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METHODS FOR MEASURING THE DIELECTRIC CONSTANT OF OBJECTS

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Relevance of the study. Professionals in many industries want to better understand the properties of the materials they work with, as this can help shorten design cycles, improve incoming inspection, process monitoring and quality control. Each material has a unique set of electrical parameters that depend on its dielectric properties. Accurate measuring these parameters can provide engineers with valuable information to make the best possible use of these materials in devices under development or to control manufacturing processes to ensure higher quality. Measuring the characteristics of dielectric materials can provide very important information for many technologies. For example, cable insulation loss, substrate resistance or dielectric resonator frequency are directly related to dielectric properties. New technologies in the aerospace, automotive, food, medical and agricultural industries can also benefit from the knowledge of dielectric properties. Table 1 shows the possible applications of dielectric constant data. Dielectric constant (DC) measurements are widely used in a variety of technologies. Table 1 shows examples of applications from various industries.

Table 1. Examples of applications for measuring DC of materials

Industry	Products
Electronics	Capacitors, substrates, printed circuit boards, printed antennas, ferrites, magnetic recording heads, radiation absorbers, masking materials, sensors
Defense industry	Radiation-absorbing coatings, radiation-absorbing materials, antenna fairings
Industrial materials	Ceramics and composites: IP enclosures, aerospace and automotive components, cement, coatings, bioimplants Hydrogel: disposable, absorbent nappies, soft contact lenses. Liquid crystals: displays. Rubber, semiconductors and superconductors.
Food processing and agriculture	Food storage (spoilage) research, food development for microwave chains, packaging, moisture measurement
Forestry and mining	Wood or paper moisture measurement, oil content analysis
Pharmaceutics and medicine	Drug research and production, bioimplants, human tissue measurement, biomass, chemical concentration, fermentation

Objective of the study. Analysis of methods for measuring DC, their capabilities and features.

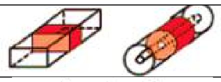
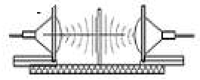
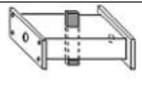
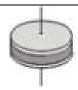
Main research materials. The choice of the most appropriate measurement method is determined by many factors, such as accuracy, convenience, shape and type of material. Table 2 shows a list of the most important factors: frequency range; expected values of ε_r and μ_r; required measurement accuracy; material properties; type of material; sample size limitations; destructive or non-destructive method; contact or non-contact method; temperature and cost.

Therefore, when choosing a method for measuring DC, it is necessary to know the possible properties of the material under study and the features of the method for measuring DC. Thus, to obtain the wood DP spectra and obtain the moisture dependence for different coniferous species, the resonance measurement technique was used. Rectangular multimode resonators of three sizes 58 × 25×480 mm^3, 35×15×450 mm^3, and 23×10×250 mm^3, covering the range of 3...12 GHz, were used as a measuring cell. The resonator was connected to the microwave path of the Agilent Technologies E8363B circuit of vector analyzer through a capacitive diaphragm. The other end of the resonator was shorted. The wood sample was placed in the hole in the middle of the wide wall of the resonator, with the wood fibres parallel to the electric field lines.

The frequency dependences of the real part of DC of wood of five species for two values of weight moisture content are shown in Fig. 1.

It can be seen that the values for conifers are relatively close to each other, in contrast to the values for birch. The dependence of the real part of DC on the weight moisture content for two birch specimens differing in the place of growth is shown in Fig. 2, a. 'Upper birch' is the name given to a tree that grew on a hill, on light loamy soils, its wood is light. The 'lowland birch' grew in a low marshy area, and its wood has a dark brown hue on the outside. This is because the soil of low-lying areas contains many mineral salts.

Table 2. Comparison of the main methods of measuring DC

Coaxial probe ε_r		Wideband, user-friendly, non-destructive. Good for high-loss materials, liquids and powdery substances
Transmission line ε_p and m_r		Broadband. Good for high-loss, solids handling materials
Free space ε_p and m_r		Wideband, non-contact. Good for sheet materials, powders and high temperatures
Volume resonator ε_r		Single frequency, accuracy. Good for low-loss materials and small samples
Parallel plates ε_r		Accuracy. Good for low frequencies and thin sheet materials
Inductance measurement μ_r		Accuracy. Good for low frequencies and thin sheet materials

These differences in the origin of trees of the same species are also evident in the value of DC. The results of the study show that the mineral composition of the moisture absorbed by the tree plays a greater role than the structure of the wood. The moisture dependence of the real part of DC for five wood species is shown in Fig. 2, b. It can be seen that the rate of increase of DC values is not the same. It increases with increasing moisture content.

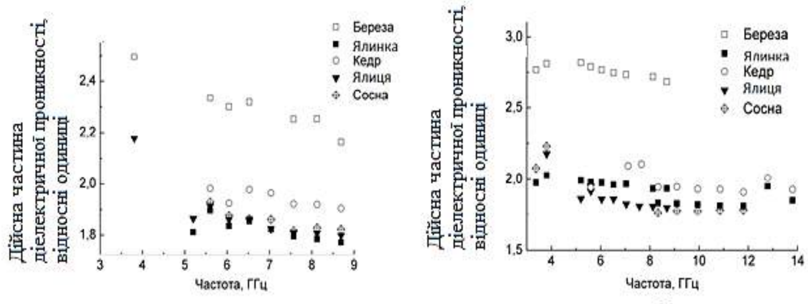


Figure 1 – Weight humidity 0.01(a); weight humidity 0.03(b)

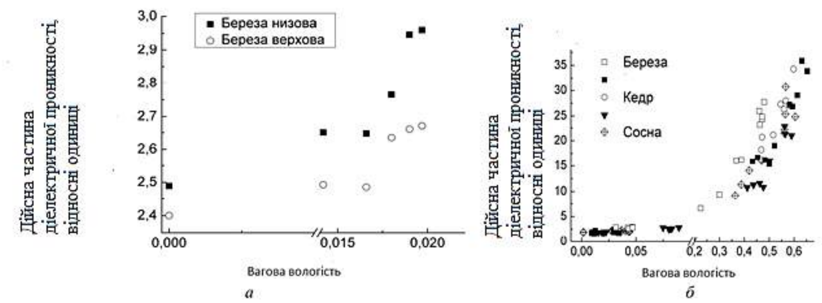


Figure 2 – Frequency 3.807 GHz (a); frequency 5.2 GHz (b)

Conclusion. Methods for measuring DC of objects are diverse, so when choosing a particular method, it is necessary to know the possible properties of the material under study and the features of the method. Thus, to measure DC, the resonator method was chosen to obtain the DP spectra of wood and obtain the moisture dependence for different coniferous species, taking into account the dielectric properties of wood and reducing the measurement error.

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