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A Novel Study on Uplink and Downlink Transceivers for LTE System

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Abstract: LTE (Long Term Evolution) or the E-UTRAN (Evolved Universal Terrestrial Access Network), introduced in 3GPP R8, is the access part of the Evolved Packet System (EPS). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time as well as flexibility in frequency and bandwidth. The new access solution, LTE, is based on OFDMA (Orthogonal Frequency Division Multiple Access) and in combination with higher order modulation (up to 64QAM). OFDM is a multicarrier technology subdividing the available bandwidth into a multitude of mutual orthogonal narrowband subcarriers. In OFDMA these subcarriers can be shared between multiple users. The OFDMA solution leads to high Peak-to-Average Power Ratio (PAPR) requiring expensive power amplifiers with high requirements on linearity, increasing the power consumption for the sender. This is a main problem in OFDMA Hence a different solution was selected for the UL i.e. SC-FDMA. SC-FDMA solution generates a signal with a low PAPR and avoiding packet loss by using interleaving. The main objective of this paper is to design uplink and downlink transceivers with low PAPR and higher capacity to transmit the data over a long distance. Analytic filtering is used here to overcome the value of PAPR. All the programming is done in the MATLAB.

Keywords: 3GPP, LTE, Interleaving SC-FDMA, PAPR.

I. INTRODUCTION

LTE (Long Term Evolution) or the E-UTRAN (Evolved Universal Terrestrial Access Network), introduced in 3GPP R8, is the access part of the Evolved Packet System (EPS). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time as well as flexibility in frequency and bandwidth. The Evolved Packet System (EPS) is purely IP based. Both real time services and datacom services will be carried by the IP protocol. The IP address is allocated when the mobile is switched on and released when switched off. The new access solution, LTE, is based on OFDMA (Orthogonal Frequency Division Multiple Access) and in combination with higher order modulation (up to 64QAM), large bandwidths (up to 20 MHz) and spatial multiplexing in the downlink (up to 4x4) high data rates can be achieved. The highest theoretical peak data rate on the transport channel is 75 Mbpsin the uplink, and in the downlink, using spatial multiplexing, the rate can be as high as 300 Mbps. The LTE access network is simply a network of base stations, evolved NodeB (eNB), generating a flat architecture.

There is no centralized intelligent controller, and the eNBs are normally inter-connected via the X2-interface and towards the core network by the S1-interface The reason for distributing the intelligence amongst the base-stations in LTE is to speed up the connection set-up and reduce the time required for a handover. For an end-user the connection set-up time for a real time data session is in many cases crucial, especially in on-line gaming. The time for a handover is essential for real-time services where end-users tend to end calls if the handover takes too long.

The motivation for LTE

- Need to ensure the continuity of competitiveness of the 3G system for the future
- User demand for higher data rates and quality of service
- Packet Switch optimised system
- Continued demand for cost reduction (CAPEX and OPEX)
- Low complexity
- Avoid unnecessary fragmentation of technologies for paired and unpaired band operation
- To enable possible deployment around the world supporting as many regulatory requirements as possible, LTE is developed for a number of frequency bands- E- UTRA operating bands- currently ranging from 700 MHz up to 2.7 GHz.

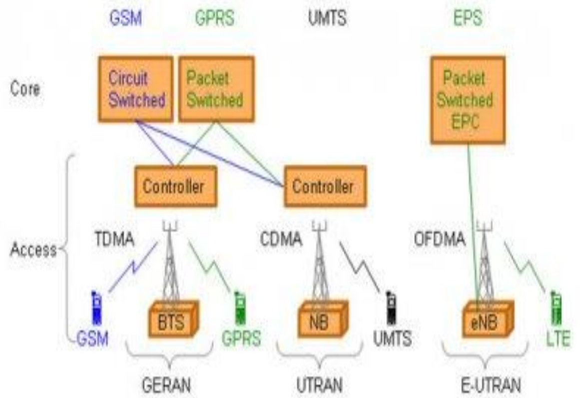

Figure 1 Network Solutions from GSM to LTE

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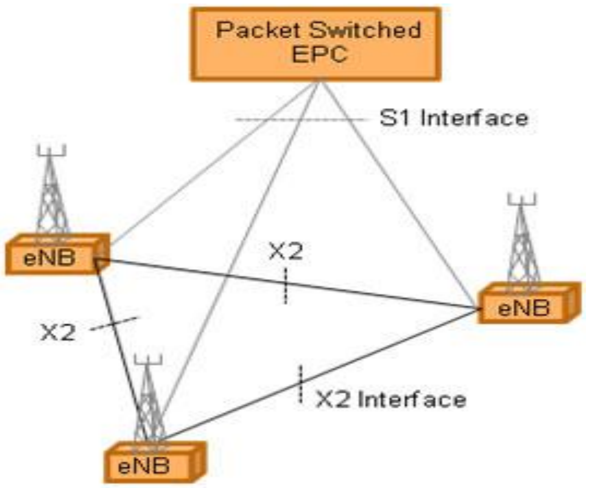

Figure 2. X2 and S1 Interfaces

He available bandwidth are also flexible starting with 1,4MHz up to 20 MHz. LTE is developed to support both the time division duplex technology (TDD) as wel as frequency division duplex (FDD) in R8 here are 15 bands specified for FDD and eight bands for TTD. In R9 four bands were added for FDD. Also added in R9 were for example Multimedia Broadcast Multicast Service (MBMS), and Home eNB (HeNB), see figure 4. MBMS is used to provide broadcast information to all users, for example advertisement, and multicast to a closed group subscribing to a specific service, e.g. streaming TV. HeNBs are introduced mainly to provide coverage indoors, in homes or offices.The HeNB is a low power eNB that will be used in small cells – femto cells. Normally it will be owned by the customer, deployed without any network planning and connected to the operators EPC (Evolved Packet Core).

To achieve high radio spectral efficiency as well as enable efficient scheduling in both time and frequency domain, a multicarrier approach for multiple access was chosen by 3GPP. For the downlink, OFDMA (Orthogonal Frequency Division Multiple Access) was selected and for the uplink SC-FDMA (Single Carrier - Frequency Division Multiple Access) also known as DFT (Discrete Fourier Transform) spread OFDMA.

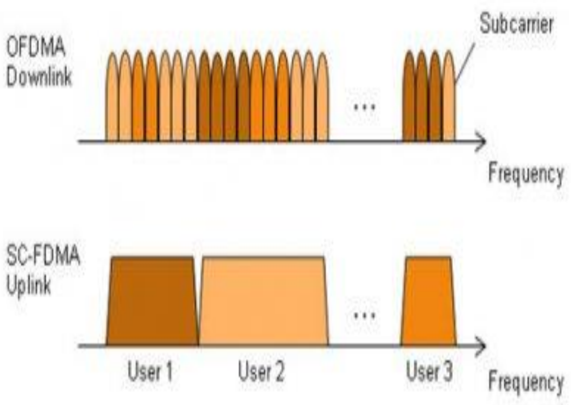

Figure 3 OFDMA and SC-FDMA

OFDM is multicarrier technology subdividing the available bandwidth into a multitude of of mutual orthoona narrowband subcarriers. In OFDMA these subcarriers can be shared between multiple users. He OFDMA solution leads to high peak-to-average power ratio (PAPR) requiring expensive power amplifiers with high requirements on linearity, increasing the power consumption for the sender. there is no problem in eNB, but would lead to very expensive handsets. Hense a different solution was selected for the zuzl. The SC-FDMA solution generates a signal with single carrier characteristics, hence with a low PAPR.

Orthogonaslity of Sub-Channel Carriers:

OFDM communications systems are able to more effectively utilize the frequency spectrum through overlapping sub-carriers. These sub-carriers are able to partially overlap without interfering with adjacent sub-carriers because the maximum power of each sub-carrier corresponds directly with the minimum power of each adjacent channel. Below, we illustrate the frequency domain of an OFDM system graphically. As you can see from the figure, each sub-carrier is represented by a different peak. In addition, the peak of each sub-carrier corresponds directly with the zero crossing of all channels. Note that OFDM channels are different from bandlimited FDM channels how they apply a pulse-shaping filter. With FDM systems, a sinc-shaped pulse is applied in the time domain to shape each individual symbol and prevent ISI. With OFDM systems, a sinc-shaped pulse is applied in the frequency domain of each channel. As a result, each sub-carrier remains orthogonal to one another. Transmitter/ Receiver Implementation. In order to use multiple sub-carriers to transmit an individual channel, an OFDM communications system must perform several steps. These steps are described in the figure shown below.

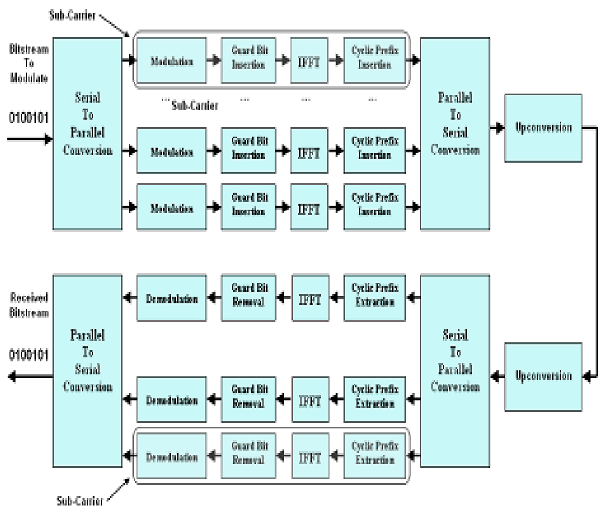

Figure 4 flow of subcarriers in OFDMA

Serial to Parallel Conversion: In an OFDM system, each channel can be broken into various sub-carriers. The use of sub-carriers makes optimal use out of the frequency spectrum but also requires additional processing by the

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transmitter and receiver. This additional processing is necessary to convert a serial bitstream into several parallel bitstreams to be divided among the individual carriers.

Once the bitstream has been divided among the individual sub-carriers, each sub-carrier is modulated as if it was an individual channel before all channels are combined back together and transmitted as a whole. The receiver performs the reverse process to divide the incoming signal into appropriate sub-carriers and then demodulating these individually before reconstructing the original bitstream.

Modulation with the Inverse FFT: The modulation of data into a complex waveform occurs at the Inverse Fast Fourier Transform (IFFT) stage of the transmitter. Here, the modulation scheme can be chosen completely independently of the specific channel being used and can be chosen based on the channel requirements. In fact, it is possible for each individual sub-carrier to use a different modulation scheme. The role of the IFFT is to modulate each sub-channel onto the appropriate carrier.

Cyclic Prefix Insertion: Because wireless communications systems are susceptible to multi-path channel reflections, a cyclic prefix is added to reduce ISI. A cyclic prefix is a repetition of the first section of a symbol that is appended to the end of the symbol. In addition, it is important because it enables multi-path representations of the original signal to fade so that they do not interfere with the subsequent symbol.

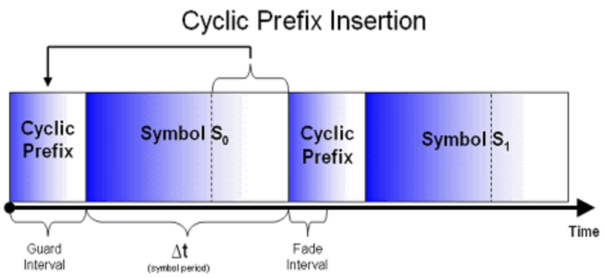

Figure 5 cyclic prefix insertion in OFDMA

Parallel to Serial Conversion: Once the cyclic prefix has been added to the sub-carrier channels, they must be transmitted as one signal. Thus, the parallel to serial conversion stage is the process of summing all sub-carriers and combining them into one signal. As a result, all sub-carriers are generated perfectly simultaneously.

OFDMA provides high spectral efficiency, overcome the multipath fading, low intersymbol interference (ISI) and high power efficiency. High peak to average power ratio (PAPR) of the transmit signals in one of the major problem in OFDMA. If PAPR is controlled by using any method like by regulatory or application constraints hen he average power I also reduces so the range of multicarrier transmission also reduces. And also it is also required to operate the power amplifier I a inear region. This also effects the battery of mobile. This is the main disadvantage of the OFDMA technique. Just because of it OFDMA is used in downlink and SC-FDMA is used in uplink in lte transmission. There are many way to reduced the PAPR value in LTE transmission. Some of them are:- Amplitude clipping, filtering, peak windowing, pea reduction carrier, envelope scaling, peak cancelation, selective mapping, tone injection clustered OFDM etc. clipping technique is the very simplest way to reduce the PAPR value. It consist of to clip the OFDM signal before amplification. It is a very nonlinear process in this clipping process in-band and out-band interference may occurs. this interfgerence destroy the orthogonality among the subcarrier. In these techniques a codeword Is selected to reduce the PAPR. One another technique is Partial Transmit Sequence(PTS) that required the transmission of side information. In these techniques there is no distortion and there is no out of band interference. Some other techniques like Selective Mapping(SM) and constellation extension or orthogonal pilot sequence (OPS) do not required the transmission of side information.

PAPR Overview: The transmit signals in an orthogonal frequency-division multiplexing (OFDM) system can have high peak values in the time domain since many subcarrier components are added via an inverse fast Fourier transformation (IFFT) operation. As a result, OFDM systems are known to have a high peak-to-average power ratio (PAPR) when compared to single-carrier systems. In fact, the high PAPR is one of the most detrimental aspects in an OFDM system as it decreases the signal-to-quantization noise ratio (SQNR) of the analog-digital convertor (ADC) and digital-analog convertor (DAC) while degrading the efficiency of the power amplifier in the transmitter. As a side note, the PAPR problem is more of a concern in the uplink since the efficiency of the power amplifier is critical due to the limited battery power in a mobile terminal.

Let's start by showing why PAPR problems are an important problem to take care of in an OFDM system. The PAPR of a signal is expressed by the following formula:

$$PAPR_{dB} = 10\log\left(\frac{max[x(t)x^*(t)]}{E[x(t)x^*(t)]}\right)$$

Where ()* corresponds to the conjugate operator. Since an OFDM symbol can be express as a sum of complex tones equally spaced in frequency, let's start by calculating the PAPR of a single complex tone. Consider a complex tone signal:

$$x(t) = e^{2\pi ft}$$

with a period T. The peak value of the signal is:

$$max[x(t)x^*(t)] = max\left[e^{2\pi ft}e^{-2\pi ft}\right] = max[e^0] = 1$$

The mean square value of the signal is:

$$E[x(t)x^*(t)] = E\left[e^{2\pi ft}e^{-2\pi ft}\right] = 1$$

This gives us a PAPR of 0 dB. Consider that an OFDM time signal is made of K complex tones (usually called subcarriers). Our signal can be represented by the following formula:

$$x(t) = \sum_{0}^{K-1} a_k \, e^{\frac{j2\pi kt}{T}}$$

For simplicity, let's assume a_k=1 for any k. In this scenario, the peak value of the signal is:

$$max[x(t)x^*(t)] = max\left[\sum_{0}^{K-1} a_k e^{\frac{j2\pi kt}{T}} \sum_{0}^{K-1} a_k^* e^{\frac{-j2\pi kt}{T}}\right] = max\left[a_k a_k^* \sum_{0}^{K-1}\sum_{0}^{K-1} e^{\frac{j2\pi kt}{T}} e^{\frac{-j2\pi kt}{T}}\right]$$
$$= K^2$$

The mean square value of the signal is:

$$E[x(t)x^*(t)] = E\left[\sum_{0}^{K-1} a_k e^{\frac{j2\pi kt}{T}} \sum_{0}^{K-1} a_k^* e^{\frac{-j2\pi kt}{T}}\right] = E\left[a_k a_k^* \sum_{0}^{K-1}\sum_{0}^{K-1} e^{\frac{j2\pi kt}{T}} e^{\frac{-j2\pi kt}{T}}\right] = K$$

Given this, the PAPR of an OFDM symbol with K subcarriers, with each subcarrier having the same modulation, is simply K.

In this paper a PAPR reduction technique has been described. And the paper is organized as follows. Section II shows some works related to LTE OFDMA technique. Section III described PAPR in OFDMA system. Section IV is the proposed work and finally section V simulation and result and section VI is the conclusion.

IV. PROPOSED WORK

The transmit signals in an orthogonal frequency-division multiplexing (OFDM) system can have high peak values in the time domain since many subcarrier components are added via an inverse fast Fourier transformation (IFFT) operation. As a result, OFDM systems are known to have a high peak-to-average power ratio (PAPR) when compared to single-carrier systems. In fact, the high PAPR is one of the most detrimental aspects in an OFDM system as it decreases the signal-to-quantization noise ratio (SQNR) of the analog-digital convertor (ADC) and digital-analog convertor (DAC) while degrading the efficiency of the power amplifier in the transmitter. As a side note, the PAPR problem is more of a concern in the uplink since the efficiency of the power amplifier is critical due to the limited battery power in a mobile terminal. The problem of high PAPR value in the System decreases energy efficiency of system. And the problem of high traffic creates high energy usage in the network which decreases the channel capacity of system. The secondary transmission capacity gets worse with the increase of throughput improvement ratio and it becomes zero when throughput improvement ratio is larger than a critical point. In downlink, the transmission capacity gets poorer with the increase of throughput improvement ratio and it becomes zero when throughput improvement ratio is larger than a critical point. Due to this, it will design a high data rate LTE system for improving PAPR Value under Rayleigh fading channel by Analytical filtering method. Adding the cyclic prefix is to transfer the time domain convolution to a circular domain convolution between the OFDM symbols and the channel response. This makes the frequency domain implementation becomes a point-wise multiplication between the complex symbols allocated in each orthogonal sub-carrier and the corresponding channel frequency response. Additive white Gaussian noise (AWGN) is added to the transmitted signal as channel modeling; this allows the multipath to be controlled.

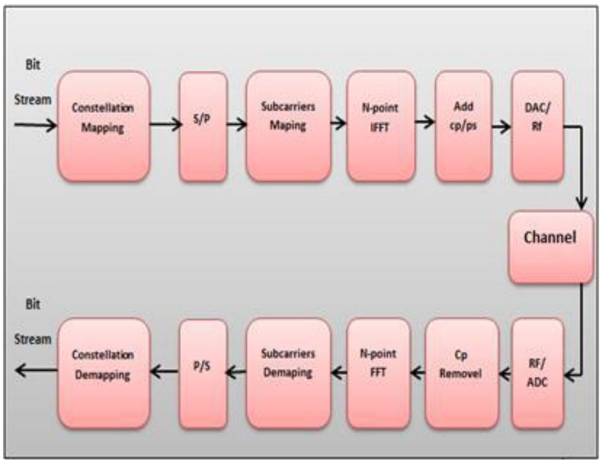

Figure 6: OFDMA system model

On the receiver side the same operations are applied inversely, first the guard band is removed; the N-point DFT is used to convert the time domain signal to frequency domain signal. After that the signal was de-mapped. Parallel to serial convertor is used here to convert the signal back to serial form. One of the most important processing in the receiver side is the channel estimation and equalization for compensating the distortion signal. Modulation and detection block are the last operation for implementing the OFDM system to recover the transmitted signal information.

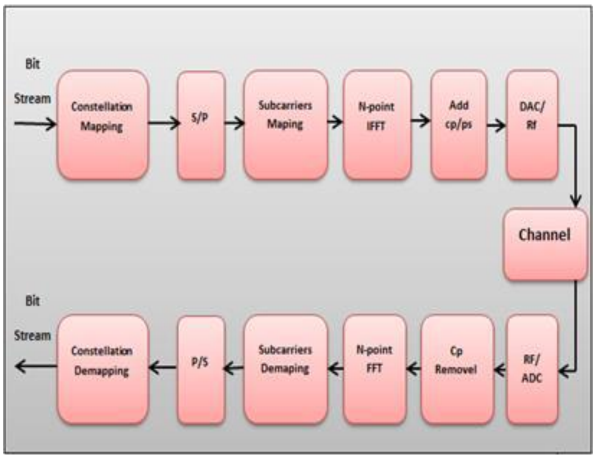

Figure 7: SC-OFDMA system model

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The block diagram for transmitter and receiver of SC-FDMA is shown in figure 6 and 7.

V. SIMULATION & RESULTS

In this paper we analyzed the PAPR of the SC-FDMA and OFDMA systems. The total number of sub-carriers, M= 1024, the number of sub-carrier per block, N= 64 and the maximum number of users, Q=4 due to M=Q. N. We assumed raised cosine and root raised cosine pulse shaping filters in case of the SC-FDMA system and assume no pulse shaping in case of OFDMA system to analyse the influences on PAPR and also employed three types of constellation mapping (QPSK , 16-QAM, 64-QAM) for comparison. The results are observed for the value of PAPR0 that exceed with probability less than 0.1% (Pr {PAPR > PAPR0} = 10-3), with raised cosine and with root raised cosine pulse shaping filter and roll of factor (α =0.22). all the simulations are done in the MATLAB software. The figures below shows the caparision between the PAPR value of the OFDMA and SC-OFDM systems in case of RC and RRC filters and with different modulation techniques like QPSK, 16 QAM, and 64 QAM. The number of subcarriers also varies from 128 to 1024 and data block size varies from 16 to 1024.

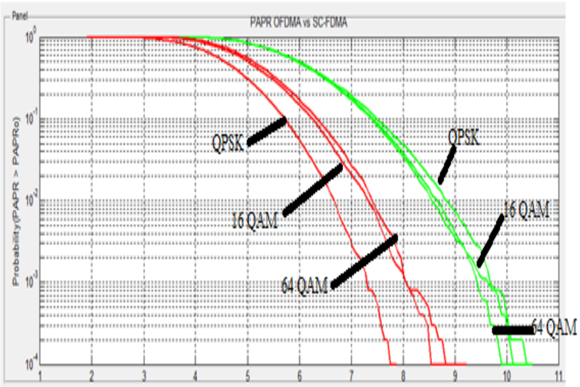

Figure 8 : graph shows PAPR comparision between OFDMA and SC-OFDM for QPSK, 16 QAM, 64 QAM with RC filter , total subcarrier 128 and data block size 16

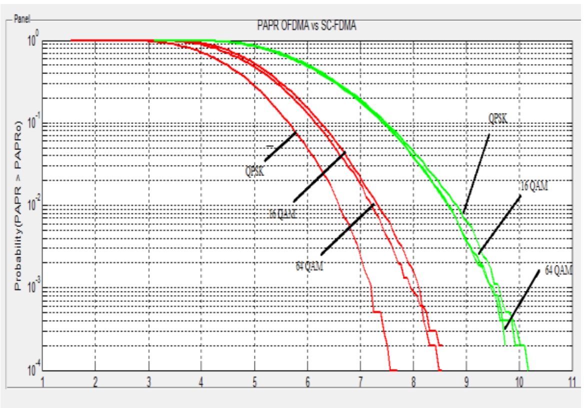

Figure 9: graph shows PAPR comparision between OFDMA and SC-OFDM for QPSK, 16 QAM, 64 QAM with RRC filter, total subcarrier 128 and data block size 16

As shown in the figures the capacity of the OFDMA system is higher in case of QPSK modulation technique than in case of 16 QAM and 64 QAM that is 13×10^7.

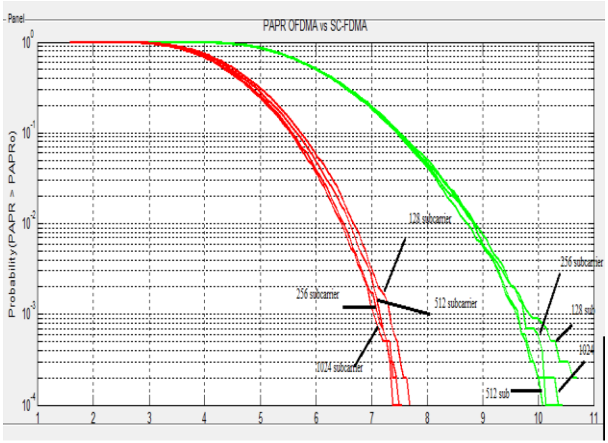

Figure 10: graph shows PAPR comparision between OFDMA and SC-OFDM for QPSK, with RC filter , subcarrier 128, 256, 512. 1024 and data block size 16

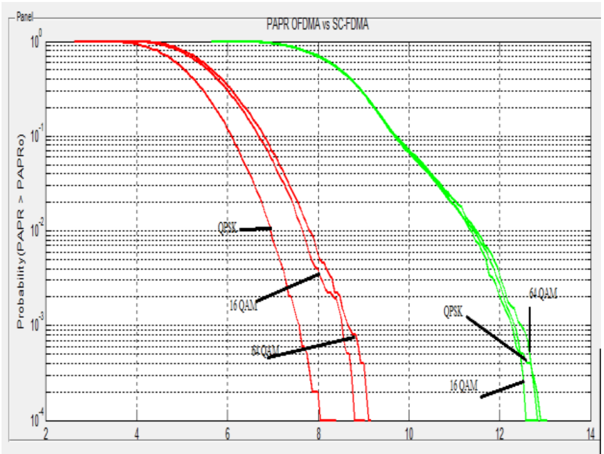

Figure 11 : graph shows PAPR comparision between OFDMA and SC-OFDM for QPSK, 16 AM, 64 QAM, with RC filter , subcarrier 128and data block size 32

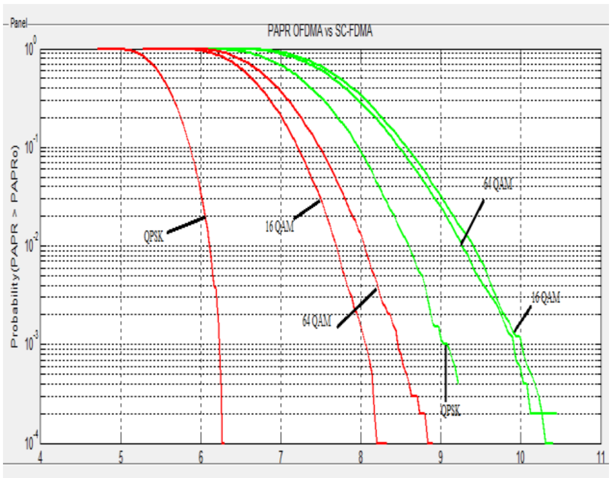

Figure 12: graph shows PAPR comparision between OFDMA and SC-OFDM for QPSK, 16 AM, 64 QAM, with RC filter, subcarrier 1024 and data block size 1024

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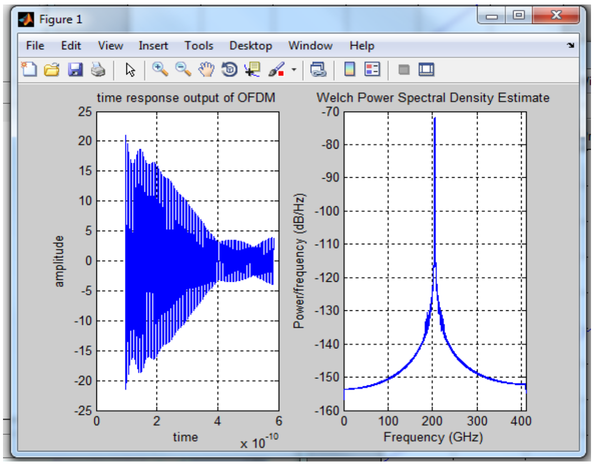

Figure 13: Graph shows the time response and power spectral density of OFDMA with QPSK, RC filter, subcarrier 128 and data block size 16

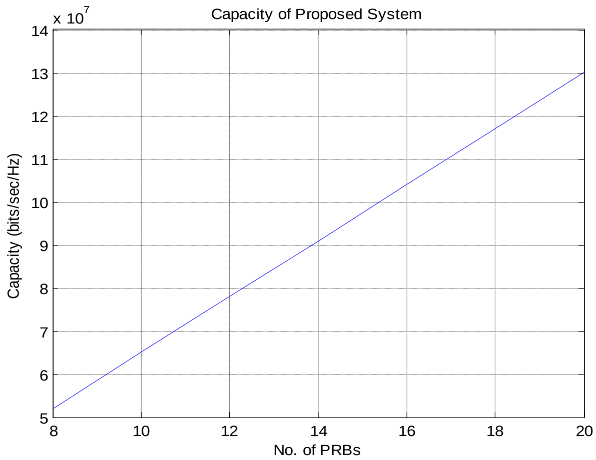

Figure 14: Graph shows the capacity of OFDMA with QPSK, RC filter, subcarrier 128 and data block size 16

VI. CONCLUSION

In this paper we have focused on the performance analysis of SC-FDMA and OFDMA systems in terms of PAPR, different pulse shaping filters have also been analysed. And different types of modulation techniques (QPSK, 16QAM, and 64QAM) are used here with different subcarriers and different block sizes. In case of adding raised cosine filter, the PAPR performance of OFDMA system improved in comparison with the system without filter. Furthermore the SC-FDMA shows better performance as compared with OFDMA. PAPR increases in both types of SC-FDMA sub-carrier mapped with respect to the type of modulation used. QPSK has lower PAPR as compared with 16QAM and 64QAM It provides an optimal structure in LTE downlink system. It also provides a solution for finding optimal result for high data rate LTE downlink receiver. For high data rate, high modulation format will be used. The main objective is to reduce high PAPR value by suitable filtering approach under downlink system. RC (raised cosine) and RRC (root raised cosine) filters are used in this work to overcome the value of PAPR in case of OFDMA technique. Three types of modulations are used here QPSK, 16QAM and 64 QAM.

We have used all of three modulations with both filters and compared the results of all graphs and concluded that the value of PAPR is lower in case of 16 QAM modulation with RRC filter and capacity is higher in case of QPSK modulation. For this, we used here analytical concept for reducing PAPR value. All the simulations has been done in the MATLAB software. We have compared the PAPR value in the OFDMA and in SC-OFDMA. The graph for the PAPR value with and without filtering is also shown here. According to this the PAPR value reduces to a small amount by using filters in the system so the performance of the system improved. Also it will prefer the optimal method for capacity of system. If system has less PAPR value then its energy efficiency is better.

VII. FUTURE SCOPE

In this study, different problems of OFDM system have been considered and appropriate solutions have been provided. It is an well-known fact, that research is never ending process, Therefore, following are the works that may be considered as a future scope in this direction:

(a) The algorithm of capacity of the system can be improved in OFDM system.
(b) The proposed PAPR reduction method can be used with MIMO OFDM system.
(c) The proposed timing offset and estimator can be used in MIMO OFDM system.
(d) The expression of BER can be derived for OFDM system with planned PAPR reduction method.
(e) The values of subcarriers and block size can be changes to improve the capacity of system and different modulations other than 16 and 64 QAM can be used in future.

And also in future scope, this work can be done on LTE-A (Advanced) system for improving capacity and also for bandwidth efficiency of system.

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