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RESONANCE PROPERTIES OF INHOMOGENEOUS EARTH-TO-IONOSPHERE CAVITY

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The Earth-to-ionosphere cavity is latitudinally inhomogeneous, which results in its peculiar resonance parameters worthy of researching interest.

In [1], the latitudinal inhomogeneity of the Earth-to-ionosphere resonance cavity is considered in terms of the homogeneous model solution by averaging the daily mean relative phase velocity $\overline{c}/v$ and attenuation rate $\overline{\alpha}$ along the field propagation paths. The field propagation paths are identified over the Earth great circle arcs in terms of their basis values $\rho = \arcsin(\sin\beta \cdot \cos\Psi)$, where β is the path deviation angle in reference to the meridional direction, and Ψ is the receiver geographic latitude. The local c/v and α latitudinal dependences for the day and night ionospheres are used as the initial data [2]. The ionosphere reflection of the field within Schumann frequency range is considered only for E region altitudes.

Figs. 1 and 2 show the frequency dependence curves $\overline{c}/v$ (Fig. 1) and $\overline{\alpha}$ (Fig. 2) for the basis different values $\rho^{\circ} = 0, 40, 60, 70, 80, 90$, according to the data from [1] . Here, the straight lines of frequency dependence values $\overline{c}/v$ and $\overline{\alpha}$ are also given for the four resonance modes $n = 1, 2, 3, 4$ derived from expression [3]

$$f_n = \frac{c\sqrt{n(n+1)}}{2\pi a \cdot \overline{c}/v}, \qquad (1)$$

where $c = 3\cdot 10^{8}\, m/s$; $a = 6.4\cdot 10^{6} m$.

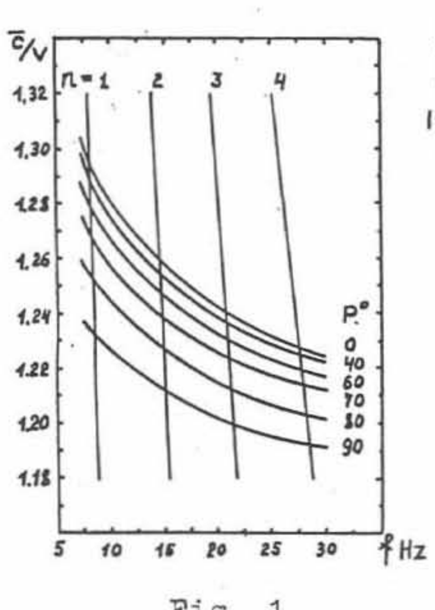

Fig. 1

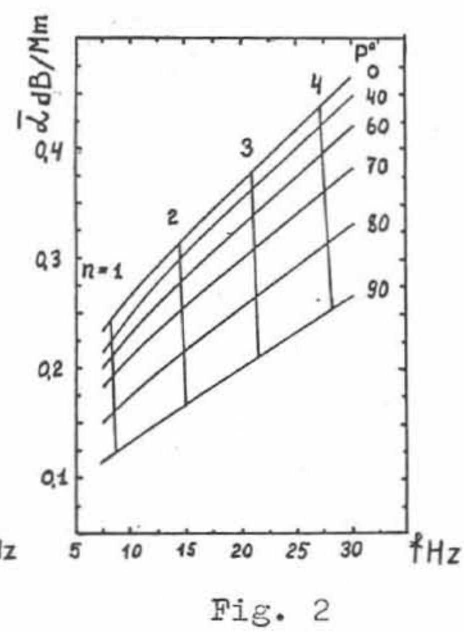

Fig. 2

The intersection of straight lines and curves of frequency dependence $\overline{c}/v$ and $\overline{\alpha}$ for different ρ results in these values for resonance frequencies. Resonance frequencies f'_n and Q'_n factors of the Schumann resonance modes are calculated in terms of detected resonance values $\bar{c}/v$ and $\bar{\mathcal{L}}$ from Figs. 1 and 2 and by normalized ionosphere surface impedance

$$\Delta_n = j k h \left(Re\, S_n^2 - Im\, S_n^2 - j 2 Re\, S_n \cdot Im\, S_n - 1\right), \qquad (2)$$

where $k = \omega_n / c$; $\omega_n = 2\pi f_n$; $Re\, S_n = \bar{c}/v$; $Im\, S_n = 5{,}49\bar{\mathcal{L}}/f_n$ and h is the lower ionosphere altitude. The Δ_n expression is derived from the equation for zero waveguide mode propagation parameter S_0 [4]. The obtained value Δ_n is substituted in the expression for complex resonance frequency of the Earth-to-ionosphere homogeneous cavity [4]

$$\dot{f}_n' = \frac{\omega_{on}}{2\pi}\left[1 - \frac{1}{4\omega_{on}^2}\left(\frac{c\,\Delta_n}{h}\right)^2\right]^{1/2} + j\frac{c\,\Delta_n}{2h}, \qquad (3)$$

where $\omega_{on} = \frac{c\sqrt{n(n+1)}}{a}$. The desired resonance frequency $f_n' = Re\,\dot{f}_n'$ and $Q_n' = Re\,\dot{f}_n' / 2 Im\,\dot{f}_n'$ factor is received. Value h from formulae (2), (3) is reduced and not involved in f_n' and Q_n' determinations.

The variations in radio noise resonance parameters f_n' and Q_n' caused by latitudinal inhomogeneity are to be quantitatively estimated. The distribution of thunderstorms in space results in different ρ basis values of the field propagation paths at the point of reception. Therefore, the dependence of the resonance cavity waveguide parameters on ρ basis for any path is to be considered in the field calculations. We introduce the notion of effective basis ρ_{ef}, in order to examine the general regularities of resonance parameters. ρ_{ef} value is derived from averaging all existing ρ with consideration of the field intensities ratio at the reception point. Thus, ρ_{ef} value is determined only by the reception point geographic latitude in the case of equatorial model of thunderstorm world-wide activity with uniform longitudinal intensity. All the field paths are meridional with $\rho = 0$, if the receivers are placed at the geographic poles of the Earth. The basis values are increased up to $\rho^\circ = 90$ at the equator, as the latitude of reception is lower. According to estimations, $20 \leq \rho_{ef}^\circ \leq 60$ if the reception points are placed in latitudes from 15° to 60° north. The Table presents the calculated f_n' and Q_n' values for $\rho^\circ = 20, 60$.

Table

n	$\rho^\circ=20$		$\rho^\circ=60$		$\rho^\circ=28$				Observed	
	f_n'	Q_n'	f_n'	Q_n'	f_n'	Q_n'	f_n	Q_n	f_n	Q_n
1	8.06	3.02	8.2	3.68	8.08	3.14	8.13	4.0	7.95	3.01
2	14.42	4.12	14.63	4.91	14.47	4.24	14.52	5.25	14.32	4.58
3	20.72	4.9	20.98	5.75	20.78	5.03	20.82	6.13	20.59	4.97
4	27.1	5.6	27.34	6.41	27.13	5.71	27.16	6.89	26.87	5.45

The f_n' and Q_n' values are increased for 1,73; 1,45; 1,25; 0,88 % and 21,85; 19,17; 17,34; 14,46 %, respectively for the four modes. A considerable increase in Q_n' with $\rho^\circ = 60$ as compared with $\rho^\circ = 20$ is caused by significant radio noise energy losses through ionosphere on meridional-close paths. It is noteworthy that f_n' and Q_n' changes are insignificant with $0 \leq \rho^\circ \leq 30$ and become noticeable only if $\rho^\circ > 30$.

The Table also gives the calculated and experimental data available at a certain reception point to make a comparative study of resonance parameter absolute values. Such a reception point is in the vicinities of Petropavlovsk-Kamchatsky and the seasonal time is summer, 1990[5] . There, radio noise electrical vertical component E_z was received by anti-interference aerial with compensating electrode [6] . Daily average values f_n and Q_n are experimentally estimated in terms of the examination of radio noise spectrum density curves with 8.5 minutes averaging time. According to the evidences of ELF radio noise space-time model, $\rho^{\circ}_{ef} = 28$ for this reception point in summer [7]. The calculated values of f_n from formula (1) and $Q_n = \bar{c}_N / 11 \cdot \mathcal{I}$ from [3] are also given in the Table for illustration. The calculated values of resonance frequencies are much coincident (see the Table) and close to experimental data. Q-factors are coincident with experimental data only in case of Q'_n with Q_n much exceeding this value.

Resonance parameters are as well dependent on the directional patterns of receiving aerial, due to latitudinal inhomogeneity. If a sensor is oriented to receive the radio noise horizontal magnetic component H_{N-S} , then the field intensity is increased for the paths with greater ρ , which results in increased f_n and Q_n values, in contrast to sensors oriented to receive H_{E-W} component. The resonance parameters of E_z component received at a vertical whip are intermediate between H_{N-S} and H_{E-W} components of radio noise. Absolute f_n and Q_n values and their difference between horizontal magnetic components is determined by ψ values for three sensors. This has been experimentally proved by the field registrations at different 44° and 70° northern latitudes in the east of Russia.

References

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