Adaptive Channel Estimation Technique in MIMO-OFDM System for LTE Uplink

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Abstract—Third generation partnership project (3GPP) long term evolution (LTE) uses single carrier frequency division multiple access (SC-FDMA) in uplink transmission and multiple input multiple output orthogonal frequency division multiple access (MIMO-OFDM) scheme for the downlink. A variable step size based least mean squares (LMS) algorithm is formulated for a single carrier frequency division multiple access (SC-FDMA) system, in its channel estimation (CE). From the simulation, it is found that the convergence speed of the NLMS algorithm is faster than the RLS and LMS algorithm.

Keywords: - LMS, NLMS, LTE, Uplink, MIMO-OFDM

I. INTRODUCTION

The significant expansion seen in mobile and cellular technologies over the last two decades is a direct result of the increasing demand for high-data-rate transmissions over bandwidth and power limited wireless channels. This requirement for high data rates results in significant inter symbol interference (ISI) for single carrier systems, and therefore requires the use of robust coding and powerful signal processing techniques in order to overcome the time and frequency selective natures of the propagation channel. In recent years orthogonal frequency division multiplexing (OFDM) has been proposed as an efficient high data rate solution for wireless applications. Particular examples include the physical layer of high-performance wireless local area networks (WLANs), such as the 802.11a/g/n, DVB-T/H, and 802.16 WiMAX standards. This trend has occurred since OFDM offers excellent performance in highly dispersive channels with low terminal complexity. The Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) radio access standard is based on shared channel access providing peak data rates of 75 Mb/s on the uplink and 300 Mb/s on the downlink. A working assumption in the LTE standard is the use of orthogonal frequency-division multiple access (OFDMA) on the downlink. This supports different carrier bandwidths (1.25–20 MHz) in both frequency-division duplex (FDD) and time-division duplex (TDD) modes [2]. OFDMA is an OFDM-based multiple access scheme [1] that provides each user with a unique fraction of the system bandwidth. OFDMA is highly suitable for broadband wireless access networks (particularly the downlink) since it combines scalability, multipath robustness, and multiple input multiple-output (MIMO) compatibility [1]. OFDMA is sensitive to frequency offset and phase noise, and thus requires accurate frequency and phase synchronization. In addition, OFDMA is characterized by a high transmit PAPR, and for a given peak-power-limited amplifier this results in a lower mean transmit level. For these reasons, OFDMA is not well suited to the uplink transmission. Single carrier FDMA (SC-FDMA), also known as discrete Fourier transform (DFT) precoded OFDMA, has been proposed in the LTE standard for the uplink. PAPR reduction is motivated by a desire to increase the mean transmit power, improve the power amplifier efficiency, increase the data rate, and reduce the bit error rate (BER). This comes at the expense of cost, complexity, and efficiency. OFDM has become a most favored technique for broadband wireless system due to susceptibility to signal dispersion under multipath conditions. OFDM can also be viewed as a multi-carrier narrowband system where the whole system bandwidth is split into multiple smaller subcarriers with simultaneous transmission. Simultaneous data transmission and reception over these subcarriers are handled almost independently. Each subcarrier is usually narrow.
enough that multipath channel response is flat over the individual subcarrier frequency range, i.e. frequency non-selective. Another way to look at is that an OFDM symbol time is much larger than the typical channel dispersion. Hence OFDM is inherently susceptible to channel dispersion due to multipath propagation.

II. ADAPTIVE FILTER

When the channel changes very quickly, we can use adaptive filtering technique to track the channel. Recursive algorithm is often used for filter coefficients in the adaptive filtering algorithms to minimize the error between expected value and received value. The channel can be represented by a linear delay model. Therefore, the problem of channel estimation can be solved with the adaptive filter [5]. The diagram of adaptive filter is shown in Figure 1.

![Adaptive filter diagram](image)

III. OVERVIEW OF OFDM AND MIMO

- **OFDM**

Orthogonal frequency-division multiplexing (OFDM) is a method of digital modulation in which the data stream is split into N parallel streams of reduced data rate with each of them transmitted on separate subcarriers. In short, it is a kind of multicarrier digital communication method. OFDM has been around for about 40 years and it was first conceived in the 1960s and 1970s during research into minimizing interference among channels near each other in frequency [2]. OFDM has shown up in such disparate places as asymmetric DSL (ADSL) broadband and digital audio and video broadcasts. OFDM is also successfully applied to a wide variety of wireless communication due to its high data rate transmission capability with high bandwidth efficiency and its robustness to multi-path delay [7-8].

The basic principle of OFDM is to split a high data rate streams into a number of lower data rate streams and then transmitted these streams in parallel using several orthogonal sub-carriers (parallel transmission). Due to this parallel transmission, the symbol duration increases thus decreases the relative amount of dispersion in time caused by multipath delay spread. OFDM can be seen as either a modulation technique or a multiplexing technique.

![Comparison between conventional FDM and OFDM](image)

- **MIMO**

MIMO has been developed for many years for wireless systems. One of the earliest MIMO to wireless communications applications came in mid-1980 with the breakthrough developments by Jack Winters and Jack Saltz of Bell Laboratories [9]. They tried to send data from multiple users on the same frequency/time channel using multiple antennas both at the transmitter and receiver. Since then, several academics and engineers have made significant contributions in the field of MIMO. Now MIMO technology has aroused interest because of its possible applications in digital television, wireless local area networks, metropolitan area networks and mobile communication. Comparing to the Single-input-single-output (SISO) system MIMO provides enhanced system performance under the same transmission conditions. First, MIMO system greatly increases the channel capacity, which is in proportional to the total number of transmitter and receiver arrays. Second, MIMO system provides the advantage of spatial variety: each one transmitting signal is detected by the whole detector array, which not only improved system robustness and reliability, but also reduces the impact of ISI (inter symbol interference) and the channel fading since each signal determination is based on N detected results. In other words, spatial diversity offers N...
independent replicas of transmitted signal. Third, the Array gain is also increased, which means SNR gain achieved by focusing energy in desired direction is increased.

- **MIMO-OFDM**

OFDM reduces BER performance and ISI with using multiplexing and modulation techniques to get higher data rate over wireless channels, the use of multiple antennas at both ends of the wireless link provide better performance. The MIMO technique does not require any extra transmission power and bandwidth. Therefore, the promising way to increase the spectral efficiency of a system, the combination of MIMO and OFDM is used over fading channels [10-11].

**IV. SPACE TIME BLOCK CODE**

Multiple-Input Multiple-Output uses multiple antennas at both sides which provides transmit diversity and receiver diversity. It’s applicable in every kind of networks like PAN, LAN, WLAN, WAN, MAN. MIMO system can be applied in different ways to receive either a diversity gain, capacity gain or to overcome signal fading.

Space-frequency coding basically extends the theory of space-time coding for narrowband flat fading channels to broadband time-variant and frequency-selective channels. The application of classical space-time coding techniques for narrowband flat fading channels to OFDM seems straightforward, since the individual subcarriers can be seen as independently flat fading channels. However, it was shown that the design criteria for space-frequency codes operating in the space-time and frequency domain are different from those for classical space-time codes for narrowband fading channels as introduced in. When operating in frequency selective fading channels, the application of conventional decoding algorithms results in a significant performance decrease [12]. This is due to the fact that the equivalent channel matrix is no longer orthogonal. Consequently, independent decoding of the two transmitted symbols, as in conventional decoding algorithms, is no longer appropriate.

**V. LMS ALGORITHM**

Least mean squares (LMS) algorithms are class of adaptive filter used to mimic a desired filter by finding the filter coefficients that relate to producing the least mean squares of the error signal (difference between the desired and the actual signal). It is a stochastic gradient descent method in that the gradient of the mean square error, the weights are updated. That is, if the MSE-gradient is positive, it implies, the error would keep increasing positively, if the same weight is used for further iterations, which means we need to reduce the weights. In the same way, if the gradient is negative, we need to increase the weights. So, the basic weight update equation is:

\[ w_{n+1} = w_n - \mu\Delta e[n] \]

Where, \( \varepsilon \) represents the mean-square error. The negative sign indicates that, we need to change the weights in a direction opposite to that of the gradient slope. LMS algorithm summary: The LMS algorithm [1] for a p th order algorithm can be summarized as Parameters: \( P = \) filter order \( \mu = \) step size Initialization: \( \hat{h}(0) = 0 \)

Computation:

For \( n = 0, 1, 2, \ldots \)

\( X(n) = [x(n), x(n - 1), \ldots, x(n - p + 1)]^T \)

\( e(n) = d(n) - \hat{h} H(n) X(n) \)

\( \hat{h}(n+1) = \hat{h}(n) + \mu e(n) X(n) \)

**NLMS ALGORITHM**

The main drawback of the "pure" LMS algorithm is that it is sensitive to the scaling of its input. This makes it very hard to choose a learning rate \( \mu \) that guarantees stability of the algorithm. The Normalised least mean squares (NLMS) filter [6], [7] is a variant of the LMS algorithm [1] that solves this problem by normalising with the power of the input. NLMS algorithm summary: Parameters: \( P = \) filter order \( \mu = \) step size Initialization: \( \hat{h}(0) = 0 \) Computation:

For \( n = 0, 1, 2, \ldots \)

\( X(n) = [x(n), x(n - 1), \ldots, x(n - p + 1)]^T \)

\( e(n) = d(n) - \hat{h} H(n) X(n) \)

\( \hat{h}(n+1) = \frac{\hat{h}(n) + \mu e(n) X(n)}{\|X(n)\|^2} \)

The TVLMS algorithm has shown better performance than the conventional LMS algorithm in terms of faster convergence and less mean square error. The TVLMS algorithm is based on utilizing a time varying convergence parameter with general power for LMS algorithm. The basic idea of TVLMS algorithm is to utilize the fact that the LMS algorithm need a large convergence parameter value to speed up the convergence of the filter coefficient to their optimal values, the convergence parameter should be small for better accuracy. In other words, we set the convergence parameter to a large value in the initial state in order to speed up the algorithm convergence. As time passes, the parameter will be adjusted to a small value so that the adaptive filter will have a smaller mean squared error.

**VI. SIMULATION RESULT**

In this section, we will build the STBC-MIMO-OFDM platform based on MATLAB, then, we will apply these two algorithms in the platform respectively. The simulation parameters are listed as follows: transmitter antennas=2, receiver antennas=2, subcarriers number=64, fourier length=64, modulation mode is QPSK, cyclic prefix length=16, max time delay=25ns, sampling
frequency=80MHz, the simulation channel is frequency selective
rayleigh fading channel. Next, we will compare the performance of
these two algorithms in the Figure 3 and Figure 4 by BER and MSE.
Figure 3 is the BER curve.
From the Figure 3, we can see that with the increase of
Eb/No, the BER performance of these two algorithms will
be smaller and smaller, and its performance is similar
before Eb/No=9.

VII. CONCLUSION
In this paper we considered the problem of distributed
adaptive estimation over communication system. We
enhanced the diffusion LMS implementation with linear
combiner model. In the proposed algorithm, the step-size
parameter the coefficients of linear combiner are adjusted
according to estimated observation noise variances. This paper
discusses the NLMS, RLS and LMS algorithms in STBC MIMO-
OFDM system and compares these two algorithms with MATLAB.
From the simulation results, we can see that the convergence speed
of NLMS algorithm is better than RLS and LMS algorithm.

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