Performance Evaluation of Energy Detection Technique Based on Haar Wavelet Transform for Spectrum Sensing in Cognitive Radio

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Abstract -With the unpredictable growth of wireless communication system, last few decades is the examples of the growing demand for wireless radio spectrum. However fixed spectrum assignment and inefficient usage of radio spectrum in which the major portion of the spectrum is under utilizes in nature. Cognitive Radio is one of the emerging techniques which are automatic adjustment of the electromagnetic environment to adapt their operation and dynamically vary its radio operating parameters. Today's scenario is based on the utilization of the frequency based on the cognitive radio system for energy detection technique using wavelet transform. This paper is deals with the design and simulation of the haar wavelet transform based spectrum sensing using energy detection for cognitive radio. This paper also proposes the performance Analysis through different value of SNR in terms of the Availability of Free spectrum and signal to noise ratio. The signal power and noise power is compare with the threshold value which predict the presence and absence of the licensed user. The proposed method which is also analysis performance of the SNR and the Decision Accuracy using Haar wavelet transform .In this paper future enhancement can be done by improving the performance analysis using different wavelet family.

Keywords: Cognitive radio (CR), Energy detection (ED), Wavelet Transform (WT), Discrete Wavelet Transform (DWT), Haar wavelet transform.

1. INTRODUCTION

The Radio Spectrum is very important and valuable resource. The new day to day upgrading technology are developed which is required a huge demand of the radio spectrum increases in the wireless communication .The main Problem is Spectrum Scarcity which trends to increases growth of radio spectrum. The National Regulatory bodies of Federal Communication Commission which assign a radio frequency to a licensed user or primary user (PU) and not to or unlicensed or secondary user (SU). In recent year the new innovative and flexible technology has been proposed by FCC through the use of the cognitive radio technology [1],[2] .Cognitive Radio is the promising and intelligent technology to address the insufficient utilization of the spectrum .Cognitive radio is an intelligent technology which is capability to aware the surrounding environment , update and adapt the its operating parameter ,which enables Secondary User (or cognitive radio) to opportunistically occupy the spectrum whenever the Licensed user /Primary user are absent and vacate them instantly [3] when PU are returns to the spectrum. Spectrum sensing techniques play a vital role in cognitive radio system because it can decide that which spectrum band is available or having vacant spectrum, for the utilization of secondary user. The utilization of frequency band is shown below.

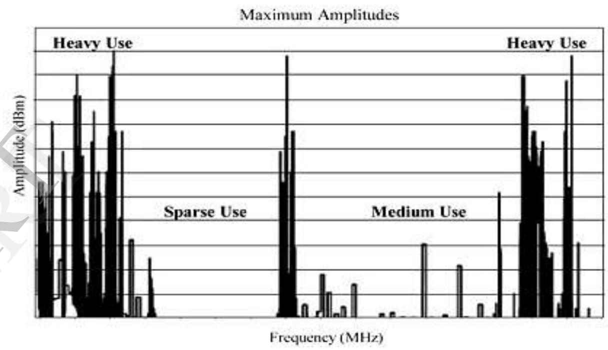

Fig.1 Occupancy of the channels

Different detection schemes have been proposed for this Energy detection is one of them In these paper are analysis Performance of the wavelet transform based energy detector spectrum sensing and its comparison for different types of wavelet family through simulation .However there is lots of experiment are performed on the present under the performance of the probability of detection under the additive white noise channel and SNR. So its motivation of the paper is attempt to establish the spectrum sensing and detection using wavelet transform and comparing it using different wavelet family This paper organised as follows: Section II & III explain is about energy detection mechanism system model. Section IV & V the energy detection algorithm based discrete wavelet packet transform are presented. It explains how to realize efficient energy detection under noise unknown. In section VI, Power measurement using the DWPT has shown. The simulation environments and results are provided in section VII. Section VIII discusses the results of the simulations and, finally the conclusions are given in Section IX .

2. SYSTEM MODEL

The energy detection technique is a non coherent type of detection technique which is used to detect the licensed user signal. It is simple method which is not required the prior knowledge of the pilot data or synchronization tone .One of popular and easiest sensing technique of non cooperative sensing in cognitive radio networks [4].In order to measure energy of the input signal w e pass This technique consist of the Band pass filter which has capability to remove those signal which is out of the band and consider those signal which has the central frequency of fc with bandwidth of W. Energy detector consist of the received signal x(t) nyquist sampling A/D converter , square –law device which gives the energy contents in N no of the samples of x(k) which is like a test of statistic and decision is taken on the basis of u and comparing with the reference value threshold, λ. to decide where the spectrum is free (H0) or busy (H1) as shown in the figure [2].

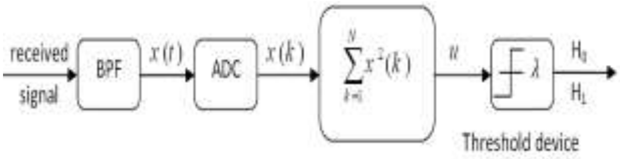

Fig. 2 Block Diagram of the Energy Detector

Thus the output is of two statistic of hypothesis which having two cases[6] .

a) When H1 is true which shows the presence of primary user i.e. P (H1/H1) is known as Probability of detection (Pd).

b) When H0 is true which shows the presence of primary user i.e P H0/H1) is known as probability of missed detection (Pm).

c) When H1 is ture which shows the absence of primary user i.e P (H1/H0) is known as probability of false alarm (pf).

H0 : y[n] = w[n] n = 1, 2, . . .,N

H1 : y[n] = x[n] + w[n] n = 1, 2, . . .,N (1)

A simple hypothesis is used to find out whether a channel is idle or busy where the H0 is the null hypothesis means the channel is idle in nature and no primary user is present , H1 is the indicate the licensed user are present. y[n] is the sample of the signal where w[n] is the sample of the noise is the Number of the samples during the observation interval[5]

$$Y' = \frac{1}{N_0}\int_0^T y^2(t)dt$$

Taking Y as decision statistic or test of statistic.

3.Energy Detection Algorithm

The model for energy detection based on wavelet packet transform is described in Fig.5

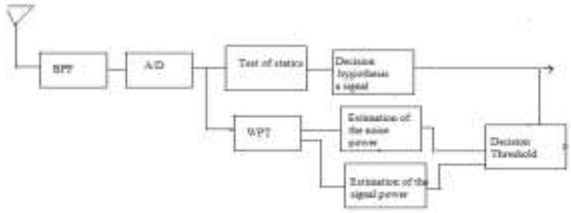

Fig.3 Block diagram of Energy Detection Model based on DWPT

The Proposed model of energy detector based wavelet transform in which is used at receiver end to find the presence and absence of the signal [8].As the signal is received through the wireless network it is pass through the Bandpass filter (BPF) fc central frequency & removes the frequency out of the band .After this the signal is passes through the analog to digital converter Which gives the digital signal y(n) which is gives

y(n) = s(n)+w(n) n= 0,1…..N-1.

Where, s(n) is the Primary User (PU) signal with zero mean and variance of & w(n) is Additive White Gaussian Noise (AWGN) with zero mean and variance .If there is primary signal is absence ths s(n) = 0 . Then hypothesis can be tested as

H0: y(n)=w(n,) n=0,1,……..N-1

If the primary user is present, s(n) ≠ 0.Then hypothsis can be tested as

H1: y(n)=s(n)+w(n,) n=0,1,…..N-1

Digital signal y(n) will be processed separately by few step which described as follows.

Step1 – A random signal is generated

Step2 – Additive White Gaussian noise is added.

Step3 –The signal is added with AWGN and the new signal is obtained whose WPT is found out.

Step 4: y(n) is sent to WPT to estimate current noise power (σ_w^{*2}) and signal power (σ_s^{*2}).

Step 5: By calculating the energy of y(n) we get the test statistic (y)

$$Y = \sum_{n=0}^{N-1} |y(n)|^2$$

Step6 – The level of threshold is decided and variance is calculated.
Step5 - Probability of detection is calculated at various SNR using WPT

The test statistic Y is a random variable whose probability density function (PDF) is chi-square distributed. When N is sufficiently large, we can approximate the PDF using Gaussian distribution according to the central limitation theorem .Referred to constant false alarm rate (CFAR) principle [9], we have probability of false alarm PF as follows,

H1 has a non central chi- square distributed with n degrees of the freedom it means zero means and variance

$$f_Y(y) = \frac{1}{2}\left(\frac{y}{2\gamma}\right)^{\frac{u-1}{2}} e^{-\frac{2\gamma+y}{2}} I_{u-1}\left(\sqrt{2\gamma y}\right) \qquad H_1$$

H0 has a central chi-square distribution with n degrees of freedom has probability density function

$$f_Y(y) = \frac{1}{2^u \Gamma(u)} y^{u-1} e^{-\frac{y}{2}} \qquad H_0$$

Where $\Gamma(.)$ is the gamma function so the probability detection and false alarm detection

$$P_d = \Pr(Y > \lambda \mid H_1)$$

$$P_f = \Pr(Y > \lambda \mid H_0)$$

Where λ is the final threshold to decide that whether the primary user is present or absence.

$$P_f = \frac{\Gamma\left(u, \frac{\lambda}{2}\right)}{\Gamma(u)} \qquad P_f = \frac{\Gamma\left(u, \frac{\lambda}{2}\right)}{\Gamma(u)}$$

Hence, Hence,

$$P_d = Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right) \qquad P_d = Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right)$$

$$\gamma = \frac{\sigma_x^2}{2\sigma_n^2} = \frac{\sigma_x^2}{2} \qquad \gamma = \frac{\sigma_x^2}{2\sigma_n^2} = \frac{\sigma_x^2}{2}$$

Where $\gamma = \frac{\sigma_x^2}{2\sigma_n^2} = \frac{\sigma_x^2}{2}$ denotes the signal to noise ratio (SNR) where Q_u is the generalized function.

4 . WAVELET TRANSFORM

A wavelet is a small oscillatory wave with finite bandwidth and energy is concentrated in both time and frequency. Wavelet is more powerful and efficient tool for analysis the signal. Wavelet transform will be able to describe the local regularity of the signals by using the two property of scaling and translation.

Discrete Wavelet Packet Transform

The Discrete wavelet Transform (DWT) is used to designed and analyzes the signal at different frequency band, with different resolution that decomposes the given signal space into approximation Vj ,and details information W j.

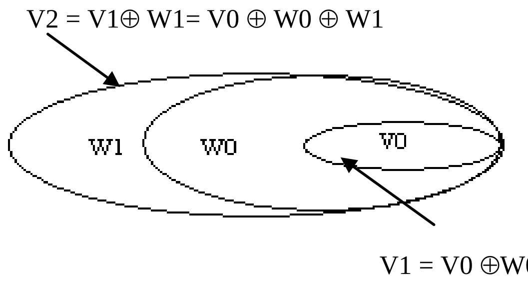

Fig.4 Wavelet coefficient of the wavelet transform

Where j=0,1,2,….n Vj and Wj are orthogonal to each other, also represents the orthogonality sum of the sub space Here approximation and details means scaling function which is denoted by φj,k, and wavelet function which is denoted by ψj,k respectively in which j is the width of the signal and k is the position of the signal. The discrete wavelet transform is computed separately for different segments of the time-domain signal at different frequencies. DWT is for the multi-resolution that can decomposes the given signal into its self consist of high pass filter and low pass filter These successive low pass and high pass filtering is occur of the discrete time signal filtering of the discrete time signal. If a signal is consist of the discrete time signal is x[n] where n is the integer .The high pass filter is denoted by H 0 and low pass filter is denoted by G0.Here each level signal has to has through high pass and low pass filter in which high pass filter is produce detail information ,d[n] while the low pass filter will produce approximations a[n].At every level of decomposition the half of the signal frequency is divided by pass signal through the half band filter as the frequency resolution is double ,the frequency become half. Here A is approximation(high frequency terms) and D is Details (low frequency terms.

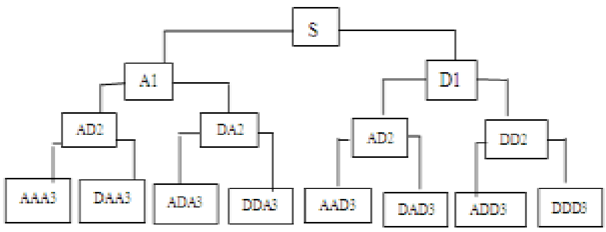

Fig.5 Block diagram of the Multi-decomposition tree

Relationship between scaling and wavelet function spaces Multi-resolution analysis: analyzes the signal at different frequencies giving different resolutions .The MRA is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies .Multiresolution analysis [7] consist of a approximation

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space Vj € Vj+1 and Vj= Vj⊕ Wj where Vj and Wj is orthogonal to each other .In Vj includes the orthonormal Scaling function of the $\phi_{j,k}(x)$ where j,k determine the width and the position of the signal f(x) i.e $\phi_{j,k}(x)$ € r(x)and Wj includes the orthonormal wavelet function of the $\psi_{j,k}(x)$

$$\psi_{j,k}(x) = 2^{j/2}\,\psi_k(2^j \cdot x - k)$$

$$\Psi j,k(x) = \sum_n gn - 2k\phi j + 1, n(x) \qquad (1)$$

$$\Psi j,k(x) = gn - 2k = \langle \Psi j,k, \phi j + 1, n \rangle \qquad (2)$$

and $$\sum_n \left| gn - 2k \right|^2 = 1 \qquad (3)$$

Similarly

$$\phi_{j,k}(x) = 2^{j/2}\phi_k(2^j \cdot x - k) \qquad (4)$$

$$\phi_{j,k}(x) = \sum_n h_\phi(n) 2^{(j+1)/2}\phi(2^{j+1}x - n)$$

So,

$$\langle \phi_{j,k}(x), \quad \psi_{j,l}(x) \rangle = 0 \qquad (5)$$

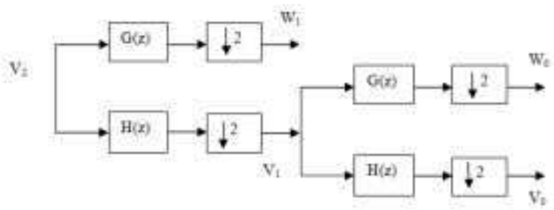

Fig6 Block Diagram of wavelet Decomposition

$$P = \frac{1}{T}\int_0^T r^2[x]\,dt$$

r(x) represented can be represented as where are scaling and wavelet coefficient respectively . Therefore, we can easily compute the power of the signal using orthonormal wavelet and scaling function properties An wavelet is hierarchically decomposes the function using wavelet coefficient algorithm is

$$dj,k = \langle f, \Psi j.k \rangle - \sum_n \overline{gn - 2k}\langle f, \phi j + 1, n \rangle \qquad (1)$$

$$dj,k = \sum \overline{gn - 2kcj + 1, n}$$

$$Cj,k = \langle f, \Psi j.k \rangle - \sum_n \overline{gn - 2k}\langle f, \phi j + 1, n \rangle \qquad (2)$$

$$Cj,k = \sum \overline{hn - 2kcj + 1, n}$$

$$C_{j_0}(k) = \langle r(x), \phi_{j_0,k}(x) \rangle = \int r(x)\phi_{j_0,k}(x)dx$$

$$d_j(k) = \langle r(x), \psi_{j,k}(x) \rangle = \int r(x)\psi_{j,k}(x)dx$$

$$= 1/T[\int_0^T \{\sum_k C_{j0}(k)\phi_{j_0,k}(x) + \sum_{j \ge j_0}^{\infty}\sum_k d_j(k)\cdot\psi_{j,k}(x)\}dt]$$

$$r(x) = 1/T[\sum_k C_{j0}^2(k) + \sum_{j \ge j_0}^{\infty}\sum_k d_j^2(k)]$$

It means that power of each sub band calculated using scaling and wavelet coefficients.

5. POWER MEASUREMENTS USING WAVELETS

The power measurement in wavelet transform is consist of the Vrms , Irms and power. The following are the definition are used for the measurement of the voltage, current and power.[7]

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v_t^2\,dt}$$

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i_t^2\,dt},$$

$$P = \frac{1}{T}\int_0^T i_t v_t\,dt$$

$$P = \frac{1}{T}\sum_k C_{j0}(k)\phi_{j_0,k}(x) + \frac{1}{T}\sum_{j \ge j_0}^{\infty}\sum_k d_j(k)\cdot\psi_{j,k}(x)$$

$$P = pj0\sum_{j \ge j_0}^{\infty} pj$$

Where vt and it are the current and voltage signals in the given interval of T where P is the low frequency sub band j0 and pj are the set of powers of each frequency sub band where j is higher than jo.

6. DISCRETE WAVELET TRANSFORMS USING HAAR WAVELET

The Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally in differences and final sum. Haar wavelet is sequence of rescaled of rescaled "square –shaped " function which together form a wavelet family or basis .The family of N haar functions are defined on the interval $0 \le t \le 1$.The shape of the haar It has property of analysing the signal with sudden transitions .

Significance of the Haar Wavelet transforms

Two sample value s0 and s1 measure the value (amplitude, height) of the function [10] f at s0 and at s1. In contract, the result from the basic function has the following significance.

1) The number (s0 +s1)/2 measures the average of the function f

2) The number (s0-s1)/2 measure the changes in the function f.

$$f = \frac{s0+s1}{2}.\phi[0,1[+\frac{s0-s1}{2}.\psi[0,1[$$

The basic transform pressures all the information in the sample, since while the transform describe the sample differently from the sample value, it also reproduce the sample exactly. The family of N Haar functions $h_k(t)$ are defined on the interval $0 \le t \le 1$ **Error! Reference source not found.**. The shape of the Haar function, of an index k, is determined by two parameters: p and q,

where $k = 2^p + q - 1$ and k is in a range of $k = 0, 1, 2, \cdots, N - 1$.

When $k = 0$, the Haar function is defined as a constant $h_0(t) = 1/\sqrt{N}$; when $k > 0$, the Haar function is defined as

$$h_k(t) = \frac{1}{\sqrt{N}} \begin{cases} 2^{p/2} & (q-1)/2^p \le t < (q-0.5)/2^p \\ -2^{p/2} & (q-0.5)/2^p \le t < q/2^p \\ 0 & \text{otherwise} \end{cases}$$

From the above equation, one can see that p determines the amplitude and width of the non-zero part of the function, while q determines the position of the non-zero part of the Haar function

S.NO	SNR	Haar Wavelet Transform
1	-40	4.7
2	-36	4.67
3	-32	4.72
4	-28	4.76
5	-26	4.708
6	-22	4.797
7	-18	4.828
8	-14	4.8
9	-10	4.445
10	-8	4.33
11	-4	4.08
12	-0	3.5

Tables for SNR verse Haar wavelet transform

7. SIMULATION AND DISCUSSION

All simulation was done on the Matlab version R2011a under AWGN channel. In this section we give the simulation of discrete wavelet transform in which chooses BPSK modulation as PU signal in the presence of the AWGN channel and SNR is Changes from -40 dB to 0 dB. Here The sampling frequency is 20 MHz signal , No of the sample is 256 . The Probability false alarm rate is 0.001and bandwidth of the each channel 1 MHz. The Primary user is 20.

We use to analysis receiver signal Characteristics for the identification the presence of the user based on the energy detector using Haar wavelet packet transform .The simulation is used for analysis the probability of the detection verses SNR .

The below Figure represent the available number of the users verses its magnitude in which vacant space shows the underutilized frequency and occupied as shown the presence of the primary user .

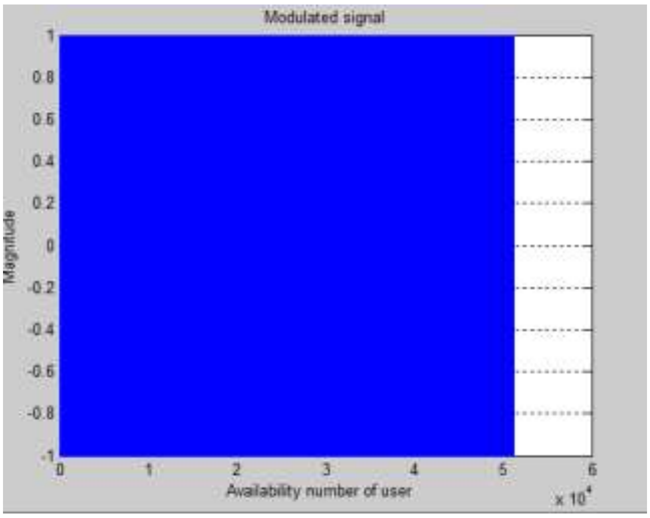

Fig.1 Shows the Presence of the Primary User

The fig 2 shows the FFT scenario of the transmitted signal which is modulated after transmission. Here second pulse is repeated pulse of the first pulse.

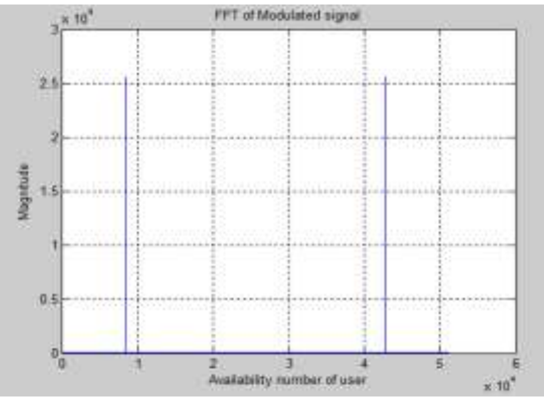

Fig.2 Shows the FFT for Transmitted signal

Further we spread the above signal as shown in figure 3 in which the high peak represents the utilization of the frequency band with respect to magnitude. Here second pulse is replica of the first pulse.

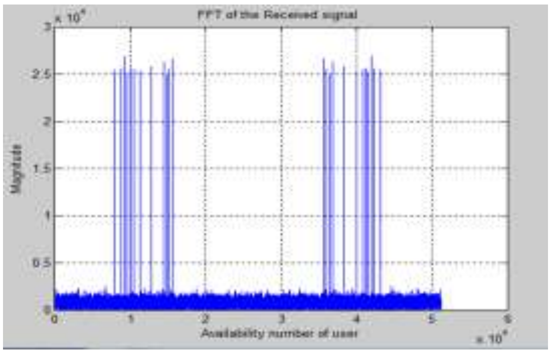

Fig 4. FFT magnitude of the Transmitted signal

The signal consist of the various central frequency and SNR are consider in this paper .The Central Frequency of the 20 primary user signals are having frequency of the 20 MHz to 39 MHz and SNR is between -40 , 36, 32, 28, 24, 20, 16, 12, 8, 4, 0 dB . Fig shows the FFT of the received signal.

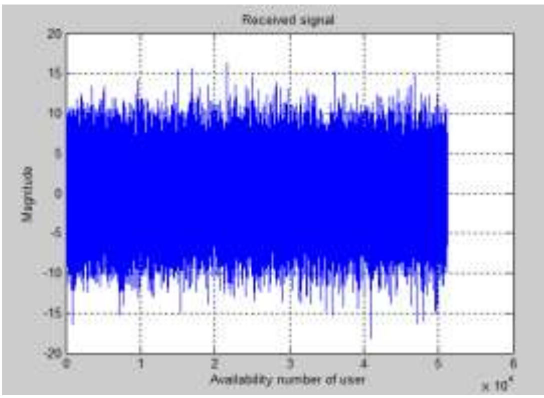

Fig .5 Shows the FFT for Received signal

From the fig.5 as the value of SNR decreases the number of primary user's availability increases. So consider the high SNR value for allocating Frequency band to the unlicensed users. The graph represents power distribution which is express by power spectral density verses frequency distribution.

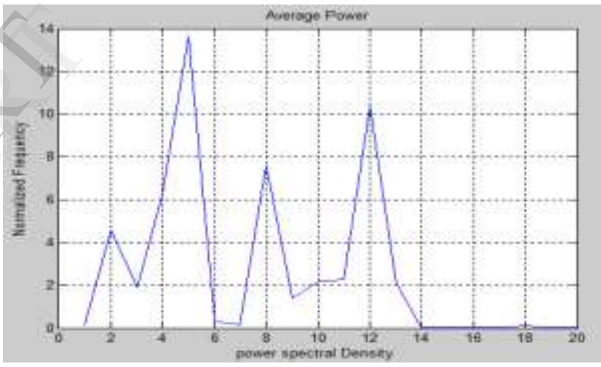

Fig.6 shows the Power spectral density vs. Normalized frequency

This is the final simulation result which shows that with increasing of the SNR the detection accuracy also increases. It shows the performance analysis of the signal detection based on the haar wavelet transform .

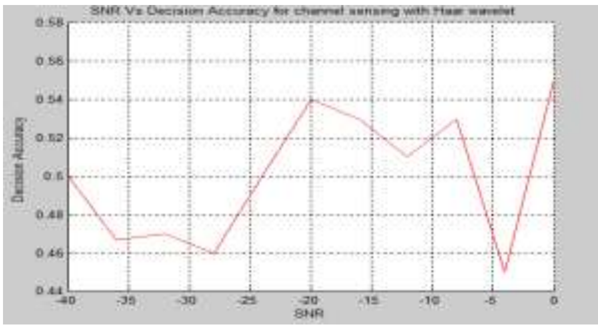

Fig.6 Performance of proposed DWT of Haar wavelet through different probabilities of Detection.

8. CONCLUSION

In this paper, we have discussed discrete wavelet transform based on energy detection method in Cognitive radio. This paper also proposes the performance Analysis through different value of SNR in terms of the Availability of Free spectrum and signal to noise ratio. It shows the occupied frequency by measuring the PSD for various SNR and calculated threshold value. The signal power and noise power is compare with the threshold value which predict the presence and absence of the licensed user. This simulation used to plots the probability of the accuracy vs. SNR. It has been observed that as the probability of the decision as increase the SNR is decrease which increase over all the performance of the system using haar wavelet transform.

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