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A Novel Discrete Spreading Scheme with RC Filter for PAPR reduction in OFDM System using Multiple Interleaver

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Abstract
In this paper, a novel discrete spreading scheme with shaping filter is proposed to reduce the peak-to-average power ratio (PAPR) in orthogonal frequency division multiplexing (OFDM) system using multiple Interleavers. In proposed algorithm, the N point discrete transform is used for spreading, and the output of discrete transform is assigned to the subcarriers of Inverse transform. The effect of PAPR reduction depends on how to assign the subcarriers to each point. In the proposed algorithm as we increased the shaping coefficient the PAPR performance is improved. The proposed algorithm is reduced the PAPR as well as improve the bit error rate performance for OFDM system with multiple Interleaver. The proposed algorithm solve the problem in 3-GPP LTE physical layer system in which to achieve the lowest PAPR value with respect to OFDM system with multiple interleaver. We have targeted uplink of the LTE system in which we have proposed the algorithm in which OFDM system used with multiple interleavers to minimize the probability of error as well as to reduce the peak to average power ratio using various shaping filter coefficient. In this paper we have compare the simulation results for OFDM system with Interleaver and without Interleaver. We have evaluated channel effect with respect to the M ary Quadrature Amplitude Modulation (QAM) technique like 8-QAM, 16-QAM, 32-QAM, 64-QAM and 128-QAM. Theoretical analysis and simulation results show that the proposed discrete spreading scheme could offer excellent performance of PAPR reduction and bit error rate for OFDM system with multiple Interleaver compare to OFDM system without Interleaver.

Keywords: Peak to Average Power Ratio (PAPR), Orthogonal Frequency Division Multiplexing (OFDM), Quadrature Amplitude Modulation (QAM), Discrete Spreading, Interleaver, Raised Cosine filter (RC filter)

Introduction
OFDM is used for wideband digital communication. In IEEE 802.11n and IEEE 802.11ac, OFDM is seen as possible technique at physical layer with multiple input and multiple output. OFDM is adopted by 3GPP-LTE system to improve the wireless broadband connectivity [9]. OFDM is used in applications such digital television, audio broadcasting, wireless networking and in wireless broadband connectivity to provide data rate of 100 Mbps for mobile users and 1Gbps for fixed users in 4G 3GPP-LTE system. [9].
The 3GPP is an international standardization body working on the specification of the 3G Universal Terrestrial Radio Access Network (UTRAN) and on the Global System for Mobile communications (GSM) [8] as well as on the current 4G wireless network. The latest specification that is being studied and developed in 3GPP is an evolved 4G radio access, widely known as LTE (Long-Term Evolution) or Evolved UTRAN (E-UTRAN), as well as an evolved packet access core network in the System Architecture Evolution (SAE) [8]. In earlier it was decided that the LTE radio access should be based on OFDMA in the downlink (DL) and Single-Carrier Frequency-Division Multiple Access (SC-FDMA) in the uplink (UL). SC-FDMA is also known as Discrete Fourier Transform Spread OFDMA (DFTS-OFDMA) [8].
In an OFDM system the one of the problem is high peak values of the signals in the time domain due to the number of subcarriers are accumulated through an IFFT block [1-2]. Because of this high PAPR value, it reduces the Signal to Quantization Noise Ratio of ADC and DAC while reduces the efficiency of the power amplifier in the transmitter [3-4]. So, the main objective in the OFDM system is to reduce this high PAPR value [5-6]. We have targeted uplink of the LTE system in which we have proposed the algorithm in which OFDM system used with multiple interleaver to minimize the PAPR value using various shaping filter coefficient and to improve bit error rate. The proposed algorithm minimize the PAPR value as we increase the shaping coefficient and the overall OFDM systems does not suffers from high PAPR.
In this paper, we have simulated the complementary cumulative distribution function versus input decibel level for OFDM with and without interleaver. We have also compared the proposed PAPR reduction technique with respect to the without shaping filter consideration. We have also measured Bit Error Rate performance with respect to the Signal to Noise Ratio for different modulation technique like 8-QAM, 16-QAM, 32-QAM, 64-QAM and 128-QAM.

System Model
In this section we have discussed the system model of OFDM transmitter and receiver with multiple interleaver and de-interleaver respectively.

OFDM Transmitter with Interleaver

OFDM is a Frequency-Division Multiplexing (FDM) technique which used as a digital multi-carrier modulation method [7]. Figure 1 shows the basic block diagram of OFDM transmitter with interleaver. The data source is a kind of digital data. Digital data is fed to the interleaver [10] which is then fed to the M-QAM modulator. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. After that data is fed to the IFFT block in which frequency domain signal is converted in to the time domain signal. Then adding cyclic prefix into the time domain signal and then convert the parallel data stream into the serial data stream and finally digital signal is converted into the analog signal using digital to analog converter and passes to the wireless channel.

In current uplink 3-GPP LTE system single carrier-FDMA technique is used. In this paper we have used OFDM system with multiple interleavers which minimized the bit error rate with respect to various modulation techniques like 8-QAM, 16-QAM, 32-QAM, 64-QAM and 128-QAM.

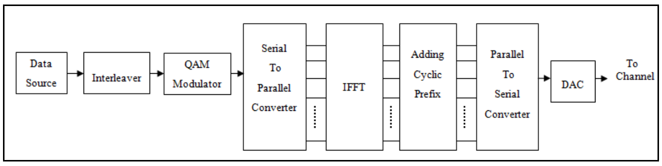

Fig.1. Block diagram of OFDM Transmitter with Interleaver

OFDM Receiver with De-interleaver

Figure 2 shows the block diagram of an OFDM receiver with de-interleaver. The signals which are received from the wireless channel are fed to the analog to digital converter which provides the digital signal.

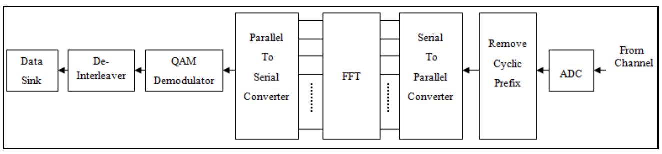

Fig.2. Block diagram of OFDM Receiver with De-interleaver

After that cyclic prefix are removed and then signal is fed to the serial to parallel converter which provides parallel data stream. Then using FFT block time domain signal is converted into the frequency domain signal and then it is fed to the parallel to serial converter which provides serial data stream. There are different types of demodulation techniques are used like 8-QAM, 16-QAM, 32-QAM, 64-QAM and 128-QAM which demodulate the signal and then it is fed to the de-interleaver block and finally receive the original signal.

In current downlink 3-GPP LTE system OFDMA technique is used. In this paper we have also present the performance comparison between the proposed OFDM with interleaver technique with the other technique like OFDMA (used in downlink of 3-GPP LTE) and LFDMA in which interleaver are not used.

Proposed Algorithm to reduce PAPR and Improve BER

In this paper we have targeted uplink of the LTE system in which we have proposed the algorithm in which OFDM system used with multiple interleavers to minimize the probability of error as well as to reduce the peak to average power ratio using various shaping filter coefficient.

In current uplink 3-GPP LTE system single carrier-FDMA technique is used. In this paper we have used OFDM system with multiple interleaver which minimized the bit error rate. Also we have proposed the algorithm which minimized the PAPR value of OFDM system. In proposed algorithm we have used M-QAM modulation technique.

The block diagram of proposed technique for PAPR reduction and improve BER for OFDM system with interleaver as shown in figure 3. Here, the input data a[p] is discrete spread to generate A[i] and then, allocated as,

$$\tilde{A}[k] = \begin{cases} A[k/S], k = Sp_1, p_1 = 0,1,2,......, P-1 \\ 0, otherwise \end{cases} \qquad (1)$$

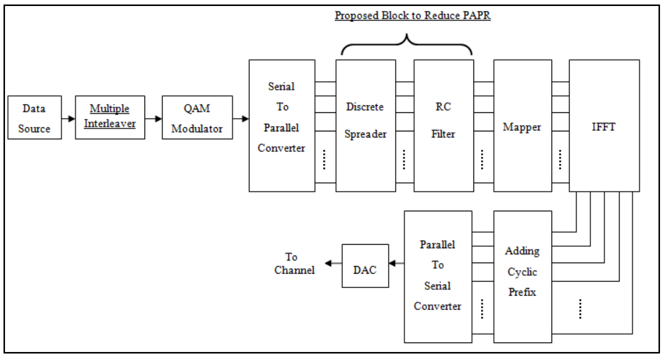

Fig.3. Block diagram of proposed technique for PAPR reduction and improve BER for OFDM system with interleaver

The Inverse Fast Fourier transforms which converts frequency domain signal into time domain signal $\tilde{a}[q]$ with q= P · s + p for s = 0,1,2,……,S-1 and p = 0,1,2,…..,P-1 can be expresses as,

$$\tilde{a}[q] = \frac{1}{Q}\sum_{k=0}^{Q-1}\tilde{A}[k]e^{j2\pi\frac{qk}{Q}} \qquad (2)$$

$$\tilde{a}[q] = \frac{1}{S}\frac{1}{P}\sum_{p_1=0}^{P-1}A[p_1]e^{j2\pi\frac{q}{P}p_1} \qquad (3)$$

Where, q = P · s + p (4)

$$\tilde{a}[q] = \frac{1}{S}\left(\frac{1}{P}\sum_{p_1=0}^{P-1}A[p_1]e^{j2\pi\frac{p}{P}p_1}\right) \qquad (5)$$

$$\tilde{a}[q] = \frac{1}{S} a[p] \quad (6)$$

which means original input signal a[p] scaled by 1/S are repeated in the time domain. In the OFDM system with interleaver, the next part is subcarrier mapping in which mapping starts with the l^{th} subcarrier, where l = 0,1,2,3,….,S-1, the discrete spread symbol can be expresses as,

$$\tilde{A}[k] = \begin{cases} A[(k-l)/S], k = Sp_1 + l, p_1 = 0,1,2,.....P-1 \\ 0, otherwise \end{cases} \quad (7)$$

Then, the corresponding IFFT output, $\tilde{a}[q]$ is given by,

$$\tilde{a}[q] = \tilde{a}[Ps + p] \quad (8)$$

$$\tilde{a}[q] = \frac{1}{Q} \sum_{k=0}^{Q-1} \tilde{A}[k] e^{j2\pi \frac{q}{Q}k} \quad (9)$$

$$\tilde{a}[q] = \frac{1}{S} \frac{1}{P} \sum_{p_1=0}^{P-1} A[p_1] e^{j2\pi\left(\frac{q}{P}p_1 + \frac{q}{Q}l\right)} \quad (10)$$

$$\tilde{a}[q] = \frac{1}{S}\left(\frac{1}{P} \sum_{p_1=0}^{P-1} A[p_1] e^{j2\pi \frac{p}{P}p_1}\right) e^{j2\pi \frac{q}{Q}l} \quad (11)$$

$$\tilde{a}[q] = \frac{1}{S} e^{j2\pi \frac{q}{Q}l} a[p] \quad (12)$$

So, the frequency shift of subcarrier allocation starting point by l subcarriers results in the phase rotation $e^{j2\pi \frac{q}{Q}l}$ in a system in OFDM with interleaver.

Now let compare the proposed OFDM system using interleaver with other approach like Localized FDMA. In the discrete spreading scheme for LFDMA, the IFFT input signal $\tilde{A}[k]$ at the transmitter can be expressed as,

$$\tilde{A}[k] = \begin{cases} A[k], k = 0,1,2,3,......P-1 \\ 0, k = P, P+1, P+2,....Q-1 \end{cases} \quad (13)$$

The IFFT output sequence $\tilde{a}[q]$ with q = S · p + s for s=0,1,2,3,.....,S-1 can be expressed as,

$$\tilde{a}[q] = \tilde{a}[Sp + s] = \frac{1}{Q} \sum_{k=0}^{Q-1} \tilde{A}[k] e^{j2\pi \frac{qk}{Q}} \quad (14)$$

$$\tilde{a}[q] = \frac{1}{S} \frac{1}{P} \sum_{k=0}^{P-1} A[k] e^{j2\pi \frac{Sp+s}{SP}k} \quad (15)$$

For s=0, equation (15) becomes,

$$\tilde{a}[q] = \tilde{a}[Sp] = \frac{1}{S} \frac{1}{Q} \sum_{k=0}^{Q-1} \tilde{A}[k] e^{j2\pi \frac{Sp}{SP}k} \quad (16)$$

$$\tilde{a}[q] = \frac{1}{S} \frac{1}{P} \sum_{k=0}^{P-1} A[k] e^{j2\pi \frac{p}{P}k} \quad (17)$$

$$\tilde{a}[q] = \frac{1}{S} a[p] \quad (18)$$

For s ≠ 0, $A[k] = \sum_{t=0}^{P-1} a[t] e^{-j2\pi \frac{t}{Q}k}$

such that equation (15) becomes,

$$\tilde{a}[q] = \tilde{a}[Sp + s] \quad (19)$$

From equation (19) it can be seen that for LFDMA the time domain signal becomes the 1/S scaled of the input sequence at the multiples of S in the time domain. In short for LFDMA the peak to average power ratio is not too much reduced as compared to the proposed algorithm which reduces the PAPR for OFDM system with interleaver.

Results and Discussion

Here we have evaluated the performance of novel discrete spreader scheme with shaping filter which minimizes the peak to average power ratio in OFDM system using multiple interleavers. We have calculated received power value with respect to the various techniques like OFDMA, Localized FDMA (used in 3-GPP LTE) and OFDM system with interleaver (proposed technique). In this section we have discussed the results with respect to the various modulation technique like 8-QAM/OFDM, 16-QAM/OFDM, 32-QAM/OFDM, 64-QAM/OFDM and 128-QAM/OFDM.

The simulation results are divided into two categories: In the first category we have compare the proposed OFDM system with interleaver technique with the OFDMA and localized FDMA (used in 3-GPP LTE) technique. Figure 4 to figure 8 represents Complementary Cumulative Distribution Function (CCDF) value versus input decibel value for 8-QAM 16-QAM, 32-QAM, 64-QAM and 128-QAM types of modulation techniques respectively. Simulation results show that in proposed OFDM system with interleaver technique, the peak to average power ratio is very low compare to the other techniques.

In second category we have simulate the proposed technique for PAPR reduction for OFDM system with interleaver using shaping filter. Figure 9 to figure 13 represents CCDF value versus input decibel value for 8-QAM 16-QAM, 32-QAM, 64-QAM and 128-QAM types of modulation techniques respectively using shaping filter coefficient 0.2, 0.4, 0.6, 0.8 and 1.0. Simulation results show that as we increased the filter coefficient from 0.2 to 1.0, the PAPR value decreases. We have achieved the lowest level of PAPR value in the proposed algorithm.

The simulations parameters are mentioned in table 1. Simulation results regarding proposed algorithm of shaping filter for OFDM system with multiple interleaver for different modulation technique are mentioned in table 2.

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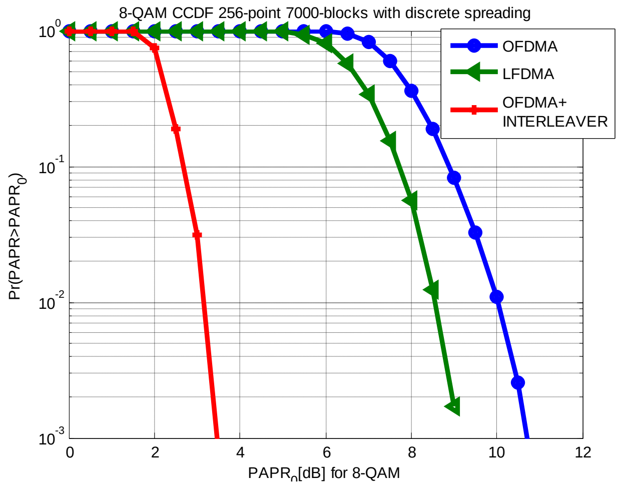

Fig.4. Compare the proposed PAPR Reduction technique with other technique for 8-QAM/OFDM

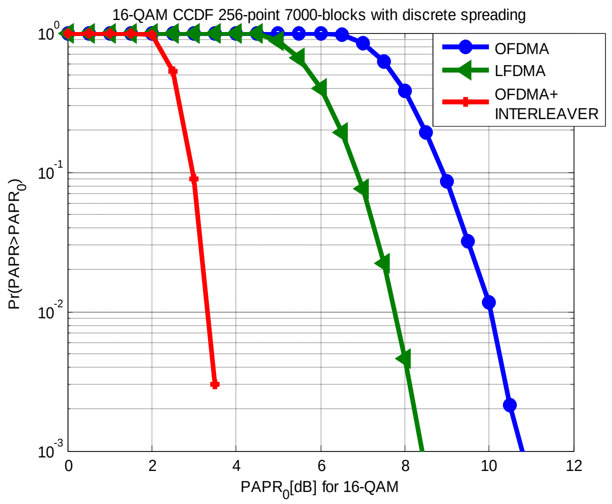

Fig.5. Compare the proposed PAPR Reduction technique with other technique for 16-QAM/OFDM

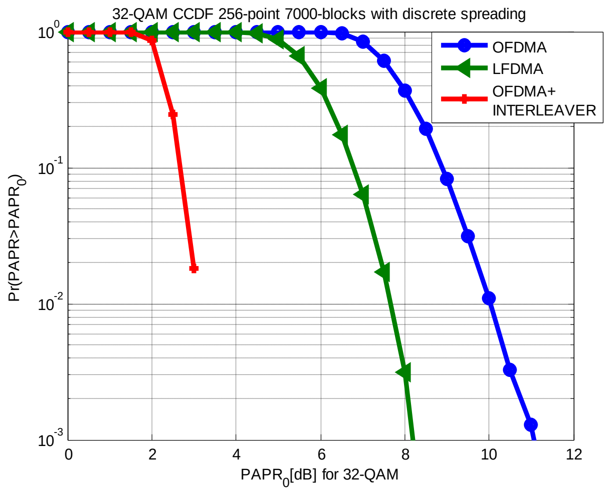

Fig.6. Compare the proposed PAPR Reduction technique with other technique for 32-QAM/OFDM

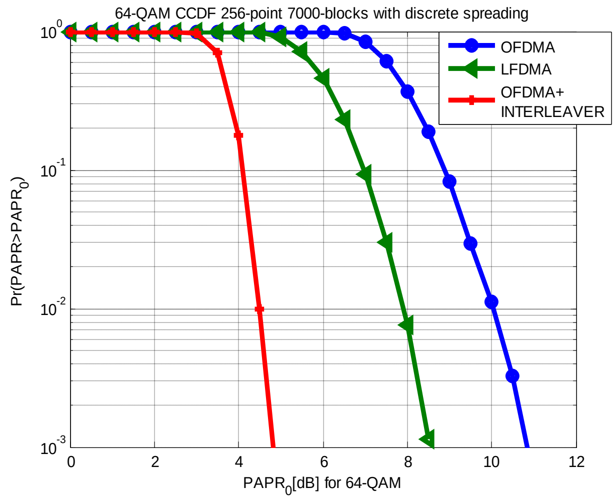

Fig.7. Compare the proposed PAPR Reduction technique with other technique for 64-QAM/OFDM

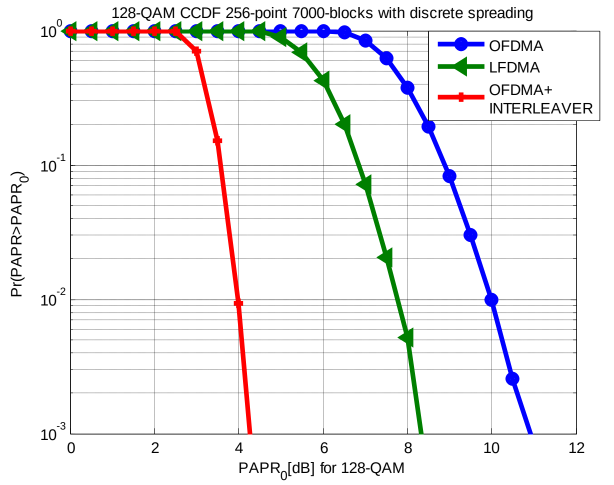

Fig.8. Compare the proposed PAPR Reduction technique with other technique for 128-QAM/OFDM

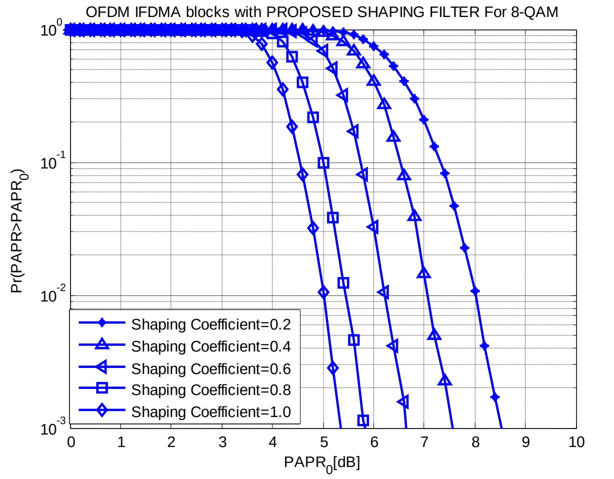

Fig.9. Proposed PAPR Reduction technique for OFDM system with interleaver using shaping filter for 8-QAM/OFDM

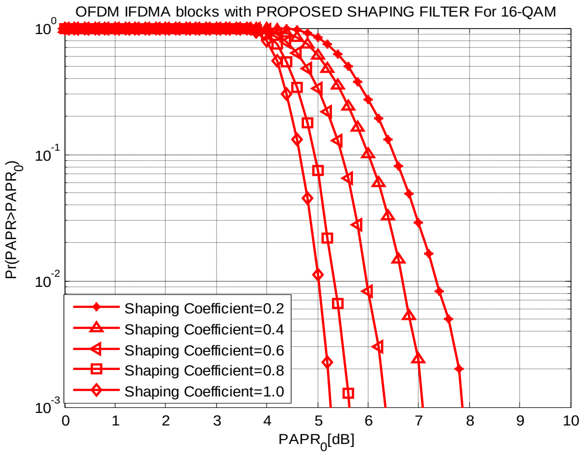

Fig.10. Proposed PAPR Reduction technique for OFDM system with interleaver using shaping filter for 16-QAM/OFDM

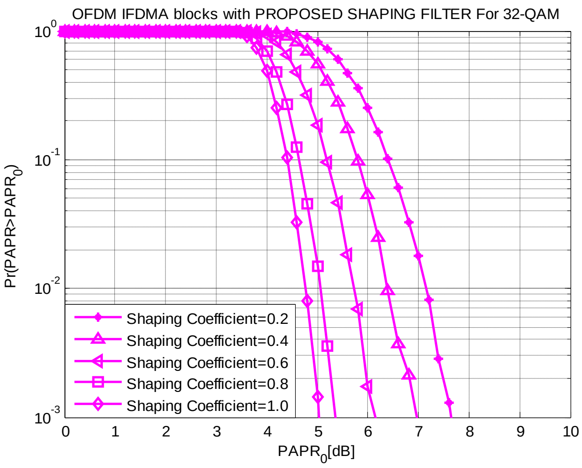

Fig.11. Proposed PAPR Reduction technique for OFDM system with interleaver using shaping filter for 32-QAM/OFDM

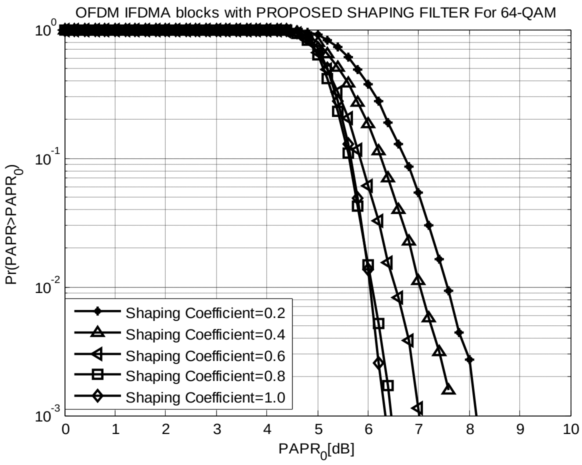

Fig.12. Proposed PAPR Reduction technique for OFDM system with interleaver using shaping filter for 64-QAM/OFDM

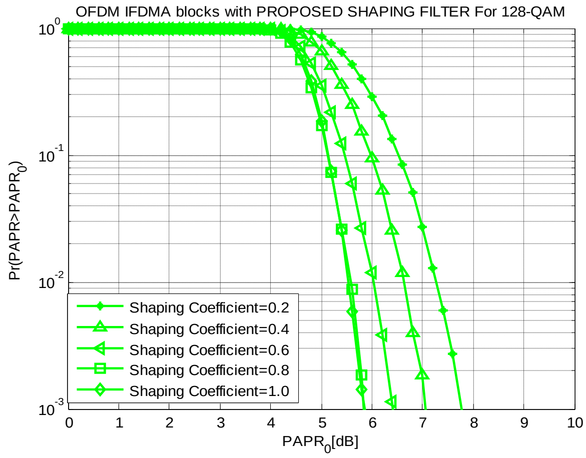

Fig.13. Proposed PAPR Reduction technique for OFDM system with interleaver using shaping filter for 128-QAM/OFDM

TABLE.1. Simulation Parameters

Sr. No.	Name of the Parameters	Value/Order of the Parameters
1.	Type of Modulation	8-QAM/OFDM
		16-QAM/OFDM
		32-QAM/OFDM
		64-QAM/OFDM
		128-QAM/OFDM
2.	Number of bits per symbol	3,4,5,6,7
3.	FFT size	256 point
4.	Data Block size (No. of Subcarriers per user)	64
5.	Number of OFDM blocks for iteration	7000
6.	Spreading Factor	4
7.	Oversampling Factor	8
8.	RC Filter Coefficient	0.2,0.4,0.6.0,8,1.0
9.	RC Filter length	6
10.	Number of Interleavers	64

TABLE.2. Simulation results regarding proposed algorithm of RC filter for OFDM system with multiple interleavers for different modulation technique

Modulation Technique	Filter Coefficient	Practical CCDF (PAPR) value at 5 dB
8-QAM/OFDM	0.2	0.9957
	0.4	0.9923
	0.6	0.8923
	0.8	0.1256
	1.0	0.0134
16-QAM/OFDM	0.2	0.9961
	0.4	0.9944
	0.6	0.8945
	0.8	0.2456
	1.0	0.0156

32-QAM/OFDM	0.2	0.9974
	0.4	0.7896
	0.6	0.1789
	0.8	0.0112
	1.0	0.0014
64-QAM/OFDM	0.2	0.9981
	0.4	0.9948
	0.6	0.8978
	0.8	0.6798
	1.0	0.5478
128-QAM/OFDM	0.2	0.9923
	0.4	0.8745
	0.6	0.6678
	0.8	0.2376
	1.0	0.1456

Conclusion

This work was devoted to the uplink of the LTE system in which we have proposed the algorithm in which OFDM system used with multiple interleavers to minimize the probability of error as well as to reduce the peak to average power ratio using various shaping filter coefficient. Simulation results shows that lowest PAPR value is achieved in proposed OFDM system with interleaver approach (figure 4 figure 8) compared to the LFDMA and OFDMA (used in 3-GPP LTE uplink system) approach. From figure 9 to figure 13 we have conclude that in proposed algorithm, as we increased the shaping filter coefficient, the PAPR value is reduced.

Future Scope

In this paper we have proposed the algorithm which minimizes the PAPR value using various modulation techniques like 8-QAM/OFDM, 16-QAM/OFDM, 32-QAM/OFDM, 64-QAM and 128-QAM/OFDM. The proposed algorithm minimizes the PAPR value for uplink of the 3-GPP LTE physical system using OFDM system with interleaver concept. After that proposed algorithm is applied on different types of interleaver and to improve the bit error rate performance in 3-GPP LTE physical system.

Appendix

The basic algorithm regarding PAPR reduction technique using proposed method as given below:
Step 1: Mention number of subcarriers (N), number of sub-blocks and number of oversampling factor.
Step 2: Mention M-ary number for different modulation technique and generate modulated symbol.
Step 3: Mention number of OFDM blocks for iteration.
Step 4: Find out CCDF value for without PAPR reduction technique.
Step 5: Using proposed algorithm find out CCDF value with PAPR reduction. The Mathematical equation for CCDF of OFDM signal with PAPR reduction technique is given by,

$$CCDF = PAPR/No.\ of\ Block\ of\ OFDM \quad (1)$$

Where,

$$PAPR = Max.\ power/Mean\ power \quad (2)$$

Where, Maximum power and average power depending on number of sub-blocks and oversampling factor.
The number of oversampling factor depends on types of modulation technique.
Step 6: Plot the CCDF value versus input decibel value.

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