Abstract: Future wireless mobile systems are required to transport multimedia traffics at much higher bit rates. Multicarrier (MC) code division multiple access (CDMA) has emerged as a powerful candidate due to its capabilities of achieving high capacity over frequency selective fading channel. It inherits the substantial advantages from both the orthogonal frequency division multiplexing (OFDM) and code division multiple access (CDMA) systems. Although MC CDMA has lot of advantages but it comes with disadvantage of high Peak to average power ratio (PAPR). In this paper a comparison of filters are described which are used to reduce the peak to average power ratio in MC CDMA systems. The maximum PAPR and used pulse shaping filters are described and it is shown by computer simulation that the filtering scheme achieves the significant improvement in PAPR reduction in MC CDMA system. Its implementation complexity is much low in comparison to the previous published methods. The advantage of filtering technique is that there is no need of extra IFFTs in implementations.

Keywords: MC CDMA, PAPR, OFDM, BPSK
1. Introduction:

The next generation wireless communication systems (sometimes also referred as 4G systems or beyond 3G) are required to support multimedia services such as speech, audio, video, image and data at much higher transmission rate. Multi-carrier CDMA is a digital modulation technique where a single data symbol is transmitted at multiple narrowband subcarriers with each subcarrier encoded with a phase offset of 0 or π based on a spreading code. The narrowband subcarriers are generated using BPSK modulated signals, each at different frequencies which at baseband are at multiples of a harmonic frequency $1/T_b$. Consequently, the subcarriers are orthogonal to each other at baseband, and the component at each subcarrier may be filtered out by modulating the received signal with the frequency corresponding to the particular subcarrier of interest and integrating over a symbol duration. The orthogonality between subcarrier frequencies is maintained if the subcarrier frequencies are spaced apart by multiples of $F_{TB}$ where F is an integer. Throughout this paper, F, which will be used to describe the spacing between subcarrier frequencies for an MC CDMA signal, will be referred to as the F-parameter. The phase at each subcarrier corresponds to one element of the spreading code. MC-CDMA is a promising technique for fourth generation mobile communications. Its benefits are from 2 modulations. One is OFDM, a multicarrier modulation, which provides high data rate while symbol interval is kept long, resulting in its robustness of transmission in frequency selective fading channels, especially at high data rate mobile communications. The other is CDMA, which provides multiple access capability.

In MC-CDMA, instead of applying spreading sequences in the time domain, it applies them in the frequency domain, mapping a different chip of a spreading sequence to an OFDM subcarrier. Hence, each OFDM subcarrier has a data rate identical to the original input data rate and the multicarrier system absorbs the increased rate due to the spreading in a wider frequency band. The transmitted signal of the kth user $s_k(t)$ is written as [1]

$$s_k(t) = \sum_{n=0}^{N-1} b_k c_k e^{j2\pi(f_0+nf_d)t} \quad \text{(1.1)}$$

Where $N$ is the number of subcarriers, $b_k$ is the source symbol of the kth user with the data duration $T_b$, $c_k$ is the spreading sequence for the kth user, $f_0$ is the lowest subcarrier frequency, $f_d$ is subcarrier separation.
If $\frac{1}{t_b}$ is used for $f_d$, the transmitted signal can be generated using the IFFT, as in the case of an OFDM system. The overall transmitter structure is implemented by concatenating a DS-CDMA spreader and an OFDM transmitter, as shown in Fig.2.3. The rate of the serial data symbols is $\frac{1}{t_b}$.

In the transmitter, the complex-valued data symbol $b_k$ is spread in the time domain by the user specific spreading sequence with the spreading gain equal to the number of subcarriers, i.e., $L = N$.

**2. Related Work:**

A lot of research has already been done on PAPR reduction in MC CDMA systems. In 1997, Hideki Ochiai and Hideki Imai gave a block coding scheme based on complementary sequences to reduce the PAPR of multicarrier signals, and evaluated over a nonlinear channel[2]. In 1997, author Branislav M. Popovic gave a technique for the selection of spreading sequences for the Multi-Carrier CDMA (MC-CDMA) systems with spectrum spreading in the frequency domain. Author have shown that the time domain cross correlation function between the spreading sequences is not a proper interference measure for the asynchronous MC CDMA users. Therefore the spectral correlation function is introduced and, together with the peak-to-average power ratio and the dynamic range of the corresponding multicarrier waveforms, is used for the evaluation of MC CDMA sequences. Some well-known classes of sequences, such as Walsh and Gold sequences, as well as Orthogonal Gold and Zadoff-Chu sequences, are evaluated with respect to the aforementioned basic criteria. It is also shown that the multicarrier spread spectrum waveforms based on the (multilevel) Huffman sequences have the lower PAPR than a single sine wave [3]. To reduce the PAPR, many techniques are proposed. The first one is the signal...
distortion technique, which introduces distortion to signals and causes degradation in the performance including clipping, windowing, peak cancelling or companding. In companding technique, compression in transmitter and expanding in receiver has been proposed by Wang et al. Clipping is simple and effective and causes In-Band-distortion and increased BER. The companding transforms’ performance is better and reduces distortion than to that of the clipping. Another proposal by Yuan Jiang is an algorithm that uses the special airy function and is able to provide an improved Bit Error Rate (BER) and minimized Out of Band Interference (OBI) in order to reduce PAPR effectively [4]. In 2000 scientists Hyo-Joo Ahn; Yoan Shin; Sungbin Im have presented new block coding scheme for reduction of peak-to-average power ratio (PAPR) of an orthogonal frequency division. Multiplexing (OFDM) system. the proposed scheme significantly improves bit error rate performance as compared to an uncoded system when an HPA is employed[5]. In 2004 authors proposed a modified PTS scheme for PAPR reduction. A modified PTS scheme for uplink communications is proposed, in contrast to the original PTS, which is generally applied in the downlink in an OFDM system. While successfully reducing PAPR, PTS alters the code correlation property which affects bit error rate when applied to the MC-CDMA system uplink [6]. In 2007 than other scientists Jizeng Wang, Jingyu Luo and Yanlong Zhang tried to reduce PAPR by a new phase sequence for SLM in MC CDMA system. A new Pseudo Random Interferometry code is proposed as the phase sequence for SLM to reduce PAPR of MCCDMA. the proposed sequence is more effective for PAPR reduction in MC-CDMA system compared with Walsh-Hadamard sequence and Golay sequence [7]. In 2010 scientists R.Manjith, S.C.Ramesh, and M.Mohamed Ismail Majeed have described Non linear companding techniques for PAPR reduction in OFDM and MC CDMA systems. Nonlinear companding technique adjust both large and small signals and can keep the average power at the same level. In addition, the schemes based on nonlinear companding techniques have low implementation complexity and no constraint on modulation format and sub-carrier size [8]. In 2011 the scientists Montadar Abas Taher, JS Mandeep, Mahamod Ismail, Hussain Falih Mahdi, Have proposed a novel algorithm to enhance the PAPR of MC CDMA system. The algorithm called Half Length Phase Updating ' (HLPU), it is called half because the phase updating will be applied to only half of the IFFT length (N / 2). The HLPU will be predefined even one bit of side information from the transmitter to the receiver. This additional block in the system will be inserted before the Inverse Fast Fourier Transform (IFFT) of the Multicarrier Code Division Multiple Access (MC CDMA) system. The simulation results proved that there is 94.2% reduction in the system complexity and a reduction in the PAPR of around 2 dB has been
obtained [9]. In 2012 authors M. F. Ghanim and M. F. L. Abdullah gives a PAPR reduction method using single carrier FDMA. They presents a novel MCCDMA which has low peak to average power ratio (PAPR). The system is designed by combining MC-CDMA with the Single carrier-frequency division multiple access (SC-FDMA) because the later has low PAPR [10].

3. Problem Formulation:

Although, combining the benefits of systems based on multi carrier transmission (such as OFDM) and CDMA multiple access, raised the idea of proposing the MC-CDMA techniques as an interesting candidate for the next generation mobile communication networks (4G), however a significant problem raises in MC which is the possibility of high peak to average ratio in transmitting signals. This means the necessity of increasing the dynamic range of the linear amplifiers or, in the case of using more efficient nonlinear amplifiers, the peak of signal may be clipped. The latter (clipping) yields an undesirable inter-carrier interference and out-of-band radiation and results in system performance degradation. Due to the strict requirements of low power consumption and low complexity at the mobile terminal, PAPR is a very critical issue especially in uplink transmissions. Peak to Average Power Ratio (PAPR) defined as:

\[
\text{PAPR}\{s(t)\} = \frac{\max[|s(t)|^2]}{E[|s(t)|^2]} \quad (3.1)
\]

Where \(E[\cdot] \) denotes the expectation. To get an accurate measure for the PAPR, the signal will be oversampled by a factor of 4. By this up sampling factor, all the PAPR will be taken. Good way to measure the PAPR is by using its complementary cumulative distribution function (CCDF). The CCDF can be defined as,

\[
\text{CCDF}(PAPR) = \Pr(PAPR > PAPR_0) \quad (3.2)
\]

For practical purposes, it is possible to distinguish between the PAPR of pass band and band pass signal. As derived in [11], the PAPR of real pass band signal is twice the PAPR of corresponding complex envelope. For realistic PAPR CCDF results, the oversampling (usually by zero-padding in the frequency domain) of multicarrier modulation signal is necessary [11]. The oversampling has been used thorough all the experiments described below. The influence of oversampling on CDF and CCDF plots for the case of OFDM system
with 64 subcarriers is given by following expression. Note the following relationship between CCDF and CDF:

$$CCDF_{PAPR} = 1 - CDF_{PAPR} \quad (3.3)$$

4. The Proposed Method:

In MC CDMA system pulse shaping is the usage of time waveforms of the different subcarriers to create the appropriate correlation that reduces the PAPR of the multicarrier signal. By using this technique it is possible to design a set of time waveforms of MC CDMA systems that decreases the peak power of the transmitted signal and improve its power spectrum simultaneously. The filtering method avoids the use of an extra Inverse Fast Fourier Transformations (IFFTs). It works with arbitrary number of subcarriers for any type of base band modulation used. The implementation complexity of the suggested technique is by far much low compared to previously established methods. This proposed method has the potential of reducing the PAPR of the MC CDMA signal without affecting the bandwidth efficiency of the system. In MC CDMA spectrum each carrier consists of a main lobe followed by a number of side lobes with reducing amplitude. As long as orthogonality is maintained, there is no interference among the carriers because at the peak of the every carrier, there exists a spectral null. At that point the component of all other carriers is zero. Hence the individual carrier is easily separated. But due to the carrier frequency offset orthogonality is lost, now spectral null does not coincide to the peak of the individual carriers. So some power of the side lobes exists at the centre of the individual carriers which is called ICI power. The ICI power will go on increasing as the frequency offset increases which, degrades the performance. ICI mitigation techniques are essential in improving the performance of an MC CDMA system is an environment which induces frequency offset error.

The PAPR performance can be improved by using Nyquist pulse. a possible solution to reduce the PAPR is to create some correlation between the different MC CDMA samples. By increasing cross correlation a multicarrier signal with very low PAPR can be obtained.

$$C(t_1,t_2) = \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} E [d_n d_m^*] U_n(t_1) U_m^*(t_2) \exp\left\{\frac{j2\pi(nt_1-mt_2)}{T}\right\} \quad (4.1)$$
Where $C(t_1, t_2)$ is cross correlation function at time instants $t_1 and t_2$, $N$ is no. of orthogonal subcarriers, $d_n$ and $d_m$ are modulated data symbols. $U_n$ and $U_m$ are pulse shapes of duration $T$ used at subcarriers $f_n$ and $f_m$ respectively.

I have compared performance of three filters that are Raised cosine, Nyquist and Rectangular Filter for PAPR reduction in MCCDMA systems.

### 4.1. Raised Cosine Filter:

The Raised Cosine Transmit Filter block upsamples and filters the input signal using a normal raised cosine FIR filter or a square root raised cosine FIR filter. The Filter type parameter determines which type of filter the block uses; choices are Normal and Square root. The impulse response of a normal raised cosine filter with rolloff factor $R$ and symbol period $T$ is

$$h(t) = \frac{\sin(\pi T/T)}{\pi T/T} \frac{\cos(\pi R t/T)}{1 - 4R^2 t^2/T^2}$$

(R is roll off factor and T is symbol period. The impulse response of a square root raised cosine filter with roll off factor $R$ is

$$h(t)=4R\cos\left(\frac{(1+R)\pi t}{T}\right) + \frac{\sin(1-R)\pi t/T}{4RT/T}\pi\sqrt{T}\left(1 - \left(\frac{4RT}{T}\right)^2\right)$$

(The impulse response of a square root raised cosine filter convolved with itself is approximately equal to the impulse response of a normal raised cosine filter. The Group delay parameter is the number of symbol periods between the start of the filter's response and the peak of the filter's response. The group delay and the upsampling factor, $N$, determine the length of the filter's impulse response, which is $2 * N *$ Group delay + 1. The Rolloff factor parameter is the filter's rolloff factor. It must be a real number between 0 and 1. The rolloff factor determines the excess bandwidth of the filter.

### 4.2. Nyquist Filter:

Nyquist filters replace raised cosine filters for a fraction of the cost because they have an optimal equiripple response. The same stop band attenuation and transition width can be obtained with a much lower order. The transition width requirement can be deduced from the roll-off and interpolation factors. An important characteristic of Nyquist filters is that along
with its shifted versions by a factor of k/L, L being the band and k = 1,2,...,L-1 should all add up to a delay, i.e. they form a set of strictly complementary filters.

4.3. Rectangular Filter:

The Rectangular Pulse Filter block upsamples and shapes the input signal using rectangular pulses. The block replicates each input sample N times, where N is the Pulse length parameter. After replicating input samples, the block can also normalize the output signal and apply a linear amplitude gain. If the Pulse delay parameter is nonzero, then the block outputs that number of zeros at the beginning of the simulation, before starting to replicate any of the input values. This block accepts a scalar, column vector, or matrix input signal. The vector size, the pulse length, and the pulse delay are mutually independent. They do not need to satisfy any conditions with respect to each other.

Generated set of pulses:

\[ U_n(t) = 0, \quad \left| t - \frac{T}{2} \right| > \frac{T}{2} \quad (n = 0,1 \ldots \ldots N - 1) \quad (4.4) \]

\[ U_m(t) = e^{j2\pi mT} = S_i(t - z_{m-i})e^{j2\pi T(t-z_{m-i})} \quad (4.5) \]

Where \( z_{m-i} [(m - i) \mod N] T_s \). Then PAPR becomes

\[ PAPR = \frac{1}{N} \max_{0 \leq t \leq T} \left( \sum_{m=0}^{N-1} |U_m(t)| \right)^2 \]

\[ \leq \frac{1}{N} \left( \max_{0 \leq t \leq T} \sum_{m=0}^{N-1} |U_m(t)| \right)^2 = N \quad (4.6) \]

5. Simulation Results:
For this purpose I have designed a routing environment which involves a medium to transmit the signal. CDMA signal has been picked from the communication toolbox. To generate multicarrier CDMA we need to put interleaver into it which interleaves the data. The Random Interleaver block rearranges the elements of its input vector using a random permutation. This block accepts a column vector input signal. The Number of elements parameter indicates how many numbers are in the input vector.

After generation of MC CDMA signal there is need for modulation. I have used the BPSK modulation technique. The BPSK Modulator Baseband block modulates using the binary phase shift keying method. The output is a baseband representation of the modulated signal. This block accepts a column vector input signal. The input must be a discrete-time binary-valued signal. If the input bit is 0 or 1, respectively, then the modulated symbol is exp(jθ) or -exp(jθ), respectively, where θ represents the Phase offset parameter.
Figure 4 describes the BER v/s Signal to Noise ratio for different filters. As observed from the figure the theoretical BER for MC CDMA signal decays exponentially between 0 to 10 db but its simulated value remains constant in the entire range.

5.1. Main Parameters Used In Simulations:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specifications</th>
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</thead>
<tbody>
<tr>
<td>Filter order</td>
<td>20</td>
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<tr>
<td>Roll off factor (α)</td>
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<tr>
<td>Signal Constellation</td>
<td>BPSK</td>
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<tr>
<td>Group delay</td>
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<tr>
<td>Number of samples</td>
<td>5</td>
</tr>
<tr>
<td>Channel</td>
<td>AWGN</td>
</tr>
</tbody>
</table>

*Table 1: simulation parameters for Raised Cosine Filter*

It is observed that by using raised cosine filter PAPR is obtained near about 8.7 db, and original MC CDMA has PAPR value of 13.8 db. So near about 5 db reduction in PAPR is obtained by using raised cosine filter.
Table 2: simulation parameters for rectangular filter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Constellation</td>
<td>BPSK</td>
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<tr>
<td>Channel</td>
<td>AWGN</td>
</tr>
<tr>
<td>Number of data points</td>
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</tr>
<tr>
<td>Number of bits</td>
<td>10,000</td>
</tr>
<tr>
<td>Number of samples</td>
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</tr>
<tr>
<td>Oversampling factor</td>
<td>4</td>
</tr>
</tbody>
</table>

![PAPR Graph](image)

Figure 6: PAPR Reduction by using rectangular filter

As observed from figure 6 near about 2.3 db reduction in PAPR is obtained by using rectangular filter.

Table 3: simulation parameters for Nyquist Filter.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
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<td>Filter order</td>
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<tr>
<td>Signal Constellation</td>
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<tr>
<td>Band</td>
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<tr>
<td>Roll off factor</td>
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</tr>
<tr>
<td>Transition bandwidth</td>
<td>.016</td>
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<tr>
<td>Number of samples</td>
<td>5</td>
</tr>
<tr>
<td>Oversampling factor</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure 7: PAPR Reduction by using Nyquist Signal

Figure 8: Comparison of all the filters based on PAPR reduction

Figure 8 shows the comparison of three filters based on their performance to reduce the PAPR in MC CDMA systems. It observed that the maximum reduction in PAPR is obtained by using Nyquist filter. Approximately 6.7 db PAPR is obtained by using Nyquist filter which is considerable reduction over PAPR value of original MC CDMA signal. PAPR comparison table is given below.

<table>
<thead>
<tr>
<th>Filter used</th>
<th>Obtained PAPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original MC CDMA signal</td>
<td>13.5 db</td>
</tr>
<tr>
<td>Rectangular Filter</td>
<td>11 db</td>
</tr>
<tr>
<td>Raised cosine Filter</td>
<td>8.7 db</td>
</tr>
<tr>
<td>Nyquist Filter</td>
<td>6.7 db</td>
</tr>
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</table>

Table 4: obtained PAPR values of all the filters
6. Conclusions:

In this paper a filtering method is described for PAPR reduction in MC CDMA system. In this method three different filters are described for PAPR reduction in MC CDMA and all the filters are compared based on their performance to reduce the PAPR in MC CDMA systems.

It is shown by simulation that the proposed method can achieve significant improvement in PAPR reduction in MC CDMA system. As the better pulse achieves better the performance in PAPR is obtained. The proposed technique is very effective and flexible for any number of carriers. Although a lot of filter algorithms are already working to reduce the PAPR in any modulation or channel estimation technique. In our approach we have applied three different levels of filter Raised Cosine, Nyquist and Rectangular filter out of which Nyquisit filter is found a better than other filters in terms of find the probabilities of PAPR and reducing it. which is near about 13.5 db.

There is to be lot to done in the term of reduction of PAPR with MC CDMA and OFDM techniques. The future researcher can try their hand in combining two filters simultaneously and also as the time trend is going on Neural Networks can not be ignored. If any researcher can find a way to combine any filter with neural network, than research would be definitely better than current scenario.

References:
1. N. Yee, J.P.Linnartz, Multi-Carrier CDMA in an Indoor Wireless Radio Channel, Univ. of California at Berkeley, Berkeley, California 94720.


