Peak-to-Average power reduction in OFCDM system to enhance the spectral efficiency

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Abstract

As we know every technology has some advantages and issues. OFCDM, which is very promising modulation technique for 4G standard like LTE (Long Term Evolution) and WIMAX (Worldwide Inter-operability for Microwave Access) also has some issues like frequency offset and Peak-to-Average Power Ratio (PAPR). PAPR issue is very severe if it is not considered. Due to PAPR, non-linear distortion occurs which causes orthogonality of OFCDM sub-carriers get lost, so Inter Carrier Interference (ICI) and Inter Symbol Interference (ISI) both arises. Several PAPR reduction techniques have been proposed in literature. These techniques are divided into two groups, signal scrambling techniques and signal distortion techniques. But both have some types of disadvantages. Here is a technique known as subcarrier processing (SCP) technique that is used to reduce PAPR by more than 5 dB and remove rigorous requirement for power amplifier and digital to analogue converter. Due to PAPR reduction, ICI and ISI both reduces considerably, so bit error rate (BER) performance of the system get improved.

1. INTRODUCTION

OFCDM is modulation technique for 4G mobile communication. It is combination of OFDM & 2D spreading. The well known disadvantage of single carrier CDMA (SC-CDMA) is multipath interference (MPI) [1], so it is not suitable for broadband wireless access. On the other hand, multicarrier technique like multicarrier CDMA (MC-CDMA), OFDM consist of large number of orthogonal subcarriers to transmit symbols in parallel, so the symbol duration is increased substantially and the system can combat MPI. But OFDM suffers from adjacent cell interference (ACI) unless the same subcarriers are not used among adjacent cells. To avoid ACI spreading has been introduced. Thus combining OFDM and 2D spreading (time and frequency domain) Orthogonal Frequency and Code Division Multiplexing has been proposed [2]. Thus it accumulate the properties of OFDM and 2D spreading. Due to which it possess many advantages as compared to other existing techniques OFDM & MC-CDMA which is as follows,

1. It has minimum BER for same SNR as compared to other two.

2. Its capacity is approx 1.5 times as compared to OFDM & MC-CDMA if spreading factor N is greater than 1.

3. OFCDM can operate at broadband channel with approximately 100 MHz and support the data rate ranging from 100Mb/s to 5Gb/s.

4. OFCDM supports again serious multipath interference so it achieve higher spectrum utilization than OFDM and MC-CDMA [3]

$$Y_{ofcdm} = \sum_{k=0}^{n} C_T^k,\ C_F^k d_{m,n,k}^l\ e^{j2\pi f_n}(t\text{-}mT)$$

Where C_T and C_F are time and frequency domain spreading code, k indicate k^{th} channel code, K is total number of channels, d^l is l^{th} data stream, m is m^{th} time index, n mean n^{th} subcarrier. Remaining part of paper is organized as follows, in part II system model of OFCDM is explained. Part III

describe the PAPR issue and reduction method of PAPR. Proposed SCP method is discussed in part IV. BER performance of OFCDM and SCP is compared in part V. Simulation has been performed in part VI and conclusion has been explained in part VII.

2.SYSTEM MODEL

The schematic of OFCDM transmitter and receiver is as

follows:

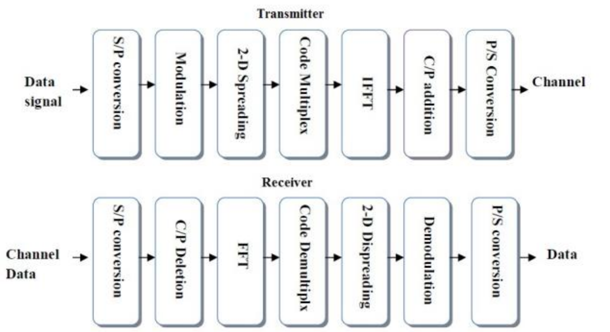

Fig -1: **OFCDM transmitter & receiver without modification**

Transmitter: At the transmitter, incoming serial data stream is converted into serial to parallel (S/P) multi stream, then parallel multi stream data is channel encoded and then modulated, after that 2D spreading is done. In 2D spreading firstly time domain spreading is done and then replicate the

Same code in frequency domain. After 2D spreading, all subcarriers data is combined and code multiplexed, then IFFT transform is taken which convert high frequency subcarrier and then cyclic prefix block is inserted to avoid the inter symbol interference. Finally OFCDM symbol is transmitted in broadband wireless channel.

Receiver: At the receiver, all process is just opposite to the transmitter side, first of all cyclic prefix is removed after that FFT is performed which down convert the subcarrier after that demodulation is done then decoding and lastly parallel to serial (P/S) converted and retrieved original data.

3.PAPR ISSUE

As from the system model of OFCDM, there is IFFT operation at the transmitter side. Due to this IFFT operation PAPR arises [4]. PAPR is defined as ratio of peak power to average power of any transmitted signal x(t), which is given by equation as,

$$\text{PAPR} = \frac{\max|y(t)|^2}{E(|y(t)|^2)}$$

Where y(t) is the time domain samples of the transmitted signal, in our scenario, Max $|y(t)|^2$ is the maximum instantaneous power and $E(|y(t)|^2)$ is the average power. It can be also represented in dB,

$$\text{PAPR(dB)} = 10 \log \text{PAPR}$$

PAPR is major issue in all multicarrier system. As OFCDM Is multicarrier system it also suffer from PAPR. Consider a single carrier system with BPSK modulated symbols s(0), s(1), s(2),... is represented by level +a, then power in each symbol is a^2 and average power $E[s^2(k)] = a^2$. Hence in single carrier system both peak and average power is a^2. Hence the ratio

$$\text{PAPR}=10\log \frac{\textit{Peak power}}{\textit{Average powe}}$$

is equal to $10\log(a^2/a^2) = 1 = 0\text{dB}$. Hence there is no significant deviation of peak power from average power level. Now suppose, symbols S(0), S(1), S(2),... S(N-1) are the IFFT of s(0), s(1), s(2),... s(N-1). Then kth IFFT sample is given by

$$S(k) = \frac{1}{N}\sum_{t=0}^{N-1} s(i)\, e^{j2\pi \frac{kt}{N}}$$

then Average power

$$E\{|S(k)|^2\} = \frac{1}{N^2}\sum_{t=0}^{N-1} E\{|s(i)|^2\}\, E\{|\, e^{j2\pi \frac{kt}{N}}|\}$$

because $E\{|\, e^{j2\pi \frac{kt}{N}}|\} = 1$

$$E\{|S(k)|^2\} = \frac{1}{N^2}\sum_{t=0}^{N-1} E\{|s(i)|^2$$

$$E\{|S(k)|^2\} = \frac{1}{N^2}\sum_{t=0}^{N-1} a^2$$

$$E\{|S(k)|^2\} = \frac{a^2}{N}$$

Hence average power = a^2/N.

For peak power suppose a symbol

$$S(0) = \frac{1}{N}\sum_{t=0}^{N-1} s(i)\, e^{j2\pi \frac{k0}{N}}$$

$$S(0) = \frac{1}{N}\sum_{t=0}^{N-1} s(i)$$

Now let s(0)=s(1)=s(2)=...s(N-1)=+a

Then

$$S(0) = \frac{1}{N}\sum_{t=0}^{N-1} s(i) = \frac{1}{N} \times aN = a$$

So Peak power = a2.

Then peak to average power ratio,

$$\text{PAPR} = \frac{a^2}{a^2/N} = N.$$

So there is significant swing of peak power from average power, as number of subcarrier N increases. Which can be shown in table

Table -1: PAPR FOR BPSK AND QPSK MODULATION IN (dB)

N	1	2	4	8	16	32	64	128
BPSK	0	3.01	6.02	9.03	12.04	15.05	18.06	21.07
QPSK	0	3.01	6.02	9.03	12.04	15.05	18.06	21.07

Thus from the table PAPR increases as number of subcarrier N increases, no matter what modulation scheme is used. Hence high value of PAPR in OFCDM is due to the IFFT operation. Due to this data symbols across the subcarrier can add up to produce high peak value. PAPR is characterized by Complementary cumulative distribution function (CCDF)

A. CCDF

CCDF stand for complementary cumulative distribution function. CCDF is defined as probability that a random variable X exceeds a particular value x means

$$F_X(x) = P(X > x) \text{ or CCDF} = 1 - \text{CDF}.$$

CCDF curve start from one and slowly goes to zero, means probability of higher value of random variable decreases.Typical CCDF curve is as follow

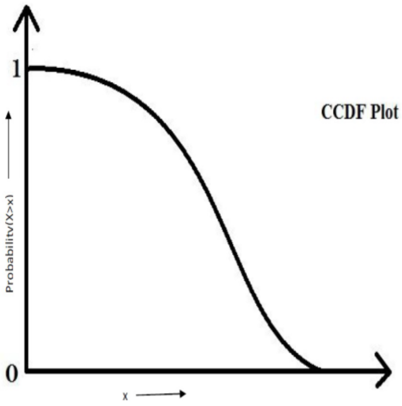

Fig -2: CCDF Curve

Idealy PAPR curve should be at zero dB line means peak power and average power both are equal. For single carrier system the PAPR curve lie on zero dB line but it vary for OFCDM system, means there is certain probability that peak power is higher than average average power.

B. Effect of PAPAR on OFCDM

Transistor work as an amplifier in linear mode but when peak deviation about average is significantly high then signal level moves into non linear region of amplifier characteristics. So output of amplifier get distorted. So non linear distortion occurs, due to this non linearity OFCDM losses its orthogonality that leads to inter carrier interference (ICI) and inter symbol interference (ISI). So the bit error rate (BER) of system increases and overall performance get decreases. Thus PAPR reduction is very necessary.

4. SUBCARRIER PROCESSING TECHNIQE

There have been many new approaches developed during the last few years. Several PAPR reduction techniques have been proposed in the literature. These techniques are divided into two groups, these are signal scrambling techniques and signal distortion techniques. Signal scrambling techniques work with side information which minimized the effective throughput since they commence redundancy. Signal distortion techniques introduce band interference and system complexity also. So to avoid these drawbacks SCP technique is proposed. One of the signal distortion methods of PAPR reduction is clipping, in which when signal level exceeds certain value (clip value), the signal clips.

But due to high clipping, power distortion occurs, which is termed as clipping noise, due to which in-band distortion occurs. Dardari [5], showed that, in-band distortion causes shrinking of signal constellation. The shrinking of signal constellation means reduction in Eb, which results reduction of overall Eb/N0

of all subcarriers, that causes degradation of bit error rate (BER)of the system. So, clipping beyond certain level (max up to 6 dB for any multicarrier system [5]) is not permitted. But clipping less than 6 dB is very effective to reduce PAPR, because it is simple and no complexity is added in the system on application of it.

In this paper, subcarrier processing (SCP) technique has been proposed, by addition of two methods, single carrier (SC) and clipping, because both techniques are simple and easy to implement. In SCP first PAPR of system is brought back to clipping range (6 dB as mentioned above) by use of single carrier (SC) method and then clipping is performed to reduce PAPR considerably. If we convert multicarrier system into single carrier, then advantages of multi-carrier system like spectral efficiency and high throughput will be lost. On the other hand, if system is purely multicarrier system, the PAPR increases. In order to reduce effect of PAPR, it is necessary to convert multicarrier into single carrier upto some level keeping in mind spectral efficiency and throughput of multicarrier system.

The proposed method of sub-carrier processing includes optimize level of conversion from multi-carrier system to single carrier system with small level of clipping (maximum up to 6 dB[5]).

The basic idea is to group the data symbols to be transmitted into blocks and use smaller size IFFT to map symbols with the same number of subcarriers. So here the system is converted into single carrier system by first taking M-point FFT and then N-point IFFT. If M is equal to N then multicarrier system completely converts into single carrier system, which is not desired because spectral efficiency and throughput of single carrier system is low. So it is desired that M should be less than N, then system will act like multicarrier system. Due to this optimized multicarrier system, again PAPR increases but lesser as compared to purely multicarrier system which can be further removed by small amount of clipping. So, SCP method reduces PAPR considerably and also limits disadvantages of clipping as well as single carrier system.

In SCP there is simple modification in transmitter as well as receiver side. At transmitter side the modulated symbol is grouped into M block symbols & then M-point FFT operation is performed which converts these data symbol from time domain to frequency domain. The frequency domain samples are mapped into N subcarriers, typically M < N & then N-point IFFT operation is performed to convert frequency domain symbols into time domain symbols after that cyclic-prefix is added & parallel data converted to serial one then transmitted. As in OFCDM each data is carried by individual

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subcarrier but in this method many subcarrier carry the same data because mapped data is less as compared to number of subcarriers. Proposed SCP transmitter and Receiver schematic is given in fig.3. Thus in SCP method FFT is performed

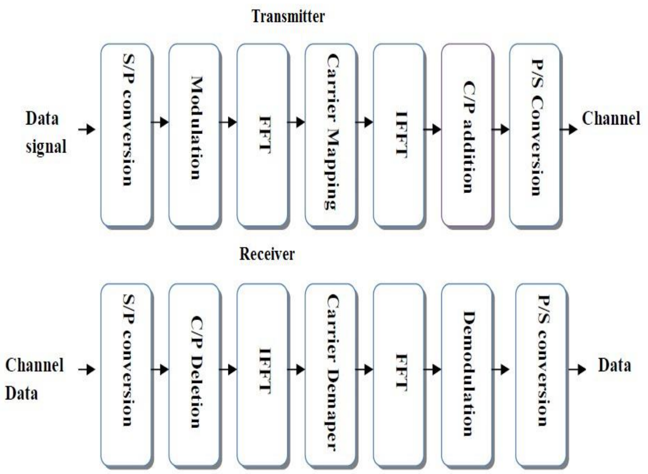

Fig -3: SCP transmitter and Receiver

before IFFT at the transmitter side and their values are different, so some types of mapping must be involve to match symbols and subcarriers. Mapping means zeroes are added to subcarriers if they are vacant. Mapping is of two types

1. Distributed Mapping

2. Localized mapping

Distributed Mapping

The distributed mapping is also called interleaving. In this mapping zeros are not added in sequential manner but follow

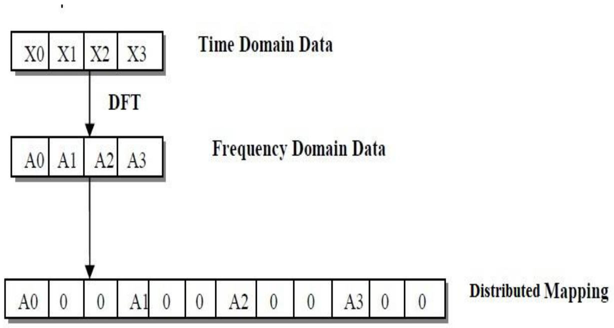

Fig -4: Distributed Mapping

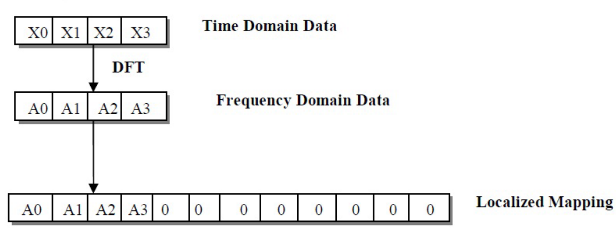

Fig -5: Localized Mapping

a fixed or variable gap between data. Proper interleaving leads to significant reduction in PAPR. When zeros are appended in such a manner that no peaks of data overlap to each other then PAPR reduces considerably. Interleaving is shown in fig.4.

Localized Mapping

In localized mapping the DFT outputs are mapped to subset of subsequent subcarriers, there by restrict them to a fraction of system bandwidth. Localized mapping are not as effective as interleaving. Localized mapping can be shown in fig.5.

5. BER PERFORMANCE OF SCP

As peak-to-average power ratio (PAPR) decreases, the value of peak power decreases, due to reduction in peak power, interference power of subcarrier PICI get reduces, so the bit error rate (BER), which depends on interference power that can be shown by equation (13), [8]. So, performance of overall system improves.

$$BER_1 = \frac{1}{2}\left(Q\left(\cos\theta \left[P(-\Delta f)\sqrt{p1c1} \right] \sqrt{\frac{2E_b}{N_0}} \right)\right.$$

$$BER_2 = \frac{1}{2}\left(\cos\theta \left[P(-\Delta f + \sqrt{P1C1} \right] \sqrt{\frac{2E_b}{N_0}} \right)$$

$$BERsymbol = BER1 + BER2$$

Where Eb/N0 is the signal-to-noise ratio per bit; Eb is the energy per bit; N0 is the double-side power spectral density of the white Gaussian noise; θ denotes the carrier phase noise; Δf is the carrier frequency offset; N is the number of sub-carriers; Q - is the error function.

Thus from equation 13, it is clear that when the value of PICI decreases the value of bit error rate (BER) decreases. p(f) is a sinc function, which is given by following equation

$$p(f) = \mathrm{sinc}(fT)\mathrm{sinc}^n(ft)$$

The total bit error rate is given by

$$BER_{OFCDM} = 1 - (1 - BER_{symbol})$$

Using above equations, simulation has been performed for BER for SCP.

6.SIMULATION AND RESULTS

The parameters that have been taken for simulation is shown in table

Table -1: SIMULATION PARAMETERS SPECIFICATION

No. of subcarriers	1024
No. Of FET Point	64
No. of IFET Point	128
Modulation	BPSK
Mapping	Distributed
No. Of time algorithm runs	100
Maximum power limit	46
SNR	15
Channal	AWGN Channal

Using above parameters, simulation has been performed for PAPR, using different modulation schemes. It is seen from simulation results that for BPSK and QPSK, PAPR graph is more reduced as compared to QAM-16, because symbols are more closer in QAM-16 as compared to BPSK and QPSK. So interference occurs more in QAM-16 as compared to QPSK and BPSK. So, PAPR reduction is lesser in QAM-16 as compared to QPSK and BPSK

Here PAPR graph is plotted using complementary cumulative distribution function (CCDF) function. When interleaving

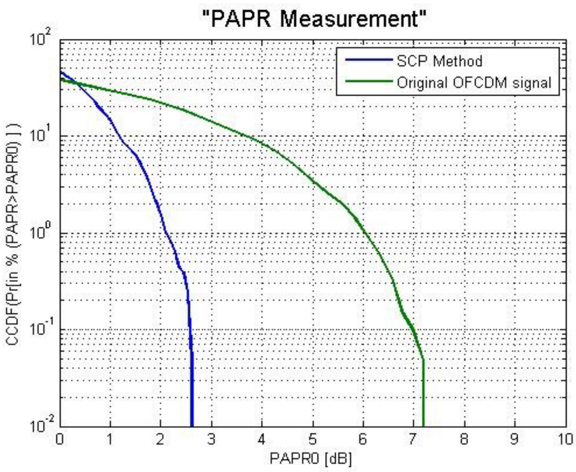

Chart -1 Result using BPSK Modulation

is performed then PAPR reduces significantly and it reaches

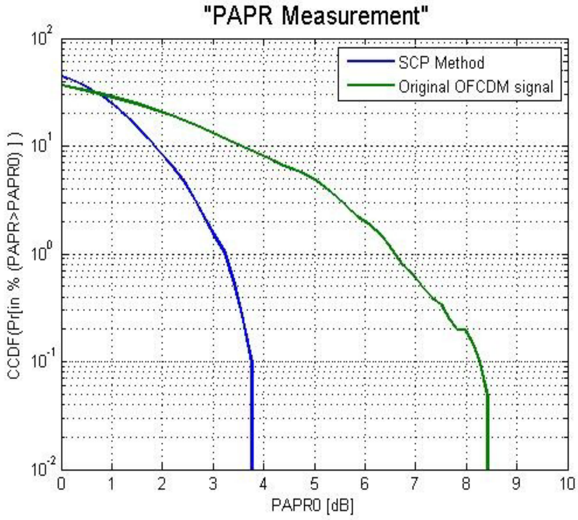

Chart -2 Result using QPSK Modulation

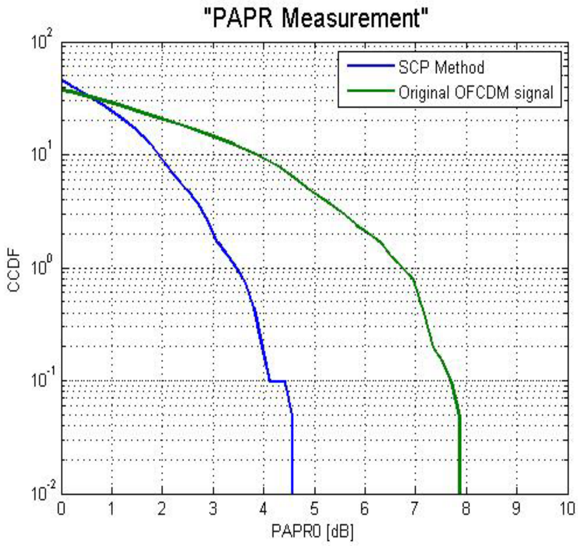

Chart -3 Result using QAM-16 Modulation

Up to 7 dB. From the graphs, it is clear that probability of PAPR being greater, in OFCDM is more as compared to SCP, means peak power of OFCDM symbols is greater than SCP symbols. So inter carrier interference power PICI is higher in OFCDM system than SCP system. Same is applicable for next two graphs, but due to application of different modulation schemes, amount of PAPR reduction is different. Here simulation is performed using above equations, by taking $\theta = 0^0$, Normalized frequency offset = 0.3, Number of subcarrier N is 52. Thus from the fig 9-11, it is clearly seen that BER performance of the proposed SCP scheme is better as compared to original OFCDM system, and it is also clear that

BER performance depends upon modulation scheme which is used to reduce the PAPR, thus if more PAPR get reduced, better BER performance will be. That is motive of proposed scheme.

8. CONCLUSIONS

In this paper, simulation has been performed for PAPR as well as bit error rate (BER). From the results, it is clear that, the proposed SCP technique gives lesser PAPR as compared to present in original OFCDM system. Reduction in PAPR means reduction in peak power, due to which, interference power of subcarrier decreases. When inter carrier interference

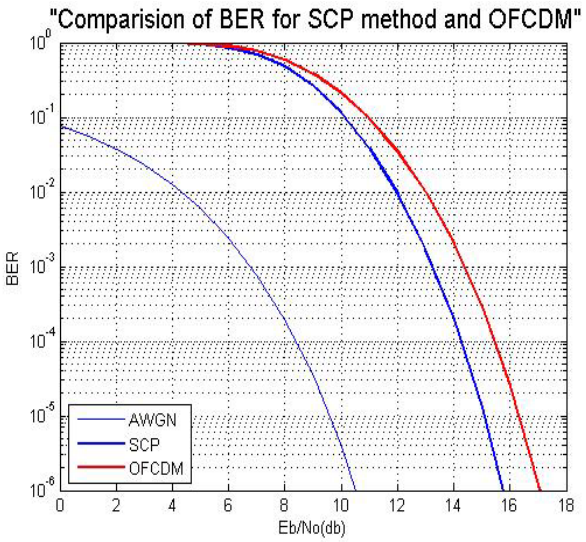

Chart -4 BER simulation result for PAPR reduction using BPSK modulation

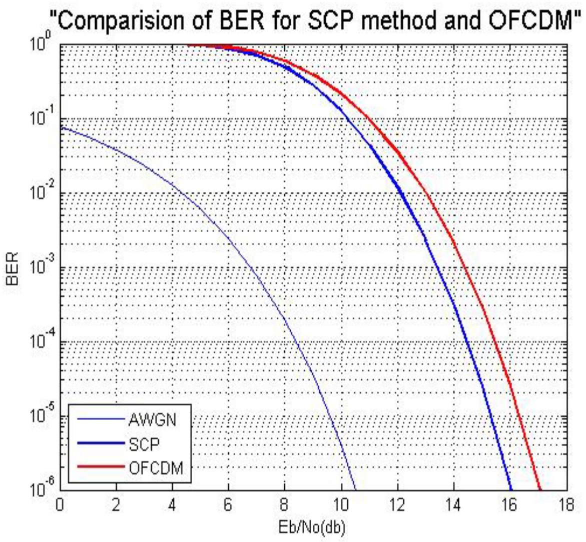

Chart -5 BER Simulation result for PAPR reduction using QPSK modulation

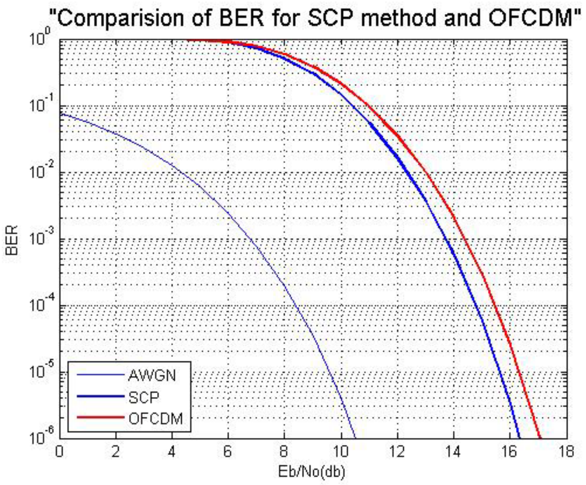

Chart -6 BER Simulation result for PAPR reduction using QAM-16

Modulation power decreases, then bit error rate (BER) decreases and then throughput of the system increases, which is desired for any communication system.

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