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Analysis of Spectrum Sensing By Using Energy Detection Technique in Cognitive Radio

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Abstract: *In wireless technologies the importance of spectrum is rapidly increases hence traffic of spectrum is also increases day by day. However, it seems that the current technologies do not utilize the licensed spectrum bands efficiently (6).So, energy detection in cognitive radio is proposed to improve the spectrum utilization. Cognitive Radios are the secondary users of the allocated spectrum bands for the primary users. In the cognitive radio system, the signal detection technique is required for spectrum sensing in order to sense the occupied and vacant bands. The challenge of spectrum sensing is the detection of poor signals in the presence of noise and interference (7).*
In this paper, have evaluated the performance of energy detection system under the real noise at -10dB, -15dB & -20dB SNR using energy detection. In general Energy detector is the one of the method used in spectrum sensing due to its simplicity; it requires no need of synchronization and knowledge of transmission information through the transmitter.

Keywords:*Cognitive Radio, Spectrum Utilization, Hypotheses, Pd, Pfa, AWGN, White Spaces*

I. INTRODUCTION

In a wireless communication system the electromagnetic spectrums becoming crowded day by day due to the increment of wireless applications. In which the cognitive radio plays a very important role for spectrum sensing. In which it is observed that the available spectrum is not utilized properly at that time and particular geographic location. To overcome this problem the cognitive radio technology is proposed to sense unused bands. Cognitive Radio is to provide effective communication and utilization of spectrum bands for users. Cognitive Radio having the ability to determine the presence of the licensed user, and also detects which portion of spectrum is available, in other words, to detect the white spaces that means empty bands, which is known as spectrum sensing .The energy based detector is the easier method for sensing primary users in the environment. The energy detector is very convenient technique and also computationally efficient with analog and digital signals. It gives the poor performance when noise variance is unknown to the sensing node. Therefore, it is difficult to distinguish between the radio signal and noise signal at very low SNR. So that it is necessary to know the information of the noise power which can be used to improve the efficiency of the energy detector [6]

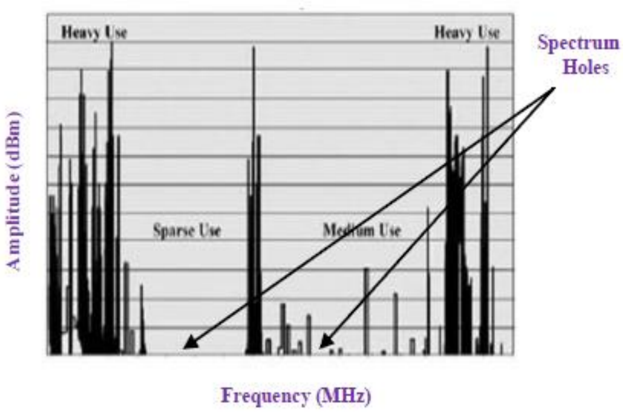

Fig.1. Utilization of the spectrum[1]

Cognitive Radio is a technology used for detection of vacant bands and utilized the same for improving the performance of spectrum sensing without affecting on Primary Users (PU) [2].

II. ENERGY DETECTOR MODEL

Energy detection is a simple technique to detect the primary signal based on energy of received signal and the advantageous as no need of prerequisites of primary user signals to detect the presence or absence of signal in the spectrum band. The approaches used in the energy detection are based on the Bayes Test &Neyman-Pearson (NP) Test. The NP is most preferable approach in Energy detection. Because, it increases the probability of detection (Pd) for a given probability of false alarm (Pfa).In this paper, the QPSK signal is transmitted through the Rayleigh fading environment with an additive white Gaussian noise (AWGN) channel

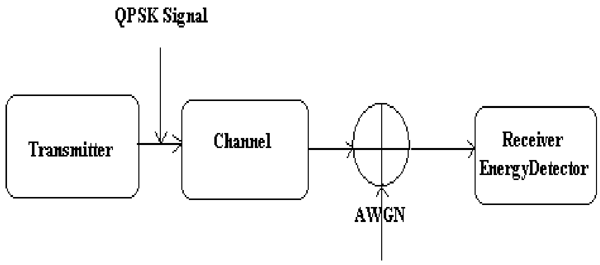

Fig.2 Block diagram of Trans-receiver

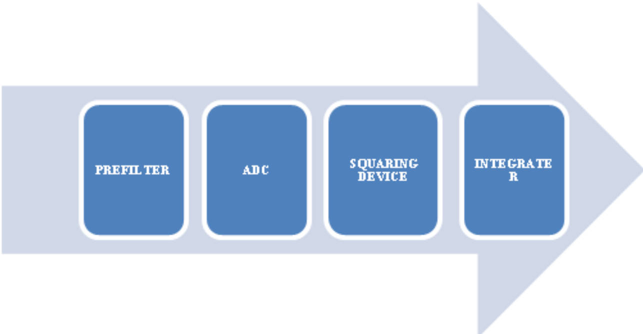

Fig.3 Block diagram of the energy detector

III. STATISTICAL ANALYSIS

Within certain time, energy detector measures the energy of the signal and compares it with the threshold. Energy detection is commonly modelled based on hypothesis testing problem and then performance is have evaluated by probability of false alarm and probability of detection. In this paper the problem is analyzed by mathematically and then evaluated the threshold. As shown in fig.3 the prefilter is used as a band pass filter of bandwidth ***W.*** The output of band pass filterpasses through the squaring device and then integrated over a predefined sensing time ***T.*** The integrator output is compared with a threshold to take a decision between two hypotheses. By using Nyquist sampling theory, each sample of the received signal is expressed as,

$r_i = r\frac{i}{2w}$ (i=1, 2,………… +∞) (1)

Where, ***W*** is the bandwidth $T_s$is the symbol duration of the signal [3]. Here the energy per sample is defined as E_s,

$$Ps = {}^{Es}/_{Ts} = E \quad (2)$$

R is a symbol rate of the system. Therefore, energy of observed transmitted signal per sample is,

$\frac{PsT}{2WT} =$ (3)

Thus, the energy per sample of noise signal at the pre filter output is,

$\frac{2NoWT}{2WT} = \frac{2NoW}{2W} = No$(4)

N_o represents the two sided noise power density. If there is only noise signal present, the energy of receiving signal is expressed as,

$$V = \int_0^T n^2(t)\,dt = \frac{1}{2W}\sum_{i=1}^{2TW} n_i^2 \quad (5)$$

The Gaussian random variable with zero mean and variance as follows respectively,

$$n_i = n(i/2W) \quad (6)$$

$$\sigma_i^2 = 2WNo \quad (7)$$

By using the definition of chi-square distribution the chi-square PDF arises as the PDF of x where [4]

$$x = \sum_{i=1}^{N} \quad (8)$$

From the above equation we find the variance of n_i must be normalized to 1.

$$b_i = \frac{n_i}{\sqrt{2WNo}} \quad (9)$$

Here V' is monotonic with V to represent statistic test as

$$V' = \frac{1}{No}V = \frac{1}{No}\int_0^T n^2(t)dt$$

$$V' = \frac{1}{No}\int_0^T n^2(t)\,dt = \frac{1}{2WNo}\sum_{i=1}^{2TW} n_i^2 = \sum_{i=1}^{2TW} b_i^2 \quad (10)$$

The simple form is,

$$V' = \sum_{i=1}^{2TW} b_i^2 \quad (11)$$

After normalization we obtain the statistic test as,

$$V' = \frac{1}{No}V = \frac{1}{No}\int_0^T s^2(t)\,dt = \sum_{i=1}^{2WT} \beta_i^2 \quad (12)$$

Where,

$$\beta_i = \frac{\alpha_i}{\sqrt{2WN_0}}$$

So energy of received signal in interval (0,T) is

$$V = \int_0^T r^2(t)dt = \frac{1}{2W}\sum_{i=1}^{2TW}(\alpha_i + b_i)^2 \quad (13)$$

And statistic test is given by normalized value

$V' = \int_0^T r^2(t)dt = \frac{1}{2W}\sum_{i=1}^{2TW}(\beta_i + b_i)^2$(14)

Where β_i is V' the normalized primary signal and b_i is the normalized noise signal

Therefore when signal is present the, V' considered the chi square distribution with N degree of freedom and noncentral parameterΥ.

$\Upsilon = \sum_{i=1}^{2TW}\beta_i^2 = \frac{1}{N_0}\int_0^T S^2(t)dt = \frac{E_T}{N_0}$(15)

Where E_T represents the signal energy in time interval T. The noncentral parameter Υ is defined as the SNR

From the chi-square distribution, we may represent the statistic test as

$V' = \begin{cases} x_N^2 & H_0 \\ x_N^2 \quad (\Upsilon) & H_1 \end{cases}$(16)

Where,
N=2TW is the number of degrees of freedom,
x_N^2 Represents the chi-square distribution and
$x_N^2 \quad (\gamma)$Represents non central chi-square distribution.

THRESHOLD DERIVATION

For energy detection the P_{fa} is predefined and only depends on the noise variance and N, therefore threshold can be set without prior knowledge of primary users. So we can select the threshold to obtain a fixed $P_{fa}$and then calculate the probability of detectionP_d.

Threshold can be derived by PDF of the, V' under two hypotheses [4]

$H_0 \; : fv'\left(\frac{x}{H_0}\right) = \frac{1}{2^{\frac{N}{2}}\Gamma\frac{N}{2}}x^{\frac{N}{2}-1}exp\left(-\frac{1}{2}x\right)$(17)

$H_1 \; : fv'\left(\frac{x}{H_1}\right) = \frac{1}{2}\left(\frac{x}{\gamma}\right)^{\frac{N-2}{4}}exp\left(-\frac{1}{2}(x+\gamma)I_{\frac{N}{2}-1}(\sqrt{x\gamma})\right)$(18)

Where, $\Gamma(x)$ = Gamma function, I (x) = Bessel function and x= the sample of the received signal. Therefore the probability of false alarm ($P_{fa)}$ is, [4]

$P_{fa}=Q_{x_N^2}(\lambda)=\int_\lambda^\infty f_{v'}(x/H_0)dx$

$$Q_{x_N^2}(\lambda) = \begin{cases} 2Q(\lambda) & if\ N = 1 \\ 2Q(\lambda) + \frac{exp\left(-\frac{1}{2}\lambda\right)\sum_{k=1}^{\frac{N-1}{2}}\frac{(k-1)!\,2\lambda^{k-\frac{1}{2}}}{(2k-1)!}}{\sqrt{\pi}} & if\ N > 1\ and\ N\ odd \\ exp\left(-\frac{1}{2}\lambda\right)\sum_{k=0}^{\frac{N-1}{2}}\frac{\left(\frac{\lambda}{2}\right)^k}{k!} & if\ N\ is\ even \end{cases} \qquad (19)$$

By using these equations the threshold λ can be evaluated for specified P_{fa} and N.

$$Q(x) = \frac{1}{2\Pi\sigma^2}\int_x^\infty exp^{\frac{-x^2}{2\sigma^2}}\,dx \quad (20)$$

*Q(x)*is the Gaussian Q function.

For Rayleigh fading channel the threshold is set to meet the specified P_{fa}.The threshold in a fading channel is to be same as in AWGN channel so for the no transmission of signal P_{fa} is considered and it is independent of SNR. When signal is present, then the threshold is applied to the data therefore the average probability of detection is computed.

$$P_{D} = \int_x P_D(\gamma,\lambda) f\gamma(x)\,dx \quad (21)$$

Where $f_\gamma(x)$ is the Probability Density Function of the SNR

IV. SIMULATION RESULTS

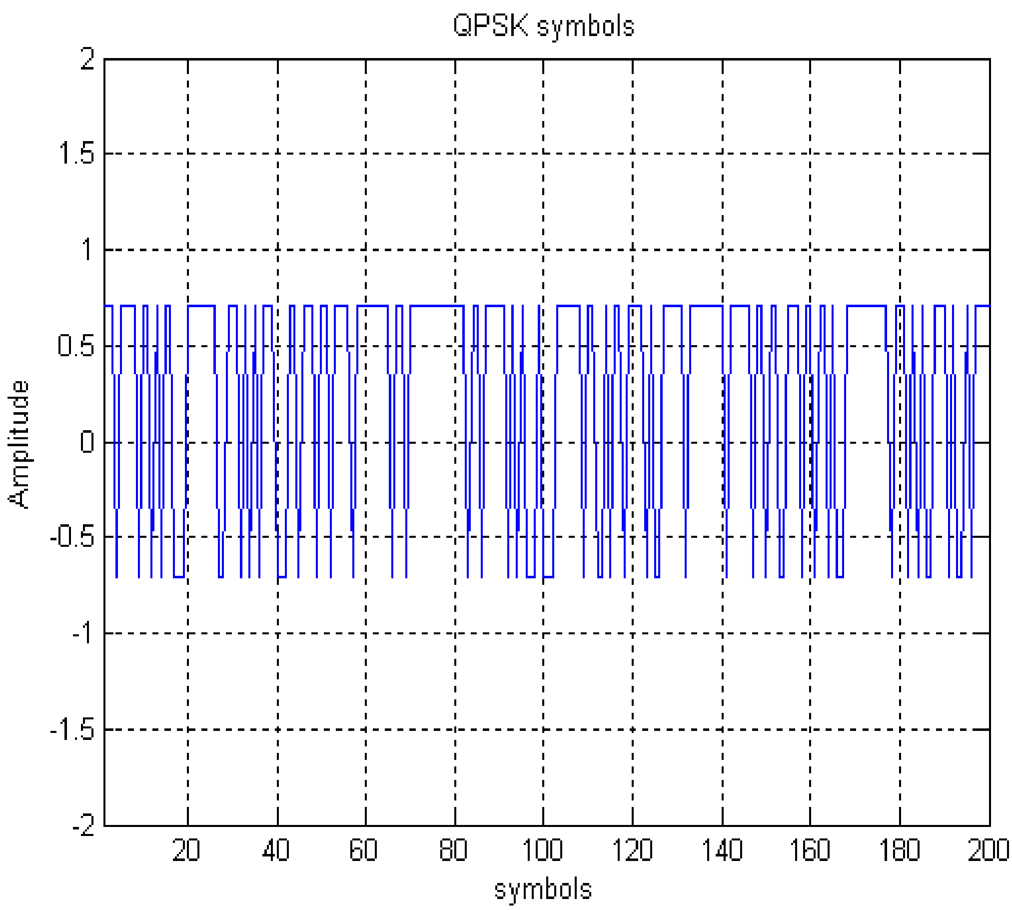

Fig.4 Generation of QPSK Signal

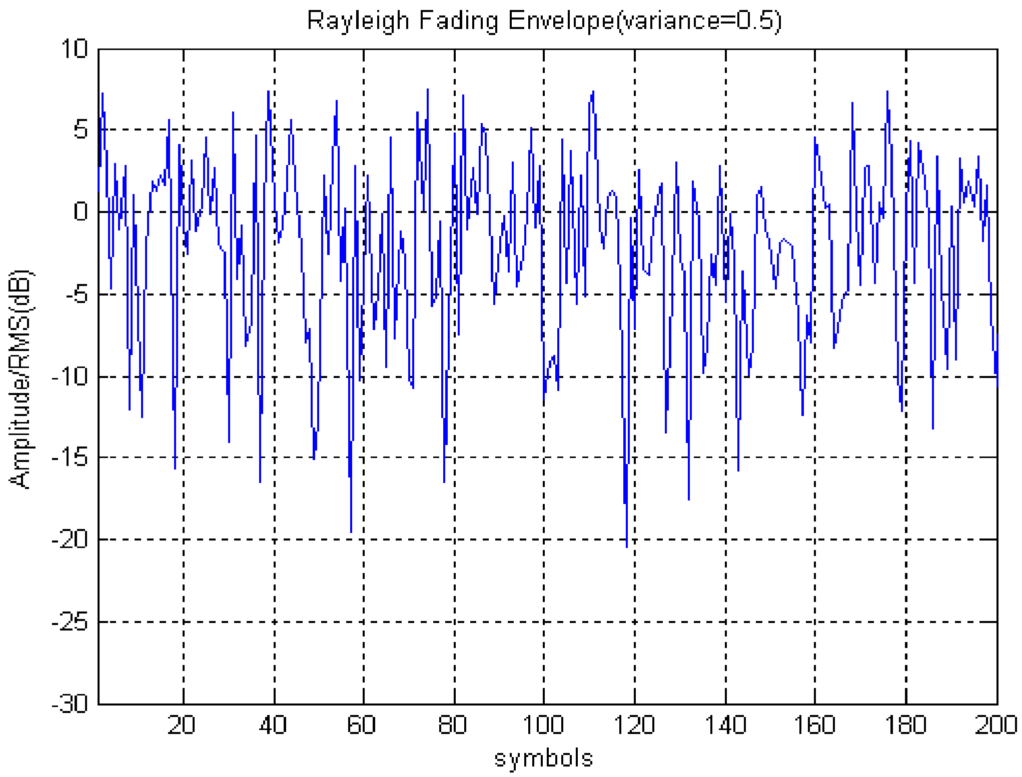

Fig.5 QPSK Signal through Rayleigh Fading

Fig.6 Fading Channel Power Response

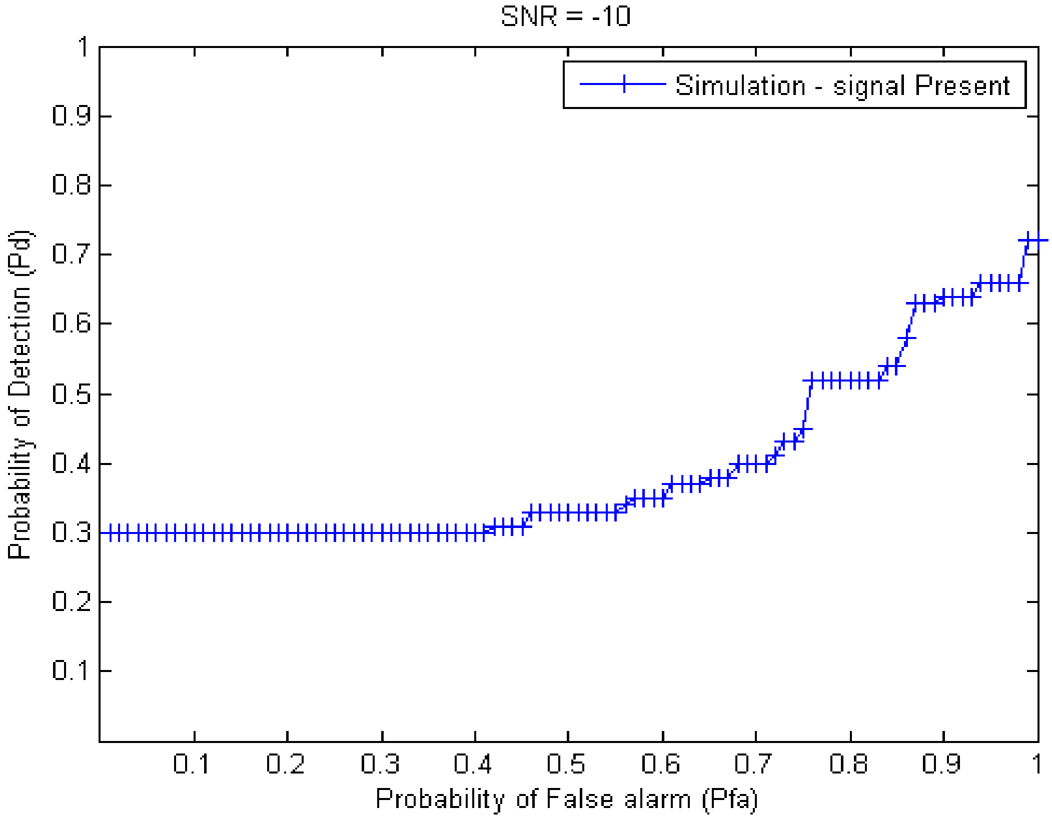

Fig.7 Probability Of Detection (P_d) Vs False Alarm (Pf_a) ForSNR=-10db

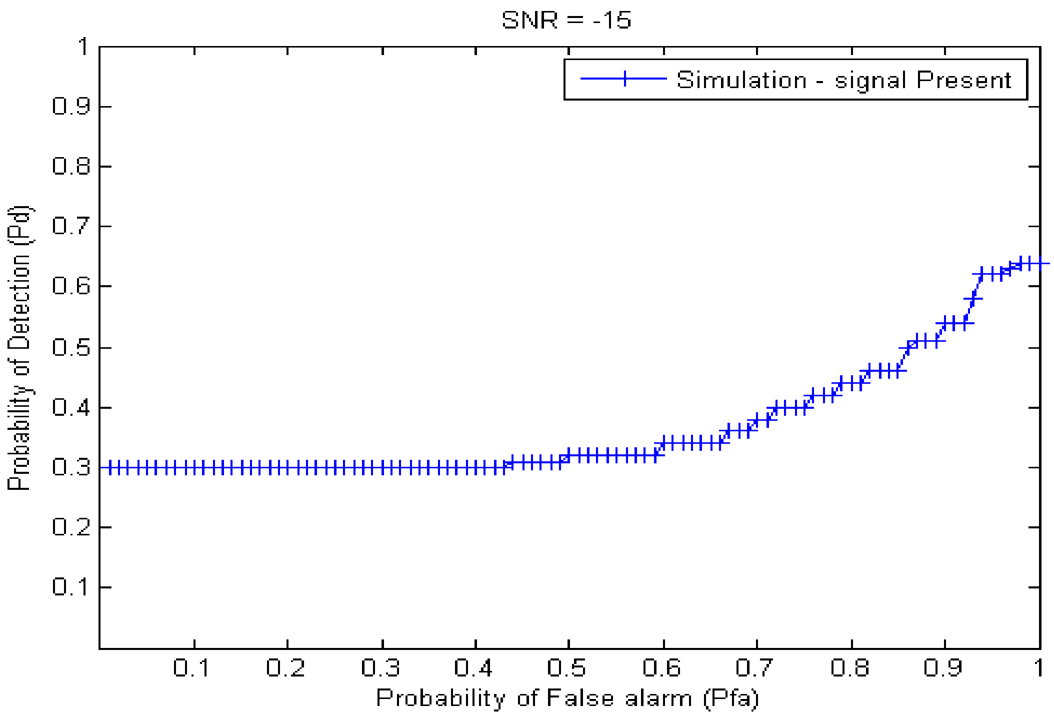

Fig.8 Probability Of Detection (P_d) Vs False Alarm(Pf_a) For SNR=-15db

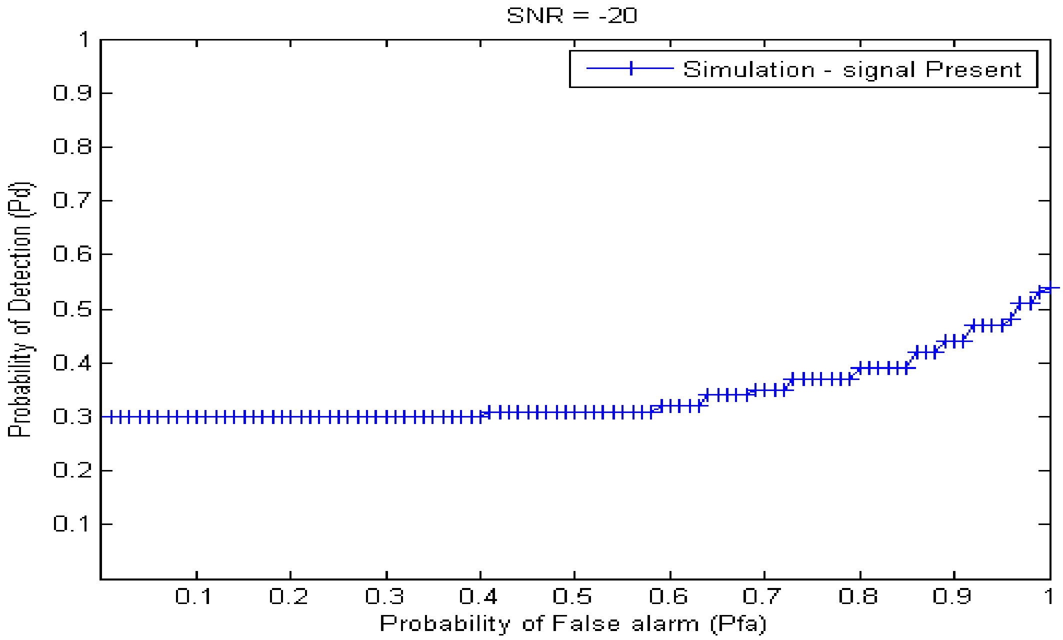

Fig.9 Probability of Detection (P_d) Vs False alarm (Pf_a) for SNR=-20db

V. CONCLUSION

In this paper we have evaluated the performance of the energy detector in AWGN and Rayleigh fading channels for different SNR. Furthermore the performance is based on the predefined value of $P_d$and P_{fa}. Fig 4 shows the generation of QPSK signals. QPSK modulation type is chosen for the convenience. Fig 5 shows the envelope of QPSK signal trough the Rayleigh fading.Fig 6 shows fading channel power response .The performance of the energy detector in fading channel with different SNR is based on measurements. From the Fig 7, 8, 9 shows the performance of$P_d$versesP_{fa}at 20 number of samples for -10db -15db and -20db SNR,it is concluded that the$P_d$gradually increases from a lower SNR value of higher SNR values.

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