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ANALYSIS OF THE TYPES OF RADAR ABSORBING MATERIALS [1]

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Abstract. The paper provides the analysis of modern radar absorbing materials. The authors describe the advantage of radar absorbing material on the basis of the metamaterial.

Key words: radar absorbing material, electromagnetic radiation, absorption coefficient, effect of neutralization, metamaterials.

Radioabsorbing materials are materials whose composition and structure provides effective absorption (with little reflection) of electromagnetic energy in a certain range of radio wavelengths.

There is no universal classification of radioabsorbing materials. Conventionally, they can be classified by composition and principle of action.

In the modern development of radar absorbing materials to absorb energy of electromagnetic waves used mainly traditional conductive particulate (soot, graphite, metal particles), fibrous (carbon, metal, metalized polymer) and magnetic (sintered ferrite plate powders of ferrites, carbonyl iron, etc.) fillers used separately or together, forming a complex composite structure.

Radioabsorbing materials, made in the form of varnishes, paints, sealants, polymers, fabrics, tiles, foams, filled rubbers, building slabs, loose mixtures and other versions of various compositions, are the main components in the creation of electromagnetic wave absorbers, which are used for the equipment of anechoic chambers.

According to the principle of action, several large groups of radioabsorbing materials are isolated [1]:

– resonance;
– non-resonant magnetic;
– metal screen;
– non-resonant bulk;
– pyramidal absorbers of electromagnetic waves.

Resonant radioabsorbing materials provide partial neutralization of radiation reflected from the surface of the absorber, part of which has passed through the thickness of the material. The neutralization effect is significant when the thickness of the absorber is equal to one quarter of the wavelength of radiation. In this case, the waves reflected by the surface of the absorber are in the opposite phase. Resonance materials are applied to the reflecting surfaces of the masking object. The thickness of the radioabsorbing materials corresponds to a quarter of the wavelength of the radar radiation. The incident energy of high-frequency radiation is reflected from the external and internal surfaces of radioabsorbing materials to form an interference pattern of neutralization of the initial wave. As a result, the incident radiation is suppressed. Deviation of the expected radiation frequency from the calculated one leads to deterioration of the absorption characteristics, which makes this material narrow-band. Therefore, this type of radioabsorbing materials is effective in masking radiation from a radar station operating on a standard, constant monofrequency.

Non-resonant magnetic radar absorbing materials containing ferrite particles, dispersed in epoxy or plastic coating.

Apply several types of ferrites:

– Nickel ferrites are used mainly in the ranges of mile-and centimeter waves, have high values of saturation magnetization and high thermal stability. Their disadvantage is the high value of initial losses.

– Magnetic ferrites are used in the middle part of the centimeter range; have low magnetic and dielectric losses, but less thermal stability compared to Nickel ferrites.

– Magnesium ferrites are used in the long-wave part of the microwave range. They have low values of induction at saturation. As with magnetic ferrites, the main drawback is low thermal stability.

The advantage of ferrite radioabsorbing materials is their small thickness (a few millimeters) and high flexibility of the material. The disadvantage is the low manufacturability of manufacturing and heating resulting from the dispersion of high-frequency radiation energy over a large surface.

Obtaining broadband material is achieved by using ferrites with different resonant frequencies. The dependence of the resonance frequency depends not only on the material (Nickel, magnetic, magnesium), but also on the size of the powder particles (tables 1, 2).

Table 1

Dependence of absorption frequency on ferrite particle size $\mu > 300$

Powder particle sizes, μm	Effective absorption frequency, GHz
1650-701	0,5-1,5
701-351	1-2
351-104	1,8-3
104-43	2,5-7,5
<43	6-12

Table 2

Dependence of absorption frequency on ferrite particle size $\mu < 300$

Powder particle sizes, μm	Effective absorption frequency, GHz
1650-701	1-3
701-351	2-4
351-104	4-6
104-43	5-7,5
<43	6-12

Metal screens – flat single or multi-layer plates, shielding electromagnetic radiation. Metal screens at almost acceptable thickness provide good shielding efficiency at all frequencies of the radio band. Efficiency increases with frequency, magnetic permeability μ, conductivity σ, and screen thickness d.

With a decrease in frequency, the attenuation coefficient in the metal decreases, and the shielding efficiency due to absorption decreases, so the screen, consisting of several thin layers of different metals, has a large shielding effect in the low-frequency region compared to a homogeneous screen by increasing the number of reflections.

The disadvantage of metal screens can be called providing a good level of absorption only at a normal angle of incidence of the electromagnetic wave on the surface. When changing the angle of incidence of the electromagnetic wave, the absorption coefficient decreases.

Non-resonant bulk radioabsorbing materials-usually used in the form of relatively thick layers that absorb most of the energy supplied to the approach and possible reflection of the wave from the metal back plate. The principle of operation is based on the use of both dielectric and magnetic losses, the latter – by adding ferrite compounds. In some cases, the introduction of graphite into the polyurethane foam matrix is used. This type of radioabsorbing materials is not only technologically difficult to manufacture, but also occupies large volumes. The undeniable advantages of this material are high absorption capacity and broadband absorption.

Another possibility of reducing the reflection of electromagnetic radiation from the external surface is associated with the use of materials in the upper layers of which are created periodic, so-called chiral conducting structures that interact cooperatively with electromagnetic radiation. The constructions of each such element and their entire ensemble can be very diverse [2; 6; 7]. In this case, the structures are calculated in such a way that the radiation pattern of the propagating energy is as two-dimensional as possible and lies in the plane of the reflecting material (coating). At the same time, to reduce the reflection from flat conductive elements, the area occupied by such structures should be minimal. Since such a structure, excited by an external source, transmits stored energy to the surrounding space, the analogue of such a structure can be a transmitting superdirectional antenna with high radiation q-factor [3]. Such radar-absorbing materials are called radio-absorbing surfaces of the metamaterial.

Metamaterials are composites with unique electrophysical, radiophysical and optical properties that are absent in natural materials [5].

The new properties of metamaterials are due to the resonance interaction of an electromagnetic wave propagating in a heterogeneous medium filled with inclusions having a special form providing resonant excitation of currents. Resonance interaction is not potential, which, along with interference collective processes, leads to the emergence of new effects. In particular, metamaterials can have both negative: magnetic permeability and electrical susceptibility, resulting in electromagnetic waves, in which the phase and group velocities have opposite directions and as a result there is a negative refraction at the boundary of the two media.

The resulting material is relatively narrow-band, although it has properties that traditional absorbing materials do not possess. Namely, at low frequencies the dielectric and magnetic permeability of the layer are small and the layer becomes transparent, which is important for solving a number of problems of electromagnetic compatibility.

Radioabsorbing material based on metamaterial (figure) is a periodic lattice of metal slit open resonators (SRR-Split Ring Resonator) made on a dielectric substrate. The main property of radioabsorbing material based on metamaterial is the absorption of electromagnetic waves at plasma resonance frequencies.

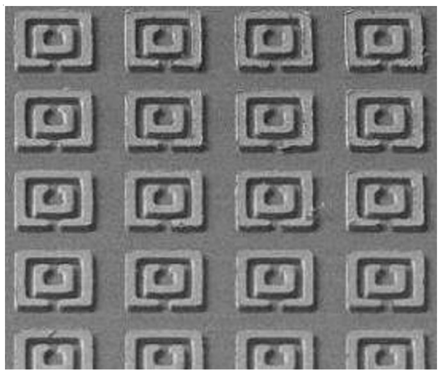

Figure. Example of metamaterial

Because of such problems as escapologist of radar absorbing materials based on metamaterial, the dependence of the absorption coefficient on the incidence angle and polarization of electromagnetic waves, currently intensive work on the creation of new types of broadband radar absorbing materials based on metamaterials to improve antenna technology, development of technologies for improving noise immunity of electronic equipment.

One of the solutions to this problem is the creation of a two-dimensional microwave absorber based on metamaterial, whose electrodynamic properties do not depend on the polarization of electro-magnetic waves. An example of a technical solution is given in [4]. Radioabsorbing material is made in the form of dielectric thickness h = 1 mm. SRR cells are applied to the dielectric surface, which are 4 rings with two slits and a metal strip across the ring with a radius of 2 mm, providing an absorption level of not less than 80 % at EMV incidence angles from 0 to 50^{o} at a frequency of 9.5 GHz.

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АНАЛИЗ ВИДОВ РАДИОПОГЛОЩАЮЩИХ МАТЕРИАЛОВ

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Аннотация. Проведен анализ современных радиопоглощающих материалов. Показано преимущество радиопоглощающего материала на основе метаматериала.

Ключевые слова: радиопоглощающий материал, электромагнитное излучение, коэффициент поглощения, эффект нейтрализации, матаматериал.