Influence of Conductivity Perturbation at the Middle Atmosphere on Schumann Resonances

S.S. De[1], S.K. Adhikari[2] and M. De[3]
[1]*Centre of Advanced Study in Radio Physics & Electronics*
Calcutta University
1, Girish Vidya Ratna Lane, Kolkata-700 009,
India
Tel : 91-033-334 9334
e-mail : de_syam_sundar@hotmail.com
[2],[3]*As(n) above*

Abstract

Due to the variation of the supply of electromagnetic energy from global thunderstorm into the earth-ionosphere cavity at the Schumann resonance frequencies, the conductivity of the medium becomes tensorial in nature. In this paper, the influences of anisotropy of the conducting medium above 70 Km height along with the day-night azimuthal and polar-cap latitudinal asymmetries of conductivity profile towards Schumann resonances are studied theoretically. The link between Schumann resonance and global warming has been explored.

Introduction

In the global electric circuit, current flows from thunderstorms in the troposphere into the ionosphere and magnetosphere, and returning to ground through fair-weather atmosphere and closing via lightning [1,2,3]. The selected frequencies and absorption of lower Schumann modes are dependent on the conductivity at various heights in earth-ionosphere cavity. The dependence is more pronounced in the height range 45 Km to 95 Km, where conductivity perturbations have pronounced effects. Uncertainties arise from spatial distribution of lightning sources exciting Schumann modes that may be inferred [4].

The changes of the nature and strength of various ionisation sources manifest the modulations in the atmospheric conductivity at heights where those ionisation sources are dominant. These variations in the conductivity profile in turn influence the Schumann resonances. Thus the observational characteristics of Schumann spectra is helpful in the study of the electrical properties of the mesospheric heights.

There are various model calculations describing the radial part of eigen functions of the earth-ionosphere system for the case of spherically symmetric, isotropic dielectric of arbitrary radial profile. From the eigen function solutions, the vertical and tangential components of electric field along with the Joule dissipation profiles have been calculated earlier and numerically analysed using some model conductivity profiles and associated perturbations. The previous models are mostly restricted to isotropic and spherically symmetric conductivity perturbations. But the true picture giving rise to significant effects may arise from several sources including anisotropy of the conducting medium above 70 Km height, the day-night azimuthal and polar-cap latitudinal asymmetries of the conductivity profile, and the eccentricity of the terrestrial magnetic dipole.

In presence of the geomagnetic field and its associated perturbations particularly due to influence of temporal and spatial variations of global lightning activity as deduced from Schumann resonance data [4], an expression of conductivity tensor for the lower ionosphere has been derived. This is used in a model calculation for the eigen function solutions from which the vertical and the tangential components of electric field are obtained.

Mathematical Method

The form of conductivity tensor may be written as

$$(\sigma) = \begin{pmatrix} \sigma_1 & -\sigma_2 & 0 \\ \sigma_2 & \sigma_1 & 0 \\ 0 & 0 & \sigma_0 \end{pmatrix} \qquad (1)$$

where σ_1, σ_2, σ_0 are obtained as

$$\sigma_1 = -\frac{n_o e}{2m\omega_c}\int_o^\infty \chi_2\,(\cos\phi - \frac{2v_o^2k_x^2}{\omega_c^2}\sin^2\phi)\,d\phi -$$

$$-\frac{n_o^2\,ek_x^2}{m\omega_c^3R_2}[\int_o^\infty \chi_2 \sin\phi\,d\phi\,]$$

$$\times\,[\int_o^\infty \chi_2\,\{\frac{\varphi v_o^2}{\omega_c}\sin\phi + \frac{\mu\omega}{2k_x^2}\cos\phi - \frac{2k_x^2v_o^4}{\omega_c^2}\sin^2\phi\}\,d\phi\,].$$

$$\sigma_2 = \frac{n_o e}{2m\omega_c}\int_o^\infty \chi_2\,(\frac{2v_o^2k_x^2}{\omega_c^2}\cos\phi\sin\phi + \sin\phi - \frac{2k_x^2v_o^2}{\omega_c^2}\sin\phi)\,d\phi +$$

$$+\frac{n_o^2\,ek_x^2}{m\omega_c^3R_2}[\int_o^\infty \chi_2\,(1-\cos\phi)\,d\phi]\times$$

$$\times\,[\int_o^\infty \chi_2\,\{\frac{\varphi}{\omega_c}\sin\phi + \frac{\mu\omega}{2k_x^2}(\cos\phi - \frac{2k_x^2v_o^2}{\omega_c^2}\sin^2\phi)\}\,d\phi\,].$$

$$\sigma_o = \frac{n_oek_z^2v_o^2}{m\omega_c^3}\int_o^\infty \phi\chi_1\,d\phi - \frac{n_o^2ek_z^2v_o^2}{m\omega_c^4R_1}[\int_o^\infty \phi\chi_1\,d\phi\,]\times$$

$$\times\,[\int_o^\infty (\varphi\phi - \frac{\mu\omega}{\omega_c}\phi^2)\,\chi_1\,d\phi\,],$$

where,

$$\chi_1 = \exp\,[-\frac{k_z^2\,v_o^2}{2\omega_c^2}(\phi-\alpha_1)^2\,] + \frac{k_z^2v_o^2}{2\omega_c^2}\alpha_1^2$$

$$\alpha_1^2 = \frac{\omega_c^2\,(\omega-\varphi)^2}{k_z^4v_o^4}$$

and

$$R_1 = 1 + \frac{\varphi\,n_o}{\omega_c}\int_o^\infty \chi_1\,d\phi - \frac{\mu n_o\omega}{\omega_c^2}\int_o^\infty \phi\chi_1\,d\phi.$$

Due to space limitation, these are not worked out here, but interested parties can obtain copies by writing to the authors. From Maxwell's equation and other constitutive relations, the wave equations can be written as

$$[(\sigma) + i\epsilon_o k\omega]\,[\nabla^2 \vec{H} + \mu_o k\epsilon_o \omega^2 \vec{H} - i\mu_o\,\omega\,(\sigma)\,\vec{H}\,] + \nabla\,[ik\epsilon_o\omega + (\sigma)] \times (\nabla \times \vec{H}) = 0 \qquad (2)$$

For vertical polarisation $\vec{H} \,.\, \vec{r} = 0$, where r is the radius vector from the centre of the earth.

In terms of spherical harmonics, consider

$$\vec{H} = \sum_{\ell m} \frac{f_{\ell m}(r)}{\sqrt{\ell(\ell+1)}}\; \vec{r} \times \nabla Y_\ell^m(\theta, \varphi) \qquad (3)$$

$Y_\ell^m(\theta, \varphi)$ are the spherical harmonics.
Using (1) and (3) in (2), the radial function $f_{\ell m}(r)$ has been calculated.

Energy flow is outward from the cavity, downward into the earth and upward into the ionosphere. With these boundary conditions, the expressions of vertical and tangential components of electric field have been derived.

Global Warming

The Schumann resonance, a global electromagnetic phenomenon, is known to be a sensitive measure of temperature fluctuation in the earth's atmosphere [3,5]. The non-linear temporal variation of the global lightning activity upon the earth-ionosphere wave guide introduces the link between Schumann resonance and global warming.

If the interacting waves due to lightning have maximum and minimum power P_1 and P_2 respectively (within one modulated cycle), the medium temperature can be expressed as

$$T(P_1, P_2, t) = T_o(\bar{P}) + \Delta T(P_1, P_2)\, e^{-j\omega t} \qquad (4)$$

$T_o(\bar{P})$ = the ambient electron temperature belonging to the average power $(P_1 + P_2)/2$.

$$\Delta T(P_1, P_2) = \frac{1}{2}\,[\,T_o(P_1) - T_o(P_2)\,]\;\left(\frac{1 + j\omega\tau_T}{1 + \omega^2 \tau_T^2}\right)$$

τ_T is the characteristic time (about 1 ms at 60 Km).

The current at the frequency ω produced by the interaction can be expressed as

$$\Delta\vec{j} = \left[\frac{d(\sigma)}{dT}\,\Delta T + \frac{d(\sigma)}{dn}\,\Delta n\right] \vec{E}. \qquad (5)$$

(σ) = conductivity tensor.

Equation (5) is the primary source current which introduces current modulation for which waves in ELF and VLF ranges are generated. The strength of the various modes depends on the magnitude of $\Delta\vec{j}$, which can be evaluated from (5).

Results and Discussion

From this analysis, it reveals that the selected frequencies and absorption of lower Schumann modes are dependent on the conductivity at various heights, particularly in the height range 45 Km to 95 Km, where conductivity perturbations have pronounced effects giving rise to frequency shifts and changes in attenuation of Schumann modes. A systematic study of diurnal and seasonal amplitude and frequency variations of resonances are also interpreted. The changes have been correlated with ionospheric disturbances. The parameters of night-time ionosphere may be clarified. The variation of ionospheric parameters and the variation of magnetic field vector along the surface of the earth may also be considered. The typical continuous ELF noise spectra between 6-40 Hz could further be investigated.

References

[1] C.L. Bhat, M.L. Sapru, R.K. Kaul, and H. Razdan, "Response of 'atmospheric' lightning to systematic changes in the global electric field," *J. atmos. terr. Phys.*, vol. 49, pp.209-215, No.3 1987.

[2] R.G. Roble, "On modeling component processes in the Earth's global electric circuiut," *J. atmos. terr. Phys.*, vol. 53, pp.831-847, No. 9 1991.

[3] E.A. Bering III, A.A. Few, and J.R. Benbrook, "The global electric circuit," *Phys. To-day*, pp.24-30, October 1998.

[4] A.P. Nickolacnko, M. Hayakawa, and Y. Hobara, "Temporal variations of the global lightning activity deduced from the Schumann resonance data," *J. atmos. terr. Phys.*, vol.58, pp.1699-1709, No. 15 1996.

[5] E.R. William, "The Schumann resonance : a global tropical thermometer," *Science*, vol. 256, pp.1184-1187, May 1992.