Energy Based Spectrum Detection using DPSS for Cognitive Radios

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Abstract – Due to limited spectrum available for use and steady expansion in the field of wireless applications, it has become necessary to organize all the applications in the same available spectrum. To provide a way out to the trouble of inefficient spectrum usage, Cognitive Radios (CR) are considered as a promising solution. A cognitive radio organization has the ability to perform spectrum sensing and transmission modifications by itself. A foremost detector put in for Thomson's Adaptive Multi-Taper Spectrum Estimation (AMTSE) has been discussed here. The detector has been employed for adapting itself to the maximum and minimum values. As a result, the detection threshold adjusts itself according to the environmental changes. The signal after being linearly pre-coded, is divided into small segments and the Discrete Prolate Spheroidal Sequences (DPSS) are multiplied with it in order to get better and smooth spectrum for detection. In case of the existence of a PU exists, the technique of interference cancellation has been applied for cancelling the interference. Whereas, when the PU is not using the spectrum band, the Secondary User's (SU) transmitter can detect the Channel condition as a result to the channel mutuality, granting the permission to use the free spectrum band by some other user who needs it. An idea to calculate the energy and detecting the availability of spectrum has been proposed, which leads to reduction in False Alarm Rate P(fa) and rise in probability of detection P(d).

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

1. INTRODUCTION

With rapidly progressing advancements and demands of wireless applications, Cognitive Radios (CR) are considered as an assuring solution for raising the productivity of the available spectrum. CR is a type of communication which is done wirelessly, where a transceiver smartly detects which interface tracks are being used and which are vacant, and quickly moves into empty channels, thereby bypassing the occupied ones. This switching technique is called dynamic spectrum management. CR allows unlicensed SU to access the licensed spectrum band.

An important 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 cognitive radio 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 cognitive radio and cognitive radio based on detection of spectrum. A full cognitive radio requires to take all 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.

The paper is organized with section 2 as literature review, section 3 as methodology, section 4 as simulation and results followed by conclusion in section 5.

2. LITERATURE REVIEW

In order to reduce the wastege of spectrum resources and increase the spectral efficiency, in 1999, Dr. Joseph Mitola proposed the concept of cognitive radio. With continuous developments, 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 scheme for energy detection. The performance of this method was better than traditional energy detection, but the actual dynamic threshold is too complex to set. The cyclic stationary feature detection method has a better sensing performance. But the computation complexity is also high. To balance the computation complexity and the sensing performance, two-stage sensing scheme is proposed by [5,6] where two sensing methods were combined. 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. The template filter was a low pass filter which is used to consummate the zeroth band of the filter bank while remaining bands are achieved via modulation of the template filter. But, the drawback of MT method was high computational cost. Hence, detection based on filter bank spectrum analysis was considered more promising and preferred. Prasad et al. [8] suggested a method involving pre-coding strategy on the Secondary Base Station (SBS) side that achieves 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 needed a committed receiver for every sort of PU.

Another challenge was about spectrum sensing and sharing, mostly on the exactness on spectral procurable decision, time needed for sensing, and destructive combatant, taking into consideration the fundamental border of spectrum sensing formulas due to noise unsure multipath fading and shadowing. To fathom hidden PU trouble and mollify the influence of such issues, a potent method of cooperative spectrum sensing has been 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 are requisite for Multi Input Multi Output (MIMO) operation for various bands operation. In this case, a differential module is utilized in order to switch and impedance matching between antennas and Power Amplifiers (PAs). To keep away interference, numerous techniques were 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 are required just to support link in unfavorable conditions.

Jung et al. [10] aimed to banish the interference which was the prominent factor in existing radio systems. Cognitive radio 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.

In other scenario when the SU who are lower priority users, needs to exchange information with each other by occasional utilizing the momentary available spectrum which was originally given to the existing primary which are the higher priority users. For such a situation, a SU customarily 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 theoretic 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 and wide channels needed to be scanned.

3. 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 Power Spectral Density (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. The detector then gives the decision 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).

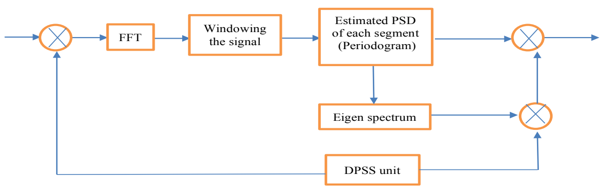

Fig1: Block diagram of multi-taper spectral estimation unit

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. Computation of DFT for N points, by denotion, takes O(N2) arithmetical operations, whereas FFT can quantify same DFT in only O(NlogN) operations.

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. 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 finds its use in the analyses of 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

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

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

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

Where, represents the t[th] eigen value in relevance to t[th] 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 are enhanced and the effects of higher order spectrum diminishes. After calculating the adaptive weights, the final PSD [14] has been calculated by

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

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

4. RESULTS AND SIMULATION

The work has been simulated in MATLAB. The simulation has been performed with numeric values of 1000 as number of samples (N), with Signal to Noise Ratio (SNR)= 0 to 40 dB, a 256 point FFT as per recent telecom era, frequency range varying from 0 to 500 Hz, 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.

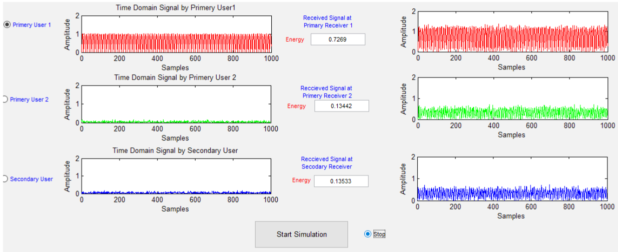

Fig 2: Case1 when PU1/PU2 is transmitting

The multi tapering unit divides the whole band into small segments called windows, calculate the Power Spectral Density (PSD) of each segment, produce eigen values for each 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.

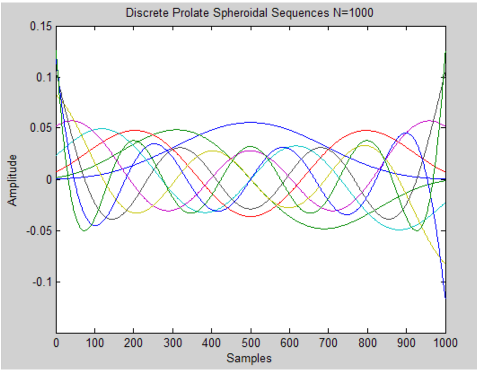

Fig 3: DPSS upto value 9

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 100 Hz with DPSS. The highest power detected at 100 Hz is 0.4 dB/Hz. It has been observed that span at 100 dB starts from the co-ordinates 88.87, 0.00907 and ends at 112.3, 0.01087 for x and y axis respectively.

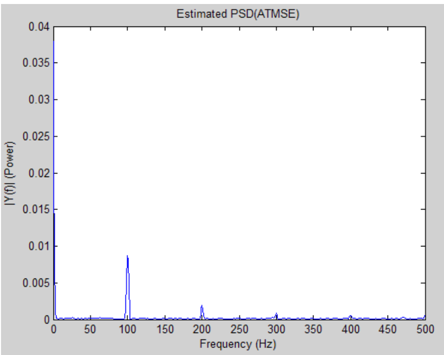

Fig 4(a): PSD calculation without DPSS

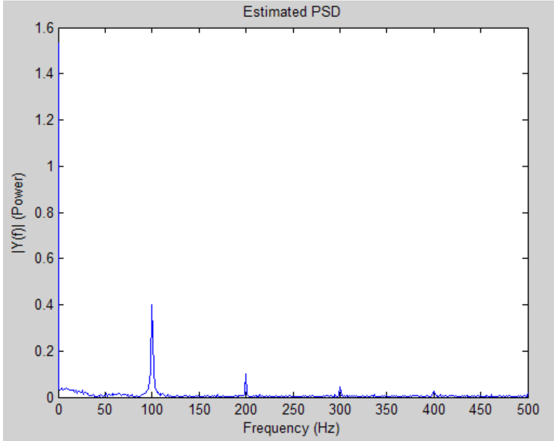

Fig 4(b): PSD calculation with DPSS

5. CONCLUSION

The paper presents a CR technique which senses the spectrum and transmission adjustments. For the purpose of spectrum sensing, an AMTSE based spectral detector has been used as it gives multi-band sensing and detection rates are found high. Including DPSS while calculating PSD helps to achieve smooth PSD value for the ease of detection. It has been seen that with DPSS results in accurate PSD value calculation with higher P(d) with reduced P(fa). As more smooth and averaged operating waveforms have been obtained with DPSS, it will reduce the requirement of hardware circuitry and processing involved in processing of signal to much less extent. Hence, the hardware cost and sensing time will be reduced.

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