Peak-to-Average Power Ratio Analysis of SCFDMA Signal by Hybrid Technique

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ABSTRACT
The low peak-to-average power ratio (PAPR) in single-carrier systems has motivated the Long Term Evolution (LTE) Third Generation Partnership Project (3GPP) to adopt single carrier frequency division multiple access (SC-FDMA) as the uplink multiple access scheme. In this paper, an enhancement of a SC-FDMA system by decreasing the PAPR is focused. A combination of clipping and Pulse shaping (RRC filter) is applied on a SC-FDMA signal with IFDMA subcarrier mapping, which results in a PAPR reduction. This PAPR reduction by hybrid (clipping & pulse shaping) technique can be used to enhance the power efficiency of the handset, or alternatively to improve uplink throughput and/or operating range.

Keywords
SC-FDMA, 3GPP LTE, PAPR, RRC.

1. INTRODUCTION
The further increasing demand on high data rates in wireless communications systems has arisen in order to support broadband services.3GPP long term evolution (LTE) has adopted orthogonal frequency division multiplexing access (OFDMA) for downlink transmission and single carrier frequency division multiple access (SCFDMA) for uplink [1]. This is to compensate for a drawback with normal OFDMA, which has a very high peak to average power ratio (PAPR).High PAPR requires expensive and inefficient power amplifiers with high requirements on linearity, which increases the cost of the terminal and drains the battery faster. SCFDMA signal has lower PAPR because of its inherent single carrier structure [2]. This paper is organized as follows. In the next section, SCFDMA system model is introduced, and then we discuss the PAPR and proposed SCFDMA system. Performance evaluation is addressed in the following section, and the final section concludes the paper.

2. SCFDMA SYSTEM MODEL
The basic principle of a LTE SC-FDMA transmission system is shown in Figure.1.At the transmitter side, a baseband modulator transmits the binary input in one of several possible modulation formats including QPSK or 16 level-QAM.N-point discrete Fourier transform (DFT) produce a frequency domain representation of these modulated symbols.The output of the DFT is then applied to consecutive inputs of a size-M IDFT (M >N) where the unused input of IDFT are set to zero. If they are equal (M=N), they simply cancel out and it becomes a conventional single user single carrier system with frequency domain equalization. However, if N is smaller than M and the remaining inputs to the IDFT are set to zero, the output of the IDFT will be a signal with 'single carrier' properties, i.e. a signal with low power variations, and with a bandwidth that depends on N. The SC-FDMA is single carrier, not single frequency. The data signal of each user consists of a lot of frequency. DFT of SC-FDMA is used to filter the frequency items and maps them into IDFT to reform single user waveform. This may justify the reduced peak-to average lower ratio (PAPR) experienced in the IDFT output [3].

In SCFDMA, there are three methods of assigning the M frequency domain modulation Symbol to subcarriers: Distributed subcarrier mapping (DFDMA), Localized subcarrier mapping (LFDMA), and interleaved subcarrier mapping (IFDMA), a special case of distributed FDMA. In the localized subcarrier mapping mode, the modulation symbols are assigned to M adjacent subcarriers. In the distributed mode, the symbols are equally spaced across the entire channel bandwidth. The distributed and localized mapping of DFT precoded data sequence to OFDM subcarriers is sometimes collectively referred to as DFT-spread OFDM. In general, SCFDMA signals have lower PAPR than OFDMA signals and LFDMA incurs higher PAPR compared to IFDMA.Though IFDMA is more desirable than LFDMA in terms of PAPR power efficiency, LFDMA is superior in terms of throughput. Therefore, LFDMA has been widely implemented in LTE [2].

Clipping, companding and pulse shaping techniques are used to improve the PAPR performance of SCFDMA signal. Clipping is the simplest method that can limit the amplitude of the signal to some desired threshold value. It is a nonlinear process and may cause in-band distortion and out of-band radiation. SC-FDMA is a single carrier modulation scheme, and pulse shaping is required to band limit the transmitted signal but it enlarges the PAPR of the SC-FDMA transmitted signals. In this paper performance of IFDMA subcarrier mapping scheme based SCFDMA system with hybrid technique (clipping and pulse shaping filter) is analyzed in terms of PAPR.

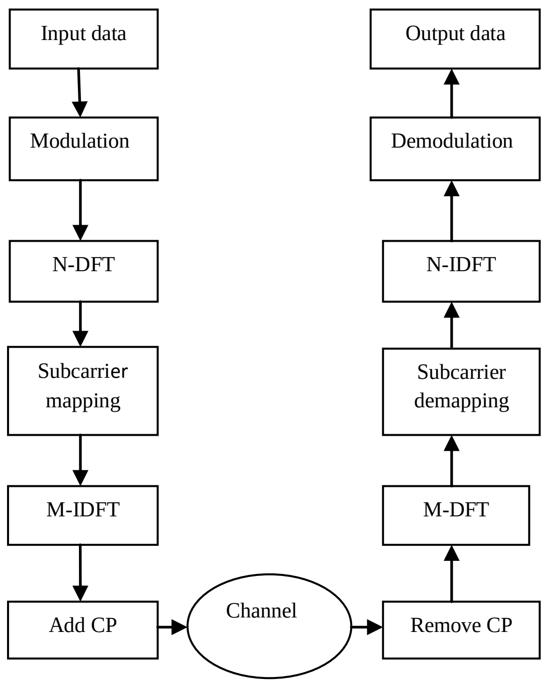

Figure 1. Transmitter and receiver structure of SCFDMA system model

3. PAPR DEFINITION

The PAPR in SC-FDMA is required to be as small as possible. The PAPR is defined as the ratio of peak power to average power of the transmitted signal in a given transmission block and is given by [4]:

$$PAPR = \frac{P_{Peak}}{P_{Av}} = \frac{MAX_{0\le m\le M-1}(x_m)}{\frac{1}{M}\sum_{m=0}^{M-1} x_m^2}$$

The cumulative distribution function (CDF) of the PAPR is one of the most performance measures for different PAPR reduction techniques. Most researches use complementary CDF (CCDF) instead of CDF. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold PAPR>$PAPR_{th}$ [5].

4. PROPOSED SCFDMA SYSTEM

After IDFT in Figure.1 the clipping and Pulse shaping (RRCF) arrangement is implemented as shown in Figure.2.

The proposed system provides enhancement in terms of PAPR. The clipping function is given by:

$$x_n = \begin{cases} Ae^{j\varphi}, & x > A \\ x, & x \le A \end{cases}$$

Where x_n *is* the clipped signal, x is the base-band signal, A is the peak amplitude and φ is the phase of the baseband signal which has no change due to clipping [5], [6].

In a single-carrier communication system, pulse shaping is required to band limit the signal and ensures it meets the spectrum mask [7]. Root raised cosine (RRC) filter is used to pulse shape the SC-FDMA signals [8].

RRC is used as the transmit and receive filter in a digital communication system to perform matched filtering. The combined response of two such filters is that of the raised-cosine filter. Its name stems from the fact that the non-zero portion of the frequency spectrum of its simplest form β = 1 (called the roll-off factor) is a cosine function. The RRC filter is characterized by two values; β and T_s (reciprocal of the symbol-rate). The impulse response of such a filter can be given as:

$$h(t) = \begin{cases} 1-\beta+4\beta/\pi & t=0 \\ \beta/\sqrt{2}[\left(1+\frac{2}{\pi}\right)\sin\left(\frac{\pi}{4\beta}\right)+\left(1-\frac{2}{\pi}\right)\cos\left(\frac{\pi}{4\beta}\right) & t=\pm Ts/4\beta \\ \dfrac{\sin\left[\frac{\pi t}{Ts(1-\beta)}\right]+\frac{4\beta t}{Ts}\cos[\frac{\pi t}{Ts(1+\beta)}]}{\frac{\pi t}{Ts}[1-\left(\frac{4\beta t}{Ts}\right)^2]} & else \end{cases}$$

Unlike the raised-cosine filter, the impulse response is not zero at the intervals of $\pm T_s$. However, the combined transmit and receive filters form a raised-cosine filter which have zero at the intervals of $\pm T_s$. Only in the case of β = 0, the root raised-cosine have zeros at $\pm T_s$ [3].

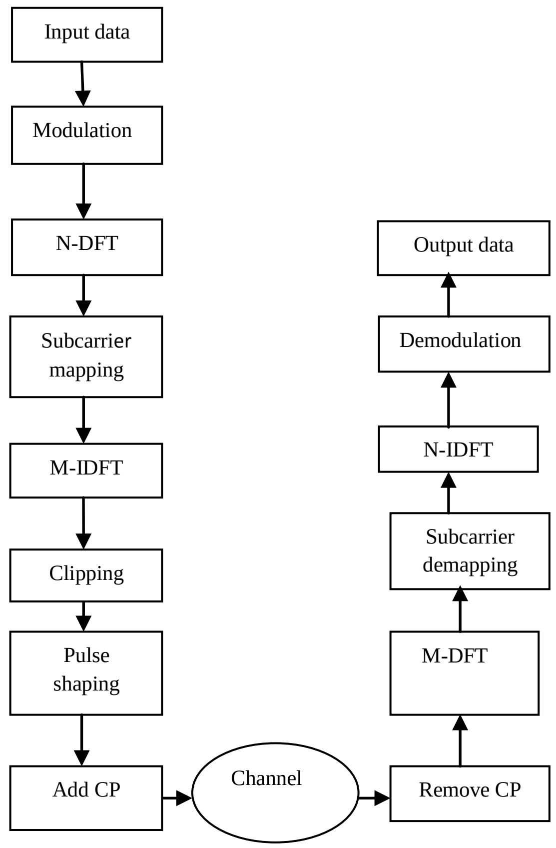

Figure 2. Block diagram of the proposed scheme

The method of applying algorithm is summarized as follow:

1. The binary input signal is passed through the modulation, introducing blocks of data symbols.
2. Each block of data symbols is converted to frequency domain by DFT operation.
3. After DFT spread, Subcarrier mapping and IDFT operation is applied to the block of symbols.
4. After that, the amplitude of the signal in the time domain is clipped and RRC filtering is applied. Then PAPR is computed.

5. SIMULATION RESULTS

Computer simulations are performed using MATLAB to validate the results. To evaluate the PAPR of system configuration we simulated the transmission of 10^5 random data points. After calculating the PAPR the data was presented as an empirical complementary cumulative distribution function (CCDF).Table.1 illustrates the parameters implemented in the simulation for the SC-FDMA system using interleaved allocation.

Table 1. Simulation Parameters

Description	Parameter
System bandwidth	5 MHz
No. of subcarriers	512
Data block size	16, 64, 128
Roll off factor	0.1, 0.3, 0.5
Oversampling factor	4
No. of iteration	10^5
Modulation data type	QAM
Subcarrier mapping	IFDMA

Figures.3 and 4 show the simulation results. The CCDF of the PAPR for proposed SCFDMA system with IFDMA subcarrier mapping scheme is shown in Figure 3.Modulation scheme is16QAM, M=512, N=16.Root raised cosine filter with roll off factor 0.1, 0.3 and 0.5 is used after clipping. With clipping technique reduction in PAPR is obtained by adjusting clipping level.

It can be seen that PAPR for proposed SCFDMA is reduced with increasing the roll off factor for RRC filter from 0.1 to 0.5. This is because as β increases (i.e. larger excess bandwidth), the RRC filter ripples decay faster. Thus, the peak value of the transmit signal waveform will reduce appropriately. RRC filter with high roll off factor reduces PAPR significantly but price paid is increased bandwidth requirement. So a middle value of roll off factor is chosen according to application.

From simulation results it is also clear that if IFDMA with clipping and RRC pulse shaping is applied on a different number of subcarriers better PAPR reductions performances can be achieved for a large number of subcarriers. In Figure.4 increasing N from 16 to 128 with roll off factor 0.5, the PAPR of proposed SCFDMA system is reduced up to 4.9dB. It is clear that there is a decrease in the PAPR for the proposed scheme compared to the conventional.

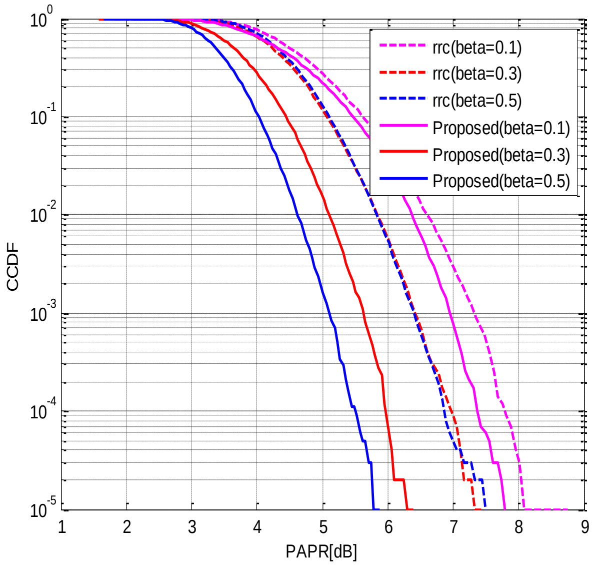

Figure 3. Comparison of PAPR for proposed and rrc pulse shaping with different roll off factor

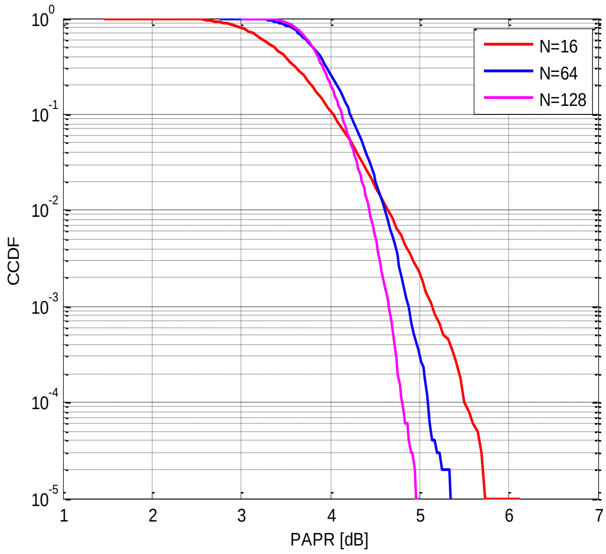

Figure 4. CCDF of PAPR for Proposed SCFDMA with different N

6. CONCLUSION

In this paper, an efficient SC-FDMA system with clipping and pulse shaping is presented and studied. Simulation results show that the proposed technique with IFDMA subcarrier mapping and 16QAM modulation performs better in terms of PAPR .The results show that proposed IFDMA system can maintain a low PAPR for a very large number of subcarriers. It is concluded that there is a decrease in the PAPR up to 4.9dB for the proposed scheme compared to the conventional by controlling number of symbols, roll off factor, clipping level. The resulting PAPR reduction can be used to enhance handset power efficiency.

7. REFERENCES

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