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Subcarrier Weighting Side lobe Suppression Technique for OFDM Based Cognitive Radio Systems

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ABSTRACT: Orthogonal frequency division multiplexing (OFDM) has its significant advantages and because of this, it has been proposed as the enabling modulation technology for cognitive radios in today's technology. In wireless communication, OFDM is playing an important part in signal processing and modulation techniques. It is also playing the vital role in emerging 4G wireless communication system. Despite many advantages in OFDM systems, the high sidelobes of the subcarriers are major disadvantages which result in out-of-band (OOB) or in-band radiation causing interference to licensed or primary users. Researchers have proposed many techniques to suppress the sidelobe interference in the spectrum. In this paper, we will discuss one of these techniques which are known as Subcarrier Weighting (SW) sidelobe suppression techniques.

The method proposed in this paper is based on the multiplication of the used subcarriers with some calculated subcarrier weight to reduce the interference. The weights are calculated in such a way that resultant subcarriers try to reduce interference in the particular range of frequency. These calculated weights are known as optimal weights. We use the minimization problem- solving method for each OFDM signal. It reduces the sidelobes of OFDM spectrum by more than 10 dB in the average without requiring the transmission of any side information. Sidelobe suppression technique called Subcarrier Weighting (SW) is almost unexplored for inband interference cancellation. This paper shows the importance of SW to protect Narrow Band systems. This scheme can produce variable notch depth (20dB to 50dB) depending on the constraints on weights. The increase in notch depth comes with sacrificing the BER performance. More variations like SW-Rectangle, SW-Circle, and SW-Ellipse are proposed to improve the performance of the system.

Keywords: Cognitive Radio, OFDM, SW, Sidelobe Suppression, Inband

I. INTRODUCTION

For today's wireless communication systems the main challenge is to meet high data rate requirements with the increasing demand of applications. The frequency spectrum is considered as a valuable and limited resource. The necessity of wireless devices which they face is utilizing the available primary spectrum as much as possible and coexists with other legacy or otherwise future systems. Recently, a new way of utilizing the spectrum has been proposed in which the secondary or non-licensed users are also allowed to use the spectrum. However, the secondary users can only use spectrum within the licensed band given that they do not interfere the licensed users. A recent study shows that wide ranges of primary spectrum are not used properly and the traffic is minimal, while other secondary bands are highly occupied [1].

By using cognitive radio (CR) the opportunistic use of spectrum has been proposed which will improve spectrum utilization significantly [2-4]. The ability to support multiple users in a spectrum and at the same time is also an important aspect of wireless communication systems. Orthogonal Frequency Division Multiplexing (OFDM) has been playing the vital role to achieve the same. It is one of the most widely used technologies in today's communication systems. OFDM is widely used in the physical layer (PHY) of legacy standards such as the Wireless Local Area Network [5-7], Asymmetric Digital Subscriber Line (ADSL) [8], and Wireless Metropolitan Area Network [9, 10]. For CR systems, OFDM emerges as the better choice because of its property of vacating the required or any portion of spectrum by simply turning off the subcarriers as explained in [11]. In IEEE 802.22 [12] for opportunistic access of spectrum the CR based OFDM is adopted.

The basic principle of OFDM signals with respect to conventional signals is shown in the Figure 1:

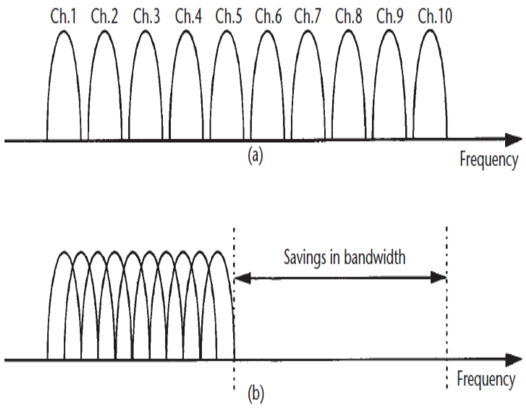

Fig. 1. Concept of OFDM signals: (a) conventional multicarrier technique, and (b) orthogonal multicarrier modulation technique.

II. LITERATURE REVIEW

At tone frequencies by turning off some subcarriers we can null the spectrum, but the active subcarriers of high spectral sidelobes have the tendency to interfere with the primary users. A traditional way of reducing the effect of sidelobes is to deactivate the required number of adjacent tones which are known as guard subcarriers although it results in the significant loss of throughput. To overcome this loss an effective sidelobe suppression scheme is used which can improve the spectral efficiency of a spectrum. Different types of sidelobe suppression techniques have been proposed by the researchers. Some of them includes Adaptive symbol transition [13], Windowing technique [14], Active Interference Cancellation (AIC) [15], Cancellation Carriers (CC) [16], Subcarrier Weighting (SW) [17, 18], Projection Precoder [19]. Windowing is a computationally efficient scheme for sidelobe suppression, but it reduces the throughput due to extension of symbol in time domain. AST is similar to windowing except the amount of extension is evaluated by optimization process, hence increases the complexity. AIC and CC schemes, insert some extra carriers and their values are optimized so as to minimize sidelobe interference in target band. In contrast to AIC, SW does not require extra protection tones but instead data symbols are multiplied with optimized real weights. Additionally bounded constraints included in the optimization problem ensure that each symbol must remain within original decision boundaries, hence facilitating direct detection at receiver without having the knowledge of weights.

III. SUBCARRIER WEIGHTING TECHNIQUE

In SW technique subcarriers are multiplied by some weights. The weights are calculated in such a way that resultant subcarriers try to reduce interference in a particular range of frequency. Let Xz is a vector of symbols at the input of IFFT with some of the subcarriers to be nulled. Now we have to choose weight vector w such that interference due to sidelobes will be less. The whole process can be viewed as two steps. In the first step we calculate interference due to sidelobes in the victim band and in a second step we find an optimum weight vector which after elementwise multiplication with Xz reduces the interference in victim band. The weighted input vector can be given as

$$\bar{X}z = W \cdot Xz$$

where $(\cdot)$ represents elementwise multiplication.

In the first step we will calculate the interference in victim band by upsampling the spectrum using upsampling matrix P. To calculate optimum weight vector, the optimization problem can be given as:

$$W = \arg\min_{w} \| P_s \times (\bar{X}z) \|$$

$$W = \arg\min_{w} \| P_s \times (X_z) \|$$

subject to following constraints:

$$\| X_z^- \|^2 = \| X_z \|^2$$

$$0 < Wmin \leq Wn \leq Wmax$$

Wmin, Wmax, Wn are real

The motive of the first constraint is to keep the total transmitted power to be constant and second constraint is imposed to supply at least the minimum amount of power to all subcarriers. The value of thresholds Wmin, Wmax should be chosen carefully because there is a tradeoff between power cancellation capability and BER performance of the system.

IV. RESULT

Simple visualization of SW can be seen in Figure 3 where active subcarriers are multiplied by some weight vectors, so that resultant interference due to the sidelobes of weighted subcarriers is less than that of unweighted. Interference due to the sidelobes of unweighted subcarriers is shown in Figure 2. Comparing the two figures, it is clear that SW results in better interference rejection capability than simple tone nulling. But we have to pay the prize for good things. In this case, the better result comes from sacrificing for BER performance.

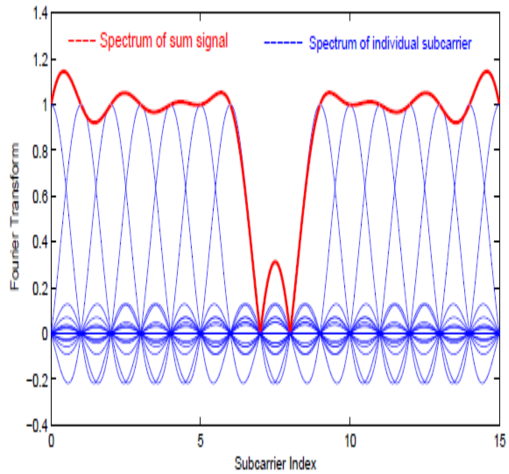

Fig. 2. Power Spectrum without Subcarrier Weighting.

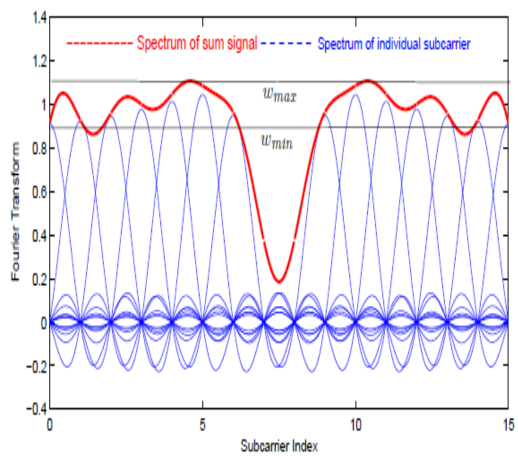

Fig. 3. Power Spectrum with Subcarrier Weighting.

V. CONCLUSION AND FUTURE SCOPE

The proposed subcarrier weighting sidelobe suppression scheme has the efficiency to reduce the sidelobes of signals by more than 10 dB and it does not require side information transmission of CR based OFDM signals. The only small drawback of this scheme is a moderate loss in BER performance. This scheme can produce variable notch depth (20dB to 50dB) depending on the constraints on weights. The increase in notch depth comes to sacrificing the BER performance. More variations like SW-Rectangle, SW-Circle, and SW-Ellipse can improve the performance of the system. In future scope, we can combine the AIC and SW technique to overcome the drawbacks of this scheme.

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