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Impact of Permittivity and Radiation Pattern on the Performance of a Dipole Antenna

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Abstract-- In this research article, a comprehensive simulative work has been made to investigate the performance of a dipole antenna using two parameters: Permittivity and Radiation pattern. Firstly, a 1m Cu dipole antenna is designed to evaluate the performance. Secondly, to inspect the efficiency of the antenna, return loss, VSWR, reflection coefficient, mismatch loss and port current are taken into consideration. It is found form the simulative study that it provides near to zero effect on the considered characteristics in case of 2-4.5 permittivity of the antenna material. In this region of the permittivity, the port current remains constant and the value is around 0.01205A. The radiation pattern of the antenna has been noticed by changing frequency 7.494811 MHz to 134.9066 MHz. The simulation work is made by using Matlab2018a and Comsol Multi-Physics simulation software.

Keywords- Permittivity; Radiation Pattern; Voltage Standing Wave Ratio (VSWR); Return loss; Bandwidth; —Reflection Coefficient; S- parameter.

I. Introduction

The dipole antenna is one of the most immensely used antennas in telecommunication systems. Two conductive elements like as rods or metal wires are consisted this antenna. The driving current is applied form the transmitter or the output signal is taken to the receiver for receiving antennas, interim of the two sections of the antenna.

In 2015, Wang and et al. proposed a Dipole Antenna in Underwater using electromagnetic wave. They designed the model of dipole antennas which have been built in a three layered conducting media (air-seawater-sea bottom). It was seen from the result that the performance of horizontal electric dipole was superior compare to the vertical electric dipole, and the performance of magnetic dipole was superior to the electric dipole and it can be noticed that the types of property antenna is significantly affect electromagnetic wave performance [1].

In 2017, Zhang and et al. the authors' proposed novel dual-wideband dipole directional antenna with double reflecting floors by using a dipole with crooked arms and parasitic Γ-shaped branches. The impedance bandwidths of the antenna is 50.6% from 1.67 to 2.8 GHz for VSWR $\leq$ 1.5 and 40.5% from 0.68 to 1.03 GHz, respectively which can be concluded in wireless communication system [2]. Cheng and et al. proposed a research work on two slotted dielectric substrates a stable gain printed log-periodic dipole antenna (PLPDA) in 2017, which is based on technologies of substrate integrated waveguide (SIW). The antenna has been consisted of a traditional PLAPDA which was fed by SIW and the simulated result provides more stable gain [3]. In 2017 [4] Suci Rahmatia and et al. performed a research work to investigate the performance of dipole (aluminum and iron) for TV channel frequency and rectangular micro-strip antenna with line feed method for radar application. In their work, performed by reviewing the bandwidth, radiation and

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return loss of both antenna in simulation. The simulation results represent the comparison of performance between the dipole antenna two materials and the rectangular micro-strip patch antenna's performance using the dimension of selected parameters.

In this present study, a dipole antenna has been designed and performance has been investigated. Such antenna can achieve a higher attainable data transmission, with lower return loss, VSWR as compared to the conventional antenna.

II. Antenna Design And Analysis

The model of the dipole antenna consists of two cylinders which represented by both of the dipole arms and arms are 1m long which aligned with the z-axis. For designing the antenna surrounding, free space air is considered. A small cylindrical gap is taken between the two arms, which works as voltage source. A uniform voltage source consisting of electromagnetic fields and surface current is applied across the conductive faces of the antenna.

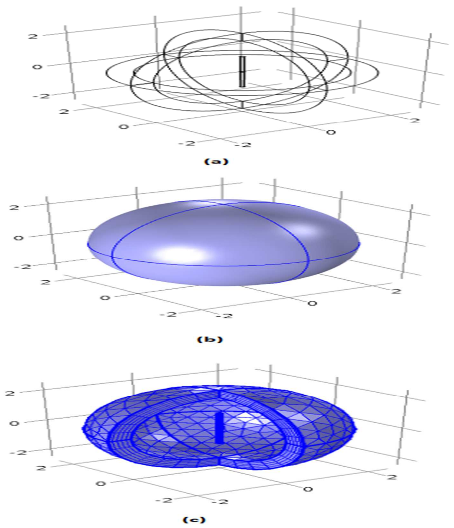


Figure 1: The (a) Geometry (b) Antenna model with PML, (c) Antenna model with Mesh of the Cu dipole antenna.

At first a sphere of air has been added to create perfectly matched layer (PML) which acts as an absorber of radiation. The radius of the air sphere has been taken as 2.5m or it can be expressed as 2.5 x arm length. Then from the global material section, Cu has been selected as the antenna material. Afterword, the mesh has been adjusted manually such that there are five elements per free space wavelength. The maximum mesh size is 0.2m wavelength in free space. To evaluate the antenna radiator with the level of the 2nd-order polynomial, the maximum element size has been set as smaller than the radius of the antenna. In this model maximum element size is 0.8m and the growth rate of maximum element size is 1.5 [6].

TABLE-1: DESIGNING PARAMETERS OF THE ANTENNA:

Operating wavelength	4m
Antenna arm length and radius	1m and 0.05m
Gap between antenna arms	0.01m
Electrical conductivity	5.998e7 S/m
Relative permeability	1
Port impedance	119+30i ohm

III. Simulation Process

In order to determine the performance and efficiency of the antenna, having the values of Return loss, Reflection co-efficient, VSWR and Mismatch loss are needed. 67.4533 MHz has been used as operating frequency as maximum return loss (13.230192743 (dB) is occurred for this frequency. Hereafter, the value of Permittivity has been changed to investigate the effect on antenna performance. For determining VSWR, Reflection coefficient and Mismatch loss following equations are used.

$\mathrm{RL} = -20\log(\Gamma)$ ……………………………….. (1)

Where, RL= Return loss, Γ = Reflelction coefficient

$\mathrm{VSWR} = \frac{1+\Gamma}{1-\Gamma}$……………………………..………… (2)

$\mathrm{ML} = -10\log(1-\Gamma^2)$…………………….……..….. (3)

Where ML= Miss Match loss

IV. Result And Discussion

In this part, Simulation results have been presented showing the impact of permittivity on various parameter of an antenna and 2D radiation pattern of a Cu dipole antenna on performance evaluation of a dipole antenna. The antenna performance has been shown by observing the impact Permittivity on different parameters.

Form the graphical illustration which is depicted in Fig 3 to Fig 7, it is keenly noticeable that the simulation system shows comparatively small changes with changing of permittivity. An illustration of the relation between Return loss (dB) and permittivity of the antenna material has been presented in Fig 3. It is presumed from the figure that if the antenna is operated within a specified bandwidth then with the increase of permittivity, antenna return loss decreases slightly. Fig 3 follows the equation: Y=0.0067*X+ 13.2, where Y = Rerun loss (dB) and X = Permittivity.

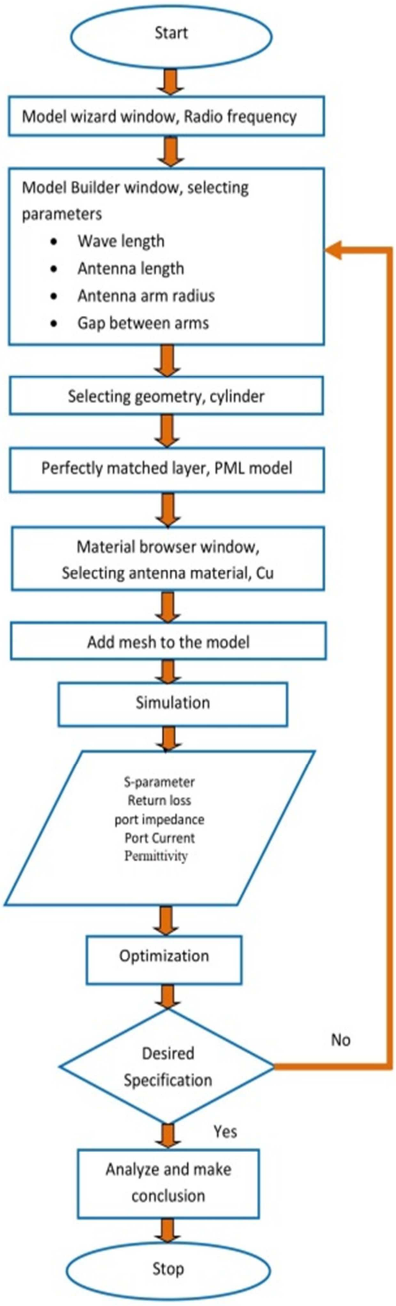


Figure 2: Flow chart of the designing procedure of the dipole antenna.

The changes in Reflection-coefficient, VSWR and Mismatch loss with the change in permittivity have been delineated in Fig 4, Fig 5 and Fig 6 respectively. It is observed from the graphical representation that all of these parameters are affected negligibly by the change of permittivity. It is found that the value of reflection coefficient is 0.218017001 for the value of permittivity 1 and then reaches to 0.21877446 for permittivity 5. The reflection coefficient increases with the raise in permittivity but the increment rate is very low. Also same scenarios are seen for VSWR and mismatch loss. For the value of permittivity 1, VSWR and mismatch loss is 1.55760036 and 0.211494486 respectively and the values get to 1.560080153 and 0.213004445 respectively for permittivity 5. Fig 7 depicts the changes of port current with respect to permittivity. It is seen from the figure that port current is almost steady for the permittivity 2 to 4.5 and the constant value is around 0.01205A. It can be considered that the performance of the antenna will not be varied considerably for this permittivity range and the antenna performance will be efficient.

Hereafter, in this research work, the changes in radiation pattern with various operating frequencies have also been taken into consideration. Fig 8 represents the radiation patterns of the antenna a various frequencies from 7.4948 MHz to 134.9066 MHz. For all he patterns, minimum radiation occurs at θ = 00. In case of first two frequencies i.e., 7.4948 MHz and 14.9896 MHz, maximum radiation occurred at θ = 600 and for both cases there were only one major lobes. However, all the patterns behaved differently with degraded radiation characteristics as the frequency increased. At higher frequencies, the radiated power was not concentrated at θ = 600 but it rather spread to the neighbor lobes.

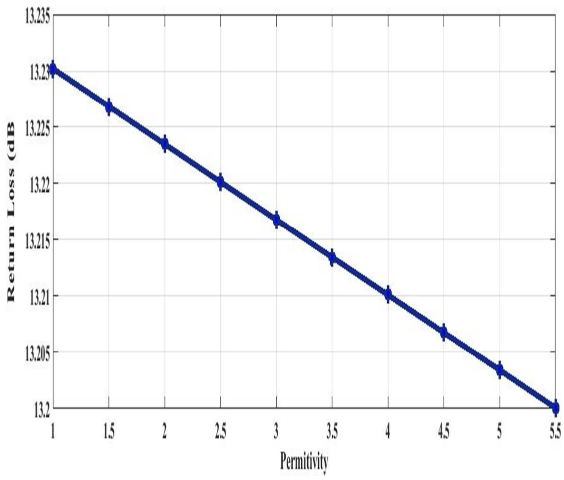


Figure 3: Graphical representation of permittivity with respect to Return-loss.

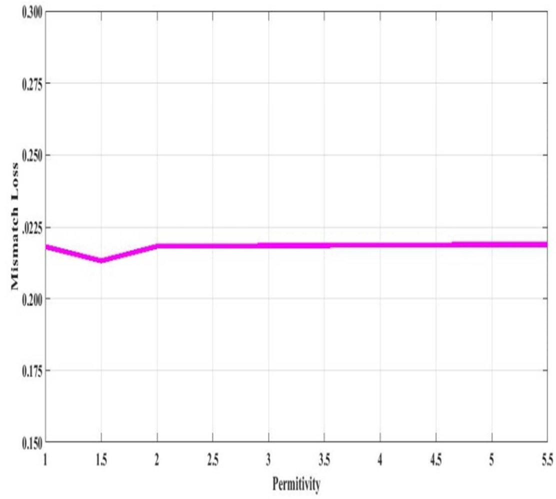


Figure 4: Graphical representation of Permittivity with respect to Reflection coefficient.

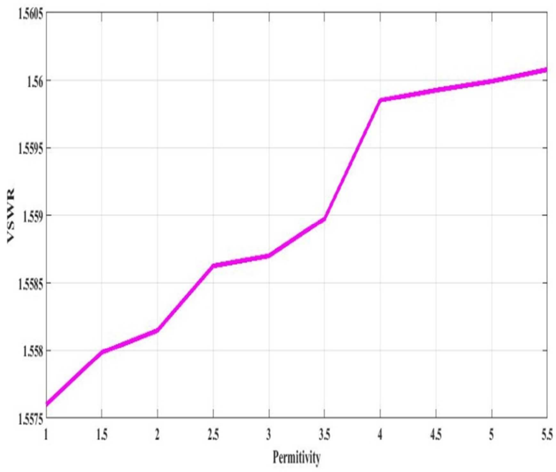


Figure 5: Graphical representation of Permittivity with respect to VSWR.

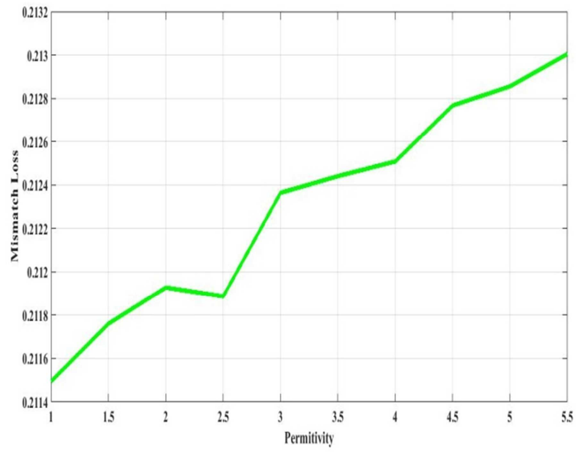


Figure 6: Graphical representation of Permittivity with respect to Mismatch loss.

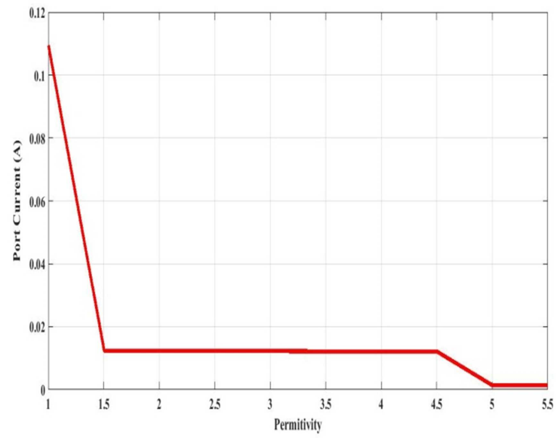
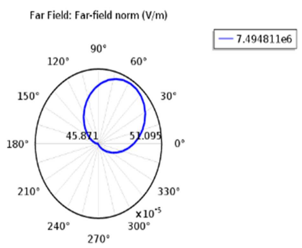


Figure 7: Graphical representation of permittivity with respect to Port Current.



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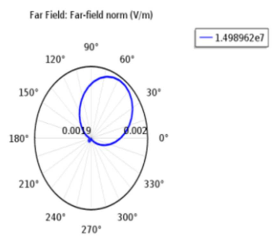

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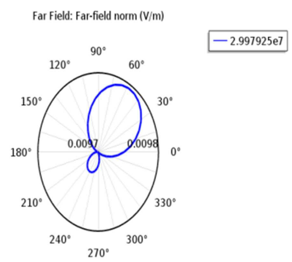

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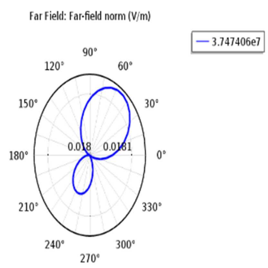

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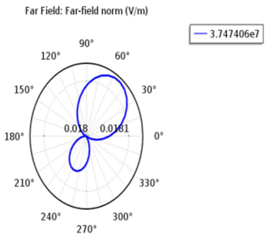

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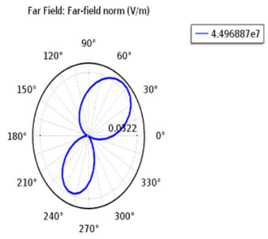

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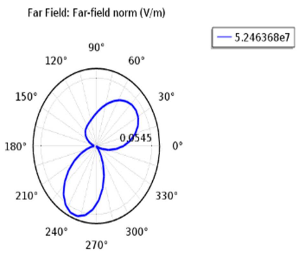

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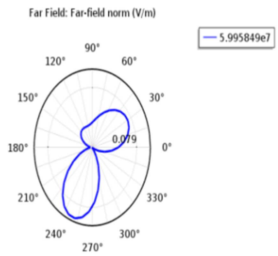

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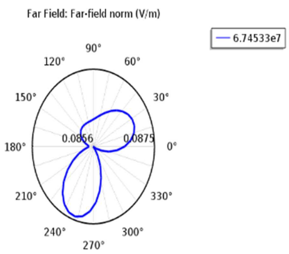

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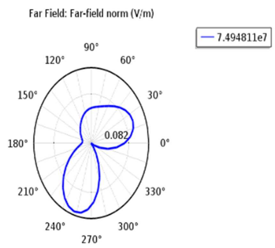

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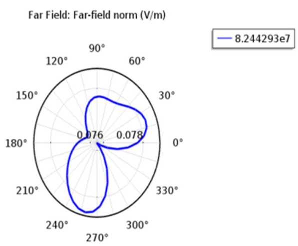

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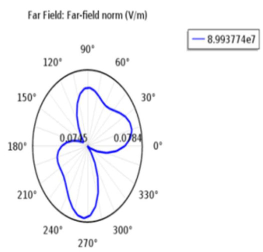

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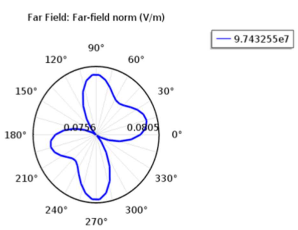

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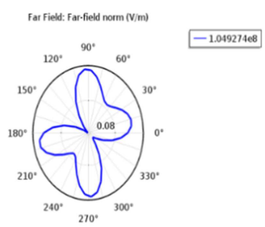

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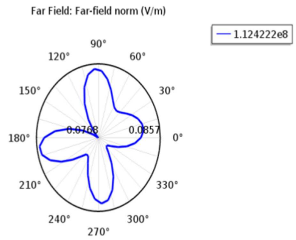

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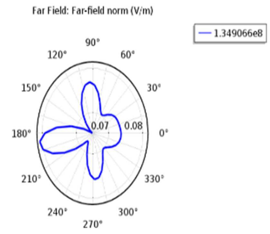

(p)

Figure 8: 2D Far-Field radiation patterns for various frequencies: a) 7.494811 MHz, b) 14.98962 MHz, c) 29.97925 MHz, d) 37.47406 MHz, e) 44.96887 MHz, f) 52.46368 MHz, g) 59.958490 MHz, h) 67.4533 MHz, i) 74.9481 MHz, j) 82.44293 MHz, k) 89.93774 MHz, l) 97.43255 MHz, m) 104.9274 MHz, n) 112.4222 MHz, o) 134.9066 MHz.

V. CONCLUSION

In this paper, a simple dipole antenna has been proposed by investigating the performance of the antenna based on permittivity and radiation pattern. Form the simulative study it is found that it provides almost zero effect on the deliberated characteristics in aspect of 2 to 4.5 permittivity. In this region of permittivity, the port current of the designed antenna remains unchanged and the value is 0.01205A. With the changes of frequency the radiated power changes frequently and the lobes increases. It can be concluded that the designed dipole antenna can be effectively considered in future generation wireless network communication and IOT applications.

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