PAPR and SER Performance Analysis of OFDMA and SCFDMA

By

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Under the guidance of
Dr. Ravi Kadlimatti

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CERTIFICATE

This is to certify that

Anshul Somvanshi 2018A3PS0405G

have successfully completed the project prepared in partial fulfilment of the course

ECE/EEE F418 : Modern Communication Technologies

Under the guidance of

Dr. Ravi Kadlimatti

[INSTRUCTOR IN-CHARGE]

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ABSTRACT SHEET

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TITLE OF PROJECT : PAPR and SER Performance Analysis of OFDMA and SCFDMA

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ABSTRACT : The single carrier multiple access scheme (SC-FDMA) is a novel method of radio transmission currently used in long term evolution (LTE) technology for uplink due to its high spectral efficiency with low bit error rate and lower peak-to-average power-ratio (PAPR) as compared to OFDM technique. Matlab simulation has been carried out to obtain PAPR performance of SC-FDMA and OFDMA techniques with different numbers of subcarriers. Two different approaches of assigning subcarriers have been assumed, distributed FDMA (DFDMA) and localized FDMA (LFDMA). Interleaved FDMA (IFDMA) is a special case of DFDMA where distribution of DFT outputs have been done uniformly with equal distance.. Comparing the forms of SC-FDMA, we find that interleaved (FDMA) has lower PAPR than localised (FDMA). We also discuss the SER (Symbol Error Rate) performance of both LFDMA and IFDMA schemes and find that the SER performance of localised (FDMA) is better than interleaved (IFDMA) technique.

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INTRODUCTION

Cellular communication has grown rapidly because of the demand of high data rates and throughputs. To support these demands of users a third generation partnership project (3GPP) has evolved a new technique called LTE/4G which uses orthogonal frequency division multiple access (OFDMA) technique for downlink communication and single carrier multiple access (SC-FDMA) technique for uplink communication. OFDMA and SC-FDMA techniques are modified forms of the orthogonal frequency division multiplexing (OFDM) and single carrier frequency division equalization (SC/FDE) techniques.

SC-FDMA is used in view of the fact that its peak-to-average-power-ratio (PAPR) is smaller and more constant. Moreover it has a similar throughput and essentially the same overall complexity as the orthogonal frequency division multiple access (OFDMA) system.

$$PAPR = \frac{max\ |x(t)|^2}{E\{|x(t)|^2\}}$$

We analyze the different mapping schemes of OFDMA and SC-FDMA in time domain and compare their PAPR and SER characteristics. We see that IFDMA performs better in PAPR reduction but at a cost of high symbol error rate (SER) as compared to LFDMA.

SYSTEM MODEL

The chain to generate an OFDMA signal starts by parallelizing the symbols that need to be transmitted, after they are modulated (in LTE the modulation can be QPSK, 16AQM, 64QAM). Then they are mapped to different subcarriers using either localised (LFDMA) or distributed (DFDMA) subcarrier mapping and then used as input bands for an inverse fast Fourier transform operation. This operation produces OFDMA symbols, which will be transmitted. Notice that a conversion from the frequency to the time domain was made when the IFFT was used. Before the transmission, however, a cyclic prefix is included in the OFDMA symbols as a guard interval to mitigate the inter-symbol interference through the transmission in the multipath channel.. These OFDMA symbols are then transmitted through a multipath channel and AWGN noise is added to simulate the noise in the channel.

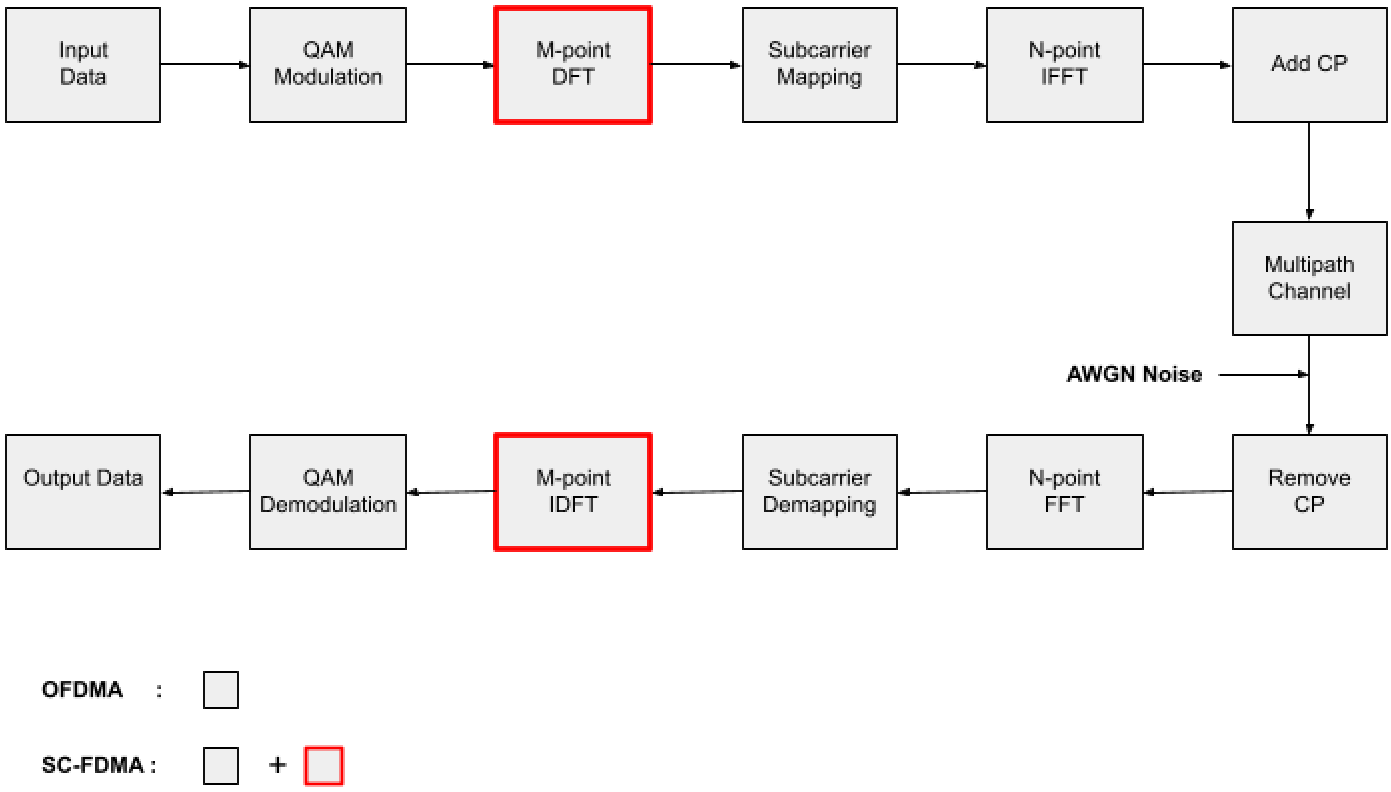

Figure 1: Model of OFDMA and SC-FDMA

(In SC-FDMA one extra module DFT is added before the IFFT module in the transmitter chain and IDFT is added in the receiver chain. This converts OFDMA chain into SC-FDMA chain. Without this two modules the chain is referred as OFDMA transmit and receive chain)

At the receiver's end CP is removed which is further followed by FFT operation to convert the symbols from time domain back to frequency domain. Subcarrier demapping and demodulation is done to get back the original symbols. Also during simulation channel equalization was applied before demodulation to mitigate the effect of inter-symbol interference (ISI) introduced by the channel impulse response variation in order to decrease the probability of error.

In SC-FDMA before applying the IFFT, the symbols are pre coded by a DFT (Discrete Fourier Transform). This way each subcarrier after IFFT will contain part of each symbol. Also, intersymbol interference will be reduced since all subcarriers on a period of time represent the same symbol.

Subcarrier mapping is one of the major considerations for LTE as multiple mobile terminals i.e. users are assigned by partitioned subcarriers in OFDMA system. In SCFDMA a subset of subcarriers is used to transmit its own data. The unoccupied carriers which are not used for transmitting its own data are filled with zero. If M is the number of subcarriers allocated to each user then, M point DFT is used for spreading purpose which will further be applied to the subcarriers of inverse DFT and the way of assigning the subcarriers to each terminal is the main key factor of the PAPR reduction.

There are three subcarrier mapping schemes available for assigning M frequency domain symbols to the subcarriers in SCFDMA. They are - localized, distributed and interleaved subcarrier mapping. (interleaved is special case of distributed subcarrier mapping)

DFT outputs are allocated to M consecutive subcarriers in the total N numbers of subcarriers (where N>M) in LFDMA. In contrast, in DFDMA, the M numbers of DFT outputs are distributed into the entire band. In both DFDMA and LFDMA zero amplitude is assigned to (N-M) unoccupied subcarriers. If the DFT outputs are distributed with an equidistance N/M=Q between the occupied subcarriers then the mapping mode is referred as the interleave FDMA (IFDMA), where Q is named as bandwidth spreading factor.

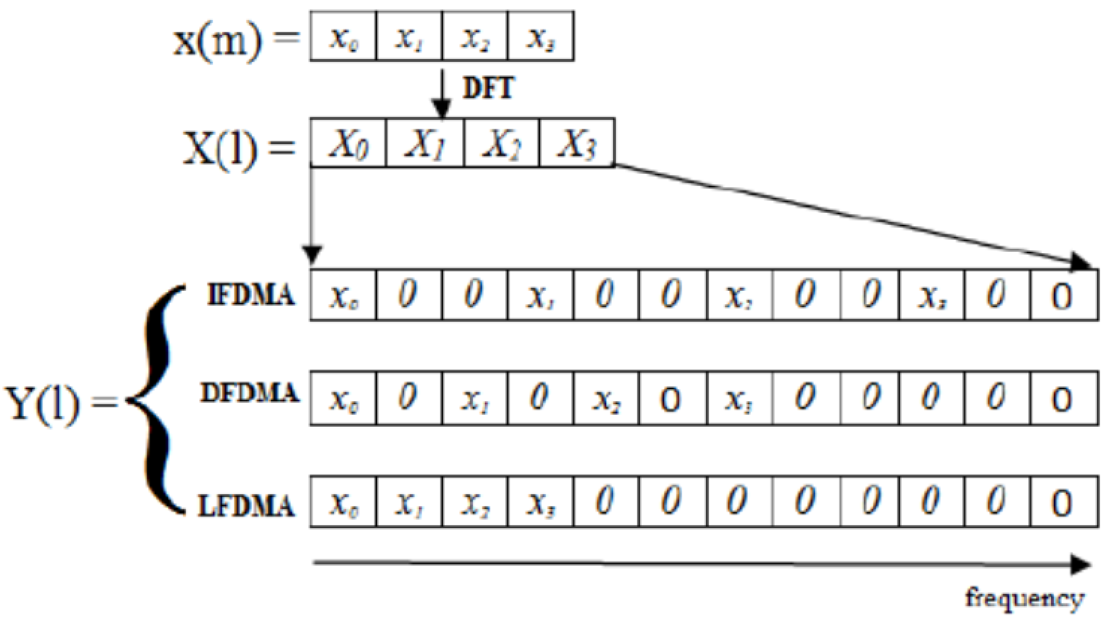

Figure 2 : Example of different subcarrier mapping modes for M=4, Q=3 and N=12

SER vs SNR (in dB) for OFDMA System

We have used the following data for our analysis:

- 64-QAM modulated signals
- FFT/IFFT length = 512
- Input-data block size = 32
- Cyclic Prefix (CP) Length = 20
- SNR $\in$ [0, 30 dB]

To evaluate the SER performance of OFDMA System three different channels were used, which are pedAchannel, vehAchannel and AWGN channel. Furthermore, the SER vs SNR [dB] plots were plotted for 3 different subcarrier mapping : localised FDMA (LFDMA), interleaved FDMA (IFDMA) and distributed FDMA (DFDMA).

A. pedAchannel

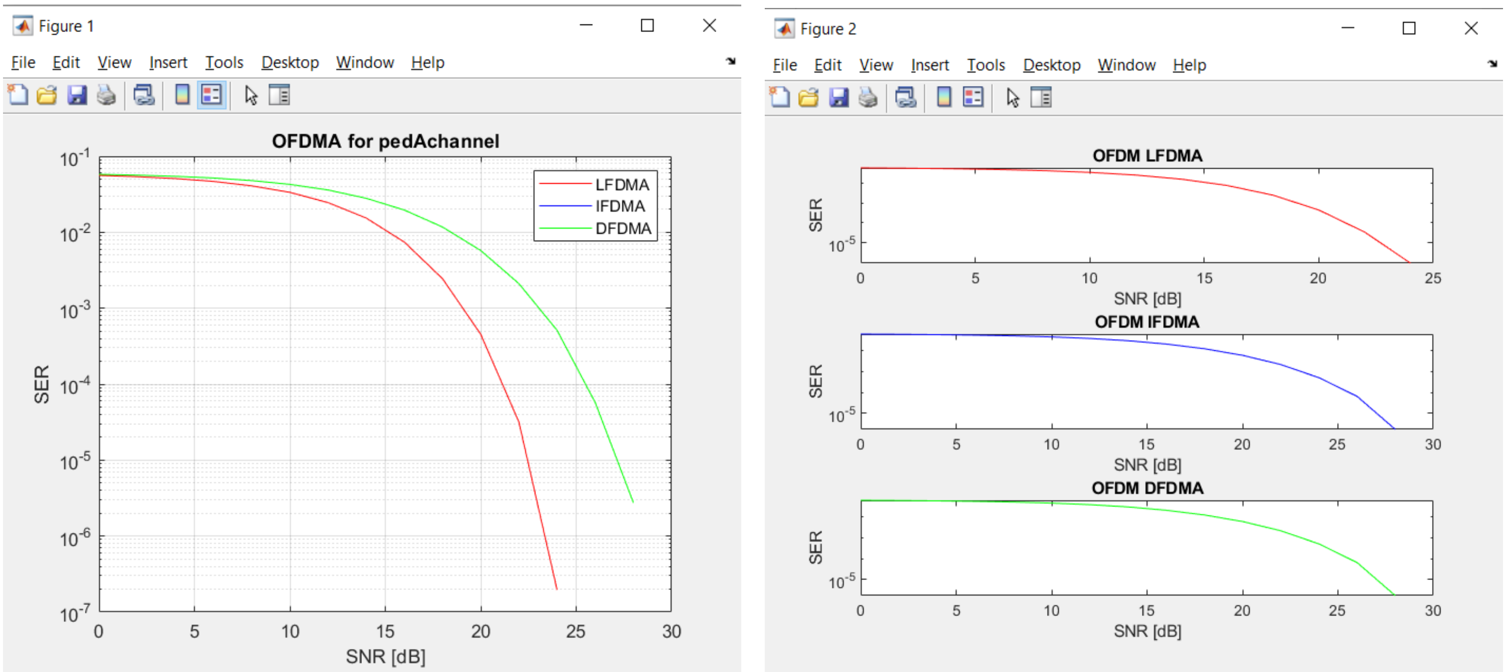

Figure 3: SER vs SNR [dB] for OFDMA in pedAchannel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one)

While using pedAchannel for OFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance (and hence are overlapped when plotted in single figure).

B. vehAchannel

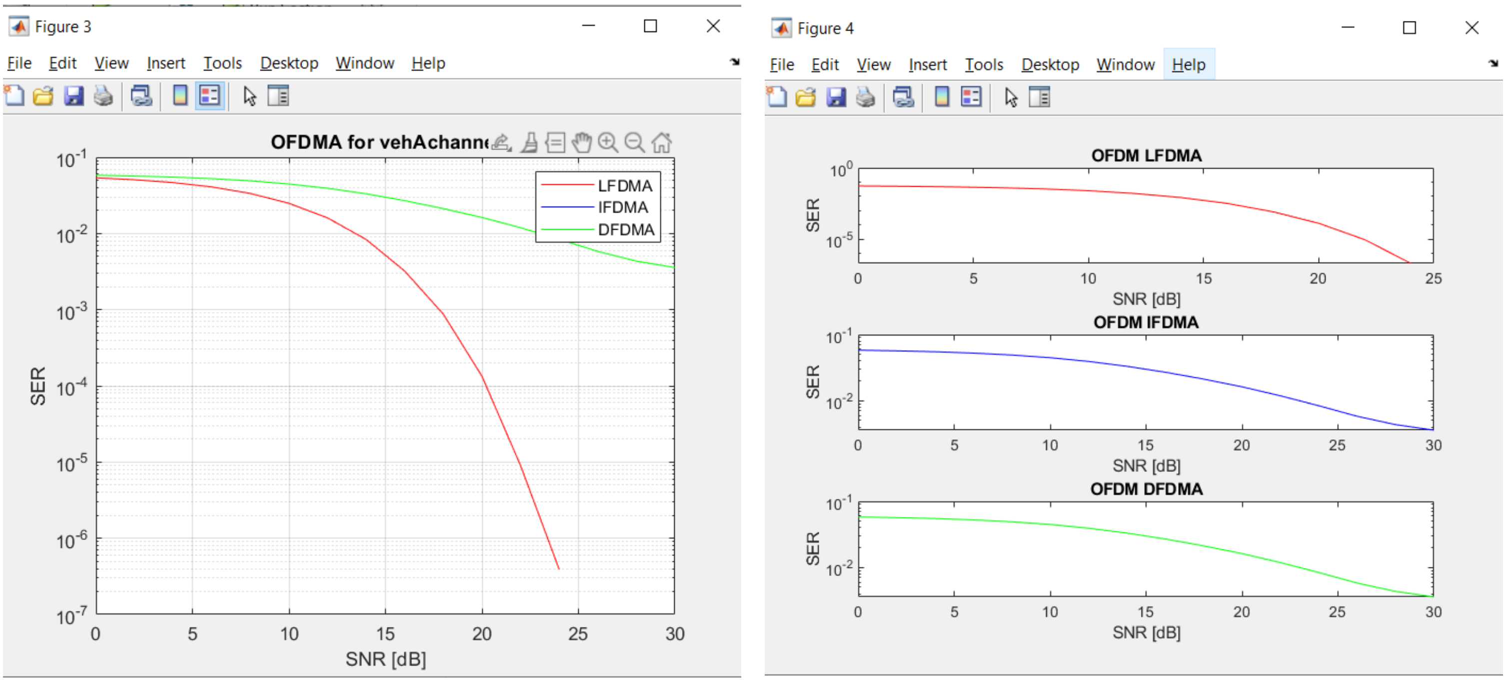

Figure 4: SER vs SNR [dB] for OFDMA in vehAchannel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values that are overlapped in left one)

While using vehAchannel for OFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance (and hence are overlapped when plotted in single figure).

When compared to pedAchannel , the LFDMA SER performance is the same as in vehAchannel but IFDMA and DFDMA SER performance is better for pedAchannel.

C. AWGN Channel

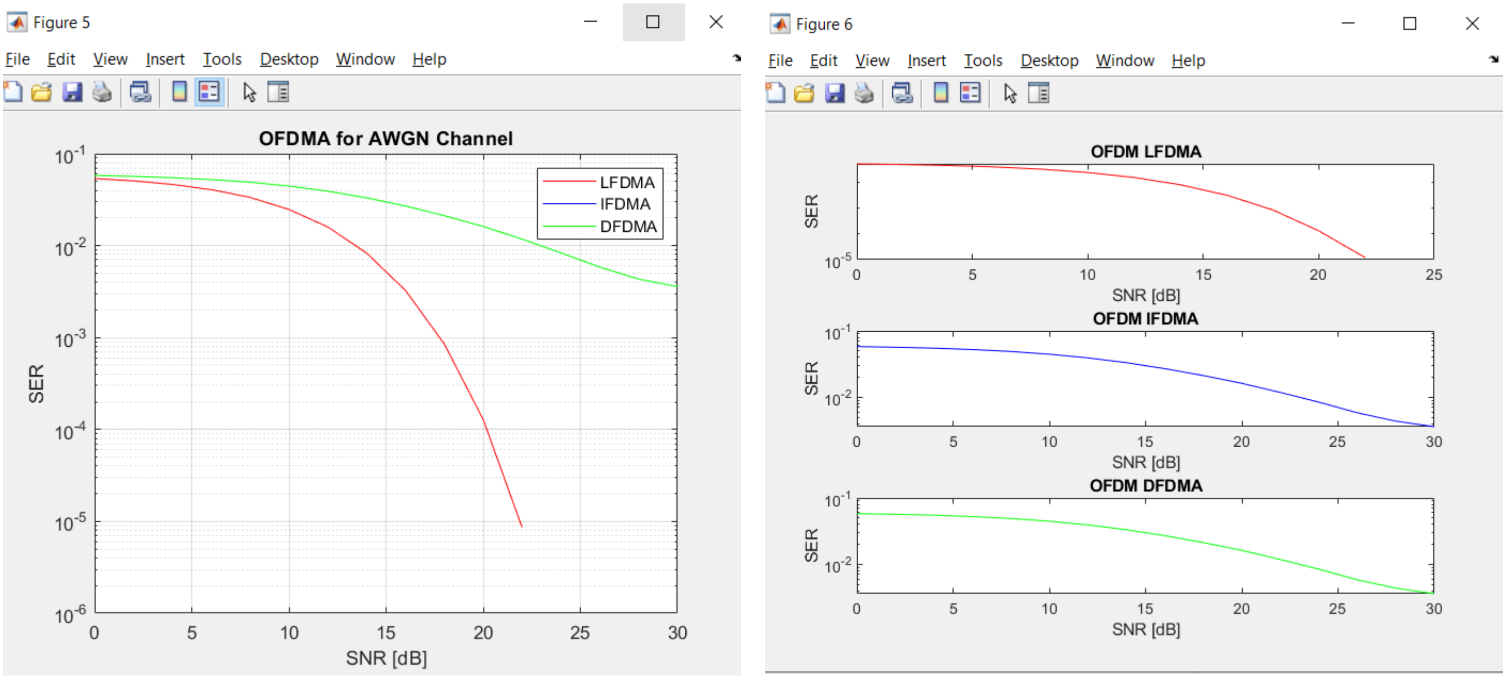

Figure 5: SER vs SNR [dB] for OFDMA in AWGN Channel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one)

While using AWGN channel for OFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance(and hence are overlapped when plotted in single figure).

When compared to pedAchannel , the LFDMA performance is slightly better in AWGN channel but IFDMA and DFDMA performance is better for pedAchannel.

When compared to vehAchannel , the SER performance of LFDMA is slightly better while IFDMA and DFDMA SER performance is almost same.

SER vs SNR (in dB) for SC-FDMA System

We have used the following data for our analysis:

- 64-QAM modulated signals
- FFT/IFFT length = 512
- Input-data block size = 32
- Cyclic Prefix (CP) Length = 20
- SNR $\in$ [0, 30 dB]

To evaluate the SER vs SNR (in dB) performance of SCFDMA System three different channels were used, which are pedAchannel, vehAchannel and AWGN channel. Furthermore, the plots were plotted for 3 different subcarrier mapping : localised FDMA (LFDMA), interleaved FDMA (IFDMA) and distributed FDMA (DFDMA).

A. pedAchannel

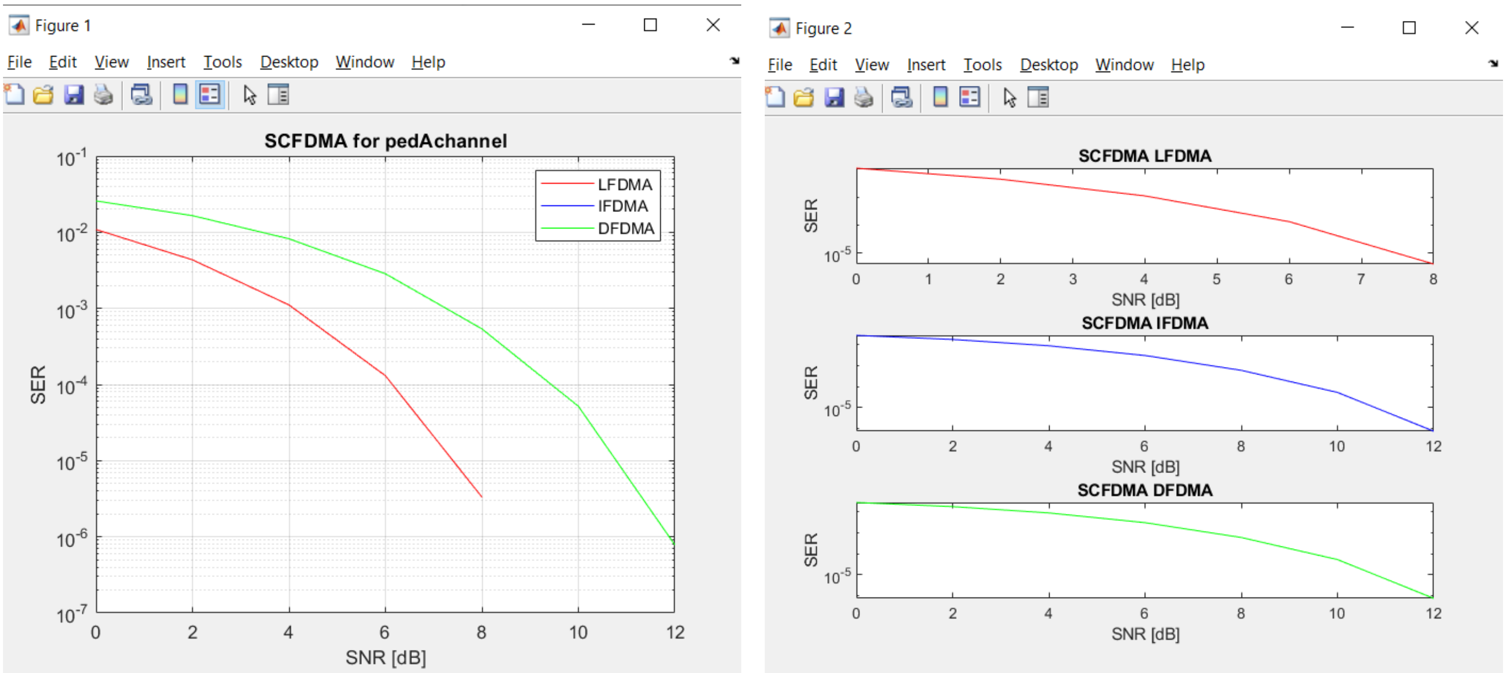

Figure 6: SER vs SNR [dB] for SCFDMA in pedAchannel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one)

While using pedAchannel for SCFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance .(and hence are overlapped when plotted in single figure).It is observed that the performance is greatly improved with SCFDMA as compared to OFDMA for all three subcarrier techniques in pedAchannel.

B. vehAchannel

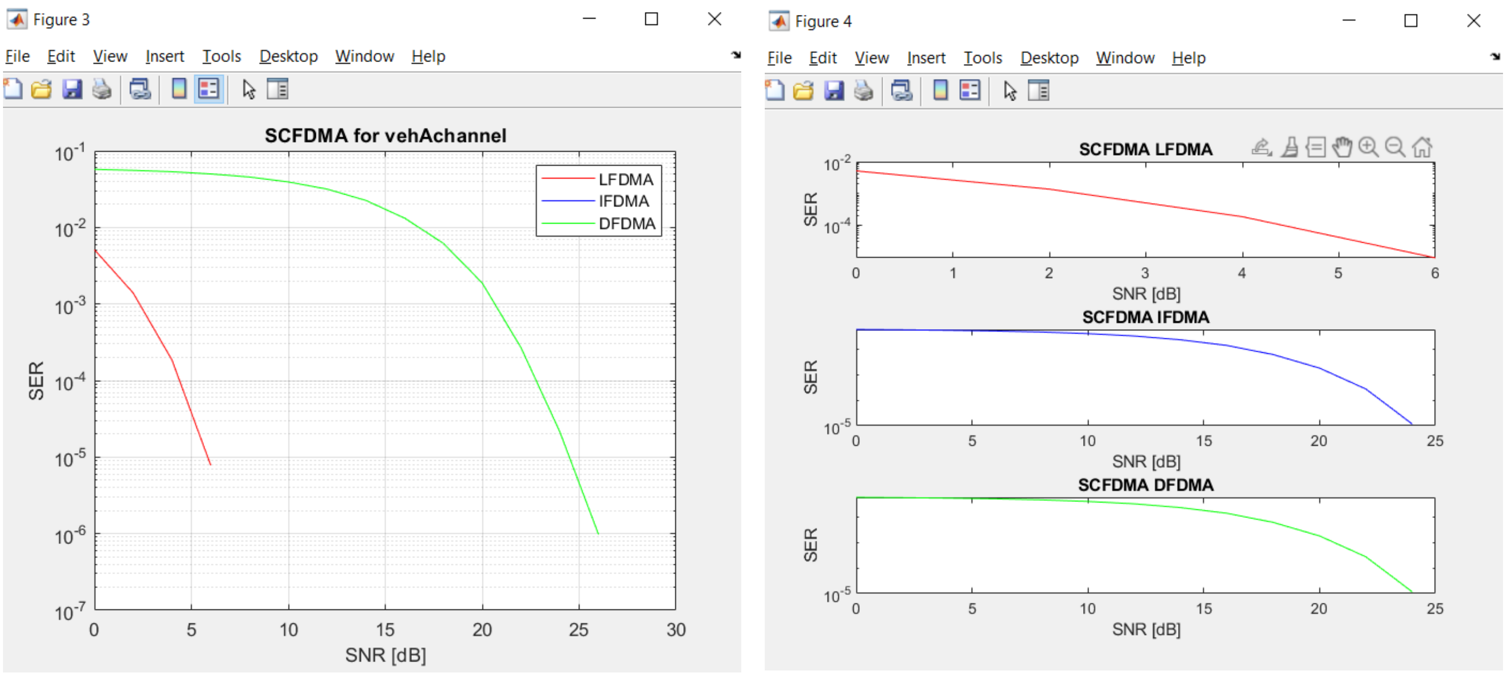

Figure 7: SER vs SNR [dB] for OFDMA in vehAchannel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values that are overlapped in left one)

While using vehAchannel for OFDMA we observe that the SER performance of LFDMA is a lot better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance (and hence are overlapped when plotted in single figure).

When compared to pedAchannel , the LFDMA performance is slightly better in vehAchannel but IFDMA and DFDMA performance is better for pedAchannel.

When compared to vehChannel performance of OFDMA , a great improvement in SER performance is observed.

Also, it must be noted that vehChannel performance of SCFDMA is better than the performance of OFDMA in all three channels.

C. AWGN Channel

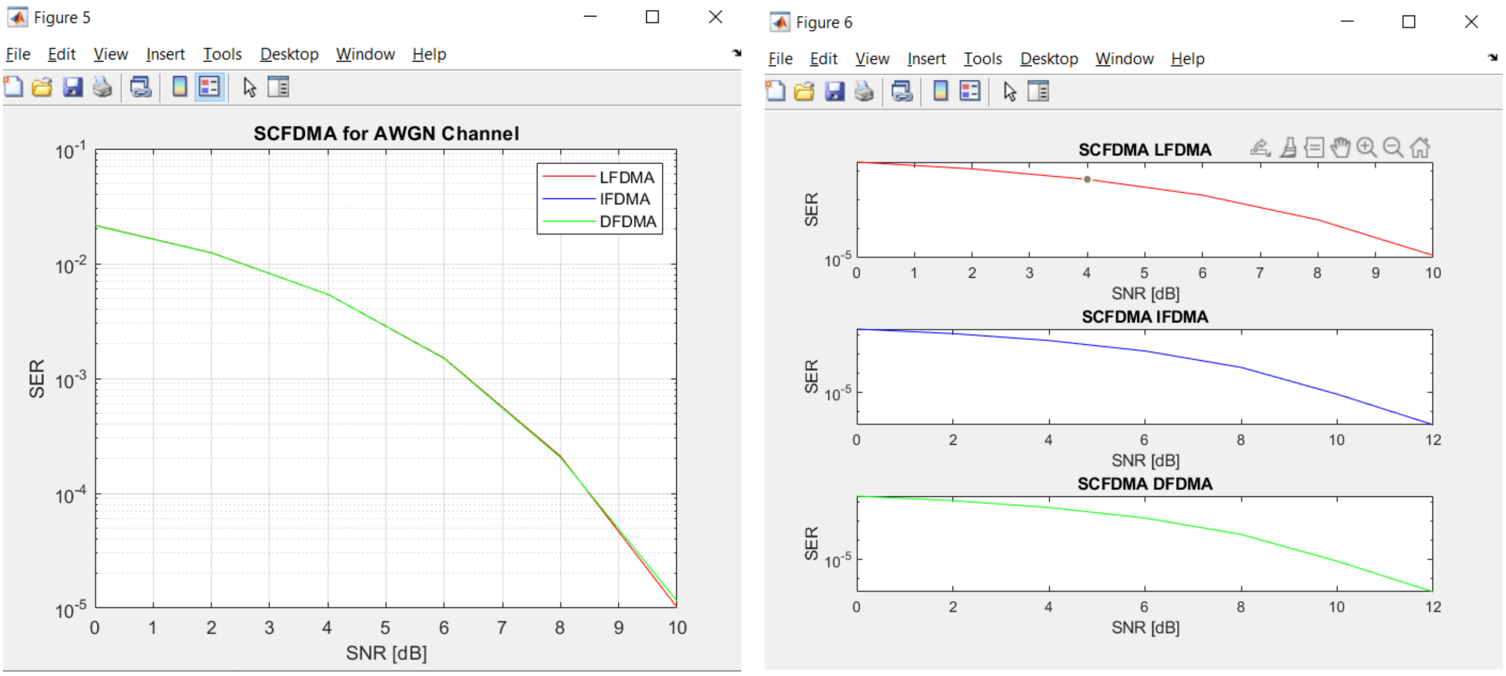

Figure 8: SER vs SNR [dB] for OFDMA in AWGN Channel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one)

While using the AWGN channel for OFDMA we observe that the SER performance of LFDMA, IFDMA and DFDMA is almost similar.

When compared to pedAchannel , there is a reduction in SER performance of LFDMA in AWGN channel but SER performance IFDMA and DFDMA is better for AWGN channel.

When compared to vehAchannel , there is a reduction in SER performance of LFDMA in AWGN channel but SER performance IFDMA and DFDMA is considerably better for AWGN channel.

Also, it must be noted that the AWGN performance of SCFDMA is better than the performance of OFDMA in all three channels.

PAPR Performance for OFDMA System

We have used the following data for our analysis:

- 16-QAM modulated signals
- FFT/IFFT length = 512
- Input-data block size = 32

To evaluate the PAPR performance of OFDMA System three different subcarrier mapping were used, which are localised FDMA (LFDMA), interleaved FDMA (IFDMA) and distributed FDMA (DFDMA).

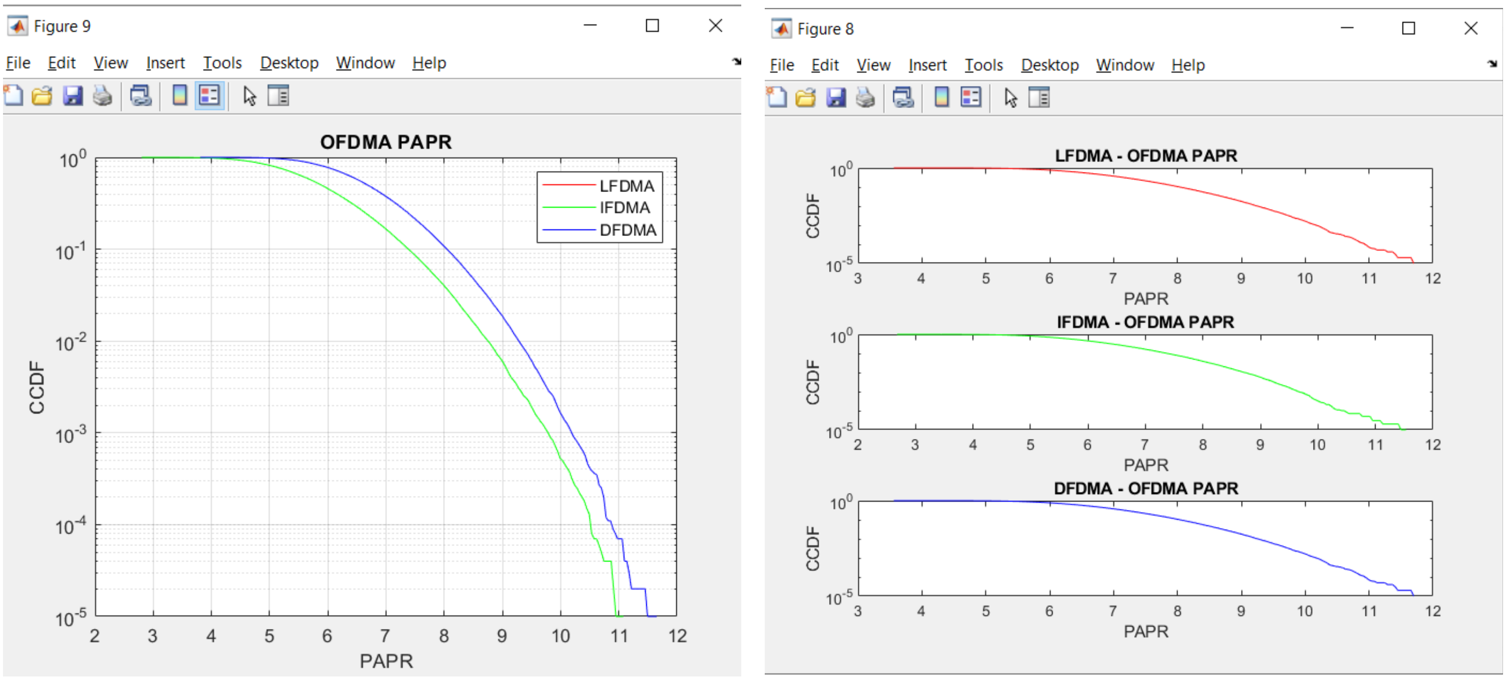

Figure 9: CCDF vs PAPR for OFDMA using LFDMA, IFDMA and DFDMA subcarrier mapping. (left side figure is without pulse shaping and left side figure is with pulse shaping)

We observed that the PAPR performance of LFDMA and DFDMA is almost similar in case of OFDMA and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA.

PAPR Performance for SCFDMA System

We have used the following data for our analysis:

- 16-QAM modulated signals
- FFT/IFFT length = 512
- Input-data block size = 32

To evaluate the PAPR performance of SCFDMA System three different subcarrier mapping were used, which are localised FDMA (LFDMA), interleaved FDMA (IFDMA) and distributed FDMA (DFDMA).

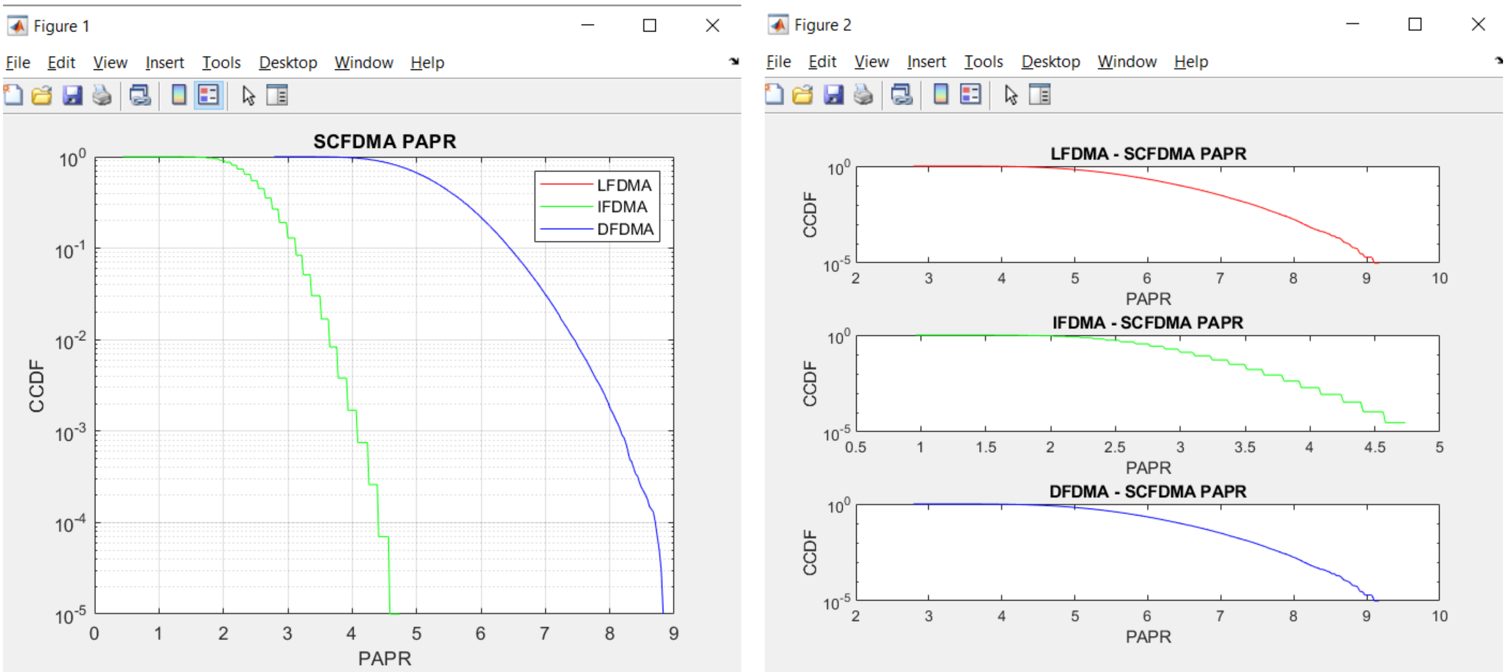

Figure 9: CCDF vs PAPR for OFDMA using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one)

We observed that the PAPR performance of LFDMA and DFDMA is almost similar in case of SCFDMA and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA.

It was observed that the PAPR performance of SCFDMA significantly improved in all three subcarrier mapping techniques i.e LFDMA, IFDMA and DFDMA, when compared to their counterparts in OFDMA.

CONCLUSION

In this project we have focused on the performance analysis of OFDMA and SCFDMA systems in terms of SER and PAPR. Three types of channel (pedAchannel, vehAchannel and AWGN channel) were introduced along with two types of subcarrier mapping (localised and distributed, IFDMA is a special case of DFDMA).

For all types of channel , it was observed that LFDMA subcarrier mapping shows better SER performance than IFDMA and DFDMA subcarrier mapping because of its better immunity to multiple access interference (MAI). Also the SER performance for IFDMA subcarrier mapping is almost similar to that of DFDMA subcarrier mapping.

Furthermore, in case of OFDMA system LFDMA sub-carrier mapping gave similar SER performance for pedAchannel and vehAchannel but a slightly better performance with AWGN channel. IFDMA subcarrier mapping and DFDMA shows similar performance with vehAchannel and AWGN channel but a slightly better performance with pedAchannel.

In the SCFDMA system LFDMA subcarrier mapping gave best SER performance with vehAchannel with slightly reduced performance with pedAchannel and least performance with AWGN channel. IFDMA subcarrier mapping and DFDMA subcarrier mapping gave best performance with AWGN channel with slightly reduced performance with pedAchannel and least performance with vehAchannel.

It was also observed that for all types of channel and subcarrier mapping, SER performance of SCFDMA is better than OFDMA systems.

For OFDMA system, the PAPR performance of LFDMA and DFDMA is almost similar and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA.

In case of SCFDMA system, the PAPR performance of LFDMA and DFDMA is almost similar in case of SCFDMA and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA.

It was concluded that the PAPR performance of SCFDMA was significantly better in all three subcarrier mapping techniques i.e LFDMA, IFDMA and DFDMA, when compared to their counterparts in OFDMA.