NOVEL PRECODING BASED PAPR REDUCTION SCHEMES FOR LOCALIZED OFDMA UPLINK OF LTE-A

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Abstract

High Peak to Average Power Ratio (PAPR) reduction is still a major challenge in Orthogonal Frequency Division Multiple Access (OFDMA) systems. The subcarrier mapping in OFDMA can be done in two modes, Localized mode and Distributed mode. The Localized mode is more suitable for the practical implementations than the Distributed mode due to its low sensitivity against the imperfect power control, phase noise and Inter Carrier Interference (ICI). In this paper, we propose two novel precoding based Multi-Carrier (MC) Multiple Access (MA) techniques for PAPR reduction, Zadoff-Chu precoding based Localized-OFDMA (L-OFDMA) technique and Generalized Chirp Like (GCL) precoding based L-OFDMA technique for L-OFDMA uplink systems of upcoming Long Term Evaluation-Advanced (LTE-A) system. These techniques are based on precoding the constellation symbols with Zadoff-Chu precoder and GCL precoder. The proposed techniques can reduce PAPR up to 6.5dB for L-OFDMA. It is noticeable from the computer simulation results, that the PAPR of our proposed precoding based MC systems have approximately equal PAPR as compared to the PAPR of competing technology called Localized Single Carrier Frequency Division Multiple Access SC-FDMA (LFDMA) system. LFDMA is implemented in release 8 of Long Term Evaluation (LTE). Additionally, these precoding based PAPR reduction techniques also takes the advantage of the frequency variations of the communication channel and can also offer substantial performance gain in fading multipath channels.

Keywords: *PAPR, OFDMA, L-OFDMA, LTE-A, LFDMA, Zadoff-Chu Precoder, GCL Precoder*

I. INTRODUCTION

OFDMA is a multiple access version of Orthogonal Frequency Division Multiplexing (OFDM). OFDMA has been adopted as MA scheme by the most of the upcoming wireless and wireline digital communication systems because of its high speed data rates, high spectral efficiency, high quality service and robustness against narrow band interference and frequency selective fading. The key difference among OFDM and OFDMA is that instead of being allocated all of the available subcarriers, the base station assigns a subset of carriers to each user in order to accommodate several transmissions at the same time.

There are two different approaches to do subcarrier mapping for uplink OFDMA, localized subcarrier mapping of OFDMA also known as L-OFDMA where the subcarrier mapping is done in adjacent and distributed subcarrier mapping of OFDMA. Distributed subcarrier mapping can be further divided in to two modes interleaved OFDMA also known as I-OFDMA, where the subcarrier are mapped equidistant to each other's and pure distributed OFDMA called D-OFDMA, where subcarriers are distributed randomly. To avoid the Inter Carrier Interference (ICI) in the uplink due to Doppler frequency shift, L-OFDMA is preferred for practical implementations than that of I-OFDMA and D-OFDMA.

OFDMA thwarts Inter Symbol Interference (ISI) by inserting a Guard Interval (GI) using a Cyclic Prefix (CP) and moderates the frequency selectivity of the Multi Path (MP) channel with a simple equalizer. This leads to cheap hardware implementation and makes simpler the design of the receiver. OFDMA is widely adopted in various communication standards like Worldwide Interoperability for Microwave Access (WiMAX), Mobile Broadband Wireless Access (MBWA), Evolved UMTS Terrestrial Radio Access (E-UTRA), Ultra Mobile Broadband (UMB), OFDMA is also a strong candidate for the Wireless Regional Area Networks (WRAN) and Layered OFDMA of LTE-A [1]-[2] etc.

However OFDMA has some drawbacks, among others, PAPR is still one of the major drawbacks in the transmitted OFDMA signal. Therefore, for zero distortion of the OFDM signal, the HPA must not only operate in its linear region but also with sufficient back-off. Thus, HPA with a large dynamic range are required for OFDM systems. These amplifiers are very expensive and are major cost component of the OFDM system. Thus, if we reduce the PAPR it not only means that we are reducing the cost of OFDM system and reducing the complexity of A/D and D/A converters, but also increasing the transmit power, thus, for same range improving received SNR, or for the same SNR improving range.

A large number of PAPR reduction techniques have been proposed in the literature. Among them, schemes like constellation shaping [3], coding schemes [4], nonlinear Companding transforms [5], Tone Reservation (TR) and Tone Injection (TI) [6, 7], clipping and filtering [8], Partial Transmit Sequence (PTS) [9], Selective Mapping (SLM) [10], precoding based techniques [11, 12] and Precoding based Selective Mapping (SLM) [13, 14] are popular.

In [11] Authors proposed a Zadoff-Chu precoding based single carrier system with zero PAPR. It is shown that, by suitably converting Zadoff-Chu sequence into a precoding matrix, it is possible to design zero PAPR OFDM system. In [15] H.G.Myung et.al, presented an excellent PAPR analysis of the SC-FDMA signals with pulse shaping. They implemented raised cosine pulse shaping filter, through computer simulations they concluded that pulse shaping increases the PAPR. They compared their results with the OFDMA conventional and found that SC-FDMA has lower PAPR because of its single carrier structure than OFDMA conventional. They also compare the PAPR of Interleaved FDMA (IFDMA) and Localised FDMA (LFDMA) with and without pulse shaping. At the end, they conclude that IFDMA has lower PAPR then LFDMA. In [16] Cristina et.al presented an analysis of PAPR and Bit Error Rate (BER) of the OFDMA, WHT precoding based OFDMA and SC-FDMA for uplink communications. They showed through computer simulations, that 2dB PAPR gain is achieved when employed SC-FDMA against OFDMA, but no significant PAPR gain is achieved when WHT precoded OFDMA is used against OFDMA for uplink transmissions. They also showed that, in the existence of robust channel coding OFDMA shows better BER performance, on the other hand in the presence of less powerful coding both precoded OFDMA and SC-FDMA outperforms. At the end, they also concluded that SC-FDMA and WHT precoding based OFDMA system has similar performance to on frequency selective channels because their spreading properties recover frequency diversity. In [17] LTE-A requirements were agreed but radio interface schemes are still debatable.

In this paper, we proposed two precoding based PAPR reduction schemes for L-OFDMA uplink system of LTE-A, Zadoff-Chu precoding based L-OFDMA uplink system and GCL precoding based L-OFDMA. Extensive MATLAB(R) simulations have been performed for the PAPR analysis of our both systems. Additionally, we also compare our MATLAB(R) simulation results with L-OFDMA, I-OFDMA, WHT Precoding based L-OFDMA and SC-FDMA (LFDMA) systems existing in the literature.

This paper is organized as follows: Section II describes the basics of the OFDMA system, SC-FDMA and PAPR reduction, In Section III, we present the proposed system model for PAPR reduction, and Section IV presents computer simulation results and section V concludes the paper.

II. OFDMA, SC-FDMA & PAPR REDUCTION

A. OFDMA System

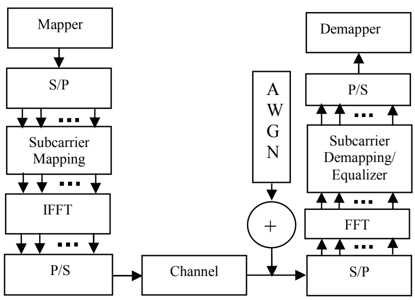

Figure 1. General Block diagram of OFDMA system

Fig. 1 illustrates the block diagram of an OFDMA system. The OFDMA system splits the high speed data stream into a number of parallel low data rate streams and these low rates data streams are transmitted simultaneously over a number of orthogonal subcarriers.

Baseband modulated symbols are passed through serial to parallel converter which generates complex vector of size *M*. We can write the complex vector of size *M* as $X = [X_0, X_1, X_2 \ldots X_{M-1}]^T$. After *N* subcarrier mapping to the X we get $Y_k=[Y_0,Y_1,\ldots Y_{N-1}]^T$. The complex baseband OFDMA signal with N subcarriers can be written as

$$\hat{x}_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} \hat{Y}_k . e^{j2\pi \frac{n}{N} k} \text{ , } n=0, 1, 2\ldots N-1 \quad (1)$$

$\hat{Y}_k$, we get after subcarrier mapping and $j=\sqrt{-1}$

B. SC-FDMA System

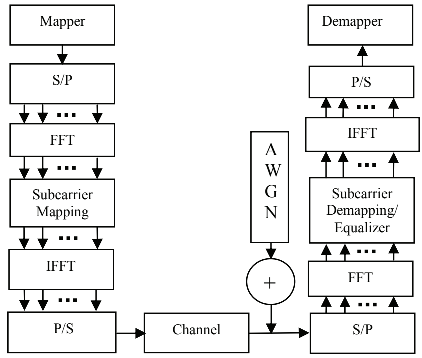

Figure .2. General Block diagram of Single Carrier System

Figure 2 shows the block diagram of SC-FDMA system. In SC-FDMA system, baseband modulated data is passed through S/P convertor which generates a complex vector of size M that can be written as X = [X0, X1, X2… XM-1] T. Then DFT precoding is applied to this complex vector. The DFT precoded signal can be written as

$$x_n = \frac{1}{\sqrt{M}} \sum_{l=0}^{M-1} X_l . e^{-j2\pi \frac{n}{M} l} \text{ , } n=0,1,2,\ldots,M-1 \quad (2)$$

This DFT precoded signal is then mapped on to the N subcarriers and we get $\hat{Y}_k=[Y_0,\hat{Y}_1,\ldots \hat{Y}_{N-1})]^T$. The IDFT precoded signal with *N* subcarriers can be written as

$$\hat{x}_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} \hat{Y}_k . e^{j2\pi \frac{n}{N} k} \text{ , } k=0,1,2,\ldots,N-1 \quad (3)$$

$\hat{Y}_k$, we get after subcarrier mapping

From *a* and *b* we get, complex baseband SC-FDMA signal with *N* subcarrier

$$\hat{x}_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} \left(\frac{1}{\sqrt{M}} \sum_{l=0}^{M-1} X_l . e^{-j2\pi \frac{n}{M} l} \right) . e^{j2\pi \frac{n}{N} k} \quad (4)$$

C. PAPR

The PAPR of signals in (1) and (4) can be written as

$$PAPR = \frac{max|\hat{x}_n|^2}{E[|\hat{x}_n|^2]} \quad (5)$$

where E [.] denotes expectation. Complementary Cumulative Distribution Function (CCDF) of SC-FDMA and OFDMA can be written as

$$P\,(PAPR > PAPR_0) = 1 - (1 - e^{-PAPRo})^{N} \tag{6}$$

where $PAPR_0$ is the clipping level and this equation can be interpreted as the probability that the PAPR of a symbol block exceeds some clip level $PAPR_0$.

III. PROPOSED MODEL

A. Zadoff-Chu Sequences

Zadoff-Chu sequences are class of poly phase sequence of length *M* and given by according to [18] are as

$$a_k = \begin{cases} W_M^{k^2/2+qk} & For\ M\ even \\ W_M^{k(k+1)/2+qk} & For\ M\ odd \end{cases} \tag{7}$$

where $k = 0, 1, 2\ldots M\text{-}1$, q is any integer and W_M^r represents a primitive M^{th} root of unity. It is a complex number given by $W_M^r = \exp(-j2\pi r/M)$, where r is any integer relatively prime to M and $j=\sqrt{-1}$.

The Zadoff-Chu precoding matrix *P* of size *M* = L×L. With the use of sequence reshaping as given in equation (8)

$$k = m + lL \tag{8}$$

Zadoff-Chu Precoding matrix *P* with column wise reshaping can be written as

$$P = \begin{bmatrix} a_{00} & a_{10} & \cdots & a_{(L-1)0} \\ a_{01} & a_{11} & \cdots & a_{(L-1)1} \\ \vdots & \vdots & \ddots & \vdots \\ a_{0(L-1)} & a_{1(L-1)} & \cdots & a_{(L-1)(L-1)} \end{bmatrix} \tag{9}$$

In other words, the L^2 point long Zadoff-Chu sequence fills the precoding matrix column-wise.

B. GCL Sequence

GCL sequences are derived from Zadoff-Chu sequences. Let $\{a_k\}$, k = 0, 1, 2…*M*-1, be a Zadoff-Chu sequence of length *M* = sm^2, where m and s are any positive integers. Let $\{b_i\}$, i = 0, 1 2… m - 1, be any sequence of *m* complex numbers having the absolute values equal to 1. The generalized chirp-like (GCL) sequence {sk} according to [19] can be defined as

$$s_k = a_k b_{(k)\ mod\ m}\,,\ \ k=0,1,2,\ldots,M\text{-}1 \tag{10}$$

where (k) mod m means that index k is reduced modulo m. The GCL precoding matrix P of size *M* = L×L. With the use of sequence reshaping as given in equation (11)

$$k = m + lL \tag{11}$$

GCL Precoding matrix *P* with column wise reshaping can be written as

$$P = \begin{bmatrix} s_{00} & s_{10} & \cdots & s_{(L-1)0} \\ s_{01} & s_{11} & \cdots & s_{(L-1)1} \\ \vdots & \vdots & \ddots & \vdots \\ s_{0(L-1)} & s_{1(L-1)} & \cdots & s_{(L-1)(L-1)} \end{bmatrix} \tag{12}$$

In other words, the L^2 point long GCL sequence fills the precoding matrix column-wise. The Zadoff-Chu sequences and GCL sequences are perfect sequences. Both sequences a_k and s_k of length *L* have ideal periodic autocorrelation function R(p) and is given by

$$R(P) = \sum_{k=0}^{L-1} s_k s^*_{(k+p)mod\ L} \tag{13}$$

$$= \begin{cases} L, & P = 0(mod\ L) \\ O, & P \neq 0(mod\ L) \end{cases}$$

where (*) represent the complex conjugate and the index $(k + p)$ is computed modulo *L*. This ideal property makes the Zadoff-Chu sequences and the GCL sequences, the proper contenders for the Precoding based PAPR reduction in OFDMA systems.

C. Precoding Based Localized-OFDMA Uplink System

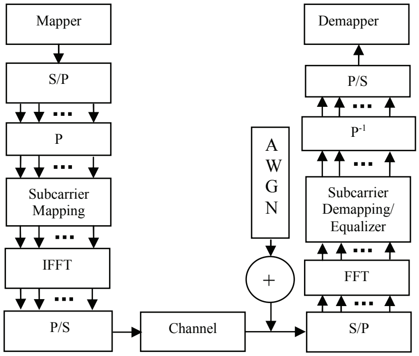

Figure 3. Block diagram of Precoding based OFDMA system.

Fig. 3 shows a Precoding based L-OFDMA uplink system. In this system a precoding matrix *P* of dimension *L* x *L* is applied to constellations symbols before the subcarrier mapping and IFFT to reduce the PAPR.

In the precoding based L-OFDMA uplink system baseband modulated data is passed through S/P convertor which generates a complex vector of size *M* that can be written as $X = [X_0, X_1, \ldots X_{M-1}]^T$. Then precoding is applied to this complex vector which transforms this complex vector into new vector of length *L* that can be written as $Y=PX= [Y_0, Y_1, Y_2 \ldots Y_{L-1}]^T$, where *P* is a precoder Matrix of size $M=L\times L$.

The value of matrix P can be used from equation (7) and (10). With the use of column wise sequence reshaping as given in equation (2), precoding X gives rise to Y as follows:

$$Y = PX \tag{14}$$

$$Y_m = \sum_{l=0}^{N-1} p_{m,l} X_m \qquad m = 0,1,\ldots L-1 \tag{15}$$

$p_{m,l}$ means m^{th} row and l^{th} column of precoder matrix. Then *N* subcarrier mapping is done in the localized mode, and after subcarrier mapping in localized mode, we get $\hat{Y}_m=[\hat{Y}_0, \hat{Y}_1, \ldots \hat{Y}_{N-1}]^T$, mathematically L-OFDMA subcarrier mapping can be defined as

$$\hat{Y}_m = \begin{cases} Y_m & 0 \le m \le M-1 \\ 0 & M \le m \le N-1 \end{cases} \tag{16}$$

The complex baseband L-OFDMA signal with *N* subcarriers, can be written as

$$\hat{x}_n = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} \hat{Y}_m \,.\, e^{j2\pi \frac{n}{N} m}, \; n=0,1,2,\ldots,N-1 \tag{17}$$

$\hat{Y}_m$, we get after subcarrier mapping, expanding (17) while using q = 0 in (7), gives

$$\hat{x}_n = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} \left\{ e^{-j\frac{\pi m^2}{L^2}} \left[\sum_{l=0}^{L-1} \left(e^{-j\pi l^2} . X_l \right) e^{-j\frac{2\pi m l}{L}} \right] \right\} . e^{j\frac{2\pi m n}{N}} \tag{18}$$

expanding (17) while using equation (10), gives

$$\hat{x}_n = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} \left\{ e^{-j\pi (m^2 + \frac{m}{L})} \left[\sum_{l=0}^{L-1} \left(e^{-j\pi (\frac{l^2+l}{L^2}} . X_l \right) e^{-j\frac{2\pi m l}{L}} \right] \right\} . e^{j\frac{2\pi m n}{N}} \tag{19}$$

Equation (18) and (19) represents Zadoff-Chu L-OFDMA and GCL L-OFDMA signals after IFFT implementations. The transmitted signal in (18) and (19) can be seen to be IFFT of phase weighted L-point DFT of constellation data X_l alternated in sign.

This is a precoded OFDMA system where DFT and phase weighting determine the PAPR gain. The PAPR of OFDM signal in (18) & (19) can be written as

$$PAPR = \frac{max|\hat{x}_n|^2}{E[|\hat{x}_n|^2]} \tag{20}$$

where E [.] denotes expectation. Complementary Cumulative Distribution Function (CCDF) of L-OFDMA can be written as

$$P\,(PAPR > PAPR_0) = 1 - (1 - e^{-PAPRo})^N \tag{21}$$

where $PAPR_0$ is the clipping level and this equation can be interpreted as the probability that the PAPR of a symbol block exceeds some clip level $PAPR_0$.

IV. SIMULATION RESULTS

Extensive simulations in MATLAB(R) have been performed in order to evaluate the performance of our proposed systems, Zadoff-Chu precoding based L-OFDMA uplink system and GCL precoding based L-OFDMA uplink system for LTE-A.

We also compared our computer simulation results with Interleaved-OFDMA original, Localized-OFDMA original, SLM conventional, WHT precoder based OFDMA system and Localized SC-FDMA (without pulse shaping) for M=16 & 256 and N=64 & 1024 for QPSK, 16-QAM and 64-QAM.

Figure.4 shows the CCDF comparisons of Localized-OFDMA, Interleaved-OFDMA, WHT Precoder Based OFDMA System, SC-FDMA (Localized-FDMA), Zadoff-Chu Precoder Based Localized-OFDMA System and GCL Precoder Based Localized-OFDMA System for M=16 and N=64 with QPSK modulation. At clip rate of 10^{-2}, the PAPR is reduced to 8.9dB, 8.3dB, 7.6dB, 7.0dB, 6.5dB and 6.5dB for L-OFDMA, I-OFDMA, WHT-Precoder Based OFDMA System, Zadoff-Chu Precoder Based Localized-OFDMA, GCL-Precoder Based Localized-OFDMA and SC-FDMA (LFDMA), respectively.

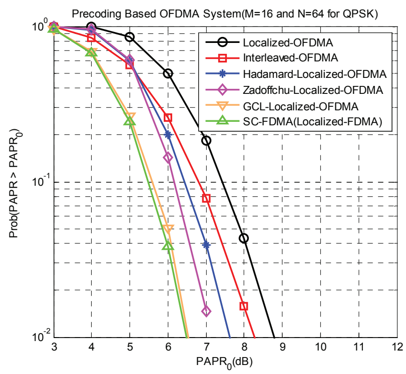

Figure 4. CCDF of L-OFDMA conventional, I-OFDMA conventional, WHT Precoder Based OFDMA, Zadoff-Chu Precoder Based L-OFDMA, GCL Precoder Based L-OFDMA and SC-FDMA (LFDMA) for QPSK.

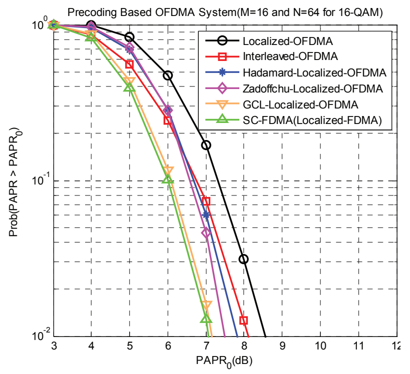

Figure 5. CCDF of L-OFDMA conventional, I-OFDMA conventional, WHT Precoder Based OFDMA, Zadoff-Chu Precoder Based L-OFDMA, GCL Precoder Based L-OFDMA and SC-FDMA (LFDMA) for 16-QAM.

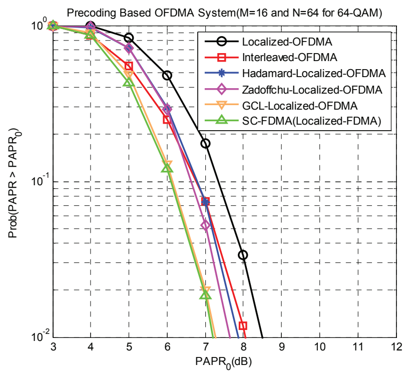

Figure 6. CCDF of L-OFDMA conventional, I-OFDMA conventional, WHT Precoder Based OFDMA, Zadoff-Chu Precoder Based L-OFDMA, GCL Precoder Based L-OFDMA and SC-FDMA (LFDMA) for 64-QAM.

Figure.5 shows the CCDF comparisons of Localized-OFDMA, Interleaved-OFDMA, WHT Precoder Based OFDMA System, SC-FDMA (Localized-FDMA), Zadoff-Chu Precoder Based Localized-OFDMA System and GCL Precoder Based Localized-OFDMA System for M=16 and N=64 with 16-QAM modulation. At clip rate of 10^{-2}, the PAPR is reduced to 8.6dB, 8.1dB, 7.8dB, 7.5dB, 7.1dB and 7.1dB for L-OFDMA, I-OFDMA, WHT-Precoder Based OFDMA System, Zadoff-Chu Precoder Based Localized-OFDMA, GCL-Precoder Based Localized-OFDMA and SC-FDMA (LFDMA), respectively.

Figure.6 shows the CCDF comparisons of Localized-OFDMA, Interleaved-OFDMA, WHT Precoder Based OFDMA System, SC-FDMA (Localized-FDMA), Zadoff-Chu Precoder Based Localized-OFDMA System and GCL Precoder Based Localized-OFDMA System for M=16 and N=64 with 64-QAM modulation. At clip rate of 10^{-2}, the PAPR is reduced to 8.5dB, 8.0dB, 7.9dB, 7.7dB, 7.2dB and 7.2dB for L-OFDMA, I-OFDMA, WHT-Precoder Based OFDMA System, Zadoff-Chu Precoder Based Localized-OFDMA, GCL-Precoder Based Localized-OFDMA and SC-FDMA (LFDMA), respectively.

Figure.7 shows the CCDF comparisons of Localized-OFDMA, Interleaved-OFDMA, WHT Precoder Based OFDMA System, SC-FDMA (Localized-FDMA), Zadoff-Chu Precoder Based Localized-OFDMA System and GCL Precoder Based Localized-OFDMA System for M=256 and N=1024 with QPSK modulation. At clip rate of 10^{-2}, the PAPR is reduced to 10.3dB, 9.9dB, 9.9dB, 8.0dB, 7.2dB and 7.2dB for L-OFDMA, I-OFDMA, WHT-Precoder Based OFDMA System, Zadoff-Chu Precoder Based Localized-OFDMA, GCL-Precoder Based Localized-OFDMA and SC-FDMA (LFDMA), respectively.

Figure.8 shows the CCDF comparisons of Localized-OFDMA, Interleaved-OFDMA, WHT Precoder Based OFDMA System, SC-FDMA (Localized-FDMA), Zadoff-Chu Precoder Based Localized-OFDMA System and GCL Precoder Based Localized-OFDMA System for M=256 and N=1024 with 16-QAM modulation. At clip rate of 10^{-2}, the PAPR is reduced to 10.4dB, 10.0dB, 10.0dB, 8.8dB, 8.2dB and 8.2dB for L-OFDMA, I-OFDMA, WHT-Precoder Based OFDMA System, Zadoff-Chu Precoder Based Localized-OFDMA, GCL-Precoder Based Localized-OFDMA and SC-FDMA (LFDMA), respectively.

Figure.9 shows the CCDF comparisons of Localized-OFDMA, Interleaved-OFDMA, WHT Precoder Based OFDMA System, SC-FDMA (Localized-FDMA), Zadoff-Chu Precoder Based Localized-OFDMA System and GCL Precoder Based Localized-OFDMA System for M=256 and N=1024 with 64-QAM modulation. At clip rate of 10^{-2}, the PAPR is reduced to 10.4dB, 10.0dB, 10.0dB, 8.9dB, 8.3dB and 8.3dB for L-OFDMA, I-OFDMA, WHT-Precoder Based OFDMA System, Zadoff-Chu Precoder Based Localized-OFDMA, GCL-Precoder Based Localized-OFDMA and SC-FDMA (LFDMA), respectively.

The Table 1 & Table 2 summarizes the PAPR analysis of our proposed precoding based L-OFDMA uplink system for the upcoming LTE-A 4G-cellular system. It is obvious from the tables that our proposed Zadoff-Chu precoding based L-OFDMA uplink system and GCL precoding based L-OFDMA uplink system have lower PAPR then L-OFDMA original, I-OFDMA original and WHT precoding based L-OFDMA at clip rate of 10^{-2}.

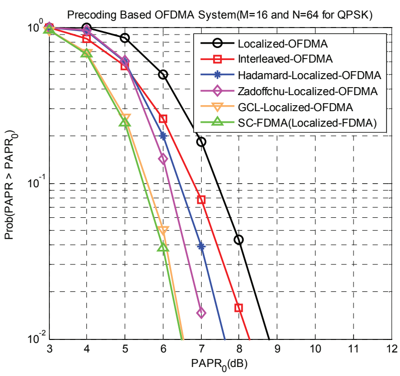

Figure 7. CCDF of L-OFDMA conventional, I-OFDMA conventional, WHT Precoder Based OFDMA, Zadoff-Chu Precoder Based L-OFDMA, GCL Precoder Based L-OFDMA and SC-FDMA (LFDMA) for QPSK

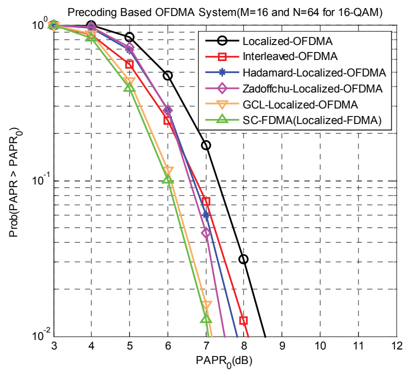

Figure 8. CCDF of L-OFDMA conventional, I-OFDMA conventional, WHT Precoder Based OFDMA, Zadoff-Chu Precoder Based L-OFDMA, GCL Precoder Based L-OFDMA and SC-FDMA (LFDMA) for 16-QAM.

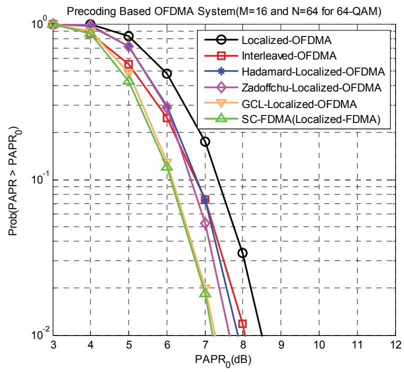

Figure 9. CCDF of L-OFDMA conventional, I-OFDMA conventional, WHT Precoder Based OFDMA, Zadoff-Chu Precoder Based L-OFDMA, GCL Precoder Based L-OFDMA and SC-FDMA (LFDMA) for 64-QAM.

Table.1. At Ccdf Of 10^{-2}, PAPR Comparisons Of LOFDMA, IOFDMA, SC-FDMA (LFDMA), ZADOFF-CHU LOFDMA And GCL-LOFDMA For M=16 (User Subcarriers) & N=64 (System Subcarriers)

Uplink Transmission Scheme	PAPR		
	QPSK	16-QAM	64-QAM
L-OFDMA Conventional	8.9 dB	8.6 dB	8.5 dB
I-OFDMA Conventional	8.3 dB	8.1 dB	8.0 dB
WHT L-OFDMA	7.6 dB	7.8 dB	7.9 dB
Zadoff-Chu L-OFDMA	7.0 dB	7.5 dB	7.7 dB
GCL L-OFDMA	**6.5 dB**	**7.1 dB**	**7.2 dB**
SC-FDMA (LFDMA)	**6.5 dB**	**7.1 dB**	**7.2 dB**

Table.2. At Ccdf Of 10^{-2}, PAPR Comparisons Of LOFDMA, IOFDMA, SC-FDMA (LFDMA), ZADOFF-CHU LOFDMA and GCL-LOFDMA FOR M=256 (User Subcarriers) & N=1024 (System Subcarriers)

Uplink Transmission Scheme	PAPR		
	QPSK	16-QAM	64-QAM
L-OFDMA Conventional	10.3 dB	10.4 dB	10.4 dB
I-OFDMA Conventional	9.9 dB	10.0 dB	10.0 dB
WHT L-OFDMA	9.9 dB	10.0 dB	10.0 dB
Zadoff-Chu L-OFDMA	8.0 dB	8.8 dB	8.9 dB
GCL L-OFDMA	**7.2 dB**	**8.2 dB**	**8.3 dB**
SC-FDMA (LFDMA)	**7.2 dB**	**8.2 dB**	**8.3 dB**

It is also noticeable from the tables, that the PAPR of GCL precoding based L-OFDMA uplink system has almost equal PAPR when we compare with SC-FDMA (LFDMA) system. Additionally, it is also concluded from tables that PAPR gain of our both proposed precoding based L-OFDMA uplink systems increases with increase in the number of subcarriers.

V. CONCLUSION

In this paper, we proposed two novel precoding based PAPR reduction techniques for L-OFDMA uplink system of LTE-A. These L-OFDMA MA techniques can be used as a Multi Carrier (MC) part of layered-OFDMA of LTE-A. Tables shows that our proposed precoding based schemes for L-OFDMA uplink system have lower PAPR as compared to L-OFDMA, I-OFDMA and WHT precoder based L-OFDMA uplink systems. It is also obvious from the tables that the both uplink systems, the GCL precoding based L-OFDMA uplink system and the SC-FDMA (LFDMA) system has almost equal PAPR. Our proposed precoding based techniques are efficient, signal independent, distortionless and do not require any complex optimizations. Hence it is concluded, that our proposed precoding based PAPR reduction techniques for L-OFDMA uplink system can take benefits from the side, multicarrier system and single carrier system. It is also concluded that our proposed precoding based PAPR reduction techniques for L-OFDMA uplink system can be considered as a best choice for the uplink communications of the upcoming LTE-A standard.

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