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Polarization properties in EHF range of carbon-containing compositional structures obtained by 3D printing method

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Polarization properties in EHF range of carbon-containing compositional structures obtained by 3D printing method

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Abstract. The polarization properties of carbon-containing compositional structures obtained by 3D printing method in extremely high frequency (EHF) range were investigated. Values of the complex dielectric constant of the acrylonitrile butadiene styrene (ABS) plastic and carbon-containing ABS plastic at frequency range of 115-258 GHz were obtained. The angular dependences of the transmittance of composite structures based on the dielectric matrix and ordered carbon-containing plastic structures at frequency range of 62-128 GHz were presented.

1. Introduction

With the development of technologies in various fields of activity, the demand for high-quality materials at low prices is becoming ever stronger. The advantage of creating parts by the method of layer-by-layer addition of material is the ability to produce 3D-objects modeled using an automated design system. In our days there are many materials with different electrophysical properties for additive technology allowing you to create objects with various geometrical, elecrophysical and mechanical properties. The creation of modern elements of extremely high frequencies (EHF) technique with the using of additive technologies are actuality now. The using of carbon-based additives with ABS plastic allows to produce filaments for 3D printing with significant conductivity [1-7]. Carbon composite materials contain carbon reinforcement in the form of continuous filaments, discrete fibers, fabrics with flat and bulk weaving. The advantage of such structures is low density, high heat capacity, high strength and rigidity, resistance to thermal shock, erosion and radiation, low friction coefficient, high corrosion resistance, a wide range of electrical properties (from conductors to semiconductors). It is of interest to apply the additive technology to research the polarization properties of carbon-containing composite structures in the EHF range.

2. Experimental work

For the experiment, two samples based on ABS plastic and carbon-containing ABS plastic were produced by 3D printing using fused deposition modeling (FDM) technology. The pre-measured frequency dependence of the complex dielectric constant of these materials is shown in Figures 1-2.

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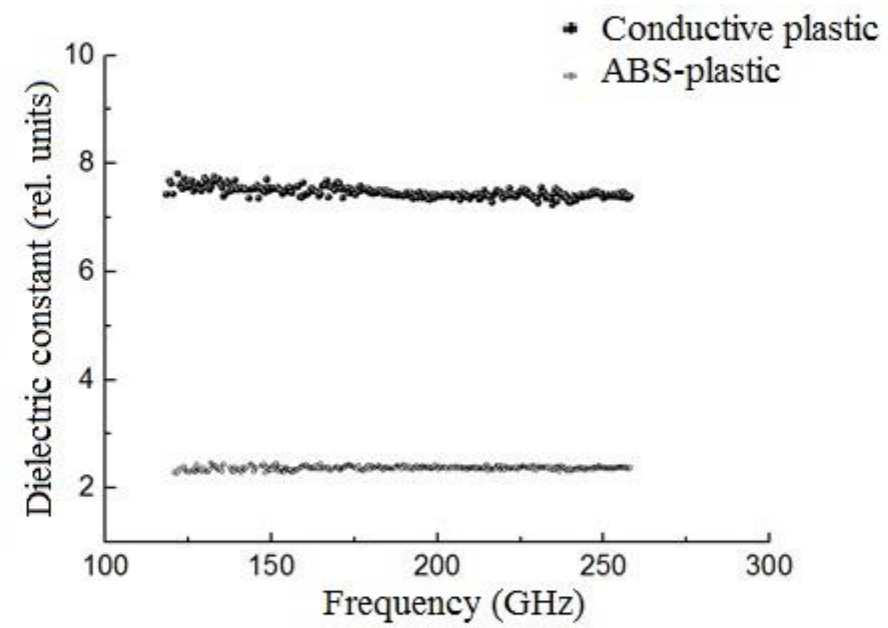

Figure 1. Dependence of the real part of the dielectric constant of ABS plastic and conductive plastic (ABS with carbon) at the EHF frequency range.

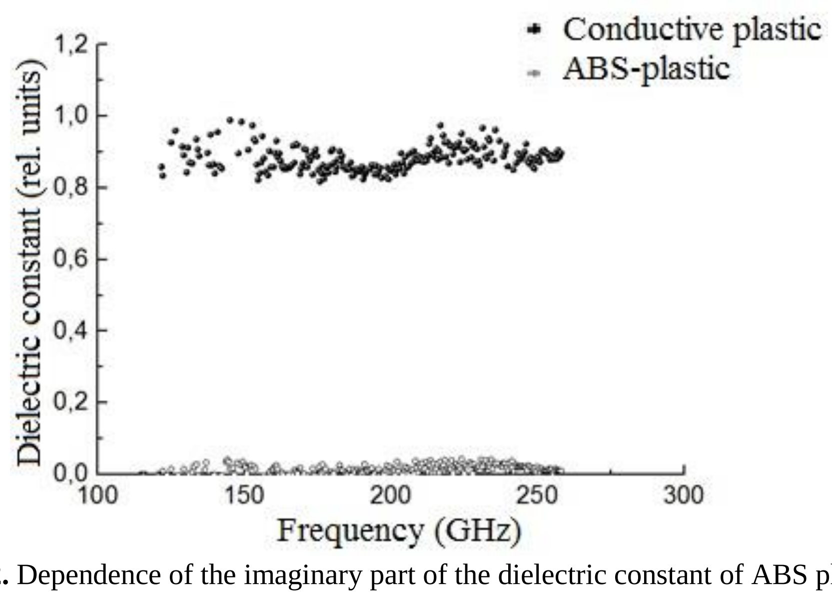

Figure 2. Dependence of the imaginary part of the dielectric constant of ABS plastic and conductive plastic (ABS with carbon) at the EHF frequency range.

Based on the graphs presented in Figure 1, the real part of the dielectric constant of the conductive plastic in the EHF range is approximately equal to 7.8. At the same time, the imaginary part is 0.9, and the specific conductivity of the plastic with a graphite content was 0.0125-0.02 μS/m with a filament diameter of 1.75 mm. In turn, the real part of the dielectric constant of the ABS plastic is 2.2, imaginary part of the dielectric constant is 0.01 - 0.03.

To test the polarization properties, two test polarizers with periods of 2 mm and 3 mm were manufactured. The samples consisted of a dielectric substrate with overlaid strips of carbon-containing plastic. The image and structure of these composites are shown in Figure 3.

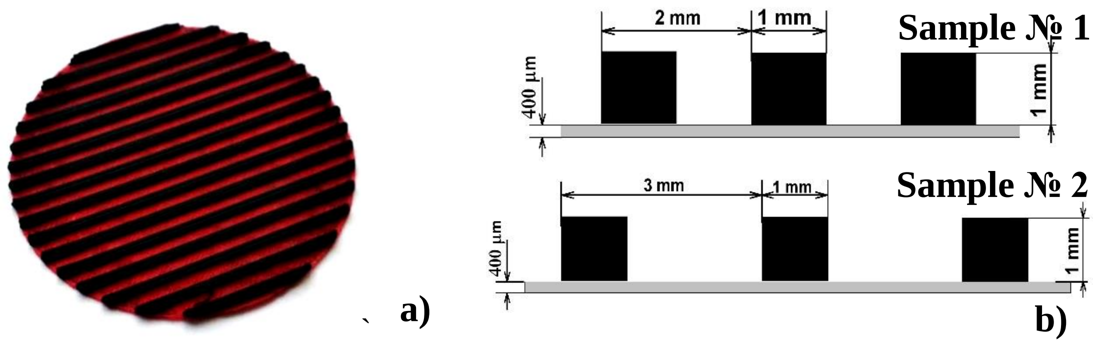

Figure 3. Image of the 3D printed material sample (a). Geometrical parameters of conductive strips (black color) in compositional material (b).

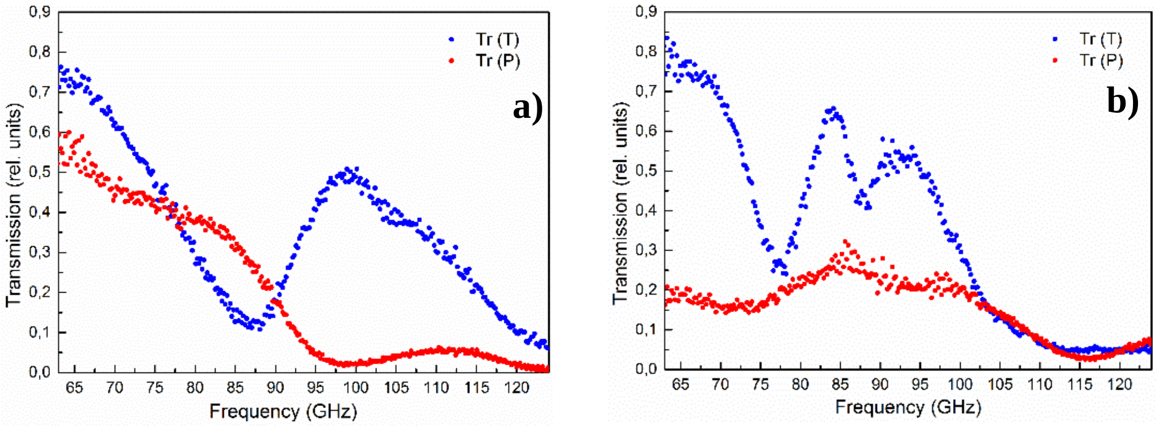

Figure 4. Measured frequency dependence of transmission coefficient of 3D printed composite materials: a) sample № 1; b) sample № 2. Label (P) and label (T) means polarization direction parallel and transverse to the direction of the conductive strips.

At Figure 4 measured frequency dependence of transmission coefficient of 3D printed composite materials (samples №1-2) at parallel and transverse polarizations is shown. Measurements of the angular dependences of the transmission coefficient of the studied material samples in the frequency range of 62-128 GHz (Figure 5) were made by using an STD-21 terahertz spectrometer modified with a precision angular positioning system.

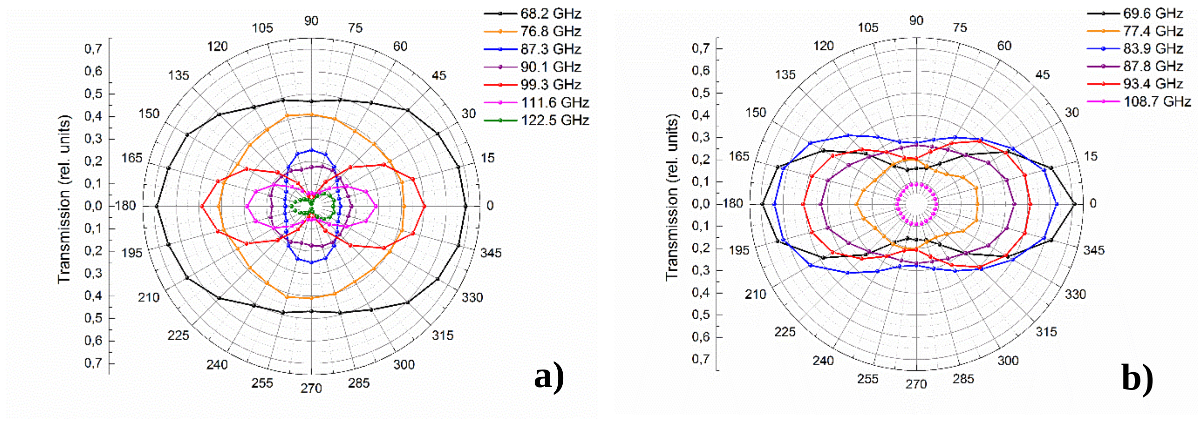

Figure 5. Angular dependence of the transmission coefficient of compositional structure: a) sample № 1; b) sample № 2.

At the frequency ranges 68-76.8 GHz and 90.1-128 GHz transmission coefficient of sample №1 at transverse polarization is greater than at parallel polarization (Figure 4a), at the frequency range of 76.8-90.1 GHz the value of the transmission coefficient with parallel polarization is higher than the transverse. Two frequencies (77 GHz and 87 GHz) of the minimum transmission coefficient of the sample №2 were found (Figure 4b).

Conclusion

One can see from the graphs at Figure 5 the maximum value of the transmission coefficient reaches at position of sample of 0 degrees when the orientation of the conducting strips is orthogonal to the vector of the electric field of the incident wave. For sample №1 there is found a change in the direction of the maximum of the angular dependence of the transmission coefficient by 90 degrees at frequency 87.3 GHz (Figure 5a). This property is due to the fact that at this frequency for a periodic structure the resonance condition is fulfilled with the absorption of an electromagnetic wave with transverse polarization when the orientation of the conductive strips is orthogonal to the vector of the electric field strength of the incident wave. These composite materials can be used to create mechanically controlled EHF attenuators, as well as in the development of frequency-selective elements.

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