

# Incoming Waves Separating Adaptive Array for ISDB-T Mobile Reception

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**Abstract** - A new combining method of Adaptive Array Antenna for ISDB-T Mobile Reception system is proposed in this paper. From experimental results, it is clarified that the BER performances of the proposed system are superior to the conventional system.

**Index Terms** — ISDB-T, OFDM, Adaptive array antenna, Vehicle, Directivity, BER.

## 1. Introduction

In terrestrial digital TV broadcasting in Japan (ISDB-T), Orthogonal Frequency Division Multiplexing (OFDM) is adopted as a modulation scheme. The communication performance of the OFDM is known to be superior to that of a single carrier communication in a multipath environment and high spectral efficiency. However, the quality of digital communication is seriously deteriorated at the high speed mobile reception (Ex. vehicle), running in a radio environment that the delayed wave exceeding guard interval or running extremely high speed. Furthermore, most of the mobile reception system, 4 antennas are mounted on a vehicle (Front:2 antennas, Rear:2 antennas). The maximum gain directions of those antennas are different in either front or rear of the vehicle. In this paper, we evaluated the BER performances in the above environment at a laboratory test. A new combining method (Incoming waves separating system by adaptive array antenna) is proposed in this paper. From experimental results, it is clarified that the BER performances of the proposed system are superior.

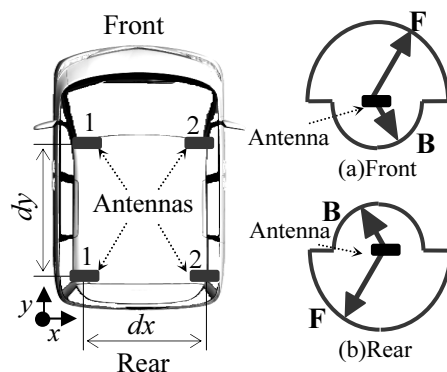


Fig. 1. Antennas position. Fig. 2. Directivities.

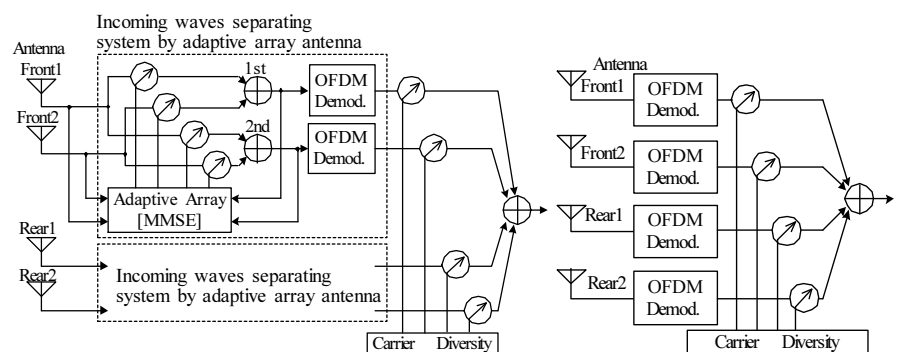


Fig. 3. Proposed System. (Pre-FFT type)

Fig. 4. 4FFT System. (Post-FFT type)

## 2. System Configurations

### (1) Antenna mounted on vehicles

In this paper, we suppose four antennas are mounted on a vehicle (Front:2 antennas, Rear:2 antennas). Fig. 1 shows the top view of the antenna position on a vehicle, and Fig. 2 shows the directional patterns of the 4 antennas. For each antenna, F/B (Front/Back) ratio is defined as shown in Fig. 2.

### (2) Proposed combining system

Fig. 3 shows the block diagram of the proposed system (Pre-FFT type). The reception signals are combined independently in the front and the rear of the vehicle. Furthermore, 1st arrival signal and 2nd arrival signal are combined each other in the front and the rear, respectively. Subsequently, these signals in front and in rear are combined again and this combined signal is demodulated. Fig. 4 shows 4FFT system (Post-FFT type) which is conventional configuration. Both systems have been implemented in the prototype which is shown in Fig. 5.

### (3) Implemented algorithms

Suppose that array antenna is equipped with  $K$ -element. The received signals  $x_k$  and weight coefficients  $w_k$  are expressed in a vector as follows,

$$\mathbf{X}(t) = [x_1(t), x_2(t), \dots, x_K(t)]^T \quad (1)$$

$$\mathbf{W} = [w_1, w_2, \dots, w_K]^T \quad (2)$$

Then, the combined output of the array is given by

$$y(t) = \mathbf{W}^H \mathbf{X}(t) \quad (3)$$

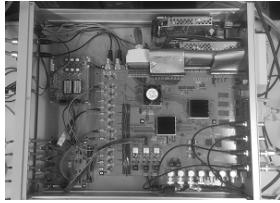


Fig. 5. Prototype. (for both systems)

Here, the superscripts T and H represent the transpose and the conjugate transpose, respectively. The OFDM modulated signal in time domain consists of the guard time GI and the effective symbol. Let  $x_{hk}(t)$  ( $k = 1, 2, \dots, K$ ) express the extracted signals from the received signal during the GI. In a similar manner,  $x_{rk}(t)$  ( $k = 1, 2, \dots, K$ ) express the extracted signals from the received signal during the last part of the effective symbol. They are expressed in a vector as

$$\mathbf{X}_h(t) = [x_{h1}(t), x_{h2}(t), \dots, x_{hK}(t)]^T \quad (4)$$

$$\mathbf{X}_t(t) = [x_{t1}(t), x_{t2}(t), \dots, x_{tK}(t)]^T \quad (5)$$

Hence the combined outputs of the extracted signals from GI and last part of effective symbol are given by

$$y_h(t) = \mathbf{W}^H \mathbf{X}_h(t), y_t(t) = \mathbf{W}^H \mathbf{X}_t(t) \quad (6)$$

In this paper, we adopt an algorithm, Minimum Mean Square Error (MMSE), and the weight coefficient vector  $\mathbf{W}_{MMSE}$  is expressed as follows [1],

$$\mathbf{W}_{MMSE} = \mathbf{R}_{XhXh}^{-1} \mathbf{W}_{AMBF} \quad (7)$$

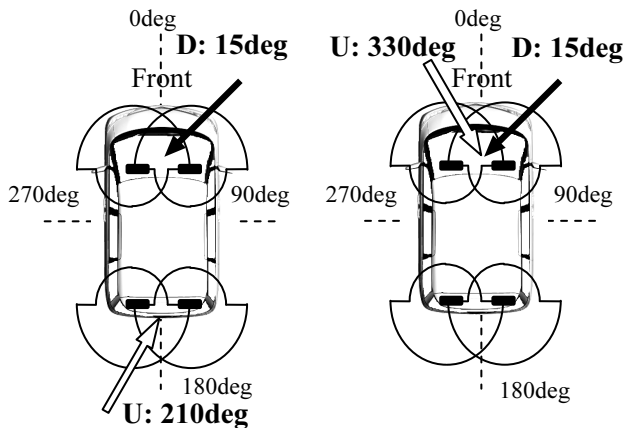
where  $\mathbf{R}_{XhXh} = E[\mathbf{X}_h(t) \mathbf{X}_h^H(t)]$ .

### 3. Validation through Experiment

#### (1) Condition

Using the fading simulator, we evaluated the BER performances and the directional patterns. The measuring frequency is 35ch (Center frequency: 605.143MHz), and Table 1 shows the OFDM signal condition.

We evaluated in a 2-arrival wave environment. Distance of 4 antennas mounted on the vehicle are  $dx=dy=0.5\lambda$  as shown in Fig. 1. The F/B ratio of antennas is varied from 0dB through 5dB. The D/U Ratio is 3dB(D: Desired signal, U: Undesired signal). Moreover, the delay time of the undesired signal to the desired signal is  $21(1/6*GI) - 273(13/6*GI)[\mu s]$ . Fig. 6 shows the radio environments.



Radio Environment (A) Radio Environment (B)  
Fig. 6. Radio Environment.

Table 1: Condition of OFDM Signal

Number of carriers	5617
Effective symbol length	1008 $\mu s$
Carrier interval	0.992kHz
GI length (1/8)	126 $\mu s$
Moduration scheme	64QAM

#### (2) Experimental Results

Fig. 7 shows the BER performances of the 4FFT system and the proposed system. In this experiment, we evaluated the Pre-Viterbi BER performances, therefore the criteria of BER performances is  $2.0 \times 10^{-2}$  (Error Free at Post-RS coding). When the delay time is large, the BER performance of the proposed system is superior to that of the 4FFT system. Further, Fig. 8 shows the directional patterns of the proposed system, thereby demonstrating a beamforming for desired wave and null steering for undesired wave.

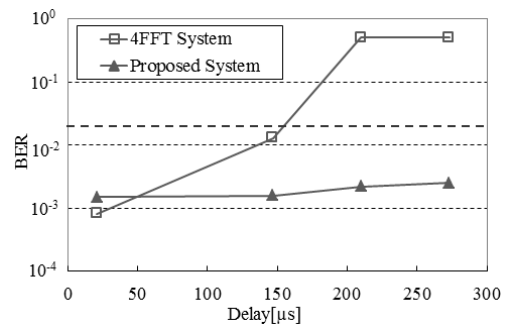


Fig. 7. BER Performances.  
(Radio Environment: A, F/B ratio: 0dB)

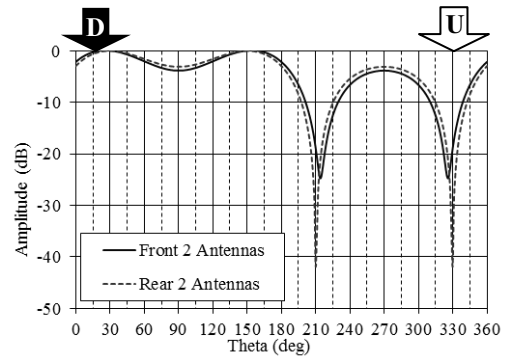


Fig. 8. Directional Patterns of Proposed System.  
(Radio Environment: A, F/B ratio: 0dB,  
Delay: 273  $\mu s$ )

#### 4. Conclusion

In this paper, we compared the BER performances of proposed system (Incoming waves separating system of Pre-FFT adaptive array antenna) with those of 4FFT system (Post-FFT carrier diversity) as a conventional system. From an experimental result, it was proved that the proposed system had superior BER performance in the case where OFDM signals arrive with delay exceeding the Guard Interval (GI) length.

#### References

- [1] S.Hori, N.Kikuma, N.Inagaki, "MMSE adaptive array utilizing Guard Interval in the OFDM systems," Electronics and Commun. in Japan, Pt.1, Wiley Periodicals, Inc., Vol.86, No.10, pp. 1-9, 2003.