International Journal of Engineering & Technology, 7 (4.42) (2018) 24-26

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Effect of Plasma Medium in Electromagnetic Wave

H.Ja'afar[1]*, R.Abdullah[2], A.N.Dagang[3], Fatemeh Sadeghikia[4], F.N.M.Redzwan[5]

[125]*Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu, Dungun, Terengganu, Malaysia*
[3]*School of Ocean Engineering, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia*
[4]*Aerospace Research Institute, Ministry of Science, Research and Technology Iran*
**Corresponding author E-mail: hajarj422@tganu.uitm.edu.my*

Abstract

In this paper, a study of analysis and design of cylindrical monopole plasma antenna for electrode-less discharge tube by using CST microwave studio is presented, as it has not been established yet. This analysis is very important which will be a basic concept of design a plasma antenna. A new design of cylindrical plasma antenna is investigated based upon the interaction of plasma elements due to the incident electromagnetic wave. The analysis for three types of gases (Argon, Neon and Hg-Ar) and different pressures are presented. It is shown that the different gases and different pressures will influenced the antenna performance.

Keywords: *Plasma antennas, conductivity, permittivity, electromagnetic wave,*

1. Introduction

The term plasma is often referred to as the fourth state of matter. As the temperature increases, molecules become more energetic and transform in the sequence of solid to liquid to gas and plasma. Due to the unique characteristic of plasma which can be a conductor, it can be combined with antenna concepts and hence, make plasma antennas. Plasma antenna is a type of radio antenna that represents the use of ionized gas as a conducting medium instead of metal conductors to either transmit or receiver the radio frequency signal [1]. When the tubes of plasma antenna were energized, they were turned into conductors, and could transmit and receive radio signals. When de-energized, these revert to non-conducting elements and failed to reflect probing radio signals. However, for plasma antenna to behave like a conducting element, some parameters, such as pressure of gases and type of gases, are necessary and need to be identified for antenna performances.

This paper discusses the analysis for the characteristics of cylindrical monopole plasma antenna and three different gases with three different pressures which were argon gas, neon gas and Hg-Ar gas (a mixture of mercury vapor argon gas) that employed plasma as its radiating element. To provide a better analysis, the measured return loss and radiation pattern for the three types of cylindrical monopole plasma antenna are presented in the section IV.

2. Antenna Design Of Cylindrical Monopole Plasma Antenna

To simulate the performance of a plasma monopole antenna design, CST MWS software was used. Before the antenna was designed, the plasma properties, such as plasma frequency and collision frequency were inserted first in Drude dispersion model in CST software. The values of plasma frequency and collision frequency can be obtained from (1) (plasma frequency) and (2) (collision frequency)

$$\omega_p = \left(\frac{n_e q_e^2}{s_o m_e}\right)^{\frac{1}{2}} \tag{1}$$

In (1), is the electron density of the plasma in the filling pressure is the electron mass, and is the charge of electron. While in (2), σ = Collision cross section and = electron speed

$$v_c = n_e \langle \sigma v \rangle \tag{2}$$

Conductivity of plasma medium is the one of important parameter in plasma antenna. The charged particles that constitute the plasma will be under the effect of the Lorentz force when interacting with an electromagnetic wave. Equation 3 shows the equation of conductivity in plasma medium

$$\sigma = \frac{n_e q^2}{m v_c} \tag{3}$$

In this work, cylindrical monopole plasma antennas were fabricated using glass borosilicate (Pyrex) with a dielectric permittivity = 4.82 and a length of 160 mm, diameter of 10 mm and thickness of 1 mm as shown in Fig.1. The discharge tubes were filled with argon gas, neon gas and Hg-Ar gas (mixture of Argon and mercury) at pressures of 0.5 Torr, 5 Torr and 15 Torr.

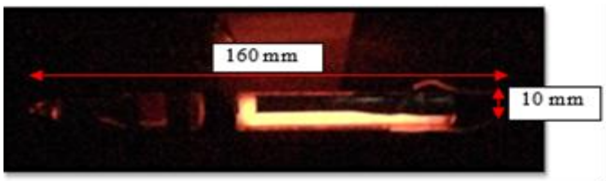
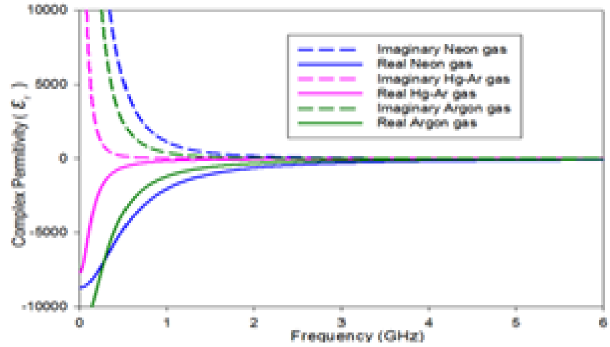


Fig. 1: Cylindrical monopole plasma discharge tube.

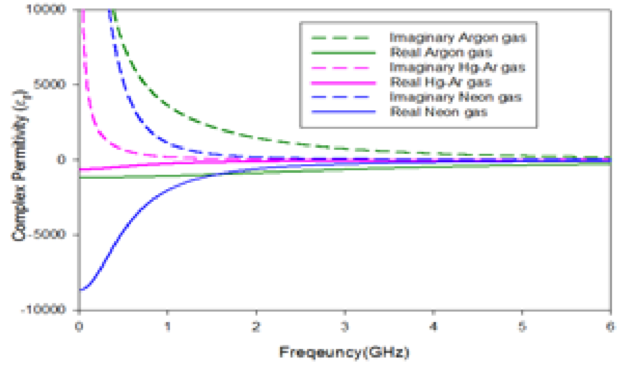
3. Analysis of Cylindrical Monopole Plasma Antenna

3.1. Effect of Plasma Frequency on Complex Permittivity

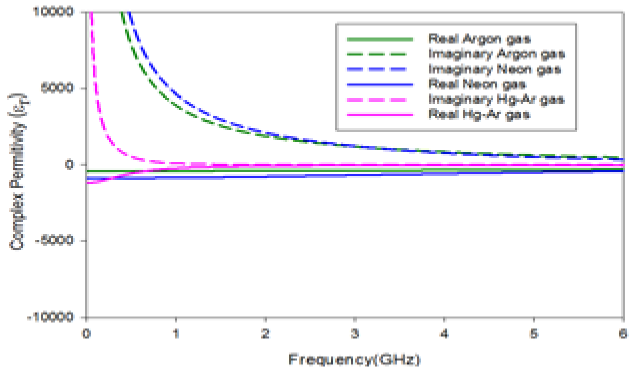
One of the electrical properties of a medium that is important in applications of electromagnetic is electrical permittivity.



(a)



(b)



(c)

Fig. 2: Relative Permittivity for argon gas, neon gas and Hg-Ar gas for (a) 0.5 Torr (b) 5 Torr and (c) 15 Torr.

Fig. 2 illustrates the plasma complex permittivity for argon gas, neon gas and Hg-Ar gas at pressures (a) 0.5 Torr, (b) 5 Torr and (c) 15 Torr respectively. From the graph, the value of imaginary increases when the operating frequency is decreased while the real part becoming more negatively when the operating frequency decreased thus loss in plasma will increase for three gases.

Meanwhile, as for Hg-Ar gas at 0.5 Torr as a plasma antenna, the operating frequency must greater than 1 GHz (>1 GHz). This because from the Fig.2 (a) shows that when the operating frequency is less than 1 GHz (< 1 GHz) the loss in plasma is increase while for Argon gas and Neon gas the starting operating frequency that suitable to act as a plasma antenna at frequency 2 GHz (>2 GHz).

On the other hand, Fig. 2 (b) portrays that the loss for Hg-Ar gas is extremely slow at frequency range >1.8 GHz at 5 Torr. For Argon gas the loss began to decrease at an operating frequency of >3 GHz, while for Neon gas, the loss occur when the operating frequency below than 2 GHz at pressure of gas at 5 Torr.

Apart from that, Fig. 2 (c) clearly shows that Hg-Ar gas the loss extremely slow at operating frequency > 2 GHz for pressure 15 Torr. However, for Neon gas and Argon gas the loss started to decrease at operating frequency >6 GHz for pressure 15 Torr.

3.3. Effect on Different Pressure on Gain

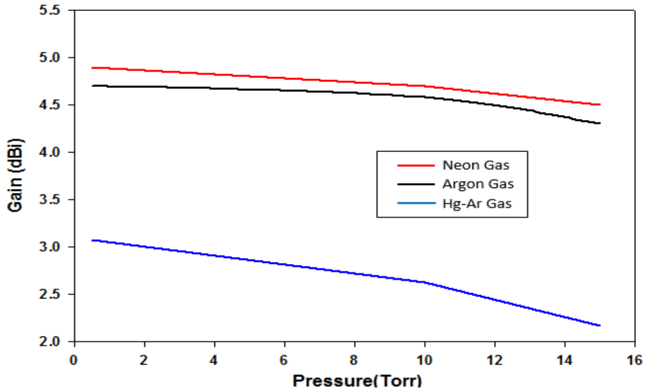


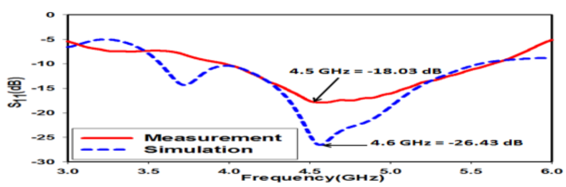
Fig.3: Effect in gain for different pressure

The result which are shown in Fig. 3, illustrate the effect in gain when changing the different pressure. From the analysis for all three gases, shows that, when increase the pressure, the gain will decrease. This because, the collision frequency, vc is pressure dependent, high pressures will increase the collision frequency, vc [2]. As a result the gain is decrease. Based on (3), when the value of collision frequency, vc increase, the plasma conductivity, σ value will decrease. Consequently, this will influence the gain of antenna. Thus from the analysis it can be concluded that the collision frequency, vc can influence the gain of antenna

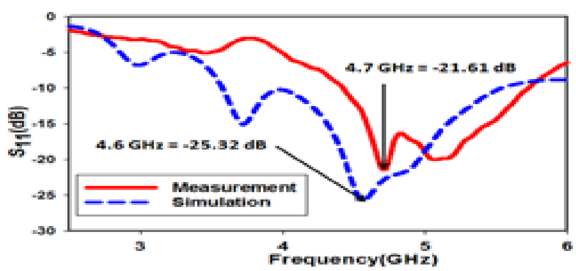
3. Experimental Result

To provide a better analysis, the measured return loss and radiation pattern for the three types of cylindrical monopole plasma antenna are presented. The comparison results between simulation and measurement for argon gas, neon gas and Hg-Ar are presented in this section.

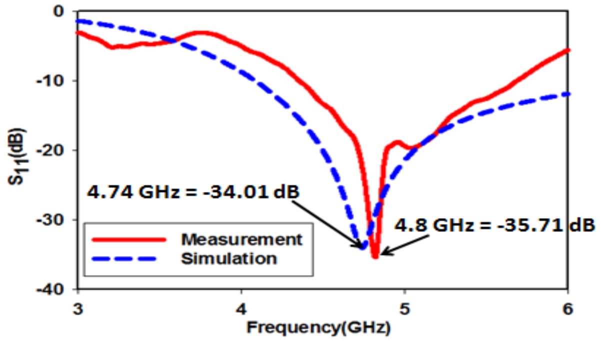
Pressure at 0.5 Torr was chosen because based on the analysis from the simulation result, 0.5 Torr was the optimum pressure value which offered higher gain.



(a)



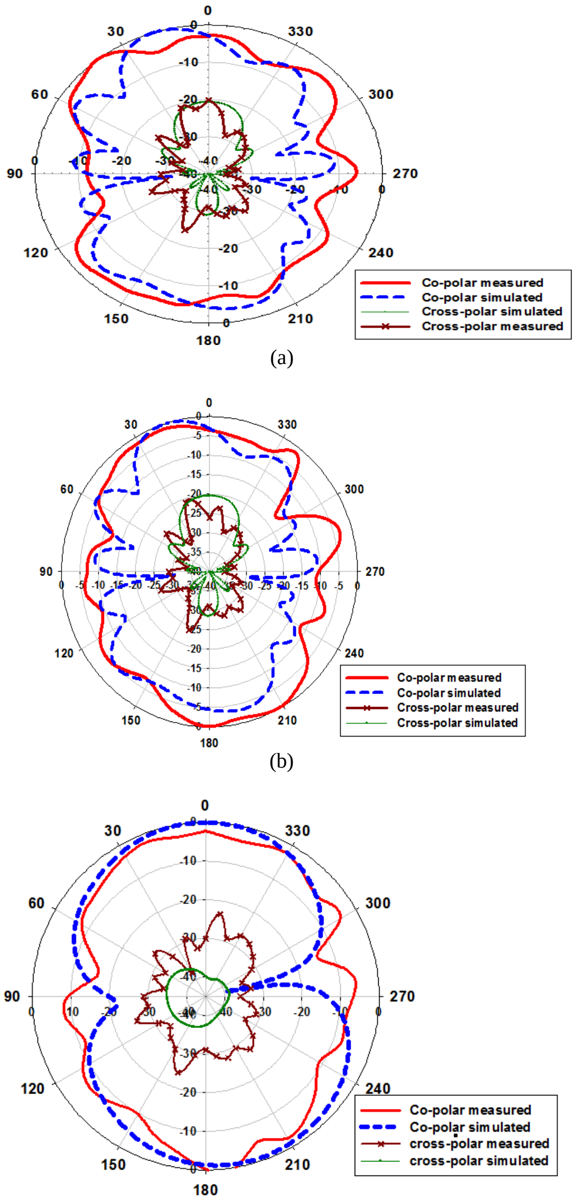
(b)



(c)

Fig. 4: Simulated and measured reflection coefficient, S11 of cylindrical monopole plasma antenna. (a) Argon gas. (b) Neon gas (c) Hg-Ar gas

Fig.4. exhibits the comparison between simulation and measurement results for reflection coefficient, S11. On the other hand, for reflection coefficient, S11 a small frequency shift that occurred between the measurement and the simulation is presumably due to the effect of flow of conduction current through the plasma element and will give effect to the plasma formation. However, in general, a good agreement has been achieved.



(c)

Fig. 5: Simulated and measured radiation patterns. (a) Argon gas (b) Neon gas (c) Hg-Ar gas

Fig.5 shows the comparison between simulation and measurement results for radiation pattern in 3 different gases. Nevertheless, the radiation pattern does not display the expected Omni-directional shape and it might be due to the fact that when the electromagnetic wave arrived at the plasma region, the interaction between electromagnetic wave and plasma will changes the surface current distribution of plasma antenna, as it is known that the radiation pattern is determined by the surface current distribution of antenna.

Thus, the shape for far-field radiation pattern of plasma antenna will be changed. However, good agreement between simulation and measurement has been achieved. This is a text of acknowledgements. Do not forget people who have assisted you on your work. Do not exaggerate with thanks. If your work has been paid by a Grant, mention the Grant name and number here.

4. Conclusion

Analysis of the effect of plasma parameters such as plasma frequency and collision frequency on the electromagnetic wave in plasma antenna have been established in this investigation. The relationship between plasma parameters and antenna performance has been proposed as the basic concept of plasma antenna design. It has been shown that the electron density, ne and collision frequency, νc can influence the performance of antenna. Thus, for an efficient and optimized development of a plasma antenna, these parameters need to be known. The results from measurements seem to agree well with the simulation results.

Acknowledgement

The authors would like to thanks Antenna group members of University Teknologi Mara UiTM for their kind help at various stages of the experiments and also our great appreciation to MOHE for their financial support under grant of 600-IRMI/FRGS5/3(086/2017).

References

[1] D.Kumar and R.A Bora, "Wireless communication capability of a recornfigurable plasma antenna," *Journal Application on Physics*, vol. 109, no. 6, pp 1-9, 2011

[2] Alexander Fridman and Lawrence A.Kennedy, Plasma Physics and Engineering. *France 1st edition:Taylor & Francis*, 2004.

[3] X. P. Wu, J.-M. Shi, Z. S. Chen, and B. Xu, "A New Plasma Antenna Of Beam-Forming," *Progress In Electromagnetics Research*, vol. 126, no. 2, pp. 539–553, 2012.

[4] H. Conrads and M. Schmidt, "Plasma Generation and Plasma Sources," Plasma Sources Science and Technology, vol. 9, 2000.

[5] E. Vecchioni, G. Cerri, P. Russo, and V. M. Primiani, "Experimental and Theoretical Investigation on Plasma Antennas," *Journal Applied Physics*, vol. 30, pp. 3–6, 2013.

[6] H.Jaafar, M.T. Ali, N.A Halili, H.M.Zali,A.N.Dagang, (2013) " A Monople Fluorescent Tube Antenna in Wireless Communication Application ", in *ECTI-CON 2013*,Krabi Thailand , 2013.

[7] H.Jaafar, M.T. Ali, N.A Halili, H.M.Zali,A.N.Dagang, (2013) " Design Monopole Antenna with Fluorescent Tubes at 4.9GHz ", in *Asia Pacific Microwave Conference (APMC)*, Seoul Korea, Nov 2013.

[8] Alexeff, T. Anderson, S. Parameswaran, E. P. Pradeep, J. Hulloli, P.Hulloli, (April 2006) "Experimental and Theoretical Results With Plasma Antennas *" IEEE Transactions On Plasma Science*, Vol 34, No. 2,pp 166-172.

[9] I. Alexeff, T. Anderson, S. Parameswaran, E. P. Pradeep, J. Hulloli, P. Hulloli, "Experimental and Theoritical Results With Plasma Antennas" *IEEE Transactions On Plasma Science*, Vol 34, No. 2,pp 166-172, April 2006.

[10] J. P Rayner, A.P. Whichello, A. D. Cheerham, "Physical Characteristics Of Plasma Antennas" *IEEE Transaction On Plasma Science*, Vol. 32, No. 1, February 2004.