Spectrum Sensing By Using Energy Detection Technique In Cognitive Radio Network

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Abstract- *Spectrum importance is increasing rapidly in wireless communication technology, due to the usage of spectrum traffic of the spectrum is also increasing. As the spectrum utilization varies from 5% to 85%, more than 70% of the available spectrum is not utilized efficiently. Due to the less availability of spectrum bandwidth is becoming more expensive. For efficient utilization of the spectrum, it is required to determine the spectrum whether it is being used by the primary user or not. Which introduces the concept of cognitive radio. Cognitive radio is referred toas the adoption of radio parameters using the sensed information of the spectrum. Spectrum sensing is the main function of cognitive radio, which enables the user to search for free bands. Which istermed as the spectrum hole and is defined as the frequency band which is free to be used. With high spectral resolution capability the spectrum hole can be utilized by the secondary user. Energy detection spectrum sensing techniqueat different SNR values with different modulation schemes isdiscussed in this paper.*

Keywords- Cognitive Radio (CR), Spectrum Sensing, Primary User(PU)and SecondaryUser (SU).

I. INTRODUCTION

Cognitive radio is first noticed in an article by Joseph Mitola III and Gerald Q. Maguire, Jr in1999. In the last decades, there has been an enormous increase of wireless communication Systems [1].As the frequency bands or spectrumutilization is strictly regulated, and allocated to specific communication techniques. Spectrum is resource which has to be protected.The licensed spectrum is intended to be used only by the spectrum owners i.e. licensed users called as primary users (PU). Cognitive radio is a new technology which allows us to reuse the licensed spectrum in an unlicensed manner.

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The unused resources are often referred to as spectrum holes or white spaces. The spectrum hole can be reused by cognitive radio, sometimes called secondary users (SU).Service providers are facing a problem in a situation in which itis required toprovide larger amount of spectrum to satisfy the increasing quality of service (QOS) requirements to the users. This problem is addressed by using cognitive radio network.

In cognitive radio (CR) a transceiver is placed which can intelligently detect theused and unused frequency bandsa nd instantly move the vacant channels while avoiding the occupied ones, which enables the use of available radio-frequency (RF) spectrum while minimizing interference the interference to other users. That's why it is known as anintelligent device that can coexist with licensed users without affecting their quality of service. There are mainly two types of users in the cognitive radio network, one is Primary User (PU) and the other one is Secondary User (SU). Primary Users (PU) are the licensed users and they have the right of priority in using certain stable frequency band for communications. Secondary Users (SU) are allowed to use the frequency spectrum only in the absence of primary users and they do not interfere with the PU. So the ability of sensing an idle spectrum and the ability to temporarily utilize a spectrum without interfering withPrimary Users are two essential components required for the success of cognitive radios.

The common definition for Cognitive Radio is given as *"Cognitive Radio is a radio for wireless communications in which either a network or a wireless node changes its transmission or reception parameters based on the interaction with the environment to communicate effectively without interfering with the licensed users*."

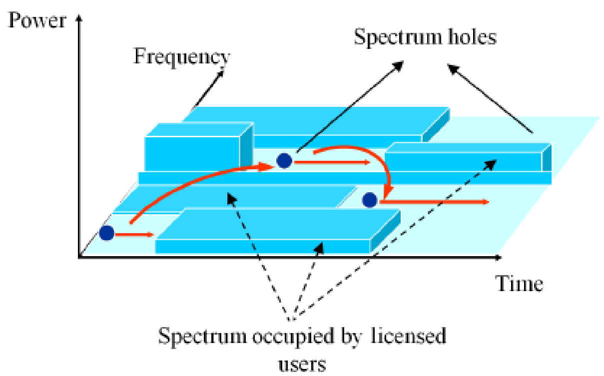

Fig1: Representation of Spectrum Holes

To implement without Interference to the primary signal, the cognitive radio needs to sense the availability of the spectrum before accessing the channel. So while designing a Cognitive Radio network the main challenges we have to consider are: spectrum sensing, interference avoidance, quality of service.

II. COGNITIVE RADIO

In wireless communication system Cognitive Radio is a technology which is aware of the environment and its changes and can adapt its transmission parameters accordingly,Fig2 shows the basic cognitive radio cycle.

A. Characteristics of Cognitive Radio

Cognitive Capability: The Characteristic which has the ability to sense the unused spectrum at a specific time and location (Spectrum Hole) is known as the Capability of Cognitive Radio.

Reconfigurability: Reconfigurability is the ability to receive and transmit signals at different frequency bands,which enables the cognitive radio to reconfigure its parameters and select the best available band [6].

B. Functionalities of Cognitive Radio

***Spectrum sensing*:**At any given time and location the user has the ability to sense the unused spectrum (spectrum hole)**.**It isthe first important functionality of Cognitive Radio system [3].

Spectrum management: After determining the spectrum holes**,** based on the available spectrumband and other policies, Cognitive Radioassigns the spectrum to the user.

Spectrum mobility: Cognitive Radio user or secondary user is allowed to vacate the spectrum in the presence of any licensed user or primary user and it has to move to next available spectrum band [2].

Spectrum sharing: Among the available multiple Cognitive Radio users the cognitive radio network has to provide a fair and optimal spectrum allocation method.

As shown in Fig 2 Spectrum sensing detects the unused spectrum band, the analysis of spectrum holes is performed in spectrum analysis and their characteristics are estimated, by using spectrum decision the available spectrum band is assigned to cognitive users. Depending upon the radio environment changes the decision of Cognitive Radio also changes.

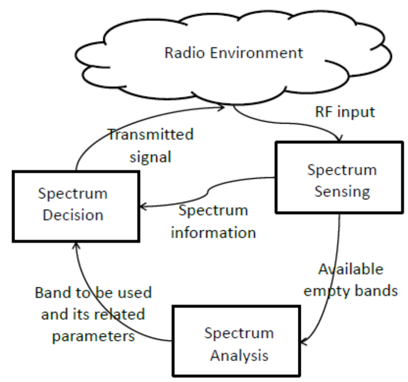

Fig 2: Basic Cognitive Radio Cycle

C. Network access types in Cognitive Radio

Basically there are three Network access types which are as shown in the below Fig 3.

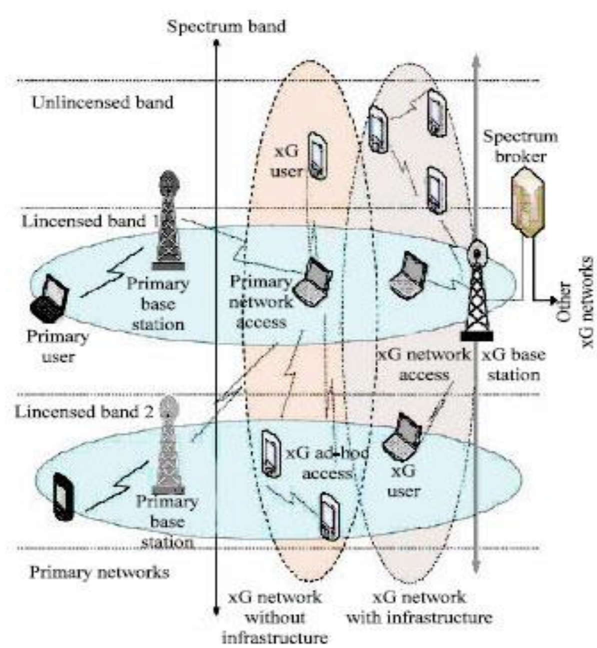

Fig 3: Architecture of Cognitive Radio

CR Network Access: On both the licensed and unlicensed spectrum bands it can access their own base station.

CR AD-HOC Access: By using the ad hoc connection on both the licensed and unlicensed spectrum bands cognitive radio can communicate with other Cognitive Radios.

Primary Network Access: Through the licensed bands cognitive radios can access their primary base station.

As shown in Fig3 [9], the network which has the right to use the licensed band is known as primary network and the user of that network is known as Primary User, primary base station is used to provide signals to primary network. The network which is able to access the spectrum in the absence of primary user is known as cognitive network and the user is known as Secondary User or cognitive radio user, cognitive base station is used to provide signals to cognitive radio network. Spectrum broker is a central network entity which is able to share the spectrum resources among different cognitive radio networks.

The network architecture may be centralized and distributed. In centralized network base station is responsible for gathering the information from all other CR users to detect the primary user. In distributed network CR exchange messages among each other to get the desired objective.

D. Applications of Cognitive Radio Networks

Cognitive Radio networks can be applied to the following cases:

Leased network: The primary network may provide a leased network by allowing cognitive radio user to accesstheir licensed spectrum without disturbing the communication of the primary user.

***Cognitive mesh network*:** Cognitive Radio technology enables the access to larger amount of spectrum (for broadband connectivity) therefore cognitive radio networks will be a good choice to meet the requirements of mesh networks.

Emergency network: In the case of natural disasters, when primary networks temporarily disable their spectrum band, it can be used by the cognitive radio users. The cognitive radio networks can communicate on the available spectrum band in an ad hoc mode withoutusing any infrastructure and by maintaining the communication priority and response time.

Military network: Cognitive radio networks can enable the military radios to choose arbitrary intermediate frequency (IF) bandwidth, modulation schemes, and coding schemes, adapting to the variable radio environment of battlefield.

E. Operation of Cognitive Radio Networks

The network architecture of cognitive radio varies greatly depending on the desired applications. Cognitive radio network can be centralized where a central node coordinates spectrum sensing, allocation and management of all serviced nodes as shown in fig 4(a). On the other hand, nodes in a distributed cognitive radio network communicate with each other in an ad-hoc manner to coordinates cognitive tasks as shown in fig 4(b). Typically a centralized network simplifies the communication and computation load of each end node, but requires more infrastructure and cost. On the other hand distributed network is more structurally flexible and require little infrastructure at the expense of increased complexity.

Regardless of architecture, cognitive radio must be flexible in detecting changes in primary user activity, hence the cognitive tasks must be performed periodically. Collectively the cognitive tasks forms a cognitive cycle to ensure the integrity of cognitive radio network and protection of primary user activities.

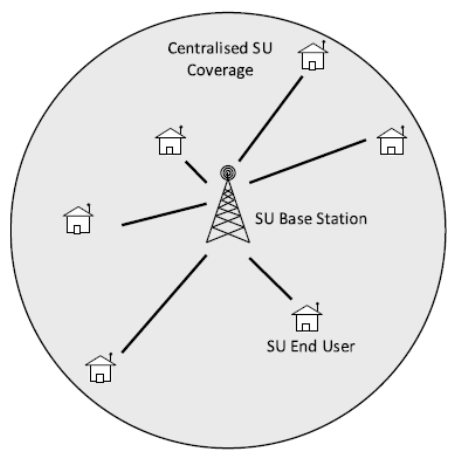

Fig 4 (a): Centralized network

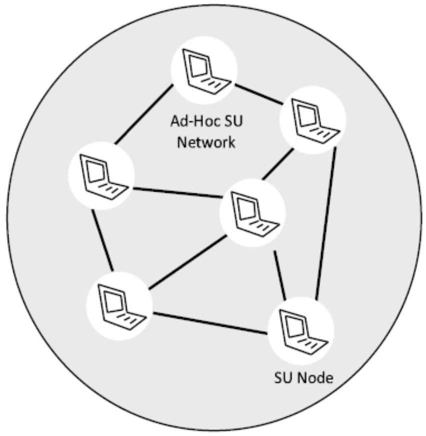

Fig 4(b): Distributed network

Hence the network architecture may be centralized and distributed. In centralized network base station is responsible for gathering the information from all other CR users to detect the primary user. In distributed network CR exchange messages among each other to get the desired objective.

III. SPECTRUM SENSING TECHNIQUES

Spectrum sensing is the main challenge to the Cognitive Radio system.A spectrum hole has to be determined by using spectrum sensing technique in the radio environment. There are so many different methods are available to identify the presence of signal transmission,which all are in the early development stage only.Finding out the spectrum status and activity by periodically sensing the target frequency band is themain goal of spectrum sensing. Cognitive radio transceiver detects the spectrum which is unused or spectrum hole and also determines the best available method to access the spectrum without interfering the transmission of licensed user.Different types of spectrum sensing techniques are shown in Fig 5.

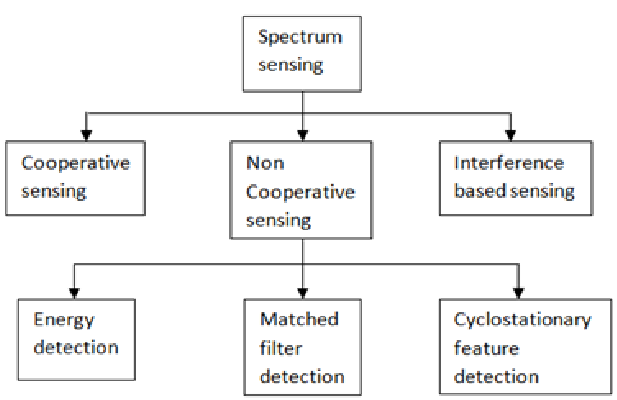

Fig 5: Classification of Spectrum sensing techniques

Detection may be cooperative and non cooperative. In cooperative spectrum sensing the effect of the communication of one node on the other nodes is considered i.e. information from many cognitive radio users are combined to detect the primary user. It helps to overcome the multipath fading and shadowing effects which will increase its usability. In Non cooperative techniqueonly a single node is considered for effective communication i.e. the cognitive radio user can detect the signal of primary user by its own observation and analysis is independent of the other CR users.Non cooperative techniques are also known as transmitter detection techniques and these are termed as narrowband spectrum sensing techniques.Based on the received signal at Cognitive radio users the detection of primary users is performed. This approach includes energy detection, matched filter (MF) detection, cyclostationary feature detection, etc.

A.PHYSICAL CHARACTERISTICS OF SPECTRUM:

The radio frequency spectrum is formed by a virtually infinite set of discreet frequencies characterized as waves with wavelengths corresponding to the simple formula, frequency equals the speed of light divided by the wavelength, or

$$f = \frac{c}{\lambda} \quad (1)$$

These radio waves operate as periodic waves and therefore the time-varying value of the signal at a point in space may be represented in the general form

$$S(t) = A(t)\cos(2\pi f t) \quad (2)$$

Where *s* is the signal strength, *t* is the time, *A* is the amplitude of the signal, and*f* is its frequency. Note that *A* can either be a constant or vary with time.

B.ENERGY DETECTION:

The availability of primary user is determined by using the spectrum sensing technique, which is the main aim to decide whether there is primary user or not. By using the transmitter detection technique each cognitive radio (CR) must have the ability to determine the presence or absence of the Primary user (PU) independently in a specified spectrum. The hypothesis model for transmitter detection that is, the signal detected by the Secondary user (SU) is given as:

$$H0: y(t) = w(t)$$

H1: y (t) =h*x (t) +w (t) (3)

Where H0 indicates that the primary user is absent i.e.no signal is transmitted, and H1 indicates that the primary user is present i.e. signal is transmitted. Y (t) is the signal received by the secondary user, x (t) is the signal which is transmitted, w (t) is the Additive White Gaussian Noise (AWGN) with zero mean and variance σ^2 and 'h' is the amplitude of the channel [8].

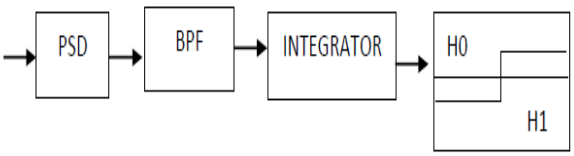

Fig 6: Block diagram of Energy detection technique

It is the common way of spectrum sensing technique for its low computational and implementation complexities. Which is a non-coherent detection methodand it is used to detect the licensed user signal. Here no prior knowledge of primary users signal is required and is based on the use of the FFT (Fast Fourier transform).FFT transforms a signal from time domain to frequency domain representationand determines the power in each frequency of the signal resulting thePower Spectral Density (PSD) function.

As Energy detector consumes less with low computational complexity when compared with other spectrum sensing techniques it is gaining more popularity. Figure 6 shows the block diagram of energy detection technique in which the signal is applied to the band pass (BP) filter to select the channel and it is integrated over the time interval. At Last output of the integrator is compared with a threshold to determine whether the primary user is present or not. Depending on the channel conditions the threshold value can be fixed or variable.

Advantages:

I. No prior knowledge of primary signal is required.
II. Computational and implementation complexity is low.
III. Low power consumption.

Disadvantages:

I. It cannot distinguish between noise and primary user especially at low SNR values.
II. Issues related to selecting a proper threshold for comparison purposes.

IV. MODULATION TECHNIQUES

Modulation is a method of encoding digital data on multiple carrier frequencies. Modulation is the addition of information to an electronic or optical signal carrier. Modulation can be applied to direct current (mainly by turning it on and off), to alternating current, and to optical signals. In a typical digital communication system, the modulation process usually occurs between the encoding process and the RF front end. After the encoding process, we need a unique signal waveform to represent each transmitted symbol. Since we are using binary sources and sinks, we can have up to 2^bpossible symbols if each symbol can represent *b* bits.

In communication systems the two main considerations are (i) Transmission power (ii) Channel bandwidth.

Various modulation schemes are used for the transmission of signals. By using the symbols the signaling rate will be reduced i.e. two or more bits are combined into symbols which reduces the frequency of the carrier. This in turn reduces the transmission channel bandwidth. By grouping the bits into symbols, the transmission channel bandwidthis reduced. To convert the bits into symbols various modulation schemes are used such as BPSK, QPSK, and M-ary PSK etc.

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing or modulating the phase of a reference signal or the carrier signal. The modulation is impressed by varying the sine and cosine inputs at a precise time. It is widely used for wireless LANs, RFID and Bluetooth communication.

A. Binary Phase Shift Keying (BPSK)*:* BPSK (also sometimes called as PRK, phase reversal keying, or 2PSK) is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this Fig 4.3 they are shown on the real axis, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol (as seen in the figure) and so is unsuitable for high data-rate applications.

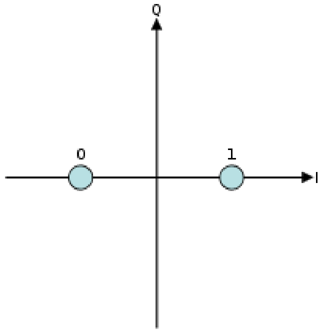

Fig 7: Constellation diagram of BPSK

This yields two phases, 0 and π. In the specific form, binary data is often conveyed with the following signals:

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)\, S_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$ for binary"1" (4)

$$S_2(t) = -\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)\, S_2(t) = -\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$ for binary "0" (5)

Where f_c is the frequency of the carrier signal.

B. Quadrature Phase Shift Keying (QPSK): In QPSK two successive bits in the data sequence are grouped together. This reduces the bits rate or signaling rate and thus reduces the B.W of the channel. In case of BPSK, we know that when sym. Changes the level, the phase of the carrier is changed by 180°. Because, there were only two symbols in BPSK, the phase shift occurs in 2 levels only. However, in QPSK, 2 successive bits are combined. In fact, this combination of two bits forms 4 distinct symbols. When the symbol is changed to next symbol, then the phase of the carrier is changed by 45 degrees.

$$S_i(t) = \sqrt{\frac{2E}{T}}\cos[2\pi f_c t + (2i-1)\frac{\pi}{4}]$$, i=1, 2, 3, 4. (6)

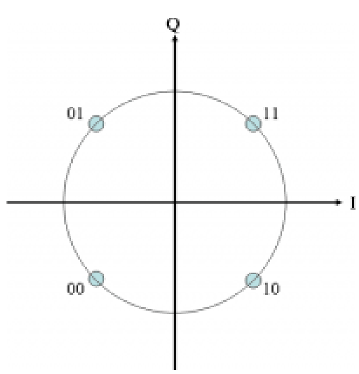

Fig 8*:* Constellation diagram of QPSK

Sometimes this is known as *quadriphase PSK*, 4-PSK, or 4-QAM. (Although the root concepts of QPSK and 4-QAM are different, the resulting modulated radio waves are exactly the same.) QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gary coding to minimize the bit error rate (BER). This yields the four phase's π/4, 3π/4, 5π/4 and 7π/4 as needed.

C.M-ary Phase Shift Keying (M-PSK): Under certain operating conditions, it is possible that the amplitude values of a transmission is more readily susceptible to the channel errors than the phase values. Furthermore, the efficient design of an RF amplifier with a sufficient linear range has always been problematic. Consequently, employing a constant-amplitude modulation technique designed to modulate the entire transmission using phase information can potentially alleviate these issues. One such modulation scheme is *M-ary phase shift keying* (M-PSK), where the *M* signal constellation points are equally spaced around a circle of constant distance from the origin.

We can achieve bandwidth efficiency when we represent each signal element to map more than one bit. In BPSK modulation digital data of 1 and 0 is represented by 180 degree phase change. In QPSK by phase shift of 90 degree, here 2 bits are mapped on each signal. In Multilevel PSK more than 2 bits are mapped using different phase angles. In 8-PSK eight different phase angles are used to represent bits, here 3 bits. Fig 9 shows the constellation diagram of 8-PSK signal.

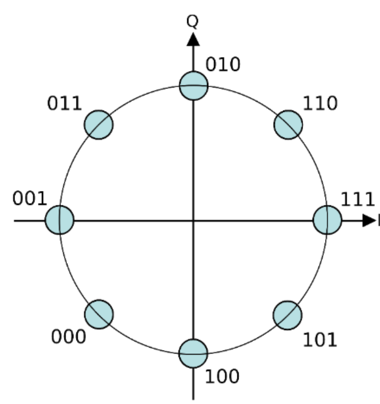

Fig 9: Constellation diagram of 8-PSK

Fig 10 shows an example of an M-PSK signal constellation for M = 16 points, where each point uniquely represents $b = \log_2(16) = 4$ bits.

As for the general mathematical expression for the *i*th signal waveform for an M-PSK signal, $S_i(t)$, it is defined as

$$S_i(t) = \sqrt{\frac{2E}{T}}\cos[2\pi f_c t + \frac{2\pi i}{M}]$$, m=1, 2, 3…M. (7)

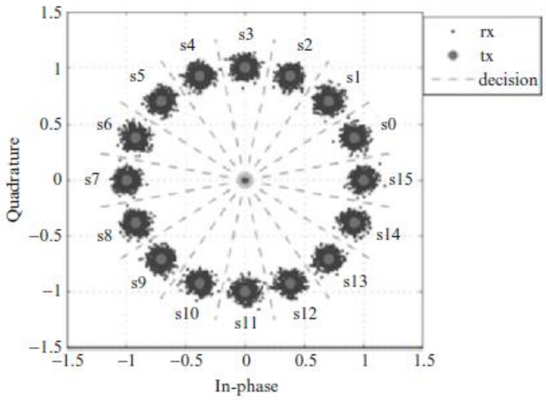

Fig 10: Constellation diagram of 16-PSK

Note that, since all of the transmission data are represented solely by the phase information, M-PSK is well-suited for nonlinear power amplifiers and is robust to amplitude distortion channels due to the constant envelope.

The best trade-off between power and bandwidth requirements is offered by the QPSK (M=4) among the family of M-ary PSK signals. For M>8, power requirements become excessive so they are not widely used in practice. As M is increased, the bandwidth efficiency is improved and also the probability of symbol error improves.

V. RESULTS AND DISCUSSION

In this paper the results are shown for different modulation techniques at various SNR values for two types of input data. One is the normal input text and another one is random data. Here the results are observed at 200HZ frequency, depending on the users requirement the frequency is also varied.

A.RESULTS FOR NORMAL INPUT TEXT

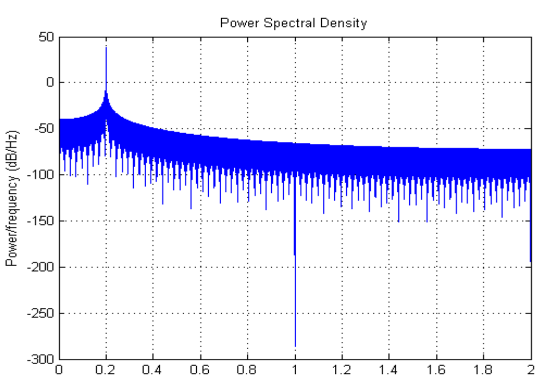

Fig 11: Energy Detector Output at SNR 30dB for BPSK when primary user is present at 200HZ

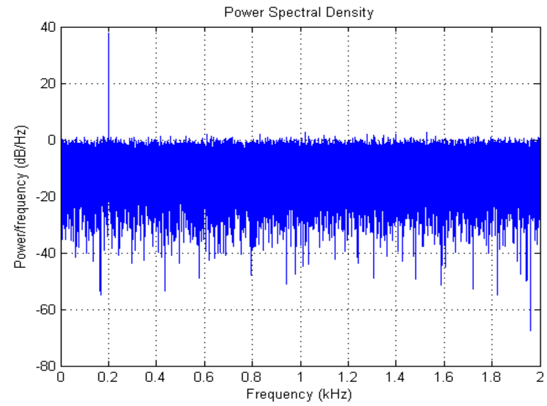

Fig 12: Energy Detector Output at SNR -30dB for BPSK when primary user is present at 200HZ

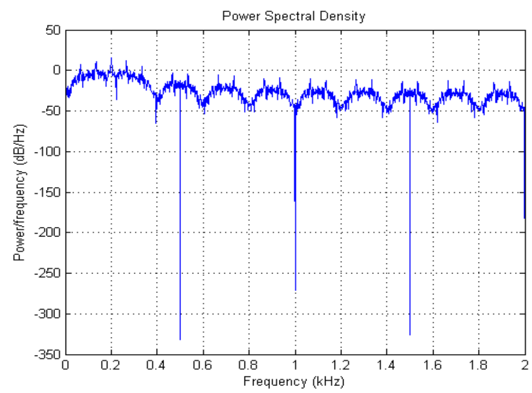

Fig 13: Energy Detector Output at SNR 30dB for QPSK when primary user is present at 200HZ

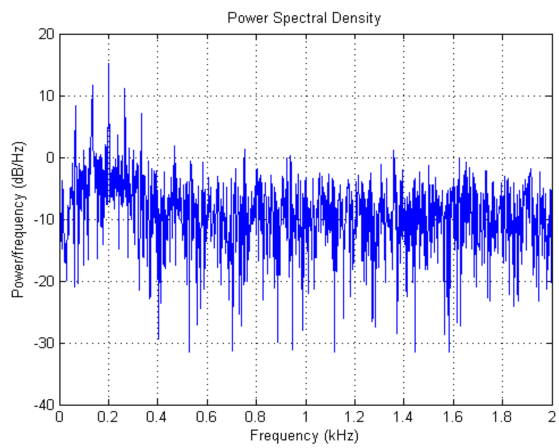

Fig 14: Energy Detector Output at SNR -30dB for QPSK when primary user is present at 200HZ

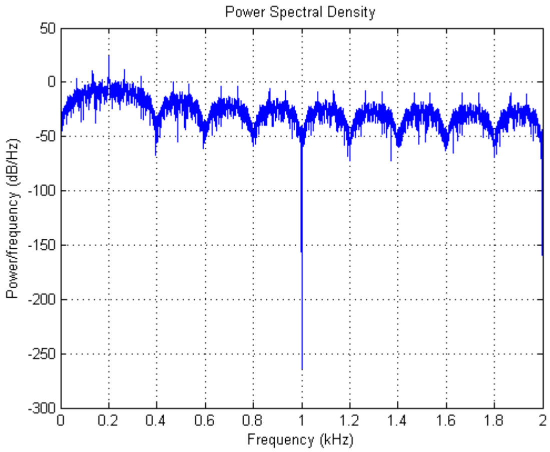

Fig 15: Energy Detector Output at SNR 30dB for 8PSK when primary user is present at 200HZ

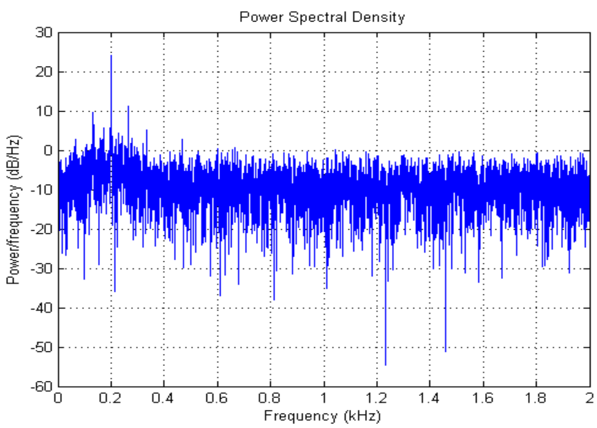

Fig 16: Energy Detector Output at SNR -30dB for 8PSK when primary user is present at 200HZ

B. RESULTS FOR RANDOM DATA OF (500, 50)

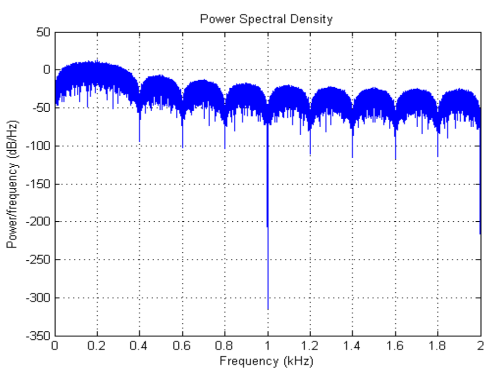

Fig 17: Energy Detector Output at SNR 30dB for BPSK when primary user is present at 200HZ

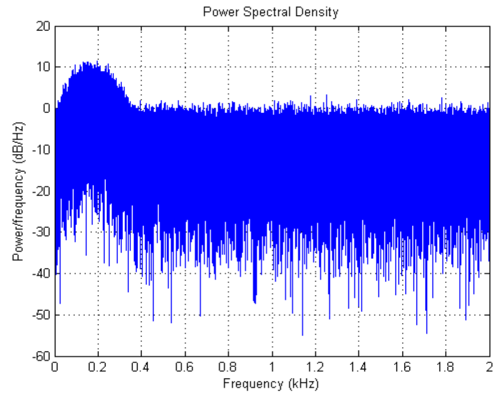

Fig 18: Energy Detector Output at SNR -30dB for BPSK when primary user is present at 200HZ

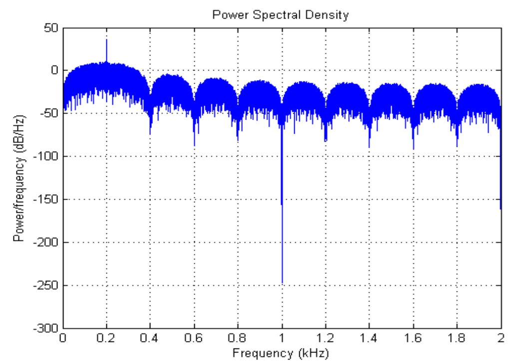

Fig 19: Energy Detector Output at SNR 30dB for QPSK when primary user is present at 200HZ

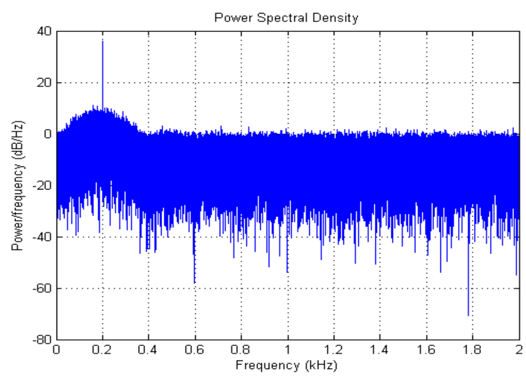

Fig 20: Energy Detector Output at SNR -30dB for QPSK when primary user is present at 200HZ

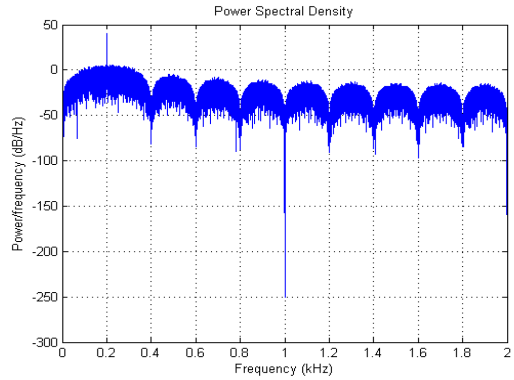

Fig 21: Energy Detector Output at SNR 30dB for 8PSK when primary user is present at 200HZ

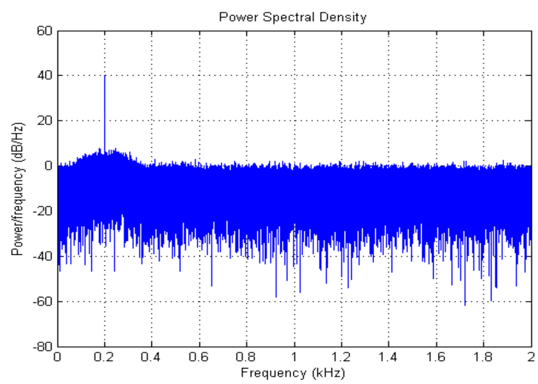

Fig 22: Energy Detector Output at SNR -30dB for 8PSK when primary user is present at 200HZ

The maximum peak in every result plot indicates the operating frequency. Depending on the transmitted data and signal to noise ratio and the modulation scheme employed the characteristics of the plot also varies. Hence the results shows that it is difficult to detect the presence of primary user at very low SNR values.

VI. CONCLUSION

As the usage of frequency spectrum is increasing day by day, it isbecoming more valuable. Soit is required to access the frequencyspectrum very wisely. For thispurpose we are using the CognitiveRadio network to access the spectrum in less time and to use the spectrum efficiently. In this paperthe discussionis aboutenergy detection spectrum sensing technique which are used for the detection of primary user and thereby allocating the spectrum hole to the secondary user (SU) in the absence of primary user (PU) with less power consumption and less computational complexity. As shown in results it is working well for high SNR values and it is not good at very low SNR values but due to the less time taking it is used widely. So the cognitive radio system can be applied in the case of leased network, cognitive mesh network, emergency network and military network.

REFERENCES

[1] S. Haykin, Cognitive Dynamic Systems, Proceedings of the IEEE, vol. 94, no. 11, Nov. 2006, pp. 1910-1911.

[2] A. Bansal, Ms. R. Mahajan, "Building Cognitive Radio System Using Matlab", *IJECSE*, Vol.1, Number 3, 2012.

[3] Samuel Cheng, 2012, Foundation of Cognitive Radio Systems.

[4] D. Cabric, S. M. Mishra, and R. W. Brodersen, "Implementation Issues in Spectrum Sensing for Cognitive Radios",in Proc. 38thAsilomar Conference on Signals, Systems and Computers, pp. 772776, Nov. 2004.

[5] P. Venkatramana#1, S. Narayana Reddy#2, "Efficient Cyclostationary Detection Based Spectrum Sensing in Cognitive Radio Networks",(IJETT) – Volume 19 Number 4 – Jan 2015.

[6] Ian F. Akyildiz, Won-Yeol Lee, Mehmet C. Vuran, ShantidevMohanty, "Next generation/dynamic spectrum access/cognitive radio wireless networks: A survey" Broadband and Wireless Networking Laboratory, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, United States, Received 2 January 2006; accepted 2 May 2006.

[7] Linda E. Doyle "Essentials of Cognitive Radio", Trinity College, Dublin.

[8] A. Sahai and D. Cabric, "Spectrum sensing: fundamental limits and practical challenges," *IEEE Proc. of International Symposium on New Frontiers in Dynamic Spectrum Access Networks(DySPAN*), Baltimore, MD, 2005.

[9] I.F. Akyildiz, Y. Altunbasak, F. Fekri, R. Sivakumar, AdaptNet: adaptive protocol suite for next generation wireless internet, IEEE Communications Magazine 42 (3) (2004) 128–138.

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