An Improved Channel Estimation Algorithm in the LTE-A System *

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Abstract -LTE-A [1] (Long Term Evolution Advanced) is a subsequent evolution of LTE. Compared with LTE, LTE-A will support a larger bandwidth, higher spectrum efficiency and higher peak rate. LTE-A introduce carrier aggregation, multi-point collaborative transmitting/receiving, multiple antennas, wireless relay and other key technologies. LTE-A uses the key technology of much higher levels of MIMO, and improve the anti-interference ability of system. Based the Successive Over-relaxation iterative algorithms, this paper pro posed an improved LMMSE algorithm. Simulation results show that improved LMMSE method can not only reduces the implementation complexity, but also has superior performance.

Index Terms - LTE-A; LMMSE; Improved LMMSE;

1. Introduction

In order to achieve the purpose of 4G communications, LTE-A version supports a variety of new features compared to LTE. Such as CoMP(Coordinated Multiple Point) transmission, strengthen MIMO transmission, etc. From the perspective of channel estimation, the MU-MIMO transmission is the biggest difference between LTE-A and LTE. In order to take advantage of MU-MIMO transmission, additional degrees of freedom should be considered in time domain. The introduction of MIMO [2] technology can improve the system throughput, and meet the requirements of the users. As the channel of LTE is without any rule, we should obtain the information of channel through the appropriate method and ensure effective equalization. At the same time, we should ensure the amount of calculation is small.

The performance of the wireless communication system [3] is mainly restricted and impacted by the wireless channel. As the signal which is through wireless channel is affected by multi-path channel and frequency selective fading, the signal that we received will be distorted. An excellent channel estimation algorithm is especially important for the performance of communication system. The channel estimation algorithm that introduced in this paper is on the basis of non-blind estimation [6], and uses the pilot that defined in the LTE system to estimate. The classic algorithm is LS algorithm and LMMSE algorithm. The LS algorithm is simple, but does not take into account the channel noise. The complexity of traditional LMMSE algorithm [4] is very high, and it's difficulty to realize. Based on successive over-Relaxation iteration algorithm that is used to solve linear equations, this paper improves LMMSE algorithm. The improved algorithm guarantees the performance and reduces the computational complexity.

2. MIMO technology in LTE-A system

The downlink of LTE-A system the highest support 8T8R antennas. The data of transmitting terminal is decomposed into several parallel data streams, and then coding, modulation, precoding and mapping. At last, send out the data streams from each antenna. Because each data stream has orthogonality in space, according to the unique feature (angle of arrival, the frequency distribution characteristics, etc.), the receiver antenna will separate data streams. Then do a series of corresponding processing at the receiving end, and work out source information.

MIMO technology is generally called technology that dependent on the use of multiple transmit/receive antennas. MIMO technology can improve the utilization rate of frequency and exponentially increase the capacity of communication system under the condition of without increasing bandwidth. OFDM technology has a strong advantage in frequency selective channel. The high-speed data stream is transformed to serial low-speed data streams through the string/and transformation with OFDM technology. Then add CP &IFFT transformation. The period length of each symbol in channel is lengthened, and is far greater than the longest Multi-path time delay. At last, avoid the inter-symbol interference.

3. Frequency-domain Wiener Filtering Algorithm LMMSE

The channel estimation of LTE-A is based on the blind estimation. Insert pilot on the transmitting terminal, and according to the received pilot and local pilot, we can do channel estimation on the receiver terminal. As the mean square error (MSE) of using LMMSE algorithm in AWGN [8] channel is minimum, LMMSE algorithm is widely used in channel estimation. The channel frequency response (CFR) which uses the frequency-domain wiener filtering of autocorrelation matrix is

$$\hat{H}_{LMMSE} = R_{HH}(R_{HH} + I\frac{\beta}{SNR})^{-1}\hat{H}_{LS} \quad (1)$$

$\beta = E\{|x_k|^2\}E\{|1/x_k|^2\}$. It is a constant that determined by the constellation chart of modulation signal. When the modulation method is QPSK, β is equal to 1. When the

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modulation method is 16QAM, β is equal to $9/16$. We generally take 1, and it has little impact on the performance of the algorithm. When the base-band symbol transmits with QPSK modulation mode, we take $R_{H_pH_p}$ as the autocorrelation function of pilot sub-carrier. After receive OFDM symbols which include pilot sub-carrier, we can do wiener filtering channel estimation of frequency domain.

$$R_{H_pH_p} = [r_{a,b}],$$

$$r_{a,b} = \frac{1-e^{-L((1/\tau_{rms})+2\pi j(a-b)/N_p)}}{\tau_{rms}(1-e^{-(L/\tau_{rms})})(\frac{1}{\tau_{rms}}+2\pi j(a-b)/N_p)} \tag{2}$$

a and b are the position of pilot sub-carrier. τ_{rms} is the normalized rms time delay. L is the most and normalized multi-path time delay. N_P is the number of pilot in one OFDM symbol. Thus, LMMSE algorithm has a good performance in the case that channel characteristic changes slowly.

4. Improved LMMSE algorithm

In order to further improve the performance of the system, the paper proposed a algorithm with a low complexity and which's performance is better than LMMSE algorithm. The algorithm is based on the successive over-relaxation iterative algorithm which is used to solve liner equation.

A. Gauss-Seidel [5] iterative algorithms

Suppose an equation $Ax=b$,

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2 \\ \vdots \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = b_n \end{cases} \tag{3}$$

A is non-singular matrix, and $a_{ii} \neq 0, i=1,2,\cdots,n$.We can obtain that:

$$x_i = \frac{1}{a_{ii}}(b_i - \sum_{j=1, j\neq i}^{n} a_{ij}x_j) \tag{4}$$

The corresponding iterative formula is:

$$x_i^{(k+1)} = \frac{1}{a_{ii}}(b_i - \sum_{j=1}^{i-1} a_{ij}x_j^{(k+1)} - \sum_{j=i+1}^{n} a_{ij}x_j^{(k)}) \tag{5}$$

$i=1,2,\cdots,n$. k is the number of iteration. The formula is called Gauss-Seidel iteration.

B. Successive Over-relaxation iterative algorithms [5]

The successive over-relaxation iteration is the most commonly used method that solves linear equations at present and is also called SOR. It is an accelerated method of Gauss-Seidel iteration.

$x^{(k)}$ is the k-th iteration vector and $x^{(k+1)}$ is the (k+1)-th iteration vector. The i-1 vectors of it are $x_1^{(k+1)}$,…., $x_{i-1}^{(k+1)}$. When calculate $x_{i-1}^{(k+1)}$, we use 1 to calculate

$$\tilde{x}_i^{(k+1)} = \frac{1}{a_{ii}}(b_i - \sum_{j=1}^{i-1} a_{ij}x_j^{(k+1)} - \sum_{j=i+1}^{n} a_{ij}x_j^{(k)}) \tag{6}$$

And then use w to do weighted average of $x_i^{(k)}$ and $\tilde{x}_i^{(k+1)}$

$$x_i^{(k+1)} = w\tilde{x}_i^{(k+1)} + (1-w)x_i^{(k)} = x_i^{(k)} + w(\tilde{x}_i^{(k+1)} - x_i^{(k)}) \tag{7}$$

Finish (6)(7), we can obtain the iterative formula:

$$x_i^{(k)} = (1-w)x_i^{(k)} + \frac{w}{a_{ii}}(b_i - \sum_{j=1}^{i-1} a_{ij}x_j^{(k+1)} - \sum_{j=i+1}^{n} a_{ij}x_j^{(k)}) \tag{8}$$

$i=1,2,\cdots,n$. This is Successive Over-relaxation iteration method. It's called SOR for short. And w is called the relaxation factor. If w=1, it is Gauss-Seidel iteration method.

$$D = \begin{bmatrix} a_{11} & & & \\ & a_{22} & & \\ & & \ddots & \\ & & & a_{nn} \end{bmatrix} \quad L = \begin{bmatrix} 0 & & & \\ -a_{21} & 0 & & \\ \vdots & \vdots & \ddots & \\ -a_{n1} & -a_{n2} & \cdots & 0 \end{bmatrix} \quad U = \begin{bmatrix} 0 & -a_{12} & \cdots & -a_{1n} \\ & 0 & \cdots & -a_{2n} \\ & & \ddots & \vdots \\ & & & 0 \end{bmatrix}$$

Order $A=D-L-U$, L is lower triangular matrix, and U is upper triangular matrix.

We can rewrite equation set $Ax=b$ to

$$x = D^{-1}(L+U)^{-1}x + D^{-1}b. \tag{9}$$

And the formula (8) is rewrited

$$x^{(k+1)} = (1-w)x^{(k)} + wD^{-1}(b + Lx^{(k+1)} + Ux^{(k)}) \tag{10}$$

At last we can obtain a formula:

$$x^{(k+1)} = (D-wL)^{-1}[(1-w)D + wU]x^{(k)} + w(D-wL)^{-1}b = B_w x^{(k)} + f \tag{11}$$

$$B_w = (D-wL)^{-1}[(1-wD+wU)], f_w = w(D-wL)^{-1}b \tag{12}$$

B_w is iterative of SOR. When calculate it, we can set the value of the initial iteration point and the termination condition.

C. Improved LMMSE algorithm

Traditional LMMSE algorithm:

$\hat{H}_{LMMSE} = R_{HH}(R_{HH} + I\frac{\beta}{SNR})^{-1}\hat{H}_{LS}$, $\hat{H}_{LS}$ is calculated by using LS algorithm. Structure the form of linear equations $Ax=b$:

$$\hat{H}_{LS} = (R_{HH} + I\frac{\beta}{SNR})R_{HH}^{-1}\hat{H}_{LMMSE} \tag{13}$$

R_{HH} is the unitary matrix, and $R_{HH}^{-1} = R_{HH}^{H}$. Therefore, formula (11) is simplified:

$$\underbrace{\hat{H}_{LS}}_{b} = \underbrace{(E + \frac{\beta}{SNR}R_{HH}^{H})}_{A}\underbrace{\hat{H}_{LMMSE}}_{x} \circ \tag{14}$$

The correlation matrix of channel R_{HH} is related to the statistical features of channel.

$$R_{HH} = E\{HH^H\} = [R(m-n)] \tag{15}$$

$$R(m-n)=\frac{1-e^{-L((1/\tau_{rms})+2\pi j(m-n)/N)}}{\tau_{rms}(1-e^{-(L/\tau_{rms})})(\frac{1}{\tau_{rms}}+2\pi j(m-n)/N)} \tag{16}$$

R_{HH} is normal matrix.

$$R_{HH}=\begin{bmatrix} R(0) & R(1) & \cdots & R(n-1) \\ R(-1) & R(0) & \cdots & R(n-2) \\ \vdots & \vdots & \ddots & \vdots \\ R(-n+1) & R(-n+2) & \cdots & R(0) \end{bmatrix} \tag{17}$$

$R(0)=1$ and $R(i)=R^*(-i)$

$$D=\begin{bmatrix} 1+\frac{\beta}{SNR} & & & \\ & 1+\frac{\beta}{SNR} & & \\ & & \ddots & \\ & & & 1+\frac{\beta}{SNR} \end{bmatrix}$$

$$L=\begin{bmatrix} 0 & & & \\ -\frac{\beta}{SNR}R^*(1) & 0 & & \\ \vdots & \vdots & \ddots & \\ -\frac{\beta}{SNR}R^*(n-1) & \cdots & -\frac{\beta}{SNR}R^*(1) & 0 \end{bmatrix}$$

$$U=\begin{bmatrix} 0 & -\frac{\beta}{SNR}R^*(-1) & \cdots & -\frac{\beta}{SNR}R^*(-n+1) \\ & 0 & \cdots & -\frac{\beta}{SNR}R^*(-n+2) \\ & & \ddots & \vdots \\ & & & 0 \end{bmatrix}$$

It is observed that L is equal to U^H. The value of $R(0),R(1),\cdots,R(N-1)$ is calculated by using software. And we put them in the memory. When work out all the value of $\hat{H}_{LMMSE}$, use $\hat{H}_{LMMSE}$ to update the data of the position of $\hat{H}_{LS}$. According to the formula (10), repeated iteration until to find the optimal $\hat{H}_{LMMSE}$. According to the needs of the project and the performance of the hardware, we can set up the corresponding number of iterations. In theory, the more the number of iterations, the better the performance of channel estimation. But the number of cycles is also more.

5. The simulation design and analysis

The simulation design is based on the downlink. In this paper, take four transmitting antennas and four receiving antennas as example, simulate the performance of the two kinds of channel estimation algorithms in EPA (Extended Pedestrian A) channel conditions of LTE-A system. The parameters of simulation environment: QPSK modulation, cell reference signal, space-frequency coding and the number of simulation is 1000.

The specific steps of simulation: Firstly, according to the mapping rules, we should extract cell reference signal. Secondly, according to the volume of RB, generate the local cell reference signal. Thirdly, calculate the channel impulse response of pilot $\hat{H}_{LS}$ using the LS algorithm. Fourthly, use the Successive Over-relaxation iteration method to calculate $\hat{H}_{LMMSE}$. Fifthly, $\hat{H}_{LMMSE}$ take the place of $\hat{H}_{LS}$, and continue to iterative until the number of iteration. At last, calculate the channel impulse response of data using interpolation method.

Fig.1 compares the BER performance of LMMSE algorithm and improved LMMSE algorithm. From the Fig.1, we can see that the BER performance of improved LMMSE algorithm is superior to the BER performance of the traditional LMMSE algorithm.

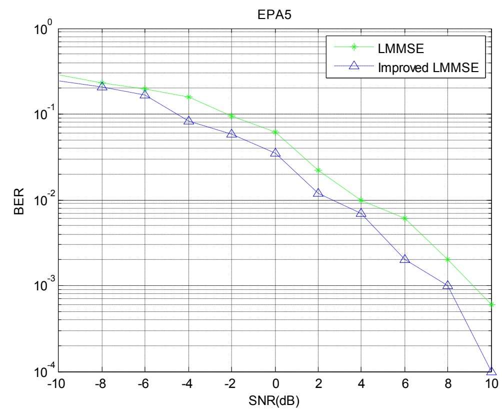

Fig. 1 performance curve of channel estimation

6. Conclusion

Based on the successive over-relaxation algorithm which is used to solve linear equations, this paper proposes an improved LMMSE algorithm. Then, compared the performance of LMMSE algorithm and improved LMMSE algorithm in the downlink LTE-A system. Compared with LMMSE algorithm, the performance of the improved LMMSE algorithm is improved. The complexity of the improved LMMSE algorithm proposed in this paper is much lower than traditional LMMSE algorithm.

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