Analysis of Energy Detection & Cyclostationary Techniques for the Utilization of Spectrum in Cognitive Radios

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ABSTRACT
Sensing of channel for detecting the presence of primary user and here use the Energy Detection and cyclostationary Techniques in Cognitive Radio the behaviors of this distribution Schemes in Cognitive Radio is mainly depends upon three parameters like Probability of Detection, Probability of False detection and Probability of Miss detection. If there is any vacant space in the channel then it must be provided to secondary users. In this paper inverse chi square with N degree of freedom has been used for the detection of presence of primary users. SCF algorithm and MIMO channel algorithm has been used for Cyclostationary and Energy detection respectively. And it has been analyzed that the cyclostationary detection technique is best for sensing and the best outcome has been found out at -23.db SNR, further by using the different channels in the media it has been found out that the Rayleigh Channel is best among the three channels being used, which gives the minimum value of false detection.

Keywords
Cognitive Radio, Sensing Algorithms, Signal Detection and Spectrum Sensing.

1. INTRODUTION
Cognitive Radio is best technology that is used for the proper utilization of Spectrum. It is a technology for eliminating the in efficient spectrum utilization problem

Under the current static spectrum-allocation policy [1-3]. Today, by increasing the demand of wireless applications, the problem of spectrum availability is becoming apparent. Most of the spectrum has been allocated to specific users, are known as primary user while other spectrum bands that haven't been assigned are secondary user. However, most of the allocated spectrums are not properly utilized. So their need a technique to deal with the problem of spectrum under utilization, which makes the requirement of cognitive radio [22].

Cognitive radio can sense external radio environment and updates the parameter with the environment. It can analyze the unused spectrum band dynamically without affects the primary users. Sensing mean identify the free frequency band in radio environment quickly and accurately. A key role in cognitive radio[23-24] is to provide highly reliable communication for all users of the networks wherever and whenever they needed and facilitate efficient utilization of the radio spectrum in a fair-minded and cost-effective manner.

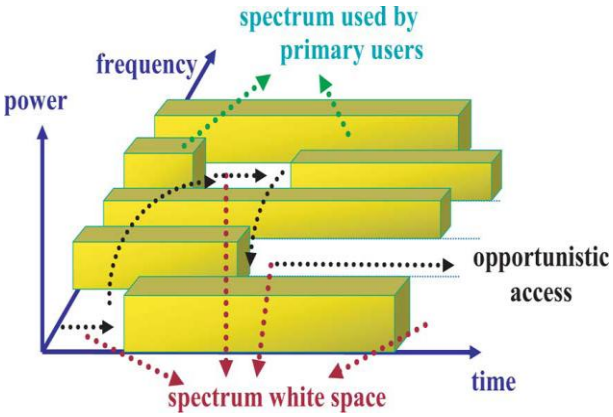

Figure: Show the utilization of frequency band

This figure shows the usage of frequency at different power and frequency level with respect to time. Here the word oppturnity for secondary users. This vacant space can be found by sensing the channel by different techniques like Energy detection and cyclostationary. In [4-9] the performance of Energy Detection was studied and it was analyzed that. but there was poor performance of Energy detector at low SNR and presence of error further reduce the performance of the system. In this way it is possible to improve the performance of traditional circuit without adding much more attention to the previous circuit.

The FCC has suggested cyclostationary detectors as a useful alternative to enhance the detection sensitivity in CR networks. Mathematically, cyclostationary detection is realized by analyzing the cyclic autocorrelation function (CAF) [12] of the received signal, or, equivalently, its two-dimensional spectrum correlation function (SCF)[13] since the spectrum redundancy caused by periodicity in the modulated signal results in correlation between widely separated frequency components [13], [14]. As a spectrum sensing scheme in CR, cyclostationary detection is specially best techniques because it is more capable of distigunished the primary signal from noise. Due to its noise rejection property of cyclostationary detection it can works even in very low SNR region, where the traditional signal detection method like Energy Detection fails. In cyclostationary detectors have been explained to enhance the detection capability especially in the presence of noise power uncertainty.

ORGANIZATION OF THIS PAPER

In this paper the energy detection and cyclostationary detection scheme for sensing the spectrum and providing the vacant spaces to secondary user without disturbing the primary users has been used. As these techniques gives the best result of detection at different SNR[25].

A ENERGY DETECTION SCHEME

Energy based detection technique is widely used in spectrum sensing and it is the primary transmitter detection technique which is used to detect the vacant hole in the spectrum. This technique is most popular because of its less computational and complex and the knowledge of primary user signal is not required in detection process. Figure shows the different steps used to find performance of spectrum using energy detection technique

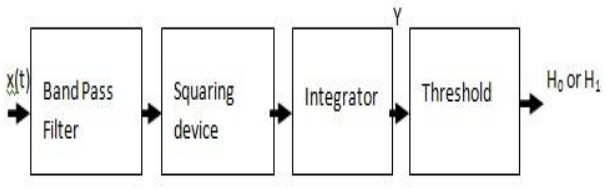

Figure: Block Diagram of Energy Detection[26].

Here x(t) is received signal for energy detection and band pass filter is used to select the particular bandwidth or frequency which we want to check and band pass filter also limiting the noise level in the incoming signal, The output of band pass filter is sent to squaring device which is used to calculate the power the selected signal after that it is transmitted to integrator block For making the signal compatible to threshold block and in this block decision about the presence or absence of primary is carried out.

In Energy Detection scheme a new algorithm inverse chi-square distribution has been used for detection .and working procedure of energy detector mathematically is shown below:-

$$Z(i) = P(i) \quad \text{.....1}$$

$$Z(i) = j * t(i) + P(i) \quad \text{.....2}$$

Where Z (i) is the sample kϵ{1, 2….N} to be analyzed at each instant i and P (i) is the noise of variance σ2 then a decision rule can be stated as,

W0…… if ε > v.....3

W1…… if ε < v.....4

Where ε = E0 |Z(i)|2 the estimated energy of the, Received signal and v is chosen to be the noise variance σ2 .

In spectrum sensing threshold calculator is used to

$$X = \text{chi2inv}(P, V) \quad \text{.....5}$$

This equation computes the inverse of the chi-square cdf with degrees of freedom specified by V for the corresponding probabilities in P.

The degrees of freedom parameters in V must be positive integers, and the values in P must lie in the interval [0 1].

The inverse chi-square for a given probability p and ν degrees of freedom is given as:

$$\alpha = F^{-1}\left(\frac{\sigma}{v}\right) = \{\alpha : F = \left(\frac{\alpha}{v}\right) = \sigma\}$$

where

$$\sigma = F\left(\frac{\alpha}{v}\right) = \int_0^x \frac{t^{\frac{(v-2)}{2}} e^{-2}}{2^{v/2}\Gamma\, v/2}$$

and Γ(·) is the Gamma function. Each element of output is the value whose cumulative probability under the chi-square defined by the corresponding degrees of freedom parameter.

B Spectrum Sensing using cyclostationary based detection

Cyclostationary sensing technique is a best technique for the detection of primary signal in sensing spectrum cyclostationary mainly works with the periodicity for checking the status of the channel [14].

Man-made signals are generally non stationary. Some of them are cyclostationary, i.e., their statistics exhibit periodicity, which may be caused by modulation, coding or even be intentionally produced to finding channel estimation and synchronization. Such periodicity can be used for detection of a incoming random signal with a particular modulation in a presence of noise and other modulated signals. It is called as cyclostationary detection. In [15] cyclostationary detection and optimal data fusion has been considered for improve the overall detection performance of CR networks

The essential conditions to be obeyed by a process to be wide sense Cyclo-stationary are:

$$\text{Eo}[q(t + \text{Ro})] = \text{E}[x(t)$$

$$R_x(t + R_o, \tau) = R_x(t, \tau)$$

Here $R_x = E\{x(t + \tau)q(t)$

Thus, both the mean and auto-correlation function for such a process needs to be periodic with some period say T0.

The periodicities of primary user signal can be found out simply by taking their correlation which enhances their similarities. When the Fourier transform of the correlated signals are taken peaks at frequencies are obtained which are specific to a signal and primary user's presence can be determined be searching for these peaks. As Noise is a random signal, no peak is obtained due to its correlation and hence it does not get highlighted. Only peak due to noise is obtained at α=0.

Cyclostationary detector implementation:

The signal for cyclostationary detector is generated in the same way as that of energy detector. Similarly the signal is modulated and noise is added. Then the signal is received and afterwards the SCF i.e. spectral correlation function is calculated then distributed into linear array which is then compared with the threshold and the decision is made accordingly.

2. FLOW CHART OF ENERGY DETECTION AND CYCLOSTATIONARY DETECTION

Flow chart represents the step by step working of both the technique which we used above under the named Energy and Cyclostationary detection for spectrum sensing or making the decision of primary presence or absence we cheak the relation between the parameters like Pd and SNR.

As shown in flow chart or theory it is sufficient to give the difference between both techniques In Energy detector there is need generate a signal first according to parameters and after that these generated signal are transmit over the channel in which it can use any channel but prefer here MIMO and then some fading noise is added to it and there is different

formulas for calculate the average noise power and compare it with threshold value and take decision about the presence of primary detection our main is to generate the signal is that how designed detector can detect upto low SNR. Similarly it can give brief information about the cyclostationary is that in this case we generate a signal and passes it to window function which are already declared, and here use Kaiser window here and after that shifting of signal take place by taking its FFT. And convolution of signals take place for found the SCF of each signal after the foundation of SCF and compare it with the threshold to take the decision.

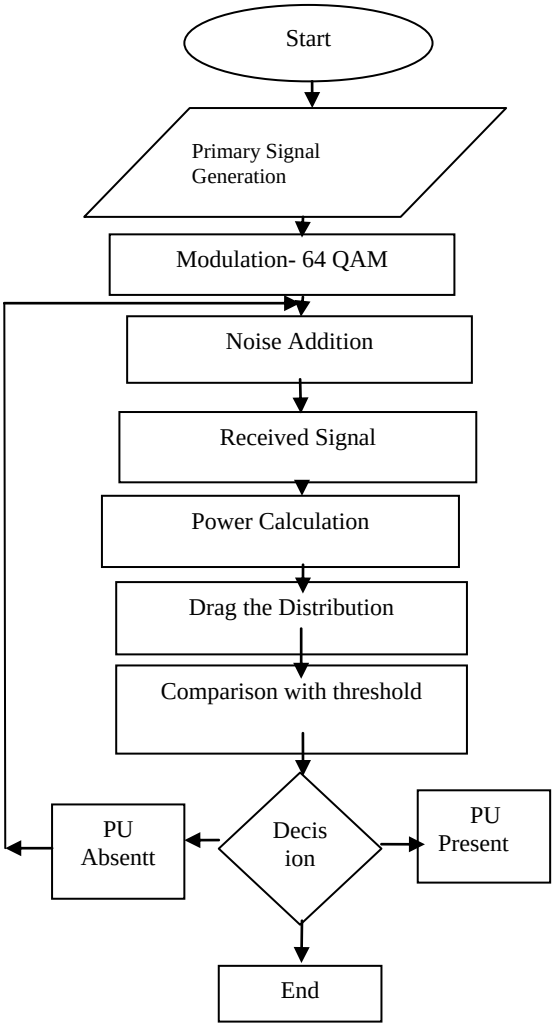

Figure: Flow Chart of Energy detector

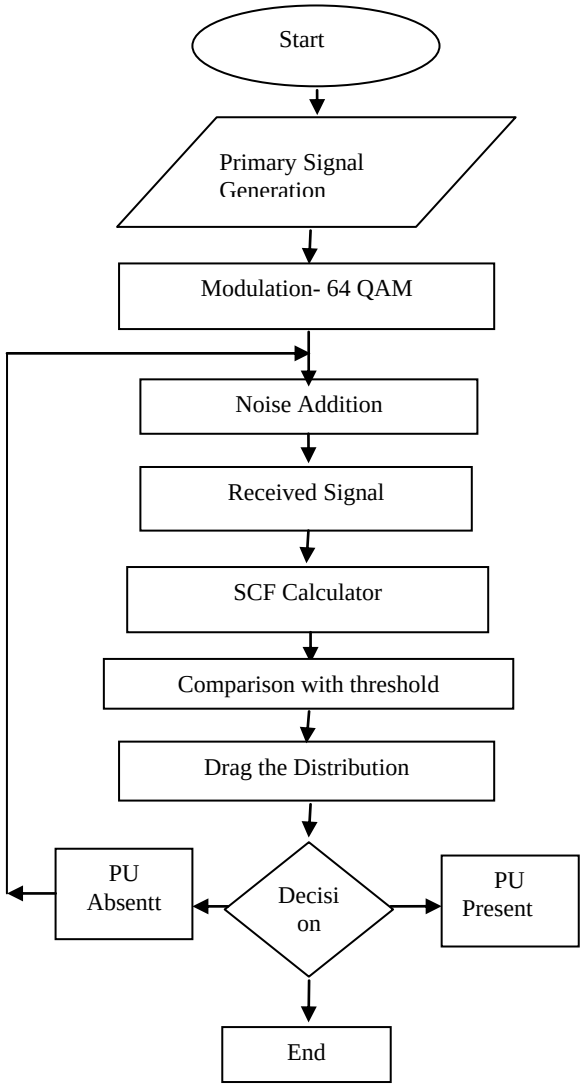

Figure: Flow Chart of Cyclostationary detector

3. SIMULATION PARAMETERS

Simulation parameter that are used in both technique are shown in table below:

In the table 1montecarlo runs were taken to be 10000 it means according to program loop will move upto 50 times and for each value of i (10000 times these will runs and check the status of channel) and it is probabostatic model, and there is sampling point that is 50 and here it use 16-PSK for modulation. These modulation works on that signal which are generated by us and as know there is necessary of some phase shift between the different signals so here take phase shift in generated signal which is 1/6*pi. And take probability of false alarm is 0.1.

Type	Energy detection	Cyclostationary detection
Montecarlo runs	10,000	10,000
Sampling points N	50	50
Modulation	16-PSK	16-PSK
Int_phase	1/6*pi	1/6*pi

Signal	A*sin(2*pi*F0/Fs*t + init_phase	A*sin(2*pi*F0/Fs*t + init_phase
false alarm rate (pf)	0.1	0.1

4. SIGNAL OVER DIFFERENT FADING CHANNELS MIMO CHANNEL

As proceed towards the edge of new technologies grow up more effectively and most efficiently. In the same way multiple antenna spectrum sensing is a new idea in cognitive radio technology the gains achievable by a MIMO system in comparison to a Single Input Single Output (SISO) one can be described stringently by information theory. A lot of research in the area of MIMO systems and Space Time Coding is based on this mathematical proof given by Shannon [17]

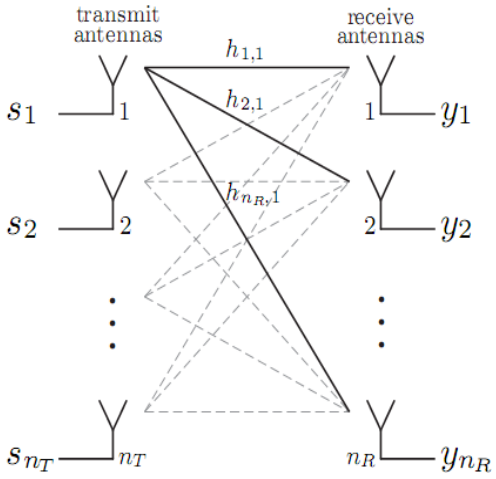

Figure: MIMO Channel with Multiple Inputs and Outputs

It is clear that if theirs are use of multiple antennas at secondary user then of probability of detection higher can be found [16].

So major benefits from MIMO [18] are Higher capacity (bits/s/Hz). (spectrum is expensive; so number of base stations are limited), Better transmission quality Increased coverage and Improved user position estimation.

RAYLEIGH Channel

In a wireless communication channel, the transmitted signal can travel from transmitter to receiver over different multiple reflective paths. This gives rise to multipath fading which causes some fluctuations in amplitude, phase and angle of arriving in the received signal at the reciver.

The delays associated with different signal paths in a multipath fading channel change in an different manner and can only be characterized statistically. In selected case the Rayleigh Fading model is considered only two multipath components X(t) and Y(t). Rayleigh Fading can be obtained from zero mean complex Gaussian processes (X(t) and Y(t)). Simply addes the two Gaussian Random variables and taking the square root (envelope) gives a Rayleigh distributed process.

RICIAN Channel:

Rician fading is a stochastic model radio propagation anomaly caused by partial cancellation of a radio signal by itself and the signal arrives at the receiver by several different multiple paths (hence exhibiting multipath fading) and atleast any one of the paths is varying (lengthening or shortening). Rician fading occurs when one of the paths is typically a line of sight is much stronger than the others..

5. RESULT AND DISCUSSION

As we studied in previous systems there was first need to generate a signal and cheak the channel for detection the presence of primary for presenting the different users on the selected signal as shown below.

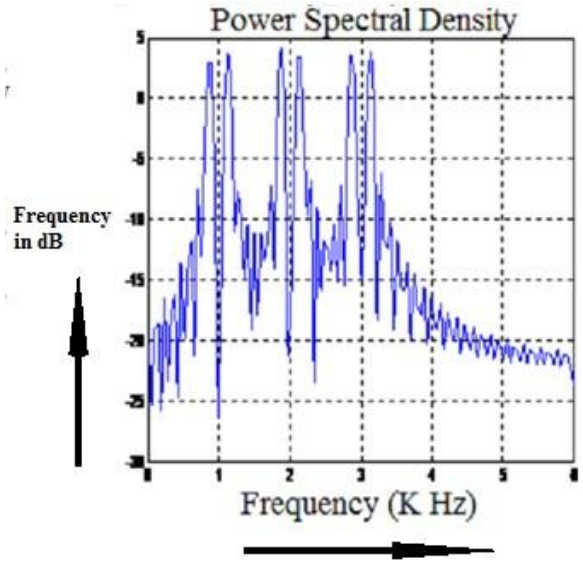

Figure: Shows the Presence of Primary Users

According to Programming code shows the first three users are Presents as a primary but last two spaces are free for the secondary one. Secondary Users can occupy these free spaces.

if want to add a secondary user at 4th position then according to designed MATLAB coding Fig becomes.

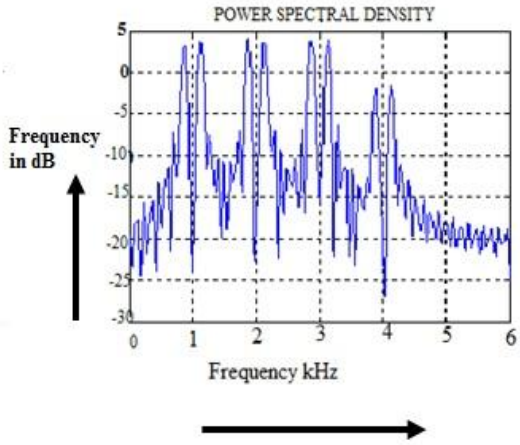

Figure:- Shows the Presence of Secondary at vacant Space

The all above graphs shown about the presence of signal but here also find the effect the noise and attenuatation on signal for different windows as discussed earlier [21]

And here showing the detecting graph of designed programming in which use two detecting technique namely

Energy Detection Technique and Cyclostationary technique for detection process As already explained mentioned use here MIMO and SCF simulation for Energy detection and Cyclostationary detection respectively. And here use 10000s simulation for better results with Monty Carlo parameter.

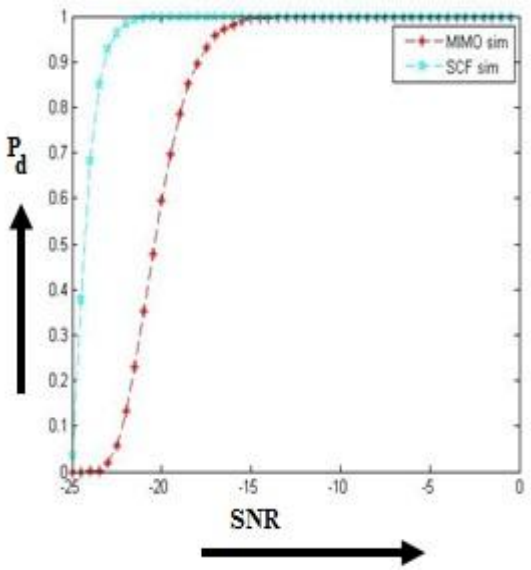

Figure:- Shows the detection in Energy and Cyclostationary detection at different SNR

As shown here it is clear that cyclostationary is better detector at low SNR. Shows the detection process at -25 low values of SNR also shows our results at -50 or at negative of hundreds it means according to designed programming it can detect the signal upto negative hundreds which are not possible in any previous system.

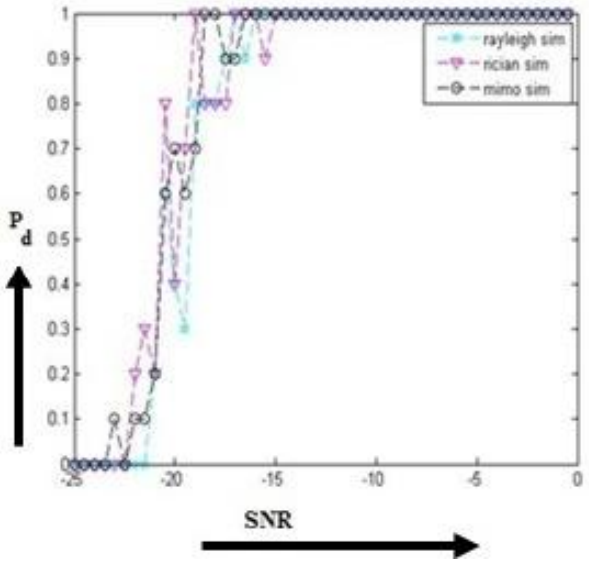

Figure:- Shows the detection on different channels

Here discuss the various kind of factors on signal pictorially and different kind of noise effects and attenuation factors are also shown on signal. And first of all shown the figure

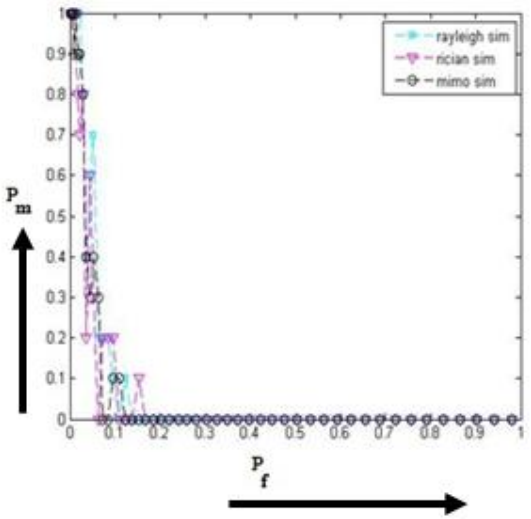

Figure:- Comparison of parameter of detector

Here in figure shown the comparison of probability of miss detection v/s the probability of false detection and here use different simulation channel for making results they shows that with the increase false detection miss detection become constant and here show the results for different channel as shown.

6. COMPARISON TABLE FOR ENERGY AND CYCLOSTATIONARY DETECTION TECHNIQUE

In the above table comparison of detection technique under the name of Energy Detection and Cyclostationary detection is shown. Here it makes the decision about the detection process. From the reading of above table it is clear that Cyclostationary detection technique is approximately (80%) better than Energy detection Techniques.

Because as seen in table cyclostationary detection achieve Pd =1 at -23.5db SNR while Pd =1 is achieve at -17db SNR. So cyclostationary is better for detection process.

	Energy Detection		**Cyclo-stationary**	
S.NO	SNR	**Pd**	**SNR**	**Pd**
1	-25.0	**0.0**	**-25.0**	**0.0**
2	-23.0	**0.0**	**-24.5**	**0.5**
3	-22.5	**0.2**	**-23.5**	**1.0**
4	-22.0	**0.1**	**-23.0**	**1.0**
5	-21.5	**0.4**	**-21.5**	**1.0**
6	-20.5	**0.6**	**-20.0**	**1.0**
7	-20.0	**0.8**	**-19.5**	**1.0**
8	-17.5	**0.9**	**-18.0**	**1.0**
9	-17.0	**1.0**	**-17.0**	**1.0**
10	-16.5	**1.0**	**-16.5**	**1.0**

Comparison Table of Detection for Differ rents Channels

	Rayleigh		Rician		MIMO	
S.NO	Pd	**SNR**	**Pd**	**SNR**	**Pd**	**SNR**
1	0.0	**-25.0**	**0.0**	**-25.0**	**0.0**	**-25.0**
2	0.0	**-24.0**	**0.0**	**-23.5**	**0.0**	**-23.0**
3	0.0	**-23.0**	**0.1**	**-23.0**	**0.2**	**-22.0**
4	0.0	**-21.5**	**0.0**	**-22.5**	**0.4**	**-21.0**
5	0.2	**-21.0**	**0.1**	**-22.0**	**0.6**	**-20.5**
6	0.6	**-20.5**	**0.4**	**-21.0**	**0.5**	**-19.5**
7	0.4	**-20.0**	**0.6**	**-20.5**	**0.9**	**-19.0**
8	0.3	**-19.5**	**0.8**	**-20.0**	**1.0**	**-18.5**
9	0.8	**-19.0**	**0.1**	**-17.5**	**0.7**	**-18.0**
10	1.0	**-17.0**	**0.8**	**-17.0**	**1.0**	**-16.0**

Here also found the results of detection at different SNR for different Channels as shown below

In this table we found the probability of detection for different value of SNR and here also compare the results for different channel. From the table it is clear that Pd =1 is achieving fast at Rayleigh channel so it is best channel for Cognitive Radio.

Comparison Table of Detection Parameter for Different Channels

	Rayleigh		Rician		MIMO	
S.NO	P_m	$\mathbf{P_f}$	$\mathbf{P_m}$	$\mathbf{P_f}$	$\mathbf{P_m}$	$\mathbf{P_f}$
1	1.0	**0.0009**	**1.0**	**0.0049**	**1.0**	**0.0025**
2	0.8	**0.0289**	**0.9**	**0.0081**	**0.8**	**0.0169**
3	0.4	**0.0361**	**0.6**	**0.0225**	**0.6**	**0.0289**
4	0.6	**0.0441**	**0.4**	**0.0361**	**0.4**	**0.0441**
5	0.7	**0.0529**	**0.3**	**0.0529**	**0.3**	**0.0841**
6	0.2	**0.0841**	**0.3**	**0.0625**	**0.1**	**0.0961**
7	0.1	**0.0961**	**0.2**	**0.0841**	**0.0**	**0.1089**
8	0.1	**0.1225**	**0.0**	**0.0961**	**0.1**	**0.1225**
9	0.0	**0.3025**	**0.2**	**0.1089**	**0.0**	**0.1369**
10	0.0	**0.9801**	**0.0**	**0.1369**	**0.0**	**0.9801**

In the above table we found the value of parameters of detection techniques whose names are probability of miss detection (Pm) and probability of false detection (Pf). And as we know that for better detection we need to found the minimum value of Pf as possible so from above table it is clear that Rayleigh Channel is best for detection technique as we already explained.

7. CONCLUSION AND FUTURE SCOPE

Spectrum sensing means to check status of channel and detect the presence of primary user on that channel and if primary user is not present then vacant band is assigned to secondary users. There are many different techniques for detection of channels. And there two techniques namely Energy Detection and Cyclostationary detection have been used. Cyclostationary feature detection (CFD) can be used to perform the task of sensing the spectrum for PUs presence. And other detection technique namely Energy Detection is also used where information of primary signal is not requires. In this thesis detection level of channel is also improved. In this coding used here Energy detector can also found the best result even at lower SNR.

In future, detection level can be improved further by using different method. Noise and Attenuatation level may be further reduced in future. Others new algorithm can be made for better results

8. REFERENCES

[1] FCC. Spectrum policy task force report. *ET Docket No. 02-135*, November 2002.

[2] FCC. Facilitating opportunities for flexible, efficient, and reliable spectrum use employing cognitive radio technologies. *ET Docket No. 03-108*, December 2003.

[3] FCC. Notice of proposed rulemaking and order. *ET Docket No. 03-322*, December 2003.

[4] Z Ye, J Grosspietsch,G Memik, "Spectrum Sensing Using Cyclostationary Spectrum Density for Cognitive Radios," *IEEE Workshop on Signal Processing Systems*, pp.1-6, 2007.

[5] K. Kim, I. Akbar, K.K. Bae, J.S. Um, "Cyclostationary Approaches to Signal Detection and Classificaton in Cognitive 96 Radio," *IEEE International Symposium on DySPAN 2007*, pp.212- 215, 2007.

[6] J Mitola, G.Q. Maguire, "Cognitive Radio: Making Software radios More Personal," *IEEE Personal Communications Magazine*, 6(4), pp.13-18, 1999.

[7] I .Akyildiz, Q Lee, M C.Vuran, "Next Generation/dynamic Spectrum Access/cognitive Radio Wireless Network: A Survey," *Computer Networks*, 50(13), pp.2127-2159, 2006.

[8] G. Vardoulias, J. Faroughi-Esfahani, G. Clemo, and R. Haines, "Blind radio access technology discovery and monitoring for software defined radio communication systems: problems and techniques," in *Proc. Int. Conf. 3G Mobile Communication Technologies*, London, UK, pp. 306–310,March 2006.

[9] S. Shankar, C. Cordeiro, and K. Challapali, "Spectrum agile radios: utilization and sensing architectures," in *Proc. IEEE Int. Symposium on New Frontiers in Dynamic Spectrum Access Networks*, Baltimore, Maryland, USA, pp. 160–169, Nov. 2005.

[10] D. Cabric, S. Mishra, and R. Brodersen, "Implementation issues in spectrum sensing for cognitive radios," in *Proc. Asilomar Conf. on Signals, Systems and Computers*, vol. 1, Pacific Grove, California, USA, pp. 772–776, Nov. 2004.

[11] E. Visotsky, S. Kuffner, and R. Peterson, "On collaborative detection of TV transmissions in support of

dynamic spectrum sharing," in *Proc. IEEE Int. Symposium on New Frontiers in Dynamic Spectrum Access Networks*, Baltimore, Maryland, USA, pp. 338–345, Nov. 2004.

[12] A. V. Dandawate and G. B. Giannakis, B Statistical tests for presence of cyclostationary,[IEEE Trans. Signal Process., vol. 42, pp. 2355–2369, Sep. 1994.

[13] W. A. Gardner, Exploitation of spectral redundancy in cyclostationary signals,[IEEE Signal Process. Mag., vol. 8, pp. 14–36, Apr. 1991.

[14] Y. G. Li and Z. Ding, BARMA system identification based on second-order cyclostationary,[IEEE Trans. Signal Process., vol. 42, pp. 3483–3494, Dec. 1994.

[15] C. R. C. M. da Silva, B. Choi, and K. Kim, B Distributed spectrum sensing for cognitive radio systems, in Proc. ITA Workshop 2007

[16] Abbas Taherpour, Masoumeh Nasiri-Kenari, and Saeed Gazor,"Multiple antenna spectrum sensing in cognitive radio ",IEEE Transactions on Wireless Communications, vol. 9 , (February 2010), pp. 814- 823,2010

[17] http://publik.tuwien.ac.at/files/pub-et_11276.pdf

[18] http://www.comlab.hut.fi/opetus/333/2004slides/topic47.pdf

[19] http://www.servinghistory.com/topics/MIMO::sub::History_Of_MIMO

[20] T. S. Rapp port, Wireless Communications, Chs. 3 and 4, Upper Saddle River, NJ: Prentice Hall, 1996.

[21] A. Jindal and S. Rani Review of Spectrum Sensing in Cognitive Radio in ICAET BGIET Conference, March 2015.

[22] K. Kim, I. Akbar, K.K. Bae, J.S. Um, "Cyclostationary Approaches to Signal Detection and Classificaton in Cognitive 96 Radio," *IEEE International Symposium on DySPAN 2007*, pp.212-215,2007

[23] S. Haykin, B Cognitive radio: Brain-empowered wireless communications,[IEEE J. Sel. Areas Commun., vol. 23, pp. 201–220, Feb. 2005.

[24] S. Haykin, B Fundamental issues in cognitive radio, in Cognitive Wireless Communication Networks, E. Hossain and V. K. Bhargava, Eds. New York: Springer, pp. 1–43,2007.

[25] D. Cabric, S.M. Mishra, R.W. Brodersen, Implementation issues in spectrum sensing for cognitive radios, in: Proceedings of the IEEE Asilomar Conference on Signals, Systems and Computers 2004,pp. 772–776,Nov.2004

[26] F. Digham, M. Alouini, M. Simon, On the energy detection of unknown signals over fading channels, in: Proceedings of the IEEE ICC 2005, vol. 5, pp. 3575–3579,May 2003.