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RESEARCH ARTICLE

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SPECTRUM SENSING IN COGNITIVE RADIO AT DIFFERENT SNRs USING MIMO TECHNIQUE

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ABSTRACT

Spectrum sensing has reborn as a very active research area in recent years despite its long history. Various techniques have been used for sensing the spectrum holes, each having its pros and cons .The introduction of MIMO technology in spectrum sensing can dramatically improve the performance of cognitive radio. In this paper a new Multiple –Input-Multiple-Output antennas have been used for the Spectrum Sensing in Cognitive Radios. The results show that Detection probability increase with the increase in Diversity order. Simulations are performed at different SNRs of -14db,-10db,-6db; -2db.The Detection probability for each antenna configurations gets alleviated at higher SNR.

Key words: Cognitive Radio (CR) Signal-to-noise ratio(SNR), Primary User (PU),MIMO, SU.

I. INTRODUCTION

The radio spectrum is a naturally limited resource, but there is an insatiable demand of it due to emerging wireless multimedia applications. Presently, wireless networks are regulated by fixed frequency allocation strategy which means that all of the frequency bands are exclusively allocated to specific services. This strategy worked well in the past, but currently it is inefficient and is proving to be a hurdle in the deployment of new wireless services. Various studies carried out around the world have revealed that most of the allotted spectrum is either not used at all or only sparsely used. A survey of spectrum utilization made by the Federal Communications Commission (FCC) has indicated that spectrum utilization varies from 15% to 85% with wide variance in time and space [1]. Thus, the actual licensed spectrum is largely underutilized in vast temporal and geographic dimensions. The spectrum utilization can be improved by opening doors to new communication paradigm of Cognitive radio technology [2]. Cognitive radio is an exciting emerging technology that deals with the stringent scarcity of the radio spectrum by exploiting the unused spectrum in an opportunistic manner. Such revolutionary and transforming technology represents a paradigm shift which is expected to deeply change the way radio spectrum will be accessed , shared and managed in the future [5] [6].

Cognitive radio (CR) is a technology having growing international interest. Currently, there is a highly active worldwide community of academic and industrial researchers working in this field. Significant efforts have been made in order to move this new technology from research concept to reality which by no means, is a simple task [8]. Cognitive Radio is characterized by the fact that it can adapt to the environment by changing its parameters, such as frequency, modulation, format etc. The basic idea of a cognitive radio is spectral reusing in which the secondary users are required to frequently perform spectrum sensing. Whenever the primary users become active, the secondary users have to detect the presence of them with a high probability and vacate the channel to avoid interference [10]. The CR must continuously sense the spectrum it is using in order to detect the reappearance of the PU so as to avoid interference [11]. The most important sensing techniques considered for CR are matched filter detection, energy detection, and cyclostationary detection , each having different operational requirements, advantages and disadvantages[15] [16]. Metrics for detection performance are the probability of detection and false alarms. The probability that a SU declares that a PU is present when the spectrum is idle is called the probability of a false alarm. Further, the probability that the SU declares that the PU is present when the spectrum is occupied by the PU is called the probability of detection. These metrics are used to define the CR system quality of service (QoS) [18] [20].MIMO is a physical layer technology that can provide many types of benefits through multiple antennas and advanced signal processing [27]. Multiple independent data streams can be transmitted or received over the MIMO antenna elements. Furthermore MIMO can also realize interference suppression. MIMO provides space diversity to combat the detrimental effects of fading [28]. Through beam-forming, a MIMO receiver can suppress interference from neighboring transmitters and a MIMO transmitter can null out its interference to other receivers. Thus, MIMO technology has served a lot in increasing the performance of wireless systems. When this technology is used in Cognitive Radio, it increases the spectrum sensing ability of the system [30]. Cognitive radio (CR) and multi-input multi-output (MIMO) communications are among the most promising solutions to improve spectrum utilization and efficiency. Dynamic and opportunistic spectrum access allow. CR nodes to communicate on temporarily idle or underutilized frequencies. MIMO systems boost spectral efficiency by having a multi-antenna node simultaneously transmit multiple data streams (i.e., spatial multiplexing). Each of the two technologies has recently achieved significant advances. Newly emerging systems and standards (e.g., WiMAX, 4G Advanced-LTE, IEEE 802.16e) adopt MIMO communications as a core feature. TV white bands have also been approved by the FCC for opportunistic secondary use. A timely issue is to embrace recent innovations of the two technologies into a single system.

II.PREVIOUS SPECTRUM SENSING TECHNIQUES

There are several factors that make spectrum sensing practically challenging. First, the required SNR for detection may be very low. Secondly, multipath fading and time dispersion of the wireless channels complicate the sensing problem. Thirdly, the noise/interference level may change with time and location, which yields the noise power uncertainty issue for detection. Combating these factors, Various sensing methods have been proposed till now[18][20][21] and the research is still on. Some are described as under:

1)Matched Filter Detection: When a secondary user has a prior knowledge of the PU signal, the optimal signal detection is a matched filter, as it maximizes the signal-to-noise ratio (SNR) of the received signal. A matched filter is obtained by correlating a known signal with an unknown signal to detect the presence of the template in the unknown signal. This is equivalent to convolving the unknown signal with a time-reversed version of the template. This method needs less time to achieve high processing gain due to coherent detection [10].But it suffers from a significant disadvantage that it would require a dedicated sensing receiver for all primary user signal types. In the CR scenario, however, the use of the matched filter can be severely limited since the information of the PU signal is hardly available at the CRs [20]. The use of this approach is still possible if we have partial information of the PU signal such as pilot symbols or preambles, which can be used for coherent detection [21].

2) Energy Detection: Energy detection is a naive signal detection approach which is referred in classical literature as radiometry. If prior knowledge of the PU signal is unknown, the energy detection method is optimal for detecting any zero-mean constellation signals. First, the input signal is filtered with a band-pass filter to select the bandwidth of interest. The output signal is then squared and integrated over the observation interval. Lastly, the output of the integrator is compared to a predetermined threshold to infer the presence or absence of the PU signal. When the spectral environment is analyzed in frequency domain and

power spectral density (PSD) of the observed signal is estimated, this approach is termed as Periodogram [21] .Advantages include its simplicity and less complexity while implementation. Some disadvantages are poor performance under low SNR conditions, inability to differentiate the interference from other secondary users sharing the same channel and the PU [24] . Furthermore, the threshold used in energy selection depends on the noise variance, and small noise power estimation errors can result in significant performance loss.

3) Feature (Cyclostationary) Detection: The idea of feature detection is based on capturing a specific signature of PU signal. Cyclostationary feature detection exploits built-in periodicity of received signal to detect primary transmissions [20]. The distinct property of cyclostationary detection is its ability to differentiate PU signal from interference and noise and even distinguish among different types of PUs. Another important advantage is robustness to noise uncertainty which allows cyclostationary detector to identify primary transmissions more than 30 dB below the noise floor [22].

5)Waveform based sensing :Waveform based approach is less complex as compared to MF and consists of a correlator which exploits the known patterns in PU signal by correlating the received primary signal at CR with its own copy [21]. Similar to MF, correlator output is compared with a fixed threshold to pick out spectrum hole. The main advantage of pilot based sensing lies in its high processing gain. Moreover, it is computationally less complex as compared to cyclostationary detection. The performance of waveform based sensing is better than ED in terms of reliability and convergence time and improves further with increasing length of known signal patterns. Waveform based detector are very sensitive to synchronization errors.

III. Spectrum Sensing In Cognitive Radio

Spectrum sensing is the ability to measure, sense and be aware of the parameters related to the radio channel characteristics, availability of spectrum and transmit power, interference and noise, radio's operating environment, user requirements and applications, available networks(infrastructures) and nodes, local policies and other operating restrictions. It is done across Frequency, Time, Geographical Space, Code and Phase. Spectrum Analysis is based on spectrum sensing which is analyzing the situation of several factors in the external and internal radio environment (such as radio frequency spectrum use by neighboring devices, user behavior and network state) and finding the optimal communication protocol and changing frequency or channel accordingly. It is also known as channel estimation Spectrum Decision Making calls for reconfiguration for the channel and protocol required for constantly adapting to mobile changing environments and adjustment of output power or even alteration of transmission parameters (such as modulation formats (e.g. low to high order QAM), variable symbol rates, different channel coding schemes) and characteristics by the Cognitive radio devices. CR should be able to use multiple antennas for interference nulling, capacity increase or range extension.

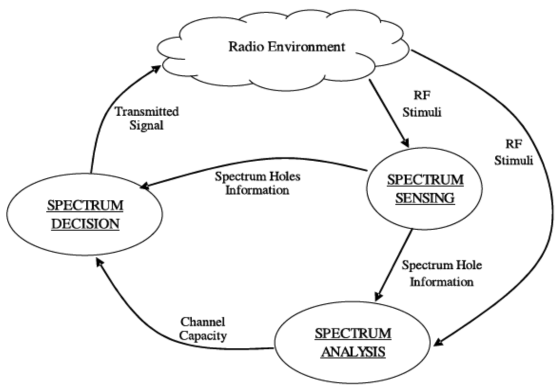

Figure 1. Cognitive cycle

IV. INCORPORATION OF MIMO ANTENNAS

In multiple antenna spectrum sensing we use single antenna at primary user and multiple antennas at secondary user. Multiple antenna techniques currently are used in communications and their effectiveness has been shown in different aspects .The efficiency of multiple antenna spectrum sensing is shown in terms of required sensing time and hardware by using a two stage sensing method The ED has been proposed for spectrum sensing by using multiple antennas. A GLR detector is proposed which do not have any primal information about the parameters like; channel gains, noise variance, and primary user signal variance [8]. It is supposed that the SU has M receiving antennas and each antenna receives L samples. It is also assumed that the PU signal samples are independent zero-mean random variables with complex Gaussian distribution. Figure 2 represents the Multiple Antenna Spectrum sensing in CR. It is assumed that the channel gain vector, i.e., h, is a constant parameter at each antenna channel. The optimal detector needs to know the values of channel gains, noise and PU variances. Detection methods for signals with correlation between the received symbols in noise and interference are of special importance in the implementation of a communication system. This new idea of multiple antenna spectrum sensing is provided in [9]. It is assumed that there is no any primal knowledge of primary user signal, the channels between the primary user and cognitive user is available to the system. A new approach that is known as generalized likelihood ratio test (GLRT) is developed to detect the presence/absence of the primary user in [9]. It is considered that multiple receiver antennas are used, and there is only one primary signal to be detected. In this case, the signal covariance matrix can be modeled as a rank 1 matrix that is an outer product of the channel vector. By exploiting this inherent signal structure, a new GLRT detector is developed. The proposed detector requires no primal knowledge of the transmitted signal, the wireless channel from the primary transmitter to the CR receiver, and the noise variance. The test statistic of the proposed detector admits a simple form that is given by the ratio of the largest eigen value to the sum of eigen values of the sample covariance matrix of the received signal. By fully exploiting the signal structure, this detector is able to achieve better performance than other existing methods when the noise variance is unknown. Another approach with GLRT detector is also used with multiple antenna based spectrum sensing in [9].

MIMO is a communication technique in which the multiple properties of the channel are utilized to support greater data through put. In a MIMO system the transmitter transmits multiple channel of data traffic through multiple antennas, the receiver learns the channel behavior between the transmitters multiple antennas and the receivers multiple antennas, and uses signal processing technique to compute what waveform was transmitted by each antenna and the corresponding data stream. By using MIMO the same frequency is reused in the same geographic region to deliver great amount of data traffic than could be expected from SISO. MIMO techniques deliver significant performance enhancement in terms of data transmission rate and interference reduction. By using multiple antennas at Receiver and Transmitter in a wireless system the rich scattering channel can be exploited to create a multiplicity of parallel links over the same radio band and thereby to either increase rate of data transmission through multiplexing or to improve the system reliability through the increased antenna diversity.

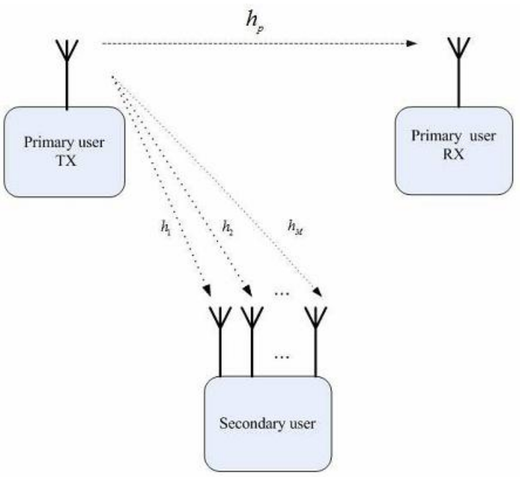

Fig. 2. MIMO for Spectrum Sensing.

V. PROPOSED ALGORITHM

In the proposed methodology the energy of the received signal is calculated and compared to a threshold (γ) to take the local decision that the PU signal is present or absent. The threshold value is set to meet the target probability of false alarm P_f according to the noise power.

i) Choose a value of SNR=-14 db and gain at transmitter antenna =15 db

ii) Choose different values for L (L=1, L=2, L=3, L=4)

iii) Generate the random matrix of L in accordance with number of samples.

ii) Generate AWGN noise having mean = 0 and variance = 1.

Iii)Generate real valued Gaussian PU signal

iv) Generate the received signal at SU

v)Calculate p_d for different antenna configurations

vi) Vary the SNR in increasing order

vii) Plot the graphs for all iterations

V1. RESULTS AND DISCUSSIONS

Case 1. SNR=-14 db, gt=15

Figure 3 gives the result for the probability of detection of the target for different MIMO configurations at SNR of -14db, with the increase in detection probability with the increase in Diversity order.4*4 showing highest Detection probability

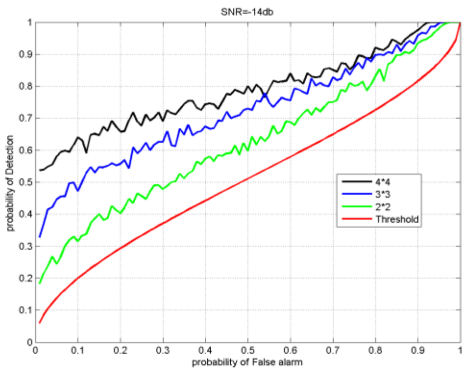

Figure 3. MIMO based P_d SNR=-14 db.

Case 2. SNR=-10 db, gt=15

Figure 5 gives the result for the probability of detection of the target for different MIMO configurations at SNR of -2db.The Detection probability is almost same for all configurations at this SNR with the curves coinciding

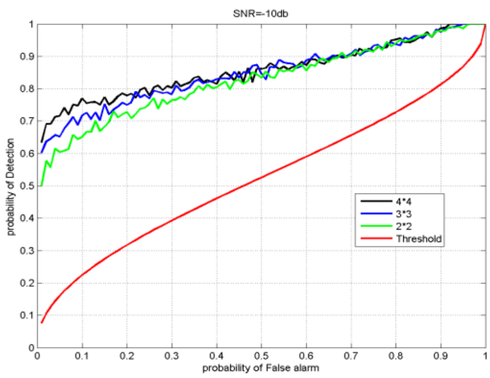

Figure 4. MIMO based P_d SNR=-10 db.

Case 3. SNR=-6 db, gt=15

Figure 5 gives the result for the probability of detection of the target for different MIMO configurations at SNR of -6db.The Detection probability is almost same for all configurations at this SNR with the curves coinciding

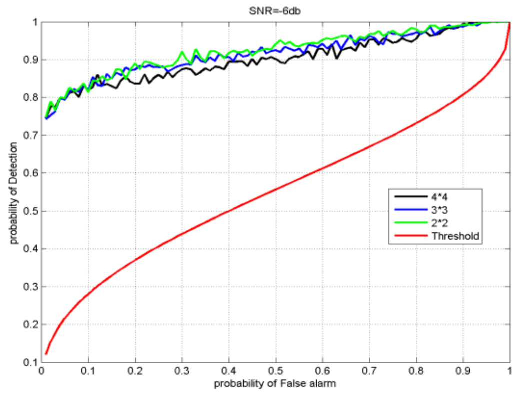

Figure 5. MIMO based P_d SNR=-6 db.

Case 4. SNR=-2 db, gt=15

Figure 5 gives the result for the probability of detection of the target for different MIMO configurations at SNR of -2db.The Detection probability with the increase in diversity order. Again 4*4 has highest detection probability

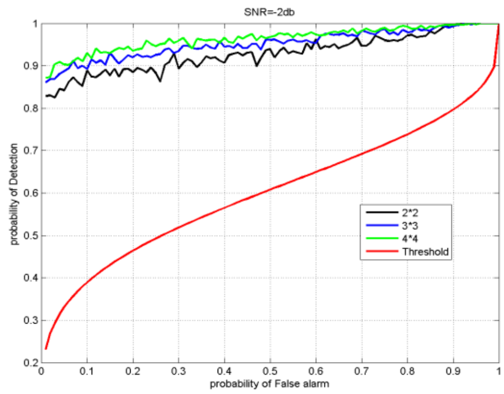

Figure 6. MIMO based P_d SNR=-2 db.

VII. CONCLUSION

In this paper one of the important aspect of Cognitive Radio i.e, Spectrum Sensing is discussed and a new technology based on smart antennas is implemented to enhance the performance of Cognitive Radios for Spectrum sensing. The P_d gets enhanced with the increase in Diversity order. The Threshold is calculated using conventional Energy detection method. Moreover, with these improvements the Spectrum Scarcity problem can be solved and CR can form the backbone of Wireless Communication.

VIII. REFERENCES

[1] FCC, "Spectrum Policy Task Force, ET Docket 02-135, Nov. 2002.

[2] FCC. (2010). Spectrum policy task force report. ET Docket No. 02–380 and No. 04–186, Sep. 2010.

[3] Joseph Mitola III “Cognitive radio for flexible mobile multimedia communications” in Sixth International Workshop on Mobile Multimedia Communications (MoMuC’99), San Diego, CA, 1999.

[4] S.Haykin, “Cognitive radio: Brain-empowered wireless communications” ,IEEE, vol. 23, pp. 201–220, Feb. 2005

[5] Linda Doyle, “ Essentials of Cognitive Radio”, Cambridge University Press ,Edition 2009,

[6] Ying-Chang Liang et al., “ Cognitive radio Networking and communications: An overview” , IEEE Transactions on Vehicular Technology , Vol.60 , No.7, September 2011.

[7] S.Kumar et al., “Cognitive Radio Concept and Challenges in Dynamic Spectrum Access for Future Generation Wireless Communication Systems” , Springer , Wireless Personal Communication ,2011(59):525-535

[8] Gianmarco Baldini et al., “The Evolution of Cognitive Radio Technology in Europe : Regulatory and Standardisation Aspects” ,Elsevier, Telecommunications Policy 37 (2013) 96–107

[9] Alexander M. Wyglinski, “Cognitive Radio Communication and Networks”, Elsevier Publications

[10] Bruce A. Fette , “ Cognitive Radio Technology” , Elsevier Publications.

[11] A. Khattab et al., “Cognitive radio Networks: From Theory to Practice”, Springer ,2013

[12] Ekram Hossain et al., “Evolution and Future Trends of Research in Cognitive Radio: A Contemporary Survey” ,Wiley Online Library, Wireless Communications and Mobile Computing, 2013

[13] Guolin Sun et al., “Benefits brought by Cognitive Radio for the Next Generation Cellular Networks: A perspective from industry” , Elsevier, Physical Communications ,2-9,2012

[14] Natasha Devroye “ Information Theoretical Limits on Cognitive Networks” ,Elsevier,2010

[15] Ekram Hossain et al., “Cognitive Radio : From Theory to Practical Network Engineering”, Springer , New Directions in Wireless Communications Research ,2009

[16] J.L. Mauri et al., “Cognitive Networks :Applications and Deployments”, CRC Press, Taylor & Francis Group”

[17] A.F.Molisch et al., “Propagation Issues for Cognitive Radio”, Proceeding of IEEE, Vol.97, No.5,May2009

[18] Amir Ghasemi et al., “Spectrum Sensing in Cognitive Radio Networks: Requirements, Challenges and Design trade-offs”,IEEE Communications Magazing, April 2008

[19] I.F Akyildiz et al., “A Survey on Spectrum Management in Cognitive Radio Networking”, IEEE Communication Magazine ,April 2008

[20] Lu et al.,“Ten years of research in Spectrum Sensing and Sharing in Cognitive Radio,” EURASIP Journal on Wireless Communications and Networking 2012, 2012:28

[21] Yonghong Zeng et al., “ A Review on Spectrum Sensing for Cognitive Radio : Challenges & Solutions”, EURASIP Journal on Advances in Signal Processing,2010

[22] Raza Umar et al., “ A Comparative study of Spectrum awareness techniques for Cognitive Radio oriented Wireless Networks”, Elsevier, Physical Communications (2013)148-170

[23] M.Adib et al., “Experimental study of Sensing Performance metrics for Cognitive Radio Network using Software Defined Radio Platform”, Springer , ICIEIS, 2011

[24] Waleed Ejaz et al., “Improved Local Spectrum Sensing for Cognitive Radio Networks”, Springer , EURASIP Journal on Advances In Signal Processing, 2012

[25] Yonghong et al., “Eigen value based Spectrum Sensing algorithm for Cognitive Radio”, IEEE transactions on Communications, Vol.57, No.6, June 2009

[26] Joseph Font-Sengura et al., “GLRT based Spectrum Sensing for Cognitive Radio with

prior Information", IEEE Transactions on Communications , Vol 58 , No. 7, July 2010

[27] Ezio Biglieri et al., "MIMO Wireless Communications", Cambridge University Press 2007

[28] Tim Brown et al., "Practical guide to MIMO radio channel with MATLAB examples", Wiley Publications

[29] Miang Jiang et al., " Multi user MIMO-OFDM for Next Generation Wireless Systems", Proceeding of IEEE, Vol.95 , No.7, July 2007

[30] Rui Zhang & Ying-Chang Liang , " Exploiting Multi-Antennas for Opportunistic Spectrum Sharing in Cognitive Radio Networks", IEEE International Symposium on Personal, Indoor and Mobile Radio Communication, September 2007