TWO-LAYER CHARCOAL-CONTAINING MICROWAVE ABSORBERS WITH A RELIEF SURFACE FOR SERVER EQUIPMENT PROTECTION FROM INTERFERENCE

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Abstract

The article presents the electromagnetic radiation reflection and transmission characteristics in the frequency range of 0.7–17.0 GHz of multilayer microwave absorbers. These absorbers consist of modules with a relief surface made of a mixture of powdered activated charcoal and a binder (polyvinyl acetate dispersion aqueous solution or polyurethane mastic). According to the presented characteristics, electromagnetic radiation reflection and transmission coefficients values in the frequency range of 0.7–17.0 GHz of the specified absorbers vary, respectively, within the limits from –2.0 to –18.0 dB and from –10.0 to –40.0 dB. The studied absorbers can be used for wall cladding or creating internal partitions in server rooms. Using such absorbers, it is possible to solve the practical problem of ensuring electromagnetic compatibility of server equipment and other information processing equipment.

Keywords: charcoal, interference, microwave absorber, reflection coefficient, transmission coefficient.

I. Introduction

Some of the tasks currently being solved when creating server rooms are:

– ensuring electromagnetic compatibility of equipment located inside these rooms;

– protection of equipment located inside these rooms from external electromagnetic interference.

As a rule, the solution to this problem is associated with the use of materials that absorb electromagnetic radiation (EMR) energy, i.e. microwave absorbers. Most of the microwave absorbers currently being developed and studied are characterized by a relief surface. This is due to the fact that such absorbers, compared to absorbers with a smooth surface, are characterized by lower the EMR reflection coefficient values due to the fact that:

– the relief elements of the surfaces of such absorbers ensure the scattering of electromagnetic waves interacting with them [1];

– the relief elements of the surfaces of such absorbers are a set of conditional resonators that ensure the absorption of EMR energy at certain frequencies. In addition, when electromagnetic waves interact with absorbers with a relief surface, as a rule, there is no formation of standing electromagnetic waves and / or passive electromagnetic interference [2]. The designated waves and interference can affect the performance of the equipment.

As shown in [3–6], the scattering of electromagnetic waves by the relief elements of the surfaces of the microwave absorbers is ensured both in the case when the size of these elements is comparable with the wavelengths and in the case when it is significantly smaller than these lengths. In this regard, microwave absorbers with a relief surface are divided into the following types.

1. Perforated absorbers, i.e. absorbers with regularly or irregularly placed through or blind holes. The presence of holes in materials causes a decrease in their impedance, which in turn causes a decrease in the value of their EMR reflection coefficient.

2. Absorbers, the surface of which is characterized by the presence of nano- and / or microroughnesses, distributed uniformly or unevenly. The surface area of such absorbers exceeds the surface area of the absorbers with a relatively smooth surface, due to which the value of the EMR reflection coefficient value of the first of the designated absorbers is lower than EMR reflection coefficient value of the second of the designated absorbers.

3. Absorbers with a profiled surface, which is a set of identical or unequal bulges and / or depressions, the size of which is from units to tens of centimeters.

The following technologies are used to manufacture microwave absorbers with a relief surface of the listed types.

1. Perforation (for the manufacture of the absorbers of the first of the above types).

2. Electrochemical treatment of material surfaces. The procedure for implementing this technology is as follows:

– the surface of the material is immersed in an electrolytic solution;

– electric current is applied to the material, which leads to the formation of a relief surface.

This technology is used to manufacture absorbers of the second of the above types.

3. Photolithography. The procedure for implementing this technology is as follows:

– applying a photosensitive layer to the surface of the material;

– exposure of the applied layer to ultraviolet radiation through a mask that creates the desired pattern;

– treatment of the surface of the material with a solution that helps remove those areas of the photosensitive layer that were not exposed to ultraviolet radiation.

This technology is used to manufacture absorbers of the second of the above types.

4. Laser cutting of materials (used to manufacture absorbers of the third of the above types).

It should be noted that at present, microwave absorbers with a relief surface of the third of the above types are most often developed, researched and used, and accordingly, the fourth of the above technologies is used for their manufacture. It should be noted that the main disadvantage of such absorbers, as a rule, is their low mechanical strength, due to the fact that porous carbon-containing materials are usually used for their manufacture [7].

The paper [8] presents the results of the development and study of the microwave absorbers with a relief surface, which are not characterized by the indicated disadvantage. This is due to the fact that such absorbers are modules in the form of solid forms with hemispherical depressions filled with a mixture of powdered activated charcoal and a binder (polyvinyl acetate dispersion aqueous solution, polyurethane mastic, gypsum binder).

The advantage of powdered activated charcoal over other carbon-containing materials currently used to manufacture microwave absorbers is its low cost and high availability. The low cost of powdered activated charcoal is due to the fact that it is usually made from industrial or agricultural waste [9–11].

The choice of the type of solid forms is due to the absence of acute-angled vertices in them, which reduces the time and financial costs of manufacturing such forms. In addition, such forms provide higher mechanical strength of microwave absorbers, in the structure of which they are included. The height and width of the recesses in these forms meet the requirements for the dimensions of the relief elements of the surface of microwave absorbers [12].

The presented study is a continuation of the study, the results of which are presented in [8]. Its purpose was to establish the patterns of change in the EMR reflection and transmission coefficients values in the frequency range of 0.7–17.0 GHz of two-layer microwave absorbers in the form of sets of the above-mentioned modules depending on:

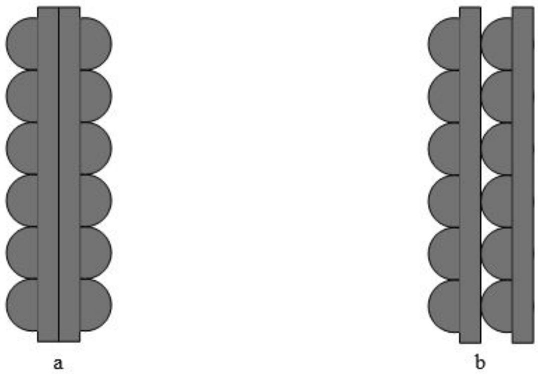
– the type of binder included in the composition of such absorbers;

– the mutual arrangement of the modules of which such absorbers consist.

Taking into account the designated patterns, it is possible to establish how EMR reflection and transmission coefficients values of the absorbers presented in work [8] change as a result of the inclusion of an additional layer in their structure.

II. Research methodology

Four groups of experimental samples were prepared for the study. Figure 1 shows a schematic representation of these samples.



a – samples of groups 1, 3; b – samples of groups 2, 4

Figure 1: *Schematic representation of the developed samples*

The appearance of one of the modules used to manufacture the experimental samples is shown in Figure 2.

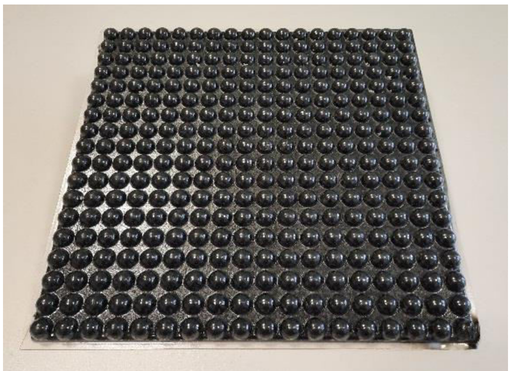


Figure 2: *The appearance of one of the modules used to manufacture the experimental samples*

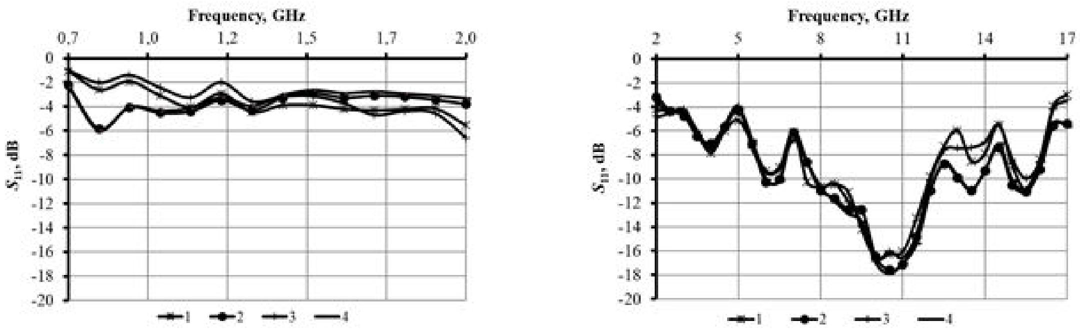
Table 1 presents the characteristics of the samples of each group.

Table 1: *The characteristics of the samples of each group*

Conventional designation of the sample	Composition of the mixture used to prepare the sample	Weight of 1 m2 sample, kg
Sample of group 1	Polyvinyl acetate dispersion aqueous solution, powdered activated charcoal	10.0
Sample of group 2		
Sample of group 3	Polyurethane mastic, powdered activated charcoal	14.5
Sample of group 4		

The measurements of EMR reflection and transmission coefficients values (S11 and S21, respectively) of the manufactured samples were carried out in the frequency range of 0.7–17.0 GHz using a setup that included a personal computer, a panoramic meter of transmission and reflection coefficients SNA 0.01–18, and two horn antennas. The measurements were carried out in accordance with the methodology presented in [13].

The frequency dependences of the EMR reflection coefficient in the range of 0.7–17.0 GHz of the manufactured samples are shown in Figure 3.



a b

Figure 3: *The frequency dependences of the EMR reflection coefficient in the range 0.7–2.0 GHz (a) and 2.0–17.0 GHz (b) for samples of groups 1, 2, 3 and 4 (curves 1, 2, 3 and 4 respectively)*

It is evident from Figure 3 that EMR reflection coefficient values in the frequency range of 0.7–2.0 GHz for all the manufactured samples vary within the range from –2.0 to –6.0 dB, and in the frequency range of 2.0–17.0 GHz – from –4.0 to –18.0 dB. It follows from Figure 3 that EMR reflection coefficient values in the specified frequency range for the manufactured samples don't depend on either the type of binder included in their composition or the relative position of the modules used to manufacture them. Consequently, most of the electromagnetic waves characterized by frequencies whose values belong to the frequency range specified above are scattered by the relief elements of the outer layer of the manufactured samples and are scattered or absorbed by the second layer of these samples.

The frequency dependences of the EMR transmission coefficient in the range of 0.7–17.0 GHz for the manufactured samples are shown in Figure 4.

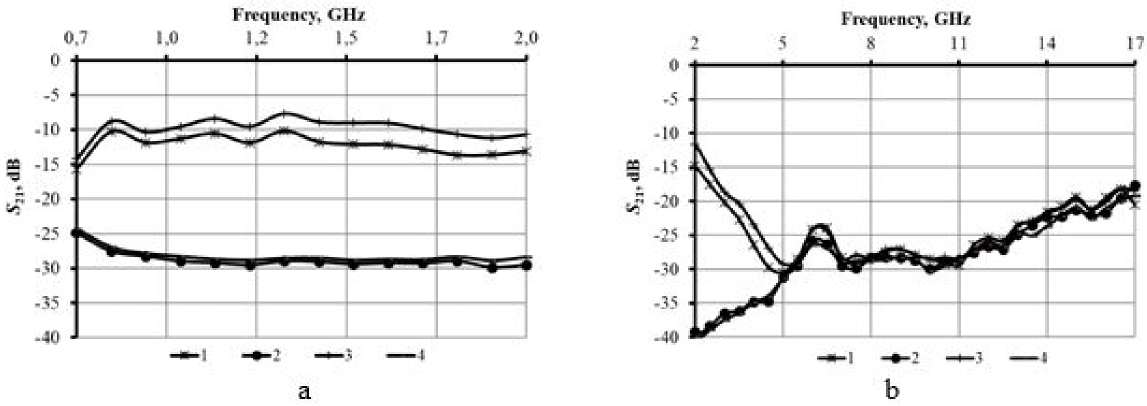
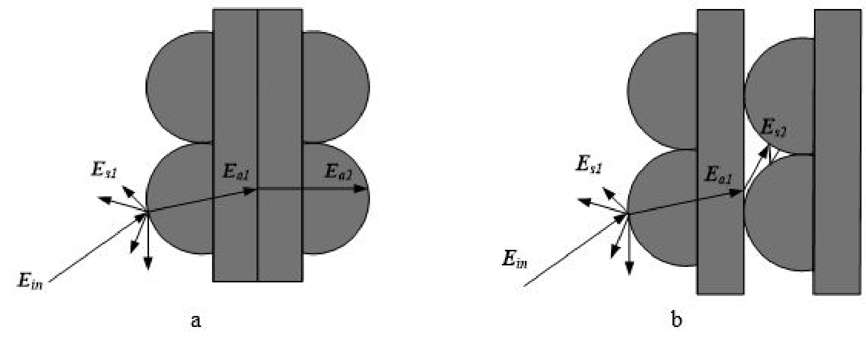


Figure 4: *The frequency dependences of the EMR transmission coefficient in the range 0.7–2.0 GHz (a) and 2.0–17.0 GHz (b)for samples of groups 1, 2, 3 and 4 (curves 1, 2, 3 and 4 respectively)*

It is evident from Figure 4 that EMR transmission coefficient values in the frequency range of 0.7–2.0 GHz for samples 1 and 3 vary, respectively, within the range of –10.0 to –15.0 dB and from –8.0 to –15.0 dB, and for samples 2 and 4 – from –25.0 to –30.0 dB. EMR transmission coefficient values in the frequency range of 2.0–17.0 GHz for samples 1 and 3 vary, respectively, within the ranges from –16.0 to –30.0 dB, from –12.0 to –30.0 dB, and for samples of groups 2 and 4 – from –20.0 to –40.0 dB. Sample of group 3 is characterized by higher EMR transmission coefficient values compared to sample of group 1 due to the fact that its wave impedance is lower than the wave impedance of sample of group 1. This feature is due to the fact that the relative permittivity value of the polyurethane mastic, using which sample of group 3 was manufactured, is higher than the relative permittivity value of the polyvinyl acetate dispersion aqueous solution, using which sample of group 1 was manufactured [9]. Lower EMR transmission coefficient values in the frequency range of 0.7–17.0 GHz of samples of groups 2, 4 compared to samples of groups 1, 3 may be due to the fact that the energy of electromagnetic waves that can be scattered by the relief elements of the surface of the second layer of samples of groups 2, 4 is higher than the energy of electromagnetic waves that can be absorbed in the thickness of the second layer of samples of groups 1, 3 (Figure 5).



Ein – incident wave; Es1 – wave scattered by the first layer; Ea1 – wave absorbed by the first layer; Es2 – wave scattered by the second layer; Ea2 – wave absorbed by the second layer

Figure 5: *Schematic representation of the mechanisms of electromagnetic waves interaction with samples of groups 1, 3 (a) and samples of groups 2, 4 (b)*

It should be noted that EMR transmission coefficient values in the frequency range of 0.7–17.0 GHz of the manufactured absorbers samples are lower by 5.0–25.0 dB, than EMR transmission coefficient values of the absorbers samples, the results of the study of which are presented in the paper [8] (Figure 6). EMR reflection coefficient values in the frequency range of 0.7–17.0 GHz of the first of the designated samples are practically equivalent to EMR reflection coefficient values in the specified frequency range of the second of the designated samples. Thus, the inclusion of an additional layer in the structure of the absorbers presented in the work [8] seems advisable.

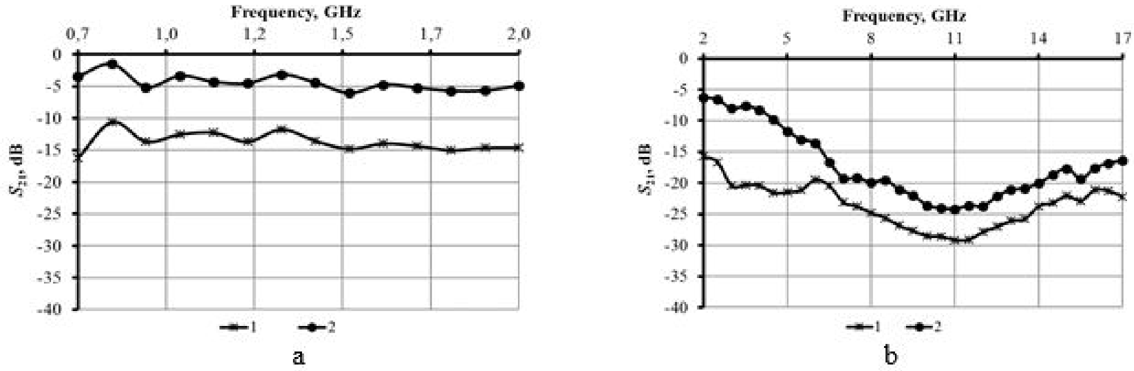


Figure 6: *The frequency dependences of the EMR transmission coefficient in the range 0.7–2.0 GHz (a) and 2.0–17.0 GHz (b) for of the absorbers samples presented in the paper [8] and made from polyvinyl acetate dispersion aqueous solution and polyurethane mastic (curves 1 and 2 respectively)*

III. Conclusion

The studied microwave absorbers are characterized by the following advantages over their analogs.

1. A wider operating frequency range (~ 9.0 GHz) due to the fact that:

– the studied absorbers are multilayered;

– electromagnetic waves interacting with the studied absorbers are scattered both by the relief elements of their surfaces (i.e. hemispheres) and by particles of powdered activated charcoal, the size of which is 1.0–5.0 mm (i.e. comparable with the lengths of electromagnetic waves in the frequency range of 0.7–17.0 GHz).

2. Lower cost due to the fact that powdered activated charcoal, which is part of the studied absorbers, is characterized by a lower cost compared to other carbon-containing powdered materials used to manufacture their analogs.

3. Increased mechanical strength due to the fact that the structure of the studied absorbers includes solid forms made of radio-transparent polymeric material and without acute-angled vertices. The studied microwave absorbers can be used for wall cladding or creating internal partitions in server rooms. With the help of such absorbers, it is possible to solve the practical problem of ensuring electromagnetic compatibility of server equipment and other means of information processing.

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