTS

The simulation of the used system model was carried out in MATLAB. The PU signal taken into consideration was an OFDM signal with 4QAM modulation scheme. Figure 1 illustrates the SCF of OFDM signal. When cyclic frequency is zero, the signal characteristics are not recognized except the 'wall' effect [4].The main purpose of using cyclostationarity to recognize the OFDM signal depends on the periodicity and symmetry of the OFDM signal to be detected [5], [6],[7]. So, the periodicity of repeated pilot subcarrier is utilized to recognize the OFDM signal shown in Figure.4 and Figure.5.

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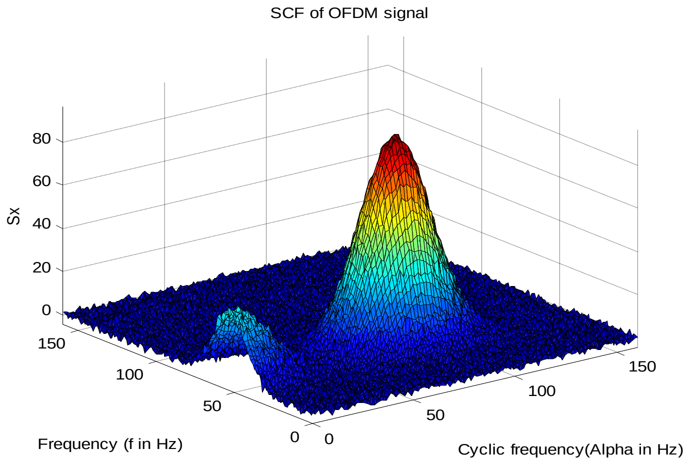


Figure.3: SCF of OFDM signal.

The purpose of allocating the pilot subcarriers in frequency domain is synchronization and channel estimation [8]. As pilot subcarriers are allocated with fixed constant spacing which guarantees the periodic characteristic of an OFDM signal.

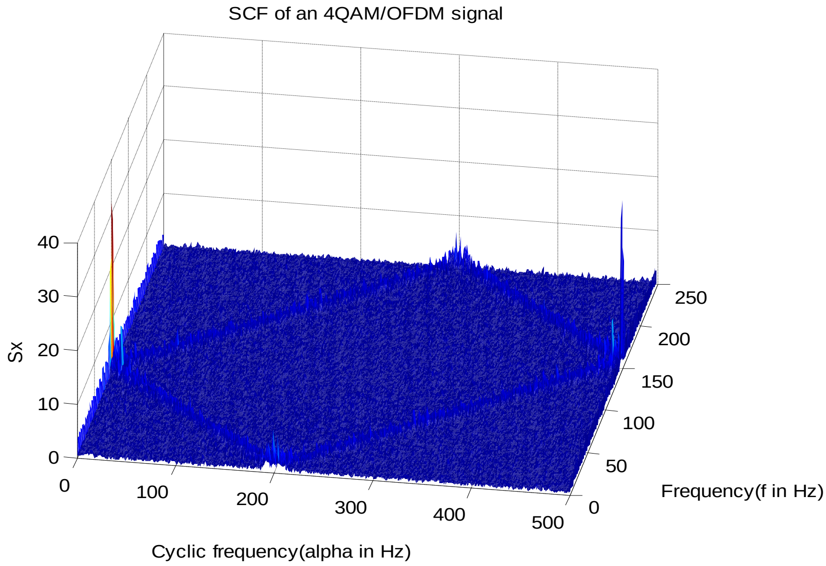


Figure.4: SCF of QAM/OFDM signal with 5dB boosted pilot subcarrier.

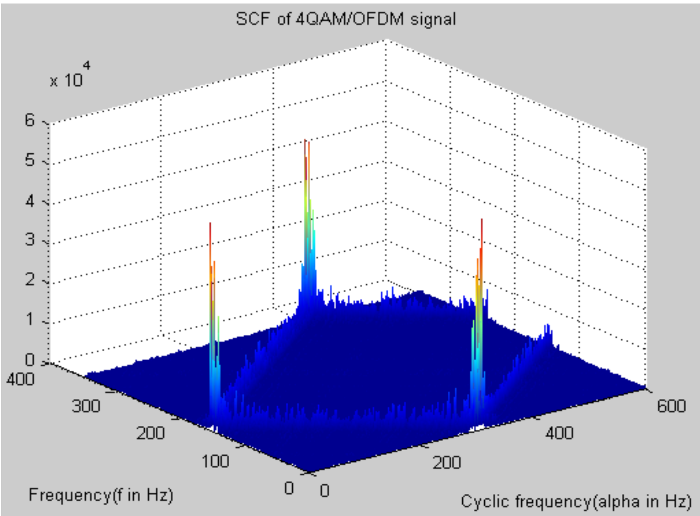
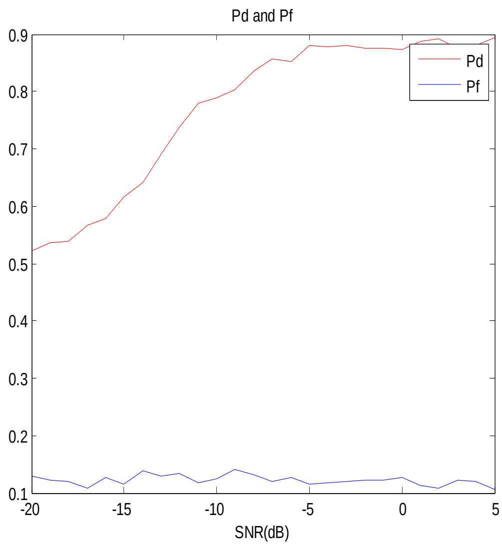


Figure.5: SCF of QAM/OFDM signal with 10dB boosted pilot subcarrier.

Therefore, larger is the power of boosted pilot subcarrier, more it would be helpful in the recognition of an OFDM signal as shown in Figure.5 with 10dB.



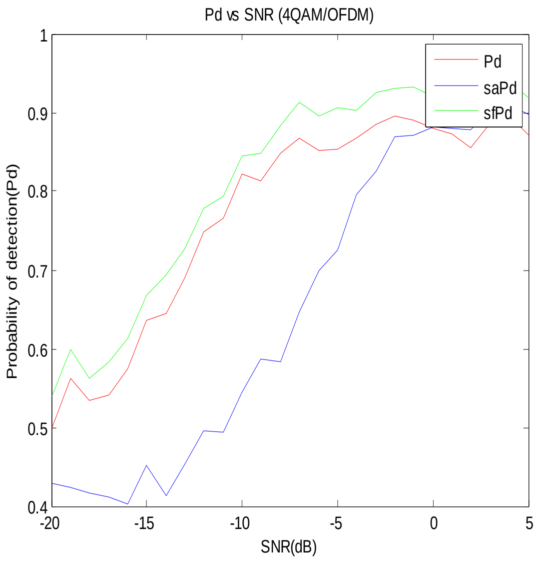


Figure.6: Illustration of P_f and P_dFigure.7: Performance of cyclostationary feature detector

With probability of false alarm, P_f the spectrum sensing algorithm declares that H_0true, when the primary user is actually absent. From the secondary user point of view, increase in false alarm will reduce the spectrum opportunities for them. Therefore, it is important to control the P_f for efficient secondary user spectrum utilization. With probability of detection, P_d spectrum sensing algorithm declares that H_1 is true, when the primary user is present. From the primary user point of view, increase in P_d will increase the interference caused to them. Therefore, it is important to control the P_d to avoid the collisions between the primary and secondary users as shown in Figure 6 and Figure 7.

CONCLUSION

In this paper, spectrum sensing in cognitive radio is done based on the cyclostationary feature detection technique and an OFDM signal. The 4QAM/OFDM signal is detected in an AWGN environment by using SCF, spectral correlation method and pilot subcarrier.SCF of the received signal is user to decide whether the PU is present or absent in the channel. Pilot subcarriers allocated with fixed constant spacing guarantees the periodic characteristic of an OFDM signal. The detection performance is determined with the help of cyclic frequency and by using probability of detection, P_d and probability of false alarmP_f.Both P_d and P_f should be controlled to increase the secondary user spectrum utilization and to avoid the collision between primary user and secondary user.

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