MICROWAVE EMISSION SIGNATURE OF SNOW-COVERED LAKE ICE

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ABSTRACT

Airborne microwave radiometer measurements of lake ice have been performed in 2004, 2007, and 2011 in southern Finland. The HUTRAD radiometer system provided data in the 6.9 to 36.5 GHz range using an incidence angle of 50 degrees off nadir. In 2011 also the interferometric HUT-2D radiometer was used to provide 1.4 GHz imagery of lake ice.

Index Terms—Microwave radiometry, HUTRAD radiometer, HUT-2D radiometer, Snow, Lake ice

1. INTRODUCTION

Microwave radiometry has proved to be the best remote sensing tool for retrieval of dry snow characteristics, especially the snow water equivalent, from space. Regional algorithms have been developed and validated for this purpose. Accuracy of retrieved snow water equivalent is decreased e.g. by the existence of several land cover types within a radiometer pixel (mixed pixel problem). The two main problems related to land use categories in microwave radiometry of snow are vegetation (forest) and water areas (lakes). Forest canopies partially mask microwave emission from snow and underlying ground, but their effect can be accounted for with adequate accuracy. On top of lake ice, snow depth and snow grain size may be substantially different from those on land and, additionally, the emission behavior of ice is different from that of frozen/thawed soil. Large lake districts in northern areas have been regularly masked out when applying snow retrieval algorithms to microwave radiometer data. Lake ice emission signature has not yet been widely investigated [1], [2], [3]. We have carried out radiometer measurements over lake ice in 2004, 2007, and 2011 in the 6.8 to 36.5 GHz range using the HUTRAD radiometer system [4]. Additionally, the HUT-2D interferometric radiometer [5] has been used in 2011 to provide data at 1.4 GHz.

2. RADIOMETER SYSTEMS AND TEST SITES

We have used our airborne microwave radiometer system HUTRAD to measure microwave emission signature of lake ice during the winters of 2004, 2007, and 2011. HUTRAD operates at 6.8, 10.7, 18.7, 23.8, 36.5, and 94 GHz, providing data for both vertical and horizontal polarization at an incidence angle of 50 degrees off nadir with the 36.5 GHz receiver operating in a fully polarimetric mode [4]. The antenna beam-width decreases from 5 degrees at 6.8 GHz to 3 degrees at 36.5 GHz; hence, results at various frequencies can be reasonably well compared with each other. The HUTRAD system is accommodated on our research aircraft Skyvan and looks to the rear along the flight track; the rear cargo door is removed before taking off for data collection. Accurate position and attitude information provide antenna footprint track on the ground.

Our airborne L-band interferometric radiometer HUT-2D was used for lake ice/snow measurements in winter 2011 along with the HUTRAD system. HUT-2D consists of 36 antenna/receiver pairs in U shape geometry and operates at 1.4 GHz [5]. It is located below the fuselage of our research aircraft. Due to its operation mode, HUT-2D provides data for incidence angles between nadir and 25 degrees off nadir without mechanical or electronic scanning of antennas. The synthesized antenna beam-width is about 7 degrees and the system provides an image of the target area with a swath equal to the flight altitude. Hence, the HUT-2D system provides an emission map over a wide area, whereas the non-scanning HUTRAD system provides data along the flight track.

The lakes over which radiometer measurements have been carried out are located in southern Finland not far from the Helsinki Airport. Lake Bodominjärvi is 5 km long and 1.4 km wide with a maximum/average depth of 12.7/4.3 m. The adjacent Lake Matalajärvi is separated from Lake Bodominjärvi by a narrow isthmus and is somewhat smaller. Ice on Lake Matalajärvi tends to disappear earlier in spring, thus providing different conditions towards late winter. The flight path (northwest => southeast) over these lakes consists of 1.7 km over Lake Bodominjärvi, 0.3 km over the...
isthmus, and 1.0 km over Lake Matalajärvi. The land areas before (forested) and after (farmland) the lake flight line offer good possibilities for comparison of results for snow-covered lake ice and snow-covered terrain. Lake Tuusulanjärvi is 8 km long and less than 1 km wide. Due to its not-so-good water quality radiometer measurements have not been made over it after 2004.

3. DATA COLLECTION

Three data collection flights were conducted in March 2004 over Lake Tuusulanjärvi, Lake Bodominjärvi, and Lake Matalajärvi. Flight altitudes of 150 m and 300 m were used to study the averaging effect of antenna footprint size. The measurement was repeated three times at each altitude. Concurrent ground truth data were collected including ice thickness, snow depth, snow and ice surface temperature, snow density and wetness, snow water equivalent, and, in selected locations, snow grain size. The ice thickness was around 40 cm, snow depth 18 to 32 cm, snow wetness by volume from 0 to 3 % and there was a layer of water on top of the ice in some areas.

In 2007 the measurements were focused on Lake Bodominjärvi and Lake Matalajärvi following the 2004 procedures for acquisition of airborne and ground truth data. A total of four measurements was carried out between late January and early April, with ice thicknesses up to 35 cm and snow depths up to 18 cm. During the latest measurements some parts of the lakes were free of ice.

The measurement program in the Lake Bodominjärvi / Lake Matalajärvi area was continued in 2011. Flight altitudes of 300 m and 150 m were used for data collection and the measurement was repeated five times at each altitude. In 2011 both winter conditions and melting period conditions were covered with five data collection flights between January 27 and April 14. The ice thickness varied from 35 to 65 cm, snow depth from 0 to 20 cm, and snow wetness by volume from 0 to 4 %.

4. EXPERIMENTAL RESULTS AND DISCUSSION

A sample of data is shown in Figure 1. In general, the experimental HUTRAD data collected so far show that the emission signature of lake ice is different from that of adjacent land areas. The horizontally polarized brightness temperature is below 200 K in the 6.8 to 36.5 GHz range for ice without any water layer on top of it. The polarization difference increases with increasing frequency. Water upon the ice increases the brightness temperature at all frequencies. Relatively large spatial variations in the brightness temperature occur due to occasional water in the ice/snow interface.

![Figure 1](image-url)

Figure 1. Experimental data for Lake Bodominjärvi (sample number 3000 to 8000) and Lake Matalajärvi (sample number 9000 to 12500) on January 30, 2007. Values around 250 K are for adjacent areas of snow-covered terrain, lower values for snow-covered lake ice. Snow surface temperature is -9 °C and snow depth varies from 10 to 18 cm.
5. REFERENCES


