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A Fullwave Loop and a Quarter Wave Monopole Antenna: a Comparative Study and Performance Analysis

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Abstract **- This paper presents the performance analysis of a Full-wave Loop Antenna and a Quarter Wave Monopole Antenna. The Radiation Patterns of the two antennas were generated using the Lab-Volt Antenna Measurement System with a view to evaluating the Half Power Beam width, Directivity and Directive Gains of the two antennas. The directivity of the quarter wave monopole antenna was found to be 4.6dB which is almost twice 2.43dB of the full-wave loop antenna. Also, the directive gain of the quarter wave monopole antenna was found to be 1.96 dB higher than that of the full-wave loop antenna which was found to be -0.22dBd.**

Keywords: Directivity, Beam width, Directive gain and Radiation pattern.

General Terms: Full wave loop antenna and Quarter wave monopole antenna

1. INTRODUCTION

In wireless radio communication, the information is a low frequency signal (audio or video). It isdesired to convey these low frequency signals to any location without difficulty. This brings about the need for antennas to send and to receive the information [1]. Wireless communication includes the radiation of waves by the transmitting stations, the propagation of these waves and their reception by the receiver. This papercompares the performance of a full wave loop antenna and a quarter wave monopole antenna based on radiation pattern plot and parameters such as; half power beamwidth, directivity and gain.Antenna can be said to be a transducer that converts electromagnetic energy to electrical energy and vice versa [2]. Different types of antennas can be categorized according to different parameters which are Bandwidth, Polarization, Resonance, Physical Structures and Number of Elements [1]. The radiation pattern or antenna pattern is the graphical representation of the radiation properties of the antenna as a function of space [3]. The antenna's pattern describes how the antenna radiates energy out into space (or how it receives energy). An antenna's beam width is usually referred to as half-power beam width. Antennas do not radiate energy equally in all direction [4]. Directivity is a measure of the concentration of radiation in the direction of the maximum. Given the half-power beam widths of the principal plane patterns, the directivity is approximately the product of the beam widths. Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. The gain of antenna can be either directive gain or a power gain [5]. Directive gain of an antenna is a relative measure of the directivity of an antenna with respect to an isotropic radiator. Because an isotropic radiator is purely theoretical, the directive gain is evaluated with a reference to an omnidirectional antenna typically a half wave dipole antenna.

Antenna is a vital component of the wireless radio communication system. Several works have been carried out with a view to analyzing the performance of different types of antenna, amongst which are [5, 7, 8, and 9]. The authors in [5] studied the characteristic behavior of the feed-point input impedance and radiation fields of two thin-wire loop antenna types (one a circular-loop and the other, a square-loop antenna) both one wavelength long. The result indicated that the antennas' directive gains and input impedance profiles may be suitable for practical applications over a wide range of frequencies. In [7], the impact of rectangular plane ground on the radiations pattern of the monopole antenna was analyzed. The result showed that the larger the ground plane, the lower the direction of maximum radiation and as the ground plane approaches infinite size, the radiation pattern approaches maximum in the x-y plane. The authors in [8] analyzed the Radiation Characteristics of a Quarter-Wave Monopole Antenna above Virtual Ground. Analysis of the result shows that, for the case of the quarter-wave monopole antenna, twice the gain of a dipole antenna of half-wave-length long was achieved and the value of radiation resistance of the monopole is half of that of a dipole. [9] Analyzed the radiation pattern of a delta loop antenna with center fed ant apex feed at 1000MHz. The antennas were constructed of solid aluminum conductor and aluminum tube with arm lengths of 30cm each. Radiation pattern measurements on delta loop were made at 1000MHz. the vertically oriented delta-loop antenna provided the highest gain of 24dB as compared to the lowest gain of 12dB provided by the horizontally oriented delta-loop antenna.

2 METHODOLOGY

The methodology adopted for this work is as follows:

1. Setting up the LAB-VOLT Antenna Measurement System with a view to evaluating the Half Power

Beamwidth, Directivity and Directive Gains of the two antennas.

2. Obtaining the characteristics of a full-wave square loop antenna
3. Obtaining the characteristics of quarter wave monopole antenna
4. Analyzing the results obtained
5. Comparison of the antennas based on the results obtained

2.1 Initializing the setup

The main elements of the Antenna Training and Measurement System that is the Data Acquisition Interface/Power Supply, the RF Generator, the Antenna Positioner and Computer were properly set up before beginning this experiment. The antenna mast with a horizontal clip was placed on the transmission support. The Yagi antenna was placed onto the mast oriented for an acquisition in the E-plane, and it was connected to the 1 GHz oscillator output of the RF Generator using the long SMA Cable. A receiving antenna was set up, the antenna mast with horizontal support was placed on the sliding support of the antenna positioner and the receiving antenna was attached to the mast for acquisition in E-Plane for both the loop and monopole. The antenna was adjusted so that it is in line with the rotation center of the antenna positioner. The 10dB attenuator was screwed to the RF output on top of the antenna positioner. And the antenna was connected to the attenuator using the intermediate SMA Cable. The antennas were positioned at a distance of r = 1m apart, and they were adjusted so that they were at the same height and facing each other directly.

The following adjustments were made
ON THE RF GENERATOR

1GHz oscillator mode……………………1 kHz

1GHz oscillator RF power…………………OFF

10GHz oscillator RF power………………..OFF

The RF Generator was powered up and then the computer was turn on and the LDVAM-ANT software was started. The 1GHz oscillator RF Power switch on the RF Generator was set up to on position. The attenuation level was adjusted to 6dB and this level was maintained throughout this experiment. An acquisition was performed and stored as an E-plane of document1. The mast with vertical clips was removed and replaced with the mast with horizontal clips and the transmitting antenna was rotated so that it was vertically polarized. An acquisition was performed and saved as an H-plane of document 1. The half power beam width of the full-wave loop antenna and quarter wave monopole antenna E-plane and H-Plane was evaluated. The antenna mast of the receiving antenna, with horizontal clips, was removed from the sliding support and was replaced with the one with vertical clips and then a $\frac{\lambda}{2}$ dipole was set up, the transmitting antenna was rotated so that it was horizontally polarized. The E-plane pattern of this orientation was taken and saved as E-Plane of document 2.The E-plane of the dipole and that of the full wave loop antenna and the quarter wave monopole antenna were compared and the gain of both the full wave loop antenna and the quarter wave monopole antenna was evaluated.

3.0 RESULT AND DISCUSSIONS

The analysis of the result are discussed as follows:

3.1 Analysis of Full-Wave Loop Antenna

Figure 1 shows the E-Plane and H-plane plots of the radiation pattern of the full-wave loop antenna in two dimensions.

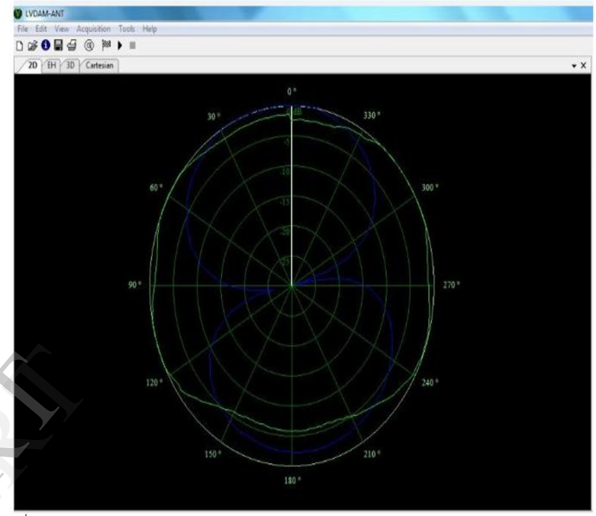

Figure 1: The 2 dimensional radiation pattern of the loop antenna

The radiation pattern plot of the full-wave square loop antenna obtained in Cartesian form is as shown in Figure 2

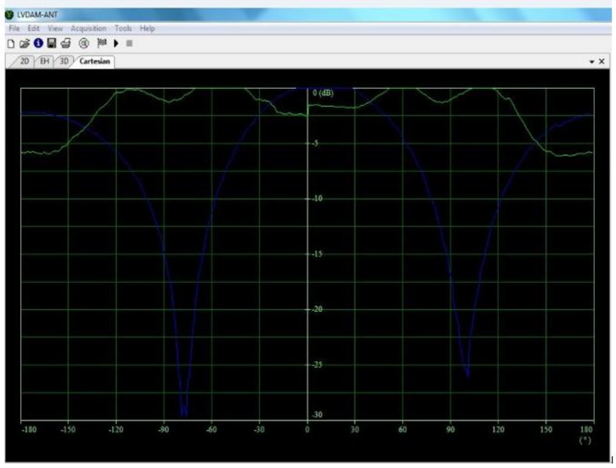

Figure 2: The E-Plane and H-Plane Radiation Pattern of the Loop Antenna in Cartesian Form

There 3 Dimensional plot of the radiation pattern of the full-wave square loop antenna is shown inFigure 3

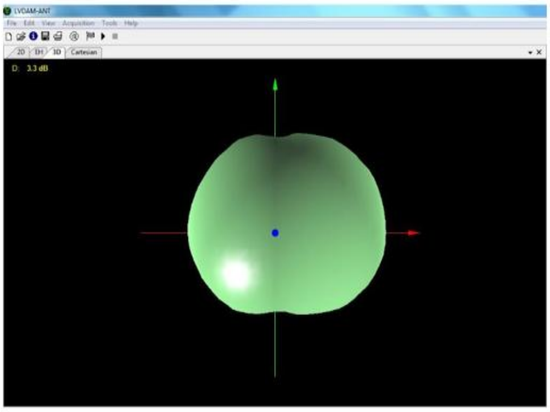

Figure3: The 3 Dimensional View of the Loop Antenna Radiation Pattern

From the radiation pattern diagrams of the full-wave square loop antenna (in Cartesian form) above, it can be seen that the main lobe occurs at about 15^0 and 195^0. This means that the antenna has a maximum radiation at 15^0 and 195^0 away from the transmission antenna.

3.1.1 Halfpower Beamwidth

This is the angular separation between which radiation pattern decreases by 50% or 3dB. For this square loop antenna, the E-Plane and H-Plane Half Power Beam widths were found by the software as 86.57^0 and 271.47^0; that is, between -32.22^0 and 53.35^0 for the E-Plane and between -135.7^0 and 135.77^0 for the H-Plane on the Cartesian Plot. These values of E-plane and H-plane half power beam width were found with the aid of the LDVAM-ANT software as in Figure 4

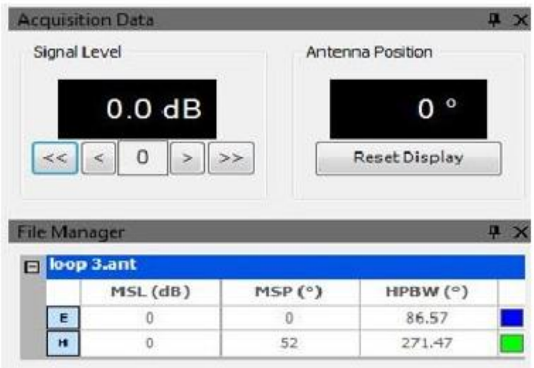

Figure 4: The E-Plane and H-Plane Half Power Beamwidth

The approximate directivity of the full-wave square loop antenna can be calculated using the relation as shown below.

$$\text{Directivity} = \frac{41252}{\text{HPBW}_E \times \text{HPBW}_H}$$

As measured by the software,
$\text{HPBW}_E = 86.57^0$ and $\text{HPBW}_H = 271.47^0$
Therefore the approximate directivity is

$$\text{Directivity} = \frac{41252}{86.57 \times 271.47}$$

$$\text{Directivity} = 1.75$$

In decibel,
$\text{Directivity} = 10\text{Log}_{10} 1.75 = 2.43\text{dB}$

In order to evaluate the directive gain, the directivity of the dipole antenna must be evaluated so as to have a reference value to which the directivity of the loop will be compared. The E-Plane Half Power Beam width of the dipole has been evaluated by the software as 124.72^0 as shown in Figure 3.10. The H-Plane Half Power Beam width of the dipole is 180^0. This due to the fact that the dipole is omnidirectional (having circular radiation pattern in the H-Plane)

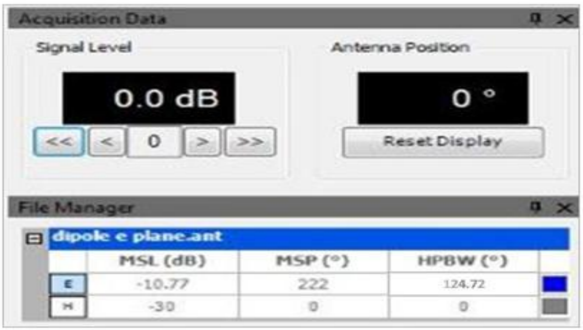

Figure 5: E-Plane Half Power Beamwidth of the dipole antenna

The approximate directivity of the dipole is calculated as

$$\text{Directivity} = \frac{41252}{\text{HPBW}_E \times \text{HPBW}_H} \quad \text{Directivity} = \frac{41252}{124.72 \times 180} = 1.84$$

In decibel (dB),Directivity $= 10\log_{10} 1.84$
$= 2.64$ dB

The directive gain of the loop antenna is obtained from

$$\text{Directive Gain} = 10\log_{10}\left[\frac{D}{D_{ref}}\right]$$

In this case, D_{ref} is the reference directivity which is the directivity of the dipole antenna.
Hence, the Directive Gain is;

$$\text{DirectiveGain} = 10\log_{10}\left[\frac{1.75}{1.84}\right] = -0.22 \text{ dBd}$$

3.2 Analysis of Quarter Wave

There two dimensional plot of the radiation pattern of the quarter wave monopole antenna is shown inFigure 6.

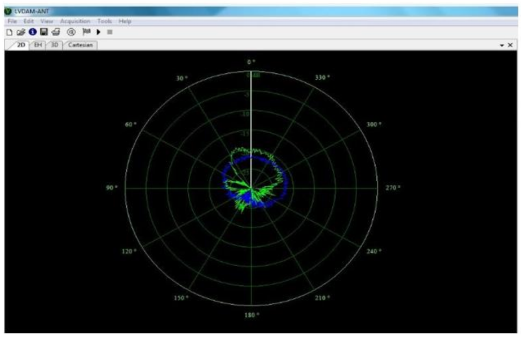

Figure 6: Two Dimensional E-Plane and H-Plane Radiation Patterns of the Quarter Wave Monopole Antenna

Figure 7 showed the E-Plane and H-plane plots of the radiation pattern of the quarter wave monopole antenna in Cartesian form

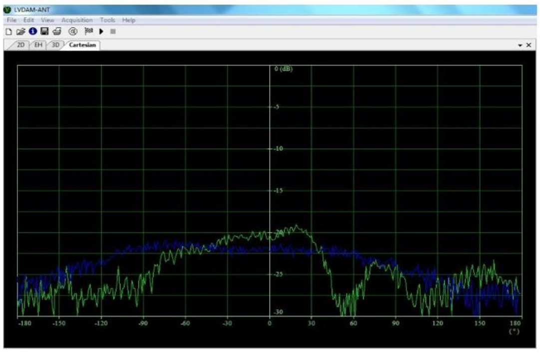

Figure 7: E-plane and h-plane radiation patterns of the quarter wave monopole antenna in Cartesian form

A 3 Dimensional plot of the quarter wave monopole antenna radiation pattern was obtained with the LAB-VOLT'S LDVAM-ANT Software as shown in figure 8

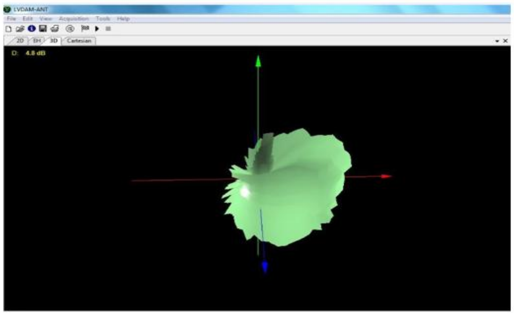

Figure 8: 3D View of the Quarter Wave Monopole Antenna Radiation Pattern

The radiation pattern plot of the quarter wave monopole antenna E-Plane is such that the radiation pattern has its main beam at about 20^0 from the transmitting antenna. Also, on the H-Plane, the main beam has its maximum at about 300^0 away from the transmitting antenna on the H-Plane.

3.2.1 Half Power Beamwidth

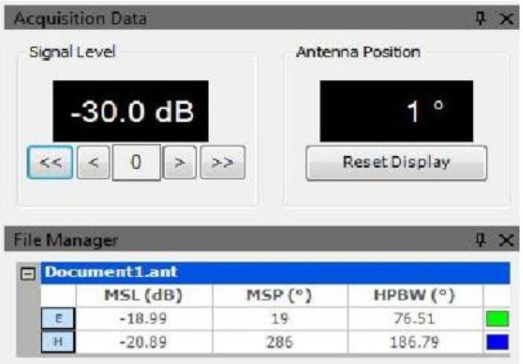

Figure 9: The E-Plane and H-Plane Half Power Beam width of the Quarter Wave Monopole Antenna evaluated with LDVAM-ANT Software

For this square loop antenna, the E-Plane and H-Plane Half Power Beam widths were found as shown in Figure 3.14 as 76.51^0 and 186.79^0; that is, between -44.24^0 and 32.27^0 for the E-Plane and between -98.85^0 and 89.19^0 for the H-Plane on the Cartesian Plot.

Directivity of the quarter wave monopole antenna

$$\text{Directivity} = \frac{41252}{HPBW_E \times HPBW_H}$$

$HPBW_E = 76.51^0$ and $HPBW_H = 186.79^0$Hence,

$$\text{Directivity} = \frac{41252}{76.51 \times 186.79} = 2.89$$

In decibel,

$$\text{Directivity} = 10\log_{10} 2.89$$
$$= 4.6\text{dB}$$

Directive gain of the quarter wave monopole antenna

$$\text{Directive Gain} = 10\log_{10}[\frac{D}{D_{ref}}]$$

$$\text{Directive Gain} = 10\log_{10}[\frac{2.89}{1.84}]$$

= 1.96 dB

The main beam of the loop E-plane radiation pattern occurs at 15^0 from the transmitting antenna (yagi antenna), while the main beam of the monopole antenna E-plane occurs at about 20^0 from the transmitting antenna. This means that the loop antenna on the E-Plane has a maximum power reception at 15^0 while the monopole has maximum reception at 20^0. On the H-Plane, the maximum reception for the loop antenna 15^0, while for the monopole it was 300^0.The half power beamwidth of the full-wave square loop antenna is larger than that of the quarter wave monopole antenna on both E-plane (86.57^0>76.51^0) and H-plane (271.47^0> 186.79^0). The implication of this large half power beamwidth for the full-wave loop antenna is that the full-wave loop antenna directs its power into a wider area, while the quarter wave monopole antenna's narrow half power beamwidth indicated that the power radiated by the quarter wave loop antenna is directed through a narrow area. Antennas with wide beamwidths typically have low gain and antennas with narrow beamwidths tend to have higher gain. In this case, the quarter wave monopole antenna has a higher directive gain (1.96 dB) over the full wave square loop antenna (-0.22 dB) as compared to the reference, half wave dipole antenna. Antennas having higher directive gain have an advantage of longer range and better signal quality in a particular direction. Therefore, quarter wave monopole antenna has a better signal quality as compared to the full wave square loop antenna.

4.0 CONCLUSION

The comparative analysis of the full-wave square loop antenna and the quarter wave monopole antenna has successfully been carried out as described in chapter three. The main objective of this project is to analyze and compare the performance parameters of the antennas. This has been achieved as seen in the previous chapter. This project has gave an insight about which antenna should be selected to suit a particular application while setting up a communication system so as to meet up with the optimal requirements. As a future work, other types of antennas such as horn antennas, aperture antennas, and parabolic antennas should be compared. The experiments should be carried out outside the laboratory so as to find the effect of weather on the performance of antenna. Phenomenon such as wind may also affect antenna performance. The performance of the antennas against an interfering signal should be compared.

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