Performance Comparison between SCFDMA and OFDMA in 4G-LTE under Two Subcarrier Mapping within Variable Channel Cases

Baha Ali Nasir

Abstract— ***The mobile communication is occupied by extra and extra facilities with information speed from little Kilobits per second reach to numerous Megabits per second. Amain choice in the communication system is the select of the multiple access structures. A selection may be the "Orthogonal Frequency Division Multiple Access" (OFDMA). Even with moreprofitsingreatflowin formation facilities, SCFDMA has bring excessive care as an smart substitution to OFDMA and nowrecommendedinportable uplink communications in fourth generation (4G) "Long Term Evolution" (LTE).in this paper the comparison between these two techniques is done in order to prove the powerful points of using the SCFDMA in LTE under two subcarrier mapping that are localized and interleaved style in dual channel kinds that are ITU and LTE channels. The results demonstrate that the SCFDMA provides the lesser "bit error rate" as compare to OFDMA in all cases of channels. Also the interleaved mode gives lower BER than localized mode.***

Index Terms—OFDMA, SCFDMA, 4G, LTE, BER, ITU.

I. INTRODUCTION

LTE definesregularizationeffort by the 3GPP to describe a new extraordinary-speed access pattern for transportable communications methods. LTE is the ending stage on a visibly plotted to system named '4G'. LTE compromises simplicity, performance and capacity. It introduced stretchy bandwidth and peak rates of at minimum 100 Mbps and 50 Mbps in downlink and uplink respectively [1],[2]. The system that is used in LTE for downlink and uplink can be displayed in fig. 1.

Fourth generation of wireless mobile structures will permit the delivery of advanced multimedia facilities with ubiquitous access thanks to the higher data rates existing. However, it is essential for the transmission tools to be able to handle with harms grow from great-information-speed spreads over wireless channels that are restricted in channel width and energy. Up till now, OFDM has been the more commonly used technique because its power against frequency selective fading problem. These features are congenital by OFDMA, the multiple access technique based on OFDM. SC-FDMA has advanced different to these techniques since, due to its small PAPR it was designated as the uplink access structure in LTE [3].

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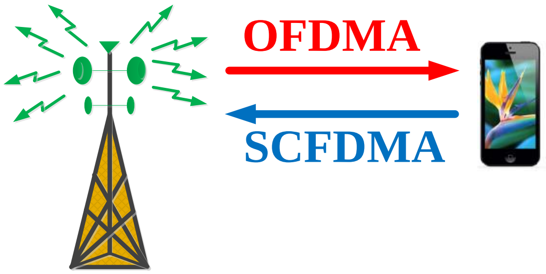

Figure 1: the techniques that use in 4G-LTE system for up and down link

The aims of LTE can be summarizing as: Flexible/scalable broadcast bandwidth., Improved cell limit bit rate keepingpositionplaceslike WCDMA, Improved spectrum efficiency, decreased Radio-access network latency, practical scheme and terminal difficulty, charge and energy consumption, Peak data rate, increase the mobility Coverage throughput spectrum efficiency and mobility aims [4],[5].

II. SUBCARRIER MAPPING

There exist three methodologies to choice the subcarriers for transmission that are distributed localized and interleaved subcarrier mapping. We will denote to the localized subcarrier diagramingway as LFDMA and distributed subcarrier diagramingtype as DFDMA whereas interleaved subcarrier diagramingway as IFDMA. The example of M = Q×N (where M denote the entire subcarrier after mapping and Q was spreading factor but N represent the original subcarrier beforehand mapping process) for the distributed manner with equal space among working subcarriers is called IFDMA [4]. IFDMA is a superior example of DFDMA and it is very effectual. Amodel of spread codes in the frequency field for N = four, Q = three with M = twelve is explained in fig.2.

III. OFDMA

In wireless cellular communications, the incomes may be time, frequency, power and space. So, the select of multiple access method can be TDMA, FDMA, CDMA and SDMA or some mixture from those methods. The styles of multiple accesses are shown in fig. 3. If the FDMA is approved in OFDM system, it is denote by Orthogonal Frequency Division Multiple Access (OFDMA) method [6]. The core dissimilar between the canonical OFDM and OFDMA is that multiple users are permitted to portion the same OFDM symbols, but via different groups of subcarriers.

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This permits for a raise in the level of bit granularity and straightforward dynamic sub channel assignment for multiuser variety. Merging with the advantages inherited from OFDM create OFDMA an encouraging candidate for multiple access technique of the upcoming broadband wireless schemes [7].

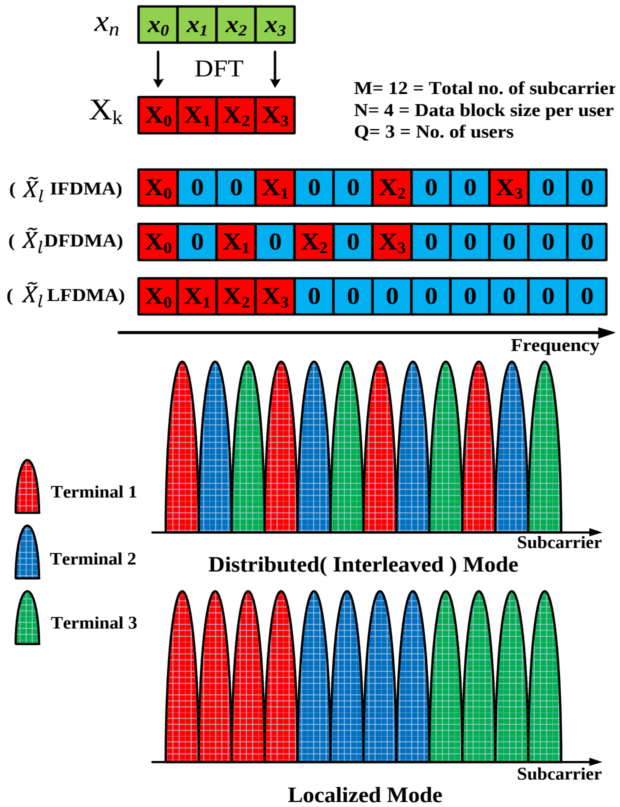

Figure 2: subcarrier spreading techniques for various customers.

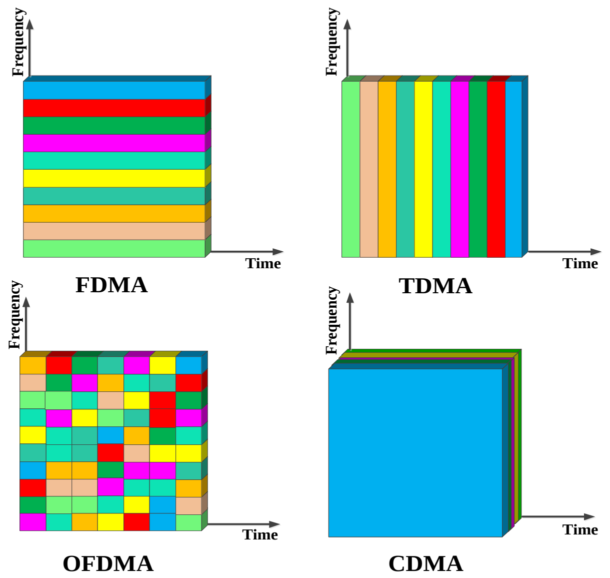

Figure 3: the different types of multiple accesses

In the downlink, OFDMA has been designated as the transmission method for LTE. In OFDMA, as displayed in fig. 4, the frequency source is distributed into parallel frequency subcarriers. Each subcarrier is adept of transport one modulation symbol. Different subcarriers are collected together to form a sub-channel that assists as the simple unit of data transmission. The centralaims why OFDMA was designated as the basic transmission structure for LTE are its great spectral efficiency, low-complexity execution, and the skill to simply support advanced features such as frequency selective arranging and interference coordination [8][9].

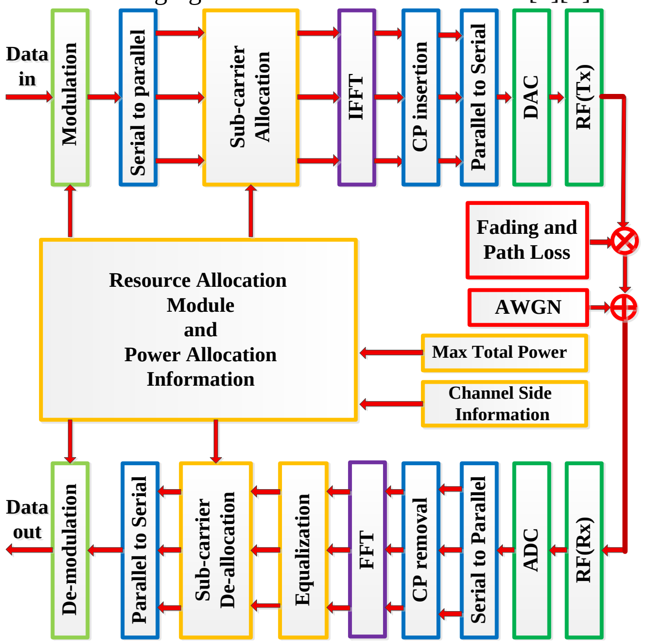

Figure 4: the block diagram of LTE-OFDMA (downlink model)

A CP is required for OFDMA transmission with the purpose of avoid interference from earlier transmitted OFDM symbols. Note that the cyclic prefix does not transport valuable data and is removed at the receiver previous to processing. As a result, it is wanted to have as minor a CP as promising so that reduces the overhead [10]. In general, the distance is selected on the basis of the predictablelowerdistribute of the broadcast channel plus certain margin to permit for imperfect timing arrangement. In LTE, two cyclic-prefix standards are supported: typical (~4.7 microsecond) and stretched (~16.6 microsecond) for split frequency space 15 kHz [7] [11]. A slot contains of 6 or 7 OFDMA symbols for the case of normal and extended cyclic prefix correspondingly as displayed in fig.5. The normal cyclic prefix length is 5.2 µs (160 × Ts) in the main OFDMA symbol and 4.7 µs (144 × Ts) in the lasting six symbols. Designed for the case of uncast traffic, the subcarrier spacing is (Δf = 15 KHz), which effects in OFDMA symbol duration of (1/Δf = 66.6 µs). The cyclic prefix distances of (160 × Ts) and (144 × Ts) were designated so that the effect is an integer quantity of samples for IFFT magnitudes of 128, 256, 512, 1024 and 2048. In the case of extended cyclic prefix, the CP size of 16.6µs (512 × Ts) is the similar in all the six symbols [11],[12]. The above parameterizations are considered to be well-matched through a frequency of 30.72 megahertz (2048 × 15 KHz). Accordingly, a simple element of time, thatentirelyfurther time limit are a several, is defined as Ts = 1/30.72 µs. In the case of a 20 MHz scheme period, an FFT demand of 2048 can be likely for well-organized execution [13].

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In LTE-OFDMA scheme, it is theoretical the data input block is$[d] = [d_0 d_1 d_2 \dots d_K]$. Where K is the quantity of entire sample, $K>>N$, N is the no. of carriers. Mainly, the stream of data $[d]$ arrives the first block which is the modulation block. The OFDMA use three kinds of modulation which are QPSK, 16QAM and 64QAM.

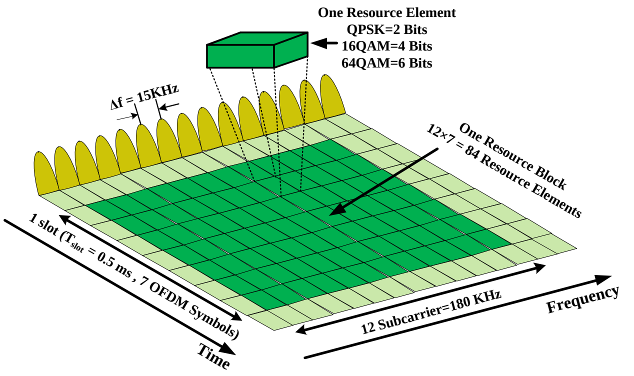

Figure 5: the resource block in time and frequency details

In overall, transmitter approves the modulation structure forsimilar the specific media circumstances and features to definite period occasion. For these elements the information is guess from the nature of the circumstances.

When use the QPSK, quad location on the collection figure, equivalent spaced nearby a circle. in four points, QPSK can encrypt twin bits each character to shrink the error in the message. The scientific analysis is:

$$sa(t) = \sqrt{\frac{2E_S}{T_S}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), \quad (1)$$

Where E_s= Energy-per-symbol and T_s= symbol duration. Therefore the signal productionafter the modulator is

$$[sa] = [sa_1 \ \ sa_2 \ \ sa_3 \dots sa_K] \quad (2)$$

Afterward the modulated signal is moved to a following block which is serial to parallel block .then the production$[sb]$ will be:

$$[sb] = [sa]^T = [sb_1 \ \ sb_2 \ \ sb_3 \dots sb_N] \quad (3)$$

Later, the signal input to the subcarrier mapping block. a three styles of subcarrier diagramingthat is localized, distributed with interleaved styles. The assortment of subcarrier mapping and the kinds of modulation is ruled by the different module which is [the resource allocation module (subcarrier and power allocation information)]. This unit is responsible on particular the mapping of subcarrier that will be specified to the carrier such as localized, distributed or interleaved unit also this unit is responsible on the location of carriers for each operator in time and frequency fields.

As shown in fig.6. Contained$M$ subcarriers, betweenthat (M>N) carriers are employedwith the coming data. Within time period, the cominginformationcodes have symbol time of T sec.with the symbol delay is compacted to $\tilde{T} = (N/M) \times symbol\ time$ sec.thenworkingcomplete OFDMA subcarrier diagraming.

- in IFDMA, the modelnextthe carrier diagraming$\{\widetilde{sb}_l\}$willdefinedby means of:
-

$$\widetilde{sb}_l = \begin{cases} sb_{l/Q} & , \ l = Q.k \ (0 \le k \le N-1) \\ 0 & , \quad otherwise \end{cases} \quad (4)$$

Where $0 \le l \le M-1$ and $M = Q.N$

- in LFDMA, the model safterwardcarrier diagraming $\{\widetilde{sb}_l\}$will termed by means of:

$$\widetilde{sb}_l = \begin{cases} sb_l \, , & 0 \le l \le N-1 \\ 0 \, , & N \le l \le M-1 \end{cases} \quad (5)$$

- in DFDMA, the codeslater carrier diagraming$\widetilde{sb}_l$willlabeledby means of:
-

$$\widetilde{sb}_l = \begin{cases} sb_{l/\tilde{Q}}, & l = \tilde{Q}.k \ \ (0 \le k \le N-1) \\ 0 & , otherwise \end{cases} \quad (6)$$

$1 \le \tilde{Q} \le Q$: Where$Q$was the width of spreading quantity . Soa signal with samples after carrier diagramingmethod is $\widetilde{sb} = [\widetilde{sb}_0 \widetilde{sb}_1 \widetilde{sb}_2 \dots \widetilde{sb}_{M-1}]$ (7)

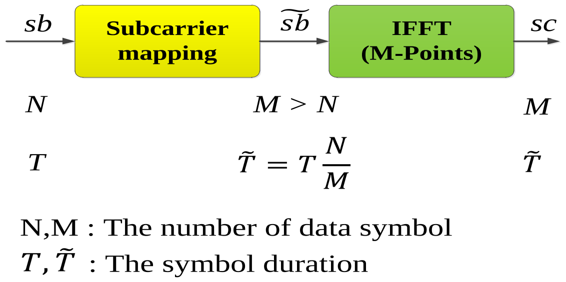

Figure 6: The subcarrier process in proposed LTE-OFDMA.

Later, the sample data production from subcarrier mapping wills inputs to the block of IFFT

$$[sc] = \frac{1}{M}\sum_{l=0}^{M-1} \widetilde{sb}\, e^{\frac{2\pi jkm}{M}} \quad m = 0,1 \dots M-1 \quad (8)$$

Later,a bits waschangedwhenadded the (CP) and the final signal (scp) is:

$$[scp] = [sc] + CP \quad (9)$$

Subsequently, the samples input to parallel to serial convertor in which the signal will be a stream of bits to transferto the next block

$$[sd] = [scp]^T = [sd_0 sd_1 sd_2 \dots sd_{M-1}] \quad (10)$$

Now, the signal enters the digital to analog convertor and at that point to radio frequency transmitter.

Now the signal later DAC and RF blocks which is denoted by $[se]$ travels through the channel.

The signal hurts from additional kinds of destroying those are additive white Gaussian noise and fading. Consequently, a signal reach to the receipt is

$$[sf] = h.[sd] + n \quad (11)$$

We can notice that h is the impulse response. Whilen$n$ is the noise.

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Totally the technique in the sending endis thenreversedon the other side. Sothat catches the unique signal inlowest BER and falsehood. The beginning stage in the downlink side is radio frequencystepafter that A/D block. Next, the signal arrives to S/P block. Then to channel equalization. The getting signal was equalized within the frequency field via the fast Fourier transform block.

Received codes$[sf]$comes in to the serial to parallel block so the signal become

$$[sg] = [sf]^T = [sg_0 sg_1 sg_2 \dots sg_{M-1}] \qquad (12)$$

Later, the structure will eliminate the part of cyclic prefix from the signal and the end signal $[sh]$become:

$$[sh] = [sg] - \text{CP} \qquad (13)$$

Next the signal $[sh]$reaches to the block of FFT and the signal convert to:

$$[Si] = \sum_{m=0}^{M_{FFT}-1} [sh]\, e^{-\frac{i2\pi m}{M_{FFT}}} \qquad (14)$$

The equalizer coefficients are calculatedalong with the kinds of the FDE in dualtechniquesthose are ZF and MMSE. In this paper use the MMSE way and the equalizer coefficient become:

$$E(m) = H^*(m)/[|H(m)|^2 + (E_b/N_0)^{-1}] \qquad (15)$$

Equalization used forremove the influence of ISI. The MMSE manner is superiortozero forcing process and provideslesser BER relatedto ZF mode.

The signal when multiply the equalization parameter E(m) with the FFT signal $[Si]$become:

$$[Sj] = E(m).[Si] = [Sj_0 Sj_1 Sj_2 \dots Sj_{M-1}] \qquad (16)$$

At that point, this signal arrive to subcarrier de-mapping so that return the number of carrier to the earlier amount which is *N*. that mean the number of carrier will be decrease from *M* to *N*. the manner of de-mapping is completely reverse to the method of mapping in the transmitter

- in IFDMA, sample afterwards carrier de-mapping $\{\widetilde{sq}_l\}$willlabeled as:
-

$$\widetilde{sq}_l = sq_{l/Q} \;\; , \; l = Q.k \; (0 \le k \le N-1) \qquad (17)$$

- in LFDMA, samples oncecarrier diagraming$\{\widetilde{sq}_l\}$definedby means of:
-

$$\widetilde{sq}_l = sq_l \, , \; 0 \le l \le N-1 \qquad (18)$$

- in DFDMA, samples when carrier diagraming$\{\widetilde{sq}_l\}$termedby means of:
-

$$\widetilde{sq}_l = sq_{l/\tilde{Q}}, \; l = \tilde{Q}.k \;\; (0 \le k \le N-1) \qquad (19)$$

Therefore a signal for samples later subcarrier mapping process is

$$[\widetilde{Sq}] = demapping[Sq] \qquad (20)$$

The signal currently is in the parallel form. In order to yield signal to the serial form the signal input to the parallel to serial method and the output becomes:

$$[sr] = [\widetilde{Sq}]^T = [sr_0 sr_1 sr_2 \;\dots\; sr_{N-1}]^T \qquad (21)$$

Lastly, the signal $[sr]$ arrive to the final block which is the demodulation that do the opposite function of the modulation block in the transmitter at that time the data output is:

$$[\tilde{d}] = demodulation[sr] = [\tilde{d}_0 \tilde{d}_1 \tilde{d}_2 \dots \tilde{d}_K] \qquad (22)$$

IV. SCFDMA

SC-FDMA is the developed form of single processing coding with frequency equalization (SC/FDE) [14]. Therefore what is the reason for named this novel multiple access structure as "Single Carrier" and "FDMA"?. From Figure 7, SC-FDMA codes are spread one after the other over a one carrier as unlike to the parallel broadcast of OFDMA over several carriers. Moreover, "the consumers are orthogonally multiplexed and de-multiplexed in the frequency domain, which provides SCFDMA feature of FDMA" [15].

The sending end in an SC-FDMA scheme uses altered perpendicular subcarriers to spread information codes serially. The benefit of such a system is the facility to eliminate ISI (Inter Symbol Interference) between two symbols. Also the DFT process in SC-FDMA distributes the power of single sub-carrier throughtotally assigned sub-carriers previously the IFFT, which means that "spectral nulls in the channel are decreased with averaging". Because of these structures, the SCFDMA provides lesser BER as compare with OFDMA [16].

In the time domain, SCFDMA broadcasts are prepared into radio structures of length 10 ms, every in that was divided into 10 similarly sized sub-frames of length 1 ms, as explained in fig. 8. Every subframe contains of twin similarly length periods of length Tslot= 0.5 ms. in each slot enclosing of an amount of OFDM codes with CP. The time period drawn in fig. 8 can therefore it is state as "T_{frame} = 307200 × Ts, $T_{subframe}$ = 30720×Ts, and T_{slot} = 15360 × Ts for the frame, sub frame, and slot durations correspondingly" [17].

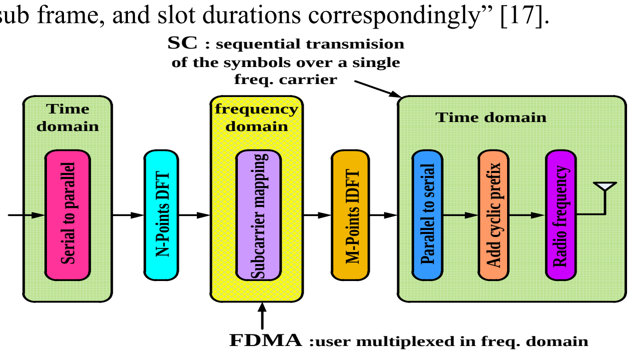

Figure 7: the reason of named SCFDMA

Fig. 9 specifies that SC-FDMA joins the signal treating structures of OFDMA and supplements a DFT at the entrance of the sending end. And a analogous IDFT at the exit of the sending end.

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Since the SC-FDMA spreader enlarges the signal frequency band to shield the frequency band of the channel. Therefore SC-FDMA is occasionally denoted to as "DFT-spread OFDMA" [18].
Real-worldschemesanimatedlyadjust the modulation system to the weather circumstances. This means taking in work the BPSK in bad channels and using either 16QAM or 64-QAM in healthy channels [4].

In SCFDMA, as shown in fig. 10, it is invented the data input block is $[x] = [x_0 x_1 x_2 \ldots x_K]$. In the beginning, the data $[x]$ pass in to the first chunk that is the modulation block. The execution of QPSK is better than BPSK. Therefore the symbol will regard as:

$$xa(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right) \qquad (23)$$

So the signal production from the modulator is

$$[xa] = [xa_1 \;\; xa_2 \;\; xa_3 \ldots xa_K] \qquad (24)$$

Where K is the amount of total sample, $K>>N$, N is the no. of carrier.
The sending endclusters the symbol $\{xa\}$ into chunks each having$N$ codes. This process is called the serial to parallel block and the results signal $[xb]$ will be in parallel form and become as

$$[xb] = [xa_1 \;\; xa_2 \;\; xa_3 \ldots xa_K]^T = [xa]^T \qquad (25)$$

Now implement the converting of signal to frequency domain by using the DFT of $[xc]$. DFT converts one function to another function which is called as the frequency domain representation. DFT calculation is denote to,

$$[xc] = \sum_{k=0}^{N-1} [xb]\, e^{\frac{-2\pi jkn}{N}} \qquad (26)$$

After that,collect every of the N DFT productions to unique of the M carriers that will spread. If"$N = M/Q$"and wholly stations spread N symbols per chunk, the scheme can dealing with$Q$ spreads devoid of interference.

The product of the carrier diagraming is the collection$l$ where "$\widetilde{Xc}_l$ (l = 0, 1, 2…, M-1)" of complex subcarrier amounts. Note that$N$ of the amounts are not be zero.

The input symbol move in to the subcarrier mapping chunk is xc_n: $n = 0, 1, 2. \ldots N-1$. While the symbol production from the subcarrier mapping is$\widetilde{xc}_m$: $m = 0, 1, 2, \ldots, M-1$.

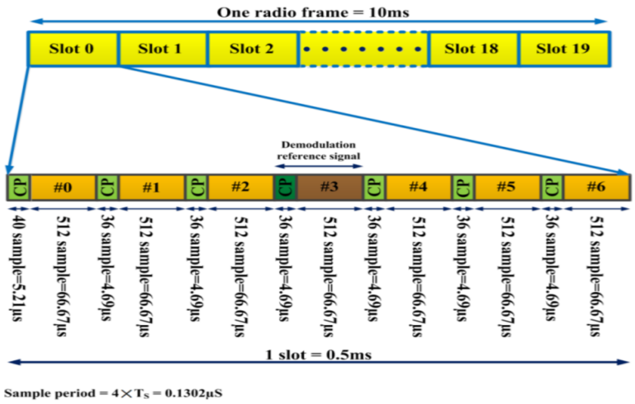

Figure 8: uplink slot structure of SCFDMA (normal cyclic prefix)

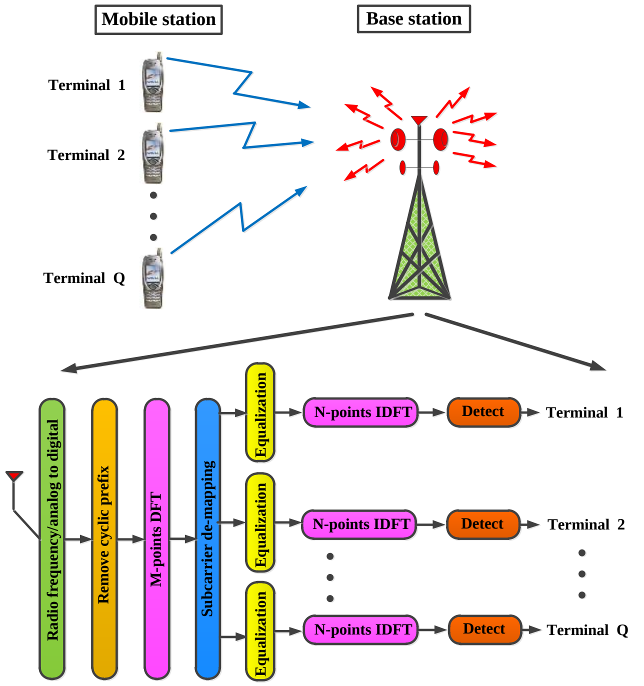

Figure 9: SCFDMA receiver with multiuser

- in IFDMA, the model after carrier diagraming$\{\widetilde{xc}_l\}$willlabeledin place of:
-

$$\widetilde{xc}_l = \begin{cases} xc_{l/Q} & , \; l = Q.k \; (0 \le k \le N-1) \\ 0 & , \quad otherwise \end{cases} \qquad (27)$$

- in LFDMA, the modelsafterwardcarrier diagraming$\{\widetilde{xc}_l\}$will designated in place of:

$$\widetilde{xc}_l = \begin{cases} xc_l\,, & 0 \le l \le N-1 \\ 0\,, & N \le l \le M-1 \end{cases} \qquad (28)$$

- in DFDMA, the models afterward carrier diagraming$\{\widetilde{xc}_l\}$istermed as:

$$\widetilde{xc}_l = \begin{cases} xc_{l/\tilde{Q}}, & l = \tilde{Q}.k \;\; (0 \le k \le N-1) \\ 0 & ,otherwise \end{cases} \qquad (29)$$

So the signal of samples after subcarrier mapping manner is

$$\widetilde{xc} = [\widetilde{xc}_0 \widetilde{xc}_1 \widetilde{xc}_2 \ldots \widetilde{xc}_{M-1}] \qquad (30)$$

After that, we implement the process of IDFT on the signal $\widetilde{xc}$ and the output signal will be denoted as $[xd]$:

$$[xd] = \frac{1}{M} \sum_{l=0}^{M-1} \widetilde{xc}\, e^{\frac{2\pi jkm}{M}} \quad m = 0,1 \ldots M-1 \qquad (31)$$

Then a set of extra codes will be add to the beginning of the symbol. The cause of this addition is to decrease the interference between the symbols and this is denoted as CP. Therefore the output $[xe]$ will be:

$$[xe] = [xd] + CP \qquad (32)$$

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Later, the signal reach to parallel to serial block and the production signal denoted by$[xf]$is:

$$[xf] = [xe_0 xe_1 xe_2 \dots xe_{M-1}]^T = [xe]^T \quad (33)$$

At that point the signal reach the digital to analog convertor and then to radio frequency transmitter.
Now,the signal suffers from degradation. As a result the signal reach to the receiving $[xg]$is:

$$[xg] = h.[xf] + n \quad (34)$$

The signal passesto the serial to parallel block become:

$$[xi] = [xg]^T = [xi_0 xi_1 xi_2 \dots xi_{M-1}] \quad (35)$$

Now the cyclic prefix will be removed and the signal comes to be:

$$[xj] = [xi] - CP \quad (36)$$

Later the signal $[xj]$ enters to the block of FFT and the signal turn into:

$$[xp] = \sum_{m=0}^{M_{FFT}-1} [xj]\, e^{-\frac{i2\pi m}{M_{FFT}}} \quad (37)$$

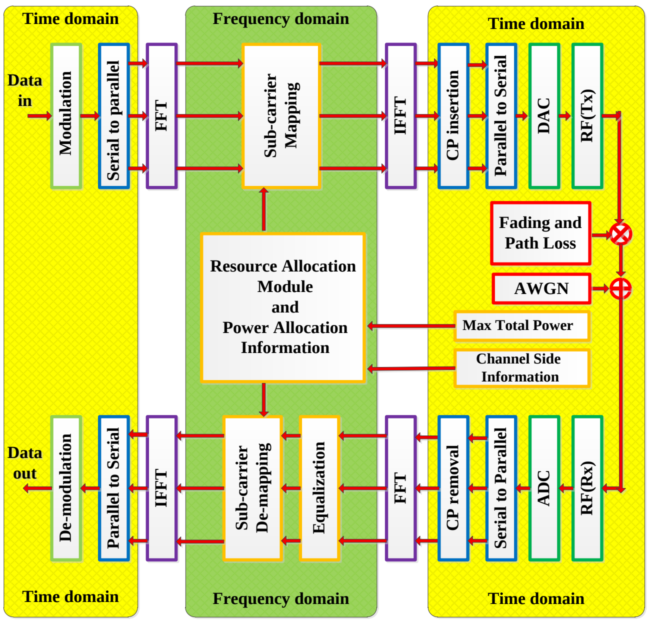

Figure 10: the block diagram of LTE-SCFDMA (uplink model)

Suppose E(m) where "(m=0, 1, 2…M_{FFT} -1)"indicate the equalizationfactorthat is collected to m[th]carrier. M_{FFT}denotes the number of Fast Fourier Transform. In MMSE technique the equalizer factor is:

$$E(m) = H^*(m)/[|H(m)|^2 + (E_b/N_0)^{-1}] \quad (38)$$

The signal when multiply the equalization parameter E(m) with the FFT signal $[xq]$become:

$$[xr] = E(m).[xp] = [xr_0 xr_1 xr_2 \dots xr_{M-1}] \quad (39)$$

Then this signal move in to subcarrier de-mapping in order to yield the amount of carrier to the earlier number which is *N*. and the signal $[\widetilde{xr}]$becomes:

- Designed to IFDMA, the model when carrier diagraming$\{\widetilde{xr}_l\}$definedin place of:
-

$$\widetilde{xr}_l = xr_{l/Q} \ , \ l = Q.k \ (0 \le k \le N-1) \quad (40)$$

- Designed in LFDMA, the modelsnext carrier diagraming$\{\widetilde{xr}_l\}$calledby way of:

$$\widetilde{xr}_l = xr_l \, , \ 0 \le l \le N-1 \quad (41)$$

- Designed in DFDMA, the modelsnext subcarrier mapping$\{\widetilde{xq}_l\}$designatedby way of:

$$\widetilde{xr}_l = xr_{l/\tilde{Q}}, \ l = \tilde{Q}.k \ \ (0 \le k \le N-1) \quad (42)$$

So the signal of samples after subcarrier mapping method is

$$[\widetilde{xr}] = demapping[xr] \quad (43)$$

The time domain equalized signal when applying IFFT which is $[xs]$ can be said as:

$$[xs] = \frac{1}{N_{FFT}} \sum_{n=0}^{N_{FFT}-1} [\widetilde{xr}]\, e^{\frac{i2\pi m}{M_{FFT}}} \quad (44)$$

After that, the signal will enter to the chunk of serial to parallel form. The output $[xz]$ will become:

$$[xz] = [xs]^T = [xz_0 xz_1 xz_2 \ \dots \ xz_{N-1}] \quad (45)$$

As a final point, the signal $[xz]$ goes into the final block which is the demodulation then the data production is

$$[\tilde{x}] = demodulation[xz] = [\widetilde{x_0}\widetilde{x_1}\widetilde{x_2} \dots \widetilde{x_K}] \quad (46)$$

V. Results and Discussion

In this paper the specifications of OFDMA and SCFDMA, which includes the connection between the BER with SNR, will be discuss in details under different channel cases to explain the benefit of using SCFDMA technique for uplink in LTE. All the simulation is done using the software(MATLAB 2014a).
These two technique will be examined under different channel cases (ITU and LTE channels) and after that the bit error rate (BER) will be calculates with respect to changedamounts of SNR. Also the modification in results will be shown when change the modulation types which are QPSK, 16QAM and 64QAM. After that the new technique that is used in LTE which is the subcarrier mapping will be discussed and the difference in activity appearswithin these dual types of carrier mapping "localized and interleaved mode".
The parameters that used in extracting the difference between two techniques in simulation can be shown in table 1

Table 1: The parameters used in simulation

Parameters	Values
Transmission BW (MHz)	20
No. of Resource Block	100

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FFT Size	2048
Sample per slot	15360
Sub-Carrier spacing	15 KHz
Band width	180 KHz
Multiple access	OFDMA, SCFDMA
Data modulation	QPSK, 16QAM, 64QAM
Channel used	ITU, LTE
Equalizer type	MMSE
Subcarrier mapping	Localized, interleaved

In the beginning when make the comparison between the two techniques with changing the channel cases it is important to note that all the tests were done under the QPSK modulation. First comparison is done in the ITU indoor office. From fig. 11 (with using the OFDMA)it can be seen that the SNR is varies from14.6 to 18.2 dB when using the ITU indoor A under using interleaved and localized mode while the SNR varies from 13.5 dB to 19.1dB when using ITU indoor B for interleaved and localized mode respectively. Now go to fig.12 (with using the SCFDMA) and make the same reading as in fig.11 we can see thatthe SNR is varies from 9.9 to 12.1 dB when using the ITU indoor A after using interleaved and localized mode while the SNR varies from 8 dB to 13.4 dB when using ITU indoor B for interleaved and localized mode respectively.

Therefore, from figure 11 and 12 it can see that when make comparison between the use of OFDMA and SCFDMA the benefit in gain can be summarized as:

- 4.7dB when using interleaved ITU indoor A
- 6.1dB when using localized ITU indoor A
- 5.5 dB when using interleaved ITU indoor B
- 5.7dBwhen using localized ITU indoor B

Repeat the same thing with figure 13 and 14 and compare between them. From fig. 13 (with using the OFDMA)it can be seen that the SNR is varies from 15.4dB to 17.5 dB when using the ITUPedestrian A after using interleaved and localized mode while the SNR varies from 12.3 dB to 20dB when using ITUPedestrian B for interleaved and localized mode respectively. Now going to fig.14 (with using the SCFDMA) and make the same reading as in fig.13 and we can see that the SNR is varies from10.8dB to 11.8 dB when using the ITUPedestrian A after using interleaved and localized mode while the SNR varies from 10 dB to 12.3dB when using ITUPedestrian B for interleaved and localized mode respectively.

So, from figure 13 and 14 it can see that when make comparison between the use of OFDMA and SCFDMA the benefit in gain can be summarized as:

- 4.6 dB when using interleaved ITU Pedestrian A,
- 6.3dB when using localized ITU Pedestrian A,
- 2.3 dB when using interleaved ITU Pedestrian B
- 7.7dBwhen using localized ITU Pedestrian B

The final comparison in ITU channel case when using the vehicular channel case. Therefore, repeat the same thing with figure 15 and 16 and compare between them. From fig. 15 (with using the OFDMA)it can be seen that the SNR is varies from14.1 dB to 20.8 dB when using the ITU VehicularA after using interleaved and localized mode while the SNR varies from 13.3 dB to 22.1dB when using ITU VehicularB for interleaved and localized mode respectively. Now going to fig.16 (with using the SCFDMA) and make the same reading as in fig.15 and we can see that the SNR is varies from7.8dB to 16.8 dB when using the ITU VehicularA after using interleaved and localized mode while the SNR varies from 8.2 dB to 14.1dB when using ITU VehicularB for interleaved and localized mode respectively.

So, from figure 15 and 16 it can see that when make comparison between the use of OFDMA and SCFDMA the benefit in gain can be summarized as:

- 6.3 dB when using interleaved ITU VehicularA
- 4dB when using localized ITU VehicularA
- 5.1 dB when using interleaved ITU VehicularB
- 8dBwhen using localized ITU VehicularB

Now, complete the comparison between the two techniques (OFDMA and SCFDM)under the ITU channel (indoor pedestrian and vehicular cases) and began anew comparison but under the new channels which are the LTE channels (EPA EVA ETU channels). We began the comparison with figure 17 and 18 and compare between them. From fig. 17 (with using the OFDMA)it can be seen that the SNR is varies from 14 dB to 18.8 dB when using the LTE EPA after using interleaved and localized mode while the SNR varies from 13.3 dB to 20dB when using LTE EVA for interleaved and localized mode respectivelyand the SNR varies from 16.1 dB to 17.2dB when using LTE ETU. Now going to fig.18 (with using the SCFDMA) and make the same reading as in fig.17 and we can see that the SNR is varies from7.7dB to 13.5 dB when using the LTE EPA after using interleaved and localized mode while the SNR varies from 9.7 dB to 12.2dB when using LTE EVA for interleaved and localized mode respectively and the SNR varies from 11.1 dB to 11.9dB when using LTE ETU.

So, from figure 17 and 18 it can see that when make comparison between the use of OFDMA and SCFDMA the benefit in gain can be summarized as:

- 6.3 dB when using interleaved LTE EPA
- 5.3dB when using localized LTE EPA
- 3.5 dB when using interleaved LTE EVA
- 7.8dBwhen using localized LTE EVA
- 5 dB when using interleaved LTE ETU
- 5.3dBwhen using localized LTE ETU.

Finally, we complete all the comparison between two techniques (OFDMA and SCFDMA) when change the wireless channels (ITU and LTE channels). Now, all the previous comparison was done under the modulation type of QPSK but now we will changethe modulation types and use three types of modulation which are QPSK, 16QAM and 64QAM.We began the comparison with figure 19 and 20 and compare between them. From fig. 19 (with using the OFDMA) it can be seen that the SNR is varies from12.8 dB to 20 dB when using the QPSK after using interleaved and localized mode while the SNR varies from 16.7 dB to 24.1dB when using 16QAM for interleaved and localized mode respectivelyand the SNR varies from 18.1 dB to 26.2dB when using 64QAM. Now going to fig.20 (with using the SCFDMA) and make the same reading as in fig.19 and we can see that the SNR is varies from9.7dB to 12.1 dB when using the QPSK after using interleaved and localized mode while the.

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SNR varies from 11.8 dB to 15.3dB when using 16QAM for interleaved and localized mode respectively and the SNR varies from 13.2 dB to 16.9dB when using 64QAM.

So, from figure 19 and 20 it can see that when make comparison between the use of OFDMA and SCFDMA the benefit of gain can be summarized as:

- 3.1 dB when using interleaved QPSK
- 7.9dB when using localized QPSK
- 4.9 dB when using interleaved 16QAM
- 8.8dBwhen using localized 16QAM
- 4.9 dB when using interleaved 64QAM
- 9.3dBwhen using localized 64QAM.

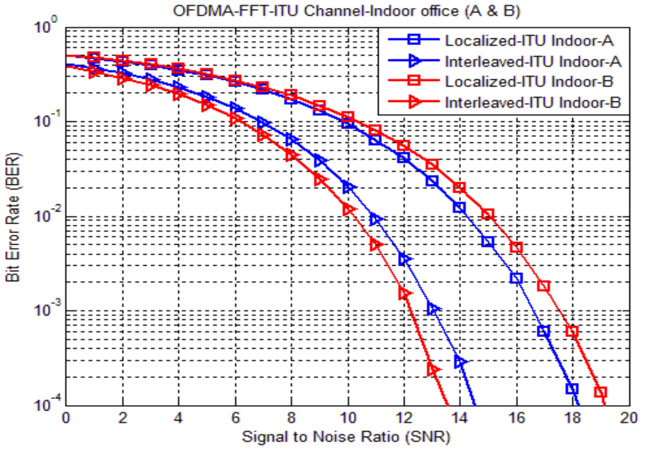

Figure 11: Performance of OFDMA under ITU Indoor (A, B)

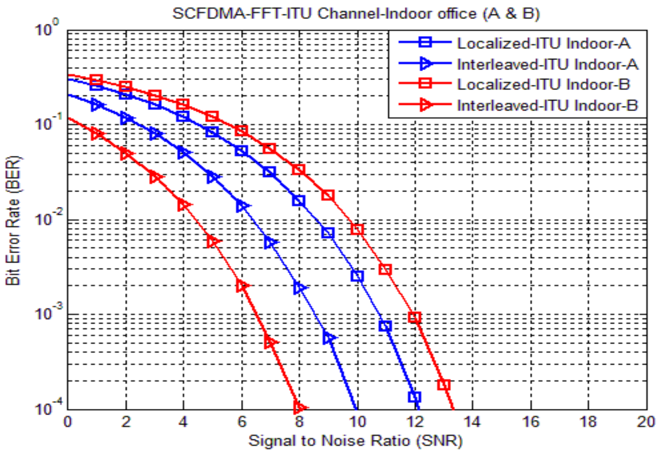

Figure 12: Performance of SCFDMA under ITU Indoor (A,B)

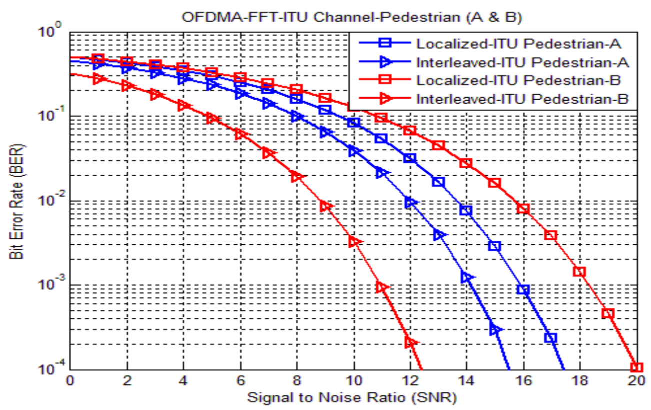

Figure 13: Performance of OFDMA under ITU Pedestrian (A, B)

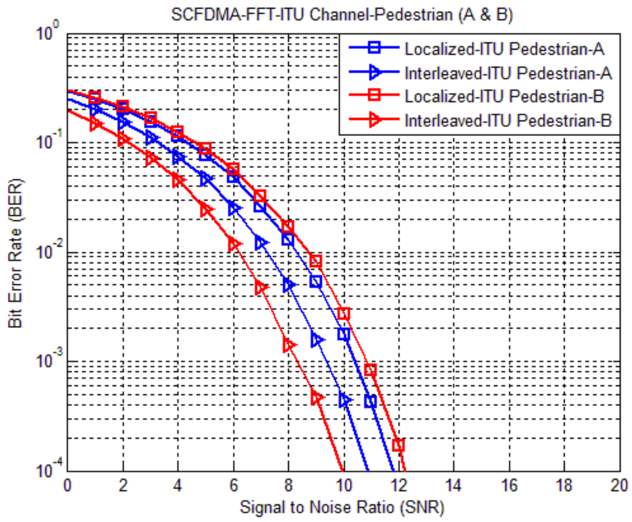

Figure 14: Performance of SCFDMA under ITU pedestrian (A,B)

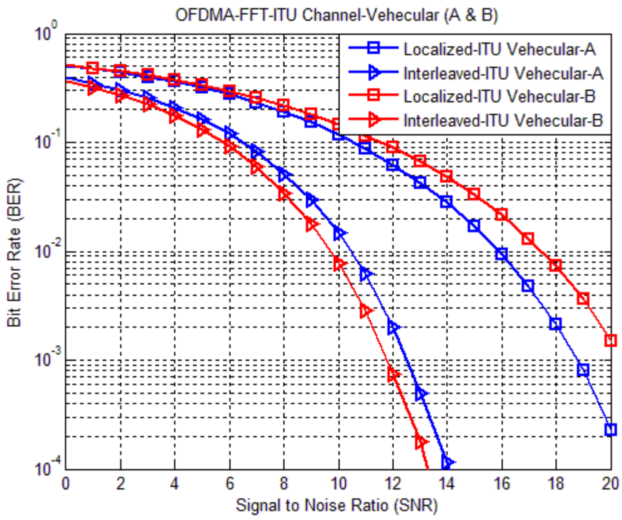

Figure 15: Performance of OFDMA under ITU Vehicular (A, B)

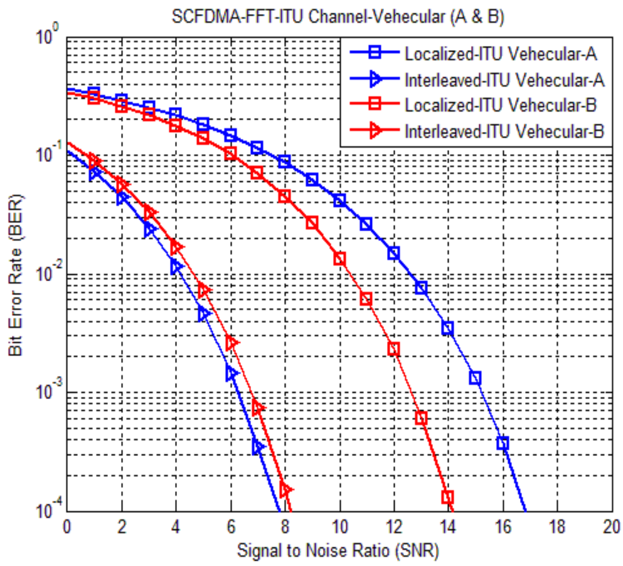

Figure 16: Performance of SCFDMA under ITU vehicular (A, B)

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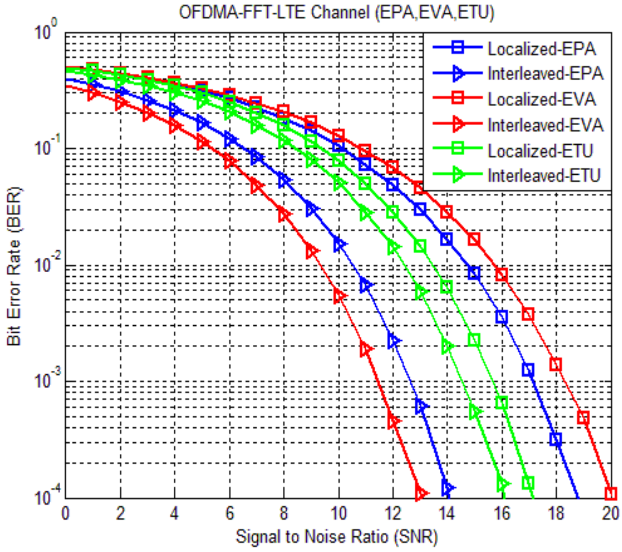

Figure 17: Performance of OFDMA under LTE (EPA, EVA and ETU)

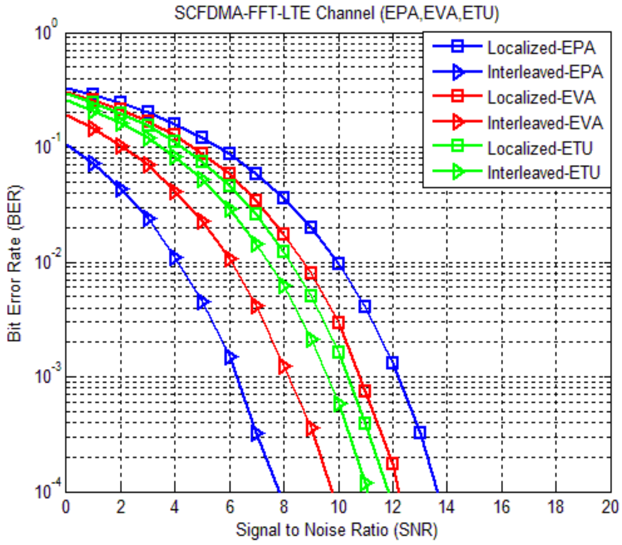

Figure 18: Performance of SCFDMA under LTE (EPA, EVA and ETU)

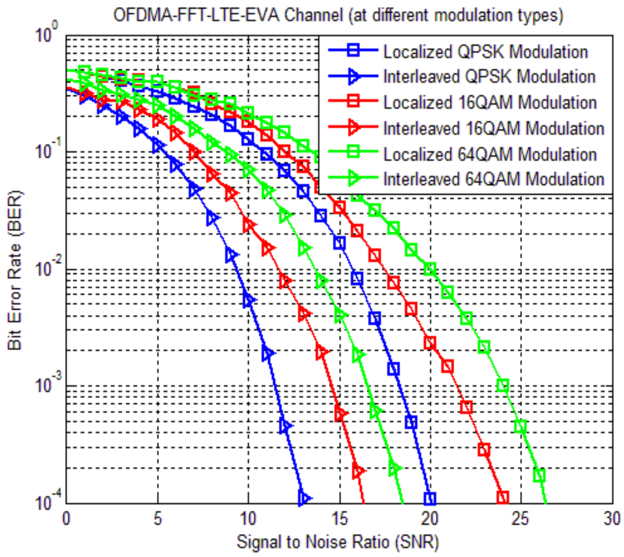

Figure 19: Performance of OFDMA under LTE-EVA (at different modulation types)

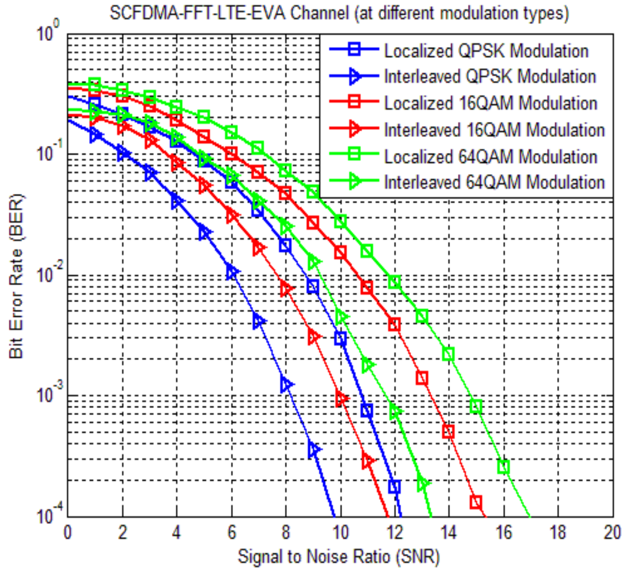

Figure 20: Performance of SCFDMA under LTE-EVA (at different modulation types

VI. CONCLUSION

In the first the comparison between OFDMA and SCFDMA was done with different cases of channels. In each case the results was calculates under dualstyles of carrier mapping. It is appeared that SCFDMA gives the lower bit error rate in all cases of channels (ITU indoor, ITU pedestrian, ITU vehicular, LTE-EPA, LTE-EVA, and LTE-ETU). In each case of channel we implement the test under the dualstyles of carrier mapping that are "localized and interleaved modes".We can notice that the interleaved mode provide the lesserBERwhen compare with the otherstyle in case of OFDMA and SCFDMA. The final comparison is done when changing the modulation types when using the two subcarrier mapping and channel (LTE-EVA as example) it can notice that the QPSK gives the lowest bit error rate with respect to other types of modulations such as 16QPSK and 64QPSK. The comparison (differences and similarities) between OFDMA and SCFDMA can be summarized in table 2.

Table 2: The Comparison Between OFDMA and SCFDMA

	OFDMA	SCFDMA
Differences	Multicarrier broadcast	Single carrier broadcast
	Parallel transmission	serial transmission
	moreBER	lessBER
	sensitive in frequency offset	Less sensitive in frequency offset
	critical to spectral null	Robust to spectral null
	High power consumption	Low power consumption
Similarities	Using DFT and IDFT for implementation	
	Using the cyclic prefix CP as guard band	
	Using the frequency domain equalization FDE	

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REFERENCES

1. D. Kumar, S. arulmozhi and r. Muthaiah (2011), “FPGA implementation of scalable bandwidth Single carrier frequency domain multiple Access transceiver for the fourth generation Wireless communication”, Journal of Theoretical and Applied Information Technology JATIT, Vol. 28 No.2, 30th June 2011, ISSN: 1992-8645, E-ISSN: 1817-3195, Page(s): 88-95
2. Christian Rom (2008), “Physical Layer Parameter and Algorithm Study in a Downlink OFDM-LTE Context”, Ph.D. thesis, Department of Electronic Systems, Faculty of Engineering, Science and Medicine, Aalborg University, Denmark
3. Dan J. Dechene and Abdallah Shami (2014), “Energy-Aware Resource Allocation Strategies for LTE Uplink with Synchronous HARQ Constraints”, IEEE Transactions on Mobile Computing,Volume: 13 , Issue: 2, DOI: 10.1109/TMC.2012.256, Page(s): 422 – 433
4. Hyung G. Myung (2007), “Single Carrier Orthogonal Multiple Access Technique for Broadband Wireless Communications”, Ph.D. thesis, Electrical Engineering Department, Polytechnic University
5. Hyung G. Myung and David J. Goodman (2008), “Single Carrier FDMA: A New Air Interface for Long Term Evolution”, first edition, John Wiley & Sons, Ltd. Publication, website at www.wiley.com , ISBN 978-0-470-72449-1
6. Huan Cong Nguyen (2008), “Synchronization for the uplink of OFDMA-based systems”, Ph.D. thesis, Aalborg University, Aalborg, Denmark
7. Amitabha Ghosh and Rapeepat Ratasuk (2011), “Essentials of LTE and LTE-A”, Published in the United States of America by Cambridge University Press, New York, Information on this title: www.cambridge.org/9780521768702, ISBN 978-0-521-76870-2
8. Andrea Ancora, Calogero Bona and Dirk T.M. Slock (2007), “Down-Sampled Impulse Response Least-Squares Channel Estimation for LTE OFDMA”, IEEE International Conference on Acoustics Speech and Signal Processing ICASSP2007, Volume: 3, DOI: 10.1109/ICASSP.2007.366530, Page(s): 293-296
9. Seong-Ho Hur and Bhaskar D. Rao (2012), “Sum Rate Analysis of a Reduced Feedback OFDMA Downlink System Employing Joint Scheduling and Diversity”, IEEE Transactions on Signal Processing, Volume: 60, Issue: 2, DOI: 10.1109/TSP.2011.2173335, Page(s): 862 – 876
10. Mustafa E. Sahin, Ismail Guvenc, Moo-Ryong Jeong and Huseyin Arslan (2008), “Opportunity Detection for OFDMA Systems with Timing Misalignment”, IEEE Global Telecommunications Conference IEEE GLOBECOM2008, DOI: 10.1109 /GLOCOM. 2008. ECP.751, Page(s): 1 – 6
11. Stefania Sesia, Issam Toufik and Matthew Baker (2011), “LTE – The UMTS Long Term Evolution From Theory to Practice”, Second Edition, A John Wiley & Sons, Ltd., Publication, ISBN: 9780470660256
12. Farooq Khan (2009), “LTE for 4G Mobile Broadband: Air Interface Technologies and Performance”, First edition, Cambridge University Press, ISBN-13 978-0-521-88221-7, www.cambridge.org
13. Abdul Basit Syed (2009), “Dimensioning of LTE Network Description of Models and Tool, Coverage and Capacity Estimation of 3GPP Long Term Evolution radio interface”, M.Sc. thesis, Department of Electrical and Communications Engineering, Helsinki University of Technology
14. Chung Him Yuen and Behrouz Farhang-Boroujeny (2012), “Analysis of the Optimum Precoder in SC-FDMA”, IEEE Transactions on Wireless Communications, Volume: 11, Issue: 11, DOI: 10.1109/TWC.2012.090412.120105, Page(s): 4096 – 4107
15. Chao Zhang, Zhaocheng Wang, Zhixing Yang, Jun Wang and Jian Song (2010), “Frequency Domain Decision Feedback Equalization for Uplink SC-FDMA”, IEEE Transactions on Broadcasting, Volume: 56 , Issue: 2, DOI: 10.1109/TBC.2010.2046972, Page(s): 253 – 257
16. Jin Xinzhu (2007), “Channel Estimation Techniques of SC-FDMA”, M.Sc. thesis, Department of Physics and Electrical Engineering, Karlstad University
17. Erik Dahlman, Stefan Parkvall and Johan Sköld (2011), “4G LTE/LTE-Advanced for Mobile Broadband”, Academic Press is an imprint of Elsevier, website at www.elsevierdirect.com, Library of Congress Control Number: 2011921244, ISBN: 978-0-12-385489-6
18. Haipeng Lei and Xiaoqiang Li (2009), “system level study of LTE uplink employing SC-FDMA and virtual MU-MIMO”, IEEE International Conference on Communications Technology and Applications ICCTA'09, DOI: 10.1109/ICCOMTA.2009.5349218, Page(s): 152 – 156

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