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Performance Analysis of a Monopole Antenna with Fluorescent Tubes at 4.9GHz Application.

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Abstract

This paper presents of analysis the performance monopole antenna with fluorescent tubes. The antenna was designed at the operating frequency which is 4.9 GHz. The commercially fluorescent tubes consist of a glass tube filled with mixture mercury vapor and argon gas. After get sufficient voltage the gas inside the fluorescent tube will ionize to plasma and formed plasma column. The plasma frequency is equal to 5.634e11 Hz. The plasma is highly conducting and acts as a reflector. When all of the tubes surrounding the antenna are electrified, the radiation is trapped inside when the plasma frequency is greater than radio frequency. An accomplishment of the design has been carried out using CST microwave studio software. The developed antenna has potential in military application. To conclude, antenna's performance was analyzed in terms of return loss, radiation pattern and gain.

Keywords : Plasma, monopole antenna, return loss, radiation pattern, gain.

1. Introduction

During the last decade, there has been a tremendous growth in plasma based technologies including a number of spin off plasma based electronic devices such as plasma mirrors for microwave reflection, plasma phase shifters and plasma switches, plasma antennas, etc.

In the area of communication, the plasma element was considered as an effective radiator to release the electromagnetic energy just as the metal element did. Several techniques for producing the plasma were also introduced and varied practicality. While, in the fields of radio detection and target directing, the plasma element was treated as a reflector in the planar shape to reflect the well configured electromagnetic wave.

In this paper, the effects of plasma elements on the monopole antenna are investigated. The investigation is carried out using CST studio software. This antenna design at operating frequency 4.9 GHz. This paper is organized as follows. In section II, the principle of plasma is presented. In section III, antenna structure and design is given out. In section IV, results and discussions are analyzed in detail. The conclusion is established in section V.

2. Principle of Plasma

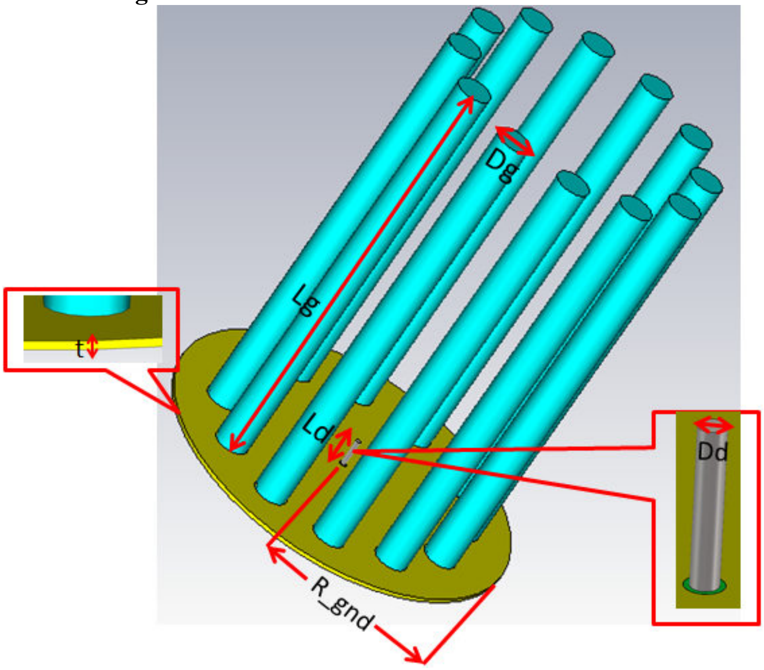
Plasma is ionized gas. Hence, they consist of positive and negative ions and electrons, as well as neutral species. The plasma state is often referred to as the fourth matter. The ionization degree can vary from 100% (fully ionized gases) to very low values or partially ionized. Plasma can be generated by the application of electric and/or magnetic fields, RF heating, laser excitation pre-ionization followed by high voltage breakdown to form the main conducting channel or by simply using commercial fluorescent tube .

The type of power source used to generate plasma can be DC, RF, and microwave. Ionization process occurs when a sufficiently high potential difference is applied between two electrodes placed in a gas; the latter will break down into positive ions and electrons. The mechanism of the gas breakdown can be explained as follows: a few electrons are emitted from the electrodes due to the omnipresent cosmic radiation. Without applying a potential difference, the electrons emitted from the cathode are not able to sustain the discharge. However, when a potential difference is applied, the electrons are accelerated by the electric field in front of the cathode and collide with the gas atoms.

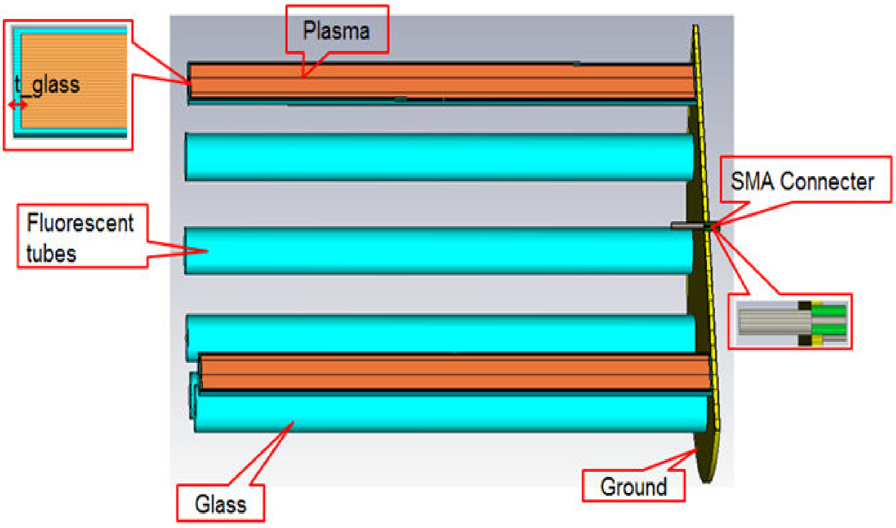
Once plasma is formed, a sheath is formed automatically between the electrode and plasma to maintain the energy and particle balance. Region outside the sheath is called the positive column, where uniform plasma exists, whose density and dimension are determined by the balance between ion diffusion to the surrounding wall of the tube and the ion generation mechanism.

For the purpose of electromagnetic reflection, plasma is used as a conductive reflector if the incoming wave frequency is lower than the plasma frequency. When switched on by a pulsed radio frequency power, the plasma conducts and transmits signal like a metal antenna and when it is off, there is only minor reflection from the glass tube and hence it has a very low RCS.

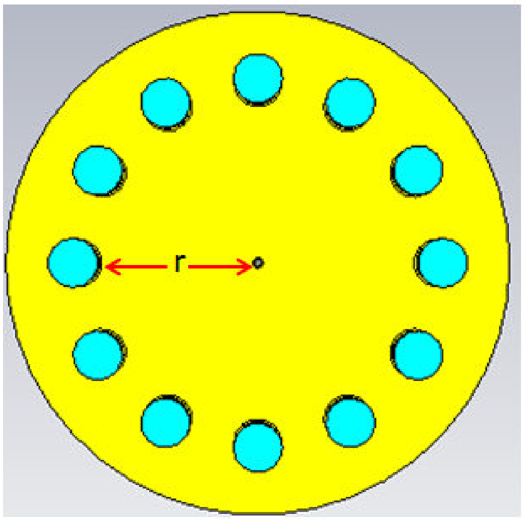
3. Antenna Structure and Design



a) Antenna Structure



b) Cross section view



c) Top view

Figure 1: Antenna Design

To simulate the performance of an antenna design, CST MWS software is used. The structure of the proposed antenna is shown in figure 1(a), (b) and (c).The antenna structure consists of 12 tubes of commercial fluorescent lamps that containing the mixture of mercury vapour and argon gas. The ground is circular aluminium with monopole antenna at the centre of ground. The antenna is fed by a standard SMA connector that is located at the middle of the ground. The probe feed (coaxial feed) is a technique that used in this project for feeding microstrip patch antennas and fed by a SMA connector. SMA connector design is according to specification in using Teflon with dielectric constant = 2.08. The impedance of feeding coaxial transmission line is 50 Ω. The tube wall (glass) has a thickness, t = 0.1mm with radius 10mm. The default antenna dimension is presented in Table 1.

Table 1: Parameter Value

Parameters	Description	Dimensions (mm)
R_gnd	Radius ground	105.000
t	Thickness ground	2.500
Dd	Diameter dipole	3.000
Ld	Length dipole	16.764
Dg	Diameter glass	20.000
Lg	Length glass	260.000

The behaviour of the plasma is given by drude dispersion model in CST software. The drude dispersion model describes simple characteristic of an electrically conducting collective of free positive and negative charge carriers, where thermic movement of electrons is neglected. The dielectric constant of the drude dispersion model is given by equation 1

$$\varepsilon = \varepsilon_0[\, \varepsilon_\infty - \boldsymbol{\omega}^2_{\mathrm{p}} / \boldsymbol{\omega}(\boldsymbol{\omega} - \mathrm{j}\nu)\,] \qquad (1)$$

Where ε_∞ is the relative dielectric constant at infinite frequency, generally $\varepsilon_\infty = 1$ and $\boldsymbol{\omega}$ is EM wave frequency. The plasma frequency ω_{p} and the collision frequency ν_{c} are called drude parameters. Plasma frequency is a natural frequency of the plasma and is a measure of the amount of ionization in plasma. Equation 2 shows the plasma frequency equation while equation 3 for collision frequency equation

$$\omega_{\mathrm{p}} = \sqrt{\frac{e^2 n_e}{\varepsilon_0 m_e}} \qquad (2)$$

Where ω_p is the plasma frequency, e is the charge on the electron, m_e is the electron mass, n_e is the electron density in 1/cm^3.

$$\nu_{\mathrm{c}} = n_e K\,(T_e) \qquad (3)$$

Where ν_c is collision frequency, n_e is the electron density in 1/cm^3, K is boltzman's constant and T_e is electron temperature of the plasma elements.

One must distinguish the difference between the plasma frequency and the operating frequency of the plasma elements. The plasma frequency is a measure of the amount of ionization in the plasma and the operating frequency of the plasma elements is the same as the operating frequency of a metal antenna. The ratio gas between argon and mercury vapor is 0.9: 0.1 for fluorescent tubes that used in this design approximately with the commercially fluorescent tubes. For simulation of antenna, drude dispersion material is designed as follow:

Table 2: Calculated Parametes

Parameter	Value
Epsilon Infinity, ∞	1
Plasma frequency, ω_p	5.634e11
Collision frequency, ν_c	10e9
Relative magnetic permeability,μ	1

The electron density in the plasma column is considered homogeneous and the collision frequency is constant.

4. Results and Discussion

In this section, simulation outcome were explained. The simulation is performed by using the commercially available simulation software CST Microwave Studio.

4.1 Monopole Antenna With Plasma and Without Plasma

The monopole antenna is fed by a standard SMA connector that is located at the centre of dipole. The line impedance generated for the antenna is 50Ω. Fluorescent tubes were added surrounding at the dipole. Figure 2 shows the S_{11} parameter at operating frequency 4.9 GHz. Refering to the Figure 2, the red line represent for dipole antenna without plasma with the S_{11} equal to -31.564dB while blue line represent monopole antenna with plasma and the S_{11} is -21.214dB.

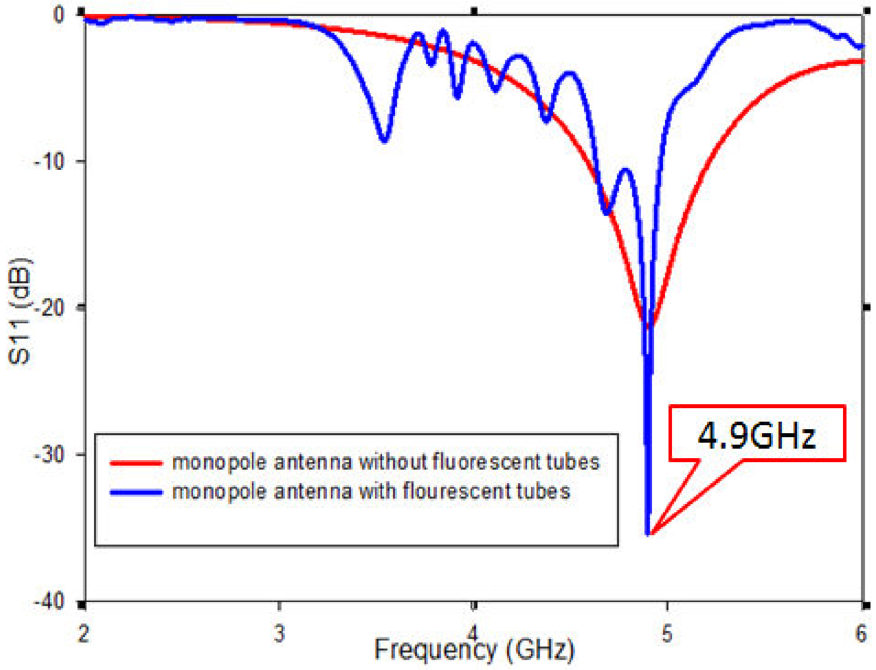


Figure 2: The return loss effect on monopole antenna with and without fluorescent tubes.

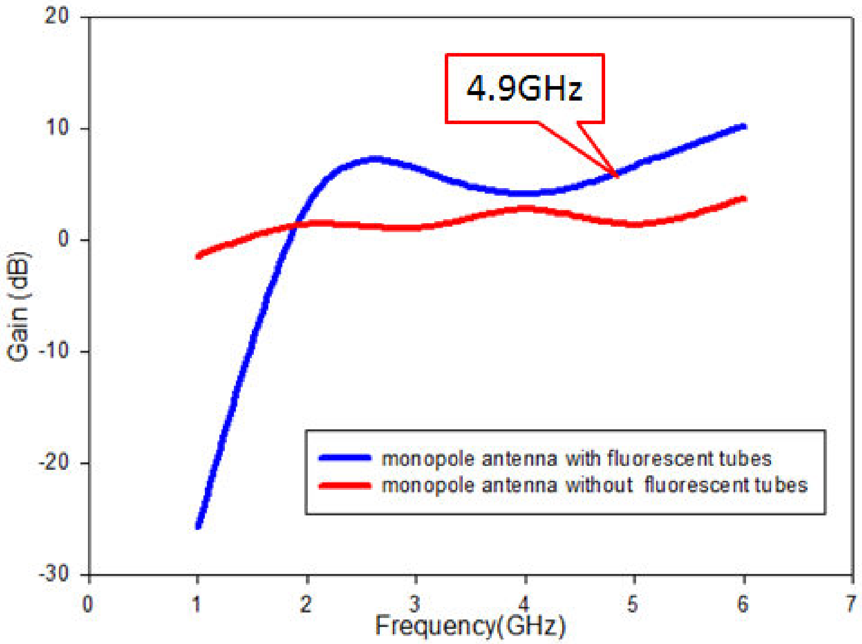


Figure 3: Gain measured during simulation result

Figure 3 shows the gain result from simulation. The blue line represent for monopole with fluorescent tubes while red line for monopole antenna without fluorescent tubes. Referring to the figure 3 the gain measured at operating frequency at frequency (4.9GHz) for monopole antenna with fluorescent tubes is 7.061dB while for monopole antenna without fluorescent tubes is 1.351dB only. From the graph, the percentage of efficiency 13% increment is noticed for monopole antenna with fluorescent tubes compared to without fluorescent tubes. Therefore the use of fluorescent tubes is can be considered effective in enhancing the gain and efficiency.

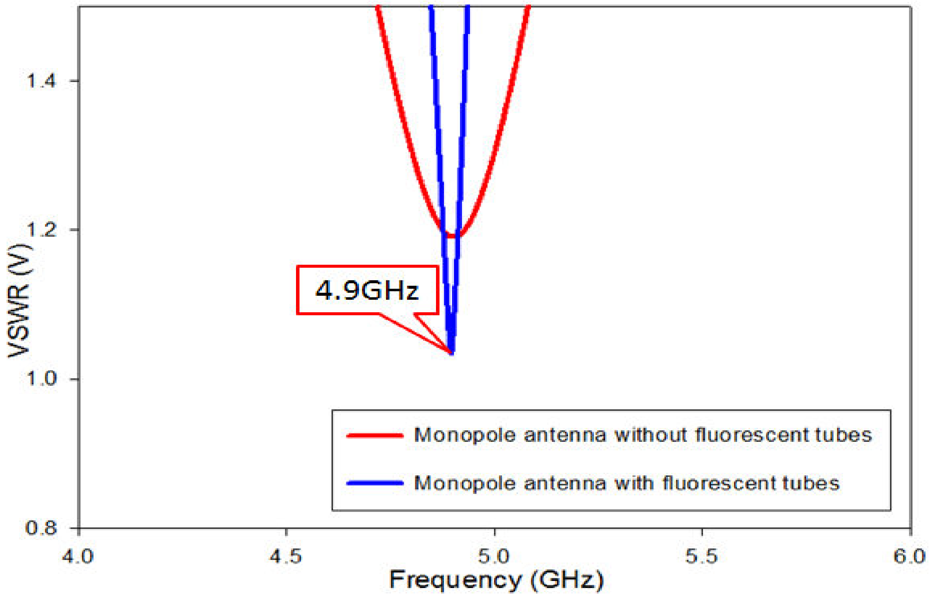
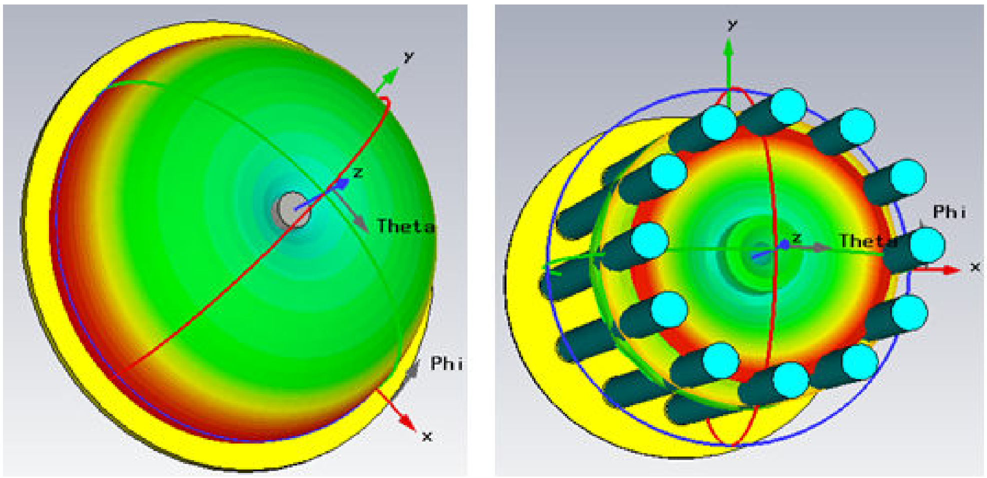


Figure 4: Voltage Standing Wave Ratio (VSWR) between Monopole antenna with fluorescent tubes and monopole antenna without fluorescent tubes

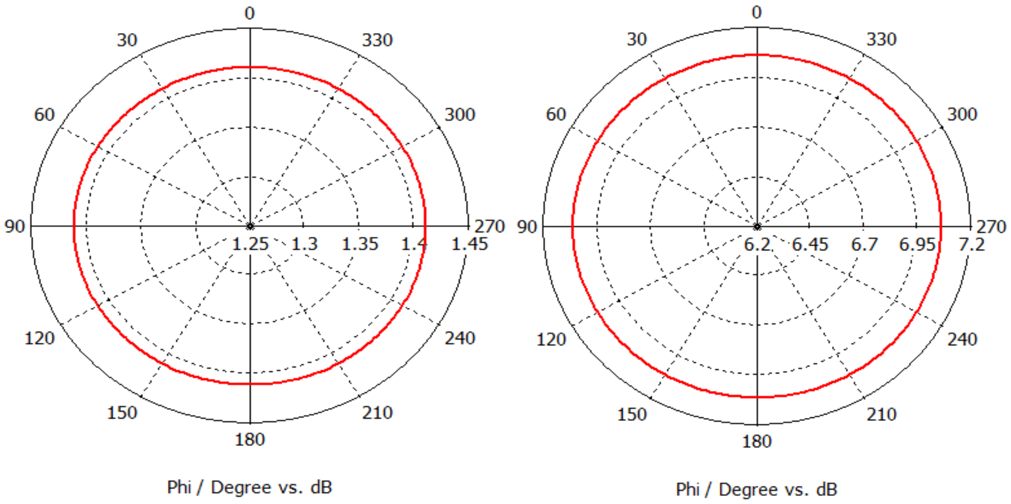
Meanwhile, VSWR is a measurement of how well matched an antenna is to the line impedance. A perfectly matched antenna would have a VSWR of 1:1. This indicates how much power is reflected back or transferred into a cable. Fig. 4 shows the VSWR between monopole antenna with and without fluorescent tubes result. Both result show a satisfy outcome since the ratio is VSWR<2. At its most optimum frequency of 4.9 GHz, VSWR for both monopole antenna without fluorescent tubes and monopole antenna with fluorescent tubes is 1.19 and 1.06 respectively.

Figure 5 shows the radiation pattern in 3D for monopole antenna with fluorescent tubes and monopole antenna with fluorescent tubes.

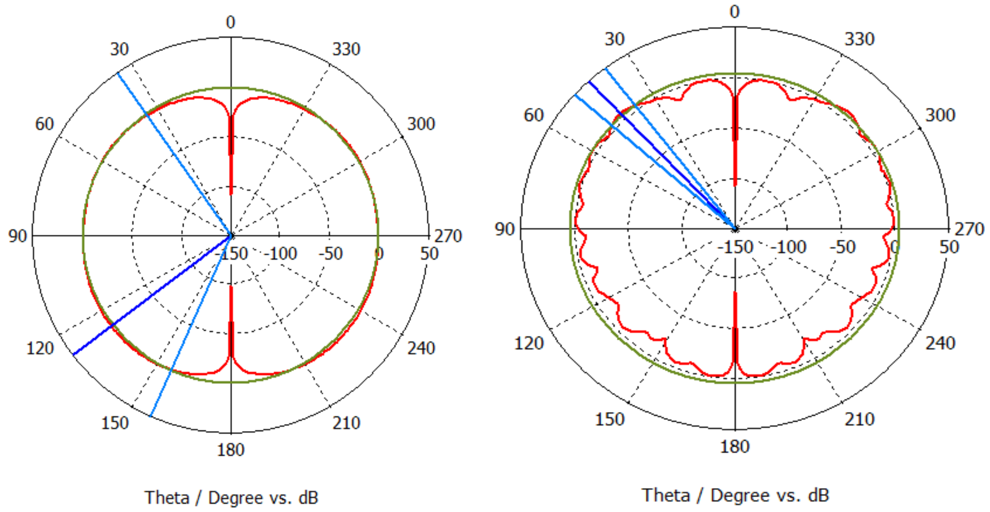


a)Monopole antenna b)Monopole antenna with fluorescent tubes

Figure 5: Radiation pattern in 3D



(a) H -plane



(b) E-plane

Figure 6: Radiation pattern of the monopole antenna without fluorescent tube and monopole antenna with fluorescent tubes for (a) H-plane and (b) E-plane at frequency 4.9GHz.

Figure 6 shows the far- field radiation patterns for proposed antenna at the selected frequency which is 4.9GHz.It can be seen from the figures that the radiation patterns are similar which is produces an omnidirectional for H-plane patterns for both antenna design. While for the E-plane patterns, the monopole antenna without fluorescent tubes and monopole antenna with fluorescent tubes are quite similar to conventional monopole antenna but for monopole antenna with fluorescent tubes the radiation pattern has a ripple because of influence from plasma elements.

4.2 Effect Due To Number of Fluorescent Tube

Figure 7 shows the return loss from simulation result when number of fluorescent tube is varied. From the graph the best number of fluorescent tubes is 12 with S_{11} equal to -31.564dB at operating frequency 4.9GHz.

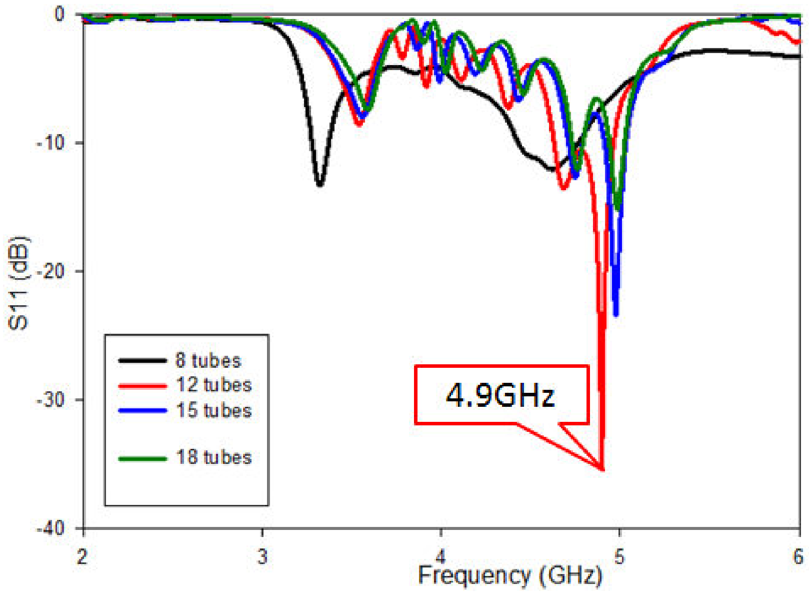


Figure 7: The return loss for changes of number of fluorescent tubes

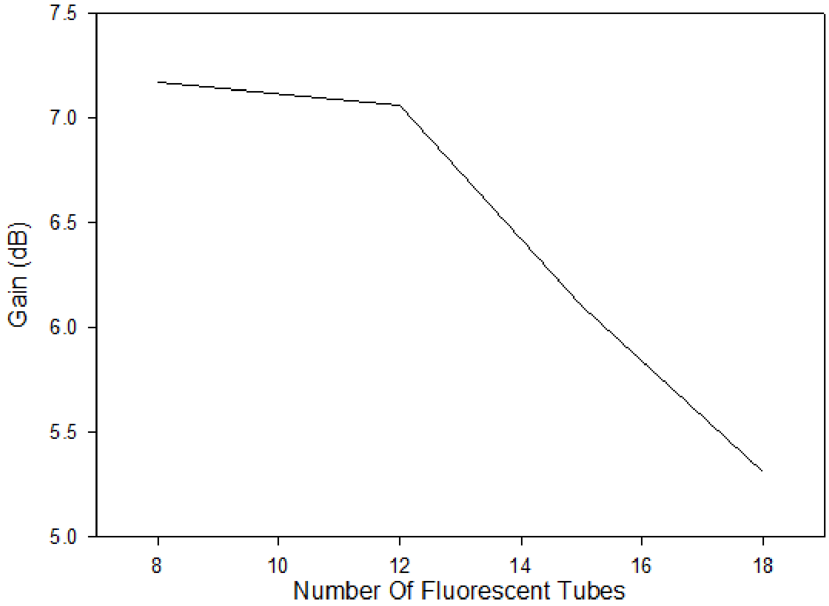


Figure 8: Relationship between gain and number of fluorescent tubes

Table 3: Relationship between gain and number of fluorescent tubes

Number of Fluorescent Tubes	Gain (dB)
8	7.172
12	7.061
15	6.105
18	5.307

Figure 8 and table 3 show the gain in dB of the changes done to number of fluorescent tubes. From the graph, as the number of fluorescent tubes is increased the gain decreases. This because the plasma elements inside the fluorescent tubes trapped the radiation inside hence reduce the gain.

4.3 Effect Due To Distance from Monopole Antenna to Fluorescent Tubes, r.

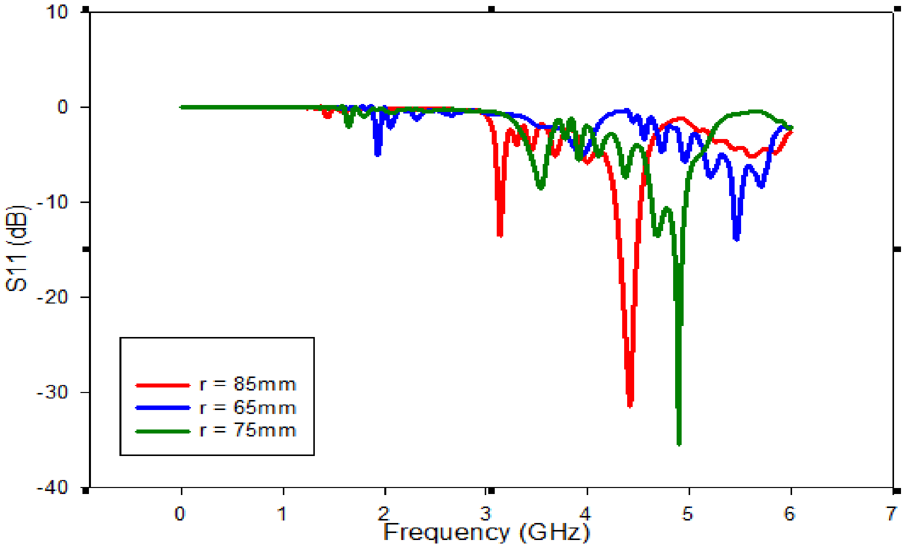


Figure 9: The return loss for changes in distance between monopole antenna to fluorescent tubes.

Figure 9 shows return loss graph when distance from monopole antenna to fluorescent tubes is varied with 10mm increment from 65mm to 75mm. When the distance is increase the curve shifted to the left. When the distance at 75mm the S_{11} drops at 4.9GHz which is operating frequency in this antenna design.

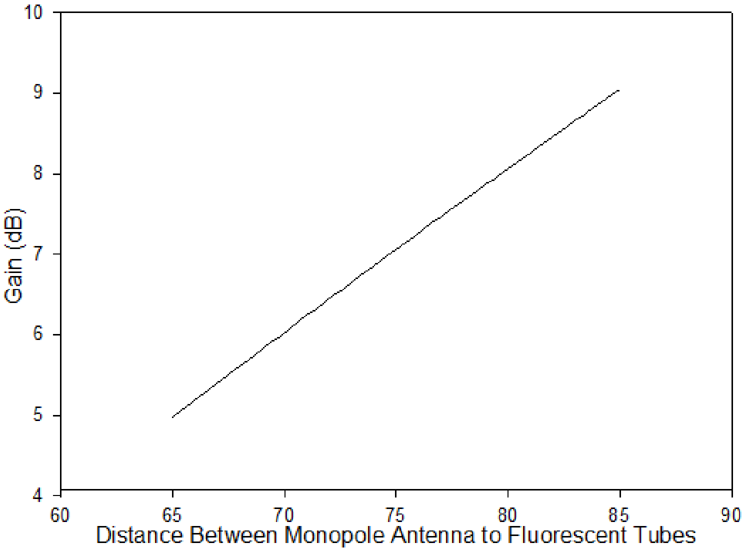


Figure 10 : Relationship between gain and distance monopole antenna to fluorescent tubes.

Table 4: Relationship between gain and distance monopole antenna to fluorescent tubes.

Distance monopole antenna to fluorescent tubes ,*r* (mm)	Gain (dB)
85	9.059
75	7.061
65	4.979

The distance between monopole antenna and fluorescent tubes also influenced the performance of the antenna. Figure 10 shows a gain when the distance increased by 10 mm for each run, starting from 65mm to 85mm. The gain increase when the distances increase. Table 4 shows the relationship between gain and distance monopole antenna to fluorescent tubes.

4.4 Effect Due To Various Height of Monopole Antenna, Ld

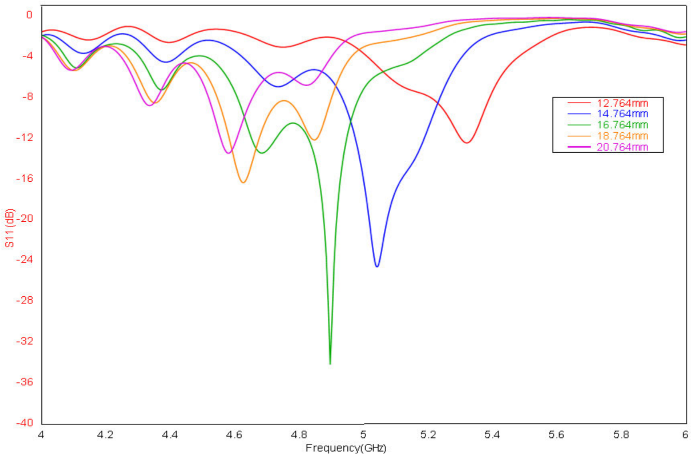


Figure 11: The return loss for changes in Ld

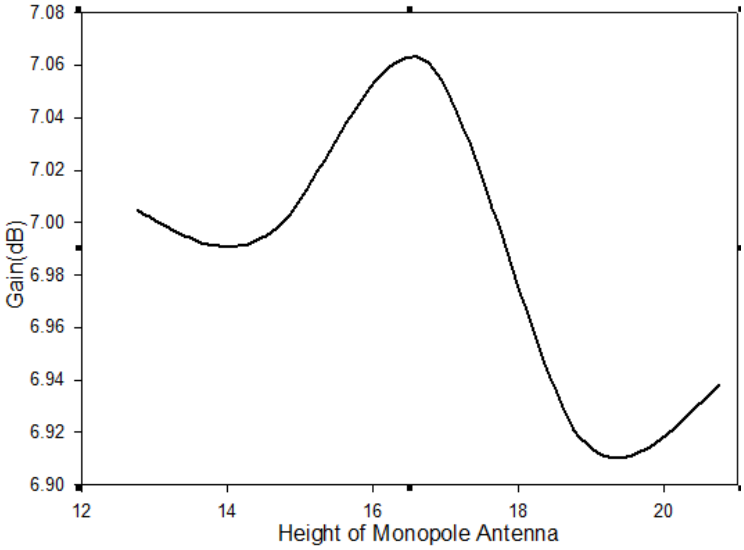


Figure12: Gain against various height of monopole antenna

Table 5: Various Dimensions of Height Monopole Antenna, *Ld*

Height, *Ld* (mm)	Gain (dB)
12.764	7.005
14.764	7.000
16.764	7.061
18.764	6.921
20.764	6.938

Figure 11 shows a pattern for return loss when *L d* is increased by 2.0 mm for each run, starting from 12.764 mm to 20.764 mm. From the graph, as the height of monopole increase, the resonant frequency shifted to the left. From figure 12 and table 5 the higher gain at height, Ld equal to 16.764mm which is 7.061dB.

5. Conclusion

The simulated performances of monopole antenna with fluorescent tubes were presented. It was shown that the utilization of plasma elements inside the commercial fluorescent tube contributes in gain and efficiency enhancement and proven to overcome the problem occurred in monopole antenna that suffers from low gain. From this paper, the design and construction of monopole antenna with fluorescent tubes can be beneficial in term of advancement in antenna's technology.

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