Scientific session of the Division of General Physics and Astronomy, USSR Academy of Sciences (January 22–23, 1975)

Usp. Fiz. Nauk 116, 741–750 (August 1975)

PACS numbers: 01.10.F

A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on January 22 and 23, 1975 at the conference hall of the P. N. Lebedev Physics Institute. The following papers were delivered:

1. F. G. Bass, S. Ya. Braude, A. I. Kalmykov, A. V. Men', I. E. Ostrovskiĭ, V. V. Pustovoĭtenko, A. D. Rozenberg and I. M. Fuks, Radar Methods for the Study of Ocean Waves (Radiooceanography).

2. A. E. Basharinov, L. F. Borodin, A. S. Gurvich, M. S. Malkevich and A. M. Shutko, Microwave Radiometry Studies of the States of Continental Covers and Bodies of Water.

3. Yu. M. Chesnokov and V. A. Kottsov, Selection of Spectral Sensitivity for Optical Systems Used in Studying the Earth from Space.

4. V. V. Bogorodskiĭ et al., Radar Sounding of Continental Glaciers.

5. R. I. Personov, The Sharp Narrowing of Spectral Bands of Organic Molecules Under Laser Excitation.

6. B. A. Volkov, Yu. V. Kopaev, and A. I. Rusinov, Relationships Between Ferromagnetic and Structural Transformations.

We publish below brief contents of four of the papers.

F. G. Bass, S. Ya. Braude, A. I. Kalmykov, A. V. Men', I. Ye. Ostrovskiĭ, V. V. Pustovoĭtenko, A. D. Rozenberg, and I. M. Fuks. Radar Methods for the Study of Ocean Waves (Radiooceanography). The phenomenon of backscattering of radio waves by the ocean surface is now being studied in great detail, both experimentally and theoretically. Studies of scattering in a broad range of radio wavelengths from hectometers[1] to millimeters[2,3] that have been made by the Ukrainian Academy of Sciences Institute of Radiophysics and Electronics since 1950 have shown that this phenomenon is of selective nature: the scattering is determined by the spectral component of the waves with the wave number

$$\varkappa_0 = 2k\cos\psi, \tag{1}$$

where $\kappa_0 = 2\pi/\Lambda_0$, Λ_0 is the length of the ocean waves, $k = 2\pi/\lambda$, λ is the radio wavelength, and ψ is the glancing angle.

Exact solution of the problem of radio-wave diffraction at the ocean surface is not now possible. Using (1), the scattered field can be determined by the method of perturbations[4]. The conditions for applicability of the method are small roughness heights compared to λ and small surface inclination angles, and can be met only at short wavelengths. Experiments and calculations[3] have shown that the ocean surface can be represented for the scattering of microwaves in the form of a superposition of ripple and large waves, the scattering from which is calculated by the method of physical optics (the so-called two-scale model).

Here one of the basic characteristics of the scattering—the specific backscattering cross section—is defined thus:

$$\sigma^0 = 16\pi k^4 B(\psi, \rho, \varepsilon, s) S(\varkappa_0), \tag{2}$$

where B is a multiplier that depends on the polarization ρ, the dielectric constant ϵ of the water, and the inclination angle s of the large-scale surface, and $S(\kappa_0)$ is the spatial spectrum of the waves (usually[5] $S(\kappa_0) \sim \kappa_0^{-4}$).

It is seen from (2) that at the small glancing angles $\psi < 10°$ at which coastal and shipboard radars operate, the variation of σ^0 with the angle ψ is determined by the function $B(\psi, \rho, \epsilon, s)$. In its general form, the analytic expression for $B(\psi, \rho, \epsilon, s)$ is complex[3], but in the particular case of horizontal polarization $B(\psi) \sim \sin^4\psi$, which, with consideration of the influence of the large waves, is manifested in amplitude modulation of the reflected signal: the slopes of the large waves vary the local angle at which the ripple is beamed. These effects are conspicuous in the horizontal polarization at $\psi < 10°$ and in the vertical polarization at $\psi < 3°$.

The large waves also cause frequency modulation of the signals scattered by the ripple. The ripple is transported by the orbital velocity of the large waves, with the resulting change in the Doppler frequency and amplitude-spectrum width of the signals reflected from different areas of the waves. The largest frequency change is observed at the crests and in the troughs of the waves, and equals $\Delta F = \pm 4\pi H/\lambda T$, where H and T are the height and period of the large waves; the plus sign corresponds to reflection from the crest in head-on observation of the waves[3]. Such are the basic features of the scattering phenomenon.

Working from the above physical conceptions of the radio scattering process at the ocean surface, and remembering that the scattering characteristics are uniquely related to the parameters of the waves, it is possible to solve the inverse problem—to determine the parameters of the waves from the characteristics of radar signals scattered by the ocean surface.

In the deka- and hectometer radiobands, it is possible to determine:

—the height of the waves and the wind velocity at the surface from measurements at a single frequency[1,6,7],

—the direction of motion of the waves[1],

—the wave-height distribution and spatial spectrum, from measurements at several frequencies[1,8],

—the distribution of the intensity of the waves over large bodies of water[1,8].

Systems working in this range can be used to study waves at large distances from the radar (up to several thousand kilometers), but the characteristics of the surface are averaged over large areas.

Use of standard microwave radars permits determination of:

– the distribution P(T) of the periods of the waves[9],

– the relative energy spectra $S(\omega)$ of the waves[9,10],

– the 90-th percentile height (from the amplitude characteristics[9]) or the present height (from the phase characteristics[10]),

– the spatial spectrum $S(\kappa)$ of the waves[11],

– the orbital-velocity spectrum[10].

It is also possible to construct charts of the level of pollution of the surface by oil from the extinction of the ripple. Using the various $B(\psi, \rho)$ dependences at different polarizations, it is possible to solve physical problems – to study the distribution of ripple height on various areas of the large wave.

These methods were applied in wave-measuring radar accessories developed by the Ukrainian Academy of Sciences Institute of Radiophysics and Electronics. Figures 1 and 2 present examples of period distributions

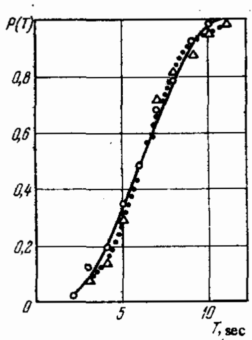

FIG. 1

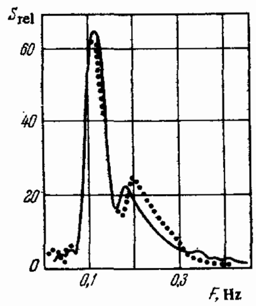

FIG. 2

P(T) and relative energy spectra $S_{rel}(F)$ measured on the "Neftyanye Kamni 1972" expedition with a Main Administration of the Hydrometeorological Service/State Oceanographic Institute wave recorder (solid curves) and the Institute of Radiophysics and Electronics accessory (dashed)[9].

We should note in conclusion that the two-scale model of the disturbed ocean surface is also effective at large angles ψ[12–15]. This makes it possible in principle to solve the inverse problem from aircraft and from space.

[1]S. Ya. Braude (ed.), Radiooceanographic Studies of Ocean Waves. Izd-vo AN UkrSSR, Kiev, 1962.
[2]A. D. Rozenberg, I. A. Ostrovskiĭ, and A. I. Kalmykov, Izv. Vuzov SSSR (Radiofizika), **9**, 234 (1966).
[3]F. G. Bass, J. M. Fuks, A. I. Kalmykov, J. E. Ostrovsky, and A. D. Rosenberg, IEEE Trans. on Antennas and Propagation **AP-16**, 554 (1968).
[4]F. G. Bass and V. G. Bocharov, Radiotekhn. i Elektron. **3**, 180 (1958).
[5]O. M. Phillips, Dynamics of the Upper Ocean, Cambridge University Press, 1966.
[6]K. Hasselman, Nature **229** (5279) 16 (1971).
[7]D. E. Barrick, J. M. Headrick, R. W. Bogle and D. D. Crombie, Proc. IEEE **62**, 673 (1974).
[8]J. L. Ahearn, S. R. Curley, J. M. Headrick, D. B. Trizna, ibid., p. 681.
[9]B. D. Zamaraev, A. I. Kalmykov, I. V. Kireev, A. S. Kurekin, V. Yu. Levantovskiĭ, I. E. Ostrovskiĭ, V. V. Pustovoĭtenko and A. V. Svechnikov, in: Proceedings of All-Union Seminar on Noncontact Methods of Measuring Oceanographic Parameters (Sevastopol', 1973), Gidrometeoizdat, Moscow, 1975, p. 7.
[10]A. D. Rozenberg, I. E. Ostrovskiĭ, I. A. Leĭkin and V. G. Ruskevich, ibid., p. 74.
[11]V. D. Zamaraev and A. I. Kalmykov, Izv. AN SSSR (Fizika Atmosfery i Okeana) **5**, 724 (1969).
[12]A. I. Kalmykov, I. E. Ostrovskiĭ, A. D. Rozenberg and I. M. Fuks, Izv. Vuzov SSSR (Radiofizika) **9**, 1095 (1966).
[13]K. Krishen, J. Geophys. Res. **27**, 6528 (1971).
[14]J. P. Claasen, H. S. Fung, R. K. Moore and W. J. Pierson, in: 1972 IEEE Intern. Conference on Engineering in the Ocean Environment, Newport, 1972.
[15]A. A. Garnaker'yan, K. L. Afanas'ev, V. T. Lobach and V. V. Timonov, Meteorol. i Gidrol., No. 12, 102 (1973).

A. E. Basharinov, L. F. Borodin, A. S. Gurvich, M. S. Malkevich and A. M. Shutko. Microwave Radiometry Studies of the States of Continental Covers and Bodies of Water. Observation of the radiothermal emissions of the earth's covers is a means of obtaining geophysical information on the state at the surface and in a subsurface layer.

The first experiments in the observation of the radiothermal emissions of the atmosphere and the earth's cover were performed in the 1950's by the radio astronomers V. S. Troitskiĭ, N. M. Tseĭtlin, N. L. Kaĭdanovskiĭ and A. E. Salomonovich.

The radiothermal survey makes it possible to perform measurements independently of lighting and cloud conditions.

The measured intensity values (radiobrightness temperatures) and degrees of polarization of the radiothermal emission depend on the effective heating temperature and the emissivities of the radiating objects.

In turn, the emissivity depends on the dielectric properties of the material, the roughness of the surface, and the observing angle.

Areas with smooth surfaces that satisfy Rayleigh's conditions have emissivities that can be determined from the Kirchhoff relation

$$\varkappa = 1 - |R|^2, \tag{1}$$

where R is the reflectance. Thus, for example, in slant sounding at an angle θ at vertical polarization

$$\varkappa_v = 1 - \left| \frac{\varepsilon \cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\varepsilon \cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \right|^2. \tag{2}$$

The radiothermal emission of a smooth surface is polarized at slant sighting angles.

The relation of the emissivity to the polarization coefficient is used to determine the parameters of the covers from radiothermal measurements.

In the radiothermal survey, the influence of the atmosphere makes itself felt in absorption of the radiation from the underlying surface and superposition of additional radiation by the atmosphere[1,2].