RF-Based Methods for Measuring Liquid Water Content in Snow

Towards New Sensing Solutions for Avalanche Prediction

Students

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Introduction: In Switzerland, avalanches claim approximately 20 lives annually, emphasizing the critical importance of accurate forecast. Predicting avalanches is a demanding task that requires a thorough understanding of the snowpack, the layered structure of snow. Wet snow avalanches are particularly difficult to predict due to their sensitivity to the liquid water content (LWC) within the snowpack. Even small amounts of liquid water can significantly increase the risk of wet snow avalanches, making precise LWC measurement essential.

Problem: The Denoth meter is widely recognized as a reliable instrument for determining LWC. However, it is not suitable for long-term monitoring or remote sensing applications. Additionally, its measurement method requires prior knowledge of the dry snow density. To advance the prediction of wet snow avalanches, a more versatile and affordable measurement system is needed. This project investigates RF-based measurement methods, focusing on their ability to measure LWC independently of density and under varying snow conditions.

Result: Two methods were identified for further investigation (see Fig. 1): The open-ended coaxial probe estimates the complex permittivity (phase and magnitude) by measuring the reflection coefficient, while the stripline method analyzes insertion loss. While both techniques show promise, existing snow permittivity models indicate that dielectric loss of snow primarily depends on LWC rather than density. This makes the stripline method particularly suitable for identifying a direct relationship between insertion loss and LWC.
Initial measurements of LWC were conducted using snow samples in a thermo cabinet (see Fig 3.). The results demonstrated measurable changes in LWC, but the snow's inherent variability structure and the experimental setup introduced significant challenges, affecting measurement consistency (Fig. 2). These findings confirm the potential of RF-based methods but also highlight the need for further methodological refinements.

Figure 1: Simulation of the stripline and coaxial probe method in Ansys HFSS.
Own presentment

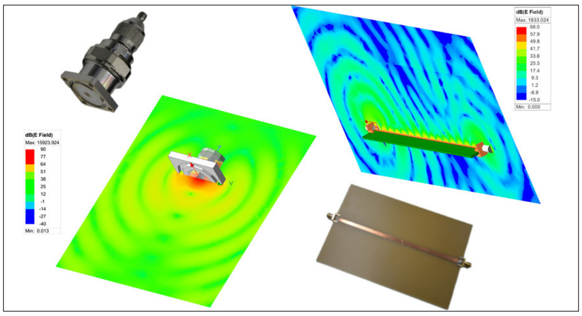


Figure 2: Insertion loss of the stripline method for different LWC compared to the simulation.
Own presentment

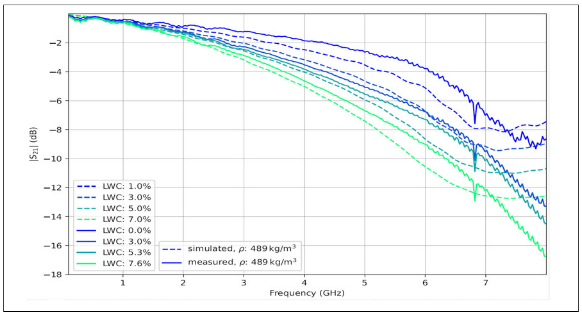
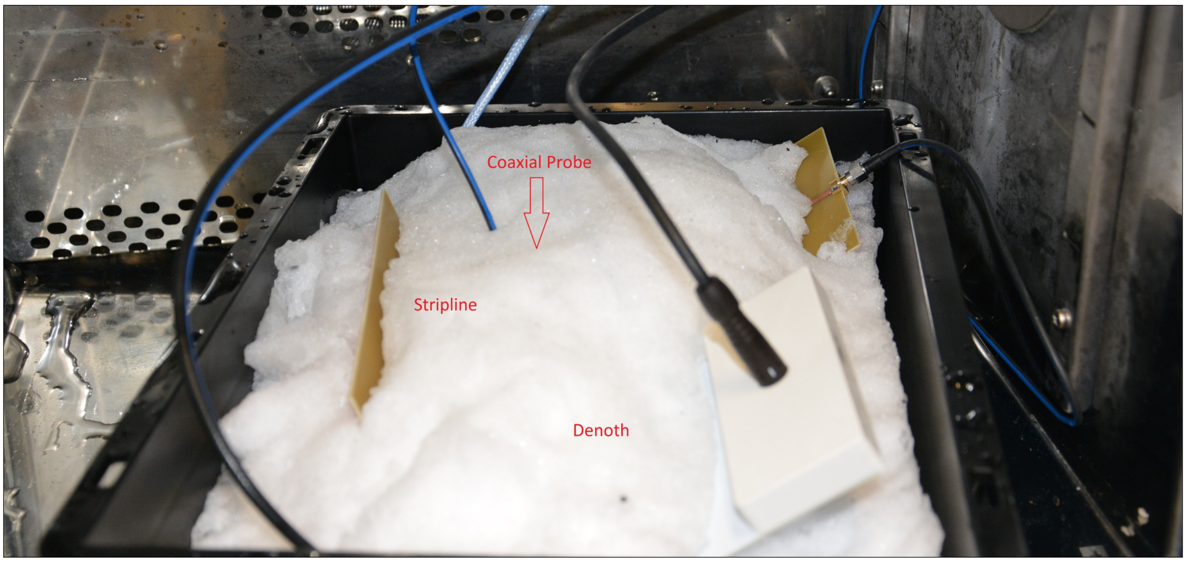


Figure 3: Setup for snow measurement with buried stripline, Denoth meter and coaxial probe.
Own presentment



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