繰返し型ノイズ低減フィルターを用いた 高精度チャネル推定・高速移動体向けＯＦＤＭ受信ＬＳＩ

ダン ハイ パム [1], 村上修二 [2]、神山一弘 [2], 水谷弘幸 [2], 當眞 聡 [2],

金田喜共 [2], 玉置 祥 [2], 和田知久 [1]

[1] 琉球大学理工学研究科 〒903-0213 沖縄県西原町千原 1

[2] マグナデザインネット 〒901-0152 沖縄県那覇市小禄 1831-1

E-mail: [1] phdang@lsi.ie.u-ryukyu.ac.jp, wada@ie.u-ryukyu.ac.jp, [2] murakami@magnadesignnet.com

あらまし 地上デジタル放送の移動体における受信性能を向上するために、２段の繰り返し型のノイズ低減フィルターをチャネル推定回路に適用し、高速移動時のドップラー周波数ずれによるチャネル推定誤差の低減を図った。時速 80km/h レイリーフェイジング環境での移動体受信実験で、本繰り替えし型フィルター適用により受信率を 91% から 97%への向上を実現した。LSI は 0.18um CMOS プロセスで実現され ADC, DAC, PLL 内蔵を内蔵する。

キーワード OFDM, チャネル推定、ISDB-T、移動体受信、LSI

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

Dang Hai PHAM[1], Shuji Murakami[2], Kazuhiro Kamiyama[2], Hiroyuki Mizutani[2], Hajime Toma[2], Yoshitomo Kaneda[2], Sho Tamaki[2], and Tomohisa WADA[1]

[1]Graduate School of S&E at the University of the Ryukyus, 1 Senbaru Nishihara Okinawa, 903-0213 Japan

[2]Magna Design Net Inc, 1831-1 Oroku Naha Okinawa, 901-0152 Japan

E-mail: [1] phdang@lsi.ie.u-ryukyu.ac.jp, wada@ie.u-ryukyu.ac.jp, [2] murakami@magnadesignnet.com

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 rate from 91% to 97% at 80km/h Rayleigh fading environment. The LSI die is fabricated with 0.18um CMOS process, including ADC, DAC and PLL.

Keyword OFDM, Channel Estimation, ISDB-T, mobile reception, LSI

1. 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.

2. 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.

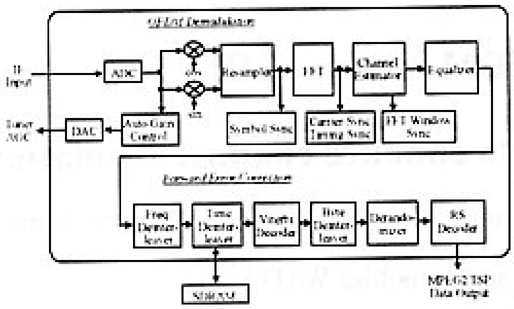

Fig. 1: Block diagram of OFDM receiver LSI

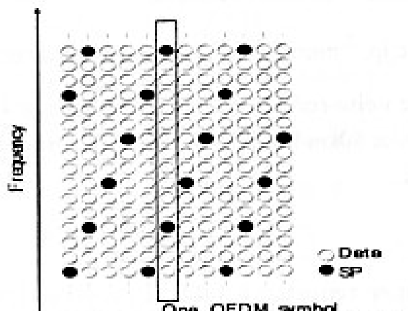

Fig. 2: SP arrangement in ISDB-T

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 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 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.

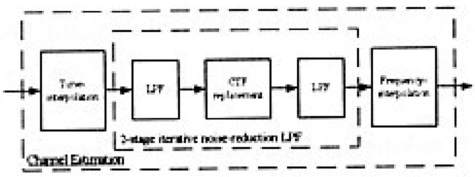

Fig. 3: Proposed iterative noise-reduction filter.

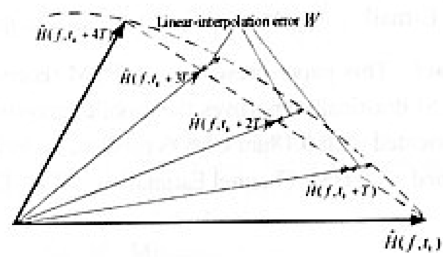

Fig. 4: Linear-interpolation method

3. 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.

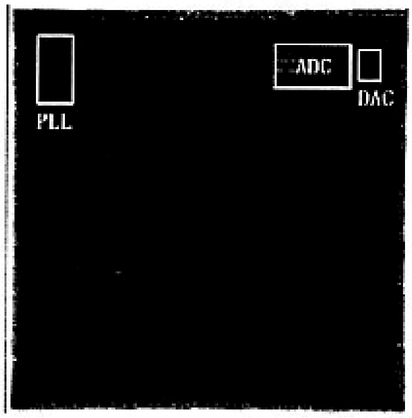

Fig. 5: Chip Micro Photograph

4. 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 2×10^{-4} after the Viterbi decoder. The proposed method improved the performance of mobile reception. 7 Hz of Doppler frequency gaining has been 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 small because the RF 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	93%	97%	97%

5. 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 proved the effects. The reception performance achieves 97 %, and clear reception in high-speed environment has been guaranteed.

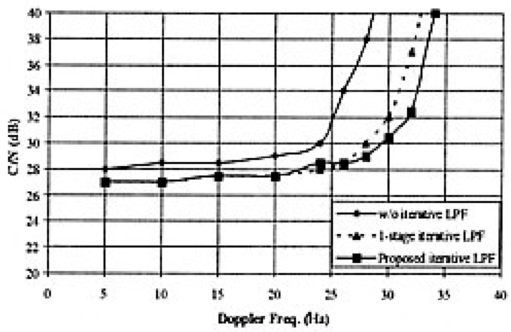

Fig.6: Performance enhancement at BER = 2×10^{-4}.

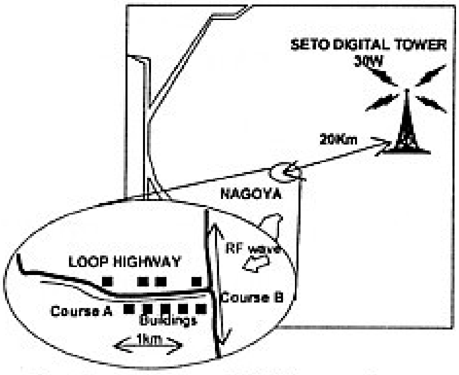

Fig. 7: Courses of field experiment

6. Acknowledgement

We thank MegaChips LSI Solutions Inc. for the co-development of the OFDM receiver LSI.

7. References

[1] Christophe et al "0.5-um CMOS Circuits for Demodulation and Decoding of an OFDM-Based Digital TV Signal Conforming to the European DVB-T Standard," *IEEE J. Solid-State Circuits*, vol. 33, pp. 1781-1792, November 1998.

[2] "Channel coding, frame structure and modulation scheme for terrestrial integrated services digital broadcasting (ISDB-T)," ITU-R WP11A, May 1999.

[3] Classen, F. and Speth, M. and Meyr, H. Channel Estimation Units for an OFDM System suitable for Mobile Communications. In *Mobile Kommunikation :ITG-Fachbericht*, München, September 1995. ITG, VDE-Verlag, Berlin Offenbach.