IMPLEMENTATION OF ADVANCED TWO-DIMENSIONAL INTERPOLATION-BASED CHANNEL ESTIMATION FOR OFDM SYSTEMS

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ABSTRACT

In this paper, we show an implementation of orthogonal frequency-division multiplexing (OFDM) systems including advanced Two-Dimensional (2D) interpolation-based channel estimation. The presented channel estimation technique improves the performance of OFDM system in terms of bit error rate (BER). The technique is based on planar equations to find accurate channel information of carriers in the edge of the user burst area. We have implemented proposed channel estimation technique using Digital Signal Processor (DSP), TMS320C6416T. The performance of proposed system is verified through Matlab® simulations in various signal environments and is compared with the performance of system including conventional channel estimation.

1. INTRODUCTION

The IEEE 802.16e, which is the telecommunication standard based on OFDM, provides internet service of high data rate on moving. To provide high-speed multimedia services, the specification includes multiple-antenna technology that can increase data throughput. The MIMO technique, using multiple antennas at transmitter and receiver, increases data throughput without additional frequency allocation or increase of transmit power. However, channel estimation at MIMO system is more complex than at SISO system which has a transmit antenna and a receive antenna, due to features of the cluster structure. To avoid above the disadvantage, many algorithms for channel estimation are invented.
In the MIMO system, since a symbol of a cluster has only a pilot, we should take the channel information at pilot frequency in adjacent symbol, and then calculate the channel information at data frequency by linear interpolating of channel information at pilot frequency. In high-speed mobile communication environment, the accuracy of previous channel estimation is decreased due to the Doppler effect. Channel estimation by linear interpolation in time axis instead of copying adjacent pilots is more accuracy. After the process in time axis, there is another linear interpolation process at frequency in each symbol. Two-step linear interpolation is named the 2D(dimension) linear interpolation. The 2D interpolation, however, need extrapolation at the edge of a user burst area. Therefore, the BER performance at the edge of burst area is worse than another area. To make up for these shortcomings, we propose an advanced 2D interpolation technique. The technique has efficiency for more accurate channel information of subcarriers at edge .We can expect better performance.
Then, we implement the advanced 2D interpolation technique using DSP boards. Last, we compare two simulation results on the test platform and a computer. Usually, the BER performance of test platform simulation is worse than that of computer.

2. SYSTEM MODELING

2.1 MIMO system in IEEE 802.16e

Firstly, introduce the MIMO system model in mobile WiMAX environment based on IEEE 802.16e.

2.1.1 MIMO system
The MIMO system which has multiple transmit antennas and multiple receive antennas can have diversity gain or increase data throughput by adaptive multiple-antenna techniques. Space time coding (STC) technique has diversity and spatial multiplexing (SM) technique has higher throughput. In this paper, only SM is considered.

2.1.2 Spatial Multiplexing
SM is the technique which transmits independent signals in the same time at different transmit antennas, so it can increase data throughput of system without additional frequency bandwidth. The serial input sequence is converted to the parallel sequences through SM encoder. At SM detector of receiver, the transmit symbols are detected from received signals by some appropriate algorithms.
There are various MIMO detection algorithms, such as maximum likelihood (ML) detection algorithm and zero

forcing (ZF) detection algorithm and so on. ML algorithm has the optimum performance. It finds the right transmit symbol which has a maximum value of correlation between a received signal and the transmit symbol from all available transmit symbols. However, to estimate a transmit symbol which has maximum correlation value, it needs lots of computations. For ZF algorithm, the detector is set to the inverse of channel matrix. It has lower computation complexity than ML, but bad spatial channel severely amplify the noise and the performance of ZF is not good.

2.2 Channel estimation

2.2.1 2D linear interpolation

Although MIMO has better performance than SISO system, it has disadvantage at channel estimation, due to the cluster structure at MIMO system. The cluster structure for MIMO system using two transmit antenna is shown in Figure 1.

A cluster consists of 28 subcarriers. There are 14 subcarriers in frequency axis, it makes a symbol. In time axis, two symbols are included in a cluster. For SISO system, there are 4 pilots in a cluster, two pilots per a symbol. For MIMO system concerned in this paper, only a pilot exists per symbol, exactly two pilots in a cluster. It means that information for channel estimation decrease to half. To make up for weakness 2D interpolation algorithm is invented. Linear interpolation, in time axis is using the pilots in the same subcairriers of every four symbols. Then, do the linear interpolation in the frequency axis using four channel information, one of them is channel information from the pilot in the symbol, the other three are from the linear interpolation in time axis.

2.2.2 Advanced 2D interpolation

The 2D interpolation needs to do extrapolation at the edge of a user burst area. Therefore, the BER performance at the edge of burst area is worse than another area. To insure a better BER performance than 2D interpolation, we propose the advanced 2D interpolation using planar equation replacing extrapolation techniques at the edge area. Figure 2 is a description of the advanced 2D interpolation channel estimation algorithm at 2×2 MIMO system.

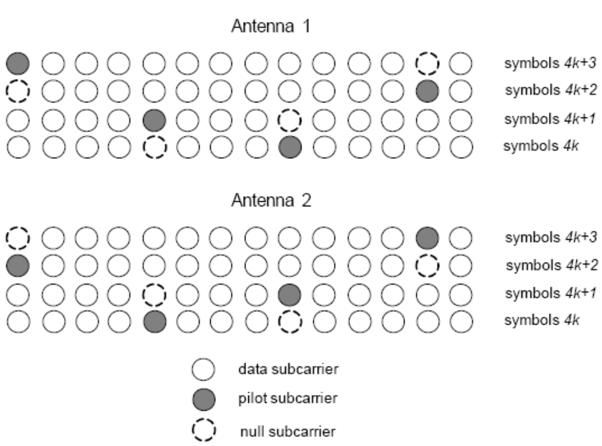

Figure 1 A cluster structure for MIMO system using two transmit antennas

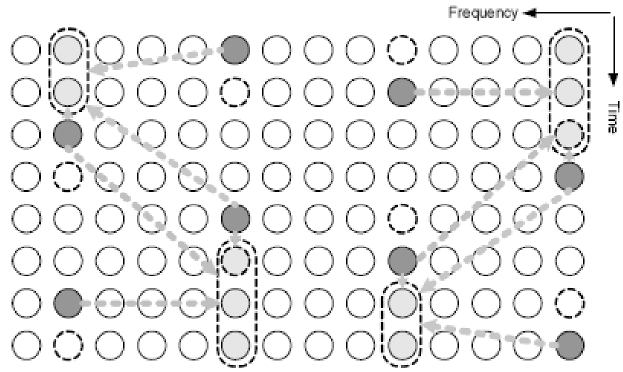

Figure 2 The advanced 2D interpolation channel estimation algorithm in 2×2 MIMO system

3. FIXED-POINT DESIGN

3.1 System block diagram

The transmit data in Matlab are floating-point variables, but the test platform computes only fixed-point variables. So, the floating-point variables should be changed to fixed-point. Figure 3 depicts the simple principles of the conversion of floating-point to fixed-point. Figure 4 depicts the block diagram for implementation of advanced 2D interpolation technique.

The system can be divided into five parts: Tx Matlab, Tx DSP, Interface Board, Rx DSP and Rx Matlab. Symbol processing, MIMO encoding, IFFT processing and channel processing are processed in Tx Matlab(transmit PC) part. Tx DSP board transmits data got from channel processing to the Interface board connected to Rx DSP board. Now, the data in Rx DSP board pass through interface board, after FFT, channel estimation like linear 2D liner interpolation or advanced 2D linear interpolation, MIMO decoding and some other operation, is transmitted to the Rx Matlab part.

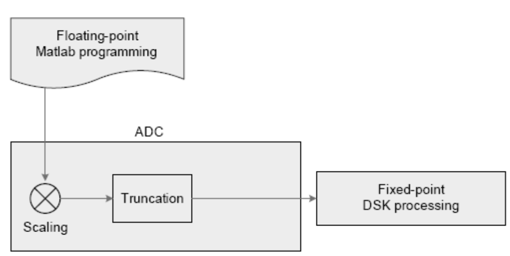

Figure 3 A simple principles of the conversion of floating-point to fixed-point

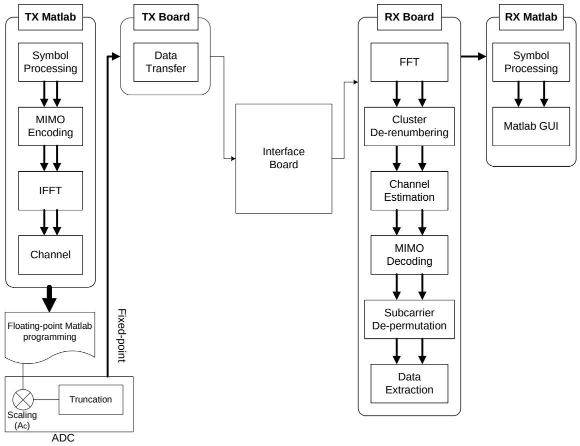

Figure 4 the block diagram for implementation of advanced 2D interpolation technique

Finally, Rx Matlab or receive PC shows simulation result such as constellation, BER performance and so on.

3.2 Fixed-point design for advanced 2D interpolation algorithm

The advanced 2D interpolation algorithm has more efficiency than other channel estimation algorithms. To find a channel information of a data subcarrier at edge, the equation given by,

$$z = -\frac{1}{a_2}\left[\frac{d_1}{d_3}\left(a_1c_2 - a_2c_1\right) + a_3c_2\right] + z_1$$

$$= \frac{b_3(a_2c_1 - a_1c_2) + a_3(b_1c_2 - b_2c_1)}{a_1b_2 - a_2b_1} \qquad (1)$$

Where, z is channel information to be found; a, b, c and z1 are the values from planar equation. The variables of planar equation are information of pilots which are most near to the data subcarrier.

The simple block diagram of fixed-point design for equation (1) is shown in Figure 5. To estimate the channel using pilot signal, at first present information to fixed-point in DSP. Then, truncate behind part of the decimal point by multiplying an optimum scale factor, it minimizes the loss information. The quantization noise and distortion of information from overflow reduce the accuracy of channel estimation and BER performance of system. Fixed-point operation and distortion from overflow show the relationship of trade-off. So it is very important to fine optimum scale factor.

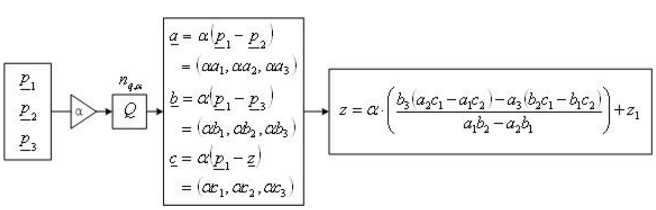

Figure 5 The simple block diagram of fixed-point design for advanced 2D interpolation algorithm

4. SIMULATION RESULT

To analysis the performance of the simulation on the implemented test platform performance mentioned previously, we compare the simulation result with computer simulation result. The test platform is based on IEEE 802.16e and has two transmit antennas and two receive antennas, so called 2×2 MIMO system. Also, we assume that the channel environment is spatial multiplexing, and the each data are independent. MIMO decoding uses maximum likelihood detection algorithm, and modulation is 16QAM, channel coding is convolution turbo coding with 1/2 coding rate. Figure 6 and Figure 7 show the BER simulation result of computer simulation and test platform which operating in 16-bit in the same environment. Dotted and solid lines represent the BER performance of computer simulation and circle and square marks represent the BER performance of test platform simulation.

Using the optimum scale factor, the BER performances of computer simulation and that of test platform simulation are almost same or have a little difference. Actually, the performance of computer simulation is better than that of test platform simulation, due to quantization noise and truncation error from bit over flow.

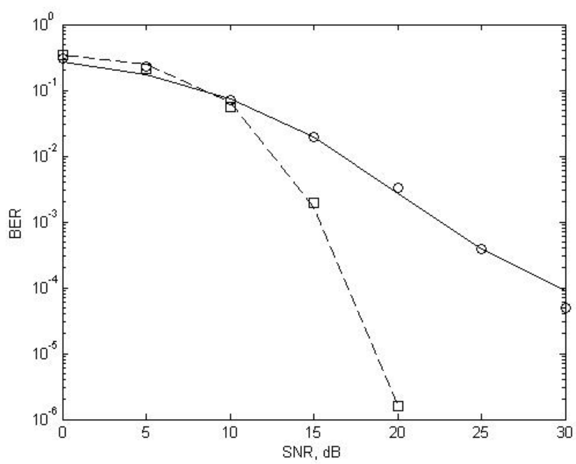

Figure 6 Comparison of the simulated BER using the computer simulation vs the simulated BER using the test platform. 60km/h mobile speed. Uncoded BER and Coded BER, which are represented by the solid lines and dotted lines, respectively.

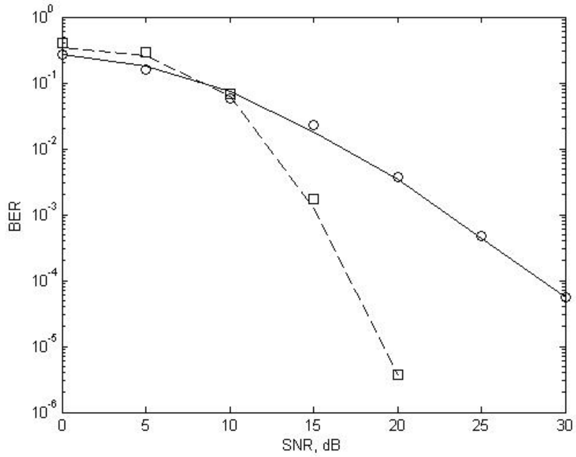

Figure 7 Comparison of the simulated BER using the computer simulation vs the simulated BER using the test platform. 3km/h mobile speed. Uncoded BER and Coded BER, which are represented by the solid lines and dotted lines, respectively.

5. CONCLUSION

In this paper, we present the method of fixed-point design for advanced 2D interpolation algorithm which is the most exact channel estimation algorithm based on IEEE 802.16e, and compare the simulation result on the test platform with the simulation result on the computer. Computer simulation is result in various simulation parameters like MCS. The result shows that the performance on the computer is better than performance on test platform. The reasons are quantization noise and truncation errors for fixed-point design.

ACKNOWLEDGMENT

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