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A COMPARATIVE ANALYSIS OF PAPR OF SC-FDMA AND OFDMA FOR LTE SYSTEMS

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ABSTRACT

Long Term Evolution is a new advancement in the era of cellular technology emerged in recent decade that can accommodate the features of quite efficient radio access with high peak data rates as well as high capacity for voice links. Actually it is a journey toward 4th generation with the recent 2G and 3G network operators. This revolution is an improvement over GSM, EDGE G, WCDMA/UMTS, and HSPDA and then HSPA+ to fulfil the demand of high speed mobile networks. This paper primarily describes a comparison of Single Carrier Frequency Division Multiple Access (SC-FDMA) and Orthogonal Frequency Division Multiple Access (OFDMA) multiple access techniques.This comparison is carried out for the selection of multiple access schemes for the implementation of Long Term Evolution (LTE) systems. Also the advantages and disadvantages of SC-FDMA and OFDMA schemes are described. SC-FDMA is proved better than OFDMA in terms of Peak to average power ratio (PAPR).SCFDMA and OFDMA systems are modelled with MATLAB for PAPR analysis.

KEYWORDS: GSM, LTE , SC-FDMA , OFDMA, HSPA+ , HSPDA, UMTS, EDGE, 2G,3G, 4G, 3GPP, PAPR

INTRODUCTION

Over the past decade, new technologies with the improved capabilities have emerged from military purpose and various researches. The number of today's wireless communication standards is growing rapidly, hence needs the design of smaller and more efficient technologies which can handle wide variety of specifications. Long Term Evolution (LTE) is the next step in mobile technology towards 4G generation. Expected in earlier time, LTE is a 3GPP standard that provides a speed of up to 50 Mbps in uplink and speed of up to 100 Mbps in the downlink. Bandwidth of LTEs is scalable from 1.25 MHz to 20 MHz. This will fulfil the requirements of different network operations that have different bandwidth allocations and also allow different services to the operators depending upon the spectrum. LTE also provides improved spectral efficiency in third generation and fourth generation networks allowing carries to provide more data and voice services over a given bandwidth. It is designed to meet carrier requirement for high speed data and media transport as well as high capacity voice support for multimedia uncast and multimedia broadcast services.

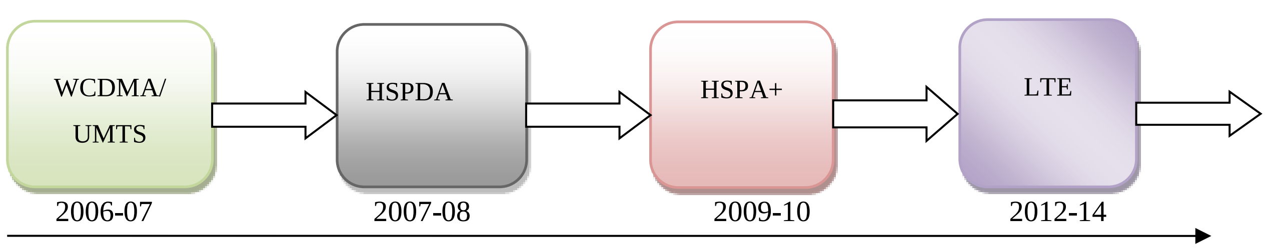

Figure 1 Time line 3GPP Evolution

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Universal Mobile Telecommunications System (UMTS) networks worldwide are being upgraded to High Speed Packet Access (HSPA) so as to extend rate and capacity for packet knowledge. HSPA refers to the mix of High Speed Downlink Packet Access (HSDPA) and High Speed transmission Packet Access (HSUPA). Whereas HSDPA was introduced as a 3GPP Release 5, HSUPA is associated important feature of 3GPP Release 6. However, even with the introduction of HSPA, evolution of UMTS has not reached it. HSPA+ can bring vital enhancements in 3GPP release 7 and release 8. Objective is to boost performance of HSPA primarily based radio networks in terms of spectrum potency, peak rate and latency, and exploit the total potential of WCDMA primarily based on five mega cycle operation. The ideas for UMTS LTE are introduced in3GPP Release 8. Objective could be a high-data-rate, low-latency and packet-optimized radio access technology. LTE is additionally referred to as EUTRA (Evolved UMTS Terrestrial Radio Access) or E-UTRAN (Evolved UMTS Terrestrial Radio Access Network).Long term evolution (LTE) development includes higher data rates and lower latencies. Basically Physical layer design is used for any of the mobile standard. To get the high speed data rate and efficient system, a new modulation scheme is used which is known as Orthogonal Frequency Division Multiplexing (OFDM). LTE standard defines a multimode air interface based on orthogonal Frequency Division Multiplexing.

MATERIALS AND METHODS

Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a multicarrier modulation scheme The basic principle of OFDM involves a sub carrier mapping in which orthogonal sub carrier signals are defined to carry the original data on multiple parallel data streams or channels. Thus OFDM can be considered as an extension of single carrier modulation to the multicarrier modulation scheme, where single data stream is sent over a number of lower data rate orthogonal subcarriers. To preserve the orthogonality criteria of subcarriers, OFDM system uses Inverse fast Fourier transform (IFFT) and Fast Fourier Transform (FFT) to get the orthogonal frequency. Thus integration of modulation and multiplexing techniques might be considered as OFDM. Figure 1 shows a frequency spectrum of orthogonal frequency division multiplexing (OFDM) with a subcarrier spacing f_0.

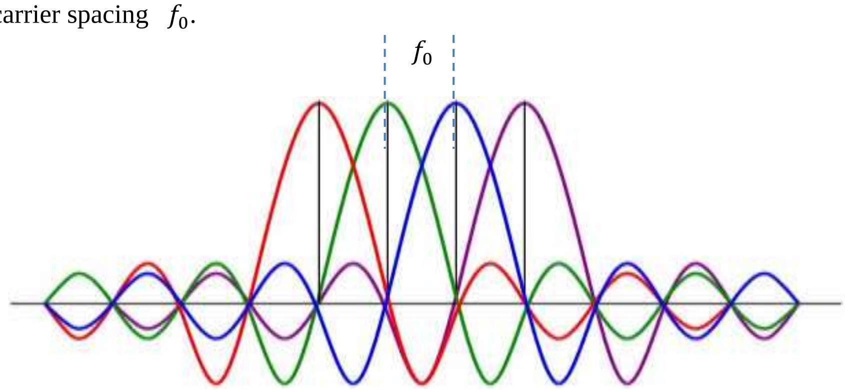

Figure 2 Frequency Spectrum of Orthogonal Frequency Division Multiplexing

Multiple Access Techniques

Orthogonal Frequency Division Multiple Access

Orthogonal Frequency division multiple access (OFDMA) is an access scheme based on the principal of orthogonal frequency division multiplexing (OFDM) modulation scheme. The main idea behind this access scheme is to partition the data into number of minor subcarriers with the help of inverse fast Fourier transform (IFFT).

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The transmitter performs two more alternative signal process operations before transmission. It inserts a collection of symbols referred to as a cyclic prefix (CP) so as to supply a guard time to forestall inter-block interference (IBI) thanks to multipath propagation. The transmitter additionally performs a linear filtering operation brought up as pulse shaping So as to scale back out-of-band signal energy. In general, CP could be a copy of the last a part of the block that is else at the beginning of every block for some of reasons. First, CP acts as a guard time between consecutive blocks. If the length of the CP is longer than the utmost delay of the channel, or roughly, the length of the channel impulse response, then, there's no IBI. Second, since CP could be a copy of the last a part of the block, it converts a distinct time linear convolution into a distinct time circular convolution.

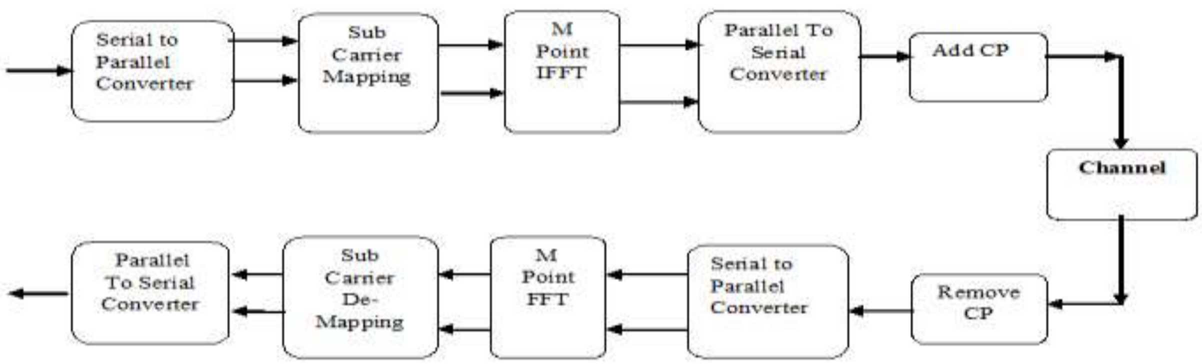


Figure 3 Block Diagram of Orthogonal Frequency Division Multiple Access (OFDMA)

Single Carrier Frequency Division Multiple Access

SC-FDMA is an abbreviation of Single carrier frequency division multiple access. It is also referred as DFT-spread orthogonal frequency division multiple access (OFDMA) since wherever time domain data symbols are transformed to frequency domain with the use of Discrete Fourier Transform (DFT) prior to OFDMA modulation.The orthogonality of the users stems from the very fact that every user occupies totally different subcarriers within the frequency domain, similar to the case of OFDMA. Similar to the case of OFDMA as a results of the overall transmit signal may be one carrier signal, PAPR is inherently low compared to the case of OFDMA which is a multicarrier modulation scheme.

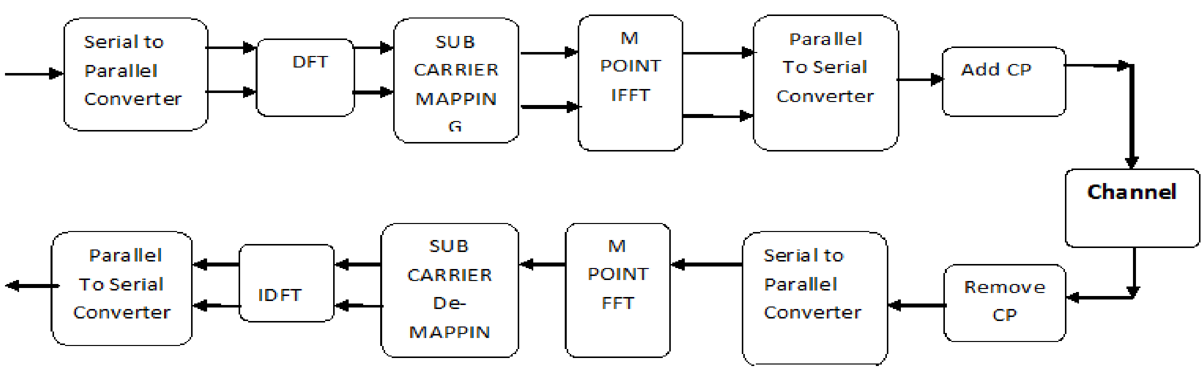


Figure 4 Block Diagram of Single Carrier-Frequency Division Multiple Accesses (SC-FDMA)

The transmitter of associate SC-FDMA system firstly groups the modulation symbols into blocks, each containing N symbols. Next it performs associate N-point DFT to supply a frequency domain illustration of the input symbols. It then maps each of the N-DFT outputs to M orthogonal subcarriers which will be transmitted. If N = M/Q and every one terminals transmit N symbols per block, the system will handle letter simultaneous transmissions while not co-channel interference. Q is that the information measure growth issue of the image sequence given by Q = $\frac{N}{M}$. M point DFT generates M number of frequency equivalent of symbols. These M outputs are then mapped into N orthogonal subcarriers over a given bandwidth given by

$$W_{channel} = N * f_0$$

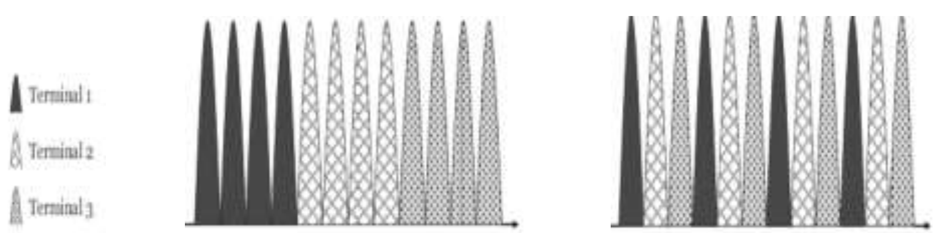
where f_0 is spacing between subcarriers. Thus overall transmission bandwidth is $R_{channel} = \frac{N}{M} * R_{source}$ Symbols/second.The working of the rest of the transmitter and receiver parts are same as that of OFDMA operations. So transmitted information propagating through the channel is modelled as a circular convolution between the channel impulse response and also the transmitted data block that within the frequency domain could be a point-wise multiplication of the DFT frequency samples. Then, to remove the channel distortion, DFT of the received signal can merely be divided by the DFT of the channel impulse response point-wise or additional refined frequency domain equalization technique is enforced.

The receiver transforms the received signal into the frequency domain via FFT, de-maps the subcarriers, and then performs Inverse Discrete Fourier Transform.Most of the well -known time domain equalization techniques, like minimum Mean sq. error (MMSE) equalization can also be used.

Subcarrier mapping

Mapping is an important operation in the SCFDMA. It is used for the mapping of the output of DFT into the form of M orthogonal subcarriers which are then transmitted for IFFT operation. This subcarrier mapping can be considered as the placements of N DFT symbols in a particular fashion. There are two kinds of Subcarrier Mappings: Localized Subcarrier Mapping and Distributed Subcarrier mapping.

In Localized Subcarrier Mapping, generated DFT outputs are mapped onto subcarriers in a continuous manner. This continuous placement of the DFT outputs constitutes only a small portion of the whole bandwidth thereby allowing the frequency reuse. While in Distributed Subcarrier Mapping, DFT outputs are placer onto the subcarriers in a non-consecutive manner as compared to Localized Subcarrier mapping.



Localized Mapping ***Distributed Mapping***

Figure 5 Localized and Distributed type of Subcarrier Mapping

SCFDMA vs OFDMA

In general SCFDMA and OFDMA have almost similar architecture. Some of the common functions of both schemes are as follows: Both are multiple access techniques based on OFDM principle, modulation and transmission in terms of N symbols, subcarrier mapping and channel equalization method and frequency synchronization using cyclic prefix or extended prefix.

There are many distinct differences between these two multiple access techniques. SCFDMA is a single carrier modulation scheme while OFDMA is a multicarrier modulation scheme. The difference though is that a DFT is performed prior to the IFFT operation, which spreads the symbols across all subcarriers carrying information and produces a virtual single carrier structure. As a consequence, SC-FDMA presents a lower PAPR than OFDMA [3]. One of the important advantages of SCFDMA is that it provides a better peak to average power ratio characteristics thus a Lower PAPR is achieved as compared to OFDMA. So SCFDMA is favoured as an emerging moultiple access scheme for the wireless communication standards such as Long Term Evolution (LTE).

Peak to Average Power Ratio (PAPR)

PAPR of OFDM signal is defined as the ratio of Maximum peak power to its average power.OFDM signal is the vector sum of a number of subcarriers with different phases. At some point, addition of coherent subcarriers with distinct phase become large and at other times it might be quite small. Resultant peak value of an OFDM signal become substantially larger than average value. This increase in the peak value is due to nonlinear characteristics of high power amplifiers.To reduce the PAPR, Peak power must be reduced The expression for the PAPR for any of the OFDM signal is represented by

$$\text{PAPR} = \frac{\max_{0 \le t < NT} |x(t)|^2}{\frac{1}{NT}\int_0^{NT} |x(t)|^2 \, dt}$$

In this expression, max{x(t)} reduction is performed by the various techniques.

Cumulative Distribution Factor

Cumulative Distribution Factor (CDF) is mostly used constraint for the determination of the efficiency of any of the PAPR reduction technique being used.

$$F(z) = 1 - e^{-z}$$

Nowadays Complementary Cumulative Distribution factor (CCDF) have been replaced the use of CDF since it can provide the better measurement of probability of PAPR threshold of data streams. So the probability of PAPR threshold measurement can be represented in terms of CCDF.

$$P(\text{PAPR} > z) = 1 - P(\text{PAPR} \le z)$$

The only disadvantage of the PAPR reduction methods is that these introduce a substantial complexity in the implementation of transmitter and receiver.

RESULTS AND DISCUSSION

Table 1 shows different parameters used for the simulation of SCFDMA and OFDMA Schemes.

Table 1. Simulation Paramaters

Parametes	Values
Data block size	16
Number of subcarriers	512
Modulation Schemes	QPSK 16 QAM
Channel type	AWGN
FFT Size	512
Cyclic Prefix	64

Figure shows CCDF plot for PAPR analysis of Single Carrier Frequency Division Multiple Access for QPSK and 16 QAM modulation schemes respectively.

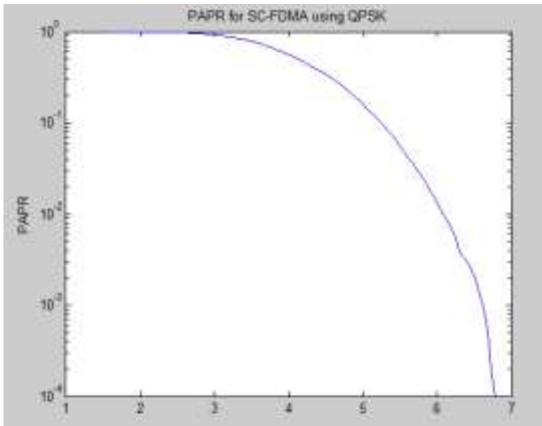


Figure 6 CCDF graph For PAPR of SCFDMA for QPSK

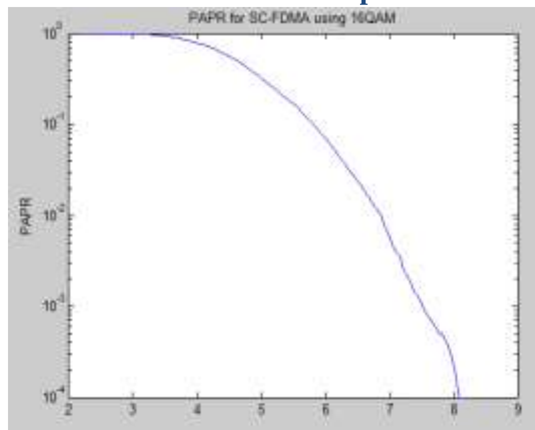


Figure 7 CCDF graph For PAPR of SCFDMA for 16 QAM

Figure shows CCDF plot for PAPR analysis of Orthogonal Frequency Division Multiple Access for QPSK and 16 QAM modulation schemes respectively.

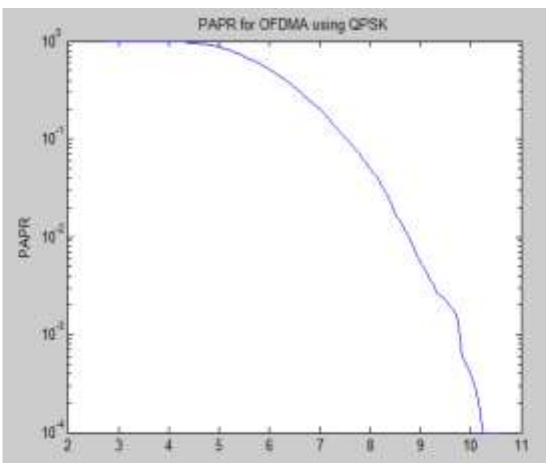


Figure 8 CCDF graph For PAPR of OFDMA for QPSK

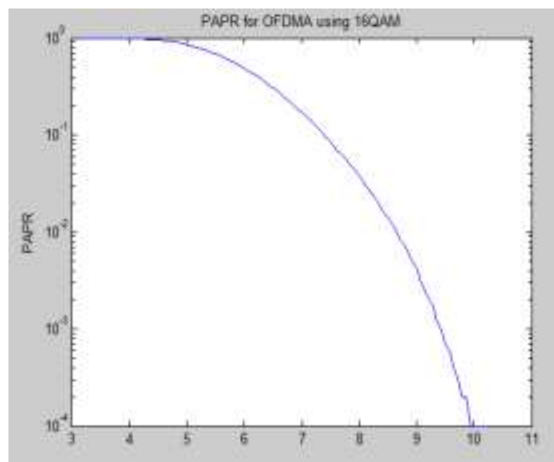


Figure 9 CCDF graph For PAPR of OFDMA for 16 QAM

From Figure 6 & 7 and Figure 8 & 9, it is concluded that with the higher order modulation schemes, PAPR somewhat increases. Also by comparing Figures 6 & 8, it is concluded that PAPR of SC FDMA is found as 3dB while PAPR of OFDAM is obtained as 4.5 dB with the QPSK. Also For 16 QAM, from figure 7 & 9, PAPR is obtainedas approximately 3dB while 4.2 dB for OFDMA.Thus SCFDMA has a lower PAPR content as compared to OFDMA .

CONCLUSION

In this paper, a comparison of PAPR analysis of multiple access techniques SCFDMA and OFDMA was proposed. It is shown from the CCDF plot that the Peak to average power ratio (PAPR) level is quite small for SCFDMA as compared to OFDMA. Here, after analysing the simulation results, it is cocluded that SCFDMA shows better result in comparison with OFDMA for LTE systems.

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