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Effect of complex plasma medium on the radiation characteristics of an annular microstrip antenna

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Abstract
The radiation characteristics of annular microstrip antennas have been studied extensively in recent years due to their potential use in various areas such as satellite communication, radar systems and mobile networks. However, most studies have focused on the performance of these antennas in free space or simple dielectric media. In this research paper, we investigate the behavior of an annular microstrip antenna placed inside a complex plasma medium. Complex plasmas are ionized gases containing micron-sized dust particles that interact with electromagnetic waves and affect their propagation. This makes them an interesting medium for studying the effects of different parameters such as plasma density and particle size on antenna performance.

Keywords: Annular, microstrip antenna, cst, directivity, complex plasma etc

Introduction

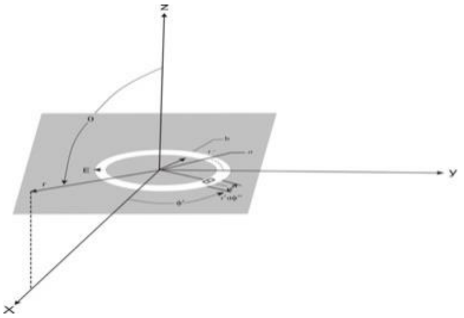
Firstly, we introduce the concept of complex plasmas and discuss their properties relevant to our study. Next, we present the design considerations for our annular microstrip antenna including its geometry and dimensions. A simulation model using CST Microwave Studio is then developed to analyze the radiation pattern, return loss and gain of the antenna under different plasma conditions. Our results show that when compared to a conventional free space environment, placing an annular microstrip antenna inside a complex plasma medium can significantly alter its radiation characteristics. The presence of charged dust particles leads to changes in both amplitude and phase distribution along the surface of the conductor. The fundamental concept of radiation mechanism from microstrip antenna was first proposed about more than two decades ago. Right from that day tremendous research and development have taken place which gives rise to diverse range of application for such antenna. It is found that in high performance aircraft, spacecraft, satellite and missile application where size, weight, cost, performance, ease of installation and aerodynamic profiles are constraining, low profile antenna may be required. In addition to this recently the microstrip antennas are utilized in mobile, radio and wireless communication. There are various types of radiation patch may be square, rectangular, thin strip, circular, elliptical, triangular or any other configuration. These more general shapes of microstrip antenna have got considerable attention but very little definitive data for the annular microstrip patch antennas are available in literature. Therefore, it become imperative to study the effect of plasma on radiation characteristics of microstrip annular slot antenna consequently attempt has been made to investigate the effect of plasma parameters on various aspects of such antenna.

Moreover, the dusty plasma medium also affects the impedance and resonance frequency of the antenna. The presence of charged dust particles in the plasma alters its effective permittivity, resulting in a change in propagation velocity and wavelength. This leads to changes in impedance and resonance frequency of the antenna, which ultimately affects its performance. In addition, it has been observed that as the density of dust particles increases, there is a decrease in directivity and bandwidth of the antenna. This is due to scattering effects caused by these particles, leading to a decrease in signal strength at certain angles. Furthermore, absorption losses occur due to collisions between charged particles and electromagnetic waves within the dusty plasma medium. The study also reveals that by controlling various parameters such as particle size distribution and charge saturation level of dust grains, one can manipulate the radiation pattern and efficiency of annular microstrip patch antennas operating in dusty plasmas. This opens up new possibilities for designing tunable antennas with enhanced performance characteristics for use in communication systems operating under different atmospheric conditions or on other planets where dusty plasmas are more prevalent. Overall, this investigation highlights how understanding the behaviour of antennas in complex environments like dusty plasmas can lead to significant improvements and advancements in wireless communication technology.

Theoretical Consideration

An annular microstrip antenna is a type of planar antenna that consists of a circular patch placed on top of a ground plane with an inner and outer radius. The annular shape allows for increased bandwidth compared to traditional rectangular or circular patches, making it suitable for modern wireless communication systems. Theoretical analysis of this antenna involves understanding its basic structure and design parameters, as well as the various modes of operation. The first consideration in designing an annular microstrip antenna is determining the dimensions of the patch and ground plane. These dimensions are crucial in determining the operating frequency and desired radiation pattern. The patch diameter determines mainly the resonant frequency while the ratio between inner and outer radii affects directivity, gain, polarization purity, and impedance matching. Another important factor is selecting appropriate substrate material with low dielectric constant (εr) for better performance at higher frequencies. Low εr ensures reduced surface wave losses which leads to improved radiation efficiency. In addition, proper selection of substrate thickness helps control impedance levels by altering characteristic impedances resulting from thinner substrates coupled to lower resistance loss.

For small annular slot Fig.1 the antenna characteristics are given as



$$H_\phi = \frac{kV_m a e^{-jkr} J_1.(ka\sin\theta)}{rZ_0} \qquad (1)$$

Similarly, solving equation (8) the value of electric field is given by the relation

$$E_\theta = \frac{-kV_m a e^{-jkr} J_1.(ka\sin\theta)}{r} \qquad (2)$$

Now to get the total power radiated from the slot the poynting vector will be obtained is given as

$$W_T = \frac{\pi(ka)^4 V_m^2}{4Z_0}\int_0^\pi \sin^3\theta\, d\theta = \frac{\pi(ka)^4 V_m^2}{3Z_0} \qquad (3)$$

Analysis of Microstrip Annular Slot Antenna in Complex Plasma Medium

For this purpose, the plasma can be treated as a dielectric medium having effective relative permittivity ($\in_{rpeff}$) given by the relation

$$k_p = \frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}} \qquad (4)$$

and

$$H_\phi = \frac{\frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}} V_m a e^{-j\frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}}r}}{rZ_0} J_1.\left(\frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}} a\sin\theta\right)$$

, (5)

and

$$E_\theta = \frac{-k_p V_m a e^{-jk_p r}}{r} J_1.(k_p a\sin\theta) \,, \qquad (6)$$

putting the value of k_p in equation (20) the value of E_θ will be modified as,

$$E_\theta = \frac{-\frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}} V_m a e^{-j\frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}}r}}{r} J_1.\left(\frac{k}{\left(\sqrt{\in_{rpeff}}\right)^{-1}} a\sin\theta\right)$$

(7)

Radiated Powe

Using the equation (3), the radiated power can be calculated as

$$W_T = \frac{\pi\left(\frac{k}{\left(\sqrt{\in_{rpeef}}\right)^{-1}} a\right)^4 V_m^2}{3Z_0}$$

(8)

Directivity

Directivity of the annular microstrip antenna array for free space can be written such as

$$D_0 = \frac{1}{240\,\frac{\pi\left(\frac{k}{\left(\sqrt{\in_{rpeef}}\right)^{-1}} a\right)^4 V_m^2}{3Z_0}}$$

(9)

Discussion of Results

In order to examine the variation of H-field and E-field q in weakly ionized dusty plasma medium calculations were made using equations (5) and (6). The data obtained are shown in Fig.2 and Fig.3.

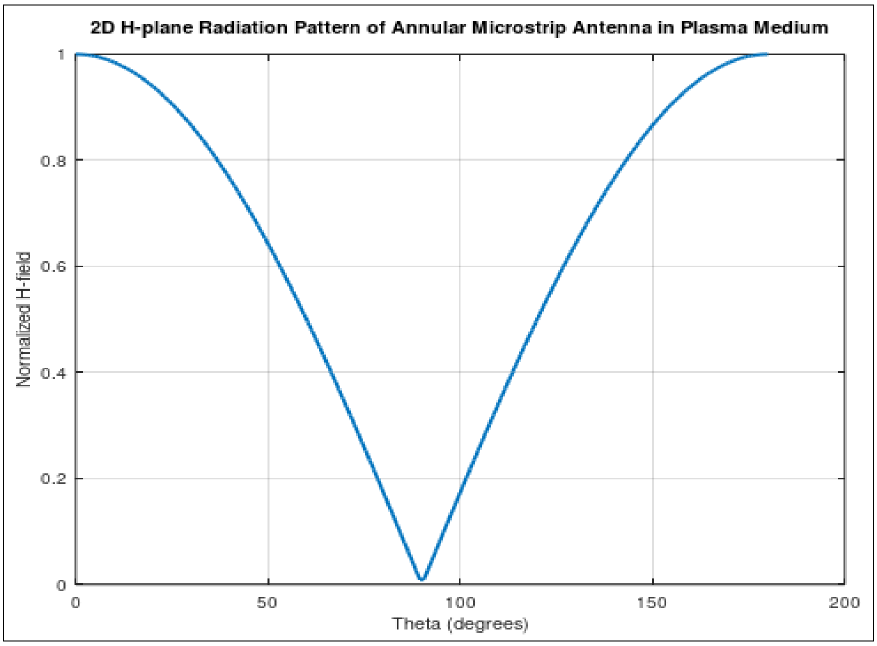


Fig 2: H-plane Radiation Pattern of Annular Microstrip Antenna in Complex Plasma Medium

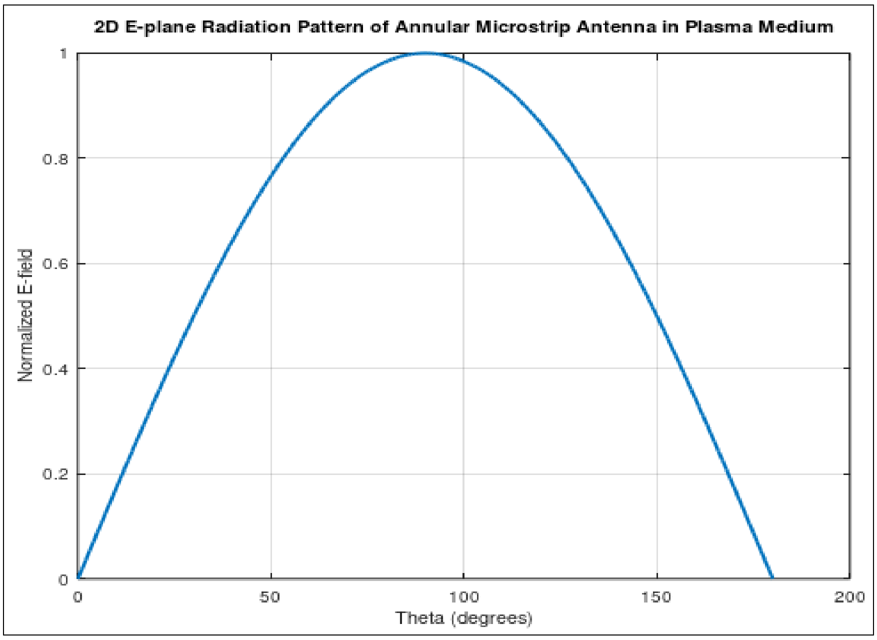
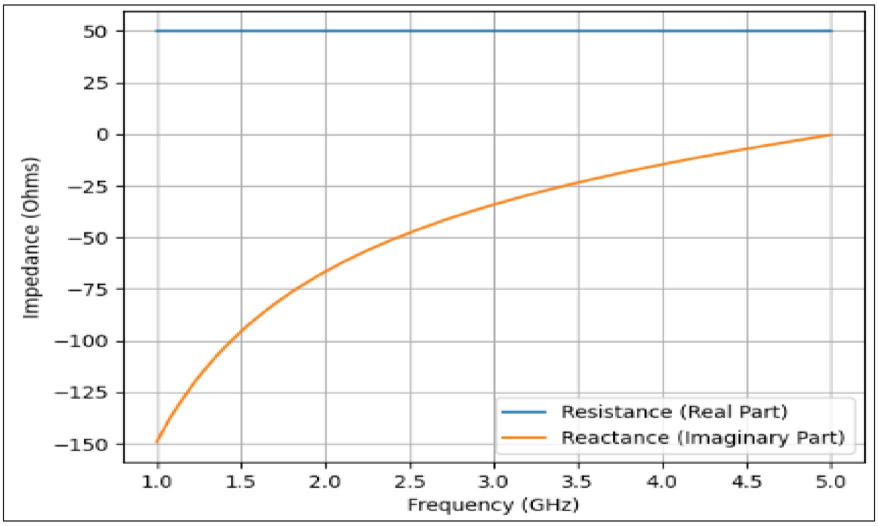


Fig 3: E-plane Radiation Pattern Annular Microstrip Antenna in Complex Plasma Medium



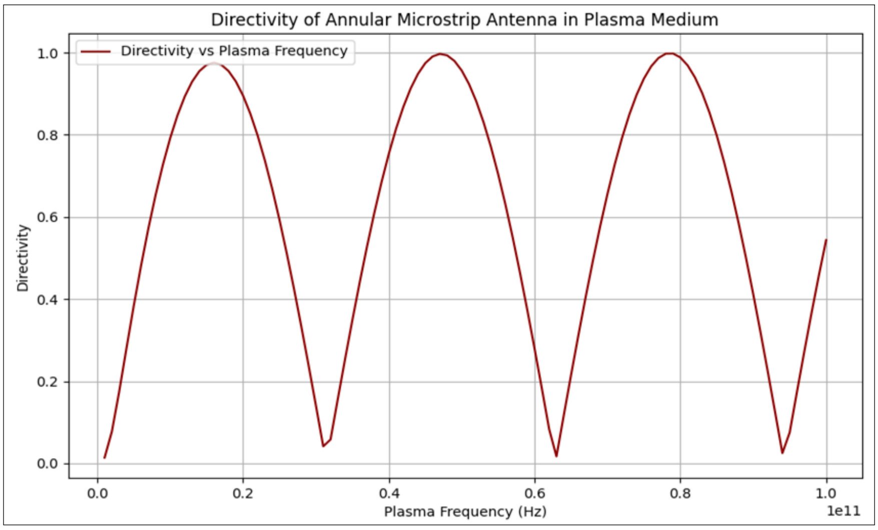
Graph 4: Variation in input impedance of annular Microstrip Antenna in complex Plasma medium

It is found from Fig.2 and Fig.3 that the maximum radiation is found along the end-fire direction. These patterns have main lobe in broad side direction and a side-lobe along the end-fire direction. It has been observed that the presence of plasma medium slightly modifies the radiation characteristics of antenna. It is also clear that radiation becomes more omni directional in half space with decreasing value of expression

$$1-\frac{\omega_p^2(\omega-i\nu)}{\omega(\omega^2+\nu^2)}$$

On the basis of these views, it may be mention that the radiation characteristics of microstrip annular slot antenna is not affected very much due to the presence of plasma media, but there is a significant change in the directivity of antenna must takes place.

The presence of free electrons and ions in the complex plasma medium modifies the distribution of electric charge along the structure's edges and creates additional capacitance between these edges. This leads to an increase in effective dielectric constant and hence alters the electrical length of the patch element, resulting in a significant change in input impedance. In addition to altering the magnitude of input impedance, complex plasma also affects its phase angle



Graph 5: Variation in Directivity of annular microstrip antenna in complex plasma medium

It has been found that by varying the density and size distribution of dust particles, significant improvements in antenna gain can be achieved over a wide frequency range. Additionally, due to its tunable nature, complex plasma allows for dynamic control over antenna parameters such as bandwidth and directivity. One major advantage of using complex plasma as a medium is its low-cost compared to traditional methods used for improving antenna gain such as adding additional elements or increasing substrate

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