Matched Filter Based Spectrum Sensing on Cognitive Radio for OFDM WLANs

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***Abstract* - For the unlicensed users to use the licensed spectrum, unused frequency bands called white spaces need to be detected. Cognitive radio does this task by dynamic spectrum access. This requires intelligent spectrum sensing techniques. In this paper such unused spectrum for OFDM WLAN (IEEE 802.11a) is predicted by exploring the signals presence in minimum time using matched filter based detection incorporating optimal threshold selection, thereby increasing the sensing accuracy and interference reduction of secondary network.**

Keywords- Cognitive radio, OFDM, Matched filter, Spectrum efficiency, Spectrum sensing, WLAN.

I. INTRODUCTION

The need for a flexible and robust wireless communication is becoming more evident in recent times. The future of wireless networks is thought of as a union of mobile communication systems and internet technologies to offer a wide variety of services to the users.

Conventionally, the policy of spectrum licensing and its utilization lead to static and inefficient usage. The requirement of different technologies and market demand leads to spectrum scarcity and unbalanced utilization of frequencies. It has become essential to introduce new licensing policies and co-ordination infrastructure to enable dynamic and open way of utilizing the available spectrum efficiently.

One promising solution to such problems is the Cognitive Radio[1]. It has an intelligent layer that performs the learning of environment parameters in order to achieve optimal performance under dynamic and unknown situations. Spectrum Sensing i.e. checking the frequency spectrum for empty bands forms the foremost part of the cognitive radio.

II. RELATED WORKS

A. *Spectrum Sensing Methods:*

Sensing spectrum is the most important factor of cognitive radio[1], which is mandatory step that needs to be performed for communication to take place. A number of schemes have been developed for detecting whether the primary user is present in a particular frequency band. Some approaches use the signal energy or some particular characteristics of the signal to identify the signal and even its type.

Some of the most common methods employed for Spectrum Sensing[2] are

- Energy Detection[3]
- Cyclo-stationary Feature Detector[4]
- Matched Filter Detection [5]

Among the above three methods energy detection is popular till now, but the major drawback with energy detection method is that the poor performance under low SNR conditions and also no proper distinction between primary users and noise. Rather the matched filter maximizes the SNR[6].

B. *Brief Introduction To Matched Filter:*

The decision making on whether the signal is present or not can be facilitated if we pass the signal through a filter, which will accentuate the useful signal sig(t) and suppress the noise w(t) at the same time. Such a filter which will peak out the signal component at some instant and suppress the noise amplitude at the same time has to be designed. This will give a sharp contrast between the signal and the noise, and if the signal sig(t) is present, the output will appear to have a large peak at this instant. If the signal is absent at this instant, no such peak will appear. This arrangement will make it possible to decide whether the signal is present or absent with minimum probability of error. The filter which accomplishes this is known as matched filter. Main purpose of the filter is, to decrease the noise component and to increase the signal component at the same instant. This is obviously equivalent to maximizing the signal amplitude to the noise amplitude ratio at some instant at the output. It proves more convenient if we go for square of amplitudes. Hence the matched filter is designed in such a way that it will maximize the ratio of the square of signal amplitude to the square of the noise amplitude.

C. OFDM Transmitter:

Many of the current and future communication standards, like the WiFi, DVB-T/T2, WiMAX use the principle of multicarrier communications. One of the most widespread representatives of the multicarrier systems is the Orthogonal Frequency Division Multiplexing. The basic structure of OFDM modulator is shown in Figure 1. The input data are divided into parallel streams corresponding to individual subcarriers. The number of data subcarriers usually spans from tens (48 in the case of IEEE 802.11a) to thousands (DVB-T/T2). The data on each subcarrier are mapped according to selected constellation diagram (usually BPSK, QPSK or M-QAM) and the OFDM modulation is implemented using Inverse Fast Fourier Transform operation.

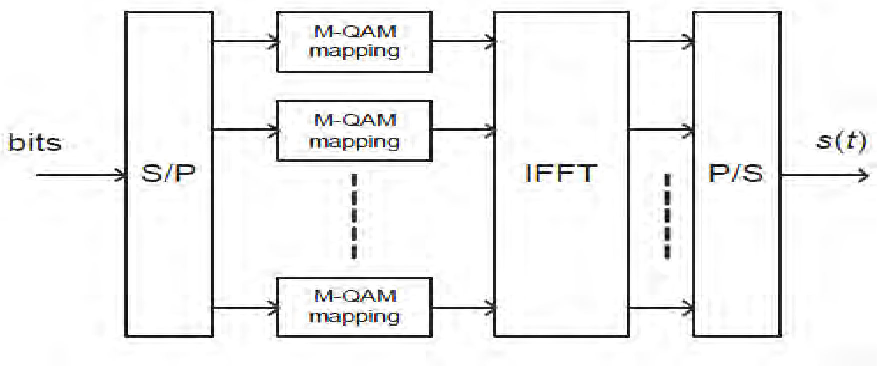

Fig 1. OFDM Modulator

III. PROPOSED WORK

In the proposed work, IEEE 802.11a signal has been generated based on the standard specification parameters. The actual data available for transmission is converted from serial to parallel form. The resulted data is modulated using 64QAM. This modulated data is subjected to Inverse fase fourier transform operation and the preambles are added as per IEEE 802.11a standard. This data is transmitted through awgn channel. Let sig(t) be the transmitted signal, w(t) is the channel noise, sig(t) + w(t) be the received signal, which is given as the input to the matched filter and $sig_0(t)+w_0(t)$ be the output of the filter. Let the matched filter's impulse response be h(t). It had been proven that, impulse response of the optimum system is the mirror image of the desired message signal sig(t) about the vertical axis and shifted to the right until all of the signal sig(t) has entered the receiver. It should be realized that the matched filter is optimum of all linear filters.

The signal component at output of the filter, at the observing instant t_m is given by

$$sig_0(t_m) = 1/2\pi \quad (s(\omega))^2 \tag{1}$$

$$sig_0(t_m) = E \tag{2}$$

Hence the output signal component has maximum amplitude of magnitude E, which is nothing but energy of the signal sig(t). The maximum amplitude is independent of the waveform sig(t) and depends only upon its energy.

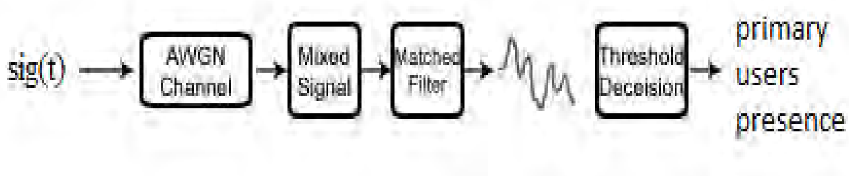

Fig 2. Block diagram of spectrum sensing using matched filter

Figure 2 shows Spectrum Sensing block using matched filter. Here the transmitted signal is passed through the channel where the additive white Gaussian noise is getting added to the signal and outputted the mixed signal. This mixed signal is given as input to the matched filter. The matched filter input is convolved with the impulse response of the matched filter and the matched filter output is then compared with the threshold for primary user detection.

The threshold of a signal, determined by two possible ways has been discussed here. One way is to estimate the energy of the signal and reduce it to half, fix it as a threshold. Another way is to compute the standard deviation of the signal by computing the mean and use it as threshold. Of the two methods, the former one is theoretically proved to be optimal. In this paper the former is chosen to detect the presence of WLAN signal.

Once the threshold is chosen, presence of signal is determined based on the following decicion rule[1].

$$rxd(t) > a : \text{signal present} \tag{3}$$

$$rxd(t) < a : \text{signal absent} \tag{4}$$

where rxd(t) is the matched filter output given by

$$rxd(T) = sig_0(T)+w_0(T) \tag{5}$$

from eqn.(2)

$$rxd(T) = E + w_0(T) \tag{6}$$

If there is no primary user signal, then received signal be

$$rxd(T) = w_0(T) \tag{7}$$

indication of only noise.

IV. RESULTS AND DISCUSSION

The simulation commences with generation of IEEE 802.11a signal. The actual data to be transmitted is 64QAM modulated before it is given to OFDM modulator. For generating IEEE 802.11a signal, the following are the parameters to be considered. The IEEE 802.11a frame structure consists of preamble followed by predetermined OFDM symbols. There are10 short preambles and 2 long preambles. Rest of the symbol consists of user data.

TABLE I
Simulation parameters for generating IEEE 802.11a waveform

Modulation Used	OFDM
Number of data sub-carriers	48
Number of pilot sub-carriers	4
Total number of sub-carriers	52
FFT size	64
Length of cyclic prefix	16

Here the assumption is that 200 OFDM symbols are transmitted in which 12 are preambles. Rest 188 OFDM symbols are stuffed with data. The generated OFDM signal is shown in figure 3.

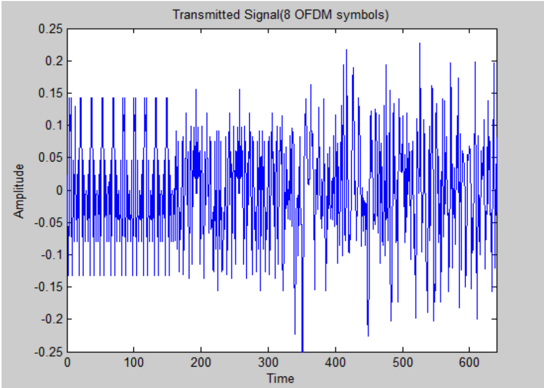

Fig 3. OFDM signal

The spectrum plot is shown in figure 4. From the spectrum plot it is proven that the sample frequency of IEEE 802.11a is 20MHz. The OFDM signal gets affected by noise when it is passed through the channel.

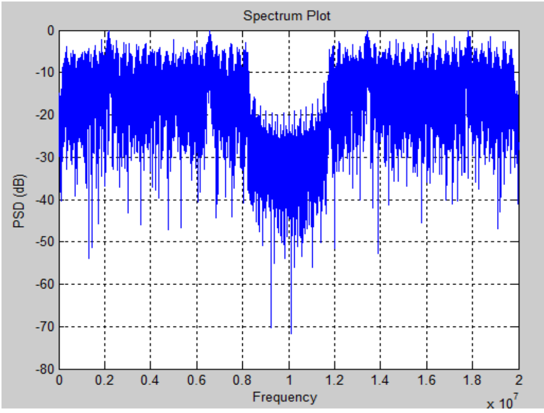

Fig 4. Spectrum plot

The signal along with noise gets received at the receiver. The received signal is shown in figure 5. This signal is then passed through matched filter for the detection of presence of primary user data. The output of matched filter is shown in figure 6.

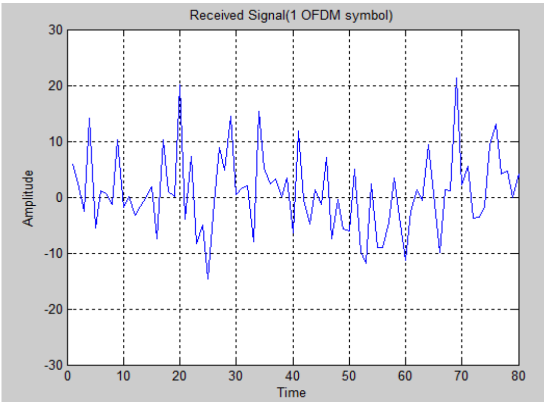

Fig 5. Received signal

From the matched filter output the threshold has been determined as per the discussion above and the signal energy which crosses the threshold is considered to be the primary users presence. The absence of primary user corresponds to spectrum holes[7]. Here the threshold is estimated to be 0.5098. From the matched filter output it is clear that all the OFDM symbol energy crosses the threshold. Hence the number of detections be 188.

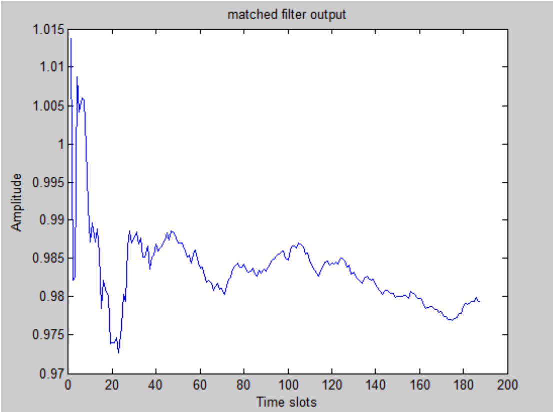

Fig 6. Matched filter output

V. CONCLUSION

To account for spectrum scarcity problem and spectrum underutilization the cognitive radio inclusive of spectrum sensing unit has been incorporated. One of the most important factors of spectrum sensing for CR network is sensing accuracy. The software simulation on improving the sensing accuracy for OFDM WLAN's by optimal prediction of primary users presence in minimal time with the help of optimal threshold fixing in matched filter has been done in MATLAB. Though this sensing technique is implemented to detect IEEE 802.11a waveform, it can be modified to detect signal of any standard.

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