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Survey on Techniques for PAPR Reduction and Sidelobe Suppression OFDM based Cognitive Radio

Shivani D. Darji[1], Jigneshkumar N. Patel[2]

PG Student, Department of ECE, Sardar Vallabhbhai Patel Institute of Technology, Vasad, India[1]

Assistant Professor, Department of ECE, Sardar Vallabhbhai Patel Institute of Technology, Vasad, India[2]

ABSTRACT: Cognitive Radio is an emerging technology for alleviating the problem of spectrum shortage. Spectrum sensing is main requirement for the establishment of cognitive radio. Moreover, Orthogonal Frequency Division Multiplexing (OFDM) is a recognized transmission technique for Cognitive Radio (CR) networks. In this paper, OFDM technique is investigated as a candidate for CR systems. However, the major drawbacks of OFDM systems is that they exhibit high Out OF Band Radiation (OOBR) due to high spectral sidelobe and Peak to Average Power Ratio (PAPR). In this paper, different techniques involving sidelobe suppression and PAPR reduction is being demonstrated.

KEYWORDS: Cognitive Radio , OFDM System, PAPR, Sidelobe Suppression

I. INTRODUCTION

Cognitive Radio Technology plays an important role as growing demand for high speed Wireless Access. This technology makes better utilization of spectrum. Cognitive Radio (CR) is a device [1] in which transceiver detect channels that are in use or not and move in to vacant channels for transmission. Dynamic Spectrum Access (DSA) [2] is specific sample where operating frequency is adjusted. Dynamic Spectrum Access reduces the problem of spectrum shortage. This spectrum shortage will create problem in allocating spectrum for wireless application. So, we refer to networks that use DSA as CR networks. Cognitive Radio Networks allows unlicensed users to access opportunistically so it contains two types of users that are Primary (license) users and Secondary (unlicensed) users.

OFDM is superior multicarrier modulation technique that transmit signals through multiple carriers. It divides broadband channel in to number of channels. OFDM is suffer from high PAPR (Peak to Average Power Ratio) and high Sidelobe Power. When PAPR is high, A power amplifier works on non-linear region. It gives non-linear distortion. It also causes Out Of Band distortion and Intercarrier Interference. When Sidelobe Power is high, it causes Sidelobe Suppression and interference with Primary Users.

This paper organized as follows. Section II provides overview of OFDM based Cognitive Radio system and drawback of OFDM the next section III provides Techniques for PAPR reduction.. The section IV presents Techniques for SidelobeSuppresion . Finally, the conclusion is specified in section V.

II. OFDM BASED COGNITIVE RADIO

OFDM is multicarrier modulation technique that can overcome many problems. OFDM has many advantages so it can full fill requirements of CR like it provides spectrum sensing, shaping etc. Hence, it becomes best transmission technique for Cognitive Radio.

A. *Spectrum Sensing*

It is important for Cognitive Radio network to sense empty spectrum. Spectrum sensing[3] is the process of determining if a primary user is present or not. It detect unused spectrum and share it without interfering other users. There are different detection techniques that are used for sensing process. Consider hypothesis for signal detection.

$H_0 : Y[n] = W[n]$

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H_1: Y[n] = X[n] + W[n]
H0 = Primary user is absent
H1 =Primary user is present
W[n] = additive white Gaussian noise
[n] = input sample sequence

B. Spectrum Shaping

After Cognitive Radio System identifies active primary user next step is spectrum shaping. CR users should be able to flexibly shape transmitted signal spectrum. OFDM system [4] provides flexibility due to its unique nature. The spectrum of OFDM signals can be shaped to fit into the required spectrum mask by disabling subcarriers.

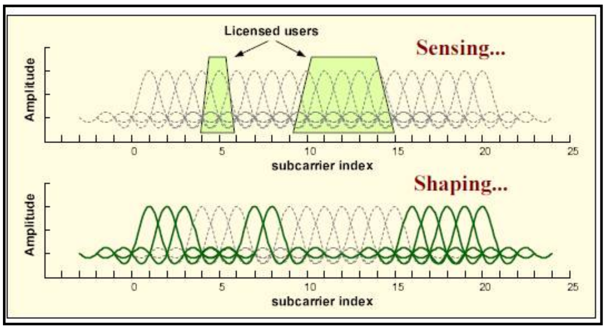

Fig: 1 Spectrum sensing and shaping using OFDM

Spectrum sensing and shaping process in OFDM based CR explained in to above figure. Two licensed users are detected using output of FFT block and subcarriers that causes interference to primary users are turned off. Here, pulse shaping filters also used to reduce interference.

III. PEAK TO AVERAGE POWER RATIO

One of the major drawback of OFDM is high peak to average power ratio(PAPR). Mathematically it is defined as,

$$\text{PAPR} = \frac{P_{peak}}{P_{avg}} = \frac{max[Xn^2]}{E[Xn^2]} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

When signal has high PAPR it will make power amplifier (PA) work into non-linear region. It will generate non-linear distortion. This non-linearity introduces out of band distortion which may results into Intercarrier Interference and Bit Error Rate degradation.

There are many different techniques available to reduce PAPR. Among them methods like Clipping and Filtering **[5]** is the simplest one. In this method amplitude is clipped which limit peak value of input signal to threshold.
In coding technique PAPR reduction done by selecting such a codeword that reduced the PAPR. This method suffers from complexity of the algorithm.

Selected mapping (SLM) method **[14]** is probabilistic based. It will not remove peaks but prevent it from frequency generation. Main drawback of this method is side information must be transmitted with chosen signal.
Partial Transmit Sequence (PTS) technique **[15]** is modified version of SLM scheme and gives better performance than SLM. It is also one of the probabilistic based method. There is no need to transmit side information.

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Techniques For PAPR Reduction

A. *Walsh-HadamardTransform(WHT)*

WHT [6] is a non sinusoidal and it is an orthogonal technique which decomposes a signal into set of basic functions. These functions are called Walsh functions, Thehadamard transform scheme reduce the occurrence of the high peaks comparing the conventional OFDM system. hadamard transform is used because it reduce the autocorrelation of the input sequence to reduce the peak to average power (PAPR) of OFDM signal. It also not requires to send side information to the receiver. The FWHT for a signal x of length N are defined as:

$$y_n = \frac{1}{N}\sum_{i=0}^{N-1} x_i \, WAL(n,i) \quad \ldots\ldots\ldots\ldots\text{(2)}$$

where$i$= 0,1,..., N-1 and WAL($n.i$)R are Walsh functions.

B. *Zadoff-Chu matrix transform (ZCT)*

Zadoff-Chu [7] are complex- valued sequences , when these sequences are applied to the radio signal and gives an electromagnetic signal with constant amplitude. These sequences are class of poly phase sequences having optimum correlation properties and having an ideal periodic autocorrelation andconstant magnitude. Zadoff-Chu matrix transform pre-coding can be reduces the PAPR parameter of any OFDM systems. Zadoff-Chu sequences can be define as equation

$$Z(k)=\begin{cases} e^{j\frac{2\pi r}{L}\left(\frac{k^2}{2}+qk\right)} & for\ L\ even \\ e^{j\frac{2\pi r}{L}\left(\frac{k(k+1)}{2}+qk\right)} & for\ L\ odd \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$

Where k=*0,1,2…,L-1,* '*q*' and 'r' are any integer relatively prime to '*L*'.

IV. SIDELOBE SUPPRESSION

Another disadvantage of OFDM is high sidelobe power. High sidelobe causes out of band radiation(OOBR). That will produce interference with primary users (PU). There are many techniques classified to reduce sidelobe as follows:
In **[8]**, adaptive symbol transition technique is used in which the OFDM symbols extended adaptively at the cost of decrease in the useful symbol energy.
The techniques which have achieve more suppression of OOBR with better spectral efficiency are Active interference cancellation (AIC) **[9]** and the introduction of cancellation carrier **[10]**.Both of these techniques results in enough suppression of OOBR but suffer from Signal to Noise Ratio (SNR) degradation and also extra power is wasted in cancellation subcarrier**.**
In **[11]** a scheme based on optimization process is proposed. However, the method in **[11]** does not have any closed form solution and hence computationally expensive. Also, the OOBR rejection is achieved at a cost of significant BER performance loss.

Techniques ForSidelobe Suppression

A. *Spectral Precoding Technique*

In these approaches, the information symbols are mapped to a new set of precoded symbols under some constraints. In this method large suppression of OOBR is achieved without losing BER performance but the notched frequencies selection algorithm is computationally more complex and expensive[12].
We Can construct individual precoders to render selected spectrum nulls, our approach suppresses the overall OOB radiation without sacrificing bit error rate performance of CR users. It also ensures user independence thus with low encoding and decoding complexities. This approach can improve bandwidth efficiency by carefully selecting notched frequencies. The block diagram of multiple spectrum precoding for OFDM based CR systems is shown in

figure. 2. While OOB leakage cannot be completely eliminated so that guard bands are usually require. As a result, the relative throughput loss brought by guard bands can be significant if CR users operate over narrow subbands. To reduce the guard bands and enhance bandwidth efficiency spectrum shaping can be included which suppresses the OOBR leakage to the adjacent frequency bands .Here for the shaping of the spectrum Existing approaches are performed in time or frequency domain.

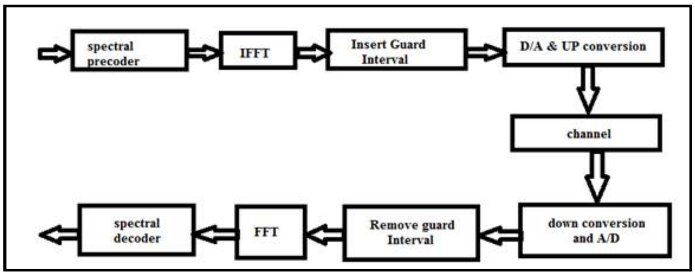

Fig 2. The block diagram of multiple spectrum precoding for OFDM based CR systems[12]

B. *Mask Compliant Precoder*

Mask Compliant precoder is designed for controlling the out-of-band emissions to a particular power level without impacting the bit error rate (BER) performance. A small distortion is added to the informationsymbols forcing the emitted spectrum under a prescribed radio frequencymask.[11]"Thespectrum mask is define as the allowable maximum in-band and out-of-band signal power spectrum."
The diagram of OFDM transmitter and receiver for mask complaint precoder is shown in figure. 3. A precoder that forces the power spectrum of OFDM signals under a given RF maskis proposed in the given work. Using the proposed precoder significant BER performance is improved compared to other precoder.

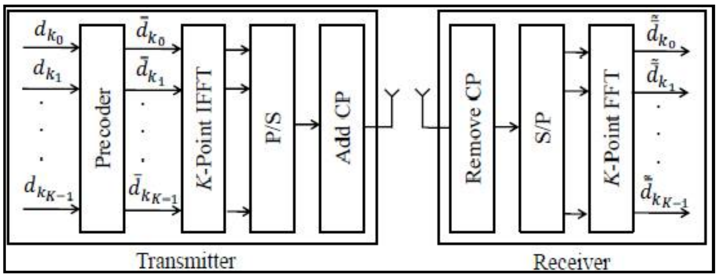

Fig 3. Mask compliant precoder block diagram of OFDM transmitter/receiver pair with sidelobe suppression.[11]

C. *Subcarrier Weighting Technique*

This method is based on the multiplication of the used subcarriers with subcarrier weights[13]. The subcarrier weights are determined in such a way that the sidelobes of the transmission signal are minimized according to an optimization algorithm which allows several optimization constraints. This subcarrier weighting method for sidelobe suppression does not require transmission of any side information and is capable of reducing the sidelobes of OFDM transmission signals by more than 10 dB.

V. CONCLUSION AND FUTURE WORK

Cognitive Radio is an exciting and promising technology that offers a solution to the spectrum crowding problem. On the other hand, OFDM technique is used in many wireless systems and proven as a reliable and effective transmission method. OFDM technique is a better candidate for Cognitive Radio systems due to its inherent capabilities. This paper identified the challenges of OFDM based Cognitive Radio systems i.e., OOBR and PAPR. This paper presented survey

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of different precoding techniques for OOBR suppression caused by secondary users to Primary Users. A number of technique that can efficiently suppression of sidelobe is being reviewed.
Future extension to this can be combine suppresion of sidelobe with PAPR reduction as spectral sidelobes can regrow after the high peak power signal passes through power amplifier. A technique that can deal with both problem together will give better performance. Moreover Practical Implementation of Cognitive Radio can be developed which support features of Cognitive Radio.

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BIOGRAPHY

Shivani D. Darji has received her Bachelor degree in Electronics and communication engineering from Gujarat Technological University, Ahmedabad, India. Currently she is pursuing M.E (Communication system engineering) from Gujarat technological University. Her area of interest include wireless communication.

Mr. JigneshKumar N. Patel has received B.E. and M.E. degrees in Electronics & Communication engineering from Dharamsinh Desai University (DDU), Nadiad, Gujarat, India, in 1997 and 1999, respectively. Since 1999, he is working as an Assistant Professor in SVIT, Vasad, Gujarat. His area of interests are Digital and Analog Communication , Digital Electronics.