# BUILDING MATERIALS AND PRODUCTS

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## SUBSTANTIATION OF THE POSSIBILITY OF USING SHUNGITE AS AN EFFECTIVE RADIO-ABSORBING MATERIAL

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**Statement of the problem.** The task of studying shungite to create effective radio-absorbing materials in construction production is considered. The need for this is dictated by a high density of electromagnetic fields in places of finding or resolving a person and a negative influence on his health.
**Results.** The influence of the composition of building mixtures based on shungite of the Zazhogihinsky membrane is investigated by the absorption of microwave energy in a wide frequency range. The use of the measuring unit based on a scalar chain analyzer and measuring paths in the form of a microwave resonator, made it possible to measure the absorption values of the electromagnetic energy in a wide range of frequencies. The increase in the absorption of shungite is shown in increasing its concentration in the samples under study with values up to 24dB/cm.
**Conclusions.** The effectiveness of the use of shungitis is proved as a filler of building mixtures or with binders (plaster, phosphogypsum) to form protective coatings of walls or wall materials from the effects of electromagnetic energy per person. The most optimal ratio is 50—60 percent of shungite and the rest of the knit, while the frequency range of the absorption is 3—12 GHz.

**Keywords:** shungite, phosphogypsum, microwave, protective coatings.

**Introduction.** The wide distribution of technical tools using electromagnetic waves, particularly in the field of ultrahigh frequencies (SHF), causes an increase in their intensity and a more pronounced effect on biological objects. Various materials to eliminate this effect [6] are being actively searched for. But each of the obtained or examined materials has those positive or negative properties, which to some extent hinders its use in practice [5]. At the same time, there is a whole class of natural materials containing carbon components with multifrequency absorption of electromagnetic energy. One of the promising natural materials is shungite from the Zazhoginsky deposit in Karelia.

Soon after shungite deposits had been discovered, it started being used in the blast-furnace production of high-silicon cast iron and in the production of various ferroalloys, and its high thermal stability made it possible to make use of the mineral in the production of heat-resistant and non-stick surfacings [7]. Further studies revealed more positive characteristics of shungite, i.e., reduction of the properties to chemically unstable substances and materials, adsorption and absorption properties, etc., including the ability of shungite to shield and absorb electromagnetic radiation [1]. This enabled shungite to be extensively used in various branches of industry and technology for a wide range of materials [2, 4, 5, 13].

**1. Material and methodology of the study.** Shungite from the indicated deposit [7], crushed into a finely dispersed phase and bound with a gypsum binder, calcium sulfate hydrate ($CaSO_4 \cdot 2H_2O$) [9, 10] (Table 1), was used as the foundation for the study.

Table 1

Chemical composition of shungite used in the study

| Chemical element or oxide | Proportion, mass % |
|---|---|
| C | 42 |
| $SiO_2$ | 43 |
| $TiO_2$ | 0.4 |
| $Al_2O_3$ | 5.3 |
| FeO | 0.83 |
| $Fe_2O_3$ | 1.53 |
| MgO | 1.13 |
| MnO | 0.16 |
| CaO | 0.55 |
| $K_2O$ | 1.3 |
| S | 1.4 |
| $H_2O$ | 2.4 |


**Fig. 1.** Measuring setup
based on R2M-18A/1 scalar network analyzer (1), attenuator (2) and measuring microwave cell (3)

A resonant microwave method with a hollow resonator was chosen [3] as a method sensitive to the absorption of electromagnetic energy. A scalar network analyzer R2M-18A/1 was used for the research. This device made it possible to measure the amount of absorption of electromagnetic energy that has passed through a layer of shungite-containing material. The measuring unit consists of R2M-18A/1 which scans in the frequency range of electromagnetic waves from 10 MHz to 20 GHz and measures the amount of energy transmitted through the measuring cell 3 where the object of measurement is located — shungite-containing material (Fig. 1). Due to the high absorption of electromagnetic waves of shungite in relation to gypsum, attenuator 2 was used [8].

In order to determine the effect of the binder concentration, thirty samples of absorbing material 10 mm thick from shungite and gypsum-based binder were made with a step of 10 %, three samples in a series.

**2. Theoretical foundation of the measurement process.** While measuring the absorption of electromagnetic energy in materials based on a mix or using a binder, it is necessary to consider the influence of the composition of the material. At the same time, some materials with low conductivity can be investigated in a transmitted wave (waveguide), for shungite in proportions with gypsum, a technique based on measuring the magnetic component of the electromagnetic field is required. The electromagnetic field of the radiator has the components = $\vec{H}_r$ and $\vec{H}_z$. The tangent component $\vec{H}_r = 0$ at $r = a$ where $a$ is the radius of the measuring cell. It is obvious that the module of the magnetic component $H_z$ takes the form

$$H_z = A \cdot J_0\left(\frac{3.832}{a} r\right)\sin\left(\frac{\pi}{l'} z\right),$$

where $J_0\left(\frac{3.832}{a} r\right)$ is the 1st zero-order Bessel function; $A$ is the amplitude of the disturbing field.

The power flux of a surface electromagnetic wave is equivalent to

$$\Pi_n = 0.5 Z_E \left|\vec{H}_z\right|^2, \tag{1}$$

where $Z_E$ is the wave resistance of the surface wave medium propagation; $H_z$ is the modulus of the magnetic component at $z = \Delta h$.

If the thickness of the investigated material layer is small $\left(\frac{\Delta h}{\lambda} \langle\langle 1\right)$ where $\lambda$ is the wavelength, only the wave of the main type propagates in the concentrating system, thus the wave resistance of the measured system is equal to

$$Z_E = W \cdot tg(k_1 \cdot \Delta h), \tag{2}$$

$$k_1 = \omega_0 \cdot \sqrt{\varepsilon_n \, \mu_0}, \tag{3}$$

where $\mu_0$ is the magnetic permeability of the surfacing; $W = \sqrt{\frac{\mu_0}{\varepsilon_n}}$; $\omega_0$ is the angular frequency.

At a small thickness of the layer $k_1 \cdot \Delta h \langle\langle 1$ considering (1)—(3) we get:

$$tg(k_1 \cdot \Delta h) \approx k_1 \cdot \Delta h . \quad (4)$$

Then the power of the radiation of the surface wave from the area $S = 2\pi a \Delta h$ is

$$P^n_{изл} = \Pi_n \cdot S = \pi a \mu_0 \omega_0 \Delta h^2 H_z^2 \quad (5)$$

and does not depend on $\varepsilon_n$ and is defined by the thickness $\Delta h$ of the investigated material.

As a contact material polyvinyl chloride (the relative dyelectric constant $\varepsilon_n = 3.2 \div 3.4$) was used with the thickness from 0.2 to 1.2 mm with small microwave losses. Hence for $\Delta h = 1$ mm, $\varepsilon_n = 3.4$ and $f_0 = 2701$ MHz — $k_1 \cdot \Delta h = 0.103 \langle\langle 1$, which proves the correctness of the expression (6).

The partial quality factor due to the influence of the leaking surface wave is thus equal to:

$$Q^n_{парц} = \omega_0 \cdot \frac{\frac{\mu_0}{2} \cdot \int\limits_V (H_z^2 + H_r^2) dV}{P^n_{изл}} = \omega_0 \cdot \frac{\mu_0 \cdot u_1}{2 \cdot P^n_{изл}}, \quad (6)$$

where $V$ is the volume of the measuring cell; $P^n_{изл} = \Pi_n \cdot S$. The coefficient $u_1$ is

$$u_1 = A^2 l' 2\pi a^2 J_0^2(3.832) \cdot (1 + \frac{\pi^2 a^2}{l'^2 \cdot 3.832^2}). \quad (7)$$

Ultimately the partial quality factor is

$$Q^n_{парц} = \frac{l'^3 a \cdot (1 + \frac{\pi^2 a^2}{l'^2 \cdot 3.832^2})}{4\pi^2 \Delta h^4}. \quad (8)$$

Identifying the microwave parameters of the measuring system enables one not only to improve the accuracy of measurements, but also to detect some patterns in the study of material based on shungite [8].

**3. Results of the study and their discussion.** Measurement of the power of an electromagnetic wave passing through shungite in a wide frequency range showed the presence of an absorption maximum in the range of 8—12 GHz (Fig. 2a). This absorption is due to the presence of carbon dispersion, multilayer fullerene-like rounded crystal structures 10—130 nm in diameter [7, 11, 12].

Under the same conditions, gypsum introduces an attenuation of 5—12 dBm (Fig. 2b). The studied shungite has a specific volume electrical resistance of about 3 ... 5 × $10^9$ Ohm/m and a specific surface electrical resistance of about $10^6$ Ohm/m which determines the ability to absorb electromagnetic energy of a wide frequency spectrum.

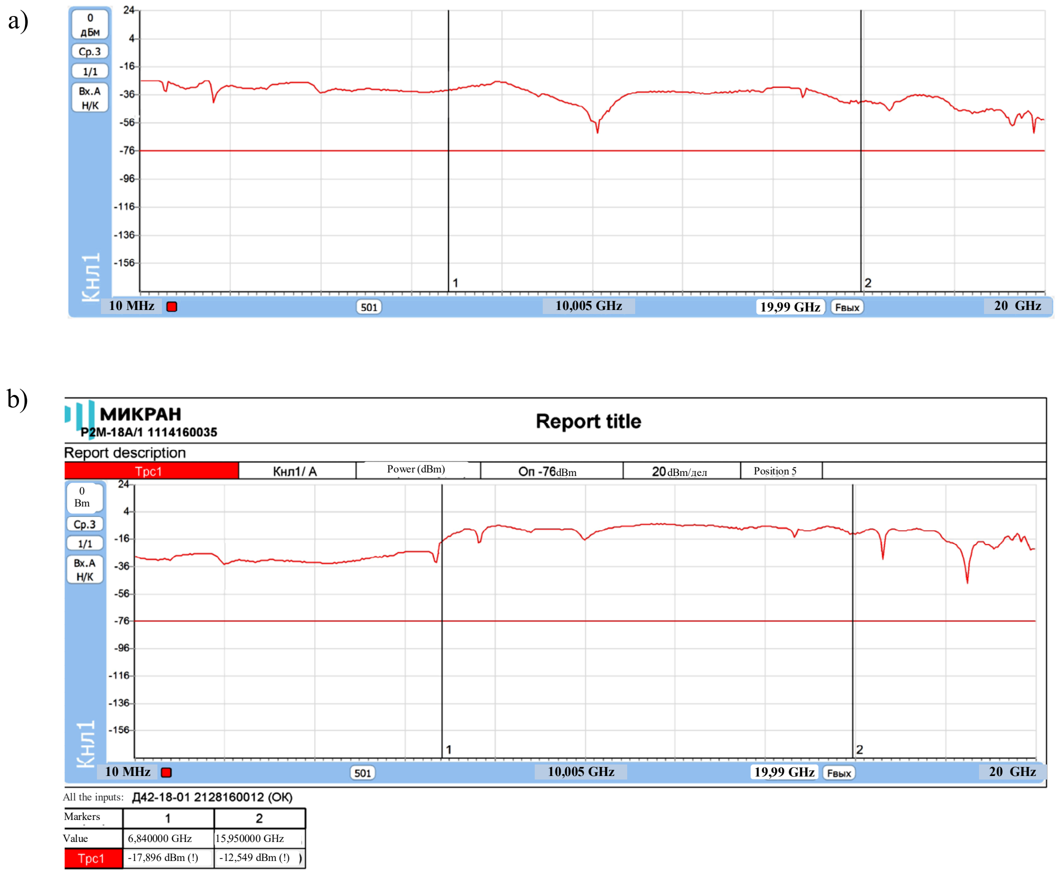


**Fig. 2.** Power of electromagnetic energy passed through shungite (a) and gypsum (b) (with respect to 0 dBm). Sample thickness — 10 mm

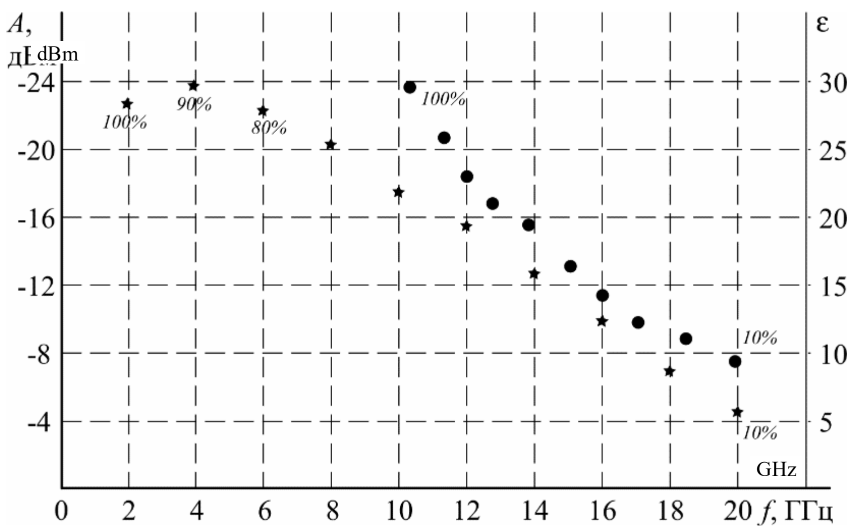


**Fig. 3.** Frequency dependence of electromagnetic wave absorption in the shielding material (circle) and permittivity (asterisk) at various concentrations of shungite

An analysis of the frequency dependence of the absorption of an electromagnetic wave in the shielding material (Fig. 3) showed that in the frequency range from 3 to 12 GHz there is an absorption maximum associated with the formation of bonds within the formed material. This suggests the possibility of using this material in places of high concentration of electromagnetic radiation (e.g., locations of operators of radar and control stations at airfields). The low reflectivity of the shielding material based on shungite and astringent gypsum enables an increase in the stealth of radio-observable military areas.

**Conclusions.** The impact of natural fullerene-like structures in shungite makes it promising to be used as a radio-absorbing material in places with a high density of electromagnetic fields that affect human health.

Shungite-containing materials are recommended for use as effective radio-absorbing materials, while the filler concentration affects both the absorption value from 18.7 dBm and the frequency notch associated with the binder ratio in the absorbing material. The most optimal ratio is 50—60 % shungite, the remainder is a binder, while the absorption frequency range is 3—12 GHz. By changing the concentration dependences, it is possible to achieve the maximum absorption in the desired or required range of electromagnetic waves.

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