# Experimental Study of the Microwave Signal Backscattered from the Ice Cover at Low Incidence Angles

M. Ryabkova*, V. Karaev, M. Panfilova, Yu. Titchenko, Eu. Meshkov, E. Zuikova, and Dmitry Kovaldov
Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Russia

## Abstract

In radar, the main source of scattering surface data is the backscattered radar cross section. The dependence of the backscattering normalized radar cross section (NRCS) for ice cover can be ambiguous, which does not always make it possible to determine the kind of scattering surface (ice/water). This paper describes an experiment on measuring the microwave signal backscattered from the ice cover on a river. During the experiment not only the RCS is measured, but air temperature as well. The photos of the ice cover are taken so that we understand what kind of surface and in what conditions correspond to the curtain radar response. The experiment started in January 2022 and will continue thought the winter and spring. The end result of the experiment is the dependence of the RCS of the ice cover on the air temperature.
The goal of this paper is to provide experimental data to remote sensing scientists, to discuss the results obtained and future experiments.

## 1. Introduction

One of the key indicators of global climate change is the area of ice cover in the Arctic and Antarctic, therefore, remote sensing methods are actively used to measure it. To perform operational monitoring of large areas, aerospace carriers can be equipped with radiometers, real and synthetic aperture radars, optical and infrared sensors [1-5]. In radar, the main source of scattering surface data is the backscattered radar cross section. If we consider the dependence of the backscattered radar cross section on the incidence angle for ice cover and sea waves, obtained from the data of the ASCAT scatterometer [6], we will see that at the middle incidence angles a solution to the problem of classifying the scattering surface (sea waves/ice cover) can exist for averaged data and the solution becomes ambiguous for non-averaged values.
In the paper [7] the semi-empirical formulas for ice cover RCS and sea waves are shown. In this paper we describe an experiment on measuring the microwave signal backscattered from the ice cover on a river. The experiment started in January 2022 and will continue thought the winter and spring.

## 2. Experiment

To carry out measurements, a remotely controlled radar complex was developed, manufactured and installed on a bridge over the Oka River. Two Doppler radars with video cameras were installed on the opposite sites of the bridge (Fig.1). All devices were connected to a laptop from which control was carried out. The data were recorded on a laptop disk and, after the measurement session, were downloaded to the operator on a computer installed at the institute.
On fig. 1 the position of Doppler radars is shown. Black arrows show the sounding direction. The parameters of Doppler radars are listed in Table 1. On the Fig.2 the radars installed on the bridge are shown (a,b) and the operator's monitor, which controls the operation of the radar complex (c,d). Video camera helps to control wave conditions and remove from data set the records the underlying surface.

**Table 1.** Parameters of the Doppler radars.

| radar | Wavelength, mm | Frequency, GHz | Antenna pattern |
|---|---|---|---|
| 1 | 9.7 | 30.9 | 6×6° |
| 2 | 8.4 | 35.7 | 4×4° |

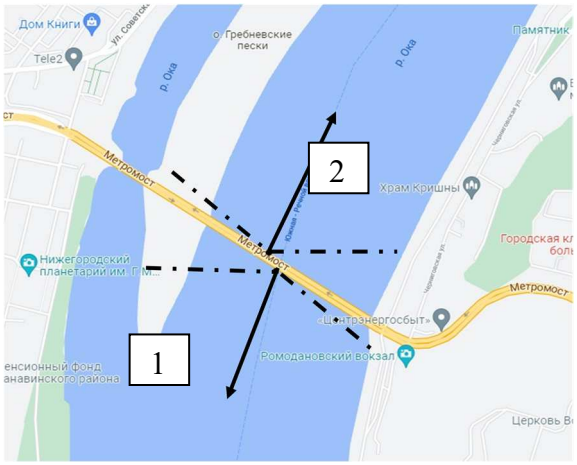


**Figure 2.** Doppler radars on the bridge.

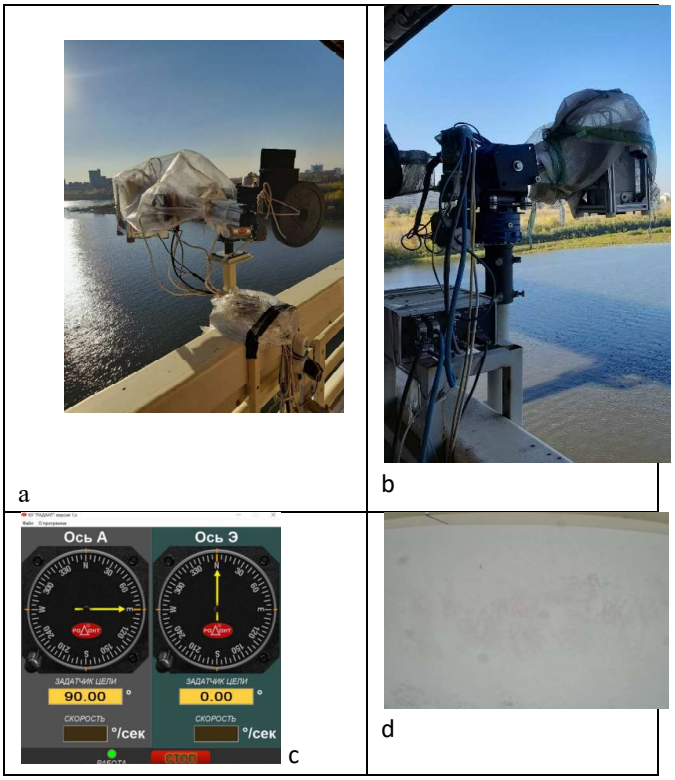


**Figure 2.** Doppler radars on the bridge. (a) radar 1, (b) radar 2, (c) interface of the program for maneuvering of radar, (d) view from camera.

The measurements started in September of 2021. The equipment is still installed on the bridge and in the winter it is used to measure reflection of microwave radiation from ice cover.

## 3. Results

The paper should include an abstract and the usual
Only radar 1 was used in the experiment. It was positioned perpendicular to the bridge so that the reflection from the metal parts of the bridge would not disturb the measurements. It was scanning the ice surface from -2° to 14° of incidence. Microwave radar measures radar signal reflected from the surface, the inclinometer measures incidence angle. To calculate backscattering radar cross section the radar measurements need to be corrected. How to take into account the antenna pattern is described in the paper [1].
On the Fig. 3 the dependence of the RCS on the incidence angle is shown. Measurements took place at 23$^{d}$ of January, 2022. Air temperature was -7 degrees Celsius.

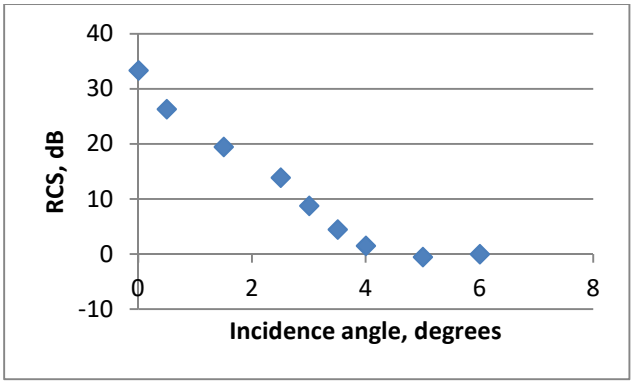


**Figure 3.** The dependence of the RCS on the incidence angle is shown. Measurements took place at 23$^{d}$ of January, 2022.

Fig. 4 shows a comparison of model scattering diagrams for ice cover (black curve, formula (7) from [7]) and Dual-frequency precipitation radar measurements over the Sea of Okhotsk in the summer season, averaged over several days.

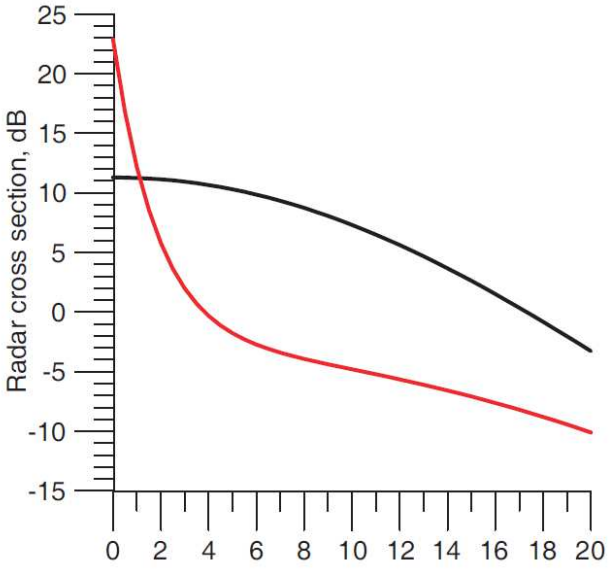


**Figure 4.** Dependence of the NRCS on the incidence angle: black curve is the ice cover and red curve is the sea waves.

It can be seen, that the experimental measurements for ice cover on the river are in agreement with theoretical calculations.

## 6. Acknowledgements

This work was supported by the Russian Science Foundation ((Project RSF 20-17-00179).). Authors express their gratitude to the metro bridge employees for the help in experiments.

## References


[1] Carsey, F. D., Microwave Remote Sensing of Sea Ice (*Geophysical Monograph 68*), American Geophysical Union, Washington D.C., 1992.

[2] Haykin, S., E. O. Lewis, R. K. Raney, and J. R. Rossiter, *Remote Sensing of Sea Ice and Icebergs*, Vol. 13, John Wiley & Sons, Hoboken, NJ, USA, 1994.

[3] Anderson, H. S. and D. G. Long, \Sea ice mapping method for Seawinds," *IEEE Transactions Geoscience Remote Sensing*, Vol. 43, No. 3, 2005.

[4] Lebedev, S. A., A. G. Kostianoy, and S. K. Popov, \Satellite altimetry of sea level and icecover in the Barents Sea," *Ecologica Montenegrina*, Vol. 25, 2019.

[5] Mitnik, L. M. and S. V. Viktorov, Radar of the Earth's Surface from Space, Leningrad, Gidrom-eteoizdat, 1990 (in Russian).

[6] Murtazin, A., K. Efgrafova, and V. Kudryavtsev, \Application of ASCAT scatterometer data to study the ice cover in the Arctic (in Russian)," *Uchenye Zapiski Rossiiskogo Gosudarstvennogo Gidrologicheskogo Universiteta*, Vol. 40, 2015.

[7] Karaev V., Panfilova M., Ryabkova M., Titchenko Yu., Meshkov E. Remote sensing of sea ice at small incidence angles: verification of the theoretical models, *Proceedings of IGARSS 2021*, pp. 5629-5632


## 7. P.S.

If you have any questions or you are interested in experimental data, you can contact Maria Ryabkova m.rjabkova@gmail.com. We are open for communication and we are interested in collaborations with other scientists. Information about our work and our experiments can be found on the Facebook of our scientific group: https://www.facebook.com/groups/171355857888355 (Group of Ocean Remote Sensing).