Spectrum Detection Using Adaptive Multi-Taper Spectrum Estimator For Higher Frequency Band In Cognitive Radios

Khyati Watve[1], Mrs. Kirti A. Adoni[2]
[1, 2] P.E.S's Modern College of Engineering, Pune

Abstract- *As the wireless spectrum available to us for use is limited and there has been a steady expansion in the field of wireless applications, it has become necessary to perform all the applications in the same available spectrum. A CR has the ability to perform spectrum sensing and transmission modifications by itself. A main detector Thomson's Adaptive Multi-Taper Spectrum Estimation (AMTSE) has been discussed here. The detector adjusts itself to the maximum and minimum values of the Power Spectral Densities (PSD). Discrete Prolate Spheroidal Sequences (DPSS) are taken into consideration in order to get better and smooth spectrum for detection. An idea to calculate the energy and detecting the availability of spectrum has been proposed, which has lead to reduction in probability of FalseAlarm Rate P(fa) and rise in probability of detection P(d). Thesimulation result of Signal to Noise Ratio (SNR) on Bit Error Ratio (BER) has been established, which shows noticeable decrease in the BER as SNR rises to a particular value of 40dB.*

Keywords- Adaptive Multi-Taper Spectrum Estimator (AMTSE), Cognitive Radio (CR), Discrete Prolate Spheroidal Sequences (DPSS), Dynamic Spectrum Management, Linear Precoding, Power Spectral Density (PSD).

I. INTRODUCTION

Due to fast advancements and demands in wireless applications, CR is regarded as an convincing way out for raising the utility of the available spectrum. CR is a type of wireless communication, where a transceiver smartly detects busy and vacant tracks and quickly moves into empty channels, thereby circumventing the occupied ones. This transition procedure is called dynamic spectrum management. CR allows unlicensed Secondary Users (SUs) to access the licensed spectrum band of other Primary User (PU).

A paramount zone in CR environments is the spectrum sensing, a technique by which the intelligent CR system can identify the existence and non-existence of a PU in the channel. The main hindrance in CR is to identify the presence of PUs accurately. CR allows the coexistence of numerous radio systems in overlapping frequency and/or time slots. The two main classifications of CR are full CR and CR based on detection of spectrum. A full CR needs to take all the transmission and reception parameters in account that a wireless system is familiar to. For detecting the channels in the radio frequency spectrum, spectrum-sensing method is used. This paper presents a method of detecting the spectrum based on AMTSE and thresholding for higher frequency range and increased number of samples.

The paper is organized with section literature review in section II, methodology in section III, simulation and results in section IV followed by conclusion in section V.

II. LITERATURE SURVEY

To minimize the wastage of spectrum resources and increase the spectral efficiency, in 1999, Dr. Joseph Mitola proposed the concept of cognitive radio. With rigorous researches, now it is possible to share the spectrum as per the requirement between the PUs and SUs. To detect the availability of spectrum, different spectrum techniques are being used each having its own pros and cons. Moreover, noise uncertainty, multipath fading and shadowing are some factors that limit the performance of spectrum sensing [1-3]. Mariani et al. [4] proposed a dynamic threshold method for energy detection. The performance of this method was found to be better than traditional energy detection, but the actual dynamic threshold was too complex to set. To balance the computation complexity and the sensing performance, two-stage sensing scheme was proposed by [5, 6] where two sensing methods were combined,which included a coarse sensing stage and a fine sensing stage. Boroujeny [7] proposed the idea of Thomson's Multi-Taper (MT) method which proposed the use of a particular group of filter banks for recognition of spectrum in CR organization. Prasad et al. [8] suggested a method involving pre-coding strategy on the Secondary Base Station (SBS) side that achieved pre-cancellation of data at the Primary Base Station (PBS). The ideal precoding matrix filters were evaluated through a rerun search but as a con it required a committed receiver for every type of PU.

Other challenge was about spectrum mostly on the exactness on spectral procurable decision, time needed for sensing due to noise multipath fading and shadowing. To fathom hidden PU trouble and mollify the influence of such issues, a potent method of cooperative spectrum sensing was used under research to enhance the detection procedure is used in distantly present CR.

Parere et al. [9] conducted the research based on energy detection for spectral sensing over multi path fading channels. Various antennas were requisite for Multi Input Multi Output (MIMO) operation for various bands operation. In this case, a differential module was utilized in order to switch and impedance matching between antennas and Power Amplifiers (PAs). To keep away interference, numerous techniques are used in combination such as frequency tuning, Orthogonal Frequency Division Multiplexing (OFDM) sub-channelization, multiplexing in time, controlling power, modulation and coding techniques for Quality of Service (QoS) adaptability, beam-forming, and space-time coding for MIMO. But, a wide range basically for Analog-to-Digital converter (ADC) and highly sensitized receiver having rapid attune to changes in interference were required just to support link in unfavourable conditions.

Jung et al. [10] aimed to banish the interference which was the prominent factor in existing radio systems.CR system in which SUs coexist with PUs, under interference constraints can be operated simultaneously by doing few pre-processing at the secondary transmitter had been proposed. Mean Square Error (MSE) IC pre-coding was a customary method subject to the interference and power constraint. The main hurdle was in the choice of an estimator for the spectrum of a stationary time series from a finite instance of the process, the problems of bias check and consistency, were supreme.

PUs of the particular spectrum are its first priority. If the band is required by any other SU, it will be allotted only when no PU is accessing it. For such a situation, a SU has to barter between two dissensions simultaneously: first is to attain utmost of its own transmit output relative to input; and the other is to lessen the quantity of interference that was being produced at each primary receiver. A study was conducted [11-12] for fundamental trade-off from a theoretical view point by determining the SU's channel potential under both cases, with its own transmit-power curb as well as a pool of interference-power restraints each exploited at one of the primary receivers. Cooperative techniques provided with great benefits of reduction in sensitivity threshold [13], but sensing was needed to be performed at periodic intervals wide channels were needed to be scanned.

III. PROPOSED METHODOLOGY

The two main concepts in regard of the work are of Adaptive Multi-Taper Spectrum Estimation (AMTSE) and linear precoding. The sensing of spectrum can be classified in two parts. First is the AMTSE and second part is the detector. AMTSE estimates the PSD of received signal. For the estimation of PSD, weight of each Eigen-spectrum has been adjusted, whereas the detector calculates the threshold value according to the minimum and maximum values. Further the detector gives thedecision on availability of spectrum. Linear precoding has been done with the aim to cancel the interference from the SU.

Fig 1 shows the block diagram of the non-parametric sensing method in Adaptive Multi-Taper Spectral Estimation (AMTSE).

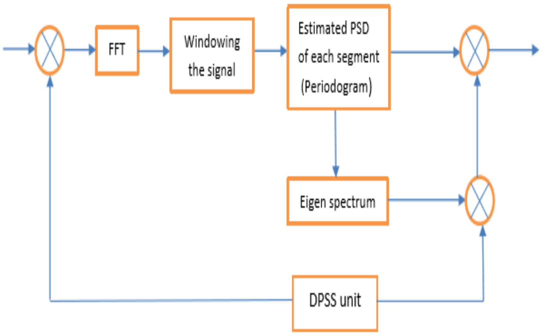


Fig1: Block diagram of multi-taper spectral estimation unit

Using Fast Fourier transform (FFT) signal has been sampled over a period of time and divided into its frequency component. FFT computes these transformations by faceting the Discrete Fourier Transform (DFT) matrix into a product of scanty factors. The motive behind using FFT is ability to compute these results more swiftly.

Periodogram gives the non-parametric estimate of the PSD in time series data. It is similar to Fourier transform but is used for unevenly time sampled data, also for types of shapes in periodic signals. MIMO channel capacity can be characterized by the Eigen values. These values convey the information regarding the strength of the parallel channels. Hence, after making some assumptions on transmission rates and power, it calculates the Bit Error Ratio (BER).

DPSS consist of the most spectral efficient set of orthogonal sequences possible. For more accurate spectrum estimation, the concept of DPSS has been used. The process begins with receiving the data from the transmitter and the initial power spectral density of the received signal [14] can be calculated by,

$$\dot{\hat{S}}_t^{(mt)}(f) \triangleq \left|\sum_{n=0}^{N-1} x[n]\cdot h_t[n]\cdot e^{-j2\pi nf}\right|^2 \quad \ldots(1)$$

Where, x[n] denotes the nth sample of received signal and N denotes the number of sample points. $h_t(n)$ is the tth DPSS. The adaptive weighing factor [14] has been calculated by,

$$d_t(f) = \frac{\sqrt{\lambda_t}\, S(f)}{\lambda_t S(f) + (1-\lambda_t)\, \mathrm{E}} \quad \ldots(2)$$

Where, λ_t represents the tth eigen value in relevance to tth DPSS and E represents the observation energy.

This adaptive weighing factor formula is based upon the Minimum Mean Square Error (MMSE) criterion in which lower spectrum is enhanced and the effects of higher order spectrum diminishes. After calculating the adaptive weights, the final PSD [14] has been calculated by,

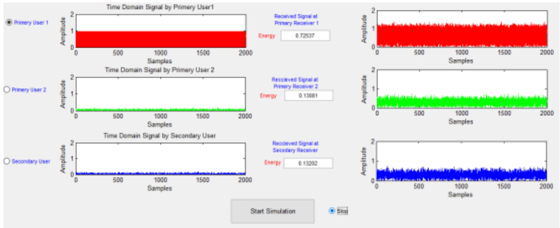
$$\hat{S}(f) = \frac{\sum_{t=1}^{K} |d_t(f)|^2 \dot{\hat{S}}_t^{(mt)}(f)}{\sum_{t=1}^{K} |d_t(f)|^2} \quad \ldots(3)$$

where, K= 2, 3, ….2NW, represents the number of windows and W represents the precoding matrix.

IV. RESULTS AND SIMULATION

The simulation had been carried out in MATLAB with frequency ranging from 0 to 1000 Hz (1 KHz) and number of sample values 1000. The work has also been verified for frequency in KHz and higher number of samples. The simulation has been performed with numeric values of 2000 as number of samples (N), frequency range from 0 to 50,000 Hz (50 KHz), Signal to Noise Ratio (SNR) from 0 to 40 dB, a 256 point FFT as per recent telecom era, DPSS (K) as 3, 5, 7 and 9.

Here a case of PU1 using its authorized band for transmission and PU2 is idle has been considered. The aim is to detect this empty band of PU 2 and assign it to the needy SU for opportunistic use



Energy 0.72537

Energy 0.13081

Energy 0.13202

Fig 2: When PU1/PU2 is transmitting

The multi tapering divides the whole band into small segments called windows, calculates the PSD of each segment, produces eigen values for each window and ultimately multiplies the PSD of each segment with its DPSS and its respective eigen spectrum values, in order to get more accurate and smooth PSD values. Fig 3 shows the DPSS generated while simulation.

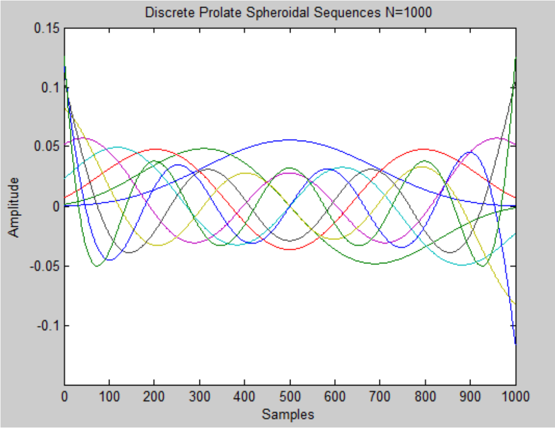


Fig 3: DPSS up to value 9

The comparitive outputs for spectrum estimation of PU1 without DPSS and with DPSS have been shown in Fig 4(a) and fig 4(b) respectively. Fig 4(a) shows that the transmission by PU1 is being done at 10 KHz The highest power detected at 10 KHz is 0.5dB. It has been observed that span at 10 KHz starts from the co-ordinates (9521, 0.0095) and ends at (10180, 0.0143). Fig 4(b) shows that the highest power detected for PU1 transmitting at 10 KHz, after the inclusion of DPSS has been found 0.0065dB with span starting at (9870, 0.00002) ending at (10080. 0.00008).

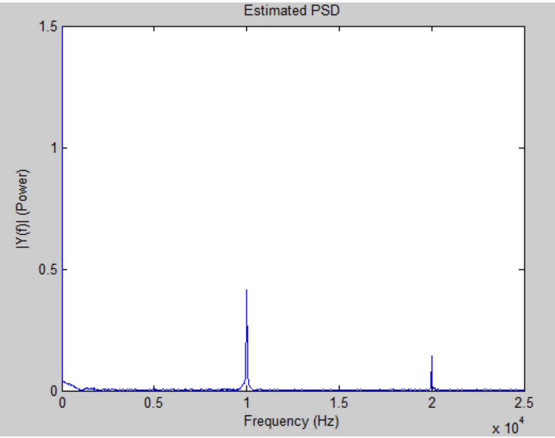


Fig 4(a): PSD calculation without DPSS

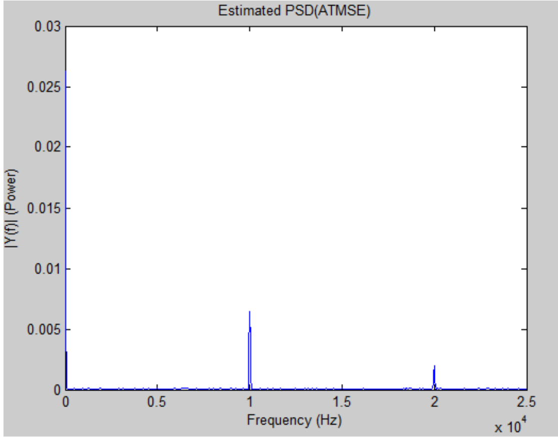


Fig 4(b): PSD calculation with DPSS

Fig 5(a) shows that, PU1 is transmitting over its band and the CR checks for the vacant band if it is vacant. A prompt box appears on the window showing spectrum detected, which indicates that PU1 band cannot be shared. Meanwhile, PU2 has done its communication and has released its band free as it no longer requires the spectrum for use, there occurs a hand-over mechanism and the band of PU2 has been allotted to the SU (on demand). Fig 5(b) shows that the empty band of PU2 has been allotted to SU for opportunistic use and it can be verified with the SU signals being received at the receiver's end.

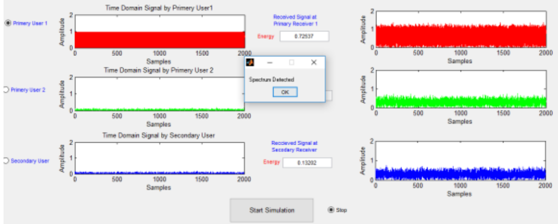


Fig 5(a): Either PU1/ PU2 transmitting

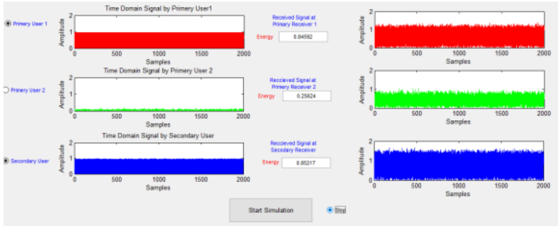


Fig 5(b): PU1 using the band & vacant band of PU2 given to SU

Fig 6 shows the BER performance for various values of SNR. The concern is to get the BER minimum, for which different SNR values have been testedvarying from 0dB to 40 dB. Fig 7 establishes the relation between P(fa) and P(d) for different values of DPSS.

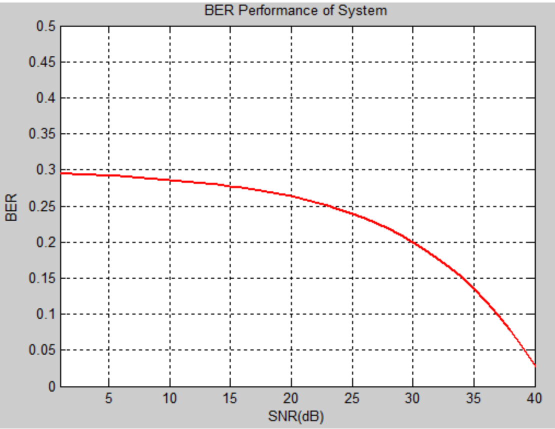


Fig 6: BER v/s SNR plot

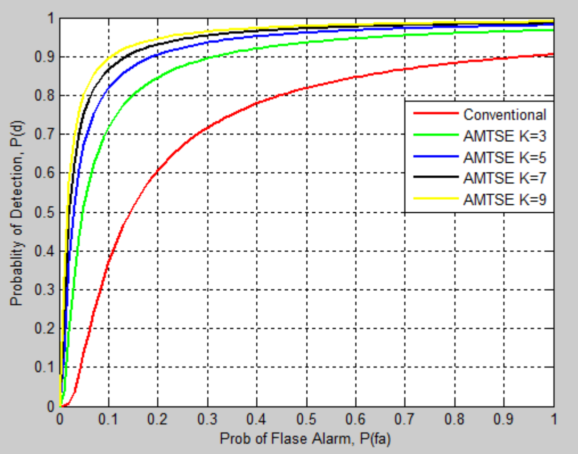


Fig 7: P(fa) v/s P(d) plot

V. CONCLUSION

An adaptive CR technique for spectrum estimation and detection has been presented in this paper. For the purpose of spectrum sensing, an AMTSE based spectral detector has been used as it gives multi-band sensing and high detection rates. The simulation results have checked for higher frequency range and more number of samples. Same can further be used for other higher frequencies. Including DPSS in calculation of PSD has helped to achieve smooth PSD value for the ease of detection. It has been seen that DPSS results in accurate PSD calculation with higher P(d) with reduced P(fa). With increased number of samples, more compressed, smooth and averaged waveforms have been obtained. Compressed graphs results in reduction of hardware circuitry and signal processing. The hardware cost and sensing time will be reduced. As the SNR has increased, the BER has approached its minimum value and shows the flow of information over communication with least error rates.

REFERENCES

[1] Ian F. Akyildiz, Brandon F. Lo, Ravikumar, “Cooperative spectrum sensing in cognitive radio networks: A survey(2011)

[2] K. Challapali, S. Mangold, Z. Zhong,“Spectrum Agile Radio: Detecting Spectrum Opportunities”, In Proc. Int. Symposium on Advanced Radio Technologies, Boulder, CO, Mar. 2004.

[3] Z. Tian, G. B. Giannakis,“A Wavelet Approach to Wideband Spectrum Sensing for Cognitive Radios”, In Proc. IEEE Int. Conference

[4] Mariani A, Giorgetti A, Chiani M. Effects of Noise Power Estimation on Energy Detection for Cognitive Radio Applications[J]. IEEE Transactions on Communications, 2011, 59(12):3410-3420.

[5] Sina Maleki, Ashish Pandharipande, Geert Leus. two-stage spectrum sensing for cognitive radios[C]. Acoustics Speech and Signal Processing (ICASSP), 2010.

[6] Omar A. M. Aly. Two-stage spectrum sensing algorithm for low power signals in cognitive radio[C]. Electronics, Communications and Photonics Conference (SIECPC), 2013.

[7] Behrouz Farhang-Boroujeny, Senior Member, IEEE transactions on signal processing, VOL. 56, NO. 5, MAY 2008

[8] R. Prasad and A. Chockalingam, “Precoder Optimization in Cognitive Radio with Interference Constraints,” in Proc. IEEE ICC ’11, Kyoto, Japan, Jun. 2011, pp. 1–6.

[9] S. Rodriguez-Parera, V. Ramon, A. Bourdoux, F. Horlin, and R. Lauwereins, “Spectrum sensing over SIMO multi-path fading channels based on energy detection,” in Proc. IEEE Global Telecommun. Conf. (GLOBECOM), 2008, pp. 1–6.

[10] M. Jung, K. Hwang, and S. Choi, “Interference Minimization Approach to Precoding Scheme in MIMO-Based Cognitive Radio Networks,” IEEE Communication. Lett., vol. 15, no. 8, pp. 789–791, Aug. 2011.

[11] R. Zhang and Y. C. Liang, “Exploiting Multi-Antennas for Opportunistic Spectrum Sharing in Cognitive Radio Networks,” IEEE J. Sel. Topics Signal Process., vol. 2, no. 1, pp. 88–102, Feb. 2008.

[12] Amir Ghasemi, Elvino S. Sousa,“Spectrum Sensing in Cognitive Radio Networks: Requirements, Challenges and Design Trade-offs Cognitive radio communication and networks”, IEEE Communication Magazine, pp. 32-39, 2008.

[13] G. Ganesan, Y. Li,“Cooperative Spectrum Sensing in Cognitive Radio, Part I: Two User Networks”, IEEE Transactions on Wireless Communications, Vol. 6, No. 6, pp. 2204 – 2213, Jun. 2007.

[14] Yi-Han Tseng, Terng-Hsing Chiu, Jung-Mao Lin, and His-Pin Ma, “Linear precoding and adaptive multi-taper spectrum detector for cognitive radios” International Symposium on VLSI Design, Automation and Test (VLSI-DAT), 2016.

[15] D. Cabric, I. O’Donnell, M.-W. Chen, and R. Brodersen, “Spectrum sharing radio,” IEEE Circuits Syst. Mag., vol. 6, no. 2, pp. 30–45, Jul. 2006.