Study the impact gas pressures levels on the loop plasma antenna efficiency

Ali Said Atiah[1], Abdurrezagh Salem Elmezughi[2]
[1,2] **Faculty of Engineering, Azzaytuna university, Tarhuna, Libya**
aliattia1@gmail.com

Abstract:
This paper investigates the influence of gas pressures on the loop plasma antenna parameters covered by two different gases: Argon and Nitrogen. Proposed loop plasma antennas have been simulated and examined its efficiency at three different pressures of 0.5, 5 and 15 Torr is investigated. The radiation properties of all loop plasma antennas have been analyzed and illustrated for three different pressures. To evaluate the efficiency of the proposed antenna, full-wave simulation using the finite integral method software, CST Microwave Studio has been done.
Keywords: *loop-shaped plasma antenna, LTE and Wi-Fi frequency, radiation Characteristics.*

دراسة تأثير الضغوط المختلفة على كفاءة عمل هوائي البلازما المصمم على شكل حلقة

علي سعيد عطية[1]، عبد الرزاق سالم المزوغي[2]
[2،1]**كلية الهندسة، جامعة الزيتونة، ترهونة، ليبيا**
aliattia1@gmail.com

الملخص:
تبحث هذه الورقة تأثير ضغوط الغاز على خصائص هوائي البلازما الحلقي التي يغطيها غازان مختلفان: الأرجون والنيتروجين .وقد تم محاكاة هوائيات البلازما الحلقية المقترحة وفحص أدائها في ثلاثة ضغوط مختلفة من 0.5و 5 و 15 تور. وقد تم تحليل الخصائص الإشعاعية لهوائي البلازما الحلقية وتوضيحها لثلاثة ضغوط مختلفة .لتقييم أداء الهوائي المقترح ومحاكاة الموجة الكاملة تم استخدام برنامج الأسلوب المتكامل المحدود، تم إجراء التجارب باستخدام برنامج الموجات الدقيقة التحليلي.
الكلمات المفتاحية: *هوائيات البلازما الحلقية، ترددات* Wi-Fi ، *الخصائص الإشعاعية لهوائيات البلازما*

Introduction:

The plasma antenna is new and growing technology which is a type of radio antenna by which plasma is used as an alternative of the metal elements of a traditional antenna. A plasma can be used for both transmission and reception. While plasma antennas have only become practical in recent years, Plasma antenna is not a new concept, its patent dates to 1919 which was awarded to J. Hettinger.

Plasma antenna based on ionized gas for guiding electromagnetic waves. It replaces a solid conductor which is widely used in the current radio antennas. Highly ionized plasma is a good conductor and thus it is used as transmission line for guiding waves. Neutral molecules can be separated into positive ions and negative ions using ionization process which helps in generation of plasma. Electrons are much lighter than positive ions and neutral ions. Thus, electrons are considered to be moving through stationary fluid of ions and neutrals with some friction. The propagation characteristics of electromagnetic (EM) waves in a uniform ionized medium can be inferred from the equation of motion of a single “typical” electron. Such a medium is called “cold plasma. (Hettinger, 1919). Although the invention of plasma came at the beginning of the ninth century, the beginning of the plasma revolution witnessed the actual start in the sixties of the last century, (Vedenov et al., 1965). Since then, we have seen several attempts to use plasma in antenna technology, (Borg et al., 1999; Rayner et al., 2004). A lot of research has been done in the manufacture of antennas using different types of materials, such as dielectric, however this research remained limited to different materials, and studies on antenna design using the plasma technology remain very limited, (Golazari et al., 2017; Mohsen Khalily et al, 2013). In the other hand most of the studies on plasma antenna parameters had done on the basic form of plasma antenna (plasma column), (Afar et al., 2012; Zali et al., 2014). (Afar et al., 2012) illustrate that the plasma monopole antenna return loss with various radius and length are stated. The return loss of cylindrical plasma antenna with various electron density are modeled and investigated, (Sharan Bonde et al. ,2014) analyzed plasma monopole antenna parameters with two different gases, argon and neon where radiation patterns and return losses of both models were described by, (Sharan et al.. 2014; Nur et al., 2012) three type of plasma antennas using various gases, xenon, argon, and neon presented by (Nur et al., 2012). Nur Aina Halili and her colleagues examined the implementation of a plasma monopole antenna that is ionized based on RF charging in various circumstances (Halili et al., 2014). The efficiency of a monopole antenna using various types of gases, pressures and coupling sleeves has been analyzed and investigated by (Dagang, 2017).

In this research, the implementation of the loop shaped plasma antenna filled by two types of gases (Nitrogen and Argon) under three different pressure levels has been simulated and modeled.

Basic theory and plasma parameter:

Plasma in terms of electromagnetic properties is a nonhomogeneous, non-linear and diffusing environment. Permeability (μ), conductivity (σ) and permittivity (ε) in plasma can be fluctuated in terms of frequency and other parameters and make plasma a special environment. Consequently, for any frequency of the incident wave and in any density of ionization, one specific response occurs. Radiated electromagnetic waves on plasma will absorb, scatter or pass through. We can choose to absorb, scatter or pass through with varying the basic parameters like electron density and collision frequency (Borg et al., 1999; Harris et al., 1999). The relative permittivity of plasma is defined by: -

$$\mathcal{E}_r = \mathcal{E}_r^{'} - j\mathcal{E}_r^{''} = 1 - \frac{\omega_p^2}{\omega(\omega - j\upsilon)} \qquad (1)$$

Where ωp is plasma frequency, ω is operating frequency and υ is collision frequency. One must characterize the difference between the plasma frequency and operating frequency of the plasma antenna. The plasma frequency is the description of the amount of ionization in the plasma and the operating frequency of the plasma antenna is the same as the operating frequency of a metal antenna. Plasma frequency is equal to: -

$$\omega_p = \sqrt{\frac{4\pi n_e e^2}{m_e}} \qquad (2)$$

Where n_e is electron density, e is the charge of electron and m_e is the electron mass. The electron density is defined by: -

$$n_e = \frac{j}{e\sqrt{\frac{kT_e^0}{m_e}}} \qquad (3)$$

In which j is current density, k is Boltzmann's constant and T_e is electron temperature (Jiayin et. al., 2011).

Theory of the plasma antenna:

In most types of antennas, there is a conductive part which is the important component that directs and radiates electromagnetic waves. The plasma antenna is a type of radio frequency antenna that is used to perform the plasma as the radiation and the guiding medium. Several types of plasma antennas have been fabricated and analyzed such as monopoly antenna, helical antenna. However, the proposed ring-shaped antenna design has a greater degree of freedom than metallic antennas which creates a great potential in their application, such as using a medium plasma as a microwave reflector in a radar system (Manheimer et al., 1991). Every plasma antenna involves three main parts. Firstly, the enclosure that settles the plasma in it. Secondly part is the plasma as the conductor and thirdly is the conducting device for receiving and transmitting the signal.

Simulated results and discussion:

The loop plasma antenna will be designed in three different stages, The basic form of plasma antenna like plasma column (Rajneesh et al., 2010; Cerri et al., 2006) received most of attention from the academic researches. In this paper, a loop plasma antenna with the dimension of commercial florescent tube (T9) according to (Golazari, 2017) is simulated and illustrated in Fig.1. Three separate stages must be designed. In order to model and simulate the proposed a loop plasma antenna. Modeling and Simulating the plasma medium is done using the CST microwave studio by which loop plasma antennas with various gases (Ar, N) at three different pressures (2.28, 5, 10 Torr) are simulated.

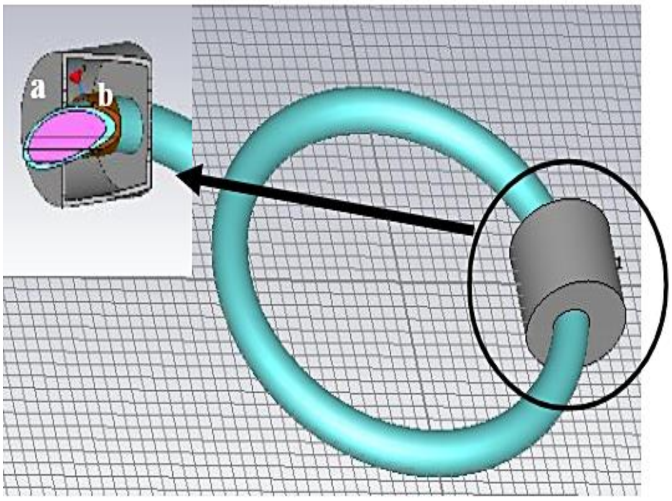

Fig. 1. Simulated Loop antenna side view and cross section view

In simulated model, the efficiency of plasma and the effect of electron collision is associated. This model is developed and designed to signify the commercially available plasma source used in the simulation activities. After that the design of the coupler that reported in (Jiayin et al., 2011), should involve of two parts, internal and external coupler as illustrated in Fig.1-b. Fig 2 and Fig 3 represent the results of the simulated return loss results of the plasma antenna with (Ar gas and N gas at pressure 2.28, 5, and 10 Torr respectively.

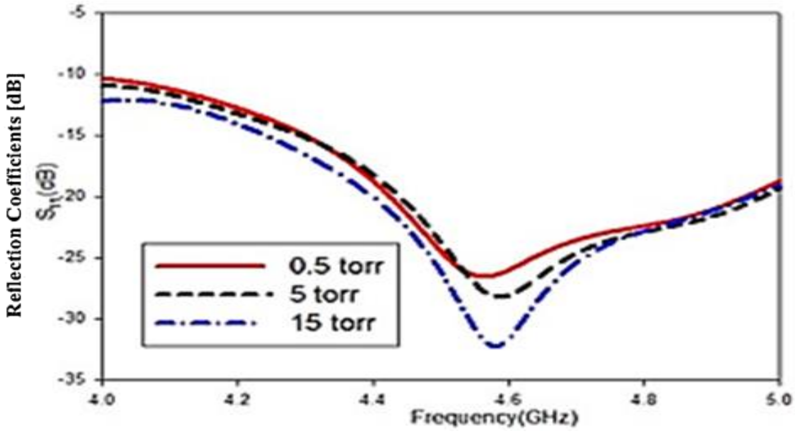

Fig.2 Simulated reflection coefficient plot of Ar loop plasma antenna at 2.28Torr, 5Torr and 10 Torr.

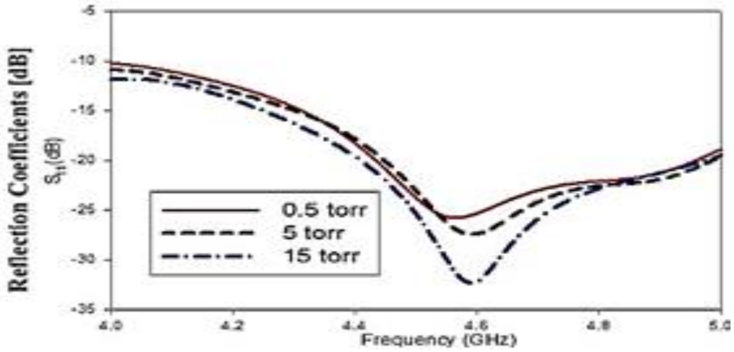

Fig.3 Simulated reflection coefficient plot of N loop plasma antenna at 2.28 Torr, 5 Torr and 10 Torr.

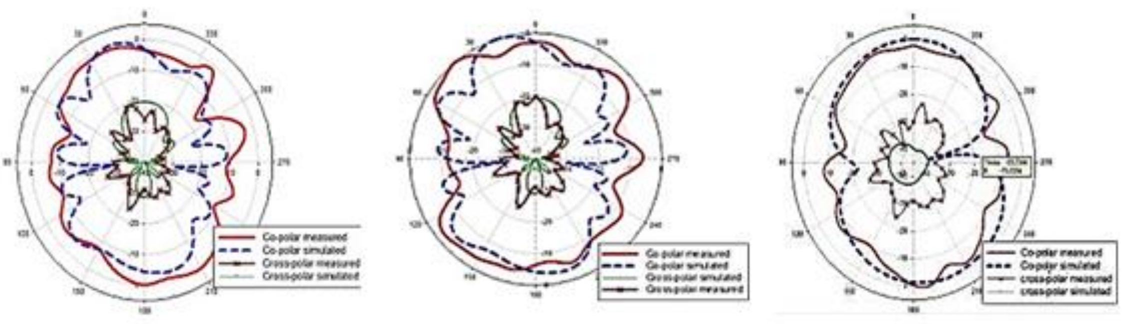

Fig. 4. The reflection radiation pattern at (a) 2.28Torr, (b) 5Torr and (c) 10 Torr.

It is quite clear in fig2 and fig 3, the return loss value of the proposed antenna has values smaller than -10 dB. It is also found that increase of pressure leads to a shift at the resonant frequency. The simulation results showed that changing the gas pressure enhances the antenna bandwidth range and shifts the resonant frequency. Although the loop plasma with N gas has very good impedance matching with respect to that of Ar gas, the best result of reflection radiation pattern related to the loop-shaped plasma antenna at the pressure of 5 Torr. reflection radiation pattern of loop-shaped plasma antenna is shown in Fig.4 at three various pressures, respectively.

The results showed that the antenna efficiency is better by using nitrogen gas in terms of matching the impedance, which results in better efficiency in the rest of the Antenna properties such as far field radiation bather antenna bandwidth.

Conclusion:

In this paper the effect of gas pressure on antenna efficiency is examined. The results showed that the efficiency of the loop plasma antenna depends on the type of the used gas and on the pressure level of the gas. It's found that the antenna radiation pattern and the antenna bandwidth and the resonant frequency of the antenna varied with the variation of the gas pressure. Very promised results were obtained which make this technology very suitable to be used in Wi-Fi and universal mobile networks.

References:

Afar H., Ja', M. T., Al, N. A., Halil, H. M., Zal, A., & Dag, N. (2012). Analysis and Design between Plasma Antenna and Monopole Antenna,1st IEEE International Symposium on Telecommunication Technologies.

Ahmad, N. D., Chan X. L., & Jaafar, H. (2017). Study on the Effect of a Variation Taypes of Gas, Pressures and Coupling Sleeves on the Efficiency of Monopole Plasma Antenna, ARPN Journal of Engineering and Applied Sciences,*12* (23) 221-236.

Borg, G., & Harris, J. H. (1999). Application of plasma columns to radiofrequency antennas, Applications and physics, Lithuania.

Golazari S. S., Amiri, N., & Kashani, F. H. (2016). Design, simulation, and measurement of loop plasma antenna in UHF band, Belgrade, 24th Telecommunications Forum (TELFOR).

Golkowski, U. S., & Inan, M. (2011). Principles of Plasma Physics for Engineers and Scientists, New York, Cambridge University Press, *23*(4) 1-19.

Halili, N. A., Ali1, M. T., Pasya1, I., Dagang, A. N., Ja'afar, H., & Zali, H. M. (2014). RF Radiation Behavior of Rare Gas in Plasma State, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE, *9*(3), 67-76.

Hettinger, J. (1919). Aerial conductor for wireless signaling and other purposes, Patent H31D- 1309031.

Jiaming, W., Jiayin, S. W., & Jiachun, X. B. (2006). Study of the Radiation Pattern of the Unipole Plasma Antenna. IEEE conf, ISAPE, International Symposium.

Li, W. Q., Jinghui, L., & Shu, S. Y, (2011). Analysis and Design of Plasma Monopole Antenna, 6th International ICST Conference on Communications and Networking in China (CHINACOM).

Manheimer, W. M. (1991). Plasma Reflectors for Electronic Beam Steering in Radar Systems, IEEE Transactions on Plasma Science *9*(6).1228-1234.

Nur, A., Halili, M. T., Ali, H., Zali, M., & Ja'afar, H. (2012) Study on Plasma Antenna Characteristics with Different Gases, IEEE International Symposium on Telecommunication Technologies.

Primiani, V., & Mariani, P. R. (2006). Measurement of the Properties of a Plasma Column Used as a Radiating Element Instrumentation and Measurement Technology Conference Sorrento, Italy, IMTC, 24-27.

Rajneesh, K. & Dhiraj, B. (2010). A reconfigurable plasma antenna", Journal of Applied Physics *107*(5).

Rayner, J. P., Whichello, A. P., & Cheetham, A. D. (2004). Physically Characteristics of Plasma Antennas, IEEE Trans., Plasma Sci. *32*(1) 269-281.

Sharan, B. V., & Ghiye, A. D. (2014). A Study of Plasma Antenna Parameters with Different Gases, 4th International Conference on Communication Systems and Network Technologies.

Theodore, A. (2011). Plasma Antennas. Artech House.

Vedenov, A. A. (1965). Solid state plasma, Soviet Physics Uspekhi, *7*(6), 809-822.