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Performance and Evaluation of Energy Detector and Matched Filter under AWGN

Probal Sarkar, Ravindra Kumar Sharma, Rakesh Kumar Saxena, Ms. Ragini Malviya

Research Scholar (EI&C), IET, Alwar, Rajasthan, India

Assistant Professor, IET, Alwar, Rajasthan, India

Professor, Global Institute of Technology, Jaipur, Rajasthan, India

Assistant Professor, Noida Institute of Engineering and Technology, Uttar Pradesh, India

ABSTRACT: This paper models the Energy detection algorithm. Different signal distributions were taken into account in determining the design parameters for the detector. Exact close form expression for probability of false alarm, probability of detection and threshold are analyzed under different PU signal models. Simulations for ROC curve in AWGN The simulation results are tabulated which provides the better understanding of the effect on the system by channel parameters. The result shows that the performance degrades under multipath fading environment. SNR vs. pd curves were simulated for Gaussian approximated signal energy distributions. Analysis on the performance metrics has been carried out in MATLAB simulation.

KEYWORDS: matched filter ,energy detection ,BPSK ,AWGN ,cognitive radio

I. INTRODUCTION

CR is an advanced technique which lessens the issue of spectrum scarcity in electromagnetic spectrum. Spectrum sensing is one of the systems which checks the vacancy of primary user designated to particular frequency spectrum. There are a several methods for spectrum sensing for non-cooperative and cooperative CR users. There are few techniques for non-cooperative CR users such as energy detection, Matched filter detection, cyclostationary feature detection. Energy detection technique is less complex than matched filter and cyclostationary methods. The energy detection technique does not require any data about the signal structure present in the permitted band to detect the occupancy of user in that band. Energy detection works in high signal – to – noise ratio values compared to other methods. The main aim of this work is to explain the problem of spectrum sensing, various spectrum sensing methods, such as matched filter detection, energy detection. We are mainly focusing on energy detector spectrum sensing algorithm, the performance Are four functions of CRN spectrum Sensing, spectrum decision, spectrum management and spectrum sharing **Spectrum Sensing:** A CR user can Occupy only the vacant spectrum band. Therefore a CR user should superintend the available bands spectrum, pick up their Information, and therefore it can check the white sp

Spectrum Decision: Depend on the availability of spectrum on internal (and possibly external) policies, CR users can allocate a spectrum band.

Spectrum Sharing: Regard to there may be multiple cognitive radio users all of them are trying to access the spectrum, access on CRN should be arranged to prevent multiple users clash in interference bands of the spectrum

Spectrum Mobility: Cognitive radio users are considered as guests on the spectrum. So if the particular servant spectrum band is wished for the primary user, the communication has to be continued in another idle spectrum band .The spectrum

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sensing is the important one cause the CR technology are depend on it by which the spectrum holes are sensed [6], and it enables CR to configure to the environment, according to this point one of spectrum sensing techniques had taken to discuss and simulate on this paper. It is a necessary issue of CR is to sense the spectrum holes, it's based on to be aware of and sensitive to changes on it surrounded environment [1], spectrum sensing algorithms enable the CR to adjust and adapt to the environment by detecting PUs which receiving data across the communication scope of CR users [7].The sensing on CRN has two-main points:

- a) To ensure that the secondary user doesn't caused interference to a primary user
- b) To aid secondary user to recognize and utilize the white space for the required quality of service [2].

The spectrum sensing is to decide and determined between two hypotheses which are:

$x(t)=w(t)$, H_0 (PU absent)

$x(t)=h n(t)+w(t)$, H_1 (PU present)

Of energy detection algorithm by varying some parameters and the performance of dynamic threshold on spectrum sensing algorithms (Matched filter detection and Energy detection).Matched filter is designed to maximize the output SNR for a given input signal. MF detection is applied when the secondary user has prior knowledge of the residing user. In matched filter operation convolution of the unknown signal is done with the filter whose impulse response is time shifted & mirrored with respect to the desired signal. The expression for Where the unknown signal is 'x' and the impulse response (h) of matched filter that is matched to the reference signal is convolved with it for maximizing the SNR. Matched filter detection is applicable only in cases where the cognitive users know the data from the primary user The block diagram of implementation of matched filter spectrum sensing algorithm is given below:-

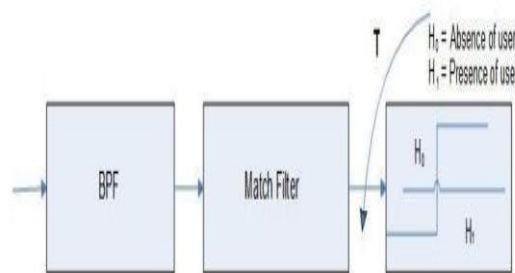


Figure 1 block diagram of matched filter detection

In this method, signal is passed through band pass filter of the bandwidth W and is integrated over time interval, the output of the block of an integrator is then compared to a predefined threshold. The goal of this comparison is to discover the existence or absence of the licensed user. The value of threshold can set to be variable or fixed based on the conditions of the channel [6]. The Blind signal detector is the another name of ED [2], because it ignores the signal structure i.e., it estimates the presence of the signal by comparing the energy received with a known threshold v derived from the statistics of the noise [8], analytically signal can be formalized as a hypothesis test

$Y(k)=n(k) \dots H_0$

$Y(k)=h*s(k)+n(k) \dots H_1$

In sample the $y(k)$ is analyzed at each instant k and $n(k)$ is the noise of variance σ^2 , say $y(k)$ be as sequence of received samples $k \in \{1,2,\dots,N\}$ at the signal detector, therefore a decision rule can be stated as

$H_0 \dots \text{if } \epsilon < v$

$H_1 \dots \text{if } \epsilon > v$

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Where $\epsilon = |E\{y(k)\}|^2$ the estimated energy of the received signal and v is chosen to be the noise variance. All radio transmitters by definition emit energy into the electromagnetic field. Energy detection (ED) is the simplest spectrum sensing method. As such it is often used as a baseline when evaluating other spectrum sensing methods. Energy detection is the optimal non-coherent detection algorithm. The test statistic γ for energy detectors is based on the definition of signal energy, which is related to the physical concept of energy. For a continuous signal, using the common notation from this paper, the formalization is:

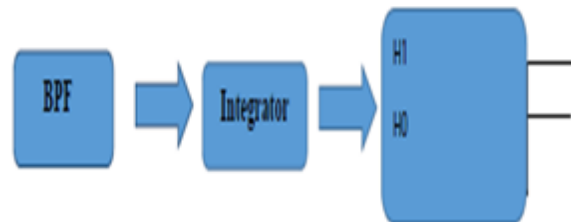


Figure 2 shows the block diagram of ED technique.

$$\gamma = \int_0^{t_s} x^2(t) dt$$

For sampled-time real signals, the equation transforms

$$\gamma = \sum_{n=0}^{N_s-1} x_n^2$$

info: (the largest disadvantage of energy detection is the fact that the test statistic is as sensitive to noise power as to the signal power. In practice the noise power varies. Internal receiver noise changes with production tolerances, temperature and other Environmental factors. Environment noise changes with time and location. This leads to a *SNR wall* where a detector is incapable of reliably detecting a signal, regardless of the choice of N_s , when signal power is small compared to noise power. The spectrum sensing algorithms are care about sensing the spectrum holes, these holes are immigrating with time and frequency so the spectrum holes detection should be real time. Spectrum sensing have a high computational and it needs to implement it a special hardware, furthermore the detection of these holes are affected by low SNR, so the used spectrum sensing algorithm should be able to distinguish the signal power from the noise power [2]. The threshold value is defined by the classical Radar detection theory which limitation a threshold voltage [9]. For the input signal the energy spectrum of the signal and the energy spectrum of the threshold had calculated firstly to calculate the energy spectrum of the signal using energy spectrum computation mentioned in eqn. 5, secondly the energy spectrum of the threshold had to calculate by using calculation of threshold and threshold energy spectrum in eqns. 5-7. So the comparison had done between energy of the threshold and energy of the signal [9], if the energy of the threshold is greater than the energy of the signal that implies to presence of the frequency holes and the cognitive radio user can use it, otherwise there is no frequency holes at all [10] All of that done based on Principal component analysis (PCA) which is a mathematical technique to minimize dimensionality of data

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Mathematical Model

$$\text{Energy spectrum} = |X(\omega)|^2 (t_2 - t_1) \quad (5) \qquad V_T(\omega) = \int_{t_1}^{t_2} V_T e^{-j\omega t} dt$$

$$\begin{aligned} V_T &= \sqrt{2\sigma_n^2 \log\left(\frac{1}{P_{fa}}\right)} \\ &= V_T \left[\frac{e^{-j\omega t}}{-j\omega} \right]_{t_1}^{t_2} \\ &= j \frac{V_T}{\omega} \left[e^{-j\omega t} \right]_{t_1}^{t_2} \\ &= \frac{V_T}{\omega} e^{j[\frac{\pi}{2} - \omega(t_2 - t_1)]} \dots \\ |V_T(\omega)|^2 &= \frac{V_T^2}{\omega^2} (t_2 - t_1) \\ P_{fa} &= 10^{-\frac{V_T^2}{2\sigma_n^2}} \end{aligned}$$

Where:

σ_n^2 = Noise Power

V_T = Threshold Voltage

ω = Frequency

P_{fa} = Probability of False Alarm

$X(n) = [x_1 \dots x_M \ x_{M+1} \dots x_{2M} \dots x_{Mn}]$

$L(n) = [x_1 \ x_2 \dots x_M]^T$

$L(n) = [x_{M+1} \ x_{M+2} \dots x_{2M}]^T$

$LLi = L(i) \times LT(i)$

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$$W_i = \sum_{i=1}^n LL_i$$

$$W_{x,N} E_j = Y_j E_j; j=1 \text{ to } M$$

$$\text{Signal power} = \frac{1}{P} \sum_{i=1}^P Y_i \quad (12)$$

$$\text{Noise power} = \frac{1}{M-P} \sum_{i=P+1}^M Y_i \quad ($$

Where $x(t)$ is the received signal by the unlicensed user, $n(t)$ is the transmitted signal of the licensed user, $w(t)$ is the Additive White Gaussian Noise (AWGN), h is the amplitude gain of the channel. H_0 is a null hypothesis, means that there is no signal from licensed user [2], according to the primary user these hypotheses means H_0 : The spectrum band is idle, H_1 : The spectrum band is occupied [2].

II. PROPOSED METHOD

Matched Filter Detection (MFD) is a spectrum sensing technique. It is one of the optimal techniques in the field of signal processing. It is known as optimal spectrum detection technique. The MFD is used for PU spectrum when the transmitted signal from the source is known already (Lee et al 2008). When an unknown signal is matched with the known signal, if the unknown signal property is similar to the known signal property, then it is assumed that the PU is present in the spectrum. If the property of the unknown signal and the known signal is not similar, then it is considered that the spectrum is free and the SU can use the spectrum, an adaptive learning process leading to Cognitive nature as defined in Cognitive Radio networks. The MFD is an optimal linear filter that is used to maximize the SNR in the additive stochastic noise environment. The output SNR is made maximum by convolution of the transmitted signal with an unknown signal with a filter whose impulse response is a time shifted version of the known reference signal.

ADDITIVE WHITE GAUSSIAN NOISE: is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics:

Additive because it is added to any noise that might be intrinsic to the information system.

White refers to the idea that it has uniform power across the frequency band for the information system. It is an analogy to the colour white which has uniform emissions at all frequencies in the visible spectrum.

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Gaussian because it has a normal distribution in the time domain with an average time domain value of zero. Wideband noise comes from many natural noise, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson–Nyquist noise), shot noise. Matched filter detector is a coherent pilot sensor that maximizes the SNR at the output of the detector. It is an optimal filter that requires the prior knowledge of the PU signals. This sensing technique is the best choice when some information about the PU signal are available at the SU receiver. Assuming that the PU transmitter sends a pilot

stream simultaneously with the data, the SU receives the signal and the pilot stream it can consider as a best sensing technique if CR has knowledge of PU. It is very accurate because it maximizes the received signal-to-noise ratio (SNR). Matched filter correlates the signal with time shifted version and compares between the final output of matched filter and predetermined threshold will determine the PU presence. Hence, if this information is not accurate, then the matched filter operates weakly.,

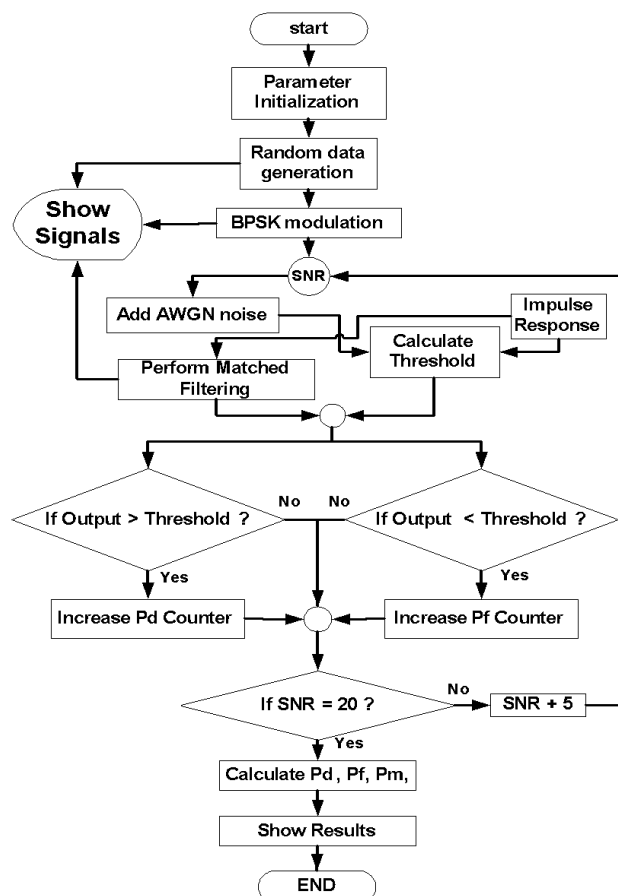


Fig 4.1 proposed flow chart

III. RESULT ANALYSIS

To evaluate the performance of the spectrum sensing techniques, a number of metrics have been proposed, including the probability of detection, P_d , the probability of false alarm, P_{fd} , and the probability of miss detection, P_{md} . P_d is the

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probability that the SU declares the presence of the PU signal when the spectrum is occupied [3][51][52]. The probability of detection is expressed as Where H_0 and H_1 denote respectively the absence and the presence of the PU signal. The higher the P_d , the better the PU protection is. The probability of false alarm, P_{fd} , is the probability that the SU declares the presence of the PU signal when the spectrum is actually free (idle). It is expressed as

$$P_{fd} = \text{Prob}(H_1/H_0)$$

The lower the P_{fd} , the more the spectrum access the SUs will obtain. The probability of miss detection, P_{md} , is the probability that the SU declares the absence of a PU signal when the spectrum is occupied. It is given by

$$P_{md} = \text{Prob}(H_0/H_1)$$

These three metrics measure the efficiency of the spectrum sensing techniques and can be expressed as: $P_d + P_{fd} + P_{md} = 1$

There are tradeoffs between the probability of false alarm and the probability of miss detection. False detection of the PU activity causes interference to the PU and missed detection of the PU activity misses spectrum opportunities. This tradeoffs can be expressed as conservative with P_{fd} and aggressive with P_{md} ; and a spectrum sensing technique has to fulfil the constraints on both probabilities [6].

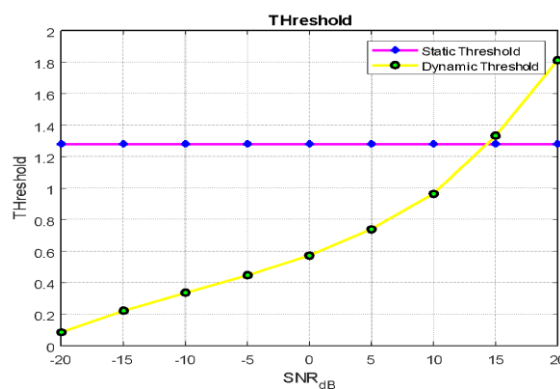


Fig 4.2 SNR Vs threshold graph

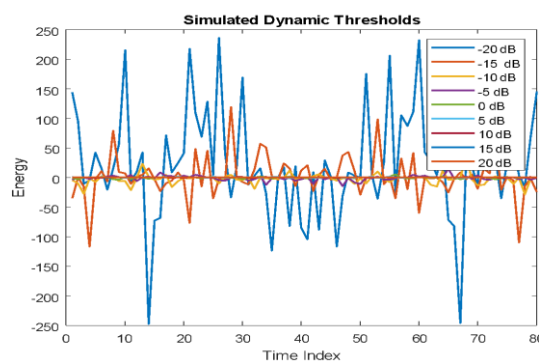


Fig 4.3 energy graph

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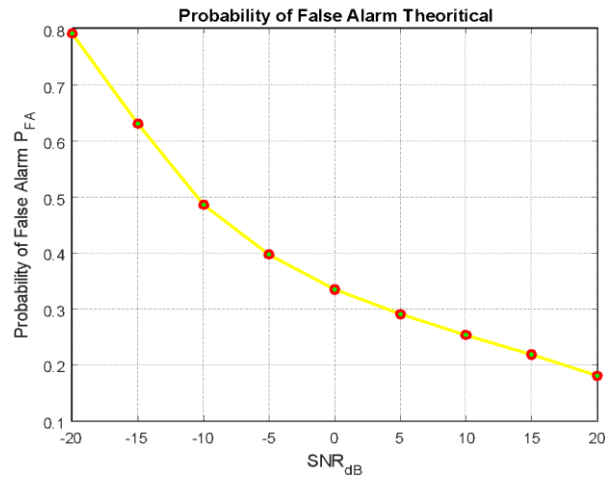


Fig 4.4 SNR Vs PFA graph

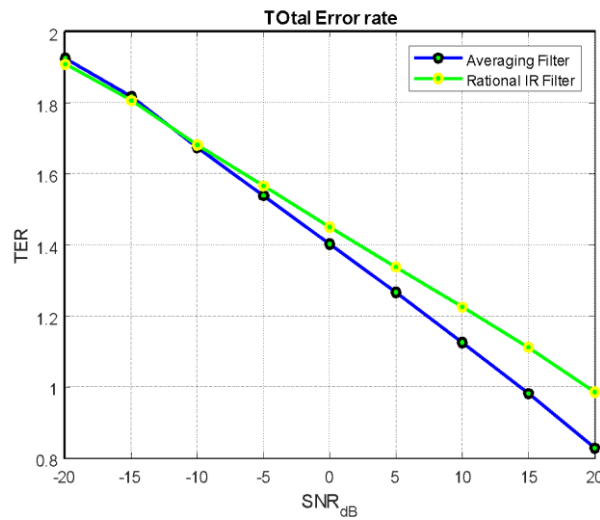


Fig 4.5 SNR

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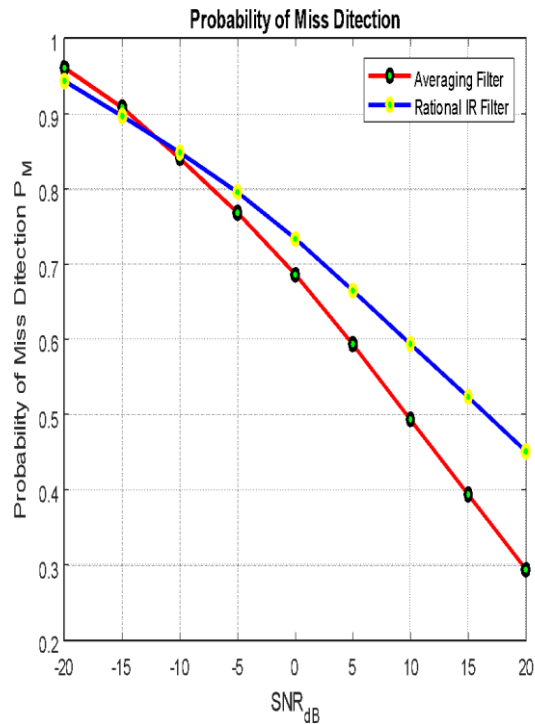


Fig.4.6 SNR Vs TER graph

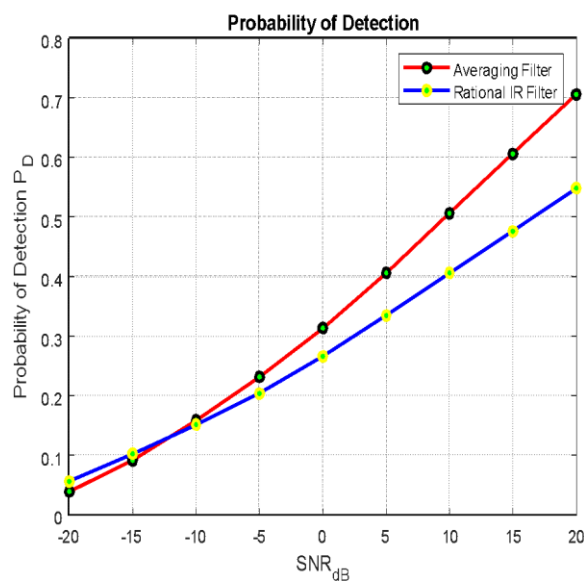


Fig 4.7 SNR Vs PMd graph

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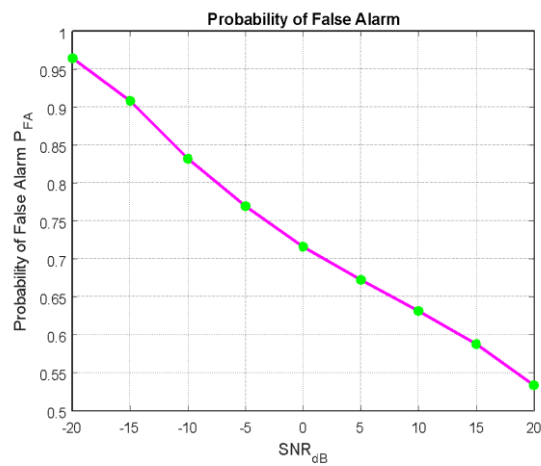


Fig 4.8 SNR Vs P_d graph

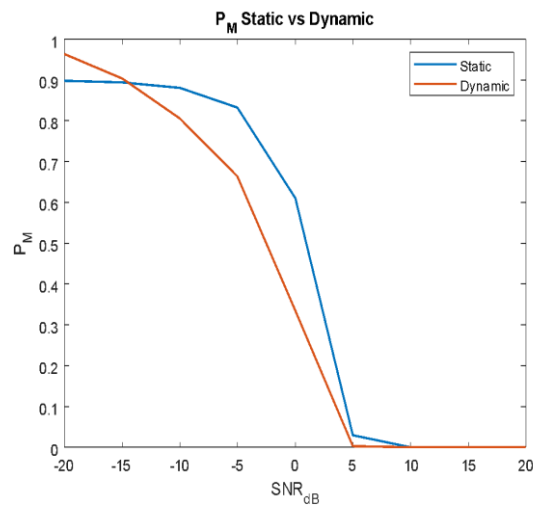


Fig 4.9 SNR Vs P_d graph

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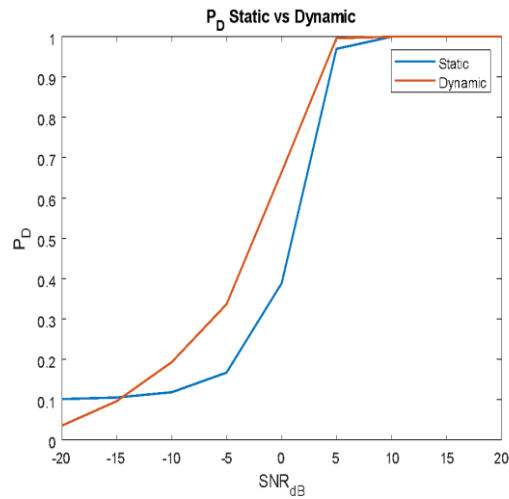


Fig 4.10 SNR Vs P_D graph

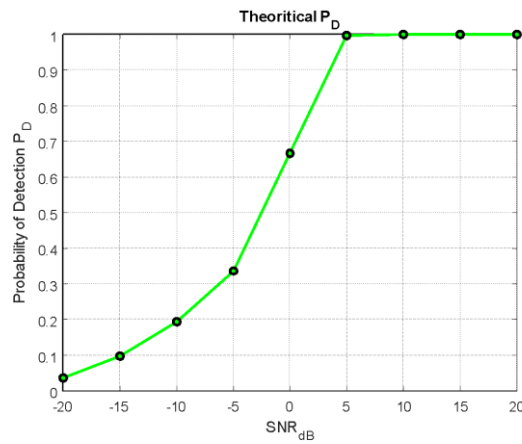


Fig 4.11 SNR Vs TP_D graph

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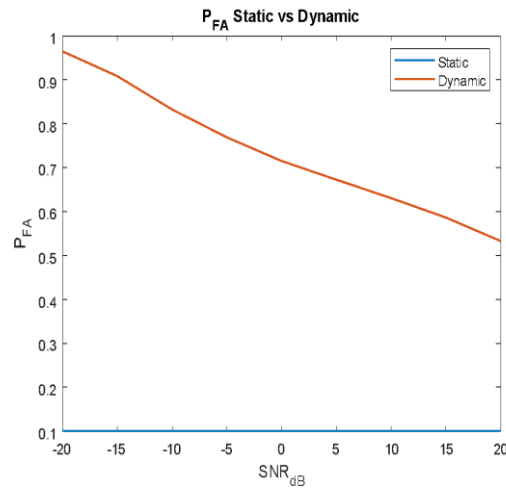


Fig 4.12 SNR Vs P

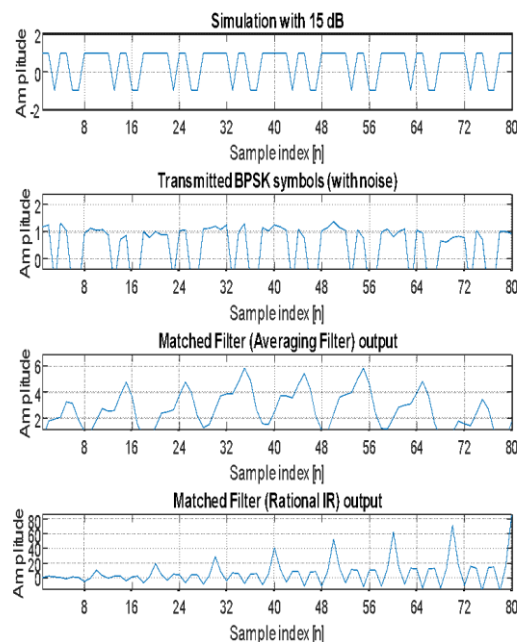


Fig 4.13 Filter output at 15 dB

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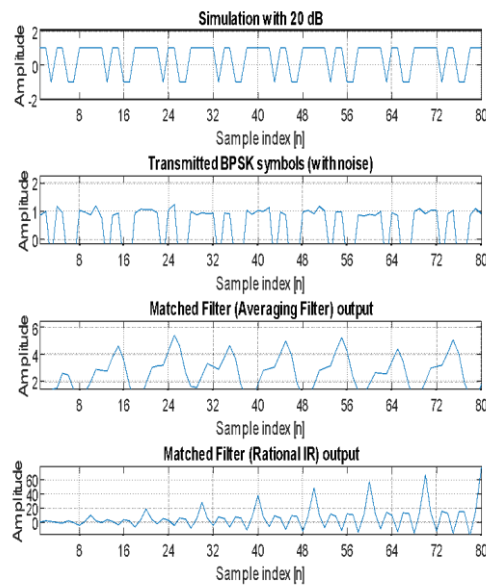


Fig 4.14 Filter output at 20dB

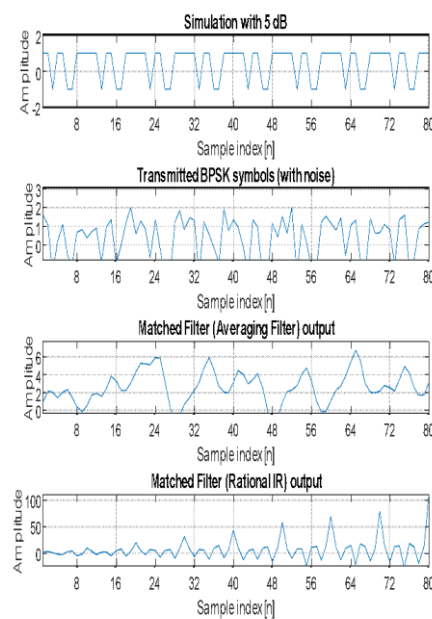


Fig 4.15 Filter output at 5dB

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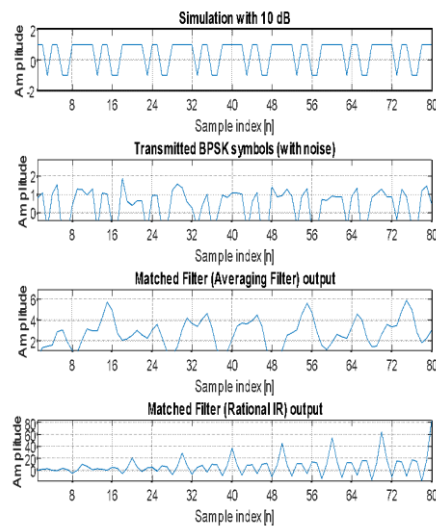


Fig 4.16 Filter output at 10dB

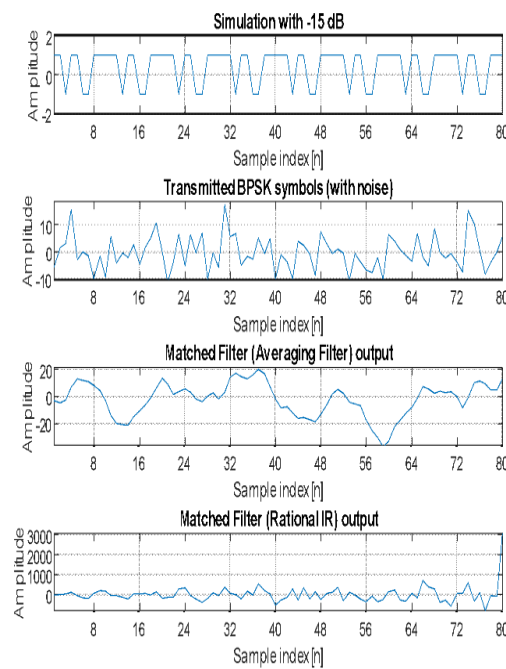


Fig 4.17 Filter output at -15dB

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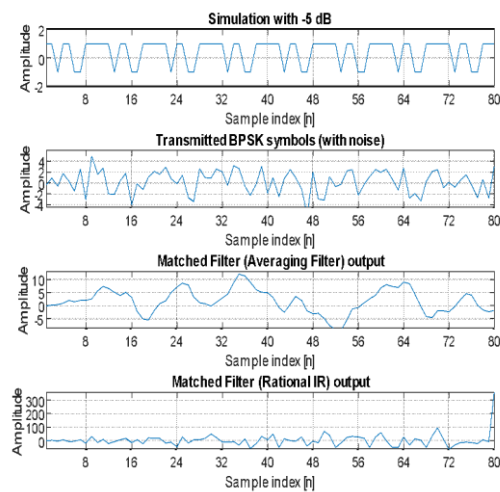


Fig 4.15 Filter output at -5dB

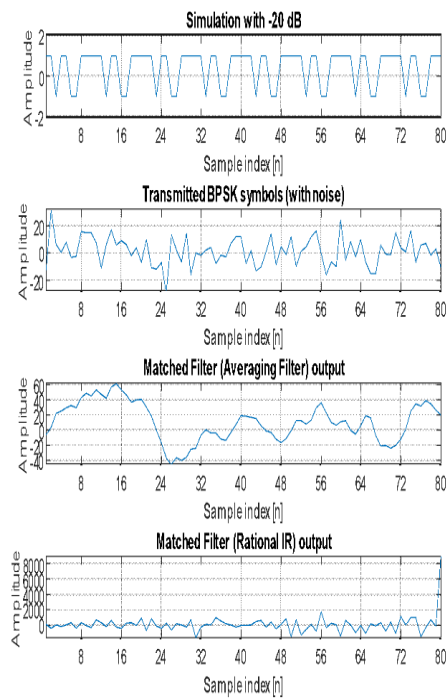


Fig 4.18 Filter output at -20dB

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SNR	PRESENT WORK	PREVIOUS WORK
	PFA	PFA
-20dB	0.091	0.7
10 dB	0.097	0.12
5 dB	0.099	0.18
20dB	0.8	*

Table 1 SNR for Different PFA Value

IV. CONCLUSIONS

Cognitive radio technology is a modernistic technology by which the idle licensed spectrum can be used by an unlicensed user which is called cognitive radio CR. The CR technology was found to overcome the spectrum incompetence and inefficiency usage troubles. The major motivation of CR technology is current heavily underutilized of spectrum. Surely the PU have all rights to use his spectrum band so CR mustn't interfere it on that band. about energy detection which is one of spectrum sensing techniques, explained how to obtain the best available spectrum, to detect the spectrum hole, to estimate the optimum Threshold voltage that produce the minimum Probability of false alarm, calculate the power of signal in special range and random one and finally to enhance Energy Detection Sensing Algorithm. Detect any type of signal, and does not need any knowledge about the signal to be detected. Moreover, the noise power needs to be known to set the determination threshold energy detection based spectrum sensing are its simplicity, low computational and implementation costs as well as its ability to work regardless of the actual signal to be detected. In the present work, without involving the sampling theorems and the accompanying approximation, we derive the expressions for probability of detection and false alarm over AWGN. Therefore, the calculation is progressively precise. Also, the performance of the energy detector in real-time is analyzed.

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