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GNU Radio Based PAPR Reduction in WIMAX-OFDM Using Channel Coding and Clipping Technique

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ABSTRACT: Latest evolution in broadband wireless technology requires the need for WiMAX which assures high-speed data services. Mobile WiMAX is based on orthogonal frequency division multiplexing/orthogonal frequency division multiplexing Access (OFDM/OFDMA) technology which is a growing vital technique in LTE systems that targets 4G services. OFDM is a bandwidth efficient multicarrier modulation where the available spectrum is divided into subcarriers, with each subcarrier containing a low rate data stream. A non-constant envelope with high peaks is a main disadvantage of Orthogonal Frequency Division Multiplexing (OFDM) i.e. Peak to Average Power Ratio (PAPR). Channel coding and Clipping methods are some the techniques that have been used for PAPR reduction. This paper focuses on the PAPR reduction and implementation WiMAX OFDM based PHY layer using GNU radio and presents a feature that combines channel coding and clipping as a PAPR reduction technique and also made a comparison between the PAPR before applying channel coding & clipping and after the channel coding & clipping.

KEYWORDS: OFDM, WiMAX, PAPR, HPA, SDR.

I.INTRODUCTION

Nowadays, all the communication processes are done on hardware but the combination of the proper hardware can cause errors in various signal processing. The hardware is of very high cost and also not easily portable. So SDR is the effective solution for the high cost and hardware based radios that are less flexible [1].

I.1 Software Defined Radio (SDR)

Software defined radio turns the hardware problems faced in communication into software problems and get the code as close to the antenna as possible [1]. In SDR, the hardware such as mixers, filters, amplifiers, modulators and demodulators can be transformed as software in a PC or on embedded systems. SDR can be used with a variety of communication modes or waveforms and can allow the same hardware to be operated with any type of waveform. Thus, the hardware complexity is reduced [2]. SDR is pertained to as a digitally programmable platform that can be programmed to realize multiple wireless standards (GSM, WCDMA, Wi-Fi, WiMAX, etc). The fundamental architecture of SDR is shown in Fig. 1 [3].

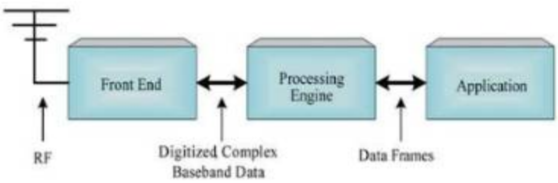

Fig. 1: Fundamental architecture of Software Defined Radio (SDR) [3]

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I.2 USRP

Universal Software Peripheral (USRP) is Universal hardware that can be accessed using software which is GNU Radio software on LINUX platform [5]. Hardware mainly consists of three parts. First one is the radio frequency (RF) frontend which transmits and receive the radio signals. Second one acts as a bridge between analog block and digital block. All signal processing is done within the third block in software form [6].

I.3 GNU Radio

The GNU Radio was developed by Eric Blossom and is a most important toolkit for software defined radios [1]. It is open source software for digital signal processing functions that was developed using C++ and Python programming languages. The high level codes are written in Python and it connects the various signal blocks to make a flow graph. The blocks are integrated into the GNU Radio Companion (GRC) [2]. GRC provides a graphical user interface and any hardware functions like mixers, oscillators, etc. can be implemented as a block and can be executed. GNU Radio is a free software development toolkit that provides signal processing blocks to implement Software defined radios and signal processing systems [4].

I.4 Orthogonal Frequency Division Multiplexing (OFDM)

In the modern age OFDM is popular modulation scheme digital communication system. OFDM provides high speed data transmission for its high demand in technology. Here the OFDM communication system is implemented in cost effective GNU Radio platform when compared to conventional system [9]. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique that divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream [10]. The subcarriers have proper spacing and pass-band filter shape to satisfy orthogonality as shown in Figure 2. Inter-symbol interference (ISI) is reduced completely by using a guard band in every OFDM symbol. The advantage of OFDM system is robustness to channel fading in wireless communication environment [11].

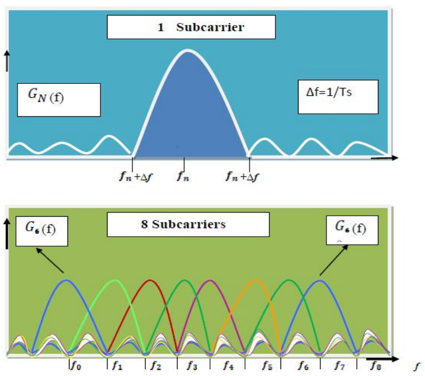

Fig. 2: OFDM subcarriers in frequency domain [11]

I.5 WiMAX Physical Layer Transmitter

WiMAX is a utilization of Ethernet that focused around the open systems interconnections (OSI) reference model. The physical layer determines the frequency band, error correction techniques, the modulation/ multiplexing techniques, data rate, the synchronization between transmitter and receiver. Encoding of binary digits is done by the WiMAX PHY layer that epitomizes MAC frames into signals and to send and gain these signals all over the communication media. The channel coding chain is framed of three steps: Randomizer, Forward Error Correction (FEC) and Interleaving [7].

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I.6 PAPR in OFDM

In OFDM technique the total bandwidth divided into many narrow sub-channels and data sends in parallel. The major drawbacks of the OFDM system is high PAPR. OFDM signal consists of lot of independent modulated subcarriers, which are created the problem of PAPR. It is impossible to send this high peak amplitude signals to the transmitter without reducing peaks. So we have to reduce high peak amplitude of the signals before transmitting [11].

I.6.1 Mathematical Definition of PAPR

PAPR Problem can be defined as when high peak signals transmitted through a nonlinear device such as a high-power amplifier (HPA), generates out-of-band energy (spectral regret) and in-band distortion (Constellation tilting and scattering) [8]. For an OFDM signal x(t), the PAPR is given as:

$$PAPR\ \{x(t)\} = \frac{\max_{0 \le t \le T} \{|x(t)|^2\}}{E\{|x(t)|^2\}} \quad (1)$$

Where, max $\{|x(t)|^2\}$the peak signal power and $E\{|x(t)^2|\}$is the average signal power.

Researchers always concern about reduction of peak- to- average power ratio. Various methods have been applied to reduce PAPR like clipping and filtering, SLM, PTS, tone injection, tone reservation, active constellation extension and coding [12].

I.7 PAPR Reduction Techniques

In the literature several techniques have been proposed to reduce PAPR of OFDM system. These are broadly classified as signal scrambling, signal distorted and other techniques [13].

The PAPR reduction techniques on which we would work upon are as follows:

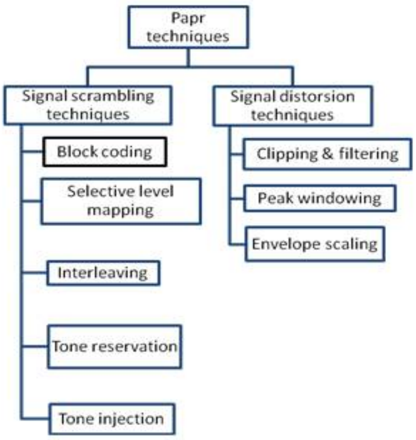

Fig. 3: Types of PAPR Techniques

From the above chart of PAPR reduction technique in my paper I use Channel coding and Clipping technique.

I.7.1 Channel Coding

Main objective of this technique is to reduce PAPR using different block coding and set of code words. This technique is used to reduce the peak to mean envelope power ratio. This technique is done in three stages. In first stage there is a selection of suitable set of code words for any number of carriers, any M-ary phase modulation scheme and any coding rate. In second stage there is the selection of set of code words that enable economical implementation of encoding or decoding. In third stage there is a selection of set of code words that offer error deduction and correction potential [14].

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I.7.2 Clipping

Clipping method is used to reduce high PAPR. Clipping is a non linear process which increases the band noise distortion and bit error rate (BER). It decreases spectral efficiency. Filtering gives better performance to reduce out of band radiation. If OFDM signal is over sampled then correction method is suitable with the clipping so that each subcarrier generated interference [14].

II. PROPOSED PAPR REDUCTION METHOD

The proposed PAPR reduction technique presented in this thesis work incorporates the feature that combines channel coding and clipping. The complete experimental setup is accomplished using GNU radio software. Although coding techniques as well as clipping techniques are widely employed and are different methods used for PAPR reduction in the literature, this proposed method focuses on their combined feature for better performance. The basic block diagram of proposed model architecture for PAPR reduction is shown in the figure 4.

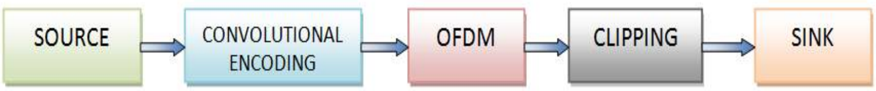

Fig. 4: Novel Architecture composes of channel coding and clipping [3]

The channel coding uses three techniques of scrambler, forward error correction code (FEC) and interleaving. Channel coding reduces bit error rate by attaching redundant bits in the transmitted symbols. Scrambler is used in order to reduce the length of strings of 0s and 1s in a transmitted signal, since a long string of 0s or 1s can cause transmission synchronization problems and can also be used as a cheap encryption technique. The channel encoder used in the experiment is a rate ½, k=7 CCSDS 27 (Convolutional encoder) which performs Convolutional encoding using CCSDS standard polynomial that provides performance better than other coders in terms of BER as well as PAPR reduction. The OFDM takes input data streams in parallel lines and maps them into symbol constellation using different mapping schemes. Clipping process clips the peak value of OFDM waveform that reduces the spectral efficiency of the multi-carrier system to a certain amplitude level that will provide low PAPR.

III.DESIGN AND SIMULATION

The system parameters considered for the design of Channel Coding and Clipping simulation model to reduce PAPR in OFDM for WiMAX are listed in table. The experimental set up of the proposed system is shown in the figure 3.1

Table 3.1: Experimental parameters considered

Parameters	Values
Channel Bandwidth (MHz)	20
Sampling Frequency (MHz)	15
Noise Source	Gaussian
FFT Size (N)	2048
No. of used sub-carriers	1440
No. of pilot carriers	240
No. of null guard band sub-carriers	368
No. of sub channels	32
Modulation schemes used	QPSK, 8 PSK, 256 QAM

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Required Scalable OFDMA-WiMAX specifications (Table. 3.1) are implemented in GNU Radio. OFDM is implemented for QPSK, 8 PSK, 256 QAM modulation scheme without Channel Coding and Clipping shown in Fig. 5 and for QPSK, 8 PSK, 256 QAM modulation scheme with Channel Coding and Clipping shown in Fig. 6.

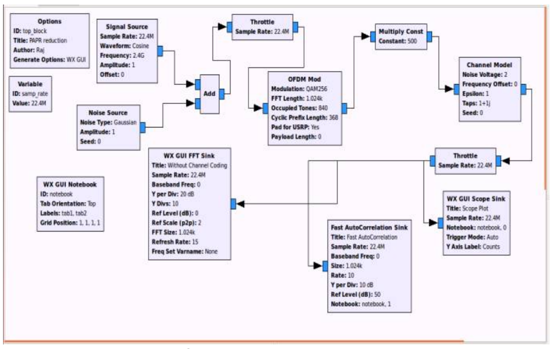

Fig. 5: Designed transmitter architecture for WiMAX-OFDM without Channel coding and Clipping

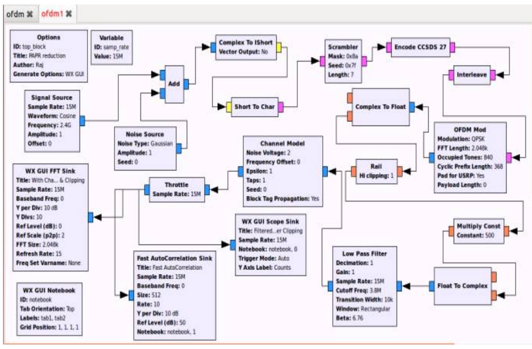

Fig. 6: Designed transmitter architecture for WiMAX-OFDM with Channel coding and Clipping

IV. EXPERIMENTS AND RESULTS

During run time, the designed system is working properly with the proposed technique. From the output of the system, the peak to peak as well as the average value of the OFDM signal is measured while varying the modulation schemes and for each modulation scheme, clipping levels are also changed. It is found that for every modulation schemes and clipping levels, the peak to peak as well as respective average value of the signal varies. Figure 7 represents the modulated original OFDM information signal from source before applying channel coding and clipping and figure 8 represents the original transmitted OFDM spectrum before applying channel coding and clipping.

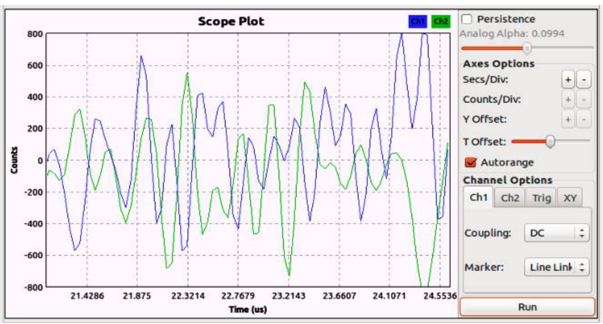

Fig. 7: Original transmitted OFDM signal waveform before applying channel coding and clipping

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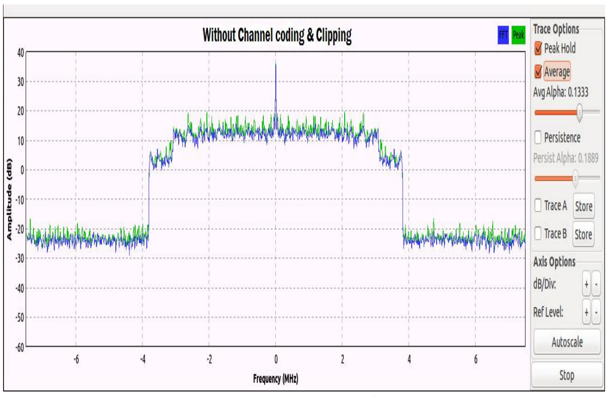

Fig. 8: Original transmitted OFDM signal spectrum before applying channel coding and clipping

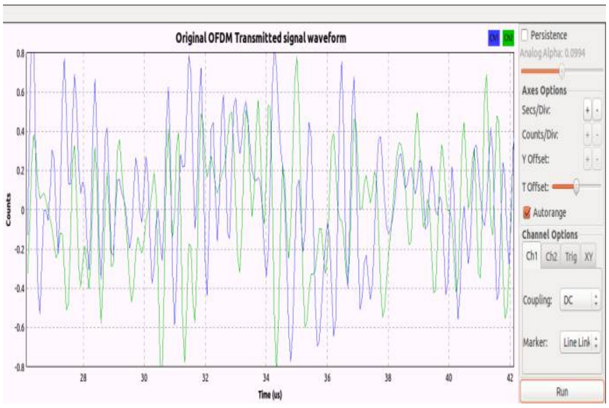

Fig. 9: Original OFDM information signal from source after applying channel coding and clipping

Figure 10 represents the original transmitted OFDM spectrum after applying channel coding and clipping at clipping level = 1.

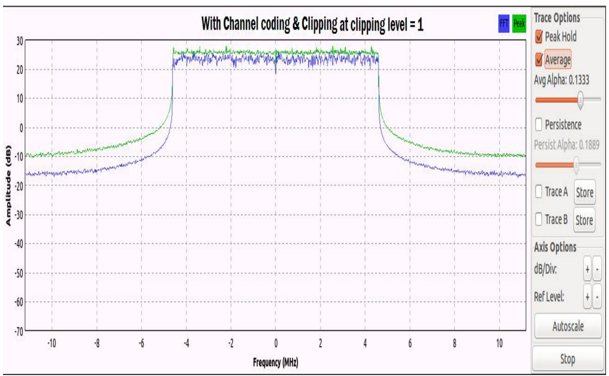

Fig. 10: Original transmitted OFDM signal spectrum after clipping at clipping level = 1

Figure 11 represents the original transmitted OFDM spectrum after applying channel coding and clipping at clipping level = 0.8.

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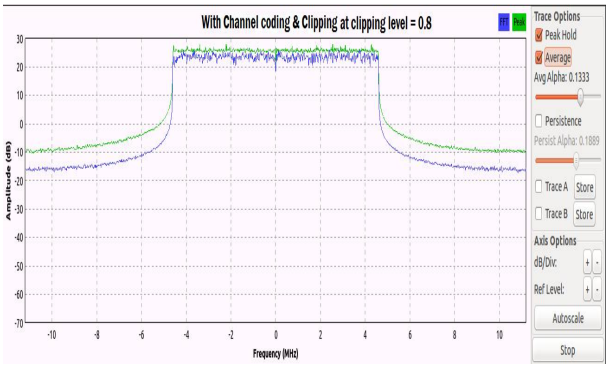

Fig. 11: Original transmitted OFDM signal spectrum after clipping at clipping level = 0.8

Figure 12 represents the original transmitted OFDM spectrum after applying channel coding and clipping at clipping level = 0.4.

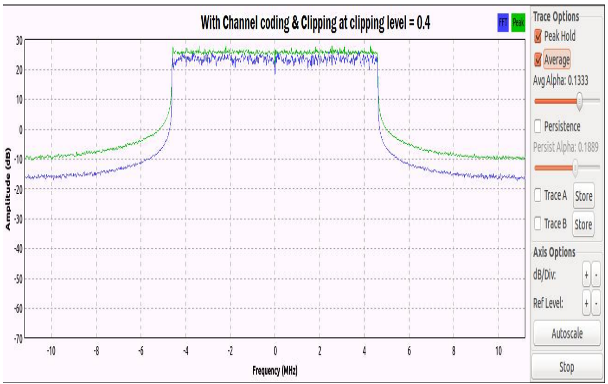

Fig. 12: Original transmitted OFDM signal spectrum after clipping at clipping level = 0.4

Table 4.1 shows the obtained result for original WiMAX-OFDM physical layer output signal's PAPR values for different modulation schemes before channel coding and clipping using SDR. It also shows the values for three modulation schemes (QPSK, 8 PSK, 256 QAM) and PAPR has reduced to 64% for QPSK, 72% for 8 PSK and 78% for 256 QAM without using channel coding and clipping.
Table 4.2 shows the calculated original WiMAX-OFDM physical layer output signal's PAPR values for different modulation scheme before clipping i.e. ideal clipping value 1.6. During the experiment, different clipping levels 1, 0.8, 0.4 are set and for each level, peak to peak amplitude as well as the average amplitude is measured with thorough inspection of the signals generated and respective PAPR value is evaluated using the methods described in chapter 1, section 1.7. The measured PAPR values for different clipping levels at 1, 0.8, and 0.4 are shown in table 4.3, 4.4 and 4.5 respectively. The experiment exploits different modulation schemes i.e. QPSK, 8 PSK, 256 QAM and PAPR are evaluated for each scheme. From the tables it is seen that 256 QAM is the most efficient modulation scheme in PAPR reduction. It is observed that clipping level at 0.8 of 1.6 i.e. the 50% of the signal amplitude yields best PAPR reduction. This means that the amount of PAPR reduced is maximum as compared to the other clipping level.

Table 4.1 Obtained result for mobile WiMAX without channel coding and clipping using SDR

Modulation Scheme	Original Signal Amplitude (dB)	Average Signal Amplitude (dB)	PAPR
QPSK	36	6	36
8 PSK	37	7	27.93
256 QAM	37	8	21.39

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Table 4.2: Measured PAPR value for the original OFDM signal for different modulation schemes.

Clipping Level	Modulation Technique	Peak to Peak Amplitude (dB)	Average Amplitude (dB)	PAPR
1.6	QPSK	47	14	11.27
	8 PSK	46	15	9.8
	256 QAM	45	21	5

Table 4.3: Calculated PAPR value after clipping at clipping level= 1

Clipping Level	Modulation Technique	Peak to Peak Amplitude (dB)	Average Amplitude (dB)	PAPR
1	QPSK	42	13	10.43
	8 PSK	43	15	8.21
	256 QAM	43	20	4.6

Table 4.4: Calculated PAPR value after clipping at clipping level= 0.8

Clipping Level	Modulation Technique	Peak to Peak Amplitude (dB)	Average Amplitude (dB)	PAPR
0.8	QPSK	41	13	9.94
	8 PSK	42	16	9
	256 QAM	42	21	4

Table 4.5: Calculated PAPR value after clipping at clipping level= 0.4

Clipping Level	Modulation Technique	Peak to Peak Amplitude (dB)	Average Amplitude (dB)	PAPR
0.4	QPSK	42	12	12.2
	8 PSK	43	16	7.2
	256 QAM	43	21	4.2

During the experiment, while applying QPSK achieved PAPR value is 9.94 dB, for 8 PSK 9 and achieved PAPR value for 256 QAM is 4, these values are obtained from the original OFDM signal. And from the obtained data tables, it can be concluded that QAM 256 is the best of all other modulation schemes for PAPR reduction and hence low error rate.
In the previous work of [8], coding technique is used to reduce PAPR, Convolutional coder greatly reduces PAPR, in that work, PAPR has reduced to 77.86% for 64-QAM and to 57.30% for QPSK using channel coding. As compared to [9], the proposed method in this thesis work reduces 73.87% of PAPR for QPSK, 53.43% of PAPR for 8 PSK and 43.06% of PAPR for 256 QAM. So, while using the proposed method in this thesis work that provides the combined feature of coding and clipping, the PAPR is remarkably reduced than [8].
The comparison between the previous work and proposed work are given in below:

Table 4.6: Comparison of results between previous work and proposed work

Previous work			Proposed work		
Modulation scheme	Channel coding	PAPR	Modulation scheme	Channel coding & Clipping	PAPR
QPSK	YES	33.06	QPSK	YES	9.94
64 QAM	YES	5.29	64 QAM	YES	5.15
			8 PSK	YES	9
			256 QAM	YES	4

V. CONCLUSION AND FUTURE SCOPE

V.1 Conclusion

This paper analyzes the implementation of WIMAX-OFDM PHY layer for PAPR reduction using GNU radio software. This thesis work also describes and focuses on the importance of the feature that combines Channel coding and Clipping as a novel technique to reduce PAPR. It may be concluded from the results that PAPR values vary for different clipping levels and clipping at 50% of the highest amplitude of the original signal achieves maximum PAPR reduction. Moreover, the problem that arises during the experiment of possible co-channel interference in the system is also eliminated by the proposed method. Thus, from the results as well as observations during the experiment it can be concluded that the technique of channel coding, clipping reduces PAPR significantly and can be adopted to increase the system performance.

V.2 Future Scope

Future works can be expanded to some alternative techniques that will further reduce PAPR. PAPR reduction approaches can be extended with distortion less transmission to increase the system performance as well as for low data error rate and efficient utilization of the channel of OFDM systems. The research work can also be extended to implement in the real time environment using the USRP (Universal Software Radio Peripheral) hardware components which are available in the R & D lab, BGIET, Sangrur that implements SDRs.

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