REPORT-5

WIRELESS COMMUNICATIONS

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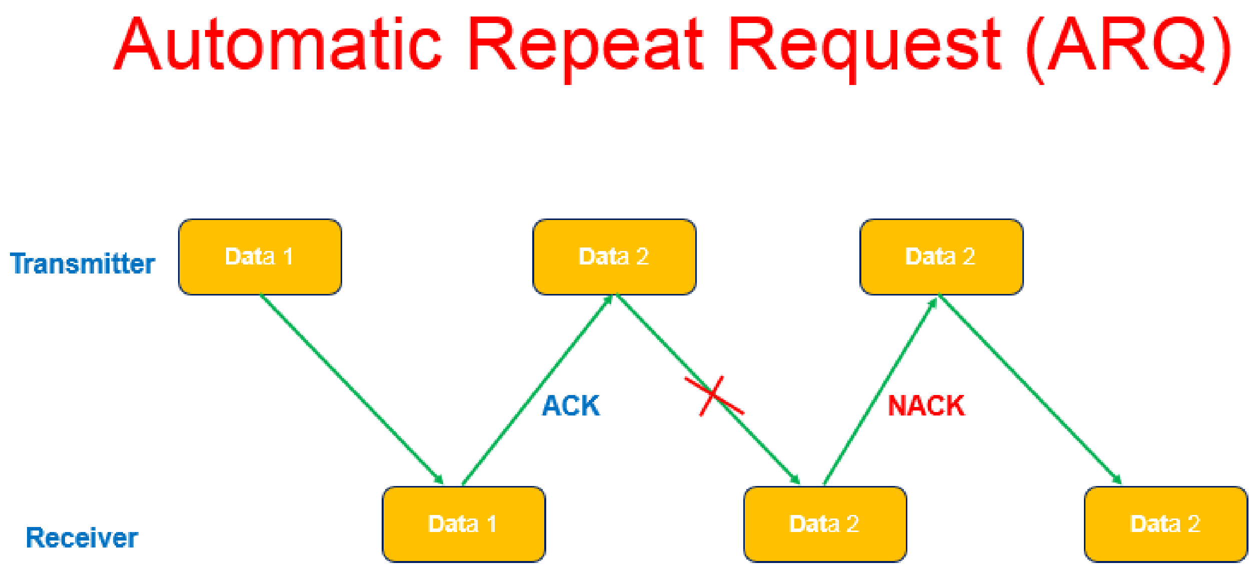
"Hybrid ARQ" Report, And A Bonus Report About Some "OFDM Features":

- Reduction Ways of the OFDM-PAPR.
- MATLAB-PAPR Reduction using Selective Mapping.
- Cyclic Prefix & Removing It At Receiver.

“Hybrid ARQ” Report

What is Hybrid ARQ?

Hybrid Automatic Repeat reQuest (HARQ) is a technique used in communication systems, particularly in wireless networks, to improve reliability and efficiency in data transmission. HARQ combines both forward error correction (FEC) and automatic repeat request (ARQ) mechanisms.



How it works:

1. Forward Error Correction (FEC): FEC involves adding redundant information to the transmitted data before sending it. This redundant information allows the receiver to detect and correct errors without needing to request retransmissions. However, FEC introduces some overhead because it increases the amount of data to be transmitted.

2. Automatic Repeat Request (ARQ): ARQ is a technique where the receiver detects errors in the received data and requests retransmission of only the corrupted portions from the sender. This reduces overhead compared to FEC because only the erroneous segments need to be retransmitted.

HARQ combines these two techniques to optimize data transmission:

- In the initial transmission, the sender uses FEC to add redundancy to the data.
- If errors occur and are detected by the receiver, instead of immediately requesting retransmission, the receiver tries to correct the errors using the redundant information provided by FEC.
- If the errors cannot be corrected, the receiver sends a negative acknowledgment (NACK) to the sender, requesting retransmission of specific portions of the data.
- Upon receiving the NACK, the sender retransmits only the requested portions using ARQ.

HARQ improves the reliability of data transmission by leveraging both FEC and ARQ while minimizing overhead. It's widely used in modern wireless communication standards such as LTE, WiMAX, and 5G to ensure robustness and efficiency, especially in environments with high interference or varying channel conditions.

Types of Hybrid ARQ (HARQ):

Hybrid ARQ (HARQ) can be categorized into different types based on how they handle retransmissions and redundancy combining. The two main types are HARQ Type I and HARQ Type II. Here's an overview of each:

1. HARQ Type I:

- In HARQ Type I, the retransmissions are based solely on ARQ.
- Forward Error Correction (FEC) is used initially, adding redundancy to the transmitted data to allow for error detection and correction at the receiver.
- If errors are detected and cannot be corrected using FEC, the receiver sends a negative acknowledgment (NACK) to the sender, requesting retransmission of the entire data packet.
- The sender then retransmits the entire packet upon receiving the NACK.

2. HARQ Type II:

- HARQ Type II, also known as Chase combining, combines both FEC and ARQ for retransmissions.
- Similar to HARQ Type I, FEC is used initially to add redundancy to the transmitted data.
- If errors occur, the receiver sends a NACK to the sender.
- However, instead of retransmitting the entire packet, the sender retransmits only the redundant bits that were not correctly received.
- At the receiver, the redundant bits from the original transmission and the retransmission are combined, typically using bitwise XOR operations.
- If the combined redundant bits provide enough information to correct errors, the receiver can successfully recover the original data without the need for further retransmissions.
- If errors persist after the first retransmission, or if the received redundancy is insufficient for correction, further retransmissions may occur.

Comparison between HARQ Type I vs HARQ Type II:

- **Efficiency**: HARQ Type II is generally more efficient than Type I because it only retransmits the redundant bits instead of the entire packet, reducing bandwidth consumption.

- **Complexity**: HARQ Type II introduces more complexity at both the transmitter and receiver due to the need for redundant bit combining. Type I is simpler in comparison.

- **Reliability**: Both types aim to improve reliability, but Type II may offer better performance in scenarios with moderate error rates since it can often correct errors without requiring full retransmissions.

In summary, while HARQ Type I is simpler, Type II typically offers higher efficiency and potentially better reliability, especially in scenarios with moderate error rates.

A Bonus Report About Some "OFDM Features"

1. Reduction Ways of the OFDM-PAPR:

1. INTRODUCTION

Today, OFDM has grown to be the most current announcement system in highspeed infrastructures. OFDM is becoming the chosen modulation technique for wireless transportations. OFDM can offer large data rates with sufficient robustness to radio channel impairments. As the most promising technique, OFDM is used in various field of communication like digital video broadcasting (DVB), wireless local area network(WLAN) and digital audio broadcasting(DAB). It is a multi-carrier modulation technique. Because of its simplicity, it is much easier to use single carrier transmission scheme but the major problem of single carrier modulation is inter symbol interference. Orthogonal frequency division multiplexing(OFDM) came into existence to remove the shortage of single carrier transmission in case of having high data rate. OFDM is good for high speed digital communication. OFDM modulation technique is used in 4G mobile system. One of the major drawback of OFDM system is high peak to average power ratio(PAPR) in time domain and form large amplitude wave form. High PAPR push the power amplifier into non-linear area result in in-band and out-ofband distortion. This PAPR should be least for powerful transmission. Number of techniques are used to overcome the Peak to average power ratio in OFDM system. In this paper we present different techniques that can be used to minimize high PAPR problem in OFDM system. This paper contain overview of all the techniques.

2.OVERVIEW OF PAPR:

The peak to average power ratio(PAPR) is the major drawback of OFDM system which decrease the performance of the transmitted signal. The large peak to average power ratio(PAPR) push the power amplifier to work in nonlinear area which result in band and out of band distortion. When subcarriers with large number are out of phase, a significant PAPR can cause the transmitter's power amplifier to run within a non-linear operating region. This cause significant signal distortion at the output of the power amplifier. In addition, the high PAPR can cause saturation at the digital to analog converter, leading to saturation of the power amplifier. PAPR also causes intermodulation distortion between the sub-carriers and distorts the transmit signal constellation. Therefore, the power amplifier must operate with a large power back-off, approximate to that of PAPR which lead to insufficient operation. Therefore it is necessary to overcome the PAPR of the transmit signal in MIMO-OFDM systems.

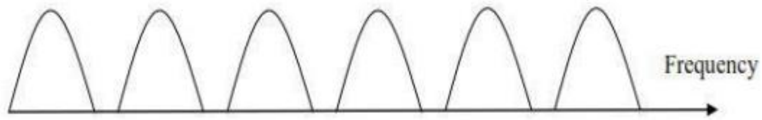


Fig 2.1 Spectrum of traditional FDM scheme

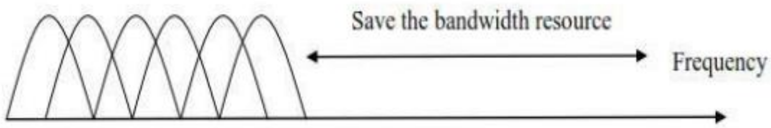


Fig 2.2 Spectrum of OFDM

To Study the Different Techniques to Reduce the PAPR in OFDM System

For continuous time signal x[t] the expression for PAPR is given below.

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

For discreate time version x[n], the expression for PAPR is given below.

$$\text{PAPR}(x[n]) = \frac{\boldsymbol{max}[\boldsymbol{x}(\boldsymbol{n})]^2}{\boldsymbol{E}[\boldsymbol{x}(\boldsymbol{n})]^2}$$

Where E[.] is the expection operator.

I. SIGNAL SCRAMBLING TECHNIQUES

a) SELECTIVE MAPPING (SLM)

The most promising technique is the selective mapping technique because no distortion is introduced and yet reduce the PAPR. In this technique the signal at the input is divided into many sub-blocks. The signal with least or minimum PAPR is selected from different phase sequence that contain same information at transmitter. The index to be selected is called side information index. The transmitter uses side information so that receiver can make uses of that side information to predict which signal is selected.

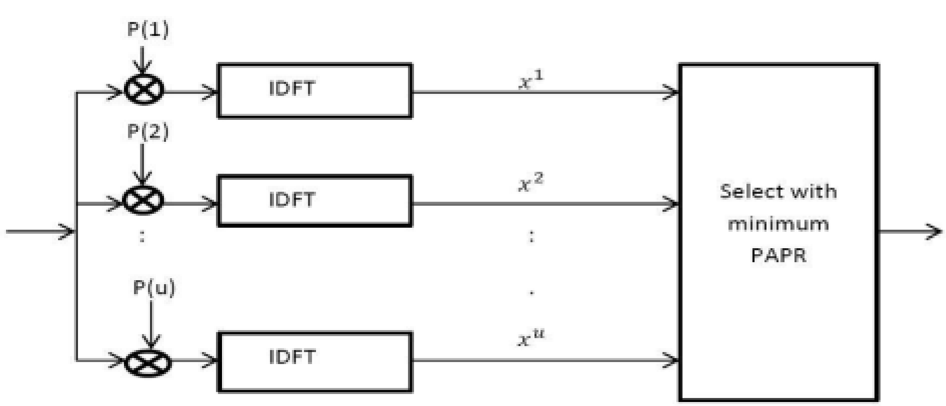


Fig.4.1.1 Block diagram of Selective Mapping.

b) BLOCK CODING TECHNIQUE

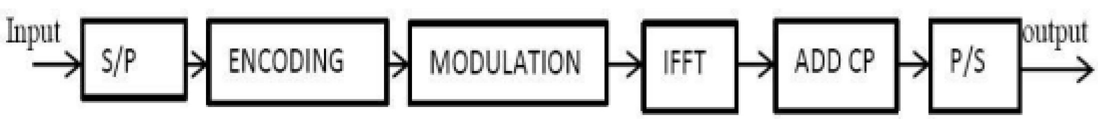
It is the easiest method which we used to overcome the peak to average power ratio(PAPR). The basics idea behind this method is to overcome PAPR by applying different blocks code and codewords. This method is applied to reduce the problem of peak to mean envelope power ratio. During the codeword's selection many point should be kept in mind, such as m array phase modulation technique, types of codes rate and also error correction correction and error decoding.

c) TONE RESERVATION(TR)

Tone reservation is the simplest way to minimize the PAPR. In this scheme reversing a small fraction of tone lead the large amount of reduction of PAPR with simple operation at the transmitter side. Some set of tones are reserved in this technique. In tone reservation side information and other additional operation are not required, so there is no complexity at the destination end.

d) LINEAR BLOCK CODE(LBC)

This is an error correcting code. This technique allows more efficient encoding and decoding algorithms as compared to other codes. Linear block codes are basically used in forward error correction and for transmitting symbols or bit on the communication channel. This is also the modification of selective mapping schemes. In this technique transmitted signal with least PAPR used scrambling code. This technique provide better performance than SLM scheme.



E) INTER LEAVING TECHNIQUE

In this technique interleavers are used for the purpose of generation of multiple OFDM signal and same information is transmitted by the signal. It is a device that run on a block of symbol and rearrange them in a specifics way. In this adaptive techniques is also overcome the complexity. Adaptive interleaving is used as an early terminating threshold. As the searching process is terminated the value of PAPR reaches below the threshold value These low threshold force the adaptive interleaver to search for all interleaving sequence. As compared to PTS this technique is less complex.

II. SIGNAL DISTORTION TECHNIQUES

a) CLIPPING AND FILTERING

It is the simplest technique to to minimize the PAPR .In this the high amplitude peaks signal are clipped before passing the signal is passed from the power amplifier. For this clipper is used which limit the signal up to determined level called as clipping level. It is a non-linear process, which result in the formation of in-band and out of band distortion. we can not remove in-band distortion by using filtering, where as out of band distortion can be removed by filtering and improve the performance of BER. By the use of clipping and filtering algorithm, more PAPR can be minimized than that of direct clipping.

b) PEAK WINDOWING

This technique is almost similar to that of clipping technique, but it provides better performance due to the addition of self interference and increased bit error rate(BER). This result in out of band distortion increased. In this technique, different windows are multiplied with large signal peaks such as Gaussian shape window, cosine, Kaiser and hamming window. The size of window should be narrow as possible otherwise it will increase bit error rate(BER).

2. MATLAB Code For PAPR Reduction Using Selective Mapping:

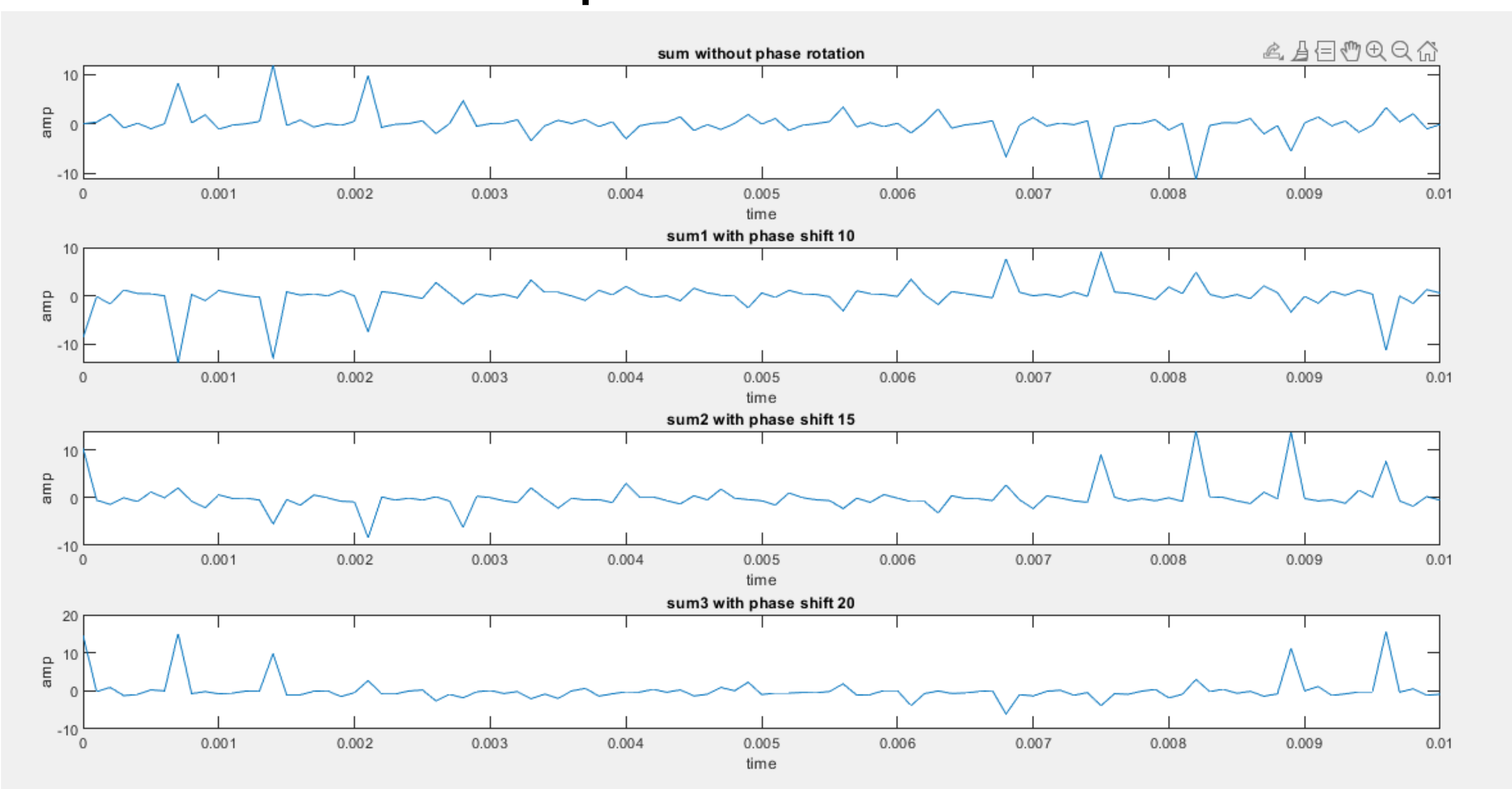
The Program Code:

```
%selective mapping as a reduction technique for PAPR in OFDM systems
t=0:.0001:.01;
g=1;
%these are the available subcarriers (BPSK modulated) assuming all ones(all positive)
x1=sin(2*180*100*t);
x2=sin(2*180*200*t);
x3=sin(2*180*300*t);
x4=sin(2*180*400*t);
x5=sin(2*180*500*t);
x6=sin(2*180*600*t);
x7=sin(2*180*700*t);
x8=sin(2*180*800*t);
x9=sin(2*180*900*t);
x10=sin(2*180*1000*t);
x11=sin(2*180*1100*t);
x12=sin(2*180*1200*t);
x13=sin(2*180*1300*t);
x14=sin(2*180*1400*t);
x15=sin(2*180*1500*t);
x16=sin(2*180*1600*t);
%here the transmitted symbol uses all the subcarriers as follows
sum=x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11+x12+x13+x14+x15+x16;
%here we use (phase rotation)by multiplying all the subcarriers in the sum by different phases to
create a new data vector, not only that but also as we don't know the optimum phases to give the best
PAR we create more than one vector and then sellect the optimum.
%first phase rotation
x1a=sin((2*180*100*t)+10);
x2a=sin((2*180*200*t)+10);
x3a=sin((2*180*300*t)+10);
x4a=sin((2*180*400*t)+10);
x5a=sin((2*180*500*t)+10);
x6a=sin((2*180*600*t)+10);
x7a=sin((2*180*700*t)+10);
```

```
x8a=sin((2*180*800*t)+10);
x9a=sin((2*180*900*t)+10);
x10a=sin((2*180*1000*t)+10);
x11a=sin((2*180*1100*t)+10);
x12a=sin((2*180*1200*t)+10);
x13a=sin((2*180*1300*t)+10);
x14a=sin((2*180*1400*t)+10);
x15a=sin((2*180*1500*t)+10);
x16a=sin((2*180*1600*t)+10);
sum1=x1a+x2a+x3a+x4a+x5a+x6a+x7a+x8a+x9a+x10a+x11a+x12a+x13a+x14a+x15a+x16a;
%second phase rotation
x1b=sin((2*180*100*t)+15);
x2b=sin((2*180*200*t)+15);
x3b=sin((2*180*300*t)+15);
x4b=sin((2*180*400*t)+15);
x5b=sin((2*180*500*t)+15);
x6b=sin((2*180*600*t)+15);
x7b=sin((2*180*700*t)+15);
x8b=sin((2*180*800*t)+15);
x9b=sin((2*180*900*t)+15);
x10b=sin((2*180*1000*t)+15);
x11b=sin((2*180*1100*t)+15);
x12b=sin((2*180*1200*t)+15);
x13b=sin((2*180*1300*t)+15);
x14b=sin((2*180*1400*t)+15);
x15b=sin((2*180*1500*t)+15);
x16b=sin((2*180*1600*t)+15);
sum2=x1b+x2b+x3b+x4b+x5b+x6b+x7b+x8b+x9b+x10b+x11b+x12b+x13b+x14b+x15b+x16b;
%third phase rotation
x1c=sin((2*180*100*t)+20);
x2c=sin((2*180*200*t)+20);
x3c=sin((2*180*300*t)+20);
x4c=sin((2*180*400*t)+20);
x5c=sin((2*180*500*t)+20);
x6c=sin((2*180*600*t)+20);
x7c=sin((2*180*700*t)+20);
x8c=sin((2*180*800*t)+20);
x9c=sin((2*180*900*t)+20);
x10c=sin((2*180*1000*t)+20);
x11c=sin((2*180*1100*t)+20);
x12c=sin((2*180*1200*t)+20);
x13c=sin((2*180*1300*t)+20);
x14c=sin((2*180*1400*t)+20);
x15c=sin((2*180*1500*t)+20);
x16c=sin((2*180*1600*t)+20);
sum3=x1c+x2c+x3c+x4c+x5c+x6c+x7c+x8c+x9c+x10c+x11c+x12c+x13c+x14c+x15c+x16c;
%now the selector should test the PAPR for the available data vectors
%and select the one with the least PAPR to use in transmission
%PAPR calculation
%calculating the PAPR
peak=max(sum);
avg=mean(sum.*sum);
papr=10*log((peak^2/avg))
peak1=max(sum1);
avg1=mean(sum1.*sum1);
papr1=10*log((peak1^2/avg1))
peak2=max(sum2);
avg2=mean(sum2.*sum2);
papr2=10*log((peak2^2/avg2))
peak3=max(sum3);
avg3=mean(sum3.*sum3);
```

```
papr3=10*log((peak3^2/avg3))
%selector
subplot (4,1,1)
plot(t,sum,t,g,t,-g)
title('sum without phase rotation')
xlabel('time')
ylabel('amp')
subplot (4,1,2)
plot(t,sum1,t,g,t,-g)
title('sum1 with phase shift 10')
xlabel('time')
ylabel('amp')
subplot (4,1,3)
plot(t,sum2,t,g,t,-g)
title('sum2 with phase shift 15')
xlabel('time')
ylabel('amp')
subplot (4,1,4)
plot(t,sum3,t,g,t,-g)
title('sum3 with phase shift 20')
xlabel('time')
ylabel('amp')
```

The Results & MATLAB Graphs:




```
>> selectiveMapping_report5
papr =
29.2900
papr1 =
22.0610
papr2 =
31.2678
papr3 =
31.3918
```

3. Cyclic Prefix & Removing It At Receiver:

The cyclic prefix acts as a buffer region or guard interval to protect the OFDM signals from intersymbol interference. This can be an issue in some circumstances even with the much lower data rates that are transmitted in the multicarrier OFDM signal.

By reducing the effects of ISI, Intersymbol Interference This provides for simplified signal processing at the receiver.

What is a cyclic prefix

The concept of using a cyclic prefix with OFDM is straightforward in its concept, but requires additional complexity in the transmitter and receiver processing.

The Cyclic Prefix is achieved by placing last few samples of the OFDM symbol before the start in addition to retaining them at the end.

The cyclic prefix symbols are placed in such a way that they act as guard interval between any two different OFDM symbols.

This guard interval helps to reduce or even eliminate the effects arising from ISI from the previous symbol. Since the prefixed symbol is cyclical in nature i.e. the CP symbol repeats the end of the OFDM data, the resulting CP-OFDM data is periodic or cyclic, unlike the case of standard OFDM.

In summary, the cyclic prefix performs two main functions.

- The cyclic prefix provides a guard interval to eliminate intersymbol interference from the previous symbol.
- It repeats the end of the symbol so the linear convolution of a frequency-selective multipath channel can be modeled as circular convolution, which in turn may transform to the frequency domain via a discrete Fourier transform. This approach accommodates simple frequency domain processing, such as channel estimation and equalization.

The cyclic prefix is created so that each OFDM symbol is preceded by a copy of the end part of that same symbol.

Different OFDM cyclic prefix lengths are available in various systems. For example within LTE a normal length and an extended length are available and after Release 8 a third extended length is also included, although not normally used.

Cyclic prefix advantages and disadvantages

There are several advantages and disadvantages attached to the use for the cyclic prefix within OFDM.

Advantages

- ***Provides robustness:*** The addition of the cyclic prefix adds robustness to the OFDM signal. The data that is retransmitted can be used if required.
- ***Reduces inter-symbol interference:*** The guard interval introduced by the cyclic prefix enables the effects of inter-symbol interference to be reduced.

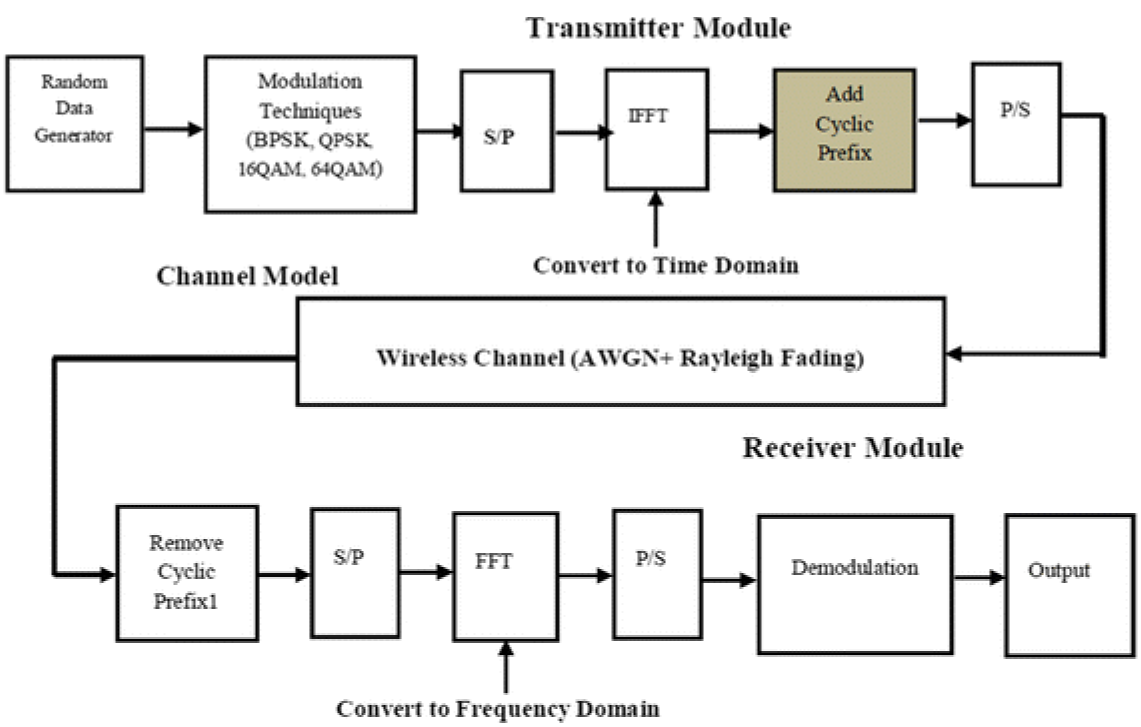
Disadvantages

- ***Reduces data capacity:*** As the cyclic prefix re-transmits data that is already being transmitted, it takes up system capacity and reduces the overall data rate.

The use of a cyclic prefix is standard within OFDM and it enables the performance to be maintaiend even under conditions when levels of reflections and multipath propagation are high.

In the designed OFDM Transmitter with single cyclic prefix for designed WiMAX system before transmitting the signal, the frequency orthogonally and cyclic prefix is added in OFDM signals. The proposed model for OFDM transmitter with single cyclic prefix for designed WiMAX system is demonstrated in below Fig.

OFDM Transmitter for Cyclic Prefix In WiMAX System



Proposed OFDM transmitter model with single cyclic prefix for WiMAX system

It is important to note that in wireless communication transmitted signals may be distorted due to multipath delay. It is defined that using proposed OFDM Transmitter with single cyclic prefix for designed WiMAX system, ISI is totally excluded when the CP length is larger compare to multipath delay. In CP additional bits at the transmitter end are added, to minimize ISI and to improve BER. Finally, bits are forwarded to the receiver via a channel.