Influence of resin cover on antenna gain for automotive millimeter wave radar

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Abstract - **When a millimeter wave radar is mounted on a vehicle, it is often installed behind a resin cover, such as an emblem, grill, or bumper. We analyzed the influence of the resin cover on the antenna gain, and clearly showed the mechanism for the degradation of the gain. It was found that a small spacing between the antenna and the cover can improve the antenna gain.**

Index Terms **— Millimeterwave automotive radar, Microstrip antennas, resin cover**

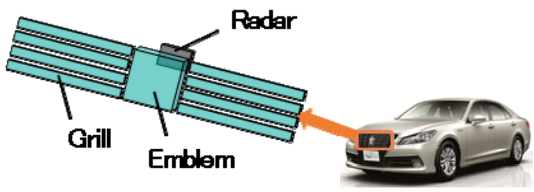

Fig1 Location of Front sensing radar

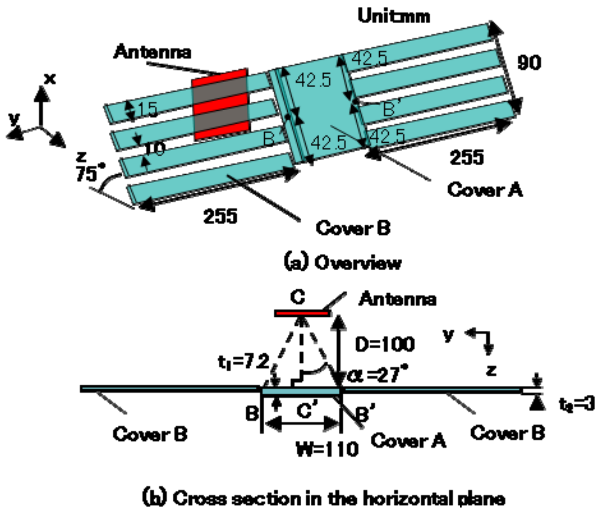

Fig. 2 Structure of the plastic cover

1. Introduction

Currently, automotive makers and suppliers are conducting a lot of research on automotive radar in order to realize autonomous driving. Sensors which can utilize millimeter-wave radar are thought to be necessary for autonomous driving to be feasible. With these radars, it is possible to measure the distance between the front of a car and another car or object, their speeds and directions.

The radar is generally mounted behind a resin cover, such as an emblem, grill, or bumper in order to protect the radar from damage, such as from impacts or exposure to rain. The thickness of these resin covers is a few millimeters, and the resulting decrease in antenna gain cannot be ignored because the wavelength in free space, λ_0, at 76.5 GHz is 3.9 mm. The shape of the resin cover depends on the exterior design of the car, so individual designs are needed, and the development of a simulation method for investigating the effect of covers on the gain is a priority.

The design for the resin cover has to take into account its dielectric constant, shape, and position in order to ensure good performance of the radar.

We analyzed the influence of the position of the resin cover on the antenna gain. The simulation results show the antenna gain degrades sharply at angles of ±30° between the resin cover and the antenna. We investigated the physical mechanism for this, and found that a small spacing between the antenna and the resin cover can improve the antenna gain.

2. Structure of the resin cover and radar antenna

We investigated an automotive radar for front sensing, which was mounted as shown in Fig. 1. Figure 2(a) shows an overview of the structure of the resin cover, and Fig. 2(b) shows a cross section in the horizontal plane. The multi-part cover consisted of a flat plate (Cover A, Emblem) and elongated resin plates (Cover B, Grill). The dielectric constant of the resin was 2.7, tan δ was 0.02, and the frequency was 76.5 GHz. The thickness of Cover A was 7.2 mm, which was chosen in order to minimize the transmission loss. The optimum thickness of the cover is an integral of the wavelength in the dielectric material when the radio wave is normally incident [1]. The other dimensions were determined from the actual vehicle cover. The total cover width was 620 mm, and the wavelength was $160\lambda_0$. The points B, and B' represent the center of the vertical side of Cover B. The horizontal center points of the antenna and the cover A are C and C', respectively. α is defined as the angle between line C-C' and line C-B', and it was 27° in the simulation model.

Figure 3 shows the structure of the radar antenna. It is an 18 × 2 rectangular patch array, and the patch element was inclined at 45° in order to realize 45° polarization. The array size was determined in reference [2]. Each patch element is fed by the wires, and the patch size is 1.2 × 1.2

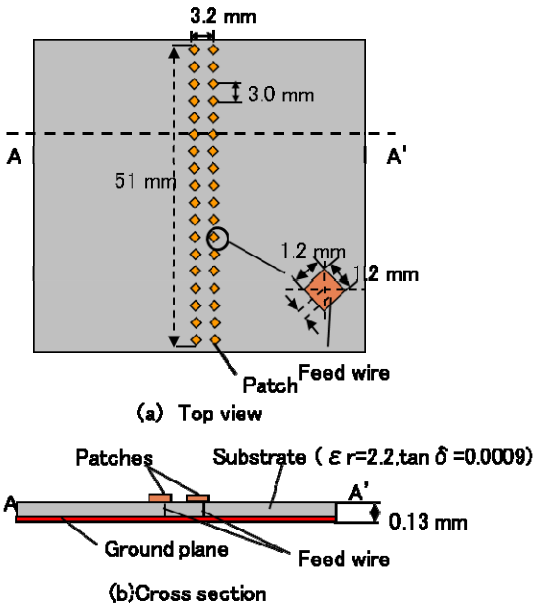

Fig.3 Structure of the radar Antenna

mm. The two horizontal elements are fed at the same amplitude, and the 18 vertical elements are fed using a Chebyshev distribution with a sidelobe level of -20 dB. Various radars can easily be simulated by changing the array size and the feed distribution in the antenna model. The simulations were performed using CST Microwave studio on the supercomputer of Tokyo Institute of Technology, TSUBAME [3].

3. Results and discussion

The simulation results for the dependence of the radiation pattern, with and without the resin cover, are shown in Fig. 4. The half beam width was ±16°, and the peak gain was 23 dBi. The two curves are seen to diverge strongly at angles of about ±30° and ±75°. These reductions in gain are thought to be due to Cover A and Cover B, respectively. Since the gain reduction at around ±30° would have the largest impact on the radar performance, we focused on this reduction.

We analyzed the relationship between the angle α and the gain. α can be varied by changing the cover width, W, or the size of the spacing between the antenna and the cover, D. Changing the width W also affects the exterior of the vehicle, so in this study only the spacing D was varied.

Figure 5 shows the radiation pattern when the spacing D was varied from 70 to 130 mm. This simulation was conducted using the model with Cover A, and not with Cover B. The gain for D = 130 mm shows a null point at around ±22°, and the gain for D = 70 mm at ±30° is about 10 dB higher than that for D = 100 mm. When D is 70, 100, and 130 mm, α is ±36°, ±27°, and ±22°, respectively. These results show that the degradation of the gain depends on the angle that α associated with the edge of Cover A.

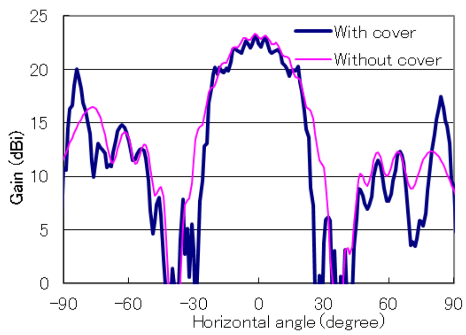

Fig.4 Radiation pattern of the antenna, with and without cover, (76.5 GHz, α = ±27°, D = 100 mm)

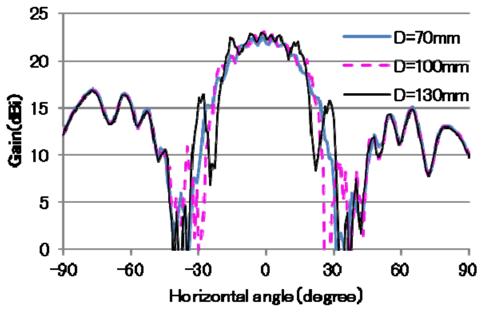

Fig.5 Radiation pattern for different spacing between the antenna and the cover (W=110 mm)

It was also found that a small spacing, D, can improve the antenna gain for wide angles.

4. Conclusion

We analyzed the influence of resin covers on the antenna gain. It was shown that there is a degradation at around ±30° when the radar is installed behind a resin cover. We analyzed the influence of the spacing between the antenna and the resin cover on the gain to determine a suitable choice of angle, α, corresponding to the edge of the central part of the cover. It was found that the degradation of the gain depends on the angle α. This result shows that a small spacing D, can improve the antenna gain. Future work will validate the simulation results with experimental measurements.

References

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[3] http://tsubame.gsic.titech.ac.jp/docs/guides/tsubame2/html/overview.html