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Categorizations of Radiation Characteristics from a Cabin Antennas at 800MHz Bands

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1. Introduction

Recently, electromagnetic simulation abilities of very large obstacles are powered up. The Multilevel Fast Multipole Method (MLFMM)[1][2] is now available in some Method of Moment simulators. Calculation time and needed memory capacity are surprisingly reduced[3].

In this paper, electrical fields inside a car and radiation patterns are simulated at 800MHz. Due to standing waves inside a car, radiation patterns happen to change dramatically according to antenna position changes. We find out that variety of radiation patterns can be categorized into some groups. And it is shown that excited standing waves in a cabin play very important roles in categorizations. Moreover, calculated results are ensured through experimental study employing a 1/7 scale model car.

2. Simulation model and conditions

The simulation model is shown in Fig.1. A half-wavelength dipole antenna is installed in a car cabin horizontally and vertically.

In order to calculate near and far field characteristics of a car, an electromagnetic simulator FEKO suite 4.1[4] is employed. This simulator is based on the Method of Moment and has capabilities of MLFMM calculations. Here, a metallic car body is divided into many calculation segments. In order to get accurate results, ordinal segment sizes are selected to be one tenths of a wave length. As for the dipole antenna, segment sizes are chosen to be 1/20 of wave length. As for a car body, larger segment sizes are studied so as to reduce needed memory size. It is recognized that sufficient convergence of calculated results is achieved at the segment size of 1/4 wave length. In this case, the memory size becomes 135MB. Rather small memory size is achieved in the case of MLFMM calculations[3]. Employed personal computer functions are clock time of 2GHz and memory capacity of 4GB. Calculation time of currents on a car body is 6 minutes. Calculation time of near and far field are 13 minutes and 29 minutes, respectively.

3. Categorizations of Electric fields and radiation patterns

By taking into account similarities of environmental situations surrounding an antenna, the inside space of a car can be categorized into

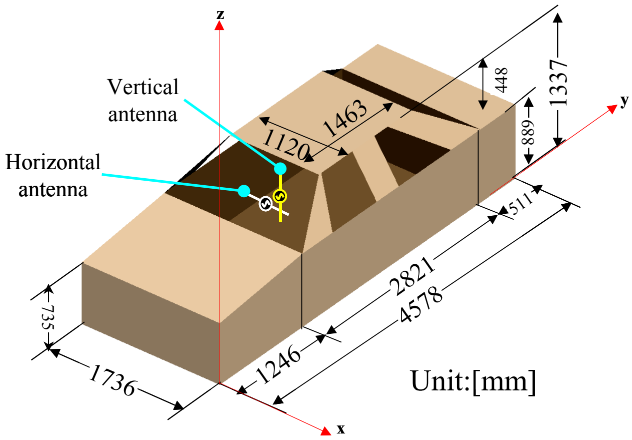
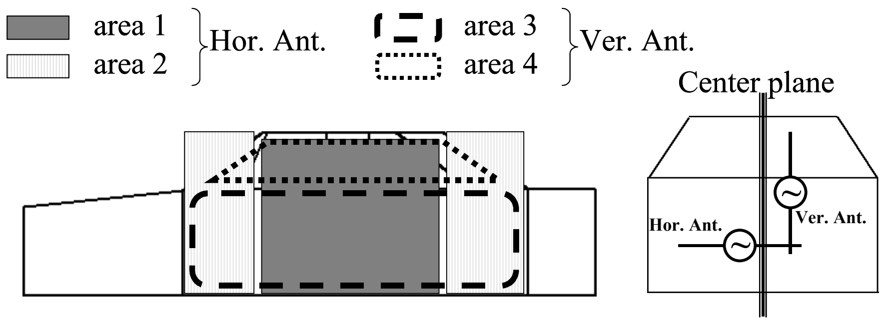


Fig. 1 Simulation model and antenna settings



(a) Side view (b) Front view

Fig. 2 Categorized area

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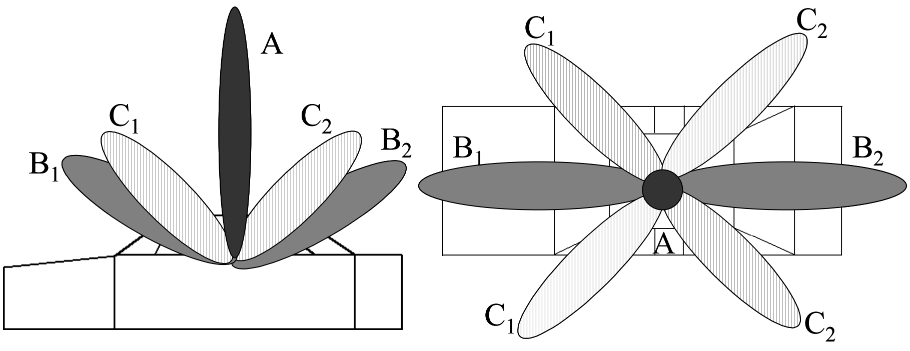


(a) Side view (b) Top view

Fig. 3 Typical Radiation Patterns

some groups as shown in Fig.2 (a). In the case of a horizontal antenna shown in Fig.2 (b), radiated waves from an antenna placed in the Area 1 are reflected by the ceiling and the floor of a car. At the Area 2, radiated waves path freely through front and rear windows. In the case of a vertical antenna, radiated waves are shut up in a car cabin in the Area 3. At the Area 4, radiated waves path freely through front and rear windows. In this simulation, antennas are moved only in the central plane as shown in Fig.2 (b).

Categorized radiation patterns are shown in Fig. 3(a) and (b). Typical radiations of main beams are shown. Type A indicates that a main beam direct to the top of a car. Types B_1 and B_2 indicate that main beams exist in the central plane. Types C_1 and C_2 indicate that main beams separate into side directions.

In table 1, a categorization of electrical fields inside a car and radiation characteristics is shown.

(1) Area 1

Excitations of standing waves are main features. When antennas are placed at peak positions of expected standing waves, strong standing waves are excited. A strong beam directed to the top of a car is produced. On the other hand, excitations of standing waves become very weak at antenna positions of expected standing wave bottoms. Major beams are produced in side directions of a car.

(2) Area 2

Disappearances of clear standing waves are main features. When antennas are placed at upper the door, major beams are produced in front and back directions according to front and rear antenna positions, respectively. When antennas are placed lower positions under the window, major beams are produced in back and front directions according to front and rear antenna positions, respectively. In this case, induced currents on adjacent metallic walls such as floor and front or rear walls become very strong.

(3) Area 3

When antennas are placed below the front and the rear windows, remarkable standing waves appear in the horizontal plane. Similar to the case of antenna positions lower the window in Area 2, major beams are produced in back and front directions according to front and rear antenna positions, respectively. In this case, induced currents on all the surrounding walls become strong. When antennas are placed under the roof, standing waves become very weak. Radiated intensities become rather low. Major beams are produced in many directions.

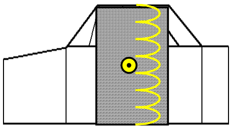
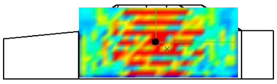
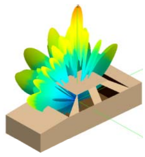
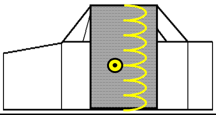
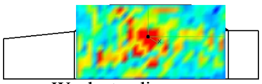
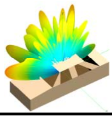
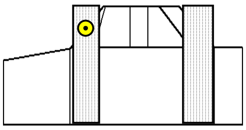
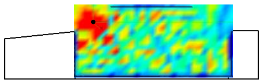
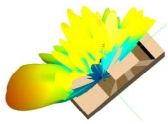
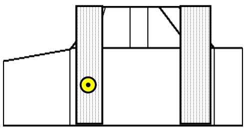
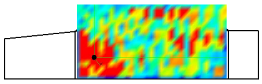
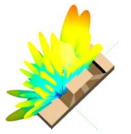
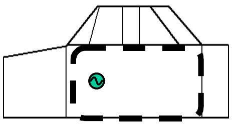
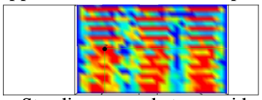
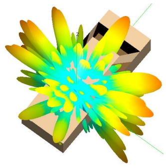
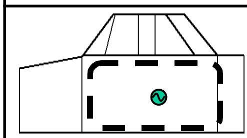
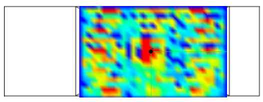
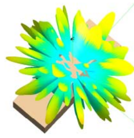
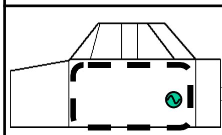
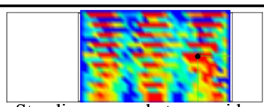
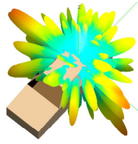
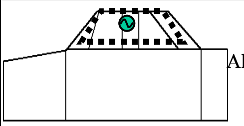
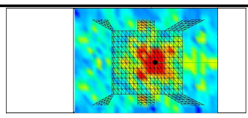
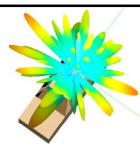
(4) Area 4

No standing waves is the feature in this case. Major beams are produced in many directions.

4. Measured and calculated results

Validity of calculated results are ensured through measured results. Area 1 is selected as a typical example. Fig.4 shows the case of antennas positioned at the peaks of standing waves. Fig.4 (a) indicates standing waves inside a car. High intensity zones spread wide under the ceiling. These zones are stacked with separations of half wave length. One flat plane of these zones is considered as a small rectangular aperture radiator. So, radiation beams are constructed in the normal direction of the ceiling. A 3D radiation pattern is shown in Fig.4 (b). A strong main beam directing to the zenith is observed. 2D radiation patterns in the Y-Z plane are shown in Fig.4 (c). A 1/7 scale down model car is employed in measurements.

Table 1. Categorizations of electric fields and radiation patterns depend on cabin antenna positions

	Area	Antenna settings	Electric Fields	Radiation Patterns (type)
Horizontal antenna	1	 Peak of standing waves	**Remarkable standing waves appeared in the vertical plane**  Standing waves between the roof and the floor	 Strong beam appeared in the top of a car (A)
		 Bottom of standing waves	 Weak standing waves	 Central and side directions $(B_1)+(B_2)+(C_1)+(C_2)$
	2	 Upper the door	 Weak standing waves	 Antennas behind the front window (C_1) Antennas inside the rear window (C_2)
		 Lower the window	 Weak standing waves	 Antennas behind the front window (C_2) Antennas inside the rear window (C_1)
Vertical antenna	3	 Under the front window	**Remarkable standing waves appeared in the horizontal plane**  Standing waves between side walls	 Rear directions $(B_2)+(C_2)$
		 Under the roof	 Weak standing waves	 Central and side directions $(B_1)+(B_2)+(C_1)+(C_2)$
		 Under the Rear window	 Standing waves between side walls	 Front directions $(B_1)+(C_1)$
	4	 All position in area	 No standing waves	 Central and side directions $(B_1)+(B_2)+(C_1)+(C_2)$

In order to compare correctly radiated levels of calculated and measured, dipole antenna levels are fitted. Measured and calculated results agree rather well. Peak gain of about 16dBi is achieved.

When antennas are placed at the bottoms of standing waves, radiation characteristics change dramatically as shown in Fig.5. In this case, standing waves become very weak as shown in Fig.5 (a). A 3D radiation pattern is shown in Fig.5 (b). Many major beam are produced in the central and side directions. In Fig.5 (c), 2D radiation patterns are shown. Measured and calculated results agree rather well. Peak gain becomes low value of 10dBi.

Through above mentioned experimental study, validities of calculated results in levels and shapes are ensured.

5. Conclusions

It is shown that near and far field results can be easily obtained through FEKO software. At 800MHz, standing waves inside a car changed rapidly according to antenna positions and polarizations. By taking into account circumferential conditions of an antenna, standing waves and radiation patterns are shown to be categorized into some groups. Through experimental study, validities of calculated results are ensured.

References

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[3] N.Nakakura et al, “Change of Electric Fields and Radiation Patterns Depending on Cabin Antenna Positions”, IEEE APS Int’l Sympo., June 2004

[4] http://www.feko.info/

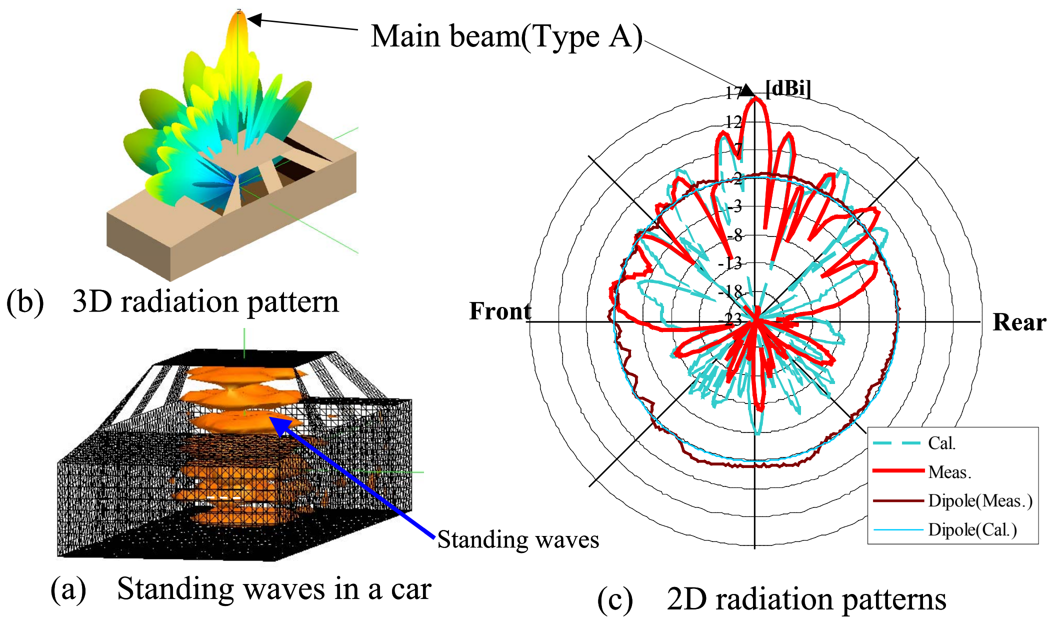

Fig. 4 Measured and calculated results
(Antenna positioned at the peak of standing waves in Area 1)

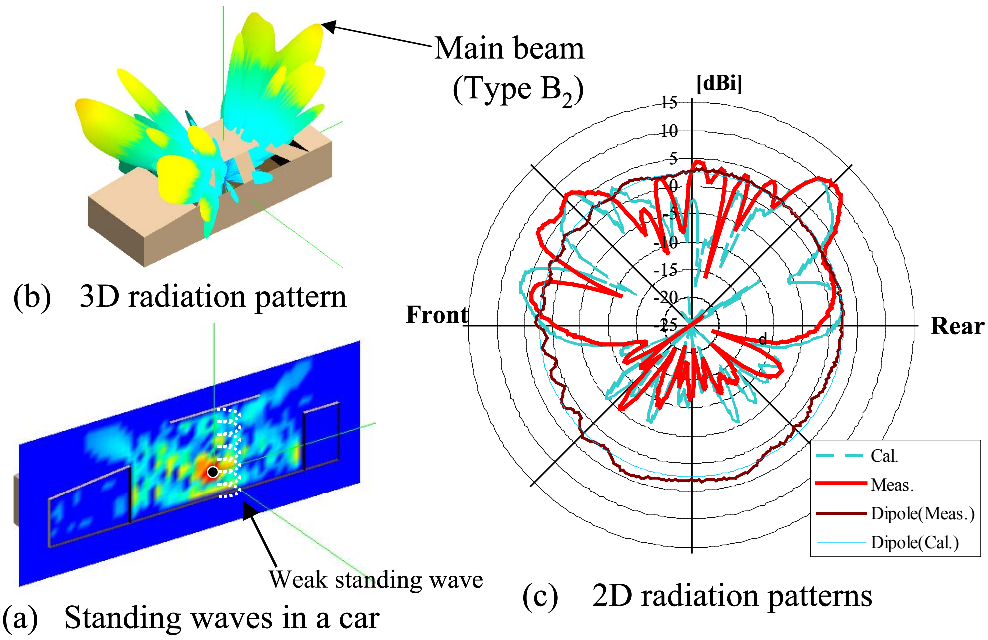

Fig. 5 Measured and calculated results
(Antenna positioned at the bottom of standing waves in Area 1)