RF-Based Sensor System for Measuring Liquid Water Content in Snow

Towards New Sensing Solutions for Avalanche Prediction

Student

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Introduction: Wet-snow avalanches remain a major challenge in avalanche forecasting due to limited understanding and lack of reliable real-time information on snowpack conditions. A key parameter for wet-snow instability is the liquid water content (LWC) of the snow. When the LWC exceeds approx. 3 %, the mechanical strength of the snowpack decreases significantly, making wet-snow avalanches more likely. Measuring the LWC in snow is technically challenging. Existing sensors typically rely on additional parameters, most notably dry snow density, which complicates field measurements and remote LWC sensing.

Approach: A preceding student project addressed these limitations by investigating a measurement approach based on a microstrip line sensor embedded in snow. The work demonstrated feasibility in principle, but could not achieve full experimental validation due to practical implementation challenges. In this project, the concept is developed into a fully functional measurement system consisting of a dedicated measurement device (Fig. 1) and a corresponding LWC sensor (Fig. 2). The sensor is designed for use in snow pits (Fig. 3), enabling rapid and minimally invasive measurements under real-world conditions. By measuring the microwave attenuation of the sensor's microstrip line, the system determines LWC without requiring auxiliary parameters, resulting in a precise, density-independent, and field-deployable measurement solution suitable for scientific and operational applications.

Conclusion: Experiments in the lab and in the field, as well as extensive full-wave electromagnetic simulations, confirmed the main feature of the proposed measurement principle: its insensitivity to snow density. Across typical snow density ranges, the inferred LWC deviates by less than 0.2 % LWC, exceeding the precision of existing sensor technologies and validating the density independence of the method. The realized system is fully operational and shows strong potential for use in avalanche forecasting and snowpack modeling. It provides a solid basis for the development of a compact, cost-effective, and mass-deployable monitoring solution.

Figure 1: Measurement device with enclosure, including a PLL, a power detector, RF switches and four TX/RX port pairs
Own presentment

Figure 2: Realized dual LWC sensor with two back-to-back microstrip lines and two TX/RX port pairs.
Own presentment

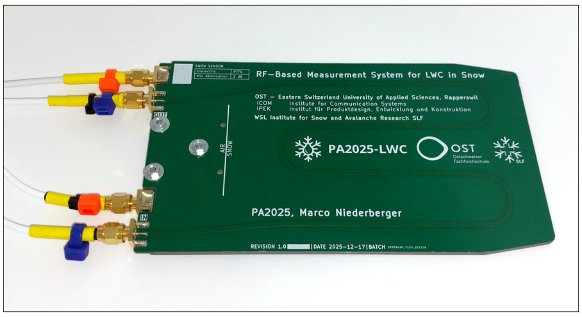
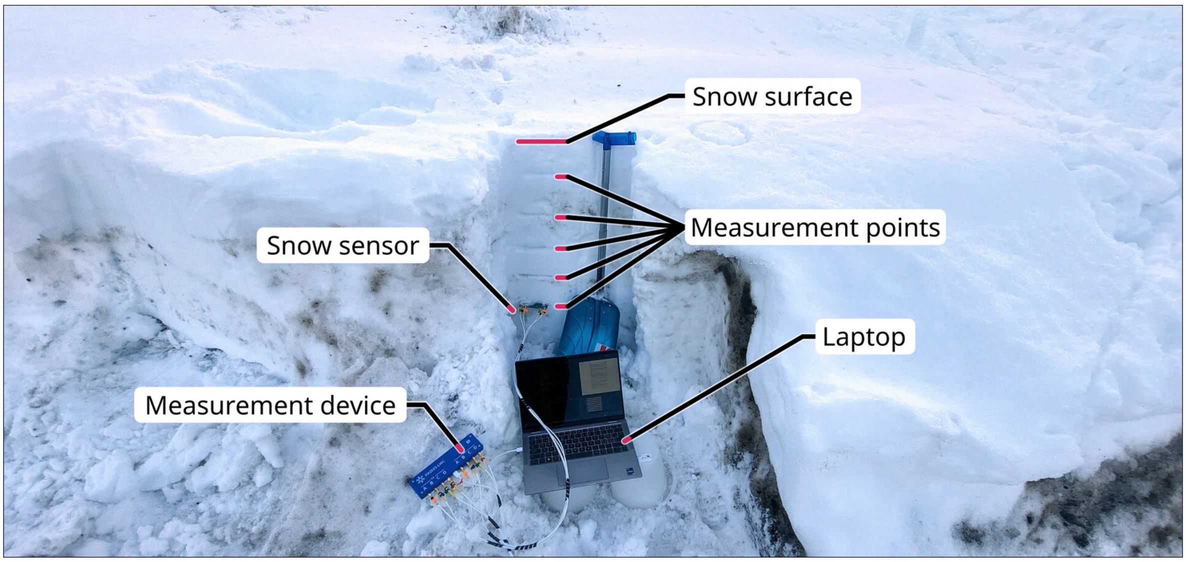


Figure 3: Measurement system deployed in a snow pit, showing sensor insertion and in situ LWC measurement.
Own presentment



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