Millimeter Wave Reflection Characteristics and Modeling on Snow-Covered Road Surfaces

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For safety validations of automated driving vehicles, simulators in the cyber world become more important, almost the same as vehicle tests in the real world do. Creating high-fidelity sensor models leads to more accurate simulation. The DIVP project is developing a simulator to reflect real environment including snowy weather condition. In last year, activities to simulate reflections from snow surface regarding light and millimeter wave were reported at the JSAE. Millimeter wave can penetrate snow to some extent. In this report, considering snow-covered road surface conditions, reflections from the multi-layered structure of snow and road material are measured in millimeter wave while varying the thickness of the snow. Also, mathematical models using S-parameters are created for simulation.

Fig.1 shows the reflection and transmission of millimeter waves when snow is accumulated on the road material. Reflection and transmission occur at the interfaces between each layer. Reflection from the snow layer 2 and another reflection from layer 3 cause interference in the air layer 1. The degree of interference varies depending on incident angle, snow thickness, and permittivity.

As shown in Fig.2, reflections in millimeter wave are measured using the vector network analyzer with changing incident angle, thickness of snow and road material.

In the simulation, as shown on the right side of Fig.1, mathematical models using S-parameters to calculate reflections and transmission at interfaces between each layer are created. Three S-parameters matrices represent reflection and transmission at the interfaces between each layer. To cascade three S-parameters matrices, convert them to T-matrices and multiply in cascade order, and convert the final T-matrix back to the S-parameters matrix. With this method, total reflection from snow on road material can be calculated.

Fig.3 shows reflectance obtained by measurement and calculated value from the mathematical model in the case of snow thickness of 10mm on asphalt. Measured results and simulated values are in good agreement.

Additionally, transmission losses in moisturized snow are measured, and the same type of mathematical model using S-parameters is created to calculate transmission loss in moisturized snow. By fitting parameters to the measured values, an approximate formula for millimeter-wave attenuation in moisturized snow is created.

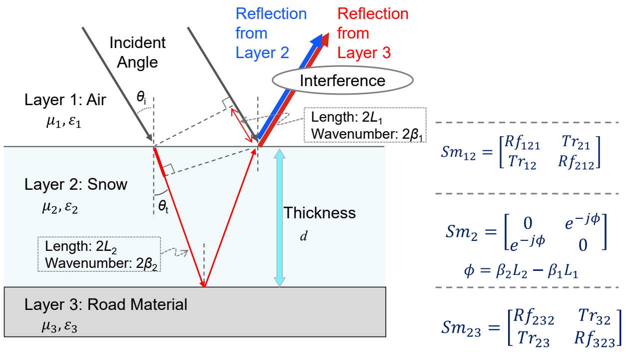

Fig.1 Reflection from Snow on Road Material

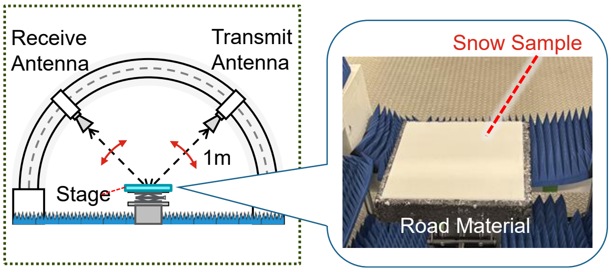

Fig.2 Reflection Measurement of Snow on Road Material

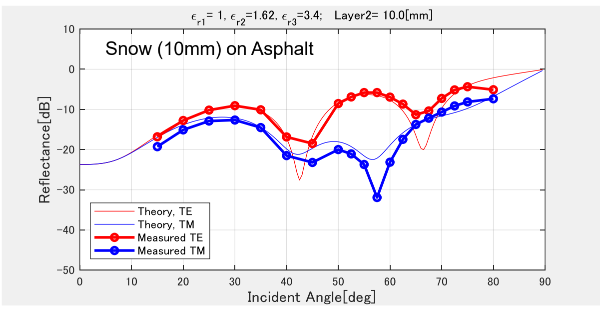

Fig.3 Reflection from Snow(10mm) on Asphalt