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Evaluation of Diversity Combining Systems for Mobile Reception in Digital Terrestrial Television Broadcasting

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Abstract-- **In this paper, we evaluated the mobile reception performance of ISDB-T receivers using scalable OFDM diversity LSIs. The receivers exploit two kinds of diversity schemes which are time-domain based array antenna (AA) and frequency-domain based carrier diversity (CD). The reception performance of some diversity systems is evaluated by laboratory and field experiments. According to the results, 4ch-CD achieves the highest performance under fading channels. Also, the performance of 4ch-AA is almost as high as that of the 4ch-CD in receiving high-correlated signals, being much better than that of 2ch-CD.**

I. INTRODUCTION

A High-Definition television reception service, such as Integrated Services Digital Broadcasting-Terrestrial (ISDB-T [1]) in a vehicle has attracted attention. However, the quality of an in-vehicle reception tends to be seriously deteriorated because of multi-path fading channels. In order to improve the problem, multi-antenna diversity combining techniques have been widely adopted.

Since Orthogonal Frequency Division Multiplexing (OFDM) is applied for ISDB-T, two kinds of OFDM combining techniques, which are the Pre-FFT scheme and the Post-FFT scheme, can be used [2]. The Pre-FFT scheme combines time-domain based signals, while the frequency-domain based Post-FFT scheme has to combine subcarrier by subcarrier. While the Post-FFT scheme provides an optimum approach in terms of maximizing carrier-to-noise ratio (CNR) for each OFDM subcarrier from the viewpoint of a reception performance, the hardware complexity of the time-domain based Pre-FFT scheme is much lower than that of the Post-FFT scheme.

We developed a diversity LSI for ISDB-T which includes the Pre-FFT and the Post-FFT combining algorithms. By using the LSIs, multiple diversity solutions for an in-vehicle receiver set can be provided. In this paper, we evaluate these diversity methods by experiments in a laboratory and vehicular tests in a field.

II. SYSTEM MODEL

For the application of an in-vehicle DTV reception, we study two solutions which are based on a two-antenna mode with low hardware complexity and a four-antenna mode for a higher reception performance. In this paper, we assume that a two-antenna mode is a post-FFT carrier diversity combining system (2ch-CD), as shown Fig.1 (a). In terms of a four-antenna mode, we configure two kinds of diversity systems, as depicted in Fig (b) and (c). One is an adaptive array antenna system (4ch-AA) which exploits a combination of Pre-FFT and Post-FFT; the other is a post-FFT carrier diversity combining system (4ch-CD).

As the 2ch-CD system is composed of two RF tuners, the circuit is smaller than those of four-antenna diversity systems. This system employs the effective combining technique, such as maximum-ratio combining (MRC), on the subcarrier- by-subcarrier basis. The 4ch-AA system can be configured by four RF tuners, two Pre-FFT blocks and one MRC block. The number of a MRC block is the same as that of 2ch-CD system. Therefore, the hardware complexity of 4ch-AA is close to the 2ch-CD, thanks to additional small Pre-FFT circuits. The 4ch-CD system simply requires two 2ch-CD systems. Thus, due to the sacrifice of more hardware complexity as three MRC blocks, the 4ch-CD system obtains the highest reception performance of all systems we consider in this paper.

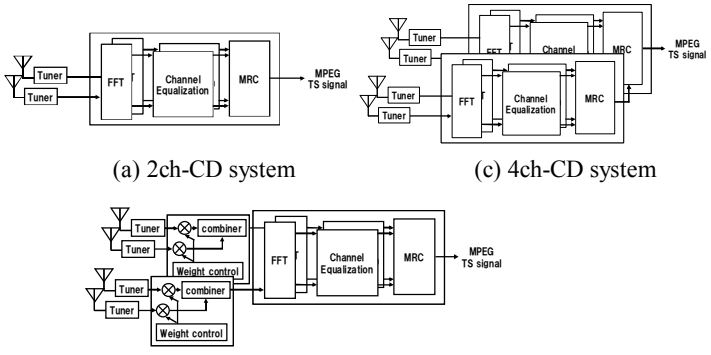

Fig. 1. Block diagram of four diversity combining systems

III. ANTENNA INSTALLATION IN A VEHICLE

To configure a four-branch diversity system in a vehicle, typical positions of antennas are in two corners of a front windshield and two corners of a rear window, as shown in Fig.2. According to this antenna installation, signals received from the front antennas and the Doppler effects tend to be similar to each other, because the direction characteristics of the front antennas are very close. Likewise, signals from rear antennas also seem to be highly correlated.

The Pre-FFT system shows a high diversity gain in the case of receiving highly correlated radio waves within a certain

amount of delay time, while the Post-FFT system can be obtained a higher diversity gain under fading channels with low signal correlation. Also these OFDM receivers have to reduce the Doppler effects for the received signals.

Hence, we propose the way of an antenna installation for the 4ch-AA system. First of all, the Pre-FFT combining is executed for the received signals from two front on-glass antennas. The same combing technique is done for the signals of two rear antennas. In this way, it is likely to combine highly correlated signals and to reduce the Doppler effects. Then, the output signals from the Pre-FFT diversity stage leads to the Post-FFT diversity stage. Herewith, we optimize the system.

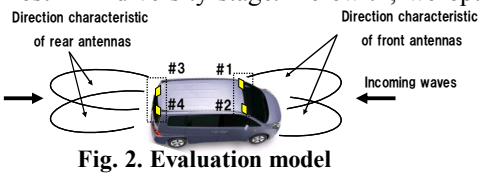

Fig. 2. Evaluation model

IV. RESULTS

A. Implementation

By using the scalable diversity LSIs, the reception performance of three receivers which include the 2ch-CD, the 4ch-AA, and the 4ch-CD systems is evaluated. Here, we have developed the smallest two-antenna diversity DTV module in the industry, which corresponds to our demodulation LSI and two silicon RF tuners, as shown in Fig.3. We also developed a LSI-based prototype receiver able to configure two types of four-antenna diversity systems.

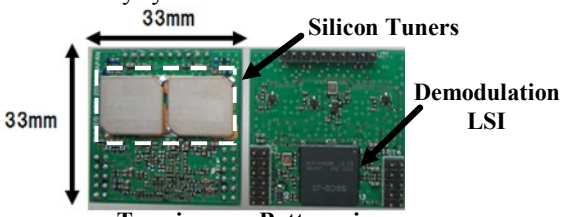

Fig. 3. Overview of 2ch-CD module

B. Lab experimentation

Three types of diversity systems were evaluated by the laboratory experiments with parameters, as seen in TABLE I. The results show that the 4ch-CD system is 16.8dB CNR in maximum Doppler frequency of 56Hz (100km/h), being the best of the three diversity receivers at quasi-error free (QEF), as shown in Fig.4. Moreover, the 4ch-AA system improves CNR to 4.8dB better than the 2ch-CD system. Therefore, the performance of the 4ch-AA system is similar to that of the 4ch-CD system in the case of input signals being highly correlated. Note that QEF is at a BER of $2x10^{-4}$ after Viterbi decoding for the ISDB-T standard.

C. Field Experimentation

We also evaluated the three diversity systems by vehicular experiments. The specifications on these systems are shown in TABLE II. Fig.5 shows the reception rate which is defined as the percentage of a duration of error-free reception in all test course. From the result, the four-antenna system obviously improves the performance of the 2ch-CD system. Moreover, the difference of the reception rate between the 4ch-AA system and the 4ch-CD system is small.

TABLE I experimental parameters

Symbol duration	1.008 μ sec
Guard interval	126μsec (1/8)
# sub-carriers	5617
Modulation method	64QAM
Channel model	Six ray – Rayleigh fading (ETSI [3] TU-6)
Received signal correlation	0.9

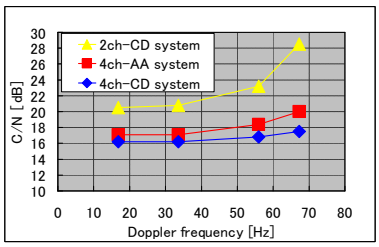

Fig. 4. Doppler vs. CNR

TABLE II Specifications on the evaluated systems

Input channel	545MHz
Signal standard	ISDB-T
Combining system	2ch-CD / 4ch-AA / 4ch-CD
Output	MPEG-2 TS

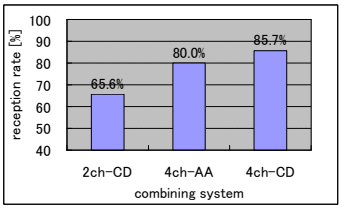

Fig. 5. Experiments in the outdoor field, Tokyo, Japan

V. CONCLUSIONS

In this paper, three diversity systems for mobile vehicle ISDB-T reception are presented and evaluated by laboratory and field experiments. As a result of the laboratory experimentation, we have shown the advantages of the 4ch-CD system under Rayleigh fading environments. Also, the 4ch-AA system can realize high performance in case of combining signals with a high correlation. In addition, in-vehicle test results tend to be almost equal to the lab experiment ones.

EXAMPLES OF REFERENCE STYLES

[1] ARIB STD-T31, "Transmission System for Digital Terrestrial Television Broadcasting," ARIB Standard Version 1.5, Association of Radio and Industries and Business (ARIB), July 2003.

[2] Minoru Okada, Shozo Komaki, "Pre-DFT Combining Space Diversity Assisted COFDM," IEEE Trans. ON VEHICULAR TECHNOLOGY, vol.E50, no.2, MARCH 2001.

[3] ETSI TS 100 910 v8.15.0 (3GPP TS 05.05 v8.15.0), "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception," April 2004.