Spectra of Electromagnetic Parameters of Multicomponent Radioabsorbing Material at Frequency Range 20 Hz – 100 GHz

Valentine I. Suslyaev[1], Lubov N. Ivanova[2], Victor A. Zhuravlev[1], Evgeny Yu. Korovin[1],
Kirill V. Dorozhkin[1], Alexandra A. Pavlova[1]
[1]Tomsk State University, Tomsk, Russia
[2]Central Design Bureau of Automatics, Omsk, Russia

***Abstract* – Measurements results of spectra of permittivity, permeability, reflection, transmission and absorption coefficients of polymer composite with nanosized filler are presented. Material absorbs electromagnetic waves intensively at superhigh and extremely high frequencies.**

***Index Terms* – radioabsorber, composite, gigahertz, terahertz, electromagnetic parameters**

I. INTRODUCTION

TODAY, microwave frequency band expands intensively. Microwave frequency band is using for construction of communication apparatus, radar-location, radio imaging, radio tomography, etc. There are few tasks for supply of effective electronics work: electromagnetic compatibility, suppression of minor lobe in antennas, personnel protection from ill effect of microwaves, information security [1 – 3].

In low-frequency band there is undesirable interaction of feed circuits with information circuits that generates noise and apparatus bugs. In high-frequency band there are effects of radiation through the ports of apparatus blocks, holes in screens. Microwave and sub microwave bands are necessary for high speed of operation with decrease of weight radio engineering equipment.

Some of above mentioned tasks are solving by the hardware-controlled way: choice of electronic circuits, disposition of elements, etc. But some tasks demand using of materials effective interacts with microwaves. These materials can be used for shielding, absorption and reflection of microwaves [4].

Unfortunately, there is no such kind of materials for making homogeneous or composite structures with following properties: broadbandness, high interaction with microwaves, simplicity of making and cheapness.

Choice of materials depends on kind of protected material. If it is necessary to decrease reflection from metal surface then one should use magnetic materials [5]. Conductive covers, dielectrics and magnetodielectric are for other cases [6].

In present work spectra of complex permittivity and permeability, spectra of electromagnetic response from composite based on polymer with magnetic filler in frequency band 20 Hz – 100 GHz.

II. THEORY

There are three coefficients to estimate interaction of microwave radiation and radiomaterial - reflection coefficient, transmission coefficient and coefficient of absorption *A=1-R-T* (relative units).

For plane sample in free space under normal incidence of electromagnetic wave R and T can be calculated as:

$$R = \frac{\rho\left(1 - e^{-2i\gamma d}\right)}{1 - \rho^2 e^{-2i\gamma d}}, \quad (1)$$

$$T = \frac{\left(1 - \rho^2\right) e^{-i\gamma d}}{1 - \rho^2 e^{-2i\gamma d}} \quad (2)$$

where $\rho = (Z - 1)/ (Z + 1)$ – coefficient of reflection from front of sample; $Z = (\mu / \varepsilon)^{0.5}$ – wave impedance; $\gamma = k_0(\mu\varepsilon)^{0.5}$ – propagation constant of electromagnetic wave in magnetodielectric layer; $k_0 = \omega/c$ – wave number of free space, c – speed of light; $\omega = 2\pi f$; f – frequency; d – thickness of layer.

In case: layer of magnetodielectric situated on perfectly conducting surface:

$$R = \frac{\rho - e^{-2i\gamma d}}{1 - \rho e^{-2i\gamma d}}. \quad (3)$$

These relations allow to simulate electromagnetic response of plane sample with known spectra of permittivity and permeability for different thicknesses and orientation of sample in space.

Equipment and method of center of Tomsk Regional Common Use Center: Center of radio-physics measurements, diagnostic and researching of parameters of natural and artificial materials were used to measure spectra of permittivity ($\varepsilon = \varepsilon' - i\varepsilon''$) and permeability ($\mu = \mu' - i\mu''$) in frequency band 20 Hz – 100 GHz [7].

III. RESULTS

Samples of composite consist of polymer with nanocrystalline powder filler. Nanocrystalline powder is particles of Fe-Cu-Nb-Si-B alloy with nanocrystalline structure. Size of particles is 1 …50 μm, there are inclusions in the particles of nanocrystall alloy of α-(Fe,Si) of different ratio and volume density (2.8…2.9)·10^{-5} g/nm^3.

In Fig 1 there are spectra of real and imagine part of composite permittivity. Dependence of ε' shows presence of conductive particles in composite. Influence of conductive particles in frequencies over 100 GHz decrease, then main mechanism of interaction with electromagnetic radiation become ion and electron polarization.

Spectra of permeability (Fig. 2) shows relaxation type of magnetic system under force of electromagnetic radiation with maximum value in 1.4 GHz. Area of increasing of imaginary part of permittivity with simultaneous decreasing of real part of one defines by natural ferromagnetic resonance. There is large width of resonance line caused by low-Q relaxation type.

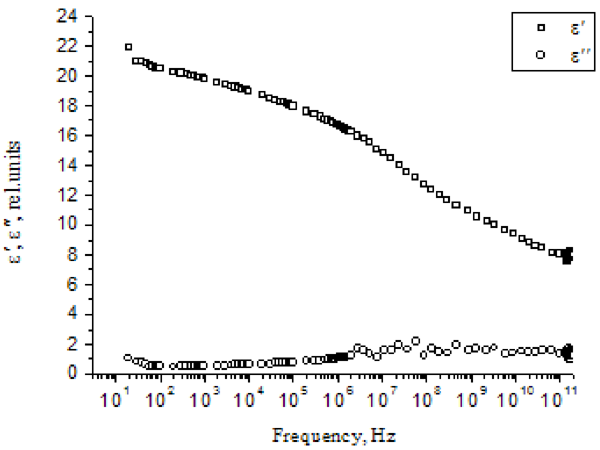

Fig.1. Spectra of permittivity in frequency band 20 Hz – 100 GHz

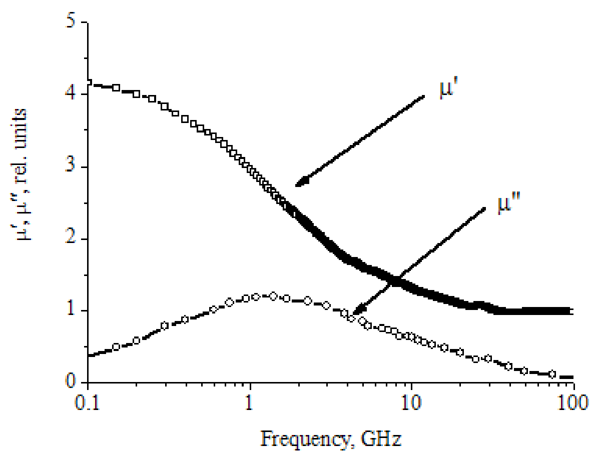

Fig.2 Spectra of permeability

There are two thicknesses of samples: 1.1 mm and 2.5 mm. Spectra of samples of composite being on the metal with different thicknesses are in Fig. 3. Obvious, in case thicknesses 2.5 mm there is decreasing of reflection coefficient more than 10 times in band 8 … 20 GHz. Decreasing of thickness shift area of effective interaction in high frequency band.

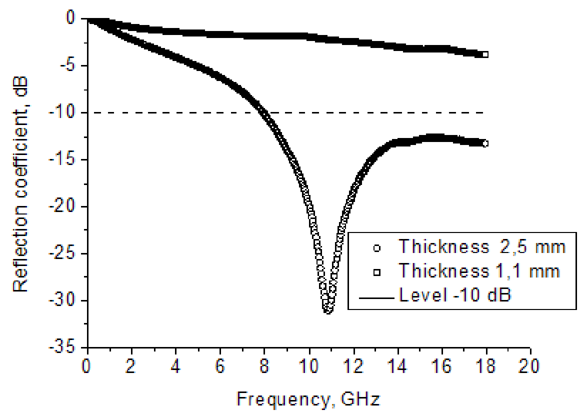

Fig.3. Spectra of reflection coefficient of plane samples being on the metal

This material can be used as screen reducing level of electromagnetic radiation in free space without any conducting surface behind. But effectiveness is decrease then (Fig. 4).

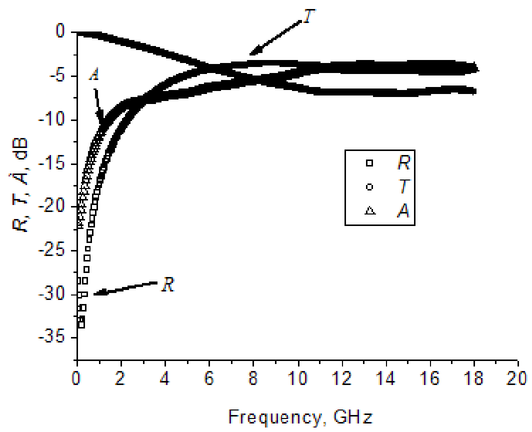

Fig.4. Spectra of R, T and A in frequency band 10 MHz –18 GHz

IV. DISCUSSION

Carried experiments proved possibility of creation of broadband radioabsorbing material based on polymer matrix with multicomponent magnetic powder. Combination of electrophysics characteristics and natural ferromagnetic resonance leads to extension of operational range. Combination of different components, such as ferrites [13], carbon nanostructures [2], microware, conducting polyanilin [16] or complication of composite construction by layers combination with different electrodynamic parameters improves characteristics of electromagnetic response.

V. CONCLUSION

Composite consisted of polymer matrix and nanocrystalline powder can be used as shield decreasing level of electromagnetic radiation at the wide frequency range. Nanocrystalline powder is particles of Fe-Cu-Nb-Si-B alloy with nanocrystalline structure. Size of particles is 1 – 50 μm, there are inclusions in the particles of nanocrystall alloy of α-(Fe,Si). Most effective interaction of composite is in microwave frequency range.

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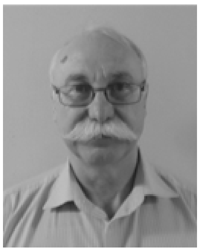
Valentine I. Suslyaev (1946) is a Ph. D., Associate Professor. Scientific interests field: methods of measurement of materials electromagnetic parameters; materials with big loses

Lubov.N. Ivanova is a lead engineer. Scientific interests field: the development of radar and radio-composite materials and their use in electronic devices.



Victor A. Zhuravlev (1953) is a Ph. D., Associate Professor. Scientific interests field: methods of measurement of materials electromagnetic parameters; materials with big loses

Evgeny Yu. Korovin (1982) is a Ph. D. Scientific interests field: methods of measurement of materials electromagnetic parameters; materials with big loses

Kirill V. Dorozhkin (1991) is an engineer. Scientific interests field: methods of measurement of materials electromagnetic parameters; materials with big loses

Alexandra A. Pavlova (1986) is an assistant. Scientific interests field: measurement of materials electromagnetic parameters; ferrofluids; polar liquids.