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Performance Evaluation of CFO Estimation Algorithm for the Downlink of 3GPP LTE

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Abstract: *LTE is a new standard towards 4th generation in LTE OFDM is used as the basic multiple access technique. OFDM is very sensitive to Synchronization error in from carrier frequency offset because it can cause due to Doppler Shift and frequency mismatch and inter carrier interefernce which results in CFO. In this paper, we present algorithms for determining carrier frequency offset (CFO) for the downlink of 3GPP LTE. Three CFO estimation techniques, cyclic prefix (CP) based technique, Moose algorithm and Classen algorithm are presented in this paper. The estimation techniques cover both time and frequency for OFDM system. Simulation of this CFO estimation algorithm is examined.*

Keywords: *3GPP-LTE, OFDM, CFO estimation, Moose and Classen algorithm*

I. INTRODUCTION

The long term evolution (LTE) is the advanced version of the 3GPP for fulfilling transmission targets of four generation (4G) mobile communication system. The downlink LTE system adopts orthogonal frequency division multiple access (OFDMA) technique both multipath effect of frequency selective channel and for achieving high data rates. In the LTE system, synchronization plays an important role in the system performance. Generally, the synchronization problems can be divided into timing and frequency synchronizations; the former mainly deals with estimating the mismatch frequency between the transmitter's and the receiver's oscillators[5]. In general, the CFO problem can be divided into fractional frequency offset (FFO) and integer frequency offset (IFO) problems[4]. In this paper, the CFO estimation for the downlink of 3GPP LTE is investigated for the CFO estimation in OFDM systems. This paper firstly review three CFO estimation techniques for the downlink of 3GPP LTE, i.e., the cyclic prefix(CP) based technique, the Moose algorithm and the Classen algorithm.
The rest of the paper is organized as follows. The radio frame structure of LTE is introduced in section II. Section III describes the system model. In section IV, several synchronization algorithms are presented. Simulation results are displayed in section V. Finally, conclusion are drawn in section VI.

II. SYNCHRONIZATION SIGNAL IN LTE

In LTE transmission frame structures can be frequency division duplex (FDD) or time division duplex (TDD).In the both frame structures, one frame is 10ms, and consists of 10 sub-frames or 20 time slots. In the LTE there are normal CP mode and extended CP mode; the former has 7 OFDM symbols, and the latter has 6 OFDM symbols[2]

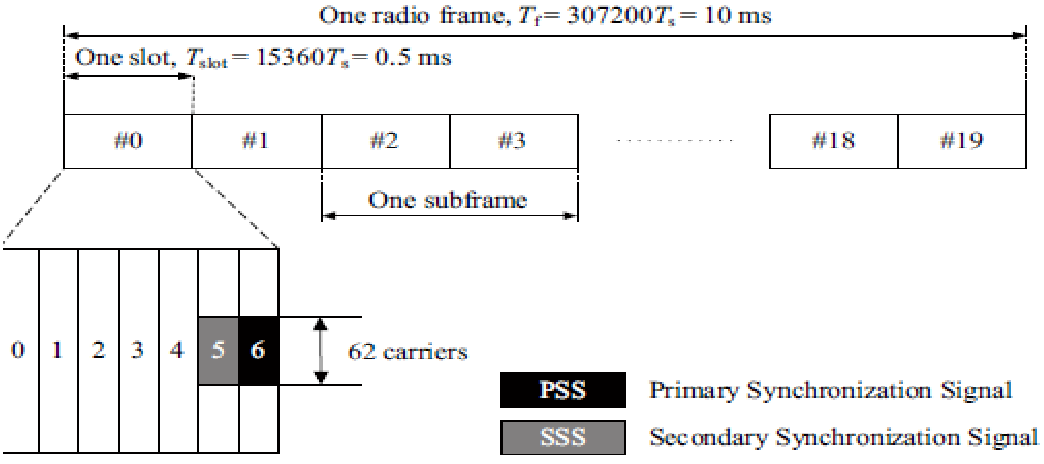

Figure 1. The radio frame structure of LTE [3]

The LTE defines primary synchronization signal (PSS), secondary synchronization signal (SSS).The PSS is made of length-62 zadoff-chu (ZC) sequence and one ZC sequence is transmitted over P-SCH, which is located at both the first subframe and the sixth subframe, as shown in Fig.1. The ZC sequence has the property of constant amplitude zero autocorrelation (CAZAC)[2], and the sequence is given by,

$$d(n) = \left\{e^{-j\frac{\pi un(n+1)}{63}} \qquad n = 0,1,\ldots,30\right\}$$
$$\left\{e^{-j\frac{\pi u(n+1)(n+2)}{63}} \qquad 31,32,\ldots,61\right\}$$

Where u is called ZC root index, and u ϵ {25,29,34} for LTE systems. The PSS and SSS are pilot signals of the LTE system for synchronization.
In this section, we construct the OFDMA system model. The time-domain OFDMA symbol s(n)

$$X_l[n] = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi kn/N} 1 \le n \le N$$

Where X_k represents the modulated data on the k-th subcarrier and N is the FFT size. By transmitted X_l(n) over a multipath propagation channel under consideration of a frequency misalignment between the transmitter's and the receiver's oscillators.

$$y_l[k] = \frac{1}{N}\sum_{n=0}^{N-1} H[k]X_l[k]e^{\frac{j2\pi n(k+\varepsilon)}{N}} + Z_l[n].$$

The received symbols under the presence of CFO ε,

$$y_l = \sum_{n=0}^{N-1}\frac{1}{N}\sum_{m=0}^{N-1} H[m]X_l[m]e^{\frac{j2\pi(m-k+\varepsilon)n}{N}} + \sum_{n=0}^{N-1} Z_l[n]e^{-j2\pi kn/N}$$

III. CFO ESTIMATION ALGORITHM

In LTE systems, the synchronization algorithm includes two parts: the timing synchronization and frequency synchronization. We first review the CP based synchronization algorithm.

A. CP based estimation technique:

The cyclic prefix (CP) of the OFDM symbol can be used to estimate the CFO in time domain[1]-[2].With perfect symbol synchronization, a CFO of ε results in a phase rotation of 2πεn/N in the received signal. Under the assumption of negligible channel effect the phase difference between CP and the corresponding rear part of an OFDM symbol is 2πεn/N = 2πε. Then, the CFO can be found from the phase angle of the product of CP and the corresponding rear part of an OFDM symbol,

$$\epsilon = \frac{1}{2\pi} arg\left\{\sum_{n=-Ng}^{-1} y_l * [n] y_l[n]\right\}$$

n = -1, -2, ... -Ng. In order to reduce the noise effect, its average can be taken over the samples in a CP interval.Arg() performed $\tan^{-1}$, the range of the CFO estimation is [0.5+0.5] .

B. Moose Algorithm:

Moose algorithm based on the preamble training sequence. To overcome the issues of CP. Moose algorithm can cover wider range of CFO. The range of CFO estimation can be increased by reducing the distance between two blocks of samples for correlation. This will prove helpful in increasing the range of the CFO.

$$\varepsilon = \frac{T}{2\pi} arg\left\{\sum_{n=0}^{\frac{N}{T}-1} y_l * [n] y_l[n + \frac{N}{T}]\right\}$$

The ratio of OFDM symbol to the repetitive length of the pattern by an integer T. An estimation range of |ε| ≤ T/2, which becomes wider as T increases and number of samples for the computation of correlation is reduced by 1/T, which degrade the MSE performance of OFDM system[1].

A. *Classen Algorithm:*

Classen algorithm based on the pilot tone technique. pilot tone technique inserted in the frequency domain and then OFDM symbols transmitted for the purpose of estimating CFO.
In this process, two different estimation modes for CFO estimation are Implemented: acquisition and tracking modes. In the acquisition mode, a large range of CFO including an integer CFO is estimated and tracking mode, only fine CFO is estimated[1]. The integer CFO is estimated by :

$$\varepsilon = \frac{1}{2\pi, T_{sub}} max \left\{ \left| \sum_{i=0}^{k-1} y_{l+D}[A[i],\varepsilon] y_l * \ [A[i],\varepsilon] X^*{}_{l+D}[A[i]] X_l [Ai]] \right| \right\}$$

Where L,A[i],and X_l [A[i]] denote the number of pilot tones, location of the i^{th} pilot tone, and the pilot tone located at A[i] in the frequency domain and l^{th} symbol period.

IV. SIMULATION RESULTS

CFO estimation is done by using three different techniques, first one is phase difference between CP and the corresponding real part of an OFDM symbol. Second is training sequence with T integer i.e. ratio of the OFDM symbol length to the length of a repetitive pattern and third one is estimation between pilot tones in two consecutive OFDM symbols.
Figure 2 and Figure 3 show MSE performance for three different techniques with taking CFO= 0.15 and 0.30. Pilot tone based estimation is better then CP and Preamble based estimation. Performances of estimation techniques depending on the number of samples in CP, the number of samples in preamble, and the number of pilot tones, used for CFO estimation. Simulations are performed to verify the accuracy of MSE analysis.
The OFDM system parameters are CFO = 0.15 and CFO = 0.30, N = 128,Ng = 32, signal to noise ratio (SNR) 0 to 30 db. For OFDM mapping 16QAM modulation used and taking signal energy Es = 1.

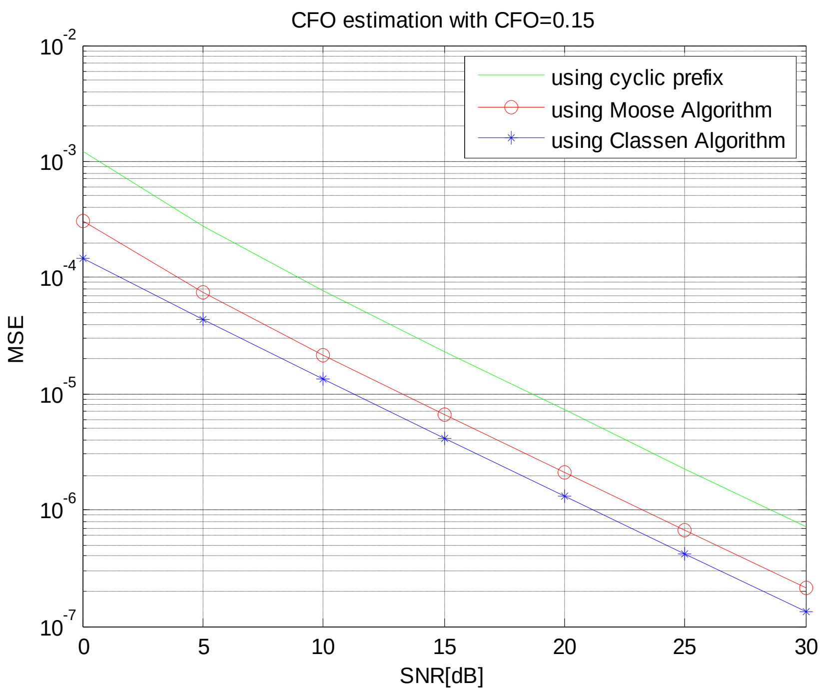

Figure 2. Simulation with CFO=0.15

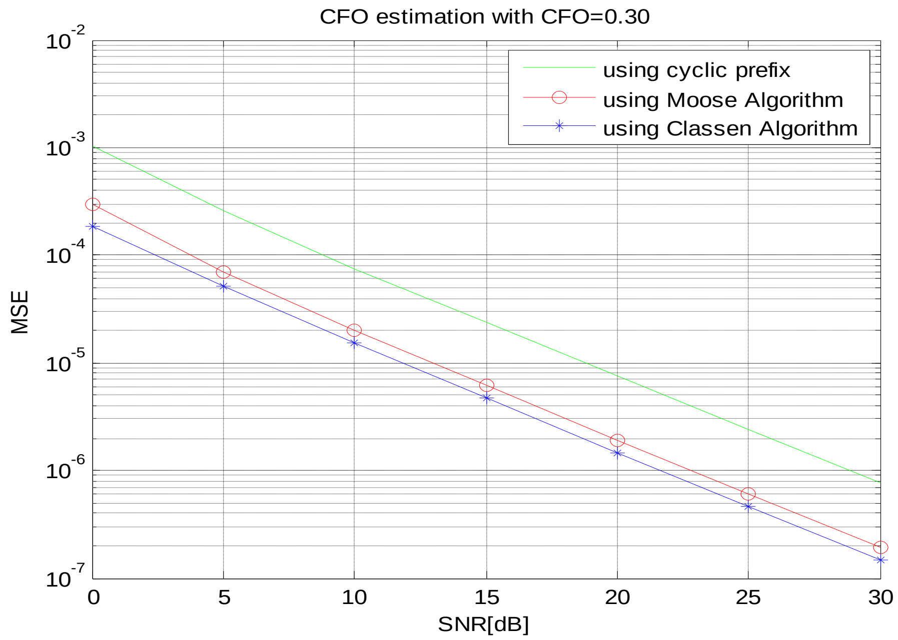

Figure 3. Simulation with CFO=0.30

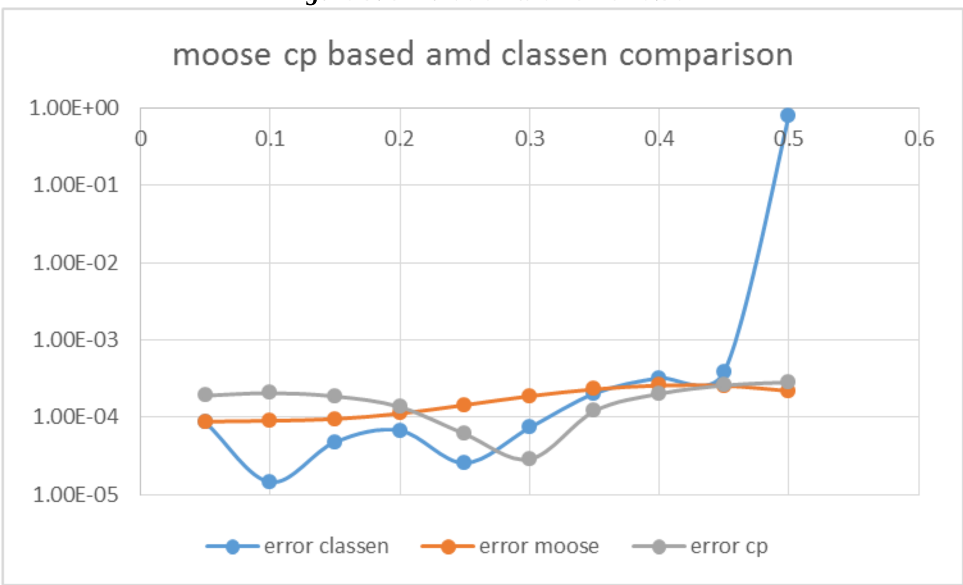

Figure 4. Error analysis of different CFO range [SNR=10 dB]

V. CONCLUSION

In this section frequency synchronization in an OFDM system is studied. Classen estimation technique gives outstanding performance compared to CP based and Moose algorithm because in classen algorithm we transmit the pilot sequence which improves the performance. But we analysis of the different CFO range and we conclude that CP and moose algorithm improve theMSE performance .

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