# PERFORMANCE COMPARISON BETWEEN OFDMA AND SC-FDMA USING RAYLEING FADING CHANNEL

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**ABSTRACT**

*To meet the increasing demands on the mobile radio systems and data traffic, a successor of UMTS, which runs on an evolution of the existing infrastructure used by over 80 percent of mobile subscribers globally, has been worked on by 3GPP, called Long Term Evolution (LTE). This will permit more powerful and better spectral efficiency of the transmission. The major parts of LTE are Single Carrier Frequency Division Multiple Access (SC-FDMA) & Orthogonal Division Multiple Access (OFDMA). OFDMA is used as multiple access method and it's providing immunity of multi-path and frequency selective fading. SC-FDMA is introduced recently and it became handy candidate for uplink multiple access scheme in LTE system.*

*In our paper, we analyzed the performance of SCFDMA and OFDMA for BPSK Modulation scheme on the basis of BER by simulating the model of SCFDMA & OFDMA in MATLAB. We used Additive White Gaussian Noise (AWGN) channel and introduced frequency flat fading in the channel by using Rayleigh fading model to evaluate the performance in presence of noise and fading.*

*Though the total channel is a frequency selective channel, the channel experienced by each subcarrier in an OFDM system is a flat fading channel with each subcarrier experiencing independent Rayleigh fading.*

***Keywords: LTE, 3GPP, SCFDMA, OFDMA, AWGN***

## I. INTRODUCTION

Designing an efficient wireless communication system is always a challenge. With increase in demand for high data rate this task has become even more challenging. To achieve this challenging goal next generation system came in to existence. Recent standard introduced by 3GPP group which promises high-speed data, multimedia unicast and multimedia broadcast services for next generation cellular concept. Single Carrier Frequency Division Multiple Access (SC- FDMA) & Orthogonal Division Multiple Access (OFDMA) are the major parts of the Long Term Evolution (LTE). OFDMA is used in the LTE downlink as a multiple access method as it provides good bandwidth efficiency, immunity to multi-path and frequency selective fading, and less complex equalization at the receiver[1].

OFDMA is a multiple access technique which uses Orthogonal Frequency Division multiplexing (OFDM) for each user. In this technique each user is allotted separate channel and available frequency band of that channel is divided into number of orthogonal frequency subcarriers. The high speed serial data from each user is first

converted into low speed parallel bit streams with increased symbol duration then it is modulated on each subcarrier using conventional modulation schemes. OFDMA allows achieving high data rate for each user. With little modification to air interface it can be deployed across different frequency bands. OFDMA reduce the effect of multipath fading because data from each user is modulated over several orthogonal frequencies rather than a fixed frequency for entire connection period. In addition, the OFDMA is bandwidth efficient as orthogonal frequency carriers with small spacing is used. All these advantage make it to be used in the downlink transmission of LTE[2][3]. OFDM is referred as multicarrier modulation. It uses multiple RF carrier signals at different frequencies which send some of the bits on each of the assigned channels. This seems to be similar to FDM but in the case of OFDM, total subcarriers are divided into sub channels and these sub channels are mapped to one single data/traffic source[4].

SC-FDMA is a multiple access method. Its structure is same as OFDMA with an addition of Fast Fourier Transform (FFT) block. The parallel data streams are first passed through FFT block then are modulated on subcarriers because of this the SC-FDMA is also called DFT-Precoded OFDM. The main difference between OFDMA and SC-FDMA is, in OFDMA, each data symbol is carried on a separate subcarrier while, in SC-FDMA, multiple subcarriers carry each data symbol due to mapping of the symbols' frequency domain samples to subcarriers. As SC-FDMA is derived from OFDMA it has same basic advantages as OFDMA but the spreading of each data symbol over multiple subcarriers gives it the profound advantage of lower PAPR value as compare to that of OFDMA. Hence PAPR is a useful parameter for uplink it is used in uplink transmission [4][5].

SC-FDMA one extra module DFT is added before IFFT module in the transmitter chain and IDFT is added in the receiver chain. This converts OFDM chain into SC-FDMA chain. Without this two modules the chain is referred as OFDM transmit and receive chain. SC-FDMA system usually will have low PAPR (Peak to Average Power Ratio) compare to OFDM system. SC-FDMA system is less sensitive to frequency offset compare to OFDM system.

Our objective of this work is to analyze the performance system by considering two multiple access techniques (SC-FDMA and OFDMA) with adaptive modulation techniques BPSK. We have considered BER parameters to evaluate the performance of LTE. We have considered these parameters because they are vital in communication systems and we have achieved our results by simulating the OFDMA and SC-FDMA models in MATLAB [5][6].

## II. EXPERIMENTAL APPROACH

In OFDMA transmitter, the high speed serial data from each user is first converted in to low speed parallel data streams. This increases the symbol duration which reduce the Intersymbol Interference (ISI) at the receiver. Then the parallel data streams are passed through modulator, where adaptive modulation schemes BPSK, is applied. This modulated data streams are then mapped to orthogonal subcarriers by dividing the available spectrum into number of orthogonal frequency subcarriers. This makes the time domain data stream from user a frequency domain data stream or signal as at different frequency different low speed data stream will be present. The IFFT stage converts these complex data streams into time domain and generates OFDM symbols. A guard band or cyclic prefix (CP) is inserted between OFDMA symbols in order to cancel the ISI at the receiver. The

CP is inserted by taking some part from end of the OFDM symbol and putting it at the start of the symbol as shown in figure 2.1. The duration of these CP should be greater than the channel impulse response or delay spread. After appending CP the data streams are converted to a serial data stream to be transmitted in the channel[8][9].

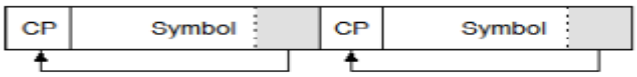


**Figure 1: Inserting Cyclic prefix (CP)**

At the receiver, the inverse processes of the transmitter occur. The serial data is converted to parallel data streams, CP is removed from each symbol and FFT stage converts the OFDM symbols in to frequency domain followed by subcarrier de-mapping and demodulation. Finally parallel data streams are converted to high speed serial data stream shows the block diagram of the model we used to simulate OFDMA system[10]. We wrote a MATLAB program to simulate the model shown in Figure 2.

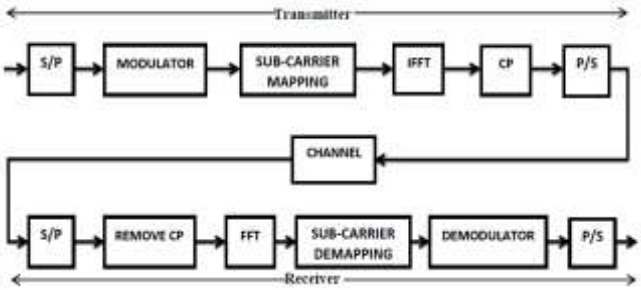


**Figure 2: Block diagram of the OFDMA system mode**

In SC-FDMA transmitter, after modulating parallel low speed data streams, the transmitter groups the modulated symbols into a block of *N* symbols. An *N*-point FFT block transforms these symbols in time domain into frequency domain. The frequency domain samples are then mapped to a subset of *M* subcarriers where *M* is typically greater than *N*. Similar to OFDMA, an IFFT block is used to generate the time-domain samples of these subcarriers, which is followed by appending cyclic prefix and parallel to serial conversion.

At the receiver just the opposite processes take place. Serial to parallel conversion, removing CP, taking FFT to convert to frequency domain, sub-carrier demapping followed by IFFT and demodulation[11].

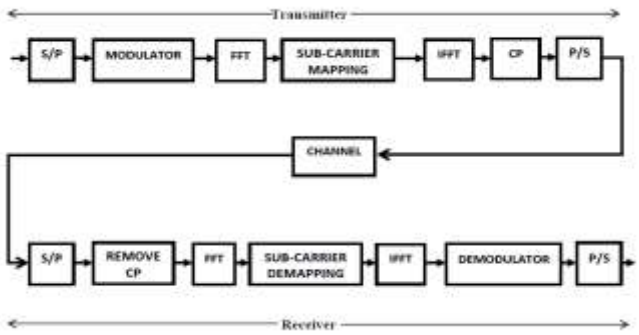


**Figure 3: Block diagram of the SC-FDMA system model**

Figure 3 shows the block diagram of the model we used to simulate SC-FDMA system. The model is same as that of OFDMA except an FFT block is inserted before sub-carrier mapping at the transmitter while an IFFT

block is placed after sub-carrier demapping at the receiver. The steps for creating the program to simulate the model are same as that of OFDMA except we took FFT before sub-carrier mapping and IFFT after sub-carrier demapping.

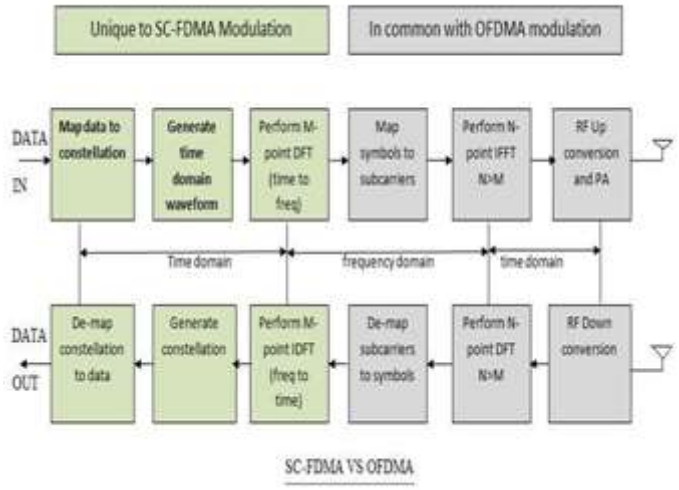


**Figure 4: Comparison between SC-FDMA and OFDMA**

The block diagram of SC-FDMA and OFDMA system in Figure 4 mentions modules unique to the SC-FDMA and in common with OFDMA system. As mentioned DFT before IFFT of OFDMA and IDFT after DFT of OFDMA system makes it SC-FDMA. The main contribution of this work is the analysis of the performance, in terms of BER and spectral efficiency, of a SC-FDMA system over fading channels. We paid special attention to the Rayleigh fading channel, which can be seen as a particular case of Nakagami-$\mu$ fading channel [12][13]. The obtained results were first validated through simulations and, then, compared to those obtained with OFDMA. These comparisons allow us to determine the difference in performance between both technologies. Other contributions made during the development of this work are listed next [15] .

## III. DESIGN & PARAMETERS

OFDM also has many advantages compare to SC-FDMA. Frequency selective fading will be able to affect few of the sub channels/subcarriers and not entire band. OFDM overcomes effect of ISI occurring mostly in multipath channel environment. OFDM is used to achieve high data rate over single carrier system. Due to multiple carriers OFDM leads to high PAPR (Peak to Average Power Ratio) to overcome PAPR scrambler (randomizer) is used in OFDM based systems which spread the energy across wide bandwidth. There are various techniques to reduce the PAPR the same is explained in PAPR article. OFDMA transmits 4 qpsk symbols in parallel, one data symbol per subcarrier. SC-FDMA transmits qpsk symbols in the series but at 4 times the rate compare to OFDMA. Here qpsk symbol occupy much wider bandwidth about M x 15KHz where M is no. subcarriers

The BER is ratio of number of error bits and total number of bits transmitted. It is given by the following formulae.

BER = Number of Error Bits / Total Number of Transmitted Bits

To plot BER performance first we simulated the developed model, calculated BER for different Signal to Noise Ratio (SNR) values using the above formulae and then we plotted these values against corresponding SNR values[4][5][9][16].

The relation between **symbol energy** and the **bit energy** Eb/No and Es/No in OFDM is as follows

$$\frac{E_s}{N_0} = \frac{E_b}{N0}\left(\frac{nDSC}{nFFT}\right)\left(\frac{Td}{Td+Tcp}\right).$$

*Expressing in decibels,*

$$\frac{E_s}{N_0}dB = \frac{E_b}{N0}dB + 10log_{10}\left(\frac{nDSC}{nFFT}\right) + 10log_{10}\left(\frac{Td}{Td+Tcp}\right)$$

| PARAMETERS | ASSUMPTION |
|---|---|
| Number of Sub-carriers | 64 |
| CP Length | 7 |
| Range of SNR in dB | 0 to 35 |
| Modulation | BPSK |
| Data Block Size | 16 |
| Channel | AWGN Channel |
| System Bandwidth | 5 MHz |
| FFT and IFFT size | 64 |
| Fading | Rayleigh (frequency flat) fading |

It is imperative that OFDMA is multi-carrier system with one data symbol carried over by one subcarrier; while SC-FDMA is a single carrier system where in each qpsk symbol is carried by one much wider bandwidth subcarrier. Refer difference between SC vs OFDM page to understand concepts of Single Carrier (SC) vs OFDM. Though symbol length remains same in both OFDMA and SC-FDMA which is about 66.7µS; SC-FDMA symbol contains more than one sub-symbol which represents qpsk data symbols. Parallel multiple data symbol transmission will lead to higher PAPR (Peak to Average Power Ratio) in the OFDMA system. In SC-FDMA, PAPR is same as that of original qpsk data symbols as M qpsk data symbols are transmitted in series at M time's rate compare to OFDMA[17].

SC-FDMA is widely used in LTE subscriber terminals in the transmit path and its variant OFDMA is used in the eNodeB downlink (or receive path of LTE subscribers). While OFDM is used in many broadband technologies such as wimax-16d/16e, WLAN-11a/11n/11ac

## IV. DISCUSSION AND RESULT

Following are the steps or algorithm we followed while writing the program to simulate the model.

1. First we generated binary stream of data.
2. We converted this stream of data in to number of parallel streams of data.
3. We modulated these streams of data using different modulation schemes.(we used BPSK)
4. Then these modulated streams of data are mapped to different sub-carriers.

5. Then we took the IFFT of these mapped streams of data
6. CP was appended by taking some portion from end of each symbol and adding it at the beginning of the symbol.
7. Then the resultant parallel streams were converted to long serial data stream.
8. Then we created an AWGN channel by using a built in function in MATLAB in which the noise level is described by SNR per sample, which is one input parameter to the function.
9. We passed serial data stream through this channel (function).
10. For Rayleigh fading channel simulation we introduced fading using a built in function in MATLAB for Rayleigh frequency flat fading.
11. Corrupted data from channel were then converted to parallel data streams.
12. From each symbol CP were removed.
13. Then FFT of the streams were taken.
14. Data streams were de-mapped from the subcarriers.
15. Demodulations of data streams were done.
16. Finally parallel data streams were converted to serial data stream.

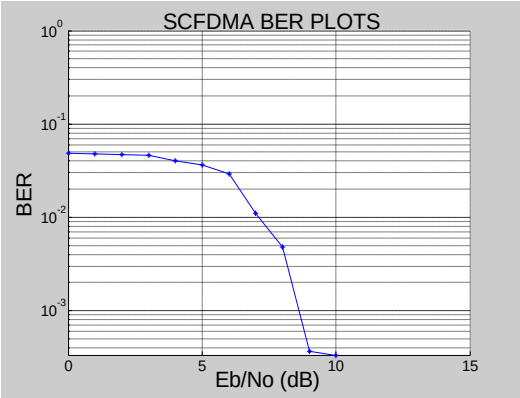


**Fig 5: BER for SCFDMA**

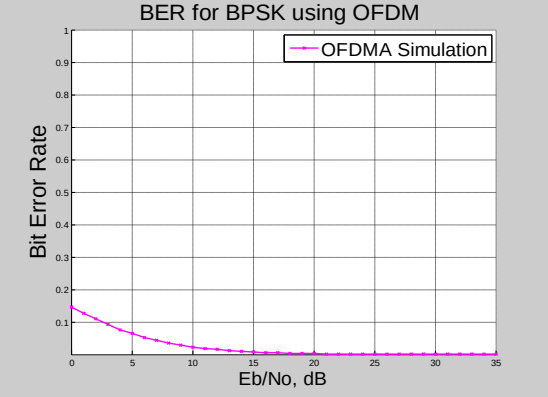


**Fig 6: Vs BER for OFDMA**

## V. CONCLUSION & FUTURE WORK

BER is the key parameter for indicating the system performance of any data link. In our paper we analyzed that for different values of SNR, the BER increases for high order modulation in both the multiple access techniques (OFDMA and SC-FDMA) used in next generation system and hence it is easily affected by the noise. BER Performance of SC-FDMA and OFDMA are very similar but a part of them SCFDMA have good performance as compare to the OFDMA

For future prospect we can add more modulation scheme and also calculate more parameter such as Peak to Average Power Ratio**,** congestion and many more**.**

## VI. ACKNOWLEDGMENT

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