Multiband Shared Aperture Adaptive Array Using the Rear Defogger

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***Abstract*— Conventional adaptive array consists of several antennas. However, for vehicular industrial design, it is preferable not to use additional antenna elements. Therefore, we propose a multiband shared aperture adaptive array antenna using a rear defogger. In addition, RSAA (reactive steered adaptive array) concept is applied for simplification and low power consumption. From simulation and experiments results, it shows that the proposed adaptive antenna can operate at 100 MHz (ISDB-T_{SB}) and 210 MHz (ISDB-T_{MM}) band and that it also has the phase diversity capabilities in the Rayleigh fading environment.**

Keywords-component; rear defogger, reactive steered adaptive array; phase diversity; symplex method

I. Introduction

A reactively steered adaptive array (RSAA) is known as an adaptive array with a single receiver and several radiating elements such as a dipole or patch [1]. Though the configuration is simple, the structure is bulky because of the use of mutual coupling between elements in the array antenna. This restricts its implementation. Also, it is impossible to form an adaptive pattern in mobile communication environments because of a large amount of calculation that results from the use of a blind algorithm. Moreover, the bandwidth has not been examined in detail.

We examine an adaptive array for the future digital radio, ISDB-T_{sb} (Integrated Services Digital Broadcasting - Terrestrial for Sound Broadcasting : 90-108MHz), ISDB-T_{mm} (Integrated Services Digital Broadcasting Terrestrial for mobile multimedia : 207.5-222MHz) [2], installed on a vehicle. Ordinary RSAA cannot be installed on a vehicle because of their large size. By the way, the use of a rear defogger for the FM and AM antenna has been examined [3]. We proposed using a defogger as the RSAA by placing several ports on it [4]. We used the simplex method to achieve robust beamforming with rapid convergence [5]. In addition, we confirmed that the proposed antenna was able to operate in multiband [6].

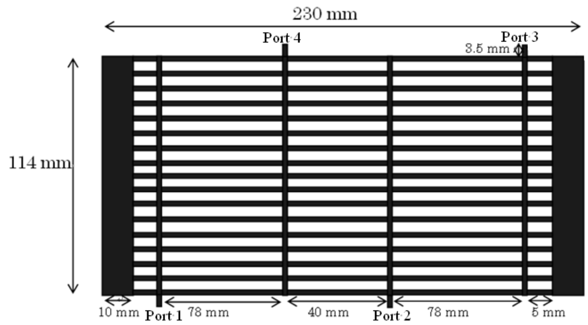
In this paper, we present the shared-aperture smart antenna using a defogger by numerical simulation and experiments. The proposed antenna can operate at 100 MHz and 210 MHz band. Also, it has the phase diversity capability in the Rayleigh fading environment, while it has the null steering capability.

II. Adaptive Array Using the Rear Defogger

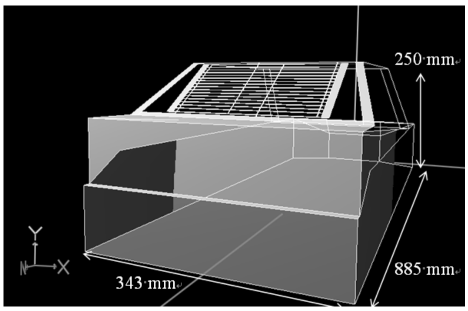
A. Shared Aperture Based on a Rear Defogger

We use a 1:5 scale model for both the experiments and numerical simulation. Therefore, the frequency of ISDB-T_{sb} and that of ISDB-T_{mm} for the scale model is set to 450−540 MHz and 1037.5-1110MHz, respectively. We examine the model by installing it on a vehicle. Figure 1 shows the defogger aperture installed on a vehicle. To increase the coupling between ports (CBP) and to decrease the spatial cross-correlation (SCC) for each band, four vertical wires are added. We place four ports on the outer heating wire and operate it as an array antenna with four elements.

Mounting it on a metal body as shown in Fig. 1 (b), we evaluate the performance on the basis of the voltage standing



(a) Detail Dimensions of the Rear Defogger



(b) Rear Defogger Installed on the Body.
Figure 1 Analysis Model

wave ratio (VSWR), CBP, and SCC. For an array that operates in a mobile communication environment, VSWR and SCC should be low over the bandwidth [7], while CBP should be large for an RSAA. We evaluated the parameters VSWR, CBP, and SCC by using an IE3D electromagnetic simulator. We examined more than 100 possible port positions to decide the port positions.

Figure 2 shows frequency characteristics of VSWR, CBP, and SCC in case of the proposed antenna scheme. Here, the output port is port 1, and the others are connected with the short. For CBP and SCC, the curves are average of all combinations of the paired ports for. The VSWR is less than 4. the CBP is larger than -11dB, and the SCC is less than 0.25 over the specified bandwidths.

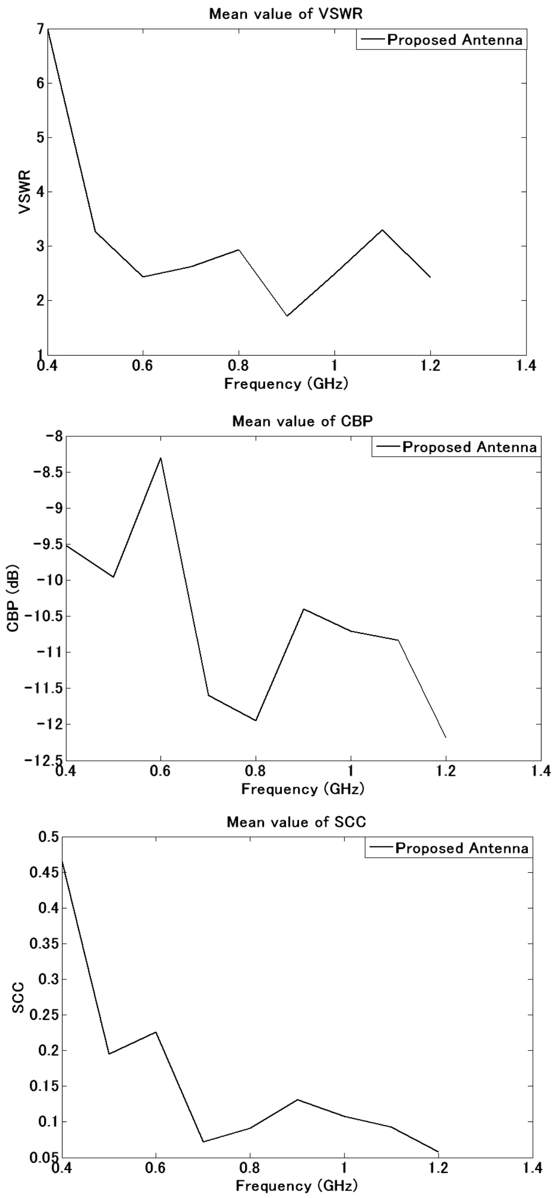


Figure 2 Frequency characteristics of VSWR, CBP, and SCC

B. *Adaptive Beamforming*

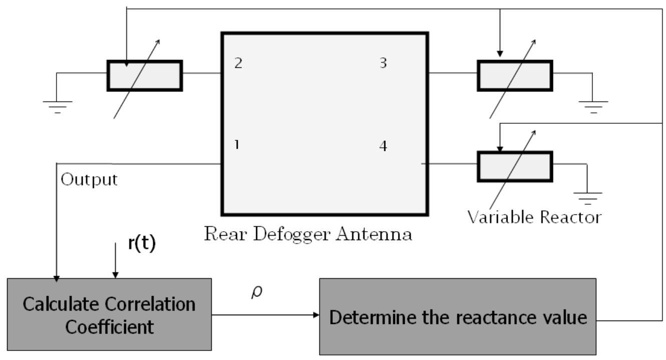


Figure 3: Implementation of RSAA to a rear defogger.

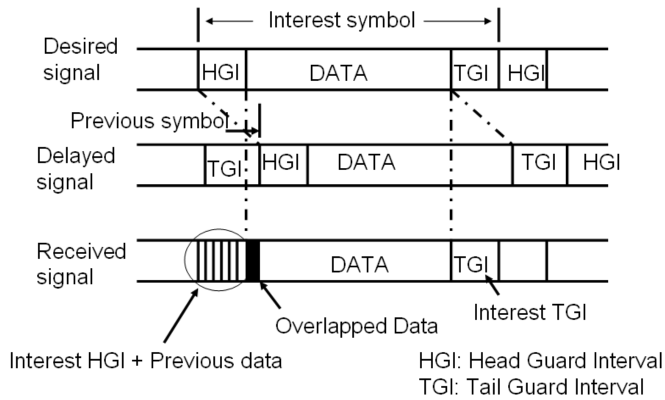


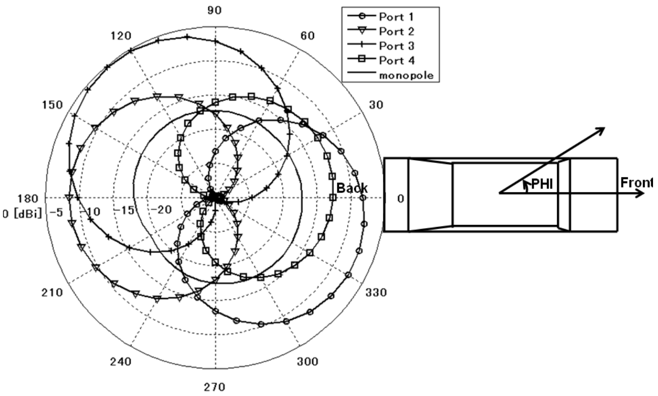
Figure 4 Reception of the delayed signal

Figure 3 shows the concept of the proposed adaptive antenna. One port out of the four ports is used for the output, while the others are connected to a variable reactance. We used an orthogonal frequency-division multiplexing (OFDM) signal as the incident signal considering the future digital radio applications. As shown in Figure 4, a delayed signal may occur by multipath propagation. In OFDM, in order to reduce the degradation of the receiving quality caused by delayed signals, a head guard interval (HGI) is placed at the head of a symbol that is identical to the tail of a symbol (TGI). The correlation coefficient between the HGI and TGI should be 1 because the HGI is a copy of the TGI. A large delayed signal beyond the HGI may occur by multipath propagation. We assume that the main signal and delayed signal are simultaneously incident on the receiver. They are superposed in the receiver. If the receiver is synchronized with the main signal, the correlation coefficient is less than 1, because the HGI is polluted by the previous symbol of the delayed signal, while the TGI is not polluted (the same symbol data is added). If the delay is beyond HGI, the data will be polluted. We can form an adaptive pattern to cancel the delayed signal by controlling three variable reactors. If the correlation coefficient between the HGI and TGI of the received signal becomes large, the delayed signal has to be cancelled. We used the simplex method in which the correlation was the objective function [5].

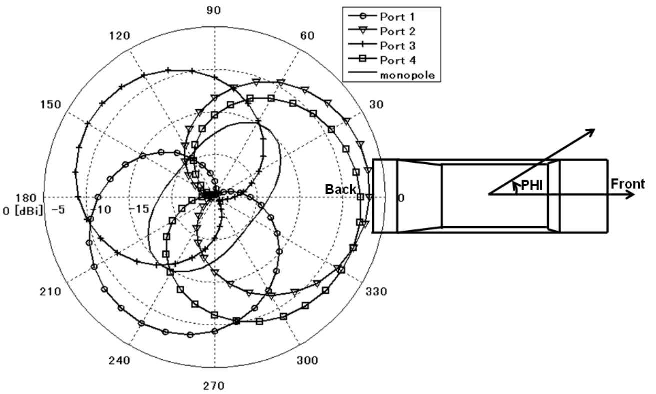
III. Simulation

We calculate radiation patterns to confirm that they cover the whole horizontal plane. Figure 5 shows the horizontal patterns for 2 bands. Coverage over 360º in the horizontal plane is achieved by 4 patterns corresponding with 4 ports.

In the next, we evaluate improvement of SINR where the environment includes the interference. We assume two incoming waves; namely as desired signal and delayed signal (interference). Both signals have the same amplitude. The DOAs in horizontal plane is randomly determined in the range of 0°-360°, while DOAs in vertical plane is set to 0.48° based on measurement field. We calculated complementary cumulative distribution function (CCDF) of SINR for 100 combinations of incident waves. From the statistical analysis, we can see that for two frequency bands more than 80% of the signals have SINR greater than 20 dB.



500MHz



1050MHz

Figure 5 Horizontal patterns of 4 ports

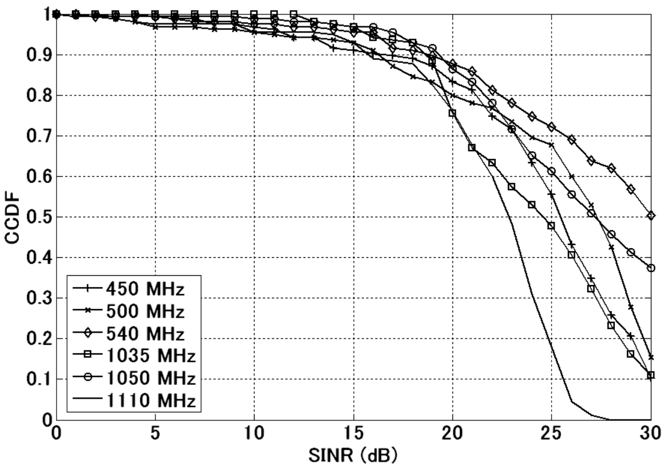


Figure 6 CDF of the SINR

IV. Experiments

A. Setup

We manufactured the proposed antenna on a 1:5 scale and installed it on a vehicular model (Fig.7). We then evaluated the antenna in the anechoic chamber. Table 1 shows the experiment conditions. The transmitting frequency is 473MHz and 900MHz, because of the experimental equipment especially the existed fading simulator. Figure 2 show that the proposed antenna has good performance at 900MHz.

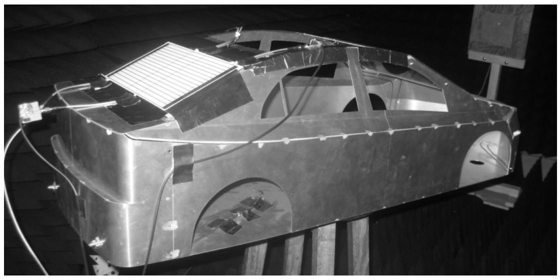


Figure 7 1/5 Scale Model

Table 1 Experiment Conditions

Modulation	OFDM (16QAM)
Data	128 bits
Guard Interval	16 bits
Polarization	Horizontal
DOA x-z plane	0-180°
DOA y-z plane	Under condition of DOA
Maximum iteration	100
Sampling rate	200 kHz
No. of incoming wave	2
Delay	32 bits

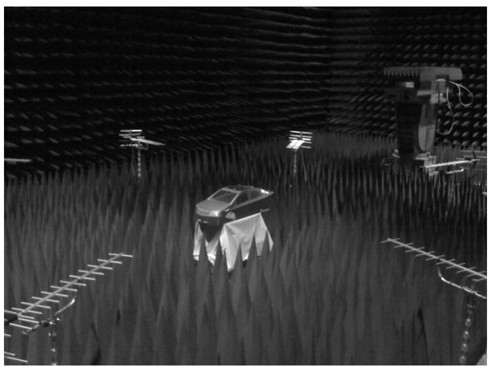


Figure 8 Experiments in the anechoic chamber

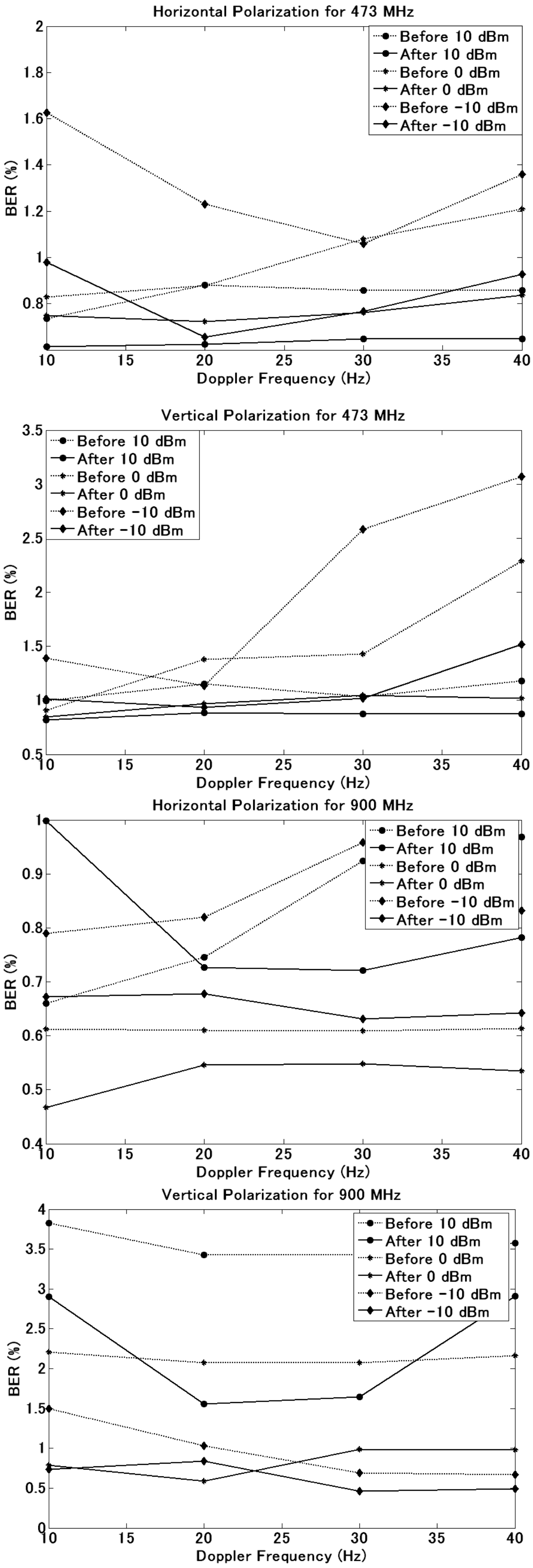


Figure 9 BER characteristics

B. Operation in the Rayleigh Fading

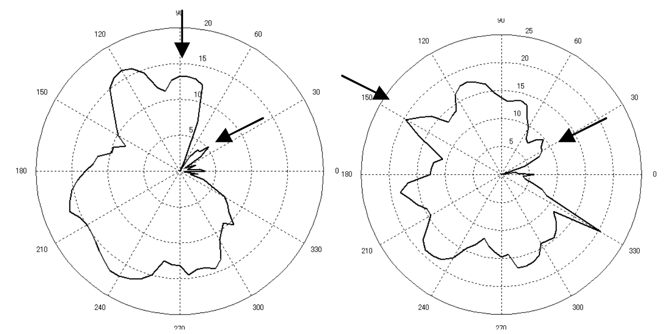
The scale model is installed in the center of the fading simulater as shown in Fig.8. The bit error rate (BER) has been measured while the Doppler frequency, transmitting power, and the polarization is changed. Figure9 shows the results. BERs of the operating conditions are improved compared with those of no operation.

C. Adaptive Beamforming

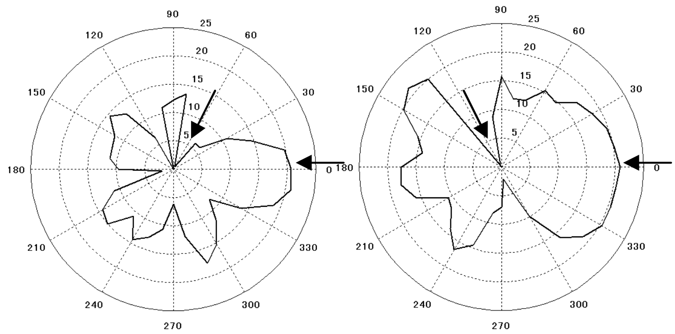
2 signals with the same amplitude are incident from a variety of DOAs. Under the situation, adaptive beamforming is carried out. VSWR of output after the adaptive beamforming, convergent time, and BER were measured. The examples are shown in Table 2 and Figure10. Adaptive beam patterns are successfully formed in the dual band.

Table 2 Adaptive Beamforming

Frequency (MHz)	DOA	VSWR	Convergence time (ms)	Iteration number	BER (%)	
					Before beamforming	After beamforming
473	60°, 300°	2.2	18	25	9.22	0.44
	30°, 90°	2.3	45	45	9.17	1.85
	30°, 150°	1.5	16.56	23	8.83	1.76
900	0,60°	1.25	20.9	29	6.94	0.84
	0,120°	1.28	18.7	26	9.9	1.44
	0,180°	1.37	10.8	15	7.43	0.52



473MHz



900MHz

Figure 10 Adaptive pattern

V. CONCLUSIONS

We propose a multiband shared aperture adaptive array antenna using a rear defogger. RSAA concept is also applied for simplification and low power consumption. From simulation and experiments results, it shows that the proposed adaptive antenna can operate at 100 MHz (ISDB-T_{SB}) and 210

MHz (ISDB-T_{MM}) band and that it also has the diversity capabilities in the Rayleigh fading environment.

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