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An Analysis of Radiation Pattern and Standing-Wave Ratio (SWR) of the Gray Hoverman Antenna

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ABSTRACT

The radio antenna may be defined as the structure associated with the region of transition between a guided wave and free-space wave, or vice versa. Antennas convert electrons to photon, or vice versa. All involve the same basic principle that the radiation is produced by accelerated or decelerated charge. In order to enhance the reading and measurement, forward scattering technique is used to acquire more data. The aim of this paper is to highlight the theory part of radiation pattern and the analysis of this parameter. From the results, the radiation pattern of the antenna with a range of 700 MHz with the range of -11.0 dB till 10.6 dB. The results show that the maximum front lobe value is 14.4 dB. The back lobe value is 3.32 dBi and the side lobe is -18 dBi. As the gain of a directional antenna increases, the coverage distance increases, but the effective coverage angle decreases due to the lobes being pushed in a certain direction because there is a little energy on the back side of the antenna. The SWR is high in the range of 1-100 MHz with 10^6 but suddenly decreased to 10 at 100 MHz. The patterns are very dynamics and it less that 10 from 530 MHz to 1000 MHz. We conclude that The simulation results of this antenna structure are quite good as this antenna structure can work in particular frequency bands with a good amount of gain of 14.4 dBi, the SWR of below 10dBi, and impedance matching around 100 ohm.

***Keywords*:** Antenna; radiation pattern; radio region; gray Hoverman antenna

1. INTRODUCTION

Since Hertz and Marconi, antennas have become increasingly important to our society and also radio astronomy. The application is everywhere; at our homes and workplaces, on our cars and aircraft, while satellites and spacecraft bristle with them. Although antennas may seem bewildering, almost infinite variety, all operate according to the same basic principles of electromagnetic. It is our electronic eyes and ears on the world. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise [1]. They are an essential, integral part of our civilization. The radio antenna may be defined as the structure associated with the region of transition between a guided wave and free-space wave, or vice versa. Antennas convert electrons to photon, or vice versa. The receiving antenna is remote from the transmitting antenna, so that the spherical wave radiated by the transiting antenna arrives as an essentially plane wave at the receiving antenna. It is usually used with a radio transmitter, or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency. Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional or high gain antennas).

Therefore, regardless of antenna type, all involve the same basic principle that the radiation is produced by accelerated (or decelerated) charge. Thus, time charging current radiates and accelerated charge radiates. For a steady state harmonic variation, we usually focus on current. For transients or pulses, we focus on the charge. The radiation is perpendicular to the acceleration, and the radiated power is proportional to the square of iL or Qv. The basic equation of radiation may be expressed simply as:

$$iL = Qv \ (Am\ s^{-1}) \qquad (1)$$

where:
I = time charging current
L = length of current element, m
Q = charge, C
V = time change of velocity, which equals the acceleration of the charge
L = length of current element, m

In radio astronomy, antenna can be used as a main instrument to detect the signal of celestial object [2]. There are many types of antenna that can be used depends on the range of frequency the gain that we decided [3]. Typically an antenna consists of an arrangement of metallic conductors (elements), electrically connected to the receiver or transmitter.

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field [4]. An antenna's normalized radiation pattern can be written as a function in spherical coordinates can be written as: F (θ, φ)

A normalized radiation pattern is the same as a radiation pattern; it is just scaled in magnitude such that the peak (maximum value) of the magnitude of the radiation pattern is equal to 1. Mathematically, the formula for directivity (D) is written as:

$$D = \frac{1}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}\left|F(\theta,\phi)\right|^2 \sin\theta d\theta d\phi} \quad (2)$$

This equation for directivity might look complicated, but the numerator is the maximum value of F, and the denominator just represents the average power radiated over all directions. This equation then is just a measure of the peak value of radiated power divided by the average, which gives the directivity of the antenna.

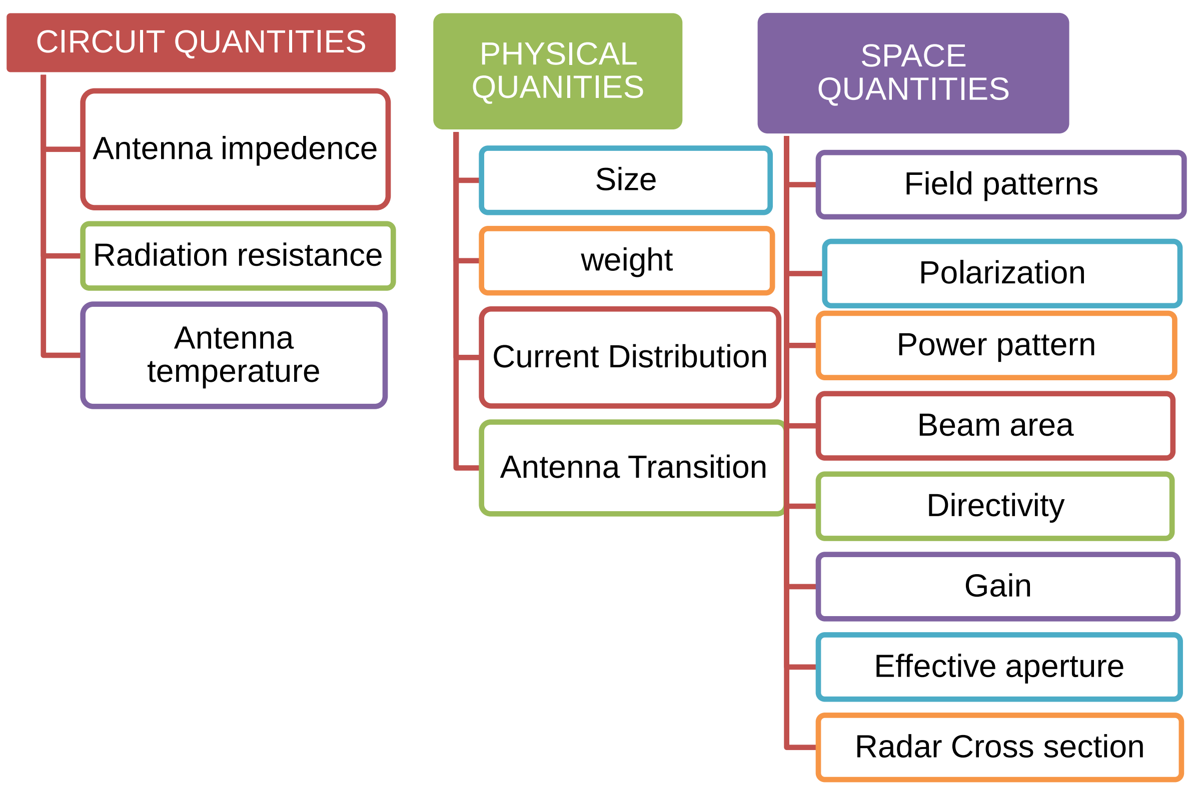

Figure 1. The duality of antenna

Most of the previous experiments using Yagi antenna which is not sensed as a Gray Hoverman antenna. Using Gray Hoverman's antenna with the higher gain hopefully can increase the sensitivity of the system. Second, the counting the number of meteor does not correspond to the actual number of meteors emerges. It is because there have many error occurrences during conducting observation. Third, most of the previous experiments do not have extra data such as an optical view of the meteor emerges that can support the data obtained [5,6].

The technique is strongly growing in popularity amongst meteor amateur astronomers [7]. In the recent years, some groups started automating the radio observations, by monitoring the signal from the radio receiver with a computer [8,9]. Even with these excellent systems, the interpretation of the observations is difficult. A good understanding of the phenomenon is mandatory.

To enhance the reading and measurement, forward scattering technique is used to acquire more data [10]. A model has been constructed which is utilizing the Ultra High Frequency (UHF) [11]. This principle has been used a long time ago, but in this project the model is modified so that it would be cost effective and easy to implement by employing available analog tv and Gray Hoverman’s 7 pair collinear rod [12]. The aim of this paper is to highlight the theory part of radiation pattern and the analysis of this parameter. There are many aspects and parameters of an antenna to be considered.

2. GRAY HOVERMAN’S ANTENNA

Gray Hoverman’s antenna is an open source antenna which was born from community of innovation. The antenna originally was designed by Doyt R. Hoverman. Doyt R. Hoverman's original design for a television antenna was granted US patents on 22 Dec 1959 and on 8th Sept 1964, which expired in 1979 and 1984 respectively. After the patent was expired, the community of thinker, maker and innovator began to explore and experimenting with the idea for modifying and optimizing the original design.

In this patent application, Hoverman describes two designs with 4 rod reflectors, full wavelength and co-linear half-wavelength reflectors, with the second design using the following specifications in Table 1:

Table 1. Gray Hoverman’s Specification

No.	Part	Specification
1	Driven Array	56" dual segments with 8 subsections of 7"
2	Reflector Spacing	
3	Full Wavelength Reflectors	Top and bottom = 29"
		The two middle = 24"
4	Half Wavelength Co-Linear Reflectors	Top and bottom = 14"
		The two middle = 10"

The original Hoverman antenna design did not have a reflector and used a driven array of 56" segments with eight zig-zag 7" sub-elements. The original patent claimed UHF and VHF reception. The modeling results did not find any positive net gain for VHF Low channels nor for VHF High channels.

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna [13]. It is a fundamental property of antennas that the receiving pattern (sensitivity as a function of direction) of an antenna when used for receiving is identical to the far-field radiation pattern of the antenna when used for transmitting [14]. This power variation as a function of the arrival angle is observed in the antenna's far field [15]. The radiation pattern or antenna pattern is the graphical representation of the radiation properties of the antenna as a function of space [16].

The antenna's pattern describes how the antenna radiates energy out into space and how it receives energy [17]. It is important to state that an antenna radiates energy in all directions, so the antenna pattern is actually a three-dimensional pattern with two planar patterns, called the principal plane patterns. These principal plane patterns can be obtained by making two slices through the 3D pattern through the maximum value of the pattern or by direct measurement.

The gain is an antenna's efficiency is a measure of how much power is radiated by antenna relative to the antenna input power [18]. The subject of antenna basics also includes a discussion of antenna gain, which is the real power radiated in a particular direction [19]. Power delivered to the antenna is radiated in a variety of directions. The antenna design may be altered so that it radiates more in one direction than another [20]. As the same amount of power is radiated, it means that more power is radiated in one direction than before. In other words, it appears to have a certain amount of gain over the original design [21,22].

Smith Charts were developed by Phillip Smith as a useful for making the equations involved in transmission lines easier to manipulate. The Smith Chart is a tool for describing the impedance of a transmission line and antenna system as a function of frequency. Smith Charts can be used to increase understanding of transmission lines and how they behave from an impedance viewpoint. Smith Charts are also very helpful for impedance matching. The Smith Chart is used to display an actual (physical) antenna's impedance when measured on a Vector Network Analyzer (VNA).

3. RESULTS AND ANALYSIS

Any field pattern can be presented in three-dimensional spherical coordinates. Two such cuts at right angles, called the principle plane patterns may be required, but if the pattern is symmetrical around the z axis, one cut is sufficient.

The Figure 2 below shows the radiation pattern of the antenna with a range of 700MHz with the range of -11.0 dB till 10.6 dB. This antenna typically, have a single peak direction in the radiation pattern; this is the direction where the bulk of the radiated power travels. The antenna has higher sensitivity in the XY direction up to 14dBi towards generating. It means that the antenna has single peak direction in the radiation pattern which are the radiated power travels are higher in XY direction. The Gray Hoverman's antenna can divert the radio frequency energy in a particular direction to the farthest distance.

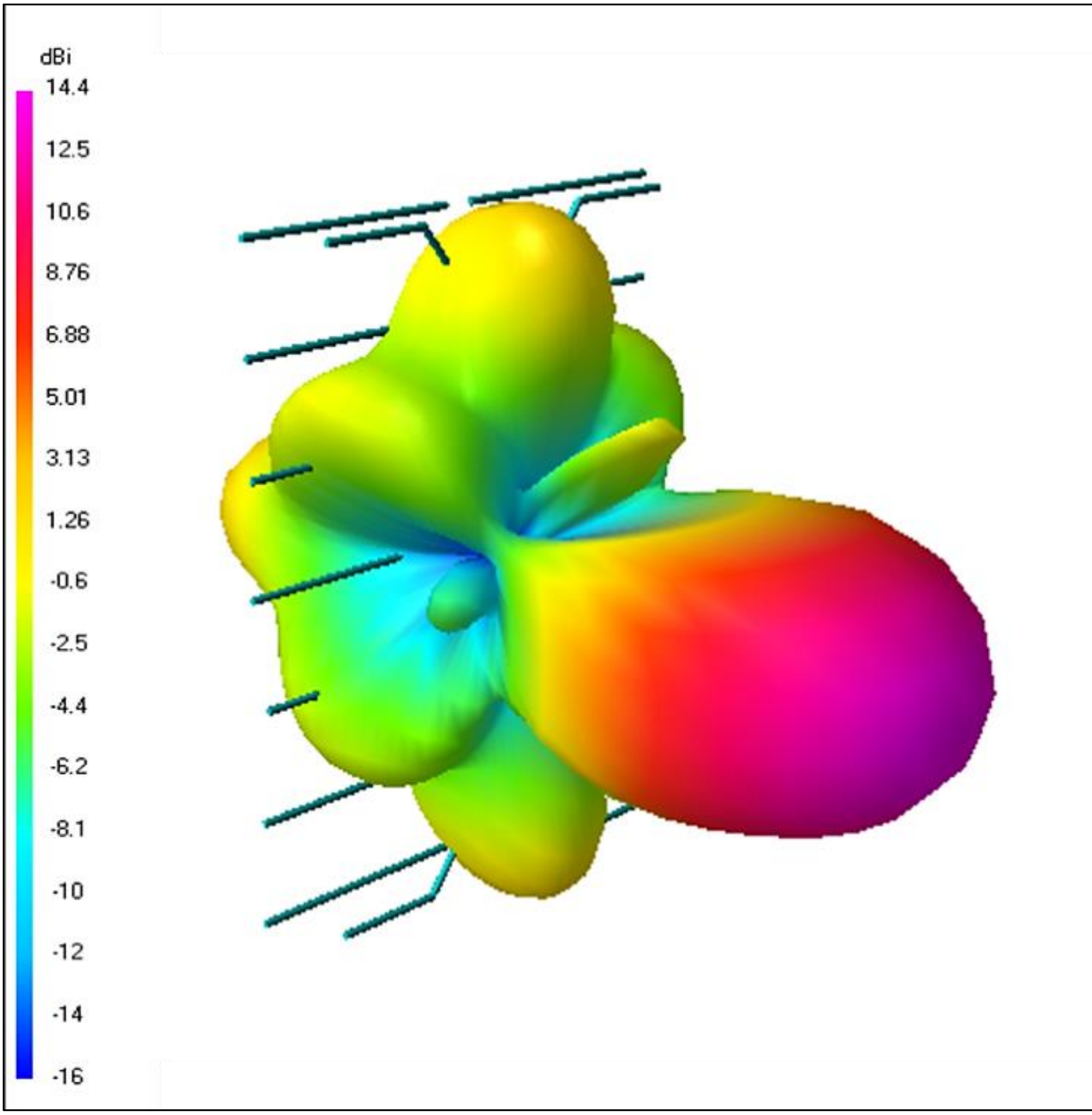

Figure 2. Radiation pattern in 3D at 700 MHz

In Figure 3, the chart describes the front lobe, back lobe and side lobe. The results show that the maximum front lobe value is 14.4 dB. The back lobe value is 3.32 dBi and the side lobe is -18 dBi.

As the gain of a directional antenna increases, the coverage distance increases, but the effective coverage angle decreases due to the lobes being pushed in a certain direction because there is a little energy on the back side of the antenna.

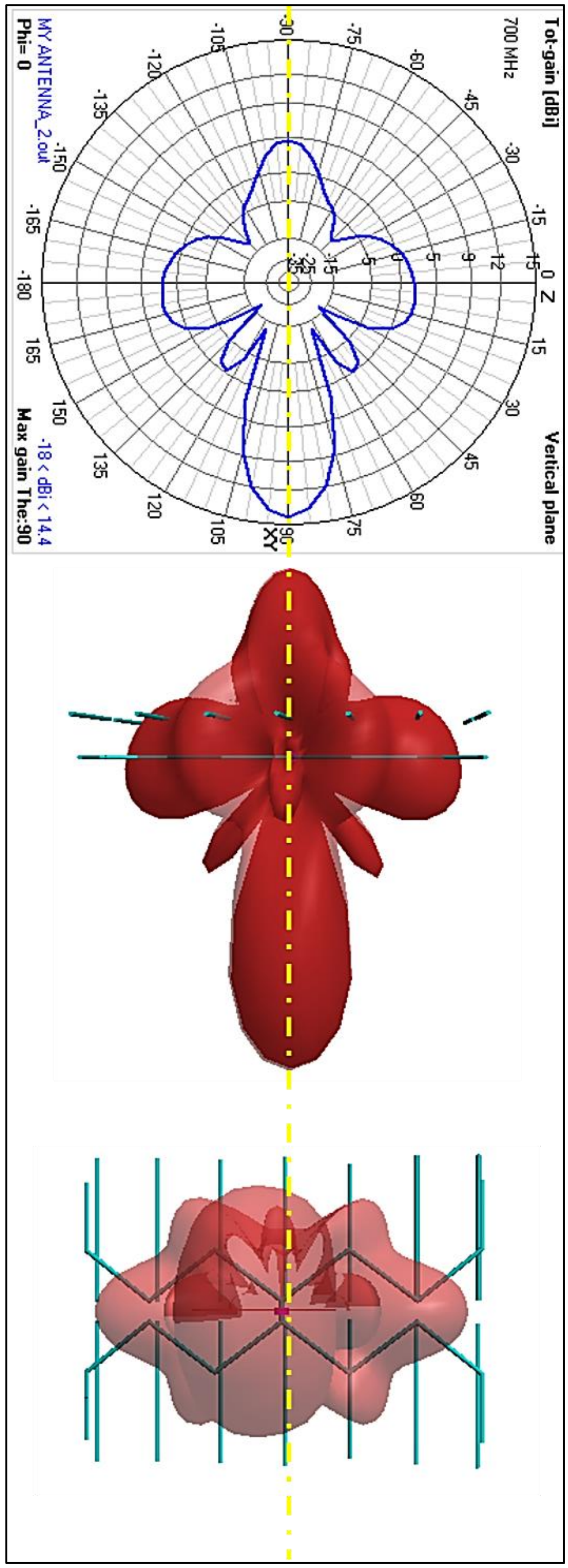

Figure 3. Radiation pattern chart (2D)

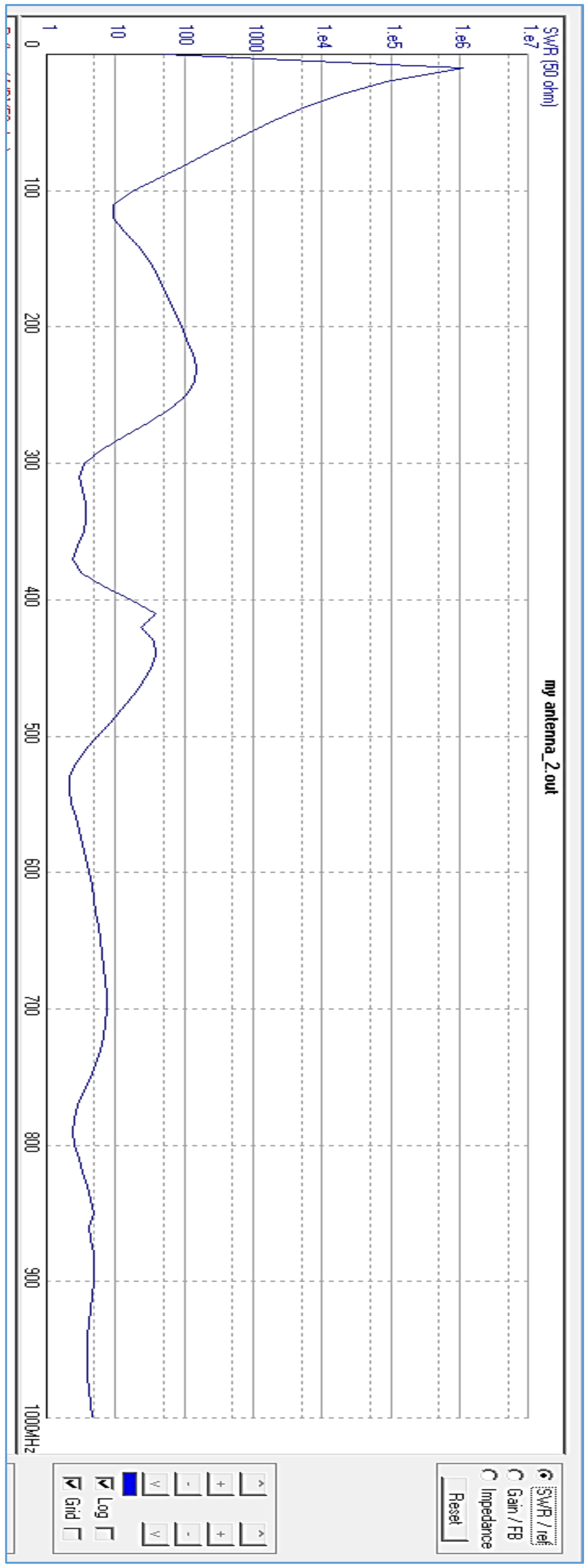

Figure 4. Standing-wave ratio (SWR) of the antenna

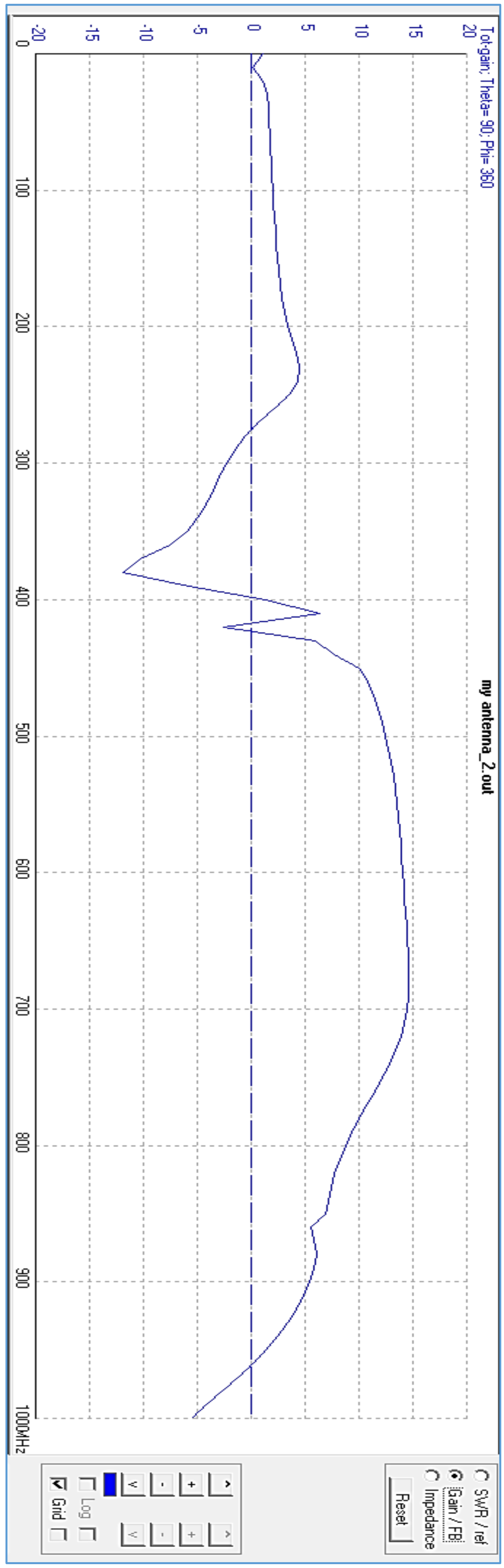

Figure 5. Graph of gain versus frequency

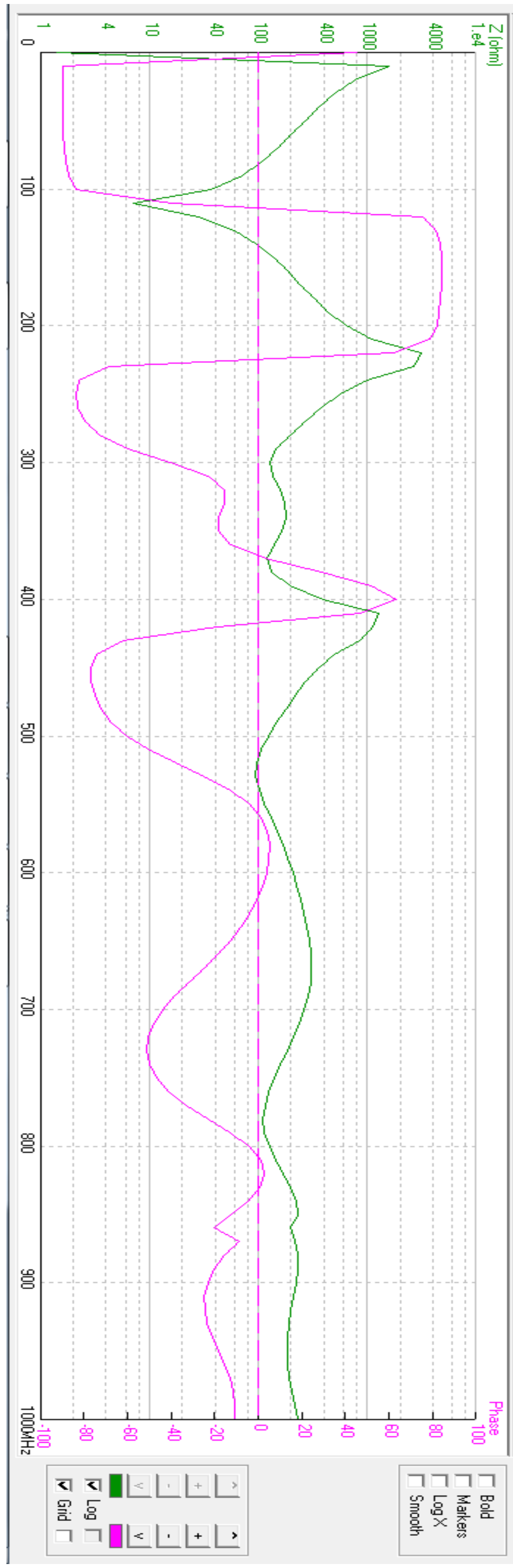

Figure 6. Graph of impedence versus frequency.

Standing-wave ratio (SWR) is a mathematical expression of the non-uniformity of an electromagnetic field (EM field) on a transmission line such as coaxial cable. SWR is a measure of impedance matching of loads to the characteristic impedance of a transmission line or waveguide. The SWR is usually thought of in terms of the maximum and minimum AC voltages along the transmission line, thus, it is also known as the voltage standing-wave ratio (VSWR). The SWR can also be defined as the ratio of the maximum RF current to the minimum RF current on the line. The Voltage Standing Wave Ratio (VSWR) indicators of the amount of mismatch between an antenna and the feed line connecting to it. The range of values for VSWR is from 1 to ∞. A VSWR value below 2 is considered suitable for most antenna applications. The antenna can be described as having a good match.

Based on the results, the SWR is high in the range of 1-100 MHz with 10^6 but suddenly decreased to 10 at 100 MHz. The patterns are very dynamics and it is less that 10 from 530 MHz to 1000 MHz. Therefore, we can conclude that it is very sensitive at low frequency rather than high frequency. As a reference, all the value used in this simulation is preset value. The cable impedance is set to 50 ohm and 190 ohm antenna. However, the impedance of a particular antenna design can vary due to a number of factors that cannot always be clearly identified. Therefore, the antenna is an impedance mismatch. Some of the power fed to the antenna terminals is always lost. For example, the mismatch between the antenna element and the feeding network causes power losses. Also the actual antenna material loses energy just by its nature and creates unintended heat.

Figure 5 shows the graph plot of gain versus frequency. The high gain obtained by the antenna is around 14.4 dBi at targeted range frequencies of 500 MHz to 700 Mhz. This region of frequency is said to be the best performance of the antenna due to high gain. The lower gain is around -11 dBi. It can be clearly observed that the designed antenna structure provides good amount of gain 14.4 dBi which is highly desirable for various applications.

4. CONCLUDING REMARKS

The Gray Hoverman's antenna is designed and simulated over 4NEC2 simulation software. The simulation results of this antenna structure are quite good as this antenna structure can work in particular frequency bands with a good amount of gain of 14.4 dBi, the SWR of below 10 dBi, and impedance matching around 100 ohm. With these improvements, the activity of radio meteor detection outcome can be improved in terms of number meteor detection.

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