The Application of the Electromagnetic Simulation Technology to the Products in the Automotive Fields

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ABSTRACT In the automotive material fields, special materials are being developed for the purpose such as recycling, on the other hand the advanced radar technology combining multiple radars is required in order to improve safety. The needs and the importance of the high-frequency simulation technology to predict the high-frequency characteristics of the surrounding objects for installing the radar on parts such as a bumper is increasing. Clarification of the high-frequency characteristics of the special materials and the development of the high-frequency simulation technology to study about the installation of radars on vehicles are introduced in this paper.

1. INTRODUCTION

In the automotive material fields, special materials are being developed for the purpose of recycling, and advanced radar technology combining multiple radars is required in order to improve the safety, then a higher-frequency and a miniaturizing of the radar are required. In addition, the needs and the importance of the high-frequency simulation technology to predict the high-frequency characteristics of the surrounding objects for installing the radar on such as the bumper are increasing. By utilizing the high-frequency simulation technology, the investigation of the influence on the high-frequency characteristics of the surrounding products, due to the difference in the material characteristics and the structure, becomes possible. In the vehicle-mounted design (for the onboard design) of the 24 GHz-band high resolution multimode radar developed by the Company, the high-frequency characteristics of the surrounding structure were clarified and the appropriate installation condition has been understood. The clarification of the high-frequency characteristics of the special materials and the development of the high-frequency simulation technology to study about the installation of radars on vehicles are introduced in this paper.

2. BACKGROUND OF THE DEVELOPMENT OF THE 24 GHz BAND HIGH RESOLUTION MULTICORE RADAR[1)]

Recently, Advanced Driver Assistance System (ADAS), that prevents accidents of vehicles by installing sensor devices to detect the surrounding objects, has been promoted.

Our 24 GHz-band high resolution multimode radar is compact and has a high degree of freedom for installation on the vehicle, for instance it can be mounted inside the bumper, so it can be applied to various applications such as front lateral side monitoring and rear lateral side monitoring. Table 1 shows the major specification of the 24 GHz band high resolution multimode radar.

Table 1 Specification of the multi-mode radar.

Item	Value	Unit
Modulation method	Pulse	—
Frequency band	24.05-24.25	GHz
Dimension	100 × 100 × 30	mm

3. TECHNICAL ISSUES FOR VEHICLE INSTALLATION

When installing the radar in the vehicle, the radiation direction of the radio wave may be affected by the bumper (dielectric) placed on the radiating surface and the vehicle body (metal) situated on the back surface. Figure 1 shows the radar installed inside of the bumper.

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Figure 1 Radar installed inside of the bumper.

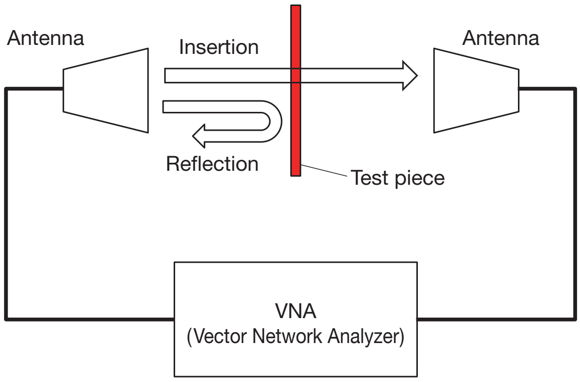

Figure 2 High frequency characteristic evaluation system of the material.

The radar transmits a radio wave and detects other vehicles, pedestrians, bicycles, obstacles and so on, by receiving the returning radio wave. The radio wave also reflects from the vehicle structures around the radar installed position. The reflections from unnecessary directions cause erroneous detection, then the appropriate conditions have been found for the onboard design including materials and shapes of the structures installed around the radar. On designing the radar to be installed inside the bumper, it is necessary to clarify the high-frequency characteristics of the materials used for the surrounding structures such as bumpers in the used frequency band (24 GHz).

Recently, an environmental approach[2)] for a special bumper material suitable for recycling, also a development of the materials[3)] that shield multi-paths that affect the radar performance have been carried out. In addition, the development of paints used for bumpers having high-class touch as designs, and the development of the environmentally friendly high-performance paint and processes are promoted[4)]. Thus, the special materials not commonly known for high-frequency performances are increasing. In particular when considering a newly developed material to install in the structure and others, it is required to visualize and quantify the influence on the radar to simulate the installation state by using a flat plate (test piece).

4. EVALUATION OF THE HIGH-FREQUENCY CHARACTERISTICS OF THE MATERIAL

The actual piece was measured in accordance with the free space method[5)].

Figure 2 shows the material high-frequency characteristics evaluation system. The amplitude and the phase of the radio wave passing through between the two horn antennas were measured on the condition of the presence or absence of the test piece, and the difference was estimated as the transparent characteristic of the test piece.

The radio waves transmitted from the horn antenna were reflected by the test piece or a same size of metal plate, and the amplitudes and the phases of the reflected radio waves returning to the transmission antenna were measured. Then the differences of the measured values were taken as the reflection characteristics of the test piece. The test piece of the material used for the measurement were conditioned as follow from the view point of the measurement accuracy.

- The incident wave shall be a planar wave. (The distance from the antenna can be sufficiently secured.)
- The sample size shall be 10 λ or more.
- The surface shall be flat.
- Uniform and no anisotropy.

The high-frequency characteristics can be calculated from the amplitude and the phase of the transparent wave and the reflected wave by using the transmission theory. Figure 3 shows the transparent characteristics analyzed by the high- frequency simulation of the effect on the radio wave characteristics due to the difference in the dielectric property of the paint in the 24 GHz-band.

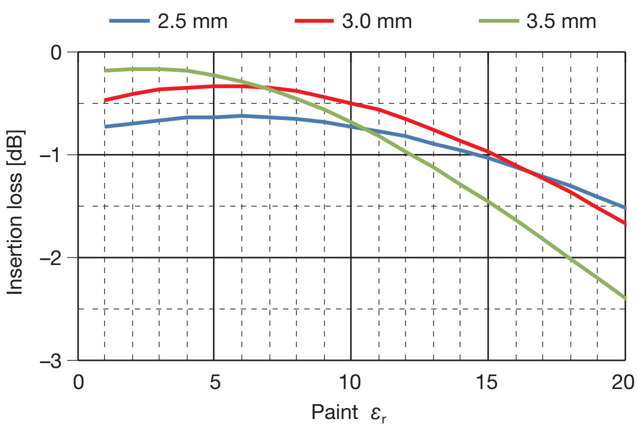

Figure 3 Insertion loss.

The thickness of the paint constant, and the thicknesses of the bumper material were 2.5 mm, 3.0 mm and 3.5 mm. The influence of the relative permittivity of the paint on the transparent characteristics of the radio waves varies depending on the thickness of the bumper material to be painted. To obtain the preferred radar characteristics, the optimization of the installation condition in consideration of the high-frequency characteristics of the materials used to the bumper and painting is necessary. In case of the resin bumper material, the surface is often processed by painting. Table 2 shows the dielectric characteristics result of the paints coated on the bumper material with known high-frequency characteristics, and the simulation model is shown in Figure 4.

Table 2 Dielectric characteristics of the paint.

Paint	ε_r @ 24 GHz	thickness (mm)
A	7 ~ 8	0.6 ~ 0.7
B	4 ~ 5	0.5 ~ 0.6
C	10 ~ 11	0.3 ~ 0.4

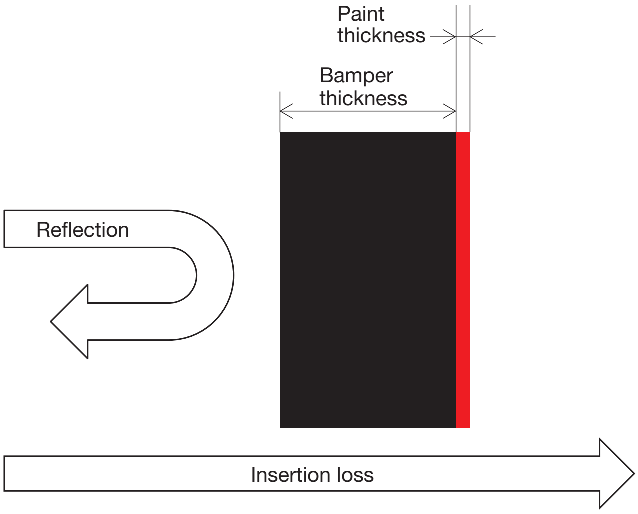

Figure 4 Simulation model.

5. SIMULATION APPLICATION EXAMPLE TO 24 GHz BAND HIGH RESOLUTION MULTIMODE RADAR

By digitizing the high-frequency characteristics of the surrounding structures of the radar, the analysis in consideration of a more practical vehicle structure becomes possible. Figure 5 shows the simulation model representing the vehicle installation conditions. Figure 6 shows an electric field distribution of Figure 5 as viewed from the top. From Figure 6, the spread of the electromagnetic field component between the body and the bumper, and the reflection inside the vehicle (between the bumper and the body) are confirmed, and the influence of the vehicle structure is necessary to be considered in the radar electric wave environment design.

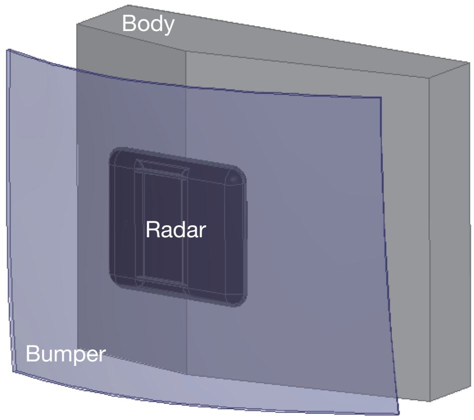

Figure 5 Simulation model.

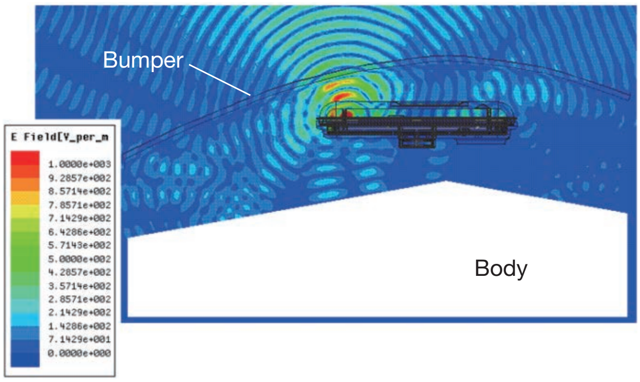

Figure 6 Electric field distribution.

In order to carry out further detailed study, the vehicle structure was converted to data with a 3D scanner, and the vehicle installation state was analyzed. Figure 7 shows the vehicle installation state. In Figure 7, a 3D scanner was utilized to record the metal body within about 1.5 m around the radar and the bumper as 3-dimensional CAD data, and imported into a simulation model. The result of the actual measurement and the high-frequency simulation were compared by normalizing the radar front direction as 0 deg. and the gain maximum value as 0dB, and confirmed that the consistency was obtained. Table 3 shows the normalized gain. Since the performance of the radar is influenced by the installation condition on the vehicle, by knowing the high-frequency characteristics of the structure, the analysis with more realistic environment simulation becomes available.

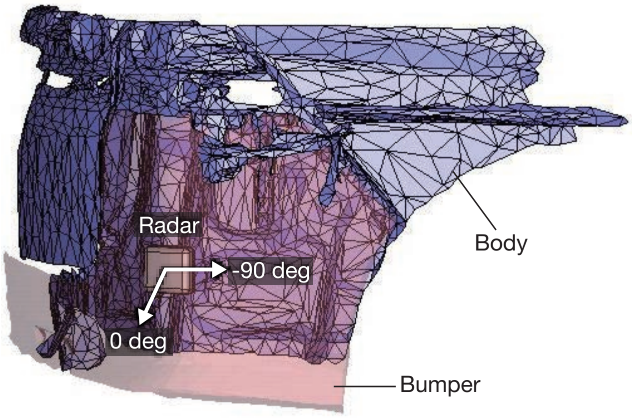

Figure 7 Radar installed in a car.

Table 3 Normalization gain. (Max. gain = 0 dB)

Angle (deg)	−20	0	+20
Experiment (dB)	−3.1	−0.3	−3.4
Simulation (dB)	−2.7	−0.4	−3.3

6. CONCLUSION

The application examples of the high-frequency simulation technology to the automotive fields at the Company was introduced in this paper.

Even when the radar is used under a new condition such as newly developed paint coating, the appropriate installation condition can be found by identifying issues and examining countermeasures for the simulation. We will continuously improve the issues-solving ability through the visualization of phenomena using virtual trial & error methods and taking appropriate measures at the right time based on the principles acquired through the appropriate utilization of the simulation in accordance with the scale and the purpose of the analysis.

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