Analysis of Spectrum Sensing Algorithm (Cyclostationarity) for Cognitive Radio Applications.

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Abstract- Dynamic Almost 80 to 90 percent of the radio range is left unutilized at any period, while in the meantime some different areas of range experience stuffing. An intellectual radio is a shrewd radio that can recognize the inactive frequencies (additionally named as unearthly openings or blank areas) and assign them for the utilization of unlicensed optional clients. The fundamental usefulness of a subjective radio is to detect the range precisely by maintaining a strategic distance from any odds for meddling with essential or authorized clients. Range detecting can be performed either in helpful or non-agreeable strategy. The different range detecting plans engaged with psychological radio have dependably been explored and talked about. A perfect identification plan ought to be quick, precise and effective. Cyclostationary highlight location is a recognition conspire that fulfils every one of these criteria. The strategy likewise has the capacity to recognize commotion and the essential client signal. It tends to be utilized for range detecting in an extremely low SNR condition (not exactly - 20 dB). The detecting calculations depend on estimation of cyclic properties of the got sign. One noteworthy bit of leeway of cyclostationary include discovery strategy is that notwithstanding distinguishing the essential client signal, it likewise recognizes the tweak conspire utilized by the essential client. This paper researches the cyclostationary highlight recognition technique under various regulation plans. The cyclostationary include identification is the range detecting technique utilized here. Bit blunder rates for the UWB channel models (CM1/CM2/CM3/CM4) are determined and analysed.

General Terms

Cognitive radio spectrum sensing

Keywords

Cognitive radio, Spectrum sensing, Cyclostationary Feature Detection, Primary User, cyclostationary feature detection, ultra-wideband (UWB) communications, Signal to Noise Ratio (SNR), Power Spectral Density (PSD).

I. INTRODUCTION

The cognitive radio concept dates back to 1998 when the idea was first conceived by Sir Joseph Mitola III at the Royal Institute Of Technology in Stockholm. CR can be termed as an intelligent wireless communication system. It is intelligent because it is aware of its environment and learns from the environment and adapt to any statistical variations in the input stimuli. Cognitive Radio turns out to be a solution to the spectral crowding problem by introducing the opportunistic usage of frequency bands. These frequency bands must not be occupied by licensed users. One most important component of a cognitive radio is its ability to measure, sense, learn, and be aware of the parameters related to the radio channel characteristics, the availability of radio spectrum as well as power, the user requirements and their applications, and also other operating restrictions. The major driving factor behind was the ever-increasing requirement for the radio spectrum. There was an unusual drive for improved communication speeds. The only way to provide communication flexibility was by efficiently utilizing the radio spectrum. Cognitive radio can sense external radio environment and learn from past experiences. It can also access to unused spectrum band dynamically without affecting the licensed users, in such a way to improve the spectrum efficiency. Sensing external radio environment quickly and accurately plays a key role in cognitive radio. Energy detection , pilot detection , and cyclostationary feature detection are three commonly used spectrum sensing methods.

Cyclostationary include recognition is a strategy for recognizing essential client transmissions by misusing the cyclostationarity highlights of the got sign. Cyclostationary highlights are brought about by the periodicity in the sign or in its insights like mean and autocorrelation or they can be purposefully instigated to help range detecting. Rather than power phantom thickness (PSD), cyclic relationship work is utilized for distinguishing signals present in a given range. The cyclostationarity based discovery calculations can separate clamor from essential clients' sign. This is a consequence of the way that commotion is wide-sense stationary (WSS) with no relationship while adjusted sign are cyclostationary with phantom connection because of the repetition of sign periodicities. Moreover, cyclostationarity can be utilized for recognizing among various sorts of transmissions and essential clients .

II. CYCLOSTATIONARY SPECTRUM SENSEING

In wireless communications, the transmitted signals show very strong cyclostationary features based on the modulation type, carrier frequency, and data rate, especially when excess bandwidth is utilized. Therefore, identifying the unique set of features of a particular radio signal for a given wireless access system can be used to detect the system based on the cyclostationary analysis at the cognitive radio node. Cyclostationary feature detection-based technique has been proposed by many researchers as a key solution for detecting these signals. One of the key challenges of CR technology is to reliably detect the presence or absence of primary users at very low signal-to-noise ratio. There are various spectrum sensing techniques available such as the energy detector-based sensing, waveform-based sensing, cyclostationarity based sensing. Cyclostationary feature detection is a method for detecting primary user transmissions by exploiting the cyclostationarity features of the received signals. It exploits the periodicity in the received primary signal to identify the presence of primary users (PU). The periodicity is commonly embedded in sinusoidal carriers, pulse trains, spreading code, hopping sequences or cyclic prefixes of the primary signals. Due to the periodicity, these cyclostationary signals exhibit the features of periodic statistics and spectral correlation, which is not found in stationary noise and interference. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation or they can be intentionally induced to assist spectrum sensing.

III. PRINCIPAL OF CYCLOSTATIONARY

A sign is said to be stationary if its recurrence or phantom substance are not changing as for time. This is on the grounds that when we create a sine wave utilizing either a capacity generator or programming, we chose the recurrence esteem and kept it steady for eternity. Accordingly the recurrence substance of the sine wave won't change with time and subsequently is a case for stationary sign. Assume in the event that you change the recurrence, at that point it through and through turns into another sine wave. Stationarity is connected to the conduct of the recurrence substance of the sign regarding time and that's it.

A cyclostationary process is a signal having statistical properties that vary cyclically with time. A cyclostationary process can be viewed as multiple interleaved stationary processes. These processes are not periodic function of time, but their statistical features indicate periodicities.

A process, say X (t), is said to be Cyclostationary in the wide sense if its mean and autocorrelation are periodic with some period, say T. The Eqn.6.1, 6.2, 6.3 shows conditions which are essential to be filled by a process for it to be Cyclostationary signal:-

$$Ex\,(t + t0) = Ex\,(t) \quad (3.1)$$

$$Rx\,(t + t0;\, T) = Rx\,(t;\, T) \quad (3.2)$$

Where

$$Rx = Ex\,(t + t0)\, x\,(t) \quad (3.3)$$

Thus both the mean and auto-correlation function for such a process needs to be periodic with some period say T0. The cyclic auto-correlation function (CAF) is represented in terms of Fourier co-efficient as:

$$R_x^{n/T_0}(\tau) = \frac{1}{T_0}\int_{-T_0/2}^{T_0/2} R_x(t,\tau)e^{-j2\pi(n/T_0)t}dt \quad (3.4)$$

Where 'n/T0' represent the cyclic frequencies and can be written as 'α' . The Cyclic Spectral Density (CSD) representing the time averaged correlation between two spectral components of a process which are separated in frequencies by 'α' is given as:

$$S(f,\alpha) = \int_{\tau=-\infty}^{\infty} R_x^{\alpha}(\tau)e^{-j2\pi f\tau}d\tau \quad (3.5)$$

The cyclic spectrum density (CSD) represents the density of the correlation between two spectral components. Cyclic Spectral Density is also named as Spectral Correlation Function (SCF). And

$$S_x^{\alpha}(f) = \int_{-\infty}^{+\infty}\left[\frac{1}{T}\int_{-\frac{1}{T}}^{+\frac{1}{T}} R_x\left(t+\frac{\tau}{2}, t-\frac{\tau}{2}\right)e^{-j2\pi\alpha t}dt\right]d\tau, \quad (3.6)$$

SCF can be measured by the normalized correlation between two spectral components of x(t) at frequencies (f + G/2) and (f - G/2) over an interval of length _t. Taking those into consideration SCF can be express as

$$S_x^{\alpha}(f) = \lim_{T\to\infty}\left[\lim_{\Delta t\to\infty}\frac{1}{\Delta t}\int_{-\Delta t}^{+\Delta t}\frac{1}{T}X_T\left(t,f+\frac{\alpha}{2}\right)X_T^*\left(t,f+\frac{\alpha}{2}\right)dt\right] \quad (3.7)$$

Where, finite time Fourier transform is,

$$X_T(t,u) = \int_{t-\frac{T}{2}}^{t+\frac{T}{2}} x(u)\,e^{-j2\pi u}du \quad (3.8)$$

Here, the power spectral density is a special form of spectral correlation function for α = 0, where α is cyclic frequency. However, cyclostationary detection requires a large computational capacity and significantly long observation times, so difficult to implement. Further, it cannot detect the type of communication, so it reduces the flexibility of CR. Cyclostationary feature detection method is also called as spectral correlation method because it uses cyclic correlation function for detecting present of signal in a given spectrum. These processes having periodicity in statistical property like mean, auto- correlations are Cyclostationary. By using periodic statistics of primary user wave-form, CR can detect random signal in presence of noise. And these features are extracted using spectral correlation function. Fig.6.2 represent basic block diagram of Cyclostationary based detection method. Man-made modulated signals are, in general, coupled with sine-wave carriers, pulse trains, coding, repeating spreading, hopping sequences, or cyclic prefixes, resulting in built-in periodicity.

These modulated signals are characterized by second order Cyclostationary if their mean and autocorrelation display periodicity. For stationary signals, no overlapping frequency bands are typically uncorrelated. However, the inherent periodicities of Cyclostationary signals imply some spectral redundancy, which results in correlation between those no overlapping spectral components separated by some multiple of the cycles. . Consider a scalar waveform x (t) is Cyclostationary in nature then the cyclic autocorrelation function given by correlation between x (t) and x (t) shifted by cyclic frequency α is given by Eqn4.

$$R(T) = x(t).x^{*}(t)\exp - j2\pi \propto t \qquad (3.9)$$

Where * is a conjugate of scalar waveform, (.) is infinite time average, α is cycle or conjugate frequency. Then the spectral correlation density is equivalent to the spectral correlation function which is obtain by taking Fast Fourier Transform of cyclic autocorrelation.

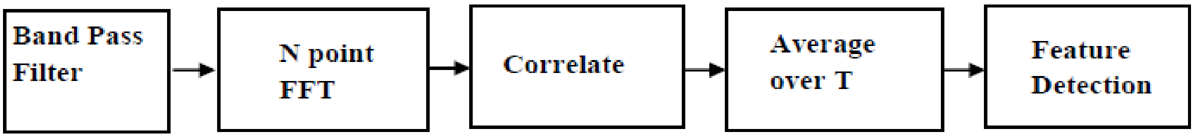

Fig.3.1 - Block Diagram of Cyclostationary Detection

The SCD function allows for modulation recognition based on the pattern of the cycle (or conjugate cycle) frequencies. The performance of the feature detector also depends on how much energy a feature contains, and different modulation schemes have features with different energy patterns. The SCF function causes peak at the cyclic frequency. The SCF function causes peak at the cyclic frequency. If the maximum value of SCF is greater than threshold then hypothesis H1 true. The SCF does not have any peak as user absent and noise is non Cyclostationary signal so the hypothesis H0 is true. The Cyclostationary Detection can be separate noise from the Primary User signal and also used to detect the weak signal in low SNR region, where energy detection is not applicable. In the Cyclostationary detection use the FFT to obtain spectral correlation density, but the magnitude of the spectrum is spread over the entire frequency range which called as spectrum leakage. So the use of windowing method can overcome the spectrum leakage.

Cyclostationary feature detection based on introduction of periodic redundancy into a signal by sampling and modulation. The periodicity in the received primary signal to identify the presence of Primary Users (PU) is exploited by Cyclostationary feature detector which measures property of a signal namely Spectral Correlation Function (SCF) given by

$$S_x^{\infty}(f)=\int_{-\infty}^{\infty} R_x^{\infty}(\tau)e^{-j2\pi f\tau}\,d\tau \qquad (3.10)$$

Cyclostationary include finder execution can separate the tweaked sign from the added substance clamor, recognize Primary User signal from commotion. It is utilized at extremely low SNR location by utilizing the data implanted in the Primary User signal which does not exist in the commotion. This procedure is strong to clamor segregation and it performs superior to vitality identifier. It has inconvenience of progressively computational multifaceted nature and longer time perception.

IV. CYCLOSTATIONARY FEATURE DETECTION MODEL

A cyclostationary process is a signal having statistical properties that vary cyclically with time. A cyclostationary process can be viewed as multiple interleaved stationary processes. These processes are not periodic function of time, but their statistical features indicate periodicities.

Sensing external radio environment quickly and accurately plays a key role in cognitive radio. Energy detection, matched filter detection, and cyclostationary feature detection are three commonly used spectrum sensing methods. Energy detection is easy to implement, but its performance degrades greatly under low signal-to- noise ratio (SNR) or with noise uncertainty. Match filter detection can detect signals with low SNR, but it needs the licensed user's prior knowledge and perfect synchronization, which is hard to realize. Cyclostationary feature detection is a method for detecting primary user transmissions by exploiting the cyclostationarity features of the received signals. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation or they can be intentionally induced to assist spectrum sensing.

Physical phenomena that involve periodicities give rise to random data for which appropriate probabilistic models exhibit periodically time-variant parameters. For example, in mechanical-vibration monitoring and diagnosis for machinery, periodicity arises from rotation, revolution, and reciprocation of gears, belts, chains, shafts, propellers, bearings, pistons, and so on; in atmospheric science (e.g., for weather forecasting), periodicity arises from seasons, caused primarily by rotation and revolution of the earth; in radio astronomy, periodicity arises from revolution of the moon, rotation and pulsation of the sun, rotation of Jupiter and revolution of its satellite and so on, and can cause strong periodicities in time series (e.g., pulsar signals); in biology, periodicity in the form of biorhythms arises from both internal and external sources (e.g., circadian rhythms); in communications, telemetry, radar, and sonar, periodicity arises from sampling, scanning, modulating, multiplexing, and coding operations, and it can also be caused by rotating reflectors such as helicopter blades and air- and water craft propellers. For these and many other examples, the periodicity can be an important characteristic that should be reflected in an appropriate probabilistic model. Therefore, stationary processes, with their time-invariant probabilistic parameters, are In general inadequate for the study of such Phenomena and Cyclostationary processes are indicated. For example, various specific models of Cyclostationary processes, including sampled and-held noise, amplitude modulation, pulse-amplitude, width, and position modulation, and phase or frequency modulation.

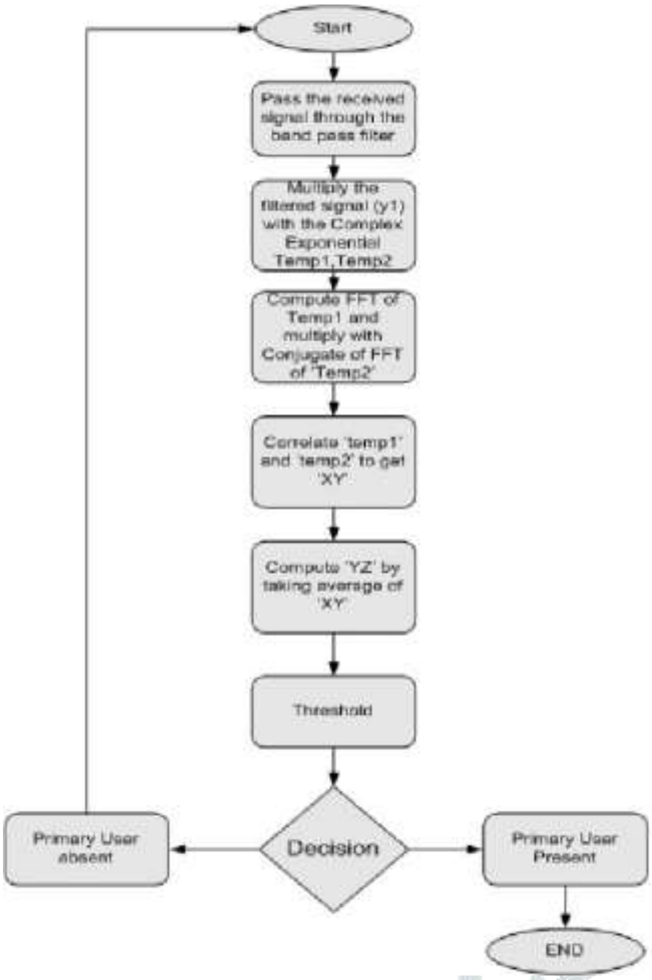

Fig.4.1 Process Flow diagram of Cyclostationary feature Detection

V. RESULTS AND ANALYSIS

An extensive set of simulations have been conducted using the system model as described in the previous section. The emphasis is to analyze the comparative performance of cyclostationary spectrum sensing technique. The performance metrics used for comparison include the "probability of false detection". The number of channels and the number primary users considered in this analysis is twenty-five and respectively. The SNR of the channels is considered to be precisely same and the channel model is A W G N with zero mean. The results are

1. Probability of Detection

It is the capacity of Cognitive Radio to recognize the accessibility essential flag by contrasting approaching sign and the edge one. For better execution estimation of this parameter ought to be high. For this we require limit esteem we taken it as chi square yet straightforward comprehension we take it as T and approaching sign is taken as P it implies it is a force level of approaching sign. what's more for vitality identification we must need a high SNR for better execution on the grounds that this technique for discovery is falls flat at lower SNR. We characterize the SNR as the proportion of the normal got sign force to the normal clamor power we require the likelihood of false caution Pf Then the limit is discovered in view of the formulae in Section For correlation, we likewise reenact the vitality discovery with or without commotion vulnerability for the same framework. The edge for the vitality location is given in. At commotion instability case, the limit is constantly situated in light of the accepted/assessed clamor force, while the genuine clamor force is changing in every Monte Carlo acknowledgment to a certain degree as determined by the commotion vulnerability element For Understand basically we take as basic e.g. as; For e.g.: - P>T then flag is accessible means no vacant band and the other way around. From this it is clear that we require a high SNR for better use So for better use this component must be higher.

Probability of detection is given by:

$$P_d = Q\left(\sqrt{SNR_{avg} * 2 * m},\left(\sqrt{Th(i)}, m\right)\right)$$

Where

$$Th(i) = gaminv\left(1 - P_f(i), m, 1\right) * 2$$

2. Probability of False Detection

Due to vicinity of considerably more Noise can command on the level on genuine approaching sign and along these lines P>T because of vicinity of commotion and cognitive Radio take it as force level of approaching sign and it can distinguish the sign and this think is called False Detection in the channel some time cognitive radio can false recognize the sign so estimation of this parameter must be low.

$$P_f = (Base)^2$$

Where

$$Base = 0.01:0.02:1$$

3. Probability of Miss Detection

Now and then cognitive Radio get to be not able to recognize the sign vicinity that is called miss identification, so estimation of this parameter ought to be low. Furthermore, chart evidence of both of these parameters indicated combinedly.

False alarm probability for energy detection is calculated as:

Probability of miss is given by:

$$P_m = 1 - P_d$$

4. SNR

Signal-to-noise ratio is defined as the ratio of the power of a signal to the power of background noise (unwanted signal) Signal-to-noise ratio is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. SNR is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.

$$SINAD = \frac{\overbrace{\underbrace{P_{signal}}_{\text{Wanted component}} + \overbrace{P_{noise} + P_{distortion}}^{\text{Unwanted component}}}^{\text{Total signal power}}}{\underbrace{P_{noise} + P_{distortion}}_{\text{Unwanted component}}}$$

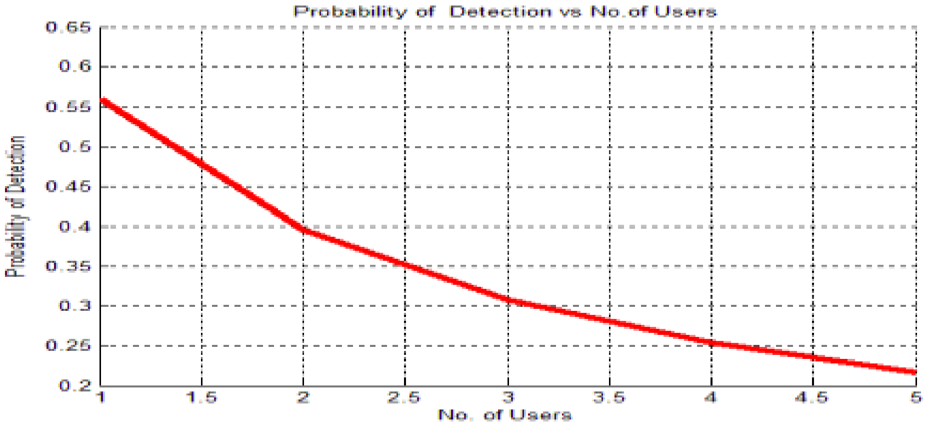

Fig.5.1

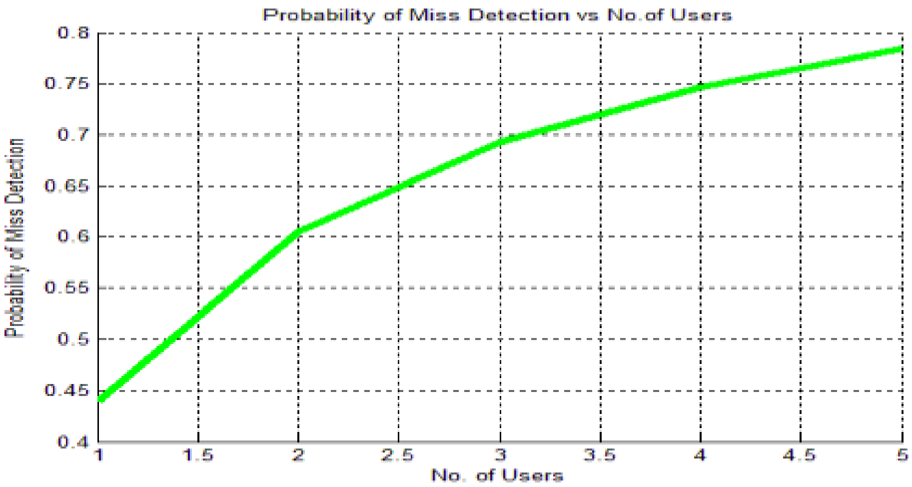

Fig.5.2

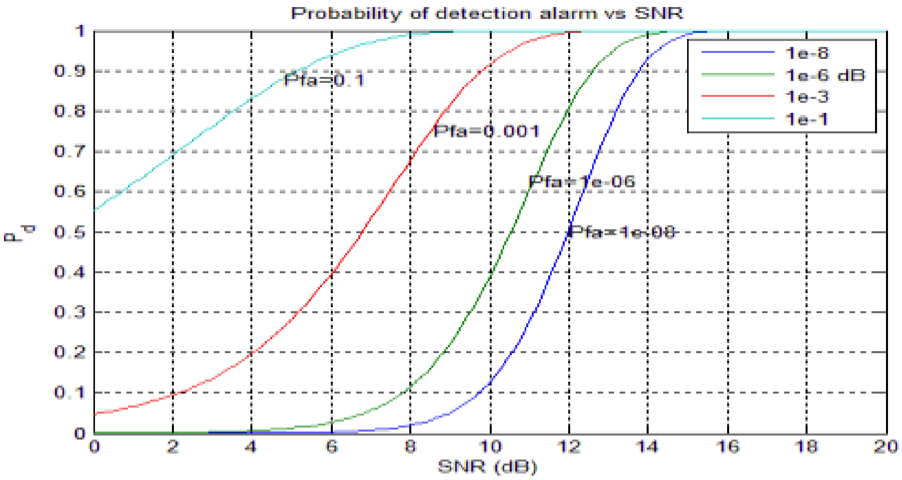

Fig.5.3

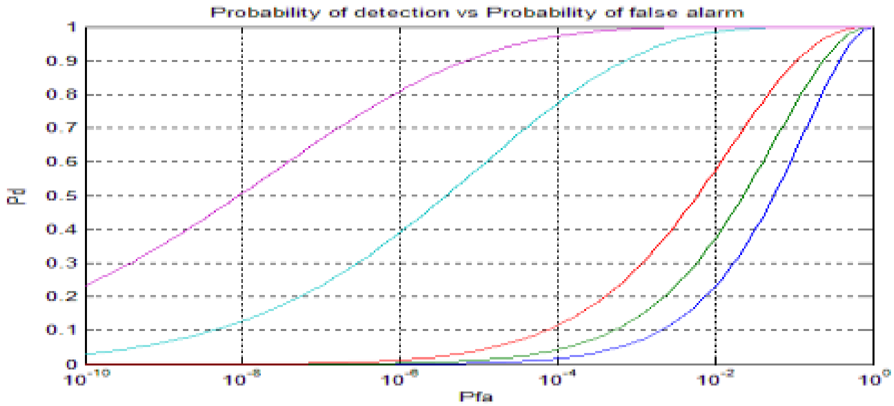

Fig.5.4

VI. CONCLUSION

To productively use the remote range intellectual radios were presented which craftily use the openings present in the range. The most fundamental part of an intellectual radio framework is range detecting and different detecting systems which it uses to detect the range. In this paper the primary spotlight was on Energy Detection, Matched Filter Detection and Cyclostationary highlight Detection range detecting methods. The benefit of Energy recognition is that, it doesn't require any earlier learning about essential clients. It doesn't perform well at low SNR values; it requires a base SNR for its working. The outcome in the paper demonstrates that Energy identification begins working at - 7 dB s of SNR. Coordinated channel location is superior to vitality identification as it begins working at low SNR of - 30 dB s. Cyclostationary include recognition is superior to both the past identification strategies since it delivers better outcomes at least SNR, for example for qualities beneath - 30 dB s. the outcomes demonstrates that the presentation of vitality recognition shows signs of improvement with expanding SNR as the "likelihood of essential location" increments from zero at - 14 dB s to 100% at +8 dB s and correspondingly the "likelihood of false discovery" improves from 100% to zero. Comparative sort of execution is accomplished utilizing coordinated channel location as "likelihood of essential recognition" and the "likelihood of false discovery" demonstrates improvement in SNR as it shifts from -30 dB s to +8 dB s. the cyclostationary highlight discovery dominates the other two detecting strategies as 100% "likelihood of essential location" and zero "likelihood of false recognition" is accomplished at - 8 dB s, however the handling time of cyclostationary include identification is more noteworthy than the vitality location and coordinated channel identification systems.

The second-request cyclic highlights worked in regulated sign is utilized to identify the sign. Because of high intricacy of cyclostationary highlight identification, we identify explicit frequencies and cyclic frequencies dependent on the sign's element to debase unpredictability incredibly. We analyze the identification execution of various focuses to locate the best recognition focuses through recreation examination and propose to blend discovery technique utilizing numerous discoveries focuses to show signs of improvement execution. Results approve the viability of the proposed discovery technique.

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