A Study on Peak to Average Power Ratio Reduction Techniques in SDR Based OFDM System

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***Abstract*—Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing and modulation approach widely utilized in communication structures because it promises flexible communications. But, due to the excessive peak-to-average power ratio (PAPR) value, OFDM employment becomes completely tough job. Intercarrier interference, excessive out-of-band radiation and decreased performance of the RF power amplifier are some of the results of high peak-to-avrage power ratio value. The radio system in which materials which have been generally applied in hardware are rather applied by method of software on a embedded device or PC is termed as Software defined radio (SDR). It offers a low cost and highly flexible system that can work with different communication standards. Moreover, it allows new features to be added to the system without requiring the underlying architecture to be changed.**

In this paper, performance of the Selective mapping PAPR reduction technique and Clipping and filtering PAPR reduction technique are analysed for SDR based OFDM system. The system prototype will be implemented using a PC and an RF front end (Universal Software Radio Peripheral). The software program will be written using LabVIEW (Laboratory Virtual Instrument Engineering Workbench) to cope with real time processing requirement. Shortening the design process, a graphical approach, and tight hardware or software integration are offered by LabVIEW. The tight hardware or software integration lets for seamless transition from design to test. High spectral efficiency, robustness against multi-path interference and high data transmission rate are the main advantages of Orthogonal Frequency Division Multiplexing systems. Some of the important applications of OFDM are internet access, audio broadcasting and digital television, mobile communication etc. SDR provides longer lifetime, flexible and multi-standard radio equipment for wireless communication infrastructure. The application of SDR includes mobile communication, cloud computing, interference detection etc.

Keywords*— *Clipping and Filtering Technique, Selective Mapping Technique, OFDM, SDR, LabVIEW, PAPR, Communication Systems.

I. INTRODUCTION

The most hopeful method for future wireless communication frameworks is the OFDM. In OFDM, the accessible spectrum range is partitioned into subcarriers. The each of these subcarriers containing a low rate information stream. Because of the robustness against interchannel interference and multipath fading, OFDM has acquired a incredible interest in the present days [1]. However, high PAPR is a major drawback in the OFDM system.

The disadvantages of excessive PAPR are expanded intricacy of the DAC and ADC, out-of-band power radiation, interchannel interference, and also decreased performance of power amplifier [2]. Therefore PAPR reduction techniques in OFDM system on SDR platform easily and efficiently decreases the high PAPR value and increases the performance of the Orthogonal Frequency Division Multiplexing system.

For the modern wireless communication system, Software defined radio is one of the significant innovation. The term SDR was first defined by the Dr. Joseph Mitola in 1990s to refer a radio that can be reprogrammed and reconfigured easily via software [3]. Software defined radio using powerful software and reconfigurable hardware for the employment of different modulation and demodulation techniques [4].

SDR decreases the cost and reduces the difficulty in the implementation and design [5]. SDRs have been found lots of uses in government, industries, and military application. Today's computers may contain high-speed interfaces and very fast processors so we can leverage these capabilities for software defined radios by employing them on a high speed computers using LabVIEW. LabVIEW is a framework plan stage and improvement atmosphere for a visual programming language. The LabVIEW development system brings an ideal way to interface with SDR for the progress and examination of communications algorithms that process received signals and produce signals for transmission.

II. BACKGROUND

J. Mitola defined architecture principles of Software defined radio in 1991 without employment particulars in a paper, "Software Radio: Survey, Critical Evaluation and

Future Directions". In 1992, this paper became the first publication in IEEE. The applications of software radio were packet radio, speech/music, modems, High Definition Television (HDTV) and telemetry [3].

Nowadays there are various techniques such as Peak windowing, Selective mapping, Partial Transmit Sequences (PTS), Clipping and filtering, etc. have been developed to get rid of excessive PAPR value. But still there is a necessity to improve performance of OFDM signal over PAPR. Universal Software Radio Peripheral (USRP) and LabVIEW are the two major tools used to evaluate the performance of Orthogonal Frequency Division Multiplexing system over PAPR [6].

During the last decade, the reduction of PAPR in the OFDM framework has acquired a lot of attention, leading to the development and progress of several PAPR reduction techniques. Latest work shows the utilization of hybrid variants of PAPR reduction techniques in order to get more benefit from these techniques [7].

Software defined radio is adaptive in nature. Wireless networks has become very flexible because of SDR radio platform which provides efficient solutions to the upcoming wireless networks. Orthogonal property was maintained by OFDM. This property removes the most common problems in wireless networks such as Interchannel interference, Delay spread, Bandwidth scarcity etc. SDR platform supports multi standard operation. So OFDM system can be easily implement in SDR platform [8].

To accomplish a lowest PAPR with low BER, new strategies are still being designed. One among them is Adaptive clipping technique. This technique adaptively changed threshold level which prompts an effective reduction in the BER and PAPR [9].

The easiest strategies to reduce the excessive PAPR value are the Selective mapping (SLM) PAPR reduction technique and Clipping and filtering PAPR reduction technique. In Clipping technique, the higher peak parts of the signal above the chosen region are clipped. In Selective mapping, the whole arrangement of data are assigned into the subcarrier and the datablock with least PAPR value is chosen for the communication [10].

With the support of USRP with LabVIEW and an embedded system, Media Based Modulation (MBM) communication framework utilize a reconfigurable antenna (RA) and by using the multiple radio frequency components, Media-Based Modulation communication system can give higher data rates. [11].

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM stands for Orthogonal Frequency Division Multiplexing. It is the technique of encoding the given digital information on multiple carrier frequencies. Hence, it is also called as digital multi-carrier modulation scheme. Closely spaced orthogonal sub-carriers carry the digital data in this scheme. The basic principle of the OFDM is splitting of higher rate data stream into numerous lower rate data streams that are transferred over the several sub-carriers at the same time.

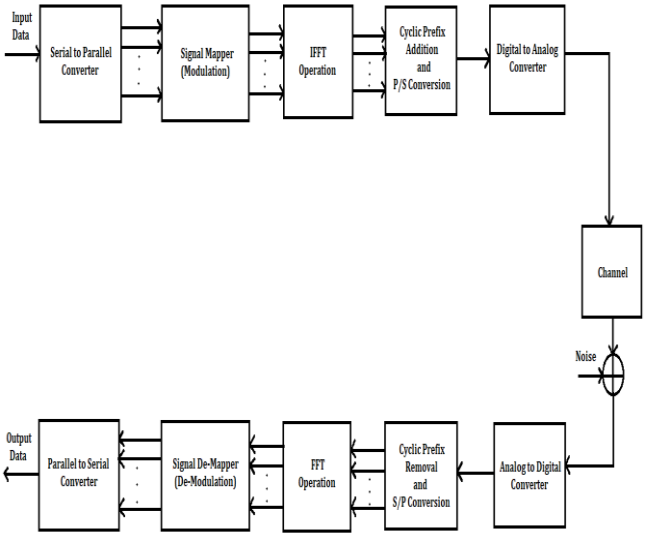

Figure 1: Block Diagram of the OFDM System

Structure of the OFDM system is given in Figure 1. In this framework, the higher rate information stream is splitted into lower rate information streams which are transferred over the orthogonal subcarriers. If the spectrum of every carrier has a center frequency at the null point of the adjacent carriers then those subcarriers are said to be the orthogonal subcarriers.

In Orthogonal Frequency Division Multiplexing system, Discrete Fourier Transform (FFT) is required to map the information streams at the lower rate on to orthogonal basis function and the multiple sub band signals are modulated by the Inverse Fast Fourier Transform (IFFT).

IV. PEAK TO AVERAGE POWER RATIO (PAPR)

PAPR of an OFDM signal is defined as the ratio of the maximum power of the OFDM signal to the average power of the OFDM signal. The amount of amplitude variation is decided by PAPR.

$$\mathrm{PAPR(dB)} = 10\log_{10}\left(\frac{P_{peak}}{P_{average}}\right)$$

$$= 10\log_{10}\frac{\max[|x_n|^2]}{E[|x_n|^2]}$$

In the above equation, P_{peak} represents the maximum output power. $P_{average}$ is the average output power. x_n is the transmitted OFDM signal obtained after Inverse Fast Fourier Transform (IFFT) operation on modulated input symbols and E denotes the expected value [12].

Large value of PAPR results when a number of subcarriers which are modulated independently are when added up coherently. N number of signal which are in same phase are summing up to produce a maximum power. This maximum power is N times that of the average power. High power amplifier (HPA) is used by most RF communication systems at the transmitter side to get sufficient transmit power. HPA is forced to have very large back-off by high PAPR ratio to ensure the linear amplification,. This results in decreasing in the efficiency of the amplifier. Unwanted distortion such as out-band radiation and in-band distortion will be caused if an amplifier works with nonlinear characteristics. High adjacent channel interference is caused when the PAPR destroys the orthogonality between the carriers. Also the high PAPR decreases the battery life of the mobile devices.

The disadvantages of increased PAPR:

- The effectiveness of the RF power amplifier is decreased.
- High out-of-band radiation.
- Intersymbol interference (ISI).

V. SOFTWARE DEFINED RADIO (SDR)

SDR is a radio communication framework where parts that have been commonly employed in hardware are rather employed by means of software on a PC or embedded structure. SDR can adjust to any modulation scheme and any range by using programmable hardware along with powerful software.

The SDR transmitter structure is given in Figure 2 [13]. Baseband signal is received as an input by the SDR transmitter. This baseband signal is produced by a DSP step as shown in Figure 2. Digital Up Converter (DUC) is the first block which transmits the baseband signal to IF (Intermediate Frequencies). The next block is Digital-to-Analog Converter (DAC) that transform the digital samples at the intermediate frequencies to the analog domain. DAC is followed by RF (Radio Frequency) converter. The signal moves towards higher frequencies by this Radio frequency converter. Lastly, the signal is amplified by the Power amplifier and then directed towards the antenna. Inside the Digital Up Converter, the baseband signal's sample rate was raised to match the operating frequency of the following components by the Interpolation Filter. Afterwards, the local oscillator and digital mixer shift the baseband signal's samples to intermediate frequencies.

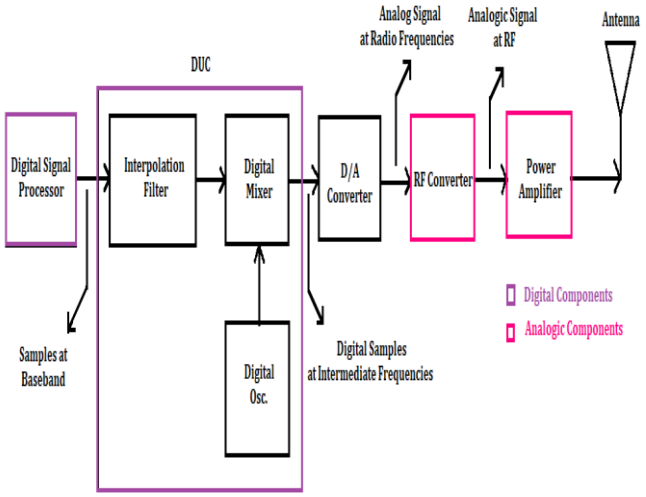

Figure 2: Block Diagram of a SDR Transmitter

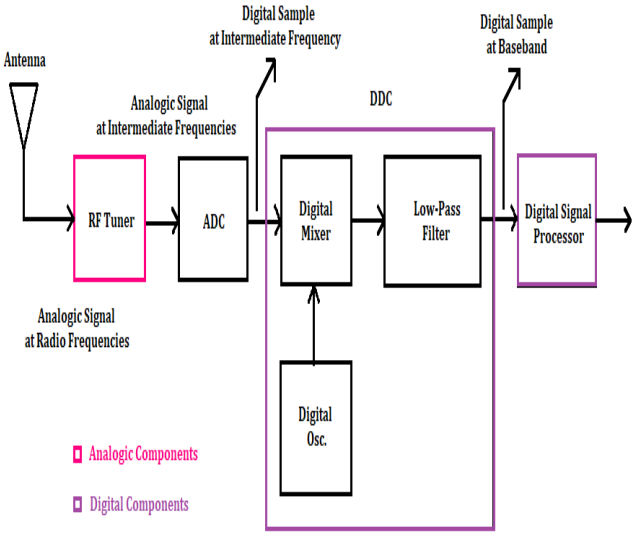

Figure 3: Block Diagram of the SDR Receiver

The SDR receiver structure is given in Figure 3 [13]. In the receiver, the Radio Frequency (RF) tuner transforms the analog signal at RF into IF. Next, the analog signal at intermediate frequencies is passed to the ADC which transforms the analog signal at IF into the digital samples. The samples are then feed to the Digital Down Converter (DDC). Digital mixer, low-pass filter and a digital local oscillator are the three main components of the DDC.

The local oscillator and the digital mixer shift the IF digital samples to baseband, although the FIR low-pass filter limits the bandwidth of the final signal. The Digital Down Converter includes a high number of shift registers, adders and multipliers for the employment of each of its parts. Then, the baseband samples are transmitted into the Digital Signal Processing (DSP) block where decoding and demodulating tasks are accomplished. The comparison between traditional radio and software defined radio was given in Table 1 below.

Traditional Radio	Software Defined Radio
Radio functionalities are primarily defined in hardware with minimum configurability in software.	Radio functionalities are defined in software
Upgrading of design is not possible.	Upgrading is easy because of software based architecture.
Less efficient	Reprogrammability makes SDR more efficient and compact
Supports a fixed number of systems	Supports multiple number of systems

Table 1: Comparison Between Traditional Radio and Software Defined Radio

.VII. SELECTIVE MAPPING (SLM) AND CLIPPING AND FILTERING PAPR REDUCTION TECHNIQUES

In software defined radio based OFDM system, OFDM method is employed by using NI USRP hardware kit and LABVIEW software. In LabVIEW software, the entire system including transmitter and receiver is designed and the signal is transmited and received by using the NI USRP hardware. With the support of different signal processing blocks and communication blocks, OFDM system is designed in LabVIEW. One of the serious problem in the OFDM communication system is excessive PAPR value. Selective mapping PAPR reduction technique and Clipping and filtering PAPR reduction technique are the most often employed techniques to decrease the excessive PAPR in the OFDM communication systems .

Clipping and filtering PAPR reduction technique is a signal distortion technique. In this technique, the peak of the signal is cut to that threshold level when the input signal's amplitude is greater than the presetted threshold level and without changing the amplitude and phase, the signal is transmitted when the amplitude of the input signal is less than or equal to the presetted threshold value [14,15]

Selective mapping PAPR reduction technique is a signal scrambling technique. In this technique, multicarrier transmission system's peak-to-average transmit power is minimized with selected mapping. A complete candidate signal set produced in this technique representing the same information. Here the random series are multiplied with the input data structure and finally the resultant series with the least PAPR is picked for communication [16].

VII. APPLICATIONS OF SDR BASED OFDM SYSTEM

- Digital Video Broadcasting (DVB).
- Power Line Communication (PLC).
- Digital Audio Broadcasting (DAB).
- Broadband Internet Access.

VIII. CONCLUSION

High PAPR is one of the major difficulty that OFDM has faced today. All hardwares that are used in the traditional radio communication systems were replaced with software by SDR. Hence with the support of Software Defined Radio kit, the employment of OFDM system becomes very easier. The implementation of the OFDM system in LabVIEW and reduction of the peak-to-average power ratio in OFDM system through Universal Serial Radio Peripheral is the main attention. In this paper, Selective mapping PAPR reduction scheme and Clipping and filtering PAPR reduction scheme were discussed.

REFERENCES

[1] Y. Wu and W.Y. Zou, "ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING: A MULTI-CARRIER MODULATION SCHEME," IEEE Transactions on Consumer Electronics, vol.41, pp. 392-399, Aug.1995.

[2] P. Gautam, P. Lohani and B. Mishra, "Peak-to-Average Power Ratio reduction in OFDM system using amplitude clipping," 2016 IEEE Region 10 Conference (TENCON), Singapore, 2016, pp. 1101-1104, doi: 10.1109/TENCON.2016.7848179.

[3] J. Mitola, "Software radios-survey, critical evaluation and future directions," [Proceedings] NTC-92: National Telesystems Conference, Washington, DC, USA, 1992, pp. 13/15-13/23, doi: 10.1109/NTC.1992.267870.

[4] H. Yeh and P. Ingerson, "Software-defined radio for OFDM transceivers," 2010 IEEE International Systems Conference, San Diego, CA, 2010, pp. 261-266, doi: 10.1109/SYSTEMS.2010.5482434.

[5] G. Berardinelli, P. Zetterberg, O. Tonelli, A. F. Cattoni, T. B. Sørensen and P. Mogensen, "An SDR architecture for OFDM transmission over USRP2 boards," 2011 Conference Record of the Forty Fifth Asilomar Conference on Signals, Systems and Computers (ASILOMAR), Pacific Grove, CA, 2011, pp. 965-969, doi: 10.1109/ACSSC.2011.6190154.

[6] S. Bhosle and Z. Ahmed, "Modern tools and techniques for OFDM development and PAPR reduction," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, 2016, pp. 290-292, doi: 10.1109/ICEEOT.2016.7755205.

[7] K. Sultan, H. Ali, Z. Zhang and F. Abbas, "Improving PAPR reduction for OFDM using hybrid techniques," 2015 IEEE International Conference on Communication Software and Networks (ICCSN), Chengdu, 2015, pp. 312-316, doi: 10.1109/ICCSN.2015.7296175.

[8] S. Venkatachalam, T. Manigandan and P. Priyavadhana, "Implementation of Orthogonal Frequency Division Multiplexing (OFDM) Using Software Definable Radio (SDR) Platform," International Conference on Computational Intelligence and Multimedia Applications (ICCIMA 2007), Sivakasi, Tamil Nadu, 2007, pp. 398-405, doi: 10.1109/ICCIMA.2007.286.

[9] R. Deshpande and D. J. Pete, "Optimized Peak to Average Power Ratio (PAPR) Reduction Techniqque for OFDM," 2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA), Pune, 2017, pp. 1-5, doi: 10.1109/ICCUBEA.2017.8463796.

[10] Agarwal, J. S. Jadon, M. Chahande, M. Pant and A. Rana, "Mitigation the Issue of Peak to Average Power Ratio in OFDM Setups," 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2020, pp. 1258-1261, doi: 10.1109/ICRITO48877.2020.9197860.

[11] O. Ertürk, K. Bölat, A. D. Başkan and İ. Altunbas, "A Media-Based Modulation Communication System Implementation Using Universal Software Radio Peripheral," *2019 27th Telecommunications Forum (TELFOR)*, Belgrade, Serbia, 2019, pp. 1-4, doi: 10.1109/TELFOR48224.2019.8971090.

[12] T. N. Munni and M. Hossam-E-Haider, "Performance Analysis of Peak to Average Power Ratio (PAPR) Reduction Techniques in OFDM System for Different Modulation Schemes," 2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT), 2018, pp. 605-610, doi: 10.1109/CEEICT.2018.8628163.

[13] Machado Fernández, José. (2015). Software Defined Radio: Basic Principles and Applications. Revista Facultad de Ingenier'ia. 24. 79-96. 10.19053/01211129.3160.

[14] P. P. Ann and R. Jose, "Comparison of PAPR reduction techniques in OFDM systems," 2016 International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2016, pp. 1-5, doi: 10.1109/CESYS.2016.7889995.

[15] B. Gordillo, F. Sandoval, P. Ludeña-González and K. Rohoden, "Increase the Range and Coverage on OFDM System using PAPR reduction by Clipping on SDR," 2018 IEEE Third Ecuador Technical Chapters Meeting (ETCM), Cuenca, Ecuador, 2018, pp. 1-6, doi: 10.1109/ETCM.2018.8580261.

[16] H. Iqbal and S. A. Khan, "Selective Mapping: Implementation of PAPR Reduction Technique in OFDM on SDR Platform," 2018 24th International Conference on Automation and Computing (ICAC), 2018, pp. 1-6, doi: 10.23919/IConAC.2018.8749039.