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Performance Evaluation of the Energy Detection using Different Wavelet Family for Spectrum Sensing in Cognitive Radio

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Abstract: Cognitive radio is one of the novel concepts from conventional exclusive spectrum assignment to dynamic spectrum assign. They provide the spectrum for efficient and sufficient utilization of the radio electromagnetic resources. The cognitive Radio built on a software- defined radio, is defined as an unpredictable growth of wireless communication system, which is automatic adjustment of the electromagnetic environment to adapt their operation and dynamically vary its radio operating parameters while bring no harmful interference to the primary use .Researches are focuses on the cooperative spectrum sensing method to improve reliability of the spectrum but for cooperative spectrum sensing method is very difficult to tolerate with each individual node of the wireless network for the short time. So most renowned spectrums sensing techniques is energy detection. This paper proposes energy detection for spectrums sensing on the basis of estimated SNR, which is calculated in advance for available channels. The proposed method which is also analysis performance of the SNR and the Decision Accuracy using different wavelet family and comparative analysis of the Haar, Symlets ,Coiflets and Dabuchesis wavelet in terms of different value of the SNR , Probability of Detection ,Probability of the false alarm. In this paper future enhancement can be done by improving the by Setting the range of the errors between the threshold value and the detected value, energy to distinguish the result within the acceptable errors.

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

I. INTRODUCTION

Cognitive radio is a metamorphosis technology in wireless communication system which is cognizant with the surroundings learn and opportunistically identify the portion of the spectrum without causing the harmfulness hindrance to the primary user such as to make secure for efficient utilization of the radio spectrum highly reliable and maximizing the quality of the services. As the number of the user in the wireless network is increase, the huge demand of the radio spectrum increase in the wireless communication. The day to day updating technologies the new wireless devices and application will trends to increase the demand of the spectrum. In 2008, the Federal Communication Commission (FCC) which assign a radio frequency to a licensed user or primary user (PU) and not to or unlicensed or secondary user (SU) [1] ,[2] and is called spectrum hole /vacant space .

The method of the detecting the availability of the primary user in a radio spectrum environment is called the spectrum sensing .There several method of the spectrum sensing technique such as matched filter detection, energy detection , cyclostationary feature detection. Energy detection is the more robust technique with the low computationally complexity. In the energy detector is used to find the frequency spectrum is vacant or not. In these paper are analysis Performance of the wavelet transform based energy detector spectrum sensing and its comparison for different types of wavelet family. The rest of the paper is organized as follows: in Section II we introduce the related work In Section III we discuss energy detection based on discrete wavelet transform. In the IV section we presented the Proposed Algorithm section V Simulation Environment and Results VI Conclusion.

II.RELATED WORK

As concern to this research topic, during research session the references of many important involvements in “Performance Evaluation of the Energy detection based discrete wavelet transform using different Wavelet family for Spectrum Sensing in Cognitive radio” has taken to start the work on the project. In literature many improvement on the spectrum sensing was proposed. A classical paper [3] in which he measure the performance of the energy detector is analyzed using probability of the detection Pd verses SNR curves for different value of probability operation of an AWGN channel, respectively, In this paper shows that by increasing in SNR performance of the energy detector is get increase .If the time bandwidth factor increase, the detection probability decreases.

The false alarm also effect on the probability of the detection ie the probability of the detection increases with increase in the false alarm. So through this paper he gave the suitable result for the SNR for the energy detector. Another paper [4] the simulation is based on the probability of the detection vs. the probability of the false alarm. The probability of the detection varies based on the SNR, False alarm probability and various time bandwidth factors. When the SNR increases the detection probability also increases and SNR =25 db is better when the probability of the detection is 1. As the bandwidth factor is increase the probability of the detection is get increase time bandwidth factor. If the false alarm increases, the detection probability increases. So through this paper we get suitable value of the SNR for the energy detector. Sakharale,M.S, in paper[5] was proposed to measure the received signal power and estimated noise power. It is also consider the probability of the detection of the received signal with the respect SNR.

The simulation results had shown the performance of the two stage wavelet packet decomposition with db5 as wavelet filter and chooses BPSK as PU signal, where the experiment is performed under AWGN channel and SNR is changed from -10 to 0 dB . The energy detection algorithm which is based for evaluating the performance of the once we decompose our signal at higher level and also by increasing the SNR range of the signal we cannot determine better result .The evaluation of the WPED is quit robust method for the spectrum sensing when the noise is unknown . Omar A. M .Aly Abdel-Rahman Al-Qawasmi also proposed a paper [6]. In this paper is proposed for the precession sensing in a cognitive radio system is the energy detector based on Wavelet Packet Transform (WPT).

However, energy detector sensing is affected by signal to noise ratio (SNR) In this paper, a new immune algorithm for spectrum sensing is introduced. This algorithm combines two powerful tools: the wavelet packet analysis and Higher-Order -Statistics (HOS).The use of the proposed technique makes spectrum sensing possible in very low SNR condition. This allows better utilization of the unoccupied spectrum and high spectrum efficiency usage. The proposed algorithm is able to identify the unoccupied subchannel especially at very low SNR, The proposed algorithm has been tested for SNR down to -4 dB and proved to work successfully. A comparison between the proposed algorithm and various energy detectors has been done. The comparison indicates that there is around 4 dB gain in the detection using the proposed algorithm.

III.ENERGY DETECTION BASED ON DISCRETE WAVELET TRANSFORM

The model of the energy detector and the concept of DWPT are included in this section

A. Energy Detection Model

Energy detection is one of the robust technique, is also called radiometer detection which is popularly used as an effective method of the spectrum sensing performance. Basically the method is deals with identification correctly the available Primary user signal. It is one of the non cooperative type of the spectrum sensing technique which is more easier and low complex in nature [7]. The Energy detector is used to find out the received signal energy and then compared with the threshold value of the signal .In order to measure the energy of the signal, signal is first pass through the band pass filter the with central frequency of fc and bandwidth of the w, which allow to pass only those frequency which is within the band. Now the signal is passing through the Analog to digital converter which is possible only through the sampling theorem. In sampling theorem $fc \geq 2fm$ by this perspective the signal is get sampled. The overall submission of the sampled is occurring using summer operation .Then after test of the static is applied of the signal to check the availability of the primary user.

The three parameter of the spectrum sensing are as follows.

1. Probability of Detection (Pd)
2. Probability of False alarm (Pf)
3. Probability of Missed Detection (Pm)

1. **Probability of Detection (Pd):** Probability of Detection and Probability of Occurrence both shows the presence of the primary user signal ie (H1/H1).
2. **Probability of Missed Detection (Pm):** The Probability Missed Detection which shows the presence of the Primary user signal but Probability of the occurrence is absence ie (H0/H1).
3. **Probability of False Alarm (Pf):** The probability of False Alarm which shows the absence of primary user but Probability of the occurrence is Presence i.e P(H1/H0).

The generalized expression for the signal detection is given as

$$H0 : y[n] = w[n] \quad n = 1, 2, \ldots, N$$
$$H1 : y[n] = x[n] + w[n] \quad n = 1, 2, \ldots, N \quad (1)$$

The Signal Detection is based on the predicating the presence/absence of the primary user signal .Where H0 is the indication of the noise signal but H1 is indication of the signal and noise signal.

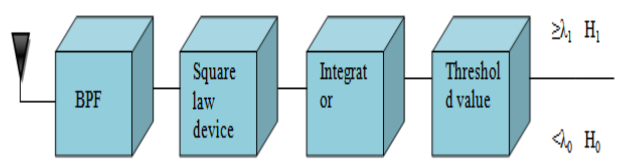

Fig1. Block Diagram of the Energy Detector

H0: The input y(t) is noise alone :

H0 : a) $y[n] = w[n] \quad n = 1, 2, \ldots, N$

b) $E[n(t)] = 0$

$$H1 : y[n] = x[n] + w[n] \quad n = 1, 2, \ldots, N \quad (2)$$

The received is consist of the restricted number of the sample (N) of band limited signal have to be observed during the sensing in the specific time interval .The energy level of the received sample having the noise power spectral density . The 3db noise power is done to get the normalized value of two sided noise power spectral density (N0/2).The test of the hypothesis is used to find out for the availability of the channel is idle or busy and also the availability of the secondary.

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]

$$Y' = \frac{1}{N_0}\int_0^T y^2(t)dt \qquad (3)$$

Taking Y as decision statistic or test of statistic under.

B. Wavelet Transform

It is one of the small oscillatory wave which contain the finite bandwidth and energy is preserved locally . Wavelet is more efficient tool for the analysis and synthesis the signals, in wavelet signal is analysis on the bases on the scaling and shifting property of the signal.

1. **Discrete Wavelet Packet Transform:** The Discrete wavelet Transform (DWT) [8] 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.It is construed on the bases of the scaling function and the wavelet function which are orthonormal scaling and wavelet function to each other.

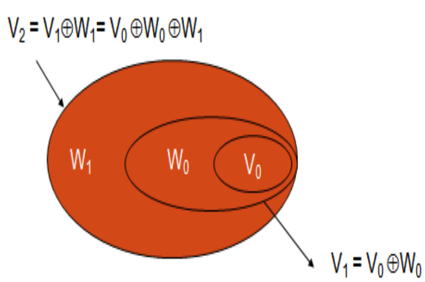

Fig2. Multi level resolution in DWPT

With the DWPT signal can be represented by the combination of scaling and the wavelet function.

$$f(x) = \sum_{j\geq j_0}^{\infty}\sum_k (c_{j,k}\phi_{j,k}(x) + d_{j.k}\cdot \psi_{j,k}(x)) \qquad (4)$$

Where $c_{j,k}$ and $d_{j.k}$ are the scaling and wavelet coefficient respectively, $\phi_{j,k}(x)$ and $\psi_{j,k}(x)$ are the scaling coefficient and wavelet coefficient where j is the width and k is the position of the signal. 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 $\psi_{j,k}(x)$

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

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

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

DWPT is for the multi-resolution that can decompose the signal at different level. The DWPT is computed by successive high pass filter and low pass filter. The discrete time domain signal is denoted by the x[n] in which n is integer of the signal. The low pass filter is denoted by G0 and high pass filter is denoted by H0. The decomposition of the signal into several stages is known as level .Each level produce the no of the approximated a[n]and details d[n] .Here the each level consist half of the frequency band .In which each band frequency resolution get doubled is reduced by half. According to the nyquists rate the central frequency fc≥ 2fm where fm is the message frequency. Thus while the half of each of stage removes the half frequency, which provides the half the resolution, the decimation is get down sampled at doubled.

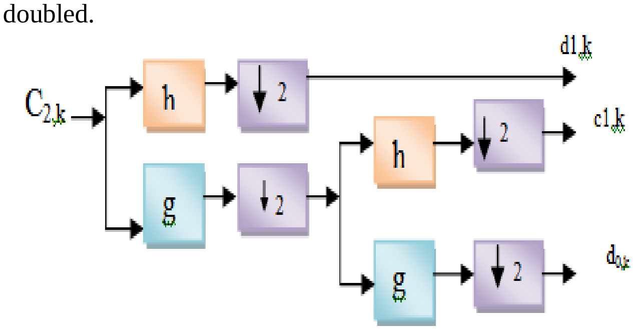

Fig3. The 2- Level analysis discrete wavelet packet transform decomposition.

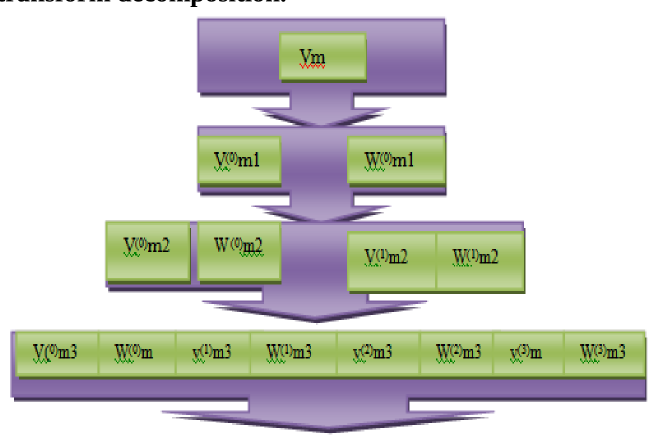

Fig4. Spliting of the Multi level resolution in the subspace DWPT [9].

Where

$$\Psi j,k(x) = \sum_n gn - 2k\phi j+1,n(x) \qquad (6)$$

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

and $\sum_{n} gn-2k^{\;2}=1$

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

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

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

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

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

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

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

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

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

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

It means the power of the each subband is calculated by

$$P=\frac{1}{T}\int_0^T\ \sum_k C_{j0}(k)\phi_{j_0,k}(x)+\frac{1}{T}\sum_{j\geq j_0}^{\infty}\sum_k d_j(k)\cdot\psi_{j,k}(x)\ (7)$$

IV. ENERGY DETECTION ALGORITHM

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

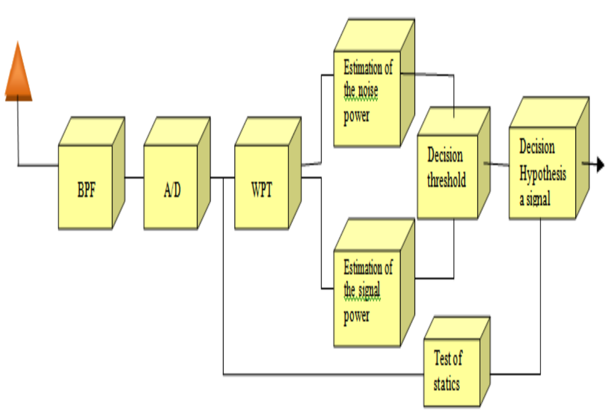

Fig.5 Block diagram of Energy Detection Model based on DWPT.

The classical method is based on the energy detection of the energy detector in which analog signal is passes through the band pass filter(BPF) with central frequency of 128MHz removes the frequency which is out of the band . This analog signal is which have central frequency fc and sideband of fc-fm , fc + fm where fm is message frequency of 64 MHz. This signal is pass through the analog to digital converter which gives the digital bit streams y[n] which is given as follows [10] .

y[n] = s[n]+ w[n] n= 0,1,2,........N-1 (8)

Where s(n) is primary user (PU) signal with Zero mean and variance of σ_s and w (n) is additive white gaussion noise (AWGN) with zero mean and variance σ_w. According to these method two hypotheses is can be tested in it.

H0:y(n) = w(n) n = 0,1,.................N-1 (9)

But if signal is represented by s(n) ≠ 0.Then it shows the presence of primary user

H0 :y(n) = s (n) + w(n) n= 0,1,……………N-1 (10)

So the digital bit stream 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.
Step4: y(n) is sent to WPT to estimate current noise power (σ_w^{*2}) and signal power $(\sigma^{*2}{}_s)$.

Step5: By calculating the energy of y(n) we get the test statistic (y)

$$Y=\sum_{n=0}^{N-1}|y(n)|^2 \qquad (11)$$

Step6: The level of threshold is decided and variance is calculated.

Step7: Probability of detection is calculated at various SNR Using different WPT families.

The test of statistic Y is a random variable whose PDF is measured on the basis of the Chi- Square distribution function, but when the value of the N is sufficiently larger then it is mandatory to focus on the Gaussian distribution function using central limit theorem. Basically in order to find out the Probability distribution function we have two methods they are

1. Chi- square distribution
2. Non Chi- square distribution

1. The Chi: Square distribution with H0 which shows the n degree of the freedom has probability density function.

$$f_y(y)=\frac{1}{2^u\Gamma(u)}y^{u-1}e^{-\frac{y}{2}} \qquad \text{H0} \qquad (12)$$

Where $\Gamma(.)$ is the gamma function

2. Non Chi: square distribution with H1 which shows the n degrees of freedom it means zero means and variance

$$f_y(y) = \frac{1}{2}\left(\frac{y}{2\gamma}\right)^{\frac{u-1}{2}} e^{-\frac{2\gamma+\gamma}{2}} I_{u-1}\left(\sqrt{2\gamma y}\right) \quad \text{H1} \quad (13)$$

We can predict out the probability of detection and the false alarm detection.

$$P_d = P_r \ (Y_> \lambda | H_1)$$

$$P_f = P_r \ (Y_> \lambda | H_0) \quad (14)$$

Where λ is the final threshold is decided whether the primary user is present or not. that

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

$$P_d = Q(\sqrt{2\lambda}, \sqrt{\lambda})$$

$$\gamma = \frac{\sigma_x^{\ 2}}{2\sigma_x} = \frac{\sigma_x^{\ 2}}{2} \quad (15)$$

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

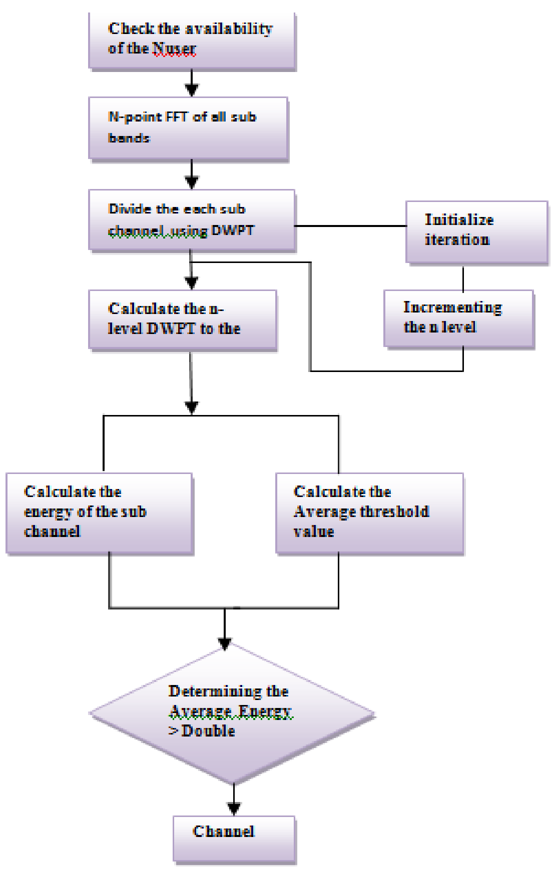

Fig.6. Proposed New Algorithm for the energy detector.

V. PROPOSED ENERGY DETECTION ALGORITHM

In order to distinguishable spectrum interest more accurately for the low computationally complexity. For which new algorithm is proposed. In the Proposed algorithm is shown in figure no 1 and described as follows. The proposed method is used to analysis the availability of the frequency spectrum in which we generate the input signal and checking the availability of the nuser with of the input signal to convert time domain signal to frequency domain signal , divide the signal with equal frequency distribution of the signal in MHz using DWPT.

VI. DISCRETE WAVELET TRANSFORMS USING DIFFERENT WAVELET FAMILY

1. Haar Wavelet: The Haar wavelet transform is a transform in which takes the input signal, storing the difference and passes the sum. This process is repeated successively by pairing the sums to get the next stage. At last resulting in difference and one final sum .Basically it is used to find out square shape function which together forms a wavelet family or basis .The family of N haar functions are defined within the interval 0 ≤ t ≤ 1. It has property of analyzing the signal with sudden transitions

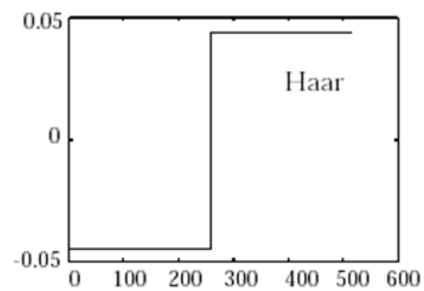

Fig.7 Haar wavelet transform

2. Symletswavelet: They are the modified version of daubechies wavelet increased in symmetry. It is also known as the least symmetry. It is defined by positive integer N. The scale function and wavelet function has the compact support length 2N. N is the vanishing moments.

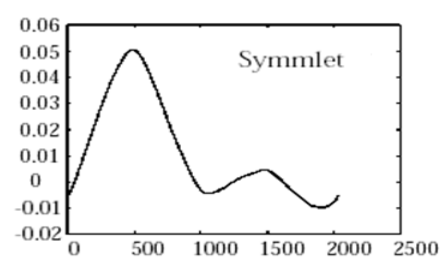

Fig.8. Symlets wavelet transform

3. Coiflet wavelet: It is used in discrete wavelet transform .To having scaling function with vanishing moment. The wavelet is the nearly of symmetric and their wavelet function is N/3 and vanishing moment and scaling function is N/3-1 .Scaling function is high pass filter and wavelet function is a low.

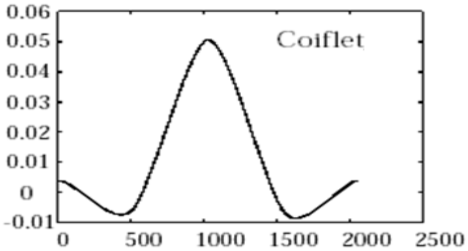

Fig.9. Coiflet wavelet Transform

4. Dabaubhsis wavelet

Dabaubhsis wavelet is used to generate progressively finer discrete samplings of mother wavelet function. So that each resolution will become twice to its pervious scale. It is a family of the orthogonal wavelet which characterized the signal with the maximal number no of the vanishing moments of a given support widen 2N and possible no of combination 2^N-1 possible solution the one is chosen for external phase .It is the one that solve broad range of the problem.

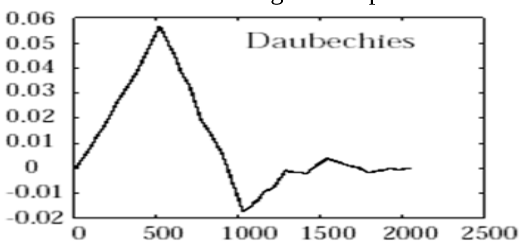

Fig.10. Dabaubhsis wavelet Transform.

VII. SIMULATION AND RESULT ANALYSIS

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 . The Probability false alarm rate is 0.001and bandwidth of the each channel 1 MHz. The Primary user is 20. With its own bit duration and time duration. Simulation Parameter

The simulation of the system has been performed for the following.

Table1: The Simulation Environment with Parameter and Value.

S. No	Parameter's Name	Value
1	Total no of the frequency band	20MHz to 40 MHz
2	Bandwidth of each channel	1 MHz
3	The of PU channel	20 user
4	SNR	-40:4:0
5	Signal processing point	256symbols
6	Frequency Resolution	64 bits
7	PFA of Threshold	0.001
8	Noise distribution	(1,0)

The Probability of detection is based on the signal to noise ratio with respect to the different wavelet transform and their comparison analysis.

Table2: For the Comparative Analysis using Different Wavelet Family.

S.no	SNR	Probability of Detection			
		Haar	Symlets	Coifelts	Daubuchies
1	-40	4.7	4.52	4	2.9
2	-36	4.67	3.562	4.453	2.79
3	-32	4.72	4.12	4.39	2.79
4	-28	4.76	4.6	4.32	2.87
5	-26	4.708	4.165	4.36	2.82
6	-22	4.797	4.64	4.235	2.882
7	-18	4.828	4.575	4.267	2.893
8	-14	4.8	4.37	4.225	2.945
9	-10	4.445	4.22	3.39	2.71
10	-8	4.33	4.18	4.03	2.63
11	-4	4.08	3.772	3.881	2.549
12	-0	3.5	3.7	2.6	1.95

The figure 11 shows the FFT scenario of the transmitted signal which is modulated before the transmission. Here second pulse is repeated pulse of the first pulse [10].

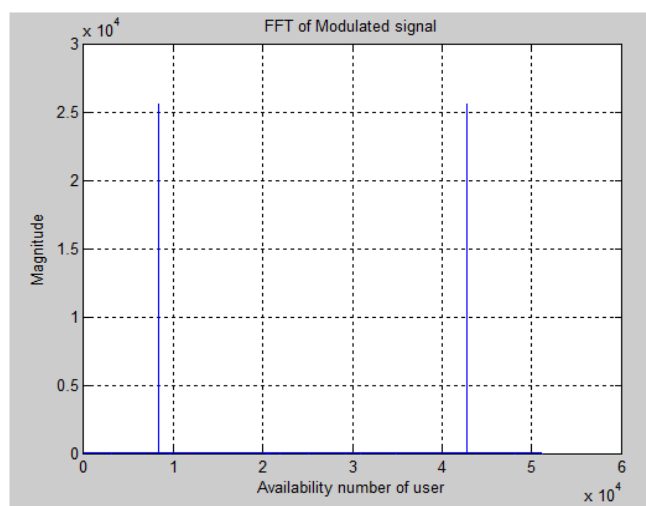

Fig11. Shows the FFT of the Modulated Signal

When we further spread the above signal it should represent as show in below figure. As shown in figure 8 shows that wherever is there high peak represents the utilization of the frequency or the user is occupied the frequency band and whenever the is vacant space the shows the absence of the primary user. Here second pulse is repeated pulse of the first pulse.

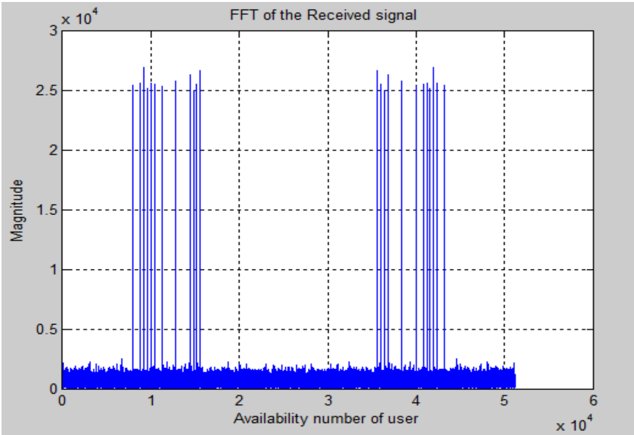

Fig12. Shows the FFT of the magnitude of the Transmitted signal.

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.

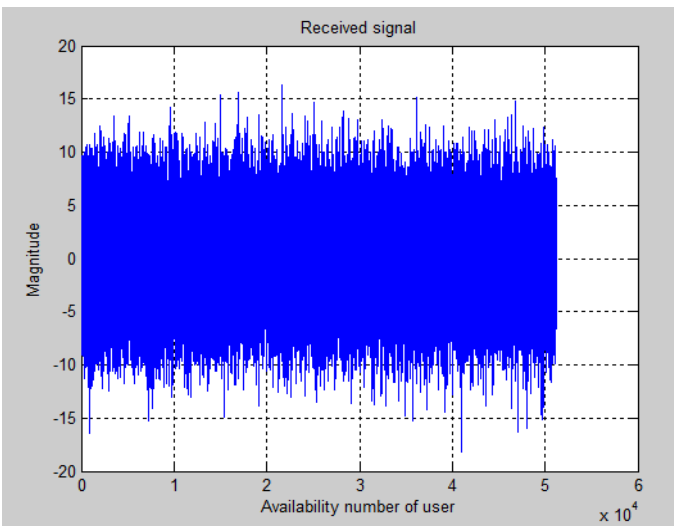

Fig13. Shows the FFT of the Received signal

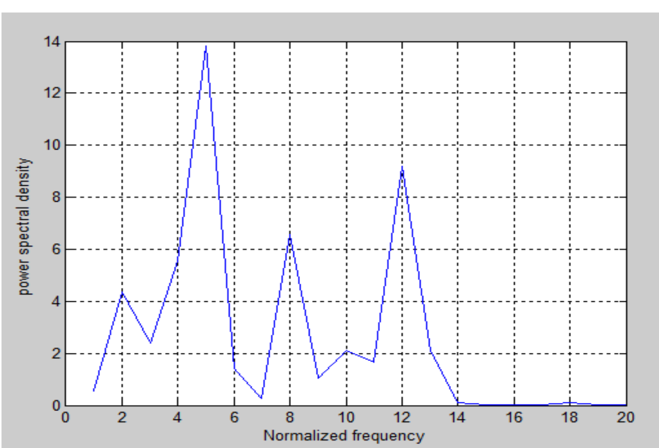

Fig14. The Power spectral density vs. Normalized frequency.

This is the final simulation 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.

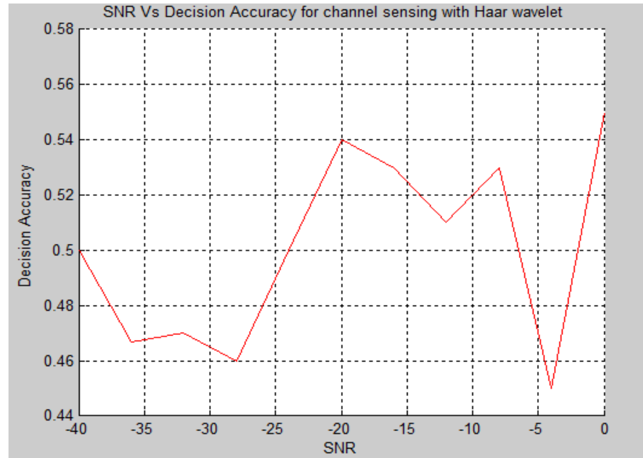

Fig15. Performance of proposed DWPT of Haar wavelet under different Detection Accuracy.

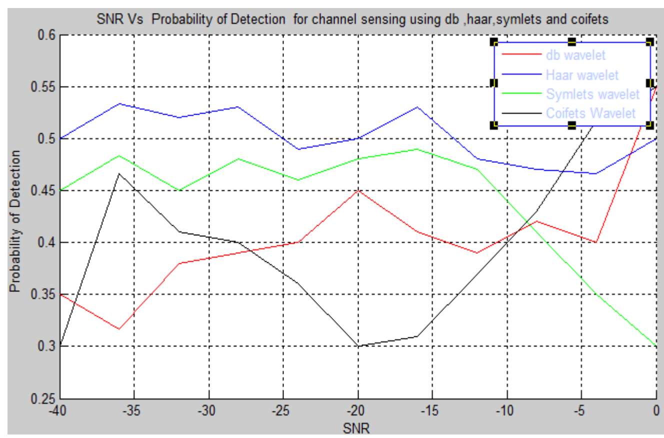

Fig16. Performance and Comparison of proposed DWPT of different wavelet under different Detection Accuracy.

VIII CONCLUSION

In this paper, we have proposed a discrete wavelet transform based on energy detection method in Cognitive radio. This paper also comparison through different value of SNR in terms of the Availability of Free spectrum and signal to noise ratio. It is an efficient perspective method to classify the spectrum which improves the performance of the energy detector by measuring the PSD for various SNR and calculated threshold value. Howerever threshold which can accurately detect the Probability of the Detection of the received signal using different types of wavelet family.

IX.ACKNOWLEDGEMENT

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