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# Study on the Material of the Inside Ring Coupler in a Loop Plasma Antenna with Circular Coupler

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**Abstract**
Plasma antennas are radio frequency antennas that use ionized gas instead of metal conducting element of conventional antenna to transmit and receive signals. In this paper, the effect of changing material of the inside coupler on bandwidth, return loss and radiation pattern at Ultra High Frequency (UHF) band is investigated. It is demonstrated that the resonant frequency can be adjusted by choosing proper material for internal coupler without changing the antenna size and structure. The antenna and its coupler is simulated by practical software Computer Simulation Technology (CST) Microwave Studio.

**Keywords:** Plasma antenna, Radiation pattern, Return loss, UHF.

## 1. INTRODUCTION

Plasma antenna is a modern and high performance technology that is designed and fabricated as appropriate replacement for current antenna which is formed by a plasma enclosure, ionized gas which called plasma and coupler. The fundamental difference between Plasma antennas and the traditional antennas is using a conductor. Ionized gases in plasma antennas work as a conductor. The first suggestion of using ionized gas for transmit and receive belongs to by J. Hettinger in 1919 and the first experimental results were done by Askaryan and Raveskii in 1960s [1-9].

These kinds of antennas can be employed in many usages and applications and they are often applied into practice in radio frequency [10-11]. Also, they have applications in variety of fields due to its unique properties, characteristics and advantages over traditional metallic antennas. Some of the applications are mentioned below.

Radio and television broadcasting; signal strength of signals emitted by plasma antennas is relatively stronger than traditionally used normal metal antennas hence it lasts longer without damping and being extinguished hence broadcasting companies may require less relay stations and repeaters to relay signals to further areas and hence it may bring down cost of the broadcasting system for service provider companies [12]. Other application is Public safety networks: Public safety networks like CCTVs are used to prevent crimes, track down criminals and also may be accepted as video evidence in court. If these devices are tampered or damaged by criminals then it is possible for a handler from safety department to diverge or reroute the traffic using plasma antennas. Military applications are other ones; Invisibility to radar means that signals sent by plasma antennas are difficult to be detected by

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any outsider and as military needs to send and receive top secret information without any outside interception plasma antennas have qualities and potential that can be used to develop and produce equipment in military applications within foreseeable future [12]. Space communications; plasma antennas are relatively lighter than normal antennas and hence can be used as communication devices in space crafts like jet planes, commercial planes, even in space shuttles and also in unmanned air vehicle sensor antennas. Faster internet: Plasma antennas can provide a faster rate of data transmission and hence can be used to provide high speed internet like Wi-Gig (Wireless Gigabit Alliance) which is faster than Wi-Fi. In the military point of view, plasma antenna can provide enormous flexibility. The ability of invisibility in the eyes of radar is a considerable advantage for an antenna. The stealth ability is the advantage of plasma which cannot be achieved by metallic materials [13]. This property can be utilized in stealing ships and submarines when they are on mission. This antenna is also a good candidate to create confusion in warfare communication since it can be disappeared within microseconds. The energized plasma elements are hardly to be detected by hostile radar since there are no metallic antenna takes place when the plasma is switched off. In other words, the radar cross section (RCS) of the plasma antenna is low [5]. Also, plasma antenna is easy to be re-configured. When the plasma antenna is de-energized, it reverts to a dielectric tube, and another antenna can transmit through it. This allows using several large antennas stacked over each other instead of several small antennas place next to each other. This results better sensitivity and directivity [10] with less occupied space. In metal antenna the effective length changes physically but in this antenna the effective length can be changed by plasma parameters and controlling the applied RF power thus allowing rapid reconfiguration of the resonant length of the antenna for different transmitting frequencies [14]. The main disadvantage of plasma antenna is its manufacturing difficulties. Also, it is fragile and almost expensive since it needs coupling device.

In this paper a loop plasma antenna with circular coupler [15] is selected and the effect of material of internal coupler on reflection coefficient and the resonant frequency is investigated. It is demonstrated that the resonant frequency can be adjusted by choosing proper material, and any size of commercial fluorescent lamps can be chosen as the base of the plasma antenna. In next sections, first the theory and general performance of the plasma antennas is stated, then the simulation results of the proposed antenna and the inner material effects of coupler is studied.

## 2. BASIC THEORY OF PLASMA ANTENNA

Plasma or fourth state of the matter is the collection of positive ions and free electrons which is a non- homogeneous, non-linear and dispersive environment. In the plasma, the permeability, conductivity and permittivity can be varied in terms of frequency and other parameters which make it a special environment [16]. Radiated electromagnetic waves on plasma will be absorbed, scattered or passed through. We can choose to absorb, scatter or pass through with changing the basic parameters like electron density and collision frequency [17]. The isotropic plasma has complex permittivity that is defined by [10]:

$$\varepsilon_r = 1 - \frac{\omega_p^2}{\omega(\omega - i\nu)} \tag{1}$$

where $\varepsilon_r$ is the complex plasma permittivity, ω is the operating angular frequency [rad/s], υ is the electron neutral collision frequency [Hz] and $\omega_p$ is the plasma angular frequency [rad/s] defined as [10], [18]:

$$\omega_p = \left(ne^2/m\varepsilon_0\right)^{\frac{1}{2}} \tag{2}$$

where $n$ is the electron density [$m^3$], $e$ is the charge of electron [C], m is the electron mass [kg], and $\varepsilon_0$ is the free-space permittivity [F/m]. When the operating angular frequency is greater than the plasma angular frequency ($\omega > \omega_p$), the plasma acts like a classical dielectric medium and in opposite case ($\omega < \omega_p$), plasma acts as a metal. Consequently, depending on the angular frequency, the plasma can transmit or reflect the microwave radiation [19].

## 3. STRUCTURE OF PLASMA ANTENNA

Each plasma antenna consists of three main parts; ionized gas (plasma), enclosure and coupler. Plasma medium is often referred to as the fourth state of matter, since its properties are much different from those of the gaseous, liquid, and solid states. In 1920s, it was shown that the characteristic electrical oscillations of very high frequency can exist in an ionized gas that is neutral or quasi-neutral, therefore, the terms plasma and plasma oscillations were introduced [20]. Enclosure is a part which plasma settle in and it usually is made of glass. The third part is a coupler, which usually consists of 2 parts, to transmit and receive signals since in plasma antennas before the radiation start, the signals should connect with the enclosure with a coupler.

In this work, the effect of changing material of internal coupler on radiation features in UHF band (300-3000 MHz) has been studied.

## 4. SIMULATION AND RESULTS

For the simulation of plasma antenna the first step is design of enclosure which contains the plasma. In this work we use the dimension of the commercial fluorescent loop tube which is made by glass. The next step is the plasma medium simulation which is shown in Fig.1. CST Microwave Studio software is utilized for simulations. The behavior of the plasma is given by Drude dispersion model. This model is a simplified model which describes simple characteristic of an electrically conducting collective of free positive and negative charge carriers where the thermic movement of electrons is neglected [21].

The dielectric constant of the Drude dispersion model is defined as:

$$\varepsilon = \varepsilon_0 [\varepsilon_\infty - \frac{\omega_p^2}{\omega(\omega - j\upsilon)}] \qquad (3)$$

where $\varepsilon_\infty$ is the relative dielectric constant at infinite frequency, generally $\varepsilon_\infty = 1$.

To transmit and receive signals, plasma antenna needs coupler. Therefore, the last part of simulation is coupler simulation. The coupler consists of two separate parts; internal coupler and external coupler. Internal coupler has the ring form and external coupler has cylindrical form and the SMA port is placed between them (see Fig. 2).

First, the loop plasma antenna with an aluminum internal coupler is simulated. Radiation pattern and the reflection coefficient are shown in Fig. 3 and Fig. 4, respectively. Then inner material of coupler is changed from aluminum to copper and each time simulation is repeated. The results are depicted in Fig.5 and Fig.6.

Fig.6 shows that changing the material of internal coupler from aluminum to copper leads to resonant frequency shift from 1864 MHz to 1528 GHz. Furthermore, impedance bandwidth and the radiation pattern are changed. Then all these properties can be regulated by choosing proper material for internal coupler without changing the antenna structure and size.


***Fig. 1. Simulation of (a) enclosure, (b) plasma.***

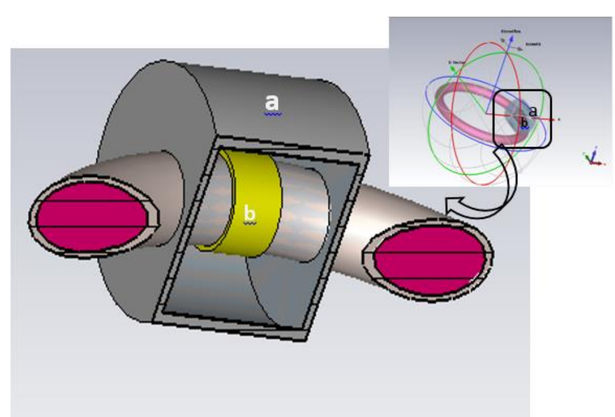


***Fig. 2. Plasma antenna (a) external coupler, (b) internal coupler.***

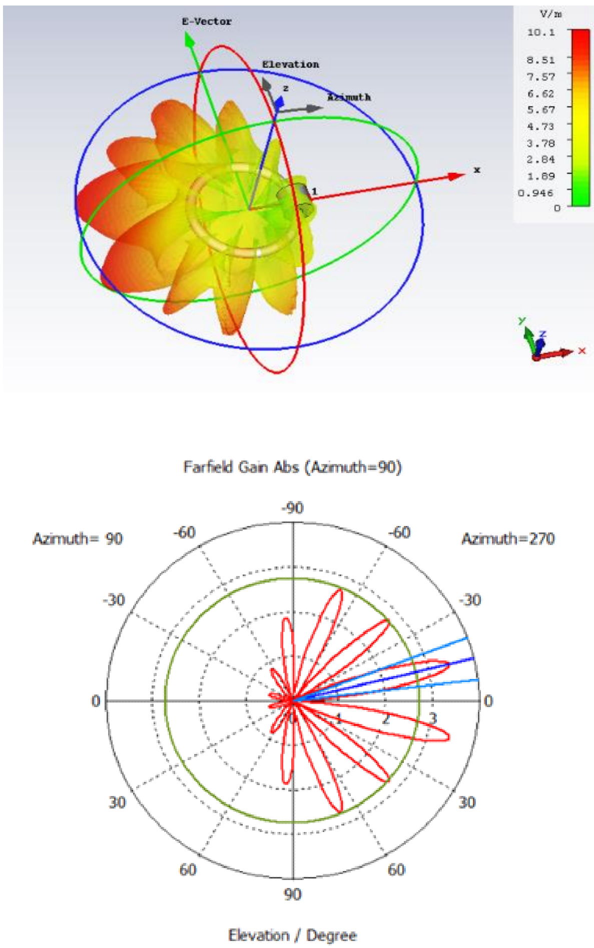


*Fig. 3. Radiation pattern of loop plasma antenna with aluminum internal coupler.*

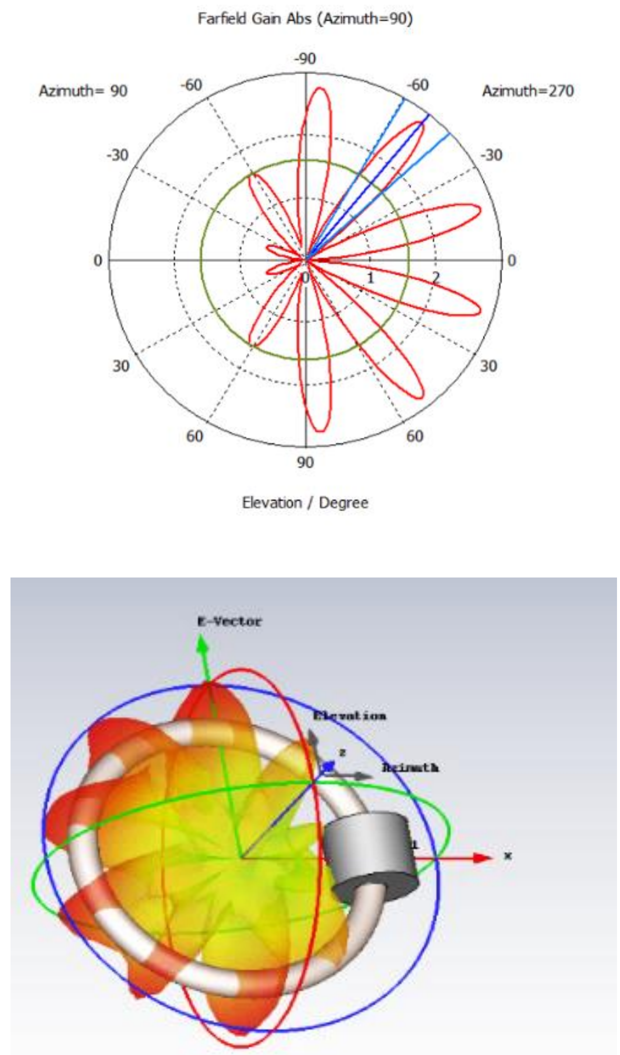


*Fig. 5. Radiation pattern of loop plasma antenna with copper internal coupler.*

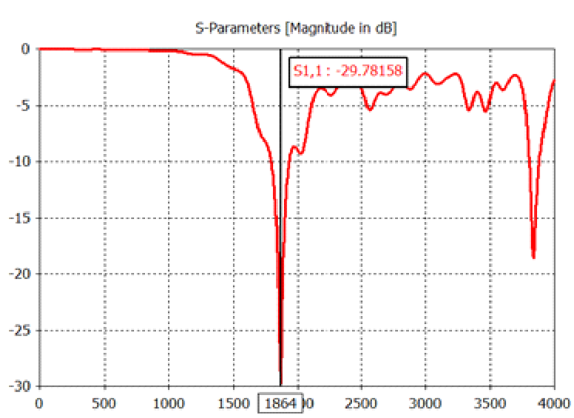


*Fig. 4. Reflection coefficient.*

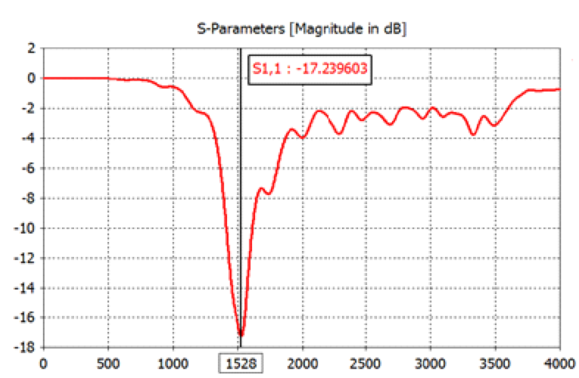


*Fig. 6. Reflection coefficient.*

## 5. CONCLUSION

In this paper, a study has been done on the effect of changing the material of internal coupler of a loop plasma antenna. It is observed that the reflection coefficient of the plasma loop antenna and the radiation pattern vary by changing the material. This allows the resonant frequency be adjusted without altering the antenna size which is usually impossible to change as the antenna is based on commercial florescent lamps.

## REFERENCES

[1] E. Robson, R. L. Morgan, R. A. Meger., “Demonstration of a Plasma Mirror for Microwaves”, IEEE Transaction on Plasma Science, Vol. 20,1992, pp. 1036-1040.

[2] W. Shen, J.E. Scharer, N. T. Lam, B. G. Porter and K.L.Kelly, “Properties of a Vacuum Ultraviolet Laser Created Plasma Sheet for a Microwave Reflector”, Journal of AppliedPhysics, 1995, Vol. 78, No. 12, pp. 6974-6979.

[3] Alexeff, W. L. Kang; M. Rader; C. Douglass; D. Kintner; R. Ogot; E. Norris, “A Plasma Stealth Antenna for U.S. Navy”, Proceeding of 1998 IEEE International Conference on PlasmaScience, 1998, pp. 277.

[4] G. Borg, J.H. Harris, N. M. Martin, J. Kircher, “Plasmas as Antennas: Theory, Experiments and Applications”, Physics of Plasmas, July 2000, Vol. 7, pp. 2198-2202.

[5] Noorine Fatima, Rishabh Chaturvedi, “A Seminar Presentation on Plasma Antenna”. Roll NO-16 EC 9/26/2011.

[6] M. Moisan, A. Shivarova, and A. W. Trievelpiece, “Experimental investigations of the propagation of surface waves along a plasma column,” Phys. Plasmas, vol. 24, p. 1331, 1982.

[7] J. Dwyer, J. R. Greig, D. P. Murphy, J. M. Perin, R. E. Pechacek, and M. Raileigh, “On the feasibility of using an atmospheric discharge plasma as an RF antenna,” IEEE Trans. Antennas Propag., vol. 32, pp. 141–146, 1984.

[8] M. Moisan and J. Pelletier, Microwave Excited Plasma. Amsterdam: Elsevier, 1992.

[9] W. Kang, M. Rader, I. Alexeff, “A Conceptual Study of Stealth Plasma Antenna”, Proceeding of 1996 IEEE International Conference on Plasma Science, 1996 , pp. 261.

[10] T. Anderson, “Fundamental plasma antenna theory,” in Plasma Antennas. Norwood, MA, USA: Artech House, 2011, pp. 31–36.

[11] John Phillip Rayner, Adrian Philip Whichello,” Physical Characteristics of Plasma Antennas” IEEE Transactions on plasma science, FEB 2004, VOL. 32, NO. 1, pp.269-281.

[12] Department of physics, S.L.I.E.T., Longowal, District Sangrur, Punjab, “the new world of plasma antennas", August 2011.

[13] J. P. Rayner, A. P. Whichello, A. D. Cheetham, "Physically Characteristics of Plasma Antennas", IEEE Trans., Plasma Sci., vol. 32, no. 1, pp. 269-281, Feb. 2004.

[14] John Phillip Rayner, Adrian Philip Whichello,” Physical Characteristics of Plasma Antennas” IEEE Transactions on plasma science, FEB 2004, VOL. 32, NO. 1, pp.269-281.

[15] S. S. Golazari, N. Amiri, and F. H. Kashani, "Design, simulation and measurement of loop plasma antenna in UHF band," in 2016 24th Telecommunications Forum (TELFOR), 2016, pp. 1-4.

[16] P. Darvish, A. B. Gorgi, B. Zakeri, “Design, Simulation and Implemetetion of a Preionized Coupled Plasma Antenna at VHF Band” Proceedings of the 2013 International Symposium on Electromagnetic Theory, 2013 IEICE.

[17] Alexeff, I., 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, 2006.

[18] U. S. Inan and M. Golkowski, “Introduction,” in Principles of Plasma Physics for Engineers and Scientists. Cambridge, U.K.: Cambridge Univ. Press, 2011, pp. 1–13.

[19] Oumar Alassane Barro, Mohamed Himdi,

and Olivier Lafond, “Reconfigurable Patch Antenna Radiations Using Plasma Faraday Shield Effect” IEEE Antennas and Wireless Propagation Letters 1536-1225 (c) 2015.

[20] U. S. Inan, M. Golkowski, "Introduction", Principles of Plasma Physics for Engineers and Scientists, Cambridge University Press, NY: New York, 2011, pp. 1-19.

[21] Wei, Qiu Jinghui, Lin Shu, Suo Ying “Analysis and Design of Plasma Monopole Antenna” 2011 6th International ICST Conference on Communications and Networking in China (CHINACOM) ©2011 IEEE.