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Estimation of Spectrum Holes in Cognitive Radio using PSD

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Abstract

As frequency is a scarce resource, so efforts are being made to use the allotted frequency spectrum as competently as possible. The concept of Frequency Reuse efficiently serves this purpose by reusing the frequencies and channels in a communication system to improve its capacity and spectral efficiency. Cognitive Radio is one of the emerging technologies that apply frequency reuse method as its working principle. Cognitive Radio is an intelligent transceiver system that continuously monitors its Radio Frequency environment in search of the unused frequency slots (known as spectrum holes) that had been provided to the primary user and supply it to another user (known as secondary user) for its use. The process of searching of these empty slots by cognitive radio is called Spectrum sensing. Out of many available processes the least complex process of Spectrum sensing is energy detection of the channels. Energy Detection technique is the method in which energy in the channel is sensed to search for the presence of primary user in the channel. In this paper Power Spectral Density (PSD) of the channel is obtained to examine the existence of user in the channel.

Keywords: Spectrum Sensing, Cognitive Radio, Energy Detector, Power Spectral Density and Electromagnetic Spectrum.

1. Introduction

Electromagnetic Spectrum [1] is the distribution of all possible frequencies of electromagnetic radiations present. It ranges from very high frequency Gamma Rays

(>$3*10^{19}$) to very low frequency Long Waves (< 3Hz). Radio spectrum is a part of electromagnetic spectrum corresponding to Radio frequencies ranging from (3 KHz-300GHz). Radio waves or Radio Frequency Signals (RF Signals) are basically used in wireless communication. For this purpose RF spectrum is again divided into different categories according to its use, which in turn is divided into various frequency slots. Now these slots are provided to the users by different governing bodies. These licensed users are called primary users. But as the technology advances demand for spectrum-based services also grows day by day. As shown in figure existing spectrum user need more space in spectrum and new users are also emerging as well.

Moreover different types of users already populate the range of 300MHz-3GHz that is termed as the "Sweet Spot" and more users are there ready to join. This increased demand of spectrum based services and devices makes frequency a very scarce natural resource. But despite of such high need it has been found in the surveys conducted by FCC [6] that the allotted frequency slots are being underutilized by the primary users for significant amount of time. As the static spectrum management provides exclusive frequency slots to the primary user to find vacant slots for new users is rare. The most creative solution for this underutilization is to reuse the frequency slots by dynamic management of RF spectrum. Dynamic spectrum management enables use of frequency slots by multiple users. Cognitive Radio is one of the Dynamic Spectrum management techniques, which authorize the use of empty frequency slots time and again by providing it to users other than primary licensed user. Such users are called Secondary users. When primary user emerges, secondary user is needed to quit the slot as fast as possible to avoid inference between them.

2. Cognitive Radio

Joseph Mitola-III first coined the term "Cognitive Radio" [4]. According to him "Cognitive Radio is a type of Software Defined Radio which continuously monitors its RF environment for Spectrum holes and provides this unused frequency band to another user". The original licensed user are called primary user whereas the users to whom the spectrum holes are provided are termed as secondary user. The Cognitive Radio (CR) uses various Spectrum Sensing methods to detect the spectrum holes in the RF spectrum. It then estimate the timing for which spectrum would be allotted, then use Dynamic spectrum management techniques to allocate the unused frequency to secondary user through different Power Control methods to communicate between its users undisturbed.

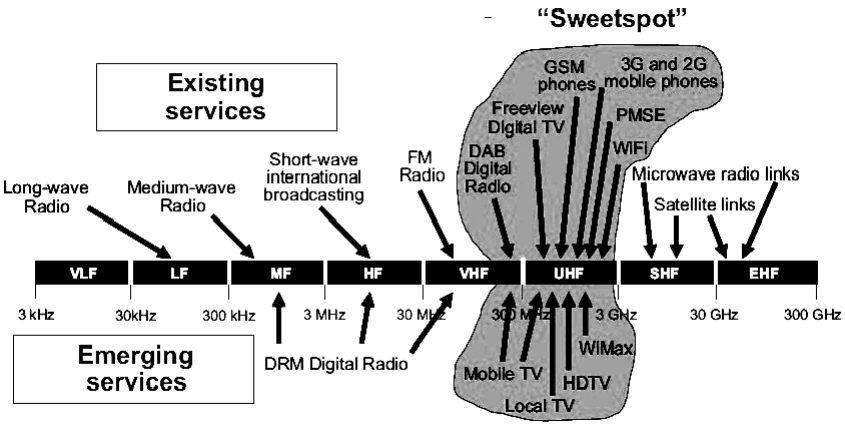

Fig. 1: Usage of Radio Spectrum [1]

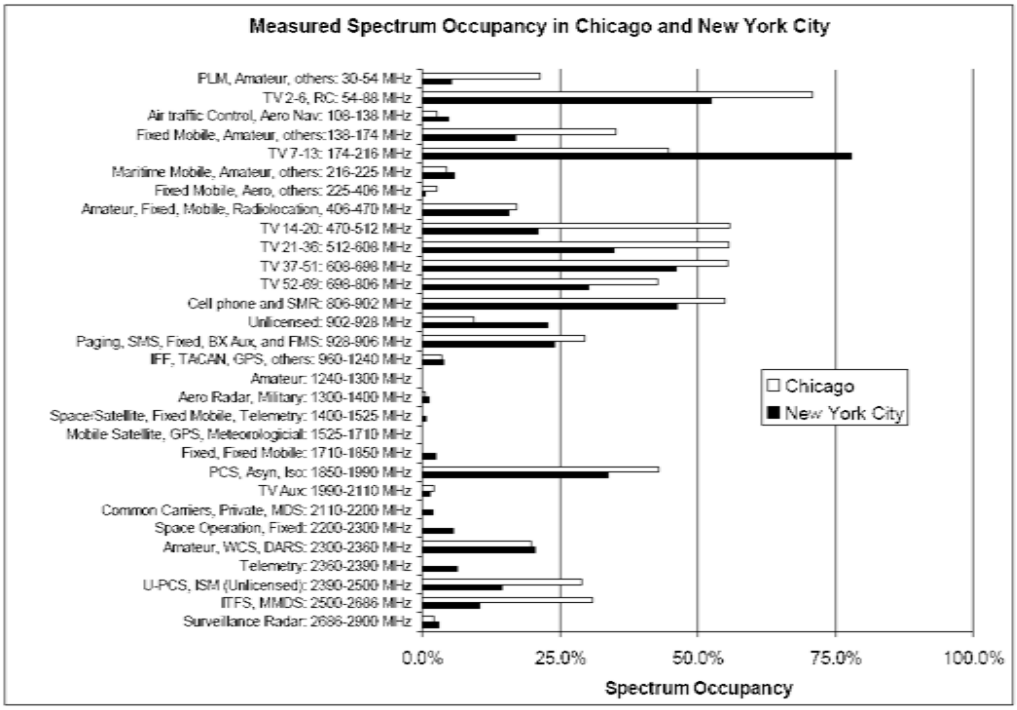

Fig. 2: Spectrum occupancy in Each Band in New York City, and Chicago (high spectrum usage) [13]

3. Spectrum Sensing

Among all its sub-systems Spectrum Sensing plays the major role in the operation of cognitive radio. Spectrum Sensing [5] is the process of detecting spectrum holes or white spaces in the allocated RF band. Here Spectrum holes or White spaces refer to the

unused RF bandwidth of the licensed primary user. The sensing should be dynamic enough to detect spectrum quickly enough and so as the switching from one band to another as soon as primary user returns. The spectrum sensing can be done basically in two ways: - a) co-operative b) non-co-operative manner. The four basic non-cooperative techniques of spectrum sensing are: - energy detector, autocorrelation detector, cyclostationary feature detector, and matched-filter detector.

4. Energy Detector

In Energy Detection [2] method of spectrum sensing energy of the primary signal is sensed. It is a simple method as it doesn't require information about the transmitting signal as well as channel information. It is also known as Blind Detector as it ignores the structure of the signal and predicts the presence of the primary user through estimation of energy contained in the channel. Energy content of any signal can be calculated by squaring each sample and then combine these squared value. According to Parseval's theorem the energy content of a signal can be calculated with the help of Fourier Transform as follows: -

$$E = \frac{1}{2\pi}\int_{-\infty}^{\infty}|X(\omega)|^2 d\omega \qquad (1)$$

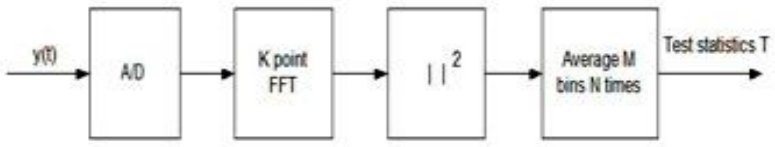

Fig. 3: Energy Detector [2]

5. Experimental

In this paper we are going to analyze the energy detection technique using Power Spectral Density (PSD). Power signals are the limiting case by assuming that the power signal is restricted in the interval (-T, T). PSD is the measurement of the power content in the signal. It is the frequency domain plot between powers per Hertz versus frequency. For calculation of energy content in a signal we had to sample the signal and then measure the PSD. In this paper a sinusoidal signal is taken as an input. This input sine wave is then modulated by 5 different carrier signals depicting 5 different channels. Also as the carrier signal ranges from (-∞, ∞) it will be a power signal. To measure the energy content we combine the output from each modulator and sample the combined signal by a sampling frequency of 10 KHz. The sampled signal is then used to obtain the PSD of the spectrum.

6. Results & Discussion

For the simulation purpose MATLAB simulation software had been used. The output of the simulation contains the input signal (sinusoidal signal), 5 channels having carrier frequency of 1KHz, 2KHz, 3KHz, 4KHz, and 5KHz. Each carrier signal is then modulated and combined output signal of each channel is taken. This combined modulated signal is then used to calculate the PSD.

Fig.4 (a) contains the sinusoidal signal as input and the carriers modulated by the sine wave. In fig.4 (b), shows the PSD graph when all channels are preoccupied by primary user.

In fig.5 (a), channel 4 is absent thus PSD of overall channel shows that the power content is very less as compared to initial condition.

In fig.5 (b), 2 channels are absent hence the powers at respective channel frequency are low.

From the above result we can say that the channels that are absent in the figures, have low power level near their respective carrier frequency in the obtained PSD of the spectrum. That is there is no modulation process is going on or the input is absent. Here the input refers to primary user. That means that when a channel is showing low power level in the PSD the primary user is absent and the channel can be allotted to other secondary user.

7. Conclusion

From the discussion and results we can conclude that Energy Detection Method is a simple and useful method for spectrum sensing. It doesn't depend on the transmitter and channel characteristics as well as the signal structure. We can also say that in the obtained PSD curves low power level signifies absence of signal and can be treated as a spectrum hole. But this method had some disadvantages also. Firstly detection of signal is difficult in presence of noise. Secondly it is difficult to distinguish the interferences because of the primary user and random noise.

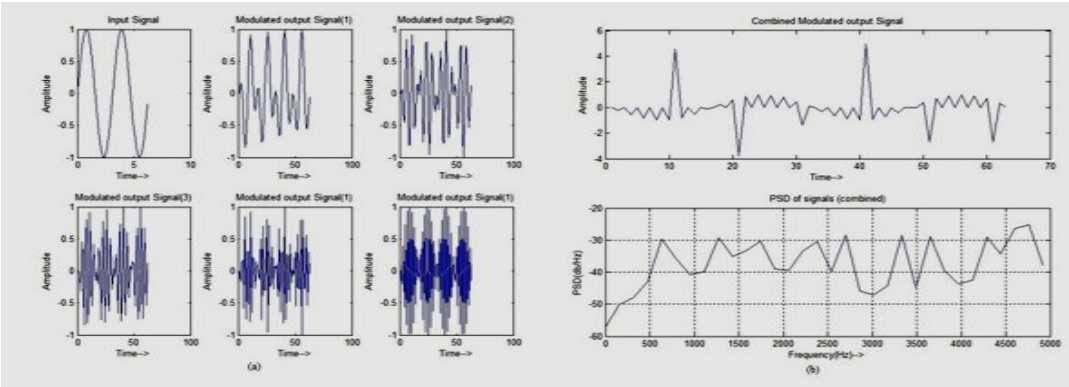

Fig. 4: Initial condition when all primary users are present output.

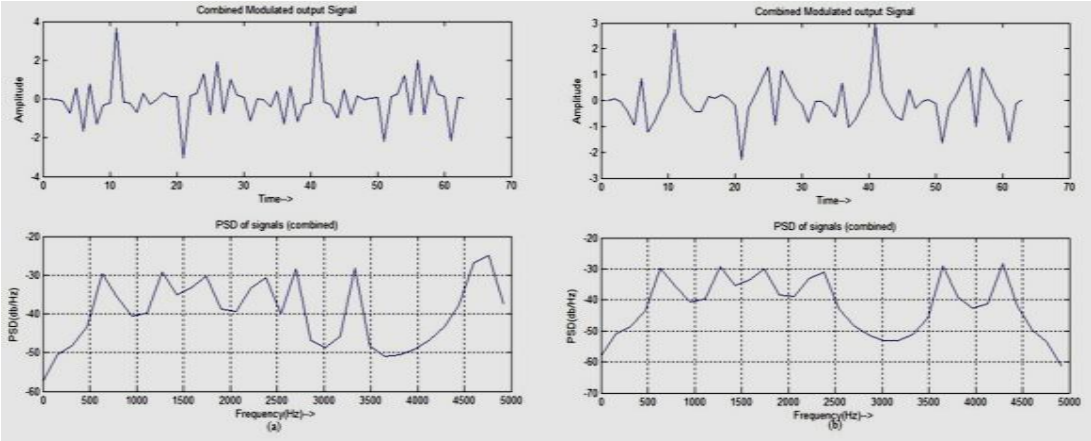

Fig. 5 (a): PSD plot when 1 channel is empty.
Fig. 5 (b): PSD plot when 2 channels are empty.

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