THE STATISTIC CHARACTERISTICS OF THE CENTRAL ASIA UPPERMOST GROUND SURFACE IMPEDANCE IN THE VLF/MF RADIOWAVES RANGES

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The main parameter characterizing the electric properties of Earth is the surface impedance Z_n taking into account the influence of the uppermost ground upon the electromagnetic field in problems of radiowave propagation and antennas. The normalized surface impedance δ is the relation $E_\tau/H_\tau Z_0$, where E_τ, H_τ are the tangential components of the electric and magnetic fields at the "air-earth" interface, Z_0 is the characteristic impedance of vacuum. There are a few data in literature concerning the real values of the module $|\delta|$ and phase φ_δ of the surface impedance as well as the effective resistivity $\underset{\sim}{\rho}$ of the earth's crust in the VLF/MF radiowaves ranges. The research described in the report being started there were no data concerning the uppermost ground characteristics of central regions of Asia necessary for the prediction of the VLF/MF radiowaves propagation. At the same time the geological and climatic conditions of these regions of Asia sharply differ from those of Europe and North America, where the systematic studies were mainly carried out. The regions of our reseach are landscapes typical of middle latitudes of Asia: mountain and forest terrain, forest-steppes and steppes, semi-deserts and deserts.

The aim of the report is to present the statistical characteristics of the surface impedance δ and effective resistivity $\underset{\sim}{\rho}$ of the uppermost ground main types of Transbaikalia and Mongolia in the VLF/MF ranges. The initial data for statistic calculations were obtained as a result of the many years ground and distant (from the plane's board) measurements of the earth electric properties. The apparatus and definition methods of the surface impedance δ and effective resistivity $\underset{\sim}{\rho}$ were described in details in our works /1,2/. The effective resistivity of the conducting heterogeneous medium $\underset{\sim}{\rho}$ is determined by the relation : $\underset{\sim}{\rho}=60\lambda|\delta|^2/[-\sin(2\varphi_\delta)]$, where λ is the wavelength. Under the distant sounding from the plane's board $\underset{\sim}{\rho}$ is defined according to the value of the imaginary part of the surface impedance $\mathcal{I}m\delta$. Over the homogeneous conducting halfspace $\mathcal{I}m\delta=Re\delta$ and $\underset{\sim}{\rho}$ is calculated according to the formula $\underset{\sim}{\rho}=120\lambda(\mathcal{I}m\delta)^2$, supposing $\varphi_\delta=-45^\circ$. The results of measurements φ_δ in the VLF range show that the most probable values φ_δ are in the range $(-30^\circ \div -60^\circ)$ and methodic error of the $\underset{\sim}{\rho}$ definition is not great.

THE SURFACE IMPEDANCE IN THE VLF/MF RANGES

The histograms of the module $|\delta|$ and phase φ_δ distributions of the surface impedance at the frequencies of 236 and 560 kHz obtained for the uppermost ground of Transbaikalia are presented in Fig.1. On the whole $|\delta|$ and φ_δ are varying in the wide range and witness the complicated enough space geoelectric structure reflecting geological, natural and climatic conditions of the region. The considerable differentiation of the surface impedance for different types of the uppermost ground constituted by the sedimentary, metamorfic and igneous rocks is established.For substantiation of this point of view we consider the surface impedance of granitoids and metamorphic rocks relating to crystal rocks and constituting the large mountain massif of Transbaikalia. The results of the statistic treatment δ in the VLF radiowave range illustrating the difference of their electric properties are given in Table 1. The average values $|\delta|$ of granitoids are higher from 2,5 to 3 times than those of metamorphic rocks.

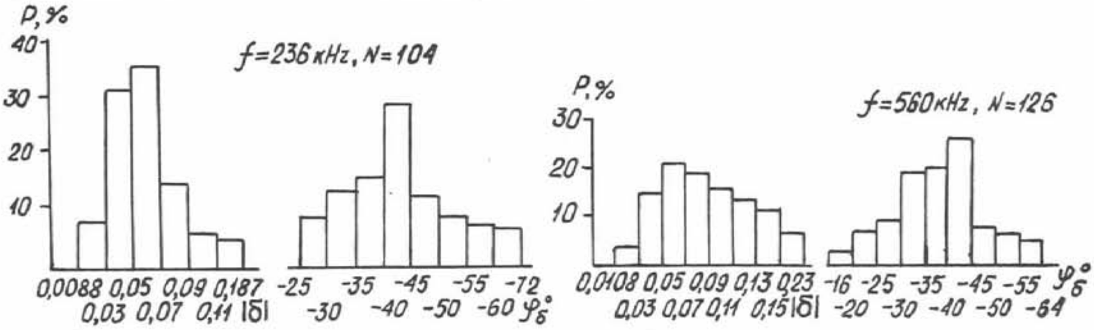

Fig.1. The histograms of the module distribution $|\delta|$ and the surface impedance phase φ_δ of Transbaikalia.

Table 1

f , kHz	granitoids $\frac{|\delta|}{\varphi_\delta^\circ}$	metamorphic rocks $\frac{|\delta|}{\varphi_\delta^\circ}$
15,1	0.063 ± 0.031 / -37 ± 9	0.023 ± 0.008 / -42 ± 11
22,3	0.072 ± 0.037 / -38 ± 9	0.028 ± 0.008 / -43 ± 8
50	0.116 ± 0.048 / -32 ± 14	0.039 ± 0.014 / -37 ± 10

The $|\delta|$ and φ_δ histograms for granitoids at the frequencies of 22,3 and 50 kHz are given in Fig.2. The $|\delta|$ histograms do not have strongly expressed bimodal distributions characteristic of monolithic rocks, partly overlapped by the cover of porous depositions.

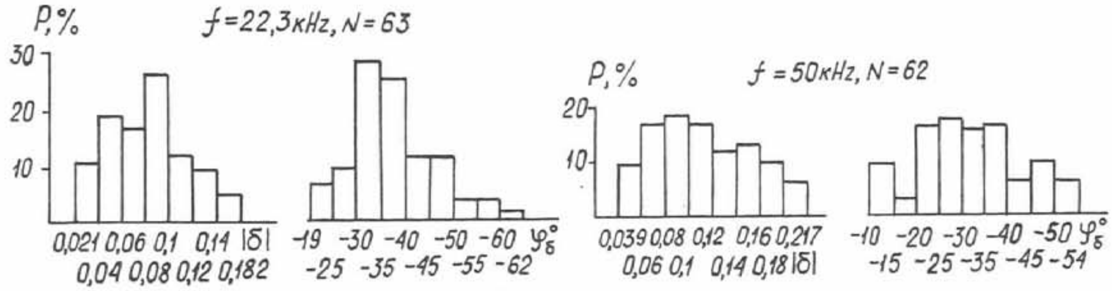

Fig.2. The histograms of the module distribution $|\delta|$ and the surface impedance phase φ_δ of granitoids.

It should be pointed out that the electric boundaries in the majority of cases are in good agreement with the geological boundaries among different types of the rocks. This important property allows to conduct the geoelectric prediction of the surface impedance according to geological maps.

We compare the surface impedance δ of the two remoted at the distance of 1000 km regions of Asia- Transbaikalia and South Mongolia. The measurements δ in Mongolia were carried out on widely spread in the Gobi desert sand-clay depositions, aeolian sands, solonchaks and basalts. The variation ranges for the resistivity and average values $|\bar{\delta}|$ and φ_δ in South Mongolia and Transbaikalia are listed in Table 2.

Table 2

f, kHz	$\|\delta\|$			φ_δ, degree			Region
	min	max	average	min	max	average	
17,4	0,0041	0,033	0,013	-73	-35	-58	Mongolia
17,4	0,0023	0,097	0,016	-76	-24	-54	Transbaikalia
50	0,013	0,054	0,029	-74	-39	-55	Mongolia
50	0,009	0,11	0,022	-63	-33	-46	Transbaikalia
227	0,013	0,186	0,059	-73	-17	-43	Mongolia
236	0,009	0,187	0,059	-72	-22	-41	Transbaikalia

The range of $|\delta|$ and φ_δ variations in the south of Mongolia is more narrow than in Transbaikalia, it is likely to be accounted for by the lesser number of $|\delta|$ and φ_δ definitions in comparison with Transbaikalia. The average estimations of $|\bar{\delta}|$ and φ_δ in both regions at the frequencies under consideration are close enough to each other. We note that in the two remoted from each other regions of the research the phase average values of the surface impedance $\bar{\varphi}_\delta$ in the VLF range are in strongly inductive region of the impedances $\bar{\varphi}_\delta = (-54^\circ \div -58^\circ)$. On the basis of the data in Table 2 we can make conclusions that the electric characteristics of the uppermost ground of the regions involved in the VLF/MF ranges are approximately identical. As a whole the $|\delta|$ variation range given in Table 2 for the involved regions of central Asia cover mainly the $|\delta|$ and φ_δ variations range of different types of the uppermost ground including both the high-conductive solonchaks and the low-conductive crystal rocks.

THE EFFECTIVE RESISTIVITY IN THE VLF RANGE

The method of the depth distant geoelectric sounding from the aircraft's board used by us permits efficiently to compile maps $\rho_\sim$ of large territories difficult of access. The layer of skin depth $h_s = 503\sqrt{\rho_\sim / f}$ of the nearsurface part of the earth's crust under the sounding varies in the wide ranges and under $\rho_\sim$=100-20000 Omm at the frequency of 17,4 kHz is 38-540 m. The $\rho_\sim$ measurement was carried out on the flight lines up to 140-180 km length /2/. In order to obtain statistical estimations of the homogeneous in geological relation region (a sort of uppermost ground) the values obtained were combined in variation series and in accordance with them the $\rho_\sim$ distribution histograms were drawn up and the distribution factors $\bar{\rho}_\sim$, $\rho_{a.g.}$, σ_ρ, $\sigma_{lg\rho}$ were calculated. In general a very wide range of variations $\rho_\sim$ from 20-100 Omm up to 15000-30000 Omm is observed in all regions. For the mountain regions consisting of crystal rocks the average values of $\rho_\sim$ are from 2000 to 6000 Omm and higher while for the hollows consisting of sedimentary rocks the average values of $\rho_\sim$ are usually lower than 500-700 Omm. The results of the $\rho_\sim$ statistical treatment of the rock complexes widely spread in the south of Siberia are given in Table 3.

The $\rho_\sim$ histograms of the region uppermost ground main types have the form of the positive assymetrical distributions abrupt from the left side and flat from the right one. The $\rho_\sim$ histograms of cambrian crystal rocks of the northern part of Aldan plateau and proterozoic metamorphic rocks of Vitim plateau presented in Fig.3 can serve as typical examples. The $\rho_\sim$ distribution corresponds to the lognormal law for the rock complexes considered in Table 3 and Fig.3.

Table 3

Uppermost ground types	f, kHz	N	$\bar{\rho}_{\sim}/\rho_{a.g}^{*}$, Omm	$\sigma_{\rho}/\sigma_{lg\rho}^{*}$	ρ_{max}/ρ_{min}, Omm
Paleozoic granitoids	15,1	185	2400 / 1700	1900 / 0,41	10600 / 120
Archean granitoids	17,4	1544	3600 / 2500	3500 / 0,42	31700 / 160
Proterozoic granitoids	17,4	325	6700 / 4500	6000 / 0,51	30700 / 160
Proterozoic metamorphic rocks	17,4	93	1600 / 1200	800 / 0,54	3600 / 10
Jurassic conglomerates	22,3	113	340 / 270	210 / 0,35	1350 / 16
Sand-clay depositions	22,3	122	280 / 220	240 / 0,32	840 / 25

* $\bar{\rho}_{\sim}$, ρ_{ag} are the average arithmetical and average geometrical values $\rho_{\sim}$; σ_{ρ}, $\sigma_{lg\rho}$ are the standard deviations ρ and $lg\rho$.

For granitoids the increase of the $\rho_{\sim}$ average values from 1700-2400 Omm to 4500-10900 Omm was marked with the increase of the research region latitude and the degree of the relief complexity. The $\rho_{\sim}$ average values of sedimentary rocks also depend on the latitude.

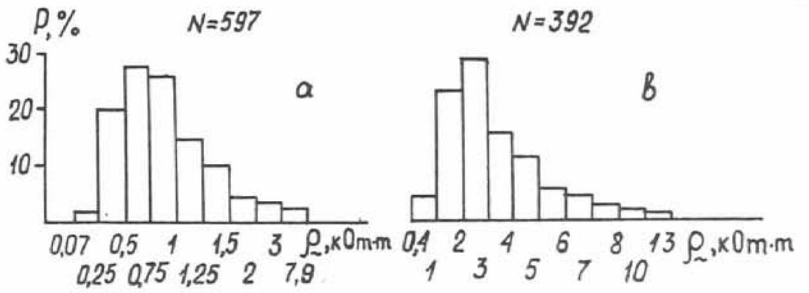

Fig.3. The histograms of the effective resistivity $\rho_{\sim}$ distribution of the crystal (a) and metamorphic (b) rocks.

The comparison of the $\rho_{\sim}$ average values of the south of Siberia with Morgan's data /3/ shows that the excessive predicted values $\rho_{\sim}$ are presented on the map /3/, for Transbaikalia being 1,5 times higher and for Aldan plateau, from 2 to 3 times higher. The results given in the report may be useful for the field attenuation function calculations on the paths of the radiowave propagation in similar natural conditions.

References

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