SNOW DIELECTRIC DEVICES AND FIELD APPLICATIONS

A. Denoth and I. Wilhelmy

ABSTRACT

Snow liquid water determination in the field is a delicate task; it should be easy and quick to perform, it should be nearly non-destructive, and the measuring error should be less than 0.5% by volume. Dielectric devices, which meet these requirements, have been developed recently. The sensors measure the electric snow permittivity at a fixed frequency of 20 MHz by detecting the change in capacitance of a flat sensor consisting of two or more thin conducting stripes. Snow wetness can easily be calculated, if snow density is known. Sensor geometry and sensor electronics define the special applications of the sensors. Two different devices have been developed; the instrument are battery-operated. Type I allows surface and volume measurements of snow wetness; the instrument has to be tuned by hand and a calibration in air should be made before measuring in snow. Type II has been improved by a built-in microcomputer and an internal standard for calibration; snow permittivity is displayed on a LCD. Type II allows also long-term measurements with buried sensors or - depending on the sensor geometry - high-resolution surface measurements of wetness, whereby surface means in this case the top 5 mm of a snow cover. Typical applications with these sensors - snow wetness profile or monitoring snow wetness variations in time - are given.

INTRODUCTION

The most efficient method for the determination of snow wetness in the field is the measurement of the dielectric constant $\varepsilon'$ at radio frequencies. Neglecting the relatively small effects of water distribution on snow dielectric properties, the liquid water content $W$ (% by volume) can be calculated from $\varepsilon'$ and the density $\rho$ (g/cm$^3$) of snow (Denoth et al. 1984, Denoth 1988):

$$\varepsilon' = 1 + 1.92\rho + 0.44\rho^2 + 0.187W + 0.0045W^2$$

For most practical applications however, this relation can be simplified for densities $\rho \leq 0.5$ and $W \leq 7\%$ to:

$$\varepsilon' = 1 + 2.05\rho + 0.21W$$

I. Associate Professor; II. graduate student, Institute of Experimental Physics, University of Innsbruck, A-6020 Innsbruck, Austria.
SNOW DIELECTRIC DEVICES

Thin (1.5 mm in thickness) flat-plate sensors with differently sized and shaped coplanar conducting stripes are used for a nearly non-destructive measurement of snow permittivity $\varepsilon'$. Three different geometries of the electrodes have been designed to achieve a sufficient spatial resolution and to average over a sufficiently large number of snow grains (Foglar, 1983; Wilhelmy, 1988). The geometry of the 3 types of sensors is shown in Figure 1.

![Figure 1 - Geometry of the electrodes of the three types of sensors, A, B, C](image)

Sensor type A allows surface and volume determinations of snow wetness; the effective measuring area is 13 x 19 cm$^2$ for surface- and 13 x 14 cm$^2$ for volume measurements; the effective measuring depth is 1.5 cm. Sensor type B is similar to type A but allows measurements with a higher spatial resolution: the effective measuring depth is 1.0 cm. Sensor type C is designed for surface measurements, whereby "surface" is defined as the top 5 mm of a snow cover. The dielectric meters are operated at a frequency of 20MHz, are battery-powered and can be operated at ambient temperatures down to $-10^\circ$C. One version of the instruments has to be tuned by hand and a calibration (in air) should be made before measuring in snow. The other version has been improved by a built-in microcomputer and an internal calibration standard, so no manual tuning operation is necessary and - in addition - also long-term measurements with buried sensors can be made.

FIELD APPLICATIONS

A typical field application of the sensors is shown in Figure 2. A measurement of a wetness profile in a natural snow cover is shown in Figure 3. The sharp peaks in the water content at a height of 180 cm and 200 cm above ground are caused by two thin snow/ice layers with a drastically reduced hydraulic conductivity. A measurement of a daily variation in wetness at the surface and in a depth of 12 cm is shown in Figure 4. The measurements have been made under clear-sky conditions at an altitude of 2300m (Figure 3) and 950m respectively (Figure 4).
Figure 2  Photograph of a typical field application of the sensors

Figure 3  Wetness profile in a natural snow cover; z is given in meters above ground.
Figure 4 Daily variation of snow wetness W at the surface, z = 0 cm, and in a depth of z = 12 cm.

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REFERENCES


