ФИЗИКА И АСТРОНОМИЯ

CALCULATION OF THE ROUTES OF THE SPREADING RADIO WAVES WITH ACCOUNT ELECTROPHYSICAL PARAMETERS LAYING UNDER SURFACES

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Abstract. Considered model of the spreading radio waves with account electrophysical parameters under lying surfaces. Represented calculations of the loss function module for different radio routes.

Keywords: function of the losses, fields of the terrestrial waves, electrophysical parameters underlying surface

Ensure by reliable communication with objects, residing on average and greater distances, requires an installation of the intermediate radio stations, which together with communication link, form the network. Radio stations are situated on significant distances one from one so for ensuring reliable communication follows to take into account the radio signal losses depending on morphological and electrophysical parameters routes of the spreading radio signals.

In figure 1 is brought card of the territory Russian Federation (RF) and adjoining region (the Morgan chart). Through these territories occur the radio signal transfer. Surface radio waves spread in close proximity surfaces of the land, but exercised by them absorption is defined by electrophysical parameters of ground, i.e., values of permeability ε and conductivity σ [1].

Electrophysical parameters different type surfaces were presented in table 1 [2]. In the last column are brought values of the frequencies, under which the current density of the offset is equal to the conductivity current density. The most influence upon parameters extreme right column renders conductivity laying under surfaces, which most for sea water. . In accordance with that maximum values reach under this frequencies

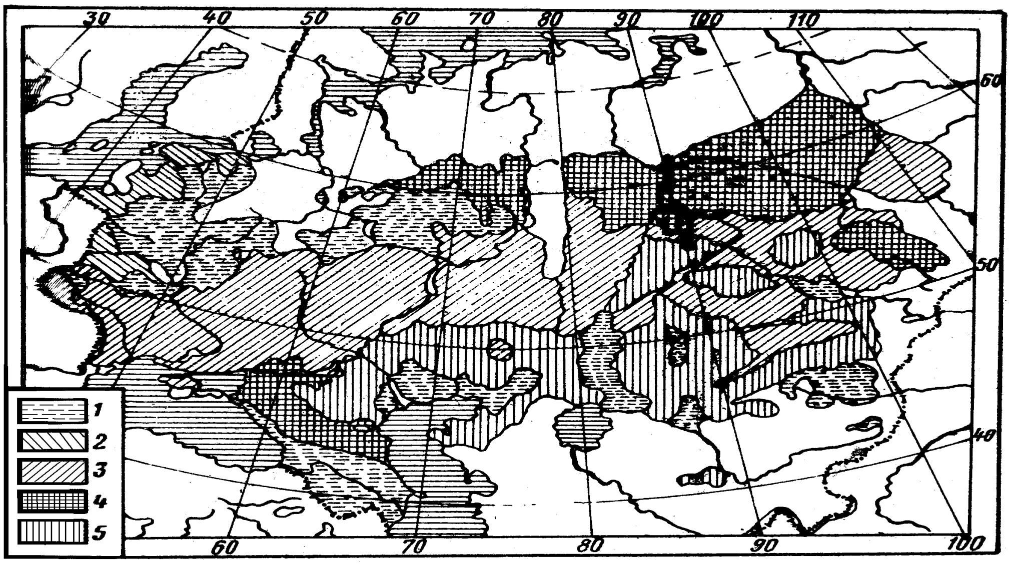

Fig. 1. Distribution to conductivities of ground RF and close territories, where numeral is marked: 1 – 5…20 mmho/m; 2 –30…40 mmho/m; 3 – 40…50 mmho/m; 4 – 50…70 mmho/m; 5 – 70… 90 mmho/m.

Table 1

VALUES OF ε AND σ FOR DIFFERENT SURFACE TYPES

Type of surface	ε_r	σ, mho/m	Frequency, under which $\varepsilon_r = 60\lambda\sigma$, MHz
Sea water	80	4…5	900…1125
Fresh water	80	0.001…0.01	0.225…2.25
Very humid ground	30	0.005…0.02	3…12
Average ground	15	0.0005…0.005	0.6…6
Arctic ground	15	0.0005	0.6
Very dry ground	3	0.00005…0.0005	0.3…0.6
Polar ice	3	0.000025	0.15

As can be seen from figure 1 it is enough extensive territory RF has a close electrophysical parameters that allows to produce the estimation of the radio signal loss on comparatively greater distances.

Radio signal loss W is defined by formula [1]

$$W = 10\ \lg(P_u/P_n), \tag{1}$$

where $P_u = I^2R$ – a power of radiated radio signal (I – an antenna current, R – a resistance of the radiating antenna); P_n – a power of radio signal in point acceptance, depending from efficient antenna length l and its resistance R.

Substituting parameters sending and receiving antennas, formula (1) may present as

$$W = 20\,lg\left(\frac{2I\cdot R_0}{l\cdot E_n}\right), \tag{2}$$

where $R_0 = 80(\pi/\lambda_0)^2$ – an antenna radiation resistance in free space; l – an efficient length receiving antenna; En – an electric field in acceptance point; λ_0 – a radio signal wavelength.

An electric field in an acceptance point is determined as

$$E_n = \frac{60Il}{n^2-1}\frac{e^{-ikL}}{L^2}, \tag{3}$$

where $i = \sqrt{-1}$ – imaginary unit; $n^2 = \varepsilon_1 - i \cdot 60\sigma_1\lambda_0$ – a square of the refraction factor of the imperfectly conducting ground; L – a radio signal route length, km; ε_1 – relative permeability of the layer under surfaces; λ_0 – a radio signal wavelength, m; l – an efficient antenna length, m.

The radio wave loss depends on distance L and laying under surface parameters ε_1 and σ_1. Substituting formula (3) in expression (2), we get

$$W(f,L) = 20\,lg\left[\frac{8\pi^2\left|\varepsilon_r - 1 - i\cdot 0{,}6\cdot 10^4\sigma/f\right|}{3}\left(\frac{Lf}{300}\right)^2\right]. \tag{4}$$

In figure 2 it is shown the influence these parameters on function of the losses for distance L=500 km for different laying under surfaces.

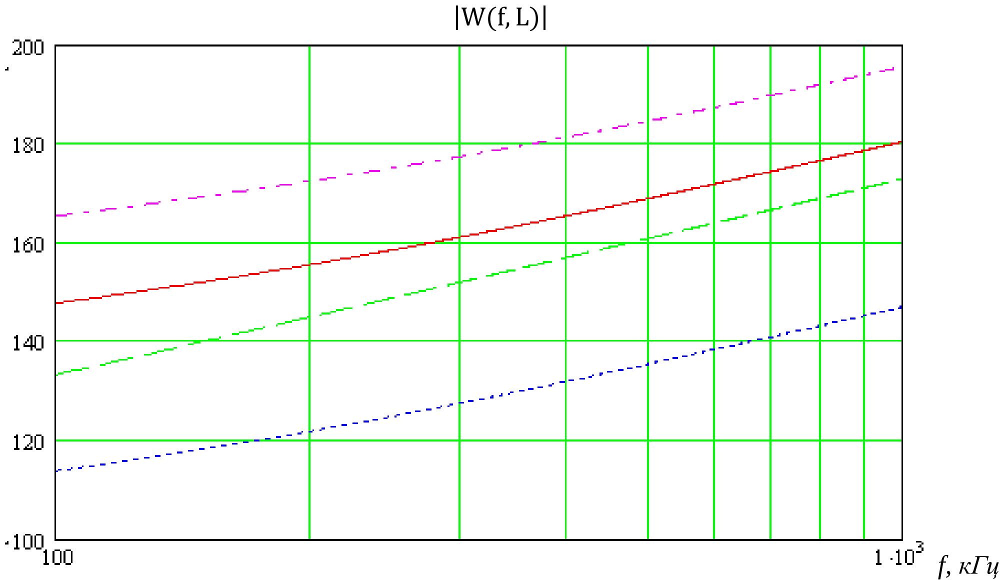

Fig. 2. The loss function W versus frequency f for distance 500 km between receiver and transmitter when radio wave spreading: 1) on Arctic ground (ε = 15, σ = 0.5, mmho/m) (the solid line); 2) on forest array ε = 1.3, σ = 0.01 mmho/m) (the dotted line); 3) on icy fields (ε = 7, σ = 0.03 mmho/m) (the hatching line); 4) on sea surface (ε = 80, σ = 4 mmho/m) (the hatch-dotted line)

Curves (fig. 2) have shown that the radio signal level losses when it spreading on woodland in frequency range 200…600 kHz on 19…21 Db less, than on naked ground. However, for lays under surfaces, saturated by water, on low frequency function losses W, computable on formula (4), gives uprated values.

Electrophysical parameters of surfaces, saturated by water, depend on frequency of the spreading radio signal. In the first place different materials content affects on this. On figure 3 are brought datas for conduction water solution for different concentration of the solutes [3].

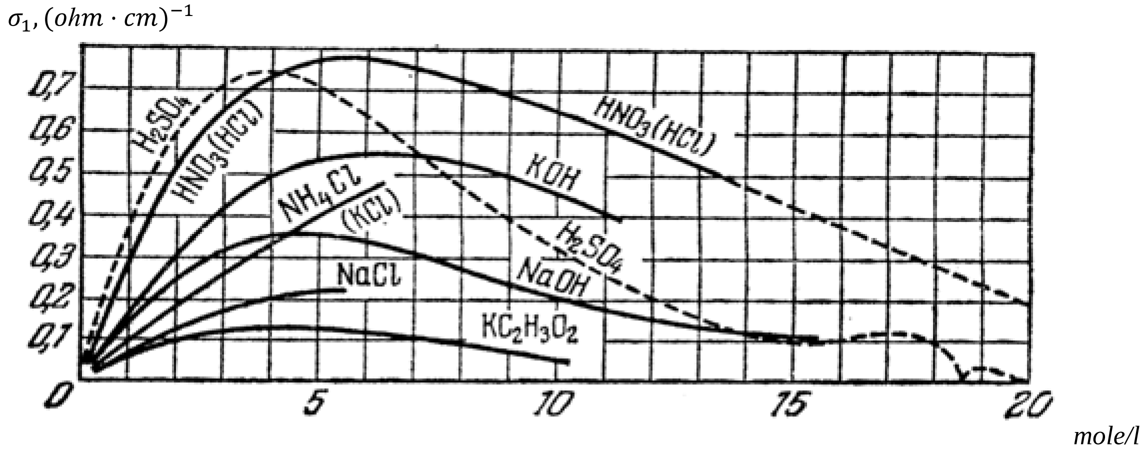

Fig. 3. Conductivity of water solutions versus concentrations of the solutes

The given curves of fig. 3 show that conduction different water solution by complex image depends on concentrations of the solutes. Depending on radio signal frequencies, spreading on water surface, exists additional change an electrophysical parameter required for calculation of the radio signal weakening.

For instance, average importance saltiness of sea water is taken equal 35 %% that forms 0,6 mole/l in recalculation on concentration NaCl, which molecular weight equals 58.5. In water solution salt NaCl disintegrates on two ions of the opposite sign. Consequently, possible consider that concentration of salts in sea water equals to 0.6 mol/l. Similarly it is possible to define the concentrations water solution other material.

Well known [4], that at passing радиосигнала in water solution of the electrolyte is directed polarization potential *Δφ*, which is defined by formula [4]:

$$\Delta\phi = \left(\frac{R_u T}{nF}\right) ln\left(\frac{c_s}{c_0}\right), \qquad (5)$$

where R_u = 8,314 Joul/(K·mole) – an universal gas constant; F = 96485 Coul/mole – the Faraday constant; c_0 – a balance concentration of the electrolyte, mole/l; c_s – a concentration of the electrolyte under influence of radio signal, mole/l; m – a number of ions, participating in elementary act.

Marking through $\Delta c_s = c_s - c_0$ detour from the balance concentrations of the water solution, we get the necessary formula [3]:

$$\Delta c_s = mFc_0\Delta\phi/R_\Gamma T. \qquad (6)$$

Δc_s is possible to define, solving diffusion equation

$$\partial\Delta c_s/\partial t = D\partial^2\Delta c_s/\partial x^2, \qquad (7)$$

where x – a coordinate along line of the radio signal spreading; D – an ion diffusion factor.

Border conditions for decision of the equation (4) possible present in the manner of

$$j = -nFD \ \ (\partial c_s/\partial x)_{x=0}, \Delta c_s|_{x\to\infty} = 0, \qquad (8)$$

where j – the current density in the point with coordinate x.

Presenting a potential in the manner of $\Delta\phi = \Psi\, exp(\, i\omega t)$, but current as $j = I\cdot exp(\, i\omega t)$, that decision of the equation (4) may present as

$$\Delta c_s = I/(mF\sqrt{i\omega D}), \qquad (9)$$

where $\omega = 2\pi a$ – a circular frequency.

Equating left parts of the expressions (6) and (9), we get

$$\Psi = I\cdot RT/(mFc_0\sqrt{i\omega D}.) \qquad (10)$$

From the last expression not difficult to go to conductivity of the water solution $\sigma(\omega)$

$$\sigma(\omega) = \alpha\sqrt{j\omega D}. = \frac{\alpha}{2}\sqrt{\omega D}(1+i), \qquad (11)$$

where α – some factor .

The exact value of the factor α depends on some electrophysical parameters of the water solution that vastly complicates its determination. However exists the simple practical way of the determination parameter formula (8) if address to data of a table 1. Searching conductivity of the water solution $\sigma(\omega)$ is defined as

$$\sigma(\omega) = \sqrt{\frac{\omega\cdot\varepsilon_r\cdot\sigma}{36\pi\cdot10^6}}, \qquad (12)$$

where parameters σ and ε_r are chosen from table 1.

The formula (9) presents depending on angular frequency $f = \omega/(2\pi)$

$$\sigma(f) = \sqrt{\frac{f\cdot\sigma\cdot\varepsilon_r}{1{,}8\cdot10^7}}. \qquad (13)$$

Substituting expression (13) in formula (4), we get.

$$W_1(f,L) = 20\,lg\left[\frac{8\pi^2\left|\varepsilon_r-1-i\cdot\sqrt{\frac{2\sigma\varepsilon_r}{f}}\right|}{3}\left(\frac{Lf}{300}\right)^2\right]. \qquad (14)$$

The formula (14) shows that on low frequency the loss function for sea water has values smaller, than in formula (4). This is confirmed in figure 4, where solid line corresponds to the formula (4), but dotted line – to the formula (14). On radio frequency curves meet, but on low frequency noticeably divergence. On frequency 100 kHz, for instance, function of the losses on 10 db has smaller values, as evidenced by in practice.

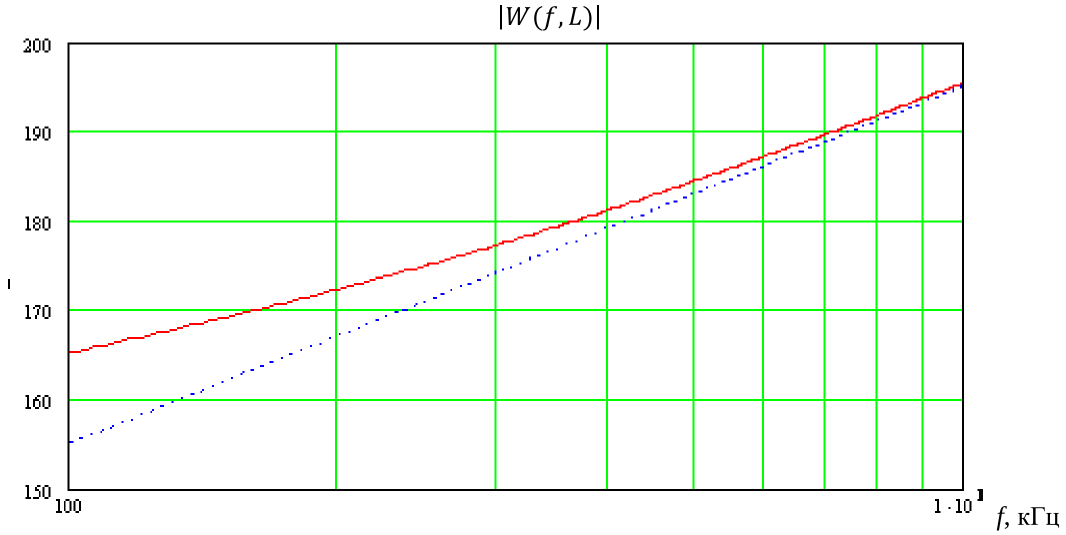

Fig. 4. The loss function *W1* versus frequencies f on distance 500 km between receiver and transmitter when spreading: 1) on sea surface (ε = 80,σ = 4 mho/m) (the solid line) according to formula (4); 2) on sea surface (ε = 80,σ = 4 mho/m) (the dotted line) according to formula (14).

The formula (14) generalises the approach to estimation of the losses on different радиотрассах that vastly raises accuracy a calculation. She shows that on low frequency function losses W1 gives values close to average statistical. The Formula (4) provides sufficient accuracy of the determination to functions of the losses when spreading радиоволн on terrestrial surface, possessing low conductivity. For instance, is confirmed reduction to functions of the losses W when spreading radio signal on woodland. The known formula of Austin [1] exact for routes by length 2000 … 10000 km. Formula (14) allows more exactly define the level an радиосигнала when spreading on terrestrial layer for small distances (100 km and more) in contrast with Austin formula.

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PANORAMIC SENSOR TARGET DETECTION AND DESTRUCTION OF ENEMY ON MODULATED LASER BEAM IN 3D-SPACE “LADOGA-1M”

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Abstract. The article is devoted to solving the urgent task of improving the performance and accuracy of bearing, detecting target and destroying potential enemy. **Objective:** to develop technologically simple and reliable optical-laser method of direction finding, target detection and destruction of enemy by modulated laser beam of guidance in 3D-space by crews of armored vehicles, aircraft, helicopters, surface ships and submarines in radio silence mode using semiconductor laser diode or solid-state laser pumped by laser diode.

Аннотация. Статья посвящена решению актуальной задачи повышения производительности и точности пеленга, обнаружения цели и уничтожения потенциального противника. **Цель работы —** разработка технологически простого и надёжного оптически-лазерного способа пеленгации, обнаружения цели и уничтожения противника по модулированному лазерному лучу наведения в 3D-пространстве экипажами бронетехники, самолётов, вертолётов, надводных кораблей и подводных лодок в режиме радиомолчания с применением полупроводникового лазерного диода или твёрдотельного лазера с накачкой лазерным диодом.

Key words: sensor; panoramic detection; destruction of the enemy; telescopic target coverage angle; irradiation; modulated laser beam; optical range; radio silence mode; semiconductor laser diode; solid-state laser pumped by laser diode; photon; electromagnetic wave; photo-sensor; phototransistor matrix; laser radiation; wavelength; signal frequency.

Ключевые слова: датчик; панорамное обнаружение; уничтожение противника; телескопический угол охвата цели; облучение; модулированный лазерный луч; оптический диапазон; режим радиомолчания; полупроводниковый лазерный диод; твёрдотельный лазер с накачкой лазерным диодом; фотон; электромагнитная волна; фотодатчик; фототранзисторная матрица; лазерное излучение; длина волны; частота сигнала.