RADIATION FROM A DIPOLE IN AN ANISOTROPIC PLASMA MEDIUM CONTAINING TIME-VARYING IRREGULARITIES

(Letter to the Editor)

S. S. DE

Centre of Advanced Study in Radio Physics and Electronics, University of Calcutta, India

and

A. C. SEN

Department of Physics, Bejoy Narayan Mahavidyalaya, Dist. Hooghly, West Bengal, India

(Received 7 January, 1989)

Abstract. The expression for power radiated from a dipole within an anisotropic plasma has been obtained in presence of a current source and time-varying irregularities. This may be useful for numerical computation in lossy media.

1. Introduction

Field solution for a dipole within an anisotropic medium has been investigated by different authors (Wait and Schlak, 1967; Alpert and Moiseyev, 1980; Pozar *et al.*, 1985; Tsalamengas and Uzunoglu, 1985; De and Sen, 1987, 1988). In the case of an anisotropic medium appropriate to the ionospheric plasma, field solutions for a dipole in presence of time-varying irregularities along with the infinitesimally small electric current source are derived (De and Sen, 1988). In this presentation, the previous work has been extended to evaluate the rate of energy transfer from such a dipole.

2. Mathematical Method

The governing equation with source term may be written as

$$\nabla \times \mathbf{H} = j\omega\varepsilon_0(\bar{\varepsilon})\mathbf{E} + \mathbf{J} . \tag{1}$$

The force equation for the stated medium is given by

$$\frac{\partial \mathbf{v}}{\partial t} = \frac{e}{m_e}\left(\mathbf{E} + \frac{\mathbf{v} \times \mathbf{B}}{c}\right) - \eta\mathbf{v} . \tag{2}$$

The effective magnetic field has been taken as

$$\mathbf{B} = \mathbf{B}_0 + \mathbf{B}_1\, e^{j\omega_0 t} , \tag{3}$$

where $\mathbf{B}_0$ is the Earth's magnetic field and $\mathbf{B}_1\, e^{j\omega_0 t}$ is due to time-varying irregularities.

By use of Equations (2) and (3) (and of other transformations) the expression for

Astrophysics and Space Science **155**: 327–329, 1989.

dielectric tensor can be derived. This has been used in Maxwell's wave equations to evaluate the field components by using inverse Fourier-transform technique (De and Sen, 1988).

Energy radiated per unit volume is given (cf. Brandstatter, 1963) by

$$W = -\tfrac{1}{2}\,\mathrm{Re}\,\mathrm{div}[\mathbf{E}\times\mathbf{H}^*]\,. \tag{4}$$

The expressions of **E** and **H*** can be taken from the work just referred to. On simplification, Equation (4) yields

$$\begin{aligned} W = -\frac{1}{2}\,\mathrm{Re}\Bigg[\frac{\omega^2\mu^2}{\pi^4}\,J_0^2\left(\frac{A_c\nu}{2}\right)\Bigg\{-\frac{j\Gamma^2}{\omega\mu}\,(\cos^2\psi+\sin^2\psi\cos^2\alpha)\,\times \\ \times\left(\frac{T_aT_d+T_aT_c+T_bT_d+T_bT_e}{T_cT_f}\right)-\frac{j\Gamma^2\sin^2\psi}{\omega\mu}\left(\frac{L_aL_c}{T_cT_f}\right)- \\ -\frac{j\Gamma^2\sin^2\psi\sin\alpha\cos\alpha}{\omega\mu}\left(\frac{S_cT_a+S_cT_b}{S_dT_c}\right)-\frac{j\Gamma^2\sin^2\psi\sin\alpha\cos\alpha}{\omega\mu}\,\times \\ \times\left(\frac{S_aT_d+S_aT_e}{S_bT_f}\right)-\frac{j\Gamma^2\sin\psi\cos\psi\sin\alpha}{\omega\mu}\left(\frac{L_aT_d+L_aT_e}{T_cT_f}\right)- \\ -\frac{j\Gamma^2\sin\psi\cos\psi\sin\alpha}{\omega\mu}\left(\frac{L_cT_a+L_cT_b}{T_cT_f}\right)+\frac{j\Gamma^2\sin\psi\cos\psi\cos\alpha}{\omega\mu}\,\times \\ \times\left(\frac{S_cL_a}{D_dT_c}\right)+\frac{J\Gamma^2\sin\psi\cos\psi\cos\alpha}{\omega\mu}\left(\frac{S_aL_c}{S_bT_f}\right)\Bigg\}\Bigg], \end{aligned} \tag{5}$$

where

$$S_a = h_1\ln v_1+\frac{h_2}{v_1}+\frac{h_3}{v_1^2}+\frac{h_4}{v_1^3}+\frac{h_5}{v_1^4}+\frac{h_6}{v_1^5}+\frac{h_7}{v_1^6}\,,$$

$$S_b = 4a_1u_1^4+3a_2u_1^2+2a_3u_1+a_4\,,$$

$$S_c = h_1^*\ln v_1+\frac{h_2^*}{v_1}+\frac{h_3^*}{v_1^2}+\frac{h_4^*}{v_1^3}+\frac{h_5^*}{v_1^4}+\frac{h_6^*}{v_1^5}+\frac{h_7^*}{v_1^6}\,,$$

$$S_d = 4a_1^*u_1^4+3a_2^*u_1^2+2a_3^*u_1+a_4^*\,,$$

$$T_a = l_1v_1^2+l_2v_1\,,$$

$$T_b = l_3\ln v_1+\frac{l_4}{v_1}+\frac{l_5}{v_1^2}+\frac{l_6}{v_1^3}+\frac{l_7}{v_1^4}+\frac{l_8}{v_1^5}+\frac{l_9}{v_1^6}\,,$$

$$T_c = 4a_1u_1^3+3a_2u_1^2+2a_3u_1+a_4\,,$$

$$T_d = l_1^* v_1^2 + l_2^* v_1 ,$$

$$T_e = l_3^* \ln v_1 + \frac{l_4^*}{v_1} + \frac{l_5^*}{v_1^2} + \frac{l_6^*}{v_1^3} + \frac{l_7^*}{v_1^4} ,$$

$$T_f = 4a_1^* u_1^3 + 3a_2^* u_1^2 + 2a_3^* u_1 + a_4^* ,$$

$$L_a = n_1 \ln v_1 + \frac{n_2}{v_1} + \frac{n_3}{v_1^2} + \frac{n_4}{v_1^3} + \frac{n_5}{v_1^4} + \frac{n_6}{v_1^5} + \frac{n_7}{v_1^6} ,$$

$$L_c = n_1^* \ln v_1 + \frac{n_2^*}{v_1} + \frac{n_3^*}{v_1^2} + \frac{n_4^*}{v_1^3} + \frac{n_5^*}{v_1^4} + \frac{n_6^*}{v_1^5} + \frac{n_7^*}{v_1^6} ;$$

and the other symbols are taken from the previous work (De and Sen, 1988).

3. Discussion

Within the upper atmosphere, specially in polar atmosphere, the time-varying irregularities give rise to time-varying magnetic field over and above the static field of the medium. The result given by (5) has been derived in a comprehensive manner which may be useful for the evaluation of fields as well as energy transfer at any arbitrary distance from the source located within the stated medium.

References

Alpert, Ya. L. and Moiseyev, B. S.: 1980, *J. Atmospheric Terrest. Phys.* **42**, 521.

Brandstatter, J. J.: 1963, 'An Introduction to Waves, Rays and Radiation', in *Plasma Media*, McGraw-Hill Book Co. Inc., New York.

De, S. S. and Sen, A. C.: 1987, *Indian J. Radio Space Phys.* **16**, 207.

De, S. S. and Sen, A. C.: 1988, *Astrophys. Space Sci.* **150**, 317.

Pozar, D. M., Kang, Y. W., Schaubert, D. H., and McIntosh, R. E.: 1985, *IEEE Trans. Antennas Propag.* **33**, 69.

Tsalamengas, J. L. and Uzunoglu, N. K.: 1985, *IEEE Trans. Antennas Propag.* **33**, 165.

Wait, J. R. and Schlak, G. A.: 1967, *Electron Letters* **3**, 421.