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Analysing the Bit-error Probability of a receiver in Multi-User MIMO SC-FDMA systems

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Abstract- SC-FDMA signals are currently espoused equally the Long Term Evolution (LTE) standard for the uplink due to its high data rate and low Peak to Average Power Ratio (PAPR). In SC-FDMA, two methods of choosing subcarriers for transmission are used; distributed using Interleaved (IFDMA) and localized (LFDMA).The Interleaved FDMA (IFDMA) is a distributed mode with equidistance between occupied subcarriers. In this paper, the PAPR for LFDMA and IFDMA techniques is simulated and compared. Simulation shows that the reduction of PAPR for IFDMA decreased more than 3 dB compared with LFDMA, which means that the IFDMA has better PAPR Performance than LFDMA. Moreover as shown as in the Figures there is a direct relationship between the Roll-off-factor (Alpha, α) and subcarriers, When the value of Alpha increases and the subcarriers increase, the result is a good performance of PAPR.

Keywords- SC-FDMA,PAPR, LTE,IFDMA,LFDMA

I.INTRODUCTION

To design a SC-FDMA, OFDMA is the inner part of SC-FDMA thus multiple user structures are not disparate as its performs at first. in toting of the SC-FDMA quite is deceptive as that technology similar OFDMA too uses sundry sub-carriers on the airborne interface.to elucidate how SC-FDMA mechanism is best to take *a* mien at OFDMA used by wi-max and to be find out the difference to SC-FDMA. SC-FDMA uses a cross format that its combine the lpar by the subcarrier network over multipath intrusion springiness and malleable sub-carrier frequency allocation.

SC-FDMA: In SC-FDMA transmits data through the communication channel in various sub-carriers then adds an extra dispensation step as shown in the below figure. In its place 4 bits are putting calm OFDM *is* one of the sample to practice the signal for additional subcarrier processing block. In SC-FDMA transfers the info to each bit to overall the sub-carriers.in this process will be done as a trails of some bits e.g. 4 signifying a 16 qam lilt are grouped calm. in the part of OFDM these group of bits obligate the input of the IDFT.

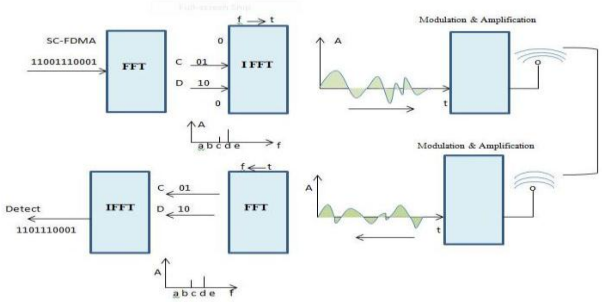

Fig.1

In some of the bits are piped into a fast Fourier function the output process for the creation of the sub-carriers are to follows IFFT. All sub-carriers are not used by the mobile station many of them are set to be zero in the following diagram. These may or may not be used in other mobile stations.

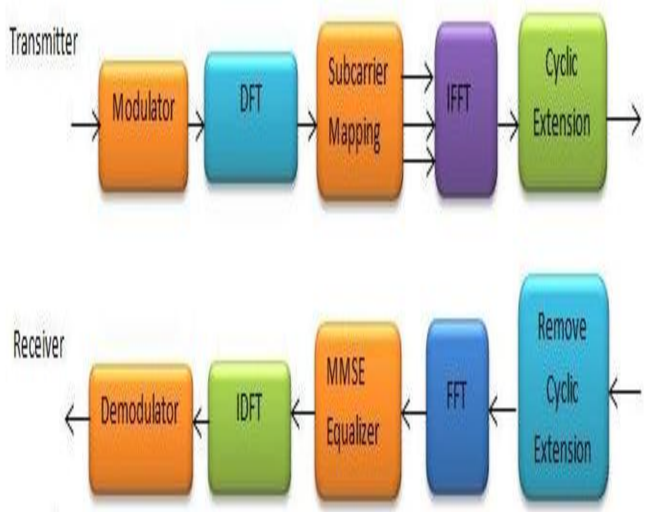

Figure2. The block diagram of an SC-FDMA system

OFDMA: OFDMA transfers a data creek through using some slender set of sub-carriers concurrently e.g. 512,1024 or even more reliant on the global open bandwidth e.g. 5 ,10, 20 mhz of the channel. Equally several bits are elated in comparable transmission speed on every sub carrier tin be ample lower than the whole ensuing data rate. This is significant in a practical radio atmosphere in edict to minimize weight of multipath fading formed by faintly

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different influx eras of the signal from different directions. on the receiver side the indicator is first demodulated and amplified. The outcome is then treated by a fast Fourier transformation function which converts the time signal hind into the frequency domain. This re-enacts the frequency/ amplitude diagram bent at the transmitter. At the centre frequency of each sub-carrier a gauge function is used to produce the bits which remained originally used to generate the sub-carrier.

I've happened to stumble over PAPR (peak to average power ratio) quite a lot lately as it seems to play a big role in wi-max and 3gpp lte mobile devices. Most papers mention that lte has a better PAPR than wi-max but fail to explain what it is and why this is so important. After some research and help from a number of expert's heres an intro to papr:

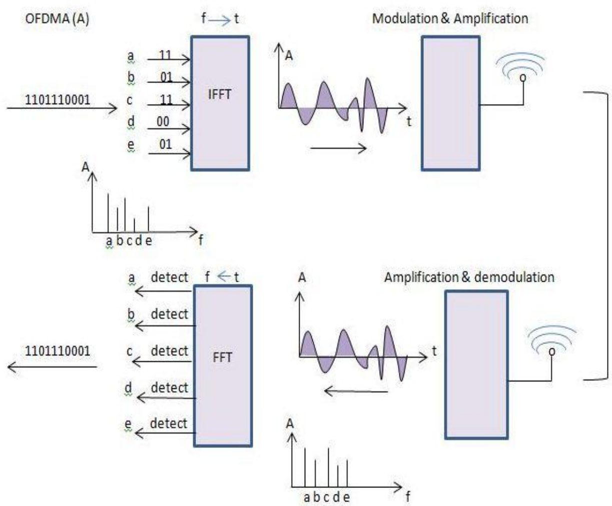

Fig.3

When diffusing data from the mobile fatal to the system a power amplifier is required to lift the outbound signal to a level high enough to be picked up by the network. The power amplifier is one of the biggest consumers of energy in a device and should thus be as power competent as possible to increase the operation stint of the device on a battery charge. The internal efficiency of a amplifier should be depends on two factors.

amplifier will able to amplify upper most value of wave due to silicon constraints utter most charge decides over the power consumption of the amplifier to take the high peaks of the waves. But do not transpose any information more than the average power signal over a time. Transmission speed does not depends on the peak output power. Output power required for the peak values of the waves but rather than average power level.as both power consumption and transmission speed are of importance for designers of mobile devices the power amplifier should consume as little energy as possible. Thus the lower the difference between the peak power to the average power papr the longer is the operating time of a mobile device at a certain transmission speed compared to devices that use a modulation schemes with a higher papr.

Now lets moving back towards the blog entry in mobile communication as I studied & analysed that LTE has better PAPR than wi-max. Different modulation schemes are used in the uplink communication. While wi-max uses the OFDMA which one is fast but has high PAPR.LTE designers to choose the SCFDMA because higher order modulation increases in PAPR.so that OFDMA and SC-FDMA fit for another blog entry.

II. SC-FDMA SYSTEM MODEL

The system model of a MIMO uplink SC-FEMA system consists of a base station bs with nr receive antennas and a user equipment ue with nt transmit antennas. The ueis allocated m contiguous subcarriers over the n available subcarriers and transmits independent streams or layers over each transmit antenna using a single code word or multiple code words. transmission starts with the encoding of the information bits for each code word and using appropriate mapping onto the streams. the bits over each stream are mapped to time domain constellation symbols s which are then converted into the so called frequency domain samples x by taking a m–point dft over each stream. The sample at the m th subcarrier x_m is represented as

$$X_m = G_L.y^m$$

The frequency domain representation of k-th user signal is **Xm**

$$X_m = G_M X^m = [X_m^{\,1}, X_m^{\,2}, \text{- - - - - - - - - - -}, X_m^{\,L}] \quad \rightarrow (1)$$

Where FM is the normalized M-point DFT operator $FM = 1/M \sum_{n=0}^{M-1} x_n e^{-i2\pi kn/M}$

SC-FDMA supports two different subcarrier mapping techniques, namely localized and inter leaved. In former the data is mapped to adjacent localized subcarriers, whereas the latter allows to fill subcarriers that are equi-distant from each other. Localized-SCFDMA (LFDMA) provides ease of practical implementation, and multi-user diversity if combined with channel dependent scheduling. For these reasons, LFDMA has been adopted in LTE. On the other hand, interleaved-SC-FDMA (IFDMA) is robust against frequency selective channels but it's practical implementation is un-convenient. In order to have a compliancy with existing and future LTE standards, we will only deal with LFDMA2 in this work. The k-th user SC-FDMA signal as in (1) is passed through N-IFFT block and is given as,

$$(x)^{-m} = G^1{}_K . G_L . y^m \quad \rightarrow (2)$$

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Where $F'N$ is the N-point IDFT matrix. The signal at each transmitter is then added with cyclic prefix (CP). that has length greater than channel impulse response (CIR). The received multi-user signal at r-th receiver antenna Yr is given as,

$$x_r = \sum_{m=1}^{m} \cdot i_r^{m} . x^{-m} + W_r \qquad \rightarrow (3)$$

Where hkr is the time domain channel impulse response between k-th transmit antenna and r-th receiver antenna and zr is the independent identically distributed (i.i.d) AWGN samples with zero-mean and covariance $\sigma 2$. For the sake of simplicity, we are dropping the user index k and receive antenna index r from the equations as received signals at the receiver are jointly detected at MUD block. The frequency domain matrix representation of (3) is,

$$X = I . X + W \qquad \rightarrow (4)$$

In (4) X is $R \times 1$ matrix corresponding to signals received at R antennas of receiver and H is the $R \times K$ channel matrix between transmit antennas and receive antennas. In this work we assume ideal channel estimation where channel estimation operation is performed at receiver for each received antenna. In the following section, we will discuss the proposed MCBEP receiver for MUMIMO SC-FDMA system.

III. PROPOSED MINIMUM CONDITIONAL BIT-ERROR PROBABILITY RECEIVER

In this section, we will derive the cost-function for the proposed minimum conditional bit-error probability (MCBEP) receiver in MU-MIMO SC-FDMA systems. Unlike classical linear detectors that aim at maximizing signal-to interference- noise-ratio (SINR) in multi-user environment, the proposed MCBEP receiver targets the minimization of conditional bit-error-rate at the output of MUD with computational complexity more-or-less the same as linear MMSE.

State-of-the-art show such criterion based on minimum-BER provides close to optimal results. The frequency domain equalizer weights w are to demodulate signal at the receiver after removal of cyclic prefix and N-point FFT FN operation. The decision variable $X'k$ for kth user is obtained after detection with the help of optimal weights wk.

The MUD output X_m is given by,

$$X_m = u_m^{i} . I_m . X + u_m^{i} . W \qquad \rightarrow (5)$$

Where, I_m is the m-th column of matrix I whose size is $(Q \times K)$ and $(\cdot)$ I is hermitian operator.

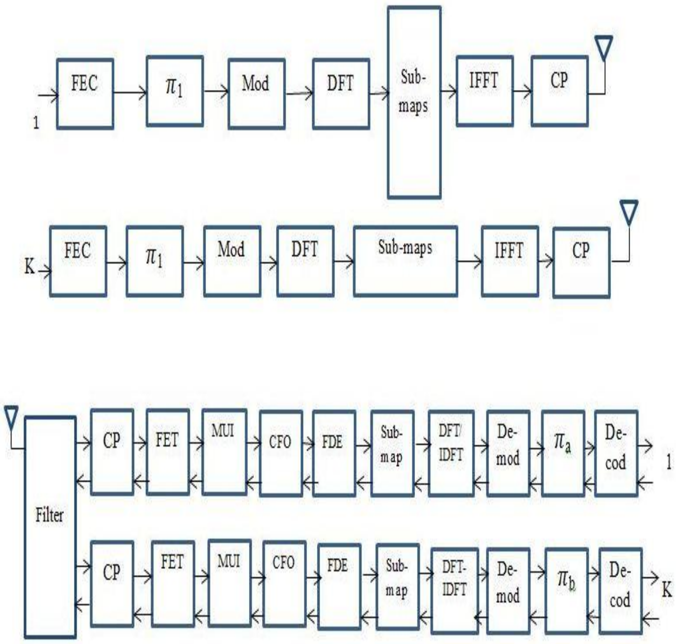

Fig.4

$$X_m = Q_m + W_m \qquad \rightarrow (6)$$

Where $Q_m = u_m^{i} . I_m . X$ and $Wm = u_m^{i} . W$

Performing M-point IDFT $F' M$ on the noiseless signal $\hat{}Xk$ at the output of MUD for k-th user, the signal $\hat{}xk$ is passed to decision device.

For only real-valued modulations like considered BPSK, the probability of error after decision depends on the real value of decision variable $x\hat{} k$. The probability density function (PDF) of noisy received signal is the mixture of Gaussian distributions associated with each possible symbol transmitted by all the users. The conditional probability of error MUD takes the $\mu + k$ as the mean of $\Re(\hat{} Sk)$ when user k transmits symbol $xk = 1$, and the mean is $\mu - k$ when $xk = -1$. We can write as,

$$\mu_m^{+} = p(Q_{m\,|}\ x_m = 1) \qquad \rightarrow (7)$$

$$\mu_m^{-} = p(Q_{m\,|}\ x_m = -1) \qquad \rightarrow (8)$$

The effective noise variance of $\hat{} Z$ in (6) is given as,

$$\sigma_m^2 = \sigma^2 \| u_m \|^2 \qquad \rightarrow (9)$$

The symbols in BPSK are assumed to be equi probable $Pr(+1,-1) = 1/2$ and with the help of BPSK error probability reported in [12], the conditional bit error probability for BPSK using (7) and (8) is given as,

$$S_{m,c} = ½ .R(\mu_m^{+} / \sigma_m) + ½ . R(-\mu_m^{-} / \sigma_m)$$

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→ (10)

Where $(v) = \sqrt{12}\int\infty\ v\ e{-}t2\ 2$, $v > 0$. The proposed MCBEP algorithm computes the filter weights W for all the transmit users by minimizing the bit-error probability as given in (10). Hence the MCBEP solution is,

$$u_{m,c} = \arg\min u_m . S_{m,c} \qquad \rightarrow (11)$$

wk, are the weights obtained as a result of minimization of Pk,. The subscript 'c' in wk, is acronym for"conditional". The MCBEP algorithm minimizes the conditional probability given in eq (10) with the help of an optimization rule. We employ conjugate gradient descent (CG) approach because of its simple implementation that allows to attain adequate performance. CG first computes the conjugate gradient of cost function (10) and iteratively reaches the minima with step size equal to λ. For the i-th iteration with step size λ, we have

$$u_{m,c}(i+1) = u_{m,c}(i) - \lambda(\blacktriangledown S_m \mid x) \qquad \rightarrow (12)$$

$\triangledown Pk|x$ is the gradient of (10) associated with k-th user and can be expressed in full form as,

$$\blacktriangledown S_m \mid x = -1/2\sqrt{2}\ \exp(-(\mu_m^{+})^2/2\ \sigma_m^{2}).\ 1/\sigma_m(I_x \mid x_m{=}1 - \mu_m^{+}.\ \mu_m / \| u_m \|^2) + 1/2\sqrt{2}\ \exp(-(\mu_m^{-})^2/2\ \sigma_m^{2}).\ 1/\sigma_m(I_x \mid x_m{=}-1 - \mu_m^{-}.\ \mu_m / \| u_m \|^2) \qquad \rightarrow (13)$$

The algorithm converges to optimal weights when (13) goes to zero or global minima. Step size λ should be adjusted properly because CG algorithm is sensitive to step size. Algorithm might not converge with larger step size, whereas small size will take too long to reach the minima.

Comparative analysis with ideal-MMSE and LMS-MMSE

In our work, we compare the performance of our proposed receiver with other two state-of-the-art approaches, namely ideal-MMSE and adaptive LMS based MMSE. MCBEP MUD receiver optimizes the filter weights of k-th user, wk, separately by estimating symbol energy conditioned on transmitted symbols computed using (7) and (8) considering only3 k-th column of H (removing interference from other terminals).

Hence it increases the terminal signal to noise ratio that is in argument of Q-function in (10) by greatly eliminating the MUI. This helps the MCBEP MUD in achieving the near optimum performance. The ideal-MMSE MUD, minimizes the mean square error between transmitted symbols and demodulated symbols, is given by:

$$Y = [\ I\ .\ I^{I} + \sigma^2.\ H_{Q \times Q}\ ]^{-1}\ .\ I \qquad \rightarrow (14)$$

The MMSE MUD increases the output SINR by appropriately using the channel matrix H when computing the filter weights W. However, MMSE MUD does not consider the MUI from other interfering users in (14) hence causing residual MUI that makes the MUD An adaptive version of MMSE is considered based on least mean square (LMS-MMSE) in frequency domain. LMS-MMSE considers training sequence that is known to receiver for estimating the channel H by minimizing the mean square error ϵ, suboptimal.

$$€ = F[\ (X - I\ .\ Y_{Tq})\ ] \qquad \rightarrow (15)$$

Where XTr is the training sequence and $\hat{}H$ is the estimate of true channel H. The filter weights wk for user k update iteratively using (15) as,

$$u_m(i+1) = u_m(i) + £\ .\ X_€ \qquad \rightarrow (16)$$

where α is the step size chosen for LMS-based filter.

IV. SIMULATION RESULTS:

We have performed simulations in MATLAB environment where we test the proposed MCBEP approach together with state-of-the-art adaptive least mean square (LMS) based MMSE and ideal-MMSE. The parameters are selected based on 3rd generation partnership program (3GPP) LTE-A [2] uplink as listed in Tab. 1 A convergence test is conducted between iterative detectors, LMS-MMSE and proposed LMSMCBEP,with fixed number of users and transmit per-bit signal to noise ratio. In Fig. 2, the measured bit-error probability versus iteration number is shown for the MCBEP MUD, considering 6 transmitting users and transmission SNR equal to 18dB. The LMS-based MCBEP reaches the obtainable BER value in less than 50 iterations. The convergence to the averaged Mean Squared Error (MSE) of the LMS-based MMSE is shown in Fig. 3. With same number of transmit users and signal to noise ratio considered for MCBEP, the convergence of adaptive MMSE is slow and requires higher number of iterations for convergence to minima. The convergence of MCBEP is lot faster with a simple-to-implement conjugate gradient algorithm. The second series of simulation results is related to BER performance of proposed MCBEP against the approaches mentioned in Tab. 1. The first use-case is single antenna two-user MU-MIMO. The BS allows paired users to transmit over the same set of radio resources hence it is equivalent to 2x2 MU-MIMO system. Due to low interference environment where only one user is causing interference to the other, the receiver is able to distinguish the uplink streams without much performance degradation, as evident in Fig. 4.

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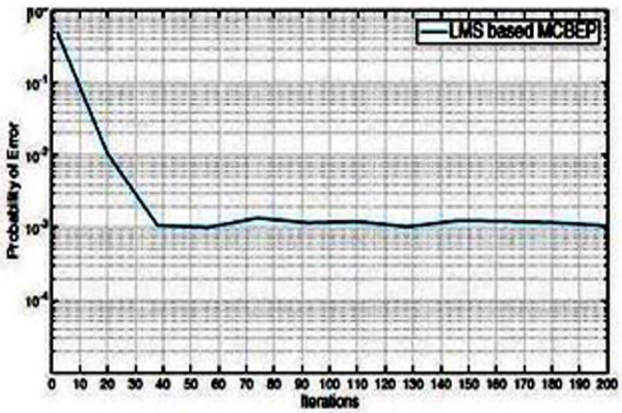

Figure 5: Convergence of MCBEP receiver with K= 6, R = 6, SNR = 18dB.

Table 1

Bandwidth	5 MHz
Number of Subcarriers	512
CP length	36
Resource Blocks (RBs)	6
Subcarriers in RB	12
Subcarrier Spacing	15 KHz
Sampling frequency	7.68 MHz
Channel Estimation	Ideal
Channel Impulse response	ExtendedVehicular A (EVA)
Receiver Algorithm	MCBEP,ideal-&LMS-MMSE

The performance of proposed MCBEP is closer to SISO-AWGN bound and shows improvement of around 3dB w.r.t ideal-MMSE MUD detector and ~ 4dB over LMS-MMSE in interference-limited region (high-SNR regime).Exactly the same trend can be observed in Fig. 5 when number of paired users increased to 4, thus forming 4x4.

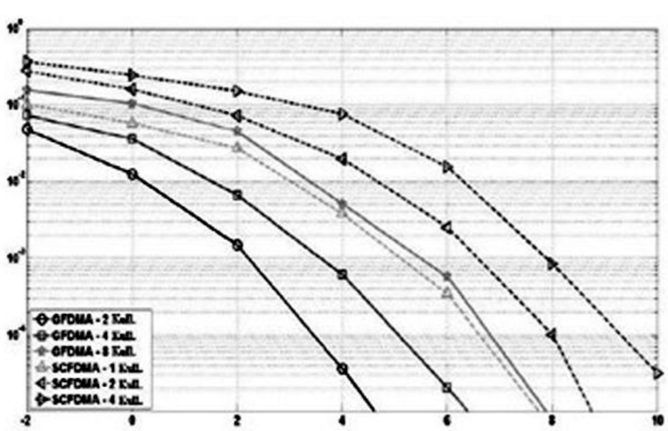

Figure 6: GFDMA with the number of users 1, 2, 4 and 2, 4, 8 SC-FDMA.

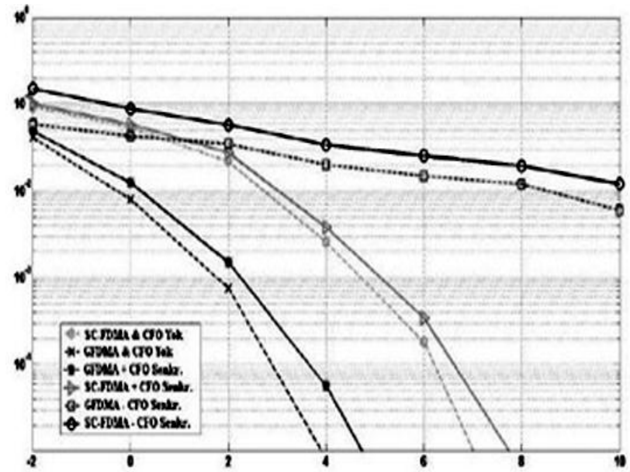

Figure 7. CFO and GFDMA with and without synchronization and SC-FDMA

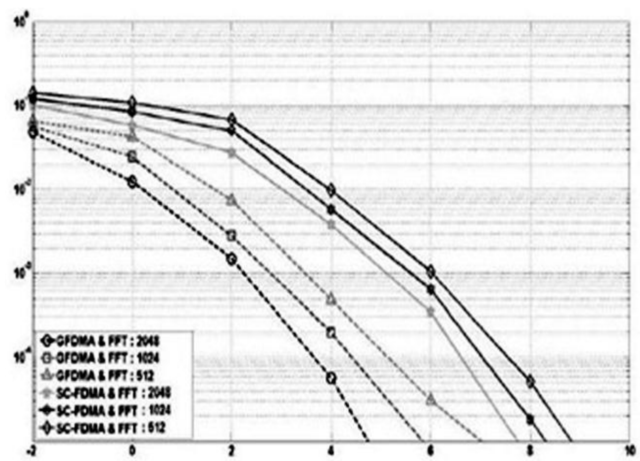

Figure 8: GFDMA with FFT sizes of 512, 1024 and 2048 and SC-FDMA.

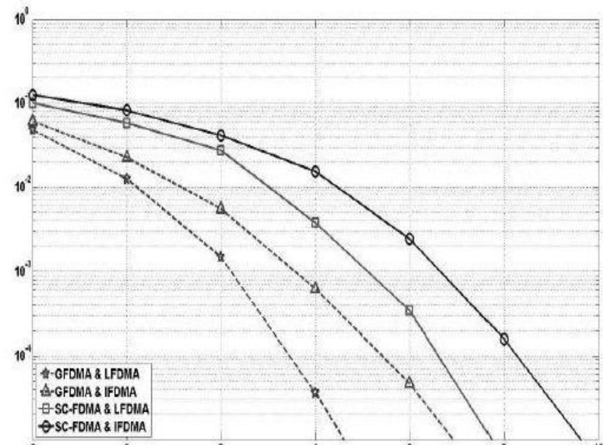

Figure 9: Sub-band approach using LFDMA and IFDMA GFDMA and SC-FDMA.

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V.CONCLUSION

In this article, a CFO synchronization using zero sub-carriers algorithm and in accordance with the algorithm GFDMA and SC-FDMA models that can operate and subcarrier suggested mapping methods. From simulations performed the findings show that the proposed method can be quite successful in influencing the CFO. Another result obtained from the simulations is the FFT increase the number of users, reduce the number of sub-bands system of using the approximate LFDMA mapping method performance. In addition, multi-user GFDMA's performance for single-user SC-FDMA and that this performance can be overcome.

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