Evaluation of the effect of raindrops on the on-glass antenna

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Abstract: In this paper, the effect of raindrops on an on-glass antenna is evaluated to appropriately design a C-band automotive antenna. A three-layer composite glass is used for the automotive window glass panel. The electromagnetic field analysis of a dipole on-glass antenna placed in the center of a 300 mm $\times$ 300 mm flat composite glass was performed. As a result, it was found that raindrop situation had no significant effect on the reflection characteristics of the antenna. However, the reflection coefficient of the antenna worsens when the raindrops were connected to each other and streaked in a direction parallel to the antenna.

Keywords: on-glass antenna, raindrops, dipole antenna, FDTD simulation

Classification: Antennas and Propagation

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1 Introduction

In recent years, the development of IT (Information Technology) in smart vehicles are widely expanded. The DSRC (Dedicated Short Range Communications) and C-V2X (Cellular Vehicle-to-everything) systems are the key technologies in the vehicular IT. In these systems, the 5.8 GHz and 5.9 GHz (sub 6 GHz frequency ranges) are used [1]. As for the antennas used in these vehicles, they comprise of a wide variety of configurations that includes rod, planar and et cetera. Antennas that
protrude outside of vehicles such as rod (also called whip) antennas and shark fin antennas are generally undesirable from an aesthetical standpoint, in addition to rod antennas particularly suffers from theft and breakage. These are some of the principal reasons that the on-glass antennas are being widely used. Previously in ref. [2], it was reported that the performance of the on-glass antenna deteriorates due to surface wave on the windshield of vehicle, and following that, improvement methods were also proposed. Besides that, another possible of the antenna’s performance degradation is raindrops on the glass due to rainfall. Therefore, this paper evaluates the performance degradation of antennas due to raindrop adhesion on windshields. The results indicated that the degradation of on-glass antenna performance due to raindrop contact was not significant. However, when the raindrops become streaky (rain streaks), the performance of the on-glass antenna dramatically worsens.

2 On-glass antenna and raindrops model

The purpose of this study is to investigate the effect of raindrops on the on-glass antenna mounted on the practical window of a vehicle, however, in this paper, the configuration is simplified by mounting the antenna on a 300 mm × 300 mm flat glass, just for the fundamental investigation. The geometry of the on-glass dipole antenna is shown in Fig. 1(a). The length of the dipole antenna element is \( L = 13.5 \) mm. The antenna element is closely attached to the glass. The cross section demonstrating a schematic view of the composite glass is also shown in Fig. 1(b). The composite glass has 3-layers where the thickness of each layer are 2 mm, 0.76 mm, and 2 mm for the top glass, interlayer and bottom glass respectively. The relative permittivity of each layers are 6.85, 2.6, and 6.85 respectively.

Rain drops models for the on-glass antenna are indicated in Figs. 2(a)-(f). First,
Fig. 2(a) shows a model of uniformly spaced raindrops, where the size of each raindrop is 2 mm cubic. The space between each raindrop is given by $s$. Next, Figs. 2(b) and (c) show the rain streak models, whereby 2 mm strip of rain are aligned at the center, perpendicular and parallel to the on-glass antenna element, respectively. Meanwhile, Figs. 2(d) and (e) models are the follow-up study for the case of Figs. 2(b), (c) and will be further explained in section 3. Finally Fig. 2(f) shows the on-glass antenna model with a raindrop layer that completely covers the glass as a sheet. The electric constant of the raindrops is set as $\varepsilon_r = 70 + j24$ [3]. In this paper, the above models were investigated.

3 Results

The reflection coefficients of the on-glass antenna with raindrops are calculated by the FDTD method [4] to estimate effect of this phenomenon on the antenna performance. Figure 3(a) shows the calculated reflection coefficients. The selected working frequency of the on-glass antenna is 5.8-5.9 GHz. The calculated and measured reflection coefficient of without raindrops were also indicated. The results indicated that the effect of raindrops (Fig. 2(a)) on the on-glass antenna is not significant. Then, the raindrops are assumed a long streak in perpendicular direction and parallel to the antenna (Figs. 2(b), (c)). In the perpendicular case, the performance degradation of on-glass antenna due to raindrop contact was not significant. However, when the raindrops become streaky in parallel with the direction of the antenna itself, the performance of the on-glass antenna worsens. In order to investigate the effect of raindrop streaks on the on-glass antenna, two models were further proposed, first of which is the effect of raindrop streaks parallel to the antenna when it is the same dimension and located just above the antenna (Fig. 2(d)), and secondly at a distance of 3 mm from the antenna (Fig. 2(e)). From the results of Fig. 3(a), it can be seen that when the raindrop streaks covers the antenna, the reflection coefficient becomes worse.
Next, actual gain patterns are also calculated at 5.8 GHz by the FDTD method. The calculated actual gain pattern is shown in Fig. 3(b). The results indicated that the degradation of an on-glass antenna performance due to raindrop contact was not significant. However, when the raindrops become streaky in parallel direction of the antenna, the performance of the on-glass antenna dramatically worsens in a similar manner to Fig. 3(a). The results show that the actual gain is degraded by about 5 dB at a zenith direction due to the effect of rain streaks.

4 Conclusion

This paper evaluates the performance degradation of on-glass antennas due to raindrops adhesion on windshields. The results indicated that the performance degradation of on-glass antenna due to raindrops contact was not significant. However, when the raindrops become streaky in the parallel direction of the antenna, its performance dramatically worsen.
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