STRATIGRAPHIC IMAGES OF SNOWPACK OBTAINED BY AN FM-CW MICROWAVE SYSTEM

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1. Introduction

Using the microwave frequency, we have developed an FM-CW radar system for sensing snowpack properties and carried out experiments for natural snowpack in Hokkaido area since 1982.

We have been trying to determine the stratigraphy and water equivalent of the snowpack in terms of density, free water content, dielectric constant and other physical parameters using the data obtained by the FM-CW system [1][2].

In this paper, the stratigraphic images in the snowpack which were composed from the data obtained by the system in the field experiments, are presented and also several interpretations of the remarkable changes in the images are reported.

2. Measuring and imaging system

The block diagram of the system used for the field experiments is shown in Fig. 1.

In this system, the microwave frequency was swept linearly over the range, 6-10 GHz, in 10 ms. The microwave emitted toward the snowpack surface at near normal incidence to get reflections from various interfaces in the snowpack. The received signals in time domain were transformed to the frequency domain and displayed on the CRT of the spectrum analyser. At the same time, the data collected were transferred to a microcomputer and processed and stored, then, using the serial data, the picture of the internal structure of the snowpack were composed and displayed on the CRT.

3. The images of the stratigraphy of the snowpack in dry snow season.

In 1984, series of experiments were carried out in dry snow season in northern part of Hokkaido. In each series of the experiment, The measurements were continued for more than 24 hours. Some of the examples of the experiments are shown in Fig. 2, as typical data of the dry snow season, using those of February 8-9, and March 8-9 in 1984. The brightness and width of lines which were observed as parallel lines to the transverse axis are corresponding to the intensity of the microwave reflection from each reflection plane such as surface, interfaces between layers within the snowpack and ground.

As is clear from the figure, the interfaces within the snowpack which were observed in February, are also recognized in March together with many layers formed by newly fallen snow above them.

4. Stratigraphy of melting snowpack

The same measurements were continuously carried out from February 28 to March 4 in 1985 using the FM-CW system. During the experiments, ambient temperature of the site rose above the freezing point and melting of the snowpack occurred in the day time but in the night, it fell down below 0

°C, so that the melt water which percolated into the snowpack froze and formed ice plate within the snowpack.

In Fig. 3, the changes of the internal structure of the snowpack with time, composed from the serial data, were shown together with those of ambient and snow temperature.

As is clear from Fig. 3, the brightness and the width of the lines, that means the intensities of the reflection from each interface within the snowpack, are remarkably different from those obtained in dry snow season shown in Fig. 1. The bright and wide lines observed in the upper part of the snowpack indicate the reflection from ice plates formed by refreezing of the percolated melt water within the snowpack and also the size distribution and configuration of ice grains composing each layer within the snowpack are remarkably different from those of dry snow season.

When the ambient temperature rises above 0 °C in the day time, melting starts from the surface of the snowpack. The melt water percolates into the surface and subsurface layers and perches there balancing with hydrodynamic potential of the layer. Then, the dielectric constant of the layer which contains the melt water increases with increasing the volume of the melt water. So that the reflection from the interface between the layers and absorption in the layer increases remarkably comparing with those from the dry snow layers. While, in the night, temperature of ambient and snowpack falls down fairly below 0 °C, the perched melt water in the layer refreezes and turns to ice, then the dielectric constant of the layer changes and penetration depth of the microwave increases comparing with those of the wet snow layers. Considering these processes which are taken place in the snowpack of melting season, the changes of the reflection as observed in Fig. 3 can be reasonably explained.

5. Formation of the strata within snowpack

For evaluation the data related snowpack parameters which were obtained by a passive microwave sensor mounting on the orbital satellite such as MOS-1, continual measurements of snowpack stratigraphy were carried out from December 22 to March 8, 1988, using our FM-CW system at the test site in Sapporo.

A stratigraphic image which was processed from the peak values in the spectra obtained by the system was shown in Fig. 4.

As is clear from Fig. 4, stratification of freshly fallen snow can be observed clearly. That is, in each intermittent snowfall, the freshly fallen snow forms stratum, then, the densification and metamorphism may take place very quickly, which can be estimated from the intensity of the reflection from the surface of the snowpack. So that, each layer within the snowpack looks homogeneous but composed from many strata. These strata are depressed by following fallen snow and densified and metamorphosed rapidly under the same condition and forms new snow layer.

These processes can be clearly observed from the serial image obtained by FM-CW system.

6. Conclusion

The FM-CW microwave system is fairly effective in remotely measuring and monitoring snowpack parameters, especially, stratigraphy within the snowpack.

References

[1] M. Suzuki, et al., "Estimation of the water equivalent in dry snowpack using a FM-CW microwave sensor", ISAP '85, Vol. II, pp.675-678 (1985).

[2] K. Fujino et al., "Snow stratigraphy observed by an FM-CW microwave system", IGRSS '86, Vol. I, pp.99-102 (1986).

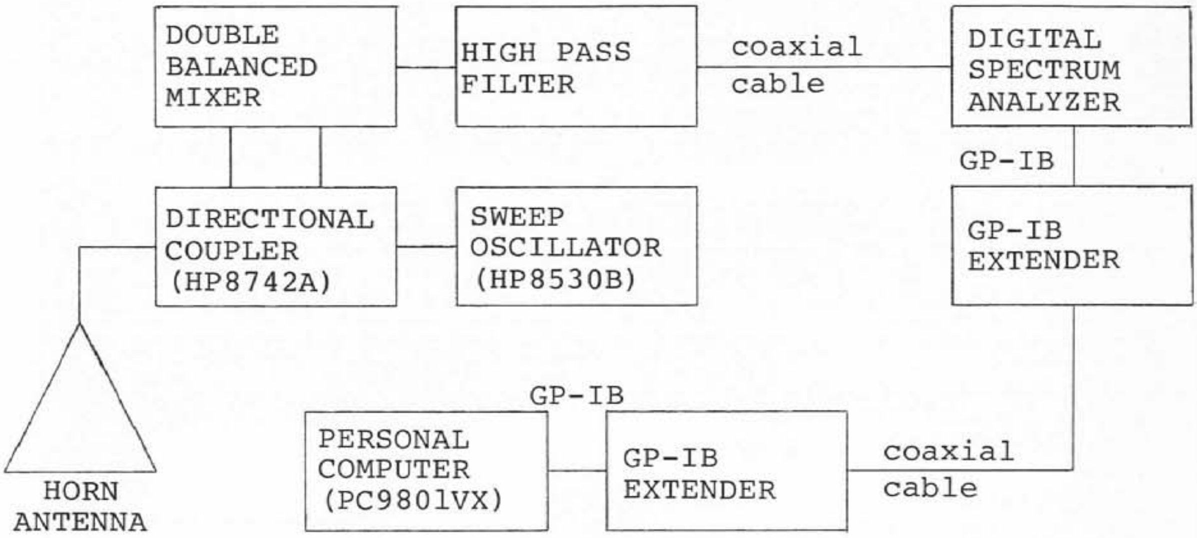

Fig. 1. Block diagram of the measuring and imaging system.

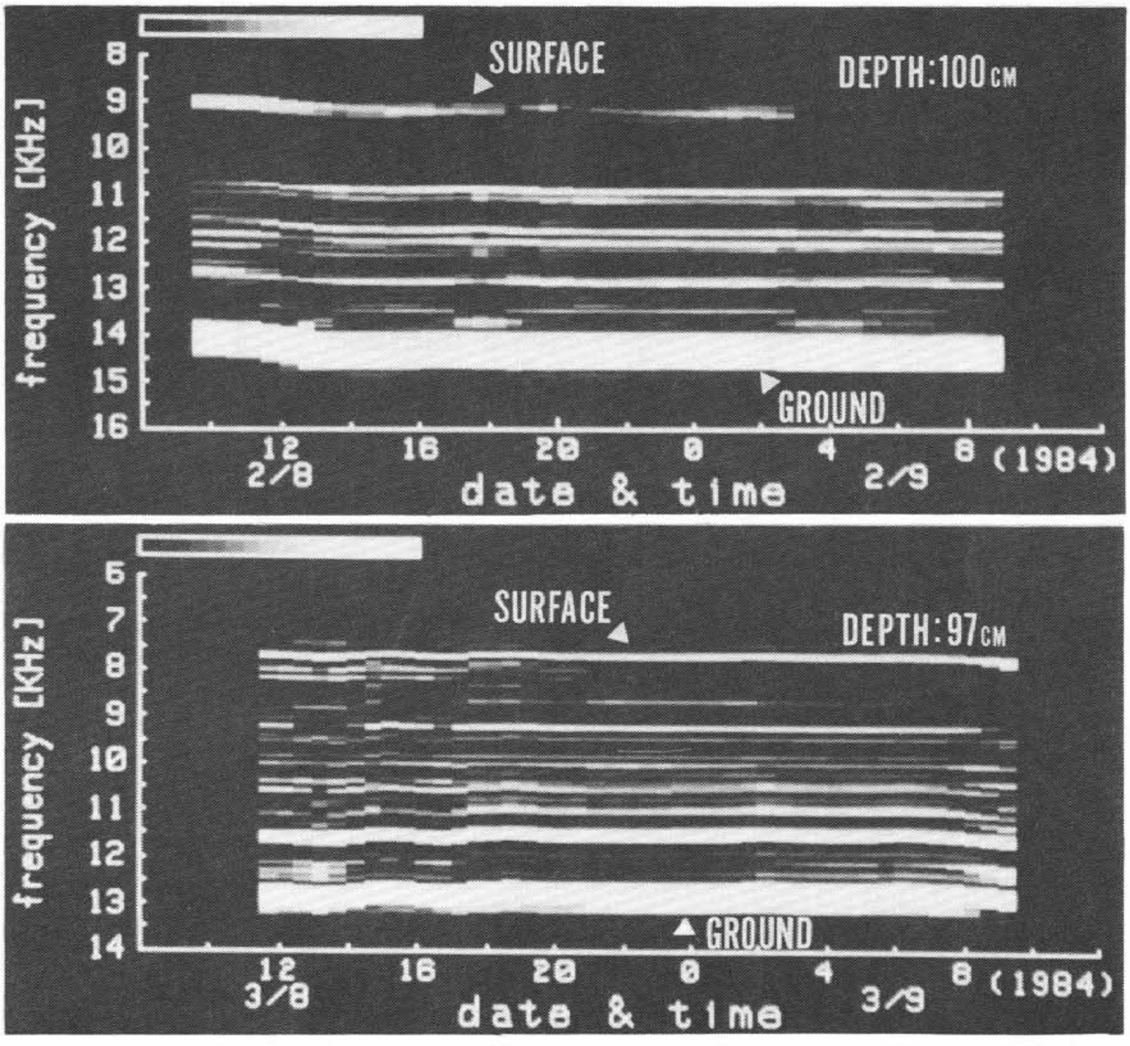

Fig. 2. Images of the stratigraphy of dry snowpack.

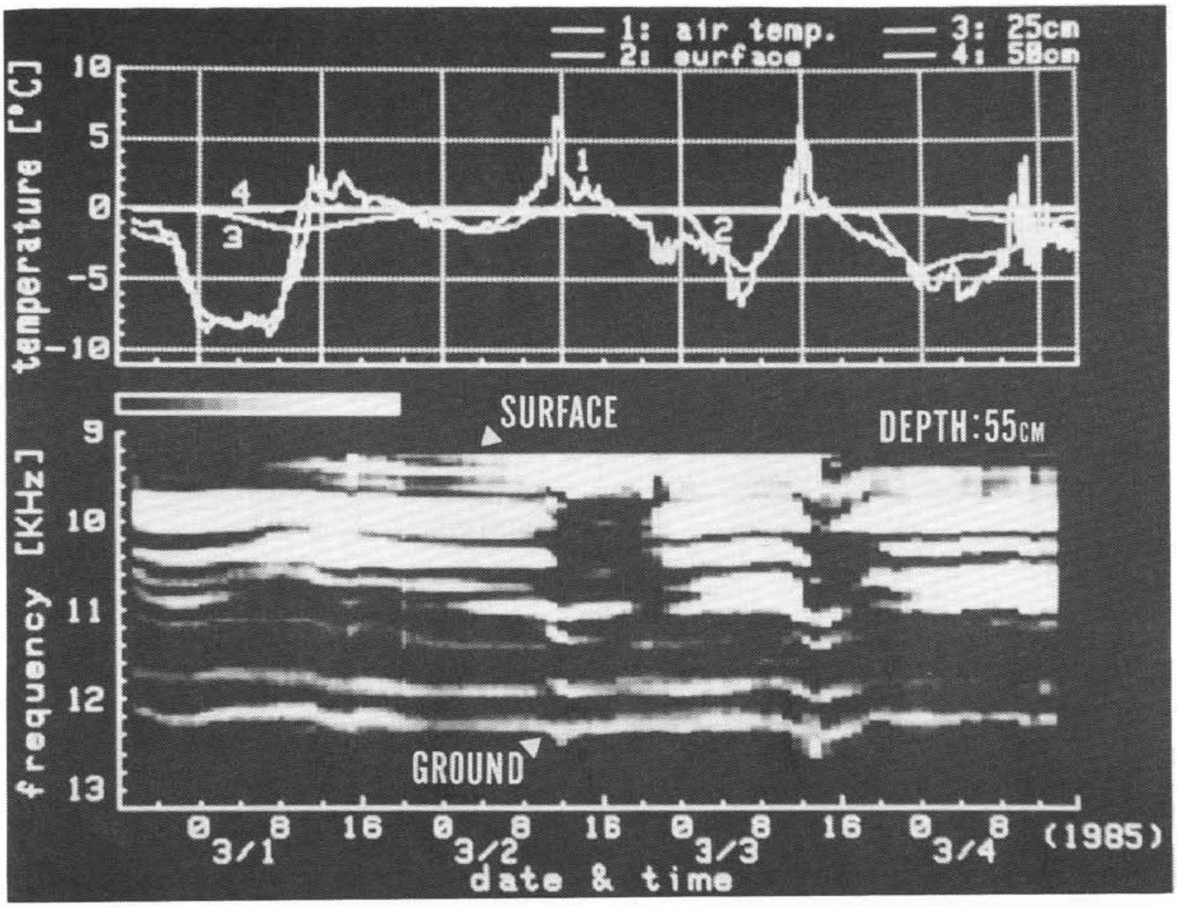

Fig. 3. Stratigraphic image of melting snowpack.

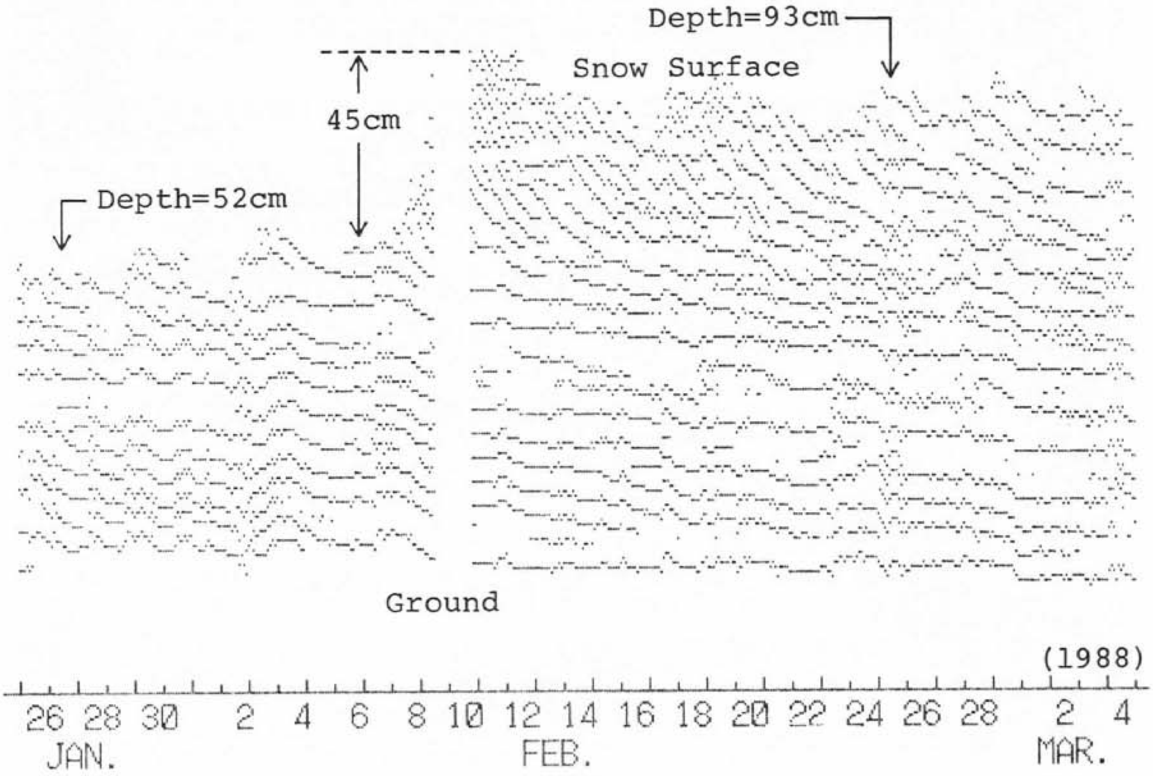

Fig. 4. Image of the formation of strata.