Study about the effect of Weakly Ionized Plasma Medium on the Parameters of Circular Microstrip Antenna

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Abstract

In present research paper an attempt has been made to study about the effect of weakly ionized plasma medium on the microstrip antenna parameters such as Radiated Power, Radiation Conductance, Directivity etc. For this purpose the radiation patterns of circular microstrip antenna in free space were taken and modified in the presence of weakly ionized plasma medium. 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 parameters such as radiated power, radiation conductance and directivity to a great extent.

Key Words: *Antenna Gain, Radiation Resistance, Radiated Power, Radiation conductance, Directivity etc.*

1.Introduction

In the era of wireless systems, the antenna is one of the critical components. A good design of the antenna can relax system requirements and improve overall system performance. The wireless systems having many applications such as in radar, navigation, landing systems, direct broadcast TV, satellite communications, and mobile communications and so on. An antenna could be as large as 100m by 100m for radio telescope or as small as the order of centimeters in built-in handsets[6-12]. An antenna is an electromagnetic transducer, used to convert, in the transmitting mode, guided waves within transmission lines to radiate free-space waves, or to convert, in the receiving mode, free-space waves to guided waves. The conventional antennas were widely used before 1970 in different systems. But due to unidirectional radiation pattern of conventional antenna systems were facing lot of problems. To overcome this problem the idea of microstrip antenna was introduced in 1950, but serious attention of researcher were paid only after 1970. To a large extent, the development of microstrip antennas has been driven by system requirements for antennas with low-profile, low-weight, low-cost, easy to fabricate into arrays and with microwave integrated circuits, or polarization diversity[13-17]. Disadvantages of the original microstrip antenna configurations include narrow bandwidth, spurious feed radiation, poor polarization purity, limited power handling capacity and tolerance problems. Much of the development work in microstrip antennas has thus gone into efforts to overcome adaptively. In the present paper attempt has been made to study about the effect of weakly ionized plasma medium on the microstrio antenna parameters such as directivity, radiation conductance, radiation resistance etc[1-5] The presence of plasma medium also enhances the parameters of microstrip antenna to a optimum value. The entire investigations have been given in different sections of this research paper.

2.Theoretical Consideration

The radiation field of circular microstrip antenna array can be is given as [4]

$$E_\theta = -je^{-jkr}\frac{(\sin\phi\cos\theta)a^2}{2r}\frac{J_1(u)}{u}J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \quad (1)$$

And

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

Also

$$H_\theta = je^{-jkr}\frac{(\sin\theta+\cos\phi)a^2}{2rZ_0}\frac{J_1(u)}{u} J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \quad (3)$$

$$H_\phi = -je^{-jkr}\frac{(\sin\phi\cos\theta)a^2}{2rZ_0}\frac{J_1(u)}{u}J_0\left(2kR\sin\frac{\phi-\phi_0}{2}\right) \quad (4)$$

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

$$\in_{r\,eff} = \left(1 - \frac{\omega_p^2}{\omega^2}\right) \quad (5)$$

where ω_p is the electron plasma frequency

and ω = angular frequency

Now the propagation constant in plasma medium is defined as

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

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

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

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

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

Putting the value of υ in the equation (7) the propagation constant in weakly ionized plasma medium can be written as

$$k_p = \frac{2\pi}{\lambda_0}\left[1-\left\{\frac{\omega_p^2\,\omega^2}{\omega^4+\omega^2\nu_0^{\,2}\left\{1+\left(\frac{T_e-T}{2T}\right)\right\}^2}+\frac{j\nu\omega_p\ \omega}{\omega^4+\omega^2\nu_0^{\,2}\left\{1+\left(\frac{T_e-T}{2T}\right)\right\}^2}\right\}\right]^{\frac{1}{2}}$$

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

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

By putting the value of K_p in equations (1), (2), (3) and (4) E and H fields of circular microstrip antenna in weakly ionized plasma medium can be written as

$$E_\theta = -jke^{-jr\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}}\frac{(\sin\phi\cos\theta)a^2}{2r}\frac{J_1(u)}{u}\ J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\phi-\phi_0}{2}\right) \tag{10}$$

And

$$E_\phi = jke^{-j\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}r}\frac{(\sin\theta+\cos\phi)a^2}{2r}\frac{J_1(u)}{u}\ J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\phi-\phi_0}{2}\right) \tag{11}$$

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

$$H_\theta = jke^{-jr\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}}\frac{(\sin\theta+\cos\phi)a^2}{2rZ_0}\frac{J_1(u)}{u}\ J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}kR\sin\frac{\phi-\phi_0}{2}\right) \tag{12}$$

$$H_\phi = -jke^{-j\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}r}\frac{(\sin\phi\cos\theta)a^2}{2rZ_0}\frac{J_1(u)}{u}\ J_0\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}R\sin\frac{\phi-\phi_0}{2}\right) \tag{13}$$

3.1.Radiated Power

The radiated power of circular microstrip antenna can be calculated as

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

$$=\frac{\pi k^2 a^2}{240\lambda^2 r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1^{\,2}(ka\sin\theta)}{ka\sin\theta}J_0^{\,2}\left(2kR\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi \tag{14}$$

Further the radiated power is modified in weakly ionized plasma medium by putting the value of k_p instead of k in equation (14) such as

$$P_r=\frac{\pi\frac{4\pi^2}{\lambda_0^{\,2}}(1-A-B)a^2}{240\lambda^2 r^2}$$
$$\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1^{\,2}\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}J_0^{\,2}\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi \tag{15}$$

3.2 Radiation Conductance

The radiation conductance of circular microstrip antenna array is given as

$$G_e=\frac{2P_r}{a_n^{\,2}}=2P_r \text{ (Since } a_n=1) \tag{16}$$

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

$$G_e=\frac{\pi k^2 a^2}{120\lambda^2 r^2}\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1^{\,2}\left(\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right)}{\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta}J_0^{\,2}\left(2kR\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi \tag{17}$$

Radiation Conductance of circular microstrip antenna in weakly ionized plasma medium can be written as

$$=\frac{\frac{4\pi^3}{\lambda_0^{\,2}}(1-A-B)a^2}{120\lambda^2 r^2}$$
$$\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1^{\,2}\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}J_0^{\,2}\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi$$

(18)

3.3 Radiation Resistance

Since the radiation resistance of is the reciprocal of Radiation conductance. Hence the radiation resistance of circular microstrip antenna array can be modified in weakly ionized plasma medium as follows

$$=\frac{120\lambda^2 r^2}{\frac{4\pi^3}{\lambda_0^{\,2}}(1-A-B)a^2}\frac{1}{\int_0^{2\pi}\int_0^{\pi}(\sin\theta+\cos\phi)^2\frac{J_1^{\,2}\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}{\left[\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]}J_0^{\,2}\left(2\left[2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}}a\sin\theta\right]R\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi} \tag{19}$$

3.4 Directivity

The directivity of circular microstrip antenna array for free space can be written as

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

Where G_e= radiation conductance of circular microstrip antenna. Now putting the value of G_e From equation (16) in equation (19) the value of directivity of circular microstrip antenna in free space is obtained as

$$D_0 = \frac{120\lambda^2 r^2}{\pi \int_0^{2\pi}\int_0^{\pi} (\sin\theta + \cos\phi)^2 \frac{J_1^{\,2}(ka\sin\theta)}{ka\sin\theta} J_0^{\,2}\left(2kR\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi}$$

Now the directivity of circular microstrip antenna array in weakly ionized plasma medium can be obtained as

$$D_0 = \frac{120\lambda^2 r^2}{\pi \int_0^{2\pi}\int_0^{\pi} (\sin\theta + \cos\phi)^2 \frac{J_1^{\,2}\left(\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}} a\sin\theta\right)}{\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}} a\sin\theta} J_0^{\,2}\left(2\frac{2\pi}{\lambda_0}(1-A-B)^{\frac{1}{2}} R\sin\frac{(\phi-\phi_0)}{2}\right)\sin\theta d\theta d\phi} \tag{20}$$

4. Numerical Computation

In order to obtain the value of antenna's parameters such as radiated power (P_r), radiation conductance (G_e) and directivity (D_0) in weakly ionized plasma medium the computational work were done using equations (18),(19),(20) respectively for $\theta = 90^o, \phi = 0^o, \frac{\omega_p}{\omega} = 0.1, 0.2, 0.3\ldots\ldots\ldots\ldots$ ………..1.0 and $\varepsilon_r = 2.5$. Thus data obtained are shown in plotted graph Fig. 1, 2, and 3

5. 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. From Fig.1 it is also found that the small value of radius of circular antenna array, the directivity approaches to higher value of antenna array increases with decreasing vale of $\frac{\omega_p}{\omega}$. Further it is also observed that radiation resistance decreases rapidly and vanished when $\frac{\omega_p}{\omega}$ becomes unity in Fig.2 and Fig. 3. 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.

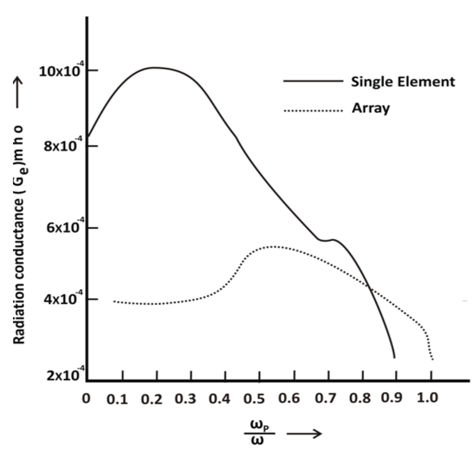
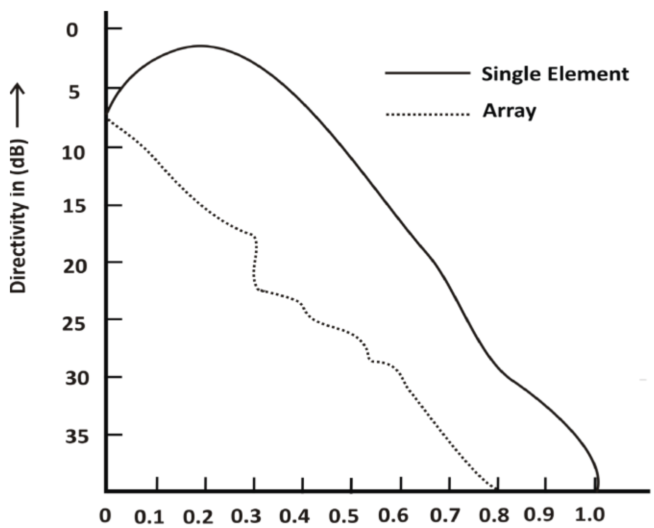


Fig.1. Variation in Radiation Conductance of Circular Microstrip Antenna in Weakly Plasma Medium with $\frac{\omega_P}{\omega}$



$\frac{\omega_P}{\omega}$ ⟶

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

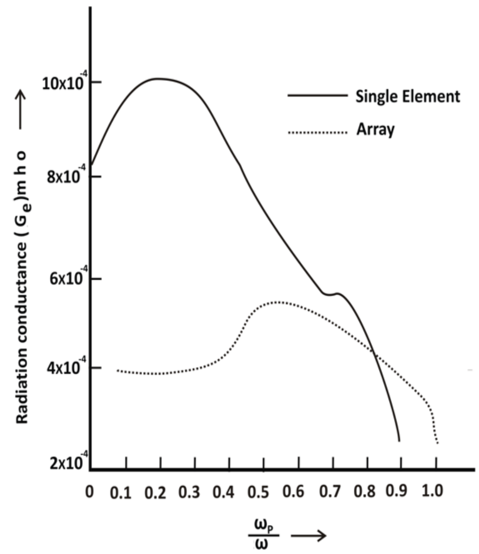


Fig.3. Variation of Radiation Conductance of Circular Microstrip Anteena in Weakly Ionized Plasma Medium with $\frac{\omega_P}{\omega}$

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