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Research paper

Plasma Antenna with Ethernet Over Ac Power (EOP) for Wi-Fi Application

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Abstract

This paper proposed a plasma antenna using a fluorescent tube that contain a mixture of Argon gas and mercury vapor. The objective of this project is to carry Ethernet from service provider by integrating the plasma antenna with AC power line so that the antenna could transmit Wi-Fi signal at many locations simultaneously. The length of the antenna tube is 586 mm and 24.3 mm in diameter. The antenna has been simulated using Computer Simulation Technology (CST) and was integrated with a router and Ethernet over power line (EoP) device. Return loss, Wi-Fi strength and signal strength were calculated and measured. The antenna is designed to operate at 2.4GHz for Wi-Fi application.

Keywords: *CST; Fluorescent; Plasma antenna; Wi-Fi.*

1. Introduction

The Plasma is the fourth state of matter after solid, liquid and gases. Hence, plasma antenna is a type of antenna in which the material conducting element of a metal is replaced by plasma, to either transmit or receive a radio signal [1-2]. Nowadays there are many researcher that have reported about the plasma antenna. There are several method used to generate a plasma such as application of electric and magnetic fields, RF heating and laser excitation [3-6]. Few shapes of plasma antenna also have been reported [7-8]. Moreover, plasma can be rapidly created and destroyed by applying electrical pulse to the discharge tube. Therefore plasma antenna can be switched on and off [9].

Plasma is also an ionized gas. The ionization degree can vary from 100% which is fully ionized gasses, to very low values or partially ionized. Plasma frequency is a natural frequency of the plasma and is a measure of the amount of ionization in plasma. Equation (1) shows the plasma frequency equation.

$$\omega_p = \sqrt{\frac{e^2 n_e}{\varepsilon_o m_e}} \tag{1}$$

Where ω_p is the plasma frequency [rad/s], *e* is the charge on electron [C], m_e is the electron mass [kg], *n* is the electron density [m^{-1}] and ε_0 is the free space permittivity [F/m]. The collision frequency equation is given in Equation (2).

$$v_c = n_e K(T_e) \tag{2}$$

Where ne is the electron density [$1/m^3$], K is Boltzman's constant and T_e is electron temperature of the plasma elements.

In this research, the simulation is performed by using the simulation software Computer Simulation Technology (CST) Microwave Studio. This paper is structured as follows: Section 2 describes the antenna design and structure, Section 3 is focused on the analysis of the plasma antenna, in Section 4 results and discussion are discussed, and finally in Section 5 is the conclusion.

2. Plasma antenna design

The design of the plasma antenna has been divided in two stages. First stage is the design of the monopole antenna using a copper ring as a coupling sleeve, while the second stage is by integrating the monopole plasma antenna with a Wi-Fi router and EoP device. The design antenna was simulated in CST software. The behaviour of the plasma is given by Drude dispersion model.

2.1. Construction of monopole plasma antenna

The monopole plasma antenna structure was constructed from a commercial fluorescent tube that contain the mixture of argon gas and mercury vapor. The length of the fluorescent tube is 586 mm and the diameter is 24 mm. The energy source was applied to the antenna through the coupling sleeve so that the antenna will resonate at 2.4 GHz. The coupling sleeve was positioned at one end of tube as an input terminal. The antenna was fed by an SMA connector. The structure of the proposed antenna is shown in Figure 1 while the optimized parameters of the monopole plasma antenna are presented in Table 1.

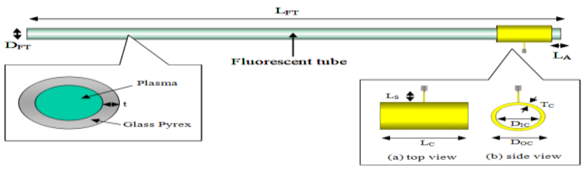


Fig. 1: Geometry of the monopole plasma antenna

Table 1: Parameters of Monopole Plasma Antenna

Parameter	Label	Dimension (mm)
Length of monopole plasma antenna	L_{FT}	586
Diameter of monopole plasma antenna	D_{FT}	24
Thickness of fluorescent tube	t	1
Position of Copper Ring at the fluorescent tube	L_A	11.66
Distance of SMA connector and Copper Ring	L_S	14.5
Length of Copper Ring	L_C	60
Diameter of inner radius of copper ring	D_{IC}	30
Diameter of outer radius of copper ring	D_{OC}	36
Thickness of copper ring	T_C	3

2.2. Construction of monopole plasma antenna with Wi-Fi router and EoP device

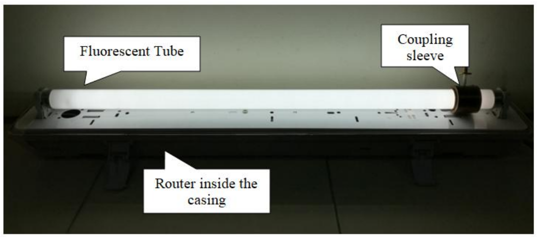


Fig. 2: Monopole plasma antenna with Wi-Fi router

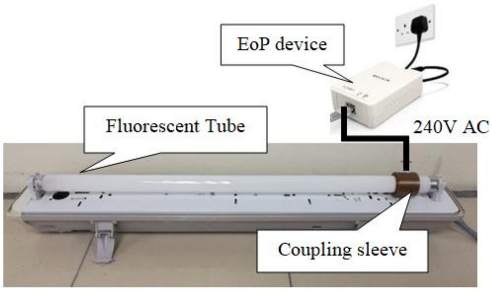


Fig. 3: Monopole plasma antenna with EoP device

The fluorescent antenna was upgraded by equipping it with a wireless router. The router was modified by adding an external antenna which is the monopole plasma antenna to improve the router performance. The antenna was also integrated with EoP device so that the network can distribute to any rooms simultaneously without adding any new wire cable. The other EoP device is connected to a black box which also contain a wireless router. Based on the configuration, it will enable data from the router to travel along the Ethernet cable into the other adapter, across the electrical wiring in the walls, out into the second adapter in the other rooms. Figures 2 and 3 show the constructed plasma antenna integrated with wireless router and EoP device.

Figure 4 illustrates the configuration of monopole plasma antenna with Wi-Fi router and EoP device in each room in a building. It shows that the plasma antenna is capable of transmitting data to each room without adding any cable wire.

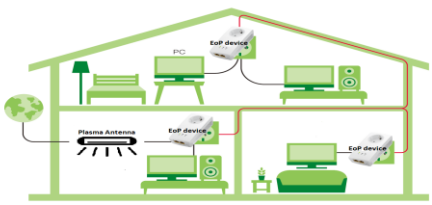


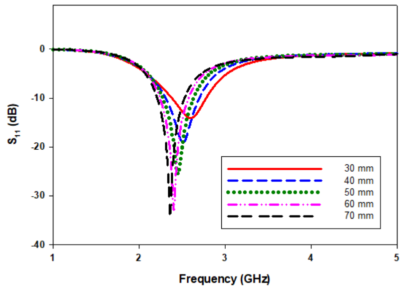
Fig. 4: The structure of plasma antenna with Wi-Fi router and EoP device in a building

3. Analysis of monopole plasma antenna

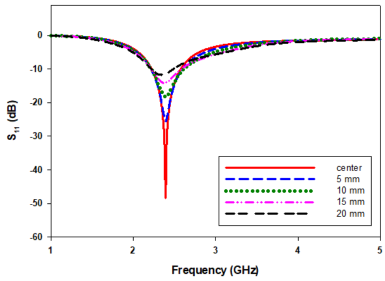
The analysis of parametric study is presented in this section to ensure that the effects were taken place at the desired target frequency which is at 2.4 GHz. A parametric analysis was accomplished to achieve the optimum performance of the antenna. In this parametric analysis, the effect on S_{11} has been investigated at frequency of 2.4 GHz. Figures 5(a)–(c) show the simulated parametric studies on the reflection coefficient S_{11}, when some parameters are varied. Figure 5(a) shows the simulation result of reflection coefficient, S_{11} on the effect of different length of the copper ring, L_C. The length of the copper ring was varied from 30mm to 70mm with increment of 10mm. Based from the graph, as the length of the copper decrease, the resonant frequency shifted to higher frequency. The best length for the antenna to operate at frequency of 2.4 GHz is when L_C = 60 mm.

The SMA location was varied from 5 mm from the end of the copper ring to 30 mm, which is the centre of the copper ring. The location was varied by an increment of 5 mm. The results are illustrated in Figure 5(b). Based from the graph, it is obvious that where ever the SMA connector was located, the resonant frequency remained operating at frequency of 2.4 GHz. However, the best reflection coefficient, S11 was obtained when the SMA was located at the centre of the copper ring.

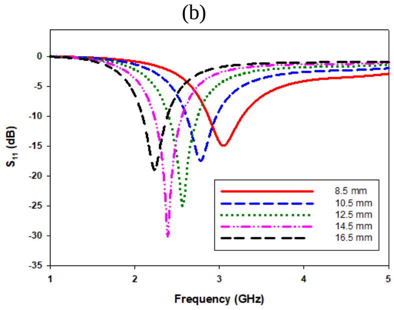
Figure 5(c) shows the simulated result with varied distance from 8.5 mm to 16.5 mm with increment of 2 mm. From the simulation results, it is observed that when the distance of L_S increased, the resonant frequency of the antenna will shift to lower frequency. From this analysis, the optimum reflection coefficient at operating frequency of 2.4 GHz is when the distance between SMA connector and copper ring is equal to 14.5 mm.



(a)



(b)



(c)

Fig. 5: Effects of (a) length of copper ring, (b) location of SMA connector, (c) distance of SMA connector and copper ring on reflection coefficient.

4. Results and discussion

Figure 5 shows the comparison between simulated and measured result of reflection coefficient, S_{11} for monopole plasma antenna using copper ring. The results indicate that both antennas were operated at 2.4 GHz. The simulated result of reflection coefficient, S_{11} was -32.88 dB while the measured result was -12.08 dB. The measured result was 20 dB lower compared to simulated result possibly due to imperfect soldering between SMA connector and copper ring. However, in general, a good agreement was achieved between simulated and measured values.

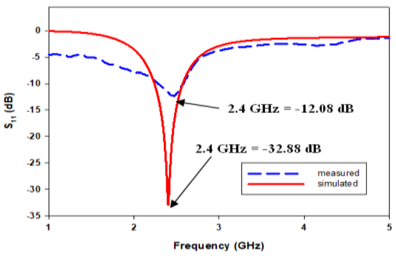


Fig. 5: The comparison of S_{11} between simulated and measured result.

Figure 6 presents the result of indoor propagation measurements of monopole plasma antenna. The measurement was taken at the Antenna Research Centre (ARC) lab, Universiti Teknologi MARA (UiTM) Shah Alam which has a dimension of 14 m x 13 m. It can be seen from the graph that the power received decreased when increasing distance between transmitter and receiver at operating frequency of 2.4 GHz. The plasma antenna can cover a minimum distance of 12 m with minimum Power transmit, P_t, which equal to 0 dBm or 1 mWatt. However, the plasma antenna is capable to transmit the signal further if the P_t is supplied higher than 0 dBm power signal.

After the monopole plasma antenna was integrated with Wi-Fi router and EoP, the Wi-Fi signal strength of monopole plasma antenna was measured using Wi-Fi Analyzer applications. This application shows all the Wi-Fi channel was available in real time. The results of the Wi-Fi signal strength are shown in Figure 7 . As can be seen from the figure, the purple line, named 'Plasma_Antenna' refers to the result of Wi-Fi signal strength of plasma antenna, while other lines represent other Wi-Fi channels in the same room. The plasma antenna possessed good signal strength, which was approximately 25 dBm. It proved that the antenna functions well and can transmit data.

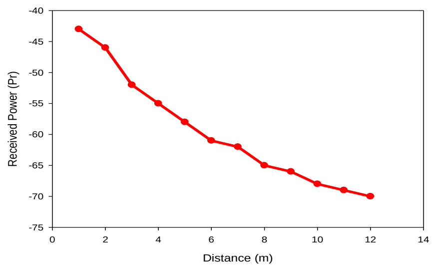


Fig. 6: Indoor signal propagation result

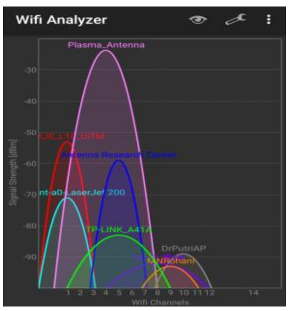


Fig. 7: Performance of signal strength of monopole plasma antenna

5. Conclusion

A monopole plasma antenna integrated with Wi-Fi router and EoP device is proposed at 2.4 GHz for indoor Wi-Fi application. The design of the antenna used a plasma as a conductor element with the help of coupling sleeve. The simulated and measured data are presented in this paper. Good agreement was achieved between simulated and measured results. This paper also include the measured result of Wi-Fi strength and indoor signal propagation. This design provides an alternative solution to route the internet connectivity from a router, through an electrical wiring, and into a wireless access point to boost the range of a Wi-Fi network at many locations at the same time.

Acknowledgement

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