PAPR Reduction in OFDM Systems

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Abstract:*Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transmission method which is most widely used in the field of communication. One of the major drawbacks of this system is Peak to Average Power Ratio (PAPR). There are various methods introduced for the reduction of PAPR in OFDM system. However these techniques have major drawback that they cause non-linear in-band distortion and out-of-band radiation, this reduces the system throughput. Thus, SHIFTING AND SWITCHING OF NULL SUB-CARRIERS, which is the proposed technique discussed in our report overcomes this problem. In this technique, we replace some of the transmitted data symbols by nulls, i.e. we introduce errors in the transmitted signal. At the receiver, an iterative decoder is used to correct the transmitter and channel errors.*

Keywords:*OFDM, PAPR, Switching and Shifting of Null Sub-Carriers*

1. Introduction

After more than thirty years of research and development carried out in the field of communication OFDM has been widely implemented in high speed digital communication [1]. OFDM has its major benefits of higher data rates and better performance. The higher data rates are achieved by use of multiple carriers and performance improved by use of guard interval which leads to removal of Inter Symbol Interference (ISI) [2]. OFDM has several features which makes it more advantageous for high speed data transmission. These features include High Spectral Efficiency, Robustness to Channel Fading, and Immunity to Impulse Interference, Flexibility and Easy Equalization. In spite of these benefits there are some drawbacks such as PAPR, Offset frequency and Inter Carrier Interference (ICI) between sub-carriers [3]. It has been widely adopted in the international standards, such as IEEE 802.11, IEEE 802.15, IEEE 802.16, IEEE 802.20, European Telecommunications Standards Institute (ETSI) Broadcast

Radio Access Network (BRAN) committees, and 3G Long Term Revolution (LTE) [5].

When the OFDM signal's super-positioned sinusoidal subcarriershappen to be in-phase at the input of the transmitter's inverse fastFourier transform (IFFT) operator, these sinusoids would add constructively,producing a high magnitude at the IFFT operator output. For anysuch peak lying

in the power-amplifier's saturation region, the correspondingoutput signal would be nonlinearly distorted, spreading theOFDM signal's spectrum, causing in-band distortion and intermodulationinterference across the OFDM subcarriers. All these woulddegrade the bit error rate (BER) at the receiver [4].

In this paper, the PAPR problem has been reduced using Switching and Shifting of Null Sub-Carriers.

A.   Null Sub-Carriers in OFDM

The null sub-carriers are those carriers where no energy is transmitted. The IEEE 802.11astandard is used which mandates 48 data-subcarriers plus 12 null subcarriers [5]:
(i) Six null subcarriers to serve as guard-band at the low-frequency edgeof the spectral band of the subcarriers
(ii) Five null subcarriers to serve as guard-band at the high-frequency edge
(iii) One mid-band null subcarrier (indexed 0) to avoid direct-current(DC) energy.

B.   Introduction to OFDM Systems

An OFDM symbol consists of N subcarriers by the frequency spacing of Δf. Thus, thetotal bandwidth$B$ will be divided into$N$equally spaced subcarriers and all the subcarriers areorthogonal to each other within a time intervalof length$T = 1/\Delta f$. Each subcarrier can be modulated independently with the complex modulation symbol $X_{m,n}$, where m is a time indexand n is a subcarrierindex. Then within the time interval T the

following signal of the mth OFDM block period can be described by equation(1) as:

$$x_m(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_{m,n} \, g_n(t - mT) \qquad (1)$$

Where, $g_n(t)$ is defined through equation (2).

$$g_n(t) = \begin{cases} \exp(j2\pi n \Delta ft), & 0 \le t \le T \\ o, & else \end{cases} \quad (2)$$

Where, $g_n(t)$ is a rectangular pulse applied to each subcarrier. The total continuous time signal $x(t)$ consisting of all the OFDM blocks is given by equation (3).

$$x_m(t) = \frac{1}{\sqrt{N}} \sum_{m=0}^{\infty} \sum_{n=0}^{N-1} X_{m,n} \, g_n(t - mT) \qquad (3)$$

Now, consider a single OFDM symbol ($m = 0$) without loss of generality. This can be shown because there is no overlap between different OFDM symbols.

Since, $m = 0$, $X_{m,n}$ can be replaced by X_n. Then, the OFDM signal can be described as follows:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \, e^{(j2\pi n \Delta ft)} \qquad (4)$$

If the bandwidth of the OFDM signal is $B = N \times \Delta f$ and the signal $x(t)$ is sampled by the sampling time of

$$\Delta t = \frac{1}{B} = \frac{1}{N\Delta f}$$

Then the OFDM signal is in discrete time form and can be written as shown in equation (5).

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \, e^{j2\pi kn/N}, k = 0,1,\dots,N-1 \qquad (5)$$

Where, n denotes the index in frequency domain and X_n, is the complex symbol in frequency domain. Furthermore, equation (5) can be expressed using the IFFT [1]. Figure 1 shows a typical system block diagram of an OFDM system. The serial input databit stream is convertedto N parallel sub-channels `mapper), resulting in N sub-channels containinginformation in complex number form.
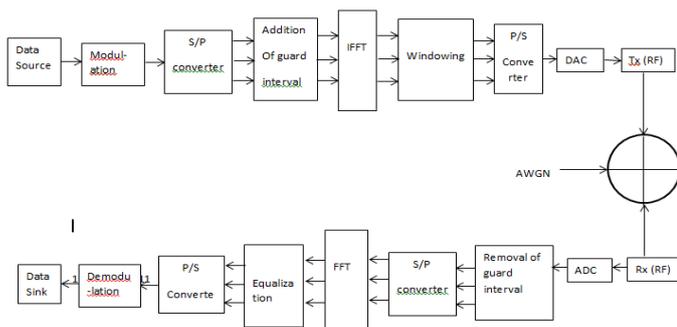
Figure 1: Block Diagram of OFDM Systems

These complex values are then sent to the N channel IFFT. Then, the parallel signals areconverted back to a serial sequence by using a P/S device. A guard interval is inserted to reducethe effect of ISI caused by multipathpropagation. Finally, the signal is converted toan analog signal and converted back up to aform suitable for transmission. At the receiver, a reverse procedure is used to demodulate theOFDM signal. In an OFDM system, only a simpleequalizer or more specifically, a single tap equalizer is needed at the receiver to removethe ISI.

C.   Peak to Average Power Ratio
        As explained earlier, one of the major drawbacks of OFDM is the very high peak-toaverage power ratio (PAPR). PAPR of OFDMincreases exponentially with the number of subcarriers.If power amplifiers are not operated with large power back offs, it is impossible tokeepthe out-of-band power below the specifiedlimits. This situation leads to very inefficient amplification and expensive transmitters, so it is highly desirableto reduce thePAPR. In this section, a detailed mathematical analysisfor PAPR is presented. The Root Mean Square (RMS) magnitude of the OFDM signal is defined as the root ofthe time average of the envelope power $\sqrt{P}$, where$P$ is defined by equation(6).

$$\bar{P} = \frac{1}{T} \int_{t=0}^{T} |x(t)|^2 \, dt = \frac{1}{N} \sum_{n=0}^{N-1} |X_n|^2 \qquad (6)$$

Where, $x(t)$ is the OFDM signal defined by equation (3). The value P in this case corresponds to a single OFDM symbol, and depends on the sequence of information carrying coefficients { X_n}. The average power of OFDM symbols can be written as $P_{av} = E\{P\}$. Thus, the PAPR of an OFDM signal can be defined as,

$$\xi = \frac{\max\limits_{t \in [0,T]} |x(t)|^2}{P_{av}}$$

$$= \frac{\max\limits_{t \in [0,T]} |x(t)|^2}{E\{|x(t)|^2\}} \qquad (7)$$

If the input data power is normalized, then $E\{|x(t)|^2\} = 1$, and we get,

$$\xi = \max_{t \in [0,T]} |x(t)|^2 \qquad (8)$$

$$\xi = \max_{t \in [0,T]} \left| \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi n \Delta ft} \right|^2 \qquad (9)$$

$$\le \frac{1}{N} \left| \sum_{n=0}^{N-1} X_n e^{j2\pi n \Delta ft} \right|^2 \qquad (10)$$

$$\le N \qquad (11)$$

It clearly shows that the maximum PAPR is equal to the number of subcarriers N. For M-PSK modulation, there are only M^2 sequences having maximum PAPR N as describedin [6].This means, the number of sequences that givesvery high PAPR is not very high. If the numberof sub-channels increases,

the ratio of the sequencethat gives very high PAPR and all distinctsequences decreases rapidly.

The overallnumber of distinct sequences for the N subcarrier OFDM system with *M-PSK*isM^N. Thus theratio can be obtained by equation (12) and (13) as [5]:

$$R = \frac{M^2}{M^N} \qquad (12)$$

$$R = M^{2-N} \qquad (13)$$

2. Peak To Average Power Ratio

A. PAPR Problem

One of the new problems emerging in OFDM systems is the so-called Peak to Average Power Ratio (PAPR) problem. The input symbol stream of the IFFT should possess a uniform power spectrum, but the output of the IFFT may result in a non-uniform or spiky power spectrum. Most of transmission energy would be allocated for a few instead of the majority subcarriers. This problem can be quantified as the PAPR measure. It causes many problems in the OFDM system at the transmitting end.

B. Effect of PAPR

There are some obstacles in using OFDM in transmission system in contrast to its advantages [3]:
(i) A major obstacle is that the OFDM signal exhibits a very high Peak to Average Power Ratio (PAPR).
(ii) Therefore, RF power amplifiers should be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region of the power amplifier causing signal distortion. This signal distortion introduces intermodulation among the subcarriers and out of band radiation. Thus, the power amplifiers should be operated with large power back offs. On the other hand, this leads to very inefficient amplification and expensive transmitters. Thus, it is highly desirable to reduce the PAPR.
(iii) These large peaks cause saturation in power amplifiers, leading to intermodulation products among the subcarriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR.
(iv) To reduce the PAPR, several techniques have been proposed such as clipping, coding, peak windowing, Tone Reservation and Tone Injection. But, most of these methods are unable to achieve simultaneously a large reduction in PAPR with low complexity, with low coding overhead, without performance degradation and without transmitter receiver symbol handshake.
(v) Complexity is increased in the analog to digital and digital to analog converter.

3. PAPR Reduction Techniques

The PAPR is considered as one of the major disadvantage in the multicarrier communication systems. In order to reduce and eliminate these problems many different methods are proposed. These methods are classified into various categories. All the proposed methods mainly aim at reducing the PAPR as much as possible and along with it they take care not to interrupt and disturb the other parts of the system. The

algorithms considered while reduction should not be complex and easily implementable. Following are the categories of PAPR reduction.

3.1. Transparent Methods

In this category the receiver does not know about the method that the transmitter has applied. The same thing takes place when it comes to the receiver. The transmitter also does not necessarily know about the method that the receiver is using.

3.1.1 Clipping

The technique with the lowest complexity is the clipping technique. In the clipping method, simply clip the high amplitude peaks. Some of these techniques use digital clipping, i.e. the signal is clipped at the output of the inverse discrete Fourier transform without any oversampling. This causes re-growth of the signal peaks after the subsequent interpolation. To avoid the signal re-growth some techniques clip the signal after interpolation and then use a filter to reduce the resulting out-of-band spectral leakage. In addition they cause peak re-growth and result in significant distortion of the wanted signal. The peak- windowing scheme presented in is one of the clipping techniques that try to minimize the out of band distortion by using narrowband windows.

3.1.2. Tone Reservation

In the tone reservation method [5] the orthogonality between the different subcarrier is exploited to generate the peak reduction signal. In the OFDM system not all subcarriers are used for data transmission. Some of them are reserved for the reduction signal. Due to the fact that all subcarrier are orthogonal the signal generated by the reserved tones does not disturb the data carrying tones. In the tone reservation method both transmitter and receiver know the set of data carrying subcarriers. The construction of the reduction signal can be done in different ways with different complexities. The PAPR reduction method using tone reservation method can be transformed into a convex optimization problem. Advantages of tone reservation include among other no side information and low complexity.

3.1.3. Active Constellation Extension

The active constellation extension method [5] proposed is an extension of the tone injection method for PAPR reduction. Here only the points at the constellation boundary have multiple representations and these points can be moved anywhere. The advantage with this method is that the decision regions for the receiver are not changing, so neither receivers nor the standard have to be changed. In systems that have very large constellations only a small part of the constellations is placed on the edges and there are fewer possibilities to move the points on the constellation boundaries, in these cases the reduction performance is low.

3.2. Non Transparent Methods

The transmitter or the receiver incorporates a method, to reduce PAPR that requires side information to be transmitted from one side to the other. Majority of the PAPR reduction algorithms are included in this category.

3.2.1. Coding Schemes

Different block coding methods [5] can be used to reduce the PAPR of OFDM system and different coding schemes are presented uses well-known block codes with constant-modulus

constellations, such as QPSK and M-PSK for PAPR reduction purposes. The basic idea is that the block codes are used to remove some constellation combinations that produce large peaks and the encoded system will have smaller peaks then the uncoded system. One of the major drawbacks of this method is that it severely reduces data rate in order to achieve a good PAPR reduction.

3.2.2. Tone Injection

The tone injection method for PAPR reduction [5] is presented. The reduction signal also uses the data carrying tones, i.e. both the reduction as well as data carrying signal uses the same frequencies. But at the same time the constellation size is increased so that each point in the original basic constellation can be mapped into several equivalent points in the expanded constellation. On the receiver side the point is brought back to the original position by a modulo operation after the FFT. This method is called tone injection because substituting the points in the basic constellation for the new points in the extended constellation is equivalent to inject a new tone of suitable frequency and phase in the multicarrier symbol. This method has a few drawbacks e.g. side information for decoding the signal is required on the receiver side and due to an extra IFFT operation it is more complex.

3.2.3. Phase Optimization Techniques

It was observed that we will get large PAPR values when symbol phases in the subchannels are lined up in such a fashion that results in a constructive superposition forming a peak in the discrete time signal. By rotating the channel constellations properly the peaks can be reduced. The partial transmit sequence optimization scheme [5] is such method.

i. Partial Transmit Sequence (PTS)

In partial transmit sequence [13] the data carrying subcarrier blocks is further divided into disjoint carrier sub-blocks and then phase transformation (phase rotation) is applied for each sub-blocks as seen in figure 5.1. A number of iterations are required to find the optimum phase rotation factor for different sub-blocks. Adaptive partial transmit sequence is proposed into reduce the number of iterations required to find optimum combination of factors for sub-blocks. Adaptive partial transmit sequence reduces the number of iteration by setting up a desired threshold and trial for different weighing factors until the PAPR drops under the threshold.
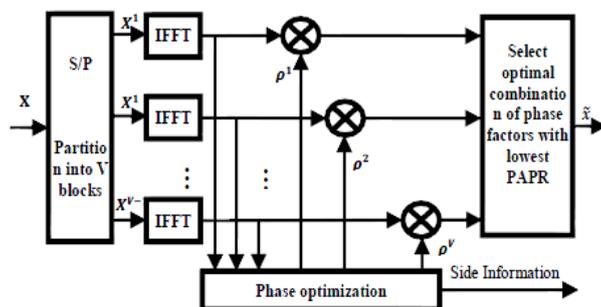
Figure 2: Block Diagram of Partial Transmit Sequence (PTS)

ii. Selective Mapping Scheme (SLM)

In the selective mapping method [5] one single data vector has multiple phase rotations, and the one that minimizes the signal peak is used as seen in figure 5.2. Information about which particular data vector and transformation was used is sent as side information to the receiver. In the presence of noise there can be a problem with decoding the signal Therefore, the ability of PAPR reduction in SLM depends on the number of phase factors and the design of the phase factors. Some extensions of SLM also have been proposed to reduce the computational complexity and number of the bits for side information transmission.
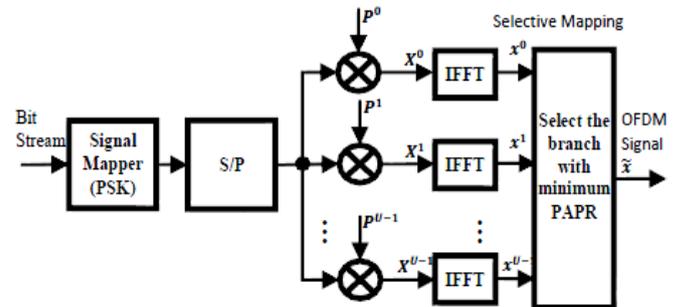
Figure 3: Block Diagram of Selective Mapping(SLM)

4. Proposed Techniques

As given above, the IEEE 802.11a standard [7] employs null sub-carriers at specific positions. In switching algorithm two null sub-carriers are switched with two other carriers which are carrying information. There are many combinations possible. We have to try all combinations in order to get minimum PAPR, which is our ultimate aim. Thus to get all combinations two nested 'for' loops are used. After each combination the PAPR is calculated and compared to the previously calculated PAPR value. Here the minimum PAPR value is retained (The PAPRmin value is initially set to 0 db.). After all combinations are exhausted we are finally left with one combination for a particular symbol which has the minimum PAPR value. This combination is later transmitted. This process is carried out for rest of the symbols.

A. Shifting Null sub-carriers

For 16-QAM, the total number of sub-carriers is 64. According to the IEEE 802.11a standard among the 64 sub-carriers- the first 6 sub-carriers, the last 5 sub-carriers and the sub-carrier at position '33' should all be null carriers. Apart from the null sub-carriers the remaining sub-carriers contain modulated data before introducing it to inputs of IFFT.

The fundamental concept of the Shifting algorithm is that the null sub-carriers are basically shifted to the positions of data sub-carriers. Now, all the null sub-carriers from either of the two sides – low frequency edge ('1 - 6') or high frequency edge ('60 – 64') - shouldn't be shifted because they also serve as guard band. Thus it is advisable to use only one null sub-carrier from each side of low frequency and high frequency edge. The null sub-carrier at position '33' shown below should be left unaltered since it serves to avoid DC energy.

According to the proposed Shifting method, the 6th null sub-carrier, from the low frequency edge is switched with every other data sub-carrier in positions '7 – 32' and the 60th null sub-carrier from the high frequency edge is switched with every other data sub-carrier in positions '34 – 59'. For every possible combination, the PAPR is calculated after the IFFT operation is performed using the new arrangement of data and

null sub-carriers. Among all the combinations, only that arrangement of data and null sub-carriers is selected for transmission which gives the least PAPR value. The purpose of shifting the null sub-carriers to positions of data sub-carriers is that the inputs to IFFT changes which in turn gives us different output and hence different PAPR values.

B. Implemented version of Shifting Null sub-carriers

According to the proposed method, the 6th null sub-carrier from the low frequency edge is switched with the 7th position which is a data subcarrier.

Then from the higher frequency edge the 60th null sub-carrier is switched with the 59th position data sub-carrier. IFFT operation is performed. PAPR is then calculated for this arrangement of data and null sub-carriers. This PAPR value is stored in a variable where only the minimum value is stored. This variable can be assumed as "minPAPR"

At next iteration of loop:

The 59th null sub-carrier is switched with the 58th position data sub-carrier. IFFT operation is performed. PAPR is then calculated for this arrangement of data and null sub-carriers. This PAPR value is stored in minPAPR only if it is less than the current minPAPR value.

At the last iteration of this loop:

From the higher frequency edge the 35th null sub-carrier is switched with the 34th position data sub-carrier. IFFT operation is performed. PAPR is then calculated for this arrangement of data and null sub-carriers. This PAPR value is stored in minPAPR only if it is less than the current minPAPR value.

The 7th null sub-carrier from the low frequency edge is switched with the 8th position which is a data subcarrier.

Then from the higher frequency edge the second loop runs for shifting the 60th null sub-carrier till it reaches position '34'. PAPR is calculated as described earlier.

At the end of the loop for low frequency edge (positions '7 – 32'), the 31st null sub-carrier from the low frequency edge is switched with the 32nd position which is a data subcarrier.

Then from the higher frequency edge the second loop runs for shifting the 60th null sub-carrier till it reaches position '34'. PAPR is calculated as described earlier.

The positions at which the null sub-carriers are shifted at both high and low frequency edge giving the minimum PAPR is stored. IFFT is calculated with null sub-carriers shifted to the respective position in both frequency edges. In the receiver end, the data sub-carriers are switched back to their respective positions and original data is recovered after zero padding is removed.

5. Simulation

To verify the proposed PAPR reduction technique, herein the IEEE 802.11a standard is used as an example, even though proposed method could be implemented in any multi-carrier system with null-subcarriers. And the simulation is based on the assumption that the spectrum will not be changed after the shifting of null-subcarriers (shifted null-subcarriers are in the transition-band of the transmit spectrum mask). We consider the number of subcarriers in an OFDM system equals 64 with QPSK data symbols, where $L - N = 48$ is the number of data-subcarriers, and P is the

number of null-subcarriers used for PAPR reduction. To minimize possible degradation to the guard-bands, we use the "innermost" null-subcarrier(s) at low frequency edge or high-frequency edge. The 64 subcarriers are divided into 8 sub-blocks with 4 times oversampling [5]. In order to generate the Complementary Cumulative Distribution Function (CCDF) of the PAPR, 10_5 OFDM data-blocks are generated randomly. For the "Simplified" version, the signal block is partitioned into $V = 8$ sub-blocks, and only the sub-block with the largest PAPR undergoes the proposed shifting scheme.

Simulation Results

- **BER Comparison**

Eb/N0 is commonly used with modulation and coding designed for noise-limited rather than interference-limited communication, since additive white noise (with constant noise density N0) is assumed. The graph shown below, figure 7.7, plots the probability of bit error at particular Eb/N0 points. One can use this graph to check whether the BER levels are within the acceptable range for the application to be used in.
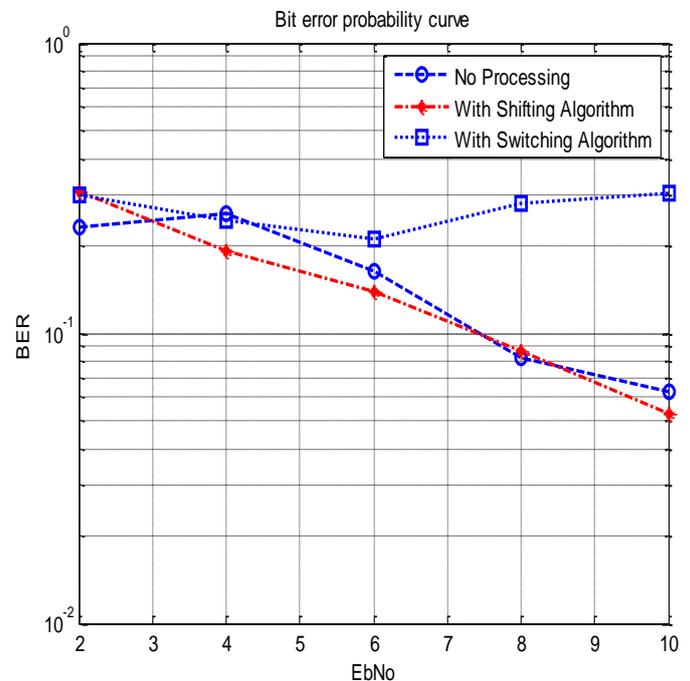
Figure 4: BER Comparison of Implemented Results

- **PAPR Comparison**

This is a CCDF graph, figure 7.8, which shows the maximum probability of PAPR which can be reached at any given dB level. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold.The horizontal and vertical axes represent the threshold for the PAPR and the probability that the PAPR of a data block exceeds the threshold, respectively.It is shown that the unmodified OFDM signal has a PAPR that exceeds 8.2 dB for less than 0.1 percent of the data blocks for 64 sub-carriers. In this case, we say that the 0.1 percent PAPR of the unmodified signal is 8.2dB. But with algorithm it's approximately 5.35 dB for a random set of inputs.

OFDM system with sub-carrier shifting
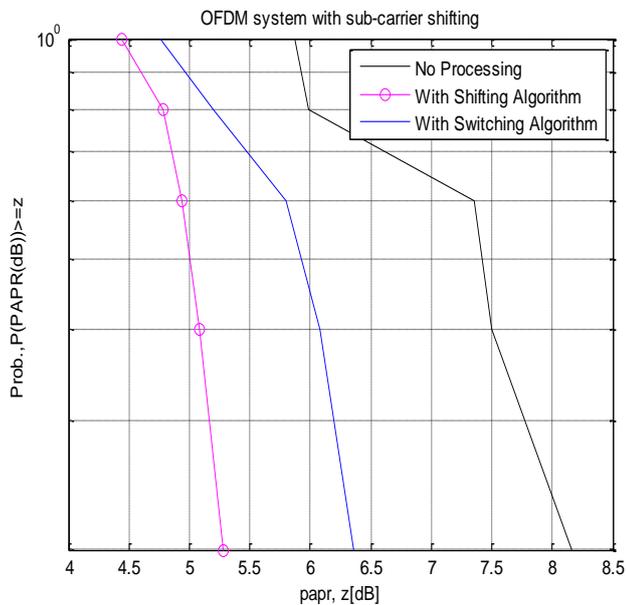
Figure 3: PAPR Comparison in a CCDF Graph

7. Conclusion

To reduce the PAPR of multi-carrier transmission, this proposed scheme reorders the null-subcarriers and data-subcarriers. This new method shifts the "innermost" null sub-carriers among different data-subcarriers to minimize the PAPR. The proposed method is distortion less, does not affect the constellation at the data-subcarriers, maintains better PAPR reduction and BER reduction performance while keeping low computational complexity, needs less CSI, can collaborate with most other PAPR-reduction methods, and can be compatible with existing standards. The Shifting/Switching method can also be coupled with other PAPR reduction techniques since the conventional methods do not alter the null sub-carriers which are used in the shifting process.

References

[1] P. Foomooljareon and W.A.C. Fernando,"PAPR Reduction in OFDM Systems", Thammasat Int. J.Sc. Tech, vol.7, No.3, September-December 2002.

[2] W. Aziz, E. Ahmed, G. Abbas, S. Saleem and Q. Islam,"PAPR Reduction in OFDM using Clipping and Filtering", World Applied Sciences Journal 18 (11): 1495-1500, ISSN 1818-4952,2012.

[3] ArunGangwar and ManushreeBhardwaj,"An Overview: Peak to Average Power Ratio in OFDM system & its Effect", International Journal of Communication and Computer Technologies vol. 01 – 02, Issue: 02 (IJCCT), ISSN NUMBER: 2278-9723, September 2012

[4] K. T. Wong, B. Wang and J. C. Chen,"OFDM PAPR reduction by switching null subcarriers and data-subcarriers", Electronics Letters,Vol. 47 No. 1, January 6, 2011.

[5] Bo Wang, Pin-Han Ho and Chih –HaoLin,"OFDM PAPR Reduction by Shifting Null Subcarriers Among Data Subcarriers", IEEE COMMUNICATIONS LETTERS, Vol. 16, No. 9, SEPTEMBER 2012

[6] Dieter Van Welden and Heidi Steendam,"PAPR Reduction by Symbol Nulling".

[7] Tao Jiang and YiyanWu,"An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals", IEEE Transactions on Broadcasting, vol. 54, NO. 2, June 2008.,

[8] S. Janaaththanan, C. Kasparis, and Barry G. Evans, "A Gradient Based Algorithm for PAPR Reduction of OFDM using Tone Reservation Technique", Published in IEEE2008.

[9] AshishGoel, "Improved PAPR Reduction in OFDM Systems", Thesis Submitted to Jaypee Institute of Information Technology University September 2012.

[10] V. Vijayarangan and DR.(MRS) R. Sukanesh, "An Overview Of Techniques For Reducing Peak To Average Power Ratio And Its Selection Criteria For Orthogonal Frequency Division Multiplexing Radio Systems", Journal of Theoretical and Applied Information Technology (JATIT),2005 – 2009.

[11] Rajesh S. Bansode, Dr. B. K. Mishra and Aqsa M. Temrikar, "Hardware Implementation of OFDM system to reduce PAPR using Selective Level Mapping on FPGA", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735. vol. 7, Issue 1, PP 05-11, July - August 2013.

[12] Thomas G. Pratt, Nathan Jones, Leslie Smee, and Michael Torrey, "OFDM Link Performance with Companding for PAPR Reduction in the Presence of Non-Linear Amplification", Based upon work supported by The National Science Foundation under Grant No. 0121565.

[13] SauravGhosh, Subhrajit Roy, Swagatam Das, Ajith Abraham and Sk.MinhazulIslam,"Peak-to-Average Power Ratio Reduction in OFDM Systems Using an Adaptive Differential Evolution Algorithm", Published in 978-1-4244-7833-0/11, IEEE 2011.

[14] C. Raja Rajeshwari and K. Manojkumar,"An Enhancement of Peak to Average Power Ratio Reduction in OFDM Using CAP-PT Method", International Journal of Modern Engineering Research (IJMER), vol.2, Issue.5, pp-3699-3704, ISSN: 2249-6645, October-October 2012.

[15] Nick LaSorte, W. Justin Barnes and Hazem H. Refai, "The History of Orthogonal Frequency Division Multiplexing", IEEE Globecom 978-1-4244-2324-8,2008

[16] S.H. Han and J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," IEEE Wireless Communications, vol. 12, issue 2, pp. 56-65, April 2005.

[17] A. Peled and A. Ruiz, "Frequency domain data transmission using reduced computational complexity algorithms," In Proc. IEEE International Conference on Acoustics, Speech, and Signal Processing, vol. 5, pp. 964-967, April 1980.

[18] Leman Dewangan, Mangal Singh and NeelamDewangan,"A Survey of PAPR Reduction Techniques in LTE-OFDM System", International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, vol-1, Issue-5, November, 2012.

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