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Statistic Cyclostationary Feature Detection and Improving Channel Estimation Accuracy in Cognitive Radio

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Abstract: **In future the basic problem is to find suitable spectrum band to fulfill the demand of services. While observations shows that the radio spectrum is unutilized. Cognitive radio is an important solution to improve the spectrum utilization. Cognitive users (CU) continuously sense the spectrum to utilize the spectrum without disturbing licensed users (LU). There are various spectrum sensing techniques but the ideal one should be fast, accurate and efficient. In this paper cyclostationary feature detection (CFD) technique is discussed and channel estimation accuracy in the systems has been improved. First of all an algorithm is proposed based on CFD and Hilbert Transformation. Algorithm is named as statistic CFD. Comparing with the conventional CFD algorithm, proposed algoritm is more flexible. Second objective is to improve channel estimation accuracy in OFDM system using Least Square (LS) method and minimum mean square error (MMSE) for initial channel estimation and then add LMS iterative algorithm.**

Keywords: Cognitive radio, cyclostationary feature detection, Hilberts Transformation, Channel Estimation, LS, MMSE and BER.

I. INTRODUCTION

The concept of cognitive radio was first introduced by Sir Joseph Mitola III at Royal Institute of Technology Stockholm in 1998. The need of the technology is to improve the utilization of radio spectrum. In cognitive radio network, cognitive user (CU) continuously sense the spectrum and came to know that when the primary user is using it or not. And it intelligently use the band when primary user is absent. There are many sensing techniques like matched filter, energy detection and cyclostationary feature detection. Out of these techniques CFD is fast, accurate and efficient and it works well in low SNR situations. Spectrum sensing and channel estimation is the first step to implement cognitive radio system. Process of spectrum sensing is shown in the figure below:

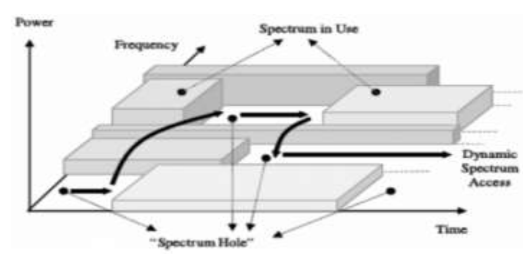

Figure 1: Spectrum hole or White Space

A. *Cyclostationary Feature Detection using Hilbert Transformation*

The properties of cyclostationary process vary periodically. Cyclostationary feature detection method deals with the feature of the signal that have a periodic statistics. CFD method is more immune to noise as it exploits this periodicity in the received primary signal to identify PU. In conventional CFD method the parameters which is used for detecting primary signal is cyclic autocorrelation function. But in statistic CFD algorithm we don't need to know about CAF of signal. Factor is $e^{-j2\pi\alpha tl}$ which is related to cyclic frequency α. After adding the factor we will calculate its average on a certain cyclic frequency.

Let us assume that r(t) is received signal. r(t) may contain both signal s(t) and n(t) because of environment. Two hypothesis of r(t) :

$$r(t) = n(t) \qquad H_0$$

$$s(t)+n(t) \qquad H_1$$

Where H0 represents absence of LU and H1 represents presence of LU means signal and noise both are present.

When we add factor $e^{-j2\pi\alpha t}$ to r(t) we get

$$x(\alpha,t)=r(t)*e^{-j2\pi\alpha t}$$

Calculate average of x(α, t) then a defined variable $M(\alpha, t_0)$ for certain cyclic frequency is given as follow and also length of detecting time is assume to be t_0

$$M(\alpha, t_0)=1/t_0\left|\int_0^{t0} x(\alpha,t)dt\right|$$

$$=1/t_0\left|\int_0^{t0} r(t)*e^{-j2\pi\alpha t}dt\right|$$

However, influence caused by noise present in channel can affect the result of detection. So to reduce this influence we use received signal's complex form and we can get complex signal from its real component $x_r(n)$ by using Hilbert Transformation as shown below:

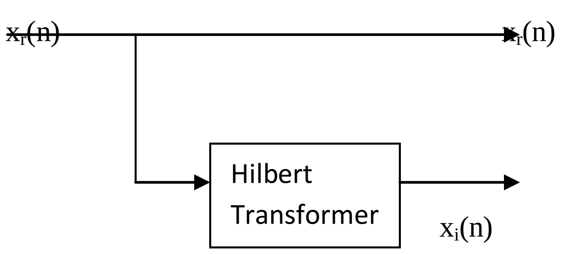

Figure 2: Hilbert Transformer

In this statistic cyclostationary algorithm two parameters will affect the amount of calculations, one is sampling time N and step size of cyclic frequency ALPHA. Large amount of calculations takes more time and energy for detection. On calculating average of several sampling results can reduce the influence of noise as AWGN is wide sense stationary.

B. Channel Estimation

Modulation technique used in cognitive radio is OFDM which divides a high data rate streams over subcarriers. Subcarriers save bandwidth in frequency domain and in time domain they are orthogonal and also cyclic prefix will avoid ISI. So OFDM is a technique that enhance the bandwidth efficiency by removing the frequency selective fading channels. During detection of the signal at the receiver end channel information is required. Pilot aided approach is chosen from the different methods of channel estimation as it is less complex.

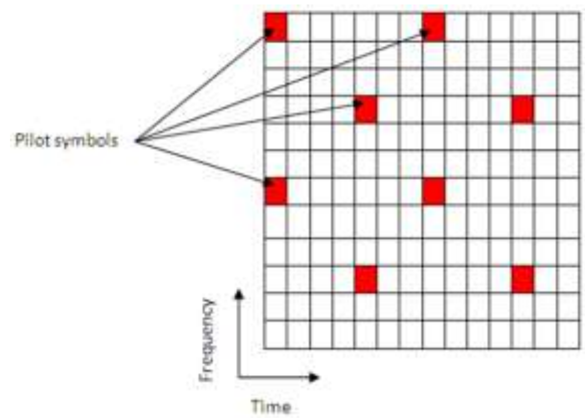

Figure 3: Insertion of Pilot Symbols

At the transmitter end we introduce pilots among subcarriers with equally spaced in frequency domain and at the receiver end they are extracted to estimate channel and interpolation is done in other subcarrier for channel estimation. In this analysis, channel is estimated with Least Square (LS) method and Minimum Mean Square Error(MMSE). Linear interpolation is done at the end to complete the estimation and then LMS iterative algorithim is used to improve the quality of channel estimation. Although channel estimation can be improved by using different iterative algorithm. Output of one iteration can be used as feedback for the next iteration. So in this way result is improved in each iteration. It can be used for SISO as well as for MIMO system. In this study pilots are transmitted along with data and LMS iterative algorithmis used.

In this algorithm channel estimation of last iteration is used. Iteration process is continued until desired result is not obtained.

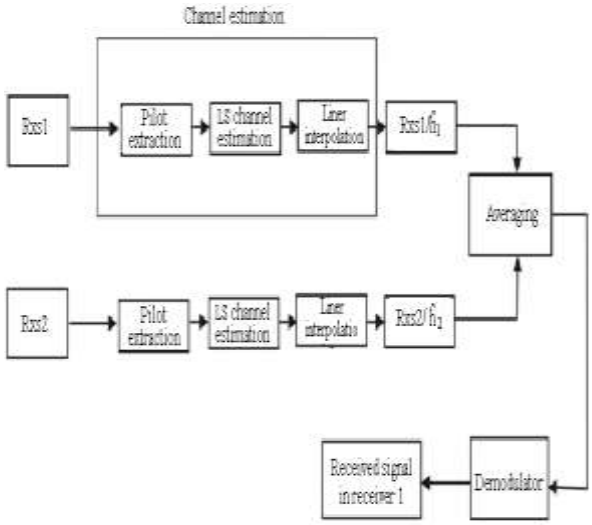

Figure 4 : Proposed Receiver for Channel Estimation

II. RESULTS & DISCUSSIONS

A. *Simulation of cyclostationary based detection*

In first case, statistic cyclostationary detection algorithim is used to detect modulated binary phase shift keying (BPSK) signal. Let us assume that modulated BPSK signal is transmitted in AWGN channel and SNR of the detector is set to be -10db. The parameters used in simulation are sampling time, sampling frequency (Fs) and step size of cyclic frequency. The unit step size of cyclic frequency is set to be 1MHz and its sampling time(N) is equals to 100. The simulation consequence is normalized to [0,1]. From result of simulation, the possible spectrum of BPSK is shown below :

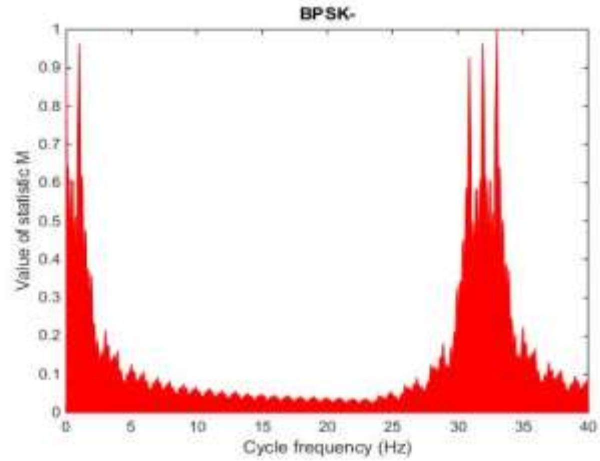

Figure 5: Spectrum of BPSK Signal

Also to form correlation between sensitivity (Pd) and specificity (Pf) of statistic cyclostationary algorithm, the ROC that is Receiver Operating Characteristics curve is shown in figure below. Also the ROC curve of standard energy detection is also shown and a comparision is made with theoretical values. On comparing we find that CFD algorithm is improved than that of energy detection

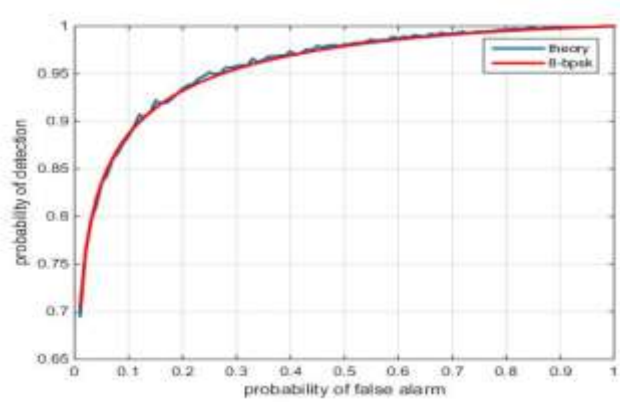

Figure 6: ROC Curve for BPSK signal

In second case detection of QPSK modulated signal is done. SNR is assumed to be -5db and AWGN channel is used to transfer data. Simulation parameters are sampling time, sampling frequency and step size of cyclic frequency. Now the step size of cyclic frequency is set to be 2MHz and sampling time is 100. Simulation outcome is normalized to [0,1] and resulted spectrum of QPSK is shown below:

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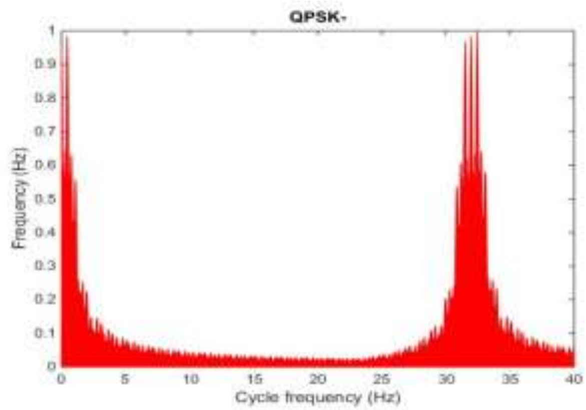

Figure 7: Spectrum of QPSK Signal

Relation between probability of detection and probability of false alarm for QPSK signal is shown below. As the no. of sample increases , the detection probability also increases.

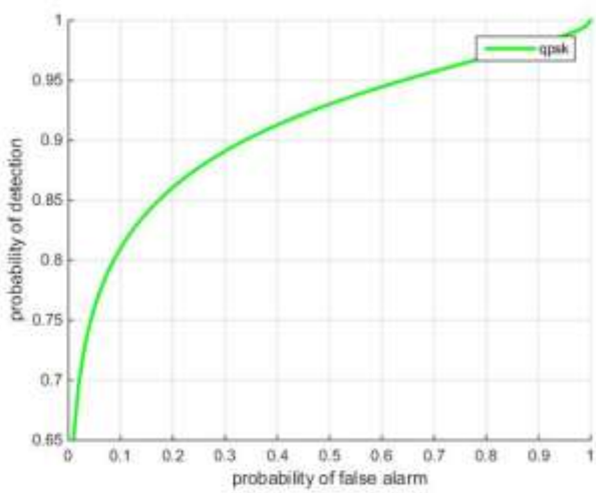

Figure 8: ROC Curve for QPSK signal

ROC curve of different modulation techniques are shown below when sampling rate N=200 and SNR of detector is -5db

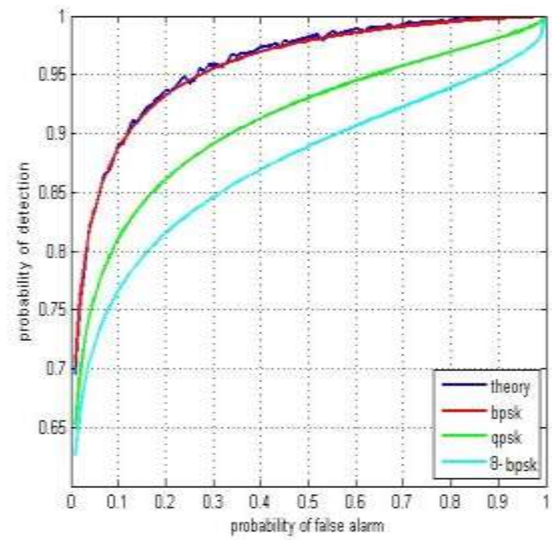

Figure 9: Comparision of ROC Curves

Statistic Cyclostationary Feature Detection is more flexible with better results and fast computation than that of conventional detection technique. The results can be improved by increasing sample size but computational time will be increased.

B. Simulation of channel estimation for the OFDM

Following figure shows the graph of Bit Error Rate (BER) v/s Signal to Noise Ratio (SNR) while applying no channel estimation and by applying Least Square (LS) method and Minimum Mean Square Error. It is clearly illustrated from the result that Ls method will produce better signal to noise ratio when the parameters are assumed to be BW=8.75MHz, FFT size = 1024, Ts = 1e-7 whereas CP is fixed at 1/8.

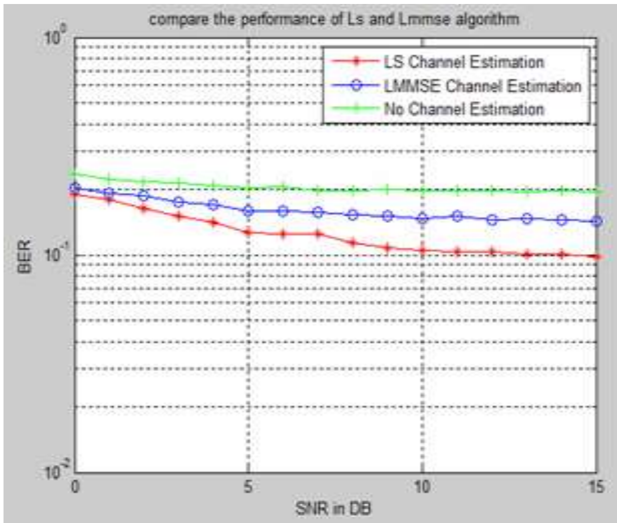

Figure 10: Performance of different Channel Estimation

C. *Simulation of LMS iterative algorithm*

For initial LS channel estimation pilots are inserted among the data. Channel is modeled by multipath Rayleigh fading channel. Channel bandwidth is set to be 1.75 MHz. FFT size of 1024 and CP length of 256 was used In which QPSK or BPSK modulation was chosen for pilots. Pilots are placed at the distance that satisfy the sampling theory . At the receiver end CP is removed. Pilots are extracted after FFT operation for LS estimation and linear interpolation.

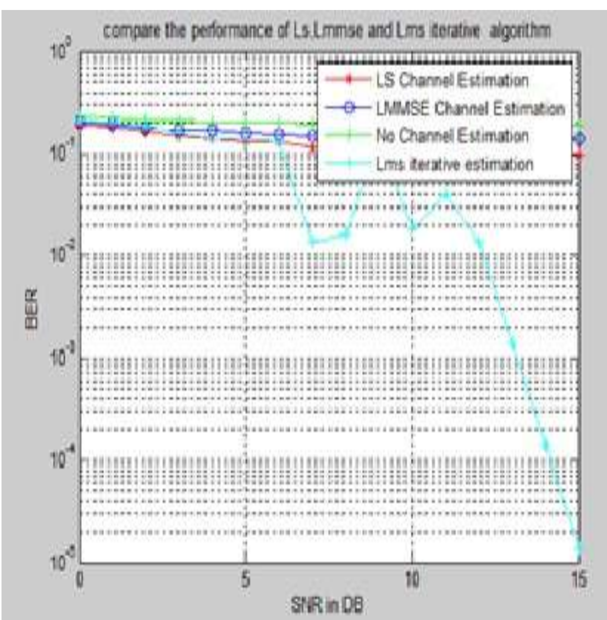

Figure 11: LMS Iterative

III. Conclusions

In this paper statistic cyclostationary detection algorithm is proposed after analyzing the other detection technique and also LMS iterative algorithm is added to the system to improve channel estimation performance. First approach is based on cyclostationary feature and theory of Hilbert Transformation and on comparision we found out that this approach is more flexible than the conventional energy detection techniques. Also this approach works great where power is unknown to secondary or cognitive user. In second approach a receiver was proposed whose structure is less complex than LS method and linear interpolation is done. Then accuracy of channel estimation is done by using LMS iterative algorithm. It improves BER performance of the system closed to the ideal channel performance.

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