

# PAPR REDUCTION TECHNIQUES IN OFDM BASED COGNITIVE RADIO: A REVIEW

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## ABSTRACT

*With the increase in wireless communication, radio spectrum becomes a very scarce resource. Unfortunately, the utilization of radio spectrum by licensed users is less and this leads to concept of spectrum holes which is the band of frequency that is not used by primary users. To overcome this problem and enhance the utilization of spectrum, cognitive radio concept has been evolved. Cognitive radio has the capability to learn and adapt their wireless transmission according to the surrounding radio environment. But in cognitive radio, there is some problem like intersymbol interference and slow data transmission because data is transmitted with single high data rate carrier. To overcome this problem, Orthogonal Frequency Division Multiplexing (OFDM) modulation technique is used in cognitive radio. It transmits the data with multiple subcarriers of low data rate which are orthogonal to each other. But it also has problems of high Peak to Average Power Ratio (PAPR) and degradation in efficiency of spectrum. The present study includes the functions of cognitive radio and then advantages and issues of OFDM based cognitive radio. It also includes the various reduction techniques of PAPR.*

**Keywords-** ISI, OFDM, PAPR, PTS, SLM

## I. INTRODUCTION

Now-a-days there is increase in the use of wireless communication. Therefore need of spectrum increases, resulting in problem of scarcity of spectrum. The main reason of scarcity is problem of accessing the spectrum in a wrong way. As we know licensed bands are less in use, this leads to the concept of spectrum holes. So it is the possible option to use the licensed bands when they are not in use. So, in 2008 FCC gave permission to the secondary users to use the licensed band when licensed channels are free. Cognitive radio is one of the efficient wireless technology to solve the problem of shortage in the spectrum[1]. It uses free licensed bands in an opportunistic manner so that it can provide services to secondary users.

OFDM (orthogonal frequency division modulation) is the most favourable modulation technique which is used in cognitive radio systems for high data rate communication. It is also used in number of wireless communication technologies such as WiFi, WiMax, Digital Television and Audio Broadcasting, 4G mobile communication[4]. OFDM solves the two main issues of cognitive radio, that is, intersymbol interference and slow data rate transmission[5]. In cognitive radio systems, data is transmitted with a single carrier of high data rate. But, in OFDM based cognitive radio system, multiple subcarriers of low data rate are used to transmit the

data. But, there is a main problem of OFDM based cognitive radio, that is, high Peak to Average Power Ratio (PAPR) of the transmitted signal. Because of high PAPR, the signal is distorted in non-linear region and the performance of bit error rate also degrades[8]. Therefore, to solve this problem, there are various techniques like clipping technique, selective mapping technique, partial transmit sequence technique etc. are discussed in this paper.

## II. COGNITIVE RADIO

Cognitive radio is a new wireless technology that is used to improve the utilization of radio spectrum in wireless communication systems. It is the further extension of software defined radio (SDR) [2]. Cognitive Radio can be described as an adaptive, intelligent radio network wireless technology that is aware of its surrounding environment in a wireless spectrum and has the capability to change transmission parameters dynamically. It is the wireless communication which adapts the statistical changes in the operating environment by changing its modulation technique, power of transmitter and frequency of the carrier. We can see in Fig. 1 that the frequency spectrum is allotted to the licensed users for large region, but it is not occupied all the time. This underutilization problem can be solved by cognitive radio[1]. It uses the licensed bands of frequency that are not used by the licensed users at some specific time and in some specific location for the unlicensed users.

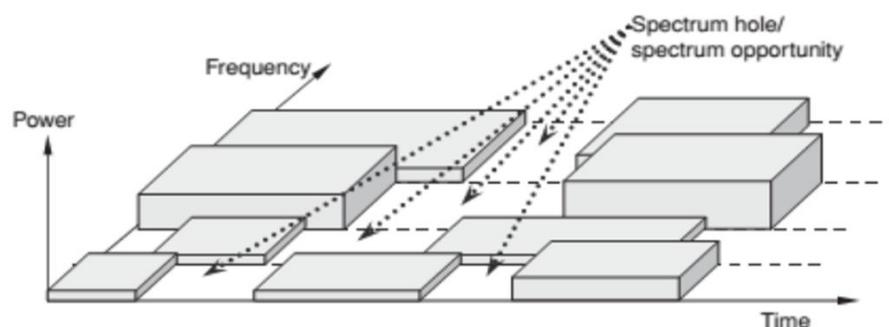


Fig. 1: Spectrum Holes

The main functions[3] of cognitive radio are:

a) *Spectrum Sensing*

It is the core function of cognitive radio technology. In spectrum sensing, cognitive user continuously senses the free available licensed channel so that there should not be any interference with primary user.

b) *Spectrum Management*

It describes how these spectrum holes (sensed during spectrum sensing process) are allocated to cognitive users so that they get the best available spectrum (do not interfere with primary user) and meet the required quality of service.

c) *Spectrum Sharing*

It is a key function of cognitive radio technology how to share the free licensed radio spectrum so that it prevent collision. Because if collision happens, valuable information is lost and quality of service decreases.

d) *Spectrum Mobility*

When primary user does not use the channel then cognitive users can use the free licensed radio channel.

When primary user is detected, cognitive users vacate the channel.

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

Orthogonal frequency division multiplexing(OFDM) is further expansion of frequency division multiplexing (FDM) modulation technique. In FDM, large frequency of the spectrum is partitioned into number of narrowband subcarriers and then each narrowband channel is assigned to the various users for the transmission of data.

OFDM is the digital modulation technique which is used to encode digital data on multiple carrier frequency. A single data stream is split across several separate narrowband channels at different frequencies to reduce interference and crosstalk. The original data blocks are transmitted in parallel. Proper spacing and pass band filter shape is necessary to satisfy orthogonality as shown in Fig. 2. When the signals are transmitted with a proper spacing and guard band then at receiving time, receiver can separate them using a filter.

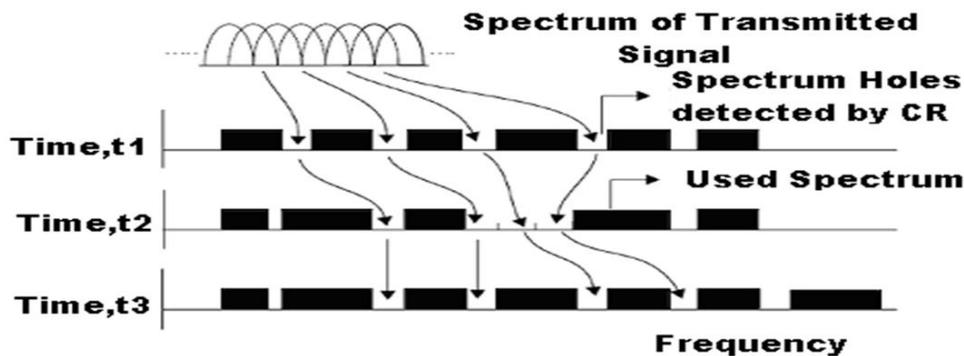


Fig. 2: Implementation of OFDM for spectrum holes detected by Cognitive Radio

3.1 OFDM Transceiver

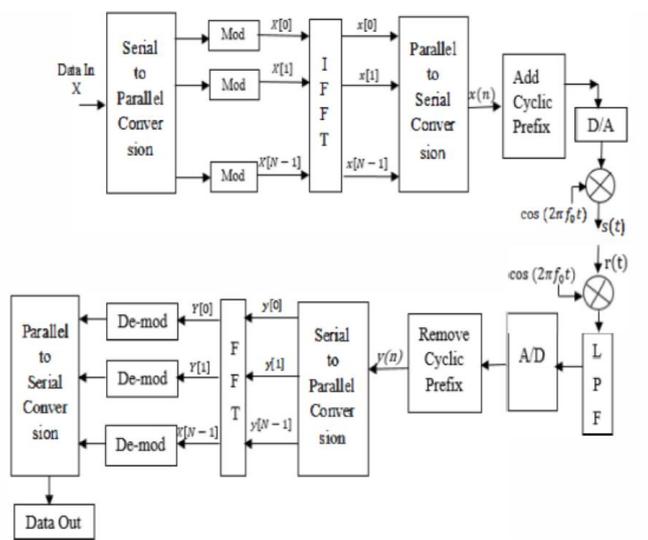


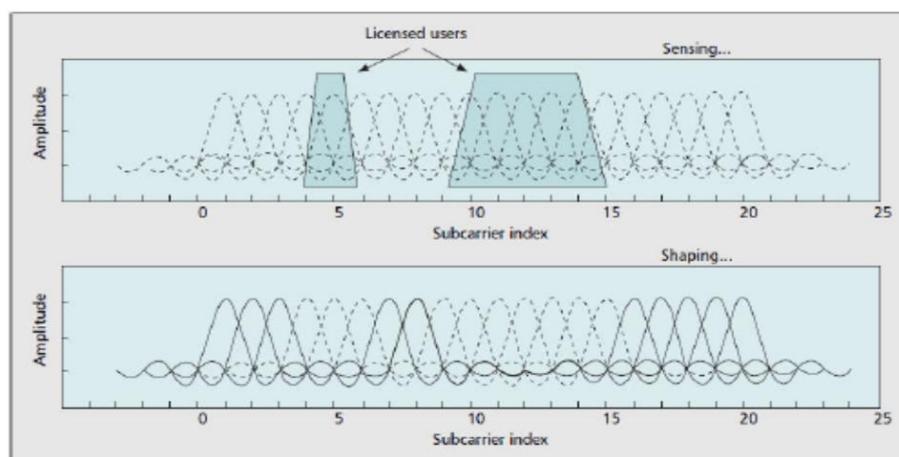
Fig. 3: Block Diagram of OFDM Transceiver

A basic block diagram of OFDM transceiver is shown in Fig. 3. The digital input signal  $X$  which corresponds to the cognitive users is divided into several sub-channels. The input signals can be modulated using different modulation schemes (like BPSK, QPSK, 16-QAM and 64-QAM) in each of the subcarriers of the transmitter side which decides the bit allocation for the system. The input to Inverse Fast Fourier Transform (IFFT) is in frequency domain which is converted to time domain and reduces the computational complexity. Cyclic prefix is then added to this signal to avoid Intersymbol Interference (ISI). With the help of digital to analog (D/A) converter, the signal is converted to analog form. The output signal  $s(t)$  is then transmitted through a multipath channel. The inverse operation on the received signal  $r(t)$  is carried out at the receiver section. The conversion of the signal from time domain to frequency domain occurs by using Fast Fourier Transform (FFT)[6]. The corresponding demodulation techniques are used on subcarriers on the receiver side to retrieve the signal and the digitally converted signal is obtained at the receiver.

### 3.2 Advantages of OFDM in Cognitive Radio

OFDM based cognitive radio have some advantages[5] which are described below:

- i) To eliminate the problem of intersymbol interference, the cyclic prefix (CP) codes are used. CP (also called guard interval) is the last  $K$  samples of the OFDM symbol which are inserted before the symbol so that if the overlapping of previous or next symbol occurs due to delay then the original OFDM symbol can be recovered with the help of cyclic prefix codes.
- ii) By using Fast Fourier Transform (FFT), it saves the hardware and computational requirement.
- iii) In OFDM, coding and transmit power of each subcarrier can be altered easily based on requirement of the user or quality of band.
- iv) Interfacing of a wireless technology with other wireless technologies is a major problem. OFDM provides interoperability with various wireless technologies such as Digital audio Conferencing, WiMAX and Digital Audio Broadcasting.
- v) By using specific mask, those subcarriers can be masked or disabled which are being used by the licensed users so that interference can be avoided as shown in the Fig. 4.



**Fig. 4: Sensing and shaping the spectrum**

### 3.3 Problems in OFDM based CR Systems

With some advantages, there are few problems in OFDM based cognitive radio[5] that are described below:

- A. *High PAPR*- It is the main issue in the OFDM based cognitive radio systems. It is the ratio of the maximum power of a sample in a given OFDM transmit symbol and the average power of that OFDM symbol[7].

PAPR can be defined as:

$$PAPR = \frac{\max |x(t)|^2}{E[x(t)^2]}$$

When modulated subcarriers are merged coherently, within an instant the power of some signals might rise which crosses the average power and it generates the problem of PAPR. In power amplifier, when peak of the signal reaches into non-linear region then it causes distortion in the signal. Due to high PAPR, the performance of the system also degrades because it increases Bit Error Rate(BER).

- B. *Mitigate the efficiency of spectrum*- Intersymbol interference(ISI) is the major issue of the wireless communication because of multipath propagation. To minimize the issue of intersymbol interference, extra samples called cyclic prefix (guard intervals) have to be added which occupy the spectral bandwidth and reduces the efficiency of the spectrum.

## IV. PAPR (PEAK TO AVERAGE POWER RATIO) REDUCTION TECHNIQUES

There are various reduction techniques to reduce PAPR[8] which are described below:

### a) *Clipping and filtering technique*

In this technique, high PAPR is reduced by cutting the amplitude of the modulated signal greater than the threshold value before the transmission at the transmitter end[6]. It reduces the PAPR but it also produces the in-band radiation and out-band radiation. But filtering after clipping may re-grow the PAPR. The advantage of clipping and filtering technique is that it does not require side information to transmit along with the data signal to the receiver[12] and no operation is performed at the receiver to recover the original signal as well.

### b) *Coding technique*

In this technique, the particular length of codes are selected and then encoding of the original signal is done with these codes to minimize the PAPR and by using these codes, the original signal is recovered at receiving end. Error reduction and correction operations are also performed. But, the coding method is only valid for short codes because it needs large calculation.

### c) *Selective mapping technique*

Selective mapping is most widely used PAPR reduction technique. The block diagram of SLM is shown in Fig. 5. Firstly, the transmitted signal is multiplied by all the possible phase factors. The number of phase factors depends on which modulation technique is used to modulate the transmitted signal. Then multiplied signals are passed through IFFT process for conversion from frequency to time domain. Then, PAPR value is calculated and compared with each other. The OFDM signal having minimum PAPR value is selected and corresponding phase factor is selected.

Both phase factor and that signal which has smallest PAPR value is sent to the receiver. It reduces the high PAPR, but its major weak point is that the side information has to be send to decode the signal at receiving end and therefore spectral efficiency reduces[9].

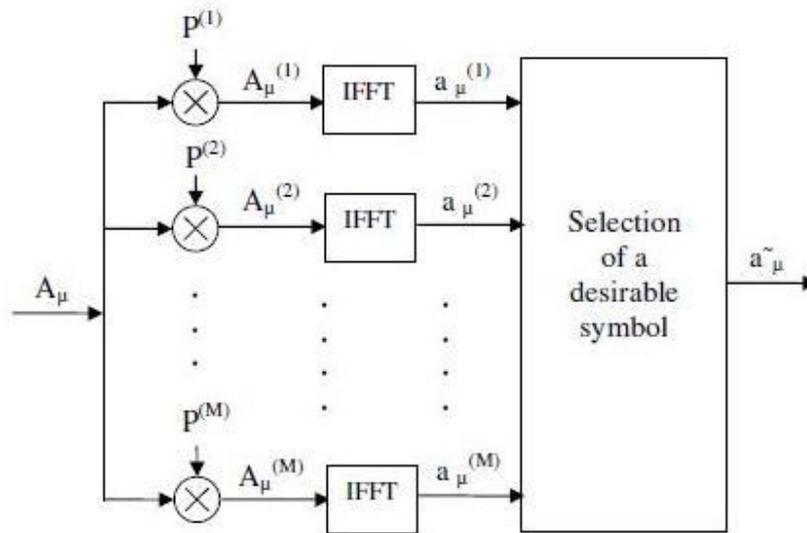


Fig. 5: Block Diagram of SLM

**d) Partial transmit sequence technique**

It is the extended version of SLM PAPR reduction technique. Unlike SLM technique, in PTS technique data signal is partitioned into  $m$ -sub parts then each part is submitted to IFFT block which convert the frequency domain to time domain[10]. After this, each sub portion is multiplied by a different phase factor and selects that phase factor for each subpart of the signal which has minimum PAPR value as shown in Fig. 6. Phase factor can be different for different subparts of the signal.

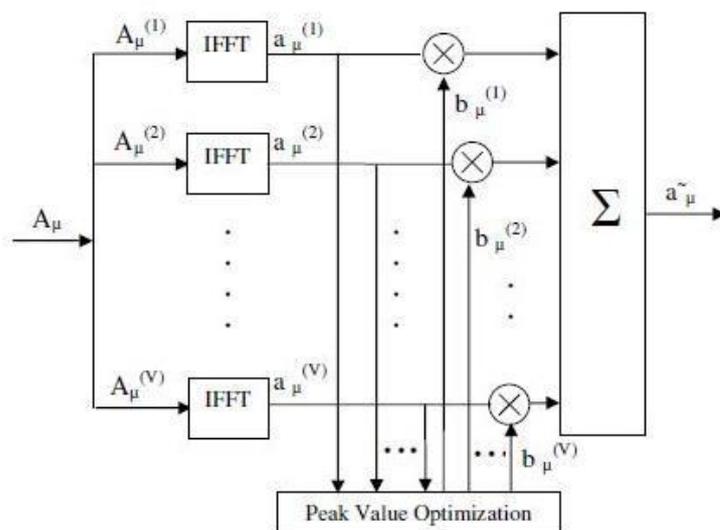


Fig. 6: Block Diagram of PTS

But it requires large number of computations to select the appropriate phase factor for each subpart of the signal which has minimum PAPR value. Unlike SLM reduction technique, there is no need to send side information to the receiver because of differential modulation.

#### e) *Tone reservation technique*

In this technique, high PAPR is reduced by using set of reserved tones. A small set of subcarriers are reserved for Peak Cancellation Signal(PCS) in this technique. This PCS helps to minimize the PAPR of the signal. The merits of Tone Reservation are: it is less complicated than other techniques of PAPR reduction and no side information is transmitted along the original signal. Its major drawback is that it consumes the extra bandwidth which decreases the data rate[11].

## V. CONCLUSION

Cognitive radio is one of the efficient wireless technology to manage the problem of shortage in the spectrum and OFDM is the most favourable modulation technique which is used in cognitive radio for high data rate transmission. Cognitive radio can be used in emergency communications(natural calamity, a terrorist attack or war zone scenarios) and public safety services. By using OFDM in cognitive radio, interoperability can be provided among first responders (police, fire, safety departments). In this paper, various advantages and problems of OFDM are discussed. But the major problem of OFDM is high PAPR because it affects the quality of performance of signal. To overcome this problem, there are various reduction techniques which are discussed in the paper so that it may increase the performance of the signal. It is very difficult to use a particular PAPR reduction technique for general communication.

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