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ABSORBERS OF ELECTROMAGNETIC RADIATION BASED ON SHUNGITE SPECIES

Abstract. In recent decades, the industries have experienced rapid development of various technologies directly or indirectly related to the emission of electromagnetic energy into the environment. The number of emitting technical means in production and in everyday life is increasing. At present, there are different ways, methods and materials to reduce the effects of electromagnetic radiation.

The properties of absorbers of electromagnetic radiation (EMR), formed on the basis of domestic natural material of shungite species from the deposit of the mining company "Koksu", Almaty region, are considered. The results of the interaction of EMR with samples of materials of absorbers and the dependence of the transmission coefficients on the angle of incidence of electromagnetic waves (EMW) in the frequency range 5.3-10.6 GHz are obtained. Research in these frequency ranges is crucial and relevant with the development and transition in the future of systems and mobile cellular networks of promising generations to higher radio frequency ranges. The use of powdered shungite for the creation of EMR absorbers in ultra-high-frequency radiation (UHFR) range has not yet been studied enough.

Technological values of the selected EMR absorbers in comparison with other geomaterials: strength of stone-like shungite species, high indicators of density (for example, 2.61 g/cm^3 – “TS” brand; 2.49 g/cm^3 – “TK” brand) and mechanical resistance, high thermal and chemical stability, low cost, good mixing with binders. The test samples provide a decrease of EMR level due to the presence of absorption effects.

Key words: ultra-high frequency, electromagnetic radiation, absorber of electromagnetic radiation, shungite, reflection and transmission coefficients.

Introduction. Human exposure to anthropogenic EMF has increased to unprecedented levels, accompanied by an increase in various health problems. The proliferation of cellular antennas and other RF-generating devices in recent decades has led to increasing concern about potential consequences of EMR exposure to human health [1].

The solution to these problems can be found by weakening the level of EMR generated by electronic equipment by using EMR absorbers. Today, various materials and methods are applied to protect against EMR [2-4].

An important task to be solved by this work was to study the absorption properties of domestic species of shungite of two brands - finely dispersed carbonate taurite "TK-D" and shale finely dispersed taurite "TS-D" in order to establish the most efficient EMR absorbers of this class.

The main processes that lead to the weakening of EMW in EMR absorbers are reflection, absorption and multiple re-reflection of EMW from the interfaces of dissimilar media inside multilayer structures. Moreover, in most cases, it becomes necessary to reduce the value of the reflection coefficient, which is implemented by such constructive solutions as multilayer structures, which can be a geometrically inhomogeneous structure with a gradient change in properties along the depth of the structure. The optimal version of the performance of wide-range EMR absorbers with reduced weight and size characteristics, not subject to corrosion, are structures based on carbon-containing fillers such as finely dispersed powdered shungite, fixed in a binder.

Shungite is a mineral of complex chemical composition with a carbon-silicate base represented by graphite-like globular carbon and silicon oxide, mainly in the form of quartz. Components such as silicon oxide and carbon usually have the largest share in the chemical composition of shungite. Other components of the mineral under consideration are oxides of aluminum, iron, titanium and some other elements, etc.

The trademarks of the Koksu shungite species "Taurit" are obtained by crushing and dry grinding operations that comply with the current regulatory requirements of the Kazakh company “GRK Koksu” LLP (ST 60-1907-23-TOO-001-2014). [5] When creating EMR absorbers in UHFR range, it is possible to use carbon-containing minerals shungite, the technological advantages of which are their low cost, chemical and thermal stability, good miscibility with binders, for which we used a silicone sealant.

The properties of shungite species are determined by two factors: properties of shungite carbon; the structure of the species and the relationship of carbon and silicates [5]. The complete chemical composition of two types of shungite from the Koksu deposit with the trademarks fine-dispersed carbonate taurite “TK-D” and fine-dispersed shale taurite “TS-D” are given in table 1 and table 2 respectively. Note that “TS-D” and “TK- D" represent a fine powder or granules from dark gray to black.

Table 1 – Chemical composition of fine- dispersed carbonate taurite "TK-D"

Determined components	C	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	TiO_2	K_2O	Na_2O
Content of components in %	7.0-15.0	30,0-55,0	9,36	1,44	4,83	9,41	0,89	2,19	0,40

Table 2 – Chemical composition of fine-dispersed shale taurite “TS-D”

Determined components	C	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	TiO_2
Content of components in %	4,0-8,0	72,0-85,0	0,35	0,67	3,67	12,8	0,78
Determined components	K_2O	Na_2O	MnO	P_2O_5	Co	Zn	Cu
Content %	2,0	0,25	0,014	<0,01	0,0025	0,006	0,001

Experimental part. Samples of materials based on shungite species, prepared for the experiment, were plates with a thickness of 3 mm and a size of 30*30 cm. The samples were sealed using a polymer film.

The experiment was carried out in November 2019 in the "Antenna-feeder devices" laboratory of the "Radio and mobile communications" department of Tashkent University of Information Technologies named after Mohammed Al-Khorezmi (Tashkent, Republic of Uzbekistan). An experimental setup was used, designed to study the phenomena of reflection and refraction of electromagnetic waves at the interfaces between media with different physical characteristics and reflection coefficient modules measurements as well as transmission of electromagnetic waves in the frequency range 5.3 ... 10.6 GHz.

The installation consists of a transmitting part, a receiving part, and a support on which plates based on shungite species are fixed (figure 1). The investigated shungite-based plate imitates the interface between two media.

The transmitting part of the antenna contains a UHFR generator (1) and a horn antenna (2) at a distance of 7-10 wavelengths from the horn antenna. Thus, a plane electromagnetic wave creates in a limited area of space. Falling at an angle φ onto the plate (7), depending on the material of the shungite plate and the type of polarization, the wave can:

a) be completely reflected;

b) partially pass through the plate and partially be reflected;

c) completely pass through the plate.

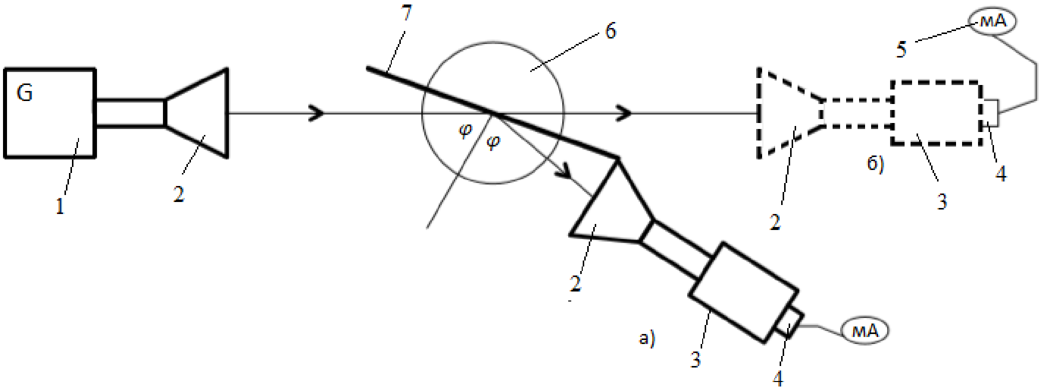

Figure 1 – Structural diagram of the measuring setup (1 - generator of UHFR range, 2 - horn antenna, 3 - variable attenuator, 4 - detector section, 5 - indicator device (microammeter), 6 - angle scale, 7 - investigated plate)

The receiving part consists of a horn antenna (2), a variable attenuator (3), a detector section (4) and a dial indicator (5). The variable attenuator is used to adjust the power supplied to the detector section from the horn antenna. The use of an attenuator allows avoiding the influence of the nonlinear characteristics of the detector on the measurement results.

The diode located in the detector section of UHFR rectifies the high frequency current. After rectification, the diode current is supplied to a DC microammeter (5). The receiving part of the installation is fixed on the platform that can move around a circle centered at point 0 (figure 1) and, consequently, can register both reflected (position a) and transmitted (position b) waves.

With direct connection of horn antennas (2) to the waveguide from the generator and the attenuator (3) in this installation, normal (relative to the plane of incidence of the wave) polarization is obtained. To obtain parallel polarization, the connection of horn antennas must be done through waveguide strands.

For experimental determination of the modules reflection coefficient and the transmission coefficient, an indirect method is applied by using a variable attenuator, graduated in decibels.

Reflection coefficient R – the ratio of the complex amplitudes of the electric field strengths of the reflected wave $\bar{E}^-$ and the incident wave $\bar{E}^\circ$, i.e.

$$R = \bar{E}^-/\bar{E}^\circ, \tag{1}$$

Transmission coefficient χ – the ratio of the complex amplitudes of the electric field strengths of the refraction of the wave $\bar{E}^-$ and the incident wave, $\bar{E}^\circ$ i.e.

$$\chi = \bar{E}^-/\bar{E}^\circ, \tag{2}$$

The reflection coefficient R and the *transmission coefficient* χ are generally complex quantities. Their modules characterize the ratio of the amplitudes of the corresponding waves, and the arguments characterize the phase shift between these fields at the interface.

Changing the weakening of the attenuator, achieving consistent microammeter readings, determine the ratio of the powers of the reflected and incident waves when determining the modulus of the reflection coefficient, and the ratio of the powers of the transmitted and incident waves when determining the modulus of the transmission coefficient.

When the receiving antenna is located in the field of the incident wave, the attenuation N_1 is introduced into the receiving path by the attenuator and the microammeter reading is recorded, which is about 5 μA. Then, by placing the antenna in the field of the reflected wave, the weakening of the attenuator is reduced to a value of N_2, at which the reading of the microammeter remains unchanged. The change in attenuation N_2-N_1 is equal to the ratio of the above powers, expressed in decibels. Since the power received by the antenna is proportional to the squares of the strengths of the corresponding electric fields, it can be written [6-7]:

$$N_2 - N_1 = 10lg\,|\bar{E}^-/\bar{E}^\circ|^2 = 20lg\,|\bar{E}^-/\bar{E}^\circ|, \tag{3}$$

where $\bar{E}^\circ$ - vector of the electric field strength of the incident wave, perpendicular to the direction of propagation. $\bar{E}^-$ - vector of reflected wave. In general case, $\bar{E}^\circ$ can be located in different ways relative to the plane of incidence and can always be represented as the sum of two mutually perpendicular vectors, therefore it is sufficient to consider two cases: vector $\bar{E}^\circ$ lies in the plane of incidence of the wave and wave $\bar{E}^\circ$ is perpendicular to the plane of incidence of the wave.

Hence, the modulus of the reflection coefficient is [6-7]:

$$|R_{\text{сл}}| = 10^{(N_2-N_1)/20} \tag{4}$$

The determination of the value of the transmission coefficient is carried out in the same way, and the modulus of the transmission coefficient is calculated by the formula

$$|\chi_{\text{сл}}| = 10^{(N_3-N_1)/20} \tag{5}$$

Experiment results. The tables 3.1-3.3 show the results of an experimental study in the absence of a media interface (without a sample), and when using sample plates based on finely dispersed powdered shungite of two brands - "TK-D", "TS-D".

At an oblique incidence of a plane electromagnetic wave to the interface between two media, it is sufficient to consider only two cases - normal and parallel polarization. Set the normal polarization of the incident wave. In this case, the vector $\bar{E}$ of the emitted wave should be perpendicular to the plane of incidence of the wave and the base of the laboratory model.

Table 3.1 – Experimental results in the absence of a sample

Incident wave polarization - normal				
Angle of wave incidence φ	Attenuation value N_1	Attenuation value N_2	Transmission coefficient	Reflection coefficient module
angle	dB	dB	–	–
20°	26,75	25,3	0,846	0,16
30°	26,75	24,8	0,799	0,3
40°	26,75	24,4	0,763	0,24
50°	26,75	22,6	0,620	0,38
60°	26,75	19,8	0,449	0,56
70°	26,75	3,8	0,171	0,929

Table 3.2 – The experimental results for a sample of a plate made of carbonate taurite "TK-D"

Incident wave polarization - normal				
Angle of wave incidence φ	Attenuation value N_1	Attenuation value N_2	Transmission coefficient	Reflection coefficient module
angle	dB	dB	–	–
20°	26,75	19	0,410	0,6
30°	26,75	17,8	0,357	0,65
40°	26,75	15,8	0,283	0,72
50°	26,75	14,2	0,236	0,77
60°	26,75	9,3	0,134	0,87
70°	26,75	4,5	0,077	0,923

Table 3.3 – The experimental results for a plate sample made of shale taurite "TS-D"

Incident wave polarization - normal				
Angle of wave incidence φ	Angle of wave incidence φ	Angle of wave incidence φ	Angle of wave incidence φ	Angle of wave incidence φ
angle	dB	dB	–	–
20°	26,75	21	0,516	0,49
30°	26,75	19,4	0,429	0,58
40 °	26,75	18	0,365	0,64
50°	26,75	14,7	0,250	0,76
60 °	26,75	11,5	0,173	0,83
70 °	26,75	5,3	0,085	0,92

As it can be seen from tables 3.2-3.3, the studied composites based on shungite species, namely shale taurite and carbonate taurite, can reduce the EMR level by an average of almost 2 times. Thus, a significant decrease in the coefficient for two samples of shungite has been established in comparison with the experiment "Without sample". The most effective weakening of EMR seen by the sample of carbonate taurite compared to shale taurite. But also, the sample "shale taurite" can be effectively used to quench the EMR level. The studies performed allow us to conclude that a composite material based on domestic shungite species has the ability to significantly attenuate electromagnetic waves in the UHFR range (figure 2).

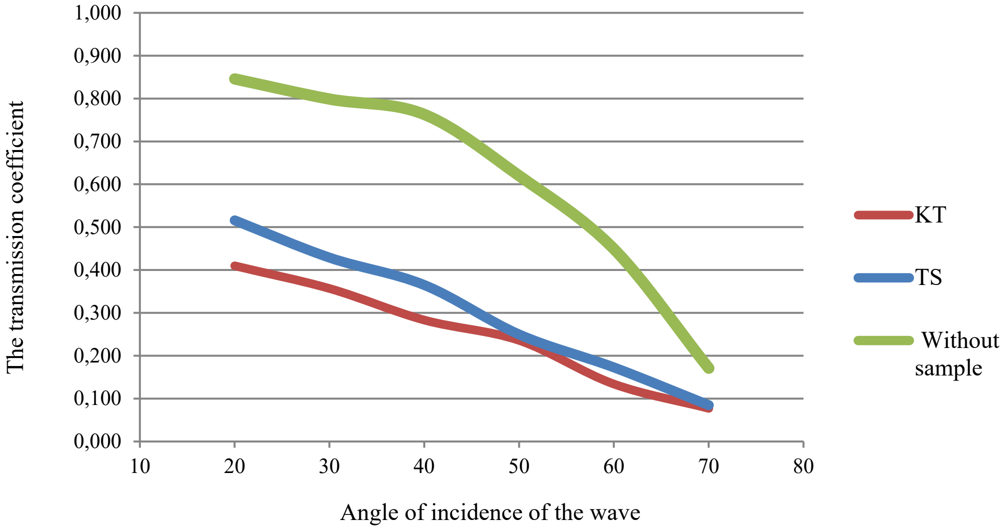

Figure 2 – Dependence of the transmission coefficient on the angle of incidence of the wave CT - carbonate taurite "TK-D"; ST - shale taurite “TS-D

Conclusion.

1. Composites based on shungite are able to withstand EMR attenuation in UHFR range.

2. A comparative analysis of the test samples has been carried out. The maximum attenuation is provided by a sample based on “TK-D” carbonate taurite. In the entire measured range, a change in the absorption coefficient is observed depending on the angle of incidence of electromagnetic waves on the examined object. The greater the degree of incidence, the lower the wave transmission coefficient. Experimental studies have shown that the level of negative radiation / effects of electromagnetic fields (EMF) when using materials based on shungite decreases, but is not completely neutralized. However, the obtained result can be considered effective, since when using plates based on shungite species, the level of EMR is significantly reduced, which negatively affects a person.

3. Taking into account the characteristics of taurite shungite species in UHFR range and the ability of these materials, separately or as part of composites, to weaken the EMR at UHFR, it is possible to create domestic wide-range EMR absorbers with controllable characteristics (for example, by selecting the type and concentration of the filler, binder, the order of alternation of layers with different electrical conductivities, and etc.), with predetermined values of the transmission and reflection coefficients.

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ШУНГИТ ТЕГІНЕ НЕГІЗДЕЛГЕН ЭЛЕКТРМАГНИТТІ СӘУЛЕЛЕНУ ЖҰТҚЫШТАРЫ

Аннотация. Соңғы онжылдықтарда салалар қоршаған ортаға электромагниттік энергия шығарумен тікелей немесе жанама байланысты әртүрлі технологиялардың қарқынды дамуын бастан кешіруде. Өндірісте және күнделікті өмірде эмиссиялық техникалық құралдардың саны артып келеді. Қазіргі уақытта электромагниттік сәулеленудің әсерін төмендетудің әртүрлі әдістері, әдістері мен материалдары бар.

Алматы облысы «Көксу» тау-кен компаниясының кен орындарынан алынған табиғи отандық шунгиттекті материал негізінде құрастырылған электрмагнитті сәулеленуді жұтқыш қасиеттерін қарастырамыз. ЭМӨ-нің сіңіргіш материалдар үлгілерімен өзара әрекеттесу нәтижелері және өткізу коэффициенттерінің 5,3-10,6 ГГц жиілік диапазонындағы электромагниттік толқындардың (ЭМҮ) құлау бұрышына тәуелділігі алынды. Жиліктің бұл дипазонында зерттеу өте маңызды және өзекті, өйткені келесі сатыдағы мобильді ұялы байланыс жүйелері мен желілері дамып, болашақта жоғары жиіліктік диапазондарға ауысуына байланысты болады. Ұнтақты шунгитті аса жоғары жиілік диапазонында электрмагнитті сәулеленудің жұтқыштары ретінде пайдалану жолдары әлі толық зерттелмеген.

Басқа геоматериалдармен салыстырғанда таңдалған электрмагнитті сәулелену жұтқыштарының технологиялық артықшылықтары мынадай: тас тәрізді шунгит тегінің беріктігі, жоғары тығыздық көрсеткіштері (мысалы, 2,61 г/ см^3 – марка «ТС» маркасына; 2,49 г/см^3 – «ТК» маркасына) және механикалық төзімділігі, жоғары термиялық және химиялық тұрақтылығы, бағасының арзан болуы, байланыстырғыштармен жақсы араласуы. Зерттелетін үлгілер жұту эффектінің болуына қарай электрмагнитті сәулелену деңгейінің төмендеуін қамтамасыз етеді.

Түйін сөздер: аса жоғары жиілік, электр магниттік сәулелену, электрмагнитті сәулеленуді жұтқыштар, шунгит, шағылысу және өту коэффициенттері.

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ПОГЛОТИТЕЛИ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ НА ОСНОВЕ ШУНГИТОВЫХ ПОРОД

Аннотация. В последние десятилетия отрасли промышленности переживают бурное развитие различных технологий, прямо или косвенно связанных с излучением электромагнитной энергии в окружающую среду. Увеличивается количество эмиссионных технических средств в производстве и в быту. В настоящее время существуют различные способы, методы и материалы для снижения воздействия электромагнитного излучения.

Рассмотрены свойства поглотителей электромагнитного излучения (ЭМИ), сформированных на основе отечественного природного материала шунгитовых пород месторождения горнорудной компании "Коксу" Алматинской области. Получены результаты взаимодействия ЭМИ с образцами материалов поглотителей и зависимость коэффициентов пропускания от угла падения электромагнитных волн (ЭМВ) в диапазоне частот 5,3-10,6 ГГц. Исследования в этих частотных диапазонах имеют решающее значение и актуальны при разработке и переходе в будущем систем и мобильных сотовых сетей перспективных поколений на более высокие радиочастотные диапазоны. Применение порошкообразного шунгита для создания поглотителей ЭМИ в диапазоне сверхвысокочастотного излучения (УВЧ) до сих пор изучено недостаточно.

Технологические значения выбранных поглотителей ЭМИ по сравнению с другими геоматериалами: прочность камнеподобных пород шунгита, высокие показатели плотности (например, 2,61 г / см3 – марка “ТС"; 2,49 г / см3 – марка “ТК”) и механической стойкости, высокая термическая и химическая стабильность, низкая стоимость, хорошее смешивание со связующими. Исследуемые образцы обеспечивают снижение уровня ЭМИ за счет наличия эффектов поглощения.

Ключевые слова: сверхвысокая частота, электромагнитные излучения, поглотитель электромагнитных излучений, шунгит, коэффициенты отражения и прохождения.

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