Multiband Shared Aperture Adaptive Array using the Rear Defogger

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Abstract

This paper presents a multiband shared aperture adaptive array antenna using a rear defogger. RSAA concept is applied for simplification and low power consumption. From simulation results, it shows that null is performed at incoming interference for frequency band 100 MHz (ISDB-T_{SB}) and 210 MHz (ISDB-T_{MM}).

Keywords : rear defogger, spatial correlation, adaptive array

1. Introduction

Nowadays, vehicular antennas have become popular among researches because many electronic devices have been installed in vehicle to provide easy and safety driving. The demand for this equipment is increased drastically. Many researches on vehicular antenna have been conducted due to this demand. As far as vehicular antenna is concern, on glass antennas are rapidly been researched in order to fulfil this demand [1-2]. For future vehicular antenna, it will be very important that the installed antenna is capable to steer at the desired signal and eliminates interference automatically. It would be advantage is the installed antenna does not spoil the vehicle design, has low-cost and easy to install.

For VHF band, the size antenna is large and it is difficult to install in the vehicle. So, in this paper we proposed a rear defogger as an array antenna. Then, we introduced the reactively steered adaptive array (RSAA) concept for an adaptive array. We have confirmed through numerical simulation that the proposed antenna can operates at dual-band frequencies.

2. Antenna design and configuration

Numerical simulation has been carried out using IE3D software. The whole car body have been considered in the simulation. The dimension of Volvo 945 is scaled at 1/10 from the actual dimension. The details dimension of the defogger and ports location are shown in Figure 1.

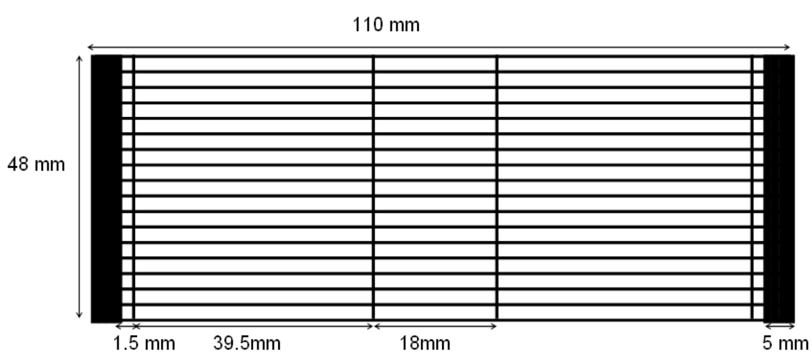


Figure 1: Antenna Configurations.

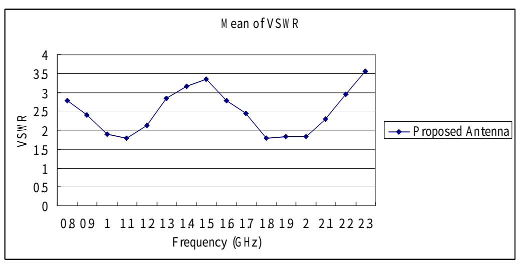
We have proposed 4 vertical lines on the defogger as shown in Figure 2. By adding these vertical lines, we can improve the coupling between port (CBP), spatial correlation coefficient (SCC) and voltage standing wave ratio (VSWR). CBP is calculated using the following equation

$$CBP = 20\log|S_{xy}|(dB) \tag{1}$$

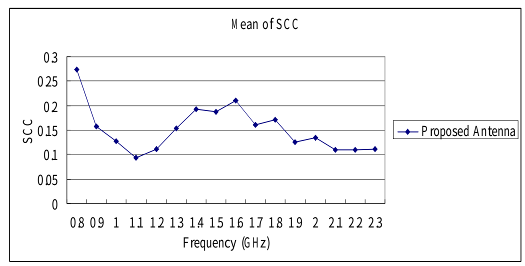
Where S_{xy} is a S-parameter for each entity of x th elements and y th elements. While SCC is determined by this equation

$$\rho_e = \sqrt{\frac{\left|\int_0^{2\pi}\int_0^{\pi} A_1^*(\theta,\phi)A_2(\theta,\phi)d\theta d\phi\right|^2}{\int_0^{2\pi}\int_0^{\pi} A_1^*(\theta,\phi)A_1(\theta,\phi)d\theta d\phi\int_0^{2\pi}\int_0^{\pi} A_2^*(\theta,\phi)A_2(\theta,\phi)d\theta d\phi}} \tag{2}$$

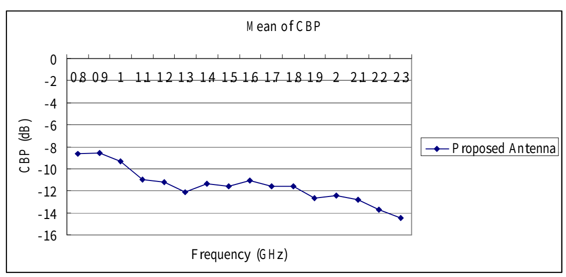
Where, $A_1(\theta,\phi)$ and $A_2(\theta,\phi)$ are directivity of element 1 and 2, while $A_1^*(\theta,\phi)$ and $A_2^*(\theta,\phi)$ are conjugate of directivity of element 1 and 2.



(a) VSWR



(b) SCC



(c) CBP

Figure 3: Average value for VSWR, SCC and CBP.

ISDB-T_{SB} band is 90 MHz - 108 MHz and ISDB-T_{MM} is 207.5MHz-222MHz. Since we used scale 1/10, therefore the frequency is set to be 900 MHz - 1080 MHz and 2075 MHz -2220 MHz. By adding 4 vertical lines on the defogger, we are able to make the defogger operated at dual band frequencies 900 MHz - 1080 MHz and 2075 MHz - 2220 MHz as shown in Figure 3 (a). To adapt the diversity concept we need a device that has a low SCC. The SCC for the proposed antenna is considered low because the value is less than 0.5. Figure 3 (b) shows the maximum SCC is around 0.3. The other concern in this design is CBP, as for this antenna, the CBP is in the range of -8 dB to -15 dB which is acceptable.

3. Adaptive Beamforming

The RSAA concept has been implemented to the defogger antenna (refer figure 4). Port 1 is used as an output port, while other ports are connected to the variable reactor [3]. In this simulation, cross correlation between received signal, y(t) and reference signal, r(t) is used as a cost function. Cross correlation, ρ is calculated using the following equation:

$$\rho = \frac{y(t)r(t)}{\sqrt{y(t)y^*(t)}\sqrt{r(t)r^*(t)}} \quad (3)$$

Simplex method is used to maximize the cost function because it has been proven that this method has a fast convergence time [4]. The cross correlation is represents a similarity of two signals. The delayed signal is cancelled when y(t) is similar to the reference signal r(t).

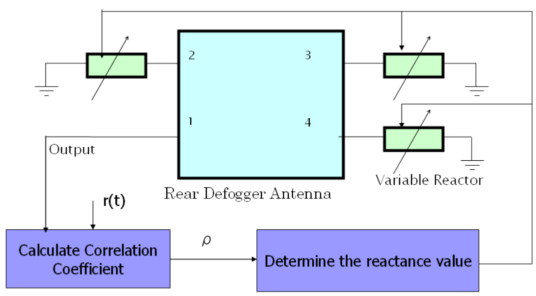


Figure 4: Implementation of RSAA to a rear defogger.

4. Simulation

In this simulation, two incoming waves have been used; namely as desired signal and delayed signal (interference). Both signals have the same amplitude which is 1. The DOAs in horizontal plane is randomly determined in the range 0°-360°, while DOAs in vertical plane is set to 0.48° based on measurement field [5]. We calculated complementary cumulative distribution function (CCDF) of SINR for 100 combinations of incident waves. From the statistical analysis shown in Figure 5, we can see that for all frequencies more than 80% of the signals have SINR greater than 20 dB.

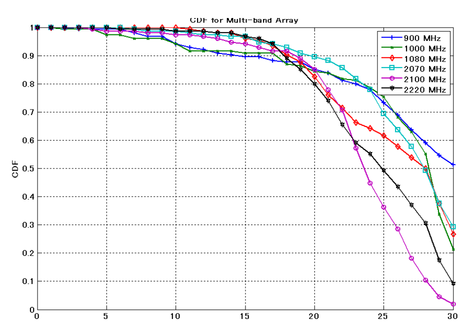
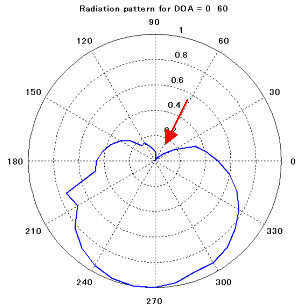


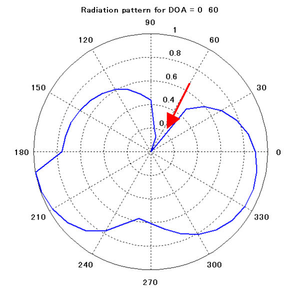
Figure 5: CCDF for both frequency band (1000 MHz and 2100 MHz)

Figure 6 shows the beam pattern after applying adaptive beamforming. Null is performed at incoming interference (red arrow), which means that interference has been eliminated. The beam is formed by adjusting the reactance value through optimization using simplex method. At the beginning the reactance value is set to 0, the value is change after optimization (refer Table 1), and the values are different for each incoming DOAs. However, the reactance range limited from

$-j300\Omega < jX < j300\Omega$ considering manufacturing. The number of iterations is less than 100 and the convergence time is less than 30 ms.



(a) 1000 MHz



(b) 2100 MHz

Figure 6: Adaptive patterns using MATLAB

Table 1: Simulation results of the downhill simplex method for proposed antenna.

Frequency	Desired signal	Delayed signal	SINR (dB)	Convergence time (ms)	Iteration number	Reactance (Ω)		
						jX1	jX2	jX3
1000 MHz	0°	60°	30.97	20.25	45	110.22	124.86	-79.79
	0°	150°	17.55	30.5	76	78.13	300	-52.78
	120°	300°	31.76	23.1	51	-102.35	14.16	-62.11
	180°	30°	19.45	29.7	68	-300	300	16.33
2100 MHz	0°	60°	27.5	16.97	47	-147.85	30.7	87.2
	0°	150°	28.95	22.09	48	264.15	-29.39	42
	120°	300°	28.74	21.76	47	238.64	141.8	-65.59
	180°	30°	29.3	22.84	45	281.13	13.46	-58.67

5. Conclusions

By implementing RSAA concept to the rear defogger we are able to design a smart antenna that can steer towards the desired signal and eliminated interference without adding any elements to the vehicle. The designed antenna can operate at 1000 MHz and 2100 MHz. This antenna is suitable for a moving system like vehicle because it has fastest convergence time.

References

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