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A high-speed mobile OFDM receiver LSI with an iterative noise-reduction filter to enhance channel estimation

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Abstract

This paper presents an OFDM receiver LSI with an iterative noise-reduction filter. Experimental results show that the LSI drastically improves the mobile reception performance, especially in high-speed environment. The die is fabricated with 0.18um CMOS process, including ADC, DAC and PLL.

Introduction

Orthogonal Frequency Division Multiplexing (OFDM) [1] is one of the most important elements for digital TV broadcasting. The OFDM exploits thousands of sub-carriers to simultaneously transmit high bit-rate data. Due to the nature of wireless communication channel, frequency-selective fading and time-selective fading are the most challenge to successfully receive the OFDM signal in mobile environment. A channel estimator is implemented to remove the channel distortions [1].

This paper reports an OFDM receiver LSI with an iterative noise-reduction filter for the channel estimation. The filter effectively rejects errors caused by the channel distortion in mobile reception. An experimental field test result show that reception performance reaches 97 % and improves by up to 6% compared to the conventional LSI.

Iterative noise-reduction filter

Figure 1 shows a block diagram of the OFDM receiver LSI for Japanese ISDB-T TV broadcasting [2]. A fast Fourier transform (FFT) block outputs the sub-carriers including data and scattered pilots (SP's). The SP's are located once every 12 sub-carriers in frequency direction and once every 4 symbols in time direction, as shown in Fig. 2. Thus, at the receiver, samples of a channel transfer function (CTF) are retrieved by a channel estimation block which are assisted by the SP's, in the following

$$\hat{H}(f,t) = \hat{p}(f,t) \; / \; p(f,t) = H(f,t) + N \quad (1)$$

where $p(f,t)$ and $\hat{p}(f,t)$ denote the transmitted and received SP's, respectively. $H(f,t)$ and $\hat{H}(f,t)$ are the CTF and its estimated value at the SP position. N is Gaussian noise at the SP's.

Figure 3 describes the channel estimator in conjunction with the proposed iterative noise-reduction low pass filter (LPF). At first, a time interpolation is performed. We chose the linear interpolation method which requires four successive

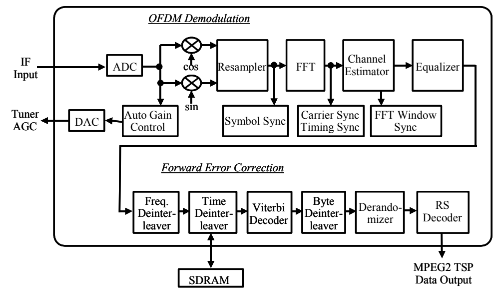

Fig. 1: Block diagram of OFDM receiver LSI

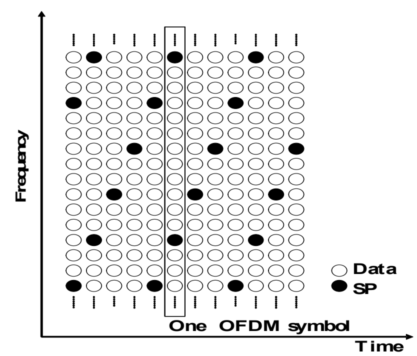

Fig. 2: SP arrangement in ISDB-T

OFDM symbols stored in a memory [1]. As illustrated in Fig. 4, this method inherently creates a linear-interpolation error W. Apparently W is rather severe in mobile environment, which degrades performance of channel estimation. We presume that W can be characterized by Gaussian process.

The proposed 2-stage iterative noise-reduction LPF suppresses Gaussian noise N of the wireless channel and the linear interpolation error W. The estimated and time-interpolated values of the CTF of one OFDM symbol are

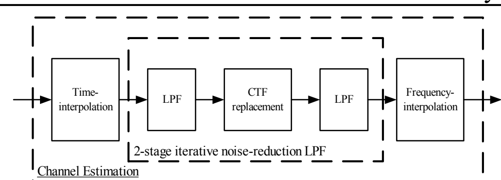

Fig. 3: Proposed iterative noise-reduction filter.

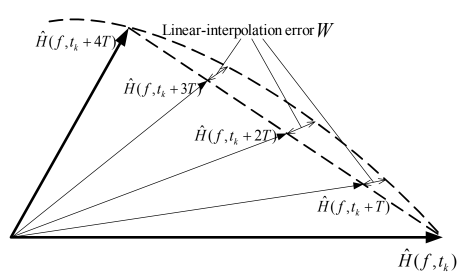

Fig. 4: Linear-interpolation method

passed through the first stage LPF. The bandwidth of the LPF is identical with the guard-interval duration [3]. Therefore, the Gaussian noise N is reduced by the first stage LPF. Since the estimated value of CTF does not contain the linear-interpolation error W, those values are appropriately replaced at the first stage LPF output. The second stage LPF is used subsequently to reduce W.

Finally, a frequency interpolation with a ratio of 1:3 is performed by a FIR filter to derive the CTF value of all sub-carriers of one OFDM symbol.

Chip Characteristics

Figure 5 show a micro photograph of the OFDM receiver LSI. The die is fabricated with 0.18-um CMOS 5-metal process, including an AD converter, a DA converter, and 800-k gate logic. Power consumption is 600mW at 1.8-V and 2.85-V supply voltages of the logic and I/O, respectively.

Fig. 5: Chip Micro Photograph

Experimental results

An experiment is conducted with an OFDM receiving system. It operates in Mode 3 of the ISDB-T and the 64-QAM modulations under a six-path Rayleigh wireless channel. Figure 6 shows the carrier-to-noise ratio (C/N) measured at a bit error rate (BER) of $2x10^{-4}$ after the Viterbi decoder. The proposed method improves the performance of mobile reception. 7 Hz of Doppler frequency gaining can be archived at a C/N of 32 dB.

Field experiments are also conducted at the courses shown in Fig 7. The vehicle velocity is 80km per hour. Table 1 shows the results. In the course A, where severe Doppler effect occurs, the performance gains by 6% using proposed method. In the course B, where Doppler effect is minimum because the signal direction is perpendicular to this course, the performance still archives 4% gaining.

Table 1: Performance in field experiment

	w/o iterative LPF	1-stage iterative LPF	2-stage iterative LPF
Course A	91%	95%	97%
Course B	91%	95%	95%

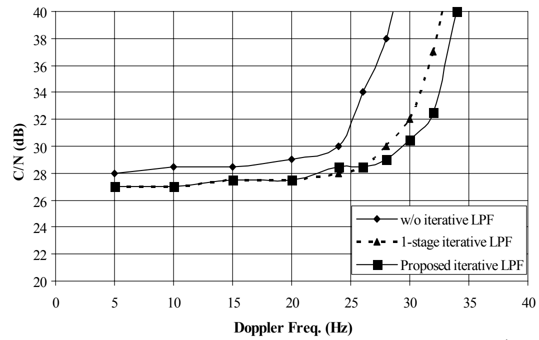

Fig.6: Performance enhancement at BER = $2x10^{-4}$.

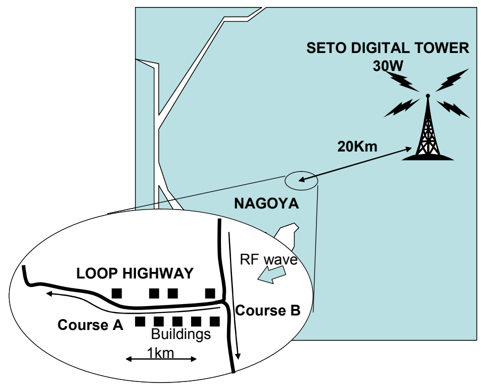

Fig. 7: Courses of field experiment

Conclusions

In this paper, the OFDM receiver LSI with the iterative noise-reduction filter for channel estimation is presented. The filter effectively eliminates the noise and error caused in mobile reception. Experiments in both laboratory measurement and field test prove the effects. The reception performance achieves 97 %, and clear reception in high-speed environment is guaranteed.

Acknowledgement

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