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Comparative Research Analysis on LTE Techniques to Reduce PAPR in Multi-Carrier Communication Systems

Ritu
Matu Ram Institute of Engineering & Management, Rohtak
ritukhatri0912@gmail.com

Tajendar Malik
Matu Ram Institute of Engineering & Management, Rohtak
tajendarmalik@gmail.com

Abstract:** New technologies emerging day by day and main focus to give a better quality of service at low cost. LTE has adopted DFT-spread OFDMA technique as the uplink multiple access schemes which use single carrier modulation and frequency domain equalization. In our research work, we show the PAPR performance of DFT-spreading technique. The performance of PAPR of DFT spreading technique is dependent on the number of subcarriers assigned to each user. In this thesis, a method for PAPR reduction in LTE system has been introduced, which is based on the DFT spread method. DFT spread method is further classified into two methods known as LFDMA (localized FDMA) and IFDMA (interleaved FDMA). It was shown that an interleaved FDMA and localized FDMA perform better than orthogonal FDMA in the uplink transmission where transmitter power efficiency is of great importance in the uplink. LFDMA and IFDMA result in lower average power values due to the fact that OFDM and OFDMA map their input bits straight to frequency symbols where LFDMA and IFDMA map their input bits to time symbols. We conclude that single carrier-FDMA is a better choice on the uplink transmission for cellular systems. Our conclusion is based on the better efficiency due to low PAPR and on the lower sensitivity to frequency offset since SC-FDMA has a maximum of two adjacent users. From results, it can also be concluded that the performance of IFDMA is far better than the LFDMA.

***Keywords:** PTS, Tone Injection, Tone Reservation, Orthogonal, Interleaved, LTE, Localized, QAM, Mapping*

I. INTRODUCTION

The use of a large number of subcarriers introduces a high PAPR in OFDM systems. PAPR can be defined as the relationship between the maximum power of a sample in a transmit OFDM symbol and its average power:

$$PAPR = 10\log_{10}\frac{P_{peak}}{P_{average}}\,(dB)$$

Where P_{peak} and $P_{average}$ are the peak and average power of a given OFDM symbol.

The same definition of PAPR is applied to MIMO-OFDM systems. A high PAPR appears when a number of subcarriers of a given OFDM symbol is out of phase with each other [6, 8, 10, 13]. Figure 1 shows the time domain representation of the 3 subcarriers of an OFDM symbol. The right column indicates that the subcarriers are out of phase, which causes an increase in PAPR of about 2.5 dB compared to the subcarriers in the left column. Depending on the out-of-phase amount per subcarrier, the PAPR can vary up to it's theoretical maximum of $10\log_{10}(N)$ (dB), where N is the number of subcarriers. In Figure 1, the 3 subcarriers reach their minimum amplitude at the same time, causing a large negative overshoot in the resulting composite OFDM signal. Nonlinear devices such as high power amplifiers (HPA) and digital to analog converters (DAC) exist in almost all communication links and demand for data transmission over longer ranges [1]. At the same time higher power efficiency of the amplifiers, require the amplifier to operate in a more non-linear region, In general, there is a trade off between linearity and efficiency.
In single-carrier modulation the signal amplitude is somehow deterministic, except for the pulse shaping filter effect, so the operating point in the amplifier can be determined accurately without destructive nonlinear impairments. But in the multi-carrier systems like OFDM, the envelope of the time domain signal will change with different data symbols [11-12]. Accordingly, the input power amplitude will change with a noticeable variance in specified operating point and the nonlinearity effect causes

distortion. Distortion acts as noise for the receiver, and also the signal constellation rotates due to phase conversion. Moreover, the out-of-band distortion of subcarriers is the result of non-linearity impairments, which causes cross talk since the subcarriers are not orthogonal anymore [5]. To estimate the distortion which is caused by non-linearity, it is desired to have a measure of the signal to show its sensitivity to non-linearity. A well-known measure for the multi-carrier signals is peak to average power ratio (PAPR). The higher the PAPR, the more fluctuation in the signal amplitude, so the operating point in the amplifier needs to be set far enough from saturation point and this input back off reduces the efficiency.

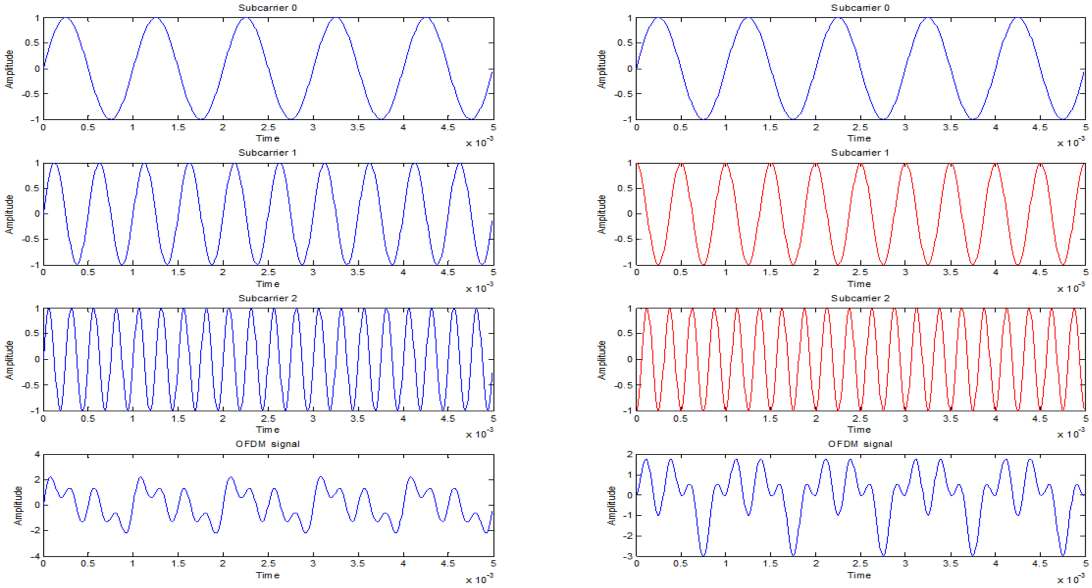

Figure 1 Simple illustration of PAPR in an OFDM symbol

II. LITERATURE SURVEY

PAPR reduction is a well-known signal processing topic in multicarrier transmission and a large number of techniques appeared in the literature during the past decades. These techniques include amplitude clipping and filtering, coding, tone reservation (TR) and tone injection (TI), active constellation extension (ACE) and multiple signal representation methods such as partial transmit sequence (PTS), selected mapping (SLM) and interleaving [17-18]. The existing approaches are different from each other in terms of requirements, and most of them enforce various restrictions to the system. Therefore, careful attention must be paid to choose a proper technique for each specific communication system. In this section, we focus more closely on the PAPR reduction techniques for multicarrier transmission. Some of the techniques are explained below:

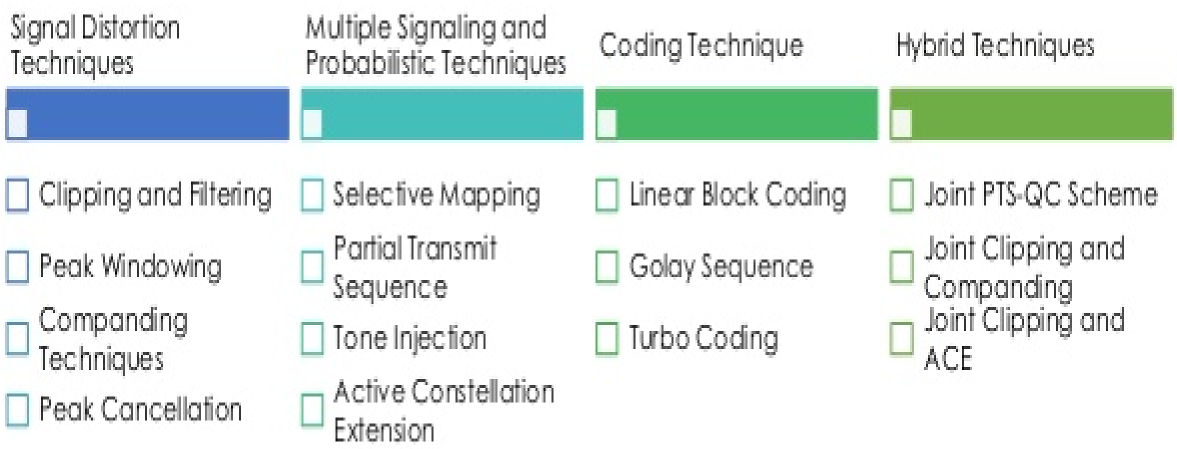

Figure 2 List of PAPR techniques

Time-domain signal clipping: Reduction of the PAPR can be achieved by clipping the time-domain of the OFDM signal in conjunction with signal filtering and distortion control. This technique does not require any redundancy or side information; hence no reduction in the system's data throughput. However, the filter and distortion control must be well-tuned in order to avoid introducing excessive inter-symbol interference (ISI) between the transmit symbols.

Selected mapping: The selected mapping (SLM) technique is an efficient approach for PAPR reduction. SLM generates statistically independent sequences from the same input and side information in order to transmit with the lowest PAPR. This leads to significant PAPR reductions. However, it turns out that a straightforward application of SLM to OFDM/MIMO-OFDM systems requires a high level of complexity. Some variants of SLM have been proposed to avoid the SLM algorithm's high level of complexity, such as decomposed individual SLM (D-ISLM) and decomposed concurrent SLM**.**

The tone reservation technique: The tone reservation (TR) technique is a simple and efficient way to reduce PAPR. The main advantages of the TR technique are no side information and less complexity when compared to the SLM technique. The drawback of the TR is dedicated subcarriers are used for PAPR reduction, leading to lower bandwidth efficiency. In general, TR is considered better than SLM in terms of performance and implementation.

Error correction: This technique relies on redundancy information used by both the forward error correction and the PAPR reduction capabilities of the system. A PAPR reduction of about 3.5 dB can be obtained with a 3/4 rate block coding scheme for a 4-carrier OFDM system [**3**]. Combined turbo coding and selective mapping techniques can be used to significantly reduce PAPR with moderate additional complexity.

Partial transmit sequences: The partially transmit sequence technique provides an approach for dividing the total number of OFDM subcarriers into multiple subsets of subcarriers with the same size. Each subset of subcarriers is weighted by pure rotation factors in order to minimize PAPR in the time domain. For example, PAPR can easily be reduced by more than 3 dB using a 128-subcarrier OFDM transmitter with 4 subsets, and weighting factors limited to (±1, ± j). The receiver must know the transmit sequences generated at the transmitter in order to recover the data [20-21]. To accomplish this, the weighting phase factors must be sent to the receiver as side information, leading to an increase in bandwidth overhead.

III.PLANNING OF WORK/METHODOLOGY

With the improvements on DSP, OFDM is proposed for 4G communication systems due to its spectral efficiency, ease of implementation with Fast Fourier Transform (FFT) operation, and strong resistance to multipath resistance. As mentioned before in this thesis, the main drawback of an OFDM is its high Peak to Average Power Ratio. This drawback is not a big problem for downlink channel (a channel from station to mobile), because the station has a steady power source, whereas this drawback is an essential issue for the uplink channel (a channel from mobile to station) because a mobile device has a limited amount of power source. Before discussing the DFT-spreading technique, let us consider OFDMA system [16]. As depicted in figure XX, suppose that DFT of the same size as IFFT is used as a (spreading) code. Then, the OFDMA system becomes equivalent to the Single Carrier FDMA (SC-FDMA) system because the DFT and IDFT operations virtually cancel each other. In this case, the transmit signal will have the same PAPR as in a single-carrier system.

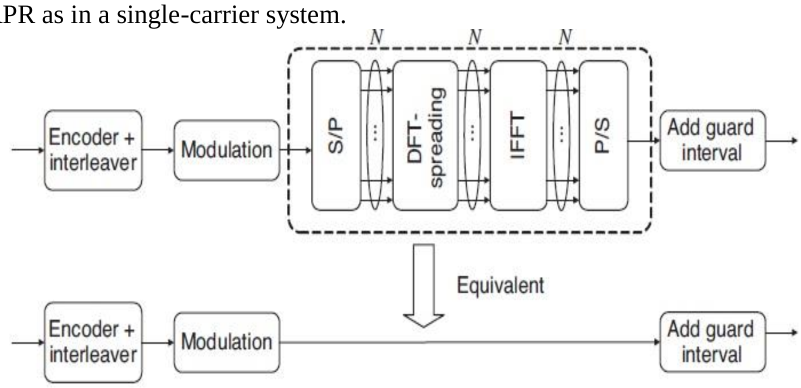

Figure 3 Equivalence of OFDMA systems with DFT-spreading code to a single-carrier system [15]

In OFDMA systems, subcarriers are partitioned and assigned to multiple mobile terminals (users).Unlike the downlink transmission, each terminal in uplink uses a subset of subcarriers to transmit its own data. The rest of the subcarriers, not used for its own data transmission, will be filled with zeros. Here, it will be assumed that the number of subcarriers allocated to each user is M. In the DFT-spreading technique, M-point DFT is used for spreading, and the output of DFT is assigned to the subcarriers of IFFT [14-15]. The effect of PAPR reduction depends on the way of assigning the subcarriers to each terminal (as it is already discussed that there are two ways of carrier mapping DFDMA and LFDMA). When DFDMA distributes DFT outputs with equidistance N/M= S, it is referred to as IFDMA (Interleaved FDMA) where S is called the bandwidth spreading factor. Figure 4 illustrates the subcarriers allocated in the DFDMA and IFDMA with M=4, S=3, and N=12.

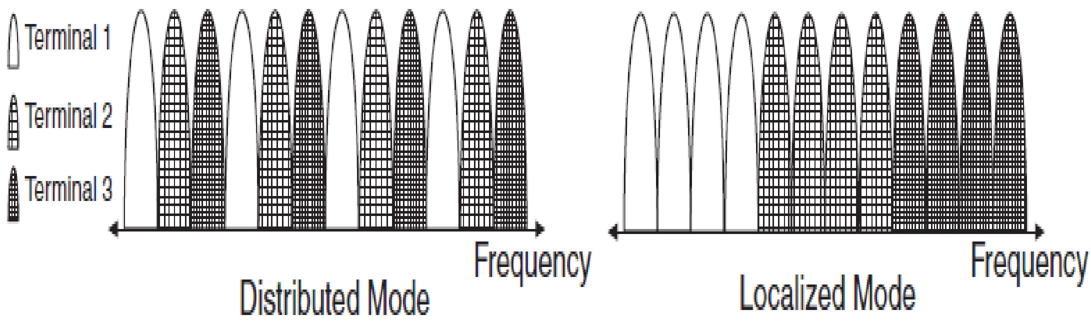

Figure 4 Examples of subcarrier assignment to multiple users: three users with N=12, M=4, and S=3

IV. SOFTWARE USED AND SIMULATION RESULT

Software: MATLAB Version R2015a: It is powerful software that provides an environment for numerical computation as well as a graphical display of outputs. In Matlab, the data input is in the ASCII format as well as binary format. It is a high-performance language for technical computing integrates computation, visualization, and programming in a simple way where problems and solutions are expressed in familiar mathematical notation. In our dissertation total number of subcarriers is 256 and the number of subcarriers assigned to each unit or mobile device is 128. This simulation helps in evaluating the performance of PAPR with different mapping schemes and modulation techniques. Our results show the effect of using Discrete Fourier Transform spreading technique to reduce PAPR for OFDMA, LFDMA, and IFDMA with N=256 and M=128.

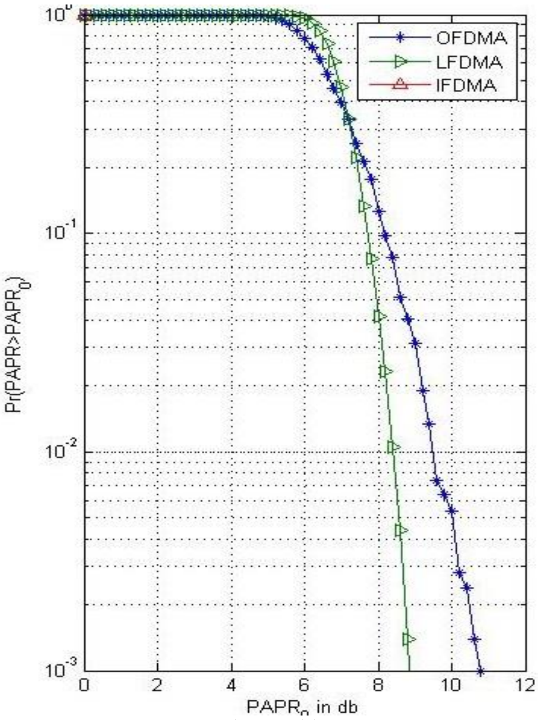

Figure 5(a): BPSK

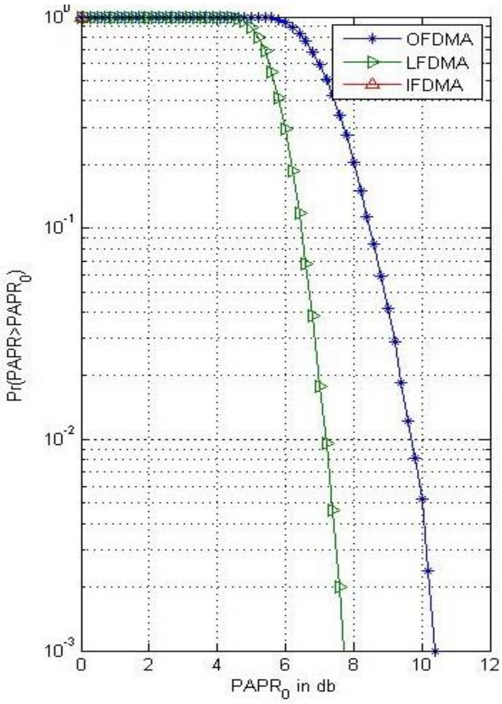

Figure 5(b): QPSK

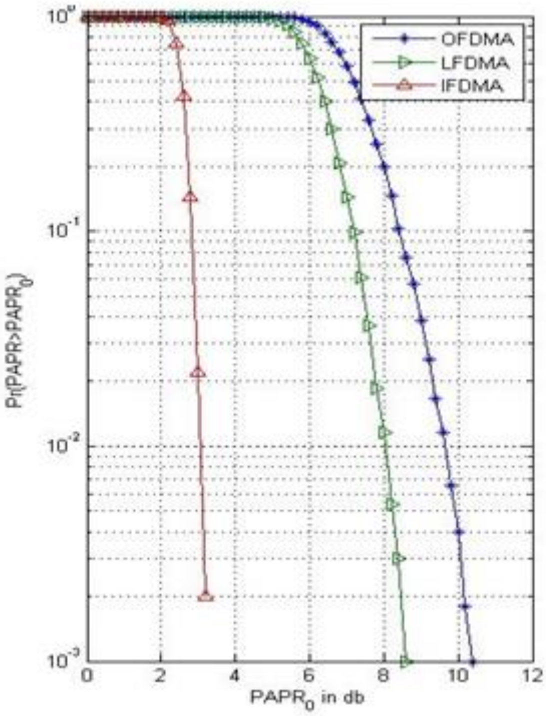

Figure 5 (c) 16 QAM

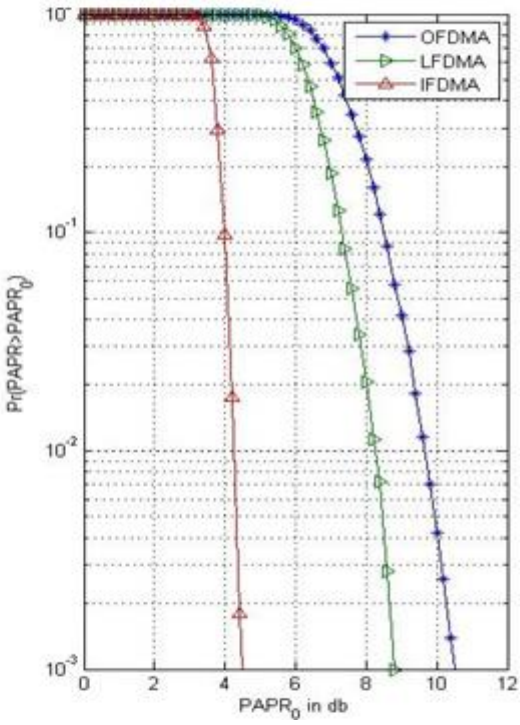

Figure 5 (d) 64 QAM

Figure 5 a comparisons is shown using BPSK, QPSK, 16QAM, 64QAM modulation techniques respectively

The performance is improved using DFT spreading technique for example in figure 5 (d) the value of OFDMA is 10.4db, the value of LFDMA is 8.8db and value of IFDMA are 4.4db. This shows that in IFDMA which utilize the DFT spreading technique reduces the PAPR by 6db. Such reduction shows the significant improvement in the performance of PAPR. So we can say that the IFDMA and LFDMA techniques are better than the OFDMA in the uplink transmission.

Now, let us see how the PAPR performance of DFT spreading technique is affected by the number of subcarriers (M) that are allocated to each user. Figure 6 (a), 6 (b) and 6 (c) shows the effect of a number of subcarriers on OFDMA, LFDMA, and IFDMA respectively. We are showing these results using 16QAM modulation technique.

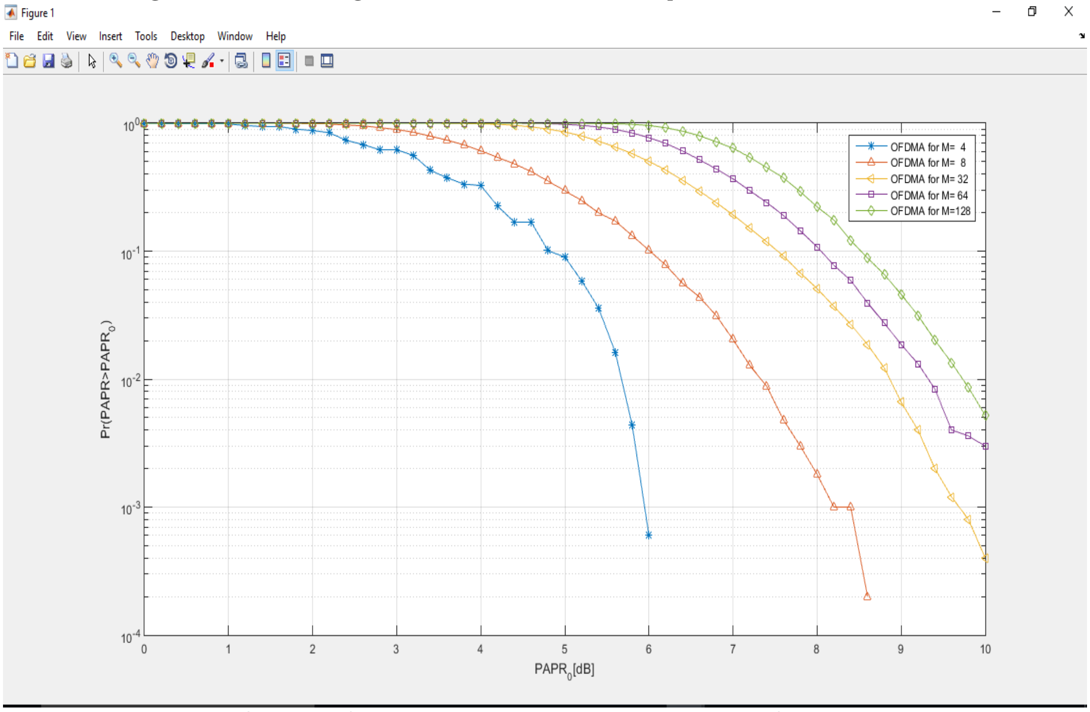

Figure 6 (a): PAPR performance of DFT-spreading technique when the number of subcarriers varies in OFDMA

It is clear from figure 6 (a) and 6 (b), as the number of subcarriers (M) is increasing the PAPR is increasing. But for M=128 the PAPR in OFDMA much greater than the LFDMA.

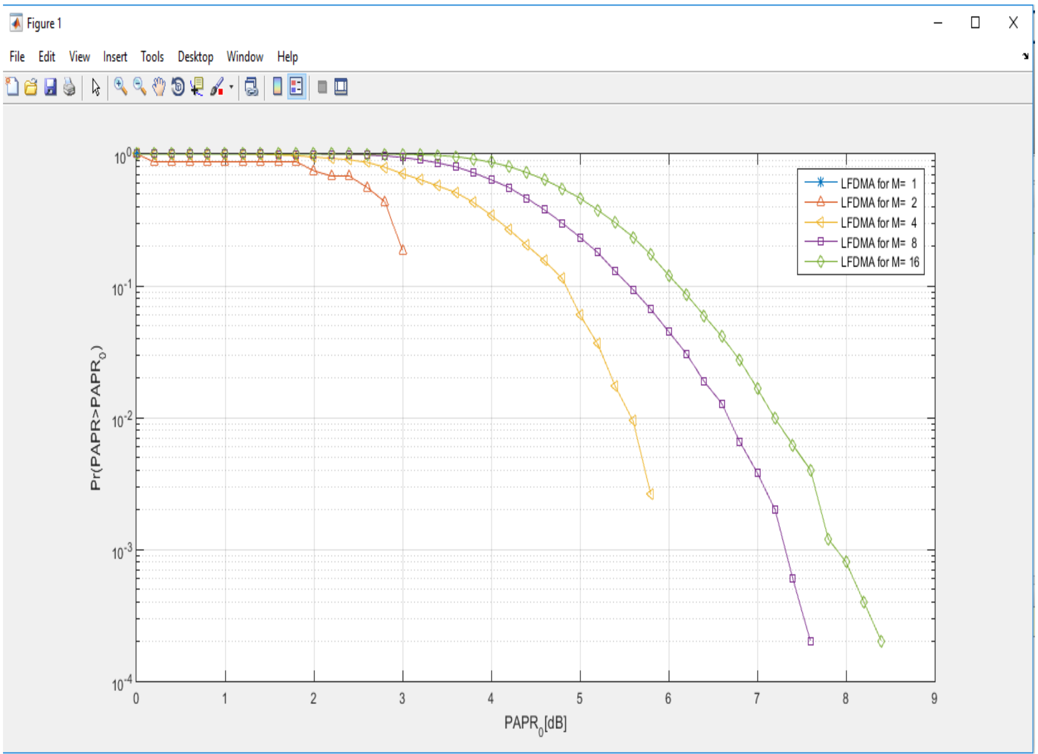

Figure 6 (b): PAPR performance of DFT-spreading technique when the number of subcarriers varies in LFDMA

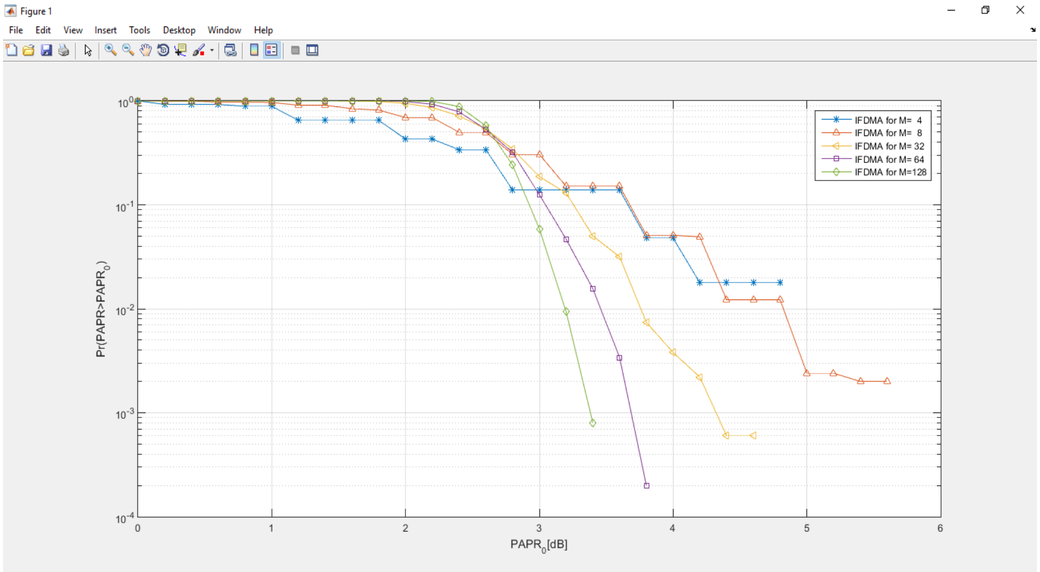

Figure 6 (c): PAPR performance of DFT-spreading technique when the number of subcarriers varies in IFDMA

But figure 6 (c) shows that the performance of the IFDMA is different than the OFDMA and the LFDMA, in IFDMA PAPR is decreasing as the number of subcarriers (M) is increasing.

Pulse Shaping: The idea of pulse shaping is to find an efficient transmitter and a corresponding receiver waveform for the current channel condition. The raised-cosine filter is used for pulse shaping because it is able to minimize Intersymbol interference (ISI). In this section, we show the effect of pulse shaping on the PAPR. Figure 7 shows the PAPR performance of both IFDMA and LFDMA, varying the roll-off factor of the raised cosine filter for pulse shaping after IFFT. The roll-off-factor is a measure of the excess bandwidth of the filter. The raised cosine filter can be expressed as:

$$p(t) = \frac{\sin(\pi t / T)}{\pi t / T} \cdot \frac{\cos(\pi \alpha t / T)}{1 - 4\alpha^2 t^2 / T^2}$$

Where T is the symbol period and ∝ is the roll-off factor (a measure of excess bandwidth).

Figures 7 imply that IFDMA is more sensitive to pulse shaping than LFDMA. The PAPR performance of the IFDMA is greatly improved by varying the roll-off factor from 0 to 1. On the other hand, LFDMA is not affected so much by the pulse shaping.

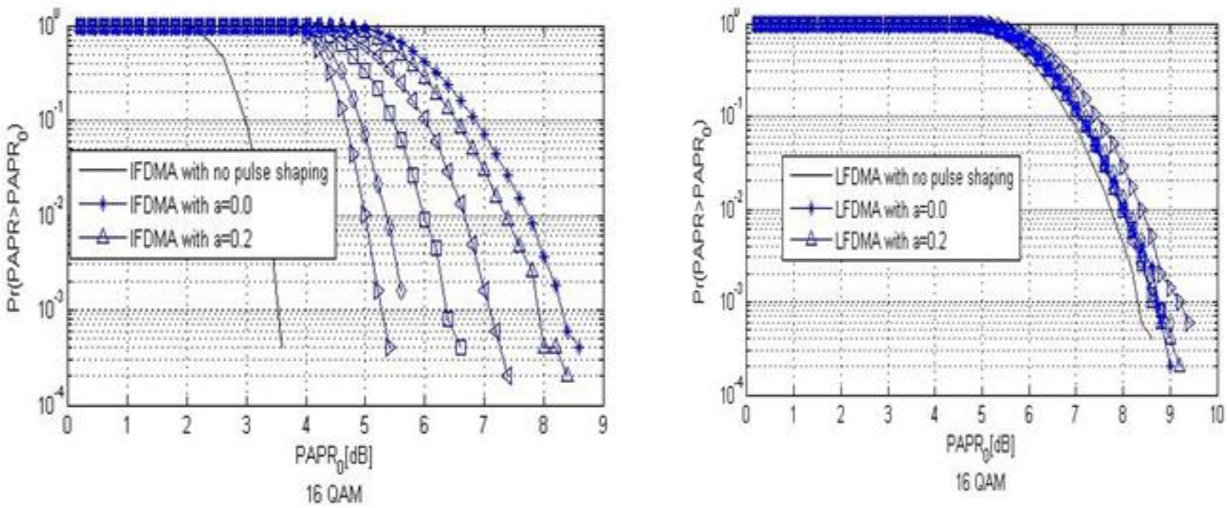

Figure 7 Pulse shaping effects on IFDMA and LFDMA for 16 QAM

Figure 7 explains the pulse shaping effects on IFDMA and LFDMA for 16 QAM whereas figure 4.6 explains the pulse shaping effects on IFDMA and LFDMA for 64 QAM. Results show that PAPR in IFDMA decreases as the roll-off factor increases. The variations can be seen easily. But in LFDMA the changes occur due to pulse shaping is neglect able.

CONCLUSION

In this thesis, a method for PAPR reduction in LTE system has been introduced, which is based on the DFT spread method. DFT spread method is further classified into two methods known as LFDMA (localized FDMA) and IFDMA (interleaved FDMA). It was shown that an interleaved FDMA and localized FDMA perform better than orthogonal FDMA in the uplink transmission where transmitter power efficiency is of great importance in the uplink. LFDMA and IFDMA result in lower average power values due to the fact that OFDM and OFDMA map their input bits straight to frequency symbols where LFDMA and IFDMA map their input bits to time symbols. We conclude that single carrier-FDMA is a better choice on the uplink transmission for cellular systems. Our conclusion is based on the better efficiency due to low PAPR and on the lower sensitivity to frequency offset since SC-FDMA has a maximum of two adjacent users. From results, it can also be concluded that the performance of IFDMA is far better than the LFDMA. We have shown the importance of the trade-off relationship of IFDMA between excess bandwidth and PAPR performance due to the fact that any excess in bandwidth increases as the roll-off factor increases. Our results show The PAPR performance of the IFDMA is greatly improved by varying the roll-off factor. On the other hand, LFDMA is not affected so much by the pulse shaping.

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