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Carrier Frequency Offset Estimation – A Review

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Abstract:-OFDM is a potential candidate for broadband wireless communication. One of the serious drawbacks of OFDM is the Carrier Frequency Offset (CFO) and its estimation is a fundamental problem of wireless era. Time domain and frequency domain methods are the two widely used techniques in estimation of CFO. This paper is a literature review about the techniques used for the estimation of CFO in the two domains. The study explains that in the time domain Cyclic Prefix (CP) method and the Training Sequence Method are used while in frequency domain Training Symbol method and Pilot Method are commonly used.

Keywords:-Carrier Frequency Offset (CFO), OFDM (Orthogonal Frequency Division Multiplexing), Time Domain, Frequency Domain.

I. INTRODUCTION

The wireless environment introduces a variety challenges to the physical channel of a communication system. Factors such as multi-path signal reflections, low signal strength, and interference can drastically reduce the performance of a receiver. While many of these effects can be modeled mathematically, there is a growing trend to record real world RF signals and use recorded data in place of simulation models. (1) Multipath Propagation: For wireless communications, the transmission medium is a radio channel and the signals can travel from the transmitter to the receiver through a number of different propagation paths. These signals get reflected at or diffracted by different Interacting Objects (IOs) in the environment. The number of these possible propagation paths is very large. Each of the paths has a distinct amplitude, delay, direction of departure from the transmitter, and direction of arrival; the components have different phase shifts with respect to each other etc… This will leads to fading. Certain modulation schemes such as orthogonal Frequency Division multiplexing (OFDM) and Code Division Multiple Access (CDMA) are well-suited for employing frequency diversity to provide robustness to fading. OFDM divides the wideband signal into many slowly modulated narrowband subcarriers, each exposed to flat fading rather than frequency selective fading.

(2)Interference-Limited systems: Interference is a strong term that completely dominates the system performance, so that the noise can be neglected or interference is anything which modifies, or disrupts a signal as it travels along a channel between a source and a receiver. There are different types of interferences such as electromagnetic interference (EMI), Co-channel interference (CCI), also known as crosstalk, adjacent (ACI), Inter Symbol interference (ISI),Inter Carrier Interference ICI), caused by Doppler shift in OFDM modulation (multitone modulation).

For any communication, synchronization is an inescapable part and MIMO OFDM is very sensitive to timing and frequency synchronization. Due to this sensitivity the orthogonality of the OFDM symbols may get affected and this should be preserved. The synchronization problem carries two major parts: Carrier Frequency Offset (CFO) and Symbol Time Offset (STO). Among these Carrier Frequency Offset (CFO) is the most common impairment found in a communication system which is the contributor of Inter Carrier Interference. There are mainly two causes for CFO:

We know that in a typical wireless communication system, the signal transmitted is up converted to a carrier frequency prior to modulation. The receiver is expected to tune the same carrier frequency for down converting the signal to baseband, prior to demodulation. But due to high expensive oscillator at the transmitter and low grade oscillator at the receiver side frequency mismatch occurs.

Doppler Shift is observed whenever the source is moving relative to receiver. The Doppler Shift can be described as the effect produced by a moving source in which there is an apparent upward shift in frequency for observers towards whom the source is approaching and an apparent downward shift in frequency for observers from whom the source is receding.

For estimating and compensating CFO there are time-domain (pre-FFT) as well as frequency-domain (post-FFT) approaches. Pre-FFT synchronization performs the estimation of CFO before OFDM demodulation (FFT processing). Pre-FFT synchronization can be classified into two categories: Non-data-aided (NDA) and Data-aided (DA). NDA methods

exploit correlation between the cyclic prefix and the corresponding OFDM which can estimate CFO in the range of ±0.5 subcarrier spacing. DA methods use a known sequence of OFDM training symbols inserted at the start of every OFDM packet to estimate fractional offset. This method provides better results and a wider CFO estimation range of about ±1 subcarrier spacing than the NDA method. Post-FFT synchronization methods perform the estimation of the remaining integer CFO by correlating the received pilot subcarriers with a shifted version of the known pilot sub-carriers. From all these analyzed factors, it is explicit that CFO estimation and compensation is crucial to eliminate distortions in transmission symbols. This paper is a review which describes the different techniques for CFO estimation in time and frequency domains.

II. LITERATURE REVIEW

An energy efficient MTC (Machine type communication) UE in the uplink under low network coverage is explained in [1] and show that it is enhanced by accurate frequency offset estimation. They propose Maximum Likelihood (ML) based algorithms for enhancing CFO estimation at low coverage, using repeated data transmission, pilot (Demodulation reference signal) transmission and both repeated and pilot transmissions.

A frequency offset estimation using PRACH (Physical Random Access Channel)is introduced in [2] which discusses a method to perform initial frequency offset estimation by utilizing the random access preambles detection outputs with simple additions. The coarse frequency synchronization is achieved here by reducing the complexity of detection implementation cost.

A novel architecture for timing and frequency synchronization in LTE is proposed by Ameneh Golnari in [3]. A fractional CFO is estimated at the pre-FFT period (symbol beginning) by averaging the phase difference of cyclic prefix samples. After the completion of the coarse frequency synchronization, a residual CFO still remains, which can cause serious ICI effects after a short period of time. Different frequency tracking methods were discussed in [3] such as a data aided (DA) method where the received subcarriers are compared with the expected pilot patterns subcarriers. The other possible method is using two consecutive pilot subcarriers and calculating the phase difference between them. However, this approach is not applicable to the LTE systems as each pilot subcarrier is at least five symbols away from the next pilot. Here they were proposing a method to perform the compensation either in the post-FFT domain or in both the pre-FFT and post-FFT domain having a low-complexity property of the post-FFT domain compensation along with the better performance of the time-domain compensation.

The CFO estimation and compensation techniques using Training based algorithm, Blind algorithm and Semi-blind algorithm were discussed in [4].The training sequence method limit the number of computation at the receiver side and have low computational complexity but reduce the effectiveness of the data throughput whereas Blind and Semi-blind algorithms use the statistical properties of the received signal, which will result in high computational complexity. Here they shows the advantage of Schmidt and Cox method over Moose method since it is not depending on the starting point of OFDM and also frequency synchronization is achieved in time domain. In their paper they used training sequence rather than cyclic prefix (CP) for increasing the offset range.

A novel scheme [5] in which the carrier frequency offset (CFO) and interference power on each subcarrier is jointly estimated through maximum likelihood (ML) methods. They exploit two pilot blocks in their architecture. The first one is composed of several repeated parts in the time-domain and provides a CFO estimate which may be affected by a certain residual ambiguity. The second block conveys a known pseudo-noise sequence in the frequency-domain and is used to resolve the ambiguity.

A number of approaches have dealt with CFO estimation in an OFDM. The works done by [6] proposed a joint estimation of carrier frequency offset and channel distortions in Orthogonal Frequency Division Multiplexing (OFDM) using trained sequences. They used OFDM as the potential candidate for 3G/4G technology and cooperates multiple input multiple output (MIMO) to offer a high data throughput and link range without additional bandwidth. But this data rate performance of MIMO-OFDM is sensitive to CFO which results in inter carrier interference (ICI). The method [6] describes a joint estimation of carrier frequency offset and channel distortion using two repeated sequences of OFDM symbols and proved that frequency offset and channel distortion can be solved efficiently.

At present scenario, CFO estimation has been widely studied and conventional offset method will give only a smaller estimation range. In Physical uplink control channel (PUCCH) LTE-A (Advanced) carrier frequency estimation is an urgent problem to be solved. They [7] compared different estimation technique and propose a double-iteration carrier frequency offset estimation algorithm. First, coarse estimation for CFO using pilot symbols is analyzed and compensate the signal. Then the data symbols are used for fine estimation, to compensate the signal again. By coarse estimation and fine estimation that phase ambiguity can be avoided, and reduce the impact of noise.

CFO estimation for 3GPP LTE downlink systems is discussed in [8]. Three traditional CFO estimation schemes, that is the PSS (Primary Synchronization Signals) correlation based scheme, the CP (Cyclic Prefix) based scheme, and the MUSIC(Multiple Signal Classification) based scheme, have been applied to the downlink of 3GPP-LTE. Furthermore, an extended CFO estimation algorithm based on the PSS

correlation scheme has been studied. Compared to the traditional PSS correlation based scheme, this scheme divides the correlation sequence of PSS into four parts instead of two parts.

Here, various estimation techniques like cyclic prefix, training sequence, pilot tones were studied for estimating and compensating CFO.

III. CONCLUSION

The above review shows the CFO estimations in time and frequency domain approaches in both 3G and 4G criteria's. For frequency domain estimation the general method known as Maximum Likelihood (ML) estimation is considered with modified preambles or pilot tones for increasing the estimation range. But in time domain cyclic prefix is the most commonly used method but the disadvantage is low estimation range.

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