Computer Engineering and Applications
Computer Engineering and Applications Vol. 5, No. 2, June 2016

Peak to Average Power Ratio Reduction in OFDM Using Pulse Shaping Technique

Diptadeep Das

School of Electronics and Communication Engineering, VIT University, Vellore

ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a special type of multicarrier modulation in which a signal is split into several narrowband channels at different frequencies. Here data is divided into parallel data streams each transmitted on a separate band. One of the major drawbacks of multicarrier transmission is the high peak-to-average power ratio (PAPR) of the transmit signal. Nyquist filters provide ISI-free transmission. In this paper we are going to propose some new filters which can formulated in an effort to reduce the peak-to-average power ratio (PAPR) of the baseband signal. While maintaining the same excess bandwidth and the zero inter-symbol interference condition. The proposed filters contain various parameters which gives an additional degree of freedom to minimize PAPR for a given roll-off factor α .

Keywords:

1. INTRODUCTION

One major limitations of OFDM is the high peak-to-average power ratio of the transmit signal which occurs due to the summation of many subcarrier modulated signals. A high PAPR requires a wide dynamic range for the power amplifier at the transmitter, or more commonly the power amplifier needs to be backed off to accommodate high peaks. This results in significant reduction of the transmission power which leads to very low power efficiency. It is therefore preferable to reduce the PAPR of the signal. Orthogonality is preserved as long as sub-carriers are harmonics to each other. If at the receiver‘s end there is a change in frequency of the sub-carriers due to any reason, then the orthogonality among them are lost and ICI occurs resulting in signal degradation. This change in frequency is called frequency offset.

An OFDM signal consists of a number of independently modulated sub-carriers, which can give a large peak-to-average power ratio (PAPR) when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. The peak power is defined as the power of a sine wave with amplitude equal to the maximum envelope value. Hence, an un-modulated carrier has a PAP ratio of 0 dB.

We have reduced the PAPR of the baseband signal by improving over the conventional square root raised cosine filter, the currently being used in pulse shaping technique. To do so we first modify the conventional square root raised cosine filter by introducing variation in parameters. These parameters can be varied independently where the roll-off factor α, is used to shape impulse response in minimizing PAPR and maintaining the zero ISI condition. Improved Parameters yields minimum PAPR which is obtained as a function of a, a, m, α and β.

2. BACKGROUND

These papers show that due to the orthogonality feature OFDM is the most preferred multi-carrier modulation. It also provides an insight to the major problems faced by it due to the increase in the number of subcarriers. The two drawbacks faced by OFDM sub-carriers are – PAPR and ICI Power.

Several existing techniques have been proposed by the researchers with clipping and filtering being the simplest of all but due to in-band and out-band distortions caused by this technique, researchers came up with several advance technique but none of them was capable of reducing both PAPR and ICI Power simultaneously.

This paper explain some advanced techniques like – MRC and SP, which ultimately led us to propose modified techniques like – ISP and SRRC, with SRRC being the most suitable technique as it alleviates both PAPR and ICI Power to maximum extent.

3. EFECT OF PULSE SHAPING ON PAPR REDUCTION

A possible solution to reduce the PAPR of OFDM signals is to create some correlation between the different OFDM samples of the same block. By making the cross-correlation close one, a multicarrier signal with very low PAPR is obtained. The cross-correlation function of the OFDM signal is obtained.

The cross correlation function is a function of the signal modulated symbol and the subcarrier waveforms. Hence, increasing the correlation between the OFDM signal samples of the same block can be increased through these two parameters. As a result, the PAPR of OFDM signal can be reduced. The use of time waveforms of the different subcarriers is suggested as a way of reducing the PAPR of the OFDM signal without affecting the bandwidth efficiency of the system.

4. MOFFIED PULSE SHAPING FUNCTIONS

Three new pulse shaping functions, denoted as Square root raised cosine (SRRC), Improved Sinc power pulse (ISP) and Modified Raised Cosine (MRC) is employed to reduce PAPR and ICI power functions of -subcarrier OFDM system. The Improve Sinc Power (ISP) Pulse is implemented considering a design parameter ‘a’ which adjusts the amplitude of the conventional sinc pulse and has a fast decaying rate decreasing the lobes of sinc function.

Certain modifications are incorporated in the raised cosine function to develop MRC pulse and SRRC pulse shape by introducing a new design parameter called the shaping parameter d and β.respectively, which shapes the impulse response and minimizes the PAPR of the transmitted signal.

5. IMPROVED SINC POWER PULSE (ISP)

The improved sinc power pulse (ISP) is inspired from the conventional SP pulse shape. The conventional sinc pulse is defined below.

$$P_{SP}(f) = sinc\ c^{m}\ (fT)$$

The Fourier transform of the continuous time Improved Sinc power pulse (ISP) is described by modifying SP as follows.

$$P_{ISP}(f) = exp\{-a(fT)2\}sincm(fT)$$

Where ‘a’ is a design parameter to adjust the amplitude and m is the degree of the sinc function.

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

6. MODIFIED RAISED COSINE (MRC)

Here modification is based on simply allowing any multiple or fraction of cosine cycles to be fitted in the transition region. This is done by introducing a multiplicative factor d that scales the period (in frequency domain) of the raised cosine function. It is found that d is inversely related to the length of cosine cycles fitted in the transition region, measured relative to one-half cycles. There can be two types of modified solutions, known as “convex” and “concave”. The names denote the curvature of the response in the first half portion of the transition region.

7. ICI CANCELLATION USING PULSE SHAPING FUNCTIONS

In OFDM communication systems, as long as orthogonality is maintained, there is no interference among the carriers because at the peak of every carrier, there exists a spectral null. Thus at that point the component of all other carriers is zero. But frequency offset in mobile radio channels distort the orthogonality between subcarriers and hence spectral null does not coincide to the peak of individual carriers. So some power of the carriers side lobes exists at the center of the individual carriers, which is called ICI power. The power goes on increasing as the frequency offset increases and this degrades BER performance. The purpose of pulse shaping is to reduce the side lobes. Performance parameters like average ICI power, average signal power to interference ratio (SIR) and bit-error-rate (BER) rate are evaluated and compared to prove the efficacy of the new pulse shapes.

8. BER PERFORMANCE OF OFDM USING PULSE SHAPING

Effect of frequency offset on BER performance of OFDM system is studied first. Different normalized frequency offset values are chosen. It is shown that with the increase of normalized frequency offset BER degrades noticeably. Hence reliable data decision is not possible at the end receiver for higher offset values.

SNR improvement is also observed using pulse shaping techniques at a fixed BER level. Hence with the proposed pulse shaping approach, effects of both the drawbacks of OFDM system, i.e., PAPR and ICI are reduced. So performance enhancement of the OFDM system is observed.

9. SQUARE-ROOT RAISED COSINE FILTER

Several attempts have been made to modify or improve the square-root raised cosine filter over the years. We are focusing only to those of continuous-time solutions; it is shown later that the improved filter can be considered to be a special case of the modified solution.

The Square Root Raised Cosine (SRRC) is implemented considering a design parameter ‘β’ which adjusts the amplitude of the conventional pulse and has a fast decaying rate decreasing the lobes of the function. Since the "root" aspect of a SRRC is in the frequency domain, simply the square root of the RC frequency response gives the SRRC frequency response. Taking its Inverse Fourier Transform will give the SRRC graph in time domain.

Reducing PAPR and ICI Power to a point where its existence is completely negligible is the principal aim of the project. In this project, we came up with an advanced technique namely Square Root Raised Cosine (SRRC) which alleviates the PAPR to the almost completely.

10. ICI POWER AND SIR PERFORMANCE FOR DIFFERENT PULSE SHAPES

Here we have simulated the results in MATLAB and we are focusing on reducing the PAPR and increasing the number of sub-carrier, so that we have better end to end communication. In order to get an optimized result, we have performed series of simulation having different constraints each time, which are being mentioned in this thesis.

Figure 1 shows the variation of the ICI power for various sample locations in a 64-subcarrier of OFDM system for which $\Delta fT = 0.01$. The ICI power drops drastically for the samples which are located near the sample locations 0 and N-1. Because these samples have fewer interference from the neighboring samples. It is also observed that SRRC outperforms all other pulse shaping functions in terms of PAPR reduction.

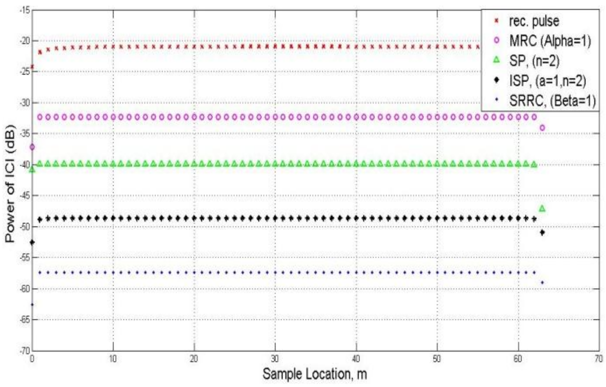

FIGURE 1: ICI Power Performance for Different Pulse Shapes

Figure 2 shows the average ICI Power Performance for different pulse shapes in an OFDM System as a function of Normalised frequency offset. It is concluded that the average ICI Power Performance is the best with SRRC pulse shape. The pulse shaping parameters are selected as: $n = 2$, $\alpha = 1$, and $\beta = 1$

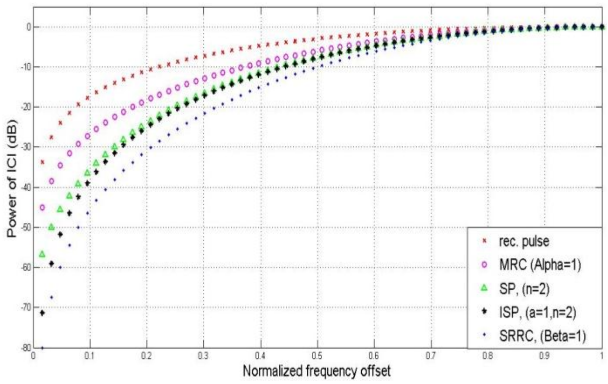

FIGURE 2: Average ICI Power Performance for Different Pulse Shaping in a 64-bit subcarrier OFDM System

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

Figure 3 shows the SIR Performance for different pulse shapes in an OFDM System as a function of Normalised frequency offset. It is concluded that the SIR Performance is the best with SRRC pulse shape. The pulse shaping parameters are selected as: $n = 2$, $\alpha = 1$, and $\beta = 1$.

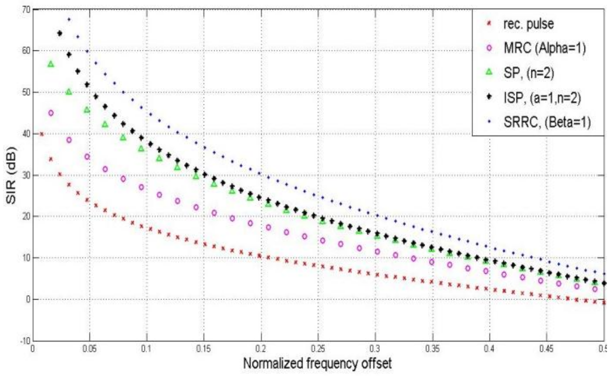

FIGURE 3: SIR performance for Different Pulse Shapes

11. DTMS ALGORITHM (DYNAMIC THRESHOLD AND MAXIMUM SUB-CARRIERS BASED PAPR REDUCTION)

DTMS Algorithm can be very useful for the user or industry who needs to know the maximum PAPR possible for a given maximum threshold level of ICI Power. This Algorithm calculates the maximum value of subcarriers (N) that can be transceived at the same time, and accordingly returns the maximum value of PAPR (considering all the subcarriers) possible. So, accordingly the user can increase or decrease the for all the maximum threshold level of ICI Power.

Algorithm:

1. Insert 10 random input values for the Threshold for 10 iteration test values ks(q).
2. Get the values of ICI Power for different subcarriers (N - 64, 128, 256, 512, 1024 and 2048) and store the value in k1, k2, k3, k4, k5 and k6.
3. Run a loop for 10 iteration values and compare each Threshold ks(q) with the predefined ICI Power of different N (subcarriers) to see if these values are less than the ICI limit in the Threshold.
4. If the above mentioned criterion matches, check for the maximum value of N (subcarriers) which satisfies the condition.
5. Store the appropriate value of N in d(q) and PAPR in h(q) for different Thresholds.
6. Display the PAPR along with maximum value of N to satisfy the criterion.
7. Plot a graph between Threshold [x-axis] vs different N (subcarriers)[y-axis].
8. Plot a graph between Threshold [x-axis] vs PAPR [y-axis].

9. Plot a combined graph between Threshold vs different N (subcarriers) and PAPR in Excel for a more prominent outlook.

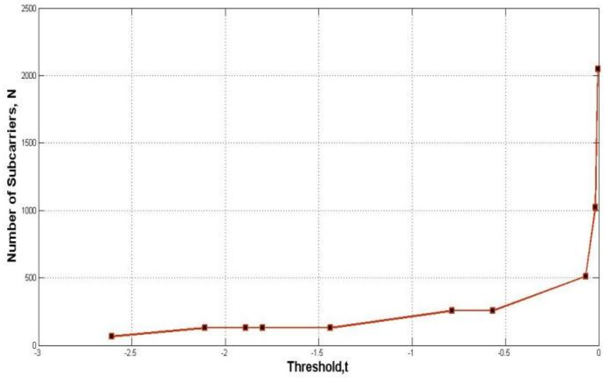

FIGURE 4: PAPR values for random threshold displayed in increasing order

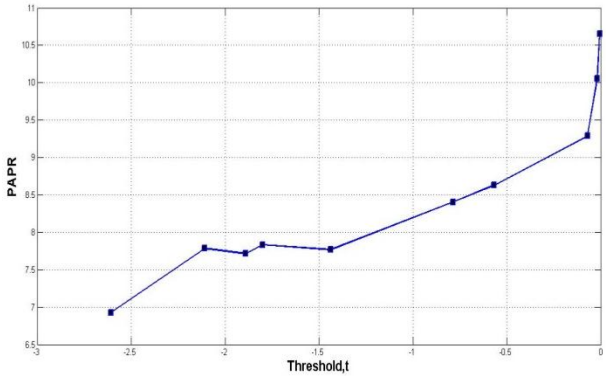

FIGURE 5: Number of Sub-carriers values for random threshold displayed in increasing order

The graphs obtained from this algorithm shows that how with the increase in the threshold (ks(q)), the no of subcarriers (N) obviously has to increase, which ultimately leads to greater PAPR in each case. Since our basic requirement is to keep this PAPR as low as possible, we find the least no of subcarriers (N) that is sufficient to satisfy the threshold (ks(q)) conditions, which is the sole aim of this Algorithm.

12. CONCLUSION

To overcome the limitations of OFDM system an efficient technique is being developed which improves its performance. OFDM spectrum of each carrier consists of a main lobe followed by a number of side-lobes with reducing amplitude. Pulse shaping techniques reduce the side-lobes so that ICI power is reduced considerably and the system performance is enhanced. Conventional pulse shapes (RC, ISP etc.) are improved by introducing new design parameters to suit the requirements. The Square Root Raised Cosine has a fast decaying rate deceasing the lobes of function. The design parameter shapes the impulse response in Square Root Raised Cosine pulse and minimizes PAPR of the transmitted signal. It is concluded that the pulse shaping technique can add to the reduction of both the major

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

problems, i.e., PAPR and ICI of the transmitted signal simultaneously without disturbing the bandwidth efficiency of the system. The application complexity of the proposed technique is less as compared to previously reported schemes like Clipping and filtering. OFDM system performance measures like CCDF of PAPR, ICI power, SIR and BER are analyzed through the Matlab simulation graphs and are proved to be efficient for the proposed pulse shaping scheme, in which SRRC outperformed the others.

REFERENCES

[1] B. R. Saltzberg, ―Comparison of Single Carrier and Multitone Digital Modulation for ADSL Applications, IEEE Comm. Mag.,vol 36,no. 11,Nov. 1998, pp. 114–21.

[2] H. Ochiai, and H. Imai,On the Distribution of the Peak to Average Power Ratio in OFDM Signals, IEEE Trans. Commun, 2001.

[3] J. Armstrong, ―Peak-to-Average Power Reduction for OFDM by Repeated Clipping and Frequency Domain Filtering, Elect. Lett., vol. 38, no. 8, Feb. 2002, pp. 246–47.

[4] Josef Urban and Roman Marsalek, "OFDM PAPR Reduction by Combination of Interleaving with Clipping and Filtering", IEEE Communication Letter, pp. 249–252, June 2007.

[5] Peng Tan and Norman C. Beaulieu, "Reduced ICI in OFDM Systems Using the "Better Than" Raised-Cosine Pulse," IEEE COMMUNICATIONS LETTERS, VOL. 8, NO. 3, MARCH 2004.

[6] R.W Chang, "Orthogonal Frequency Division Multiplexing," U.S Patent 3388455, Jan 6, 1970, Filed Nov.4.1966.

[7] Slimane Ben Slimane, "Peak-to-Average Power Ratio Reduction of OFDM Signals using Broadband Pulse Shaping," Royal Institute of Technology Department of Signals, Sensors, and Systems Radio Communication Systems.

[8] S. H. Han and J. H. Lee, ―An overview of peak-to-average power ratio reduction techniques for multicarrier transmission, IEEE Wireless Comm, vol. 12, no.2, pp.56-65, Apr. 2005.

[9] Srabani Mohapatra and Susmita Das, "Peak-to-average power Reduction (PAPR) by pulse shaping using a modified raised cosine filters" , Annual IEEE India Conference, 18-20 Dec. 2009.

[10] Suverna Sengar and Partha Pratim Bhattacharya, " Performance Improvement In OFDM System By Papr Reduction," An International Journal (SIPIJ) Vol.3, No.2, April 2012.

[11] V. Kumbasar and O. Kucur, ―ICI Reduction in OFDM Systems by using Improved Sinc Power Pulse, Digital Signal Processing, Vol.17, Issue 6, pp. 997-1006, Nov. 2007.

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)