INVESTIGATION OF COMPOSITE MATERIALS WITH CONTROLLABLE ELECTRODYNAMIC PROPERTIES

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ABSTRACT

The method of electrodynamic analysis of single conducting fibres having various configuration is offered. Numerical experiments on studying the influence of wire elements geometry on properties of a scattered field are carried out and the possibility to control these properties is shown.

In recent time much attention of researchers is given to creation of various types of artificial composite materials having gyrotropic and anisotropic properties in microwave range. Such materials allow to project various waveguide microwave devices that can transform polarization of electromagnetic waves. Generally composite materials are a collection of particles of arbitrary geometry and internal structure embedded in a dielectric. Thus the main task is to define the effective material parameters of artificial medium knowing the sizes of separate inclusions and the nature of particle distribution in a dielectric.

The composite materials on the basis of conductive fibres are of interest for creating media with controllable properties. In this work the method for analyzing the properties of single fibre scattering is offered. This method can be used for later reconstruction of material parameters of a composite material. The analysis is based on the numerical solution of Poklington's integral equations for current distribution in a thing conductor (the so-called thin-wire approximation) by the collocation method with step basis function application [1]. Knowing the current makes it possible to define the field parameters scattered by the particle.

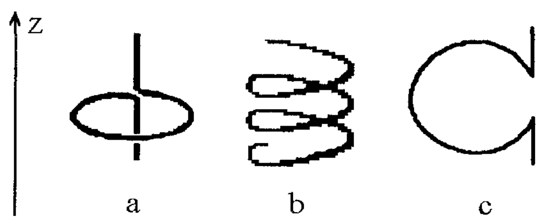


Fig. 1.

The wire structures that are widely used for constructing composite materials were

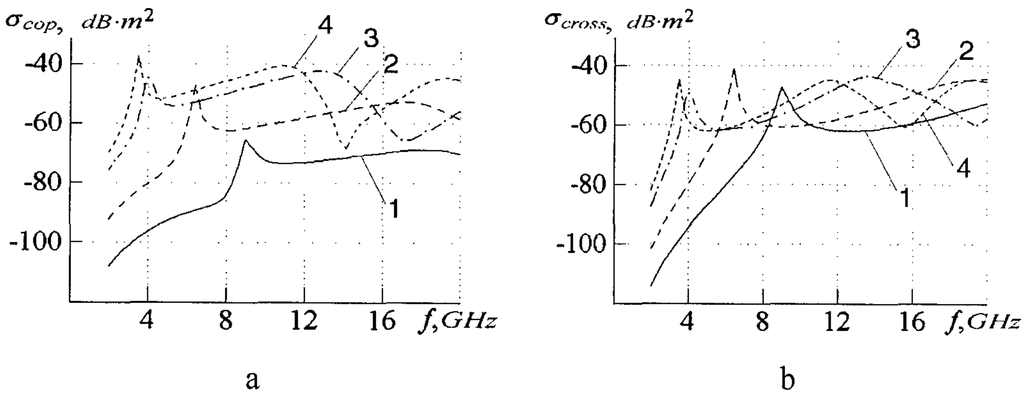
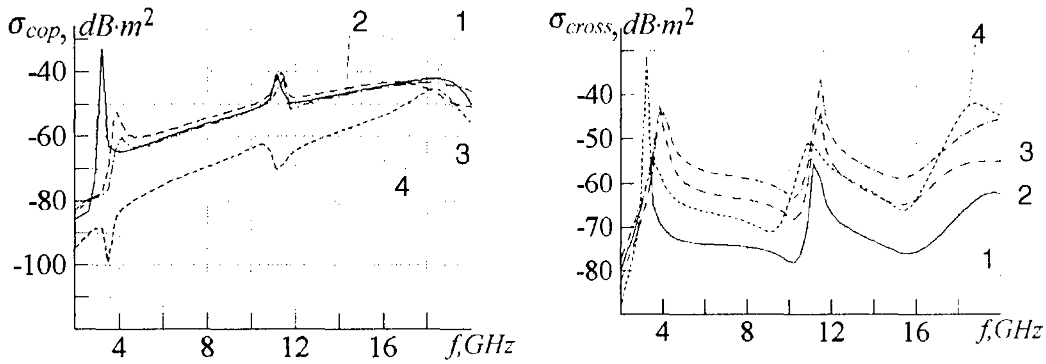


Fig. 2.



a b

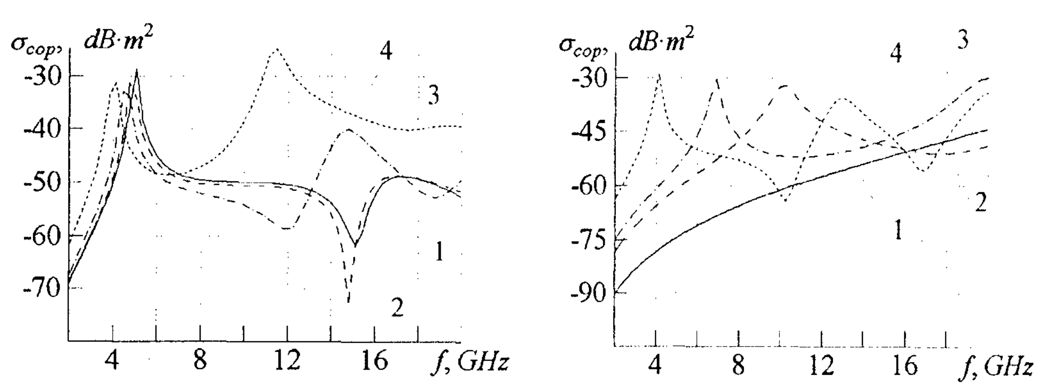
Fig. 3.

considered: a spiral particle with attached conductors, few-coil helix and omega-particles (fig. 1). The estimation of electrodynamic properties was carried out on the basis of analysis results of the radar cross section σ (RCS).

On fig. 2 the frequency dependences of co-polarized (fig. 2a) and cross-polarized (fig. 2b) RCS components for back-scattered radiation are shown at various vibrator lengths l of a particle represented on fig. 1a (l: *1* - 0; *2* - 2mm; *3* - 4mm; *4* - 8mm). The direction and polarization of the incident wave are chosen so that the **H** vector was polarized along the axis Z. In this case the most effective interaction between an incident electromagnetic field and a particle is provided. The spiral radius is a=5mm, wire width is r_0=0.2 mm. The spiral loop works as a receiver providing particle excitation, and vibrators of the particle are the source of the field parallel to axis Z. On fig. 2a one can see that the increase of vibrator length leads to little changes of copolarized RCS. It is the result of the vibrators being perpendicular to the copolarized field and not contributing to its production. At the same time the value of crosspolarized RCS (fig. 2b) is greatly increased when the vibrators length rises.

Similar dependences can be received by varying the spiral radius. In this case the variation of spiral radius a gives the considerable changes of copolarized RCS only at $2\pi a<\lambda$. Change of radius almost does not influence the crosspolarized RCS. In work [2] the research of interaction between similar particles was also carried out.

At the analysis of few-coil helices (fig. 1b) the direction of an incident wave is chosen



a b

Fig. 4.

so that the **H** vector was polarized along the axis *Z*. On fig. 3 the frequency dependences of the back-scattered RCS from a winding angle α of the three-coil helix are given (α: *1* – 5^0; *2* – 15^0; *3* – 30^0; *4* – 60^0). The total length of a helix l_{SP} is constant and equal l_{SP}=40mm. The results of calculation have shown, that the variation of the angle is effective up to the certain value (up to 30^0) and essentially influences only crosspolarized RCS. The general features of dependence are determined only by the total helix length, not by the number of coils.

In case of an omega-particle (fig. 1c) the **E** vector was along the vibrators and the **H** vector was perpendicular to the planes of a particle loop. On fig. 4 the frequency dependences of back-scattered RCS on various length of vibrators *l* (fig. 4a. *a*=5mm; length of vibrators *l*: *1* – 0; *2* – 2mm; *3* –*4*mm;.*3* –*8*mm) and various loop radius *a* of the omega-particle (fig. 4b. *l*=5mm; loop radius *a*: *1* – 0; *2* – *1*mm; *3* –2mm;.*3* –5mm). are shown. Apparently, the change of wire element geometry does not lead to considerable changes of scattered radiation power.

The results of calculations also show that RCS dependence from frequency has oscillatory feature that is caused by the resonance phenomena when the total length of a conductor is approximately equal to the whole number of half-waves. The empirical results and other authors' data [3] verify the similar character of frequency dependence RCS for chiral elements as few-coil helices.

In paper [4] the method for calculating effective material parameters of composites with known scattering characteristics of a single particle and the information about the whole structure is given. On this basis within the scope of thin-wire approximation the method for computing the effective dielectric permittivity and magnetic permeability of the composite materials containing conducting particles considered above is developed.

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