Anisotropy of electrical properties of rocks at THz frequency range

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***Abstract* — Considered possibility of application of terahertz waves at geological researches. Investigations of anisotropy of electrical properties of rocks are conducted. Coefficients of transmission, reflection and permittivity for plane samples of rocks are obtained.**

I. INTRODUCTION

Now the short-wave part of gigahertz and the terahertz waverange are intensively developed and investigated. A new element base is appeared, properties of materials are investigated. All this allows to hope that in the near future the devices and the methods using these frequencies will go beyond research laboratories and will find the application in the industry [1]. Application in the field of radiowave nondestructive contactless control of parameters of materials can be one of such applications. Using of more short waves can significantly increase locality and resolution of supervising devices.

In geology to determine the lamination and porosity of rocks the optical refractometers and x-ray methods of diagnostics are traditionally applied, such as electronic microscopy. They are very labor-consuming and need in precise preparing of samples. By means of these methods the anisotropy of material is investigated with which the definite parameters of rock are connected [2].

II. RESULTS

For research 9 samples of the rocks in the form of plane-parallel polished plates 3.1 – 7.2 mm thick were selected. As experimental equipment spectrometer based on Mach-Zehnder interferometer operating in the frequency range 0.034 - 1.2 THz was used. Geometry of experimental equipment for measurement of transmission and reflection coefficients is shown on Figure 1.

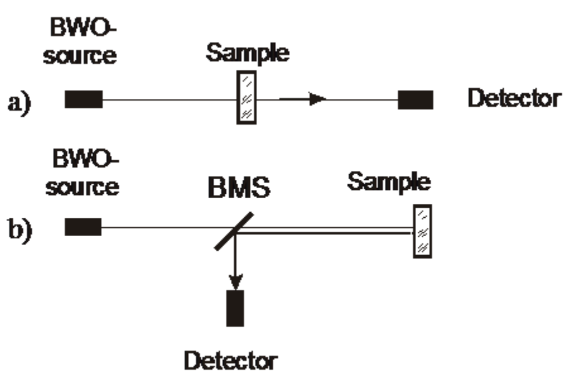

Fig.1. Schematic representation of main measurement configurations of the quasioptical millimeter-submillimeter Spectrometer. Geometry (a) for measurement of transmission coefficient, geometry (b) for measurement of the reflection coefficient. BMS is a half-transparent beamsplitter.

Backward-wave oscillator with water cooling was used as a source of monochromatic polarized electromagnetic wave. Focusing of quasi-optical beam carried out with teflon lenses. Amplitude modulation was set by chopper. As a detector of terahertz radiation used optoacoustic converter (Golay cell). The polarization of the radiation was set by grid splitter. Automated sample holder with using of the analog-to-digital converter and a portable computer allows control the measurement of frequency dependences of transmission and reflection coefficients with a specified accuracy (maximum 1/3 degree). Holder of investigated samples was calibrated relative to optical axis of the spectrometer in order to avoid the influence of unbalance position.

On the Figure 2 presents appearance and polar orientation of flat rock sample № 3 (thickness 4.36 mm) relative to the polarization of the incident electromagnetic wave, perpendicular to a quasi-optical beam. It is natural dielectric material, magmatic rock of basic composition consisting of minerals olivine and plagioclase. The presence in the sample elongated longitudinal mineral inclusions in dielectric matrix of rock causes anisotropy of texture, and as a result the anisotropy of electrical properties. Average measured real part of dielectric permittivity of the sample at the location of minimum transmission coefficient was 6.45.

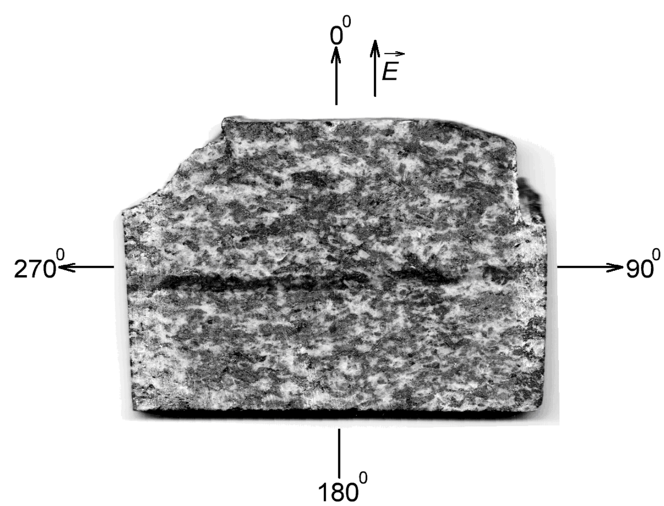

Fig.2. Orientation of rock sample № 3 relative to the polarization of the electromagnetic wave

Figure 3 shows frequency dependence of the transmission coefficient of rock samples № 3.

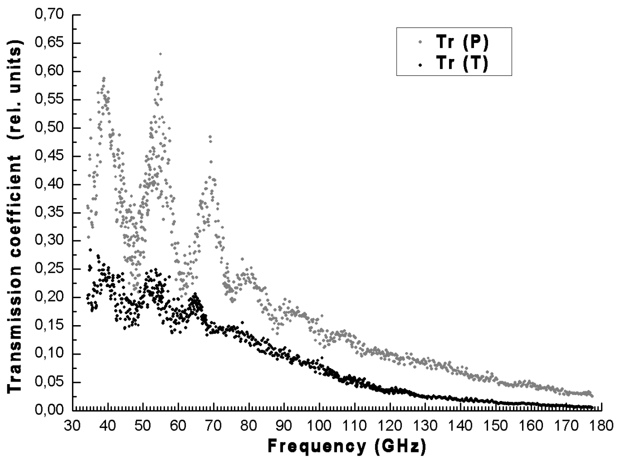

Fig.3. Frequency dependence of transmission coefficient of sample №3 of rock. Label (P) and label (T) means polarization direction parallel and perpendicular to direction of distribution of minerals in rock.

The measurement (Figure 3) showed that in the frequency range 34-75 GHz anisotropy value of the transmission coefficient for the plane-parallel layer of rock reaches 2.4. Transmittance of samples with increasing of frequency was decreased. With increasing frequency electromagnetic wave transmittance decreased to 177 GHz becomes lower than 0.05. Therefore the possibility of schemes, which are used for raying of samples, is limited by low-frequency part of the range. The coefficient of reflection is in limits 0.05 – 0.4 in all band of frequencies. Therefore schemes on reflection will give more possibilities in variation of frequency, in search of optimum values, and in using of samples with only one surface.

In the frequency range 34 – 177 GHz when the size of the mineral inclusions in the rock below wavelength is good theory in order to assess anisotropy coefficient (A) of dielectric permittivity of composite, which consist of inclusions and matrix [2]

$$A = 1 + p(\frac{\varepsilon^{\text{int}}}{\varepsilon^{ext}} - 1) \quad (1)$$

where ε^{int} and ε^{ext} - dielectric constants of inclusions and matrix respectively, p – ratio of volume of inclusions to volume of matrix.

The dependences of transmission and reflection coefficients at various orientations of samples relative to polarization of incident field were also investigated. The analyzer on an input of the receiving detector was set up on polarization of an input signal of radiation in wideband of frequencies [3].

The analysis of the obtained data and their comparison with the results received by optical methods showed correlation of angle dependence of reflection coefficient and anisotropy of permittivity of samples with their geological parameters, such as porosity, direction of distribution of minerals in rock. However this correlation has complicated character and is different in various parts of investigating frequency range. In figure 4 shows angular dependence of reflection coefficient for the flat sample of rock №6 (thickness 3.85 mm) in frequency region 640-700 GHz.

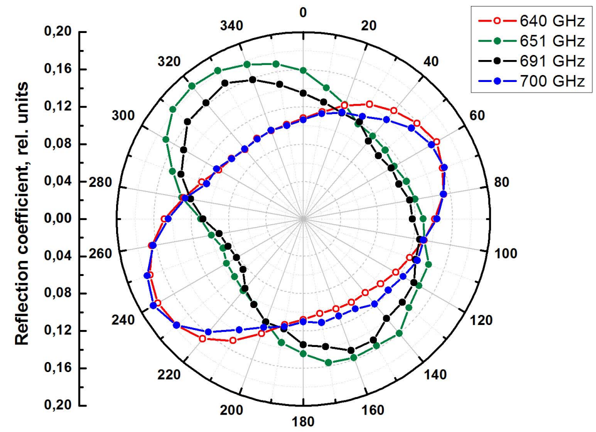

Fig. 4. Angular dependence of reflection coefficient for sample of rock №6 in frequency region 640-700 GHz.

Distinctive feature of sample №6 is small scattering inclusions of minerals dimensions smaller than the wavelength.

Rotation angular distribution diagram of the reflection coefficient at 90 degrees at different frequencies may be caused by interference of waves in the sample. In contrast to the variation of the angular diagram 90 degrees when changing the values of the permittivity of the matrix and the inclusions from $\varepsilon^{\text{int}} > \varepsilon^{ext}$ to $\varepsilon^{\text{int}} < \varepsilon^{ext}$ [2].

III. Summary

Thus, the dependence of anisotropy of electric parameters in the submillimeter waverange on geological properties of studied samples can be based on the development of nondestructive contactless radiowave control methods of natural materials with use of terahertz radiation in wideband of frequencies.

IV. ACKNOWLEDGMENT

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