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ALGORITHM FOR DETECTION OF PRIMARY USERS IN COGNITIVE RADIO BY SPECTRUM SENSING USING PSD

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ABSTARCT:
Cognitive Radio (CR) is Software Defined Radio (SDR) that continuously monitors its spectral environment in search of spectrum holes and allots the unused frequency slot to the secondary user. Spectrum sensing division of CR does the work of this searching. For the purpose of this exploration the simplest technique which can be used is Energy Detection technique in which energy of the received signal is calculated to detect the presence of primary user. An improved version of energy detection is by detecting the users using power spectral density (PSD) of the received signals. This paper elaborates this method using MATLAB simulation software. Here the receiver distinguishes the empty channel for the use of secondary user which may or may not be affected by noise.

Keywords: *Spectrum Sensing, Energy detection, Power spectral density, Dynamic spectrum management, Cognitive radio.*

1. INTRODUCTION:

One of the major challenges that the world of wireless communication is facing today is the ever increasing demand of spectral bandwidth. The present distribution of spectrum is static i.e. only those users to whom the bandwidth is allotted can only use it. But the spectrum is limited and the growing population of wireless network and users is resulting in shortage of available frequency bandwidth for use. Moreover, according to survey conducted by spectrum task force of FCC [1] [6] [14] the allocated bandwidth is highly underutilized. It has also been emphasized that instead of static allocation, dynamic management of spectrum can be used to solve the spectral inefficiency problem. It will help in dealing with the recent boom of wireless users and network also.

One of the pioneer techniques for dynamic management of spectrum is Cognitive radio. It may be defined as an intelligent radio transceiver [5][6][12] that is designed for automatic detection of available unused wireless spectrum then accordingly changes its transmission and reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. It allows more and more unlicensed user to use the licensed band for wireless communication. The primary aim of cognitive radio network is to provide highly reliable communications whenever and wherever needed and to utilize the radio spectrum efficiently. The 3 major tasks that the cognitive radio has to perform are [2]:-

1. Radio-scene analysis, which includes :-
   a. Estimation of interference temperature of the radio environment
   b. Detection of spectrum holes.
2. Channel identification, which includes :-
   a. Estimation of channel-state information (CSI)
   b. Prediction of channel capacity for use by the transmitter.
3. Transmit-power control and dynamic spectrum management.

The term ‘Spectrum Holes’ here refers to the band of frequencies assigned to a primary user, but, at a particular time and specific geographic location, the band is not being utilized by that user [6].

2. SPECTRUM SENSING

The portion or part of the cognitive radio which deals with this spectrum holes is known as Spectrum sensing. It enables the cognitive radio to continuously monitor a licensed frequency band and opportunistically transmit whenever it doesn't detect a primary signal. With an ability to autonomously detect and respond to the spectrum usage, these type of secondary users can be considered as the primitive forms of cognitive radio. The basic requirements for spectrum sensing are the full awareness of its radio environment and knowledge of its geographical location. The tasks performed spectrum sensing unit involves:

1. Detection of spectrum holes;
2. Spectral resolution of each spectrum hole;
3. Estimation of the spatial directions of incoming interferes;
4. Signal classification.

The different techniques through which spectrum sensing can be done are as shown in figure1:-

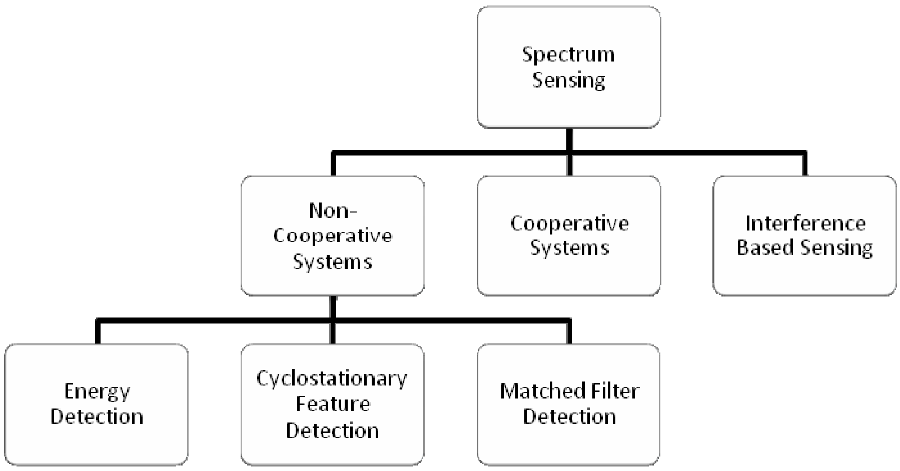

Fig. 1 Classification of Spectrum Sensing Technique [2]

However, there are different challenges and issues related to spectrum sensing [2]. These are:-

1. Channel Uncertainty
2. Noise Uncertainty
3. Aggregate Interference Uncertainty
4. Sensing Interference Limit

3. ENERGY DETECTION TECHNIQUE

The Energy detection method is the simplest spectrum sensing mechanism [12]. Here energy of the received signal is calculated to detect the presence of primary users in the spectrum. Its biggest advantage is that it doesn't depend upon the characteristics of the input signal for signal detection. The primary user is said to be present if the calculated energy level of incoming signal is greater than the threshold energy level. Suppose that y (n) is sampled signal to be analyzed and x (n) is the intelligent signal and w(n) be the noise of variance σ^2 such that [9],

$$y(n) = h(n) * x(n) + w(n) \ldots\ldots\ldots H_0 \quad \text{(signal present)}$$
$$y(n) = w(n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots H_1 \quad \text{(signal absent)}$$

The hypothesis H_0 denotes that primary user is present and H_1 denotes that the primary user is absent. The hypothesis H_0 will be true only if y(n) is greater than threshold energy level ε and H_1 will be true if y(n) is less than the threshold energy level ε.

$$H = H_0 \ldots\ldots\ldots\ldots\ldots\ldots y(n) > \varepsilon$$

$H = H_1$……………….y(n) < ε

4. ENERGY DETECTION USING PSD

The estimation of energy using energy spectral density analysis is suitable only for transient signals (like pulse). For continuous time signals it is advantageous to have power spectral density instead. It is due to the reason that power of a signal will be a finite quantity even if its energy content is infinite. Power Spectral Density is the distribution of average power over some range of frequencies. The total power of a signal x (t) may be calculated as under:-

$$P = \lim_{t\to\infty} \frac{1}{2T} \int_{-T}^{T} x(t)^2\, dt$$

The quantity S_x (ω) is the Power Spectral Density if x (t) is considered to be a WSS process.

$$S_x(\omega) = \lim_{T\to\infty} \left[\frac{E\left[\left|F_{x_T}(\omega)\right|^2\right]}{2T} \right]$$

It is a real-valued, non negative function for which if x (t) is real-valued the power spectrum will be the even function of ω. Here x_t (t) is the truncated process given by

$x_t(t) = x_t(t)$ Rect (t/2T).

5. ALGORITHM

For the detection of spectrum holes a mere calculation of the PSD of the received signal can be used. Comparing the PSD values at each channel we can estimate the presence of spectrum holes [3]. As shown in fig.2 the first step in algorithm for the detection of primary users in the radio environment of cognitive radio using PSD is modulation of incoming input signal at different channels having different carrier frequencies. This is followed by multiplexing and transmission of the modulated signals through the channel where noise may or may not corrupt the signals. Calculation of threshold power level is also done. At receiver, PSD of received signal from different channels using Bartlett’s method is calculated. Lastly, a comparison of the calculated power with the threshold power level is done to finally make a decision on the presence of primary user. If power level is less than the threshold level, primary user is absent and channel can be used by secondary user. If the power level is high, primary user is present.

6. EXPERIMENTAL

For the simulation purpose we had taken 5 different channels each having different carrier frequencies. Here the inputs taken are sinusoidal signal and exponential signal. At transmitter, input signal is first modulated using carrier frequencies of different channel and sent through different channels as per the user. The outgoing signal is then finally multiplexed to obtain a combined signal and then transmitted. Before reception the channel may incorporate noise (AWGN) as specified by user. At receiver the received signal is processed to obtain the PSD of the incoming signal so as to obtain power content (in Db) of the received signal at channel frequencies. Now the calculated PSD value is compared with the calculated threshold value. If the obtained power content is less than the threshold value primary user is absent in that particular channel and vice versa.

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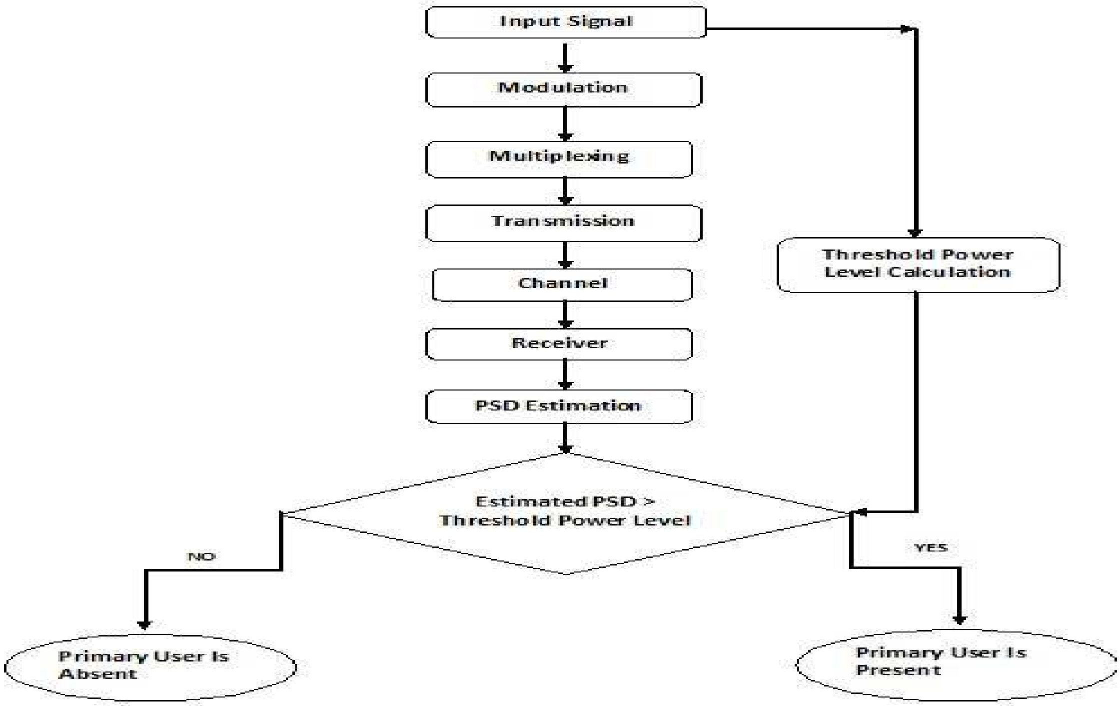

Fig. 2 Algorithm for primary user detection

7. RESULTS AND DISCUSSION

Following the above algorithm it has been found the presence of primary users can be detected by calculating PSD of the received signal.

```
Transmitter Operation
I/P is an Exponential Signal!
Enter the duration of the signal N = 10
Enter the scaling factor a = 0.2
Warning: Integer operands are required for colon operator when used as index
> In M_P_Exp at 36

Do you want to enter first primary user Y/N: y

Do you want to enter 2nd primary user Y/N: n

Do you want to enter 3rd primary user Y/N: y

Do you want to enter 4th primary user Y/N: n

Do you want to enter 5th primary user Y/N: y
```

Fig. 3 Simulation of Transmitter operation

As shown in figure 3 during transmitter operation the user has been asked whether he wants to use the channel or not (answer being in y for yes and n for no). The results have been shown in the figure 4 where receiver compares the threshold value with the calculated Power content of the received signal and estimate the presence. Moreover AWGN noise has also been induced so as to make the simulation more realistic. For this purpose, user is asked to provide the required SNR value of the system according to which noise is added. In figure 4(a)

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noise has been added such that the SNR value of the system becomes -10db. In figure 4(b) again noise had been added but this time SNR value is further decreased to -30db. For the first case detection has been true that the channel is free and can be used by secondary user. But as the SNR value is decreased the increased noise level result in incorrect detection of primary user. As shown primary users are absent in channel 2 and 4 but receiver has made erroneous detection.

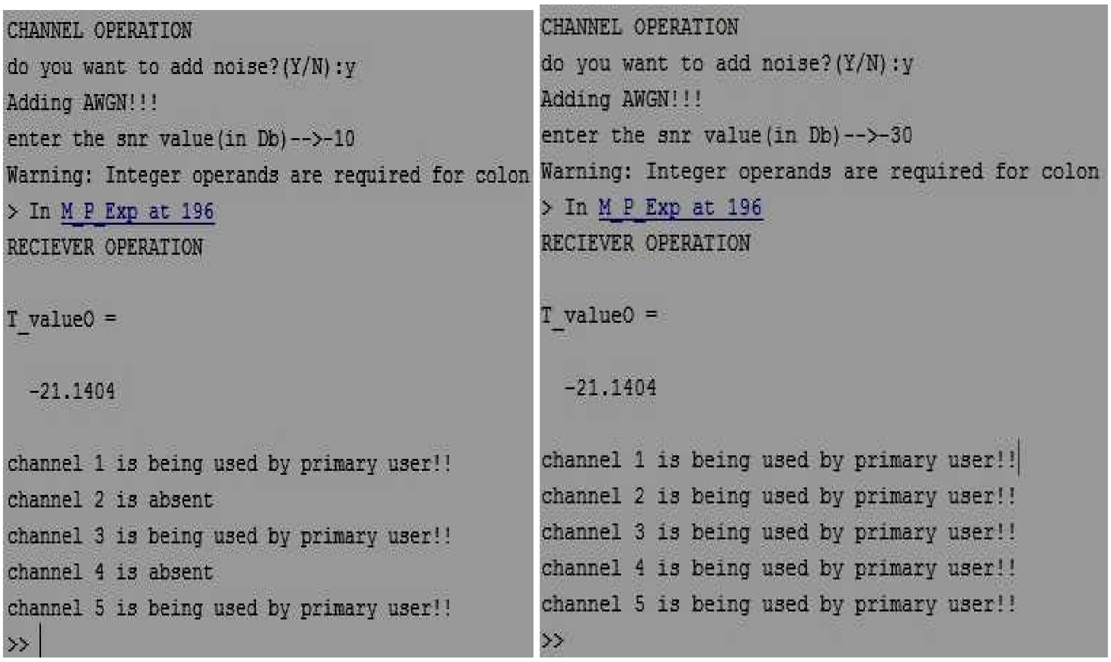

Fig. 4 Detection of primary users when (a) -10 SNR (b) -30db SNR

8. CONCLUSION

Cognitive Radio is an emerging technology which can be extensively used for the efficient use of the radio spectrum thus fulfilling the increasing demand of frequency bands. For the smooth functioning of cognitive radio spectrum sensing plays an important role. Different techniques of spectrum sensing can be used for detection of spectrum holes in the radio spectrum. Energy Detection is one of the easiest techniques of sensing the spectrum holes. It does not depend on the signal or channel characteristics for detection of spectrum holes. The above proposed algorithm makes use of Power spectral density of the received signal to detect the presence of primary user. Furthermore, there are some cases of false detection of primary user due to noise interferences. The proposed algorithm suggests that the system doesn't work as efficiently if the SNR value of the receiver goes below -30db. It is because of the fact that signal power is low as compared to the noise affecting the system. There exist a number of issues like false alarm, high noise interference, etc which are need to be considered for better working of the system.

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