Abstract— Due to fixed available spectrum and the incomplete use of spectrum use necessitate a new communication technology, known as cognitive radio (CR). Cognitive radio is an intelligent device which can easily sense the available channel in an available spectrum. For spectrum sensing it basically uses three techniques Energy Detection, Matched Filter Detection and Cyclostationary Detection. In this paper spectrum detection is done by using cyclostationary detection which provide better results at low SNR in comparison to other techniques, here BPSK signal is used for finding cyclostationary spectrum and detection at low SNR.

Keywords— Cognitive Radio, Spectrum Sensing, Cyclostationary Feature Detection , Spectrum correlation function (SCF).

I. INTRODUCTION

The best way to solve the spectrum underutilization is by using cognitive radio (CR) technology. Cognitive radio devices are invented to give reliable communication for all users which uses wireless network when they required and to facilitate effective utilization of the radio spectrum [1].One of the most important application of cognitive radio is spectrum sensing. Cognitive radio can sense the available spectrum for the secondary users when primary user is not using the allotted spectrum, so that spectrum utilization can be improved. Many techniques like matched filter, cyclostationary detection, energy detection are used for spectrum sensing. In Matched filter it can detect signal even in low SNR environments but it requires a prior knowledge of the primary user signal. Furthermore a matched filter needs a dedicated receiver for every primary user class and cannot be exploited for blind spectrum sensing [2,3,4].In Energy detector no requirement of prior knowledge of primary signal. It is the simplest method for spectrum detection. But it have one drawback that it performs poor when the signal to noise ratio SNR level is low, it is used only for higher SNR. The wireless communication signals mixed with sine, cosine, pulse trains, repeating codes and the signal are cyclostationary because their mean value and autocorrelation functions exhibit periodicity [12]. This periodicity concept is used to perform various signal processing tasks that includes detection, identification and admiration of the received signals.

Even this is complex, a cyclostationary feature detector is mostly preferred for spectrum sensing in low SNR due to its robustness against noise [6, 7, 8, 9, 10]. In this paper, cyclostationary spectrum and Detection of BPSK signal with different SNR and comparison between Energy detection, Matched filter detection and Cyclostationary detection and the algorithm FFT Accumulation method (FAM), simulation results have been discussed.

II. PRINCIPAL OF CYCLOSTATIONARITY

In Cyclostationary signals, their mean value and autocorrelation function have periodicity. In this paper a signal is taken which can be called as primary signal:

\[ x(t) = s(t) + w(t) \]  

Where \( s(t) \) is the primary user transmitted signal and \( w(t) \) is the noise signal.\chie{AWGN} and \( f_o \) is a carrier frequency. It has periodic components that can be find by CR to eliminate it from noise. The periodicity of the mean and autocorrelation functions are expressed by the equations as follows:

\[ N_o(t) = E[x(t)] = N_o(t+T_o) \]  

\[ R_x(t,\tau) = E[(t+\tau/2)x^*(t-\tau/2)] \]

\[ = R_x(t+T_o,\tau+T_o) \]

Where \( T_o = 1/f_o \). Eq.3 indicates that the autocorrelation function is periodic in time \( t \) for each time lag \( \tau \). Using the Fourier series, the autocorrelation function can be expanded as:

\[ R_x(t+\tau/2,\tau-\tau/2) = \sum R_x^\alpha(\tau)e^{i2\pi\alpha t} \]

Where \( \alpha \) is called cycle frequency.

The Fourier coefficient can be obtained by:

\[ R_x^\alpha(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} R_x(t,\tau)e^{-j2\pi\alpha t} \, dt \]  

Where, \( T \) is the measurement interval. Equation (5) will be non-zero when evaluated at \( \alpha = f_o \). For stationary processes like noise, Eq.5 will be zero-valued for \( \alpha \neq 0 \). By taking the Fourier transform of the cyclic autocorrelation in equation (5), the spectral correlation function can be obtained as:

\[ S_x^\alpha(f) = \int_{-\infty}^{\infty} R_x^\alpha(\tau)e^{i2\pi\alpha t} \, dt \]
2.1 BPSK Signal

Generally BPSK modulated signal is defined as follows:

\[ x(t) = a(t) \cos(2\pi f_0 t + \phi_0) \]

Where \( \phi_0 \in (0, \pi) \), and \( a(t) \) is the amplitude.

\[ S_x^c(f) = \begin{cases} 
\frac{1}{T} Q \left( f + \frac{2}{T} - f_0 \right) Q^* \left( f + \frac{2}{T} + f_0 \right) e^{-j2\pi f_0 T/4} & \text{for } a = \frac{T}{2} + kT \\
\frac{1}{4T} Q \left( f + \frac{2}{T} - f_0 \right) Q^* \left( f - \frac{2}{T} - f_0 \right) + \frac{1}{4T} Q \left( f + \frac{2}{T} + f_0 \right) Q^* \left( f - \frac{2}{T} + f_0 \right) & \text{for } a = 0 \\
0 & \text{otherwise}
\end{cases} \]

In both AM and BPSK modulated signal feature using SCF is almost same. But BPSK signal detection feature is thicker then the AM signal.

Here on three axis that is X, Y and Z axis are taken, at X axis spectral frequency, at Y axis cyclic frequency and at Z axis Amplitude of SCF is drawn. Using the autocorrelation function and spectral correlation function for a signal, it can detect weak wireless signals buried in noise [10,11].

III. CYCLOSTATIONARY FEATURE DETECTION

By finding Periodicity in a received signal it can identify the presence of Primary User. The periodicity is commonly embedded in sinusoidal carriers, pulse trains, hopping sequences or cyclic prefixes of the primary signals. Due to periodicity these cyclostationary signals have periodic statistics and spectral correlation which is not found in AWGN noise.

Consider a hypothesis test for signal detection:

\[ x(t) = \begin{cases} 
\eta(t) + n(t) & H_0 \\
\eta(t) + s(t) & H_1
\end{cases} \]

Here \( x(t) \) is the signal received by the unlicensed user, \( s(t) \) is the signal transmitted by the licensed transmitter, \( n(t) \) is the noise introduced by AWGN and is the channel gain. \( H_0 \) is the null hypothesis when there is no primary signal and \( H_1 \) indicates the presence of primary signal. Here Primary user signal is detected and if it not uses the available spectrum then at a particular time it is used by secondary user (Unlicensed user).

3.1 The algorithm used to calculate the Spectral Correlation Function (SCF).

1. Read n samples into vector \( z \)
2. Multiply vector \( z \) with \( \exp(-i\pi\alpha t) \) store in \( x \) (alpha is the cyclic frequency) which will take a series of values for each vector \( z \), \( t \) is the time.
3. Multiply \( x \), \( y \) with a Kaiser window
4. Multiply \( x, y \) with \( a \)\( \times \)Kaiser window
5. Take the N-point FFT of \( x, y \) (N < n)
6. Conjugate \( X \) (the FFT of \( x \))
7. Multiply \( X^* \) and \( Y \)
8. Repeat from 5 until all n samples are processed and sum up the results from 7
9. Normalize the result from 8
10. Repeat from 2 until the entire series of alpha-values are processed

Table 1: Comparison between different spectrum sensing techniques:

<table>
<thead>
<tr>
<th>Detection Method</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Detector</td>
<td>No need of Primary user information, low computation &amp; less expensive</td>
<td>Performance poor at low SNR, Lead to false detection.</td>
</tr>
<tr>
<td>Matched Filter</td>
<td>Require less time to achieve high processing gain.</td>
<td>Prior knowledge of primary user required, need coherent detection.</td>
</tr>
<tr>
<td>Cyclostationary</td>
<td>Perform well at low SNR</td>
<td>Computationally complex, Require large observation time.</td>
</tr>
</tbody>
</table>
IV. SIMULATION RESULTS

Cyclostationary spectrum and detection is performed by using Kaiser window at -5dB and algorithm for finding SCF. By using FFT Accumulation Method (FAM) we generate large peak values at \( \alpha = 0 \) & \( \alpha = \pm f_o \) (carrier frequency).

BPSK signal is used with carrier frequency \( f_o = 30 \) Hz, sampling frequency \( f_s = 100 \) Hz, cyclic frequency \( \alpha = mf_o \), \( m \) is any integer.

![Fig.2. Cyclostationary Spectrum Feature of BPSK signal at -5dB](image)

![Fig.3 Detection of BPSK signal at 10% False alarm](image)

V. CONCLUSION

In this paper study the Algorithm for finding spectrum Correlation function (SCF), Differences between three type of detection techniques shown in Table1, Simulation result to find out SCF of BPSK signal using kaiser window and Fig.4. shows that Cyclostationary detection (CD) performs well at low SNR in comparison to Energy detection (ED). Here Probability of detection of CD shows good detection capacity at -20 dB in comparison to Energy detection.

REFERENCES


