

Improved PAPR Reduction in OFDM Systems

*Synopsis of the Thesis submitted in fulfillment of the requirements for the
Degree of*

DOCTOR OF PHILOSOPHY

By

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DECLARATION BY THE SCHOLAR

I hereby declare that the work reported in the Ph.D. thesis entitled **“Improved PAPR Reduction in OFDM Systems”** submitted at **Jaypee Institute of Information Technology University, Noida, India**, is an authentic record of my work carried out under the supervision of **Dr. Prerana Gupta, Dr. Monika Agrawal and Prof. N. Kalyanasundaram**. I have not submitted this work elsewhere for any other degree or diploma. I am fully responsible for the contents of my Ph.D Theses.

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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled “**Improved PAPR Reduction in OFDM Systems**”, submitted by **Ashish Goel** at **Jaypee Institute of Information Technology University, Noida, India**, is a bonafide record of his original work carried out under our supervision. This work has not been submitted elsewhere for any other degree or diploma.

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1. Introduction

Traditional single carrier modulation techniques can achieve only limited data rates due to the restrictions imposed by the multipath effect of wireless channel and the receiver complexity. High data-rate is desirable in many recent wireless multimedia applications [1]. However, as the data-rate in communication system increases, the symbol duration gets reduced. Therefore, the communication systems using single carrier modulation suffer from severe intersymbol interference (ISI) caused by dispersive channel impulse response, thereby needing a complex equalization mechanism. Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multicarrier modulation scheme, which divides the entire frequency selective fading channel into many orthogonal narrow band flat fading sub channels. In OFDM system high-bit-rate data stream is transmitted in parallel over a number of lower data rate subcarriers and do not undergo ISI due to the long symbol duration[2].

Major advantages of OFDM systems are

- High spectral efficiency due to nearly rectangular frequency spectrum for high numbers of sub-carriers.
- Simple digital realization by using the FFT operation.
- Less complex receivers due to the avoidance of ISI with a sufficiently long cyclic prefix.
- Different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier.

Due to the above mentioned advantages, OFDM modulation has been used in many wireless applications such as Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB). It is also being considered for IEEE 802.20, 802.16 and 3GPP-LTE. With the use of cyclic prefix for eliminating the effect of ISI, there is a need for a simple one tap equalizer at the OFDM receiver. OFDM brings in unparalleled bandwidth savings, which leads to high spectral efficiency.

Despite the widespread acceptance of OFDM, it has its drawbacks:

- OFDM signals with high peak-to-average power ratio (PAPR) require highly linear amplifiers. Otherwise, performance degradation occurs and out-of-band power will be enhanced.
- More sensitive to Doppler spread than single-carrier modulated systems.
- Phase noise caused by the imperfections of the transmitter and receiver oscillators influences the system performance.
- Accurate frequency and time synchronization is required.
- Loss in spectral efficiency due to cyclic prefix (CP).

As listed above, large envelope fluctuation in OFDM signal is one of the major drawbacks of OFDM. Such fluctuations create difficulties because practical communication systems are peak power limited. Thus, envelope peaks require a system to accommodate an instantaneous signal power that is larger than the signal average power, necessitating either low operating power efficiencies or power amplifier (PA) saturation.

In order to amplify the OFDM signal with large envelope fluctuations, PAs with large linear range are required, which makes it very expensive. If PA has limited linear range then its operation in non linear mode introduces out of band radiation and in band distortion. It is also necessary to have D/A and A/D converters with large dynamic range to convert discrete time OFDM signal to analog signal and vice versa.

PAPR is generally used to characterize the envelope fluctuation of the OFDM signal and it is defined as the ratio of the maximum instantaneous power to its average power.

In addition to this, OFDM system requires tight frequency synchronization in comparison to single carrier systems, because in OFDM, the subcarriers are narrowband. Therefore, it is sensitive to a small frequency offset between the transmitted and the received signal. The frequency offset may arise due to Doppler effect or due to mismatch between transmitter and receiver local oscillator frequencies. The carrier frequency offset (CFO) disturbs the orthogonality between the subcarriers, and therefore the signal on any particular subcarrier will not remain independent of the remaining subcarriers. This phenomenon is known as inter-carrier interference (ICI), which is a big challenge for error-free demodulation and detection of OFDM symbols.

2. Literature Review

Many PAPR reduction techniques are proposed in the literature [3]-[18] to reduce the PAPR of the OFDM signal. The PAPR reduction schemes are majorly divided into two categories

- a) Distortion based Techniques [4]-[10]
- b) Non-distortion Techniques [11]-[18]

The schemes that introduce spectral re-growth belong to distortion based category. These techniques are the most straightforward PAPR reduction methods.

The clipping [3] is one of the simplest distortion based technique to reduce the PAPR of OFDM signal. It reduces the peak of the OFDM signal by clipping the signal to the desired level but it introduces both in-band distortion and out-of-band radiation. To limit out-of-band radiation and PAPR, Jean Armstrong proposed iterative clipping and filtering scheme [4].

Companing is another popular distortion based scheme for PAPR reduction in OFDM system. In [5], Wang *et al.* proposed a scheme based on μ -law companing to reduce the PAPR of OFDM signal. In μ -law companing scheme the peak value of the OFDM signal before and after companing remains same, which keeps peak power of the OFDM signal unchanged but the average power of the OFDM signal after companing increases and therefore the PAPR of the OFDM signal gets decreased. But due to increase in the average power of the OFDM signal the error performance of μ -law companing scheme degrades.

Jiang *et al.* proposed exponential companing (EC) function [6] to transform Rayleigh distributed magnitude of OFDM signal to a uniformly distributed OFDM signal using an exponential function and this scheme is known as “Exponential Companing” scheme. Exponential companing scheme can effectively reduce the PAPR of the OFDM signal but its BER performance also degrades with PAPR reduction. Huang *et al.* proposed four companing transformation functions [7] to reduce the PAPR of the OFDM signal, which includes: linear symmetrical transform (LST), linear non symmetrical transform (LNST), non-linear symmetrical transform (NLST) and non-linear non-symmetrical transform (NLNST). It has been shown that LNST performs the best among four companing function [7]. In LNST an inflexion point is introduced to treat large and small signals on different scale to achieve better BER and PAPR performance. Linear companing transform (LCT) [8] has been proposed by Aburakhia *et al.* to reduce the PAPR of the OFDM signal. LCT also treats large and small signals on different scale but has two inflexion points to achieve more

flexibility in designing the companding function. The abrupt change in the transformed signal at inflexion point degrades the power spectral density (PSD).

Trapezoidal companding (TC) [9] proposed by Hou *et al.* is an efficient method to reduce the PAPR of OFDM signal with low BER. TC [9] transforms the Rayleigh distributed magnitude of original OFDM signal to a trapezoidal distribution and called “Trapezoidal Companding”. Trapezoidal companding utilizes a piecewise function defined in three intervals of OFDM signal magnitude. Jeng *et al.* proposed [10] trapezium distribution based companding (TDBC) to transform the Rayleigh distribution of original OFDM signal to biased linear distribution called “Trapezium distribution”.

All the companding schemes [5]-[10] distort the shape of the original OFDM signal and PAPR reduction capability is achieved at the cost of BER performance degradation.

Non-distortion PAPR reduction schemes do not distort the shape of the OFDM signal and therefore no spectral re-growth takes place. Coding technique [3] is one of the simplest non-distortion PAPR reduction schemes, which can be applied for reducing the PAPR of OFDM signal. But these type of schemes result in significant loss of data rate in OFDM system.

Two more distortion-less PAPR reduction techniques namely partial transmit sequence (PTS) [11] and selective mapping (SLM) [12] are also proposed in the literature. In PTS scheme all the subcarriers are partitioned into multiple disjoint sub blocks and then each of the sub blocks is multiplied by a set of rotating phase factors and combined to achieve a signal with lowest PAPR. In SLM, parallel data signal of length N is multiplied by a predetermined set of U phase vectors of length N and generates U alternative signals. Out of U alternative signals, one of them with the least PAPR is selected for transmission. In both of the schemes the information about the phase factors by which these sub blocks/data symbols are multiplied, needs to be conveyed to the receiver and it is known as side information (SI). The SI has the highest importance because it is used to recover the original data signal. If SI gets corrupted then entire OFDM symbol block can be damaged and error performance of SLM- and PTS-OFDM system degrades severely. In PTS technique, if the number of sub blocks increases then it not only increases computational complexity for selecting the optimum set(provide least possible PAPR) of phase sequence but also increases the amount of SI to be conveyed to the receiver. The SI results loss of data rate in OFDM system. Similarly in SLM-OFDM systems as the number of alternative OFDM signal increases, the number of bits required to encode the side information also gets increased, which results in data rate loss.

The SI bits are extremely important for data recovery and it may be necessary to allocate few redundant bits to ensure accurate recovery of SI, but this operation will further increase the loss of data rate in OFDM system.

Many schemes for embedding the SI have been proposed in [13]-[14] for PTS-OFDM systems. In [15]-[17] many SI embedding schemes have been proposed for SLM-OFDM system. These schemes [13]-[17] embed SI in the OFDM signal without using any extra bit. At the receiver, SI is extracted from the received OFDM signal, and decoded to obtain the information about the phase factor used at the transmitter to minimize PAPR. The demodulated signal is multiplied by the reciprocal of recovered phase factors, due to which the computational complexity at the receiving end gets increased. In many of the SI embedding schemes, the SI detection at lower values of SNR is very poor, due to which error performance of the OFDM system degrades severely.

Existing SI embedding schemes [13]-[17] eliminate the requirement of SI transmission but these suffer from one drawback or the other, whether in terms of computational complexity, poor PAPR reduction capability or incorrect SI detection.

In [18], Zhou *et al.* proposed MPSM-PTS scheme which extends the QPSK constellation points to disjoint points of 16-QAM constellation and eliminates the requirement of side information. The MPSM-PTS scheme [18] is completely free from SI, i.e. extraction of SI from the received signal is not required. Hence the receiver structure of the scheme proposed in [18] is computationally less complex.

In wireless standards like LTE, OFDM is used in downlink, where mobile station acts as receiver. The mobile stations have limited computational resources; therefore, a PAPR reduction scheme with less computational complexity at receiving end will be more beneficial. As discussed above, the schemes proposed in [13]-[17] have computationally complex receiver in comparison to the schemes proposed in [13], [14]. Hence, MPSM-PTS scheme is a viable choice for PTS-OFDM system.

Based on our review of the existing literature, the MPSM-PTS method of [18] is a suitable scheme to eliminate the requirement of SI in PTS-OFDM system, in terms of complexity and performance.

As discussed earlier, OFDM system is very sensitive to small carrier frequency offset; a small carrier frequency offset in between transmitter and receiver carrier frequencies can disturb the

orthogonality of the subcarriers and causes ICI. The ICI interference degrades the overall performance of the OFDM system. It is generally characterized by carrier to interference ratio (CIR).

Various ICI cancellation techniques have been proposed in the literature to eliminate the effect of ICI, these include ICI self-cancellation[19], New ICI self-cancellation[20], General ICI self-cancellation scheme[21], ICI conjugate cancellation scheme[22], General phase rotated conjugate transmission ICI cancellation scheme[23] etc.

In [19] Zhao and Haggman proposed an ICI cancellation scheme called “ICI self-cancellation” to combat the effect of ICI. In this scheme the data symbols are repeated on multiple adjacent subcarriers using polynomial coding but it results in PAPR performance degradation. The CIR performance of ICI self cancellation can be further improved by the scheme [20] proposed by Santhanathan *et al.* and called “New ICI self-cancellation scheme”. In this scheme [20] data symbols are repeated symmetrically using polynomial coding, which achieves frequency diversity effect of multipath fading channel. The CIR and the BER performance of ICI cancellation schemes [19], [20] are claimed to be further improved by General ICI cancellation scheme[21], proposed by Seyedi *et al.*, which is based on windowing technique used at the transmitter and receiver of OFDM system.

In [22] ICI cancellation schemes called “ICI conjugate cancellation” have been proposed. In these schemes time domain OFDM signal and its conjugate signal are transmitted over two parallel paths. It has been shown that ICI conjugate cancellation scheme[14] in presence of small frequency offset provides better CIR performance and BER performance in fading channels as compared to ICI self -cancellation schemes [19], [20].

The CIR and BER performance of [19]-[22] are further improved by the scheme proposed by Wang *et al.* [23] called “General phase rotated conjugate transmission ICI cancellation scheme”. It [23] is a combination of carrier frequency estimation technique and ICI conjugate cancellation scheme [23]. It has been shown that ICI conjugate cancellation scheme [22] is a special case general phase rotated conjugate cancellation [23]. But one of the main disadvantages of this scheme is that it requires knowledge of CFO to perform the operation.

3. Motivation

The current implementations of OFDM do not fully exploit the capabilities of OFDM. There are still several avenues which can be explored to reduce the peak-to-power ratio (PAPR) of OFDM signal. The PAPR performance of existing ICI cancellation schemes is either same or worse than normal OFDM signal. Therefore, the necessity to reduce the PAPR of normal OFDM signal and OFDM signal obtained from ICI cancellation schemes has been a prime motivating factor for this work. The thesis aims at exploring and arriving at the schemes for PAPR reduction in OFDM based systems (with and without ICI cancellation scheme) of practical use.

4. Work Done

As discussed earlier, companding can reduce the dynamic range or PAPR of the OFDM signal at the cost of BER performance degradation. In order to improve the BER performance of companding based PAPR reduction scheme a quadrilateral companding transform (QCT) is proposed. The proposed QCT transforms the original distribution of OFDM signal into quadrilateral distribution hence the name “Quadrilateral Companding Transform”. To achieve this transformation, we have derived the mathematical expression of companding function used to perform the companding operation on OFDM signals. The proposed companding function is monotonic increasing function and its inverse function exists. At the receiver an expanding function to retrieve the original OFDM signal is used, for which we have also derived the mathematical expression. The proposed scheme has five parameters to design the companding function, two dependent and three independent. The three independent parameters offer good flexibility in designing the companding function because its degree of freedom is more in comparison to existing companding scheme like exponential companding (EC), trapezoidal companding (TC) and trapezium distribution based companding (TDBC). The proposed QCT is the most generalized companding transform because exponential companding, trapezoidal companding and trapezium distribution based companding methods are special cases of the suggested quadrilateral companding transform. The proposed QCT can effectively reduce the PAPR of the OFDM signal with least possible BER degradation. The PAPR and BER performance of the proposed scheme is compared with other existing companding transforms and it is found that the proposed companding scheme outperforms in

terms of BER performance in comparison to existing companding schemes for PAPR reduction.

As discussed earlier, PTS is one of the most promising PAPR reduction schemes to reduce the PAPR of the OFDM signal but it suffers from the problem of SI. In order to completely eliminate the requirement of side information, a novel quaternary to concentric circle constellation mapping for PTS based PAPR reduction scheme is proposed. In this scheme first we have proposed a novel concentric circle constellation having 13 constellation points. The constellation points lie at origin and on circles of radius 2 and 4. We have used a quaternary to concentric circle constellation mapping (CCM). In this mapping scheme the quaternary data points (0, 1, 2 & 3) are initially mapped to four different points of concentric circle constellation and these after multiplication with the phase factors (1, j , -1, $-j$) cover all 13 points of the constellation in such a way that SI is not required at the receiver to recover the original OFDM signal. For CCM, a new decoding scheme called as circular boundary is also proposed besides the conventional minimum distance decoding. A complete SER analysis of CCM with both the decoding schemes and MPSM-PTS [18] with minimum distance decoding over additive white Gaussian noise (AWGN) channel is done. We have also proposed the method for coupling the CCM with PTS based PAPR reduction scheme. The PAPR and BER performance of PTS based OFDM system utilising CCM is evaluated. It is found that the proposed scheme achieves same PAPR reduction capability as conventional PTS-OFDM system but eliminates the requirement of SI and improves the BW efficiency of the OFDM system.

Like PTS, SLM is also a non-distortion PAPR reduction scheme suffer from the problem of SI. The PAPR reduction capability of SLM based OFDM system mainly depends on the number of alternative sequences and the generation of phase sequence set used to produce the alternative sequences. We have proposed a novel M-ary chaotic sequence to generate the phase sequence set for achieving better PAPR reduction capability in SLM-OFDM system. We have also utilized the CCM mapping scheme to avoid the requirement of SI. The proposed scheme can effectively reduce PAPR of the OFDM signal. The PAPR reduction capability of the proposed scheme is compared with existing Riemann matrix based phase sequence set generation and it has been found that the PAPR reduction capability of proposed scheme with eight alternative sequences is very close to SLM-OFDM system utilizing Riemann matrix phase sequence. The SER performance of SLM-OFDM system utilizing Riemann matrix phase sequence is mathematically analysed and it has been found that as the

number of alternative sequences increases the PAPR reduction capability of SLM-OFDM system increases at the cost of SER performance degradation, whereas in the proposed scheme the SER performance remains unchanged by increasing the number of alternative sequences. The SER performance of the proposed scheme has also been evaluated over fading channel and is found to be better than SLM-OFDM system with Riemann matrix based phase sequence for same number of alternative sequences.

The CCM and MPSM-PTS scheme utilize four phase factors to reduce the PAPR of the OFDM signal. We have also proposed a novel M-2M mapping scheme utilizing two phase factors to completely eliminate the requirement of SI. The proposed scheme starts with M constellation points and generates 2M constellation points after multiplication with two phase factors $(1, j)$. The PAPR reduction using M-2M mapping is only possible because of using $(1, j)$ in place of conventional phase factors $(1, -1)$. The justification for this choice is demonstrated by taking various possible mapping & using $(1, -1)$ as the phase factors and by evaluating the PAPR performance, it is shown that PAPR reduction using M-2M mapping is possible only if $(1, j)$ are chosen as phase factors. The M-2M mapping scheme is a generalized mapping scheme, which has been extended for Binary, quaternary, octal and hexadecimal etc, data types. The proposed mapping scheme can be easily coupled with SLM and PTS based PAPR reduction schemes. But the choice of $(1, j)$ as a phase factors, requires a new mechanism to generate a phase sequence set for SLM-OFDM system. Therefore to fulfil this requirement and to achieve good PAPR reduction capability we have proposed two new phase sequence set generation scheme based on Binary chaotic sequence and Walsh Hadamard sequence. It has been found that in SLM-OFDM system the PAPR reduction capability does not increase by increasing the number of phase factors in the phase sequence set, it majorly depends on how phase sequence set is generated and the number of alternative sequences. The BER performance of the proposed mapping scheme is evaluated over AWGN and fading channel and compared with the OFDM system with MPSM-PTS scheme. It is found that the M-2M mapping scheme has better PAPR and BER performance in comparison to MPSM scheme.

As discussed earlier, OFDM also suffers from the problem of ICI, which degrades the overall performance of the system. Many schemes for reducing the effect of ICI have been proposed in the literature, these include correlative coding, ICI self-cancellation, new ICI self-cancellation and ICI conjugate cancellation and phase rotated conjugate cancellation (PRCC) etc. Many of the ICI cancellation schemes introduce correlation among the subcarriers, which

results in high peak formation and therefore PAPR performance of such schemes is poor than normal OFDM signal. Therefore, it is important to consider PAPR performance of ICI cancellation scheme while evaluating the overall performance of the OFDM system. Motivated by this observation, we have performed the mathematical analysis of PAPR for ICI self-cancellation, new ICI self-cancellation and ICI conjugate cancellation schemes and found that PAPR performance of most popular ICI self-cancellation scheme is poor than conventional OFDM, while PAPR performance of other ICI cancellation schemes remain same. Therefore, after understanding the need of PAPR reduction for ICI cancellation schemes a multipoint PTS based PAPR reduction scheme is proposed to reduce the PAPR of OFDM signal resulting from ICI cancellation scheme, the combined scheme is known as “Joint ICI Cancellation and PAPR Reduction”. The proposed PTS based PAPR reduction scheme is free from the requirement of SI. The mathematical analysis of CIR performance of ICI cancellation schemes is done and a comparison of standard ICI cancellation schemes has been performed by taking PAPR, CIR and BER as the performance metric. Based on the comparison, New ICI cancellation scheme with multipoint PTS based PAPR reduction technique has been suggested to use for achieving good PAPR, CIR and BER performances.

5. Conclusions

PAPR reduction and ICI cancellation are two major challenges in implementing an OFDM system. This thesis presents the study of existing PAPR reduction and ICI cancellation schemes and proposes improved schemes for PAPR reduction in OFDM systems. This thesis also proposes a PAPR reduction scheme for OFDM system utilizing ICI cancellation scheme. Based on the study of companding based PAPR reduction schemes it has been found that the error performance of existing companding schemes degrade by increasing the parameter controlling the nonlinearity. Based on our findings, an improved companding scheme i.e. quadrilateral companding transform has been proposed, which has better flexibility to design the companding function in comparison to existing companding schemes. Quadrilateral companding transform has better BER performance with good PAPR reduction capability in comparison to existing companding based PAPR reduction schemes.

Non-distortion PAPR reduction techniques like PTS and SLM are the two most promising techniques to reduce the PAPR of the OFDM signal but both of them suffer from the problem of SI, the MPSM-PTS and proposed CCM-PTS schemes completely eliminate the requirement of SI transmission and therefore these are found to be the good alternatives of

existing SI embedding schemes. Proposed CCM-PTS scheme can effectively reduce the PAPR of the OFDM signal and its SER performance over AWGN and fading channel, is superior than existing MPSM-PTS scheme.

It has been found that the PAPR reduction capability of SLM-OFDM system mainly depends on the generation of phase sequence set and number of alternative sequences, the proposed M-ary chaotic sequences based phase sequence set generation scheme for SLM-OFDM system achieves good PAPR reduction capability in comparison to existing Hadamard sequence and its coupling with concentric circle constellation mapping makes it SI free. The SER performance of M-ary chaotic sequence is found to be better than Riemann matrix based phase sequence set generation and its SER performance does not degrade by increasing the number of phase sequences in phase sequence set.

The proposed M-2M mapping scheme for SLM and PTS based OFDM systems also completely eliminates the requirement of SI transmission by increasing the constellation size by a factor of 2. The error performance degradation in M-2M mapping scheme is less in comparison to existing MPSM-PTS scheme.

For OFDM system with frequency offset, ICI self-cancellation, New ICI self-cancellation and ICI conjugate cancellation schemes can be applied to effectively mitigate the effect of ICI but the PAPR performance of these schemes are either same or worse than normal OFDM signal. The proposed Joint ICI cancellation and PAPR reduction scheme can effectively reduce the PAPR of the OFDM signal with same ICI cancellation capability.

Publications from the thesis work

International Conferences:

- [1] A. Goel , P. Gupta Poddar and M. Agrawal, “Two New Phase Sequence Sets for PAPR Reduction in SLM-OFDM Systems Without Side Information” In Proceedings of IEEE International Conference on Wireless Technologies for Humanitarian Relief (ACWR2011), December 2011, Amritapuri, India, pp 41-46.
- [2] A. Goel , P. Gupta and M. Agrawal, “Concentric Circle Mapping Based PTS for PAPR Reduction in OFDM without Side Information” In Proceedings of 6th IEEE Conference on Wireless Communication and Sensor Networks(WCSN2010), December 2010, Allahabad, India, pp 201-204.

International Journals:

- [1] A. Goel, P. Gupta Poddar and M. Agrawal, “M-ary Chaotic Sequence Based SLM-OFDM System for PAPR Reduction without Side-Information” International Journal of Computer and Communication Engineering, WASET, vol. 6, 2012, pp. 299-304.
- [2] A. Goel, P. Gupta and M. Agrawal, “SER Analysis of PTS Based Techniques for PAPR Reduction in OFDM Systems” accepted for publication in Digital Signal Processing, Elsevier. <http://www.sciencedirect.com/science/article/pii/S1051200412002187?v=s5>
- [3] A. Goel, P. Gupta Poddar and M. Agrawal, “A Novel Quadrilateral Companding Transform for PAPR Reduction in OFDM Systems” Submitted to IEEE Transactions on Broadcasting.
- [4] A. Goel, P. Gupta Poddar and M. Agrawal, “Generalized M-2M Mapping Scheme for SLM and PTS Based Methods for PAPR Reduction in OFDM Systems without Side-Information” Submitted to Wireless Personal Communications, Springer.
- [5] A. Goel, P. Gupta Poddar and M. Agrawal, “Joint ICI Cancellation and PAPR Reduction in OFDM Systems without Side-Information” Submitted to Wireless Personal Communications, Springer.

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- 8.1 MOTIVATION TO PAPR REDUCTION OF ICI CANCELLATION SCHEMES
- 8.2 PAPR ANALYSIS OF ICI CANCELLATION SCHEMES
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CHAPTER 9

CONCLUSIONS AND FUTURE WORK

- 9.1 CONCLUSIONS

9.2 FUTURE WORKS

REFERENCES

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APPENDIX B

AUTHOR'S PUBLICATION LIST

SYNOPSIS

Important References

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