Microwave signatures of sea ice from ARKTIS 93 experiment

K. Flückiger, H. Gmünder, Ch. Mätzler

Institute of Applied Physics
University of Bern, Switzerland

ABSTRACT

In March and April 1993 the German research icebreaker POLARSTERN undertook its first winter expedition to the Arctic under extreme weather conditions. Our group measured passive microwave signatures of sea ice by radiometers at 11, 21, 35 and 48 GHz. First results are discussed.

1. INTRODUCTION

During the ARKTIS 93 expedition on board the German research vessel "POLARSTERN" from February 26 to April 17 we studied passive microwave signatures of sea ice.

On the first part of the campaign (February 26 - March 24) "POLARSTERN" occupied a fixed position relative to a large multiyear ice floe in the Framstrait. We started at 81° 28' N, 100 km within the arctic sea ice and drifted about 10 km a day south towards the ice edge. We made observations on the multiyear ice floe with our radiometers mounted on a sledge which could be easily moved over the ice surface. In this paper we present first results of this part of the expedition (March 9 - March 17). The objective of these observations was to improve the knowledge of sea ice microwave signatures under winter conditions.

On the second part of the campaign "POLARSTERN" cruised in the Greenland Sea between 79° and 72° N. We made observations of the mostly new sea ice from the ship with our radiometers fixed to the railing on the port side of the A-deck. Results will be reported later.

Figure 1 shows the geographical location of our working areas during this expedition.

2. MEASUREMENTS

For our measurements we used 4 radiometers at frequencies of 11 GHz, 21 GHz, 35 GHz and 48 GHz. These radiometers were mounted on a platform which allowed variation of the nadir angle from 30° to 60° and switching between horizontal and vertical polarisation. This platform was fixed to an aluminium frame on skis, 1.5 m above ground. For sky measurements we used a reflector. Figure 2 illustrates the construction of the sledge. Photo 1 shows the sledge in operation on the ice floe.

On the multiyear year ice floe we marked 5 fields taking into consideration typical ice topographies (Photos 2-6):

M-1 a pond with drifting snow (Photo 2 with profile)
M-2 a flat snow covered surface (Photo 3)
M-3 a pressure ridge (Photo 4)
M-4 a flat topped mound with a hard snow crust (Photo 5)
M-5 bare ice (Photo 6)

Each spot was measured once or twice during a measurement day. The program of our field experiments is summarized in Figure 3. In addition to our microwave measurements we dug pits through the snow cover down to the ice surface to take temperature, density and salinity values.

The output of our radiometers is a voltage proportional to the brightness temperature. Therefore we need two calibration points. For each of these calibration points we need the voltage and the brightness temperature. We get one such point by the blackbody measurement with the brightness temperature equal to its physical temperature. The second point is given by measuring the brightness temperature of the sky at two different angles. This allows us to extrapolate to the voltage of the extraterrestrial cosmic radiation at 2.73°K [1]. The resulting brightness tem-

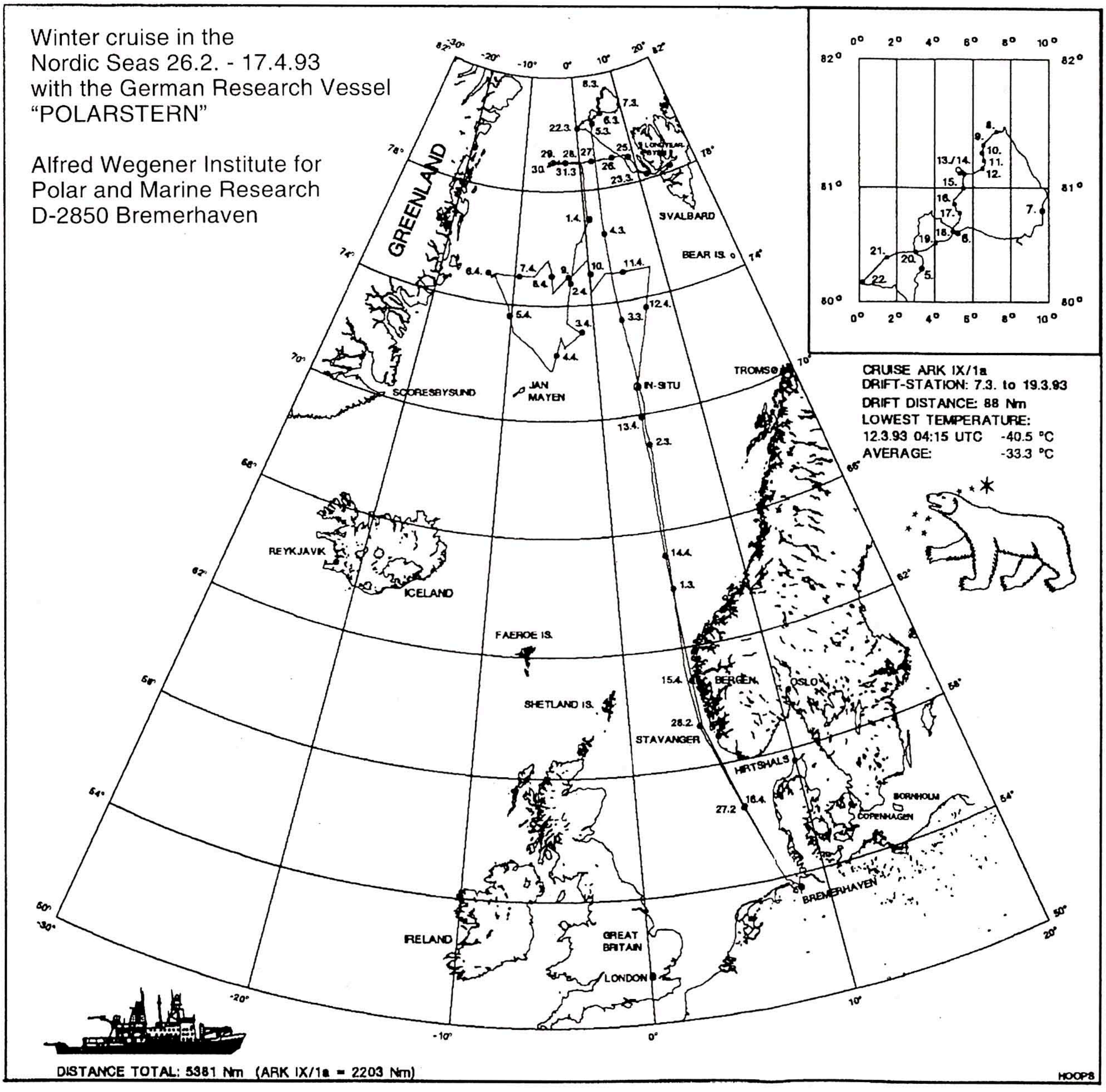

Fig. 1 - Operational area of the "POLARSTERN" - expedition in Framstrait (7.3.-22.3.93) and the Greenland Sea (24.3.-13.4.93).

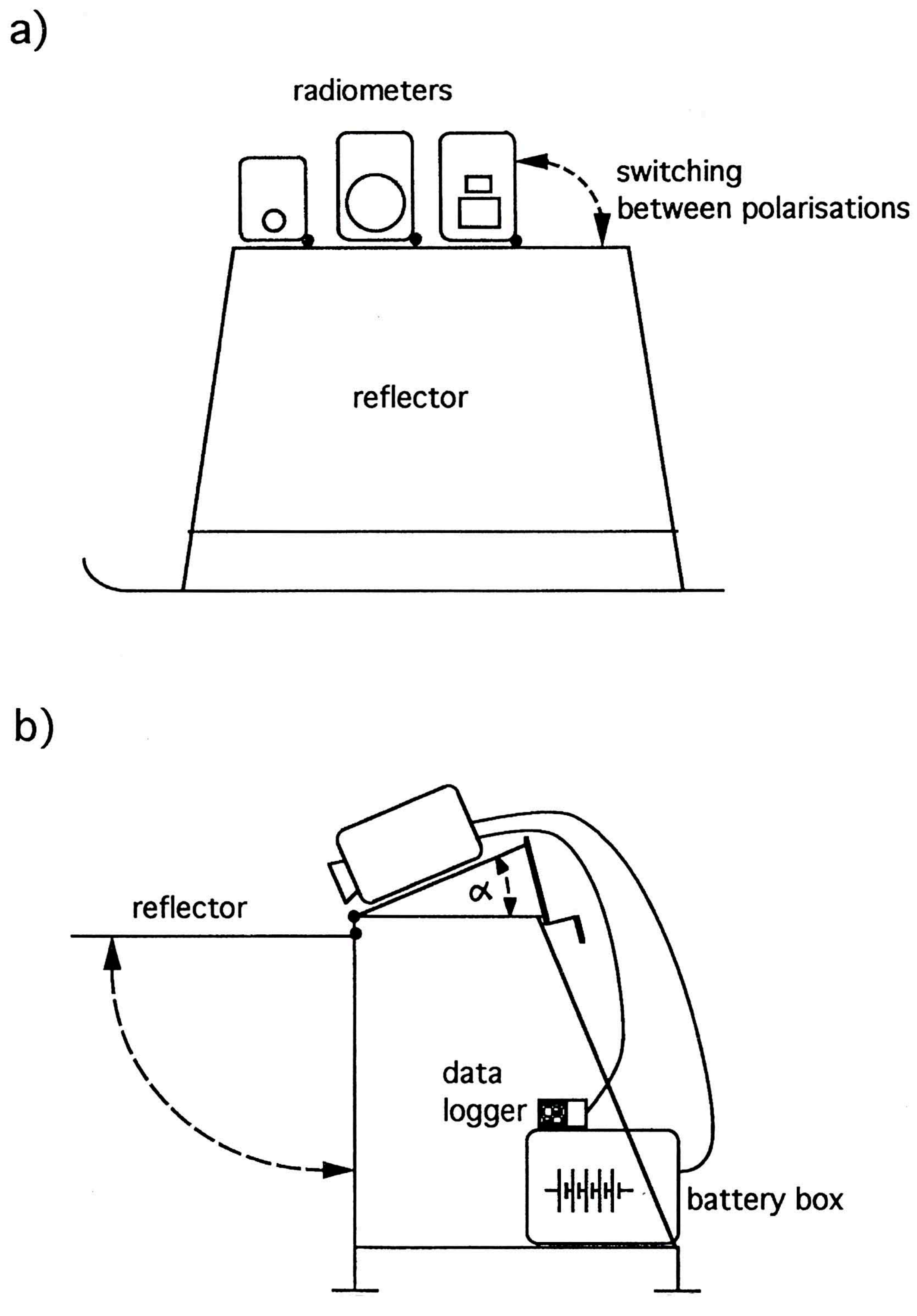

Fig. 2 - Sledge with the mounted radiometers (11 GHz, 21GHz, 35 GHz and 48 GHz)
a) front view
b) side view with the reflector for sky measurements and adjustment of the depression angle (a)

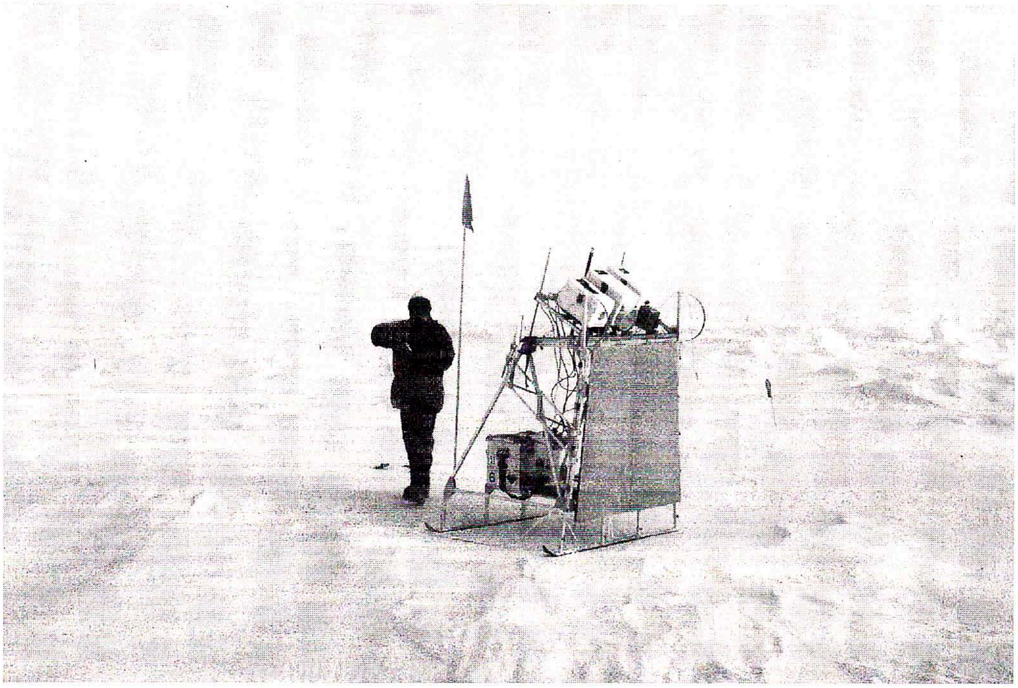

Photo 1 - Sledge in operation on the ice floe

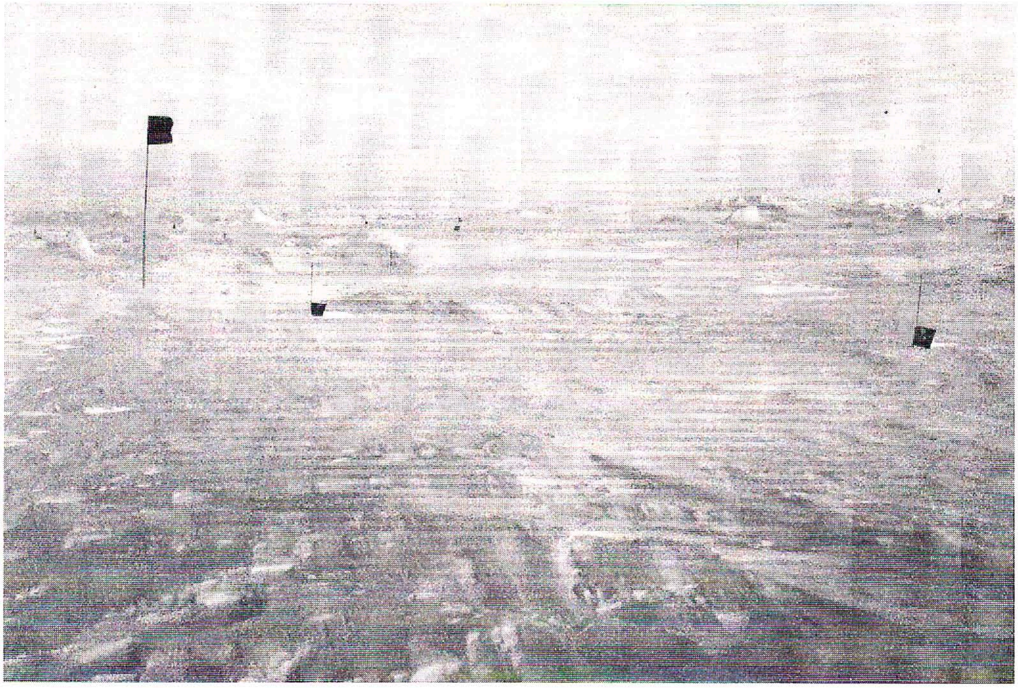

Photo 2

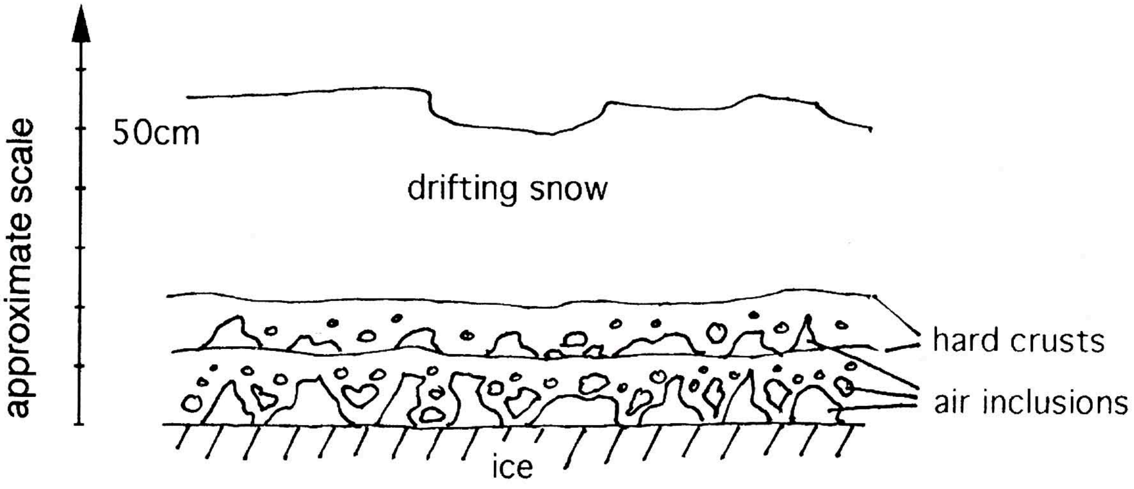

Photo 2 - Test site M-1 with profile
M-1 pond with drifting snow
snow depth 30 - 80 cm
powdery snow with a rough surface; lower layers of snow crusted with air pockets

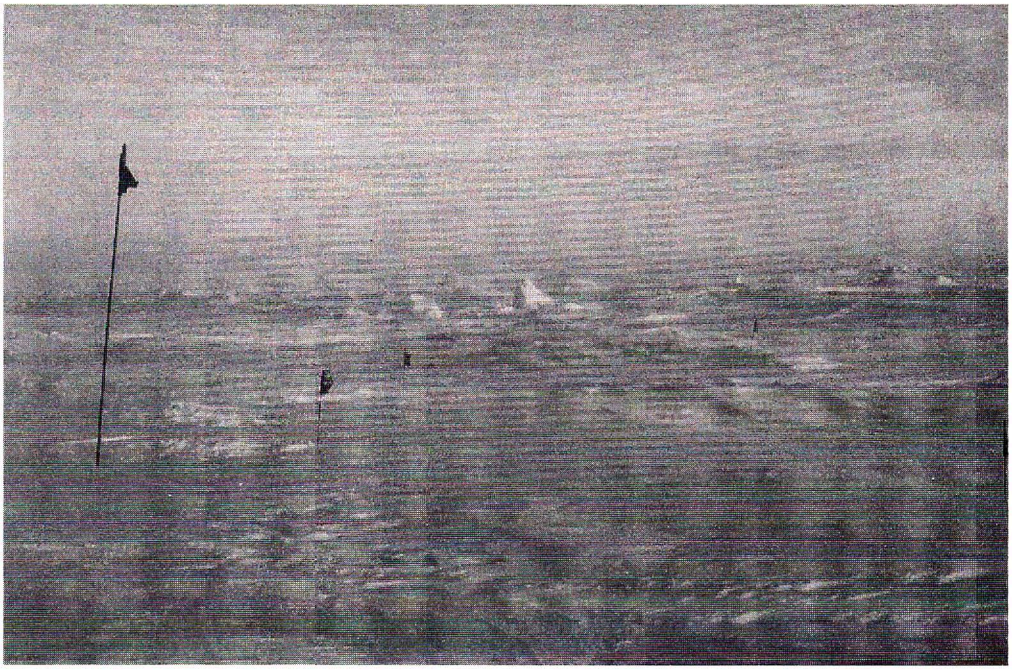

Photo 3 - Test site M-2
M-2 flat snow covered surface
snow depth 30 - 50 cm
crusted surface

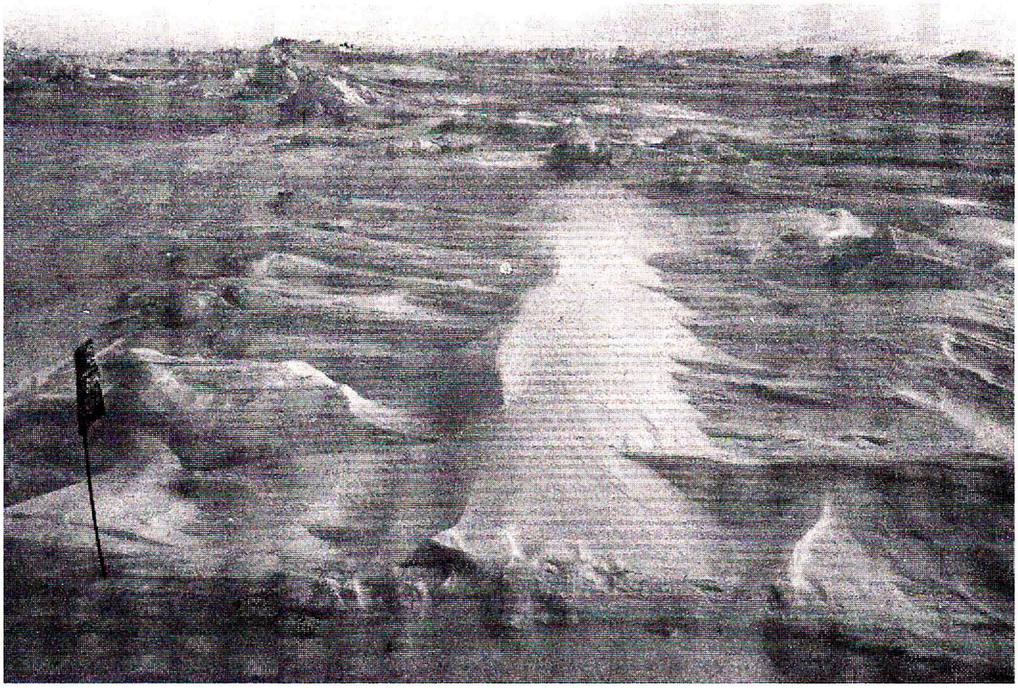

Photo 4 - Test site M-3

M-3 pressure ridge
inhomogenous surface
. broken ice in diffent directions covered with powdery snow

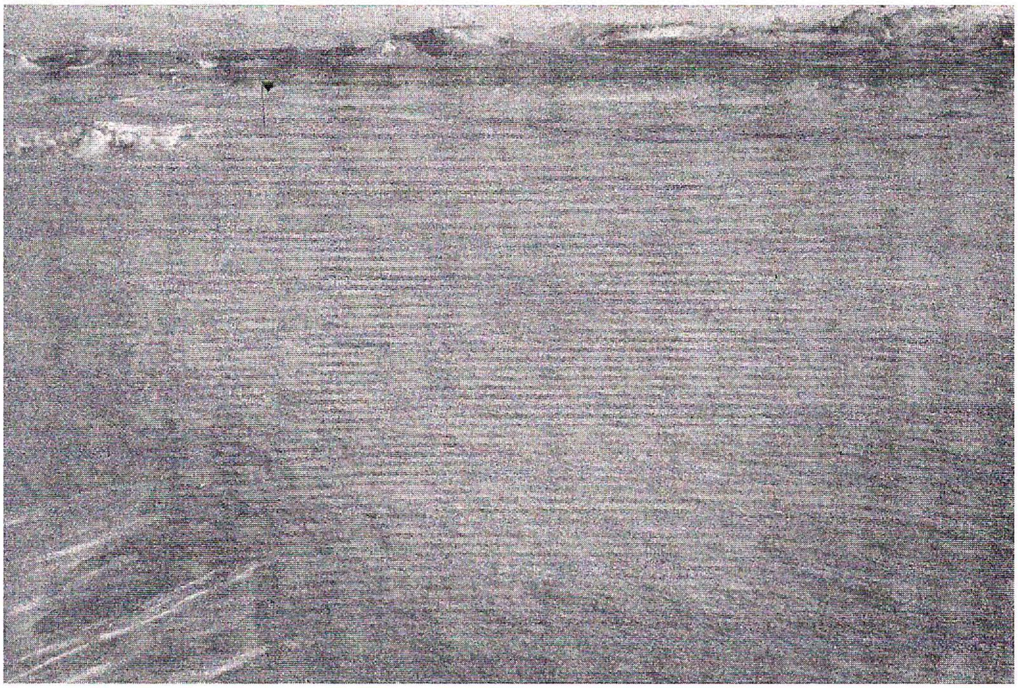

Photo 5 - Test site M-4

M-4 flat topped mound
snow depth 60 cm
very hard snow crust surface

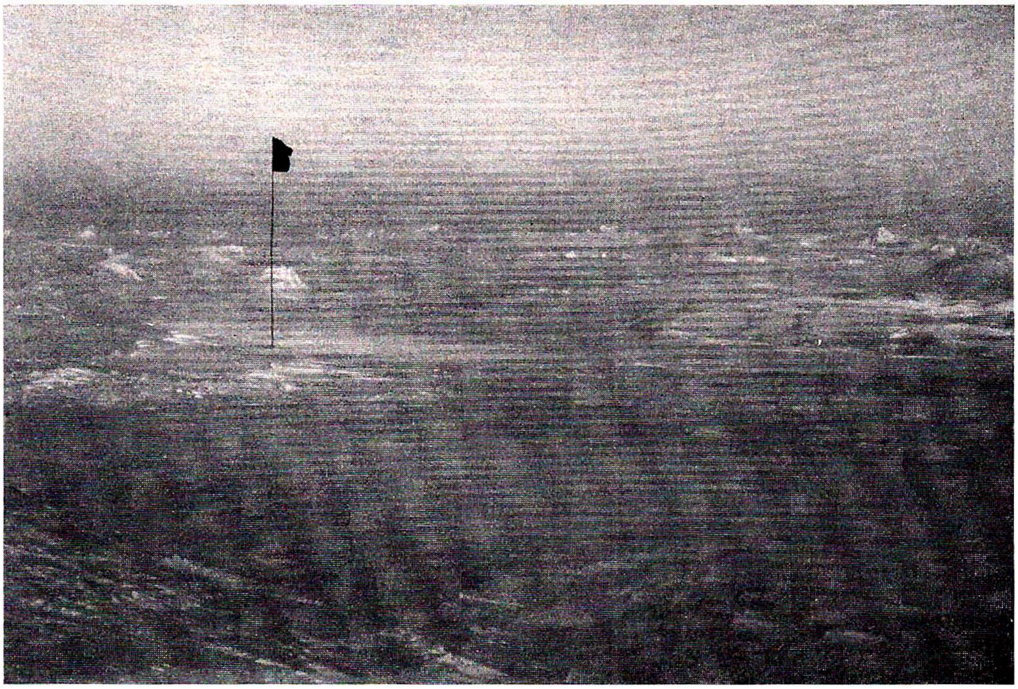

Photo 6 - Test site M-5
M-5 bare ice
snow depth 0 - 2 cm
ice without air bubbles; coloured dark blue

peratures of snow and ice are close to the blackbody temperature, therefore this calibration point is much more important than the other one. The two calibration points allow the determination of a total brightness temperature for any radiometer voltage (including reflected downwelling radiation) by linear interpolation. The linearity of the radiometers was tested by measuring calm lake water with a known emissivity.

3. FIRST RESULTS

Radiometer measurements started on March 11, then were interrupted for 2 days due to strong winds and poor visibility. The main measurements took place from March 14 to 17. Average spectra and their standard deviations for vertical and horizontal polarized brightness temperatures at an incidence angle of 50° are shown in Figure 4 and Figure 5 for sites M-1 and M-2, respectively. These data are from March 16 and 17 when the meteorological variables remained almost constant (see Figure 6). The standard deviation can be regarded as a measure of the reproducibility of the measurements. There is a large difference between the two figures: At M-2 the data were much more stable than at M-1. We do not know if the relatively deep snowpack at the M-1 site was responsible for the variation.

The time variation of the brightness temperature at M-2 is shown in Figure 7. These variations are strongly correlated with the air temperature. Coefficients ai and bi of the linear regression of the radiometer channel i against air temperature

$$T_i = a_i + b_i T_{air} \qquad (1)$$

are given in Table 1 together with the square of the correlation coefficient R and the standard deviation σ of the regression. Common to both test sites M-1 and M-2 is the decrease of the brightness temperature from 11 to 35 GHz followed by an increase to 48 GHz (see Figure 4 and 7). The difference is in the amplitude of this variation indicating variable amount of volume scattering. (see Photo 2 with profile).

Table 1 - Regression coefficients for parameter of eq.(1) for the temporal variation at site M-2 on March 11 to 17

	a_i [°K]	b_i	σ [°K]	R^2
TH11	22.27	0.76	2.5	0.75
TH21	-113.01	1.29	1.7	0.95
TH48	-181.91	1.60	4.3	0.81
TV11	-9.24	0.99	1.5	0.93
TV21	-207.09	1.77	3.2	0.90
TV48	-120.51	1.44	2.5	0.91

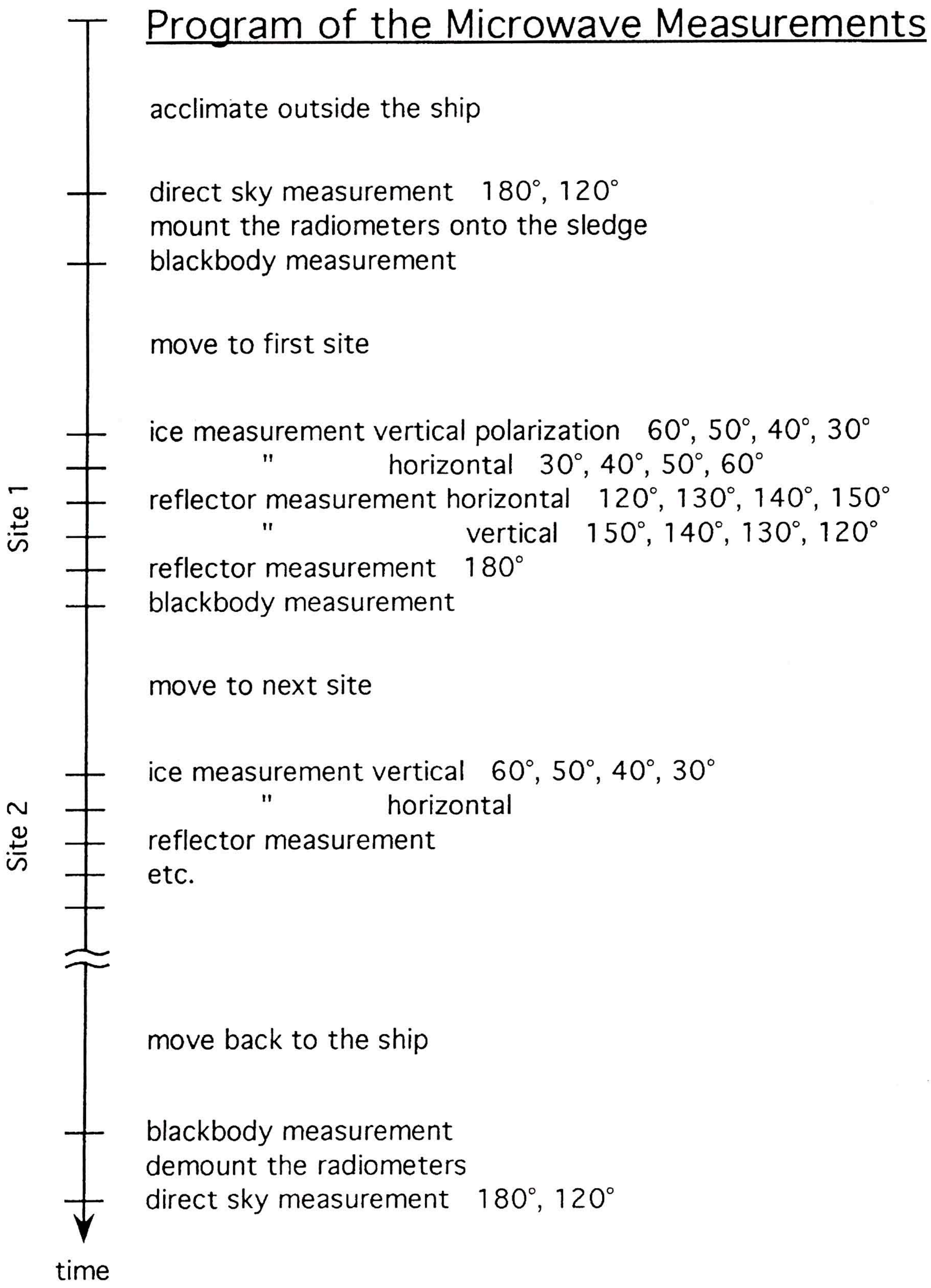

Fig. 3 - Program of the measurements

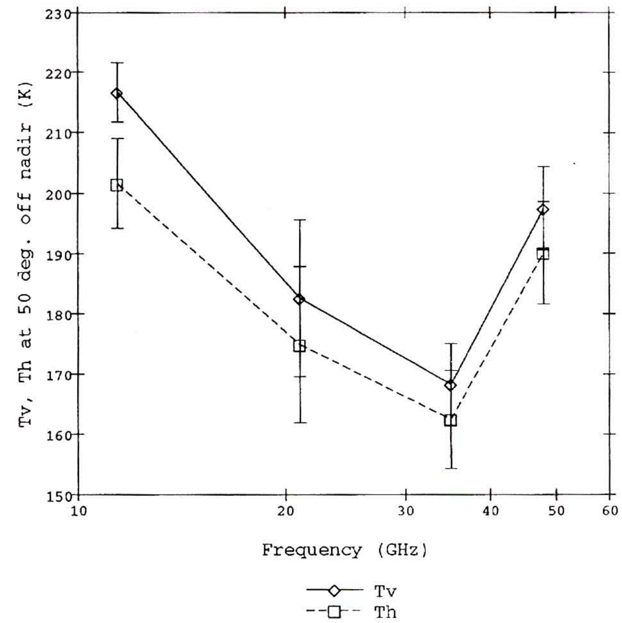

Fig. 4 - Brightness temperature at 50° off nadir of the test site M-1 for the time period of March 16 to 17: mean values and standard deviations. Air temperature was 246.7 ± 0.4°K.

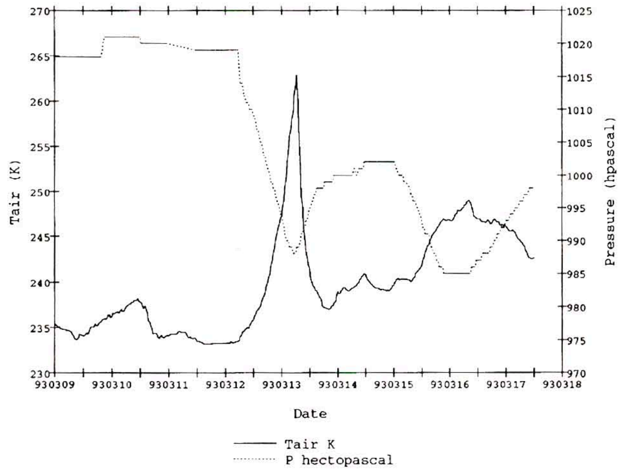

Fig. 6 - Air temperature and pressure during ARKTIS 93 expedition (INDAS-data; Alfred Wegener Institute for Polar and Marine Research, Bremerhaven)

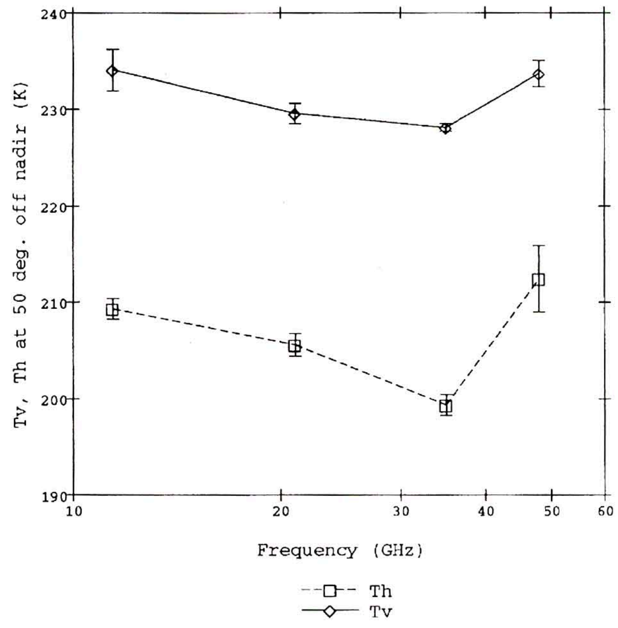

Fig. 5 - Brightness temperature 50° off nadir of the test site M-2 for the time period of March 16 to 17: mean values and standard deviations. Air temperature was 246.7 ± 0.4°K.

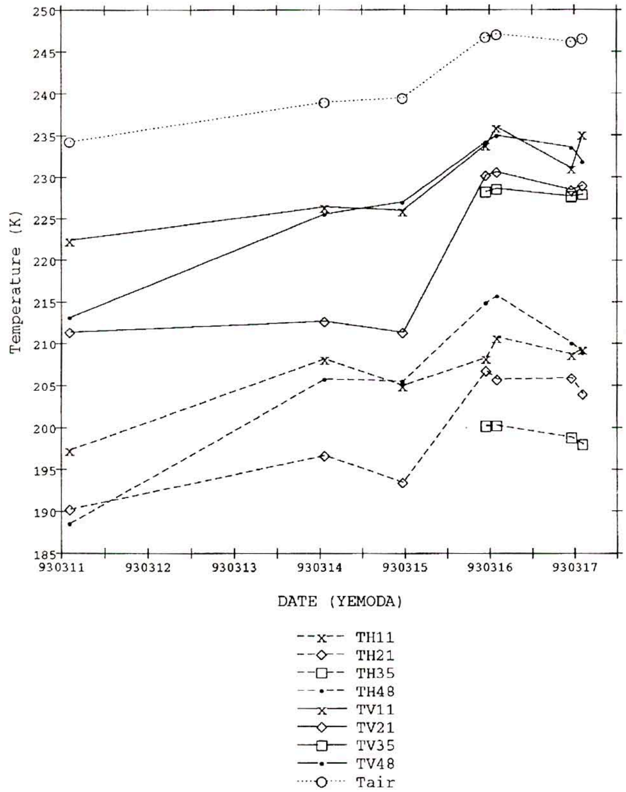

Fig. 7 - Time variation of air and brightness temperature (50° off nadir) of test site M-2

The angular variation of T_v and T_h at 11 GHz of the ice site M-5 on March 14 is shown in Figure 8. Since the ice surface was flat and no air bubbles were visible we expect that the emission can be modelled by the Fresnel formula. Results for an assumed bulk ice temperature equal to the surface temperature are also shown in Figure 8. At horizontal polarisation the observed angular variation is parallel to the Fresnel curve but with an offset of at least 10°K. This indicates that the warmer ice in deeper layers determined the effective microwave temperature.

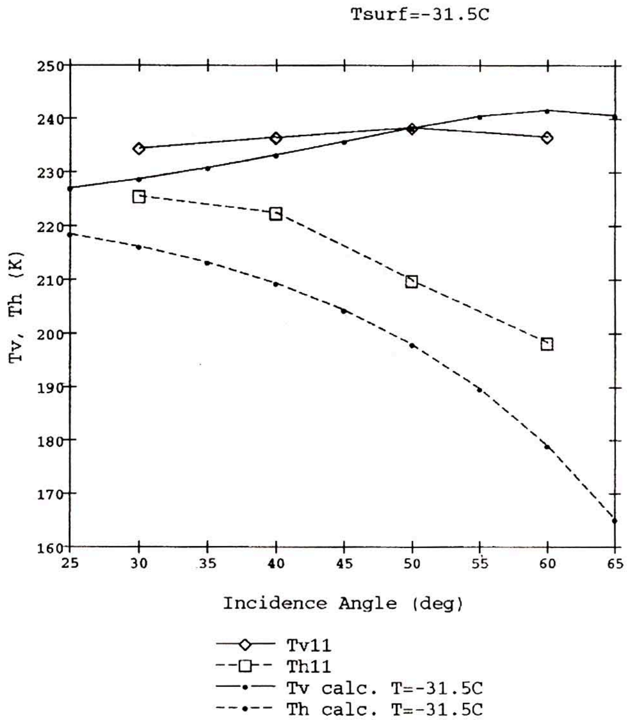

Fig. 8 - Angular variation of brightness temperature T_v and T_h at 11 GHz of the ice site M-5 on March 14 and comparison with calculated values

4. CONCLUSIONS

First surface based microwave observations of sea ice during winter conditions were performed during the ARKTIS 93 experiment. Successful measurements on the fixed ice station were made with the radiometers mounted on a sledge. Difficulties occurred due to the extreme arctic conditions under which the experiment took place. This reduced the observing time considerably and limited the amount of data collection. First results of some of the test sites were presented in this contribution. A significant variation of the brightness temperature from site to site was observed. Indeed it was even difficult to reproduce the measurement at the same site due to local variations. Some brightness temperatures are rather high due to the warmer ice below the surface (Figure 8).

ACKNOWLEDGEMENTS

The field work under extreme arctic weather conditions was greatly facilitated on board the well equipped "POLARSTERN". Our thanks go therefore first to the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven which invited us to join the expedition. Many thanks go to the staff of the electronic and mechanical workshops of our Institute for the technical support. Further we are very grateful to the group of scientists from the Scott Polar Research Institute of Cambridge for the good collaboration.

REFERENCE

[1] Mätzler C., 1992, Ground-based observations of atmospheric radiation at 5, 10, 21, 35 and 94 GHz. Radio Science, Vol. 27, No. 3, pp. 403-415, 1992.