

**DEVELOPMENT OF MICROWAVE RADIATION ABSORBERS  
BASED ON COMPOSITE MATERIALS****S.T. AZIZOV<sup>1</sup>, O.B. TAGIEV<sup>1</sup>, I.N. IBRAHIMOV<sup>1</sup>, S.I. QULIEVA<sup>2</sup>**<sup>1</sup>*Ministry of Science and Education Republic of Azerbaijan, Institute of Physics,  
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The article presents the results of research on the development of absorbers for complete absorption of incident microwave radiation based, on composite materials. The absorbers are designed to neutralize residual and unwanted electromagnetic radiation. These coatings can be used to protect living organisms from the harmful effects of microwave radiation of specific frequencies (e.g., in radar, television broadcasting, and mobile communications).

**Keywords:** Dielectric spectroscopy, dielectric relaxation, polar liquids, microwave, condensed state of matter, permittivity, dielectric losses, dielectric properties of liquids, reflection coefficient of electromagnetic waves.

**INTRODUCTION**

Various types of electromagnetic radiation absorbers made of composite materials are described in the scientific literature [1,2]. Their principle of operation is based on the absorption of electromagnetic radiation in the surface layer of fillers containing thin metal conductors or highly dispersed metal particles, due to the skin effect [1-3]. However, the absorption efficiency of such materials decreases with increasing radiation frequency, which complicates the creation of high-frequency absorbers based on existing conductive materials.

A solution is known where the electromagnetic radiation absorber consists of a metal base with a thin layer of dielectric. A polar substance with maximum dispersion near a given wavelength range is used as the dielectric. The thickness of the dielectric layer is determined by the condition of minimizing the wave reflection coefficient from the polar dielectric layer on the metal substrate [4].

Polar liquids can also be used to absorb microwaves. Technical implementation is possible by using polar liquids in the form of encapsulated inclusions in a solid coating. With a small volume of such inclusions, the absorber retains the necessary structural rigidity. It is important to note that at a certain concentration of inclusions, complete absorption of incident microwave radiation is achieved. One such absorber was developed based on the study of the dielectric properties and reflection characteristics of a “water-epoxy resin” composite in the centimeter range [5]. Experiments have shown, that at a given frequency of incident radiation and solution temperature, complete absorption is achieved at strictly defined layer thicknesses and composite material compositions. However, the absorption efficiency of such absorbers based on the “water-epoxy resin” composite in the centimeter range deteriorates with increasing radiation frequency, which complicates the creation of high-frequency absorbers [5,6].

The main disadvantage of these microwave

radiation absorbers is a sharp decrease in the efficiency of selective radiation absorption at high frequencies. In addition, to achieve complete absorption even at low frequencies, the coatings must be sufficiently thick, which increases the weight of the objects being protected. The use of more effective ferrimagnetic materials as fillers reduces the mechanical strength of the absorbers [7-12].

The aim of this research is to improve the selectivity and sensitivity of coatings designed to absorb electromagnetic radiation.

**EXPERIMENTAL PART**

In the developed electromagnetic radiation absorber based on a composite material, which is a coating with a distributed liquid phase (encapsulated liquid) and dispersion near the required wavelength range, a homogeneous material is used as the solid base of the coating, and a polar liquid is used as the absorbing filler. The concentration of the polar component and the thickness of the coating were selected based on the condition that the reflection coefficient modulus is zero. Since this effect manifests itself in composites whose polar components have dispersion in the microwave range, a composite based on acetonitrile and epoxy resin is proposed as a material for microwave radiation absorption. An experimental study of total absorption using this composite was conducted taking into account the dispersion regions of acetonitrile in the centimeter and millimeter wave ranges. The studies were conducted at wavelengths  $\lambda = 1.5$  cm and  $\lambda = 8.15$  mm at a temperature of 20°C. To determine the optimal values of layer thickness and composite composition at which complete absorption of microwave radiation is observed, data on the dielectric permittivity ( $\epsilon'$ ) and dielectric loss ( $\epsilon''$ ) of the composites under study were used. The experimentally obtained values of  $\epsilon'$  and  $\epsilon''$  for composite materials with different component concentrations were used for graphoanalytical determination of the resonance concentrations of polar components at which the effect

of complete absorption of microwave radiation of a given wavelength occurs in a wide frequency range. For this purpose, the concentration dependencies of the wave reflection coefficient  $\rho$  were recorded sequentially for each successive number  $N=1,2,3$  of the minimum of the function  $\rho(l)$ . The experimental values  $\varepsilon'$  and  $\varepsilon''$  of the “acetonitrile-epoxy resin” composite

were used to construct the dependencies  $\varepsilon'$  on  $\varepsilon''$  in the Cartesian coordinate system  $[\varepsilon', \varepsilon'']$ . We proposed a graph-analytical method for solving equations describing the conditions for the realization of the effect of complete absorption of electromagnetic waves in a substance. In accordance with this method, the intersection points of the dependence of  $\varepsilon''$  on  $\varepsilon'$  in the coordinate plane  $[\varepsilon', \varepsilon'']$  were determined (Fig. 1).

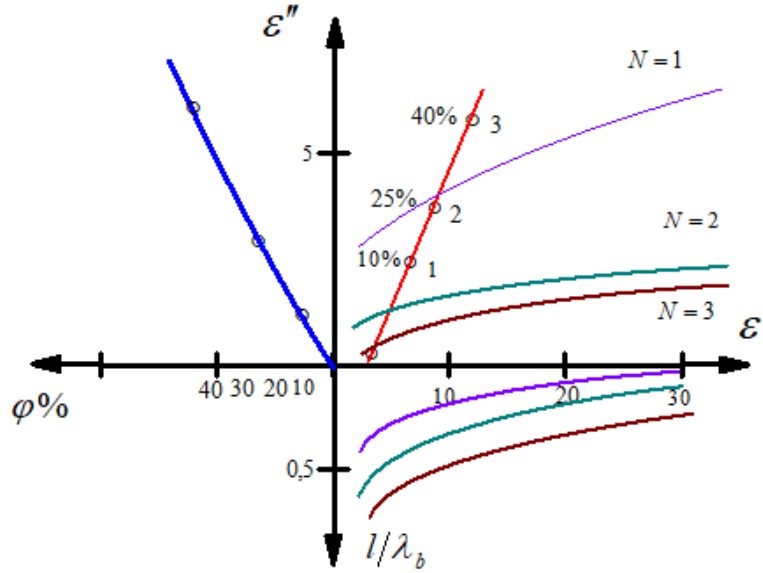


Fig. 1. Graph-analytical method for determining the conditions for the occurrence of complete absorption of microwave radiation.

Then, using the experimentally obtained dependence of  $\varepsilon''$  on  $\varepsilon'$ , the resonance values of the acetonitrile concentration  $\varphi_0$  and the layer thickness  $l_0$  at which complete absorption of microwaves occurs were calculated. The obtained theoretical values of  $\varphi_0$  and  $l_0$  were compared with the experimental values.

### DISCUSSION OF RESULTS:

The calculated values of layer thickness and composite composition were compared with data obtained directly from experimental studies of the dependence of  $\rho$  on  $l$ . As can be seen in Fig. 1, for the “acetonitrile-epoxy resin” composite, all minima of the dependence of  $\varepsilon'$  on  $\varepsilon''$ , starting with the first, reach zero values when the composite concentration changes.

Polar liquids characterized by high values of both dielectric loss  $\varepsilon''$  and dielectric permeability  $\varepsilon'$  in a given wavelength range are used as fillers for microwave coatings. For the practical implementation of such absorbing coatings, a polar liquid can be used as a filler for a solid material. With a small volume of encapsulated liquid inclusions, the developed absorbers can have the necessary structural rigidity, and with the

optimal selection of the concentration of inclusions, they can ensure the complete absorption of incident microwave radiation. The inclusions themselves are capsules of liquid polar substances placed in protective polymer film shells. Since the non-polar matrix substance of the absorber has  $\varepsilon''=0$ , and  $\varepsilon'$  does not depend on frequency, at a given temperature  $t$  and wavelength  $\lambda$  of the incident electromagnetic radiation, the selection of the resonant values  $\varepsilon_0'$  and  $\varepsilon_0''$  of the absorber is achieved by varying the concentration of its liquid phase [12-16].

The possibility of creating electromagnetic radiation absorbers based on composite materials containing highly dispersed encapsulated polar liquids at given  $t$  and  $\lambda$  is demonstrated by the following example. To simplify the analysis, we assume that the dielectric properties of the absorber are additive to the dielectric properties of its components and that the liquid capsules are small compared to the wavelength of the radiation.

According to the data in [1-4], the conditions for complete absorption of microwave radiation in a two-layer “dielectric-metal” system are described by the following equations:

$$\pi(2N - 1) + \operatorname{arctg} \frac{2\pi y}{n(1+y)-1} = \frac{1}{y} \ln \sqrt{\frac{(1+n)^2 + (ny)^2}{(1-n)^2 + (ny)^2}}, \quad (1)$$

$$\frac{l_0}{\lambda_0} = \frac{1}{4\pi n} \left[ \pi(2N - 1) + \operatorname{arctg} \frac{2ny}{n^2(1+n^2)-1} \right], \quad (2)$$

where  $l_0$  is the layer thickness;  $N$  is the number of zero minima of the dependence of the wave reflection coefficient on the layer thickness of the material.

The wave refractive index  $n$  and dielectric loss factor  $\gamma$  of the coating material, which are included in equations (1) and (2), are related to its dielectric permittivity  $\varepsilon'$  and dielectric loss  $\varepsilon''$  by the following known relationships:

$$\varepsilon' = n^2(1 - \gamma^2) \quad \varepsilon'' = 2n^2\gamma \quad (3)$$

The quantities  $\varepsilon'$  and  $\varepsilon''$ , which are part of equations (3), are related to the dielectric permittivity  $\varepsilon_0'$  and dielectric losses  $\varepsilon_0''$  of the liquid phase, as well as to  $\varepsilon_0$  of the matrix material, by the following equations:

$$\begin{aligned} \varepsilon' &= \varepsilon_1'(\varphi_0) + \varepsilon_2(1 - \varphi_0), \\ \varepsilon'' &= \varepsilon_1''\varphi_0 \end{aligned} \quad (4)$$

where  $\varphi_0$  is the concentration of the liquid phase in the coating material.

Solving equations (1) – (4) together allows us to calculate the optimal values of the liquid phase concentration  $\varphi$  and the coating layer thickness  $l_0$  for given values of  $N$ , the wavelength  $\lambda$  of the incident radiation, and the dielectric coefficients.

Below are the results of calculating  $\varphi$  and  $l$  using equations (1) – (4) at a wavelength  $\lambda = 1.5$  cm for a microwave absorber formed on the basis of epoxy resin with the addition of encapsulated acetonitrile as a filler. The dielectric permittivity of epoxy resin is  $\varepsilon = 2.7$ . For acetonitrile at  $\lambda = 1.5$  cm and  $t = 20^\circ\text{C}$ ,  $\varepsilon' = 36.8$ ,  $\varepsilon'' = 3.64$ . From the joint solution of the system of equations (1) – (4), it follows that the conditions for complete absorption of microwave radiation are met at a volume concentration of the liquid phase  $\varphi = 0.077$  and an absorber layer thickness  $l = 0.173$  cm, which approximately corresponds to  $\lambda g/4$  (at  $N = 1$ ).

## CONCLUSION

The results of the studies led to the creation of coatings based on composite materials that utilize residual and unwanted electromagnetic radiation. These coatings can be used to protect living organisms from the harmful effects of microwave radiation, in radar systems, and in other areas of technology where complete absorption of electromagnetic radiation of a given frequency is required. The absorber matrix is made of a homogeneous solid material with good adhesive properties. A polar liquid is used as the absorbing filler of the matrix, the concentration and thickness of the coating of which are selected based on the condition of zero wave reflection coefficient modulus.

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