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CARRIER FREQUENCY OFFSET ESTIMATION IN DIRECT-CONVERSION RECEIVER – A REVIEW

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Abstract - *OFDM is a systematized technique for broadband wireless systems. Nowadays, super-heterodyne receivers are replaced by direct-conversion receivers in terms of power consumption, cost and size. But the latter suffer from RF analog impairments such as I/Q imbalances which may degrade the performance. OFDM is very sensitive to the Carrier Frequency Offset (CFO) and its estimation is a major problem in wireless communication.. The aim of this paper is to discuss various literature works that are used for estimation of CFO in I/Q imbalanced direct-conversion receivers. In this paper, we first present an overview of direct-conversion receivers and thereafter we represent various CFO estimation techniques.*

***Key Words*: Multiple Input Multiple Output (MIMO), inter symbol interference (ISI), carrier frequency offset, direct-conversion, in-phase/quadrature(I/Q) imbalance, orthogonal frequency division multiplexing (OFDM).**

1. INTRODUCTION

There are various techniques developed to meet the increasing demands for higher data rate and better services. One of the technique is the Multiple Input Multiple Output (MIMO) technology, which is predominantly used in wireless broadband systems. This technology is mainly used as it improve the system's performance by increasing its data throughput and spectral efficiency. MIMO exhibits frequency selective fading and therefore result in Inter Symbol Interference (ISI). Eventhough MIMO adds complexity to the system in terms of processing, it allows far high data rates to be achieved along with better spectral efficiency. A multicarrier modulation technique such as orthogonal frequency division multiplexing (OFDM) converts the frequency-selective channel into a set of parallel flat fading channels and is therefore a captivating way of coping with ISI. OFDM has many advantages including its robustness to multipath fading and interference. OFDM are being used in many broadband wireless standards (e.g. DVB-T, IEEE 802.11a/g, IEEE 802.16a). The combination of MIMO-OFDM and high order modulations imposes stringent requirements on RF devices. In terms of the receiver architecture, recently there has been an interest in direct-conversion receivers (DCR) as they offer significant advantages over super-heterodyne receivers. In super-heterodyne receivers, the received RF signal is converted to a lower intermediate frequency by mixing with local oscillator, amplified before shifting to baseband. Signal amplification at an intermediate frequency (IF) stage, however requires IF filters to be biased with large current causing substantial power dissipation. Furthermore, these filters use many off-chip passive components adding to receiver cost and size.

Although the DCR has many advantages over super-heterodyne receivers, it possess a disadvantage of in-phase/quadrature (I/Q) imbalances. One is the amplitude and phase mismatches generated by the phase shifters at the output of the local oscillators at the transmitter and receiver. These mismatches cause an image interference which degrades the detection of data. The parameters of local oscillator I/Q mismatches are assumed to be constant over the whole bandwidth. The other is the time impulse response mismatch of the filters at the transmitter and receiver which cause a frequency dependent I/Q imbalance that must be estimated and compensated per carrier.

Synchronization is one of the most important design constraint that have to be considered for any communication. The advantage of OFDM, in combating the frequency selectivity of the channel can be fully achieved only if the transmitter and the receiver are synchronized in both time and frequency. Poor synchronization in either the time or frequency domain can result in inter symbol interference or inter carrier interference, which in turn can result in a severe degradation of performance. MIMO OFDM is sensitive to timing and frequency synchronization as the orthogonality of the OFDM symbols can be lost. Carrier Frequency Offset (CFO) and Symbol Time Offset (STO) are the main synchronization problems. Among these two, Carrier Frequency Offset is the major problems that will result in inter carrier interference in a system and thereby degrading the bit error rate performance. There are two types of distortions that arise while down-converting the RF signal to baseband signal. One is the phase noise which arises due to instability of local oscillators at the transmitter and receiver and other is the CFO caused by Doppler frequency shift due to relative motion between transmitter and receiver. The normalized CFO can be divided into two parts: integral CFO and fractional CFO. Integral frequency offset (IFO) produce a cyclic shift but does not affect the orthogonality of the subcarrier frequency components. But the fractional frequency offset (FFO) destroys the orthogonal properties of subcarriers and will lead to inter carrier interference. Therefore, the estimation and compensation of CFO is an integral part of any communication system as the orthogonality of subcarrier frequency components can be preserved. The conventional CFO estimation techniques cannot work accurately on a DCR architecture.

This paper is a review that describes the different techniques for CFO estimation in an I/Q imbalanced direct-conversion receivers.

2. LITERATURE REVIEW

A novel CFO estimator for I/Q imbalanced direct-conversion receiver is discussed in [1]. Here, the useful signal component and its mirror image are considered as two independent sources embedded in noise and have opposite CFO values. The approach used here is based on ESPRIT algorithm and the conventional training preamble is formed by the repetition of a given pilot sequence. The sign ambiguity which affects the CFO estimate in the presence of I/Q imbalance, is removed by passing the received samples into two filters matched to the estimated CFO values and selects the filter having highest output power.

A low complexity maximum likelihood channel estimator using a pilot sequence design criterion is discussed in [2]. Based on the specified pilot sequence both the channel and I/Q frequency dependent imbalance coefficients can be estimated. Based on both estimates, the compensation is done by using a low complexity two tap frequency domain equalizer.

A cost-effective carrier frequency offset estimation algorithm using the preamble in IEEE 802.11a standard is discussed in [3]. Here the frequency offset can be estimated by using the short OFDM symbols very accurately. The estimation performance is independent of I/Q imbalance.

Adaptive compensation algorithm that considers both transmitter and receiver I/Q imbalance under carrier frequency offsets in an OFDM system developed by Tandur is discussed in [4]. The algorithm is very efficient and used to correct the distortions in digital domain.

A pilot-based scheme for compensation of both carrier frequency offset and I/Q imbalance is explained in [5]. A low cost nonlinear least square frequency estimator is used due to its robustness to the I/Q imbalance. An FIR filter along with an asymmetric phase compensator has been developed to compensate both I/Q imbalances.

A space-alternating generalized expectation-maximization (SAGE) algorithm for estimation of CFO in OFDM direct-conversion receivers is explained in [6]. The scheme exploits a conventional OFDM training preamble formed by the several repeated parts. The algorithm provides improved CFO estimate with reduced complexity.

The CFO estimators that uses the specialized periodic structure of the preamble sequence is discussed in [7]. The method does not require any knowledge about the channel impulse response and the exact value of the training samples. A new LLS algorithm is used to estimate the parameters of the I/Q imbalance.

3. CONCLUSIONS

The aim of this paper is to provide a detailed description on various CFO estimation methods used in OFDM direct-conversion receivers. Carrier Frequency Offset is the major drawback of OFDM and its estimation is serious issue in wireless communication. Estimation of frequency offset in an I/Q imbalanced direct-conversion receiver proves to be an interesting research area.

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