# Design & Performance Evaluation of a Dipole Antenna Using Various Lengths of Antenna Material

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**Abstract**--In this paper, a comprehensive study has been undertaken on designing and the performance evaluation of a dipole antenna. The performance of the proposed antenna has been conducted by observing the return loss, bandwidth, reflection coefficient, VSWR for different antenna lengths ranging from 0.4m to 1m. This antenna design and simulative study has been made by using COMSOL multi-physics, Matlab2018a simulation software. The designed antenna provides robust performance for 0.8m length of Cu material with 14.89 dB maximum return loss, 1.4390 VSWR, 0.1799 reflection coefficient and 149.89 MHz of bandwidth. It can be proposed for the future generation of wireless communication.

**Index Terms** -Voltage Standing Wave Ratio (VSWR), Return loss, Bandwidth, Reflection Co-efficient, Dipole antenna, S-parameter, Return-loss, Port current.

## 1. Introduction

NOW a days, wireless communication is being very popular all over the world. Antenna is an electromagnetic device which is regarded as a construction that makes transition between a guided wave and a free spaced wave [1]. The basic construction of antenna consists of electrical conductor and is designed in such a way so that it can work on radio frequency. Dipole antenna is one of the simplest antennas and it can be fabricated very simply by using just a wire. Because of its simple fabrication, this type of antenna is commonly used [2].

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 ≤ 1.5 and 40.5% from 0.68 to 1.03 GHz, respectively which can be concluded in wireless communication system [3].

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 [4].

In 2018, Akimoto and at el. Proposed and designed an integrated diversity antenna by using both dipole and monopole modes with a high isolation property and a simple configuration. In their works, the disposed dipole element radiates horizontally and the disposed GND of the micro-strip line for feeding the dipole radiates vertically respectively in dipole mode and monopole mode. On their presented design, the micro-strip line has been constructed across the gap with a feed point for monopole mode. [5] In 2018, Alshrafi and et al. designed and presented an antenna for all global navigation satellite systems (GNSS) bands. The authors made their antenna with a wideband crossed bowtie dipoles placed on top of wideband artificial magnetic conductor (AMC). From their work it can be seen that the efficiency is more than 90% over all GNSS bands with a very good impedance matching at below 3 dB axial ratio. A dual-band dual-polarized (DP) omnidirectional antenna presented by Lai and et al. in 2018, for 2G/3G/Long Term Evolution (LTE) indoor communication systems. From their works, it is seen that the simulated results indicated that an impedance bandwidth of 1.72–3.51GHz and 790 MHz-1.14 GHz can be achieved for VP while another one of 1.68–2.99 GHz and 806–980 MHz is also obtained for HP.

In this paper, we have tried to observe the performance of the designed antenna in data transmitting and receiving. From the simulation it is found that it will provide good performance in data transmitting and receiving. This designed antenna can be concluded in future communication system.

### 1.1 Review of Comsol Multi-physics Software

The COMSOL Multi-physics is a finite element analysis, solver and simulation software/FEA Software package and is being used for various applications of physics and engineering, especially coupled phenomena, or multi-physics. In addition to conventional physics-based user interfaces, COMSOL Multi-physics also allows for entering coupled systems of partial differential equations (PDEs). The PDEs are possible to entered directly or using the so-called weak form [8].

RF module has been used for this research. The RF Module is used by engineers and scientists to predict, understand and resonance effects in high-frequency

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applications, design electromagnetic wave propagation. The simulations and results of this in are more powerful and efficient products and engineering systems. It provides quick and accurate predict electromagnetic field reflection, transmission, distributions and power dissipation in a proposed design. Compared to traditional prototyping, it serves lower cost and the ability to predict and evaluate entities that are not directly countable in experiments. The explorations of operating conditions are also allowed by this, which would destroy a real prototype or can be hazardous [8].

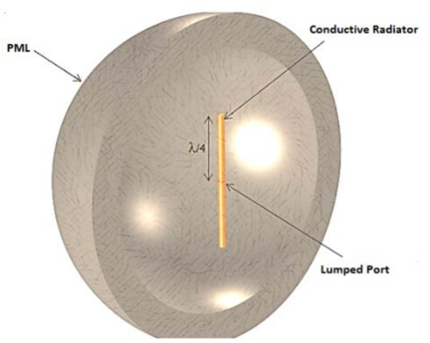


Figure 1: Structural representation of a dipole antenna [8].

The module covers waves and electromagnetic fields in three-dimensional and two-dimensional spaces along with traditional circuit-based modeling of active and passive devices. All modeling arrangements are founded on subsets and special cases of these together with material laws for propagation in various media or Maxwell's equations. The modeling capabilities are accessed via referred to as RF interfaces, predefined physics interfaces, which allow us to set up and solve electromagnetic models. The RF interfaces cover the modeling of electromagnetic fields and Eigen frequency, waves in frequency domain, mode analysis, and time domain [8].

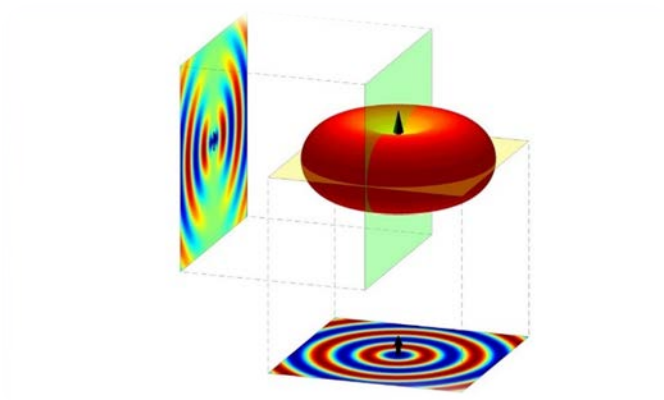

Figure 2: Radiating procedure of a dipole antenna [8].

Under the hood, the RF interfaces solve and formulate the differential form of Maxwell's equations together with the boundary and initial conditions. The equations have been solved using the finite element method with numerically stable edge element discretization in combination with state-of -the-art algorithms for preconditioning and solution of the resulting sparse equation systems. The results have been presented using predefined plots of electric and magnetic fields, S-parameters, power flow, and dissipation. The results are displayed as plots of expressions of the physical quantities that you define freely, or as tabulated derived values obtained from the simulation. The model in "Figure 1"made of two cylindrical arms of conductive material and a voltage source. Perfectly Matched Layer (PML) surrounds the antenna has been bounded a region of free space [8].

## 2. The ANTENNA designing concept

The model of the antenna consists of two cylinders representing each of the dipole arms. The free space wavelength at the antenna's operating frequency is 4m. Thus each of the antenna arms is 1m long and aligned with the z-axis. Copper with 5.998e7[S/m] electrical conductivity, 1 relative permittivity is used for the antenna material. Air is used for surrounding area of the antenna.
The arm radius is chosen to be 0.05 m. In the limit as the radius approaches zero, this antenna will approach the analytic solution. A small cylindrical gap of size 0.01 m between the antenna arms represents the voltage source. The power supply and feed structure are not modeled explicitly, and it is assumed that a uniform voltage difference is applied across these faces. This source induces electromagnetic fields and surface currents on the adjacent conductive faces. This antenna model is shown in "Figure 3". The dipole arm surfaces are modeled using the Impedance Boundary Condition, which is appropriate for conductive surfaces that have dimensions much larger than the skin depth.

This boundary condition introduces a finite conductivity at the surface as well as resistive losses. The air domain around the antenna is modeled as sphere of free space of radius 2 m, which is approximately the boundary between the near field and the far field. This sphere of air is truncated with a PML that acts as an absorber of outgoing radiation. The far-field pattern is computed on the boundary between the air and the PML domains. This model is shown in "Figure 4". The mesh is manually adjusted such that there are five elements per free space wavelength and that the boundaries of the antenna are meshed more finely. This model is shown in "Figure 5". The PML is swept with a total of five elements along the radial direction.

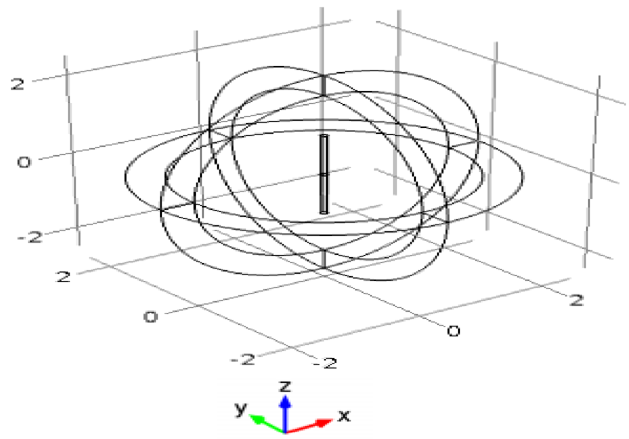


Figure 3: Geometry of the proposed dipole antenna.

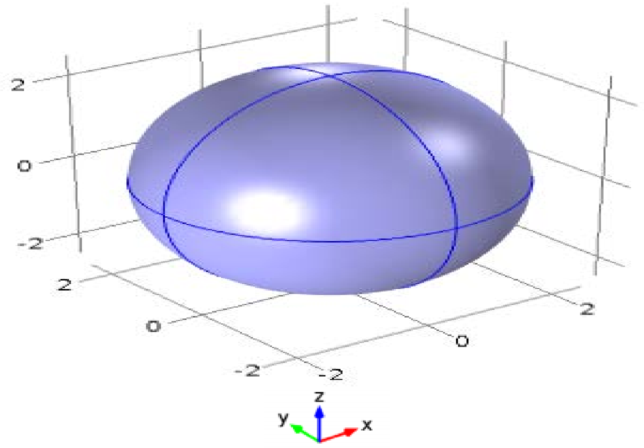


Figure 4: Antenna model with PML.

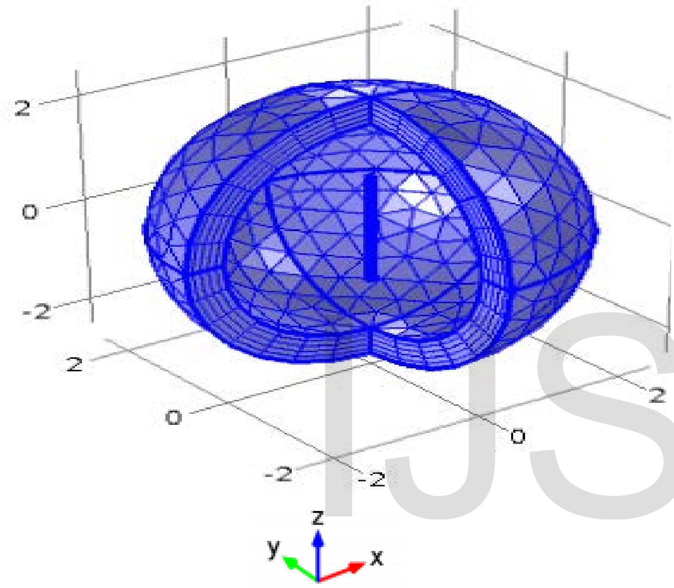


Figure 5: Antenna model with mesh.



## 3. Design and Simulation Process

At first the proposed antenna has been designed for 1m long and then the length has been varied from 0.9m to 0.4m for the sake of determining the return loss and other antenna parameters such as refection coefficient, VSWR for every length. In order to evaluate and check the antenna performance, The S-parameters of 1m to 0.4m long dipole antenna at various frequencies have been measured from the global evaluation tool of the COMSOL software. Hence the S-parameter has been denoted by S11.

The designing procedure is done in several steps. "Figure 6"represents the flowchart in this paper.

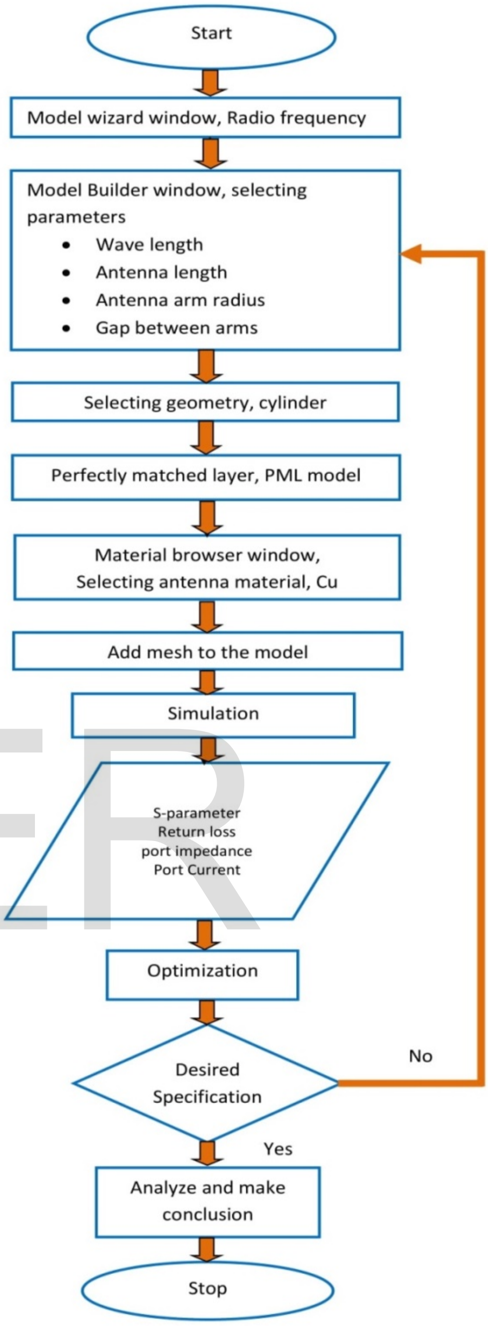


Figure 6: Flow chart of the designing procedure of the dipole antenna.

## 4. Result and Discussion

Hereafter, the performance of the designed Cu dipole antenna has been summarized.

In "Figure 7"the S11 parameters of the antenna for various lengths (0.4m to 1m) in respect with different frequencies have been depicted. The lowest value of S11 parameter is less than -15 dB for each aspect. Considering the simulative values of S11 parameters, it can be presumed that energy from the antenna is fully transmitted.

"Figure 8"and "Figure 9"demonstrate VSWR and reflection coefficient respectively considering the maximum return loss for specific antenna lengths. The ideal VSWR value is 1 and for practical antenna VSWR ≤ 2 is required for antenna match. "Figure 7"it can be observed that for each antenna with different lengths, this value is less than 1.6. Moreover, 0.8m length has the best VSWR value is 1.439.

The reflection coefficient for an antenna must be zero; in that case the antenna match will be perfect, though for practical antennas Reflection Coefficient ≤ 0.2 is considered as the good characteristic. From "Figure 10"it is seen that for all length antennas this value belongs within 0.21 and 0.8m antenna has the best value which is 0.1799. S11 parameters as well as the maximum return loss for 0.8m is also better than other antenna. According to the simulative result, maximum return loss for 0.8m dipole antenna is 14.89 dB.

It is noticeable from "Figure 10"that the port current increases with the increase in antenna length and the curve is 98.75% linear which has been done in between the antenna lengths and port currents. Therefore, it can be concluded that the designed antenna is closest to an ideal antenna.

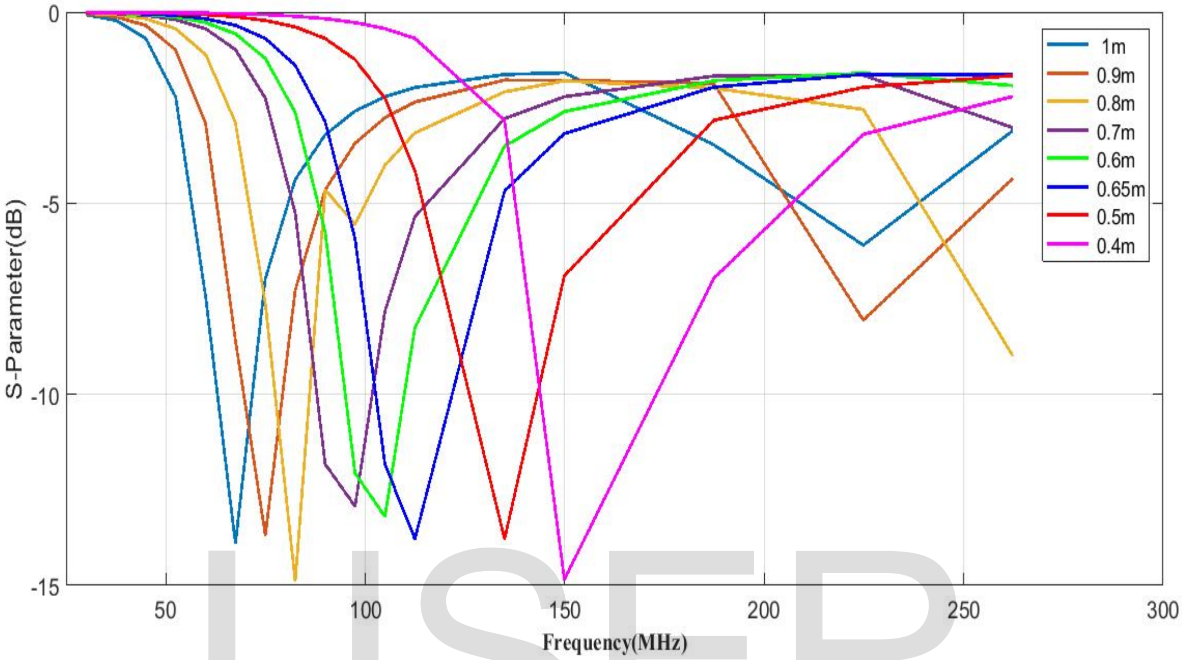


Figure 7: Graphical representation of S-parameter vs. frequency curve for various length of the dipole antenna.

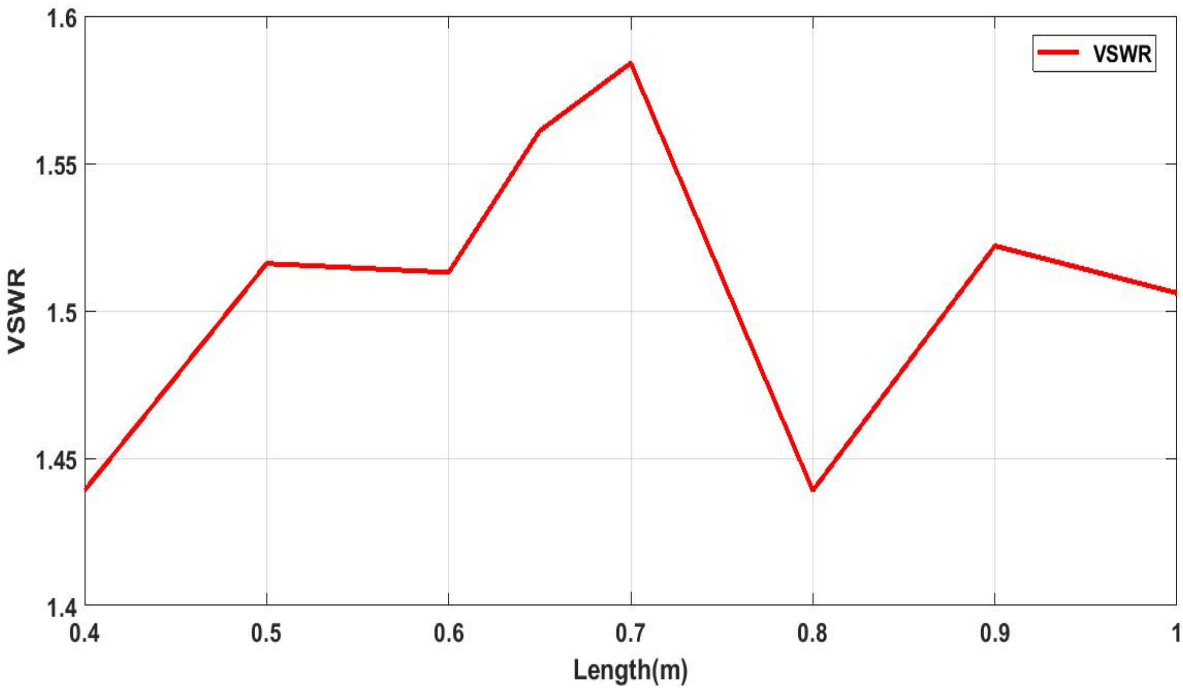


Figure 8: Graphical representation of VSWR with respect to the Length of dipole antenna.

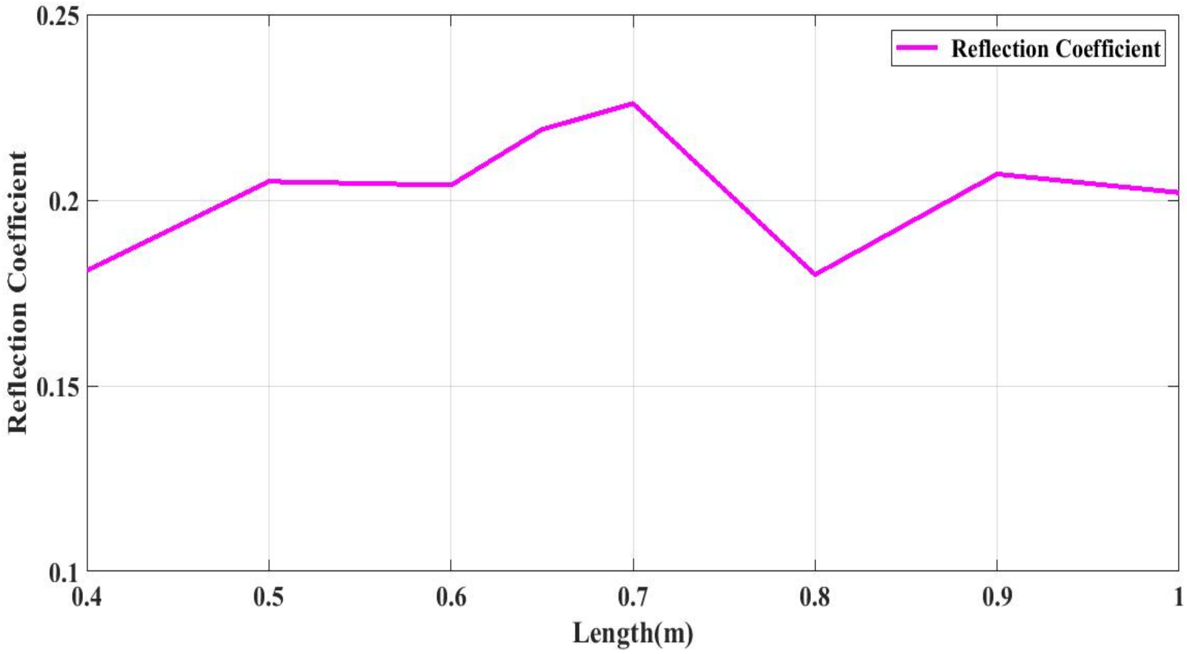


Figure 9: Graphical representation of Reflection Coefficient with respect to the Length of the dipole antenna.



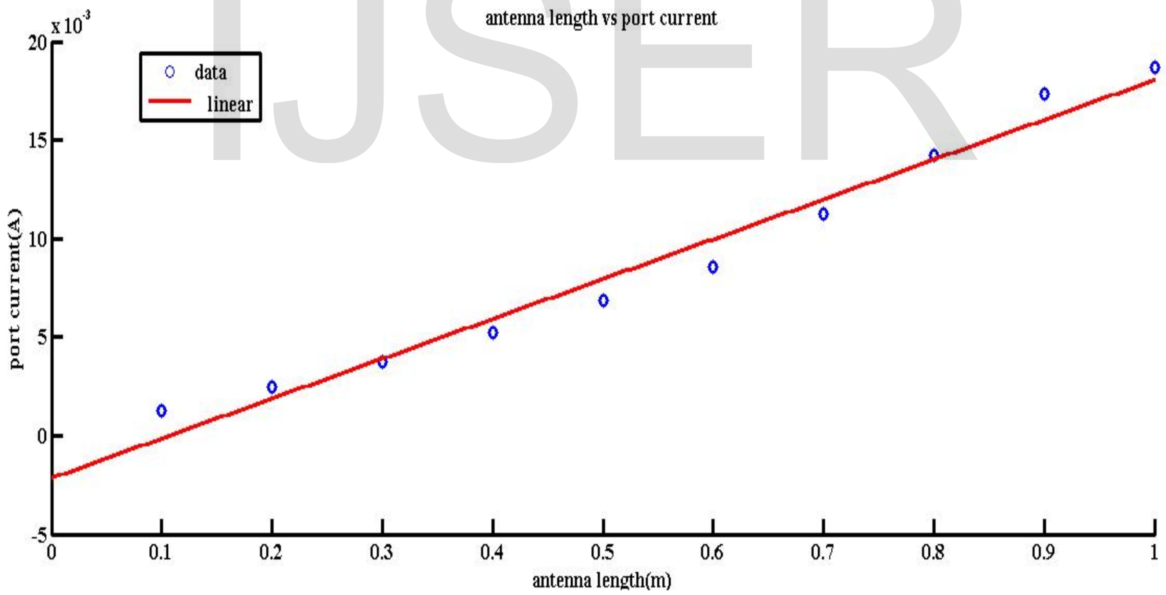


Figure 10: Graphical representation of the dipole antenna length with the respect of port current.

## 5. CONCLUSION

In this paper, a fruitful investigation has been made to evaluate the performance of the designed Cu based dipole antenna with various lengths. From the simulative study, it is observed that the designed antenna provides robust performance in data transmitting and receiving as all the values of maximum return loss, reflection coefficient, VSWR are very close to ideal values. The best performance is obtained in case of 0.8m Cu dipole antenna with 14.89 dB maximum return loss, 1.4390 VSWR, 0.1799 reflection coefficient and 149.89 MHz of bandwidth. It can be assumed from the performance of this simulated antenna that it will provide excellent performance in physical data transmitting. It can be concluded that the designed antenna can be used in future generation of communication, wireless networks and Internet of Things (IoT).

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