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Peculiarities of dielectrometry in the shortwave and subterahertz bands

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Introduction

Measuring the real and imaginary parts of dielectric permittivity as a function of various factors (frequency, pressure, temperature, etc.) is a complex scientific and technical task. Especially it concerns the study of electro-physical parameters of biological objects in the shortwave part (EHF) and subterahertz ranges, which include water as the main component.[1]

For measuring the electrophysical parameters of substances, resonance methods are the most widespread due to the high accuracy of the obtained results. When measuring substances with large losses, the sample must occupy only a small part of the resonator volume, so as not to disrupt the working type of oscillations. Therefore, in the microwave range cylindrical resonators with oscillations of the type TE01n are the most widespread.[2] Here n is the number of half-waves stacked along the axis of the resonator. However, with the shortening of the wavelength, the geometric dimensions of the resonator decrease and losses in the metal of which it is made increase.

A tunable cylindrical resonator operating on the type of TE01n oscillations is also known. It is used to measure the dielectric permittivity of substances in the microwave range.[3] Use of tunable resonator allows using a generator, operating at a fixed frequency. This makes it possible to stabilize the frequency of the generator and, therefore, increase the accuracy of measurements. Location of the sample along the axis of the resonator, where the electric field strength is minimal, just allows to measure the electrophysical parameters of dielectrics with large losses.

When using such resonant systems in the EHF, and even more so in the terahertz range, the geometric dimensions of the cylindrical resonator, which are proportional to the operating wavelength, are reduced. At the same time with a shorter wavelength the surface resistance Rs of the metal of which the resonator is made increases, since.[4] Here is the specific conductivity of metal. If we increase the geometric dimensions, i.e. move to oversized resonators, then in the volume along with the type of vibrations TE01n will be excited other types of vibrations, for example, TM11n, which has the same phase velocity as the working type of vibrations. Therefore, it is necessary to take additional measures for spectrum selection in such resonators. And this is quite a complicated technical task. In this regard, in the EHF, and especially in the subterahertz ranges, to determine the electrophysical parameters of substances it is necessary to switch to resonance systems, which use wave propagation in free space - open resonators (OR).[5,6] The peculiarity of OR is that, in addition to high quality factor, their geometrical dimensions are several tens of wavelengths and there is a connection with the free space. This provides additional selection of the vibration spectrum.

When conducting investigations of electrophysical parameters, as a rule, flat samples are used, and the main type of oscillations TEM00q (q - longitudinal index of oscillation) is excited in the resonator. Due to the use of the hemispherical geometry of the resonator, the errors connected with the determination of the angular position of the sample are eliminated, since the latter in this case is placed on the flat mirror of the OR.[7,8] At the same time, the sample should be located in the maximum of the electric component of the standing wave field in the OR, which provides the greatest accuracy of measurements. In this case, one of the main conditions of applicability of the OR method for measuring the electrophysical parameters of substances is small power losses in the measured sample, because only in this case the OR with the sample remains a high quality resonance system, and all the advantages of this measurement method are preserved. Therefore, for diagnostics of strongly absorbing substances, for example, moisture-containing samples, its thickness should be less than the value of the skin layer.

In a number of practical cases it is necessary to investigate cylindrical samples, which are various liquids in glass or quartz tubes. However, in this case there is a technical difficulty related to the location of such a sample in the resonator volume, because during each measurement the latter should be placed in the area with the same electric field strength. The use of samples with large losses can lead to the failure of oscillation in the OR.

Thus, we can say that the most promising for studying the electrophysical parameters of substances in the EHF and subterahertz ranges is an open resonance system, proposed in the IRE NAS of Ukraine.[9,10] Such a resonant system is a composite OR, in the center of one of the mirrors is a segment of a circular waveguide. Only the TE01 wave is excited in such a waveguide, although its diameter may be several wavelengths, i.e., it is supersized. In the resonator itself, due to the section of the waveguide, the axially symmetric type of TEM*11q oscillations is excited by the "wave-eye".[11,12] Studies have shown that the section of the circular waveguide practically does not worsen the quality factor of the composite OR due to anomalously small wave losses TE01. Such an open resonant system has a unimodal resonance response in a wide frequency band. This allows operation at a fixed frequency. This is very important for the frequency stabilization of the oscillator and therefore contributes to a higher measurement accuracy. On the other hand, the location of the cylindrical sample in the area of linear change of the electromagnetic field also provides an increase in the accuracy of measurements.[13] The cylindrical sample is located along the axis of the whole composite resonator.

The above mentioned is relevant for absorbing polymer composites containing mineral moisture-containing fillers or fillers with a developed pore surface.[14,15]

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Conflicts of interest

There are no conflicts of interest.

References

1. Kuznetsov AN, Turkovsky II, Volkova IA. EHF dielectrometry of biological fluids under conditions of disturbed water exchange. *Biophys*. 2001;46(6):1122–1126.
2. Tkach VK, Stepin LD, Kazanskii VB. Resonator method for measuring dielectric permittivity and loss angle tangent of liquid dielectrics. *Radio Engineering and Electronics*. 1960;5(12):2009–2014.
3. Brandt AA. A study of dielectrics at super high frequencies. Moscow: State Publishing House of Physical and Mathematical Literature; 1963.108 p.
4. Shirman YD. Radio waveguides and volumetric resonators. Moscow: State Publishing House on Communications and Radio; 1959. 89 p.
5. Afsar MN, Button CJ. Measurement of dielectric characteristics of materials in the millimeter wave range. *Proc of the Institute of Electrical and Electronics Engineers*. 1985;73(1):143–167.
6. Afsar MN, Li X, Chi H. An automated 60 GHz open resonator system for precision dielectric measurement. *IEEE Trans Microwave Theory Tech*. 1990;38(12):1845–1852.
7. Breeden KH, Langley JB. Fabry – perot cavity for dielectric measurement. *Rev Sci Instr*. 1969;40(9):1162–1163.
8. Jones RG. Precise dielectric measurements at 35 GHz using an open microwave resonator. *Proc IEE*. 1976;123(4):285–290.
9. Kuzmichov IK, Hlybitsky GM, Melezhyk PM. Open resonator for measuring the dielectric constant of materials.
10. Kuzmichev IK, Melezhik PN, Poedinchuk AYe, An open resonator for physical studies. *International Journal of Infrared and Millimeter Waves*. 2006;27(6):857–869.
11. Kuzmichev IK, Popkov A Yu. Open resonator for measuring of electro-physical parameters of substances. Part I. Model of the resonator. *Physical bases of instrument engineering*. 2013;2(3):94–103.
12. Kuzmichev IK, Popkov AYu. Open resonator for measuring of electro-physical parameters of substances part II. experiment. *Physical bases of instrument engineering*. 2013;4(9):108–115.
13. Kuzmichev IK, Popkov AY. Resonance system for analyzing cylindrical samples in millimeter wave band. *Telecommunications and Radio Engineering*. 2012;71(14):1247–1257.
14. Glyva V, Guzii S. Design of liquid composite materials for screening electromagnetic fields. *Eastern-European Journal of Enterprise Technologies*. 2021;3(6):25–31.
15. Guzii S, Khodakovskyy O. Investigation of the rheological properties of liquid geocement composite materials for protection from electromagnetic fields. *Solid State Phenomena*. 2022;338:161–166.

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