An Efficient Cognitive Radio Spectrum Sensing Approach Using Modulation Schemes

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Abstract- Due to the various number of diverse wireless devices and technologies, there is a increase in the number of wireless subscribers. Thus the radio frequency (RF) spectrum is becoming more crowded. The main wireless Communication resources are bandwidth and power. Hence conservation and proper utilization of available spectrum is needed. Thus, spectrum sensing is becoming progressively more important for identifying underutilized spectrum. Spectrum sensing in cognitive radio (CR) is an essential method that identifies the presence or absence of primary user signals in a channel. In this paper average information based spectrum sensing is used for the modulated signal to identify the presence of the primary user (licensed user) accurately. I.e. Here, QAM/PSK modulation schemes are used for spectrum sensing. Here average information based spectrum sensing is used. Here the average information refers to entropy. The average information of primary users (with and without the presence of licensed or primary users in spectrum) is calculated using MATLAB. The Entropy that occurs when the primary user is present or absent is H0 hypothesis and H1 hypothesis respectively and a threshold is calculated. If Entropy for H1 hypothesis is less than the threshold then the primary user presence is identified.

***Keywords*—**Cognitive radio (CR), Entropy, Spectrum sensing, QAM, PSK, Threshold value, SNR

I. INTRODUCTION

The growing demand for wireless applications usage has put a lot of constraints on the usage of the available radio spectrum which is a limited in resource. This limited resource leads to congestion or data traffic in the usage of the spectrum. The above data traffic is because the spectrum is not utilized properly due to the static allocation spectrum sensing. So, for proper utilization of spectrum, dynamic spectrum allocation management is introduced. This dynamic spectrum allocation laid as a principle for Cognitive Radio (CR) i.e. this cognitive radio has the ability to sense the unused spectrum. The main task in implementing the cognitive radio is for Spectrum Sensing (SS).

So, the Cognitive radio (CR) technology is used to predict the unutilized spectrum in wireless communication. The users of wireless communications are divided in to two types, they licensed or Primary User and unlicensed or Secondary User. Allocated spectrum portions are not always used by their owners (licensed users), which creates spectrum holes.

With the vast number and diversity of wireless devices and technologies, exponential increase in the number of wireless subscribers, the emergence of new applications, and the continuous demand for higher data rates, RF spectrum is becoming increasingly crowded. These developments in the communications market demand systems and devices which are aware of their RF environment and can facilitate flexible, efficient, and reliable operation and utilization of available spectral resources. Therefore, spectrum sensing and its ability to identify underutilized spectrum is becoming progressively more important to current and future wireless communication systems to identify underutilized spectrum with characterizing interference and consequently, achieving reliable and efficient operation

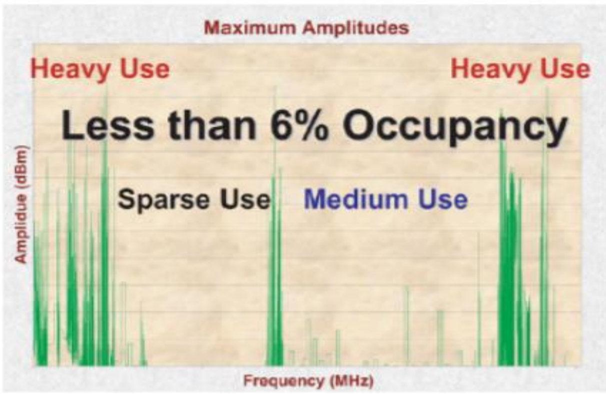


Fig1:Band Occupancy

A spectrum hole, is a frequency band assigned to a primary user, but it is not being used at a particular time and at a particular location. Therefore, the radio spectrum is inefficiently utilized. Thus, the scarcity and inefficiency of the spectrum management needs an enhancement in the radio spectrum access and to achieve high network performance. The spectrum scarcity issue is solved by sharing unoccupied channels with unlicensed users, called secondary users.

1.1 Cognitive Cycle

A cognitive radio network performs a 3-process cycle called sensing, deciding, and acting

- The first process i.e. sensing, is a critical stage where the measurements are taken and the also sensing of spectrum is performed. Due to multipath fading, varying channel conditions and uncertainty affects this sensing process. In the observation process, measurements taken by the SUs may also uncertain.

- In the next process i.e. deciding, secondary users make a decision based on prior knowledge(i.e. information observed in first process) using their knowledge basis, this may have been impacted by the uncertainty in the detected measurements, results to the wrong decisions.
- In the last process i.e. acting, the uncertainty spreads over the cognitive radio cycle, and sometimes the wrong actions are taken by the secondary users. Thus, uncertainty propagation impacts the radio spectrum processes, which degrades the cognitive radio performance.

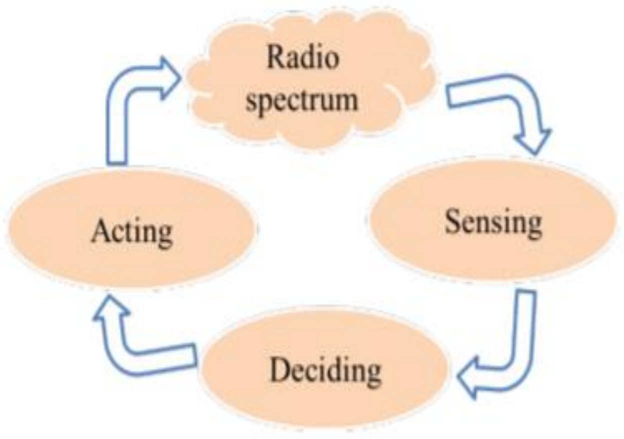


Fig2: Spectrum sensing cycle

1.2 Spectrum Sensing Using Cognitive Radio

Spectrum sensing is considered as a key function of cognitive radio which is used to identify the available spectrum for improving the spectrum's utilization. Secondary user can access the licensed node in the spectrum only when the Primary user is absent. If the secondary user is accessing the licensed node, and when the PU starts retransmitting, then secondary user must be relocated. For relocation, primary user presence should be detected by the secondary user and also should identify whether the node is idle or busy. Thus, cognitive radio with a high capability of sensing is required to satisfy all above requirements. However, the presence of primary user signal estimation becomes more challenging, if the network becomes denser**.**

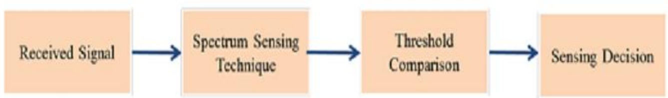


Fig3: Block Diagram of Spectrum Sensing

1.3 Different Spectrum sensing Techniques

Some of the techniques which are available to detect the presence or absence of primary user are Energy Detection(ED), Cyclostationary Feature Detection (CFD), and the Matched Filter (MF),Eigen value detection etc.

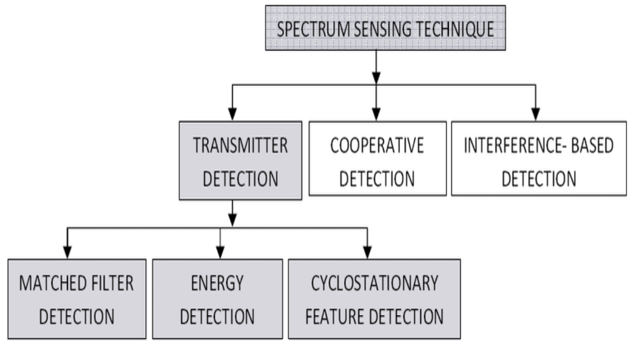
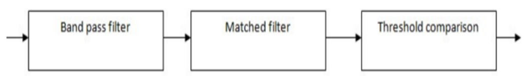


Fig4: Spectrum Sensing Techniques

- **Energy detection** is the simplest sensing technique where there is no need of priori knowledge of the primary user . Here the primary user is detected by sensing the energy. Generally, the energy of the signal must be greater than noise energy. The detector compares its energy with a predefined threshold value to identify the presence of the primary user. By keeping false alarm probability constant as per the constant false alarm rate principle, the threshold value is calculated. This fixed threshold causes the degradation of performance in the low SNR region. But this energy-based detection is frequently used for its less complexity and efficient performance, as it does not requires the prior knowledge of the primary user's signal. ED can considered as blind signal detector as it does not require the structure of the signal.

- **A matched filter** is a linear filter that maximizes the output SNR for a given input signal. This matched filter detection technique is used when the prior knowledge of primary user is known. In this matched filter (MF) operation the unknown signal is convolved with the filter's impulse response which is the mirror and time-shifted version of the primary user signal.

$$Y(n) = \sum_{k=-\infty}^{\infty} k\, h(n-k)\, x(k)$$



- **Cyclostationary** detection is robust to noise uncertainty. The performance of this technique is far better than the Energy Detection(ED) technique. This technique deals with the features of the signal. These signals have spectral correlation and spectral statistics which are not found in any other interference signals. Cyclostationary detection identifies the primary user by exploiting the periodicity in the received primary signal. It also performs better in low signal to noise ratio, but it has high computational complexity and longer sensing time. So, it is less common than ED.

- **Eigenvalue detection** does not require prior knowledge of the primary signal which becomes more advantage when compared to others methods. By comparing the ratio of maximum to the minimum eigenvalue of the covariance matrix with the threshold value it identifies the presence of users.. Computational complexity is its main drawback.

II. LITERATURE REVIEW

In [1] the problem of detecting whether a frequency band is being used by a known primary user or not is considered. Here fundamental bounds on detection performance in low SNR in the presence of noise uncertainty - the noise is assumed to be white, but we know its distribution only to within a particular set.

In [2] the evaluation of a spectrum sensing strategy based on the frequency domain entropy applied to cognitive radio networks is presented. A trade off between variance and the spectral resolution for Bartlett periodogram is presented. But this trade off affects the probability of detection and false alarm of the spectrum sensing strategy in environments with low signal-to-noise ratio and noise uncertainty.

In [3] a comprehensive performance comparison of energy detection, matched-filter detection, and cyclostationarity-based detection, the three popular choices for spectrum sensing by cognitive radios. Analytical expressions for the false alarm and detection probability achieved by all the detectors are derived.

In [4] a survey of spectrum sensing methodologies for cognitive radio is presented. Various aspects of spectrum sensing problem are studied from a cognitive radio perspective. The Wavelet Edge Detection is one of the most widely used Spectrum Sensing techniques

In [5] to improve the reliability of detection, a two stage entropy-based cooperative spectrum sensing scheme using two bit decision is proposed and a robust detector based on the entropy of spectrum amplitude was proposed.

In [6] the average information based spectrum sensing method is used. It tells about the detection of of primary users by using entropy value. But here the accuracy of detection is low.

III. EXISTING METHOD

Average information based spectrum sensing technique is used in existing work. Here average information is nothing but entropy. This entropy is the measure of information or randomness of an event. The entropy is said to be less when predictability of event becomes high. For example, rain may or may not come has higher entropy when compared to a sure event that rain comes today. Here measure of information means detection of presence or absence of primary users. The entropy of the received signal is reduced if the modulated signal is present.

The entropy-based detection in the time domain performs lesser than that of the entropy-based detection in the frequency domain. Because the Entropy-based detection in the frequency domain provides higher sensing reliability in low SNR. Here, average information is calculated by using histogram, which reduces the complexity in implementation.

3.1 SYSTEM MODEL

Spectrum sensing can be modelled as a binary hypothesis test problem. The hypotheses under test are: H0 : x (n) = ω (n) (1)

H1 : x (n) = s (n) +ω (n) (2)

n = 0, 1…. N-1,

Hypotheses H_0 idle frequency band and H_1 is for busy frequency band . In (1) and (2), x(n), s(n), ω(n) correspond to the received signal, the modulated signal, and the noise samples respectively. Shannon's entropy is denoted by the letter H, is a measure of the uncertainty present in the random variable. It can be calculated by the following equation:

$$H(X) = -\sum_{i=1}^{L} \frac{ni}{N}\, log2\, \frac{ni}{N} \quad (3)$$

$$\lambda = HL + Q\text{-}1\ (1 - Pf\ a)\ \sigma n \quad (4)$$

Where, $HL = \ln(2\frac{-1}{2})\, L + 2^{-1}\gamma + 1$ (5)

λ - Threshold

P_{fa} - Probability of false alarm is set as 0.2

Q^{-1} - Inverse Q function

γ - Euler-Mascheroni constant

σ_n - Standard deviation

Let the number of elements in X falling inside the i^{th} bin such that

$$\sum_{i=1}^{L} Ni = N.$$

For EnBD, the detection strategy consists of testing the entropy obtained as:

$$H(X) \underset{H_1}{\overset{H_0}{\gtrless}} \lambda$$

The previous detection techniques, are robust to noise uncertainty because the entropy is calculated from the amplitude spectrum. But here, the entropy is calculated using histogram. From the equation (4), threshold value is calculated. By comparing this threshold with the entropy of H1 and H0, the probability of detection is calculated as given in equation (6).

The performance of spectrum sensing is evaluated by the “Probability of detection” (Pd). The probability of detection quantifies the ability to correctly detecting the presence of a primary signal.

- Here, Entropy is calculated for the random signal by using equation (3),
- A threshold is determined to calculate the presence or absence of user using the condition in equation (6) and then finally probability of detection is calculated.

3.2 DISADVANTAGES

- Probability of detection is low.
- Computational complexity is high.
- Accuracy is low

IV. PROPOSED METHOD

In this proposed method the entropy is calculated by using the QAM/PSK technique. By comparing the entropy’s H0 and H1 we can measure the probability detection. A threshold is used to determine or calculate the presence and absence of user. The probability of detection is used for spectrum sensing. The below block describes the proposed method.

- Quadrature Amplitude Modulation (QAM), uses both phase and amplitude components. So that this modulation technique is able to provide efficient spectrum utilization. QAM uses two carriers ,offset in phase by 90 degrees—and varying symbol rates (i.e., transmitted bits per symbol) to increase throughput.

- QAM provides an efficient modulation for data used in everything from cellular phones to Wi-Fi and other form of high speed data communications system.

- QAM codes are also used for transmission in micro wave digital radio with more enhanced spectral efficiency over limited channel bandwidths. Quadrature amplitude modulation is a signal in which two carriers shifted in phase by 90 degrees (i.e. sine and cosine) are modulated and combined.

- Phase Shift Keying (PSK) is one of the digital modulation technique. Here in PSK, by varying the sine and cosine inputs at a particular time, the phase of the carrier signal is changed. This technique is widely used for wireless LANs, bio-metric and Bluetooth communications. The term PSK is broadly used in a radio communication system. This type of technique is mostly used in data communications. Based upon the phases the signal gets shifted, the PSK is divided in to two types. They are –BPSK and QPSK.

- BPSK (Binary phase shift keying) the name itself says as it is a 2-phase PSK .It is a phase reversal keying in which the sine wave carrier takes two phase reversals such as 0° and 180°.It is normally a Double Side Band Suppressed Carrier (DSBSC) modulation scheme, for message being the digital information.

- QPSK is one of the PSK technique, in which the sine wave carrier takes four phase reversals such as 0°, 90°, 180°, and 270°.This PSK technique can be furtherly extended, by eight or sixteen values , based upon the requirement.

Procedure:

- In this proposed method the entropy is calculated by using the QAM/PSK technique.

- The entropy for the hypothesis H0 and H1 is calculated.

- The presence of primary user in the spectrum is identified when entropy of H1 is less than the defined threshold value λ.

- The absence of primary user in the spectrum is identified when the entropy of H0 is greater than the threshold value λ. A threshold is used to calculate the presence or absence of primary user. Thus the probability of detection is calculated by comparing the entropy of H1 and H0 with the threshold values.

BLOCK DIAGRAM

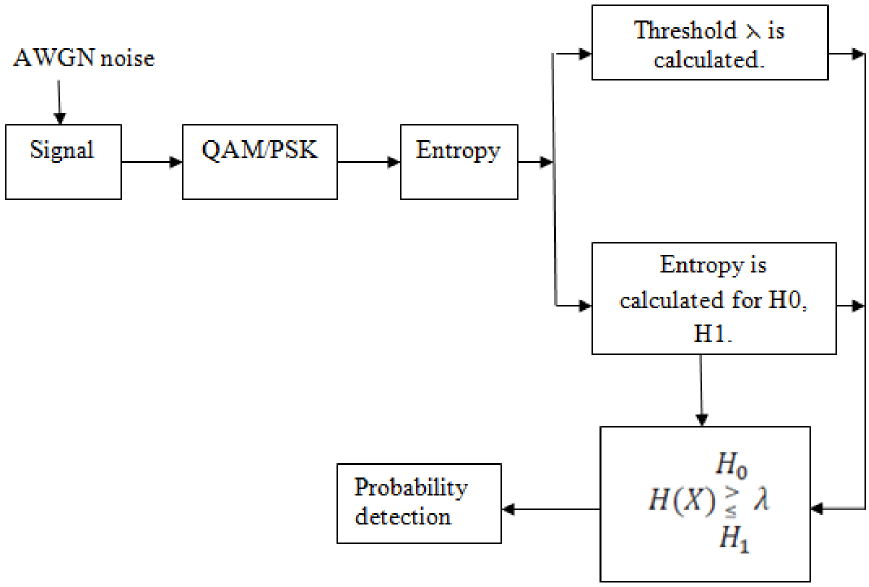


Fig5: Block Diagram

V. RESULTS

PROBABILITY OF DETECTION VS SNR IN DB **(Without Using QAM)**

SNR(in DB)	**PROBABILITY OF DETECTION**
-20	**0**
-10	**1**
-5	**1**
10	**1**
20	**1**

From above analysis we can notice that the probability of detection of primary user occurs from -10 onwards. i.e, when we compare the previous works with the proposed work the probability of detection becomes 1 at low snr values itself (i.e, here at -10db but in previous works we get 1 as probability detection at -5db)

5.1 COMPARISON OF RESULTS:

5.2

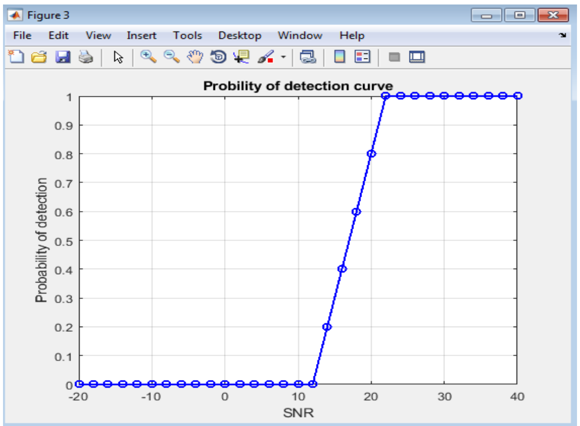


Fig 6 :Probability of detection curve(without using QAM)

5.2 USING QAM MODULATION SCHEME

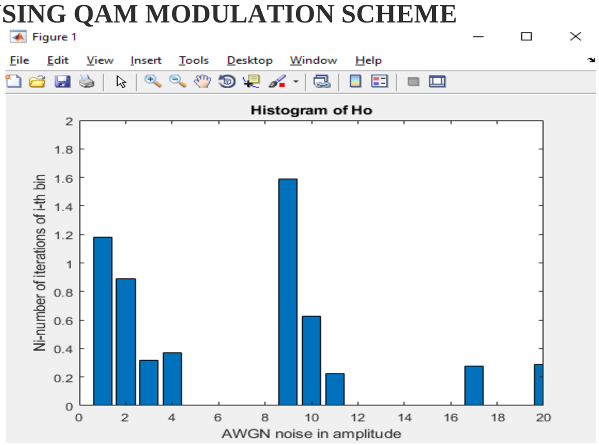


Fig8: Histogram of H0

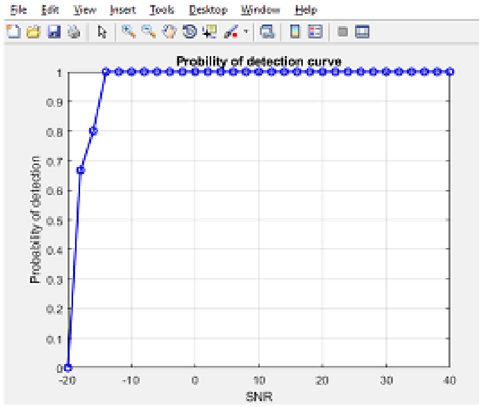


Fig 7 :Probability of detection curve(using QAM)

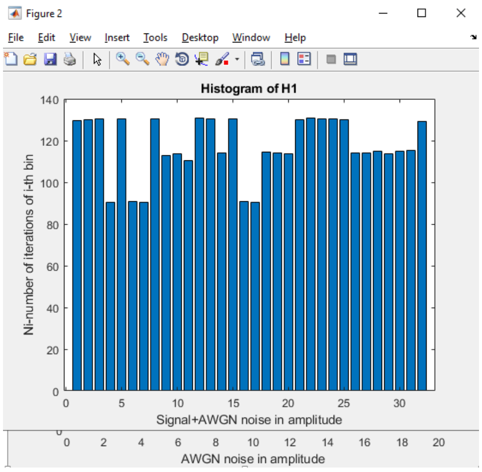


Fig9: Histogram of H1

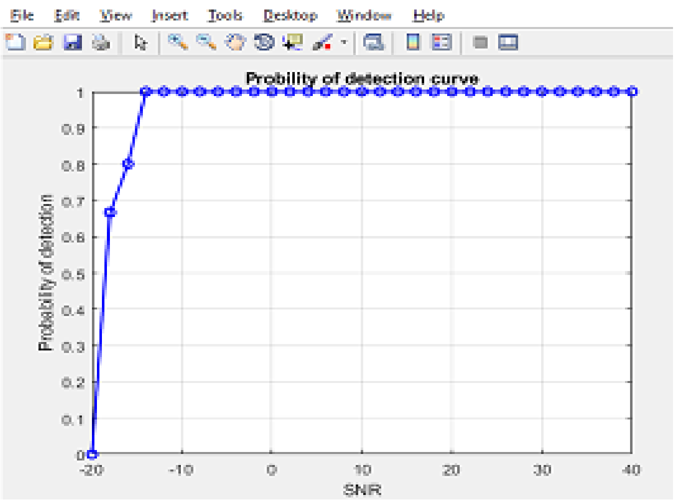


Fig 10: Probability of detection curve

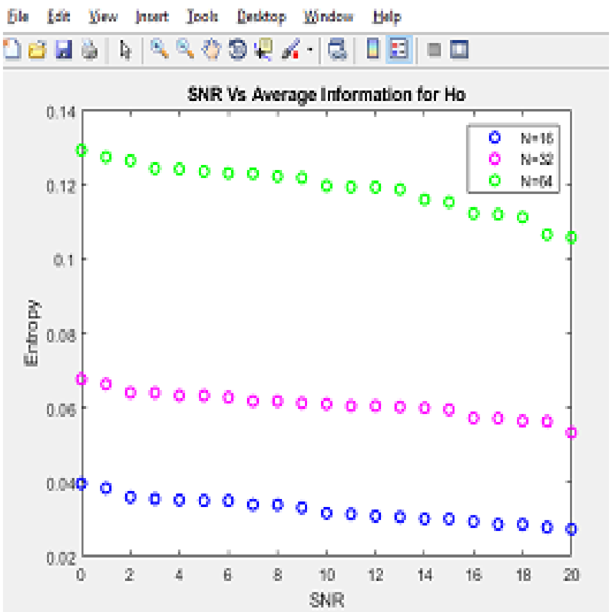


Fig 11: SNR (dB) Vs Average Information

5.3 USING PSK MODULATION SCHEME

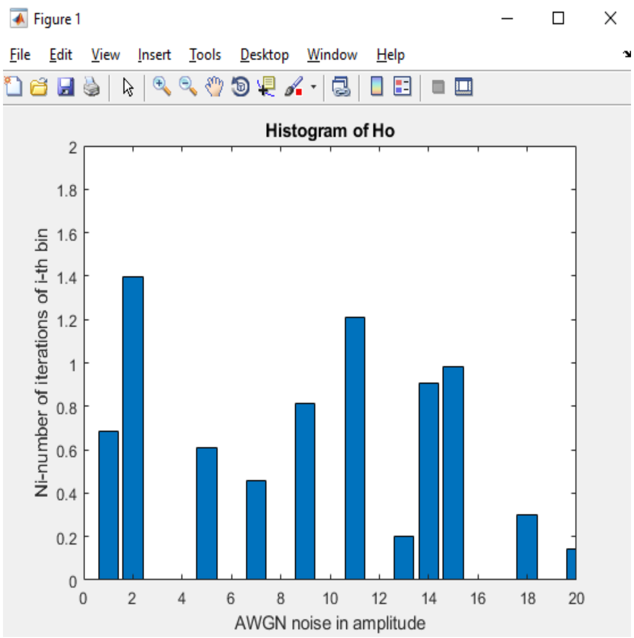


Fig 12:Histogram of H0

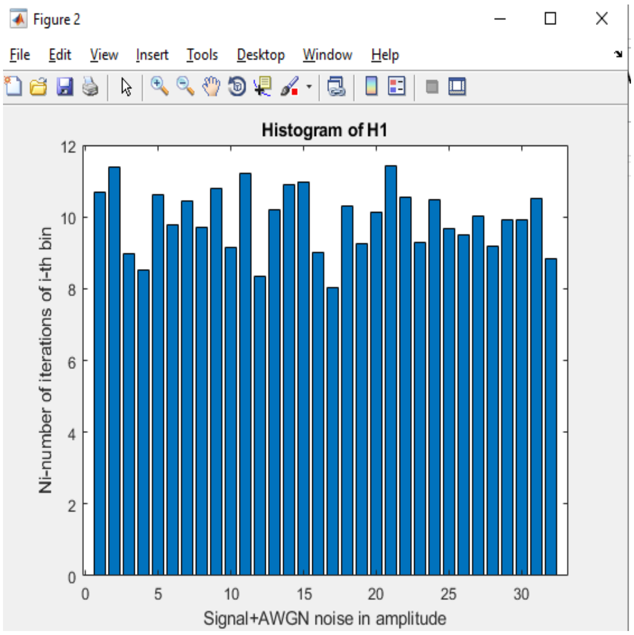


Fig 13:Histogram of H1

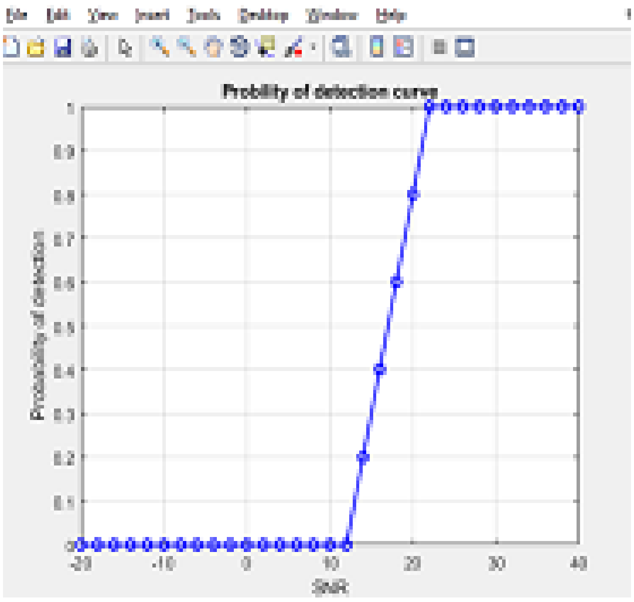


Fig 14: Probability of detection curve

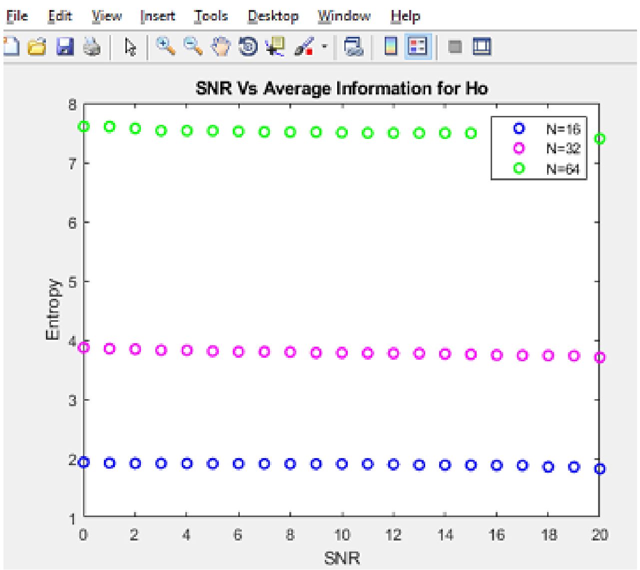


Fig 15: SNR (dB) Vs Average Information

VI. CONCLUSIONS

Thus by using the proposed method the entropy value decreases which means probability of detection of user increases. QAM/PSK is used in this proposed method. This method is used to detect the presence of primary users. By calculating the entropy the presence of primary user is detected. If the entropy value is lower than the primary user is absent. The probability detection is calculated for spectrum sensing.

VII. REFERENCES

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