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Effect of the rotating plasma column on the radiation due to the source of electric currents

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The effect of the rotating dielectric property of the plasma on the radiation pattern has been discussed. It can be pointed out that the plasma column (cylindrical shaped) while excited with the help of electric ring source gives more radiations for higher modes.

1. INTRODUCTION

An appreciable amount of research work has been carried out on the excitation of the plasma column with the help of various types of sources by Bachynski (1967), Dhani Ram *et al* (1972) and Ram Chandra *et al* (1974, a review on the subject to be published). Also Ram Chandra *et al* (1974) and Dhani Ram *et al* (1972) have studied the excitation of the plasma column with the help of ring sources. They discussed the problem only for lowest mode assuming plasma column to be stationary. Here we have studied the problem taking the plasma column to be rotating and its effect on the radiation field has been given.

2. ANALYSIS

The geometry to be analysed here is same as that of Dhani Ram *et al* (1972) except that the source is placed outside the plasma column. The ring source here is of electric currents having radius a and placed in the air. The conductor (along the z-axis of the cylindrical coordinates) is of radius a_1 and gaseous plasma column of b ($a > b > a_1$). Following Dhani Ram *et al* (1972) and assuming the variation taken by Shigoyuki *et al* (1975) one can easily arrive at the expression of E_φ *i.e.*, $F(\theta)$

$$|F(\theta)| = \frac{C_{21}}{(C_7\,C_{22}+C_{12}C_{21})}$$

$$C_{21} = \frac{C_6C_{20}}{C_{12}}+C_6,\ C_7 = H_n(V_0a)$$

$$C_{22} = \frac{C_{10}(C_4\,C_{18}-C_{14}\,C_{17})}{C_{13}\,C_{17}-C_3\,C_{18}}+C_{11},\ C_4 = Y_n(V_0b)$$

$$C_{12} = V_0 a H_m^{(1)}(V_0 a) - H_n^{(1)}(V_0 a)$$

$$C_5 = J_n(V_0 a),\ C_{18} = C_{15} - C_8 \frac{C_{16}}{C_9}$$

$$C_{15} = V_1 b J_m(V_1 b) - J_n(V_1 b)$$

$$C_{16} = b V_1 Y_m(V_1 b) - Y_n(V_1 b)$$

$$C_9 = Y_m(V_1 a_1),\ C_8 = J_m(V_1 a_1),\ C_1 = J_n(V_1 b)$$

$$C_2 = Y_n(V_1 b),\ C_{17} = C_1 - \frac{C_8 C_2}{C_9}$$

$$C_{14} = b V_0 Y_m(V_0 b) - Y_n(V_0 b),\ C_3 = J_n(V_0 b)$$

$$C_{13} = b V_0 J_m(V_0 b) - J_n(V_1 b)$$

$$C_{11} = Y_n(V_0 a) - V_0 a Y_m(V_0 a)$$

$$C_6 = Y_n(V_0 a),\ V_0 = k_0 \cos\theta,\ V_1^2 = k_0^2(\epsilon_p - \sin^2\theta)$$

$$k_0 = w(\mu_0 \epsilon_0)^{\frac{1}{2}},$$

J_n, Y_n and $H_n^{(1)}$ are Bessel function of first kind, second kind and Hankel function of first kind of nth order respectively. w is the source frequency, ϵ_p is the permittivity of the plasma given by Shigoyuki *et al* (1975)

$$\epsilon_p = 1 - \frac{W_p^2}{(W - n\Omega)^2},\ W_p = (ne^2/m\epsilon)^{\frac{1}{2}}$$

where W_c is the electron plasma frequency and n, e and m are density, charge and mass of the electron respectively. Ω is the angular rotation frequency given by

$$\Omega = W_c/2 \left[1 + \left(1 - \frac{2W_p^2}{W_c^2}\right)^{\frac{1}{2}}\right]$$

W_c is the cyclotron frequency. In the expression for C_s, $m = n-1$ where $n = 2, 3, 4$ for higher modes.

3. Characteristics of the Radiation Field

The calculations for $|V_0 F(\theta)|$ have been done with the help of IBM-1130 computer. Various features of the radiation field for different modes are following.

3.1. *Effect of the radius of the plasma column*

The plasma column plays an important role in this geometry. For $a = 10{\cdot}0$ cm and $n = 2$ (table 1) first the radiation field decreases (for $b = 6{\cdot}0$ and $7{\cdot}0$ cm). For $a = 11{\cdot}0$ cm and for $b = 6{\cdot}0$ cm there is decrease in the amplitude of the radiation field than that for $a = 10$ cm. But for $b = 7{\cdot}0$ cm there occurs an continuous increase in the radiation field amplitude for $a = 11{\cdot}0$ cm than that of for $a = 10{\cdot}0$ cm. The amplitude of the field is sufficiently enough for $b = 6.0$ cm (table 2) for $n = 3$ For this mode increase in b causes decrease in the ampli-

Table 1. Effect of $n = 2$ on the radiation pattern

Direction of the radiation (in degree)	Magnitude of the radiation field (in relative units) For $a = 10.0$ cm		$a = 11.0$ cm	
	$b = 6.0$ cm	$b = 7.0$ cm	$b = 6.0$ cm	$b = 7.0$ cm
1	0.7524	0.2881	0.5687	0.2959
2	0.7443	0.3013	0.5580	0.3095
3	0.7308	0.3231	0.5399	0.3320
4	0.7118	0.3534	0.9143	0.3632
5	0.6876	0.3917	0.4310	0.4028
6	0.6584	0.4375	0.4398	0.4502
7	0.6247	0.4901	0.3905	0.5047
7	0.5875	0.5484	0.3330	0.5654
9	0.5487	0.6114	0.2680	0.6310
10	0.5111	0.6772	0.1971	0.6992
11	0.4790	0.7439	0.1269	0.7702
12	0.4580	0.8093	0.0896	0.8396
13	0.4545	0.8705	0.1388	0.9054
14	0.4729	0.9245	0.2313	0.9645

Table 2. For $n = 3$

Direction of the radiation field (in degree)	Magnitude of the radiation field (in relative units) For $a = 10.0$ cm		$a = 11.0$ cm	
	$b = 6.0$ cm	$b = 7.0$ cm	$b = 6.0$ cm	$b = 7.0$ cm
1	1.0819	0.7770	1.0925	0.7647
2	1.0835	0.7879	1.0937	0.7744
3	1.0858	0.8035	1.0953	0.7902
4	1.0883	0.8259	1.0971	0.8115
5	1.0911	0.8534	1.0984	0.8378
6	1.0829	0.8852	1.0984	0.8679
7	1.0930	0.9201	1.0962	0.9006
8	1.0906	0.9565	1.0908	0.9344
9	1.0846	0.9928	1.0810	0.9674
10	1.0739	1.0269	1.0656	0.9975
11	1.0574	1.0566	1.0431	1.0223
12	1.0341	1.0792	1.0122	1.0390
12	1.0031	1.0923	0.9715	1.0448
14	0.9635	1.0931	0.9199	1.0368
15	0.91539	1.0791	0.8562	1.0119

tude of the radiation field for some directions while increase in the same for some other ones. Table 3 shows the decrease in the amplitude while increasing $b = 6 \cdot 0$ cm to $b = 7 \cdot 0$ for $a = 10 \cdot 0$ and $11 \cdot 0$ cm separately (table 3) for $n = 4$. Also at $\theta = 90°$ there occurs no radiation.

Table 3. For $n = 4$

Direction of the radiation (in degree)	Magnitude of the radiation field (in relative units) For $a = 10.0$ cm		$a = 11.0$ cm	
	$b = 6.0$ cm	$b = 7.0$ cm	$b = 6.0$ cm	$b = 7.0$ c
1	0.8477	0.2426	0.6740	0.2492
2	0.8406	0.2295	0.6642	0.2357
3	0.8287	0.2076	0.6478	0.2133
4	0.8119	0.1769	0.6244	0.1817
5	1.7903	0.1372	0.5938	0.1410
6	0.7638	0.0887	0.5557	0.0912
7	0.7387	0.0314	0.5095	0.0323
8	0.06974	0.0315	0.4550	0.0355
90	0.0	0.0	0.0	0.0

It therefore can be pointed out that the theoretical values for $|V_0F(\theta)|$ for different values of various parameters are appreciably large for higher modes while plasma is assumed to be having the rotating dielectric property which cannot be ignored while excitation of the plasma column is studied for constructing a plasma antenna system to have the radiations in some preferred directions.

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