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Analysis of Radio Propagation Characteristics for a Moving Vehicle

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***Abstract* – The radio propagation characteristic for a moving vehicle is studied in this paper by analyzing the receiver power of wireless communication signal at 2.4 GHz. The study includes measurement and ray-tracing based electromagnetic simulation. In both approaches, the inside and outside of the vehicle are analyzed. The measurement result agrees with the simulation one, and thus verifies the effectiveness and practicality of the simulation approach.**

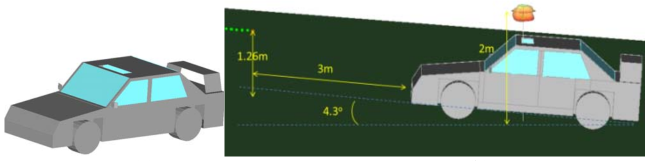
***Index Terms* — Moving vehicle, Radio propagation, Ray-tracing, Electromagnetic simulation.**

I. INTRODUCTION

With the development of wireless communication systems, communication is required to be available anywhere and anytime; whether people are walking or driving. This behavior leads to the requirement of stable wireless communication inside vehicle or among vehicles, in particular, when the vehicle is moving. To facilitate this issue, propagation characteristics for radio signal in vehicle is needed to be analyzed. Some studies have been conducted for the evaluation of the propagation characteristics in vehicles [1-2]. It was reported that penetration loss for various kinds of moving vehicles, such as minivan, full-size car and sports car, can be evaluated by measurement [1] and the penetration loss for a minivan at different frequencies can be determined by electromagnetic (EM) simulation [2]. In addition, the built simulation model is useful to predict the variation of penetration loss subject to any changes of model parameters. However, the analysis of radio propagation characteristics for a moving vehicle using electromagnetic simulation method is not thoroughly studied. In this paper, ray-tracing based simulation approach is used to study the receiving power strength outside and inside a full-size moving car and followed by measurement in order to verify the effectiveness and practicality of the simulation method.

II. SIMULATION WITH RAY-TRACING

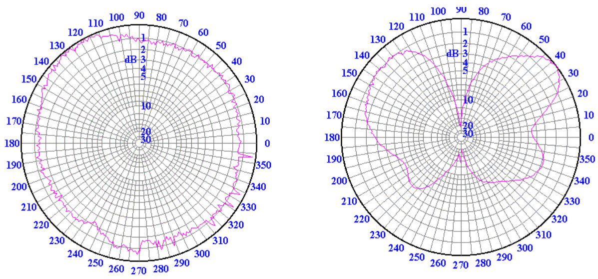
A full-size car model with reference to a Mitsubishi GDI Lancer is built in Remcom Wireless InSite [3]. The model is mainly consisted of a metalic car body with glass windows, as shown in Fig. 1(a). The car body is modeled as perfectly electrically conducting (PEC) panels and windows are modeled by glass. The environment for the car movement is assumed to be flat ground with a ramp-up slope of 4.3 degree, as shown in Fig. 1(b). The transmitter antenna is placed 18 meters apart from the front of the car at the beginning of simulation and this distance will be gradually reduced to 3 meters to emulate that the car is moving straight forward to the transmitter antenna. In the simulation, the step size of the car movement is set as 1 meter. Since only dominate components in simulation are considered, the number of ray paths is set to be two reflections, in which one is for transmission and the other is for diffraction.



(a) (b)

Fig. 1. Simulation model in Wireless InSite: (a) car model; (b) simulation setup.

A vertical polarized monopole antenna is assumed as the transmitter antenna and the model Xinmin RM321-ANT152-2-E with gain of 5 ± 1 dBi and VSWR$\leq$ 1.5 is selected. Since there is no built-in antenna model for the selected monopole antenna, a digitized model is built according to antenna patterns provided by the manufacturer datasheet [4]. The horizontal and vertical pattern of the built antenna model is shown in Fig. 2. The simulation is then conducted in the Wireless InSite.



(a) (b)

Fig. 2. Antenna pattern for built antenna model: (a) horizontal; (b) vertical.

III. MEASUREMENT

Measurements are also conducted with a real car which has been modeled for simulation in section II. As shown in Fig. 3, the measurement system is consisted of a transmitter and a receiver. The Xinmin RM321-ANT152-2-E monopole antenna is mounted on a tripod with a 1.26 meter height and it is connected to a function generator by coaxial cables for radio signal transmission. A 2.4GHz sinusoidal wave signal with input power of 10 dBm is provided by signal generator and fed to transmit antenna. The receiver is setup by connecting the same type of monopole antenna to a spectrum analyzer with coaxial cables. The receiver antenna is mounted on a tripod and placed inside the car, and its height can be adjusted by stretching the antenna out from the sliding glass sunroof of the car in order to measure the signal level of either outside or inside the vehicle. Each cable has a power loss of about 7 dB at 2.4 GHz. A 12V DC lead acid battery with DC to AC invertor is used to supply power in the measurement.

Fig. 3. Measurement system setup

For the measurement of the power strength outside the vehicle, the tripod is set as 2.0 meter height thereby the receiving antenna is out from the sunroof. 16 location points from 3 to 18 meters in front of the car with a step of 1 meter are marked and the transmitter traverses all these points so as to emulate the car movement with a static transmitter. The receiving power was recorded by spectrum analyzer, and average values of the measurement from repeated experiments are taken. Changing the height of tripod with receiving antenna to 1.2 meters, the receiving antenna is inside the car. The same measurement procedure is repeated and average receiving power inside the vehicle can thus be obtained.

IV. Simulation Results and Comparisons

With the full-size car and antenna models, electromagnetic simulation using ray-tracing can be carried out to simulate the power strength outside and inside the car. Usually fast fading effect will form a large power level and significantly reduced power signal at the same time, then sharp peak will appear in the result data. This phenomenon can be removed by taking average and average interval is set as 10 times wavelength in this work.

Fig. 4 and Fig. 5 show the measured power strength and average simulated power strength outside and inside the full-size car, respectively. By simulation, the power level outside and inside the car with respect to the distance between transmitter and receiver is also obtained. The simulation result shows a good agreement with the measurement. The measured power strength decreases from -51.2dBm to -68.8dBm outside the vehicle and from -53.9dBm to -70.7dBm inside the vehicle with the increase of distance. It can be found that the power strength outside and inside the vehicle decreased as the distance between receiver and transmitter increased since the path loss is proportional to the distance between the transmitter and receiver. Besides, power strength inside the car is usually weaker than that outside the car because of penetration loss.

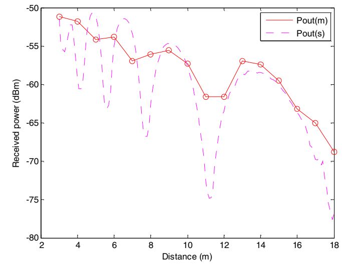


Fig. 4. Measured and average simulated power strength outside the vehicle.

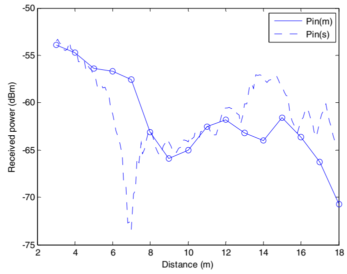


Fig. 5. Measured and average simulated power strength inside the vehicle.

V. Conclusions

In this paper, investigation of radio propagation characteristics for a moving vehicle using measurement and simulation is performed. Ray-tracing based electromagnetic simulation and direct measurement for the power strength inside and outside a car are conducted at 2.4 GHz. The agreement between simulation and measurement results verifies the effectiveness and the practicality of the proposed simulation method. In addition, simulation approach is beneficial in offering an accurate and more efficient analysis in contrast to the conventional measurement approach.

Acknowledgment

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References

[1] I. Kostanic, C. Hall, J. McCarthy, "Measurements of the vehicle penetration loss characteristics at 800MHz," in *Proc. 48th IEEE Veh. Technol. Conf.*, Ottawa, ON, Canada, May 1998, pp. 1–4.

[2] E. Tanghe, W. Joseph, L. Verloock, L. Martens, "Evaluation of Vehicle Penetration Loss at Wireless Communication Frequencies," *IEEE Trans. Veh. Technol.*, vol.57, no.4, pp. 2036-2041, July 2008.

[3] http://www.remcom.com/wireless-insite

[4] http://www.sbellxm.com.cn/products_listDetail.asp?id=379