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Spectrum Sensing and Error rate analysis by cognitive radio users using Welch's power spectral for high data rate applications

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***Abstract*—Cognitive radio is a technique which overcomes the spectrum underutilization. One of the key techniques of Cognitive radio is spectrum sensing. By using Energy detection technique, we evaluate the presence or absence of the signal in the received frequency band of a spectrum. Evaluated Bit Error Rate (BER) by using conventional periodogram and Welch's power spectrum density and compared the results. In this survey, we can able to prove that BER reduction using Welch's spectral density is more efficient than conventional periodogram techniques.**

Keywords— *cognitiveradio, spectrum sensing,Energy detection,conventional periodogram techniques,Welch's power spectral sensity*

INTRODUCTION

With the increasing demand for high quality of services (Qos) and data rates there occurs spectrum overcrowding due to the prevalent use of static spectrum allocation methods which does not allow unlicensed users to use licensed spectrum. There are two types of users- primary user and secondary user. Primary users are licensed user whereas secondary users are unlicensed user. Sometimes the spectrum is unused by the primary user, the spectrum becomes unutilized. With the consideration of increasing demand of spectrum by the users, by using cognitive radio we are able to maintain the demands in the nearby future. Cognitive radio allows the secondary users to use the spectrum which is unutilized by the primary users. Spectrum sensing is the core of cognitive radio which means detection of free spectrum. For detection purpose Energy detection technique is used. Initially conventionalperiodogram technique is used for the better transmission and reception of signal. In this survey we are defined to prove that Welch's power spectral density technique is more efficient than conventional periodogram technique.

A. Spectrum Sensing Techniques

Spectrum sensing is a method used in cognitive radio for the detection of free spectrum. It can also be defined as the task of collecting the information regarding spectrum resource utilization and presence of primary users [1,2] which can be used to accommodate secondary users on a non-interfering basis. For the frame to be transmitted from transmitter to the receiver first it should be sensed before transmitting.

B. Energy detection technique

This technique is one of the spectrum sensing technique which is used to detect whether the signal is present or absent. The block diagram for the energy detection technique is given below,

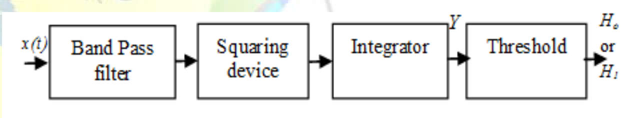

Fig.1 Block diagram of energy detection technique

The input signal x (t) is given to the band pass filter to limit the noise and to select the bandwidth of interest. The output of the band pass filter is given to the input of the squaring device. Then the squared output is integrated by passing through the integrator. The output of the integrator is checked based on the hypothesis.

H_0: y (n) = w (n)

H_1: y (n) = s (n) + w (n)

Where y(n),s(n) and w(n) denotes the received signal at the cognitive user, transmitted signal from licensed us er, additive white Gaussian noise with zero mean and σ2 variance respectively,

$$T = \sum_{n=1}^{N} [Y(n)]$$

Where T i.e. the energy of the received signal energy is used as a decision statistic for comparison.

Detection occurs when secondary user detects the licensed primary user correctly when it is present, whereas false detection detects interference pulse as primary user when primary user is not present. There is a cap on the SNR called SNR wall below which the signal cannot be traced. For that purpose probability of detection is high as possible (Pd) and probability of false alarm is small as possible.

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If the output is greater than the threshold then it defines that the signal is present, if it is below threshold then it defines that the signal is not present[3].

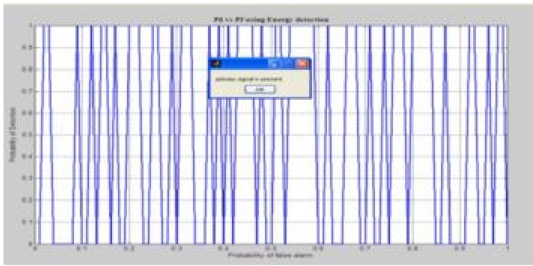

Fig.2 P_d vs. P_f using Energy detection (Simulated)

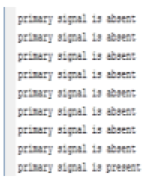

Fig.3 Primary user present or not (simulated result)

C. Analysis of BER based on conventional periodogram:

After Energy detection technique, conventional periodogram PSD simulated is treated as single signal. The signal is then transmitted by cognitive radio transmitter. Bit error rate (BER) estimation is carried out by different methods for transmitted signal by BCH error correction codes, convolution codes and standard error function method. The simulated result obtained as follows,

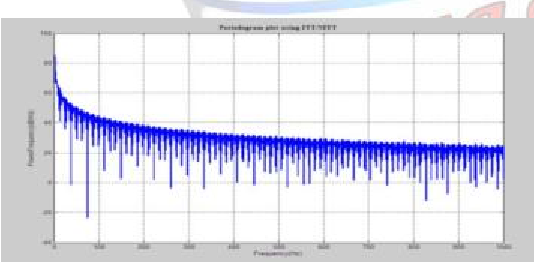

Fig.4 PSD using conventional Periodogram

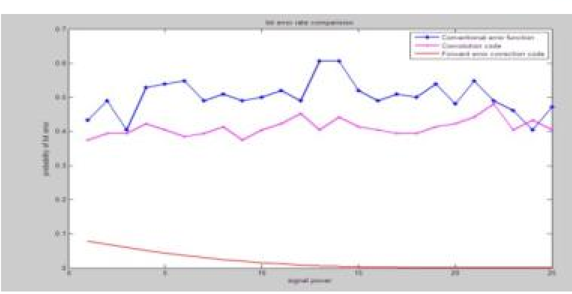

Fig.5 Biterror rate comparison using conventional periodogram

D. Analysis of BER based on CWPS with Hamming window:

The Welch's PSD obtained by splitting the signal into 2048 overlapping segments of length 3999 samples. The segmented samples are then windowed and applied in time domain.

The cross power spectral calculation in Welch's method considering hamming window:

$$x(n) = \begin{cases} x(n + iD), \; n = 0,1,2....,M-1 \\ \qquad\qquad l = 0,1,2.....,\; L-1 \end{cases}$$

When D = M, no overlapping of segments will be there and along with the Length of the data sequence L will be equal with Bartlett method's data segments. Below equation shows the Conventional PSD estimation by Periodogram data segments. These are further passed through the Welch's method and then compared.

$$P_{XX}(f) = \frac{1}{MU}\left|\sum_{x=0}^{M-1} x(n)w(n)e^{-j2\pi fn}\right|^2 \quad l = 0,1,....L-1$$

Where, U denotes the power of normalization factor and can be represented as:

$$U = \frac{1}{M}\sum_{n=0}^{M-1} w^2(n)$$

The Welch power spectral density is given by:

$$P_{XX}^{w} = \frac{1}{L}\sum_{i=0}^{L-1} \tilde{P}_{XX}^{i}(f)$$

This also represents the average of modified Periodogram.

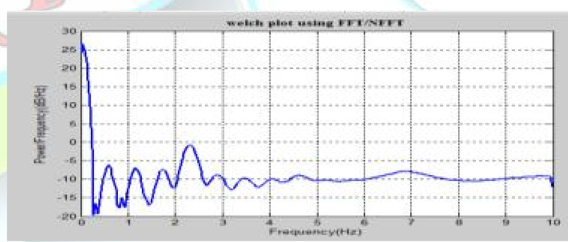

Fig.6 Welch's power spectral plot (Hamming Window)

Mean value of Welch estimate,

$$E[P_{XX}^{w}(f)] = \frac{1}{L}\sum_{i=0}^{L-1} E\,\tilde{P}_{XX}^{i}(f)$$

The modified hamming window is taken for proper convexing the resolution of the PSD as windows are triangular in nature. [4] proposed a secure hash message authentication code. A secure hash message authentication code to avoid certificate revocation list checking is proposed for vehicular ad hoc networks (VANETs). The group signature scheme is widely used in VANETs for secure communication, the existing systems based on

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E. Error calculation through FEC and Convolution Code:

BCH (FEC): Here the Forward Error Correction operation is done using BCH (Bose-Chaudhuri-Hocquenghem) code is used. BCH code is one of the most powerful linear cyclic block codes. The values from Covexed Welch's PSD are treated as single signal (channel from 100 MHz-1000 MHz). The signal is then transmitted by CR transmitter. In forward error correction, first the encoding of the signal is done and then at the receiver side it's decoded for calculation of the error [5].

According to modulation technique (here we are using QAM), Energy per bit to noise power spectral density ratio Eb/N0 for the encoded transmission is denoted as $E_b'/N_0=k/n$. Eb/N0 is denoted as P, which is close to zero. In other hand *PB* is probability of upper bounded uncorrectable error. Here n=7 and k=4 and n=2 $^{m-1}$, so m=3 and no of errors can be bounded as t<2 $^{m-1}$, *i=t+1* no. or more number of uncorrectable errors in the codeword.

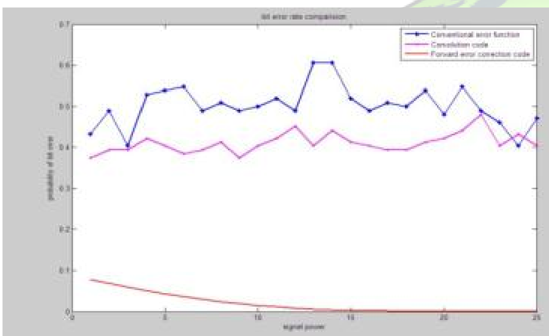

Fig.6 Bit error rate comparison using Welch Spectral

Error estimation using Convolution Codes:

In this case Covexed Welch's PSD data is used as transmitted signal and it is encoded by Convolution Code technique, where at the encoding part from the code generation matrix HDL code is generated from Matlab code and then convolution codes polynomials are converted into trellis description. The decoding of the signal is hard decision decoding, done using Viterbi algorithm and the error is calculated.

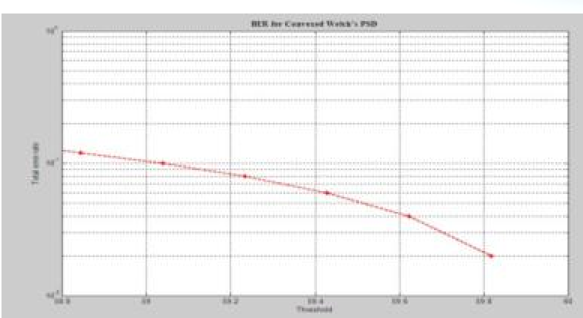

Fig.7 BER for Convexed Welch's PSD

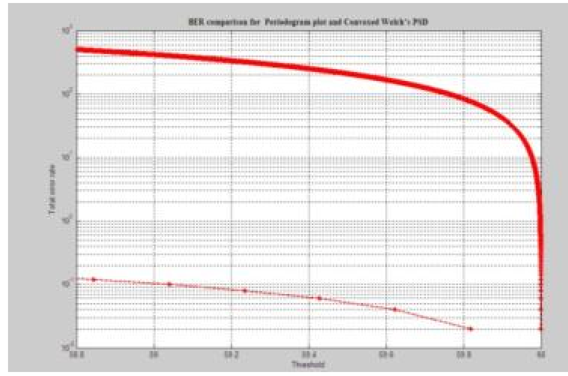

Fig.8 BER comparison for periodogram plot and Convexed Welch's PSD

CONCLUSION :

As per the simulation graphs, it is clearly shown that the forward error correction methods of BCH error correction codes when implemented through Welch's power spectral gives better results as compared to the conventional error correction and convolution codes. The mathematical derivation has been shown which justifies the significant improvement in error analysis. The allotment of CR user also depends on the error rate and particular SNR values. So, less error rate means more suitable for communication. Here, the BER is calculated by CWPS method and in other error correcting methods. The error corrections are done through BCH and Convolution Code. At last the error values are compared and it is observed that the error rate is coming less in Forward Error Correction through BCH code. So, it means that BCH code is the best between three methods for Cognitive Radio operation in less error channel.

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