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Compensation of CFO Affected SC-FDMA System

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Abstract
The Single-Carrier Frequency Division Multiple Access (SC-FDMA) system is a well-known system, recently become a choice for uplink channels. In this type of system, the Carrier Frequency Offsets (CFOs) will affect the orthogonality between the subcarriers and will give rise to Intercarrier Interference (ICI) and Multiple Access Interference (MAI) among the various users. In this paper the impact of CFOs on the performance of the system in Discrete Cosine Transform (DCT) and SC-FDMA (DCT-SC-FDMA) system is proposed. This will introduce comparative analysis for different types of equalization schemes which were used to correct the effect of carrier frequency offsets optimization by using the BER/SER analysis. The performance analysis of the system is given for different types of adaptive equalizers & its effect on these systems. The performance and complexity of these schemes were tested for Single Carrier Frequency Division Multiple Access (SC-FDMA) system

Keywords— SC-FDMA, OFDM, ISI, MAI, ICI, PAPR, Cyclic Prefix, BER/SER, CFO

I. INTRODUCTION

Single Carrier Frequency Division Multiple Access (SC-FDMA) is a technique for high data rate uplink communication which is promisingly adopted by 3GPP for its next generation cellular system, called Long-Term Evolution (LTE). SC-FDMA is a modified form of OFDM with similar performance throughput and its complexity. This is often viewed as before going through the standard OFDM modulation the DFT-coded OFDM passed through time-domain data symbols and are transformed to frequency-domain by a Discrete Fourier Transform (DFT. Thus, SC-FDMA system inherits all the advantages of OFDM over other well -known techniques. Single-Carrier (SC) transmission is well-known for its low Peak-to-Average-Power-Ratio (PAPR) property and robustness to carrier frequency offsets, but a multi-path channel can severely impact the performance of a high data-rate SC signalling by causing Inter-Symbol-Interference (ISI). The SC-FDMA system is sensitive to CFOs, the CFOs weakens the orthogonality between subcarriers and give rise to ICI among users. LTE is a next generation mobile system based on Single-Carrier Frequency Division Multiple Access (CP) in the downlink. The 3GPP Long Term Evolution (LTE) is the telecommunication network of the next generation, following 3G nodes in an efficient manner. This assured various research challenges to design appropriate equalizer. The main advantages of this new technology are packet optimized radio access technology, high data rate and low latency. One of the actual problems is to provide the reliable transmission over the LTE, and for this reason it is necessary to choose the equalization methods for the received signal. The main goal of this paper is to analyse the performance of the various equalization methods for SC-FDMA and its effect on CFOs by analysing the BER .SC-FDMA is a technique used for the mostly uplink channels, so the results of the complexity and BER performance analysis could be applied to the appropriate equalization method .The effect on PAPR and CFOs on the SNR and BER will be going to studied on SC-FDMA system.

II. CARRIER FREQUENCY OFFSET DESCRIPTION

(SC-FDMA) with cyclic prefix in the uplink and Orthogonal Frequency Division Multiplexing (OFDM) with cyclic prefix In order to obtain a reliable system performance, efficient CFO synchronization is very important. Similar to the OFDMA system, the SC-FDMA system is sensitive to CFOs, which are mainly due to oscillator mismatches and/or Doppler shifts. However, like all the orthogonal frequency-division multiplexing (OFDM) based schemes, SC-FDMA also suffers from carrier frequency-offset (CFO), and this is a major problem especially for LTE uplink, where more than one CFOs exist.CFO synchronization is harder in uplink than downlink, due to this multiple CFOs. There are two kinds of effects that occur owing to CFO; inter-carrier interference (ICI), which occurs between a user's own subcarriers and multiple-access interference (MAI), which occurs between different users' subcarriers. In uplink communications, multiple signals sent from multiple users are affected by different CFO values. After passing from these channels, these signals are

combined at the receiver. This combination results in MAI .As a result, in this system, the CFOs disrupts the orthogonality between subcarriers and gives rise to ICI and MAI among users. Moreover, CFOs compensation is difficult in uplink communications since the CFOs compensation for a certain user may result in the misalignment of the other Synchronized users. In this proposed work an equalizer to mitigate the impact of the residual MAI after the CFOs compensation process in the DFT-SC-FDMA system is going to studied.

SC-FDMA Block Diagram and Description

The process transmission of SC-FDMA scheme is very similar to OFDMA. For multiple users the sequence of bits transmitted is mapped in a complex constellation symbols for BPSK, QPSK, and MPSK. These different transmitters are assigned different Fourier coefficients with each assignment are carried out in the mapping and demapping blocks. The receiver side includes one subcarrier demapping block, one N-point IDFT block and one detection block for each user signal to be received. Just like in OFDM, guard intervals (or called cyclic prefix) with cyclic repetition are introduced between blocks of symbols in view to efficiently eliminate time spreading (caused by multi-path propagation) among the blocks in transmitter side.

In SC-FDMA, multiple accesses among users is made possible by assigning different sets of non-overlapping Fourier-coefficients sub-carriers and different users. This is achieved at the transmitter by inserting silent Fourier-coefficients, and removing them on the receiver side after the FFT. In contrast to OFDMA which is a multi-carrier transmission scheme, the distinguishing feature of SC-FDMA is that it leads to a single-carrier transmit signal. Subcarrier mapping can be classified into two types viz localized mapping and distributed mapping.

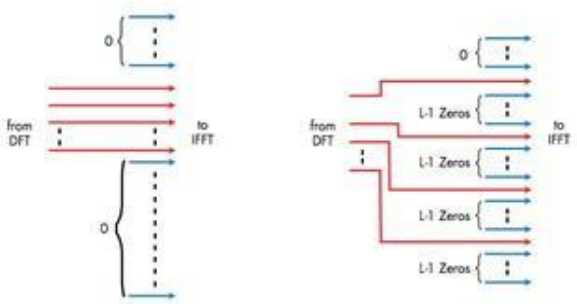

Fig 1.Localized Mapping and Distributed Mapping

Owing to its inherent single carrier structure, a prominent advantage of SC-FDMA over OFDM and OFDMA is that its transmit signal has a lower power resulting in relaxed design parameters in the transmit path of a subscriber unit. Interestingly, the reasoning lies in the fact that while in OFDM the transmit symbols directly modulate the multiple sub-carriers, but in SC-FDMA the transmit symbols are first pre-processed by a N-point DFT block.

CFOs compensation is difficult in uplink communications since the CFOs compensation for a certain user may result in the misalignment of the other synchronized users. Frequencyoffsets estimation for high-speed users in uplink were proposed in this paper. Up to now, the impact of CFOs on the performance of the DCT-SC-FDMA system has not been investigated and according to it the affect of BER performance analysis has been introduced in this paper.

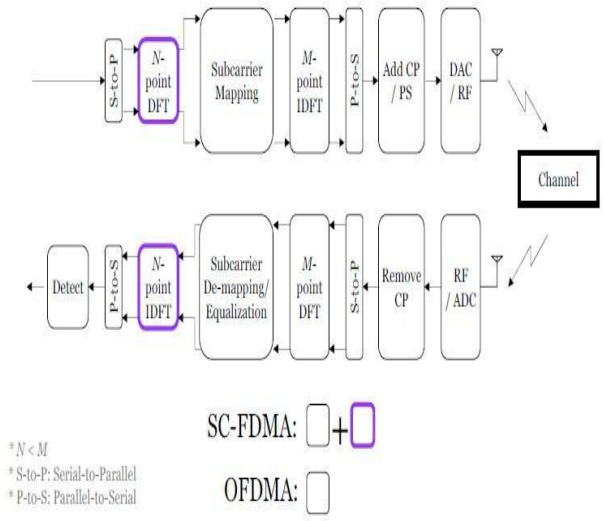

Fig 2. SC-FDMA Block Diagram

Since, they do not keep track of the states of all the nodes in the network

III. CFO INTRODUCTION SNR FADING EFFECT

In the signal-to-noise ratio (SNR) degradation due to the carrier frequency offset was derived for the additive white Gaussian noise (AWGN) channel. SNR has also been analysed for a time-invariant multipath channel, a shadowed multipath channel, and a general multipath fading channel. In this section, the effect of the carrier frequency offset on the SNR is analysed for multipath fading channels. The average SNR provides useful information about the receiver performance when appropriate coding and interleaving is used. Thus, an approximate average SNR expression is derived for multipath fading channels and is examined for the special case of flat fading channels and the additive white Gaussian noise (AWGN) channel.

IV. THE PROPOSED TECHNIQUE

It is known that the DCT-IFDMA system is more sensitive to CFOs than the DCT-LFDMA system. So, at high CFOs and SNR values, the residual MAI after the proposed adaptive equalization may degrade the Bit Error Rate (BER) / Symbol Error Rate (SER) performance of the DCT-IFDMA system. To solve this problem, the proposed adaptive equalizers are used to furth er reduce the effect of the residual MAI on the DCT-IFDMA system. The main goal is to acquire and find out the various equalization methods by which the effect of CFOs can be improved. The SER/BER of the system has been studied and used for comparison. Low BER increases bandwidth utilization and reduces CFO offset and noise from the channel at the receiver.

V. COMPENSATION OF CARRIER FREQUENCY OFFSET

Frequency mismatches among the uplink users as well as between the uplink users and the base station (BS) cause power leakage among the subcarriers. This leakage has mainly two effects, like ICI and MAI. ICI is caused by the leakage or interference Frequency mismatches among the uplink users as well as between the uplink users and the base station (BS) between a user's own subcarriers whereas MAI is caused by the power leakage from other users' subcarriers. Two main approaches, namely *feedback* and *compensation* methods, can be used to mitigate the frequency offset in the uplink of OFDMA systems.

In OFDM as well as SC-FDMA, equalization is achieved after the FFT calculation on the receiver side, by multiplying each Fourier coefficient by a complex number. Thus, frequency selective fading and phase distortion can be easily combated. The advantage is that frequency domain equalization and FFT requires less computation power than the conventional time-domain equalization.

A related concept is the combination of a single carrier transmission with the single-carrier frequency- domain-equalization (SC-FDE) scheme. The single carrier transmission, unlike SC-FDMA and OFDM employ no FFT and IFFT at transmitter, but introduce the cyclic prefix to transform the linear channel convolution into a circular one. After removing the cyclic prefix at receiver, an FFT is applied to arrive in the frequency domain, where a simple single-carrier frequency-domain-equalization (SC-FDE) scheme can be employed, followed by the IFFT operation. First we will try to use the traditional equalizers and then we will be using different adaptive equalizers to minimize the effect of CFOs.

VI. SIMULATION RESULTS

To evaluate the performance of the proposed schemes, some simulation experiments are carried out. Here, an uplink DCT-SC-FDMA system with 512 subcarriers is considered.. In this system, there are four users with 128 subcarriers allocated to each user. The users employ Quadrature Phase Shift Keying (QPSK) mapping for their data symbols. The channel model used for simulations is the vehicular A model. A convolution code with rate 1/2, constraint length 7, and octal generator polynomial (133,171) is used. Each frequency offset is a random variable with uniform distribution in [−0.3, 0.3]. The CFOs are chosen randomly to simulate more practical scenario. For the comparison purpose, single user detector [7], and the circular convolution detector [7, 10] are simulated for the uplink DCT- SC-FDMA system. Figure 4 shows a comparison in the BER performance between the single-user detector, the circular convolution detector, and the proposed equalization scheme for the DCT-SC-FDMA system. The DCT-SC-FDMA system without CFOs and the DCT-SC-FDMA system with CFOs are also studied for comparison.

Figure 3 shows the BER performance of the proposed Schemes for the DCT-IFDMA system. From this figure, it is clear that the PIC can avoid the MAI and provide better BER performance than the MMSE scheme. It is observed from Figure that the performance loss due to the proposed scheme is 0.5 dB at a BER =10−3, which is acceptable.

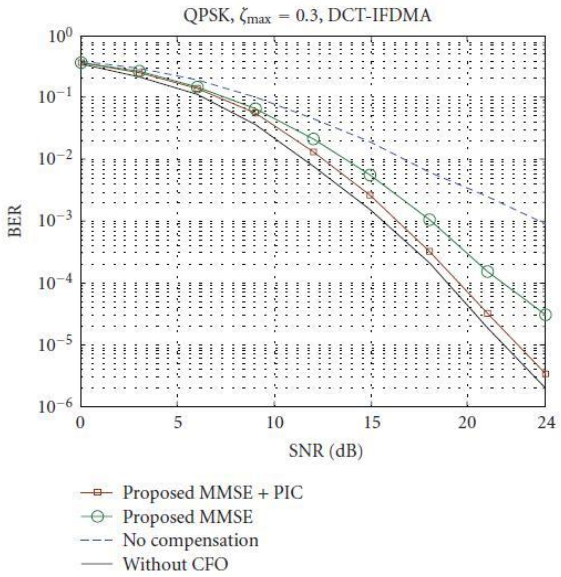

Fig 3. BER versus the SNR for the DCT-IFDMA system with the proposed schemes.

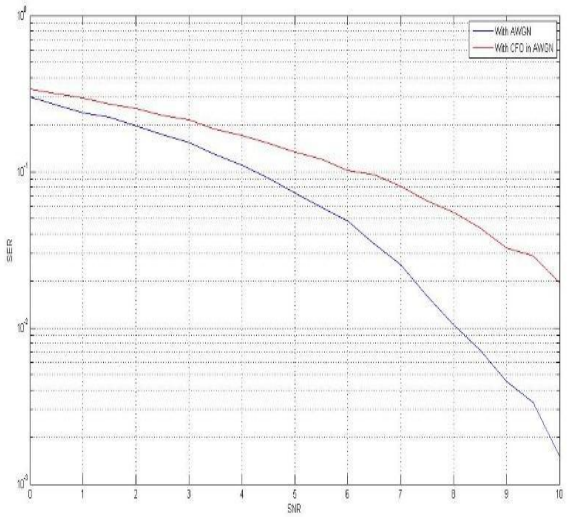

Fig 4. BER/SER versus the SNR for the DCT-IFDMA system with the proposed schemes with CFO

Figure 4 illustrates the BER/SER performance of the proposed schemes versus the maximum normalized CFO for the DCT-IFDMA system with CFO. It can be seen that the performance of the proposed scheme is always better than the MMSE scheme, especially at large CFOs values.

VII. CONCLUSIONS

In this paper, the issue of the CFOs in the uplink DCT-SCFDMA system is compensated and investigated. Simulation results show that CFOs destroy the orthogonality of the subcarriers and result in ICI and MAI, which degrades the BER performance. Simulation results show that the proposed MMSE + PIC schemes are able to mitigate the impact of CFOs to provide a better BER performance for DCT-SCFDMA system. This paper presented new compensation scheme. Also, simulation results demonstrate that the proposed and MMSE + PIC schemes outperform both the circular convolution detector and the single user detector. Moreover, it is found that the proposed MMSE + PIC schemes are robust to the estimation errors.

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