Electrical field simulations around a car in the AIRwatch system

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Abstract

In order to support the vehicular safety drive, TPMS are introduced in U.S.A and Europe. In Japan, the AIRwatch system is developed. This paper clarifies electrical field environments of this system through electromagnetic simulations.

First of all, electrical wave emissions from an antenna contained in a tire become larger than that of an antenna in free space. Next, electrical field distributions on a front window where a received antenna is placed are simulated. Electrical field intensities agree well with that estimated by the Friis transmission formula. So, accuracies of calculation results are ensured. Electrical field changes owing to tire rotations are also clarified. Deviations of intensities during tire rotations are about 10dB. It is concluded that sufficient electrical field strengths are achieved on a front window.

1. INTRODUCTION

Automobile industries have been making efforts to develop safe systems for the vehicular safety drive. Recently, TPMS (Tire Pressure Monitoring System) are introduced in U.S.A and European countries[1]. In Japan, AIRwatch system is developed[2]. Here, radiated power is severely restricted by the radio regulation. So, estimation of radiated powers from a transmitter contained in a vehicle tire is very important. Here, owing to rapid power up of MoM simulators, electromagnetic simulations of a car become rather easy[3]. Simulations of antenna received power from transmitters contained in tires were mode[4],[5]. However, obtained data was not sufficient.

In this paper, electrical field distributions in a tire and radiation levels from a tire are clarified through electromagnetic simulations. Electrical field distributions on a front window and induced current on a car body are also calculated. Moreover, variations of electric fields on a front window in accordance with tire rotations are clarified.

2. AIRwatch SYSTEM

Commercialized AIRwatch system is shown in Fig.1[2]. The system consists of four transmitters connecting to air pressure sensors contained in tires, an on-board receiver unit on a dashboard and a receiver antenna (film antenna) on a windshield. In the sensor, 315MHz continuous wave is modulated by tire pressure data in FSK scheme. 315MHz modulated wave is transmitted through a small loop antenna in a sensor. By the receiver antenna, transmitted waves are gathered. Pressure levels are displayed by the on-board receiver unit. When a tire pressure becomes too low, warning alerts are given to a driver.

In Japan, electrical field strength from a transmitter is restricted less than -66dBV/m at 3m distant point by the Japanese radio regulation. So, the design of the high sensitivity system is necessary.

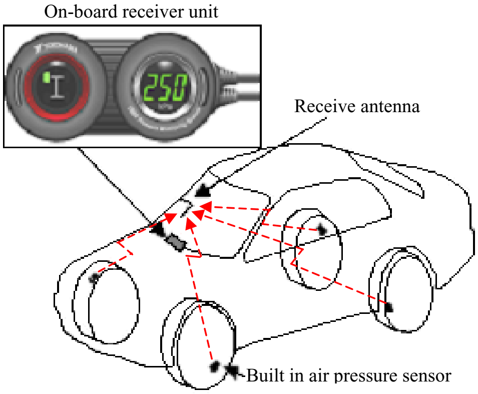

Fig.1 AIRwatch system configuration

3. SIMULATION METHOD

Personal computer specifications, electromagnetic simulator functions and simulation conditions are summarized in Table1. A personal computer of clock frequency 3.6GHz and memory capacity of 4GB is employed in simulations. An electromagnetic simulator employing the Method of Moment (FEKO) is used. The FEKO can use the multilevel fast multipole method (MLFMM). So, calculation memory size and time are surprisingly lightened. In the case of a car body, for unknown current number of 18,201 memory size of only 711.9MB is needed. This memory size is less than one hundredth of that without MLFMM scheme. So, calculation time is speed up to 468 seconds.

Table1 Simulation conditions

PC spec.	Clock time	3.6G Hz	
	Memory	4G Byte	
	OS	Windows XP professional	
EM sim.	Method	MoM with MLFMM	
	Frequency	315MHz	
		Tire	Car body
	Segment size	1/10Wave length	1/10Wave length
	Unknown currents	671	18,201
	Memory requirement	12.3M byte	711.9M byte
	Calculation time	21.6 sec	468 sec

A simulation model of a tire is shown in Fig.2. The tire steel belt is modeled as a conducting plate. Diameters of a wheel and a steel belt are denoted by D_1 and D_2, respectively. D_1=380mm and D_2=580mm are used. As a radiating element, a small loop antenna is employed. This antenna is attached on a wheel. The circumference length of a loop antenna is 40mm.

A simulation model of a car is shown in Fig.3. A car body is composed of 1/10 wavelength segments. Tire rubbers and window glasses are not included for ease of calculations.

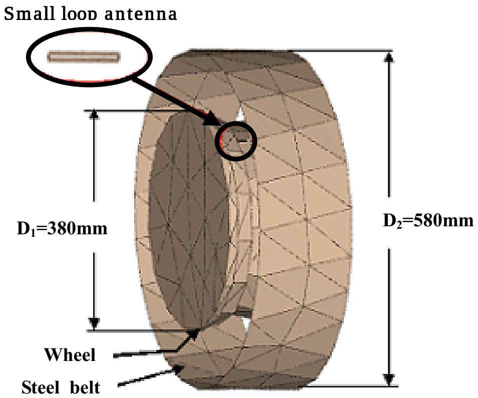

Fig.2 Simulation model of a tire

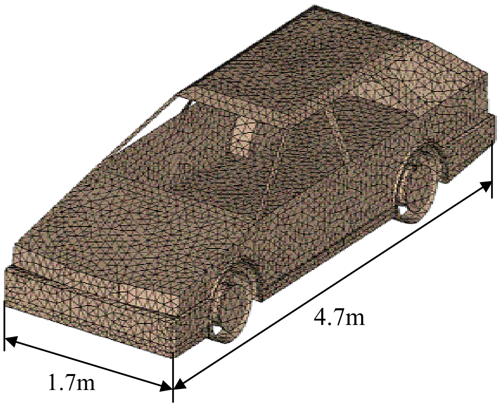

Fig.3 Simulation model of a car

4. RADIATION FROM A TIRE

Radiation patterns of a loop antenna are shown in Fig.4. The maximum level becomes –28.56dBi. This level coincide with the theoretical value estimated through resistance values of radiation and conductivity of the given loop antenna. In Fig.5, radiation pattern from a tire is shown. The maximum level becomes –21.34dBi. This level is about 7dB larger than the level of Fig.4. This result is rather surprising.

Measured radiation patterns of the loop antenna and from a tire are shown in Fig.6. The radiation pattern of an antenna in a tire is similar to that of Fig.5. The radiated level of an antenna contained in a tire becomes about 3dB larger than that of a loop antenna in free space. This level increase is about 4dB smaller than the increase of 7dB in the case of Fig.4 and Fig.5. This is attributed to the loss of tire rubber.

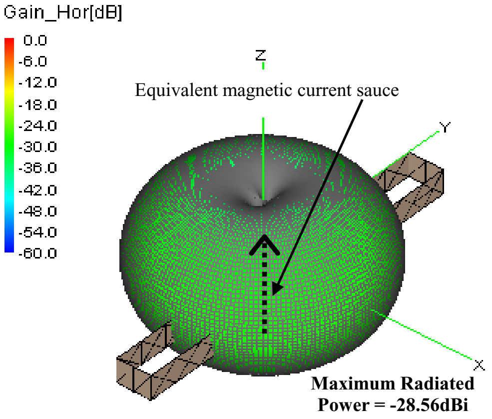

Fig.4 Radiation pattern from a loop antenna in free space

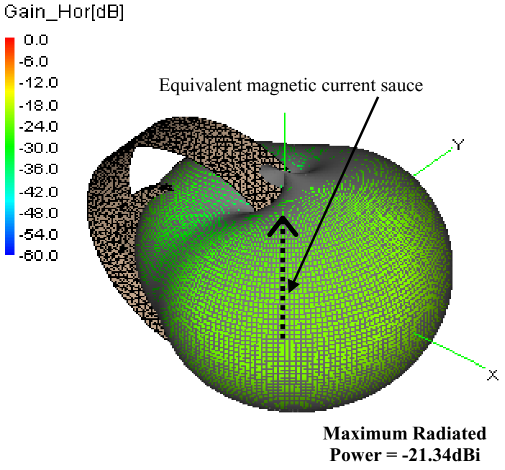

Fig.5 Radiation pattern from a loop antenna in a tire

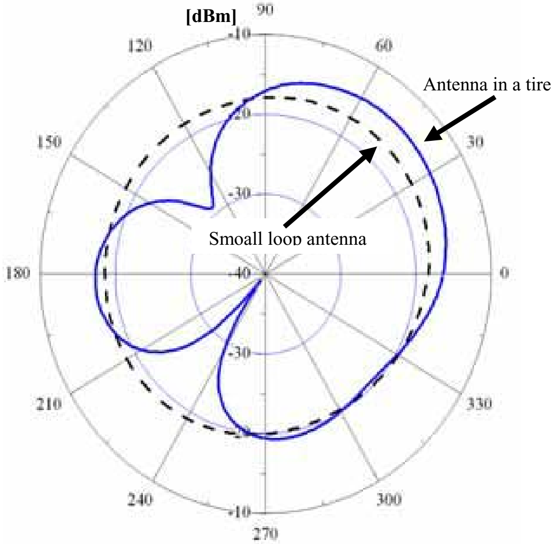

Fig.6 Measured radiation pattern of a loop antenna in free space and in a tire

5. ELECTRICAL FIELDS ON A FRONT GLASS

Electrical field intensities on a front window and induced currents on a car body are calculated. The case of a front tire antenna excited is shown in Fig.7. Here, one receive is used for four tires as shown in Fig.1. The tire side position indicates the case when a receive antenna side tire is excited. And the opposite side position indicates the case when an opposite side tire of a receive antenna is excited. The calculated electrical intensity at the tire side position becomes, -49.7dBV/m. In this case, input power to a loop antenna inside a tire is 0.1mW. And the excited loop antenna positions at the top of a tire. The estimated field intensity by the Friis transmission formula becomes –50.7dBV/m. Because the calculated and estimated intensities agree well, reliability of the calculated value is ensured. The calculated electrical field intensity at the opposite side position becomes –53.8dBV/m. This intensity is lower about 4dB than that of the tire side position. It is interesting that intensities around the pillar near the excited wheel become very strong. In calculated results of current intensities on car body, high intensity regions are only around the excited wheel. Currents on pillar are very weak. So, the reason of high intensities areas are thought that these areas are rather rear to the exciting tire.

The case of a rear tire antenna is exited is shown in Fig.8. Field intensities at the tire side and opposite side positions are -55dBV/m and -61dBV/m, respectively. Currents on a car body become strong around the rear tire.

As a summary of electrical field intensities on a front window, intensity changes in accordance with tire rotations are shown in Fig.9. Solid and dotted lines indicate cases of a front and rear tire is excited, respectively. In both cases, intensities change about 10dB in accordance with tire rotations. Intensities show maximum and minimum values at loop antenna positions on the top and the bottom of a tire, respectively.

As a whole, intensities of a front tire excited become larger than that of a rear tire excited.

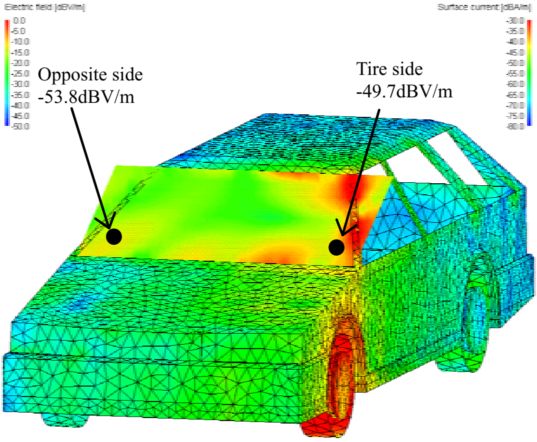

Fig.7 Electrical field intensities on a front window produced by a front tire antenna excitation

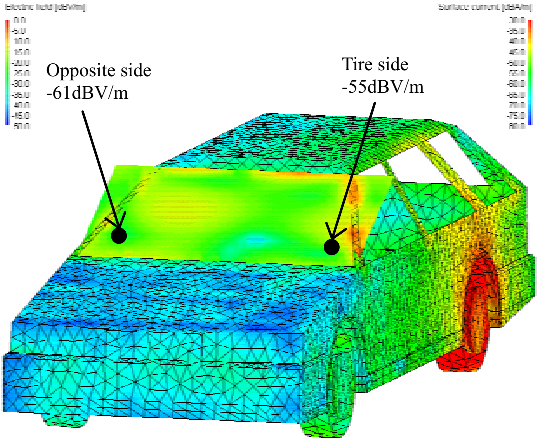

Fig.8 Electrical field intensities on a front window produced by a rear tire antenna excitation

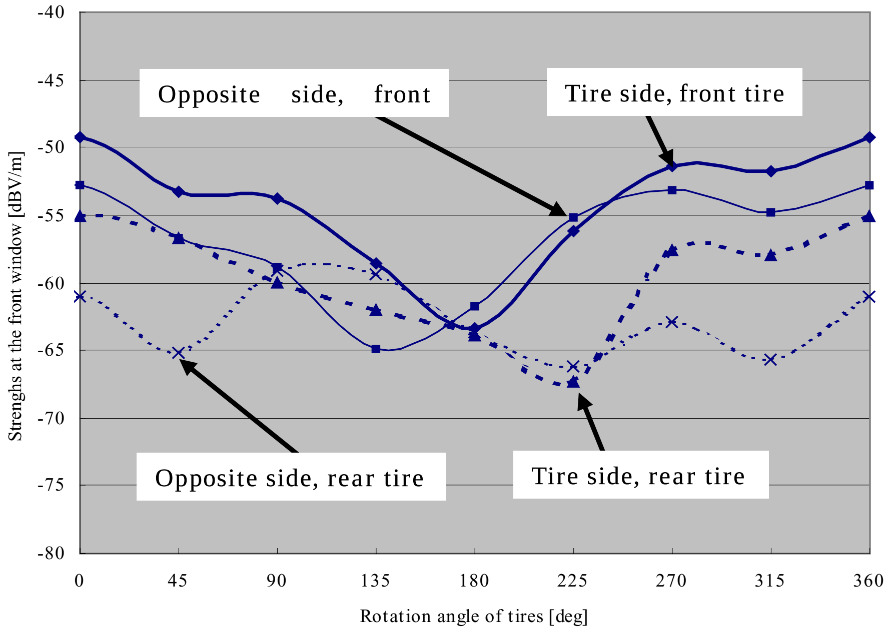

Fig.9 Electrical field intensity changes depending on tire

6. CONCLUSIONS

In the case of the AIRwatch system, electrical field environments of a car are simulated. First of all, it is shown that electrical wave emissions from an antenna contained in a tire become larger than that of an antenna in free space. Next, electrical field distributions on a front window where a received antenna is placed are simulated. Electrical field intensities agree well with that estimated by the Friis transmission formula. So, accuracies of calculation results are ensured. Electrical field changes owing to tire rotations are also clarified. Deviations of intensities during tire rotations are about 10dB. It is concluded that sufficient electrical field strengths are achieved on a front window.

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