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Scattering due to plasmas

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Scattering amplitude of the field due to ring of electric currents (wrapping around the gaseous plasma column of radius a) is calculated when the semiconductor plasma column is also present. The semiconductor plasma surrounds the gaseous one. Scattering (backwards radiations) due to plasma cylinder shows continuous increase with the direction for different permittivities of the plasma columns. Scattering due to cylinder of semiconductor plasma exhibits the peak value in certain direction which undergoes a shift when permittivity of semiconductor plasma is altered. Increase in the radius of semiconductor plasma column causes the increase in the magnitude of scattering field in the direction of 62 and 90°. A plot showing the general behaviour of the field is also supplied

1. INTRODUCTION

Excitation of plasma columns have been discussed by various authors in recent years. Tamir *et al* (1962) provided a tool to study such columns with the help of steepest descent path for far field calculations. Following this work, Gupta *et al* (1967), Dhani Ram *et al* (1972), Ram Chandra *et al* (1974) also studied the plasma column excitation by employing the ring of magnetic or electric currents. Also more complicated geometries were looked into with the same approach by Sharma *et al* (1976a, b, c, d, e) while considering the radiation mode. One can also study the scattering field amplitude also by taking the suitable choice of Hankel's function. Scattering due to transmission lines has also been studied by Sharma *et al* (1976f) when ionized gas is assumed to be present. Here we report the scattering due to gaseous and semiconductor plasmas when the ring of electric currents is being the excitation source.

2. ANALYSIS

The configuration analysed here is cylindrical shaped. The gaseous plasma (radius a) is exactly being wrapped by the source in presence of semiconductor plasma of radius b ($b > a$). The medium beyond $\rho > b$ is free space. Starting with the source form of Maxwell's equations

$$\nabla \times \bar{E} = -\dot{\bar{B}}_0 \qquad \text{... (1a)}$$

$$\nabla \times \bar{H} = \dot{\bar{D}}^0 + \bar{I}_e. \qquad \text{... (1b)}$$

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One can solve these equations in cylindrical coordinates for first asymmetric mode and can end up with the following inhomogeneous equation.

$$\left(\frac{1}{\rho}\frac{\partial}{\partial\rho}\rho\frac{\partial}{\partial\rho}+\frac{1}{\rho^2}\frac{\partial^2}{\partial\phi^2}+\frac{\partial^2}{\partial z^2}+k_0^2\epsilon_p\right)E_\phi = -j\omega\mu_0 I_e \qquad \dots (2)$$

$\bar{I}_e = \hat{\phi}\delta(\rho-a)\delta(z)$. $\bar{I}_e$ is the presentation for electric ring in $z = 0$ plane. $\hat{\phi}$ and δ are respectively the unit vector along ϕth direction and Kronecker's delta function. Now following Dhani Ram *et al* (1972), one can arrive at the equation.

$$\frac{d^2f}{d\rho^2}+\frac{1}{\rho}\frac{\partial f}{\partial\rho}+\left(k_0^2\epsilon_p-k^2-\frac{1}{\rho^2}\right)f = 0. \qquad \dots (3)$$

Here f is Fourier's transform of E_ϕ given by

$$f(\rho, k) = \int_{-\infty}^{\infty} E_\phi(\rho, z)\exp(-jkz)dz$$

and inverse transform of f is taken as

$$E_\phi(\rho, z) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(\rho, k)\exp(jkz)dk.$$

Eq. (3) furnishes the following solutions in various radial zones

$$f_1 = A_1H_1^{(2)}(V_1\rho) \qquad 0 \leqslant \rho < a \qquad \dots (4a)$$

$$f_2 = A_2J_1(V_2\rho)+B_2H_1^{(1)}(V_2\rho) \qquad a \leqslant \rho < b \qquad \dots (4b)$$

$$f_3 = A_3H_1^{(1)}(V_3\rho) \qquad b < \rho \qquad \dots (4c)$$

J_n, $H_n^{(1)}$ and $H_n^{(2)}$ are respectively Bessel's function of first kind, Hankel's function of first and second kind, each of order n.

$$V_1^2 = k_0^2\epsilon_{p1}-k^2, \quad V_2^2 = k_0^2\epsilon_{p2}-k^2 \quad \text{and} \quad V_3^2 = k_0^2-k^2$$

$\epsilon\rho_1$ and $\epsilon\rho_2$ are the relative dielectric permittivities of gaseous and semiconductor plasma respectively. Subjecting to proper boundary conditions. the magnitude of A_1 and B_2 can be made known and then by applying the steepest descent path (Collins 1961) one may come across with amplitude of the desired field by substituting $k = k_0 \sin\theta$ (Dhani Ram *et al* 1972).

3. Discussion

The amplitude of the scattering due to gaseous and semiconductor plasma is computed with the help of IBM-1130 computer for the parametric values e.g. gaseous plasma freq. $= 3\times10^{10}$ rad sec^{-1}, collision freq. $= 2\times10^{8}$ rad sec^{-1} semiconductor plasma freq. $= 3\times10^{12}$ rad sec^{-1} collision frequency $= 7\times10^{11}$ rad

sec^{-1}, $a = 0{\cdot}3$ cm, $\epsilon_{p1} = {\cdot}51$, $\epsilon_{p2} = -1{\cdot}25$ and $b = 0{\cdot}5$ cm. The magnitude of the scattering field due to gaseous plasma is reported in table 1 which exhibits that there occurs continuous increase in the scattering field magnitude (backward radiation) as one moves towards the increasing θ. This is affected by the relative

Table 1. Magnitude of the scattering field due to cylinder (radius a)

S.No.	Direction (in deg.)	Magnitude of the field (in rel. units) for		
		$b = 1{\cdot}0$ cm, $a = 0{\cdot}3$ cm	$\epsilon_{p2} = -1{\cdot}03$, $\epsilon_{p1} = 0{\cdot}85$	$\epsilon_{p2} = -0{\cdot}833$, $\epsilon_{p1} = 0{\cdot}85$
1	10	1·09	0·58	0·55
2	20	1·12	0·59	0·56
3	30	1·16	0·60	0·58
4	40	1·21	0·62	0·60
5	50	1·27	0·64	0·62
6	60	1·31	0·66	0·64
7	70	$1{\cdot}73\times10^3$	0·67	0·65
8	80	$1{\cdot}76\times10^3$	10·74	11·54
9	90	$1{\cdot}71\times10^3$	10·86	11·31

Table 2. Magnitude of the scattering due to cylinder (radius b)

	Direction (in deg.)	Magnitude (in rel.units)
For $a = {\cdot}3$, $b = 1$ cm	62 90	0·852 0·0543
For $a = {\cdot}3$, $b = 1{\cdot}3$ cm	62 90	0·876 0·548
For $a = {\cdot}3$, $b = 1{\cdot}6$ cm	82 90	0·893 0·551
$a = {\cdot}3$ cm and $b = {\cdot}5$ cm		
For $\epsilon_{p1} = {\cdot}85$, $\epsilon_{p2} = -1{\cdot}03$	77·5 90	1·874 1·122
For $\epsilon_{p1} = {\cdot}85$, $\epsilon_{p2} = -0{\cdot}833$	77·5 90	2·323 1·282
For $\epsilon_{p1} = {\cdot}95$, $\epsilon_{p2} = -1{\cdot}03$	0 90	0·3646 0·2935
For $\epsilon_{p1} = {\cdot}95$, $\epsilon_{p2} = -0{\cdot}633$	32 to 36 90	0·303 0·296

permittivity of semiconductor plasma and undergoes a steady increase with increase of permittivity of semiconductor plasma. In all these cases the direction of 90° happens to be that of maximum scattering amplitude. The scattering due to semiconductor plasma is shown in table 2. This reports that there occurs certain direction in which the amplitude happens to be maximum for particular values of *a* and *b*. This direction gets changed while changing the relative permittivity of semiconductor plasma. Table 2 gives the idea that the direction of 90° contains the appreciable scattering magnitude. One plot showing the scattering due to semiconductor plasma is also supplied. This also ensures about the peak value of scattering magnitude. The radius of semiconductor plasma also causes the shift in peak of scattering field (Plot 1). The calculated values confirm that thicker plasma columns invite the change in scattering. Enhancing of backward radiation are due to more blocking of the same due to the presence of semiconductor plasma. Explanation for scattering mode existence may be borrowed from Tamir *et al* (1962) on the parallel lines of radiation modes.

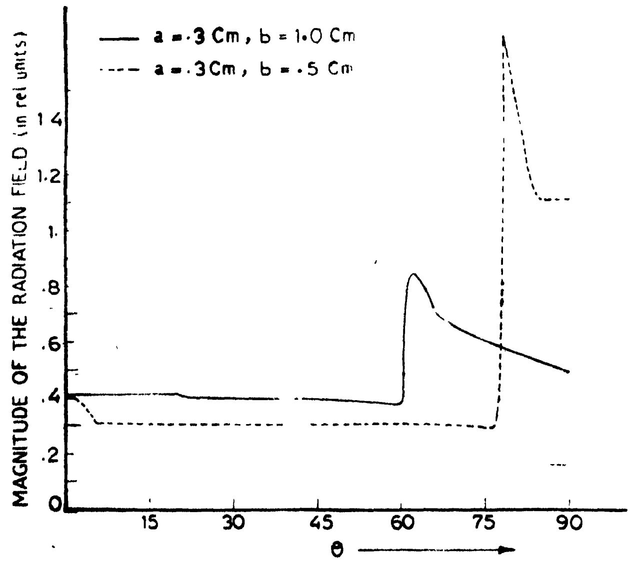

Fig. 1. Magnitude of the scattered field due to cylinder (radius *b*).

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References

Collin R. E. 1961 *Field theory of guided waves*, McGraw-Hill Book Co. Inc.. New York, page 485.
Dhani Ram & Verma J. S. 1972 *Ind. J. Pure Appl. Phys.* **10**, 716.
Gupta K. C. & Singh A. 1969 *Int. J. Electron*, **23**, 323,

Ram Chandra & Verma J. S. 1974 *Ind. J. Pure Appl. Phys.* **48**, 910.

Sharma, Subhash Chandra, Ram Chandra & Verma J. S. 1976a *JIETE* (New Delhi) 22, 536.

Sharma, Subhash Chandra & Verma J. S. 1976b presented in the symp. on *Solar Planetary Phys.* held at PRL, Ahmedabad during Jan. 20–24, 1976.

Sharma, Subhash Chandra & Verma J. S. 1976c *Pramana* **7**, 385.

Sharma, Subhash Chandra & Verma J. S. 1976d to appear in *Ind. J. Phys.*

Sharma, Subhash Chandra, Ram Chandra & Verma J. S. 1976e *Ind. J. Rad. Space Phys.* **5**, 245.

Sharma, Subhash Chandra & Verma J. S. 1976f *Ind. J. Pure Appl. Phys.* **14**, 510.

Tamir T. & Oliner A. A. 1962 *IRE Trans. Antenna Propag.* **10**, 55.