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# Performance of Single Carrier Frequency Division Multiple Access Under Different Channel Cases

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***Abstract*: *Single Carrier Frequency Division Multiple Access (SCFDMA) is currently a favorable tool for uplink broadcast in 4G mobile communications method. It merges the "single carrier frequency domain equalization (SC-FDE)" and "frequency division multiple access (FDMA)" methods. It inserts DFT before OFDMA modulation to drawing the sign from every operator to a subsection of the existing subcarriers. It is a new system joining best of the benefits of OFDMA with the small "Peak-to-Average Power Ratio (PAPR)". For that aims, it accepted as a promising technique on the uplink of wireless systems. In this paper the performance of SCFDMA was measured under different variable parameter in order to verify the robustness of the system. The system is tested under parameters like modulation type, subcarrier mapping, Doppler frequency, time of sample, second path gain and roll-off factor.***

***Index Terms*: SCFDMA, 4G, PAPR, BER, SNR.**

## I. INTRODUCTION

The noteworthy development realized in mobile skill over the last periods is a straight outcome of the growing claim for great data rate broadcasts over bandwidth and energy restricted wireless channels. This needs the use of strong coding and influential signal processing methods so that overawed the time and frequency selective florae of the broadcast channel. Forthcoming wireless structures are predictable to deliver great data rate mobile combination facilities [1].

OFDMA is a hopeful numerous access structure for broadband wireless schemes due to its strength compared to "frequency selective fading channels" and the easiness of the receiver. Drawbacks of OFDMA contain great PAPR and great sensitivity to frequency offset. To overwhelm these drawbacks, the LTE examines an adapted formula of OFDMA, denoted to as SCFDMA for the uplink broadcasts in LTE [2].

SCFDMA is a solitary carrier block broadcast system with "cyclic prefix (CP)". Every chunk is termed an SCFDMA symbol. By the assistance of CP, SCFDMA changes fading channel into numerous flat fading sub-channels and allows effective "frequency domain equalization (FDE)" in the receiver. SCFDMA delivers low PAPR that greatly raise the energy effectiveness of "user equipment (UEs)" [3].

The frequency (sub-carriers) is orthogonal. This means the ultimate of single sub-carrier matches with the null of a neighboring sub-carrier. Each subcarrier could be demodulated individually without "inter-channel interference (ICI)". Numerous essential benefits of SCFDMA can be mention as [4]:

- SCFDMA may assign altered sub-carriers to altered users to accomplish several accesses transmission.
- SC-FDMA promises orthogonal between users in multi-path network.
- SC-FDMA contains low PAPR associated to OFDMA, thus given high talking period.
- The receiver could work iterative equalizations to satisfy good activity from linear equalization.

In the time division, SCFDMA broadcasts are structured into radio frames with length 10 ms. which separated to ten similarly sized sub-frames with interval of 1ms as shown in Figure 1. Every sub-frame involves of two similarly sized slots of length Tslot= 0.5 ms. each slot containing of a amount of OFDM symbols with cyclic prefix [5]. The time period sketched in Figure 1. This can accordingly similarly be said as Tframe = 307200 × Ts, Tsubframe = 30720×Ts, and Tslot = 15360 × Ts for the frame, subframe, and slot periods correspondingly [6].

Furthermore, this paper summary the elementary basics of SCFDMA schemes with altered kinds of sub-carrier mapping arrangements. Simulation output shows the activity of altered subcarrier mapping arrangements in different channel situation.

## II. SYSTEM MODEL

Figure 2 demonstrates the organization of SCFDMA. In The transmitter the SCFDMA system first enters to the coding system which decreases the error in the output and easy the process of discovering the original signal. Then enter to the block of modulation or signal mapping which transfer the signal to real and imaginary parts and have three types which are QPSK, 16QAM and 64QAM. After that the signal enters the block of serial to parallel block in order to change the shape of signal to parallel form and clusters the symbols to blocks every holding *N* symbols.

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Then it does an *N*-point discrete Fourier transform (DFT) to create a frequency domain symbol of the input symbols [7]. This process will do according to the equation:

$$X_k = \sum_{n=0}^{N-1} x_n \, e^{\frac{-2\pi ikn}{N}} \quad k = 0,1,\dots N-1 \qquad (1)$$

It then records every of the *N*-DFT productions to single of the *M* (> *N*) carriers that will be spread. Usually, *N* = *M*/*Q*. *Q* is "the bandwidth expansion factor" of the symbol arrangement. For sample, if wholly terminals spread *N* symbols per block, the organization will holder *Q* instantaneous broadcasts with no interfering. That procedure is named "the subcarrier mapping".

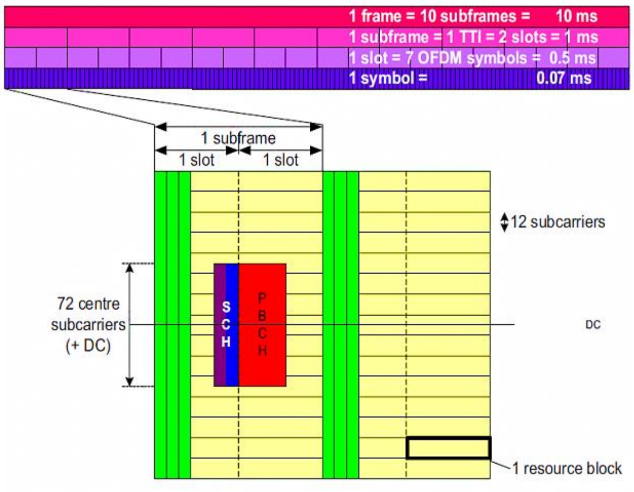


**Figure 1: the time and frequency division used in SCFDMA**

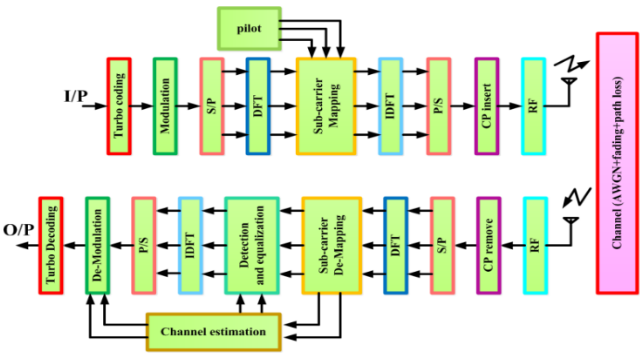


**Figure 2: the transmitter and receiver used in SCFDMA**

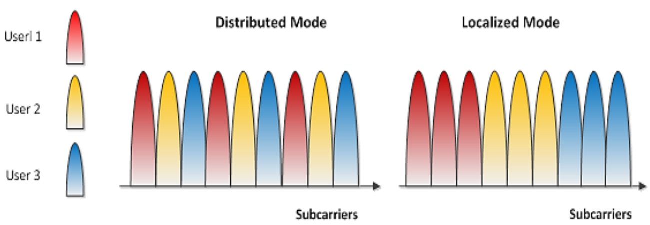


**Figure 3: the types of subcarrier mapping used in SCFDMA**

Figure 3 demonstrate dual approaches of allocating subcarriers to DFT productions: distributed carrier mapping (DFDMA) and localized carrier mapping (LFDMA). In the situation of LFDMA, the DFT productions are allocated to neighboring carriers. Through DFDMA, DFT productions are spread above the complete bandwidth with nil amplitude allocated to the idle carriers. Once *M/N* is a numeral, the busy carriers are similarly spread out and the DFDMA consignment is denoting as Interleaved FDMA (IFDMA) [8].

An *M*-point IDFT alters the carrier to a time area signal. The process of the IDFT is done under the complex equation which is:

$$x_n = \frac{1}{N}\sum_{k=0}^{N-1} X_k \, e^{\frac{2\pi ikn}{N}} \quad n = 0,1,\dots N-1 \qquad (2)$$

Then the signal arrives to the block of parallel to serial in which the signal becomes in serial form. The transmitter carries out dual other signal processing processes prior to transmission. It attachments a set of codes mentioned to as a "cyclic prefix (CP)" to deliver a protector time to avoid ICI as shown in figure 4. The transmitter furthermore carries out a linear filtering process denoted as pulse shaping so that decrease out-of-band sign power.

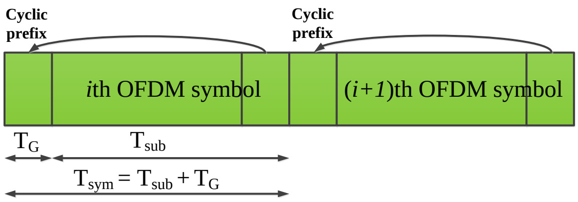


**Figure 4: SCFDMA symbol with cyclic prefix (CP)**

The PAPR (in dB) will be definite by :

$$PAPR = 10\log_{10}\left(\frac{\max_{0\le t\le KT}|x(t)|^2}{\frac{1}{KT}\int_0^{KT}|x(t)|^2 dt}\right) \qquad (3)$$

Note that x(t) denotes the spread sign in the time. K is the amount of symbols. T is the symbol period. KT denotes the sign period. Great PAPR needs great energy that decreases the energy effectiveness of the RF amp. The spreader similarly carry out a linear filtering process denoted as "pulse shaping" that decrease out-of band power. Some of the normally shaping filter is the "raised-cosine filter". The demonstrations of the filter are as follows in frequency and time domain [9].

$$P(f) = \begin{cases} T & 0 \le |f| \le \frac{1-\alpha}{2T} \\ T/2\left\{1+\cos\left[\frac{\pi T}{\alpha}\left(|f| - \frac{1-\alpha}{2T}\right)\right]\right\} & ,\frac{1-\alpha}{2T} \le |f| \le \frac{1+\alpha}{2T} \\ 0 & |f| \ge \frac{1+\alpha}{2T} \end{cases} \qquad (4)$$

$$P(t) = \frac{\sin(\pi t/T)}{\pi t/T} \times \frac{\cos(\alpha\pi t/T)}{1-4\alpha^2 t^2/T^2} \qquad (5)$$

The symbol (α) represents roll-off factor. The parameter α fluctuations from zero to one and it govern the quantity of out-of-band energy. α = 0 produces less out-of-band energy and as α rises, the out-of-band energy rises. So, the selection of α need to find the middle ground among the aims of low out-of band energy and low PAPR**.**

The signal now transfers in the channel and suffer from more than one type of degradation and distortion according to the type of the channel. Such degradation includes the additive white Gaussian noise, path loss and fading. The signal now enters to the radio frequency block in order to return the signal to original form and amplify it.


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Then remove the CP in order to return the signal to original form. After that do the process of serial to parallel form. Then the receiver converts the signal to the frequency field by DFT. de-maps the carriers, and now achieves the equalization. The equalized signal is changed to the time field by means of an IDFT. Then the parallel to serial process id done and also the demodulation in order to return the original form and finally the turbo decoder is applied to get the original signal [10].

## III. Results and Discussion

The system of SCFDMA was designed and implements using the MATLAB program. This system is done and work within more than one variables in order to test the performance of the system under all the variable parameters. The parameters that are used in the system are shown in table 1. The tests are divided into two types one for bit error rate (BER) and the other for peak to average power ratio (PAPR). For the first test the system was examine under multi parameter which are: (modulation types, Doppler shift, path delay and second path gain). The first parameter that will be changed is the modulation types this parameter will effects on the amount of bit error rate BER of the received signal. Three types of modulation will be used in simulations which are QPSK, 16QAM and 64QAM. The best results was got with QPSK and then with 16QAM and bad one with 64QAM. The Doppler shift is selected to be three values which are 10Hz, 100Hz and 200Hz. The best value is got with minimum value which is 10Hz. The next one is path delays which are 1Ts, 5Ts and 10Ts. the best one is got with 1Ts value. The last one is second path gain. Three values are selected which are -20dB, -10dB and -1dB. The best result is done with -20dB. The second type of test is done on PAPR. Three parameters is changed to measure the performance of the system which are: (roll off factor (alfa), modulation type and subcarrier mapping). The alfa is changed from zero to one and the best results are got with maximum alfa which are one. And when change the modulation type the best result is got with QPSK. In this paper three type of subcarrier mapping which are interleaved, distributed and localized. The best result is got with interleaved mode.

**Table 1: the parameters used in SCFDMA system**

| Parameters | Values |
|---|---|
| Carrier frequency | 2GHz. |
| Symbol rate | 15.36MHz. |
| Transmission bandwidth | 5MHz. |
| TTI length | 0.5ms. |
| Number of subcarriers | 128 |
| FFT block size | 512 |
| CP length | 32 samples. |
| Roll off factor | From zero to one |
| Subcarrier mapping | Interleaved, Localized and distributed. |
| Modulation types | QPSK, 16QAM, 64QAM |
| Doppler shift (Hz) | 10, 100, 200 |
| Path delay (Ts) | 1, 5, 10 |
| Second path gain (dB) | -1, -10, -20 |
| equalizer | MMSE |
| Channel estimation | Perfect |

## IV. Conclusions

From the experiments that are done it can be conclude that when change the parameters the performance of the system is changed. This parameter some time increased and sometime decreased in order to get the best results. When change the modulation type the QPSK is the best type of modulation and gives the higher performance and lower BER. The lower value of Doppler shift gives the higher performance (lower BER). The lower value of time delay provides best performance. The small value of second path gain gives igher performance. The higher value of roll-off factor gives best results and gives lower PAPR. Also the interleaved mode of subcarrier mapping gives the best result as compare with other type of subcarrier mapping which are distributed and localized mode.

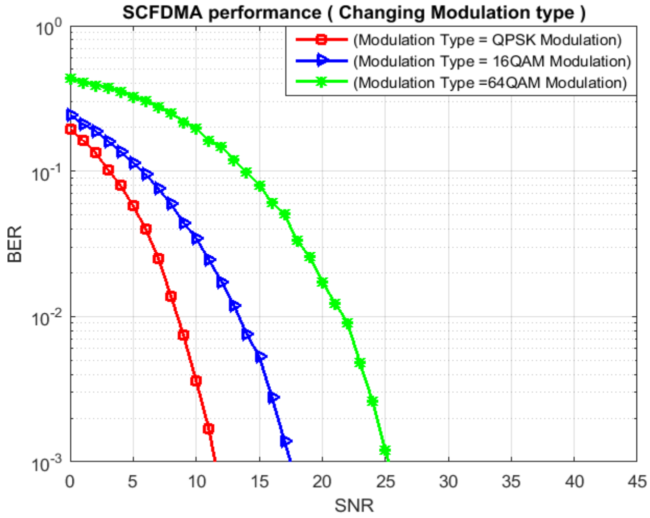


**Figure 5: The performance under different modulation types**

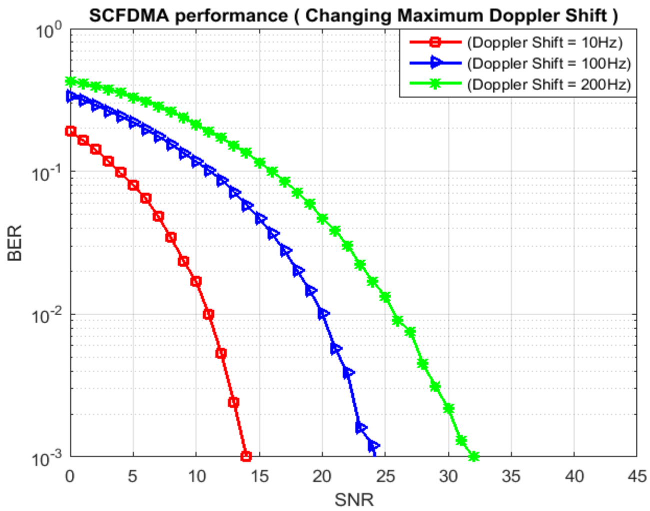


**Figure 6: The performance under different Doppler shift values**


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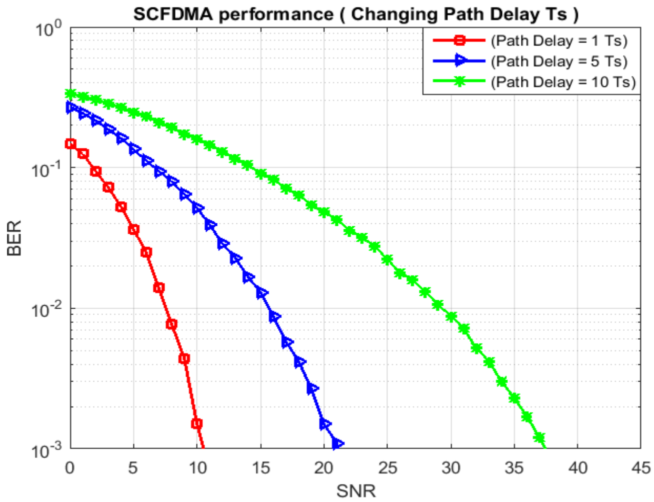


**Figure 7: The performance under different path delay values**

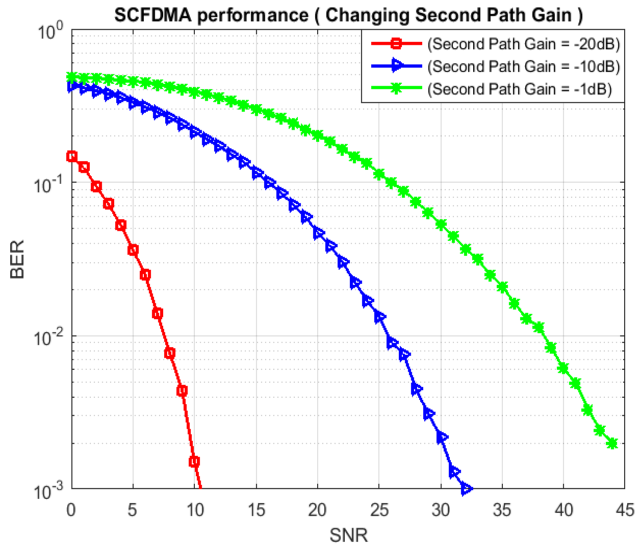


**Figure 8: The performance under different second path gain values**

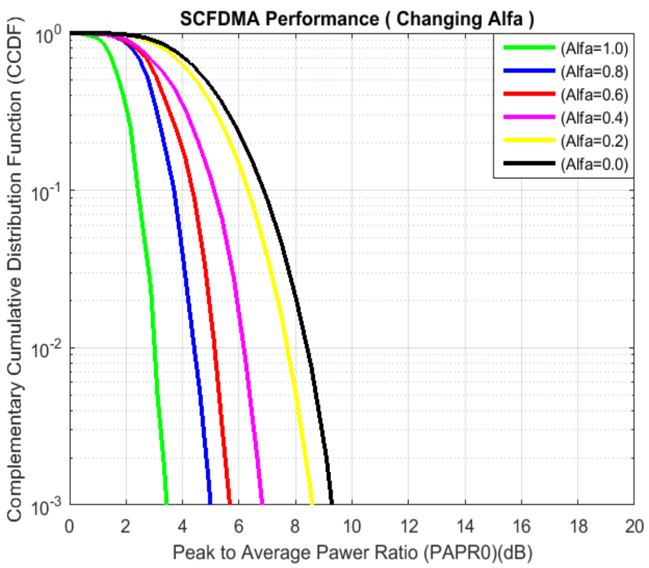


**Figure 9: The performance under different Alfa values**

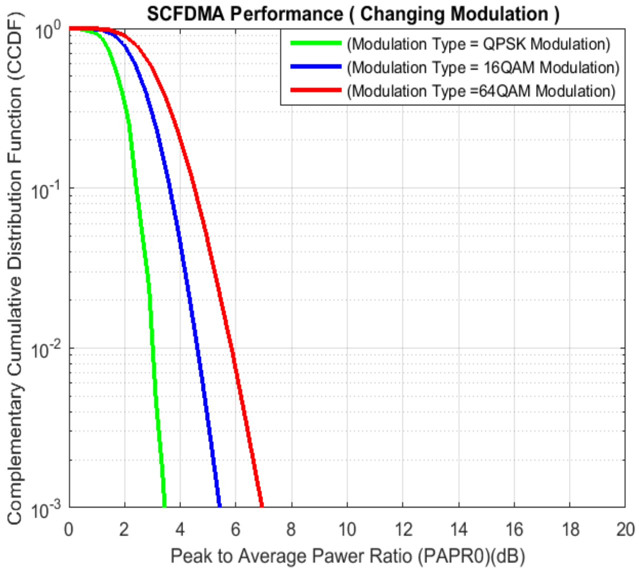


**Figure 10: The performance under different modulation values**

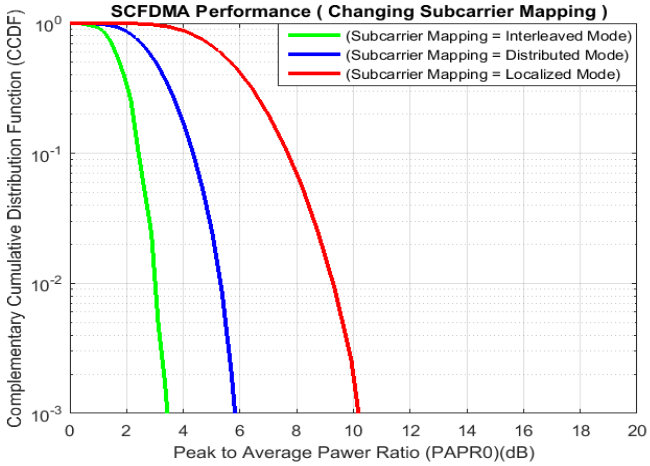


**Figure 11: The performance under different subcarrier mapping**

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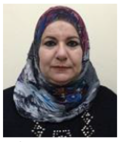

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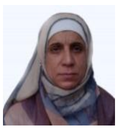

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