Analysis of Circular Microstrip Antenna in Plasma Medium

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Abstract- In this research paper the analysis of parameters of circular microstrip antenna in ionized plasma medium is carried out. For this purpose the antenna parameters such as Directivity, Radiation conductance, and Radiated power were analyzed in weakly ionized plasma. The properties of antenna parameter are changed to a great extent in a weakly ionized plasma medium.

Keywords: Antenna gain, Radiation resistance, Radiated power, Radiation conductance, Directivity

1. INTRODUCTION

In the field of digital and telecommunication antenna is playing vital role. The performance of antenna depends upon the designing which will ultimately improve the efficiency and overall performance of antenna. Now a day's microstrip antenna is widely used in place of conventional antenna due to its Omni-directional radiation pattern. Microstrip antennas are widely used in radar, satellite communication, broadcast TV, mobile communication and navigation landing system.

Due to less size and ease to fabrication microstrip antenna are found suitable in mobile communication.[6-12]. Before the decade of 1980 conventional antenna has been used in different communication systems but due to unidirectional radiation pattern obtained in free space limited its used. Although the concept of microstrip antenna have introduced before 1950 but attention of researcher came out after 1980 and it found suitable for system requirement of satellite and telecommunication system. In the presence of plasma medium it was performance of antenna has been improved to a great extent (13-17).Besides of some disadvantages of microstrip antenna such as narrow band width, low polarization, limited power handling power capacity and tolerance problem. In the present paper ionized plasma medium investigation is carried about the effect of weakly ionized plasma medium on the radiation characteristics of microstrip antenna. Also the effect of plasma medium on different parameters of Circular microstrip antenna were also analyzed.

2. FORMULATION OF ELECTROMAGNETIC FIELD

In the case of circular microstrip antenna, the electromagnetic field may be modified as [2]

$$\frac{(\sin\varphi\cos\theta)a^2}{2r}\frac{J_1(u)}{u}J_0\left(2\text{kRsin}\frac{\varphi-\varphi_0}{2}\right) \quad (1)$$

And

$$E_\varphi = \text{j}e^{-\text{jkr}}\frac{(\sin\theta+\cos\varphi)a^2}{2r}\frac{J_1(u)}{u}J_0\left(2\text{kRsin}\frac{\varphi-\varphi_0}{2}\right) \quad (2)$$

Also

$$H_\theta = \text{j}e^{-\text{jkr}}\frac{(\sin\theta+\cos\varphi)a^2}{2\text{rZ}_0}\frac{J_1(u)}{u}J_0\left(2\text{kRsin}\frac{\varphi-\varphi_0}{2}\right) \quad (3)$$

$$H_\varphi = -\text{j}e^{-\text{jkr}}\frac{(\sin\varphi\cos\theta)a^2}{2\text{rZ}_0}\frac{J_1(u)}{u}J_0\left(2\text{kRsin}\frac{\varphi-\varphi_0}{2}\right) \quad (4)$$

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

$$\varepsilon_{rpeff} = \left(1 - \frac{{\omega_p}^2}{\omega^2}\right) \quad (5)$$

In which ω_p =electron plasma frequency

And ω= angular frequency

Now in weakly plasma medium the value of k_p can be modified as

$$k_p = \frac{2\pi}{\lambda_0}\left[1-\left(\frac{\omega_p}{\omega}\right)^2\right]^{\frac{1}{2}} \quad \textbf{(6)}$$

By taking account of collision effect in the presence of plasma medium can be rewritten as

$$k_p = \frac{2\pi}{\lambda_0}\left[1-\left\{\frac{\omega_p^2\omega^2}{\omega^4+\omega^2\nu^2}+\frac{j\nu\omega_p\omega}{\omega^4+\omega^2\nu^2}\right\}\right]^{\frac{1}{2}} \quad (7)$$

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

$$\nu = \nu_0\left\{1+\left(\frac{T_e-T}{2T}\right)\right\} \quad (8)$$

Putting the value of υ in the equation (7) in the presence of plasma medium the value of k_p can be written as

$$k_p = \frac{2\pi}{\lambda_0}\left[1-\left\{\frac{\omega_p^2\omega^2}{\omega^4+\omega^2\nu_{0^2}\left\{1+\left(\frac{T_e-T}{2T}\right)\right\}^2}+\frac{j\nu\omega_p\omega}{\omega^4+\omega^2\nu_{0^2}\left\{1+\left(\frac{T_e-T}{2T}\right)\right\}^2}\right\}\right]^{\frac{1}{2}}$$

Let

$$A = \frac{\omega_p^2\omega^2}{\omega^4+\omega^2\nu_{0^2}\left\{1+\left(\frac{T_e-T}{2T}\right)\right\}^2}$$

$$B = \frac{j\nu\omega_p\omega}{\omega^4+\omega^2\nu_{0^2}\left\{1+\left(\frac{T_e-T}{2T}\right)\right\}^2}$$

Then k_p is modified as

$$k_p = \frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}} \quad (9)$$

By replacing the value of K_p in plasma medium the E and H field can be evaluated as

$$E_\theta = -\text{jk}e^{-\text{jr}\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}}\frac{(\sin\varphi\cos\theta)a^2}{2r}\frac{J_1(u)}{u} J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\varphi-\varphi_0}{2}\right) \quad (10)$$

And

$$E_{\varphi} = \mathrm{jk}e^{-j\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}r}\frac{(\sin\theta+\cos\varphi)a^2}{2r}\frac{J_1(u)}{u}J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\varphi-\varphi_0}{2}\right) \quad (11)$$

Now using the relation $E_\theta = H_\varphi Z_0$ may evaluate the magnetic field components such as

$$H_\theta = \mathrm{jk}e^{-\mathrm{jr}\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}}\frac{(\sin\theta+\cos\varphi)a^2}{2\mathrm{r}Z_0}\frac{J_1(u)}{u}J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}\mathrm{k}R\sin\frac{\varphi-\varphi_0}{2}\right) \quad (12)$$

$$H_\varphi = -\mathrm{jk}e^{-j\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}r}\frac{(\sin\varphi\cos\theta)a^2}{2\mathrm{r}Z_0}\frac{J_1(u)}{u}J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\varphi-\varphi_0}{2}\right) \quad (13)$$

3.1. Radiated power

The microstrip parameters of radiated power of circular microstrip antenna can be modified as

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

$$= \frac{\pi k^2a^2}{240\lambda^2r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2\frac{J_1{}^2(\mathrm{k}a\sin\theta)}{\mathrm{k}a\sin\theta}J_0{}^2\left(2\mathrm{k}R\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi \quad (14)$$

The radiated power of a circular microstrip antenna may modify in weakly plasma medium by replacing the k_p instead of k in equation k

$$P_r = \frac{\pi\frac{4\pi^2}{\lambda_0{}^2}(1-A-B)a^2}{240\lambda^2r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2\frac{J_1{}^2\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}J_0{}^2\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi \quad (15)$$

3.2 Radiation Conductance of Circular Microstrip Antenna in Weakly Ionized Plasma Medium

In the presence of weakly plasma medium the radiation conductance of the circular microstrip antenna array may be written such as

$$G_\theta = \frac{2P_r}{a_n{}^2} = 2P_r (\text{Since } a_n=1) \quad (16)$$

Now putting the value of P_r from equation (15) in equation (16) value of Radiation conductance may be obtained as

$$G_\theta = \frac{\pi k^2a^2}{120\lambda^2r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2\frac{J_1{}^2\left(\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right)}{\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta}J_0{}^2\left(2\mathrm{k}R\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi \quad (17)$$

Radiation Conductance of circular microstrip antenna in weakly ionized plasma medium may be modified such as

$$= \frac{\frac{4\pi^3}{\lambda_0{}^2}(1-A-B)a^2}{120\lambda^2r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2\frac{J_1{}^2\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}J_0{}^2\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi \quad (18)$$

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3.3 Effect of weakly ionized plasma medium on Radiation Resistance

In the presence of weakly ionized plasma medium the radiation resistance of circular microstrip antenna can be written as

$$= \frac{120\lambda^2 r^2}{\frac{4\pi^3}{\lambda_0^2}(1-A-B)a^2} \frac{1}{\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2 \frac{J_1^2\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]} J_0^2\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi} \quad (19)$$

3.4 Directivity

In free space the Directivity of circular antenna can be re-written as

$$D_0 = \frac{(k_0 a)^2}{120 G_e}$$

Where G_e= radiation conductance of circular microstrip antenna. Using the value of G_e in equation (19) the directivity of circular microstrip antenna can be written

$$D_0 = \frac{120\lambda^2 r^2}{\pi\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2 \frac{J_1^2(ka\sin\theta)}{ka\sin\theta} J_0^2\left(2kR\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi}$$

In the presence of weakly ionized plasma medium the directivity can be modified as

$$D_0 = \frac{120\lambda^2 r^2}{\pi\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\varphi)^2 \frac{J_1^2\left(\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right)}{\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta} J_0^2\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{(\varphi-\varphi_0)}{2}\right)\sin\theta\, d\theta\, d\varphi} \quad (20)$$

4. NUMERICAL COMPUTATION

To calculate the different antenna parameters such as radiation conductance G_e, radiated power (P_r) and directivity D_0 computational work done using equations (18),(19),(20) respectively for

$\theta = 90^o, \varphi = 0^o, \frac{\omega_p}{\omega} = 0.1, 0.2, 0.3$…………… ……..1.0 and $\varepsilon_r = 2.5$. The result can be shown in graph 1, 2& 3

3.5 Result Analysis

On the basis of analysis of radiation for circular microstrip antenna in presence of weakly ionized plasma medium indicates that plasma medium enhances the gain of microstrip antenna to a optimum value.

. In electro-acoustic medium the E and H pattern mode exhibits an infinite number of maxims and minims in a fixed angle range may further change with plasma frequency. From Fig.1. the small values of the radius of a circular micristrip antenna, the directivity approaches to maximum value directivity and increase with decreasing value of $\frac{\omega_p}{\omega}$

Further, it also observed that radiation resistance decreases rapidly and vanished when $\frac{\omega_p}{\omega}$ becomes unity in Fig.2 and Fig. 3.

It may summarized that there is a remarkable change in the presence of weakly ionized plasma medium compare to free space.

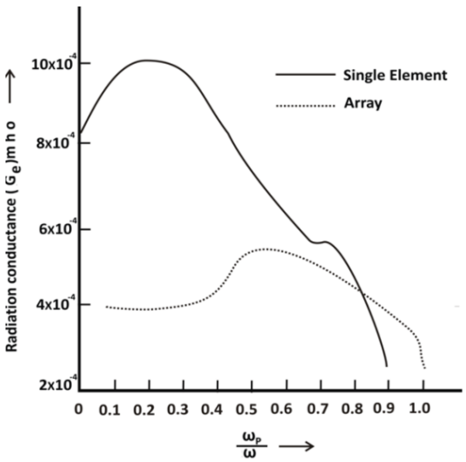

Fig.1. Variation in Radiation Conductance of Circular Microstrip Antenna in Weakly Plasma Medium with $\frac{\omega p}{\omega}$

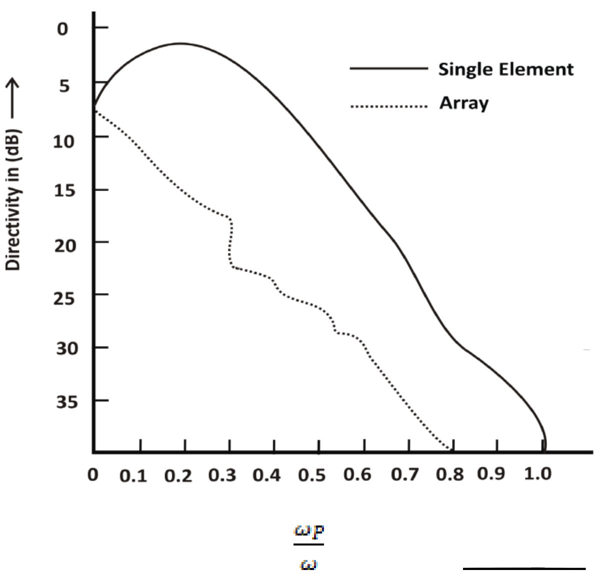

Fig.2. Variation of Directivity of Circular Microstrip Antenna in Weakly Ionized Plasma Medium with $\frac{\omega p}{\omega}$

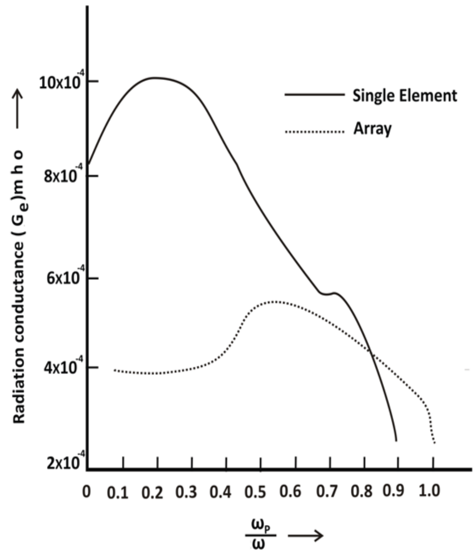

Fig.3. Variation of Radiation Conductance of Circular Microstrip Antenna in Weakly Ionized Plasma Medium with $\frac{\omega p}{\omega}$

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