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Optimized Analytical Study to Show the Impact of CFO on the Performance of LTE Uplink

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Abstract

Although tremendous progress has been made in the past decade on wireless communications domain, but still the impact of carrier frequency offset (CFO) on system performance especially on orthogonal frequency division multiplexing (OFDM) is an area of concern. As reported in the literature the conventional research works shows that the carrier frequency offset (CFO) occurs mainly due to oscillator instability and Doppler shift introduced in the channel. In this paper, the impact of carrier frequency offset (CFO) on the system performance is discussed and the impact of the carrier frequency offset (CFO) drawback even worse in uplink scenario where every user experiences the different offset because of random nature of users. The usage of DFT based SC-FDMA over IFFT based OFDM shows good impact on system uplink scenario where DFT based SC-FDMA is free of PAPR which is common problem in IFFT based OFDM system as mobile handsets have limited battery power. Finally the Bit error graphs and constellation diagrams in the results section reveals the fact that the CFO impact on the system uplink is so severe that in order to save the user integrity data suppression techniques needs to be employed in an efficient way.

KEYWORDS: OFDM, SC- FDMA, CFO, BER, System uplink

INTRODUCTION

In olden days people used to communicate with distant counterparts by make usage of traditional approaches like sending the information with birds, sending people as ambassador to convey the information. Most of the researchers termed 21st century as

Communication arena due to the high end technological advancement in this area which makes communication fast and reliable. The intense research classified communication into two categories a) wire based communication b) wireless based communications. Wire based communications is considered as most useful tool in world wars to convey information from one end to another in 1940's and optical fiber plays a crucial role in wire based communication mechanism and after completion of war the dominance of United States of America (USA) and Union of Soviet Socialist Republics (USSR) over the world makes the research on communication so fast that in two decades communication research grows from daily life communication to satellite communication and this development mainly because of wireless communication.

Wireless communications are broadly classified into three different categories namely i) Conventional communication systems such as FDMA, TDMA which mainly has two drawbacks one is low data rate and low spectral efficiency. ii) Existing communication systems like CDMA are suitable for mobile and radar communication but the main drawback is drawback is data rate (speed). iii) Future generation communication models such as OFDM are used in Applications like 3G, 4G, LTE, WIFI, and WIMAX.

Orthogonal frequency division multiplexing (OFDM) has been attracted many research organizations related to high speed communication area due to its many attractive features like Orthogonality, acceptable to all types of scenarios like SISO, MIMO, MISO AND SIMO, no inter carrier interference and on the other hand it has so many drawbacks namely delay, distortion and finally peak to average power ratio.

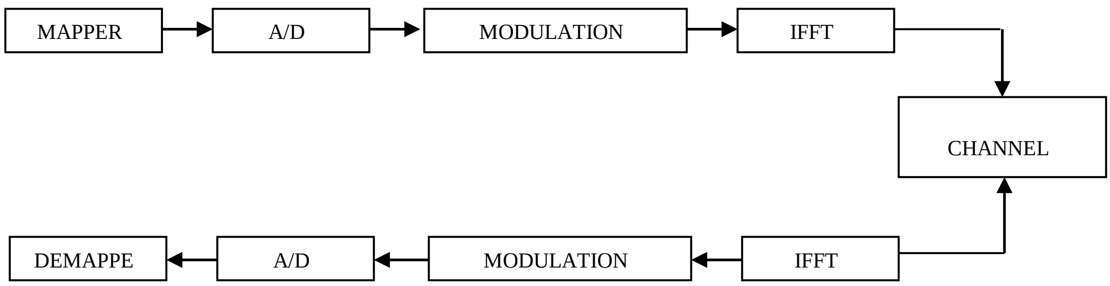

Figure 1: OFDM block diagram

Long term evolution is the successful extension of 3GPP which ahs better data rate and high end applications for the users and by the advance characteristics LTE attracts more attention from the international research organizations and as well as from the users. As LTE is growing as a promising technology and many nations around the globe already started working on LTE and in some cases its have been already completed.

The synchronization of the physical layer in the communications network are considered as major obstacle in the present generation communication systems. Although OFDM offers good flexibility and performance over conventional communications techniques but due to its easy prone approach to frequency errors and sensitive approach towards CFO makes way to think for alternative which can tackle the issue of

CFO in an successful way. Typical CFO correction methods which are normally designed for downlink are not appropriate in uplink because they are designed for single user system and in uplink system there are multiple frequency offsets with each user having different CFO. The estimation for each user has to be separate due to different propagation characteristics and MAI.

In the proposed method the impact of CFO on multiple users in different modulation techniques have been studied based on the SC-FDMA instead of OFDM

THE PROPOSED SC FDMA MODEL APPROACH

As discussed in earlier section the proposed method approach is mainly relies on the SC-FDMA which is used as multiple access technique as shown in SC-FDMA block diagram of transmitter and as well as receiver respectively for multiple users.

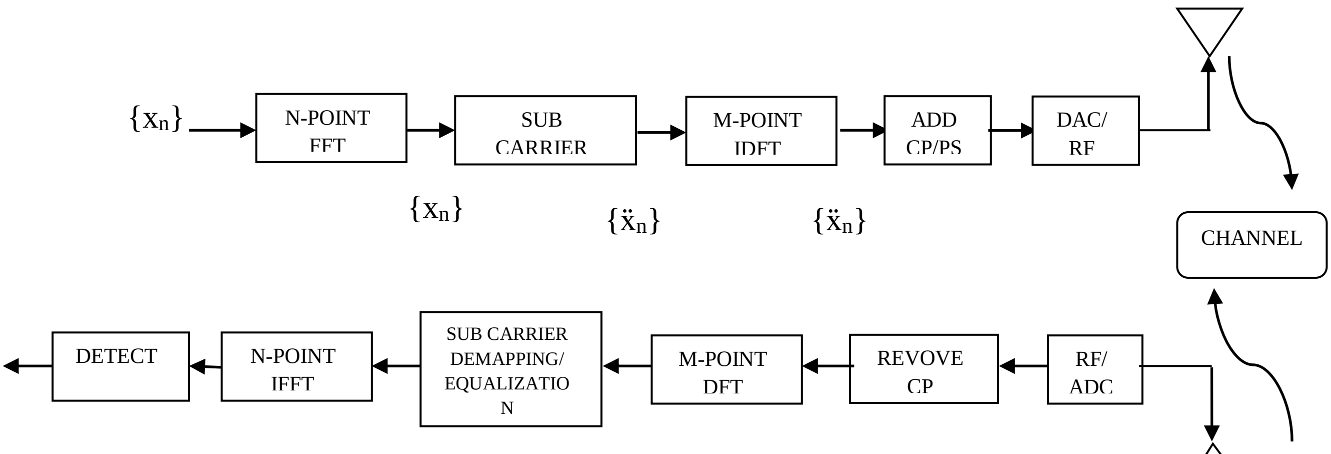

Figure 2: SC-FDMA block diagram

The approach of the synchronization at uplink is difficult because time variation between the user and the base station and this offset variation occurs as different users follows different path and observes different multipath environment. Therefore, when they are finally received by the base station, they have different frequency and timing offsets. Due to this fact, synchronization in uplink is considered difficult. In order to overcome this drawback in uplink communication scenario a novel approach is designed instead of uplink values downlink values in uplink for synchronization. In detailed analysis every individual user have their respective downlink values and these values are used overcome the uplink errors in the synchronization. But these approach solves the problem of uplink synchronization to some extent as the downlink values are very small.

Let’s consider an LTE uplink SC-FDMA system where data is being transmitted by M users to central eNodeB (Evolved Node B). This communication takes place block-wise in which the data stream of the m-th user is decomposed into parts of length P, with bm,i denoting the i-th block of user m. Based on predefined sub carrier allocation strategy, the user data consisting of P symbols in each block is mapped over P subcarriers. This allocation is done by inserting N – P zeroes in data $b_{m,i}$. This insertion is necessary in order to obtain vector of dimension N, which is given as $a_{m,i}$. Next step is to perform IDFT operation and then cyclic prefix is inserted. After this operation each initial $a_{m,i}$ block is now converted into time domain samples as given in (1).

$$S_{m,i}(k) = \begin{cases} \frac{1}{N}\sum_{n=0}^{N-1} a_{m,i}(n)\, e^{j2\pi nk}/N, & if -N_g \leq k \leq N-1 \\ 0, & otherwise \end{cases} \quad (1)$$

By combining multiple incoming blocks of time domain samples, uplink signal is obtained which is expressed as in (2).

$$s_m^{(T)}(k) = \sum_i s_{m,i}(k - iN_T) \quad (2)$$

Where $N_T = N_g + N$ is the length of block along in terms of cyclic prefix and M incoming signals are collected by the receiver at central base station where they are down converted and then passed to analog to digital unit. The signal obtained after this operation is given in (3).

$$r(k) = \sum_{m=1}^{M} s_m^{(R)}(k) + w(k) \quad (3)$$

Where w (k) is the additive white Gaussian noise (AWGN) contribution while $s_m^{(R)}(k)$ is the signal component from the mth user given in (4).

$$s_m^{(R)}(k) = e^{j2\pi nk}/N \sum_{l=0}^{L_{m-1}} h_m(l) s_m^{(T)}(k-l) \quad (4)$$

Where $h_m = [h_m(0).h_m(1), \ldots., h_m(L_{m-1})]^T$ and $\epsilon_m = f_{m.d}/\Delta f$ denotes the discrete-time channel impulse response and the frequency offset Δf of the m-th user, respectively. The distance between two neighboring subcarriers in the frequency domain is $\Delta f = 1/NT_s$.

Many methods have been prescribed to counter this offset. This is done by using the Demodulation Reference Symbol (DMRS) which are utilized in LTE uplink. Each LTE uplink frame consists of two slots where each slots comprises of 7 SCFDMA symbols, center symbol on each slot is the DMRS symbol which has pilot sequences and is formed using Constant Amplitude Zero Autocorrelation (CAZAC) sequences. These sequences are already known to the receiver and offset can be compensated by comparing received and transmitted CAZAC sequence. Another method can be by comparing DMRS of both slots by using fact that DMRS of 2nd slot is actually time shifted version of DMRS of 1st slot

SIMULATION RESULTS

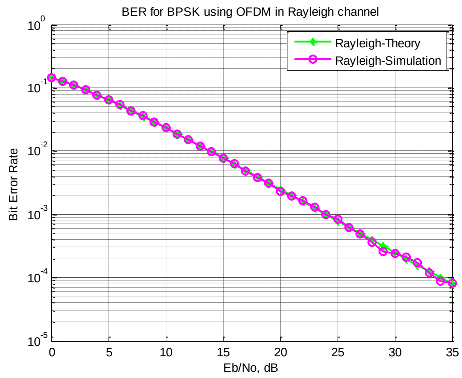

Figure 3: BER for BPSK using OFDM in Rayleigh channel

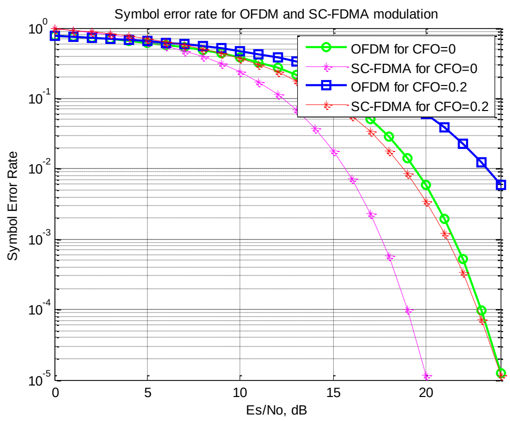

Figure 4: Symbol error rate for OFDM and SC-FDMA modulation

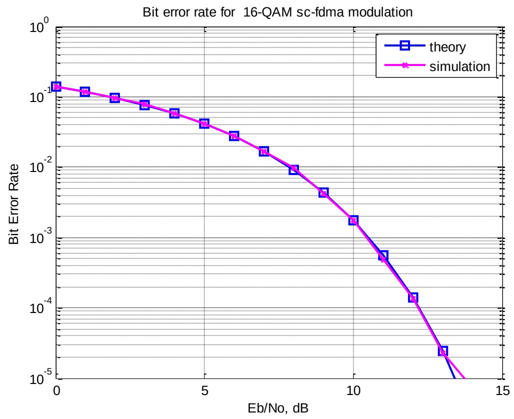

Figure 5: Bit error rate for 16-QAM SC-FDMA modulation

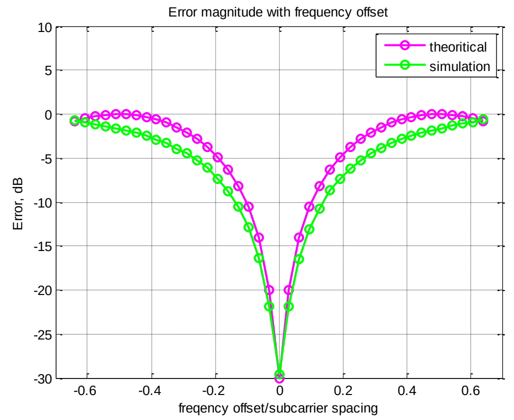

Figure 6: Bit error rate for 16-QAM SC-FDMA modulation

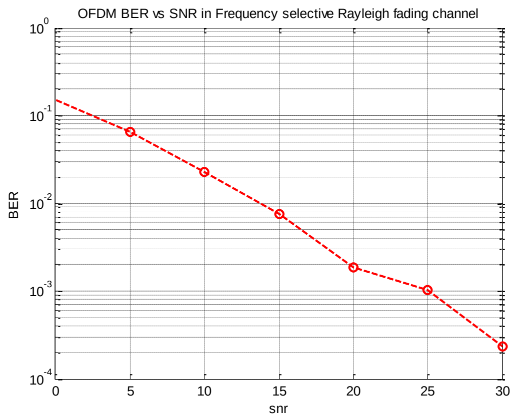

Figure 7: OFDM BER vs SNR in Frequency selective Rayleigh fading channel

CONCLUSION

In this paper, the impact of carrier frequency offset (CFO) on the system performance is discussed and the impact of the carrier frequency offset (CFO) drawback even worse in uplink scenario where every user experiences the different offset because of random nature of users. The usage of DFT based SC-FDMA over IFFT based OFDM shows good impact on system uplink scenario where DFT based SC-FDMA is free of PAPR which is common problem in IFFT based OFDM system as mobile handsets have limited battery power and the Bit error graphs and constellation diagrams in the results section reveals the fact that the CFO impact on the system uplink is so severe that in order to save the user integrity data suppression techniques needs to be employed in an efficient way.

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