Electrophysical characteristics of water of the rivers of Siberia and Altai

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ABSTRACT

The results of measurements of the complex permittivity at the range of 100 MHz - 40 GHz and the conductivity of the water out of the reservoirs of Tomsk and Kemerovo regions and the Altai Territory are presented in the article. The method of the open-end-coaxial was applied. The conductivity was measured with LCR-meter at a frequency of 100 kHz. All the measurements were performed at temperatures of 10 ° C and 23 ° C. The samples are varied significantly in the values of conductivity, which is related to the geographical sampling place. Differences in permittivity values are greater at the low temperature and low frequencies and at the same time they are also significant at the high temperature and at high frequencies. The results of this study in order to improve the reliability of the analysis of the pollution degree and water salt content of natural water reservoirs should be taken into account the measurement made at wide frequency range.

Permittivity of water, natural water sources, microwave remote sensing of the Earth, specific conductivity.

1. INTRODUCTION

The problem of ecological state of natural water sources is becoming more and more urgent. It is caused by the increasing demands of people for fresh water, the growing number of technological disasters and accidents, as well as unauthorized discharge of waste processing cycles and volley emissions wastewater. Currently, the problem of tracking such events is being solved "manually" at places with convenient access such as near the roads and settlements, with the widely use of standard low-frequency or DC conductivity sensors[1, 2]. Moreover, the monitoring of the seasonal changes of conductivity and permittivity in the natural water sources are of particular interest for the researchers. Recent studies have revealed that the specific conductivity of water that was formed as a result of ice melting and precipitations (rain, snow, etc), at high latitudes, differs from that of water resulting from permafrost melting. This can be used to monitor climate change. A promising direction is the appliance of high-frequency sensors that operate at frequencies used by satellites. The problem of determining salt-affected areas can be solved by the method based on the results of high-frequency conductivity measurements of water in small rivers. In addition, radiophysics research methods based on the study of the microwave spectra of the complex permittivity of polar liquids, have a number of advantages over other tracer methods used for remote monitoring of water properties changing. Microwave range of the spectrum of the dielectric constant and, in particular, the region of anomalous dispersion is most sensitive to changes of the content and the structure of water and water solutions[3, 4].

The Center of Excellence program "BioClimLand" at Tomsk State University carries out the study of the surface waters of the subarctic region and makes monitoring the conductivity of the rivers and streams of Tomsk, Novosibirsk, Kemerovo regions, the Altai Territory and the Altai Republic. The laboratory studies of water from natural water sources over a wide frequency range allows determining the possibility of using a high-frequency method to solve the above problems, to estimate shelf life of samples, and to perform the temperature study, which is difficult to carry out in real-world conditions.

2. MATERIALS AND METHODS

Study subjects were samples of water from a number of reservoirs Tomsk and Kemerovo regions and the Altai Territory. The conductivity of the water samples was measured using the LCR-meter E7-8 at 100 kHz. Measuring cell is a glass tube with the brass electrodes at the ends. One electrode is hermetically closes the tube at the bottom, second electrode is movable to place it on different levels. Water under investigation was poured into the tube and electrodes were connected with clamps of LCR measuring apparatus. Then the conductivity value G was found for liquid column with known length L and cross-sectional area S. Specific conductivity was calculated by formula:

$$\sigma = GL/S.$$

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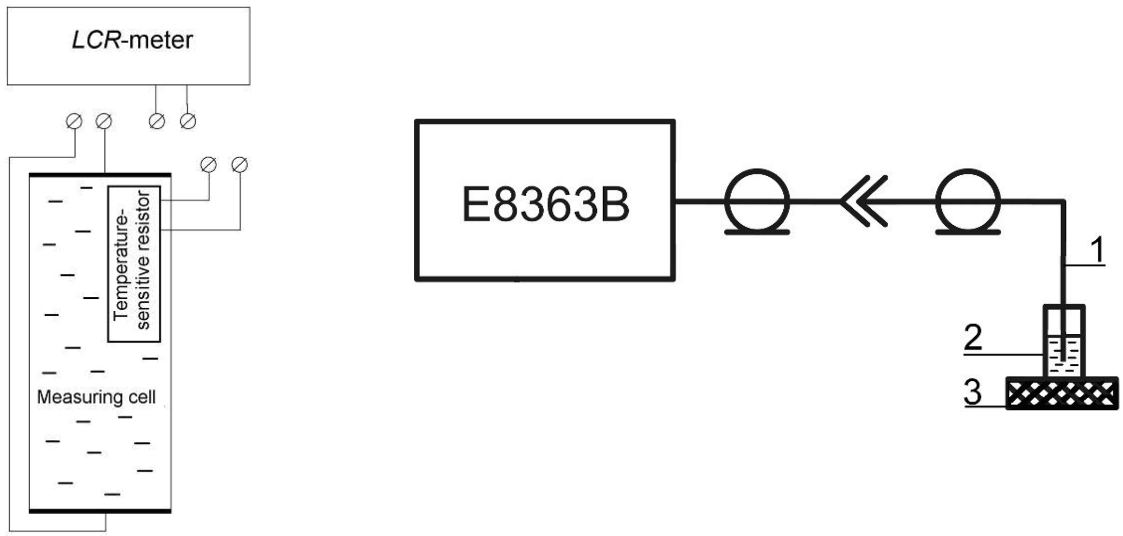
In addition, temperature-sensitive resistor was attached to the movable electrode to measure temperature of water sample. Resistance values of the temperature-sensitive resistor have been previously calibrated using a mercury thermometer with a scale division 0.1 ºC.

Complex permittivity at a range from 500 MHz to 40 GHz was measured by the open-end-coaxial probe with use of the vector analyzer Agilent Technologies PNAE8363B. Apparatus charts are shown in fig. 1.



a b

a – conductivity measuring apparatus; б – microwave apparatus: 1 – open-end-coaxial probe; 2 – cell with a sample; 3 – dielectric stand

Fig.1. Measuring apparatus charts

3. RESULTS AND DISCUSSION

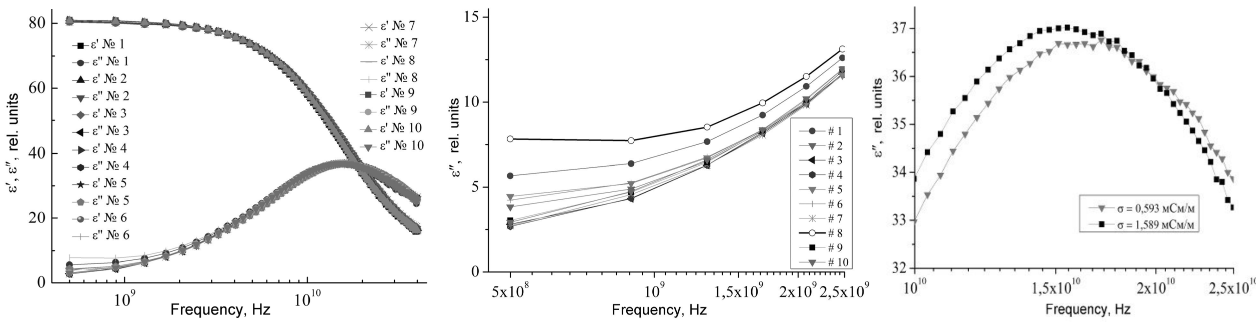
Results of specific conductivity measurements are given in Table 1.

Table 1. Specific conductivity of the samples of water reservoirs of Tomsk, Kemerovo regions and Altai territory

Water reservoirs of Tomsk region (first series of samples)			water reservoirs of Tomsk, Kemerovo regions and Altai territory (second series of samples)			
Number	Place of sampling	σ, mS/m T = 23 ºC	Number	Place of sampling	σ, mS/m T = 15 ºC	σ, mS/m T = 23 ºC
1	Tom river, Tomsk	0,191	1	Aba river	0,918	1,242
2	Shudelka river	0,389	2	Bolshaya Chernaya river	0,417	0,517
3	Ob river, Molchanovo village	0,291	3	Biya river, Biisk	0,155	0,191
4	Ob river, Leboter village	0,480	4	Katun river	0,095	0,122
5	Ob river, Krivosheino village	0,344	5	Lebyazhie lake, Proskovo village	0,593	0,718
6	Ob river, Kargasok settlement	0,420	6	Malaya Chernaya river	0,529	0,638
7	Chaya river	0,615	7	Ob river, Barnaul	0,171	0,217
8	Ob river, Chazhemto settlement	2,495	8	Tom river, Kemerovo	0,185	0,232
9	Brovka river	0,679	9	Razboinaya river	1,589	2,053
			10	Tom river, Novokuzneck	0,232	0,298

All the samples are different at specific conductivity that relates to geographic places of sampling. For example, it is well known that water from Chazhemto settlement has high mineral salts and iron concentration and its specific conductivity is also high. On the contrary, water of the Katun river is so pure that it results in small specific conductivity values. The current work does not provide with chemical analysis of samples since the indicator of impurities and pollutions is specific conductivity.

The results of complex permittivity measurements $\varepsilon = \varepsilon' - i\varepsilon''$ are given in Fig. 2 and 3. The form of full spectrum indicates a good agreement of obtained results with a well-known conception about permittivity of pure water. There is a slight difference in the real part of permittivity ε' for all the samples.



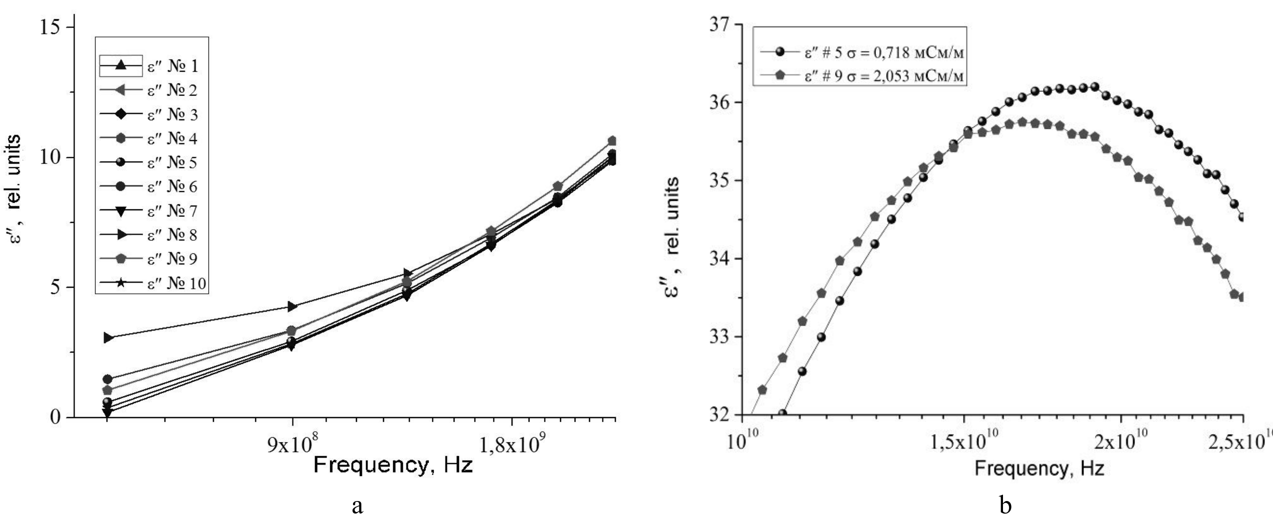
a b c

a – full spectrum, б – low frequencies, в – high frequencies

Fig. 2. Permittivity of water samples of the second series. Temperature $T = 15$ ºC

A detail analysis of the imaginary part of permittivity at low and high frequencies shows that differences for the samples with different specific conductivity are more expressed for cold water (15 ºC) at low frequencies as well as for the water at 23 ºC for high frequencies. There is the shift at the frequency of maximum of the imaginary part of permittivity and, correspondingly, the growth of relaxation time for water samples with greater specific conductivity. This fact can be explained by the appearance of additional hydrogen bonds between water molecules and molecules of impurities, which leads to mobility decrease.

When specific conductivity increases, the imaginary part of permittivity increases at low frequencies too. It is a good agreement with the theory.



a b

a – low frequencies, б – high frequencies

Fig. 3. Permittivity of water samples of the second series. Temperature $T = 23$ ºC

It is known that the spectrum of the permittivity of water is described by Debye model with a single relaxation time[5]. Relaxation time τ was determined using measured frequency dependence of the imaginary part of the permittivity from the condition $2\pi f_{max} \tau = 1$, where f_{max} is frequency of imaginary part maximum. The dependence of relaxation time of the water samples on its specific conductivity is shown in Fig .4.

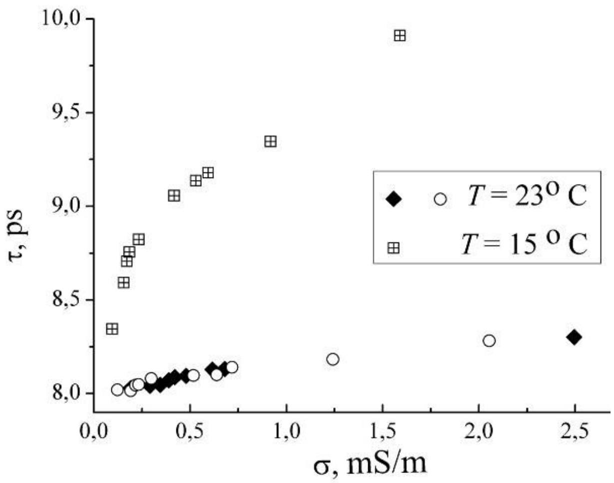


Fig. 4. Relaxation time of water samples at temperature 15 ºC and 23 ºC

Relaxation time reducing with temperature increasing is a natural consequence of growth of kinetic energy of water molecules. Also we can see the increase of relaxation time with the increment of specific conductivity. It is known that the specific conductivity of water may serve as a measure of water purity. The increase of specific conductivity indicates the presence of impurities in the water. It may be natural minerals or technogenic pollution. Water molecules form hydrogen bonding with the impurity molecules and lose their mobility. This result is the increase of the relaxation time. Moreover, the lower the temperature the stronger the dependence of the relaxation time on the specific conductivity.

Thus, we can determine the degree of mineralization and the presence of impurities of natural water sources by measuring the spectrum of water permittivity at the microwave range.

CONCLUSION

The values of specific conductivity depend on geographic sampling places and indicate the presence of water impurities. The differences in permittivity values are greater at the low temperature and low frequencies. They were also significant at the high temperature and high frequencies. The results of our investigations show that account should be taken of the measurements made at wide frequency range in order to improve the authenticity in the analysis of the impurities.

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