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Radiation Characteristics of Circular Microstrip Antenna in Weakly Ionized Plasma medium

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Abstract

In present research paper an attempt has been made to study about the radiation characteristics of circular microstrip antenna in weakly ionized plasma medium. For this purpose the basic concept of linear array has been considered to further obtain the radiation pattern of circular microstrip antenna. The effect of change in plasma frequency, electronic temperature, gas temperature and collision frequency appeared due to presence of plasma medium has been taken account. It is found that the weakly plasma medium having significant effect on radiation pattern such as E-plane and H-plane to a great extent. The characteristics parameters of microstrip antenna depends upon the E-plane and H-plane radiation pattern. Also reduction in size of circular microstrip anteena gives significant improvement in gain of anteena and beams become more directive.

Key Words:-Circular wave guide, E-plane, H-plane Radiated Power, Directivity etc.

1.Introduction

Recently for the strong revival of research and development in the field on communication engineering several practical applications of microstrip anteena have been carried out. To improve the characteristics of microstrip antenna such as higher gain, been scanning or steering capability of conventional microstrip antenna it is necessary to combine discrete radiation to form arrays. The array anteena provides the fixed beam of specified shapes. In array antenna to increase the gain only option is to increase the number of arrays which ultimately increased the shape of microstrip anteena which is not desired [1-4]. Reduction in size of an anteena is very cost effective and eases to utilize for different purposes. In this research paper attempt has been made to study about the radiation characteristics of circular microstrip antenna in weakly ionized plasma medium. The radiation pattern of circular microstrip anteena shows that when size of anteena is reduced then gain is increases to a great extent which was not possible in case of linear array antenna [5-12]. The presence of plasma medium also enhances the parameters of microstrip antenna to a optimum value. Therefore it is very imperative to study about the effect of weakly plasma medium on radiation characteristics of circular microstrip antenna. The entire investigations have been given in different sections of this research paper.

2.Theoretical Consideration

To obtain the radiation field of circular microstrip antenna array the concept of linear array has been utilized. For this purpose the electric field of nth radiating element is given as [2]

$$E_n(\theta,\phi)= f_n(\theta,\phi)\frac{e^{-jkr_n}}{r} \qquad (1)$$

Where $f_n(\theta,\phi)$ is angular distribution of the radiation intensity of the nth radiating element and r_n be the distance to the far fields from the nth radiating elements.

For identical elements, the far field of linear array becomes

$$E_n(\theta,\phi)=E(\theta,\phi)f(\psi) \qquad (2)$$

Where $f(\psi)$= array polynomial and $E(\theta,\phi)$=element pattern

Now in the case of circular microstrip anteena, the array element is consisting in circle in Fig-1. Further for isotropic elements the far field of circular microstrip antenna array is given from equation (1) as

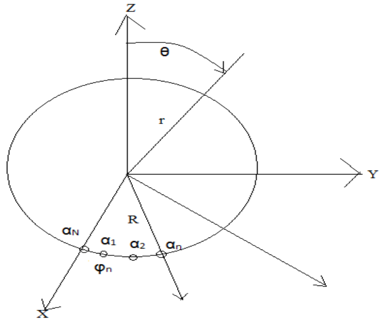

Fig. 1. Circular Microstrip Anteena

$$f(\theta,\phi)=\sum a_n\frac{e^{jkr_n}}{r_n} \qquad (3)$$

Where a_n= currents in the array elements which is given as

$$a_n = A_n e^{j\alpha n} \qquad (4)$$

If the N elements are equally spaced around the circle the azimuth angle of nth element s given as $\phi_n=\frac{2\pi n}{N}$ (5)

Now from geometry of the fig-1 the value of r_n can be written as

$$r_n = r-\cos(\phi-\phi_n)\sin\theta \qquad (6)$$

Where, r is the radius of circular microstrip antenna array.

Further combining equations (3), (4), (5) and (6) the far field of circular microstrip anteena can be written as

$$f(\theta,\phi) = \sum A_n \exp\left[j\{\alpha_n - kr\sin\theta\cos(\phi-\phi_n)\}\right] \tag{7}$$

In the case of uniform array in which all elements have equal amplitude or unity currents, the far field of circular microstrip antenna reduces to

$$f(\theta,\phi) = \sum \exp\left[j\{\alpha_n - kr\sin\theta\cos(\phi-\phi_n)\}\right] \tag{8}$$

From Fig.1 the peak of mean beam is occur at the angle in space (θ_0,ϕ_0) and exponent of equation (8) must be zero at that angle. Hence the value of α_n becomes

$$\alpha_n = kr\sin\theta_0\cos(\phi_0-\phi_n) \tag{9}$$

Combining equations (8)and (9) one has

$$f(\theta,\phi) = \sum \exp\left[j\{kr\sin\theta_0\cos(\phi_0-\phi_n) - kr\sin\theta\cos(\phi-\phi_n)\}\right] \tag{10}$$

To solve the above equation the space angle ψ is given as [3-4]

$$\cos\psi = \frac{\sin\theta\cos\phi - \sin\theta_0\cos\phi_0}{\left[(\sin\theta\cos\phi-\sin\theta_0\cos\phi_0)^2 + (\sin\theta\sin\phi-\sin\theta_0\sin\phi_0)^2\right]} \tag{11}$$

And scaling the radius of array

$$\rho = \left[(\sin\theta\cos\phi-\sin\theta_0\cos\phi_0)^2 + (\sin\theta\sin\phi-\sin\theta_0\sin\phi_0)^2\right]^{\frac{1}{2}} \tag{12}$$

Using the equations (11) and (12) $f(\psi)$ can be written as

$$f(\psi) = \frac{1}{N}\sum_{n=1}^{N} e^{-jk\rho\cos(\psi-\phi_n)} \tag{13}$$

Where, the factor 1/N is added to normalize the far field to unity at the peak of the mean beam.

Further the value of $f(\psi)$ can be modified for large number of array element such as [3-4]

$$N \to \infty$$
$$\phi_n \to \phi$$
$$\nabla\phi_n = \frac{2\pi}{N} \to d\phi$$

Using above relation one has

$$f(\psi) = \frac{1}{2\pi}\int_0^{2\pi} e^{-jk\rho\cos\phi}\,d\phi = J_0(k\rho) \tag{14}$$

If mean beam is on horizontal plane one has

$$\theta = \theta_0 = \frac{\pi}{2} \tag{15}$$

Combining equations (12) and (15) one has

$$f(\psi) = J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \tag{16}$$

The field components of circular microstrip antenna can be calculated by utilizing the field components of elemental area n circular patch such as

$$E_\theta = -je^{-jkr}\frac{(\sin\phi\cos\theta)}{2\lambda r}\iint f(r',\theta')e^{-jkr'\cos\psi}r'\,dr'\,d\theta \tag{17}$$

And

$$E_\phi = je^{-jkr}\frac{(\sin\theta+\cos\phi)}{2\lambda r}\iint f(r',\theta')e^{-jkr'\cos\psi}r'\,dr'\,d\theta \tag{18}$$

Where

$$\cos\psi = \sin\theta\sin\theta'\sin\phi+\cos\theta\cos\theta' \tag{19}$$

Also

$$\cos\psi = \sin\alpha\cos(\beta-\beta') \tag{20}$$

Now combining equations (17), (18), (19) and (20) one has

$$E_\theta = -je^{-jkr}\frac{(\sin\phi\cos\theta)a^2}{2r}\frac{J_1(u)}{u} \tag{21}$$

And

$$E_\phi = je^{-jkr}\frac{(\sin\theta+\cos\phi)a^2}{2r}\frac{J_1(u)}{u} \tag{22}$$

Where, a is the radius of circular loop and $J_1(u)$ is the Bessels function order 1 with augment $u = ka\sin\theta$. Further combining equations (20), (21) and (22) the electric field components of circular microstrip antenna can be written as

$$E_\theta = -je^{-jkr}\frac{(\sin\phi\cos\theta)a^2}{2r}\frac{J_1(u)}{u}J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \tag{23}$$

And

$$E_\phi = je^{-jkr}\frac{(\sin\theta+\cos\phi)a^2}{2r}\frac{J_1(u)}{u}J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \tag{24}$$

Now using the relation $E_\theta = H_\phi Z_0$ one can evaluate the magnetic field components such as

$$H_\theta = je^{-jkr}\frac{(\sin\theta+\cos\phi)a^2}{2rZ_0}\frac{J_1(u)}{u}J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \tag{25}$$

$$H_\phi = -je^{-jkr}\frac{(\sin\phi\cos\theta)a^2}{2rZ_0}\frac{J_1(u)}{u}J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \tag{26}$$

3.ANALYSIS OF CIRCULAR MICROSTRP ANTEENA IN WEAKLY IONIZED PLASMA MEDIUM

For this purpose the plasma medium is treated as dielectric medium with effective relative permittivity $\in_{rpeff}$ is defined as [5-6]

$$\in_{r\,eff} = \left(1 - \frac{\omega_p^2}{\omega^2}\right) \qquad \textbf{(27)}$$

where, ω_p is the electron plasma frequency

and ω = angular frequency

Now the propagation constant in plasma medium is defined as

$$k_p = \frac{2\pi}{\lambda_0}\left[1 - \left(\frac{\omega_p}{\omega}\right)^2\right]^{\frac{1}{2}} \qquad (28)$$

Further taking the collision effect, the propagation constant in plasma medium may be modified as

$$k_p = \frac{2\pi}{\lambda_0}\left[1 - \left\{\frac{\omega_p^2\,\omega^2}{\omega^4 + \omega^2 v^2} + \frac{j\,v\omega_p\ \omega}{\omega^4 + \omega^2 v^2}\right\}\right]^{\frac{1}{2}} \qquad (29)$$

where ν is the collision frequency, which is given by the relation

$$v = v_0\left\{1 + \left(\frac{T_e - T}{2T}\right)\right\} \qquad (30)$$

Putting the value of υ in the equation (29) the propagation constant in weakly ionized plasma medium can be written as

$$k_p = \frac{2\pi}{\lambda_0}\left[1 - \left\{\frac{\omega_p^2\,\omega^2}{\omega^4 + \omega^2 {v_0}^2\left\{1 + \left(\frac{T_e - T}{2T}\right)\right\}^2} + \frac{j\,v\omega_p\ \omega}{\omega^4 + \omega^2 {v_0}^2\left\{1 + \left(\frac{T_e - T}{2T}\right)\right\}^2}\right\}\right]^{\frac{1}{2}}$$

Let

$$A = \frac{\omega_p^2\,\omega^2}{\omega^4 + \omega^2 {v_0}^2\left\{1 + \left(\frac{T_e - T}{2T}\right)\right\}^2}$$

$$B = \frac{j\,v\omega_p\ \omega}{\omega^4 + \omega^2 {v_0}^2\left\{1 + \left(\frac{T_e - T}{2T}\right)\right\}^2}$$

Then k_p is modified as

$$k_p = \frac{2\pi}{\lambda_0}(1 - A - B)^{\frac{1}{2}} \qquad (31)$$

By putting the value of Kp in equations (23), (24), (25) and (26) E and H fields of circular microstrip anteena in weakly ionized plasma medium can be written as

$$E_\theta = -jke^{-jr\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}}\frac{(\sin\phi\cos\theta)a^2}{2r}\frac{J_1(u)}{u}\, J_0\left(2\frac{2\pi}{\lambda_0}(1 - A - B)^{\frac{1}{2}} R\sin\frac{\phi - \phi_0}{2}\right) \qquad (32)$$

And

$$E_\phi = jke^{-j\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}r}\frac{(\sin\theta + \cos\phi)a^2}{2r}\frac{J_1(u)}{u}\, J_0\left(2\frac{2\pi}{\lambda_0}(1 - A - B)^{\frac{1}{2}} R\sin\frac{\phi - \phi_0}{2}\right) \qquad (33)$$

Now using the relation $E_\theta = H_\phi Z_0$ one can evaluate the magnetic field components such as

$$H_\theta = jke^{-jr\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}} \frac{(\sin\theta+\cos\phi)a^2}{2rZ_0}\frac{J_1(u)}{u}$$
$$J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}kR\sin\frac{\phi-\phi_0}{2}\right)$$

(34)

$$H_\phi = -jke^{-j\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}r} \frac{(\sin\phi\cos\theta)a^2}{2rZ_0}\frac{J_1(u)}{u}$$ (35)
$$J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\phi-\phi_0}{2}\right)$$

4.Radiated Power and Gain

The radiated power of circular microstrip antenna can be calculated as [7]

$$P_r = \frac{1}{2}|E_\theta|^2|H_\phi|^2$$

$$= \frac{\pi k^2a^2}{240\lambda^2r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1{}^2(ka\sin\theta)}{ka\sin\theta}J_0{}^2\left(2kR\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi$$

(36)

Further the radiated power is modified in weakly ionized plasma medium by putting the value of k_p instead of k in equation (36) such as

$$P_r = \frac{\pi\frac{4\pi^2}{\lambda_0{}^2}(1-A-B)a^2}{240\lambda^2r^2}$$
$$\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1{}^2\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}J_0{}^2\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi$$

(37)

$$G_e = \frac{\pi k^2a^2}{120\lambda^2r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1{}^2\left(\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right)}{\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta}J_0{}^2\left(2kR\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi$$

(38)

5.Numerical Computation

In order to obtain the value of $E_\theta, E_\phi, H_\theta$ and H_ϕ in weakly ionized plasma medium the computational work were done using equations (32), (33),(34), (35) and (37) respectively for $\theta = 90^o, \phi = 0^o, \frac{\omega_p}{\omega} = 0.1,$ 0.2, 0.3…………………..1.0 and $\varepsilon_r = 2.5$. Thus data obtained are shown in plotted graph Fig. 2, 3.

6.Discussion of Result

The examination of radiation pattern for circular microstrip antenna array in weakly ionized plasma medium reveals that the presence of such plasma medium enhance the directive gain of antenna array t a significant value. In electro acoustic mode the radiation pattern exhibit large number of maxim's and minima's in a limited angle range which further get changed with plasma parameters value. It is observed from Fg.2 that the radiation pattern of circular microstrip antenna array is almost constant with scan angle. Further the investigations also show that due to finite size of ground plane the radiation pattern splits over on to the back side of ground plane in Fig.3. From Hence it may be concluded that there is a significant change in working capability of circular microstrip antenna array in weakly plasma medium than free space.

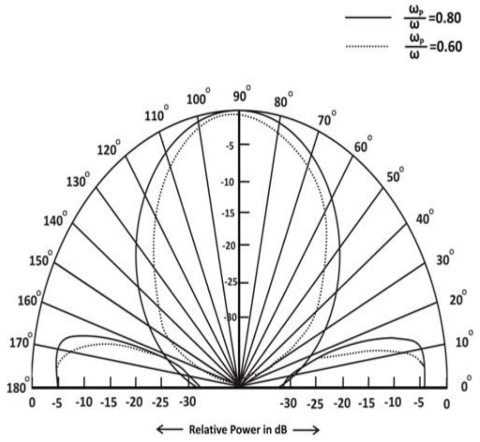

Fig-2. E-Plane Radiation Pattern of Circular Microstrip Antenna in Weakly Ionized Plasma Medium.

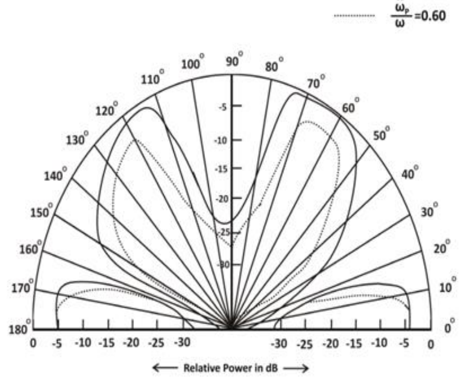

Fig-3. H-Plane Radiation Pattern of Circular Microstrip Antenna in Weakly Ionized Plasma Medium.

References

[1] E. A Wolf, “Antenna Analysis”, ISBN, Artech House Bostan, Londan, pp. 166-168, 1965.

[2] Bishwanath Chackrabarty, “Principles of Plasma Mechanism” 2/E, Wiley Eastern Limited, ISBN, pp.120, 1978.

[3] Scinda T, Awanoto K ,” Plasma display technology for large area screen and cost reduction “, vol.34, pp 279-286, 2009.

[4] J.A. Bittencourt, “Fundamentals of Plasma Physics” SIE publication, Third edition, 2006

[5] K. R. Carver and J. W. Mink “Micro strip Antenna Technology” IEEE Trans Antennas and propagation, Vol-29, 1981,pp2-24

[6] I. J. Bahl and P. Bhartia “Micro strip Antennas” Artech House, 1982, pp.96-97.

[7] C. A. Balani "Antenna Thing Analysis 2 design John Willey and Sons New York 1982.

[8] R. P. Yadav et al, "Design of Planar Circular Microstrip Anteena 2x2 Element Array and its Performance and Evaluation on in the Free Space and Plasma Medium" Indian J. Physics. IE(T)journal ET, Vol. 84, 2004, pp.61-72

[9] I. Alexeff, T. Anderson, S. Parameswaran, E. P. Pradeep, J. Hulloli, and P. Hulloli, "Experimental and theoretical results with plasma antennas," IEEE Transactions on Plasma Science, vol. 34, no. 2, pp. 166–172, Apr. 2006.

[10] I. Alexeff, T. Anderson, E. Farshi, N. Karnam, and N. R. Pulasani, "Recent results for plasma antennas," Physics of Plasmas, vol. 15, no. 5, p. 057104, 2008.

[11]` U. S. Inan and M. Gokowski, Principles of Plasma Physics for Engineers and Scientists. Cambridge University Press, Dec. 2010.

[12] J. A. Bittencourt, Fundamentals of plasma physics. Springer Science & Business Media, 2013.