The Attenuation Characteristics of Millimeter-wave by Snow Accretion

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Abstract: The millimeter-wave band is being focused as a frequency band in which high-speed and large-capacity communication can be realized, and various approaches for practical use have been made. In this paper, we studied the attenuation characteristics of the 45 GHz with the moisture contents and thickness of snow, which had never been studied and is expecting to be used in next-generation train communication systems and 5G. The characteristics are also compared with ones of 60 GHz which can be used for new Wi-Fi standard (IEEE 802.11ad). As the result, it is found that when snow accretes to the surface of the antenna radome, the attenuation increases as the moisture content increases and we can not neglect the influence on wireless communication using millimeter-waves.

Keywords: snow, millimeter-wave, attenuation, thickness, moisture content

Classification: Antennas and propagation

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1 Introduction

In recent years, the various systems utilizing millimeter-waves are being studied for railways [1-3]. It is known from previous studies that the propagation characteristics of the wireless communication systems using millimeter-waves are affected by rain [4] and snow [5]. In particular, on the assumption of using millimeter-wave radar [5], the characteristics of snow had been studied for 50-75 GHz band. However it was not a study focusing on the moisture content. Furthermore, no studies have been done on the effect of snow against 40 GHz band millimeter-wave, which is expected to be used in next-generation train communication systems and 5G. In this paper, we report the results of measurement and comparison of the attenuation, assuming the case that snow accrete to the surface of the antenna radome at the 45 GHz, which is being considered for next generation ground-to-train communication system [6], and the results are compared with 60 GHz, which can be used without a license.

2 The Measurement method of attenuation of snow accretion

The measurement tests of attenuation of snow accretion were carried out in a cold room in which the temperature was kept at -5 to 0 degrees Celsius. The test configuration is shown in Fig. 1. The antennas used for the transmitter and the receiver are both standard horn antennas with the gain of 23.5 dBi and the half-power beam width of E-plane and H-plane are approximately 10 degrees. The measurement was done using CW waves of linear polarization of 45 GHz and 60 GHz. The snow plates with various moisture content and thickness were set on the acrylic plate between the antennas, assuming snow accrete to the surface of the antenna radome. The acrylic plate was intended to be a radome, not just a snow
support. The size of the snow plate was 400 mm in length and 400 mm in width, and the height (thickness) was prepared from 10 to 80 mm, referencing to the results of the previous study [7]. The size of the exposure surface of this snow plate is sufficiently large compared to the exposure area calculated from the half-power beam width of the antenna, so it is considered that the wraparound can be ignored. In addition, the plastic racks, which have almost no effect on radio propagation, are used to set the antennas and a snow plate. Furthermore, the setting distance is 225 mm, which is more than twice the Fresnel radius (44.4 mm @ 45 GHz). The moisture content of snow was set to 5.5%, 10%, and 14.6% by adding water to the natural snow stored in winter, referring to the previous study, where 10-15% is said to have the highest adhesion strength [8]. In the test, the receiving power was measured through the snow plate with varying thickness and moisture content. The amount of attenuation was defined as the difference between the receiving power when the snow plate was placed and not placed.

Fig. 1 Measurement configuration

3 Measurement and analysis results

The test results and approximation lines in terms of attenuation versus thickness of snow are shown in Fig. 2, and in terms of attenuation versus thickness of snow are shown in Fig. 3. The moisture contents shown in these results were measured by the melting calorimetry method used by an Endo-type snow water content meter [9]. In the range of moisture contents and thicknesses of snow where the tests were done, when the moisture contents of snow are same, the attenuation increases as the thickness increases. And the slope of attenuation with increasing thickness of snow is almost the same at 45 GHz and 60 GHz, but the attenuation at 60 GHz is larger than at 45 GHz, in Fig. 2. In Fig. 3, the difference in the amount of attenuation due to the differences in moisture contents of snow are that the thinner the thickness of snow, the larger the slope of the approximation line, and more significant at 45 GHz than at 60 GHz. On the other hand, for the same snow
thickness exceed 40 mm, the amount of attenuation at 60 GHz almost does not change even if the moisture content increases. Further, it can be seen that as the moisture contents of snow becomes higher, the difference in the attenuation amount, depending on the thickness and frequency of the snow, becomes smaller and tends to converge.

Considering the above results and the thickness of snow accretion to the antenna surface was about 70 mm in the previous research [7], it is necessary to assume that the attenuation is about 45-50 dB due to the effect of snow accretion.
4 Conclusion

In this paper, to contribute to designing a ground-to-train communication system using millimeter-wave, we studied the attenuation due to adhesion of snow with varying water content and thickness at 45 GHz, which had not been studied. This result is also compared with the measurement results of 60 GHz. As a result, it is found that the received power is significantly attenuated by the containing moisture in the snow on the surface of the antenna. For example, the maximum attenuation at 45 GHz is 45 dB at a thickness of 80 mm and a moisture content of about 15%. It is also found that the effect tends to more significant at 60 GHz than at 45 GHz even with same moisture content. From these results, it is considered that the snow accretion on the surface of the antenna radome can not be neglected regarding the influence on the wireless communication using millimeter-waves. Therefore, it turned out that when designing the radio circuit, it is necessary to have an enough margin or to design an antenna structure that snow does not accrete to the surface.

In the future, we plan to deeply study the propagation characteristics of millimeter-waves in the railway environment, which are necessary for designing the wireless circuits of millimeter-wave communication systems for trains, through simulations and experiments.