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GENERALIZED FREQUENCY DIVISION MULTIPLE ACCESS ALLOCATION SCHEME FOR LTE-A

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ABSTRACT

Frequency Division Multiple Access (FDMA) is one of the important features of Long Term Evolution Advanced (LTE-A). For LTE-A downlink, Orthogonal FDMA (OFDMA) scheme is used to provide frequency orthogonality. Whereas, for uplink, Signal Carrier FDAM (SC-FDMA) is preferred since it provides improved PAPR performance over OFDMA. Interleaved FDMA (IFDMA) and Localized FDMA (LFDMA) are forms of SC-FDMA usually used in LTE-A. User subcarrier allocation method is the main distinction between IFDMA and LFDMA schemes. Users are allocated destributed frequency carriers in IFDMA while they are allocated localized carriers in LFDMA. Whereas IFDMA scheme provides better PAPR performance over LFDMA scheme, the latter has lower complexity requirements. In this paper a new user subcarrier allocation scheme is introduced. The proposed scheme provides a variable interleaved allocation of subcarriers in the bandwidth, hence it is named Generalized FDMA (GFDMA). This variable interleaved allocation scheme made the transition from IFDMA to LFDMA to be seamless. Theoritical derivation of the proposed scheme shows that both IFDMA and LFDMA are subclasses of GFDMA. Simulation results of the proposed GFDMA show that the signal PAPR calculated varies according to the interleave level selected. The simulation has been conducted for different QAM modulation schemes and bandwidths. In all the cases, GFDMA PAPR performance is in good match to the calculated IFDMA and LFDMA PAPR. Moreover, further enhancement in GFDMA PAPR is achieved as the number of users in a given bandwidth increased.

Keywords: *SC-FDMA, LTE-A, IFDMA, LFDMA, GFDMA*

1. INTRODUCTION

Nowadays the demanding on wireless high data rates is rapidly increases, high data rates is very important because it supports broadband services. Long Term Evolution (LTE) is based on downlink and uplink accesses, which is depends on Orthogonal Frequency Division Multiple Access (OFDMA), the signal carrier Frequency Division Multiple Accesses (SC-FDMA). OFDMA accommodates Frequency Division Duplex (FDD) and Time Division Duplex (TDD) operation, Whereas SC-FDMA uses single carrier modulation and frequency domain equalization and gathering most of the advantages of Orthogonal Frequency Division Multiple Access [1, 2].

The reason of using SC-FDMA as uplink technique is that it has similar achievements and complexity of OFDMA technique. Furthermore its signal has lower PAPR than the signal of OFDMA due to its inherent signal carrier structure. Therefore the drawback of OFDMA can be compensated and PAPR reduced [3, 4]. Low PAPR means that low cost and efficient power amplifiers with fewer requirements on Linearity. The consequent is the cost of the terminal decreases and the life battery increases.The advantage of SC-FDMA over OFDMA is that the SC-FDMA has the ability to remove ISI (Inter Symbol Interference) between two symbols, and uses different orthogonal subcarriers to transmit in parallel; and has lower PAPR than OFDMA. The Receiver is designed to deal with inter-symbol interference, but because the cyclic prefix prevents inter-symbol interference between a block of symbols, so there will be inter-symbol interference between the cyclic prefixes. The receiver will thus run the equalizer for a block of symbols until it reaches the cyclic prefix that prevents further

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propagation of the inter-symbol interference. SC-FDMA is the better choice for a cellular uplink in LTE, Due to higher efficiency and low PAPR, and because it has only two adjacent users, it is less sensitive to frequency offset furthermore; its capacity is nearly the same as OFDMA [5].The orthogonal frequency division techniques use Disconnected set of orthogonal subcarriers divided over the bandwidth that they have disconnected transformers to transfer signals between frequency domain and time domain, and to send many signals at one time the multiple access techniques appoint the signals to reciprocally specific sets of subcarriers, due to broadband channels experience frequency-selective fading . In order to obtain multi-user diversity, the FDMA techniques can assign channel dependent scheduling, by appointing each terminal to subcarriers with suitable transmission characteristics at the location of the terminal [6]. The remainder of this paper is arranged as follows, Section II gives a brief overview of LTE in SC-FDMA, and Section III explains the mapping schemes. Section IV provides Mathematical modeling. Section V. explain the methodology VI. Highlights the results and the Discussion. While the paper is concluded in section VII.

2. LTE IN SC-FDMA

It is logically that the transmission power of uplink is less than the transmission power ofdownlink,hence highly power-efficient transmission is needed for uplink, therefore some factors must added to the uplink design to enable highly power effective transmission. The consequences are improvements of coverage, minimizes terminal cost and power consumption at the transmitter, therefore these features meet in signal carrier frequency-division multiple access (SC-FDMA), which is referred discrete Fourier transform (DFT)-pre- coded OFDM , which is adopted for LTE uplink, due to its lower peak to average power ratio [7].

Single carrier Frequency division multiple Accesses (SC-FDMA) system transforms time domain data symbols into the frequency domain by using DFT. SC-FDMA uses prefix(CP) periodically, because it transmits symbol rate faster in the time domain than in OFDMA system, and to prevent inter-Block interference (IBI) , between two successive blocks and provides a guard time between two successive Blocks [3]. However it has drawback that it does not carry any new information, and so it will lower the efficiency of the transmission and in the system yield inter-symbol interference between the cyclic prefixes. The receiver needs equalizer for block of symbols to prevent further propagation of the inter-symbol interference [1]. SC-FDMA use two different techniques of Distributed FDMA, which use Interleaved Frequency division Multiple Accesses (IFDMA) and Localized frequency division multiple accesses (LFDMA) Figure 1 below shows a block diagram of the transmitter and the receiver of the SC-FDMA with generalized frequency division multiple accesses mapping.

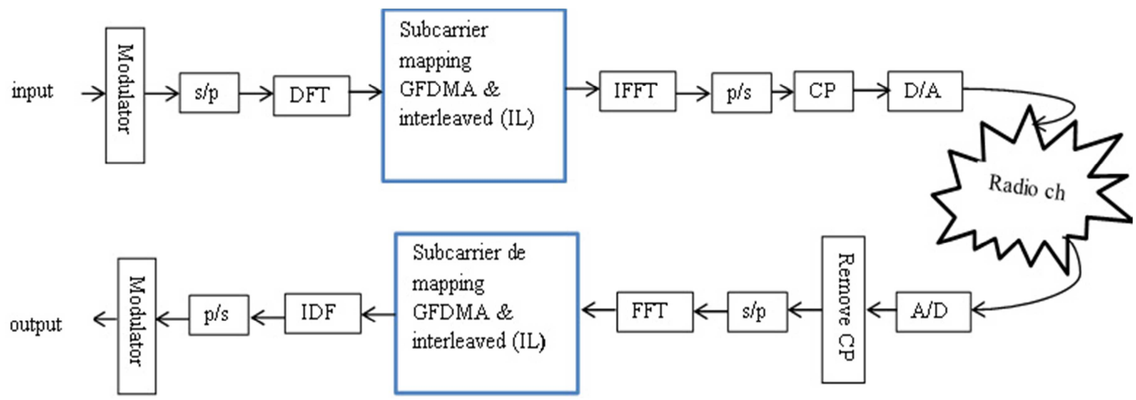

Figure 1: SC-FDMA Transmitter and Receiver

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3. MAPPING SCHEMES SC-FDMA

The study shows that Subcarrier mapping can be assorted into two types: (localized and distributed scheme) [8] of mapping as follows:

3.1 Localized scheme (LFDMA)

In localized mapping, the DFT reserve a fraction of the system Bandwidth for each user by using a group of adjacent subcarriers to transmit its data. The feature of this way is that it supplies multi user diversity in a frequency selective channel, where as its deficiency that it loses frequency diversity in the channel [9]. Figure 2 is a general process of localized mapping (LFDMA) shows an example of three users with four subcarriers each.

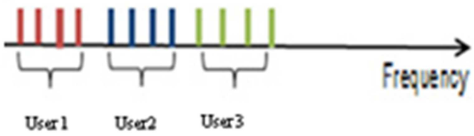


Figure 2: LFDMA Subcarrier assignment to multiple users.

3.2 Distributed Schemes (IFDMA)

In distributed mapping, the subcarriers are distributed over the entire bandwidth; in this way the subcarriers are equally spaced over the entire bandwidth. The feature of this way is supplies frequency diversity in, on the other hand its weakness that it loses user diversity in the channel [10]. Figure 3 is show a general process of distributed interleaved mapping (IFDMA).

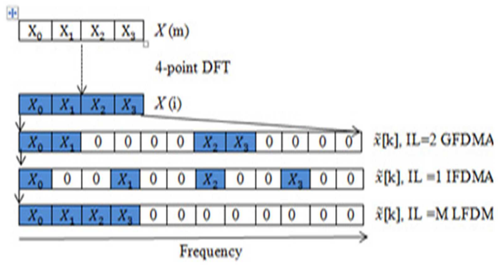
Figure3. IFDMA Subcarrier assignment to multiple users.

3.3 GENERALIZED FDMA (GFDMA)

In this work a new mapping scheme is proposed. In this scheme the subcarriers allocation for users may vary according to the level of interleaving in the entire bandwidth Unlike the hybrid allocation scheme, the level of interleaving in the proposed scheme is. fixed for all users in the one frame; however, it may vary for different frames. Let's assume the level of interleave is I_L for a given frame, for I_L=2, for example, each user is allocated 2 consecutive subcarriers in the bandwidth as illustrated in Figure 4 as compared to the conventional IFDMA and LFDMA.

Figure4. GFDMA Subcarrier assignment to multiple users.

The proposed scheme is a general subcarrier allocation scheme where IFDMA and LFDMA are considered as special cases by selecting I_L to be 1 for IFDMA and I_L to be the total number of subcarriers allocated per user (M) for LFDMA. Figure 5 is show the DFT spreading.



4. MATHEMATICAL MODELING

To investigate the effects of the introduced level of interleave I_L on the retrieved signal; let's represent the relation between the retrieved signal and the transformed signal as follows:

$$\hat{x}[k] = \begin{cases} x[\acute{k}] & k = m_1 S I_L + l,\ \ m_1 = 0,1,\ldots\frac{M}{I_L} - 1 \\ 0 & otherwise \end{cases} \quad (1)$$

Where

$$l = 0 \ldots\ldots, I_L - 1 \quad (2)$$

$$\acute{k} = k - (S-1)\, I_L m_1 = I_L m_1 + l \quad (3)$$

It can be noticed that in this scheme the entire domain is subdivided into blocks of I_L subcarriers length. And the indexing of the subcarriers is controlled by m_1 to account for the number of blocks and l to account for the subcarrier index within the block as illustrated in Figure 5.

Therefore, the index of the retrieved signal can be written as

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$$n = [(S-1)m_1 + s]I_L + m \quad (4)$$

Where

S= number of users

$$s = 0, 1 \ldots S-1 \quad (5)$$

The total bandwidth is calculated as:

$$N = SM \quad (6)$$

Example: I_L =2, 1, 4 *respectively*. In this example the bandwidth considered in Fig. 4 is N=12, and the number of subcarriers per user M=4 and spreading factor S= N/M. by applying equation (4) the retrieved signal can be calculated for GFDMA when I_l=2 *will be* shown in Table 2. For IFDMA when I_L =1 *will be* shown in Table 3. And for LFDMA when I_L =4 *will be* shown in Table 4.

Table1: GFDMA with I_L =2 and the indexing l and m_1 for transmitted signal

	X_o	X_1	0	0	0	0	X_2	X_3	0	0	0	0
l	0	1	0	0	0	0	0	1	0	0	0	0
m_1	0	0	0	0	0	0	1	1	0	0	0	0

The user's symbols can be retrieved by following the allocation scheme for each user and mapped into $m = 0, \ldots, M-1$as shown in Table 2.

1st and 2nd symbol of 1st user 3rd and 4th symbol of 1st user

Table 2: GFDMA with I_l=2 and the indexing for retrieved signal

	Xo	X1	0	0	0	0	X2	X3	0	0	0	0
m	0	1	0	0	0	0	2	3	0	0	0	0
m1	0	0	0	0	0	0	1	1	0	0	0	0
s	0	0	0	0	0	0	0	0	0	0	0	0
S	3	3	0	0	0	0	3	3	0	0	0	0
n	0	1	0	0	0	0	6	7	0	0	0	0

Assuming I_L=1, IFDMA case, then $m_l$and m will have the sequence

$$m = m_1 = 1, 2, \ldots, M-1 \quad (7)$$

And l will be always zero. The retrieved signal index for IFDMA will be

$$n = S\,m_1 + s \quad (8)$$

Table 3: IFDMA with I_l=1 and the indexing for retrieved signal

	Xo	0	0	X1	0	0	X2	0	0	X3	0	0
m	0	0	0	1	0	0	2	0	0	3	0	0
m1	0	0	0	1	0	0	2	0	0	3	0	0
s	0	0	0	0	0	0	0	0	0	0	0	0
S	3	0	0	3	0	0	3	0	0	3	0	0
n	0	0	0	3	0	0	6	0	0	9	0	0

On the other hand, if I_L=M which represents the LFDMA case then m and $l$will take the sequence

$$l = m_1 = 1, 2, \ldots, M-1$$

And m_l will be zero so that the retrieved signal index will be

$$n = sM + m$$

Table 4: LFDMA with I_l=4 and the indexing for retrieved signal

	Xo	X1	X2	X3	0	0	0	0	0	0	0	0
m	0	1	2	3	0	0	0	0	0	0	0	0
m1	0	0	0	0	0	0	0	0	0	0	0	0
s	0	0	0	0	0	0	0	0	0	0	0	0
S	3	3	3	3	0	0	0	0	0	0	0	0
n	0	1	2	3	0	0	0	0	0	0	0	0

This example clarifies a subcarrier mapping relationship between 4-point Discrete Fourier Transform (DFT) and 12-point Inverse Discrete Fourier Transform (IDFT) [10]. In the mapping process the DFT is used as spreading code and the users symbols are distributed over the entire bandwidth for consecutive subcarriers, where the unused location filled by zero [9, 11]. IFDMA mapping produces a signal which is a scaled copy of the original signal, the scaling factor is 1/*M*. on the other hand, and the LFDMA produces phase shifts in the symbols of the original signal [12].

$$\hat{x}[n] = \frac{1}{N}\sum_{K=o}^{N-1}\hat{x}[\acute{k}]\,e^{j2\pi\frac{n}{N}\acute{k}} \quad (9)$$

Substituting equation 1 in 9 and arranging:

$$\hat{x}[n] = \frac{1}{SM}\sum_{\acute{k}=o}^{M-1}\hat{x}[\acute{k}]e^{j2\pi\frac{n}{SM}[m_1 S I_L + l]} \quad (10)$$

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$$\hat{x}[n] = \frac{1}{SM}\sum_{\acute{k}=o}^{M-1} \hat{x}[\acute{k}]\, e^{j2\pi\frac{nm_1 SI_L}{SM}} e^{j2\pi\frac{n}{SM}l} \quad (11)$$

Noting that $\acute{k}$ can written as:

$$I_L m_1 = \acute{k} - l \quad (12)$$

Substituting equation 12 in 11 yields:

$$\hat{x}[n] = \frac{1}{SM}\sum_{\acute{k}=o}^{M-1} \hat{x}[\acute{k}]\, e^{j2\pi\frac{n(\acute{k}-l)}{SM}} e^{j2\pi\frac{n}{SM}} \quad (13)$$

Rearranging equation 13 to have:

$$\hat{x}[n] = \frac{1}{SM}\sum_{\acute{k}=o}^{M-1} \hat{x}[\acute{k}]\, e^{j2\pi\frac{n}{M}\acute{k}} e^{j2\pi\frac{n}{M}l(\frac{1}{S}-1)} \quad (14)$$

It can be noted that the equation 14 contains the transformed signal with each symbol rotated with a phase angle represented as:

$$R = e^{j2\pi\frac{n}{M}l(\frac{1}{S}-1)} \quad (15)$$

By selecting the value of I_L the mapping of the users can vary from IFDMA to LFDMA. For example, selecting I_L=1 and substituting in equations 1, 2, 3, and 4 yields the IFDMA case, as follows:

$$I_L=1 \quad l = 0, \quad m_1=0, 1\ldots M-1 \quad (16)$$

So there are M blocks, each of length I_L and the index m_l is used to designate the symbols. Thus, equation 14 becomes:

$$\hat{x}[Sm_1 + s] = \frac{1}{SM}\sum_{\acute{k}=o}^{M-1} \hat{x}[\acute{k}]\, e^{j2\pi\frac{n}{M}\acute{k}} \quad (17)$$

$$\hat{x}[Sm_1 + s] = \frac{1}{S}X(m) \quad (18)$$

So for IFDMA the retrieved signal is a scaled copy of the original transmitted signal. On the other hand, selecting I_L=M and substituting in equations 1, 2,3, and 4 yields the LFDMA case, as follows

$$I_L = M, \quad m_1 = 0, \quad l = 0, 1 \ldots M-1 \quad (19)$$

Unlike the IFDMA case, in this case there is one block of length M symbols and the l index is pointing to the users symbols in the block.

$$\acute{k} = l = m \quad (20)$$

$$n = sM + m \quad (21)$$

Substituting equations 19 and 20 in equation 14 yields:

$$\hat{x}[sM + m] = \frac{1}{SM}\sum_{l=o}^{M-1} \hat{x}[l]\, e^{j2\pi\frac{sM+m}{M}l} e^{j2\pi\frac{sM+m}{M}l(\frac{1}{S}-1)} \quad (22)$$

Rearranging the variables we have:

$$\hat{x}[sM + m] = \frac{1}{SM}\sum_{l=o}^{M-1} \hat{x}[l]\, e^{j2\pi\frac{(sM+m)l}{SM}} \quad (23)$$

For s=0

$$\hat{x}[m] = \frac{1}{SM}\sum_{l=o}^{M-1} \hat{x}[l]\, e^{j2\pi\frac{(m)l}{SM}} = X(m) \quad (24)$$

It can be deduced that the developed mapping scheme is generalized mapping where IFDMA and LFDMA are special cases, hence the proposed scheme is called Generalized FDMA (GFDMA). The mapping can vary with the level of interleaving selected. The signal retrieved is a copy of the transmitted signal with rotations that alternately change from IFDMA to LFDMA mappings.

5. METHODOLGY

The proposed scheme is simulated for different bandwidths and subcarrier allocation per user M. for each subcarrier allocation M, the interleaved level I_L takes the values:

$$I_L = 2^x \quad (25)$$

where

$$x = 0,1, \ldots, log_2(M) \quad (26)$$

For $x = 0, I_L = 1$ representing IFDMA case and $x = log_2(M), I_L = M$ which signifies the LFDMA case. The GFDMA case is when $1 \le x \le log_2(M) - 1$.

For every value of the interleave level IL, a random data set contains 5000 frames is generated and transmitted. The shaping filter parameters are listed in Table 5.

Table 5: shaping filter information

Parameter	value
Roll off factor	0 and 1
Bandwidth	5MHz
oversampling	8bit
Shaping filter type	Raised cosine impulse

The PAPR is calculated for every frame according to the following equation:

$$PAPR = \frac{\max(x_n)}{\text{mean}(x_n)} \quad (27)$$

where xn is the received signal.

The PAPR is represented as a complementary cumulative distribution function (CCDF) defined as:

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$$F_c(X) = P(X > x) = 1 - F(X) \quad (28)$$

Furthermore, for every interleave value IL the average PAPR values are recorded to compare the behavior of PAPR for different interleaving schemes for different filter roll off factors. The system considers QAM-16, and QAM-64 coding with different Bandwidth.

6. RESULTS AND DISCUSSION

The CDF of the PAPR for the proposed scheme is shown in Figure. 6 to Figure 13.whereas figure 14 to 17 show the interleave level versus PAPR average. The GFDMA is slightly low in terms of PAPR in Figure 7 compare to Figure 6 particularly and moreover ; it shows that the improvement of PAPR increase as long as the roll-off factor increase as depicted in Figure 9 compare to Figure 8. Furthermore, the display is a clear deviation process with slightly improved PAPR for IFDMA and GFDMA,as same as of the comparison of Figures 10 and Figure 11 demonstrates some significant improvement for IFDMA and very slightly improvement for LFDMA and GFDMA in terms of PAPR. It is also noteworthy that the IFDMA PAPR in Figure 13 decreased about 1 dB compared to Figue 12, However GFDMA and LFDMA very slightly decreased. The result in Figure 15 and is a good PAPR remarkable compared to Figure 14 and 16 respectively further more as long as the users increase the PAPR decrease

Finally increases the PAPR improved for the proposed scheme. However, GFDMA PAPR shows slight improvement over the LFDMA when the total bandwidth is shared by 2 users, i.e. $M=N/2$ as illustrated in Figure 16. Although the study is to create a new scheme that monitors the transition from IFDMA to LFDMA by using GFDMA without significantly affecting of the PAPR; however all the figures have shown that the PAPR is being improved about 0.5 to 1 dB for IFDMA, LFDMA and GFDMA as well.

7. CONCLUSION

This paper has introduced a Generalized FDMA for user subcarrier allocation in SC-FDMA schemes. The proposed GFDMA allowed the smooth transition from IFDMA to LFDMA by defining Interleave level metric. Theoritical investigation showed that IFDMA and LFDMA are special cases of the proposed GFDMA.The unity interleave level in GFDMA signifies the IFDMA scheme while the LFDMA scheme is represented by interleave level equal to the subcarriers allocated per user. The introduction of the interleave level made the transition from IFDMA to LFDMA schemes feasible. Simulation results for QAM-16 and QAM-64 for different bandwidths and different subcarrier allocation per user are presented. Simulation results showed that the signal PAPR is increasing with higher interleave level. However, in all cases the PAPR for GFDMA with interleave level higher than two shows slight increase compared to the LFDMA scheme PAPR with the exception is noticed when the bandwidth is divided between two users. Moreove, the PAPR of the proposed GFDMA is improved with higher shaping filter roll off factor. Similarly, lower subcarrier allocation per user for a given bandwidth improves the PAPR in all the interleaving schemes in GFDMA. On the other hand, the effects of different QAM modulation schemes and the bandwidth on the PAPR behavior of GFDMA are negligible.The proposed GFDMA provides a compromise between the superior PAPR performance of the IFDMA and the reduced complexity requirements of the LFDMA schemes.

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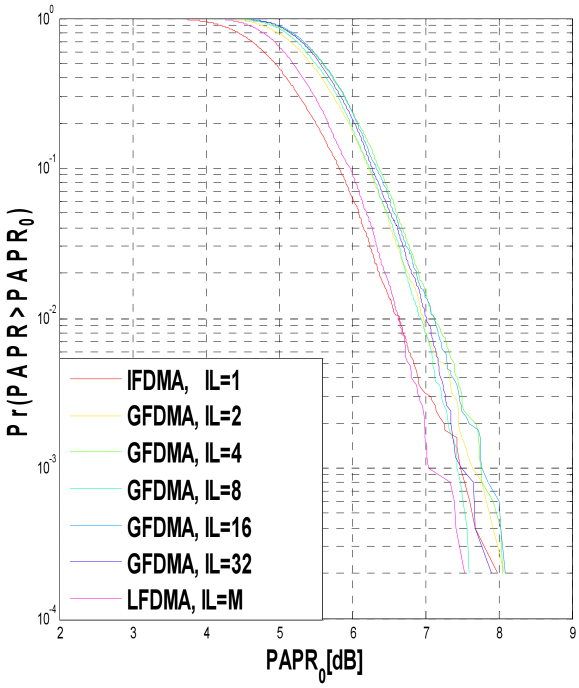

Figure 6 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=16 N= 256 M=64 α=0

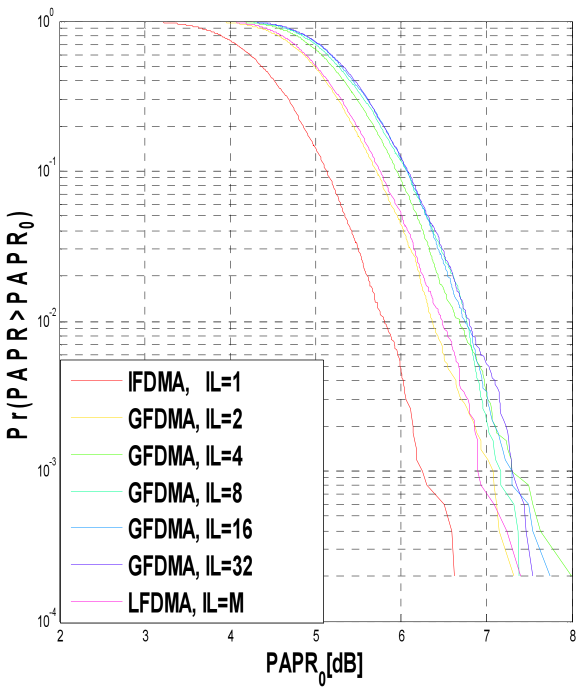

Figure 7 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=16 N= 256 M=64 α=1

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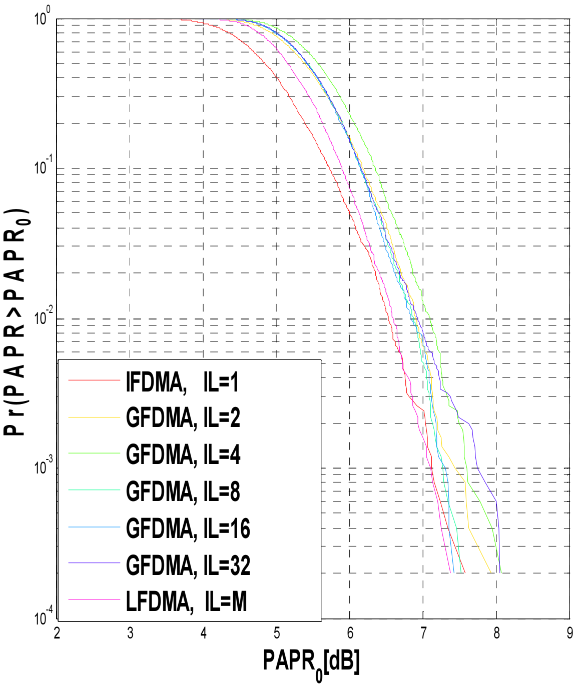

Figure 8 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=16 N= 1024 M=64 α=0

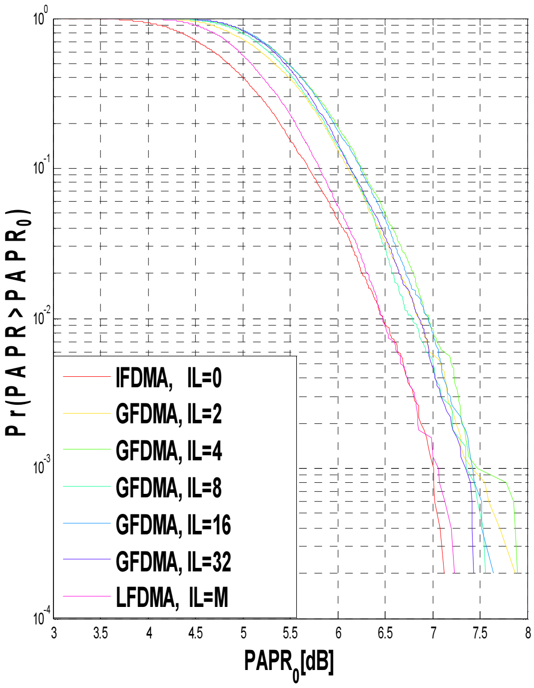

Figure 10 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=64 N= 256 M=64 α=0

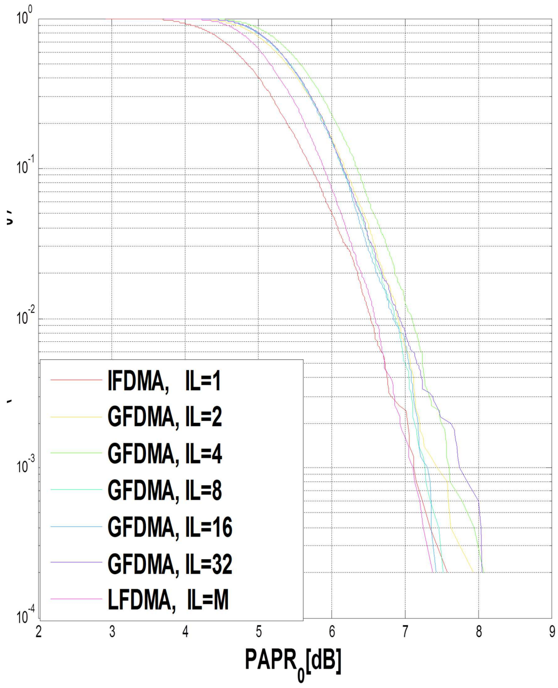

Figure 9CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=16 N= 1024 M=64 α=1

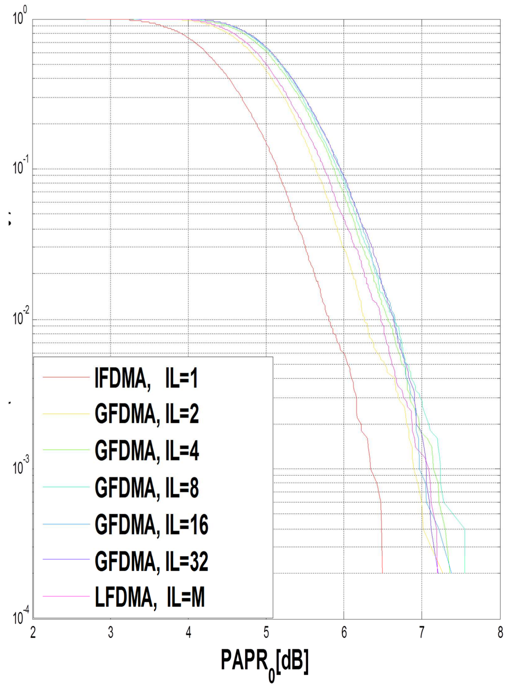

Figure 11 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=64 N= 256 M=64 α=1

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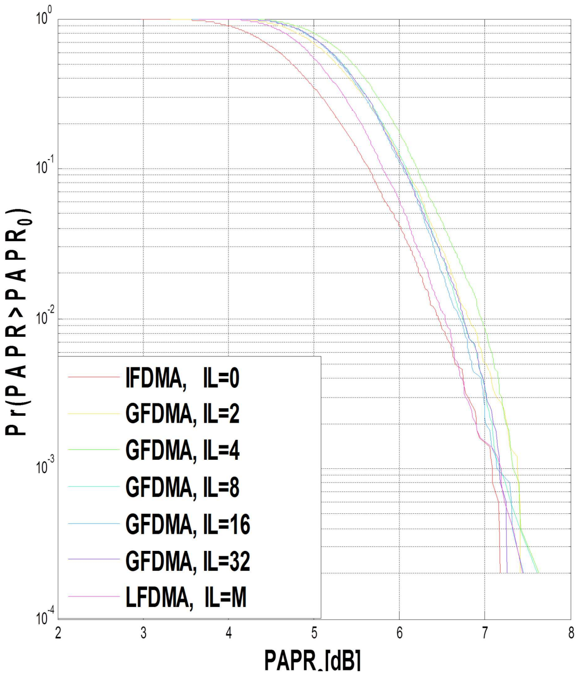

Figure 12 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=64 N= 1024 M=64 α=0

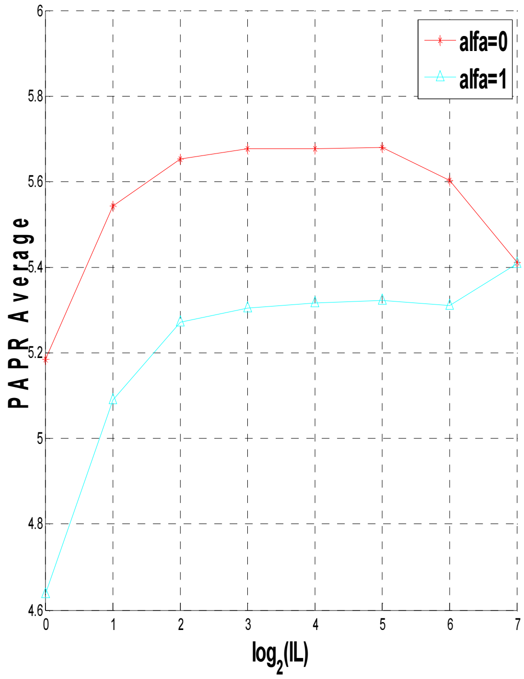

Figure 14 the Change of PAPR Average with Respect to The Interleave Level for N= 256 M= 128 users =2

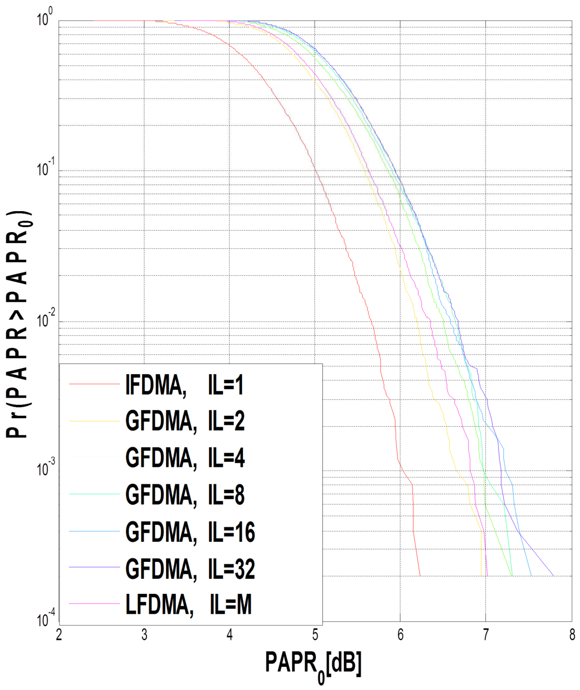

Figure 13 CDF of PAPR for IFDMA, GFDMA and LFDMA for QAM=64 N= 1024 M=64 α=1

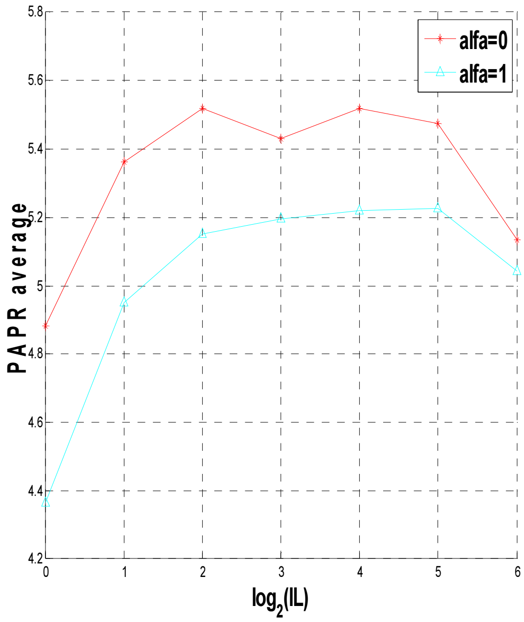

Figure 15 the Change of PAPR Average with Respect to The Interleave Level for N= 256 M= 64 users =4

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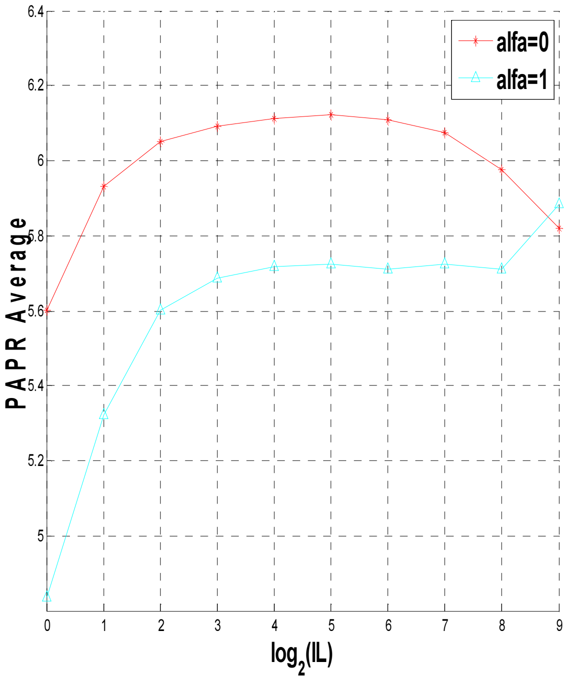

Figure 16 the Change of PAPR Average with Respect to The Interleave Level for N= 1024 M=512 users

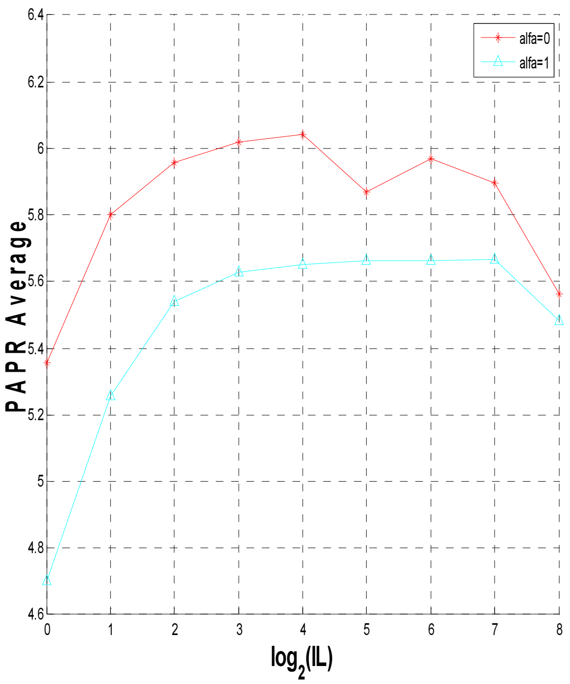

Figure 17 the Change of PAPR Average with Respect to The Interleave Level for N= 1024 M=256 users =4