ELECTROMAGNETIC BACKGROUND GENERATED BY LOW EARTH ORBIT SATELLITES ON THE EARTH'S SURFACE

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ABSTRACT

A methodology for evaluation the levels of electromagnetic background (EMB) created near the earth's surface by mega-constellations of low earth orbit satellites is proposed. Analysis of EMB levels at the earth's surface created by these satellite's mega-constellations indicate that with their full-scale deployment, the average level of artificial EMB of the SHF range at the earth's surface can exceed the average intensity of natural EMB by many orders of magnitude. Such an essential change in physical characteristics of operating electromagnetic environment for ground radio services and habitat requires serious attention and further in-depth analysis.

KEYWORDS: *low orbit satellite, electromagnetic radiation, total radiated power, electromagnetic background*

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1 Introduction

The observed deployment in the near-earth space of megaconstellations of low earth orbit communication satellites (Starlink, OneWeb, Astra, Kuiper, GuoWang, etc.) will increase by 2-3 orders of magnitude the number of low-orbit sources of SHF electromagnetic radiation (EMR) in the direction of the earth's surface and also will increase in the total density of downlink satellite communication area traffic capacity on the earth's surface, especially when integrating these satellite communication systems with global 5G/6G mobile communication systems.

This alarms specialists who are concerned about both the obvious increase in the probability of collisions of satellites of various affiliations and the problem of "space debris" [1, 2], and the expected complication of the electromagnetic environment (EME) near the earth's surface, which may cause interference for various terrestrial radio services that use frequency bands of satellite systems on a secondary basis, as well as aggravation of problems of electromagnetic safety of the population and electromagnetic ecology of the habitat [3, 4].

The goal of this work is to summarize a base technique and models presented in [5] that makes it possible to analyse EME presented as an ensemble of radio frequency electromagnetic fields (EMF) created near the earth's surface by EMRs of megaconstellations of low earth orbit satellites (LEOS).

2 Initial models and assumptions

A. Model of LEOS radiation to the earth's surface

The main LEOS megaconstellations are characterized by layered placement of subsets (separate constellations) of satellites in different orbital planes and with different orbital inclinations, ensuring their uniform quasi-regular distribution above the Earth's surface [5].

From a ground-based observation point (OP), the location of N satellites of the LEOS megaconstellation in n spherical orbital shells of radii $R_i = H_i + R_E$, $i \in [1, n]$ over N_i satellites in the shell can be considered random and uniform over the shell area with an average density ρ_i [LEOS/m^2]:

$$N = \sum_{i=1}^{n} N_i, \quad \rho_i = N_i \Big/ \left[4\pi (H_i + R_E)^2\right], \tag{1}$$

where 300 km ≤ H_i ≤ 2000 km is the altitude of the orbit of the i-th LEOS constellation, R_E is the Earth radius.

As a model of the LEOS antenna radiation pattern in the direction of the earth's surface, a two-level model with a conical beam of equal width $\Delta\varphi$ in azimuth α and zenith angle β can be used, described by the following relations:

$$\left.\begin{aligned}
&G_{ML} = \frac{C_P}{(1+C_P)\sin^2(\Delta\varphi/4)},\ C_P = \frac{P_{ML}}{P_{SL}},\ P_{ML}+P_{SL} = P_{TRP};\\
&G_{SLR} = \frac{G_{SL}}{G_{ML}} = \frac{tg^2(\Delta\varphi/4)}{C_P};\ G_{SL} = \frac{1}{(1+C_P)\cos^2(\Delta\varphi/4)};\\
&g_N(\alpha,\beta) = \begin{cases} 1, & \alpha,\beta \in \Delta\Omega_{ML};\\ G_{SLR} = tg^2(\Delta\varphi/4)/C_P, & \alpha,\beta \in \Delta\Omega_{SL}, \end{cases}
\end{aligned}\right\} \tag{2}$$

where G_{ML} is the gain in the main lobe (ML), G_{SL} and G_{SLR} are absolute and relative levels of side lobes (SL), C_P is the ratios of powers emitted in the ML (P_{ML}) and SLs (P_{SL}), respectively; $\Delta\Omega_{ML}$ and $\Delta\Omega_{SL}$ – solid angles corresponding to the main and side lobes, $g_N(\alpha,\beta)$ – normalized radiation pattern, P_{TRP} – LEOS total radiated power.

Since all LEOS in a constellation can be considered the identical, their equivalent isotropically radiated powers (EIRP) both in ML ($P_{eML}=G_{ML}P_{TRP}$) and SL $P_{eSL}=G_{SL}P_{TRP}=G_{SLR}P_{eML}$) can also be considered the identical.

The potential LEOS service area is limited by the minimum elevation angles $\square_{min}$ of arrival of signals at the terrestrial user equipment (UE) and the maximum length of the LEOS-to-UE radio link is equal to R_{max} (Fig. 1). The actual LEOS service area determined by an inclined ML position has the form of a spot, which is roughly close in shape to an ellipse with axes L_X, L_Y having area $S_S \approx \pi L_X L_Y$.

The curvature of the Earth surface and the LEOS orbital shells determines the difference between the minimum viewing angle of a LEOS from a ground-based OP and the minimum viewing angle of a given OP from that LEOS: $\varepsilon_{min} > \theta_{min}$ (Fig. 2).

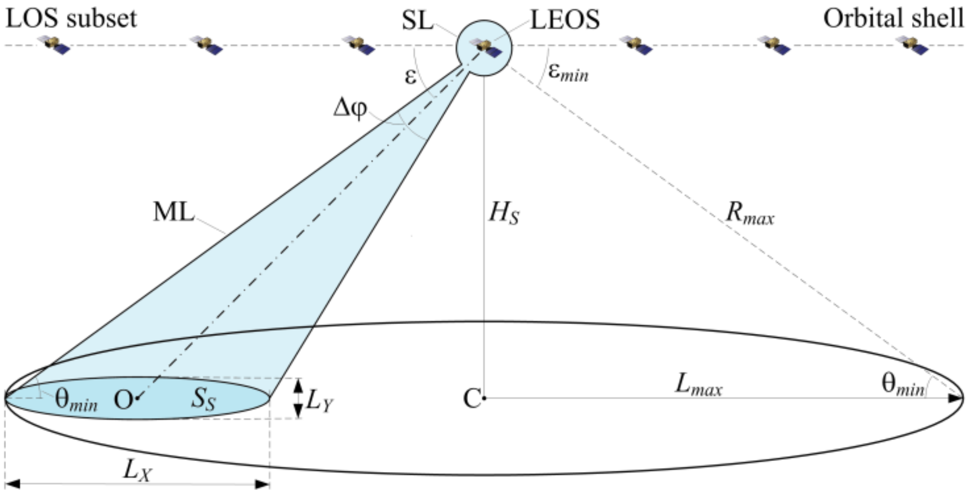

Fig. 1. Direction of the ML of LEOS EMR onto the earth's surface at $\varepsilon = \varepsilon_{min} + \Delta\varphi/2$; O – point of intersection of ML axis with earth's surface.

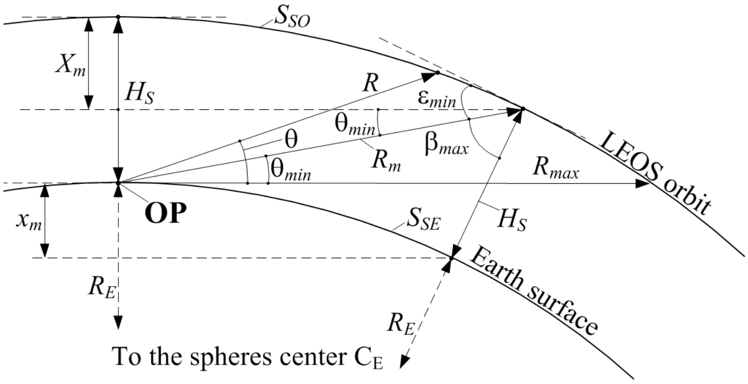

Fig. 2. Model of OP location on the earth's surface and of the part of LEOS canstellation in a spherical segment of height X_m and area S_{SO} of an orbital shell of height H_S, which provide irradiation of the earth's surface from viewing angles $\varepsilon \in [\varepsilon_{min}, 90°]$.

The relationship between these angles is determined by the following relations:

$$\left.\begin{aligned} \varepsilon_{min} &= \frac{\pi}{2} - \beta_{max} = \frac{\pi}{2} - arccos\left(\frac{(H_S + R_E)^2 + R_m^2 - R_E^2}{2(H_S + R_E)R_m}\right); \\ R_m &= \sqrt{R_E^2 \sin^2\theta_{min} + H_S^2 + 2R_E H_S} - R_E \sin\theta_{min}, \end{aligned}\right\} \quad (3)$$

where R_m is the maximum distance between LEOS and OP at $90^\circ \geq \theta \geq \theta_{min}$, β_{max} is the maximum angle between the perpendicular to the earth's surface (nadir) at the LEOS location point and the direction to the border of its potential service area, determined by the value θ_{min}. Distance R_{max} in Figure 2 corresponds to the line-of-side distance of LEOS from OP at $\theta = 0$.

B. Model of RWP conditions

We will assume that all analysed OPs of the earth's surface are in direct visibility from the orbital positions of LEOS – EMR sources, which allows us to use the worst-case model of radio wave propagation conditions (RWP) in free space:

$$Z = P_e \big/ \left(4\pi R^2\right), \tag{4}$$

where P_e is the LEOS EIRP, R is the distance between the OP and the LEOS; Z [W/m^2] is the scalar power flux density (PFD) of EMF created in OP by LEOS EMR.

C. Electromagnetic background (EMB) in OP, created by LEOS radiations

The intensity Z_Σ of EMB created in OP by the set M of LEOS – EMR sources is defined as the scalar sum of M random PFD values of radiofrequency EMFs reached the OP:

$$Z_\Sigma = \sum_{m=1}^{M} Z_m \, . \tag{5}$$

D. Algorithm for Analysing the EME Characteristics

The technique of system analysis of the EME characteristics near the earth's surface created by LEOS constellations is based on the results of [6, 7, 10, 11] and involves the sequential implementation of the following procedures:

a) Define the analyzed EMR scenario of the LEOS constellation in dependence on the corresponding characteristics of the mutual spatial location of the OP, randomly selected on the earth's surface, number N_{ML} of LEOSs, which irradiate OP by main lobe with EIRP P_{eML}, and number N_{SL} of LEOSs, which irradiate OP by side lobe with EIRP P_{eSL}.

b) Define the probability distribution densities (p.d.d.) $w_{ML}(R)$, $w_{SL}(R)$ of distances from LEOS irradiating the earth's surface by ML and SL with EIRP P_{eML} and P_{eSL} to the OP.

c) Define p.d.d. $w_{ML}(Z)$, $w_{SL}(Z)$ of PFDs created in OP by LEOSs radiation via ML and SL respectively, as p.d.d. of random variable transformed using the inversion of (4) with $P_e = P_{eML}$ or $P_e = P_{eSL}$:

$$w(Z) = w\left(R = \Phi^{-1}(Z)\right)\left|dR/dZ\right|, \quad R = \Phi^{-1}(Z) = \sqrt{P_e \big/ \left(4\pi Z\right)} \, . \tag{6}$$

d) Determine the expectations $m_1(Z_{ML})$ and $m_1(Z_{SL})$ for PFDs created in OP by ML and SL of LEOS antennas.

e) Determine the average EMB components $Z_{\Sigma ML}$ and $Z_{\Sigma SL}$ created in OP by LEOS ML and SL respectively as the products of the average number of corresponding LEOS (N_{ML}, N_{SL}) determined at stage "*a*", and the average PFD values ($m_1(Z_{ML})$, $m_1(Z_{SL})$, see item "*d*"):

$$Z_{\Sigma ML} = N_{ML} \cdot m_1(Z_{ML}), \quad Z_{\Sigma SL} = N_{SL} \cdot m_1(Z_{SL}) \, . \tag{7}$$

f) Determination of the total average EMB level Z_Σ in OP as the sum of components formed by ML and SL radiations of the given set of LEOS:

$$Z_\Sigma = Z_{\Sigma ML} + Z_{\Sigma SL} \, . \tag{8}$$

3 Analysis of LEOS constellations spatial models and Earth irradiation scenarios

Since satellite systems may differ in EMR characteristics in the direction of the earth's surface, an analysis of EMR characteristics for several LEOS EMR implementation scenarios was performed using the above algorithm.

A. LEOS with isotropic EMR, scenario 1 (hypothetic)

A model of the spatial placement of the LEOS constellation with isotropic EMR and OP on the Earth's surface is shown in Figure 3.

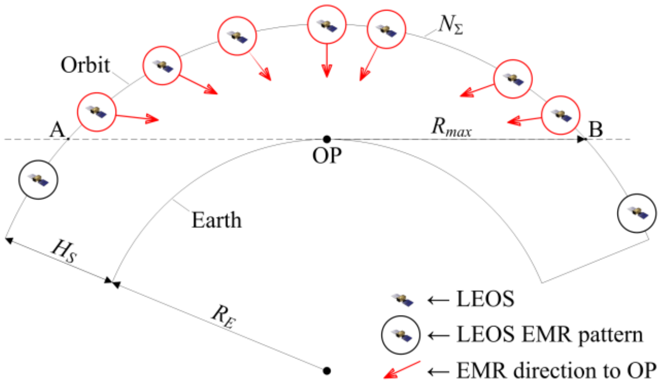

Fig. 3. Spherical model of the distributed above the earth's surface constellation of LEOS with isotropic EMR. LEOS from radio visibility zone capable of OP irradiating are highlighted in red.

If LEOS are distributed uniformly with density ρ_i = *const* over the *i*-th orbital shell of height H_S, then their average number in the shell segment limited by the radio visibility zone of radius R_{max} from OP is equal to

$$N_\Sigma = 2\pi\rho_i \left(R_E + H_S\right) H_S . \qquad (9)$$

Using the algorithm described above, for the considered scenario we obtain the following:

a) P.d.d. *w*(*R*) of the distance *R* from LEOS to the OP:

$$w(R) = R/\left(H_S R_E\right),\ H_S \le R \le R_{max} = \sqrt{2R_E H_S + H_S^2} . \qquad (10)$$

b) P.d.d. of PFD *Z* created in OP by LEOS with EIRP P_e:

$$\left.\begin{array}{l} w(Z) = Z_{min} Z_{max} \Big/ \left[\left(Z_{max} - Z_{min}\right) Z^2\right],\ Z_{min} < Z < Z_{max}, \\ \quad Z_{min} = P_e \Big/ \left(4\pi R_{max}^2\right),\ Z_{max} = P_e \Big/ \left(4\pi H_S^2\right) \end{array}\right\} \qquad (11)$$

c) The expectation $m_1(Z)$ is determined by the relation

$$\left.\begin{array}{l} m_1(Z) = \displaystyle\int_{Z_{min}}^{Z_{max}} Z \cdot w(Z) dZ = \frac{Z_{min} Z_{max}}{\left(Z_{max} - Z_{min}\right)} ln \frac{Z_{max}}{Z_{min}} = \\ \quad = P_e\, ln\left[\left(2R_E + H_S\right)/H_S\right] / \left(8\pi H_S R_E\right). \end{array}\right\} \qquad (12)$$

d) The average value Z_{Σ} of the EMB in OP:

$$Z_{\Sigma} = N_{\Sigma} \cdot m_1(Z) = \frac{\rho_i P_e (R_E + H_S)}{4R_E} \ln\left[\frac{2R_E + H_S}{H_S}\right] \tag{13}$$

B. LEOS with cuasi-isotropic EMR, scenario 2

In Scenario 2 (Fig. 4) LEOS EMRs are isotropic only for OP on the earth's surface; radiations occurs only in the direction of the Earth in the solid angle $\Omega_E=2\pi(1-cos\beta_{max})$, corresponding to $\theta_{min} = 0$ and to the following value of β_{max} :

$$\beta_{max} = arccos\left\{\left[(H_S + R_E)^2 + R_{max}^2 - R_E^2\right] / \left[2(H_S + R_E)R_{max}\right]\right\}. \tag{14}$$

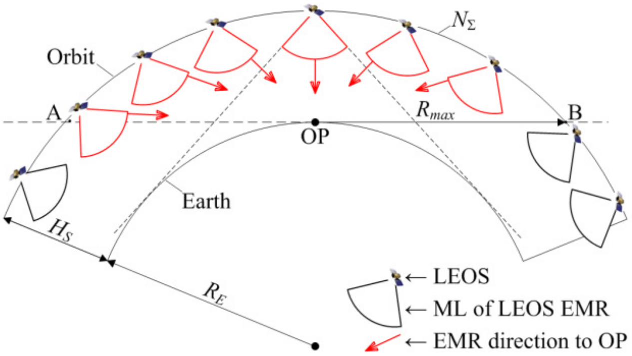

Fig. 4. Spherical model of the distributed above the earth's surface constellation of LEOS with quasi-isotropic EMR. LEOS from radio visibility zone capable of OP irradiating are highlighted in red.

In this case, at a fixed total radiated power P_{TRP} the LEOS EIRP in the direction of the earth's surface will increase relative the previous case (13) by an amount K_P equal to the ratio $4\pi/\,\Omega_E$, and the average EMB level at the earth's surface will be determined by the following ratio:

$$\left.\begin{aligned} Z_{\Sigma} &= \rho_i P_e K_P (R_E + H_S) ln\left[(2R_E + H_S)/H_S\right]/4R_E\,, \\ K_P &= 2(H_S + R_E)\Big/\left(H_S + R_E - \sqrt{H_S^2 + 2R_E H_S}\right), \\ \Omega_E &= 2\pi\left[1 - \sqrt{H_S^2 + 2R_E H_S}\Big/(H_S + R_E)\right]. \end{aligned}\right\} \tag{15}$$

C. LEOS with vertical directional EMR, limited size of service area, scenario 3.

If the service area of LEOS with a relatively wide ML is limited by the elevation angle θ_{min} of its observation from the ground OP (Fig. 5), then the following occurs:

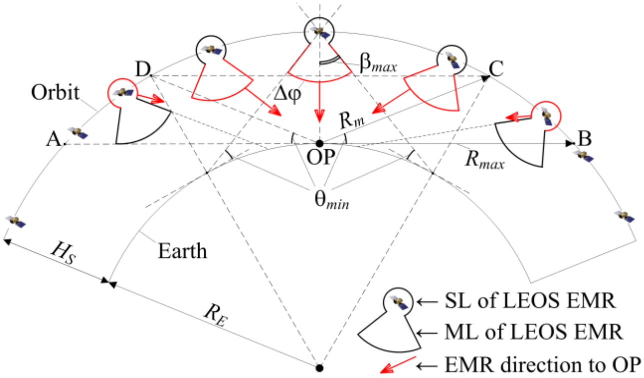

Fig. 5. Spherical model of the distributed above the earth's surface constellation of LEOS with wide conical ML and vertical EMR. Parts of LEOS EMR patterns capable of OP irradiating are highlighted in red.

a) LEOS EMRs are not isotropic; their antennas with a radiation pattern (2) are oriented vertically down to the nadir and provide service in the range of elevation angles $\theta \in [\theta_{min}, 90°]$. This is determined by the ML conical shape with width $\Delta\varphi$, equal to twice the value of the maximum viewing angle from OP: $\Delta\varphi = 2\beta_{max}$. The width $\Delta\varphi$ of the LEOS EMR ML turns out to be related to the value θ_{min} and the altitude H_S of the LEOS orbit, which determine the value of the maximum viewing angle β_{max} of OP at the orbital point observed from the OP under the angle θ_{min}.

b) EIRP of LEOS in ML (P_{eML}) and SL (P_{eSL}) are determined by the P_{TRP} value and the antenna gains (2).

c) Localization area on the orbital shell of the LEOS set irradiating the OP by MLs, is a spherical segment with height X_m (Fig. 2), determined by the R_m (3), and the base diameter DC in Fig. 5; p.d.d. of the distance R from these LEOS to the OP has the following form

$$w(R) = 2R / \left(R_m^2 - H_S^2\right),\ H_S \le R \le R_m\,. \tag{16}$$

d) Localization area on the orbital shell of the LEOS set irradiating the OP by SLs, is a spherical belt ABCD in Figure 5; p.d.d. of the distance R from these LEOS to the OP retains the form (16) for $R_m \le R \le R_{max}$.

For this scenario, expressions (7) for the average EMB intensity created in the OP by LEOS radiations along the main ($Z_{\Sigma ML}$) and side ($Z_{\Sigma SL}$) lobes, have the following forms:

$$Z_{\Sigma ML} = \frac{\rho P_{TRP} G_{ML}\left(R_E + H_S\right)\left(H_S - R_m \sin\theta_{min}\right)}{R_m^2 - H_S^2} \ln\frac{R_m}{H_S}\,; \tag{17}$$

$$Z_{\Sigma SL} = \frac{P_{TRP} G_{ML} \rho\left(R_E + H_S\right) R_m \sin\theta_{min}\, tg^2 \dfrac{\Delta\varphi}{4}}{C_P\left(R_{max}^2 - R_m^2\right)} \ln\frac{R_{max}}{R_m}\,. \tag{18}$$

D. LEOS with inclined narrow ML, scenario 4.

This scenario (Fig. 6) is most adequate to the analysis of Starlink LEOS constellations, the ML width $\Delta\varphi$ in which is 3.5º–5.5º depending on the angle of beam inclination, and many orbit inclinations for many orbital planes allows to consider the ML azimuth of a separate LEOS in the radio visibility zone from OP equal to the random equiprobable with its relatively small constant elevation angle θ_{min} (Fig. 1) which provides the required service zone for the ground-based UE in the LEOS moving direction.

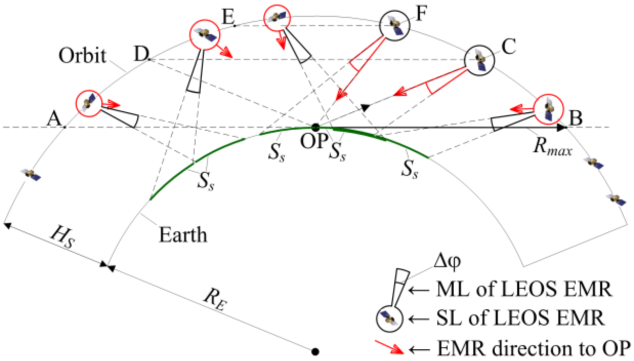

Fig. 6. Model of the distributed above the earth's surface constellation of LEOS with narrow conical ML inclined in different directions. Parts of LEOS EMR patterns capable of OP irradiating are highlighted in red.

Due to the noted differences of this scenario from the previously considered, at its analysis a different approach was used, based on scalar averaging the set of EMFs PFD radiated by LEOS, along the earth's surface, as well as a probabilistic approach based on the representation of the irradiation of the ground OP by LEOS ML as a rare event and determining the average EMB level in OP using Poisson probabilistic model.

Area S_S of the "spot" on the earth's surface (Fig. 1), irradiated by the LEOS narrow conical beam with a width of $\Delta\varphi$, is determined by the following expressions:

$$\left.\begin{array}{l} S_S \approx \pi \cdot L_X L_Y / 4; \quad L_Y \approx 2H_S tg(\Delta\varphi/2)/sin(\varepsilon); \\ L_X = H_S \cdot \dfrac{tg(\varepsilon + 0.5\Delta\varphi) - tg(\varepsilon - 0.5\Delta\varphi)}{tg(\varepsilon + 0.5\Delta\varphi) tg(\varepsilon - 0.5\Delta\varphi)}. \end{array}\right\} \quad (19)$$

The relative total average area S_{RA} of irradiation of the earth's surface by the constellation of N_{Σ} LEOS in the orbital shell with orbit height H_S, will be equal to:

$$S_{RA} = N_{\Sigma} S_S / S_E \approx \pi L_X L_Y N_{\Sigma} / (4 S_E), \quad S_E = 4\pi R_E^2. \quad (20)$$

Estimates using (18), allow us to conclude that upon completion of the Starlink system ($N_{\Sigma} \approx 30\,000$ on 10-15 orbital shells with altitudes ranging from 340 to 640 km), a scenario assuming an inclined position of the ML with an elevation angle $\theta_{min} = 25°$, provides almost complete “single-layer” coverage of the entire earth’s surface, in which any point on the surface at any given time is in the service area of at least one of the LEOS.

Since the S_{RA} parameter can be interpreted as the average number of LEOS MLs irradiating an OP at an arbitrary moment, we can assume that the probability $p(k)$ of its irradiation at that moment by a specific number k of LEOS is determined by the Poisson distribution:

$$p(k) = S_{RA}^k exp(-S_{RA})/k!. \quad (21)$$

The average PFD Z_a created in the “spot” of LEOS ML on the earth’s surface is equal to:

$$Z_a \approx \left(C_P P_{TRP} sin^2 \varepsilon\right) / \left[4\pi H_S^2 (1 + C_P) sin^2(\Delta\varphi/4)\right]. \quad (22)$$

At the discrete distribution (21) of the probabilities of an OP falling into the service area of exactly k LEOS MLs, the average EMB intensity created in this OP is equal to:

$$Z_{\Sigma ML} = \sum_{k=1}^{K_m} k Z_a p(k), \quad K_m >> 1. \quad (23)$$

It is obvious that the adequacy of Poisson model in relation to the considered scenario is limited, since the relative OP and LEOS position cannot be considered completely random, since the relative position of LEOS in the orbital shell of constellation has the regularity necessary to ensure acceptable waiting times and a minimum probability of UE service failure. But taking into account the presence of many orbital shells in constellation, as well as the independence of separate LEOS constellations and relative smallness of S_{RA}, positions of LEOS relative to OP can be considered random, and model (23) can be considered adequate under certain restrictions on k values.

The number $N_{\Sigma SL}$ of LEOS irradiating the earth's surface by SLs is determined by the number N_{Σ} of LEOS in the radio visibility zone from OP and the ratio of the solid angle Ω_{ML}, corresponding to ML, and the solid angle Ω_H, subtended by the earth's surface along the horizon and corresponding to the angle β_{max} (14) at $\theta_{min} = 0$:

$$\left.\begin{array}{c} N_{\Sigma SL} = N_{\Sigma}(\Omega_H - \Omega_{ML})/\Omega_H \\ \Omega_H = 2\pi\left(1 - \sqrt{H_S^2 + 2R_E H_S} / (H_S + R_E)\right) \\ \Omega_{ML} = 2\pi(1 - cos(\Delta\varphi/2)) \end{array}\right\}; \quad (24)$$

LEOS SL radiations in the direction of the earth's surface are considered isotropic in a solid angle of magnitude $\Omega_H - \Omega_{ML}$, therefore, to determine the average EMB intensity $Z_{\square SL}$ created by these radiations at the earth's surface, we can use relations (12, 13) for isotropic LEOS EMR (scenario 1) by substituting into them P_{eSL} of SL EIRP values:

$$\left.\begin{aligned} P_{eSL} &= P_{TRP} \big/ \left((1 + C_P) cos^2 (\Delta\varphi/4) \right), \\ Z_{\Sigma SL} &= N_{\Sigma SL} P_{eSL} \, ln\left(R_{max} / H_S \right) \big/ \left[2\pi \left(R_{max}^2 - H_S^2 \right) \right], \end{aligned}\right\} \tag{25}$$

the average total EMB level $Z_{\square}$ is determined similarly to (8) as the sum of (23) and (25).

4 Quantitative analysis of average EMB intensity at the considered scenarios

Analysis of dependences of EMB components $Z_{\Sigma ML}$, $Z_{\Sigma SL}$ and of the total level Z_Σ of the average EMB intensity created by LEOS ML EMRs at the earth's surface for different scenarios on the quantity N_Σ of LEOS in the constellation with typical parameters $P_{TRP} = 100$ W, $H_S = 550$ km, indicates the following:

1) EMB level at the earth's surface significantly depends on the C_P parameter, which characterizes the loss of EMR power due to the SLs, which reduces the part of the LEOS total radiated power P_{TRP} that reaches the earth's surface. At an increase in C_P and a decrease in θ_{min}, the dependences $Z_\Sigma(N_\Sigma)$ tend to the pessimistic one peculiar to scenario 2 (relation (15)), in which all energy radiated by LEOS falls on the earth's surface. In scenarios 3, 4, with a fixed P_{TRP} and excluding MLs from falling beyond the earth's surface ($\theta_{min} - \Delta\varphi/2 > 0$), a change in ML width is accompanied by a corresponding change in G_{ML} and ML EIRP with practical constancy of the covering total radiated power – the P_{TRP} fraction, emitted in solid angle Ω_H (24) [7]. Therefore, for given N_Σ, θ_{min}, P_{TRP} and C_P, the average EMB intensity at the Earth's surface is practically independent of ML width $\Delta\varphi$ and on LEOS orbit height H_S. At multi-beam LEOS EMR, an increase in the number of beams is accompanied by a decrease in the radiated power of each beam in such a way that the total radiated power P_{TRP} remains constant, limited by LEOS energy capabilities, which can be interpreted as an expansion of the equivalent single ML, under the accepted restrictions does not affecting on the average intensity of the created EMB.

2) The very weak dependence of the average EMB intensity created by the LEOS constellation at the earth's surface on the orbital altitude H_S, noted above in relation to scenarios 3, 4, indicates the applicability of (17-25), at least for analyzing the EMB intensity created by the entire constellation of non-geostationary satellite communication and navigation systems, in particular, global navigation satellite systems GPS, GLONASS, Galileo, Beidou, etc.

3) Pessimistic estimates of the average EMB levels created by LEOS constellations (worst case estimates) can be performed using relation (15), and a more detailed analysis using (17-19, 23, 25) allows to assess the impact on the average EMB levels of the power efficiency and directionality of LEOS EMR (parameters C_P, $\Delta\varphi$), orbit altitudes H_S, restrictions on the elevation angle θ_{min} of the served LEOS, etc.

5 Conclusion

The above relations (9-19, 23, 25), obtained as a result of the analysis of several operation scenarios for the LEOS constellations, provide the possibility of a preliminary multivariant pessimistic (worst-case) quantitative analysis of the average intensity of the EMB created by these systems near the earth's surface. The results obtained using probabilistic schemes (6) and (21-23) are practically identical, which in general can be considered as evidence of the adequacy of these different approaches and methods for analyzing the average EMB intensity created by LEOS constellations.

Comparison of the average level of natural EMB in SHF frequency band, which is of about $10^{-20}…10^{-19}$ W/m^2 according to [8], with the average levels of artificial EMB created by the LEOS megaconstellations indicates that these levels can exceed the level of natural EMB by many orders of magnitude. And although, in general, levels of artificial EMB created by the radiation of LEOS megaconstellations remain quite low, such a quantitatively significant change in physical characteristics of the operating environment of ground-based technical systems and the habitat of the population requires serious attention and analysis.

Taking into account the problem relevance, presented results require further development and clarification. In terms of a more detailed comparison of the EMB levels created by LEOS megaconstellation emissions with various components of natural EMB created by extraterrestrial sources. In accordance with [9], as well as the EMB levels created by the subscriber terminals emissions of satellite communication systems.

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