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# PAPR Reduction and Sidelobe Suppression in OFDM based Cognitive Radio

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**ABSTRACT**: Cognitive Radio emerges as a design paradigm which can potentially alleviate the problem of spectrum shortage. Spectrum sensing is the main requirements for the establishment of cognitive radio. Orthogonal Frequency Division Multiplexing (OFDM) is a recognized transmission technique for Cognitive Radio (CR) networks. In this work, OFDM technique is investigated as a candidate for CR systems. However, the major drawbacks of OFDM systems is that they exhibit high Sidelobe Suppression due to high spectral sidelobe. The high spectral sidelobe which are caused in OFDM systems based Cognitive Radio can cause interference with Primary Users (PU) that indirectly affects the performance. Moreover, another major drawback of using OFDM systems is that they exhibit large Peak to Average Power Ratio (PAPR) values. The entered signal to the power amplifier (PA) must be in the dynamic range in order to operate well, but when the signal has high PAPR, the PA work in nonlinear region leading nonlinear distortion. PAPR reduced by using ZCT technique and Sidelobe Power is reduced by using MCS technique.

**KEYWORDS**: Cognitive Radio , OFDM System, PAPR, Sidelobe Suppression, ZCT,MCS

## 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 in which transceiver detect channels that are in use or not and move in to vacant channels for transmission. Dynamic Spectrum Access (DSA) 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 (Orthogonal Frequency Division Multiplexing) 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.

There are many different techniques for reducing PAPR and Sidelobe Power. In this paper for PAPR reduction Zadoff-chu Transform (ZCT) precoding technique is used. As ZCT precoding method for PAPR reduction do not require any power increment, side information to be sent and complex optimization. For Sidelobe suppression Multiple Choice Sequences (MCS) method is used as it is less complex and gives better result compared to other techniques.

The rest of paper organized as follows: Section II describes the system model, in section III we present ZCT precoding and MCS techniques, section IV presents simulation Results and Section V concludes the paper

## II. SYSTEM MODEL

Figure 1 illustrates that in OFDM based CR first of all, input OFDM symbols are converted in to a parallel stream. These symbols have high PAPR and that will generate non linear effects in power amplifier so it is necessary to reduce PAPR. So PAPR reduction ZCT precoding technique is used in proposed model. As ZCT method is simplest in

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computation and gives better result compared to other methods we are using this method. Similarly OFDM symbols generate high sidelobes that will give out of bound radiation and interference with Primary users. So for reducing sidelobe power Multiple choice sequence (MCS) method is used in proposed model as it is simplest approach.

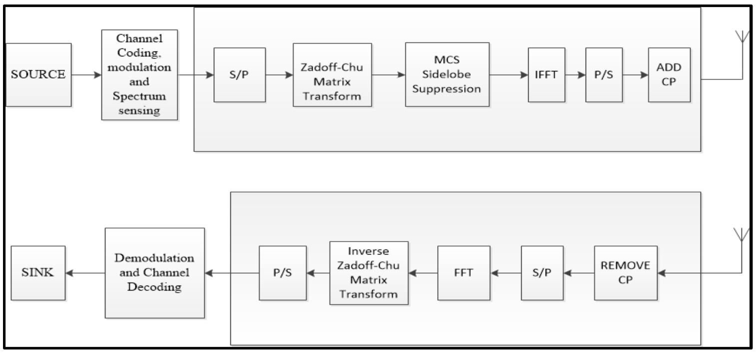


Fig: 1 block diagram of proposed method

## III. PROPOSED TECHNIQUES

### A. ZADOFF-CHU MATRIX TRANSFORM (ZCT)

Zadoff-Chu are complex- valued sequences. when these sequences are applied to the radio signal and gives an electromagnetic signal with constant amplitude. These sequences have optimum correlation properties and have an ideal periodic autocorrelation with constant magnitude. Zadoff-Chu matrix transform is a pre-coding technique that can be reduces the PAPR parameter of any OFDM systems.

Zadoff-Chu sequences can be define as equation:

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

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

Figure 2 shows block diagram for ZCT method. Here the input sequences of OFDM symbols are converted in to parallel form using serial to parallel converter. Then these symbols are multiply with ZCT matrix. At the output of this matrix we get new OFDM sequences. After that IFFT is done on those sequences of symbols. This is the process at transmitter side. At the receiver side inverse ZCT matrix is multiplied and total reverse process is done.

Using above Zadoff-chu sequences the Zadoff-Chu matrix can be defined by equation

$$R=\left[r_{m,l}\right]=\begin{bmatrix} r_{0,0} & r_{0,1} & \cdots & r_{0,N-1} \\ r_{1,0} & r_{1,1} & \cdots & r_{1,N-1} \\ \vdots & \vdots & \ddots & \vdots \\ r_{N-1,0} & r_{N-1,1} & \cdots & r_{N-1,N-1} \end{bmatrix}$$

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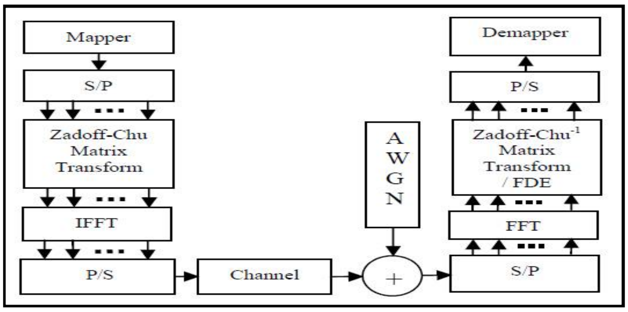


Figure 2 block diagram of ZCT method

B. MULTIPLE CHOICE SEQUENCES (MCS)

Figure 3 shows block diagram of MCS at transmitter side. As shown in to figure the input sequence dn is converted in to parallel form using S/P converter that is d1,d2…dN. This sequence of array is fed to MCS block that reduces the sidelobes. In this MCS block average power of each sequence is calculated. Here the output of MCS block is d1,d2….dN which gives minimum sidelobe power. Then the IFFT is done on selected sequence from MCS block.

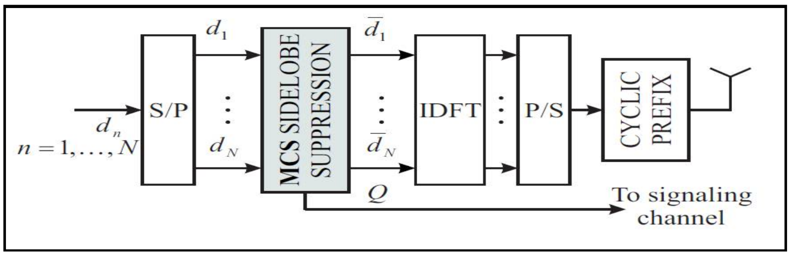


Figure 3 block diagram of MCS at transmitter side

The principle of MCS is shown in Fig. 4. A sequence d is divided in to d(*p*) =(*d*(*p*)1 ;*d*(*p*)2 ;….. ;*d*(*p*)*N* )$^T$ sequences. Where, *p* = 1*;* 2….. *P*. For each sequence d(*p*) the average sidelobe power is calculated. Average sidelobe power is denoted as A(p). To determine *A*(*p*) given equation is used. The spectrum of an individual subcarrier equals to si-function si(*x*) =sin(*x*)=*x*.
Average sidelobe power *A*(*p*) is given by,

$$A^{(p)} = \frac{1}{K}\sum_{k=1}^{K}\left|\sum_{n=1}^{N} d_n{}^{(p)} si\left(\pi(y_k - x_n)\right)\right|^2 \qquad \text{............... (2)}$$

Here $x_n$ is normalized subcarrier frequency where: n = 1*;* 2… *N*
$y_k$ is normalized frequency sample where: k = 1; 2*;*…. *;K,*

The index *Q* is a sequence of minimum sidelobe power which gives maximum sidelobe suppression. So index Q is denoted as:

$$Q = arg\ min\ A^p, \text{ p=1,2…P} \qquad \text{............... (3)}$$

So the sequence with maximum sidelobe suppression d=d(*Q*) is selected for further transmission from the MCS unit.

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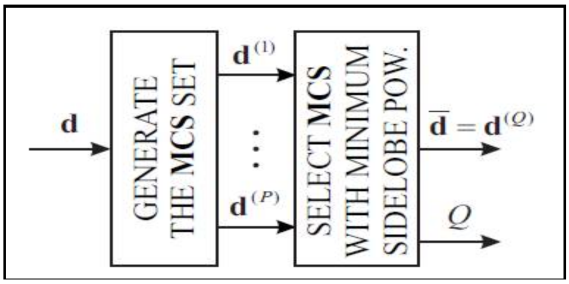


Figure 4 Block diagram of the MCS sidelobe suppression unit

## IV. SIMULATION RESULTS

We performed simulations in MATLAB in order to evaluate performance of ZCT precoding for PAPR reduction and MCS(Multiple Choice Sequences) for Sidelobe suppression. In the simulation QAM modulation scheme is used with 64 no. of subcarriers. Here we have taken length of FFT and IFFT 64 and no. of frames are 100.

Figure 5 shows complementary CDF performance of general OFDM ,WHT and ZCT in cognitive radio network. The performance of PAPR is shown by above graph. As we can see PAPR decreases in ZCT method compared to WHT and general OFDM. Figure 6 shows the performance of Signal Set Expansion technique (SSE) and proposed zadoff-chu Matrix Transform (ZCT) in cognitive radio. Here variation of CCDF with PAPR for different number of subcarriers is shown in to figure. Figure 7 shows ACC method for sidelobe suppression in OFDM based Cognitive Radio. This method reduces sidelobe power that is compared with general OFDM and the result is shown in figure. Figure 8 shows comparison of different methods for sidelobe suppression. Proposed MCS (multiple choice sequences) technique is compared with ACC and general OFDM. As we can see that proposed method gives better result compared to other techniques.

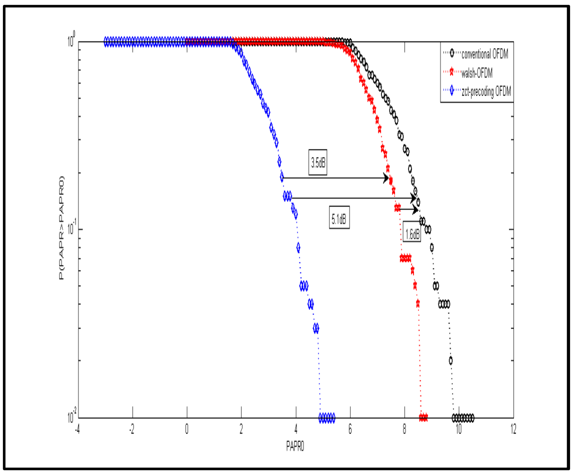


Figure 5:PAPR Performance of Precoding Methods

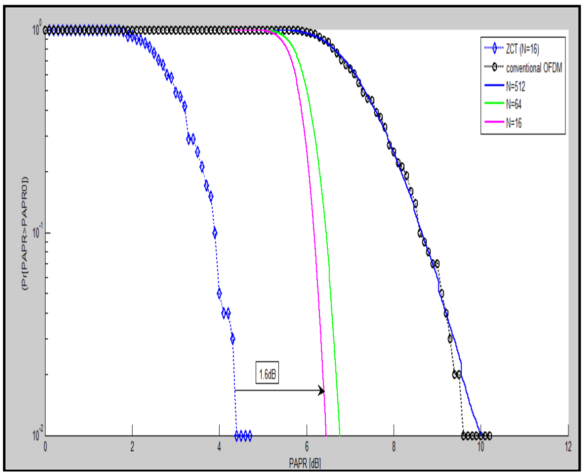


Figure 6: CCDFs of PAPR for SSE and ZCT method

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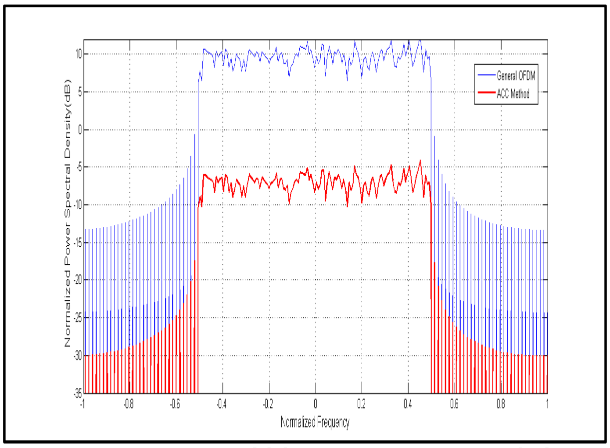


Figure 7 : Sidelobe suppression in ACC method

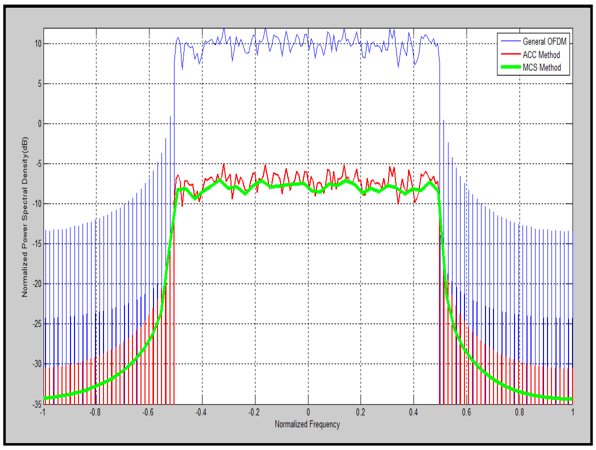


Figure 8 : Sidelobe suppression in MCS method

## V. CONCLUSION

PAPR is reduced by using Zadoff-chu matrix transform (ZCT) precoding technique. This technique gives better result compared to other techniques like conventional OFDM, SSE, WHT. ZCT method does not require any power increment and complex optimization. ZCT technique reduces 1.6 dB more PAPR than SSE method. Sidelobe power is reduced by multiple choice sequences (MCS). The result is compared with existing techniques that is ACC. MCS technique reduces complexity and gives better result compared to other methods.

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## BIOGRAPHY

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