Suppression of side lobe power for Cognitive Radios based on OFDM using Windowing Techniques

Jameel Ahamed, Hemendra Kumar Tiwari

***Abstract*—With the introduction of new technology in wireless applications with high data rate and increase of existing wireless services, need for additional bandwidth is speedily enhancing. Existing spectrum allocation policies of the Federal Communications Commission (FCC) forbids unlicensed access to licensed spectrum, confining them to various heavily populated, interference-prone frequency bands, which causes shortage in spectrum. Orthogonal frequency division multiplexing (OFDM) is used for cognitive radio (CR) transmission because it supports high data rates that are vigorous to channel impairments. The immense problem for transmission of OFDM is high out-of-band (OOB) radiation, which is due to sinc-type function representing the symbols throughout one time constant. Thus, high sidelobe may happen that will intervene with neighboring transmissions. In this paper we used windowing techniques to decrease the effects of sidelobe transmission.**

***Index Terms*—OFDM, CR, Windowing**

I. INTRODUCTION

The Federal Communication commission (FCC) identified a technical challenge for the allocation of spectrum for expansion of already active services or for extra services. The existing technique for allocation of spectrum depends upon segmentation of available spectrum and allocating the fixed blocks to the licensed users. In such a system of allocation of spectrum, unlicensed users are not allowed to use the already licensed bands due to strict rules are enforced on their access. Due to these prohibitions of unlicensed to licensed spectrum, most populated and majorly interference prone frequency bands have to be accessed. As a result, this will prove in reduction of performance. Furthermore, measurement movements proved that such an allocation results in wastage of the spectrum both in frequency and time [1]. Figure 1 show a measurement campaign conducted at the Information Technology and Telecommunications Center (ITTC) on 8/31/2005 [2]. The occupancy of spectrum from 9 kHz to 1 GHz is shown in figure 1 and it is observed that there are several spectral white spaces in the licensed portions of the spectrum describing that allocated spectrum are under-utilized. So existing spectrum allocation techniques causes apparent scarcity of spectrum [1]. Thus, the requirement for a novel spectrum allocation policy has been discovered.

Revised Version Manuscript Received on March 22, 2016.

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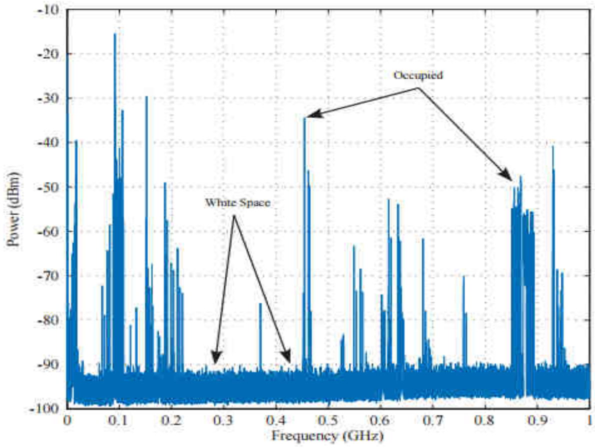

Figure 1 Spectral occupancy from 9 kHz to 1 GHz

The important goal of the new policy for spectrum allocation is the promotion of secondary utilization of unused portions of the spectrum in the form of spectrum pooling, wherein, unlicensed users rent licensed portions of the spectrum from a common pool of spectral resources from different owners [3]. This enhances the utilization of the spectral resources while potentially generating additional revenue to the licensed users. However, the implementation of a spectrum pooling system raises many technological, economic and political questions that need to be answered for the successful coexistence of the legacy and rental systems. Efficient pooling of the radio spectrum is achieved by using a cognitive radio [4] which is a multi-band, spectrally agile radio that employs flexible communication techniques and detects the presence of primary user transmissions over different spectral ranges to avoid interference to the licensed users.

Orthogonal Frequency Division Multiplexing (OFDM) is a promising candidate in the physical layer design of any multi-band, spectrally agile radio, since it can achieve high data rate communications by collectively utilizing a number of orthogonally spaced frequency bands which are modulated by many slower data streams [3]. Moreover, this division of the available spectrum into a number of orthogonal subcarriers makes the transmission system robust to multipath channel fading [5]. Furthermore, it is possible to turn off the subcarriers in the vicinity of the primary user transmissions, and thus the spectral white spaces can be filled up efficiently [6].

The mobile radio channel is contaminated with multipath fading, i.e., the transmitted signal is reflected by various terrain sources and multiple reflected copies of the signal arrive at the receiver at different times. These reflected,

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delayed versions of the signal interfere with the direct line-of-sight (LOS) wave and cause inter-symbol interference (ISI) which results in significant degradation of the system performance. Even though adaptive equalizers can be employed at the receiver to mitigate the effects of ISI when the transmission data rate is of the order of kilobits per second, such a setup would become extremely complex and expensive when the transmission bit rate is of the order of several megabits per second. To overcome the effects of such a multipath fading environment, a parallel data transmission scheme needs to be used which reduces the influence of multipath fading and makes the use of complex equalizers unnecessary [12].

II. INTERFERENCE TO LEGACY SYSTEM

With respect to the interference caused by the unlicensed user to the licensed user, the important issue that needs to be taken into consideration when designing an OFDM-based overlay system is that its impact on the legacy system should be very small. Thus, the basic aim of any algorithm for sidelobe suppression is to reduce the sidelobe power levels while causing little or no effect to the other secondary system parameters.

As an example, Figure 2 shows the power spectral density of an OFDM modulated carrier. This figure also shows the subcarrer spacing and the interference power due to the first sidelobe in the first adjacent band. It is observed that as the distance between the location of the subcarrier of the rental system and the considered subband increases, the interference caused by it reduces monotonically, which is a characteristic of the sinc pulse. However, it should also be noted that in a practical scenario consisting of N subcarriers, the actual value of the interference caused in a particular legacy system subband is a function of the random symbols carried by the sinc pulses and N.

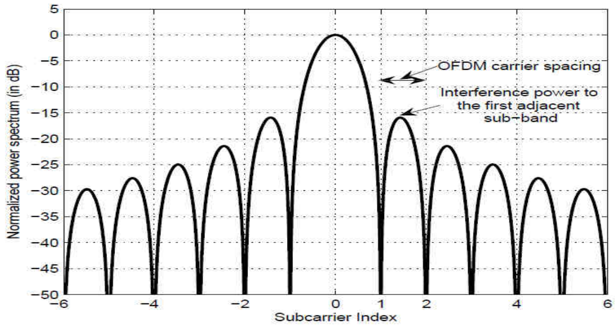

Figure 2: An example of the interference due to one OFDM modulated carrier

III. TECHNIQUES FOR SUPPRESSION OF INTERFERENCE FROM SIDELOBES

The problem is the interference suffered by the legacy system that is present in the vicinity of the bands used by the rental system. This is a result of using OFDM, which is the de-facto multiplexing scheme in most of the spectrum pooling based cognitive radio systems [3]. As OFDM uses sinc-type pulses in representing the symbols transmitted over all the subcarriers during one time instant, the large sidelobes that occur can potentially interfere with the signal transmissions of the neighbouring legacy systems or with the transmissions of other rental users.

Thus, the fundamental objective of this paper is to reduce the interference caused by the secondary user while not significantly affecting the system performance of the rental user.

Sidelobe suppression in OFDM-based cognitive radio systems is a relatively unexplored area of research. Even though OFDM-based transceiver systems are the research focus of many groups at different universities all over the world, only a few sidelobe suppression techniques are available in the technical literature [7–11].

The major techniques for suppression of interference from sidelobes are as given below:

(i) Windowing.

(ii) Use of guard bands.

2.1 Windowing: A simple countermeasure to the interference from rental system. One of the simplest and the earliest solutions offered to counter the effects of OOB interference is windowing the OFDM transmit signal in the time domain [7, 8]. There are three types of windowing techniques which are given below. Out of these three two are taken by us for sidelobe suppression.

i. Equiripple low pass window

ii. Kaiser window

iii. Raised cosine window

(i) Equiripple Low Pass window: Equiripple has equal ripples in low pass band. A low-pass filter is an electronic filter that passes low-frequency signals but attenuates signals with frequencies higher than the cutoff frequency.

(ii) Kaiser window: It is an approximation to the prolate-spheroidal window, for which the ratio of the mainlobe energy to the sidelobe energy is maximized. For a Kaiser window of a particular length, the parameter β controls the sidelobe height. For a given β, the sidelobe height is fixed with respect to window length. The statement kaiser(n,beta) computes a length n Kaiser window with parameter beta.

$$w[n] = \begin{cases} \dfrac{I_0\left(\pi\alpha\sqrt{1-\left(\frac{2n}{N-1}-1\right)^2}\right)}{I_0(\pi\alpha)}, & 0 \le n \le N-1 \\ 0 & \text{otherwise}, \end{cases}$$

Where: N is the length of the sequence.

I0 is the zeroth order Modified Bessel function of the first kind.

α is an arbitrary, non-negative real number that determines the shape of the window. In the frequency domain, it determines the trade-off between main-lobe width and side lobe level, which is a central decision in window design.

When N is an odd number, the peak value of the window is w[(N-1)/2] = 1, and when N is even, the peak values are w[N/2-1]= w[N/2] < 1.

IV. SIMULATION SETUP AND RESULTS

In this paper, a baseband OFDM as shown in figure 4.1 is implemented in matlab Simulink environment. The Fast Fourier Transform (FFT) based Modern Control using Matlab schemes are implemented and spectrum performance study is carried out under Rayleigh multipath channel scenario. The implemented program simulates a 64 subcarrier OFDM

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system; constellation mapping or message modulation is performing using rectangular quadrature amplitude modulation (RQAM).

Simulation setup havening different functional block as shown in figure 4.

- Bernoulli binary generator
- Rectangular quadrature amplitude modulation (RQAM AT TX SIDE)
- Rectangular quadrature amplitude demodulation (RQAM AT RX SIDE)
- OFDM modulator (AT TX SIDE)
- OFDM demodulator(AT RX SIDE)
- WINDOW at both side TX and RX
- Rayleigh multipath channel

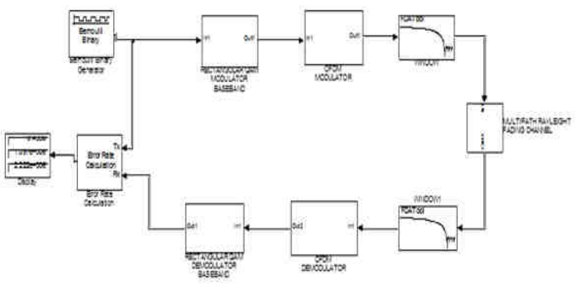

Figure 4. OFDM based Cognitive Radio

V. Results and Discussion

1. Equiripple low pass window

In given figures the characteristics of equiripple low pass window for different order is shown and its impact on ofdm signal is also shown for 60th order.

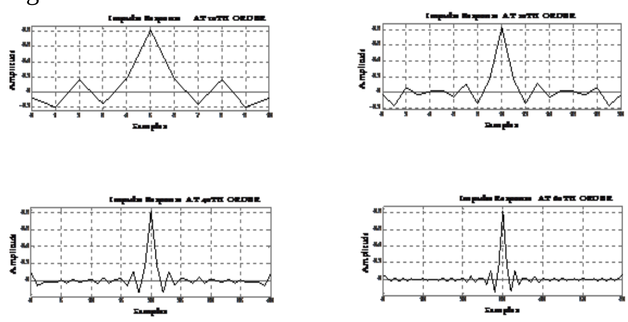

Figure 4.1 Impluse responc of equiripple low pass window for different 10th,20th,40th,60th order

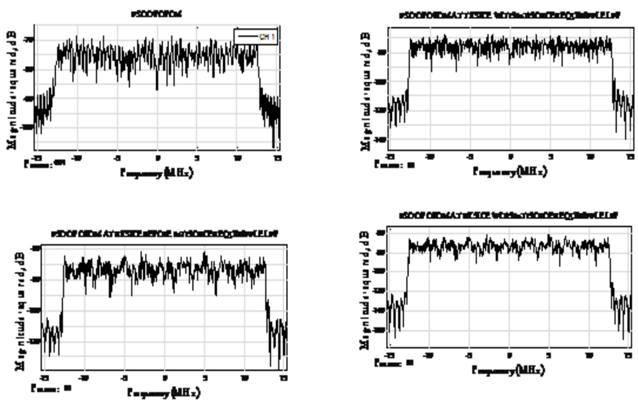

Figure 4.2 PSD of ofdm signal with and without equiripple low pass window for 60th order

2. Kaiser window

In given figures the characteristics of Kaiser Window for different values is shown and its impact on ofdm signal is also shown.

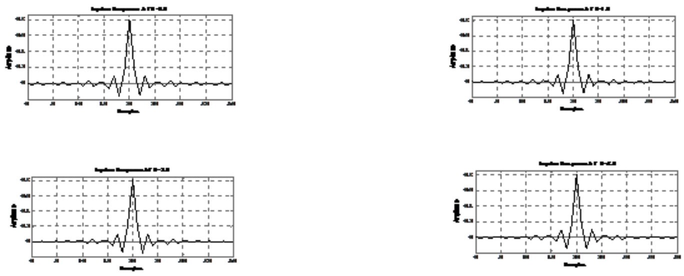

Figure 5.1 Impluse responc of Kaiser window for 40th order and different β 0.5,1.5,2.5,3.5

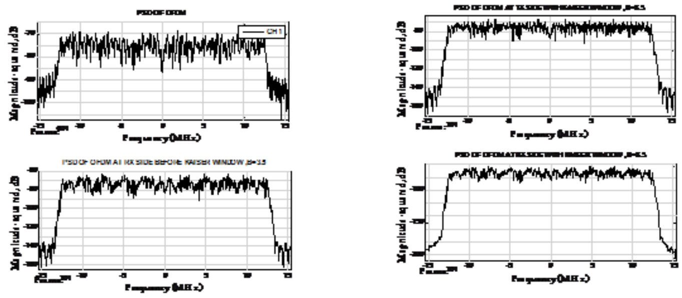

Figure 5.2 PSD of ofdm signal with and without Kaiser window for 3.5

VI. Discussion

Table 1 and table 2 are given with the values calculated from results for Equiripple Low Pass window and Kaiser window in accordance with the filter order and Beta factor respectively.

Table 1: Equiripple Low Pass Window

Filter Order	Peak of sidelobe without window	Peak of sidelobe with window	Difference
10th	-82 dB	-100 dB	-18 dB
20th	-82 dB	-108dB	-26 dB
40th	-82 dB	-118 dB	-36 dB
60th	-82 dB	-125 dB	-43 dB

Table 2: Kaiser Window

Beta Facto r	Peak of sidelobe without window	Peak of sidelobe with window	Diffference
0.5	-82 dB	-120 dB	-70 dB
1.5	-82 dB	-145 dB	-63 dB
2.5	-82 dB	-160 dB	-78 dB
3.5	-82 dB	-187 dB	-105 dB

word “data” is plural, not singular. The subscript for the permeability of vacuum μ_0 is zero, not a lowercase letter “o.” The term for residual magnetization is “permanence”; the adjective is “remanent”; do not write “remnance” or “remnant.” Use the word “micrometer” instead of “micron.” A graph within a graph is an “inset,” not an “insert.” The word

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"alternatively" is preferred to the word "alternately" (unless you really mean something that alternates). Use the word "whereas" instead of "while" (unless you are referring to simultaneous events). Do not use the word "essentially" to mean "approximately" or "effectively." Do not use the word "issue" as a euphemism for "problem." When compositions are not specified, separate chemical symbols by en-dashes; for example, "NiMn" indicates the intermetallic compound $Ni_{0.5}Mn_{0.5}$ whereas "Ni–Mn" indicates an alloy of some composition Ni_xMn_{1-x}.

Be aware of the different meanings of the homophones "affect" (usually a verb) and "effect" (usually a noun), "complement" and "compliment," "discreet" and "discrete," "principal" (e.g., "principal investigator") and "principle" (e.g., "principle of measurement"). Do not confuse "imply" and "infer."

Prefixes such as "non," "sub," "micro," "multi," and "'ultra" are not independent words; they should be joined to the words they modify, usually without a hyphen. There is no period after the "et" in the Latin abbreviation "*et al.*" (it is also italicized). The abbreviation "i.e.," means "that is," and the abbreviation "e.g.," means "for example" (these abbreviations are not italicized).

An excellent style manual and source of information for science writers is [9].

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