Spectrum Sensing in Cognitive Radio using TSA

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***Abstract* – A cognitive radio is a transceiver which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so more wireless communications may run concurrently in a given spectrum band at a place. The key requirement in cognitive radio is accurate detection of vacant spectrum bands. In this paper, an energy detector based on tree structure quadrature mirror filter bank (TQMFB) is proposed for detecting the centre frequencies of the channels(frequency bands).It is found that as the value of FFT size increases, the error in estimation decreases for smaller window sizes and does not change significantly for larger windows. Simulation results show that the proposed method estimates the centre frequency of channel with high accuracy and low SNR.**

***KEYWORDS* – Cognitive radio, Spectrum sensing, Energy detection.**

I.INTRODUCTION

Cognitive Radio is an intelligent wireless communication system that is cognizant of its environment, learns from it and adapts its transmission features according to statistical variations in the environment to maximize utilization of premium resources such as spectrum while ensuring good Quality of Service (QoS).A cognitive radio (CR) receiver is required to robustly detect the presence of a primary user signal [1]. CR is an intelligent radio, which uses the electromagnetic spectrum based on the usage of primary users (PUs). Ideal CR must be able to detect all these channels dynamically with only a little or even no priori knowledge of the channel locations. Robust detection of wideband signal with low complexity in low signal-to-noise ratio (SNR) is a challenging task due to the high input sampling rate and large bandwidth of the signal. This aspect of CR is known as spectrum sensing.

To sense the spectrum three popular techniques are used: Matched Filtering, Energy Detection and Cyclostationary Feature Detection [2]. Since CR has minimum knowledge about the signal received. Energy Detection is the most common method to detect the presence of a signal. In an ideal CR scenario, accurate estimation of center/edge frequencies is a key task. The estimation of the location of the primary user's signals helps in determining the spectrum vacancies. The proposed tree-structured quadrature mirror filter bank (TQMFB) based energy detector is given in this paper.The main functions of Cognitive Radios are: Spectrum Sensing: Detecting the unused spectrum and sharing it without harmful interference with other users. It is an important requirement of the Cognitive Radio network to sense spectrum holes. Detecting primary users is the most efficient way to detect spectrum holes.

Spectrum Management: Capturing the best available spectrum to meet user communication requirements. Cognitive radios should decide on the best spectrum band to meet the Quality of service requirements over all available spectrum bands, therefore spectrum management functions are required for Cognitive radios.

Spectrum Mobility: is defined as the process when a cognitive radio user exchanges its frequency of operation. Cognitive radio networks target to use the spectrum in a dynamic manner by allowing the radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during the transition to better spectrum.

Spectrum Sharing: providing the fair spectrum scheduling method. One of the major challenges in open spectrum usage is the spectrum sharing. It can be regarded to be similar to generic media access control MAC problems in existing systems.

This paper is organized as follows section II, two stage sensing architecture for CR is given. Section III is divided in to four sub-topics, Flowchart for TSA is explained in details in first sub topic, second explains windowing method, third sub-topic emphasize on window power calculation and center frequency detection is given in fourth sub-topic. Simulation results and result analysis using Matlab is presented in section IV. Finaly paper is concluded in section V.

II. SPECTRUM SENSING

Spectrum sensing is a technique to recognize unused or idle spectrum, which is a key function for cognitive radio (CR) and requires high precision and fast signal processing technique [8]. To satisfy these requirements, two-stage sensing architecture that combines an energy detector and a feature detector was proposed by IEEE 802.22 working group (WG)

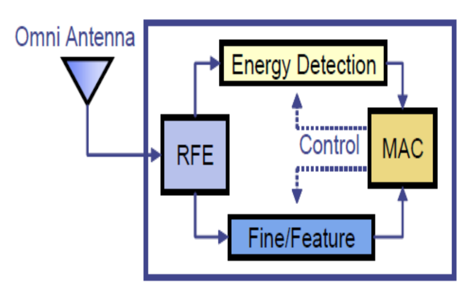


Fig.1Two stage sensing architecture

Energy Detection is the most common method to detect the presence of a signal [3]. This is because it is non-coherent and it requires no knowledge of the input signal.

This paper deals with a spectrum sensing technique for Cognitive Radio using the energy detection method along with a specific algorithm to determine the center frequencies of the channels present in the sub-band. Methods based on energy detection like period-gram method, multi-taper method (MTM) and filter bank method are available. For an energy detector, various techniques such as receive signal strength indicator (RSSI), multi resolution spectrum sensing (MRSS), fast Fourier transform (FFT) have been suggested and recently discrete wavelet packet transform (DWPT) based method was proposed. Disadvantage of DWPT is lesser the number of stages lesser the accuracy[4]. Tree Structure Algorithm been chosen for high accuracy.

III. IMPLEMENTATION OF TSA

The present paper assumes a priori knowledge of the number of primary user signals and their respective channel bandwidths. This assumption simplifies our objectives to determine the locations of all the channels present in the input signal and hence to find the exact location of the vacant spectrum bands. For this purpose, accurate estimation of center frequencies needs to be done because the primary user standards are of different bandwidths and locations. This can be achieved by estimating the approximate center frequencies of the channels present in the input spectrum. The proposed architecture consists of an *M*-channel TQMFB with an energy detection block at each stage of the tree, which consists of a windowed average power detector as shown in Fig2. Each stage of the tree structure decomposes the input spectrum into low and high frequency sub bands at quadrature frequency[5,6]. Each stage consists of a prototype low pass filter *H0* and its mirror image high pass filter *H1*. The number of stages required for the TQMFB can be determined by the number of channels present in the input signal. An *M* channel TQMFB splits the input spectrum into *M* sub bands.

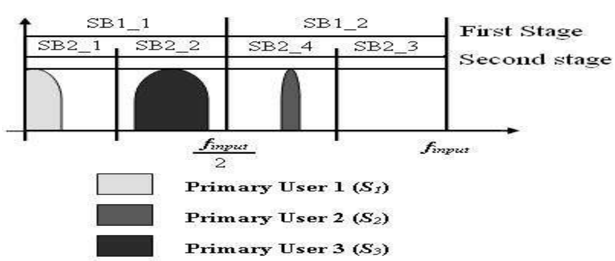


Fig2.Spectral scenario of a *4*-channel TQMFB

The input spectrum is split into two uniform bandwidth sub bands SB1_1 (0 to *finput/2*) and SB1_2 (*finput/2* to *finput*) at the first stage [7, 9]. Note that SB1_2 is the mirror image of the spectral region between *finput/2* to *finput* where, *finput* is the input frequency.In the next stage, the SB1_1 is divided into SB2_1 and SB2_2, while SB1_2 is split into SB2_3 and SB2_4, as shown in Fig3.

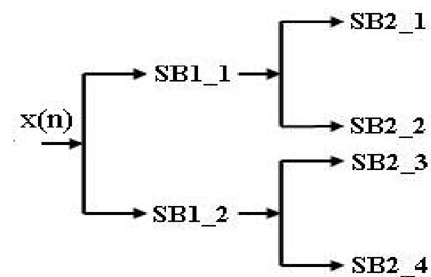


Fig3.Sub band splitting of a *4*-channel TQMFB

The advantage of using a tree structure is the reusability of TQMFB. The same TQMFB used for spectrum sensing can be used for channelization, to extract the channels once they are detected. The detailed algorithm is divided into two stages

III.1 FLOWCHART

A. Stage first

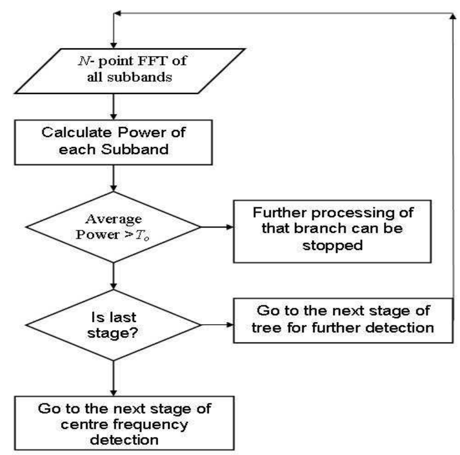


Fig4. First stage of the algorithm for center frequency detection

The first stage is the conventional energy detection, where the average power obtained from each sub band is compared with a threshold, *To,* to determine the presence of a primary signal. This method merely detects the presence of a signal in the sub band. The energy detection is done at each stage of the tree structure. At each stage, a decision is made about the presence of input signal in a sub band. If a sub band shows absence of any PU signal, then it is not processed further down the tree structure thereby reducing the computations involved in later stages. The power spectrum values are further divided into *w* windows of length *k* each.

B. Stage second

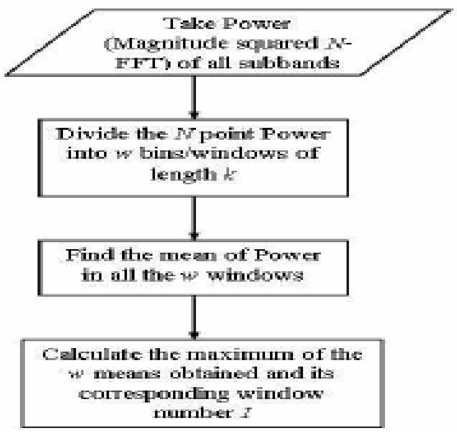


Fig5. Second stage of the algorithm for center frequency detection

In the second stage of detection, the average values of the power spectrum in each of the *w* windows are calculated. It gives window number no, which has the maximum average power. The window with maximum power has high probability to contain the center frequency.

III.2 WINDOWING METHOD

The power spectrum values are further divided into w windows of length k each. Assume that the wideband input signal has several channels of distinct bandwidths. Let the bandwidth of the channel which has the least bandwidth among all the channels are BW-Min. An appropriate value of k can be determined by the minimum bandwidth signal available in the PU as follows:

$$k = [(BW\ Min)/\ f\text{-}input] \times N \qquad (1)$$

Equation gives a fractional value of k, if BW-Min and f-input are not exact multiples of each other. In that case, the next integer value of k is taken. The idea behind such a formulation is that, the minimum bandwidth signal present in the input determines the working of the algorithm.

III.3 WINDOW POWER CALCULATION

If there is more than one channel in the sub-band, all the local maxima present in the sub-band can be found in order to determine the center frequencies of various channels in the specified sub-band. The average power of all the windows are taken and compared to determine the maximum, in order to determine center frequency. The mean power of the j^{th} window P (i) is given as

$$P(i)=\sum_{j=1}^{k}[P(I,n)]/k \qquad (2)$$

P (i, n) are the values of power spectrum of the sub-band,in the i^{th} window region of the spectrum. This average power of each window is basically the windowed average of the magnitude squared FFT of the input spectrum. These windows form the required bins for detecting the signal and finding its center frequency. The maximum of mean power obtained using (2) is calculated for each sub-band.

III.4 CENTRE FREQUENCY DETECTION

The position of the center frequency in any sub-band can be intuitively obtained as shown in (3).

$$fc= [I\times t\ ]/[W\times 2^{n}] \qquad (3)$$

Where I is the window/bin number in the specified sub-band which has the maximum mean power, w is the total number of windows (bins) in the sub-band and n is the number of stages of the TQMFB.

IV. RESULTS

Tree structure algorithm is simulated using Matlab. For channel sensing a signal is assumed as

x =sin(*pi*200*t)+sin(2*pi*1270*t)+sin(2*pi*3000*t);

Showing the primary user at 200 hz, 1270 hz and 3000 hz.

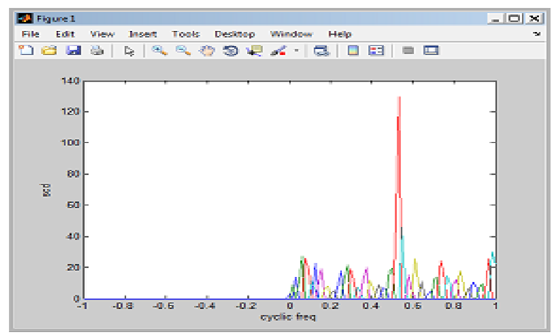


Fig6. Primary user location in the spectrum.

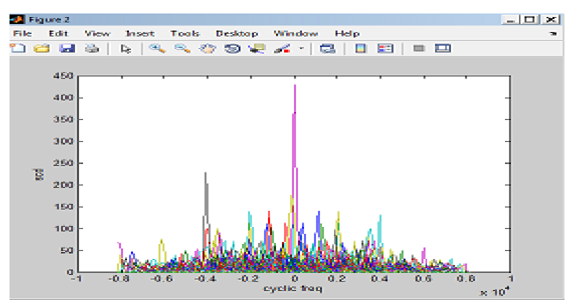
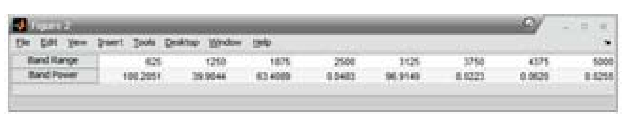


Fig7. Primary user location in the spectrum.

Result in fig.1 gives primary user location in the spectrum after running first stage of algorithm and Fig.2 gives primary user location in the spectrum after running second stage of algorithm. After the spectrum is divided into sub-bands, the algorithm calculates the power of each sub-band. The table below shows the band power of each sub-band and based on the power of each sub-band Primary users in the spectrum are detected. Following table gives power of each sub-band.



Band Range	625	1250	1875	2500	3125	3750	4375	5000
Band Power	100.2051	39.9044	63.4089	0.5483	96.9149	0.0223	0.0626	0.0258

Table1. Band power of each sub-band in spectrum

IV.1 ANALYSIS OF RESULTS

Power analysis of TSA algorithm:

Band range	Band 1 0-625	Band 2 626-1250	Band 3 1251-1875	Band 4 1876-2500	Band 5 2501-3125	Band 6 3126-3750	Band 7 3751-4375	Band 8 4376-5000
Band power	100.2051	3.9044	63.4089	0.0483	96.9149	8.0223	0.0620	0.0255

Table2. Analysis Table

Analysis table consisting of 2 rows namely BAND RANGE and BAND POWER. For assumed signal, band of interest is 0-5000Hz. Band range is divided into 8 equal sub-bands of the spectrum each part indicates area of 625Hz. BAND POWER shows power of each sub band. Primary users are present at 200 Hz, 1270 Hz and 3000 Hz. It means sub-band ranging from (0-625) Hz, (1251-1875) Hz and (2501-3125) Hz should have their energy/band power above Threshold energy (50.10255). Same is been shown in BAND POWER row for each sub-band. For other bands power is very low. Which means except 1st,3rd and 5th Sub-band all other are vacant but band 2 corresponding to range (626-1250)Hz has little higher power as it is influenced by primary users in adjacent band noise level is high in this band.

V. CONCLUSOION

A tree-structured quadrature mirror filter bank (TQMFB) with windowed average magnitude squared FFT is proposed for spectrum sensing in cognitive radios. The proposed technique simplifies the issues associated with the detection of center frequency. The proposed architecture has the advantage that further processing of signal can be stopped, if a sub band at a stage does not show energy above the threshold. This, in turn reduces the computational complexity and hence the dynamic power consumption of the system. Simulation results show the performance of the proposed system using different window sizes and FFT sizes. Simulation results show that the proposed method estimates the center frequency of channel with high accuracy and low SNR.

REFERENCES

[1]. M. Narendar and A. P. Vinod, "**An Algorithm for spectrum Sensing in Cognitive Radio using Tree-structured Filter Bank**" in 17th International conference on Telecommunications 2010

[2] Carlos Cordeiro and Kiran Challapali, "**IEEE 802.22: An introduction to the first wireless standard based on cognitive radios**" in journal of communication, vol.1, April 2006

[3] J. Mitola and G. Q., Maguire, "**Cognitive radio: making software radios more personal**", IEEE Personal Communications Magazine, vol. 6, no. 4, pp. 13–18, Aug. 1999.

[4] YoungwooYoun, HyoungsukJeon, Hoiyoon Jung and Hyuckjae Lee, "**Discrete Wavelet Packet Transform based Energy. Detector for Cognitive Radios**",65th VTC Spring, pp. 2641-2645, Dublin, 2007.

[5] Xiqi Gao, Truong Q. Nguyen, Gilbert Strang, "**On Factorization of M-Channel Paraunitary Filter banks**", IEEE transactions on signal processing, vol. 49, no. 7, july 2001..

[6] B. Farhang-Boroujeny,"**Filter Banks Spectrum Sensing for Cognitive Radios**", IEEE Transaction on Signal Processing, Vol. 56, pp. 1801-1811, May 2008.

[7] S. J. Darak, A. P. Vinod, R. Mahesh, E. M-K. Lai,"**A Reconfigurable Filter Bank for Uniform and Non-uniform Channelization in Multi-Standard Wireless Communication Receivers**",17th International Conference on Telecommunications,2010.

[8] Aleksandar Joviˇci´c, Pramod Viswanath,"**Cognitive Radio: An Information-Theoretic Perspective**",Seattle, USA, July 9-14,2006.

[9] Simon Haykin, Life Fellow, IEEE, "**Cognitive Radio: Brain-Empowered Wireless Communications**", IEEE journal on selected areas in communications, vol. 23, no. 2, february 2005

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