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 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].

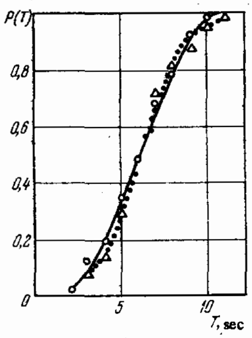

FIG. 1

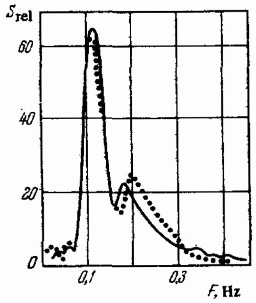

FIG. 2

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.

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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].

By performing simultaneous measurements in several segments of the spectrum, it is possible to separate the radiation contributions of the underlying surface and the atmosphere and thereby correct for atmospheric distortions.

The radiothermal emission of water surfaces is formed in a thin surface layer.

The intensity and polarization of the radiothermal emission depend on temperature, the content of salts in the water, the height of the waves, coverage of the surface by foam and oil films, and the presence of ice cover (temperature, impurity content, and state of the water surface).

Measurements in several spectral segments can be used for radiometric determinations of temperature, salinity, and wave intensity[1,3-5].

Thus, measurements in the decimeter band can be used to estimate the thermodynamic temperature and salinity of ocean water when the ocean surface is calm[1,3,6].

Figure 1 shows estimates of the latitudinal surface temperature variations of the Atlantic Ocean based on Kosmos 234 (1968) measurements of radiation intensity at 8.6 cm[5].

Figure 2 presents variations of radiobrightness temperature and salinity in the area of the Sivash neck.

The considerable radiobrightness-temperature contrast between areas with open water and icefields makes it possible to locate the drift-ice boundary[4-5]. A difference in the spectral characteristics of the emission from first-year and old sea ices has been observed experimentally in the millimeter band; it is due to scattering effects on air bubbles and inhomogeneities[67].

Wind waves and the appearance of foam and spray are accompanied by an increase in the centimeter-band emissivity. The increase in the intensity of the radiation as the wind speed changes is monotonic and nearly linear[4-6].

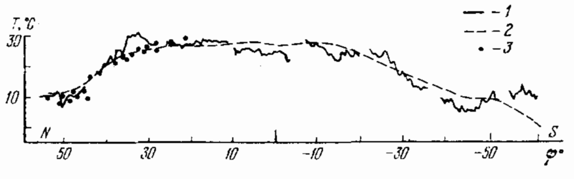

FIG. 1. Comparative values of Atlantic Ocean surface temperature. 1) Estimates from radiothermal emission (Kosmos 243, September 1968); 2) climatic average values; 3) results of shipboard measurements.

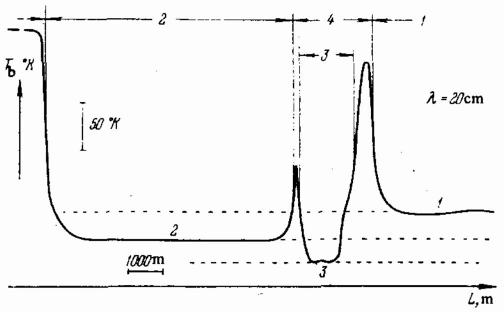

FIG. 2. Variations of radiobrightness temperatures of emission from bodies of water with various salinities [6]. 1) Sea of Azov (salinity 13% to 15%0; 2) Sivash lagoon (salinity about 100%0; 3) salt lake on Arabat spit (salinity about 200%); 4) Arabat Spit.

The radiothermal emission of continental covers is shaped in a layer whose thickness ranges from a few centimeters into the meters.

The emissivities of continental covers are subject to substantial variations due to variations in the dielectric constant of the material, the effects of terrain micro- and macrorelief forms, and the screening influence of vegetation[5,7,8].

An increase in the moisture content of soil is accompanied by an increase in its dielectric constant and a corresponding decrease in its emissivity (Fig. 3).

For exposed soils, the slope of the brightness-moisture curve is 2-3 deg/%. Vegetation cover has a screening action that becomes stronger as the wavelength becomes shorter. The presence of a thick canopy may completely screen out the emission from the underlying soil layer.

Because of the penetrating ability of the radio waves, radiometric measurements in the decimeter band are sensitive in the detection of ground water at depths in the meters[6]. Measurements in the region of the Arabat Spit (Crimea) yielded soil radiobrightness temperature profiles at wavelengths of 3.4, 10, and 20 cm. A decrease in the radiobrightness temperature of the soil at the 10- and 20-cm wavelengths was due to the presence of ground waters at several depths.

The radiothermal emission of ice cover and snow is formed in a comparatively thick layer in which the layering of the ice and the structural inhomogeneities that produce the volume-scattering effect exert a strong influence.

Anomalously low radiothermal-emission values were obtained in high latitudes for the continental and shelf glaciers of the Antarctic Continent and Greenland in satellite observations of the radiothermal emission of the earth[6]. A quantitative description of these anomalies was given in [9] on the basis of a correlation theory of the emission that took account of scattering on random dielectric-constant inhomogeneities of the glaciers.

The radiothermal survey can register changes in the heating temperatures of ground areas that result from seasonal and climatic variations, manifestations of geothermal activity, and local heating of the surface[6,10].

Regular latitudinal variations of radiobrightness temperature due to the variations of the monthly average temperature in the surface air layer have been detected in cases of homogeneous covers (deserts and semiarid areas)[5,6,11].

An influence of terrain relief has been observed in

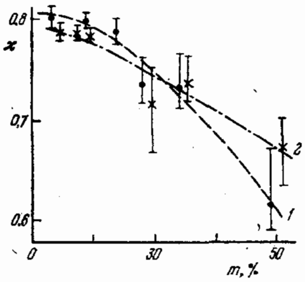

FIG. 3. Experimental curves of emissivity vs. moisture content for exposed soils (aircraft measurements, Crimea, 1973) [6].

flights over mountainous regions, which detected a decrease in radiobrightness due to the lower temperatures of areas at high elevations above sea level[5,6].

In 1973-1974, aircraft instruments registered radiobrightness contrasts caused by the appearance of foci of geothermal activity in the Kamchatka region. The performance of measurements in several bands of the spectrum makes it possible to obtain estimates of the geothermal gradient and the strength of the heat source.

Local heating foci due to forest and peatfield fires can be detected by the radiothemal survey through clouds and smoke.

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Yu. M. Chesnokov and V. A. Kottsov. Selection of Spectral Sensitivity for Optical Systems Used in Studying the Earth from Space. The spectral brightnesses of elements of the earth's natural landscapes are recognition criteria for these elements. The choice of spectral sensitivity in a surveying system determines the use that is made of the spectral differences between the objects photographed, assuming that they are spatially resolved.

Since technical difficulties impose limits on the spectral and spatial resolution possibilities inherent in the optical systems, the problem of optimizing parameters arises. We treat the surveying system as an analog device that performs integral conversions on the optical-characteristic fields of the objects. By evaluating the resulting image in terms of the object brightnesses, we can discuss the performance of the surveying system within the framework of a linear theory.

When spatial resolution conditions are met, the spectral sensitivity of the surveying system can be optimized on the basis of analysis of a priori data on the surveyed objects for a specified optimality criterion. To this end, let us introduce the object-space concept. It characterizes the object uniquely for a given range of wavelengths and, in the general case, is a Hilbert space. Each of the objects on the landscape is represented in the object space by a vector whose position is determined by the brightness distribution over the spectrum, while its norm is given by the integral brightness in the specified spectral band.

The construction of a set of images consists in mapping of a finite number of surveyed objects represented in an infinite-dimensional space onto a finite-dimensional image space. Each image is formed by a scalar product. At unit sensitivity of the surveying system, formation of an image means projection of the vector characterizing the surveyed object onto the spectral-sensitivity vector of the surveying system. The number of independent surveying-system channels determines the number of dimensions of the image space.

We choose the spectral response curve of the surveying system on the basis of an optimality criterion. This criterion may vary depending on the nature of the problems to be solved[1]. For example, to distinguish an object against its background, given the maximum signal/noise ratio, it is necessary to perform a mapping onto a vector collinear with the object-difference vector.

In view of the variety of natural objects and the many purposes for which the results of a space survey will be used, we choose an optimality criterion in the statistical sense. We find the spectral characteristics of the surveying system to represent the maximum differences with a minimum number of channels. Generality of problem formulation implies the criterion of maximum brightness dispersion, and the results in different channels should yield different information. The Carounin-Loew expansion[2] can be used as a solution for choosing the spectral sensitivity of the surveying system in the sense of the brightness dispersion of the images obtained.

The set of objects composing each of the landscape types is limited, and the effects of the set of miscellaneous factors make it possible to regard the spectral brightness of each of the objects as a realization of a random process. After consideration of the mean spectral-brightness value of the ensemble of objects, the Loew expansion makes it possible to obtain an optimum finite-dimensional basis for representation of the ensemble of objects. The norm of the error for representation of the individual realizations, averaging over the ensemble of objects, will be minimal. Geometrically, the expansion can be represented as successive determinations of pairwise orthogonal vectors in the direction of maximum dispersion. The instrumental and methodological errors determine the error norm obtained and limit the required number of channels.

A priori optimization requires knowledge of the spectral brightnesses of the objects under survey conditions. The optical characteristics of the objects have not yet been studied adequately for final solution of the problem. About 2000 spectral response curves suitable for the design of surveying systems have been obtained for natural-landscape features on the territory of our country, but the flora of the USSR alone runs to 15,000 species of plants. For joint analysis, we used only data obtained by a single instrument under metholologically comparable conditions. The mean standard atmosphere was used in the calculations.

To choose the spectral response curves, we analyzed various ensembles of natural objects on a computer. These included various classes of natural objects, the