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An alternative theoretical model of the Earth's EM field based on two-component field hypotheses

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Abstract:

Introduction/purpose: The paper describes an alternative theoretical model of the Earth's EM field based on two-component field hypotheses. The paper consists of several parts, one part of which is a model showing the rotation of the magnetically conducting sphere of magnetization M in a foreign magnetic field. The last part defines theoretical models for the calculation of the components of the electromagnetic field of electrically conductive, dielectric and magnetically conductive spheres which are exposed to the influence of a foreign electromagnetic field.

Methods: In the work, the responses of electrically conductive, dielectric and magnetically conductive spheres to the influence of external EM fields were investigated using the analytical method.

Results: The obtained solutions in the form of analytical formulas will be applied to research the impact of the Sun's EM field on the planets and especially on the Earth.

Conclusion: The resulting formulas of the electric and magnetic field strength and induction and their solutions can be applied to electrically conductive, dielectric and magnetically conductive spheres. In comparison to already known formulas, they are simple and have higher accuracy.

Key words: theory, model, electromagnetism, components, spheres, rotation, magnetic field.

Introduction

Since the Earth's magnetic field protects life on Earth from the effects of cosmic particles, the weakening of the field reduces protection. In astrophysics, the Earth's magnetic field is defined as a physical field created and maintained by the rotation of charged magma in the nucleus (dynamo theory) (Jacobs, 1987). The axis of the magnetic poles moves towards the geographical axis but there is no real explanation for the phenomenon. In 2019, magnetic lines of force entered the northern magnetic pole in part of the Arctic soil in Canada, and the position of the pole moved towards Siberia at a speed of 55 km/year. F. Laimorver (University of Leeds) says that the location of the North Magnetic Pole oscillates between two magnetic fields between Canada and Siberia and is currently dominated by the Siberian field. Although field disturbances are not considered a cataclysm, bird and fish deaths in Arkansas in 2011 were explained by their sensitivity to gender shifts. Changes in the location of the magnetic poles occur every 250,000 years. The N-magnetic pole is moving towards Siberia due to the movement of larger masses of waterway between the Arctic and Siberia, with small but influential charges (Bjelić, 2021a).

The vectors of the electric field of solar waves are a sign that components of the Earth's EM field are just a response to Sun's EM waves. The Van Allen radiation belt is a zone of charged particles, created by the solar wind, cosmic rays and particles, and the magnetic fields of the planet, no matter how they are created, keep them. The planet Earth has 2 main Van Allen (VA) bands at 640-58000 km above the ground and radiation levels vary. VA probes discovered the third one (lasted 4 weeks until it was destroyed by the interplanetary wave of the Sun). The hypothesis of 2 magnetic fields (Canada, Siberia) is controversial because in the same part of space there can only be a resultant field. The sun's rays bring particles to Earth (ionized) and propagate through the atmosphere like EM waves (non-ionized part).

Electric and magnetic field and the postulate of amplitude attenuation from the kinetic theory of gases

The division of the Earth's EM field into electric and magnetic components is relative because static loads create the electric field component and their displacement the magnetic field component, Figure 1.

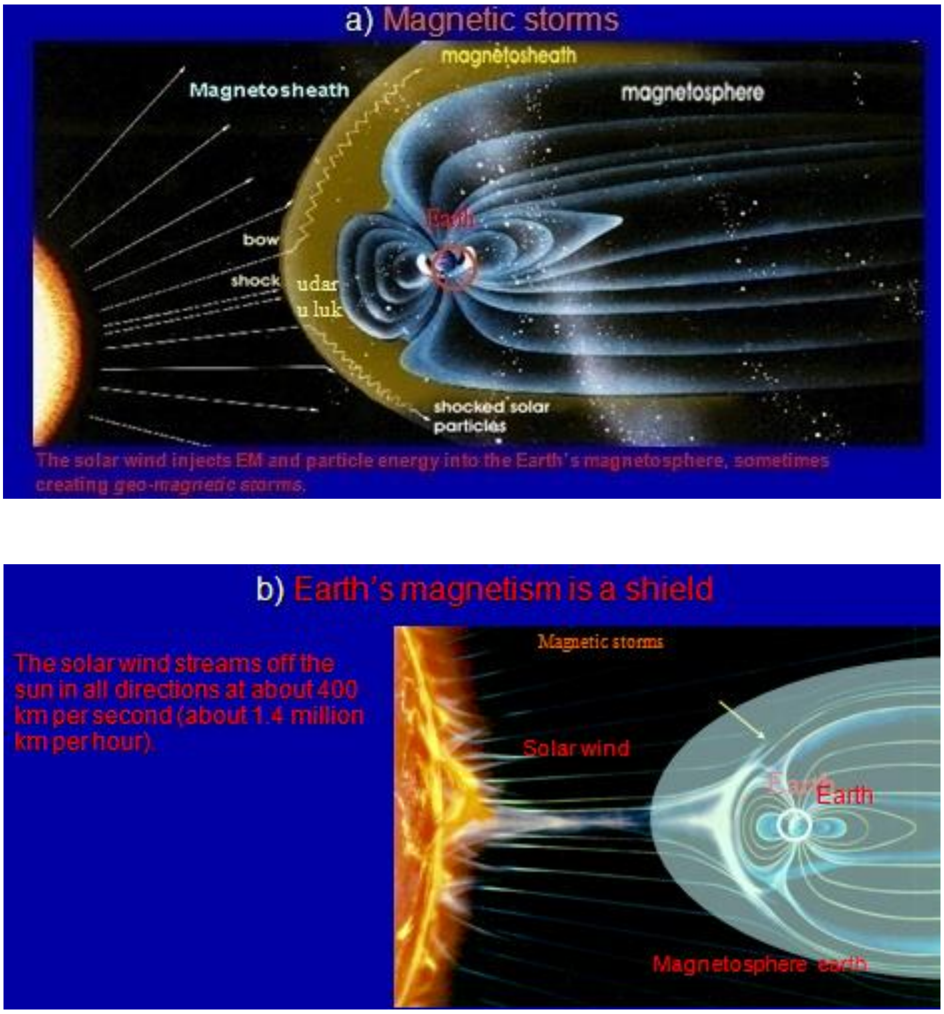

Figure 1 – a) Solar wind brings EM energy into the Earth's magnetosphere and creates geomagnetic storms, b) The Sun does not support permanent radiation belts because it does not have a stable, global dipole EM field (Bjelić, 2021b)

Рис 1 – а) Солнечный ветер приносит электромагнитную энергию в магнитосферу Земли и создает геомагнитные бури, б) Солнце не поддерживает постоянные радиационные пояса, поскольку у него нет стабильного глобального дипольного ЭМ поля (Bjelić, 2021b)

Слика 1 – а) Соларни ветар уноси ЕМ енергију у магнетосферу Земље и ствара геомагнетне олује, б) Сунце не подржава трајне појасеве зрачења јер нема стабилно, глобално диполно ЕМ поље (Bjelić, 2021b)

In the vicinity of stationary charge carriers, there is only a component of the electric field, and the moving carrier creates a component of the magnetic field. At EM wave velocities much lower than the light velocity, $v << c$ changing the coordinate system does not change ratios of electric and magnetic field strengths at the same load distribution or for the same currents: field components have the same relationship defined in any mathematical space coordinate system (Mihajlović, 1993).

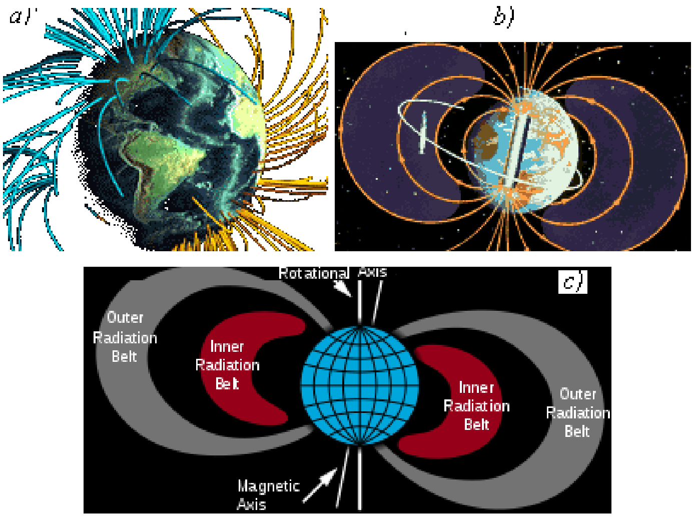

Figure 2 – Earth's magnetic field: a) line of the Earth's field, b) line of the magnetic field with respect to the rotation, c) belts of Van Allen radiation rings, red-inner, gray-outer radiation belt (Bjelić, 2021b)
Рис 2 – Магнитное поле Земли: а) силовые линии Земли, б) силовые линии магнитного поля по отношению к направлению вращения, в) радиационный пояс Ван Аллена, красная-внутренняя, серая-внешняя полоса излучения (Bjelić, 2021b)
Слика 2 – Магнетно поље Земље: а) линије поља Земље, б) линија магнетног поља у односу на смер ротације, в) појасеви Ван Аленових прстенова радијације: црвени – унутрашњи, сиви – спољни појас радијације (Bjelić, 2021b)

The parameters ε_a , μ_a , σ (dielectric, magnetic and specific electrical parameters) at each point of space where the EM field acts connect two pairs of vectors (Lamb, 1883a; Prodanović, 2006):

$$\varepsilon_a = \varepsilon_0 \varepsilon_r \, , \; \varepsilon_0 = 8.854 \cdot 10^{-12} \text{ F/m}, \; \vec{D} = \varepsilon_a \vec{E} \text{ F/m}, \quad (1)$$

$$\mu_a = \mu_0 \mu_r \, , \; \mu_0 = 1.256 \times 10^{-7} \text{ H/m}, \; \vec{B} = \mu_a \vec{H} \text{ H/m}, \quad (2)$$

$$\sigma = \text{ Sm}, \; \rho = \sigma^{-1} \; \Omega\text{/m}, \; \vec{J} = \sigma \cdot \vec{E} \text{ Sm } \Omega\text{/m}, \quad (3)$$

where $\vec{D}$ is electrostatic induction, $\vec{E}$ is electric field strength, $\vec{B}$ is magnetic induction, $\vec{H}$ is field strength, and $\vec{J}$ is current density.

Under normal conditions, the parameters of the media are constant scalar values, and the media are linear and isotropic. As the field strength increases, the linearity may be disturbed, the mean becomes nonlinear, and the parameters depend on the field strength. In anisotropic media, the relations between pairs of vectors depend on orientations and are not parallel, and asymmetric tensors $\|\varepsilon_a\|$, $\|\mu_a\|$, $\|\sigma\|$, are used to describe the medium. The medium is homogeneous if these parameters are the same at all points of the EM field and inhomogeneous if they are different.

In equation (1,2,3) the pairs of vectors $\vec{D}$, $\vec{E}$, $\vec{B}$, $\vec{H}$ and $\vec{J}$ are collinear and the values are linearly dependent. For the analysis of EM fields on the ground and in higher layers of the Earth's space, alternative models are:

- electrostatic system: solid sphere and outer layers with charge carriers (ionosphere),
- electrostatic and magnetic dipole which can create the electric and magnetic components of the EM field,
- elementary resonator of the electric component of the EM field, as suggested by Tesla,
- planet – a body that rotates under the action of forces created by the components of the EM field.

EM waves of a foreign source (the Sun) penetrating the ionosphere bring ions (electrons) in that layer into a state of forced oscillations and by means of an electric field transfer to electrons part of their energy which passes into kinetic energy of electrons and, when there is no electron collision with neutral ionic gas molecules, it returns to the wave during the half-cycle when electrons slow down.

In real conditions in the ionosphere, despite the great dilution of the gas, collisions of electrons and neutral molecules are inevitable. Electrons in collisions transfer part of the energy from the EM wave to neutral molecules and it is lost for the wave because there is no interaction between neutral molecules and the wave that would allow the energy to return to the wave. The consequence of energy loss is a weakening of the amplitude of the waves - the greater the loss, the greater is the number of waves per unit volume and the average number of collisions suffered by an electron per unit time.

A group of EM waves moving through the layers of the atmosphere has different amplitudes and frequencies. For the movement of part of the EM spectrum (groups of EM waves) through the layers of the atmosphere with the parameters ε_0, μ_0 the general solution is determined from Maxwell's equations (Lamb,1883b; Bjelić, 2021b):

first (I): $rot\vec{H} = j\omega\varepsilon_0\vec{E} + \vec{J}$, (4)

others (II): $rot\vec{E} = -j\omega\mu_0\vec{H}$. (5)

The general solution abstracts the cause of the vectors $\vec{H}$, $\vec{E}$ and $\vec{J}$, but must take into account the dependences:

- individual components of the total current density $\vec{J}_{tot}$, of the electric field strength, and
- the strength of the magnetic field $\vec{H}$ from the total current density $\vec{J}_{tot}$.

If the values for $\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m, $\sqrt{\mu_r / \varepsilon_r} \approx 1$, $c \approx 2.988 \times 10^8$ ms^{-1}, $\mu_0 = 4\pi \times 10^{-7}$ ms^{-1}A^{-1}V, the average value of the Earth's magnetic field strength is:

$$\vec{H} = \frac{1}{\mu_0}\sqrt{\frac{\mu}{\varepsilon}}\frac{1}{c}\vec{E}, \quad (6)$$

where $H_0 \approx 24$ A/m.

In the unit of volume $\tau = z$ length in the time interval (t), the number of particles $n(\tau)$ moves without collisions and the longer the interval, the smaller the number of collisions $n(\tau)$. Therefore, the interval length function $n(\tau)$ must be decreasing and the increment-differential of the function must be negative and proportional to: $d\tau$, $n(\tau)$ and some constant α:

$$dn = -\alpha \cdot n(\tau)d\tau, \; n(\tau) = A \cdot e^{\alpha \cdot t}. \quad (7)$$

The number of particles $\tau = z = 0$ moving without collision is equal to the sum of particles in a unit of volume $A = N_1$, a $dn(\tau)$ and the number of particles for which the duration of free movement without collision is between $d\tau$ and $\tau + d\tau$.

The mean collision-free travel time T is then:

$$T = -\int_{\tau=0}^{\infty} \tau \frac{dn}{N_1} = -\int_{0}^{\infty} \tau \cdot d\left(e^{-\alpha\tau}\right) = -\left|\tau \cdot e^{-\alpha\tau} + \frac{1}{\alpha} e^{-\alpha\tau}\right|_0^{\infty} . \qquad (8)$$

From equation (8), $\alpha = 1/T$. The mean number of particle collision per unit time is:

$$n(\tau) = N_1 e^{-\nu \cdot t} \;\; (\nu = 1/T \, , \; \alpha = \nu). \qquad (9)$$

The EM field is changed according to the simple periodic law and the calculation of complex numbers can be:

$$dv / dt = (q / m) E_0 e^{j\omega \cdot t} . \qquad (10)$$

If the velocity of the ion v_0 at the time of the last collision $t - \tau$, in direction of the EM field, at the time t, the velocity is:

$$v = \int_{t-\tau}^{t} \frac{q}{m} E_0 e^{j\omega \cdot t} dt + v_0 = \frac{q}{j\omega \cdot m_m} E_0 e^{j\omega \cdot t}\left(1 - e^{-j\omega \cdot t}\right) + v_0 . \qquad (11)$$

The number dn of ions (electrons) having the velocity v is equal to the number of ions in which the duration of motion at that number of collisions is between τ and $\tau + d\tau$:

$$dn = -N_1 v \cdot e^{-\nu \cdot t} d\tau . \qquad (12)$$

The number of dn ions moving at a speed v form a convection current having an elemental density:

$$dJ = qv|dn| = qV_1 v \cdot e^{-\nu \cdot t} d\tau . \qquad (13)$$

The total convection current density $\tau = 0$ and $\tau = 0$ is obtained by integrating this equation within the limits of:

$$J = \frac{N_1 q^2 v}{j\omega \cdot m} E_0 e^{j\omega \cdot t} \int_0^{\infty} \left(1 - e^{-j\omega t}\right) e^{-vt} d\tau + N_1 q \bar{v}_0 . \qquad (14)$$

For the mean ion velocity after the collision v_0, after integration, the current J is:

$$J = \frac{N_1 q^2}{m} \frac{1}{\nu + j\omega} E_0 e^{j\omega \cdot t} . \qquad (15)$$

The value of J in equation (15), can be added to the component of current density of dielectric displacement:

$$\partial D / \partial t = dD / dt = j\omega\varepsilon_0 E_0 e^{j\omega \cdot t} , \qquad (16)$$

and the value of the total current density is obtained, which also contains the common attenuation factor $\omega_c = N_1 q^2 / m\varepsilon_0$:

$$J_{tot} = J + \frac{dD}{dt} = \left[\frac{N_1 q^2}{m} \frac{1}{\nu + j\omega} + j\omega\varepsilon_0 \right] E_0 e^{j\omega t} = \\ = \left[\frac{N_1 q^2}{m\varepsilon_0} \frac{1}{\nu + j\omega} + j\omega \right] \varepsilon_0 E_0 e^{j\omega t} = \left[\frac{\omega_c}{\nu + j\omega} + j\omega \right] \varepsilon_0 E_0 e^{j\omega t} . \quad (17)$$

The parameter ε in equation (17) is the part in constant $\hat{\varepsilon} = \varepsilon - j(\sigma / \omega)$ that describes the monochromatic wave ω ionosphere:

$$\varepsilon = \varepsilon_0 \left(1 - \frac{\omega_c^2}{\nu^2 + \omega^2} \right) - j \frac{\varepsilon_0 \omega_c^2 \nu}{\omega \left(\nu^2 + \omega^2 \right)} . \quad (18)$$

The ionosphere in which collisions are not neglected acts as a semiconductor with constants:

$$\text{dielectric: } \varepsilon = \varepsilon_0 \left(1 - \frac{\omega_c^2}{\nu^2 + \omega^2} \right), \\ \text{electrical conductivity: } \sigma = \frac{\varepsilon_0 \omega_c^2 \nu}{\nu^2 + \omega^2} . \quad (19)$$

For the velocity $v = 0$, the conductivity is zero and the ionosphere can be treated as a dielectric with an apparent dielectric constant if the impact of collision of ions and the Earth's magnetic field component is neglected:

$$\varepsilon = \varepsilon_0 \left(1 - \frac{\omega_c^2}{\nu^2 + \omega^2} \right) = \varepsilon_0 \left(1 - \frac{N_1 q^2}{\varepsilon_0 \omega^2 m} \right) . \quad (20)$$

Theory influence of ionized medium on EM waves was formulated by Eccles-Larmour in the postulate that electric load is squared and that charged particles, positive ions and negative electrons, have the same effect on the apparent dielectric constant. The influence on propagation of EM waves is inversely proportional to the mass of particles and the main influence in the ionosphere has electrons-particles of lower mass. For a free hydrogen ion, lightest+ion effect is 1830 times less than the effect of an electron because it has 1830 electron masses. The influence of a free ion of geocoronium is not known because its mass and charge of protons and electrons are not known. If $f -$ is the frequency of the $m - hr$ EM wave, then the apparent dielectric constant is:

$$\varepsilon = \varepsilon_0 \left(1 - \frac{f_c^2}{f^2} \right), \qquad (21)$$

where $f_c^2 = \dfrac{N_1 q^2}{4\pi^2 \varepsilon_0 m}$.

For low-conductivity dielectrics ω_c^2 is proportional to the number of free electrons N_1 and the number $n(\tau)$:

$$\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} \Rightarrow \alpha = \frac{1}{2c}\frac{\nu\omega_c^2}{\left(\nu^2 + \omega^2\right)n}. \qquad (22)$$

The attenuation factor ω_c^2 (depending on nN_1) is largest in the ionosphere in which this product is greatest.

If collisions are ignored as for a monochromatic EM wave, the following force components act on the ion:

- $q\vec{E}$ – force of action of the alternating electric field of the EM wave,
- $\mu_0 q \cdot \vec{v} \times H_0$ – EM forces due to the movement of ions in the unchanging magnetic field of the Earth,
- $\mu_0 q \cdot \vec{v} \times \vec{H}$ – force due to the movement of ions in the alternating magnetic field of the EM wave.

In the ionized environment, $\vec{H} = \dfrac{1}{\mu_0}\sqrt{\dfrac{\mu}{\varepsilon}}\dfrac{1}{c}\vec{E}$ and in accordance to the 2nd Newton's law, the equation of motion of ions is:

$$m\frac{d\vec{v}}{dt} = q\vec{E} + \mu_0 q \cdot \vec{v} \times H_0 + \mu_0 q \cdot \vec{v} \times \vec{H} = q\vec{E} + \mu_0 q \cdot \vec{v} \times \left[H_0 + \frac{1}{\mu_0}\sqrt{\frac{\mu}{\varepsilon}}\frac{\vec{E}}{c} \right]. \qquad (23)$$

Nikola Tesla was the first to realize that higher layers of the atmosphere are important for the Earth's electrical conductivity due to a stable line of conductivity and that the Earth resonantly oscillates at 6.2 and 30 Hz (according to measurements 8.14 and 20 Hz).

Tesla's principles of transmission using Super Low Frequency Resonance, SNF, in the ionosphere, and NF waves (1-300 Hz) are used to transmit radio signals. According to the assumption, the Sun as a source of EM fields has two components: electric and magnetic, and the magnetic poles of the Sun change their polarity every 22 years. According to Maxwell's theory: the components of the electric and magnetic fields are part of the EM field, and if there is one in space, there must be another component as well. Solar EM waves propagate towards the Earth through several layers of the atmosphere at various speeds. The ionized layer of the atmosphere has heterogeneous properties and the linearly polarized EM wave is divided into two components of opposite directions of rotation and natural velocities of propagation. The speed of propagation and the refractive index depend on the orientation of the Earth's magnetic field towards the direction of propagation of the Sun's EM waves.

Alternative theoretical model of the EM field of the Earth by authors

The model is based on two hypotheses for the Earth's interior and on two hypotheses for the EM field components:

- the interior is only a well-conducting medium for the strength of the electric field generated by solar ion waves in the ionosphere and exosphere,
- the interior is only a well-conducting magnetic medium for the magnetic field created by solar ionic winds in the upper layers (ionosphere exosphere),
- the first-electric is formed by the parameters of stable conductivity of the solid Earth and the ionosphere; the higher layers of the Earth are a good dielectric medium for the component of the electric field generated by ionic winds and EM waves from the Sun in the upper layers of the atmosphere (exosphere and ionosphere),
- the second-magnetic is formed by the parameters of the current of stable conductivity of the solid Earth and the domain of the ionosphere.

The Earth is only a well-conducting magnetic medium for the magnetic field of solar ionic winds in the upper atmosphere (exosphere + ionosphere with stable electrical conductivity parameters).

The total current density in addition to four basic ones also has two new components (in the first Maxwell's equation):

$$\vec{J}_{tot} = \sigma\vec{E} + \partial\vec{D} / \partial t + \rho v_{\rho} + \sigma\vec{E}_{out.side} + \sigma\left(\vec{v} \times \vec{B}\right) + rot\left(\vec{D} \times \vec{v}\right), \qquad (24)$$

where $\sigma\vec{E}$ – is the current density of conduction, $\partial\vec{D} / \partial t$ – is the current density of dielectric conductivity, ρv_{ρ} – is the convection of free charges and foreign field conductivity $\sigma E_{out.sid}$, $rot\left(\vec{D} \times \vec{v}\right)$ – is the density due to the motion of polarized dielectric, and $\sigma\left(\vec{v} \times \vec{B}\right)$ – is the density of motion of the medium with the velocity v in the field induction B .

Any EM source in space, which creates components of the total current J_{tot}, or currents generated during the movement of electrostatics of a neutral body, is a source of EM energy because the propagation of the current allows its transmission:

$$\int_V \vec{J} \cdot \vec{E}_e \cdot dV = \frac{\partial W}{\partial t} + \int_V \frac{J^2}{\sigma} dV + \oint_S \left(\vec{E} \times \vec{H}\right) \cdot \vec{dS} \ . \qquad (25)$$

Equation (25) defines the principle of radiation or EM energy transfer ($J = J_{tot}$). The member on the left is the power of the radiation source and on the right there are the members of its distribution and the propagation of the current components J, in connection with the propagation of EM energy. The system of fixed electrostatic loads determines the character of the electrostatic field and defines a stationary field in the environments where the electrical conductivity is equal to zero:

$$rot\vec{E} = 0 \, , div\vec{D} = \rho_{conv.} \, , \quad \vec{D} = \varepsilon_a \vec{E} \ . \qquad (26)$$

The electrostatic field is vortexless because $rot\vec{E} = 0$ at all points of the field and $\vec{E} = -grad\varphi$ shows that the vortex-free potential field is shown as a gradient of some potential function. The sign (–) means that the vector $\vec{E}$ is directed from a point of higher to a point of lower potential. In the area where $J_{cond} = 0$, the magnetic field is: $rot\vec{H} = 0$, $div\vec{B} = 0$, $\vec{B} = \mu_a \vec{H}$.

Elementary electric and magnetic dipoles

The elementary electric source of radiation (Hertz's dipole) is a simple system of EM wave radiation: a short straight conductor of the length $l = d$ connects two small spheres that alternately charge and empty and maintain the time-varying current in the conductor, Figure 3.

The current and the load are connected by the relation $i = dq / dt$ and the dipole length is small in relation to the wavelength of the emitting waves. The current along the dipole is uniformly distributed (similar to the effect of an AC generator that would maintain forced electrical oscillations in the center of the dipole). For the electric and magnetic dipole model of the Earth, the basic condition that the dipole model of the Earth $\Delta\vec{\ell} = \vec{d} \to 0$ is not realistic is not fulfilled, but the obtained solutions will be useful for the development of a theoretically correct alternative model of the Earth's EM field. The equations of magnetostatics and the equations of electrostatics are identical for the domain $\rho_{con} = 0$. If the circulation in the loop is I $\int_l Hdl = 0$, the magnetic field in the area without conduction current is potential. Similarly to the electrostatic field in a dielectric according to Gauss's theorem, the strength of the magnetic field is $\vec{H} = (B/\mu_0) - M$, and the general form of Ampere's law is $rot\vec{H} = \vec{J}$. The macroscopic magnetization of the medium has a dimension and a unit as a vector $\vec{H}$ (on the surface $\vec{S} = |S|\vec{n}$ of ferromagnets are Ampere surface currents with the longitudinal density $\vec{J}_{sa} = \vec{M} \times \vec{n}$). Magnetization is mathematically described by the equation:

$$\vec{M} = \frac{\sum m}{\Delta V},\ m = \sum m_i = \sum \frac{1}{2}\oint \vec{I} \cdot \vec{r} \times d\vec{r} = \frac{1}{2}\int_{\Delta V} \vec{r} \times \vec{J}_a dV . \qquad (27)$$

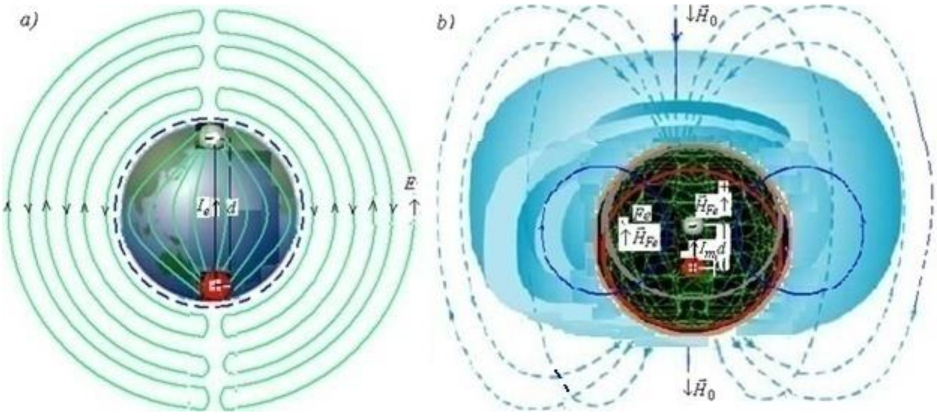

Figure 3 – Earth as: a) elementary resonator of the electric component of the EM field, b) Earth as a system that acts as an elementary dipole of the magnetic field (Bjelić, 2021b)
Рис 3 – Земля как: а) элементарный резонатор электрической составляющей ЭМ поля, б) Земля как система, которая ведет себя как элементарный диполь магнитного поля (Bjelić, 2021b)
Слика 3 – Земља као: а) елементарни резонатор електричне компоненте ЕМ поља, б) Земља као систем који се понаша као елементарни дипол магнетног поља (Bjelić, 2021b)

In the domain where the density of the conductivity current is equal to zero, the magnetic field is: $rot\vec{H} = 0$ and the field strength is a degradant of some scalar function φ_m, $H = -grad\varphi_m$. The vector field $\vec{B}$ is always vortexless (without original $div\vec{B} = div\mu_0(\vec{H} + \vec{M}) = 0$, $div\vec{H} = -div\vec{M}$). If the operation div is applied:

$$div\vec{H} = -divgrad\varphi_m = -\Delta\varphi_m , \qquad (28)$$

where $divM = \Delta\varphi_m$.

By introducing the density of the magnetic pseudomass $\rho_m = div\vec{M} = -div\vec{H}$, equation (28) can be written as for the electric scalar potential without parameters $1/\varepsilon_0$ on the right side (Laplace and Poisson equation):

$$\Delta\varphi_m = -\rho_m ,\ \Delta\varphi = -(\rho / \varepsilon_0). \qquad (29)$$

The solutions of both equations with a negative sign must have the same form:

$$\varphi_m = \frac{1}{4\pi}\int_V \frac{\rho_m}{R} dV ,\ V_{\mu 0} = \frac{1}{4\pi}\int_V \frac{\rho_m}{R} dV . \qquad (30)$$

Magnetic dipoles and resonators are fictitious quantities (not real), but their use is justified because closed and alternating currents in closed contours and permanent magnets can be replaced by equivalent linear magnetic currents and concentrated magnetic loads.

The missing components for a full symmetry of electrical and magnetic quantities are introduced into Maxwell's equations: $J^m_{outside}$ – foreign magnetic current and $\rho^m_{outside}$ – foreign magnetic load.

The rotor of the magnetic field strength in the first Maxwell's equation can be equal to the sum of several components of the total current density: conductivity currents, dielectric displacement currents, and foreign source currents.

The rotor $rot\dot{H}$ in the 2nd Maxwell's equation can be equated with a similar sum of current densities (inverse): displacement magnetic currents $i\omega\vec{B}$, magnetic conductivity currents and foreign source currents.

If the volumetric densities of magnetic loads are introduced in the 4th equation, it becomes symmetric with the 2nd Maxwell's equation. With these additions, the system of equations becomes pairwise symmetric (Petković, 2016):

$$rot\dot{H} = i\omega\tilde{\varepsilon}_a\dot{E} + \vec{J}_{ct}\ (1),\ rot\dot{E} = -i\omega\tilde{\mu}_a\dot{H} - \vec{J}^m_{ct}\ (2),$$
$$\tilde{\varepsilon}_a div\dot{E} = \rho_{ct}\ (3),\ \tilde{\mu}_a div\dot{H} = \rho^m_{ct}\ (4). \qquad (31)$$

Although experiments still have not confirmed the existence of magnetic loads in nature, the symmetrical form of Maxwell's equations has become attractive. Magnetic currents and loads in equations as well as electric currents and static loads are related by continuity equations in the system of Maxwell's equations.

Invariance of equations and replacement of electrical and magnetic quantities

In equation (31), all electrical quantities can be replaced by magnetic ones, and magnetic ones by electric ones. With respect to certain rules for signs, without changing the coordinate system and the system of Maxwell's equations, Figure 4.a,b, the quantities only change places in pairs: the vector $\vec{E}$ with the vector $\vec{H}$, where the flux of EM energy, defining the Pointing vector $\vec{\Pi} = \vec{E} \times \vec{H}$, remained unchanged.

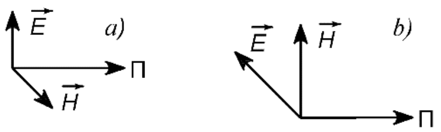

Figure 4 – Pointing vector $\vec{\Pi}$ is determined by: a) electrical and magnetic quantities, b) their invariance

Рис 4 – Вектор Пойнтинга определяется: а) электрическими и магнитными величинами, б) их инвариантностью

Слика 4 – Поинтингов вектор $\vec{\Pi}$ одређују: а) електричне и магнетне величине, б) њихова инваријантност

Equation (2) of system (31) $rot\dot{H} = i\omega\tilde{\varepsilon}_a\dot{E} + \vec{J}_{outside}$ passes into (1) if it is $\tilde{\varepsilon}_a$ replaced by $\tilde{\mu}_a$, and $\vec{J}_{outsid}$ replaced by $-\vec{J}^m_{outsid}$. From equation (2) of system (31) equation (1) can be obtained if it is $\tilde{\mu}_a$ replaced by $\tilde{\varepsilon}_a$, and $-\vec{J}^m_{outsid}$ and replaced by $\vec{J}_{outsid}$. The rules are similar for the replacement of electrostatic and magnetic load parameters $divB = 0$ in (3) and (4) equations $divD = \rho$. Common rules in the process of changing the values of parameters and sizes are:

$$\vec{E} \to \vec{H},\ J \to J^m,\ \rho \to \rho_m,\ \tilde{\varepsilon}_a \Leftrightarrow \tilde{\mu}_a,$$
$$\vec{H} \to \vec{E},\ J^m \to J,\ \rho_m \to \rho,\ \tilde{\varepsilon}_a \Leftrightarrow \tilde{\mu}_a. \qquad (32)$$

The principle of permutation and invariance are the properties of Maxwell's equations: The source of the EM field can be foreign: electric $\vec{J}_{outsid}$ and similar magnetic currents $-\vec{J}^m_{outsid}$. If solutions of variant 1 are known, the solution of variant 2 is determined by applying the second substitution $\tilde{\varepsilon}_a \Leftrightarrow \tilde{\mu}_a$ rule in wave impedance:

$$Z_w = |Z_w| e^{j\varphi_w} = \frac{\dot{E}}{H} = \frac{j\omega\tilde{\mu}_a}{\tilde{\varepsilon}_a}. \quad (33)$$

The principle of permutation in Maxwell's equations was first applied by A.A. Pistolkorso also gave a pre-message for solving physical fields in infinite space. This principle is used in solving the problem of the Earth's magnetic field, because the universe is a sphere with the infinite radius $R \to \infty$, which is also the outer boundary surface of that sphere. The monochromatic EM field is defined in the infinite domain unambiguously if:

- there are electrical or magnetic losses at every point in the domain of the physical environment,
- the field source is given in the domain of the environment and the EM field weakens infinitely faster than the value $1/R''$,
- there are the tangential components $\vec{E}$ or $\vec{H}$ on the inner side of the boundary surface of the area,
- all field sources are at the final distance from the coordinate origin.

A magnet is considered to be analogous to a dielectric, although a magnetic conductor similar to an electrical conductor does not exist - there are no magnetic conductors (Đorđević & Olćan, 2012). The EM field on the Earth and in its atmosphere can be formed by elementary electromagnetic dipoles radiation sources in two variants, as:

- a resonator of the electric component of the EM field, and
- a system in which the Earth acts as an elementary magnetic dipole and a source of magnetic field.

Any source in space, capable of creating the total current J_{tot}, is a source of EM energy radiation because the propagation of total current components is related to the transmission of EM energy. Problems in electrostatics are easier to solve if the potential φ is used instead of the vector $\vec{E}$ and the relationship between the components of field strength and potential in the Cartesian system are the equations:

$$E_x = -\frac{\partial\varphi}{\partial x},\; E_y = -\frac{\partial\varphi}{\partial y},\; E_z = -\frac{\partial\varphi}{\partial z}. \quad (34)$$

By introducing the equations of the components into the differential form of Gaussian theorem, Poison equation becomes:

$$\left(\frac{\partial \varphi}{\partial x}\right)^2 + \left(\frac{\partial \varphi}{\partial y}\right)^2 + \left(\frac{\partial \varphi}{\partial z}\right)^2 = -\frac{\rho}{\varepsilon_0}, \qquad (35)$$

and it determines the relationship between the scalar potential and the electrical load density.

The general form of Poisson equation is obtained by substituting $div\vec{E} = \rho / \varepsilon_0$ when $\vec{E}$ is substituted by $\vec{E} = -grad\varphi$ and then $divgrad\varphi = -(\rho / \varepsilon_0)$ in the domains where there are no electrical loads $\rho = 0$. Then for $divgrad\varphi = 0$ one obtains:

$$\left(\frac{\partial \varphi}{\partial x}\right)^2 + \left(\frac{\partial \varphi}{\partial y}\right)^2 + \left(\frac{\partial \varphi}{\partial z}\right)^2 = 0. \qquad (36)$$

$divgrad\varphi$ refers to the square of the Laplace operator $\Delta = \nabla^2$ (nabla Hamilton operator). Poison equation $\Delta\varphi = -\rho / \varepsilon_0$ combines the potential and charge densities of a field at a point in the field.

The electric field strength of dielectric and metal loaded and unloaded spheres in an external homogeneous electric field of strength is E_0. Poisson equation in the spherical coordinates is:

$$\Delta\varphi = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial \varphi}{\partial r}\right) + \frac{1}{r^2 \sin\alpha} \cdot \frac{\partial}{\partial \alpha}\left(\sin\alpha \frac{\partial}{\partial \alpha}\right) + \frac{1}{r^2 \sin^2\alpha}\frac{\partial^2 \varphi}{\partial \beta^2}. \qquad (37)$$

Dielectric sphere: The potential at any point of the field depends on all the charges that create the field, and not only on the free ones, and therefore equation (37) is used to solve electro- and magnetostatic fields. Laplace equation was first used to describe the potential fields of celestial mechanics and then for EM fields. In domain V, Figure 5, three charge densities can be distributed and the field is created by three components:

- volumetric – $\rho \neq 0$, $\rho \cdot dV \neq 0$ in the volume; $\frac{\rho \cdot dV}{4\pi\varepsilon_a r}$,
- surface – $\eta \neq 0$, $\eta \cdot dS \neq 0$ on the surface; $\frac{\eta \cdot dS}{4\pi\varepsilon_a r}$,
- linear – $\tau \neq 0$, $\tau \cdot d\ell \neq 0$ on the line; $\frac{\tau \cdot d\ell}{4\pi\varepsilon_a r}$.

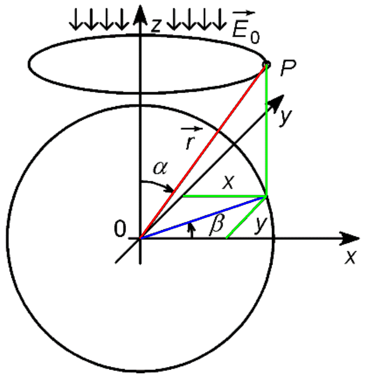

Figure 5 – Effect of a foreign electric field $\vec{E}_0$ on a dielectric sphere
Рис 5 – Воздействие постороннего электрического поля $\vec{E}_0$ на диэлектрическую сферу
Слика 5 – Дејство страног електричног поља $\vec{E}_0$ на диелектричну сферу

In a spherical system, the field is symmetric and the potential components at the point $\vec{r} \neq 0$ are calculated in accordance with:

$$\vec{E} = \vec{E}_r = -\frac{\partial \varphi}{\partial r} \leftrightarrow \varphi = -\int \vec{E} \cdot d\vec{r} = \frac{q}{4\pi\varepsilon_0 \varepsilon_r} + C \,. \tag{38}$$

The functions $\rho = \rho(r)$, $\eta = \eta(r)$ and $\tau = \tau(r)$ are not known, which makes integration difficult and rarely used.

The value of the potential is the sum (integral) of the elementary components of the potential of all charges:

$$\varphi = \frac{1}{4\pi\varepsilon_a} \int_V \frac{\rho \cdot dV}{r} + \frac{1}{4\pi\varepsilon_a} \int_S \frac{\eta \cdot dS}{r} + \frac{1}{4\pi\varepsilon_a} \int_\ell \frac{\tau \cdot d\ell}{r} \,. \tag{39}$$

The assumptions are: at infinity, the potential is equal to zero and all charges that can create a field are distributed in the domains of defined limits. The foreign field E_0 of the direction $(-z)$ acts on the sphere. Near the sphere, the field is deformed and not homogeneous which depends on ε_a the size of sphere and the load q on the sphere.

Metal (conductive) sphere: The field lines come to the boundary surface at right angles.

If there was no previous charge on the sphere, the charge generated by electrostatic induction is distributed on the surface of the sphere, and the field lines end or begin with these charges. The metal sphere can be a carrier of additional charge, which is also distributed on the boundary surface.

Under the influence of a foreign electric field, the dielectric sphere will be polarized, and due to the influence of the charges created by the polarization of the dielectric, the foreign electric field E_0 is deformed. The shape of the field lines on the surface depends on the boundary conditions in the spherical system, ie. on the conditions-equality:

- tangential components of the field strength at the boundary surface $E_{it} = E_{et}$, the index i for the internal space, the index e for the external space, which arises from $\oint_{\ell} \vec{E} d\vec{\ell} = 0$ field domain,
- normal components of electrostatic induction (according to Gauss's theorem).

If a sphere is a dielectric and there are no free charges on it, Laplace equation must be integrated to solve the field in the sphere. The field strength and potentials of the charged dielectric sphere are calculated according to Gauss's law and the solutions are given in Table 1.

Table 1 – Field strength in the sphere
Таблица 1 – Напряженность электрического поля внутри сферы
Табела 1 – Јачине електричног поља на сфери

$\alpha = 0$, Field strength, *N* pol		Equator $\alpha = 90^0$, Field strength		$\alpha = 180^0$, Field strength, *S* pol	
$E_{R1} = -3E_0$	$E_\alpha = 0$	$E_{R1e} = 0$	$E_\alpha = E_0\left(1 - R_1^3 / R_1^3\right) sin\alpha = 0$	$E_{R1} = -3E_0$, $E_\alpha = 0$	$E_\alpha = 0$

In the conductive sphere, $\vec{E} = 0$ and $\varphi = const.$:

$$\varphi^M(r) = C_1 / r + C_2 \text{ , } C_1 = A_1 A_4 \text{ , } C_2 = A_2 A_4 \text{ .} \tag{40}$$

The solution of the first part of the equation is:

$$\frac{1}{M(r)} \frac{\partial}{\partial r}\left[r^2 \frac{\partial M(r)}{\partial r}\right] = p \text{ or } 2r\frac{dM}{dr} + r^2 \frac{d^2 M(r)}{dr^2} = p \text{ .} \tag{41}$$

By applying the Euler shift, the following was obtained:

$$M = Cr^n \text{ , } \frac{dM}{dr} = nCr^{n-1} \text{ , } \frac{d^2 M}{dr^2} = Cn(n-1)r^{n-2} \text{ .} \tag{42}$$

By replacing the derivative in the equation:

$$2rnCr^{n-1} + r^2Cn(n-1)r^{n-2} = pCr^n \text{ or } n^2 + n - p = 0, \quad (43)$$

the roots of the quadratic equation are obtained: $n_{1,2} = -\frac{1}{2}\sqrt{\frac{1}{4} + p}$.

The value for p is determined if it is adopted that $N = B\cos\alpha$:

$$\frac{1}{N(\alpha)\sin\alpha} \cdot \frac{d}{d\alpha}\left(\sin\alpha \frac{dN}{d\alpha}\right) = \frac{-2B\sin\alpha\cos\alpha}{B\cos\alpha\sin\alpha} = -p \Leftrightarrow p = 2. \quad (44)$$

Substituting p in the root of the quadratic equation gives $n_{1,2} = 1,2$ and the solution for that part of the potential is:

$$\varphi^N = \left(C_3 r + C_4 / r^2\right)\cos\alpha. \quad (45)$$

The general solution for both parts is:

$$\varphi = \varphi^M + \varphi^N = (C_1 / r) + C_2 + \left(C_3 r + C_4 / r^2\right)\cos\alpha. \quad (46)$$

The constants C_1, C_2, C_3 and C_4 determine the type of a sphere: conductive, dielectric or magnetic. The conditions on the boundary surface are important for determining the constants conducting a sphere in a foreign field. Very distant points can be conditionally considered to be infinitely distant. The field of an unloaded dielectric or metal sphere in a foreign electric field is defined by Laplace equation (there are no free charges in the sphere and outside it).

Model of a dielectric sphere in a foreign homogeneous electric field: For an electrostatically unloaded dielectric sphere, the solution is determined from the general solution of equation (46), and the potentials and the constants have an index i for internal space, and e for external space (Dziewonski & Anderson, 1981):

$$\varphi_i = \frac{C_{1i}}{r} + C_{2i} + \left(C_{3i} r + \frac{C_{4i}}{r^2}\right)\cos\alpha, \quad (47)$$

$$\varphi_e = \frac{C_{1e}}{r} + C_{2e} + \left(C_{3e} r + \frac{C_{4e}}{r^2}\right)\cos\alpha \quad (48)$$

Eight constants are determined. The potential φ for r and $r \to \infty$ is $\varphi = \varphi_o + E_0 r\cos\alpha$. After replacement in equation (48), we get $C_{2e} = \varphi_0$, $C_{3e} = E_0$. For a point charge, the field strength is $E = q / 4\pi \cdot \varepsilon_0 \varepsilon_r r^2$ and the potential is:

$$\varphi = -\int E dr = (q / 4\pi \cdot \varepsilon_0 \varepsilon_r r) + C. \quad (49)$$

Analogously, a component C_{1e}/r is a component of the total charge of a sphere. If there is a total of electricity sphere $q = Q = 0$ in the equation for φ_e, this constant is equal $C_{1e} = 0$. The constant C_{4e} is determined from:

$$\varphi_e = \varphi_0 + \left(E_0 r + C_{4e} / r^2\right) cos\,\alpha\,. \qquad (50)$$

The potential in the dielectric φ_i is the final value for all points $C_{1i} = 0$, $C_{4i} = 0$. If there were $C_{1i} \neq 0$, the component in the center of the sphere C_{1i}/r for $R_1 = 0$ of the sphere would be infinite. The constants C_{2i} for the potential in the field of spheres and the potential in the outer domain C_{2e} of the field are equal to the constants for the outer domain $C_{2i} = C_{2e} = \varphi_0$. The potential in the dielectric is: $\varphi = \varphi_0 + C_{3i} r\, cos\,\alpha$. The constants C_{4e} and C_{3i} are determined from the boundary $E_{it} = E_{et}$ conditions. From the equations of the potential φ_e and φ_i for $r = R_1$ (this is a condition equivalent to the condition), it follows:

$$C_{3i} R_1 = E_0 R_1 + \left(C_4 / R_1^2\right). \qquad (51)$$

From the equality of normal electrostatic inductions at the limit, there is $D_{1n} = D_{2n}$:

$$-\varepsilon_i \left(\frac{\partial \varphi_i}{\partial r}\right)_{r=R_1} = -\varepsilon_e \left(\frac{\partial \varphi_e}{\partial r}\right)_{r=R_1},$$
$$\varepsilon_i \left(C_{3i}\right)_{r=R_1} = \varepsilon_e \left(E_0 - \frac{2C_{4e}}{R_1^3}\right)_{r=R_1}. \qquad (52)$$

The potential in the dielectric, given the common solution of these two equations, is:

$$C_{3i} = E_0 \frac{3\varepsilon_e}{2\varepsilon_e + \varepsilon_i},\ C_{4i} = C_{4e} = R_1^3 E_0 \frac{\varepsilon_e - \varepsilon_i}{2\varepsilon_e + \varepsilon_i}, \qquad (53)$$

$$\varepsilon_i E_0 \frac{3\varepsilon_e}{2\varepsilon_e + \varepsilon_i} = \varepsilon_e E_0 \left(1 - 2\frac{\varepsilon_e - \varepsilon_i}{2\varepsilon_e + \varepsilon_i}\right). \qquad (54)$$

For the selected spherical coordinate system, the potential component in the dielectric is:

$$\varphi_i = \varphi_0 + E_0 r \frac{3\varepsilon_e}{2\varepsilon_e + \varepsilon_i} cos\,\alpha = \varphi_0 + E_0 \frac{3\varepsilon_e}{2\varepsilon_e + \varepsilon_i} z,\ z = r\, cos\,\alpha\,. \qquad (55)$$

The electric field strength in the dielectric is:

$$E_{zi} = -\frac{\partial \varphi_e}{\partial z} = -E_0 \frac{3\varepsilon_e}{2\varepsilon_e + \varepsilon_i}. \tag{56}$$

The strength of the field E has the direction of the axis z, it does not depend on the coordinate and the field is homogeneous. The dielectric potential:

$$\varphi_e = \varphi_0 + E_0 \left(r + \frac{R_1^3}{r^2} \frac{\varepsilon_e - \varepsilon_i}{2\varepsilon_e + \varepsilon_i} \right) \cos\alpha , \tag{57}$$

$$\begin{aligned} E_{re} &= -\frac{\partial \varphi_e}{\partial r} = E_0 \left(1 - \frac{2R_1^3}{r^3} \frac{\varepsilon_e - \varepsilon_i}{2\varepsilon_e + \varepsilon_i} \right) \cos\alpha , \\ E_{\alpha e} &= -\frac{1}{r} \frac{\partial \varphi}{\partial \alpha} = E_0 \left(1 + \frac{R_1^3}{r^3} \frac{\varepsilon_e - \varepsilon_i}{2\varepsilon_e + \varepsilon_i} \right) \sin\alpha . \end{aligned} \tag{58}$$

For $Q = 0$ on the surface of the sphere, there is $r = R_1$, $E_r = -3E_0 \cos\alpha$ i.e. E_r the components at all points on the sphere are three times larger than the components of the foreign field.

Conclusion

The field of a statically unloaded sphere that has no free charges is dielectric and is located in a foreign electric homogeneous field defined by Laplace equation. In the new model, equation (29) is used, but eight integration constants must be determined (in the sphere – index *i*, and outside the sphere – index *e*).

The conditions on the boundary surface are important for determining the constants conducting a sphere in a foreign field. Very distant points can be conditionally considered to be infinitely distant. The field of an unloaded dielectric and metal sphere in a foreign electric field is defined by Laplace equation (there are no free charges in the sphere and outside it).

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Альтернативная теоретическая модель электромагнитного поля Земли, основанная на гипотезах о двухкомпонентном поле

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РУБРИКА ГРНТИ: 37.15.00 Геомагнетизм и высокие слои атмосферы
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: В данной статье описана альтернативная теоретическая модель ЭМ поля Земли, основанная на гипотезах о двухкомпонентности. Статья состоит из нескольких частей, в *одной из которых представлена модель, показывающая вращение магнитопроводящей сферы с намагниченностью M во внешнем магнитном поле. В последней части статьи представлены теоретические модели расчета составляющих электромагнитного поля электропроводящих, диэлектрических и магнитопроводящих сфер, которые подвергаются воздействию постороннего электромагнитного поля.*

Методы: В статье аналитическим методом были исследованы отклики электропроводящих, диэлектрических и магнитопроводящих сфер на воздействие внешних электромагнитных полей.

Результаты: Полученные решения в виде аналитических формул будут применяться в исследованиях воздействия ЭМ поля Солнца на планеты и особенно на Землю.

Выводы: Полученные формулы напряженности и индукции электрического и магнитного полей и их решения применимы к электропроводным, диэлектрическим и магнитопроводящим сферам, а по сравнению с известными формулами они отличаются простотой и большей точностью.

Ключевые слова: теория, модель, электромагнетизм, компоненты, сферы, вращение, магнитное поле.

Алтернативни теоријски модел земљиног ЕМ поља заснован на хипотезама о две компоненте поља

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ОБЛАСТ: теоријска електротехника, електромагнетика
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: У раду је описан алтернативни теоријски модел ЕМ поља Земље заснован на хипотезама о две компоненте. У једном делу рада модел приказује ротацију магнетно проводне сфере магнетизације M у страном магнетном пољу. У последњем делу дефинисани су теоријски модели за прорачун компоненти електромагнетног поља електрично проводне, диелектричне и магнетно проводне сфере које су изложене утицајима страног електромагнетног поља.

Методе: Аналитичким методама истраживани су одзиви електрично проводне, диелектричне и магнетно проводне сфере на утицаје спољних ЕМ поља.

Резултати: Добијена решења у облику аналитичких формула биће примењена за истраживање утицаја ЕМ поља Сунца на планете и посебно на Земљу.

Закључак: Добијене формуле јачине и индукције електричног и магнетног поља и њихова решења могу се применити на електрично проводну, диелектричну и магнетно проводну сферу и, у односу на познате формуле, једноставне су и тачније.

Кључне речи: теорија, модел, електромагнетизам, компоненте, сфере, ротација, магнетно поље.

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