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Improving RF Spectrum Utilization using Matched Filter based Spectrum Sensing for CRN

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Abstract- **In this paper we proposed matched filter based spectrum sensing method for two different modulation techniques. Matched filter uses convolution of the known signal with a conjugated time reversed version of the template maximizing signal to noise ratio in the presence of additive noise. In matched filter method sum of filtered received signal is compared with predetermined threshold. Simulation result shows that our proposed method gives higher detection performance than energy detection method.**

Keywords- Cognitive radio, spectrum holes, spectrum sensing, matched filter, signal to noise ratio, energy detection.

I. INTRODUCTION

Due to raised in amount of wireless communications in personal, commercial, and governmental capacities, efficient spectrum utilization has become a prime topic of interest. The Federal Communications Commission (FCC) governs spectrum usage and allocates specific ranges to legitimate users. However, some spectrum ranges are beyond the desire limits, while some are under-utilized [3].

The overcrowded spectrum decreases overall quality of service for users in that allotment. This result in to diminish data transmission rates, low latencies, and increased probability of errors. A noumenon solution to this inefficiency problem is cognitive radios (CR), which perform two major tasks. First, a CR searches the spectrum and determines which parts are unoccupied, a technique known as spectrum sensing. Second, a CR determines a method of assigning secondary users to the unoccupied spectrum without interfering with the primary users [1]. Cognitive radio networks could drastically change the current methods that wireless communications operate in the future by dynamically allocating spectrum usage and ultimately provide a better quality of service to users [4].

Cognitive radio has four important functions, depends on the parts of a spectrum available for use as spectrum management, spectrum sharing, spectrum sensing and spectrum mobility. Spectrum sensing by far is the most weighted component for the settlement of cognitive radio. Spectrum sensing is the task of acquiring awareness about the spectrum utilization and existence of licensed users in a geographical area [1].

There are various spectrum sensing technique are investigated to detect the presence of primary user which are done by detecting the spectrum holes also known as white space. The sensing techniques are classified according to reception and transmission parameter used for sensing i.e., co-operative system, non-cooperative system and interference based system is illustrated in Fig.1. The non-cooperative spectrum sensing is classified by primary transmitter detection. This approach include matched filter based detection, Cyclostationary based detection, waveform based detection, energy detection etc [5].

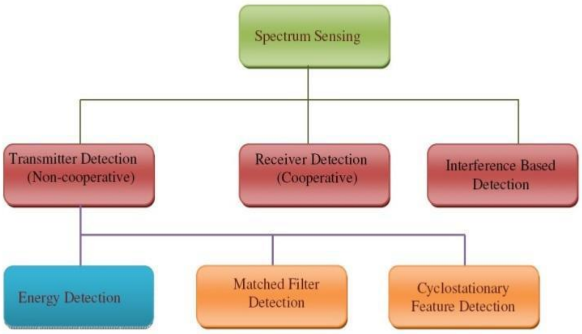

Fig.1. Classification of spectrum sensing

Being the focus of this paper, the performance of matched filter based spectrum sensing technique is investigated at lower SNR. Additionally, a complete system is described to determine the threshold of the matched filter to obtain stricter requirements of the probability of false alarm and the probability of miss detection.

This paper is organized as follows: Section II explains the system model. Section III describes simulation result and discussion. And finally conclusion is drawn in section IV.

II. SYSTEM MODEL

The matched filter method has very accurate output since it maximizes signal to noise ratio for a given input signal in presence of Additive white Gaussian noise (AWGN). The matched filter is known as coherent detector. It is the optimum method for detection of PUs when the transmitted signal is known. Matched filter coefficients are given by the complex conjugate reversed signal in terms of discrete signals. . Hence, it requires perfect knowledge of the PUs' signaling features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame format [10].

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To endow the SNR a matched filter is often used at the receiver front end. Coherent or non-coherent receivers are used based on signal analysis either as complex signals or noises. When amplitude and phase of the received signal are known then coherent receivers are used. This results in a perfect match between the matched filter coefficients and the signals. For non coherent receiver, the received signal is modeled as a replica of the original signal with a random phase error. With a non coherent receiver the detection after the matched filter is generally based on the power or magnitude of the signal. Figure 2 shows the Block diagram of system model with non coherent receiver.

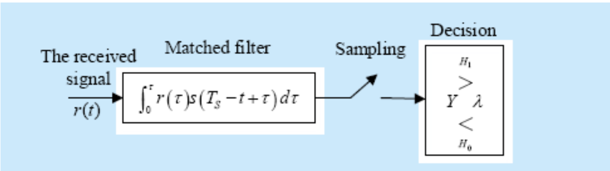

Fig.2 Matched filter detection

Decision of a detector is detected by using the spectrum white space which is vacant place present at the primary user spectrum. This presence or absence are differentiated by binary hypothesis testing model as,

H0: primary user absent

H1: primary user present

H0 hypothesis tells that no primary signals are present in the spectrum and only noise is present. And hence it can be allotted to the secondary users.

H1 hypothesis tells that primary signals are present in the spectrum along with the noise. And hence it cannot be allotted to the secondary users else it will cause harmful interference to the primary users [8].

For any received signal at CR user based on present and absent of primary user is given by

Yi (t) =H0: n_i (t) (1)

Yi (t) =H1: hi (t) xi (t) +n_i (t) (2)

Where the received signal at the i^{th} CR user is represented by y_i (t) and h_i (t) is the gain of the channel between the primary user and i^{th} CR user. Additive white Gaussian noise at the i^{th} CR user represented by n_i (t) with the power spectral density S_n (f) = N0/2 W/Hz. The hypothesis is made by comparing a test statistic T(x) with a threshold γ. The matched filter performance is characterized by two metrics as probability of miss detection and probability of false alarm. Low probability of miss detection increases the interference on primary user whereas high probability of false alarm increases the amount of missed spectral opportunity in secondary users [9].

The operation of matched filter detection is expressed as:

Y[n] = Σ h [n-k] x[k] (3)

Where 'x' is the unknown signal and is convolved with the 'h', the impulse response of matched filter that is matched to the reference signal for maximizing the SNR.

With a non coherent receiver we need both real and imaginary parts to define the signal entirely [13].

Y (n)= $\sum_{n=0}^{N-1} \omega(n) \times {x_p}^{*}$ (n) (4)

The value of y (n) is greater than the threshold value (λ) under alternative hypothesis H1 while H1 is true. During the probability of detection input signal x (n) will be,

$x(n) = s(n)h(n) + \omega(n)\ \ ;H1$ (5)

This means the detection is H_1 while H_0 is true. Now, during the probability of false alarm input signal x (n) will be

X (n) =ω (n), H0 (6)

Now, from equation (5) and (6), the received signal y (n) can be written as,

y(n) = $\sum_{n=0}^{(N-1)}[s(n)h(n) + \omega(n)] \times Xp^{*}$(n) (7)

Now, the probability of PU detection alarm for the Matched filter detection method can be calculated by the given equation,

P_d=P [H_1/H_1]

$P_d = P[(y(n) > \lambda)/H_1]$ (8)

From equation (10) and (11), the final expression for probability of detection is,

$P_d = Q(\sqrt{\frac{2E}{\sigma^2\omega}}, \sqrt{\frac{2\lambda^2}{\omega\sigma^2}})$ (9)

Where, λ = threshold value. Q (,) = Generalized Marcum Q Function.

$Q(a,b) = \frac{1}{a^{(m-1)}}\int_{b}^{\infty} x^{m} e^{-\left(x^2+\frac{a^2}{2}\right)} I_{(m-1)}{}^{(ax)}dx$ (10) 'a' and 'b' are non-negative real numbers, m is positive integer's $I_{(m-1)}$ ( )= modified Bessel functions of the first kind of order (m-1) Now, the probability of false alarm for the Matched filter detection method can be calculated by the given equation

$P_f = P[H_1/H_0]$ (11)

$P_f = P[(y(n) > \lambda)/H_0]$ (12)

From (11) and (12), the final expression for probability of false alarm which is,

$P_f = \exp[\frac{-\lambda^2}{E\sigma\omega^2}]$ (13)

Where, λ= Threshold Value. exp ( ) = Exponential function. E = Input signal Power. $\sigma\omega^2$= Noise variance.

Now, for the probability of miss detection, the decision is H_0 while H_1 is true.

$P_m = P[H_0/H_1]$ (14)

$P_m = 1 - [(y(n) > \lambda)/H_1]$ (15)

From equation (14), (15) the probability of miss detection for matched filter detection can be,

P_m = (1 - P_d) (16)

$P_m = 1 - Q(\sqrt{\frac{2E}{\sigma^2\omega}}, \sqrt{\frac{2\lambda^2}{E\sigma^2\omega}})$ (17)

Power Spectral Density (PSD) of the AWGN signals is given

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$$PSD_{AWGN}(f) = \frac{N_0}{2} \quad (18)$$

Where,

N0 is the noise signal and AWGN channel Signal to Noise Power measured at the output of the matched filter is given by

$$SNR = \frac{|S(t)|^2}{|N(t)|^2} \quad (19)$$

The output noise power Pn calculated of the nth primary user is found to be

$$p_n = \frac{N_0}{2} \int_{-\infty}^{+\infty} |H_n(f)|^2 \, df \quad (20)$$

The output signal power Ps calculated of the nth primary user is found to be

$$P_s = \left| \int_{-\infty}^{+\infty} H_n(f) S_i(f)^{ej2\pi ft} df \right|^2 \quad (21)$$

Now the SNR of the primary user is simplified to SNRo

$$SNR = \frac{2P_{is}}{N_0} \quad (22)$$

The above equation represents the PU signal over the noise. The acquisition process of MF will give probability of false alarm and probability of detection that can be calculated as:

$$p_{fa}^{MF} = 1 - (\frac{\lambda MF}{\sigma}, 2) \quad (23)$$

$$p_d^{MF} = Q(\sqrt{2n(SNR)}, \sqrt{\frac{\lambda MF}{\sigma 2}}) \quad (24)$$

Where λMF is the threshold setting for MF, the non-centrality parameter s2 = 2n (SNR) is the output of the filters in I and Q branches at the correct offset. The correlation process of MF has a central chi-square distribution with 2 degree of freedom with a variance.

III. RESULT AND DISCUSSION

Our simulation is conducted in MATLAB 13(a) to investigate the performance of our proposed scheme. The sensing performance of detection scheme is measured by the receiver operating characteristic (ROC), such as *Pf* versus *Pd*. Monte Carlo simulation is used for the experimentation under the following system settings: there are 5 randomly distributed Gaussian channels with zero mean and variance 1, and an SU looking for spectrum holes in these channels. First signal is modulated with two different modulation techniques such as BPSK and AM modulation. After modulating this signal additive white Gaussian noise is added and this signal is considered as received signal. This received signal is filtered using matched filtering with impulse response of filter h=1. Resultant output of matched filter is compared with predetermined threshold calculated with the help of probability of false alarm.

Fig.3 shows the probability of false alarm verses probability of detection for both AM and BPSK modulation technique. The results are conducted for probability of false alarm from 0.01 to 1 respectively. 96

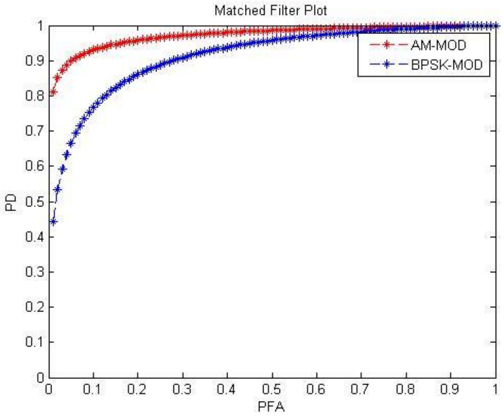

Fig.3 PD vs. PFA for BPSK and AM modulation

For 0.01 PFA, AM modulation gives higher detection probability of 0.8946 whereas BPSK gives 0.41732. As we goes on increasing the PFA value towards 1 AM modulation and BPSK modulation has reach to nearly equal detection probability. At PFA 0.9, AM has 0.9988 and BPSK has 0.9954 probability of detection.

Fig.4 shows PD vs. SNR for different values of probability of false alarm with range of SNR is from -10 to 10 dB respectively.

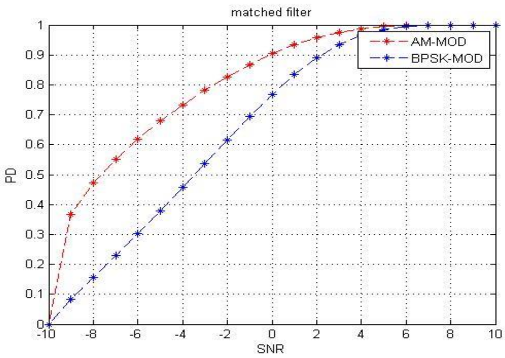

Fig.4 PD vs. SNR for matched filter detection

From Fig.4, it can conclude that for -6 dB probability of detection is 0.726 whereas 0.3088 for BPSK modulation. As SNR is increased positively both gives modulation scheme gives nearly the same results from 6 dB it gives PD 0.9988 for AM and 0.9949 for BPSK. For low SNR AM modulation gives the maximum detection probability.

Fig.5 shows ROC curve for probability of miss detection verses probability of false alarm.

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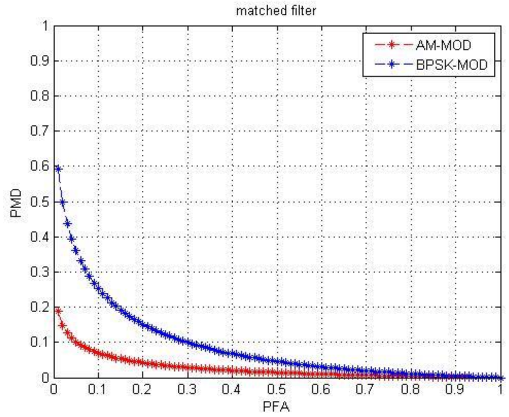

Fig.5 PMD vs. PFA for matched filter method

From Fig. 5, it can conclude that for AM modulation probability of miss detection is lower value of 0.1053 for PFA 0.01 compare to BPSK has 0.5826. As value of PFA increases probability of miss detection has nearly same value as at point 0.8 of PFA AM has 0.02 and for BPSK has value of 0.01 and after both will reach to 0 miss detection probability.

IV. CONCLUSION

An effective cognitive radio spectrum sensing method which can be utilized in low SNR region is introduced for effective spectrum utilization. It gives result of AM modulation technique with the value of probability of detection 0.8946 and for BPSK 0.41732 at 0.01 value of PFA. Performance matrix of the spectrum sensing is improved by using the AM modulation technique for matched filter method.

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