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Implementation of Modified Time - Smoothing Algorithms and Its Comparative Analysis in Spectrum Sensing

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Abstract

Spectrum Sensing is a primary conception in Cognitive Radio (CR) to improve the spectrum utilization in the current wireless communication with exponential growth in wireless technology. Spectrum allocation governed by the government agencies or the service providers who are in need of spectrum, to manage the increasing frequency demands from the end users as the technology increases exponentially. Current scenario of Spectrum sensing needs to improve in terms signal to noise ratio (SNR) values, less complexity and throughput. Even though there are different methods available for Spectrum Sensing, the need for improved sensing are accomplished by the Cyclostationary sensing method. A Cyclostationary Signal having statistical properties those vary cyclically with time. This comes under the Time Smoothing Method (TSM) includes two algorithms, the FFT Accumulation Method (FAM) and the Strip Spectral Correlation Method (SSCM). The comparison of FAM and SSCM algorithms in terms of SNR, execution speed and benefits of the conventional methods are debated in this proposed article.

Keywords: Spectrum Sensing, FFT Accumulation Method (FAM), Strip Spectral Correlation Method (SSCM), Cyclostationary Signals, Time Smoothing.

1. Introduction

Cognitive Radio (CR) is the technology which helps Spectrum Sensing and Sharing. CR technology is an intelligent method which collects information from its environment and uses it as the input to find out the spectrum availability with the aim of providing better communication. Consequence behind CR is to sense the unused frequency bands from the Primary User (PU) or Licensed User and make it available for the Secondary User (SU) or Unlicensed User to make the efficient utilization of the available radio frequency resource [1].

To sense the resource availability there are different techniques available like dynamic change the detection time duration to gain maximum throughput Detection Method used to detect the signal without any prior knowledge of the signal the disadvantage of this method is that the threshold varies with Signal to Noise Ratio (SNR) for different signals and the distinction between signals and the interfering signals are more difficult, throughput is also an major issue even in the dynamic change of the detection time [2]. Further to minimize spectrum sensing error by reducing the threshold. Fixing threshold leads to the determination of noise factor is feeble and prior knowledge of the PU that cannot be assured at the real-time environment [3], and Probabilistic approach, Hidden Markov Model (HMM) i.e., the probability of staying in a given state falls off exponentially or suddenly, which does not map well to many real-time applications where a linear decrease in probability in duration is appropriate[4] Aleksandar et al. proposed the interference reduction method, based this method the throughput will degrade if the number secondary users are more [5]. In this proposal the Cyclostationary Method which works well in noisy environment is its basic advantage. The Cyclostationary property of the signals varies cyclically with time is used to sense the spectrum availability, can be utilized efficiently. In FFT Accumulation Method (FAM) the variation in Time Smoothed Periodogram proves to be a better method in analyzing the entire bi frequency spectrum. Strip Spectral Correlation Algorithm (SSCA) proves to be better than FAM for its less complexity with improved speed of execution.

This paper is organized as follows: Section 2 describes the Cyclostationary property of communication signals. In section 3 we deal with Time Smoothing Algorithm (TSA) and its modification. Section 4 and 5 illustrates the FAM and SSCA methods. Sections 6 speak about the comparison between the algorithms and Section 7 and 8 deals with simulation results and conclusion.

2. Cyclostationarity

A Cyclostationary process can be viewed as a multiple interleaved stationary process. It can be expressed as,

$$R_x(t,\tau) = R_x(t+T_0,\tau);\ for\ all\,[t,\tau]$$

A Cyclostationary signal has statistical properties that vary cyclically with time. Physically, signals used in the communication system exhibit periodicities of statistical parameters due to operations such as sampling, modulation and multiplexing. These Cyclostationary properties which are named as Spectral Correlation features used for Spectrum Sensing [6]. This method is used for signal detection and classification and the advantage of this method is the ability to distinguish the co-channel interference and to provide High Signal to Noise Ratio (SNR).

3. Time Smoothing Algorithm

A basic Time Smoothing Algorithm can be formed by evaluating the Time Smoothed Cyclic Periodogram at Cycle Frequency pairs (f_0, α_0) of interest. The Time Smoothed Cyclic Cross Periodogram is given by,

$$S_{xy}^{\alpha_0}(n, f_0)_{\Delta t} = [X_T(n, f_0+\alpha_0/2)Y_T^*(n, f_0-\alpha_0/2)]_{\Delta t}$$

Modification in the Time Smoothed Cyclic Periodogram leads to several computationally efficient algorithms [7].

1. The FFT Accumulation Method (FAM)
2. The Strip Spectral Correlation Algorithm (SSCA)

The FAM is a Fourier Transform of the correlation product between the Spectral Components smoothed over time is shown in Figure.1. The SSCA method is almost similar to the FAM method differs with Complex Demodulate calculation. The SSCA method is the Fourier Transform of the Correlation Products between the Spectral and Temporal Components Smoothed over time. In SSCA, only single frequency is taken in hand to shift the input signal and is correlated with a random input sequence directly after holding the calculated demodulate. The Cyclic Spectral plane is the result of Fourier Transform here the frequency varies from –fs/2 to +fs/2 and the Cycle Frequency varies from –fs to +fs, in both the cases the sampling frequency is fs.

4. FFT Accumulation Method

The FAM Cross Spectral Estimate [8] is given by,

$$S_{xy}(pL, f_{kl})_{\Delta t} = \sum XT(rL, f_k) YT^*(rL, f_l) gc(p-r) e^{(j2\pi rq/P)} \quad (1)$$

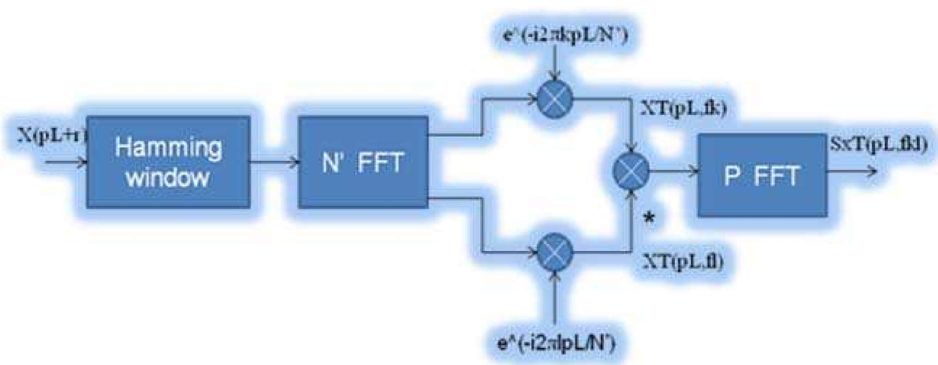
The FAM Auto Spectral Estimate is given by,

$$S_{XX}(pL, f_{kl})_{\Delta t} = \sum X\,T(rL, f_k) YT^*(rL, f_l)\, gc(p-r) e^{(-j2\pi rq/P)} \quad (2)$$

XT (rL, fk) and YT (rL, fl) are the complex demodulates inputs for the FFT block and gc (p-r) represents the Hamming Window. The FAM Cross Spectral Plane which is the output of the first FFT has number of frequencies represented in a 2-D plane. Each cell in the 2-D plane is represented as (f, α). The block for FAM is shown in Figure.1.

The FAM is implemented by forming an array from X (kT), where k varies from 0 to N-1. Two dimensional arrays with Columns representing constant frequencies are obtained by applying the input to the Hamming Window, Fast Fourier Transformed and then down converted to baseband.

Figure 1: FFT Accumulation Method (FAM)



The FAM technique is implemented by Input Channelization, Windowing, FFT, Down conversion and Data Reduction. In the frequency array, the starting point of each succeeding row is offset from the previous rows starting positions from L samples as shown in Figure.3.

The result at this point is a 2 - Dimensional Frequency Plane [9] with Columns representing constant frequency as in Figure.3. Each Column was point wise multiplied in turn with the conjugate of the Columns resulting from the processing Y (kT). The input sample data is formed into a 2-D array with N = 48, N' = 16, L = 4 and P = 8. The array Row length is equal to the number of input channels N'. For a given number of input sample points N, a row size of N' and a chosen offset L, there are P = (N - N') / L = N / L, number of Rows are formed. Here the value of N' must be chosen, such that the time frequency resolution product must be greater than unity. The 'L' value must always be less than one quarter N'. Now the completely filled array is with P Rows and N' Columns [10].

The input signal is windowed and Fast Fourier Transformed, the result obtained will vary from 0 to N'-1. Each row is down converted to baseband signal by multiplying the output with the exponential term. The signal is then multiplied with its correlated value and then Fast Fourier Transformed (FFT) with L samples skipped to obtain the P point FFT. Finally the Data reduction is done to reduce the number large output data files [11].

5. Strip Spectral Correlation Algorithm

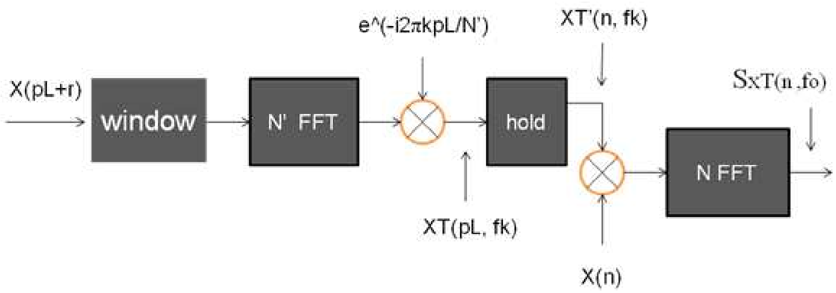
The SSCA Cross Spectral Estimate is given by,

$$S(n, f_k / 2)_{\Delta t} = \sum X\,T(r, f)Y^*(r)gc(n-r)e^{(j2\pi rq/n)} \tag{3}$$

The SSCA Auto Spectral Estimate is given by,

$$S_{XX}(n, L, f_{kl} / 2)_{\Delta t} = \sum X\,T(r, f)Y^*(r)\,gc(n-r)e^{(-j2\pi rq/n)} \tag{4}$$

Figure 2: Strip Spectral Correlation Algorithm (SSCA)



The SSCA is implemented by forming an array from X (kT) with rows which are N' points long from the input sample data. The starting point of each succeeding row is offset from the previous rows starting positions from L samples [12]. A Hamming Window is applied across each row which is then Fast Fourier Transformed and down converted to baseband. The result at this point is a 2-D array with columns representing constant frequency. Each row is transposed and replicated L times for a total of PL columns. Each column is then multiplied by a sample Y (kT), where k varies from 0 to (PL-1) [13]. Each resultant row is then Fast Fourier Transformed and placed into a strip of the final Cyclic Spectral Plane at the appropriate location. SSCA method too follows the same assumptions as what FAM algorithm used [14].

6. Comparison of Complexity

The FAM and SSCA methods follow similar flow till the Down conversion step and there after the change occurs with multiplication and second FFT [15]. The number of parameters gets reduced in the SSCA compared to FAM from multiplication implies there will be no change in the complexity even if the window is changed. When the two algorithms are simulated using MatlabR2010 the speed of execution increases in SSCA compared to FAM. And the execution time is reduced as one half in SSCA compared to FAM.

Table 1: Comparison of Complexity

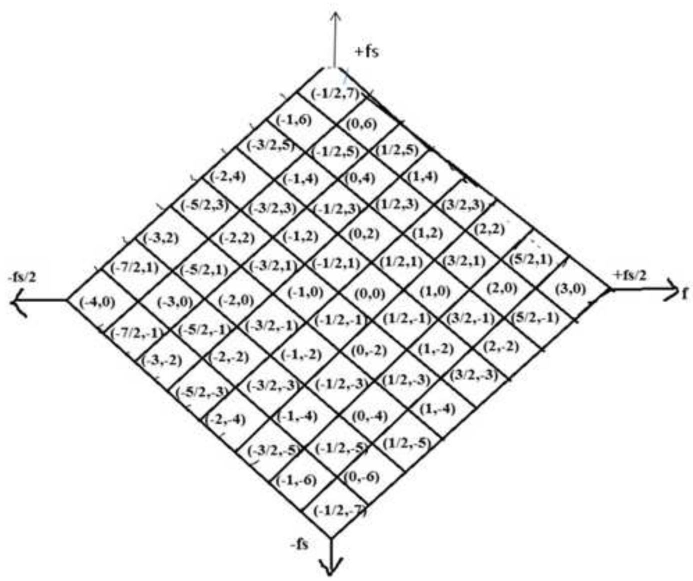
STEPS	FAM	SSCA
APPLYING THE WINDOW	2*P*N’	2*P*N’
FIRST FFT	2*P*N’ *$\log_2$N’	2*P*N’ *$\log_2$N’
DOWN CONVERSION	4*P*N’	4*P*N’
MULTIPLICATION	4*N’*N’*P	4*N*N’
SECOND FFT	2*N’*N’*P*$\log_2$P	2*N*N’*$\log_2$N

The simulated comparison of speed of execution between FAM and SSCA are given in Table.2.

Table 2: Comparison of Speed between FAM and SSCA

TRIAL	FAM (TIME IN SEC)	SSCA (TIME IN SEC)
1	0.9592	0.5780
2	1.0101	0.5776
3	0.9500	0.5795

Figure 3: Frequency Plane



7. Simulation Results

The Spectral Correlation Density (SCD) found from equation 2 and 4 is simulated and plotted in Figure. 4 and Figure.5. This SCD is used to generate the spectral redundancy which says whether there is leakage of spectrum or not i.e., if spectral redundancy is present at one of its Cyclic Frequencies implies that there is spectrum of PU is available and can be utilized by the SU.

Figure 4: Spectral Estimate of FAM

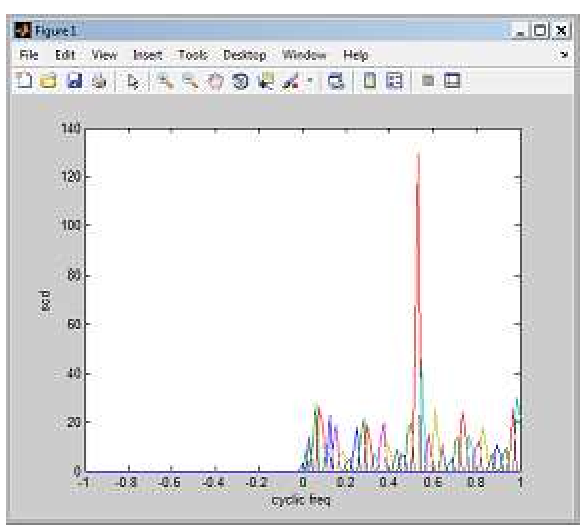
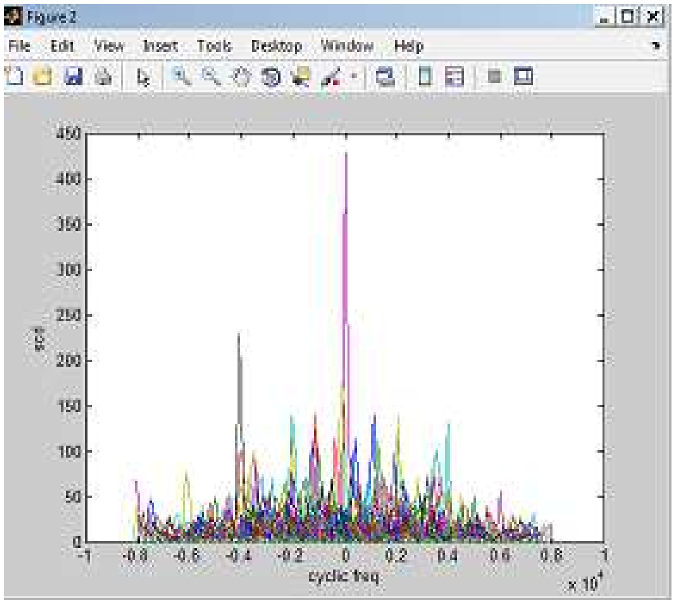


Figure 5: Spectral Estimate of SSCA



Thus from the Figure.4 it is clear that the highest value of Spectral Correlation Density (SCD) is obtained at a particular frequency which is the redundant frequency.

8. Conclusion and Future Work

Thus SCD and the speed of execution are calculated for FAM and SSCA algorithms and from the results it is concluded that SSCA algorithm proves to be better than the FAM Algorithm in terms of execution time. The future work includes finding the frequency which suits best for SSCA by assigning a fixed SNR and considering any two frequencies.

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