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REMOTE INDICATION OF THE MOISTURE SUPPLIES OF THE ATMOSPHERE AN--ETC(U)
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REMOTE INDICATION OF THE MOISTURE SUPPLIES OF THE ATMOSPHERE AND THE UNDERLYING SURFACE

by

K. Ya. Kondrat'yev, V. V. Melent'yev, et al.

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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REMOTE INDICATION OF THE MOISTURE SUPPLIES OF THE ATMOSPHERE AND THE UNDERLYING SURFACE.

K. Ya. Kondrat'yev, V. V. Melent'yev, Yu. I. Rabinovich, Ye. M. Shul'gin.

(GGO [Main Geophysical Observatory]).

The solution to the problem of the adequate estimation of the water resources of the atmosphere, marine and river basins, moisture supplies of soil, the acquiring ever more important practical value, is hinder/hampered by the insufficiency of available observations [7]. One Of the most promising methods of obtaining the missing information it is connected with the use of possibilities of the remote indication. The remote indication of the natural medium is based on research on the field of the outgoing electromagnetic radiation of system the Earth - atmosphere whose quantitative characteristics depend on the parameters, which are determined by the properties of the underlying surface and atmospheres [6, 10].

This survey is dedicated to the discussion of the different aspects of microwave remote indication of the moisture supplies of the atmosphere and soil, based on the use measurement data of radio emission in centimeter band, which has a series of advantages in comparison with use for the analogous target/purposes of these measurements in the infrared and visible regions of the spectrum. The basic special feature/peculiarity of the radio emission of range 0.5-10 cm is its large informativeness. So, the radio emission of wavelengths of more than 3 cm passes through the atmosphere (even containing the clouds of large liquid-water content and hydrometeors) almost without weakening. This means that the receiving radiometric instrumentation, establish/installed on flight vehicle, obtains the information about surface condition of the Earth, including information about the state of water surface, the moisture supply of the surface layers of soil, since, as it will be shown below, the humidity of soil to a considerable degree determines its radio emission. On the other hand, the emission/radiation of shorter wavelengths (0.5-2 cm) substantially is attenuate/weakened in transit through the atmosphere, the clouds and residue/settlings. Thus, measuring the radio emission at these wavelengths, it is possible to obtain information about the common/general/total moisture content of the atmosphere, water content of clouds, intensity of liquid precipitations, extent of the zones of residue/settlings.

The studies of the properties of the atmosphere and the underlying surface in the centimeter region of the spectrum can be conducted by the means of active and passive radar. Passive radar (IR radar) utilizes the highly sensitive radiometric receivers, which record its own noise the radio emission of the atmosphere and the underlying surface. Such receivers fairly complicated; however, one of the advantages of this method before active radar is the absence of the transmitter which generates powerful radio pulses.

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Small overall sizes, small requirements for the consumption of energy make it possible to easily place IR radar equipment on aircraft and satellites, which makes it possible to obtain the data on the properties of atmosphere and surface of the Earth on global scale [2, 8, 10].

The moisture supplies of the atmosphere. the urgent problem of satellite meteorology is the determination of common/general/total moisture content and vertical distribution of the water vapor in the atmosphere [1, 16, 21]. In the microwave region of the spectrum, there is line of the absorption of water vapor at wavelength 1.35 cm which is not overlapped by other lines of absorption. Measurement data of emission/radiation in this line can be used for the solution of the problem of the remote indication of the moisture supplies of the atmosphere. The width of line λ = 1.35 cm is approximately 0.1 cm^{-1}, and the dependence of the coefficient of the absorption of the water vapor on frequency ν, pressure P and temperature T is determined by the following formula:

$$\alpha_{H_2O}=1{,}05\cdot 10^{-28}\frac{N\nu^2e^{-644/T}}{T^{5/2}}\left[\frac{\Delta\nu_p}{(\nu-\nu_0)^2+\Delta\nu_p^2}+\frac{\Delta\nu_p}{(\nu+\nu_0)^2+\Delta\nu_p^2}\right]+$$
$$+7{,}6\cdot 10^{-52}\frac{N\nu^2\Delta\nu_p}{T^{3/2}}\,cm^{-1}, \quad (1)$$

where N is a quantity of molecules H_2O per unit of volume, ν_0 - resonance frequency, $\Delta\nu_p$ - the half-breadth of line, caused by intermolecular collisions;

$$\Delta\nu_p=2{,}62\cdot 10^9\frac{P/760}{(T/318)^{5/8}}(1+0{,}0046\,\rho)\ s^{-1}, \quad (2)$$

where P is atmospheric pressure, ρ is density H_2O in g/m^3. One should in this case note that the problem of the duct of spectral lines still does not have the conventional solution (for example, see [34]).

The initial measured value during the solution of the problem of the remote indication in question is the radio brightness temperature of system the Earth - atmosphere. The determination of this value by the integration of the equation of transfer of microwave emission/radiation is led to the following formula, which indicates communication/connection between the measured value of radio brightness temperature and the unknown parameters.

$$T_s = \varepsilon T_p e^{-\sec\theta_1 \int_0^h \beta dz} + \sec\theta_1 \int_0^h T(z)\beta e^{-\sec\theta_1 \int_z^h \beta dz'} dz + \\ + \left\{ \int_0^{2\pi} d\varphi' \int_0^{\pi/2} r(\theta_1, \varphi_1, \theta', \varphi') \sin\theta' \cos\theta' d\theta' \times \\ \times \left[\sec\theta' \int_0^{\infty} T(z)\beta e^{-\sec\theta' \int_0^z \beta dz'} dz \right] \right\} e^{-\sec\theta_1 \int_0^h \beta dz}, \quad (3)$$

where T_p is temperature of the underlying surface; T(z) - the temperature of air; β is a total coefficient of weakening in water vapor, oxygen and other atmospheric gases; θ', ϕ' - the angular coordinates of incident radiation; θ_1 - sighting angle; ϕ_1 - the azimuth of sighting; ε is the emissivity of the underlying surface; $r(\theta_1, \phi_1, \theta', \phi')$ - the brightness coefficient of the earth's surface; h is the height/altitude at which is placed the radiation detector; z is a vertical coordinate.

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First term in formula (3) determines the emission/radiation of the earth's surface, weakened by the layer of the atmosphere and reaching the height/altitude at which is arrange/located the radiation detector, the second - emission/radiation of the layer of the atmosphere from the level of the earth's surface to height/altitude h, the third - emission/radiation of an entire thickness of the atmosphere, is reflected from the earth's surface that which was weakened by the layer of the atmosphere from the level of the Earth to height/altitude h.

From formula (3) it follows; that the measured radio brightness temperature depends on temperature, pressure, and the content of the water vapor. As shown in work [16], this is made it possible, in particular, to utilize measurement data of radio brightness temperature for determining the common/general/total content of the water vapor in the atmosphere.

Figures 1 [16] gives the results of the calculations of the radio brightness temperatures of system the Earth - atmosphere (λ = 1.35 cm) depending on a quantity of precipitated water in entire thicker atmosphere; here are given the results of aircraft measurements.

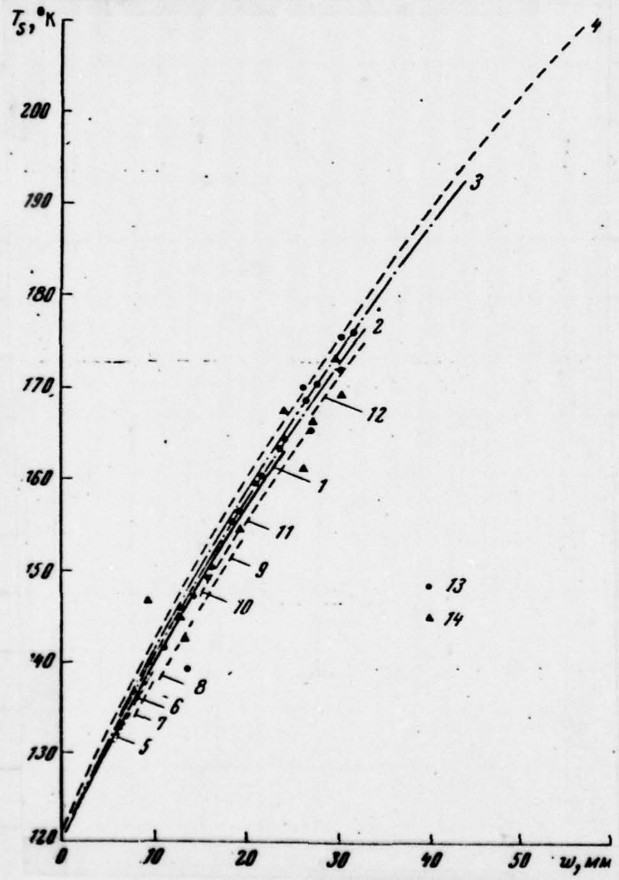

Fig. 1.

Fig. 1. Radio emission of system Earth - atmosphere (λ = 1.35 cm); sea water (T_p=298° K, 40o/oo). 1 - T_0 = 288°K, 2 - T_0 = 293°K, 3 - T_0 = 298°K, 4 - T_0 = 303°K, fresh water (T_p=273° K): 5 - T_0 = 273°K, 6 - T_0 = 278°K; fresh water (T_p=283° K): 7 - T_0 = 278°K, 8 - T_0 = 283°K, 9 - T_0 = 288°K; fresh water (T_p=293° K): 10 - T_0 = 288°K, 11 - T_0 = 293°K, 12 - T_0 = 298°K, 13 - T. for real airfoil/profiles, 14 - experimental T.. T_0 — temperature of air of the surface of the Earth.

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Work [16] also shows, that on the measurements of radio brightness temperature can be not only determined common/general/total content of the water vapor in the atmosphere, but also is restore/reduced the elevation profile of humidity - during the use of several frequencies within absorption band.

Measurement data of the outgoing radiothermal emission/radiation are especially informative from the point of view of determining the characteristics of powerful cloud formation/educations and detection of the zones of residue/settlings on regional and global scales. The radio emission of clouds and precipitation in microwave range essentially differs in value from the emission/radiation of the cloudless atmosphere. In the real cases of cloud formation/educations and residue/settlings, the optical thickness τ composes less than 0.5, but the probability of the survival of quantum $\lambda_* < 0,1.$ Since stratified clouds and feeble residue/settlings have thickness τ, which do not exceed 0.2, and $\lambda_* = 0,02-0,04,$ the calculations of microwave emission/radiation can be performed without taking into account of scattering by the formula

$$T_s = (1-R)T_p e^{-\tau \sec \theta} + T(1-e^{-\tau \sec \theta}) + RT(1-e^{-\tau \sec \theta})e^{-\tau \sec \theta}, \quad (4)$$

where T_p is temperature of spreading surface, t - the temperature of the medium in which occurs the radiation transfer, τ - the optical thickness of layer, θ - an angle between the standard to layer and the sighting direction, R - the coefficient of reflection of the underlying surface.

As shown in work [17], from the examination of theoretical and experimental data, it follows that for the detection of the zones of cloudiness and residue/settlings it is expedient to utilize measurement data on two wavelengths: 0.8 and 3.2 cm. On λ = 0.8 cm is obtained the greatest radio brightness contrast, and range 3.2 cm is necessary for determining form and temperature of the underlying surface, and also the residue/settlings at the presence of multilevel cloud cover.

The measurements, made with the aid of the IR radar equipment, establish/installed on ISZ [artificial earth satellite] "Kosmos-243" [15], made it possible to obtain the statistical evaluations of water vapor and drop water above oceans. It was reveal/detected that the average/mean latitudinal distribution of integral humidity above calm, the Atlantic and Indian by oceans is similar. Work [15] shows, that the average/mean liquid-water content $\bar{w}_z \approx 0,2$ kg/m², i.e., approximately 1o/o of water is found in liquid-drop state. measurements were made from 23 to 27 September 1968. In accordance with season, the content of the water vapor and drop moisture in the atmosphere is approximately 1.5 times more in the Northern Hemisphere, than in south, with the average on terrestial globe of approximately 2.4 g/cm².

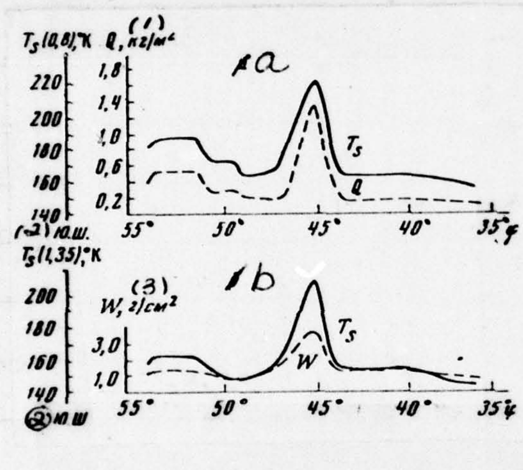

Fig. 2. airfoil/profiles of radio brightness temperature T. on waves 0.8 cm (a) and 1.35 cm (b), water supply of clouds Q and moisture content of atmosphere w at of intersection with orbit of satellite of frontal cloudiness.

Key: (1). kg/m². (2). South latitude. (3). g/cm².

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Figures 2 gives the profiles of radio brightness temperature at wavelengths 0.8 (a) and 1.35 cm (b), the water supply of clouds and the moisture content of the atmosphere during the intersection by the projection of the orbit of satellite "Kosmos-243" of frontal cloudiness (on 24 September 1968, Indian Ocean, the 15th turn) [1].

Thus, utilizing spectral data on the field of the radio emission of system the Earth - the atmosphere, it is possible to obtain the data on the common/general/total content of liquid and vaporous moisture in the atmosphere in global scale.

The moisture supplies of soil. In recent years has been proposed a whole series of the methods of the remote sensing of the humidity of soils [31], which can be realized with agree, that the observations are accompanied by an estimate of the cloud cover, and, furthermore, are preliminary data about the observed territory (character of soil, the type of coverings). Their number includes following methods.

1. Method of determining humidity from measurement data of solar

radiation reflected into close of infrared region (1.0-1.5 μm), which is based on that fact that reflectivity strongly it decreases with increase in humidity [32]. The estimation of the real possibilities of this method, which is characterized by comparative simplicity, is hinder/hampered by the facts that thus far are still insufficient the data, which characterize the numerical ratios between reflectivity and humidity. The majority of these according to reflectivity soils is related to dry materials [9, 36]. In this case, is noted powerful effect on the reflection of roughness and surface slope which in many instances cannot be known. Furthermore, the dependence of reflectivity on the type of soils in certain cases is more than from humidity. finally, the most main lies in the fact that the method in question is inapplicable in the presence of cloudiness. Even with the cloudless atmosphere the solution of problem is complicated by the need for account for the transforming emission/radiation effect of the intermediate thickness of the atmosphere.

2. Is much more sensitive to humidity changes degree of polarization that which was reflected by soil of world/light in visible region, that gave grounds for developing polarizational method [36]. It is important also that in this case considerably pain the weak dependence on the type of soils and roughness. The degree of polarization of reflected light strongly depends, however, on phase angle. Conducting satellite measurements at optimum angle of

approximately 10° is possible only in the narrow region of the very high latitudes. To the advantages of polarizational method they are related high resolving ability and the possibility of its use without the need for the realization of any other measurements. Fundamental deficiency/lacks are the nonrealizability of method in the presence of cloudiness and the need for the account of the effect of the thickness of the atmosphere.

3. Increase in heat capacity of soil with an increase of humidity creates contrast of temperatures of surface, and consequently, thermal radiation of humid and dry sections of soil, which serves physical as basis of method of determination of moisture content from measurement data of infrared thermal radiation. in work [35], for example, it was established that in night time the temperature of humid sections and surfaces of water approximately 7° is higher than the temperature of the sections of dry soil. Unfortunately, not smaller than humidity, effect on infrared emission/radiation exert the texture, the thermal conductivity and some other characteristics of soil and at present obtained reliable approaches for the separation of these effects.

4. Method of humidity measurement, close in physical nature to method of passive radar, consists in measurement of reflectivity of coverings, which depends on humidity, with the aid of active radar

[18-20, 27].

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However, the important advantage of this method - the possibility of the immediate determination of reflectivity, not connected with additional change of the radiation temperature of surface in the infrared region of the spectrum, unfortunately does not compensate for its deficiency/lacks, caused by the strong dependence of the echo signal from roughness, the composition of soil and, most importantly, by the complexity of tool house technicians.

5. Let us pause in more detail at discussion of possibilities of determining humidity of soil with the aid of method of passive radar [3, 11, 26, 31].

The radio brightness temperature of soil, measured in the direction of standard, is determined as follows:

$$T_s = \varepsilon(w) \int_0^\infty \alpha(w, z) T(z) \exp\left(-\int_0^z \alpha(z', w) dz'\right) dz, \qquad (5)$$

where $\varepsilon(w)$ - the emissivity of soil; α (w, z) - the absorption coefficient; T(z) - temperature profile in soil; w, z is humidity and vertical coordinate respectively.

The emissivity of soil depends both on its properties (soil composition, its electrical parameters, the special feature/peculiarities from distribution according to depth) and on the characteristics of interface (smoothness or the roughness, the presence of coverings).

For a smooth surface or the surface a radius of roughness of which is much greater than wavelength, radiation coefficient $\varepsilon(w)$ can be determined through the factor of specular reflection R(w), if the radiating layer of soil is uniform in the depth:

$$\varepsilon(w)=1-|R(w)|^2. \quad (6)$$

We obtained expressions for the coefficients of reflection of soil, linear-heterogeneous in depth. The analysis of these expressions showed that for real soils the effect of heterogeneity on reflection coefficient small and in the first approximation, these coefficients can be calculated from Fresnel's formulas (only at long wave lengths, on the order of 60 cm, for the soils, which have dry surface, the effect of heterogeneity is substantial).

In that case the radiation coefficient is determined dielectric by the permeability of the medium which for soil in microwave range bears real character. The real part of the dielectric constant of sand and clay and the absorption coefficient linearly grow/rise with an increase in humidity [13]. Thus, the radio brightness temperature of soil is the functional of temperature and humidities. Therefore in the general case the problem of remote sensing must be the study both of the characteristics of moisture content and the temperature conditions of soil.

Thus, as the physical basis of the possibility of the determination of the moisture content of soil with the aid of passive radar serves the fact that with an increase in the humidity increases the dielectric constant of soil and, therefore, it decreases its emissivity and radio brightness temperature.

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The fact of a decrease in the radio brightness temperature with an increase in the humidity of soil distinctly is outlined during treatment/working measurement data of microwave emission/radiation from ISZ "Kosmos-243" at wavelengths 0.8-8.5 cm. In works [2, 3], it is noted that a reduction in the radio clearness of the sections of continents to 30-50° is observed in the places of moistening coverings where emissivity factor does not exceed 0.7-0.8.

The data of the ground-based measurements of radio brightness temperature confirm the fact of its dependence on humidity [30, 37].

The made in work [28] measurements of the radio brightness temperature at wavelengths 21, 2.2 and 0.81 cm under the controlled/inspected terrestrial conditions showed that its sensitivity to surface humidity changed from 9°K for a wavelength 0.81 cm up to 12°K for a wavelength 2.2 cm during humidity change from 9.5 to 14o/o. An even highr sensitivity to humidity was observed at wavelength 21 cm: $\Delta \dot{T}_{a} = 14-18°$. Analogous results are given in work [26].

The authors [29] undertook an attempt at the determination of optimum sighting angle for the sounding of humidity. It turned out that at wavelength 0.97 cm there is a strong dependence of radio brightness temperature from humidity at all sighting angles during horizontal polarization, but on vertical - at angles less than 50°. Somewhat different sensitivity of the radio brightness temperature to humidity, indicated by the different authors in the named works, can be explained by the nonidentity of observation conditions. In review paper [23] it is noted, that the typical sensitivity of radio brightness temperature to moisture is 3-5°K per 1o/o.

The vast statistical material, obtained as a result of treatment/working measurement data of microwave emission/radiation from satellite "Kosmos-243", made it possible to establish/install the linear character of a decrease in the radio brightness temperature with an increase of humidity at wavelengths 3.4 and 8.5 cm during the measurements above cultural landscape [5].

It should be noted that all works enumerated above are dedicated in essence to the qualitative investigation of the dependence of radio brightness temperature from the humidity of soil. The authors of these works are not proposed the determination of quantitative communication/connections between the radiation field and moisture or any procedures of the quantitative determination of moisture content. However, recently appeared a series of the works in which are made the attempts to theoretically or experimentally solve the inverse problem of determining the physical parameters of soil in the field of its thermal emission/radiation.

In works [11, 12], is theoretically obtained system of equations, which relate the physical parameters of the surface layer of soil with the radio brightness temperature of its emission/radiation. Solution to these equations makes it possible to determine the value of humidity, gradient of temperature and other parameters of soil by measurement data of radio brightness temperature at several wavelengths of microwave range. Is proposed the differential procedure of the measurement of the components of the radio brightness temperature, sensitive to changes sub-surface parameters of soil.

Work [4] is among of first experimental studies into which is solved the reverse/inverse problem of the determination of moisture content from the data of radiometric measurements. The use of results of the ground-based measurements of radio emission at wavelength 10 cm made it possible to obtain the satisfactory quantitative conformity of the values of humidity, determined by radiometric method with the use of a calculated dependence of the coefficient of polarization on humidity, and these direct measurements.

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It should be noted; that this procedure of the solution to the inverse problem in question can be used only under conditions of the stationary controlled/inspected experiment, which assumes knowledge of the type of soil and its uniformity within the limits of effectively radiation layer.

The problem of the determination of moisture content under natural conditions for the data of radiometric measurements becomes complicated another dependence of radic emission on the temperature of the medium, and also of state and degree of the surface roughness. The roughness of the surface, the presence of coverings mask the dependence of radiometric temperature from humidity [28]. In experimental work [37] is reveal/detected an increase in the radio brightness temperature of the vertically polarized radiation at wavelength 2.2 cm with an increase of roughness, that under conditions of uncontrollable experiment could be interpreted as fall in the humidity of soil.

Effective radiation layer in microwave range depending on wavelength has an extent from several centimeters to meters [22-24]. This circumstance makes it possible to assign the missions of the sounding of the sub-surface properties of the medium, estimation of the airfoil/profile of temperature and humidity, since under natural conditions the vertical distribution of the latter is nonhomogeneous. It is natural that the solution of problems is possible only on the basis of the use of results of the spectral measurements of radio brightness temperature [4, 11, 22, 23, 31].

Is known at present only one experimental work [33], in which is undertaken the attempt to rate/estimate the distribution of a quantity of water in soil according to depth according to measurement data of radio brightness temperature at four wavelengths - 0.81, 2.2, 6.0 and 21.4 cm. By the authors [33] is noted a good agreement of these radiometric and direct measurements of humidity. However, as were indicated authors themselves, the procedure of experimental studies in some measure "was intuitive", on he has theoretical substantiation. Furthermore, the analysis of the given in this work results of restoring the airfoil/profile of humidity shows that the best fit with data of direct measurements is reached with the constant or insignificantly changing in depth humidity. In the same cases when humidity is variable, i.e., when the restoration/reduction of its vertical distribution is most interesting, they are observed considerable disagreements.

As can be seen from survey/coverage of the literature, dedicated to the problem of the determination of moisture content from radiometric observations, this problem is complex and requires further study. From the viewpoint of theoretical studies of the problem of serious attention, deserves the composite formulation of the problem. at the composite formulation of the problem of a variation in the radio brightness temperature δT_s they are determined by changes in all variable parameters of equation (5):

$$\delta T_s = A_\varepsilon \delta\varepsilon(w_0) + A_T \delta T + A_w \delta w. \quad (7)$$

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To evaluate the values of variations and effect of the unknown parameters of the physical state of soil you obtained the analytical expression of the radio brightness temperature of the layer of soil during a linear with depth change in the temperature and humidity (with the output of temperature to constant value at certain depth)

$$T_s = \varepsilon\left\{T_0 + \frac{\overline{dT}}{dz}\exp\left(\frac{\alpha_0}{2a}\right)^2\left[\frac{\alpha_1}{a}\Phi\left(\frac{1}{2},\frac{3}{2}-\frac{\alpha_1^2}{2a}\right) - \frac{\alpha_0}{a}\Phi\left(\frac{1}{2},\frac{3}{2},-\frac{\alpha_0^2}{2a}\right)\right]\right\}, \quad (8)$$

where T_0 is soil surface temperature which can be determined by the data of infrared measurements; $\overline{dT}/dz$ is an average/mean gradient of the temperature in soil, α_0 and α_1 - the coefficients of the absorption of soil of surface and at that depth beginning with which temperature of soil it is possible to consider constant; a - the gradient of the absorption coefficient; Φ (1/2, 3/2, x) is the degenerate hypergeometric function.

The analysis of this expression shows that the possibilities of restoring the characteristics of humidity depend on the degree of the nonisothermicity of temperature profile. It is obvious that in the case of isothermy is possible only the determination of the moisture content of near-surface layer, which determines the emissivity of soil [4].

Numerical experiment for a series of the real airfoil/profiles of temperature and humidity confirmed the data of model calculations and made it possible to draw the conclusion that the radio brightness temperature of soil most strongly depends on the temperature of surface and emissivity of the soil which in turn, is determined by the humidity of near-surface layer. So, variations in the radio brightness temperature due to humidity change from 3 to 8o/o reach 30-40° depending on wavelength, while the contrasts of radio brightness temperature as a result of a change in the deep airfoil/profile of humidity or temperature of the soil by an order of value are less.

For research on the dependence of the emissivity of the soil on humidity, was developed the procedure of the laboratory measurements of the emissivity which makes it possible to measure the radiation coefficients of different surfaces under strictly controlled/inspected conditions [14]. Under laboratory conditions were made the measurements of the radiation coefficients of the specimen/samples of the soils whose results were compared with calculations.

Figures 3 depicts calculated curves of the emissivity of sand and clay depending on humidity at wavelength 3.2 cm. By points are noted the results of measurements for sand at the same wavelength. As can be seen from figure, the emissivity of sand is the strongly changing characteristic. With an increase in the humidity from 3 to 15o/o, the emissivity decreases from 0.93 to 0.65. As is known, the value of the complete moisture capacity of sand-podzolic soils is approximately 20-25o/o, emissivity in this case at wavelength 3.2 cm proves to be equal to 0.61. Thus, and experiment, and calculation they indicate the considerable dependence of the emission/radiation of sand on its humidity: contrasts of radio brightness temperatures because of a change in the emissivity compose several dozen degrees.

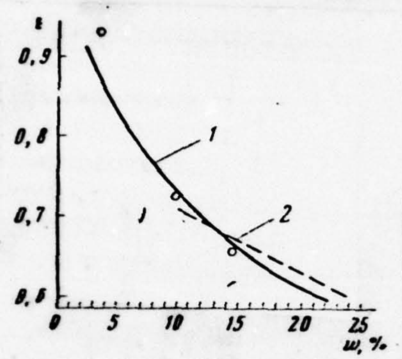

Fig. 3. Dependence of emissivity on humidity at wavelength 3.2 cm 1 - sand; 2 - clay (points are experimental values).

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For research on the possibilities of the remote indication of the characteristics of surface layer, were made the investigations of the emitting properties of different real coverings (table) in the range of wavelengths 0.8-3.2 cm. Data of this table are acquired by means of the averaging of the large number of uniform measurements, which showed that the emissivity of the investigated specimen/samples changes sufficiently considerably. For wet and dry sand is investigated the dependence of their emitting ability on wavelength and in this case it is reveal/detected that with an increase in the latter the reflection increases. The effect of humidity on all wavelengths is equal: the emissivity of the underlying surface decreases with an increase in the liquid-water content.

Thus, the theoretical and experimental studies of the field of the radiothermal emission/radiation of system the Earth - the atmosphere, successful experiment in radiothermal measurements from ISZ "Kosmos-243" show the prospect of the methods of IR radar for the remote indication of the moisture supplies of atmosphere and upper layer of soil.

(1) Вид поверхности	(2) Краткое описание	(3) Длина волны, *см*	(4) Излучательная способность
(5) Песок	(6) Речной, средней крупности; поверхность ровная, толщина слоя 25 *см*, сухой	1,6 0,8	0,933 0,939
»	(7) Речной, мокрый, поверхность ровная, толщина слоя 25 *см*	3,2 1,6	0,749 0,769
»	(8) Речной, влажностью:		
	w = 3,4%	3,2	0,927
	w = 10%	3,2	0,703
	w = 14,5%	3,2	0,655
(9) Травяной покров	(10) Высота травы 15—20 *см*, толщина слоя почвы 20 *см*, сухой	3,2 1,6	0,935 0,961
(11) То же	(12) Мокрый, высота травы 15—20 *см*, толщина слоя почвы 20 *см*	3,2	0,890

Key: (1). the type of surface. (2). Short description. (3). Wavelength, cm (4). Emissivity. (5). Sand. (6). River, average/mean size; surface even, thickness of the layer 25 cm, dry. (7). River, wet, surface even, thickness of the layer 25 cm. (8). River, by humidity. (9). The vegetation. (10). Height/altitude of grass 15-20 cm, the thickness of the layer of soil 20 cm, dry. (11). The same. (12). Wet, the height/altitude of grass 15-20 cm, the thickness of the layer of soil 20 cm.

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