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Multiband Spectrum Sensing Using SDR Technology

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Abstract— *Cognitive Radio system is a smart wireless communication system that can sense the radio spectrum and detect unused spectrum holes. CR is an application of SDR. CR involves four stages i.e., spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility. In this project Matched filter, Energy detection and Compressive sensing are implemented. These techniques are coded in MATLAB Software.*

Energy detection method is one of the most commonly used signal sensing methods in spectrum sensing due to its low implementation complexity. It is a simple technique as it does not require prior knowledge about the primary user signal. The primary goal of spectrum sensing is to identify empty spectrum gaps across broad frequency ranges so that secondary users can use them to fulfil their needs. However, sensing process requires a great deal of time, compressive sensing is used to speed up the spectrum sensing.

Keywords — *Cognitive radio, Spectrum sensing, Matched filter, Energy Detection, Compressive spectrum sensing, Threshold, SNR, PFA, PD.*

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I. Introduction

Modern wireless networks provide a broad range of high data rate apps to multiple users concurrently. To achieve this goal, they must surmount the actual limitations set by the resources they require, such as electricity and spectrum, which are restricted in nature. As the number of wireless devices grows rapidly, the scarcity of these resources, particularly the frequency band, becomes increasingly problematic. So, Software-defined radio (SDR) is a radio transmission system that modulates and demodulates radio signals using software. At the moment, software-defined radio can be used to create basic radio modem methods. SDR is anticipated to become the main technology in radio transmission in the long term. Enhancements to software-defined radios can be added fast and simply. Software-defined radios can communicate and listen to numerous stations simultaneously. Cognitive radio is an SDR program. Clever radios or cognitive radios (CRs) can analyze the use of the RF band in their immediate vicinity and optimize their performance.

CR techniques allow you to use or share a spectrum in the most efficient way possible, as well as function on the best accessible channel. CR technology, in this manner, enables secondary users (SU), also known as unlicensed users, to identify which parts of the spectrum are accessible and recognize the existence of licensed users or primary users (PU). When an SU functions in an unauthorized band, the CR chooses the best available channel, coordinates its access, and, when a PU is identified, departs the channel to prevent interferences.

A. Functionalities of CR

1)Licensed band: CR uses try to exploit the unused spectrum holes in the licensed spectrum band. However, priority is given to primary users, so CR uses must able to detect the presence of a primary user and should vacate the spectrum band immediately if a primary user appears in the spectrum band occupied by the CR user.

2)Unlicensed band: if no primary user is occupying the spectrum, then CR uses have equal right to access the spectrum. In this case, access should be coordinated between the CR uses by employing a suitable spectrum sharing methods to increase the spectrum efficiency and support high QoS.

B. Stages of CR

1)Spectrum sensing: Due to a growing demand for high data speeds, static frequency cannot meet this demand. As a consequence, new techniques for utilizing the spectrum are presented. Exploiting unused spectrum is a novel method to acquire spectrum in cognitive radio. Spectrum sensing is the method of determining the frequency of interference across the spectrum in order to find vacant channels. In this way, spectrum is effectively used. Spectrum sensing is also used to determine the sort of information, such as the transmission frequency, encoding scheme, waveform, and so on.

2)Spectrum sharing: One of the major obstacles in open spectrum utilisation in CR networks is spectrum sharing. Two of the primary causes of the particular difficulties of spectrum sharing in CR networks are the coexistence with licensed users and the broad variety of available spectrum. It allows the CR (unlicensed user/secondary user) to transmit along the selected spectrum band provided that the licensed user is not affected.

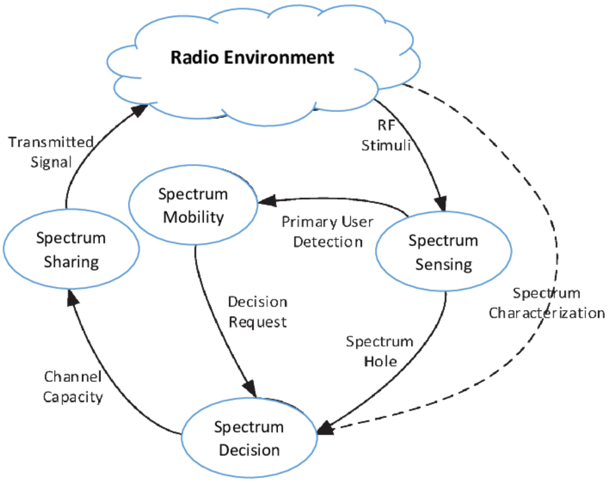


Fig.1: Stages of CR

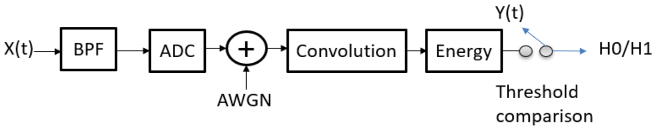
3)Spectrum decision: The capacity of a cognitive radio (CR) to choose the optimal spectrum frequency to meet the quality of service (QoS) needs of secondary users (SUs) without negatively affecting licensed or primary users is known as spectrum decision. (PUs). Spectrum classification, spectrum choice, and CR reconfiguration tasks are all part of the spectrum decision process.

4)Spectrum mobility: The Cognitive Radio (CR) empties the channel when an approved (Primary) user is identified. This cognitive radio characteristic is represented by spectrum movement, also known as handoff. It occurs when the frequency of operation changes.

High data rates, and thus high bandwidth, are required for the next iteration of communication networks. Secondary users, from this viewpoint, must detect broad frequency ranges of the radio spectrum in order to locate the best available channels. As a consequence, several methods to wideband spectrum sensing have been suggested. The frequency range of wideband spectral detection starts at a few GHz. Wideband sensing methods are presented in this paper, including matched filter detection, energy detection, and compressive spectrum sensing.

II. Matched filter detection

In spectrum sensing, a matched filter is created by comparing an unknown signal to a known delayed signal, or template, in order to determine whether the unknown signal contains the template. As a result, the unknown signal will be combined with a conjugated, time-reversed version of the template. In the presence of additive stochastic noise, the matched filter is the best linear filter for maximising the signal-to-noise ratio (SNR). If CR is aware of PU, the matched filter (also known as coherent detector) can be considered as the finest detecting method. It is extremely precise because it optimizes the obtained signal-to-noise ratio. (SNR). The PU presence is found by correlating the signal with a time-shifted version and comparing the end output of the matched filter to a preset level. As a result, if this information is incorrect, the paired filter performs poorly**.**



The Threshold comparison for the matched filter technique is given by:

$$\lambda = {}^{1}/_{L} \sum_{n=1}^{L} y(n)^{*} x\,(n)$$

where L denotes number of samples, y is the vector of samples and x is input of samples and λ is the Threshold comparison such that:

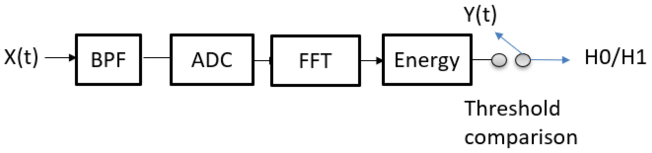
$E < \lambda$ H0: Primary user absent
$E > \lambda$ H1: Primary user present

where λ depends upon the noise level present in the received signal.

While matched filter methods are ideal in that they only need a small number of samples to achieve accurate performance recognition, they are not frequently used because previous knowledge of the main user signal is frequently unavailable. Hence, prefer energy detection to improve efficiency and performance of sensing.

III. Energy detection

It is not necessary to have any prior knowledge of the signal properties to use the approach of energy detection, which is quite straightforward. Calculating the samples energy and comparing it to a threshold is the process of energy detection.



By limiting the likelihood of a false alarm and repeatedly updating the threshold's value to increase the likelihood of detection, the threshold is chosen using a constant false alarm rate technique. Using the prior choices as well as a few additional factors, such as the intended probabilities of false alarm and detection, SNR, and sample count, this technique dynamically determines the threshold.

The idea is illustrated in and determines the energy of the samples as the FFT's squared magnitude divided by the sample count L. It is provided by

$$E = \frac{1}{L} \sum_{n=1}^{L} |y(n)|^2$$

where E denotes signal energy and L is number of samples.

We assume that H0 indicates that the primary user signal is not present does not exist and H1 indicates that the primary user signal is present. The model of the received signal under these two assumptions, H0 and H1 , can be expressed as:

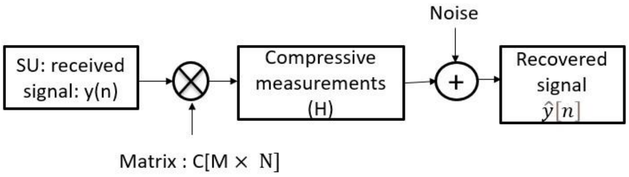
$Y(n) = s(n)$ H0: Primary user absent
$Y(n) = x(n)+s(n)$ H1: Primary user present

where Y(n) represents the received signal, s(n) represents a Gaussian white noise and x(n) is the transmitted signal, and n denotes the sensing time.

IV. Compressive Spectrum Sensing

Compressive sensing has been suggested as a way to speed up the wideband spectral sensing procedure. The initial sparse signal is recovered from the few measurements used in this approach, which decreases the number of observations that must be sampled. Sparse representation, measurement or encoding, and sparse recovery or decoding are the three primary steps involved. Sparsity and reciprocal consistency are two key ideas in compressive sensing theory. The sparse recovery problem, which is an indeterminate linear system, must satisfy these two requirements in order to be solved. The majority of signals used in wireless transmission are sparse in the frequency domain because only a small number of frequency channels are consistently used by their primary users, while the rest are either not used at all or only occasionally.

. The model of the received signal under these two assumptions, H0 and H1, can be expressed as:



y = ϕn H0: Primary user absent

y = $\phi(s+n)$ H1: Primary user present

where, ϕ denotes fixed measurements of matrix M×N.

A. Parameters: The parameters of above techniques are given as follows:

1)Probability of False alarm (PFA): The probability of a false alarm should be kept to a minimum when using spectrum sensing because it occurs when the detector chooses the wrong signal, such as primary signal H1 instead of secondary signal H0. The secondary user wouldn't use it in this case because the monitor didn't pick up the open channel. PFA should be kept as low as is practical to prevent the detection from reaching a poor decision. As a result, the effectiveness of the spectral detection is evaluated using the probability of a false alarm.

PFA= $\{y > \lambda \backslash \mathrm{H0}\}$

In MATLAB simulation, Probability of false alarm Threshold is given by:

$\lambda = [Q^{-1}(Pf)/\sqrt{L} + 1]$

where Q(.) is the Q-function.

2)Probability of detection (P_D): The primary signal H1 is present in the channel depending on the chance of discovery, or P_D. The auxiliary user is protected from primary user disturbance by PD. So, for band identification in cognitive radio, P_D should be strong.

$P_D = \{y > \lambda \backslash \mathrm{H1}\}$

In MATLAB simulation, Probability of detection Threshold is given by:

$P_D = Q(\sqrt{2e}, \sqrt{\lambda}) = \mathrm{marcumq}(\sqrt{2e}, \sqrt{\lambda})$

where, Q(.) is the Marcum-Q function

$e = 10^{0\cdot 1(SNR)}$

V. Flowchart

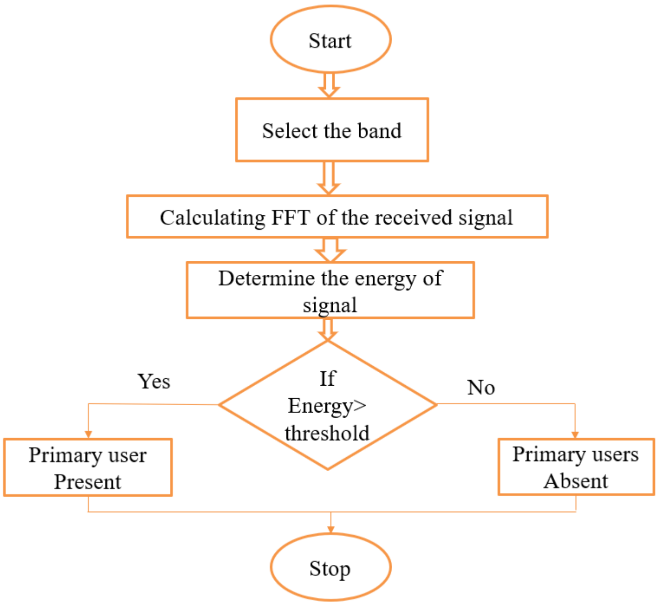


Fig.2: Flowchart of Energy detection algorithm.

In this proposed flow chart, a band is selected to transfer the transmitted primary signal. A band pass filter, also referred to as a BPF or a pass band filter, is a device that only permits frequencies that fall within a given frequency range and refuses (attenuates) frequencies that fall outside of that range. First, add up all the received signals to get the received signal (y) at the recipient. The energy of the incoming signal is calculated in MATLAB using the square and absolute functions. The energy signal is compared with the threshold value. When it exceeds the threshold value, the detector indicates the presence of the Primary user signal.

VI. Results & Analysis

Energy detector to detect the primary signal is coded in MATLAB. To determine the probability of detection of primary signal, compare the threshold value to the received signal H1. The threshold value is evaluated taking fixed proposed PFA value 0.1, 0.01, 0.001 and 0.0001 considering a single user. The algorithm is evaluated for signal to noise ratio range between -15dB to 30 dB in interval of 5dB. Probability of detection of primary signal is computed using threshold by 1000 iterations. The probability of detection is obtained by using QPSK modulation for better spectrum sensing. Result shows that the probability of detection is directly proportional to the Signal-to-Noise Ratio (SNR). If P_D increases, the SNR value also increases simultaneously.

A. Figures and Tables:

Here taken number of samples 1000 and SNR is -15dB for both fig.3 and fig.4. By comparing both signals, observed that changes in the energy. Hence, the detection changes.

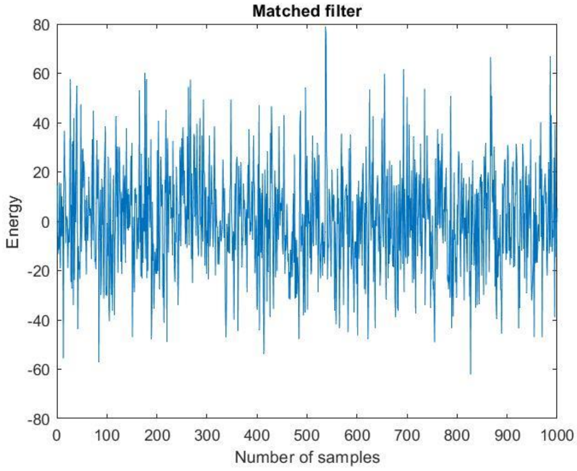


Fig. 3: Presence of primary users

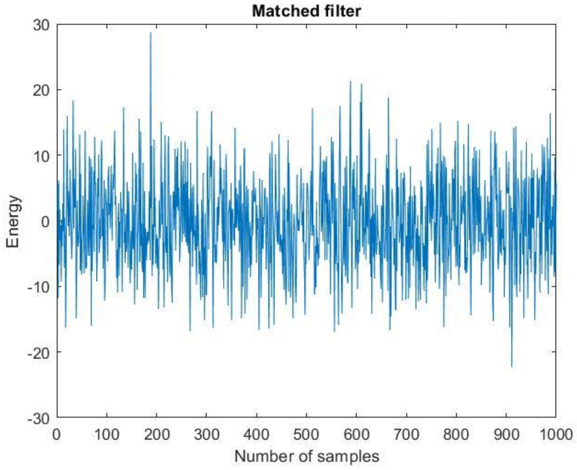


Fig. 4: Absence of primary users

The below figures shows energy detection method for SNR vs Pd of Pf 0.1 and SNR ranges between -30dB to 20dB in interval of 5dB.

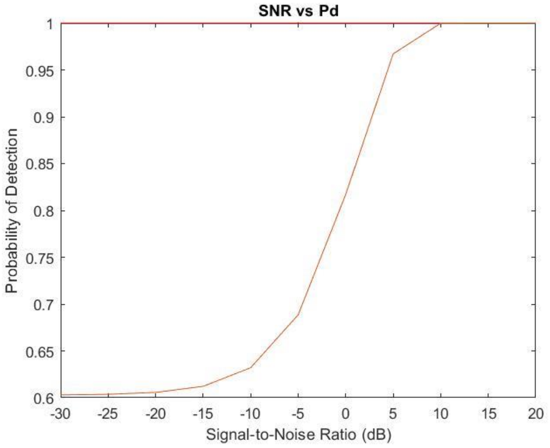


Fig.5: SNR vs Pd

The fig.6 shows SNR vs Pd for different Pf values i.e., 0.01, 0.001, 0.0001, 0.00001 and giving low SNR ranges between -10dB to 15dB in interval of 5dB.

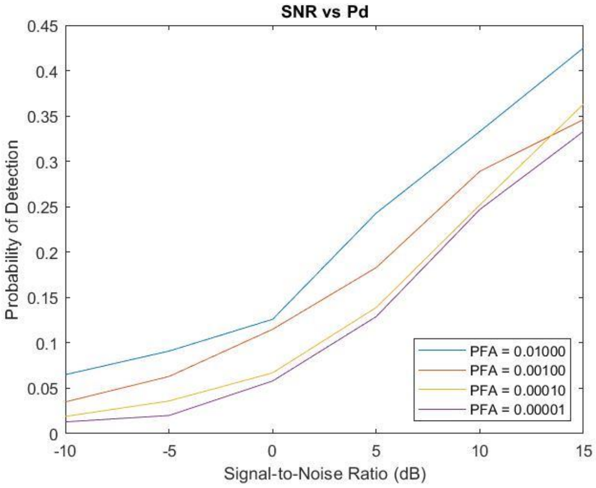


Fig.6: SNR vs Pd for different Pf values

The fig.7 and fig.8 shows SNR vs Pd using QPSK modulation. Here the Pf values are 0.001 and 0.01 for fig.7 and fig.8 respectively and SNR ranges between -15dB to 20dB in interval of 5dB.

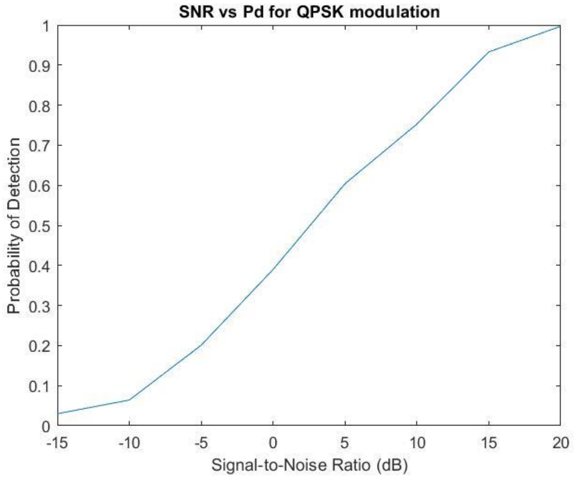


Fig.7: SNR vs Pd for QPSK modulation of Pf 0.001

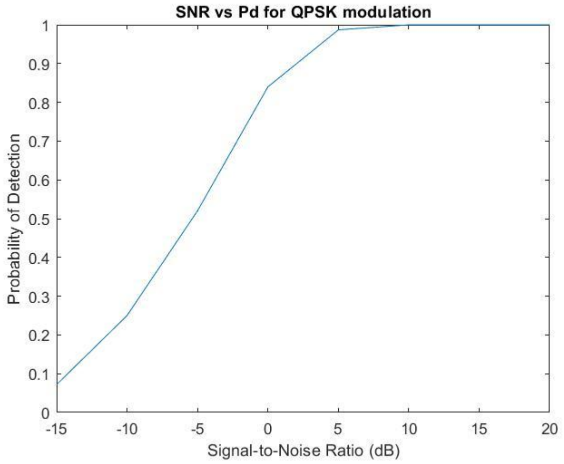


Fig.8: SNR vs Pd for QPSK modulation of Pf 0.01

The below figures shows compressive spectrum sensing. In fig.9 shows that SNR vs Pd using normal sensing and SNR ranging from -20dB to 20dB in interval of 5dB and taking measurements [128, 256, 512, 1024] and pf is 0.1.

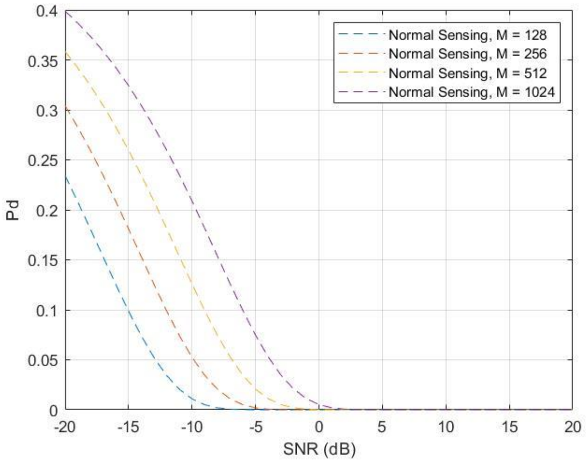


Fig.9 SNR vs Pd using Normal sensing

Fig. 10 shows that SNR vs Pd using Compressive sensing and SNR ranging from -20dB to 20dB in interval of 5dB and pf value is 0.1 and taking measurements [128, 256, 512, 1024].

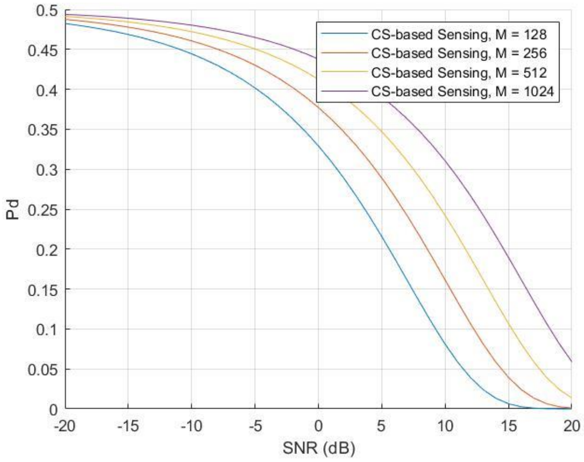


Fig.10 SNR vs Pd using compressive sensing

Fig.11 and fig.12 shows comparison between compressive sensing and normal sensing. The SNR ranges between -20dB to 20dB in interval of 5dB and taking measurements [128, 256, 512, 1024] and pf values are 0.1 and 0.01 for fig.11 and fig.12 respectively.

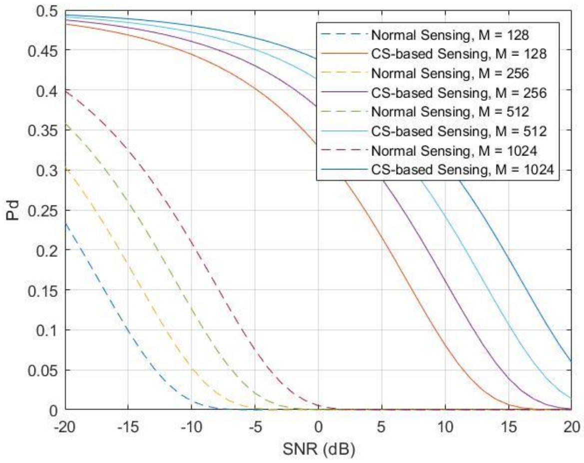


Fig.11 compressive sensing and normal sensing for pf value 0.1

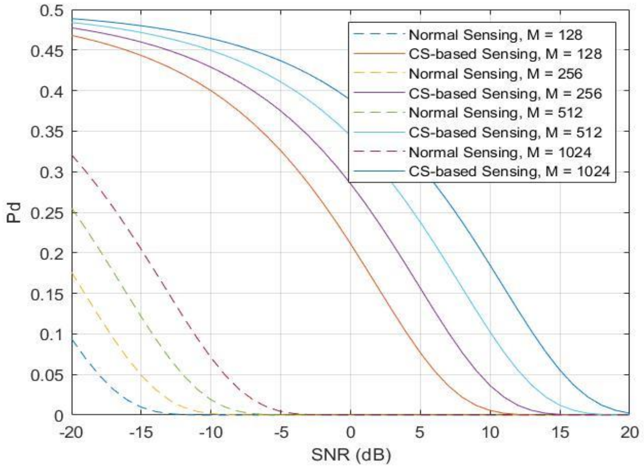
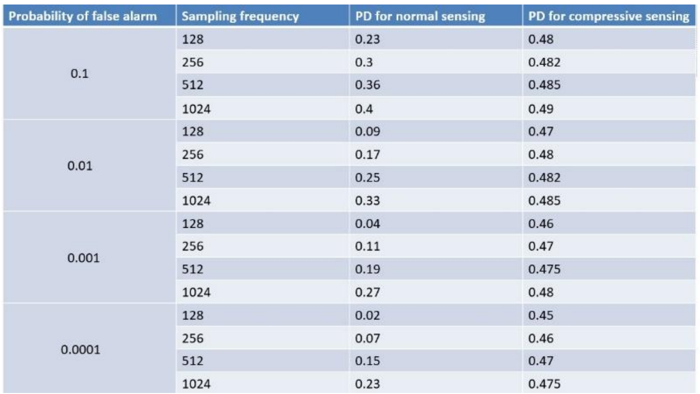


Fig.12 compressive sensing and normal sensing for pf value 0.01
The comparison of Pd between normal sensing and Compressive sensing



Probability of false alarm	Sampling frequency	PD for normal sensing	PD for compressive sensing
0.1	128	0.23	0.48
	256	0.3	0.482
	512	0.36	0.485
	1024	0.4	0.49
0.01	128	0.09	0.47
	256	0.17	0.48
	512	0.25	0.482
	1024	0.33	0.485
0.001	128	0.04	0.46
	256	0.11	0.47
	512	0.19	0.475
	1024	0.27	0.48
0.0001	128	0.02	0.45
	256	0.07	0.46
	512	0.15	0.47
	1024	0.23	0.475

Fig.13 Table

VII. Conclusion

This paper gives some idea about cognitive radio technology andand spectrum sensing methods. The methods are Matched detection, E

Energy detection, and Compressive sensing are implemented using Matlab simulation. In this work, the graph between SNR and Probability detection is plotted using QPSK modulation, Normal sensing and Compressive sensing techniques. The simulation results are given for number of samples like 1024, 512, 256, 128 and different values of SNR in the range of -15dB to 20dB with fixed value of Pf. If Probability detection increases then SNR also increases. Finally, Pd value should reaches to value 1 the detection probability ranges between 0.23 to 0.4 and finally reaches to 1.

References

[1]. Yanqueleth Molina-Tenorio, Alfonso Prieto-Guerrero and Rafael Aguilar-Gonzalez, “Real-Time Implementation of Multiband Spectrum Sensing Using SDR Technology”. IEEE Access 2021.
[2]. Youness Arjoune and Naima Kaabouch, “Wideband Spectrum Sensing: A Bayesian Compressive Sensing Approach” 2018.
[3]. Ashish Ranjan, Anurag and Balwinder singh, “Design and Analysis of Spectrum Sensing in Cognitive Radio based on Energy Detection” 2016.
[4]. Ulversoy, “Software Defined Radio: Challenges and Opportunities”. IEEE Commun. Surv. Tutor. 2010, 12, 531–550

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