

REVIEW ON SPECTRUM DETECTION TECHNIQUES UNDER BLIND PARAMETERS

Noblepreet Kaur Somal¹, Gagandeep Kaur²

¹*M.tech, Electronics and Communication Engg., Punjabi University Patiala Yadavindra College of Engineering, Talwandi Sabo, Punjab, India, Email: noble.somal90@gmail.com*

²*Department of Electronics and Communication Engg., Punjabi University Patiala Yadavindra College of Engineering, Talwandi Sabo, Punjab, India, Email: ergagan84@gmail.com*

ABSTRACT: From last ten years, cognitive radio gains much interest due to the complexity in management and limited spectrum access for wireless communication. Some major obstacles are occurred in the spectrum sensing such as false alarm, missed detection, complexity and time consumption, because we cannot observe all parameters like frame size, modulation technique, data rate of primary user (PU) signals due to some security issues.

For reducing these problems a new blind cyclostationary technique is introduced in which sum value of magnitude square of cyclic spectral density (SCSD) is created. In this paper, the requirements of cognitive radio are investigated. The main goal of this paper is to propose an another solution for the reduction of sensing time to sense the spectrum by implementing the combination of FAM and blind cyclostationary technique by assuming some parameters of primary user signal in existing techniques and this technique will reduces the complexity too.

KEYWORDS: Cognitive radio, Spectrum sensing, Blind Cyclostationary, FAM

I. INTRODUCTION

In present days, wireless communication is most popular communication technique. There are lots of constraints on the available radio spectrum. We know that the radio spectrum is very limited for wireless communication. The Federal Communication Commission (FCC) research report [6] states that, seventy percent of the allocated spectrum is underutilized. So we need a technique to deal with the problem. Cognitive radio is the promising solution for the problem of ‘spectrum scarcity’ caused by rapid development of wireless services[12]. In this paper, we use the definition adopted by Federal Communications Commission (FCC) “Cognitive radio: A radio or system that senses its operational electromagnetic environment and can dynamically and automatically changes its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets”[5]. This capability is a matter that involves technology, standardization and spectrum policy and even requires changes in the business model.

1.1 SDR - CR is an intelligent radio which is considered as software define radio (SDR). The main dissimilarity between the SDR and CR is that in SDR the radio system is described by software to process the all functions to SDR hardware platform. The sensing node of cognitive radio is SDR dependent, because the CR parameters are dynamically changes. To access the radio spectrum there are two types of users:

- Primary users (PUs) – licensed users

- Secondary users (SUs) – unlicensed users

Primary users have legacy rights for the particular frequency spectrum band and secondary users are unlicensed users and have lower priority. They access licensed frequency bands without interfering the PUs at some specific times in some specific locations. In particular frequency band of primary user spectrum there are three types of spaces:

- Black spaces – fully occupied slots due to the presence of signal plus noise.
- Grey spaces – partially occupied slots due to interferences and noise.
- White spaces – blank slots except noise from artificial and natural sources.

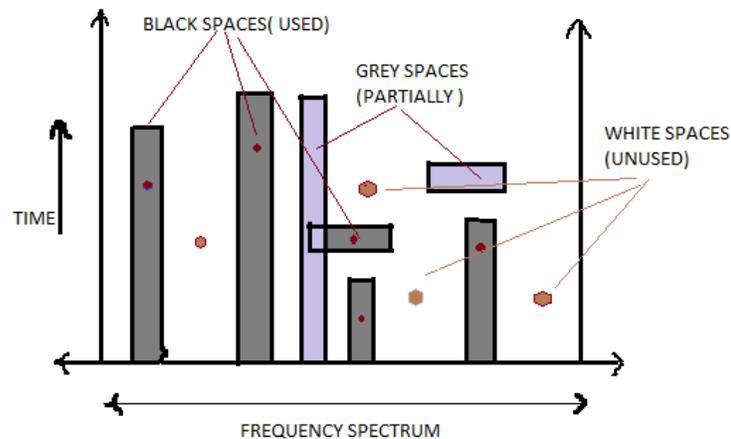


Figure 1. Frequency spectrum of primary user

II. COGNITIVE RADIO

Communication system operates in diverse environment, which leads to the fading effect. So spectrum sensing must be performed in fading or noisy environment. There are two types of fading such as small scale fading (due to the multiple versions of transmitted signal arrive at receiver), and large scale fading (due to the large distance between Tx and Rx for propagation the signal(s)). In 2002, FCC identifies some features of cognitive radio which makes it more efficient and flexible usage of the spectrum [6].

- Change its operating frequency for its adaption to environment.
- Sense signal from nearby transmitter to choose optimal environment.
- Reconfigured the transmission characters and waveforms.
- Controls the transmission power.
- Able to define the location of other devices and itself.
- Enable the algorithms to share the spectrum under agreements between licensed user and third party.

Cognitive radio performs mainly four tasks:

- Spectrum sensing
- Spectrum sharing
- Spectrum management
- Spectrum mobility

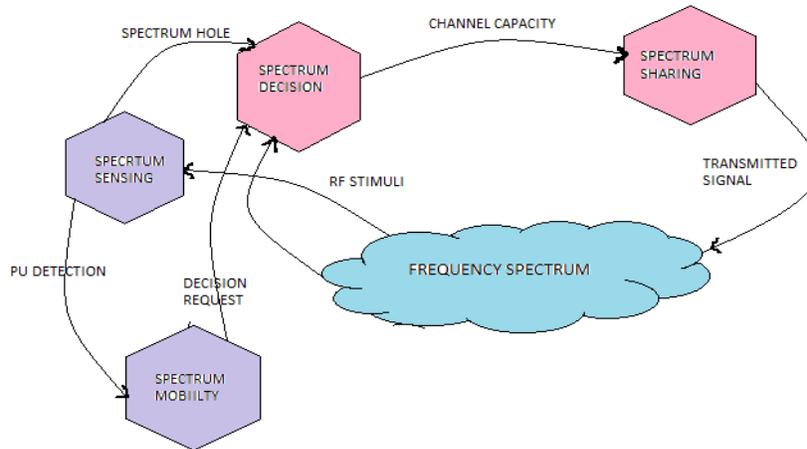


Figure 2. Cognitive cycle of spectrum access

Most cognitive users cannot predict the signal parameters, due to the primary user’s information security and their own aspirations [13].

III. SPECTRUM SENSING

Detecting the presence of signals in the frequency spectrum is called spectrum sensing. Cognitive radio has ability to sense the spectrum and observe the unused frequency slots. By dynamically varying its driving parameters, cognitive radio can make use of vacant bands in an accurate way. By these abilities cognitive radio can performs in licensed band without interrupting the communication of primary user. Various techniques are used for spectrum sensing as energy detection, feature detection & matched filter.

3.1 Matched filter- In this technique we should have some prior knowledge about the primary user signal parameters such as modulation technique, signal shape and frame size then this technique is optimal choice for signal detection. But, if the prior knowledge is not correct then matched filter technique performs poorly.

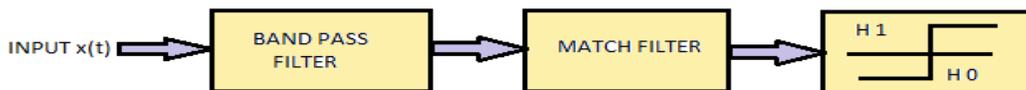


Figure 3. functional block diagram of matched filter detection

3.2 Energy detection method- In this technique PU signal parameters are assumed to be unknown to the cognitive user. This method is straight forward and referred to as radio meters. The energy of received waveform is measured by squaring the output of band pass filter with bandwidth, then integrating the received power over a particular time interval. Output of integrator is compared with predefined threshold to determine absence and presence of PU signal. This technique has main drawback that is it has poor performance in low signal to noise ratio and minimum SNR which is must for efficient energy detection is -3.3db when variation in noise power is 1db.

$$Z = \frac{1}{N} \sum_{T-1}^N |x(t)|^2 \quad (1)$$

Here the threshold γ and Z is compared and the decision is taken by the SU is that the PU is available or not. By increasing the sensing duration there is not sure that there is better detection. There are many improvements over the basic idea of energy detector that mostly focus on the threshold calculation adaptively [8][14].

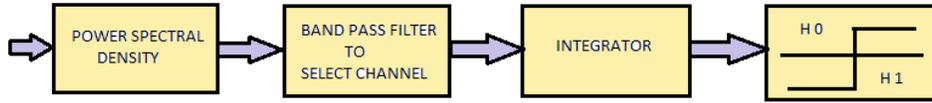


Figure 4. Block diagram of energy detection

3.3 Cooperative spectrum Sensing-There are some situations where a radio system is not able to be aware of the surrounds, like in fading channels, local interference, hidden source, etc. Data recovering could become impossible in such scenarios. But if multiple radios are performing around and could share their knowledge acquired by its individual spectrum sensing devices, then the probability of detection would increase [1].

IV. CYCLOSTATIONARY FEATURE DETECTION

In the literature, we can find many different approaches to get into the idea behind signal feature detection. A good start is to get into the definition of periodicity in a signal $x(t)$. First order periodicity could be pictured like;

$$x(t) = x(t + t_0) \quad (2)$$

This method deals with the inherent cyclostationary properties of a signal. Wireless signals are loaded with pulse train, cyclic prefixes, hopping sequences, repeating codes, sinusoidal carrier signals which all are cyclostationary in nature. Such properties of signal with spectral correlation and periodic statistics are not found in stable noise and in interference medium. In this technique cyclic spectral correlation function (SCF) is used to detect the signals present in a given frequency band and cyclic SCF of received signal is calculated as:

$$S_{yy}^x = \sum_{\tau=-8}^{\infty} R_{yy}^x(\tau) e^{-j2\pi f\tau} \quad (3)$$

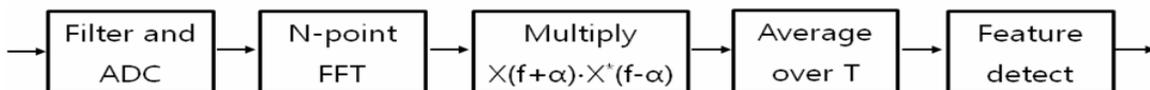


Figure 5. Implementation of a cyclostationary feature based detection [9]

Cyclostationary detection presents a valuable and viable tool when energy detection algorithms are not sufficient to detect users over the scanned bandwidth. There is no doubt that in terms of the computational complexity, cyclostationary detections is more demanding when compared with energy detection; the resolve time could very well meet many applications real time requirements. Such applications could consist of signal identification or merely signal presence. It has to be considered data transfer, video, video and voice, video and voice on real time, voice alone, etc. Probably the most complex scenario consists of voice alone running on a Cognitive Radio System that requires continuous awareness of possible primary users ready to claim bandwidth, rapid allocation of new spectral holes and rapid switching of secondary user communication without losing the link.

These types of scenarios remain under study and require more complex assistance than local capabilities as in the case of central-base-station-based strategies. Other applications could be a simple to recognize empty channels and stepping into as a co-existence rule. It is also true that the spectrum sensing device could be working as out-of-band, independent of the receiver and transmitter duties.

4.1 Blind cyclostationary technique : This technique is accomplished for predicting the spectrum when the parameters of PU signal are completely unknown. In it, estimation of PU signal is made by the SCF using cyclostationary properties. This method is able to detect real time spectrum efficiently by directly creating the sum value of the magnitude square of the CSD (SCSD) instead of predicting cyclic spectral density (CSD) at all cyclic frequencies (CFs). This method is less complex as compared to the other ordinary cyclostationary feature detection methods. For different decisions various hypothesis tests are made which are denoted by H0 and H1.

$$H1 : X(n) = S(n)h + W (n) ;$$

$$H0 : X(n) = W(n) ; \quad (4)$$

Here X(n) is a output signal in which S(n)+W(n) is assumed as noise i.e AWGN (additive white Gaussian noise)

The cyclic autocorrelation function of the signal $x(t)$ at a cyclic frequency (CF) α is defined as [17], [16]

$$R_x^\alpha(\tau) = \lim_{T \rightarrow \infty} \frac{1}{T} \int_{-T/2}^{T/2} x(t) x(t - \tau) * e^{-j2\pi\alpha t} dt e^{j\pi\alpha\tau} \quad (5)$$

The superscript(*)denotes the complex conjugate operation. With $\alpha = 0$, $R_x^0(\tau)$ becomes the conventional autocorrelation. The Fourier transform of cyclic auto correlation function is called cyclic spectral density [9].

$$S_x^\alpha(f) \triangleq \int_{-\infty}^{\infty} R_x^\alpha(\tau) e^{-j2\pi f\tau} d\tau \quad (6)$$

And the corresponding PSD is found as $S_x^0(f)$.The CSD can be considered as SCF [2]

$$S_x^\alpha(f) = \lim_{T \rightarrow \infty} 1/T X_T \left(f + \frac{\alpha}{2} \right) X_T \left(f - \frac{\alpha}{2} \right) * \quad (7)$$

CSD is only non zero for CFs, the SCSD $z(\alpha)$ is an impulse train with each impulse of different weights located at all CFs. The impulse can be missed if we do not have infinitesimal cyclic spectral resolution for a fourier transform. To avoid this negligible problem, we introduce a function[9];

$$G(\alpha) = \int_{-\infty}^{\alpha} Z(\beta) d\beta \quad (8)$$

called the cumulative value of the magnitude square of CSD(CCSD). The CCSD can be obtained as ;

$$G(\alpha) = \int_{-\infty}^{\infty} \{ Y_T(\beta) \otimes Y_T(-\beta) * \} U(\alpha - \beta) d\beta \quad (9)$$

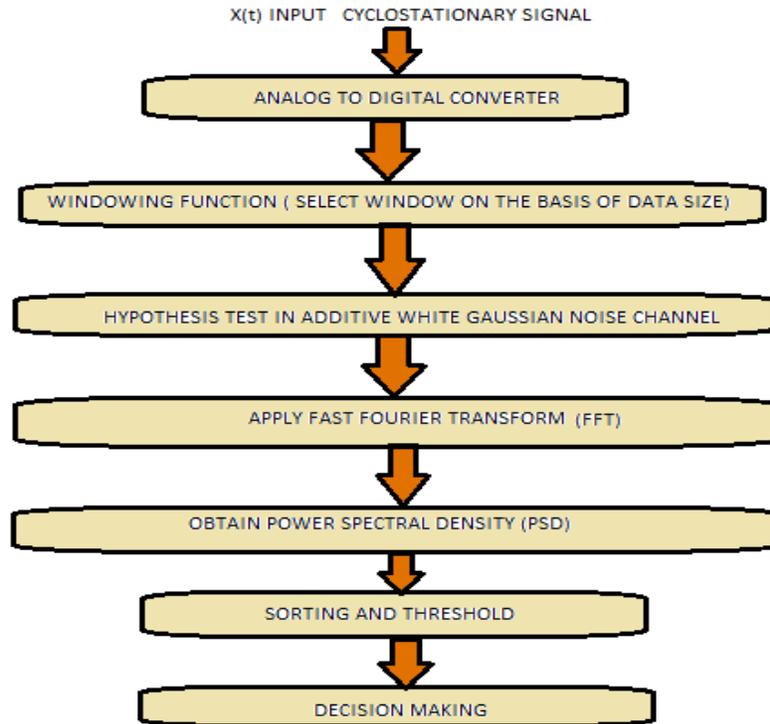


Figure 6. Flow chart of blind spectrum sensing for cyclostationary signal

Table 1. Simulation parameters

Parameter	Description
Modulation technique	QPSK
Channel	Additive white Gaussian noise channel
Window function	Hamming window
N	512
α	-N/4 to N/4
M	8000
SNR	-20

4.2 RESULTS-

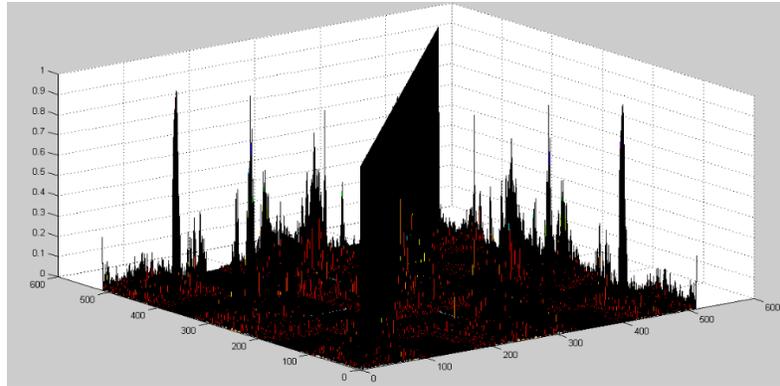


Figure 7. Magnitude square of CSD, QPSK

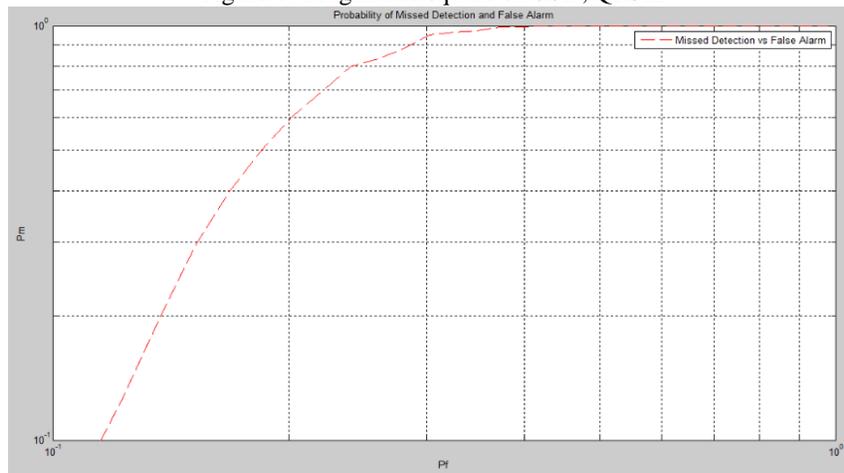


Figure 8. Probability of detection P_d and false alarm P_{fa} , QPSK, SNR=-20

4.3 FAM- FAM is one of the methods under time-smoothing classification which has good efficiency, computation wise. There are parameters involved that are used to trade-off resolution, reliability and of course computation reduction[2]. FAM consists of capturing in a time length Δ_t a piece of the incoming signal $x[n]$ which is the result of $x(t)$ sampled at f_s . Estimation of the $s_x^\alpha(n, f)\Delta_t$ is performed over this time length. This computation is performed iteratively over consecutive pieces in the time domain until acceptable results for a summation of several $s_x^\alpha(n, f)\Delta_t$ satisfy the application, in terms of time of computation and objective to meet.

CONCLUSION- In this paper we reviewed and simulated the blind cyclostationary technique that detect the primary user signal by using QPSK. The simulation result shows the sum of the average magnitude of cyclic spectral density(CSD) and the probability of missed detection and false alarm for QPSK. We plan to extend our analysis for improving the SNR by assuming some parameters of primary user signal and using FAM technique in existing spectrum detection techniques for cyclostationary signals for Wi-fi, Wi-Max. We expect that our proposal will be more feasible to improve the time consumption and SNR for signal detection by making the proper choice of FFT, frame size, data carriers, modulation technique and BPS.

V. FUTURE SCOPE

Nowadays, feature detection technique becomes a good choice to follow for many communication systems such as Wi-Fi, Wi-Max as well as DVB-T. With the help of orthogonal frequency division multiplexing (OFDM) technique, we may improve the probability of missed alarm and false detection upto large extent but this scheme has some drawbacks such as this makes the system more complex and consumes more time for computation the long sequences of algorithms. Data is of random character but the presence of pilots is almost fixed although different strategies are used among different OFDM schemes. Pilots are fixed in the sense of its presence in the signal spectrum and the power used on them. Cyclostationary detection search for these repetitive patterns and according the application the target could be any of them requiring more or less efforts.

Correlation in time domain will tell about the signal with no need to proceed to perform cyclostationary detection, assuming the application can afford correlation and the positive results already show signal presence. In future research, we will attempt to reduce the time consumption for detection and improves the signal to noise ratio with the implementation of FAM and cyclostationary techniques.

REFERENCE

- [1] A.Ghasemi and E.Sousa, “*Collaborative Spectrum Sensing for opportunistic acces in fading environments*”, in Proc. IEEE Int. Symposium on new Frontiers in Dynamic Spectrum Acces Networks, vol 1 Baltimore Maryland.
- [2]A. A.L habashna, O.A Dobre, “*WiMAX Signal Detection Algorithm Based on Preamble-Induced Second-Order Cyclostationarity*” global telecommunication IEEE conference, 2010.
- [3]Chad M. Spooner, *Cyclostationarity in Communications and Signal Processing*, Chapter 2: Higher-order statistics for nonlinear processing of cyclostationary signals, IEEE Press, 1994.
- [4]EeruR.Lavudiya, Dr.K.D.Kulat and Jagdish D.Kene,“*Implementation and Analysis of Cognitive Radio System using MATLAB*”, International Journal of Computer Science and Telecommunications, Vol. No. 4, Issue No. 7, July 2013, pp 23 – 28.
- [5]Federal Communications Commission, “*Notice of proposed rulemaking and order: Facilitating opportunities for flexible, efficient, and reliable spectrum use employing cognitive radio technologies,*” ET Docket No. 03-108, Feb. 2005
- [6]Federal Communications Commission. Spectrum Policy Task Force Report. Washington: *ET Docket*, 2002:2-135.
- [7]F.I. Akyildiz, W.Y. Lee, M.C. Vuran and S. Mohanty, “*A Survey on Spectrum Management in Cognitive Radio Networks*”, in IEEE Communications Magazine, 2008, pp. 40- 48.
- [8]F.Weiding, D.Datla, “*A framework for RF spectrum measurements analysis*”, in Proc. IEEE Int. Symposium on new Frontiers in Dynamic Spectrum Acces Networks, vol 1 Baltimore Maryland.
- [9]Jang Won Mee,” *Blind Cyclostationary Spectrum Sensing in Cognitive Radios,*” iee communications letters,2014.
- [10]Lee Jaekwon , “ *Blind Spectrum Sensing Techniques for Cognitive Radio System*” International Journal of Multimedia and Ubiquitous Engineering Vol. 3, No. 2, April, 2008.
- [11]MansiSubhedar and GajananBirajdar, 2011“*Spectrum Sensing Techniques in Cognitive radio Networks: A Survey*” International journal of next generation networks, Vol. No. 3,June 2011
- [12]S. Haykin, “*Cognitive radio: brain-empowered wireless communications,*” IEEE J. Sel Areas Commun., vol. 23, pp. 201–220, Feb. 2005.
- [13]Tang Chengkai et.al “*Cyclo-stationary Detection of the Spectrum Holes under Blind Parameters in Cognitive Radio*”IEEE 2010
- [14]T. Yucek and H. Arslan, “ *A Survey of Spectrum Sensing Algorithms for Cognitive Radio Applications*”, IEEE Communications Surveys & Tutorials, Vol. 11 2009.

- [15] Vo Nguyen Quoc Bao, “*Spectrum Sharing-based Multi-hop Decode-and-Forward Relay Networks under Interference Constraints: Performance Analysis and Relay Position Optimization*”, *Journal of Communications and Networks*, 2013, pp 1 – 11.
- [16] W. A. Gardner, A. Napolitano, and L. Paura, “*Cyclostationarity: half a century of research*,” *Signal Process.*, vol. 86, pp. 639–697, Apr. 2006.
- [17] W. A. Gardner, *Cyclostationarity in Communications and Signal Processing*, Chapter 1: An introduction to cyclostationary signals. IEEE Press, 1994.