ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 7, Issue 6, June 2018

Eigen value Detection for Spectrum Sensing in Cognitive radio Network over Nakagami Fading Channel

Er Shraddha Jain, Er Deepak Pancholi, Er Pawan Sharma

Abstract— **With the rapid development in wireless communications, the demand for the high data transmission require increases in spectrum resources because of fixed spectrum assignment policy is characterized in wireless network these lead to low spectrum utilization in many frequency bands but the availability of the spectrum resources is limited. In this paper Eigenvalue based spectrum sensing method in cognitive radio is carried out over Nakagami fading channels. The proposed detection method overcomes the drawback of other detection method and also, there will not need to know about noise parameter such as noise variance & other. Eigen ratio and Threshold is computed using random matrix theory (RMT) is exploited to formulate the detection method depending on sample covariance matrix of received signal. Simulation Result shows that Eigenvalue algorithm using Hankel matrix approach gives 0.067 to 0.103 better performance of detection at low SNR by using Nakagami fading channel.**

Index Terms— **Spectrum sensing, Energy detection, RMT, Eigen Value, fading channels, Probability of detection, probability of false alarm.**

I. INTRODUCTION

The tremendous advancement in ISM Bands provide a Strength Criticism of FCC's traditional process in which Bands is allocates to a single use, issues excluding licence to a single existence of user within a geographical area, and restricts other devices from transmitting power within these bands. As a result, the FCC is acknowledge reverting its spectrum allocation policies [1], and is move forwarding with process. A Cognitive Radio is efficient technique to take advantage of a more open spectrum policies [2,3]. The design of Cognitive radio is such that, it can dynamically adapt its transmission parameter to find and take advantage of frequencies while minimizing interference. The concept of cognitive radio is proposed by Joseph Mitola, to solve the issue of under-utilization of spectrum and has been receiving an increasing attention in recent years, According to a survey based on the spectrum sensing & Management conducted by American Federal Communication Commission (FCC) at the end of 2003, the utilization of allocated spectrum ranged from 15 to 85 % [4]. Some of the bands assigned to mobile network were highly used while; the bands assigned for amateur radio were not properly exploited. Hence, the cognitive radio (CR) technology is used to solve the problem of low utilization of

Spectrum and increases the spectrum efficiency. In other word, we can say that Cognitive radio is key enabling technology for improving the utilization of electromagnetic spectrum. It senses the spectral environment over wide range of frequency band and exploits the unoccupied band.

In responding to the idea of cognitive radio (CR) coined by Joseph Mitola [5], IEEE 802.22 working Group was formed in 2004. IEEE 802.22 standard is known as Cognitive radio standard, because it contains cognitive features. Federal Communications Commission (FCC) coordinates the usages of radio spectrum resources and the regulation of radio emissions. In order to maintain the primary (licensed) users right to interference free operation, the secondary users which are unlicensed user need to regularly sense the allocated band and reliably detect the presence of the licenced user signals in this way, secondary user need to have cognitive radio capability. As an example, in the IEEE 802.22 standard, the secondary users need to detect the TV and wireless microphone signals and upon their detection, they are required to vacate the channel within two seconds [6]. For TV primary signals, a probability of detection of 90% and a probability of false alarm of 10% should be maintained [7]. Therefore, spectrum sensing plays an important role in the cognitive radio technology to prevent interference to the primary users and to reliably and quickly find the spectrum hole and utilizes the opportunity.

II. RELATED WORK

In early 1990s, the concept of software defined radios (SDRs) which introduced by Joseph Mitola [8]. SDR is used to minimize hardware requirements; it gives user a cheaper and reliable solution. CR is the new version of SDR implement in 2000 by J. Mitola and also, investigated the concept of dynamic spectrum sensing [9]. In particular, need for antennas that can make a cognitive radio (CR) system work with other devices across multi-bands, multi-standards or multi-channels was also described. Since these new devices must both learn and adapt to their RF environment for the purpose of establishing seamless communication with other RF devices according the need. That defined

Manuscript received June 5, 2018.
Er Shraddha jain*, Electronics and Communication Engineering Department, Lakshmi Narain College of Technology (LNCT), Indore, India, (shraddhajain30@gmail.com)*
Er Deepak Pancholi*, Electronics and Communication Engineering Department, Lakshmi Narain College of Technology (LNCT), Indore, India, (erdeepakpamcholiind@gmail.com)*
Er Pawan Sharma*, Electronics and Communication Engineering Department, Lakshmi Narain College of Technology (LNCT), Indore, India, (er.pa1.sharma@gmail.com)*

ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
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characteristics of the cognitive radio as Capability & Re-configurability. Cognitive radio as a new approach for efficient utilization of electromagnetic spectrum concept is given by S. Haykins [10]. In 2015, Min Jia, Xue Wang, Fang Ben, Qing Guo and Xuemai Gu developed the concept of Energy detection and Covariance Detection [11], proposed a new method (An improved spectrum sensing algorithm) which overcome the limitation of both method and give better performance in term of probability of detection at low SNR as well as improved method result as comparing to detection result of each method. So we can say that the proposed method find the balance point with computation complexity and detection performance at same time, this introduce more reliability in detect results.

Implementation of an Adaptive spectrum sensing scheme is presented by Slavonia, B.Sindhuja, M.A.Bhagyaveni in 2015 [12]. Adaptive spectrum sensing scheme is used to adapt sensing according to available information and frequency changing wireless environment. In adaptive Spectrum sensing method, Matched filter technique is applied when there is prior knowledge about licensed signal, when SNR value is greater than 4dB ED is applied and EVD is preferred for low SNR value or less than 4dB. In such a way, complexity of spectrum sensing process is reduced by adaptive spectrum sensing method.

III. System Model

For system model, We consider a system of one cognitive radio (CR), one primary user (PU) and fusion center (FC).When a signal from PU is transmitted, the received signal by the CR for the detection of PU can be modeled under two hypotheses (H0 & H1), is gives as follows

H_0: y(k) = n(k) : PU is Absent (3.1)

H_1: y(k) = h*s(k) + n(k) : PU is Present (3.2)

Where y(k) the received signal by secondary users is ,s(k) is the transmitted signal of the primary user, h is the channel coefficient and n(k) is AWGN with zero mean and σ^2 variance (i.e. N $(0,\sigma^2)$). H_0 & H_1 are the sensing states for absence and presence of signal respectively. The decision statics D, to check about the presence or absence is made by making the test on the received signal at Cognitive radio receiver,

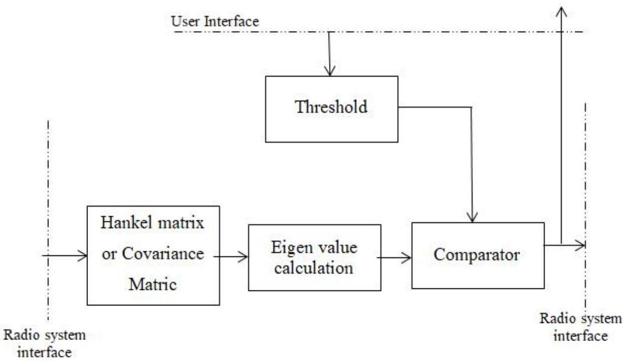

Fig 1. Block Diagram of EVD Technique

The main component of EVD technique is shown in Figure 1 as he samples of received signal comes from system interference to build Hankel matrix or the covariance matrix, the Eigenvalue is matrix are calculated by using a specific algorithm to make the ratio of maximum to minimum, and also threshold computation is based on user interface and comparator give the output in the term of hypothesis test.

The received signal at receiver can be given as:

$$x(n) = \sum_{k=0}^{N} h(k)\, s_j(n-k) + \eta(n)$$

At receiver the discrete signal denoted by $x(n)$, s(n) is the source signal, $h(k)$ is channel response and order of the channel is N. η(n) are the noise samples.

Considering a subsample L of consecutive outputs are as follow

$$X(n) = [x(n), x(n-1), \dots\dots, x(n-L+1)]^T \quad (3.4)$$

$$\eta(n) = [\eta(n), \eta(n-1), \dots\dots, \eta(n-L+1)]^T \quad (3.5)$$

$$S(n) = [s(n), sx(n-1), \dots\dots, s(n-L+1)]^T \quad (3.6)$$

As we get,

$$X(n) = H\, S(n) + \eta(n) \quad (3.7)$$

Where H is matrix of row L and column is N+L.

$$H = \begin{bmatrix} h(o) & \cdots & h(N) & \cdots & 0 \\ \vdots & \ddots & & \ddots & \\ 0 & \cdots & h(0) & \cdots & h(N) \end{bmatrix} \quad (3.8)$$

The following assumption is to be assumed on the basis of statistical properties of transmitted symbols a channel noise

1) Noise is white
2) transmitted signal and Noise are uncorrelated

As $R_x(N_s)$ is the sample covariance matrix of the received signal

$$R_x(N_s) = \frac{1}{N_s} \sum_{n=L-1}^{L-2+N_s} \hat{x}(n)\hat{x}^{\dagger H}(n) \quad (3.9)$$

Where L is the smoothing factor, N_s is the number of samples From the samples covariance matrix we can calculate and get the largest and smallest Eigenvalue. Eigenvalue represent the variance in the element as λ_{max} is the largest Eigenvalue and λ_{min} denote the smallest Eigenvalue. The ratio of maximum to minimum Eigenvalue ($\lambda_{max}/\lambda_{min}$) is termed as Eigen ratio.

IV. Methodology

For Eigen value Detection technique, First we calculate First step is to calculate the number of received samples and make the Hankel matrix from it. Hankel matrix is also known as catalecticant matrix and it is a square matrix having each skew diagonal is in ascending from left to right values is constant. Choose the smoothing factor (L) to make number of column in Hankel matrix. Hankel matrix with row N-l+1 and L columns are as in equation (4.8)

$$Q = \begin{bmatrix} q(1) & q(2) & q(L) \\ q(2) & q(3) & q(L) \\ \vdots & \vdots & \vdots \\ q(N-L+1) & q(N-L+2) & q(N) \end{bmatrix} \quad (4.1)$$

Step second is decomposition of matrix as matrix decomposition means to transformation of given matrix from one form to another form. Factorization of matrix is the help of singular value decomposition; SVD determines original data in a coordinate system in which covariance matrix is diagonal. In SVD, Q can be factorized as

$$Q = U \sum V^T \quad (4.2)$$

Where

$$U^T U = I_{M\times M} \qquad (4.3)$$

$$VV^H = I_{L\times L} \qquad (4.4)$$

Therefore, U and V is orthogonal matrix. As U and V are M×M and L×L unitary matrix, as M is the N-L+1. U is left singular vector for Q and column matrix V is right singular vector for Q. ∑ is the rectangular matrix with same dimension. ∑ is the diagonal matrix whose non negative entries are the square root of positive Eigenvalues of QQ^T.

Step three is calculation of Eigenvalue. From above step two we get the singular values which are the diagonal entry in ∑ matrix whose non negative entries are the square root of positive Eigenvalues of QQT. Arrange the Eigenvalue in the ascending order and obtain maximum and minimum Eigenvalue (λ_{max} and λ_{min}) and the compute Eigen ratio as decision static and compare it with threshold we get, the result in term of hypothesis as H0 & H1.

A. *Threshold Determination*

In general model of spectrum sensing, a threshold must be determined to compare with the decision statistic of sensing metric in order to determine the presence of primary user signal. The decision static (for EVD) is defined as the ratio of maximum to minimum eigenvalues as follows

$$T = \lambda_{max}/\lambda_{min} \qquad (4.5)$$

Probability of false alarm and decision threshold are derived based on limiting distribution of eigenvalue based on random matrix theory. The detection threshold, y, must be estimated for a required probability of false alarm, by the above decision statistic. the probabilities of detection and probability of false alarm are derived based on asymptotical (limiting) distributions of eigenvalue which is less complicated and mathematically tractable [16]. The detection threshold in terms of desired probability of false alarm is calculated by using the results of the theorem in [17] and [18],

$$\gamma = \left((\sqrt{N_s}+\sqrt{L})^2/(\sqrt{N_s}+\sqrt{L})^2\right)\times\left(1+\frac{(\sqrt{N_s}+\sqrt{L})^{\frac{2}{3}}}{(N_s L)}.F_1^{-1}(1-P_f)\right)$$

as follows (in our case, M = l)

Where

N_s = Number of Samples
L = Smoothing factor
P_f = Probability of false alarm
P_d = Probability of detection
γ = Threshold value

F^{-1} Represent the inverse of cumulative distribution function (CDF) of Tracy widom distribution of order 1 [19]. Tracy widom distribution is Probability distribution function of the largest Eigenvalues of random Hermitian matrix.

B. *Algorithm*

` Algorithm for Eigen value algorithm are as follow :

1) Initialization of Parameter which include Number of samples (N), Smoothing factor (L) and Probability of false alarm (Pf).
2) Construct Hankel matrix, Q given in equation (4.2).
3) Decomposition of matrix, as given in equation (4.3), by using SVD, to form equation Q = U ∑VT.
4) After decomposition, Obtain Maximum and minimum Eigenvalue of matrix as represent as λ_{max} and λ_{min}.
5) Compute threshold value, γ by using equation (4.6)
6) Calculate the ratio of maximum Eigenvalue to minimum Eigenvalue and compare it with the threshold. If (λ_{max})/(λ_{min})> γ it means primary signal is present otherwise the signal is absent.

V. Flow Chart

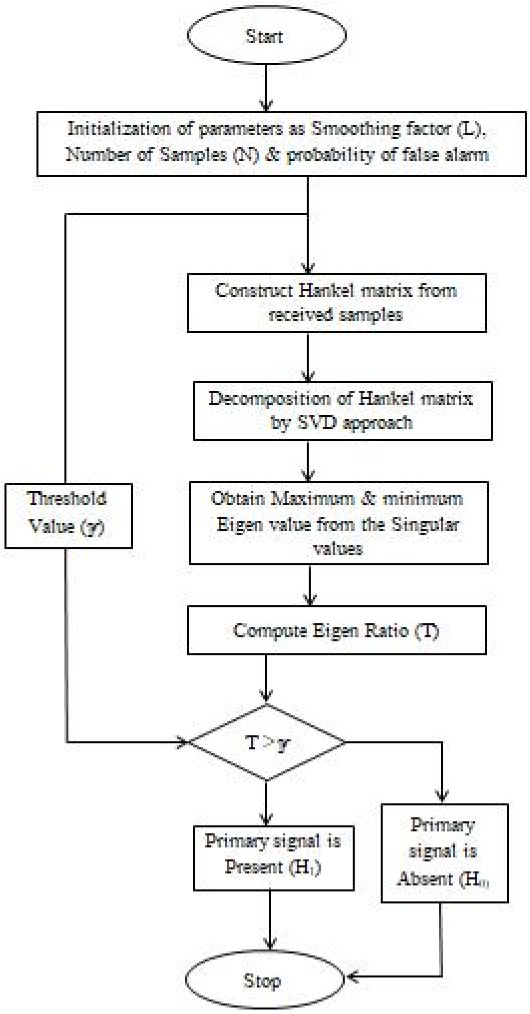

Fig 2. Flow Chart for EVD Technique

VI. Result

The results are averaged over minimum 1500 test using Monte-Carlo Simulation written in MATLAB. Simulation results are taken using BPSK modulated random primary signal. Independent and identically distributed noise samples with Gaussian distribution are used.

Table 1. Various Simulation Parameters

S.No.	PARAMETER	VALUES
1.	Smoothing factor (L)	8, 16, 24, 32
2.	Noise variance	0.2
3.	Number of Samples	200 to 2000
4.	Probability of detection	0.1 to 1
5.	Probability of False alarm	0.01 to 0.1

ISSN: 2278 – 909X
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6.	SNR Range	-20 to 3 dB
7.	Bandwidth	5e6
8.	Sample time	1e-5
9.	Replica of Signal	4
10.	Number of test in Monte Carlo Simulation	1500
11.	Detection technique	Eigenvalue Detection
12.	Modulation technique	BPSK
13.	Simulation Software	MATLAB 9.0.0.341360 (R2016a)
14.	Simulation tool (Package MATLAB Program using Deploy tool)	Standalone Application (Executable file) GUI
15.	Channel	Nakagami Fading Channel

Figure 3 depicts Receiver operating characteristic (ROC) curve of Eigenvalue detection method with Probability of detection versus Probability of false alarm at different value of SNR (SNR =-5dB, SNR=-10dB, SNR=-15dB & SNR = -20dB), For Smoothing factor = 16, Number of Sample = 500.

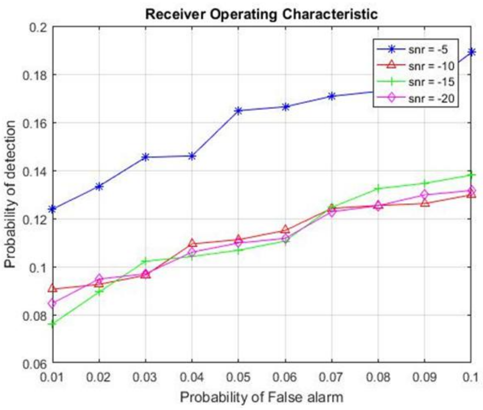

Fig 3. ROC for Probability of detection (P_d) Versus Probability of false alarm (P_f) at different value of SNR in Eigenvalue based detection

ROC curve in Figure 3, it clear that P_d values is higher at -5dB SNR level when compare with various SNR level from higher to lower value (-10dB, -15dB and -20dB) which proves the good performance of Eigenvalue detection method at higher SNR.

Figure 4 depicts Receiver operating characteristic (ROC) curve of Eigenvalue detection method with Probability of detection versus Probability of false alarm at different Number of Samples (N =500, N =1000, N =1500 & N =2000), For Smoothing factor = 16, Signal to noise ratio = -10dB. that the values probability of detection at 2000 samples is approximately 0.132 to 0.178 greater than the probability of detection at 500 samples at different points. The values P_d at 2000 samples is approximately 0.854 to 0.114 greater than the P_d at 1000 samples at different points.

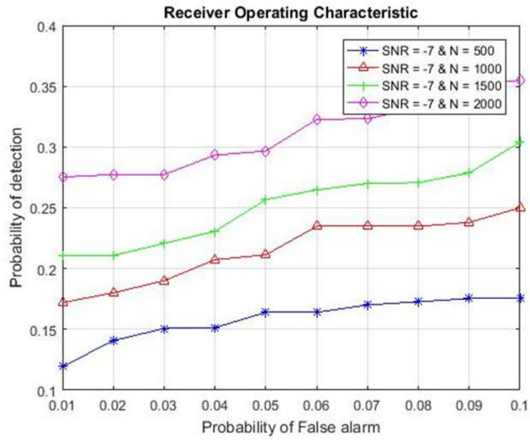

Fig. 4 ROC for Probability of detection (Pd) Versus Probability of false alarm (Pf) at different value of Number of samples (N) in Eigenvalue based detection

The values probability of detection at 2000 samples is approximately 0.040 to 0.066 greater than the probability of detection at 500 samples at different points.

From ROC, it is clear that P_d values is higher at 2000 samples as compare to varying numbers of samples in decreasing order having a difference of 500 (500, 1000, 1500) which proves good performance of Eigenvalue detection method at higher number of samples.

Figure 5 depicts Receiver operating characteristic (ROC) curve of Eigenvalue detection method with Probability of detection versus Probability of false alarm at different value of Smoothing factor (L =8, L =16, L =24, L =32), SNR = -10dB, .Number of Sample = 500

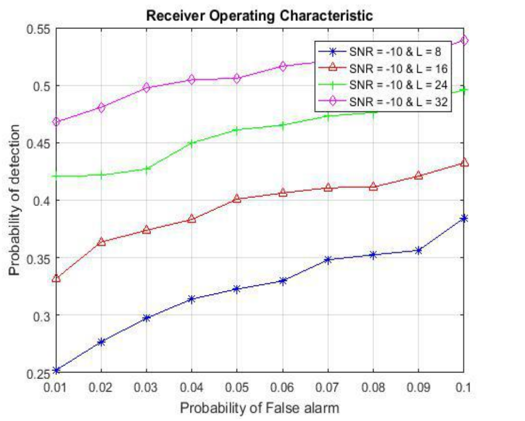

Fig 5. ROC for Probability of detection (Pd) Versus Probability of false alarm (Pf) at different value of Smoothing factors (L) in Eigenvalue based detection

It clear that P_d values is higher at smoothing factor is 32 as compare to varying smoothing factor is constantly decreasing with difference of 8 (8, 16, 32) which proves good performance of Eigenvalue detection method at higher smoothing factor .

Figure 5 depicts Receiver operating characteristic (ROC) curve of Energy detection method with Probability of detection versus SNR level at different value of Smoothing factor (L =8, L =16, L =24, L =32), For SNR range from -21 to -3, Number of Sample = 500 & Probability of false alarm = 0.01. It is clear that from SNR level -22 dB to -9 dB probability of detection is 0.185 to 0.211 higher at value of Smoothing factor from 32 to 8. From SNR level -9dB to -6dB probability of detection is gradually increase approx. 0.06 at smoothing factor is 32. When the smoothing factor is vary from 32 to 16 than values probability of detection is approximately 0.011 to 0.149 greater at different SNR level.

VII. Conclusion

Spectrum is a very precious resource in wireless communication systems but it become a limited due to increase in demand of radio spectrum over past few years and licensed bands are used inefficiently. So it has become a center point for research and development.

In our work, several spectrum sensing algorithm are studied. Here, we enhance the performance of cognitive radio with using proposed spectrum sensing technique in which does not require knowledge of signal properties, channel and uncertainty noise parameter, it also overcome the drawback of energy detection method. In our work. Good performance of Eigenvalue detection method at higher number of samples and also, the good performance of Eigenvalue detection method at higher SNR. The brief simulated result show that Eigenvalue algorithm using Hankel matrix approach gives 0.067 to 0.103 better performance of detection at low SNR with compare to other detection method and for higher SNR values energy detection performance is better.

REFERENCES

[1] S. Chen, B. Mulgrew, and P. M. Grant, "A clustering technique for digital communications channel equalization using radial basis function networks," *IEEE Trans. on Neural Networks*, vol. 4, pp. 570-578, July 1993.

[2] J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," *IEEE Trans. Electron Devices*, vol. ED-11, pp. 34-39, Jan. 1959.

[3] C. Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, and M. Miller, "Rotation, scale, and translation resilient public watermarking for images," *IEEE Trans. Image Process.*, vol. 10, no. 5, pp. 767-782, May 2001.

[4] John G. Proakis and Masoud Salehi, *Digital Communication*, McGraw-Hill, New York, Fifth Edition, 2001.

[5] J. Mitola, "The software radio architecture," *IEEE Communications Magazine*, vol. 33, pp. 26-38, 1995.

[6] F. K. Jondral, "Software-defined radio: basics and evolution to cognitive radio," *EURASIP Journal on Wireless Communications and Networking,* vol. 3, pp. 275-283, 2005.

[7] W.-Y. L. I. F. Akyildiz, M. C. Vuran, and S. Mohantly, "*Next Generation/dynamic spectrum access /cognitive radiowireless network: A survey*," Elsevier Computer Networks Journal, vol. 50, 2006. pp. 2127-2159,

[8] J. Mitola III, "Cognitive Radio: An integrated agent architecture for software radio architecture," Ph. D Dissertation, *Royal Institute of Technology (KTH)*, 2000.

[9] T. C. Clancy, "Dynamic Spectrum Access in Cognitive Radio Networks " Ph.D Thesis , *University of Maryland,* 2006.

[10] Beibei Wang and K. J. Ray Liu, "Advances in Cognitive Radio Networks: A Survey," *IEEE J. Sel. Top. Sign. Proces.*, vol. 5, no. 1, pp. 5-23, Feb. 2011.

[11] I.F. Akyildiz, Y. Altunbasak, F. Fekri, R. Sivakumar, "AdaptNet: adaptive protocol suite for next generation wireless internet", *IEEE Communications Magazine* 42, 2004, pp. 128–138.

[12] Zhai xuping, pan Jianguo, "energy-Detection based Spectrum Sensing for cognitive radio," *Iet conference on wireless, Mobile and Sensor Networks*, , 2007, pp. 944–947.

[13] Y. Zeng and Y.-C. Liang, "Covariance based signal detections for cognitive radio, " in Proc. IEEE Int. Symposium on New Frontiers in Dynamic Spectrum Access Networks, Dublin, Ireland, Apr. 2007, pp. 202-207

[14] Pawan Sharma, Angeeta Hirwe, "Simulation Platform for Performance Analysis of Energy Detection based Spectrum Sensing Technique in Cognitive Radio", International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)", Vol. 4, Issue 7, July 2016,

[15] Zhuan Ye, Gokhan Memik, John Grosspietsch, "Energy detection using estimated noise variance for spectrum sensing in cognitive radio networks", *Wireless Solution Research Center, Motorola Labs, Schaumbarg, IL, USA, Department of EECS, Northwestern University, Evanston, IL, USA*, 1525-3511/08/$25.00, IEEE, 2008.

[16] Y. Zeng, Choo Leng Koh, and Y. Liang, "Maximum eigenvalue detection: theory and application," *IEEE International Conference on Communications,* Beijing, 2008, pp. 4160-4164.

[17] Syed Sajjad Ali, Chang Liu, Minglu Jin, "Minimum Eigenvalue Detection for Spectrum Sensing in Cognitive Radio", *International Journal of Electrical and Computer Engineering (IJECE),* Vol. 4, No. 4, August 2014, pp. 623~630.

[18] Min Jia, Xue Wang, Fang Ben, Qing Guo, Xuemai Gu, "An improved spectrum sensing algorithm based on energy detection and covariance detection" *IEEE/CIC International Conference on Communications in China (ICCC)*, 2015

[19] S.Lavanya, B.Sindhuja, M.A.Bhagyaveni, "Implementation of an Adaptive Spectrum Sensing Technique In Cognitive Radio Networks" presented in *a International level conference on International Conference on Computing and Communications Technologies (ICCCT)*, organised by IEEE, 2015, India.

Er Shraddha Jain, M.Tec Student, Department of Electronics and Communication Engineering, Lakshmi Narain College of Technology (LNCT), Indore. She has completed his engineering from Rishiraj Institute of Technology, Indore. Research Interests are Communication, Wireless Network.

Er Deepak Pancholi, Assistant Professor, Department of Electronics and Communication Engineering, Lakshmi Narain College of Technology (LNCT), He has nearly more than two years of Industrial experience and Eight Years of teaching experience. He completed his master's Degree from Indore Institute of Science and Technology - [IIST], Indore. He has published about Four Research paper including International and National Journals. Research Interests are Communication, Electronic Device & Circuits, Microprocessor & Microcontroller, and Digital Electronics.

Er Pawan Sharma, Assistant Professor, Department of Electronics and Communication Engineering, Lakshmi Narain College of Technology (LNCT), He has nearly one years of Industrial experience and 7 month of teaching experience. He completed his master of engineering degree from Institute of Engineering & Science IPS Academy, Indore. He has Published about Eight Research paper in various International and National Journals. Research Interests are Communication, Wireless Sensor Networks, Cooperative Communication, and Cognitive Radio.