ISLAMIC UNIVERSITY OF TECHNOLOGY

DESIGN OF LINEAR WIRE ANTENNAS AND YAGI-UDA ANTENNA USING 4NEC2

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ABSTRACT

In today's modern communication industry and RF applications antennas are the most important components required to create a communication link. The dipole antennas are most widely used for mobile telecommunication system. The Yagi-Uda Array antennas are most widely used for broadband communications as well as Television, Radio, and many RF applications. The objective of this project is to design a half-wavelength dipole antenna and a VHF Yagi-Uda Array antenna especially under various considerations.
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In this work, an antenna designing and simulating software **4NEC2** has been introduced with its various operating functions and with the help of those, a **"Half-wavelength Dipole Antenna"** and its designing procedures have been described. Moreover, the obtained results have been verified with the theoretical values and some parameters have also been simulated in MATLAB in some very specific cases. Next a "**VHF Yagi-Uda"** antenna has been designed with it and its parameters have been observed. Finally the work has been concluded with the promising future in designing Ultra band and Wi-max antennas with 4NEC2.

LIST OF FIGURE

CHAPTER-1

INTRODUCTION AND MOTIVATION

1.1 Introduction to antenna

An antenna is defined by Webster's dictionary as "a usually metallic device (as a rod or wire) for radiating and receiving radio waves." The *IEEE Standard Definitions of Terms for Antennas* (IEEE Std. 145-1983) defines the antenna or aerial as "a means for radiating or receiving radio waves." In other words, an antenna is a transitional structure between free space and a guiding device and it is used to transport electromagnetic energy from the transmitting source to to the antenna, or from the antenna to the receiver. [1]
In this project, we mainly focused on the design of linear wire antenna designs and showed its various parameters. We also compared the experimental values with the theoretical values. Next we designed a Yagi-Uda antenna and also verified its parametric values.
Nowadays, various types of software are available for the design and simulation of antennas. For convenience in design process, we have used 4nec2 software. We have also used MATLAB for some simulation.

1.2 Applications of antenna

Now a days antennas are widely used due to its unique characteristics. Some of the applications are given below :

- Wireless Communication
- Satellite Imaging Systems
- Radar Communication
- Aerospace
- Military application

- Television Reception etc

1.3 Motivation/Objective

Linear wire antennas and Yagi-Uda array antennas are very popular in the field of telecommunication and are widely used now-a-days.In many RF applications it is required to get the desired antenna parameters for better communication.We can easily design any linear wire antennas or Yagi-Uda antenna using “4NEC2”software and simulate various parameters using it . 4NEC2 is one of the most popular antenna design and simulation software. The term NEC stands for “Numerical Electromagnetic Code”. It is a very simple and widely used software for designing and analysing now a days.We will also simulate different parameters using MATLAB for better analysis.

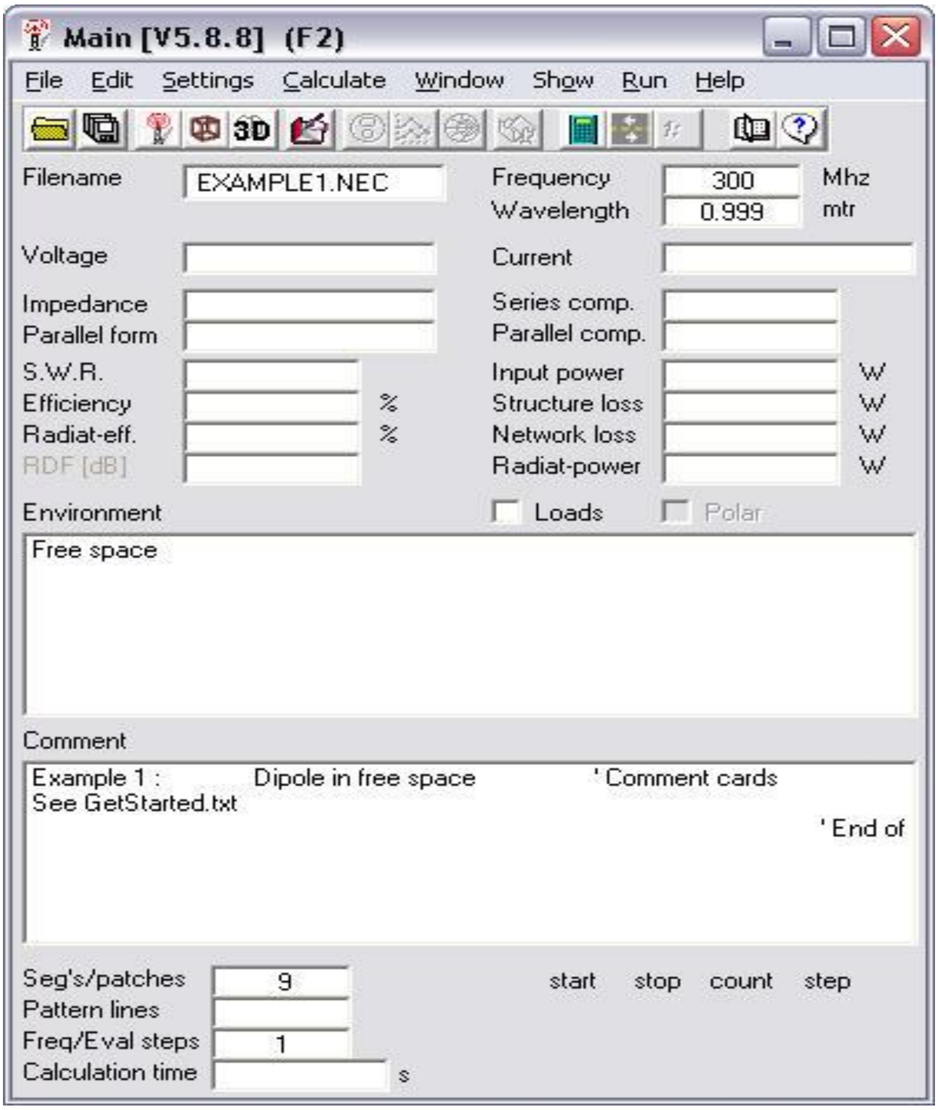


Fig 1.1:4NEC2 Main Window

CHAPTER-2

INTRODUCTION TO LINEAR WIRE ANTENNA

2.1 LINEAR WIRE ANTENNA

In the previous chapter we defined that an antenna is a metallic device (usually rod or wire) for radiating radio waves.
Wire antennas, linear or curved are the oldest, simplest, cheapest and are more versatile for many application. If we use a thin wire for designing any antenna then it is known as linear wire antenna.

Fig 2.1: Linear Wire Antenna

2.2 Classifications

There are mainly five types of linear wire antennas. They are given below:

- Infinitesimal dipole
- Small dipole
- Half wavelength dipole
- Finite-length dipole
- Vertical electric dipole

The descriptions of various linear wire antennas are given below.

2.2.1 Infinitesimal dipole

In an infinitesimal dipole antenna, the length *dl* is much smaller than the wavelength λ of the exited wave , i.e. $dl << \lambda$ $(dl < \lambda/50)$. The infinitesimal dipole is equivalent to a current element *Idl*, where $Idl = -(dq/dt)dl$.

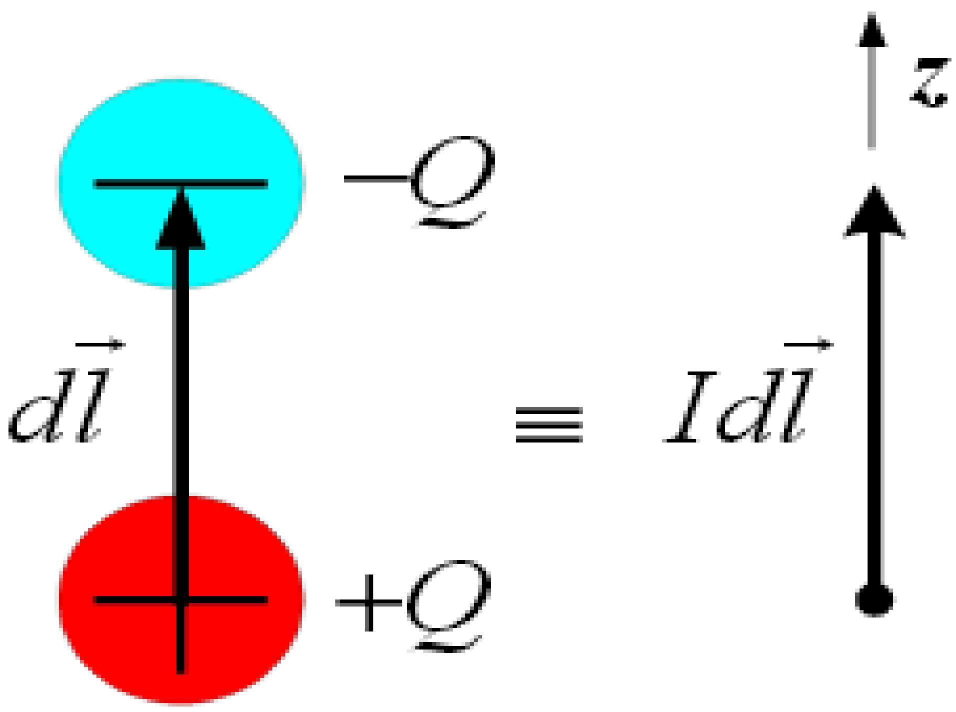


Fig 2.2: Infinitesimal dipole antenna

2.2.2 Small dipole

The small dipole antenna is the simplest of all antennas. It is simply an open-circuited wire, fed at its centre as shown in figure.

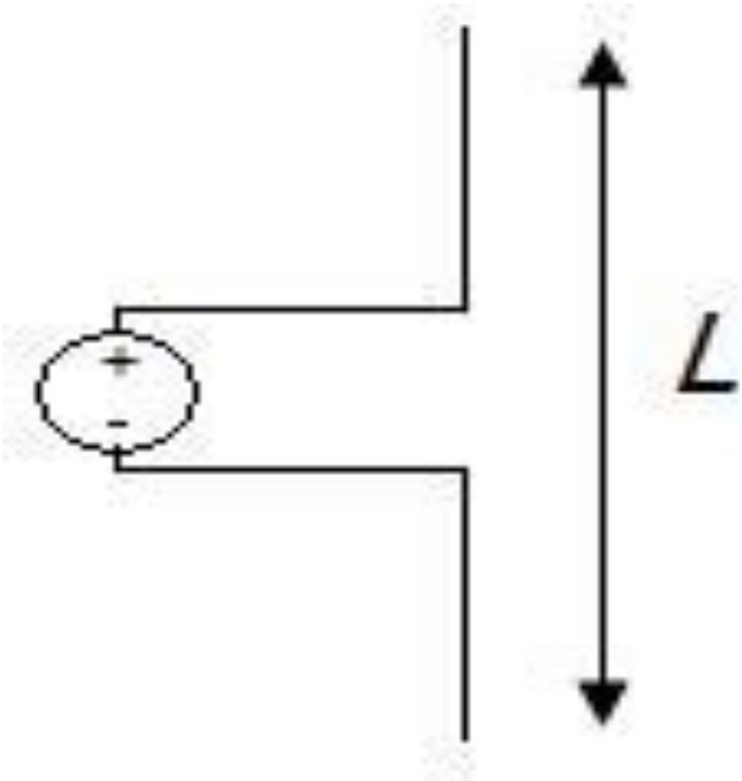


Fig 2.3:Small Dipole Antenna

The words "short" or "small" in antenna engineering always imply "relative to a wavelength". So the absolute size of the above dipole antenna does not matter, only the size of the wire relative to the wavelength of the frequency of operation. Typically, a dipole is short if its length is less than a tenth of a wavelength:

$$L < \frac{\lambda}{10}$$

2.2.3 Half-wavelength dipole

One of the most commonly used antennas is the half-wavelength (l=λ/2) dipole. Because its radiation resistance is 73ohms. The input impedance of the half-wavelength dipole antenna is **Zin = 73 + j42.5**[1].

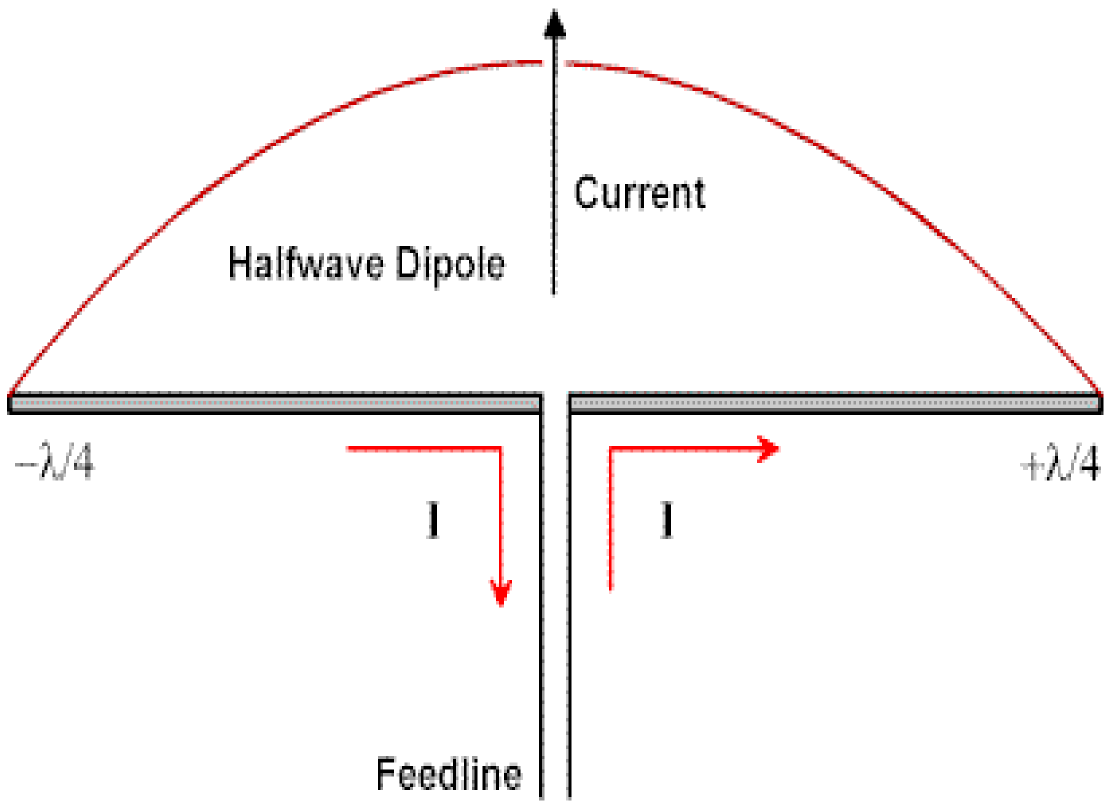


Fig 2.4: Half-wavelength Dipole

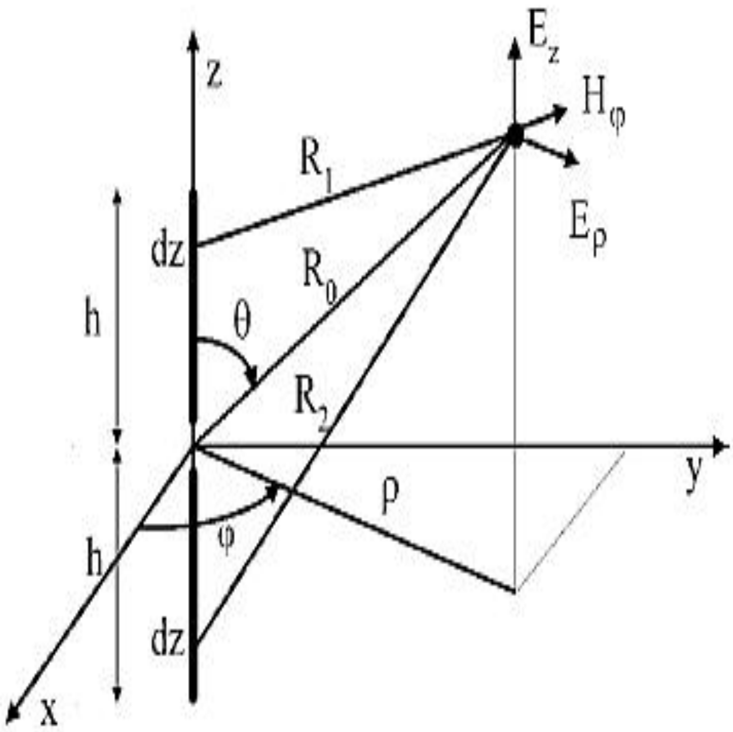
The electric field and magnetic field of a half-wavelength dipole can be obtained from these equations:

$$E_{\theta} \cong j\eta \frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right] \quad \text{...} (1)$$

$$\boldsymbol{H}_{\emptyset} = j\frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right] \text{... (2)}$$

2.2.4 Finite length dipole

A finite length dipole antenna is more directional than the other dipole antennas. Its length is large and as so, its normalized radiation pattern is also larger than the other dipole antennas. For ignoring complexities in case of designing these antennas it is assumed that the dipole has a negligible diameter(ideally zero).Current distribution in these antennas assumes that the antenna is a centre fed and current vanishes at end points(z'=±l/2)[1].



<u>Fig 2.5: Finite Length Dipole And Radiated Fields</u>

The electric field and magnetic field of a finite length dipole can be obtained from these equations:

$$E_{\theta} \cong j\eta\frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right)-\cos\left(\frac{kl}{2}\right)}{\sin\theta}\right] \text{.. (3)}$$

$$H_{\emptyset} \cong \frac{\boldsymbol{E_\theta}}{\eta} \cong j\,\frac{I_{0}e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{kl}{2}\cos\theta\right)-\cos\left(\frac{kl}{2}\right)}{\sin\theta}\right] \quad \text{...} (4)$$

2.2.5 Vertical electric dipole

Vertical electric dipole antennas are those antennas whose position is placed vertically. It is generally used in high frequency application. For designing vertical electric dipole antennas it is considered far field approximation(r>>h) where 'h' is the antenna height.[1]

Fig 2.6:Vertical Electric Dipole Antenna

As there is always a consideration of antenna height for designing vertical electric dipole antennas so the radiation resistance, radiated power, directivity (D_0), radiation intensity (U) etc. parameters are varied with changing antenna height.
The formulas related to radiation resistance, radiated power and directivity are as follows:

$$P_{rad} = \pi\eta \left|\frac{I_0 l}{\lambda}\right|^2 \left[\frac{1}{3} - \frac{\cos(2\pi h)}{(2\pi h)^2} - \frac{\sin(2\pi h)}{(2\pi h)^3}\right] \quad \text{.......... (6)}$$

$$R_{rad} = \frac{2P_{rad}}{|I_0|^2} = 2\pi\eta \left(\frac{l}{\lambda}\right)^2 \left[\frac{1}{3} - \frac{\cos(2\pi h)}{(2\pi h)^2} - \frac{\sin(2\pi h)}{(2\pi h)^3}\right] \quad \text{.......... (7)}$$

$$U_{max} = \frac{\eta}{2}\left(\frac{I_0 l}{\lambda}\right)^2 \quad \text{.......... (8)}$$

$$D_0 = \frac{4\pi U_{max}}{P_{rad}} = \frac{2}{\left[\frac{1}{3} - \frac{\cos(2\pi h)}{(2\pi h)^2} - \frac{\sin(2\pi h)}{(2\pi h)^3}\right]} \quad \text{.......... (9)}$$

Here, I_0 =initial current; λ=wavelength (m) ; U_{max} =maximum radiation intensity

2.3 Antenna Parameters

2.3.1 Input Impedance

Input impedance is defined as "the impedance represented by an antenna at its terminals or the ratio of the voltage to current at a pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point". The input impedance by formula is : **Z=(R+jX)Ω**

Where, R=antenna resistance (ohm), X=antenna reactance (ohm)

2.3.2 Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or graphical representation of the radiation properties of the antenna as a function of space co-ordinates [1].The radiation pattern for an antenna is defined here. We have 3D graphs of real antenna radiation patterns, with a discussion on isotropic, omnidirectional and directional radiation patterns. Radiation patterns are of the utmost importance in the discussion of antenna basics.

2.3.3 Gain

Antenna gain is defined as how much power is transmitted in the direction of peak radiation to that of an isotropic source. It also gives the measurement of actual losses that occur [7].
Absolute gain of an antenna is defined as "the ratio of the radiation intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna was radiated isotropically.

$$\text{Gain} = 4\pi \frac{radiation\ intensity}{total\ input(accepted\ power)} = 4\pi \frac{U(\theta,\emptyset)}{P_{in}} \quad \text{.............................} (10)$$

2.3.4 Efficiency

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antennas input radiated away.
A low efficiency antenna has most of the power absorbed as losses within the antenna or reflected away due to impedance mismatch. The losses associated within an antenna are typically the conduction losses and dielectric losses.

$$\eta = \frac{P_{radiated}}{P_{input}} \quad \text{..} (11)$$

2.3.5 Directivity

Directivity is a fundamental antenna parameter. It is a measure of how directional an antenna's radiation pattern is. An antenna that radiates

equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 or 0 dB [13].
The directivity of an antenna is defined as “the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions”. The average radiation intensity is equal to the total radiated power divided by 4π [1].

Therefore, Directivity, $D_0 = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}$ .... (12)

2.3.6 Bandwidth

The bandwidth of an antenna is defined as “the range of usable frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. The bandwidth can be the range of frequencies on either side of the centre frequency where the antenna characteristics like input impedance, radiation pattern, beam width, polarization, side lobe level or gain. For broadband antennas the bandwidth is expressed as the ratio of the upper to lower frequencies of acceptable operation. For example, 10:1 bandwidth means the upper frequency is 10 times greater than the lower frequency[1].

2.3.7 SWR

In telecommunications, the standing wave ratio (S.W.R) is defined as the ratio of the amplitude of a partial wave at an antinode (maximum) to the amplitude at an adjacent (minimum) node, in an electrical transmission lines.
S.W.R is an efficiency measure of transmission lines, electrical cables that conduct radio frequency signals , used for purposes such as connecting radio transmitters and receivers with their antennas, and distributing cable television signals[13].

CHAPTER-3

INTRODUCTION TO ARRAY ANTENNA

3.1 ANTENNA ARRAY BASICS

An **antenna array** is a set of individual antennas used for transmitting and/or receiving radio waves, connected together in such a way that their individual currents are in specified amplitude and phase relationship. This allows the array to act as a single antenna, generally with improved directional characteristics (thus higher antenna gain) that would be obtained from the individual elements. The resulting array in fact is often referred to and treated as "an antenna," particularly when the elements are in rigid arrangement with respect to each other, and when the ratio of currents (and their phase relationships) are fixed. On the other hand, a steerable array may be fixed physically but has electronic control over the relationship between those currents, allowing for adjustment of the antenna's directionality without requiring physical motion.
The array uses electromagnetic wave interference to enhance the radiative signal in one desired direction at the expense of other directions. It may also be used to null the radiation pattern in one particular direction, especially for a receiving antenna in the face of a particular interfering source.

3.2 CLASSIFICATIONS OF ARRAY ANTENNA

An antenna array may be classified as parasitic or driven [14]. The best known parasitic array is the "*Yagi-Uda antenna*" consisting of several elements but only one of which has an electrical connection to the transmitter or receiver. The other elements are electromagnetically coupled to that element (and to each other) through proximity, and are tuned so that their currents will be in the appropriate phases to enhance the directionality of the resulting array.

A driven array implies that all of the elements have an electrical connection to the transmitter or receiver, through circuitry that tailors their respective currents to the same end. One common example is the "*log-periodic dipole array*" frequently used as a rooftop TV antenna. Driven arrays, in which all the radiating elements are connected to the energy source, have smaller losses than parasitic arrays.

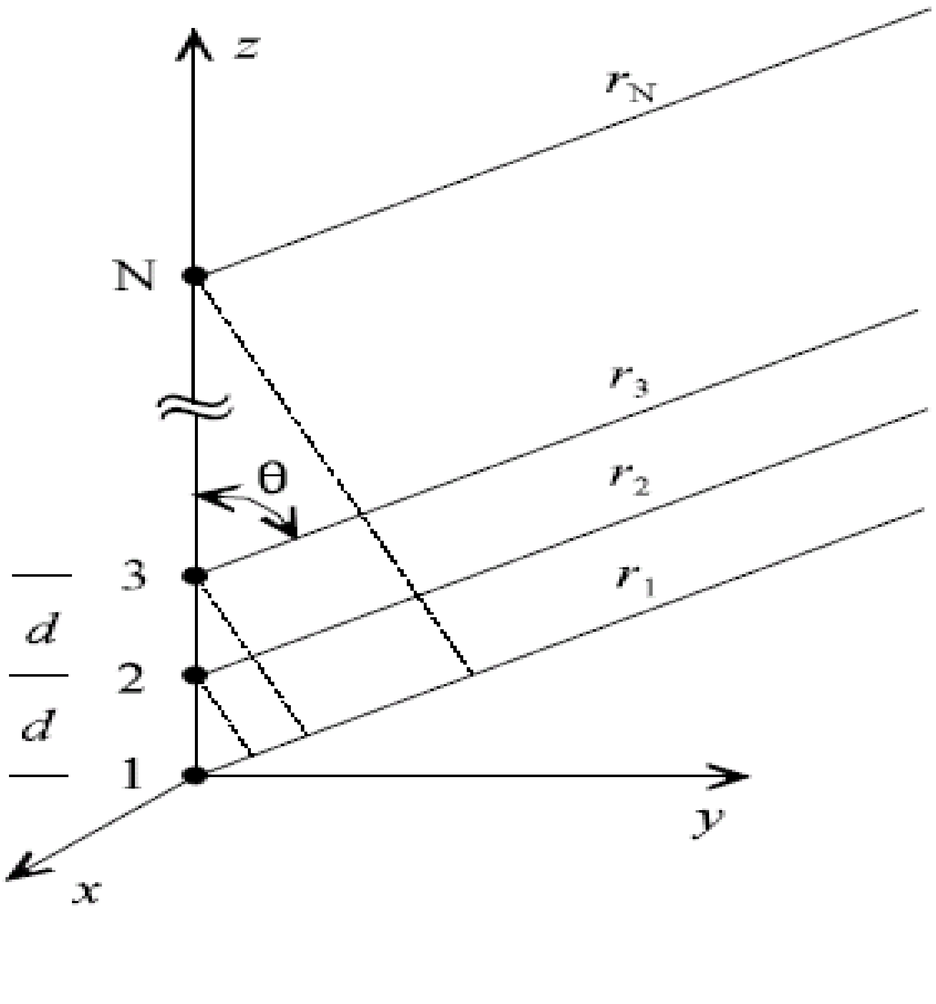
Driven arrays often (but not always) consist of elements which are identical; frequently these are just half-wave dipole or quarter –wave monopole (vertical) elements. The resulting array inherits the characteristics of that basic element, but the resulting array behaviour is determined more by the geometrical arrangement of the elements and the phases (and sometimes amplitudes) which each is assigned. Typically there will be a number of identical elements equispaced along one direction. In that case, an "*end-fire" array* is one in which the intended directionality is *in* the direction of the array. A "*broadside array"* has its intended directionality *at right angles* to the array direction. Of course there are also more complex arrays possible in which these classifications do not apply.

Sometimes a broadside array consists of identical elements arranged vertically. In this case, the directional pattern of the resulting antenna in the horizontal plane may be unchanged from that of a single such element. However by adding those additional elements, the antenna pattern in the *vertical* plane is altered in order to supply a greater amount of power in horizontal directions (in order to communicate with terrestrial locations) at the expense of directions aimed more toward the sky or ground which are not useful. Consequently the gain of antenna is increased without sacrificing directionality towards any intended stations [15].

3.3 CHARACTERISTICS OF ARRAY ANTENNA

The main purpose of creating a fixed antenna array is an increase in the antenna's directional gain; an array consisting of N identical elements can achieve an increase in gain of up to a factor of N if optimally fed. A parasitic array does not achieve such an increase since there are more constraints on the distribution of currents attainable through passive coupling.

Use of arrays for increasing antenna gain are an alternative to so-called" *aperture antennas"* in which the gain is achieved using a single geometric structure, more akin to an optical focusing device. Designs such as the horn antenna and parabolic dish antenna become more practical at higher frequencies (shorter wavelengths) whereas antenna arrays may be practical at any wavelength. At lower frequencies, where rigidly turning a large structure may be unfeasible, an array may be made steerable (or may just be tuned to optimize a particular radiation pattern) through electronic adjustment of the elements' relative phases. This principle is often used in
AM broadcast.



<u>Fig 3.1: Arrays In Antenna forming</u>

CHAPTER-4

OVERVIEW OF YAGI-UDA ARRAY ANTENNA

4.1 HISTORY OF YAGI-UDA ANTENNA

A Yagi-Uda array antenna , simply known as Yagi-Uda antenna is a directional antenna consisting of multiple dipole elements usually made of metal rods. The antenna was invented in 1926 by **Shintaro Uda** of **Tohoku Imperial University, Japan,** with a lesser role played by colleague **Hidetsugu Yagi.** However, the "Yagi" name has become more familiar with the name of "Uda" often omitted. This appears to have been due to Yagi filing a patent on the idea in Japan without Uda's name in it, and later transferring the patent to the **Marconi Company in the U.K.** Yagi-Uda antennas were mostly used during World War II in radar systems by the British, Germans and U.S.A.

4.2 A SMALL BRIEF OF YAGI-UDA ANTENNA

Yagi-Uda antenna is a very practical radiator antenna in HF(3-30 MHz), VHF(30-300MHz) and UHF (300-3000 MHz) ranges. This antenna consists of multiple linear dipole elements. [1]
The most common fed element of Yagi-Uda antenna is a folded dipole. The radiator is exclusively designed to operate as an end-fire array. The Yagi-Uda antenna is mostly used in home T.V applications.

The Yagi antenna offers many advantages for its use. The antenna provides many advantages in a number of applications:

- Antenna has gain allowing lower strength signals to be received.
- Yagi antenna has directivity enabling interference levels to be minimized.

- Straightforward construction. – The Yagi antenna allows all constructional elements to be made from rods simplifying construction.
- The construction enables the antenna to be mounted easily on vertical and other poles with standard mechanical fixings

Fig 4.1: A Typical Roof-top Yagi-Uda Antenna

4.3 COMPONENTS OF YAGI-UDA ANTENNA

It contains mainly of 3 elements-

- Driven element
- Reflector
- Director

Driven Element

1. Two conductors of length $= \lambda/4$
2. One connected to signal, the other to ground
3. The driven element in the system, no electrical connection to reflectors and directors

Reflector

1. Larger than dipole
2. Prevents antenna from sending backwards

Director

1. Length is smaller than dipole, continuously decreasing
2. Excited by the field of dipole
3. Make antenna directional

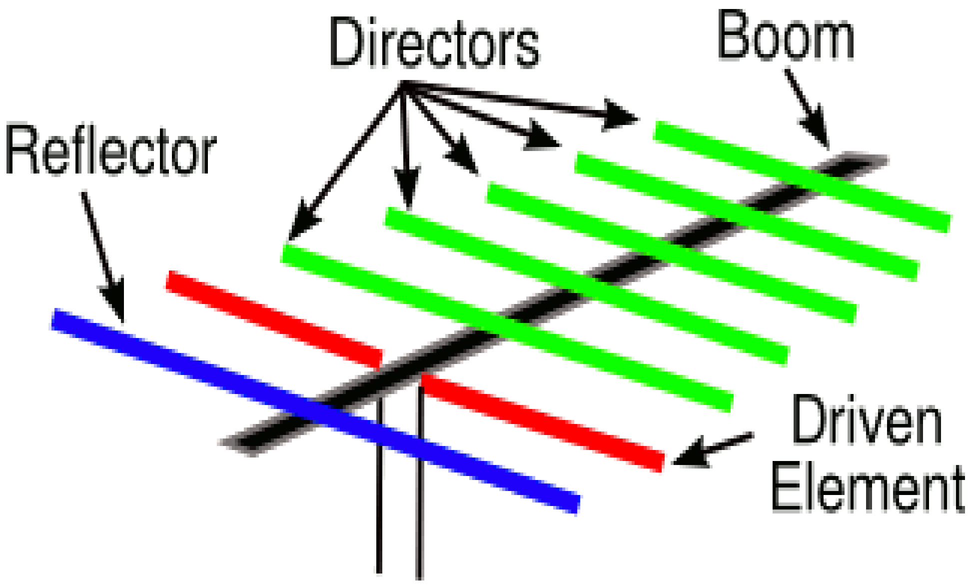


Fig 4.2 : Components Of Yagi-Uda Antenna

CHAPTER-5

DESIGN AND SIMULATION

5.1 DESIGN OF A HALF-WAVELENGTH DIPOLE

For a half-wavelength dipole the length of the corresponding antenna should be "λ/2". We will now design a half-wavelength dipole via 4NEC2 software under free space environment as well as under ground(earth) effect.

5.1.1 Design equations

i. $E_{\theta \cong} j\eta \frac{I_{0e^{-jkr}}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$ ....(13)

ii. $\boldsymbol{H}_{\emptyset=} j \frac{I_{0e^{-jkr}}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$ ....(14)

iii. $D_0 = \frac{4\pi U}{P_{rad}}$ ....(15)

iv. $P_{rad} = \eta \frac{|I_0|^2}{8\pi} C_{in}(2\pi)$..........(16)

v. $R_{rad} = \frac{2P_{rad}}{|I_0|^2}$ ....(17)

5.1.2 Design specifications

- Resonant frequency=1250MHz
- Corresponding wavelength=0.24m
- Required Antenna length=0.12m
- No. Of Wire =1
- No. Of segments=9
- Required radius of the wire=0.01e-8

➢ Required environment= “Free space”

5.1.3 Antenna view after designing via 4NEC2

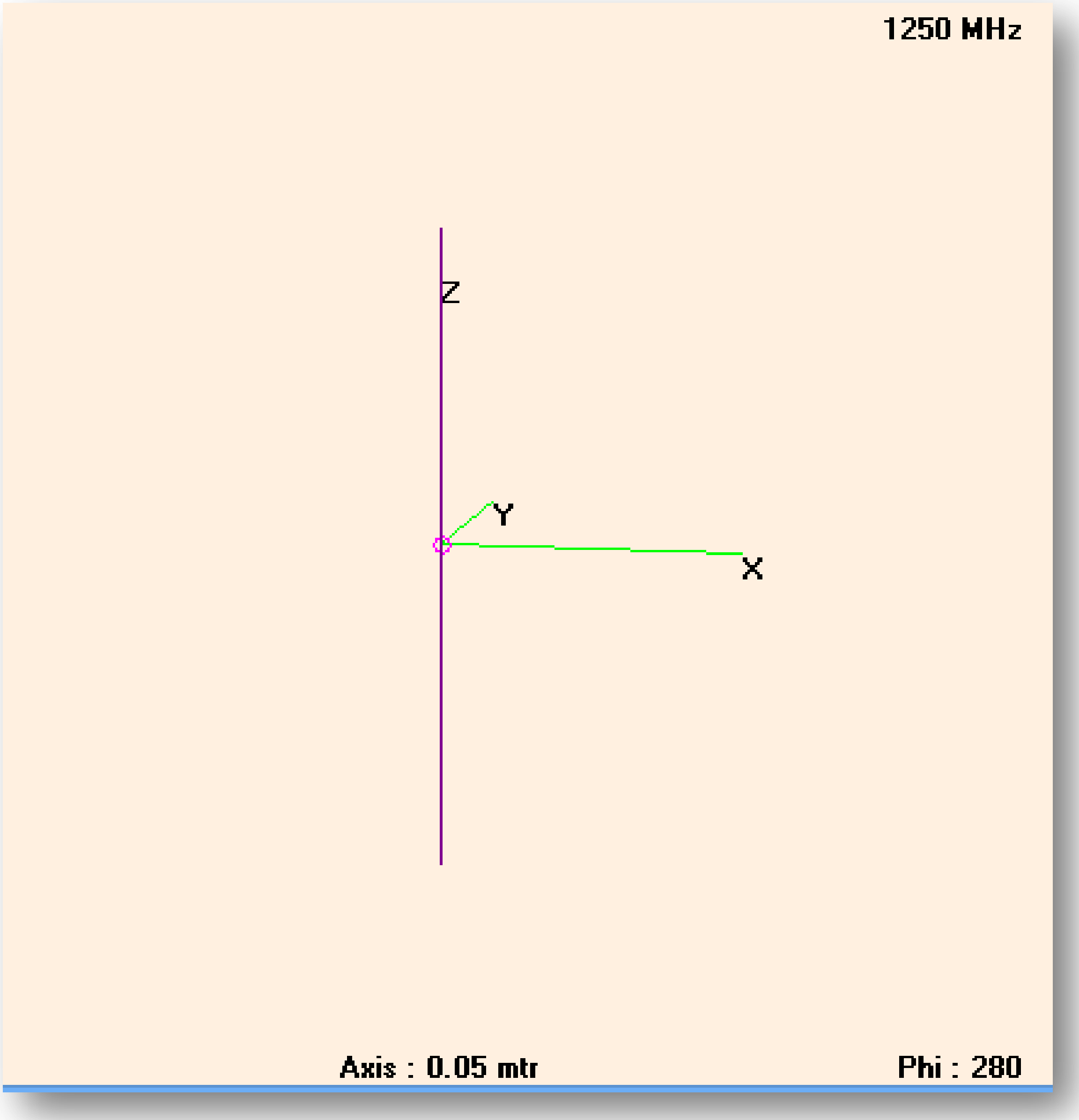


Fig 5.1: Antenna view (l=λ/2)

After editing the geometry editor at 4NEC2 software for designing a half-wavelength dipole antenna the schematic view of the antenna like the above figure can be seen.

5.1.4 Radiation Pattern

After designing the half-wavelength antenna via 4NEC2 software and simulating it we get the radiation pattern from that antenna. From the figure we can see two sided small lobes when the antenna will radiate.

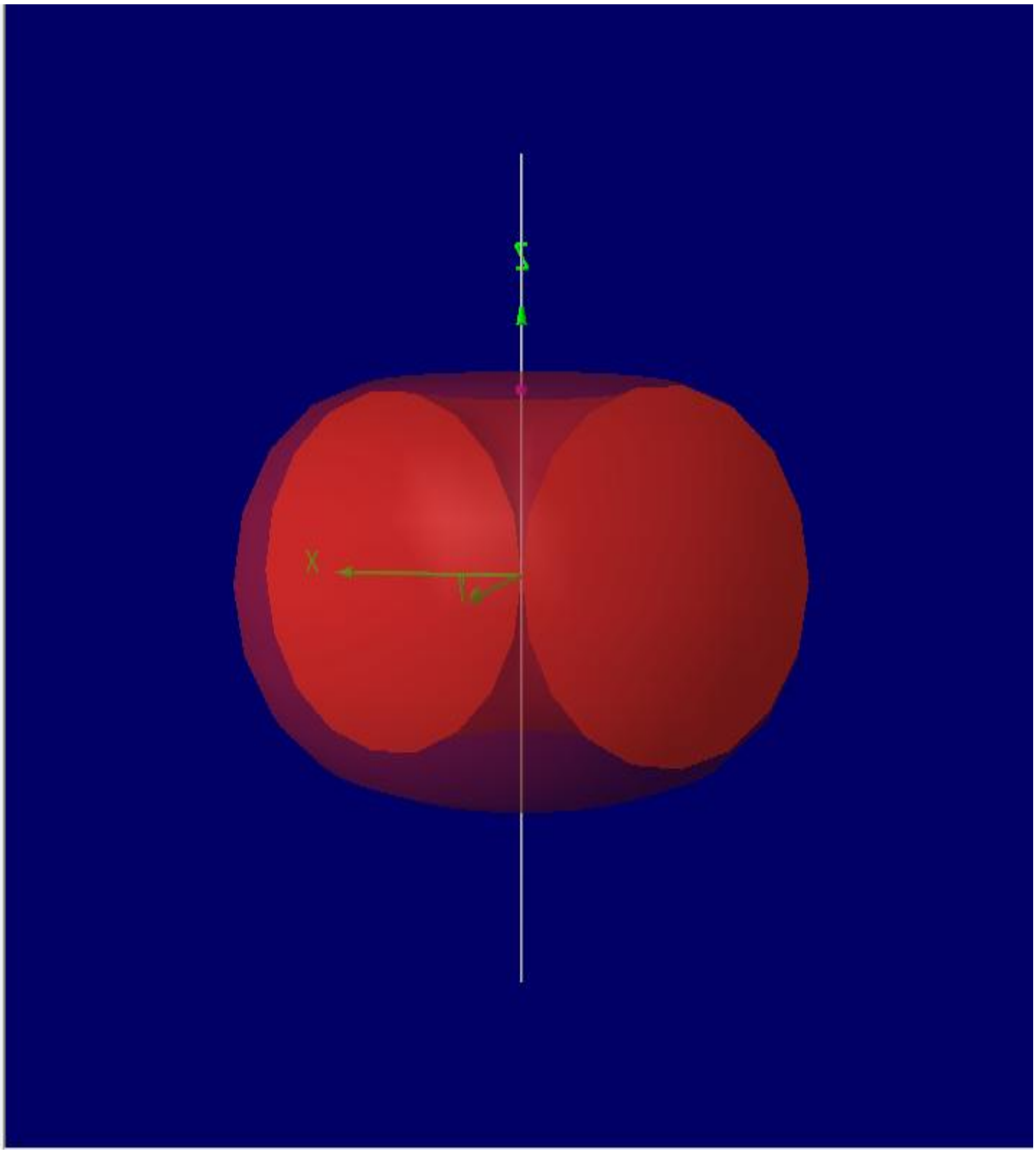


Fig 5.2: 3D View Of Radiation Pattern

5.1.5 Impedance Curve

We know that the radiation resistance of a half-wavelength dipole is 73ohm.After simulating the above antenna via 4NEC2 we find the radiation resistance of 73ohm.

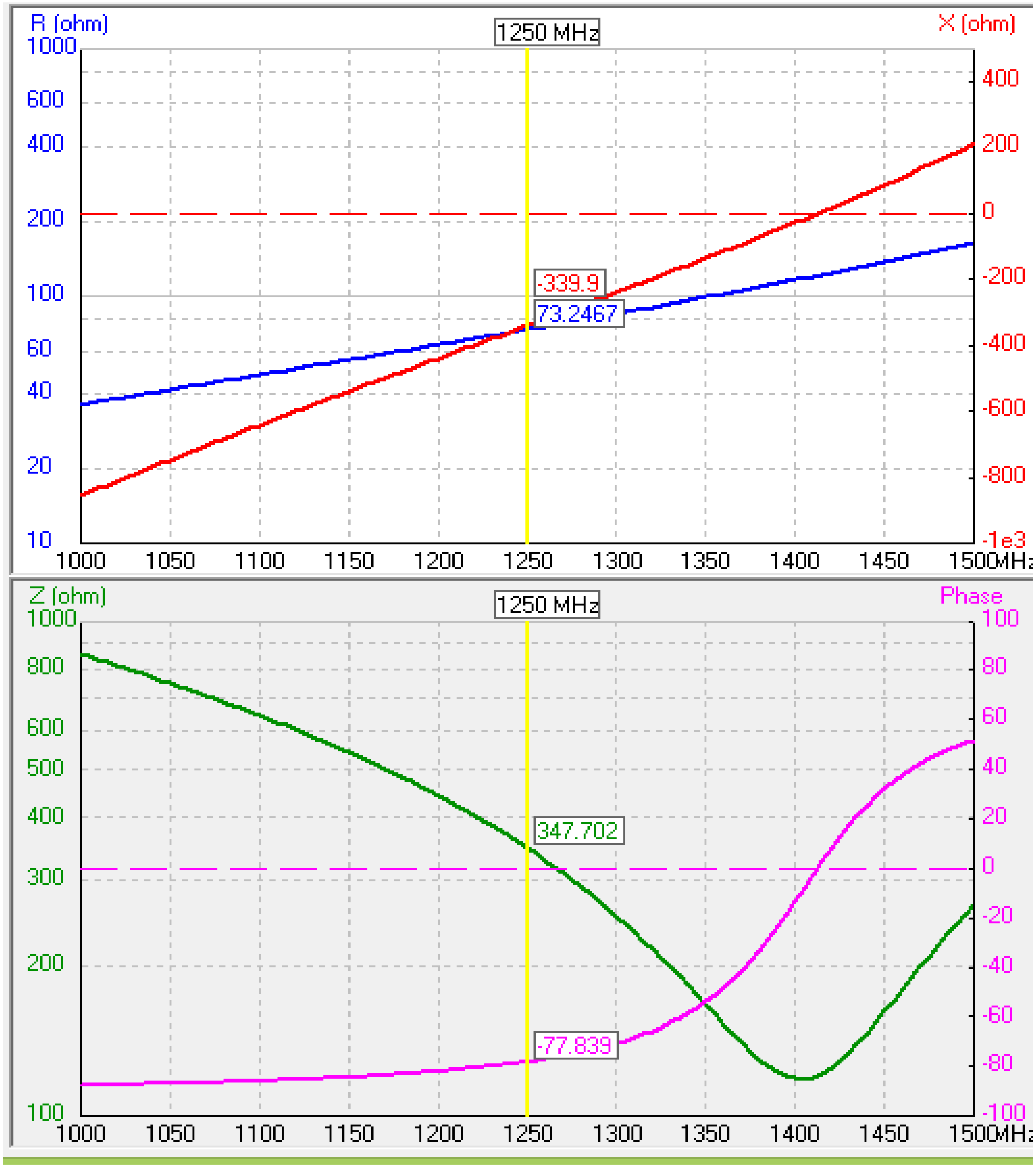


Fig 5.3: Impedance curve (magnitude+phase) For(l=λ/2) Antenna

- The blue line marked on the above figure shows that the radiation resistance, $R_{rad} = 73\Omega$.

5.1.6 SWR Curve

We are familiar the the term "SWR (Standing Wave Ratio) for antenna designing. After designing via 4NEC2 software the half-wavelength antenna we also get the SWR pattern.

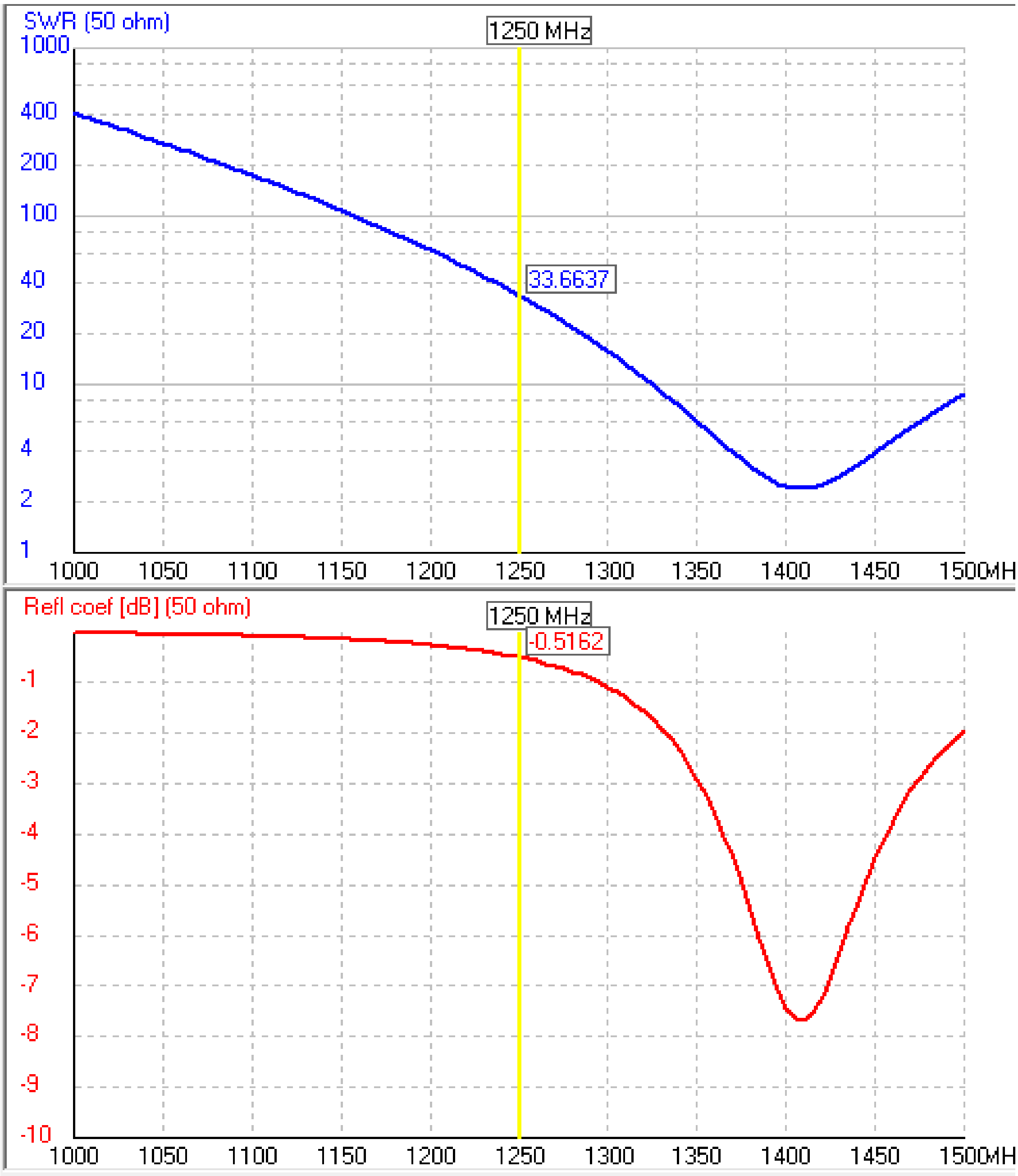


Fig 5.4: SWR Curve For (l=λ/2) Antenna

5.1.7 Gain Curve

We know that gain is an important parameter for designing antenna.4NEC2 software also provides us with the gain curve of the corresponding antenna we are designing. Thus we can easily find the relation between antenna gain and radiation pattern.

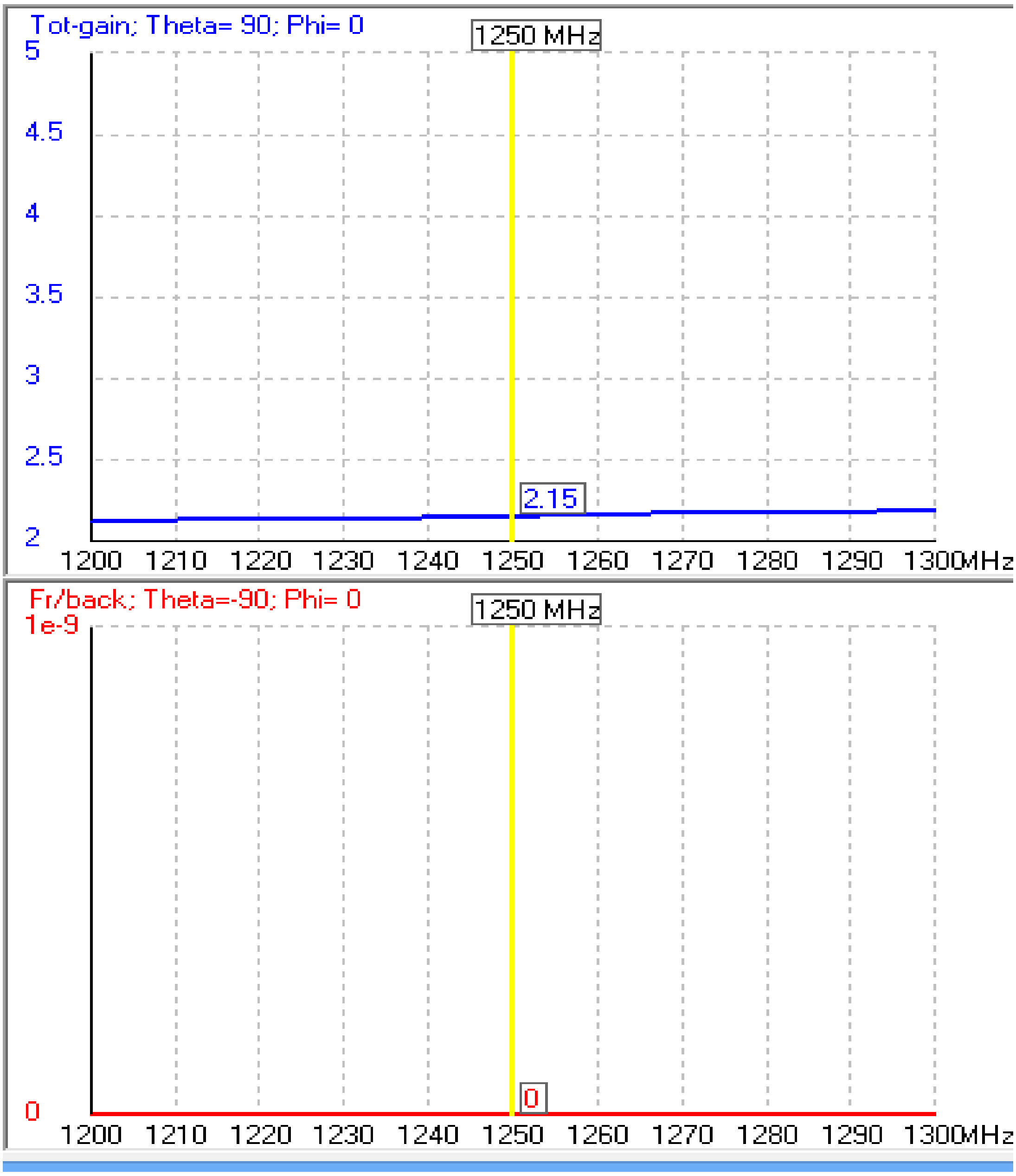


Fig 5.5: Antenna Gain Curve

5.2 DESIGN OF A (l=λ/2) DIPOLE WITH GROUND EFFECT

- Although ideal electric conductors (σ = ∞) are not realizable, dipole antennas have ground effects also [20].
- Antennas are typically used in an environment where other objects are present that may have an effect on their performance. Height above ground has a very significant effect on the radiation pattern of some antenna types [21].
- At frequencies used in antennas, the ground behaves mainly as a dielectric [22].

5.2.1 Design Considerations

- Resonant frequency =1250MHZ
- Corresponding wavelength=0.24m
- Required Environment= perfect ground effect
- No. Of wire =1
- Connect wire Z=0 to ground

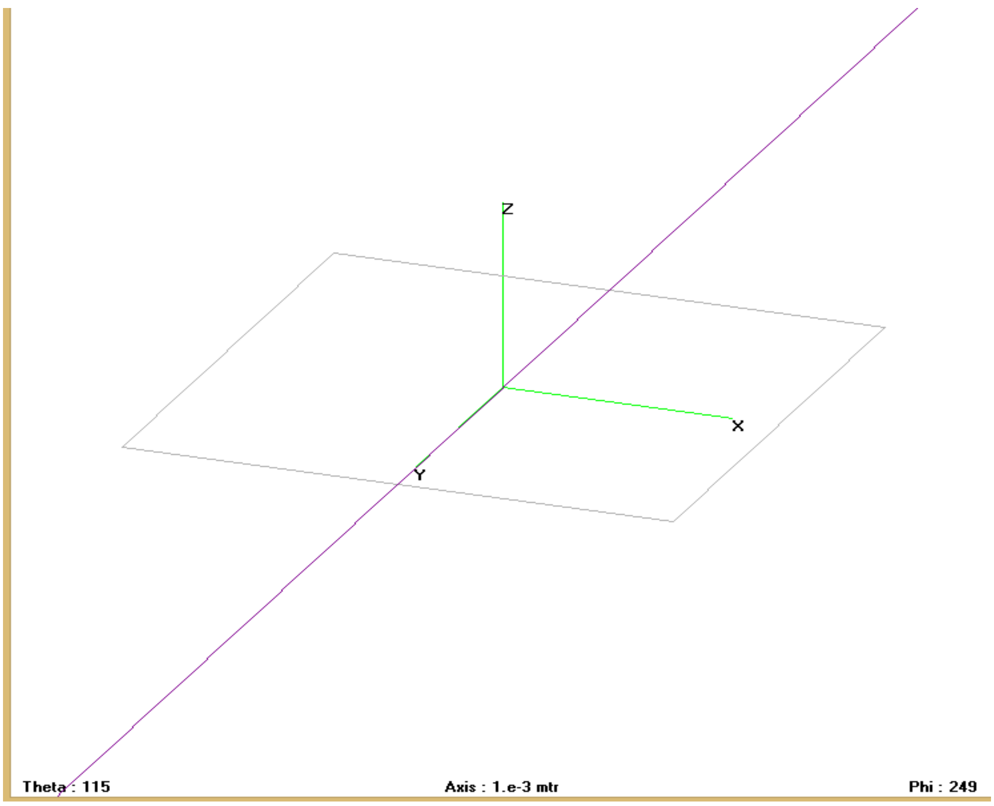


Fig 5.6:Antenna View Under Ground Effect for Dipole Antenna

5.2.2 Radiation Pattern

- After choosing a fast ground there is change in the radiation pattern than before.
- The radiated field pattern by an electric dipole antenna when placed above a fast ground can be obtained by referring to the geometry editor of NEC file.
- As there is a ground (earth) effect on the corresponding antenna the vertical plane will only constitute the upper half plane.

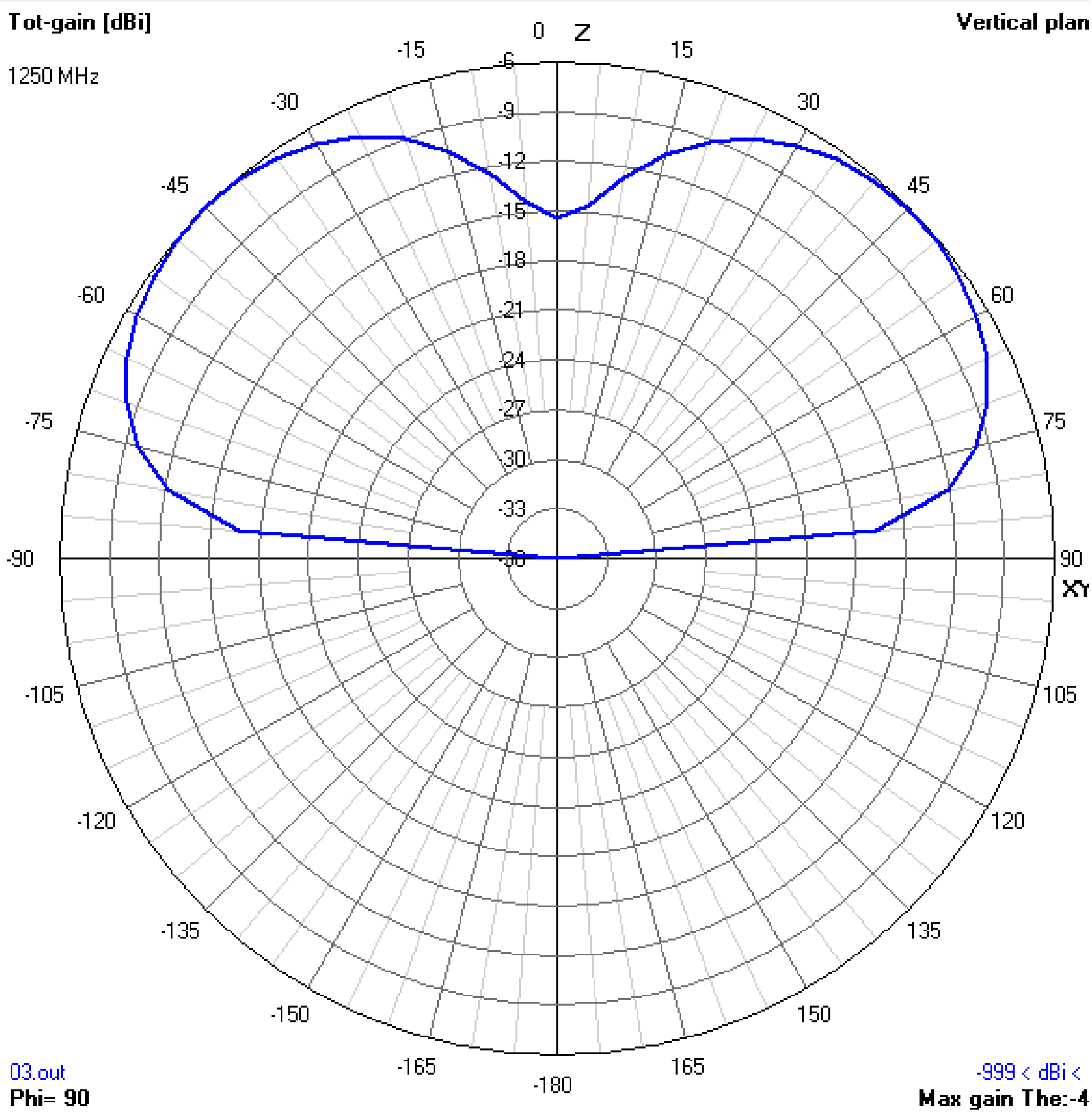


Fig 5.7: Radiation Pattern Of Dipole Antenna(Ground Effect)

5.3 Directivity Vs. R_{rad} Vs. Height Simulation via MATLAB

In case of designing a dipole antenna directivity is an important parameter as we have seen before. The directivity parameter (D_0) changes with radiation resistance,R_{rad} and antenna height (h).There are some equations which will show the relationship between these parameters. The relevant equations are as follows:

$$D_0 = \frac{4\pi U_{max}}{P_{rad}} = \begin{cases} \frac{4\sin^2(kh)}{R(kh)} & for\ \ kh \le \frac{\pi}{2} \\ \frac{4}{R(kh)} & for\ \ kh > \frac{\pi}{2} \end{cases} \qquad \text{........................ (18)}$$

$$R(kh) = \left[\frac{2}{3} - \frac{\sin(2kh)}{2kh} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right] \qquad \text{....................... (19)}$$

If we plot these two equations via **MATLAB** then we will see the variation of these parameters with each other. The relevant MATLAB code for this simulation is:

MATLAB CODE

```
lc;clear;close
lambda=0.12;
k=2*pi/lambda;
h=0:0.001:2;
x=k.*h;
R=2/3-(sin(2.*x))./(2.*x)-
(cos(2.*x))./((2.*x).^2)+(sin(2.*x))./((2.*x).^3);
xx=length(x);
D0=zeros (1,xx);

for i=1:xx
if x(i)<=pi/2
D0(i)=4.*(sin(x(i))).^2./R(i);

else D0(i)=4./R(i);
end
end

[AX,H1,H2] =plotyy(h,D0,h,R);
legend('diectivity','radiation resistance')
set(H2,'LineStyle',':','linewidth',2)
set(H1,'LineStyle','-','linewidth',2)
xlabel('\bfheight h (wavelengths)','fontsize',12')
ylabel('\bfDirectivity (dimensionless)','fontsize',12)
set(get(AX(2),'Ylabel'),'string','\bfRadiation Resistance
(Ohms)','fontsize',12)
```

If we use this **MATLAB** code and simulate it then we get :

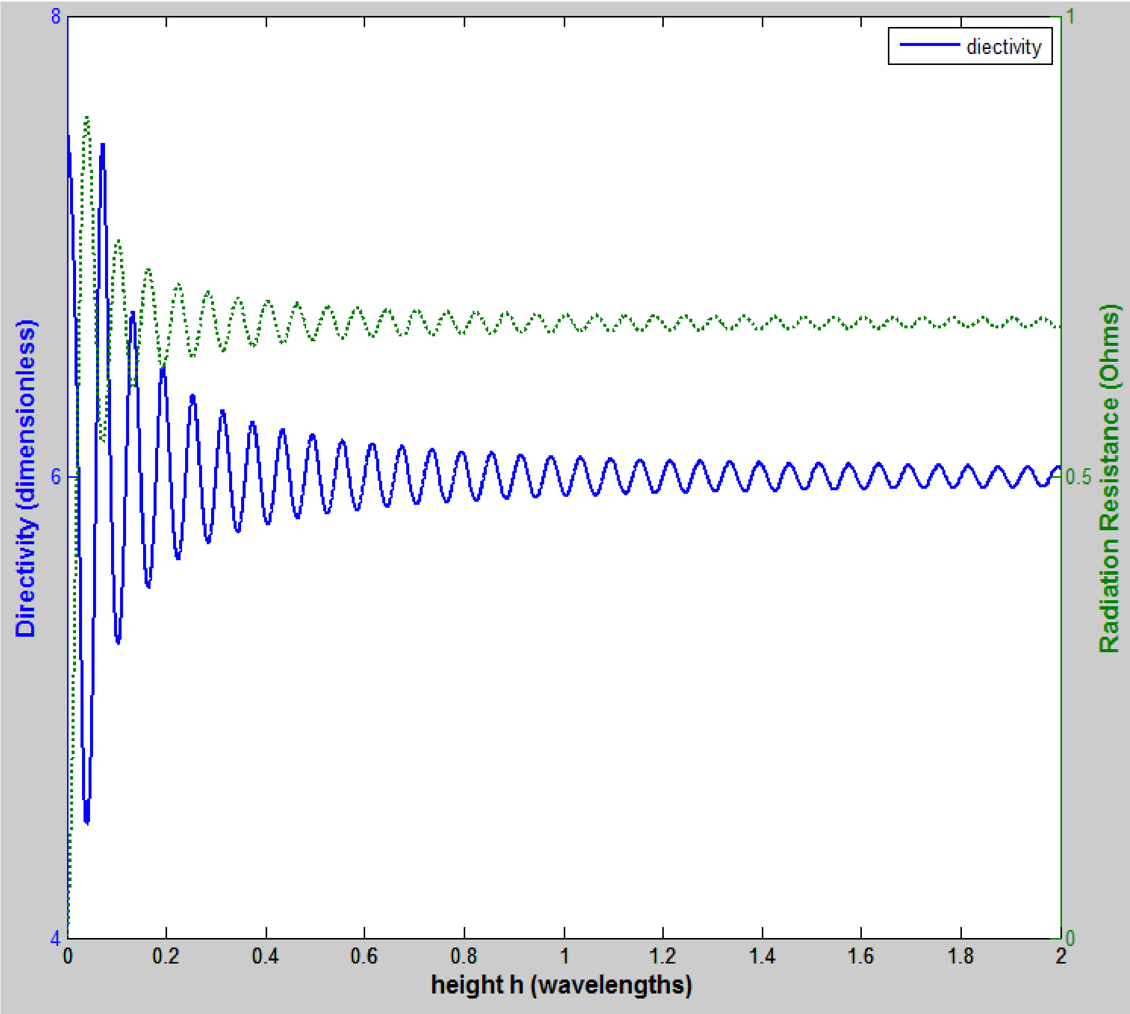


Fig 5.8: Directivity Vs. Radiation Resistance Vs. Height

5.4 Designing A VHF(30-300MHz) Yagi-Uda Array Antenna

Yagi-Uda array antennas can be operated in the VHF mode(very high frequency) mode whose frequency range lies in between 30-300Mhz.In this part we will design a “15 element Yagi-Uda array antenna” operating at 220Mhz as the frequency is in the VHF region.

5.4.1 Design Modifications of a 15 element Yagi-Uda Antenna

In order to design a 15 element Yagi antenna, the design modifications are given below:

- No. of elements =15
- No. of directors =13
- No. of reflectors =1
- No. of exciters =1
- Total length of reflectors = 0.5 λ
- Total length of feeder= 0.47 λ
- Total length of each director= 0.406 λ
- Spacing between reflector & feeder = 0.25 λ
- Spacing between adjacent directors = 0.34 λ
- radius= 0.003 λ

5.4.2 Radiation Pattern

After designing a 15 element Yagi-Uda Array antenna under above modifications via 4NEC2 we get the radiation pattern from the antenna. We will see that the radiation pattern is totally different than before that we saw from a single dipole antenna.

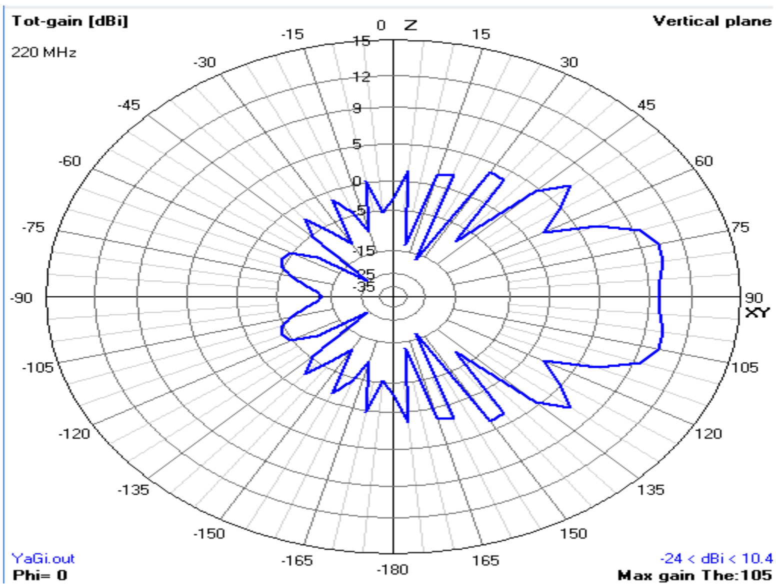


Fig 5.9:Normal View Of Radiation Pattern(Yagi-Uda)

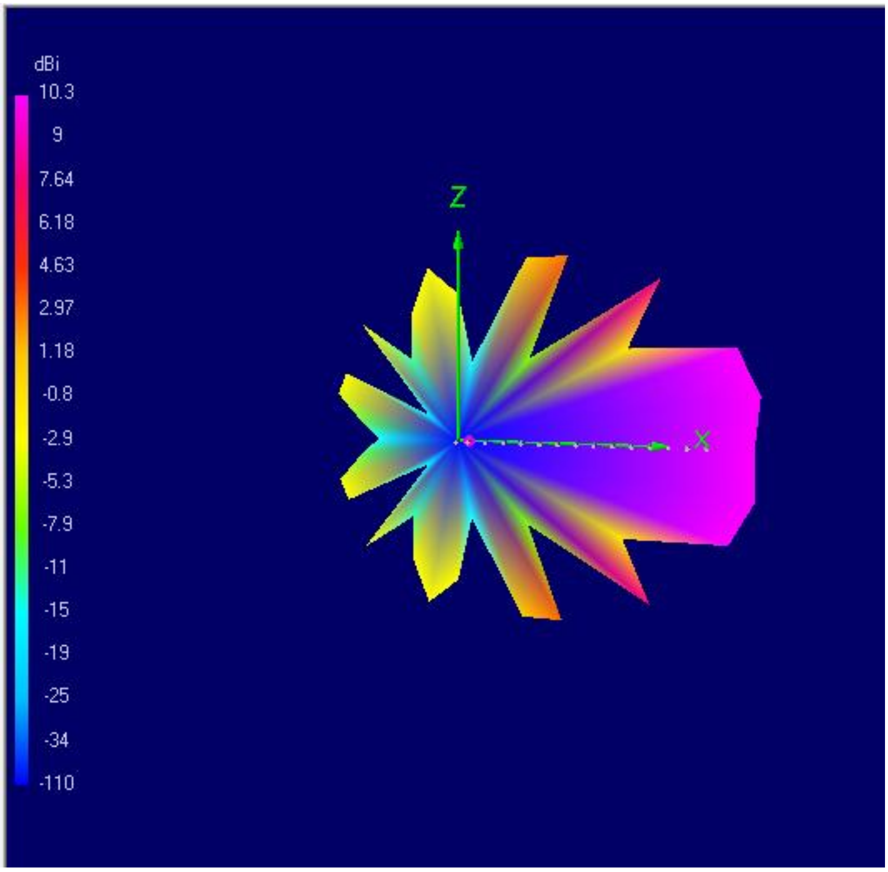


Fig 5.10: 3D View Of Radiation Pattern(Yagi-Uda)

5.4.3 SWR Curve

Like previous cases, after designing the 15 elements Yagi-Uda array antenna via 4NEC2 software the SWR pattern(Standing Wave Ratio) can be achieved by running the software in the frequency sweep.
In the frequency sweep mode we have to select the range of frequency. As we are designing the antenna at resonant frequency of 220MHz,we can select the range of frequency between 100 to 1000MHz.

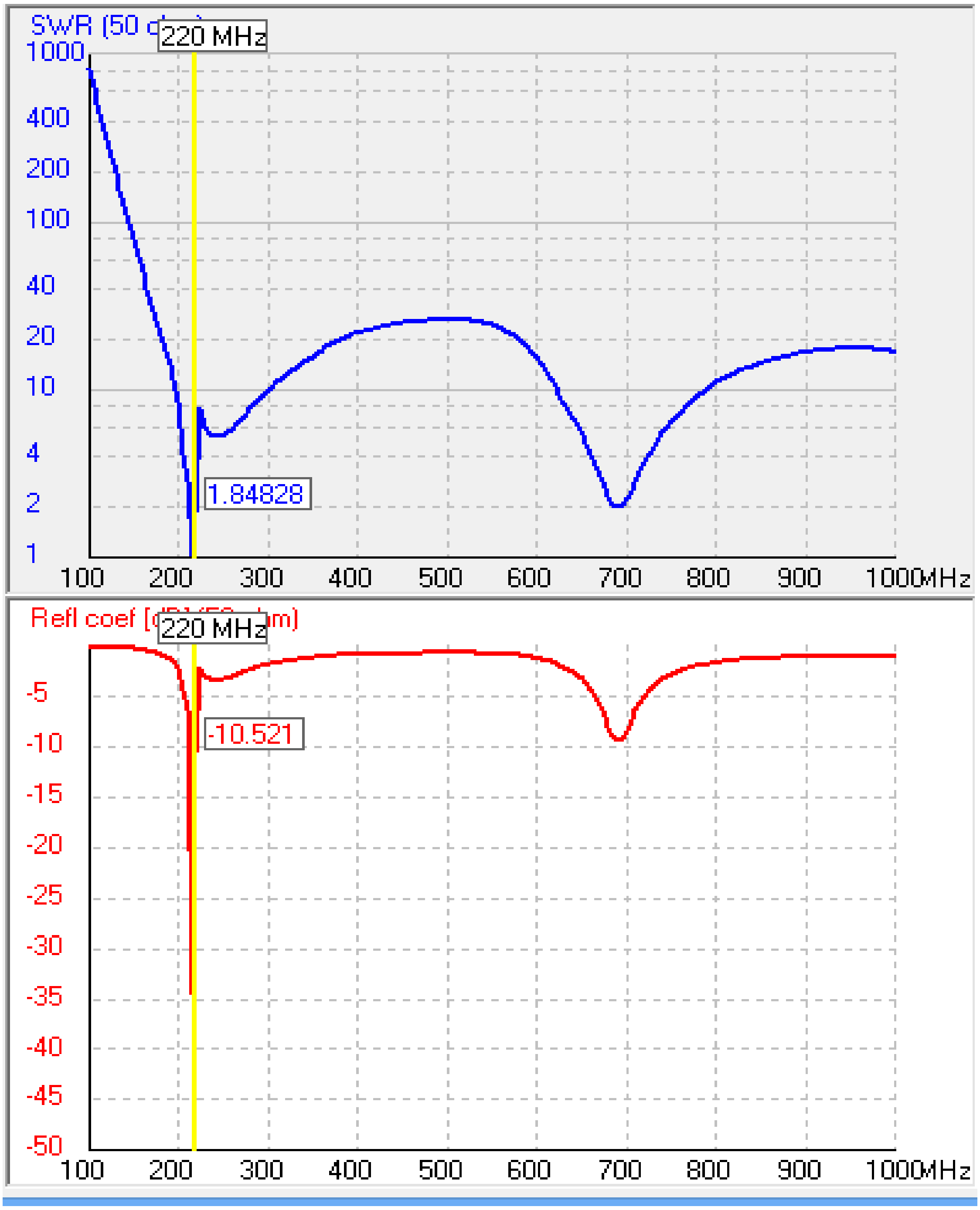


Fig 5.11: SWR Curve Of Yagi-Uda Antenna

We see,the above SWR curve is totally different from the SWR pattern of the dipole antenna.Rather,it is better than before.So,Yagi-Uda array antenna is better for telecommunications.

5.4.4 Gain Curve

Gain is the most valuable and important parameter of antenna designing in case of RF applications and telecommunications. Accuracy of the communications depends largely on this parameter. Yagi-Uda array antenna provides better gain for telecommunications. The gain of a Yagi-Uda is only moderate, but for the frequency range given above it is cheap and relatively simple to build. t is found that as the Yagi gain increases, so the beam-width decreases. Antennas with a very high level of gain are very directive.

After designing the 15 elements Yagi-Uda Array antenna via 4NEC2 software and then running the software in the frequency sweep we can get the gain curve for the corresponding antenna.

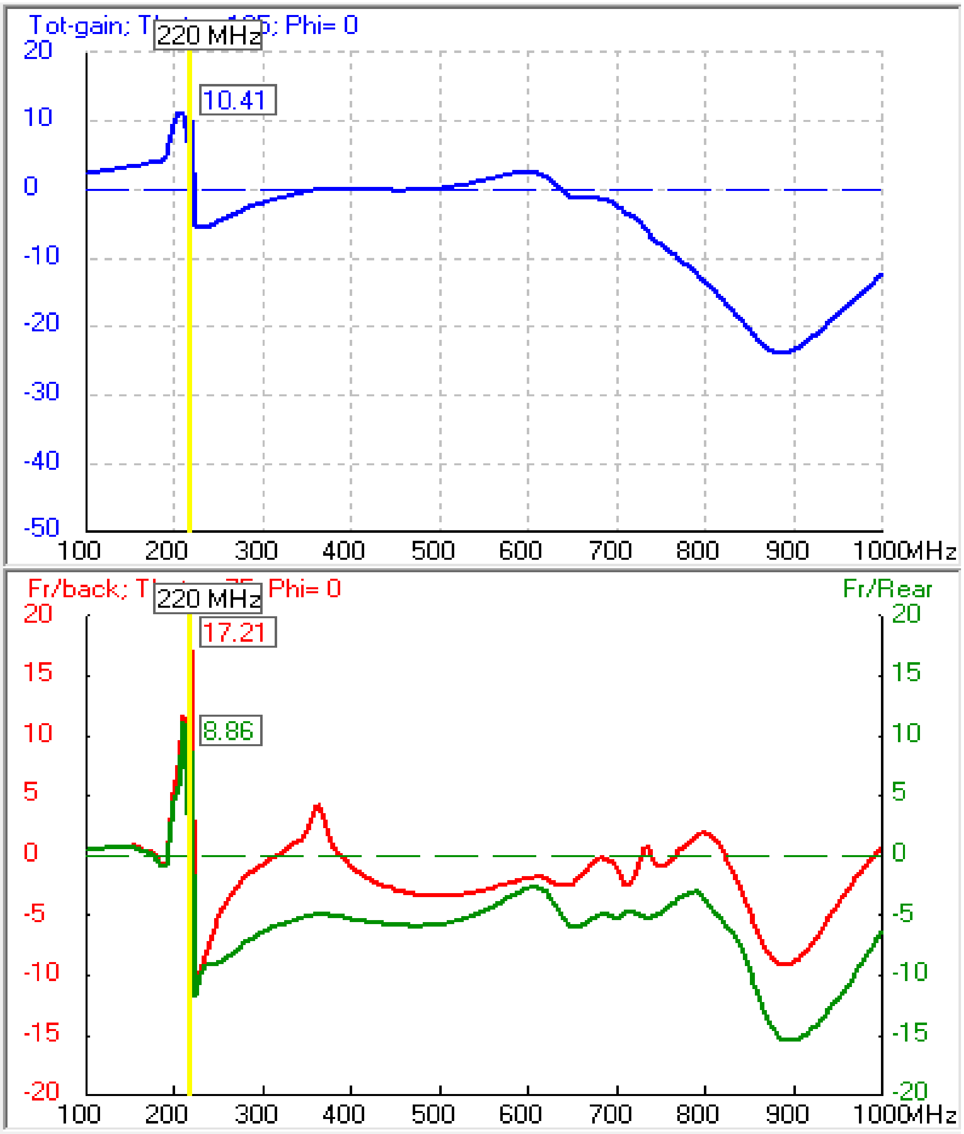


Fig 5.12:Gain Curve Of Yagi-Uda Antenna

5.4.5 Impedance Curve

It is possible to vary the feed impedance of a Yagi antenna over a wide range. Although the impedance of the dipole itself would be 73 ohms in free space, this is altered considerably by the proximity of the parasitic elements [16].

Nevertheless the proximity of the parasitic elements usually reduces the impedance below the 50 ohm level normally required. It is found that for element spacing distances less than 0.2 wavelengths the impedance falls rapidly away [16].

After designing via 4NEC2 the 15 elements Yagi-Uda antenna we can get the impedance curve like this-

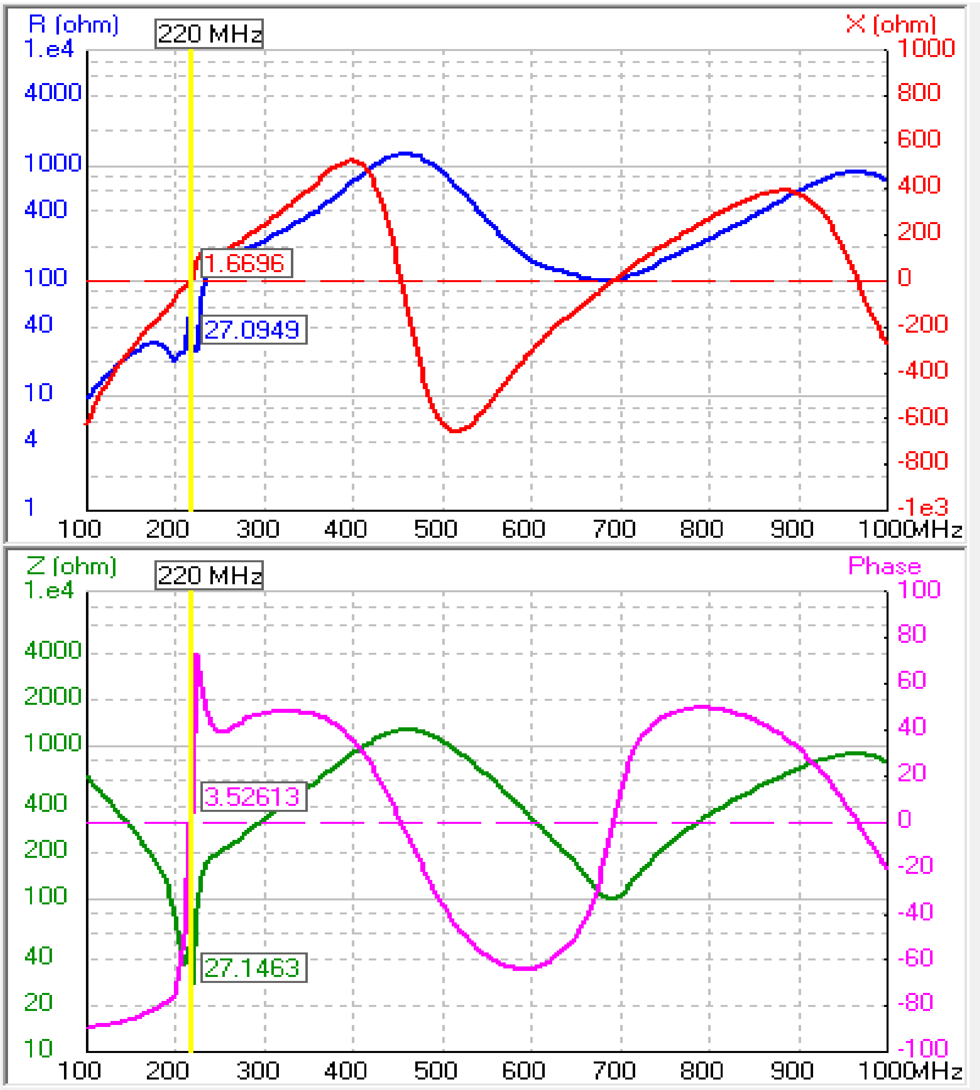


Fig 5.13: Impedance diagram Of Yagi-Uda Antenna

The **Blue Line** denotes the radiation resistance. From the figure we can see that the value of $R_{rad} = 27.0949\Omega$ which is below 50Ω.

5.4.6 Parameters Analysis via MATLAB

The design parameters of Yagi-Uda antenna can also be simulated via **MATLAB coding.** Simulation via a MATLAB coding we have found some design parameters of Yagi-Uda Array antenna.

5.4.6.1 Radiation pattern

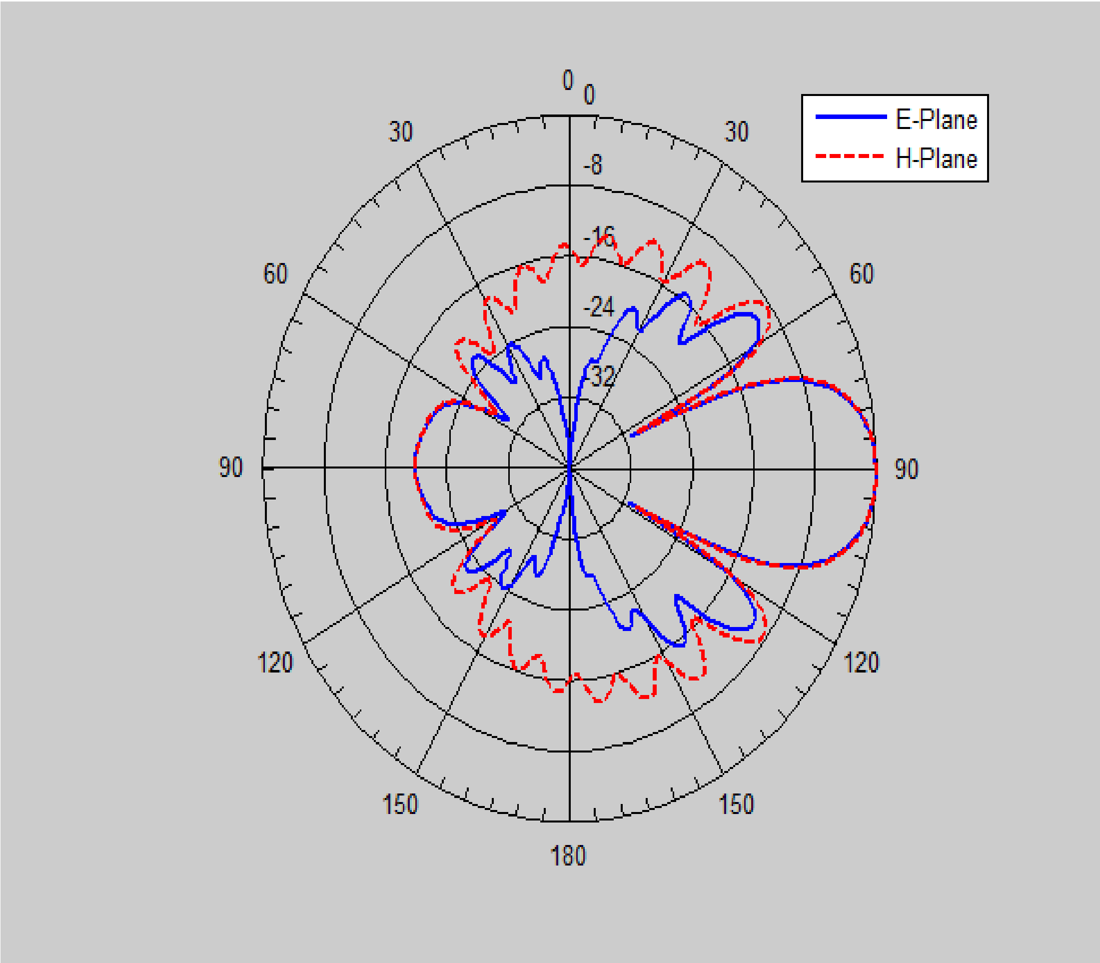
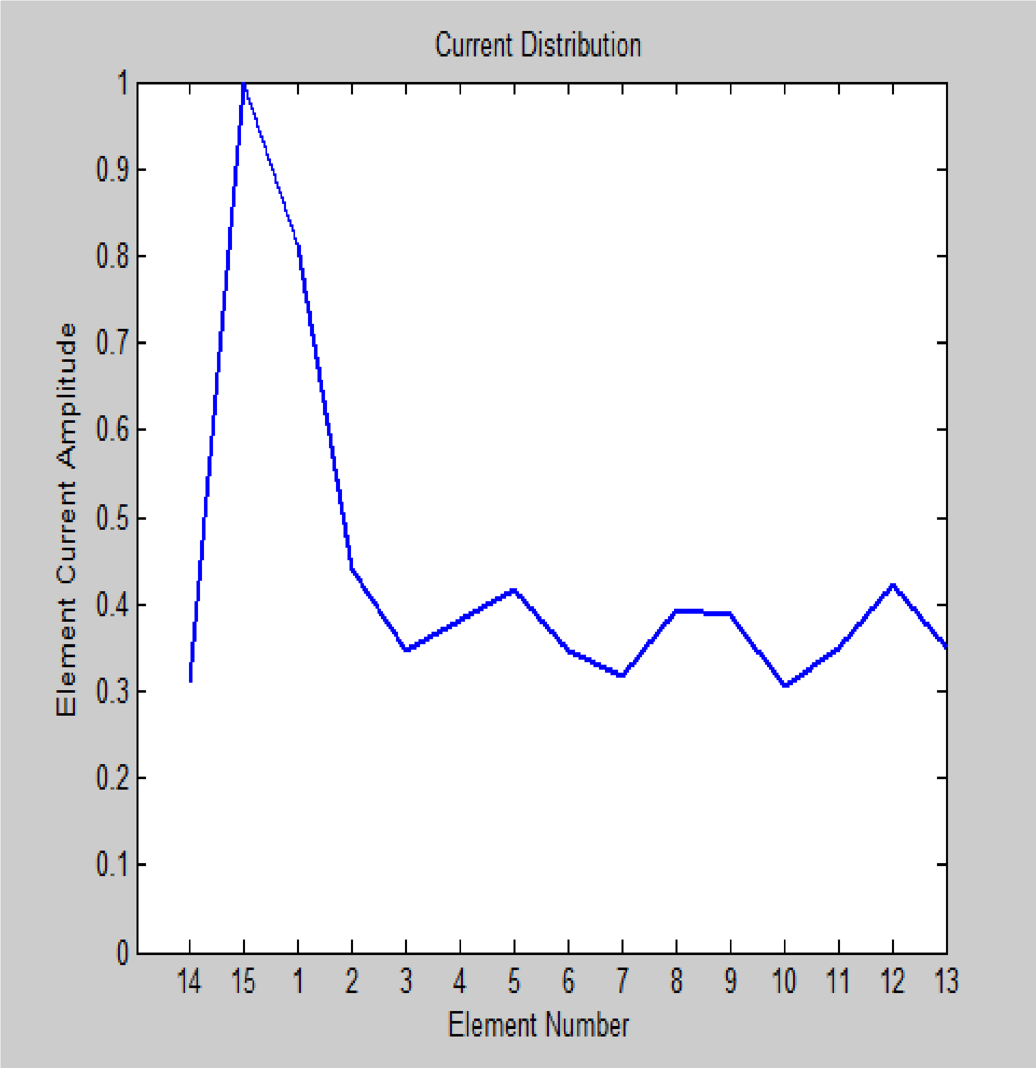


Fig 5.14: Radiation Pattern Via MATLAB Coding(Yagi-Uda)

5.4.6.2 Current Distribution



<u>Fig 5.15: Current Distribution In Yagi-Uda Antenna</u>

After simulating the Yagi-Uda Antenna current parameter via MATLAB we get the current distribution like above. We see from the figure that the current distribution of the corresponding Yagi-Uda Antenna is not uniform. With the increase of elements of the Yagi-Uda array antenna the current distribution also changes.

CHAPTER-6

RESULTS AND COMPARISON

6.1 Half-wavelength dipole of $R_{rad} = 73\Omega$

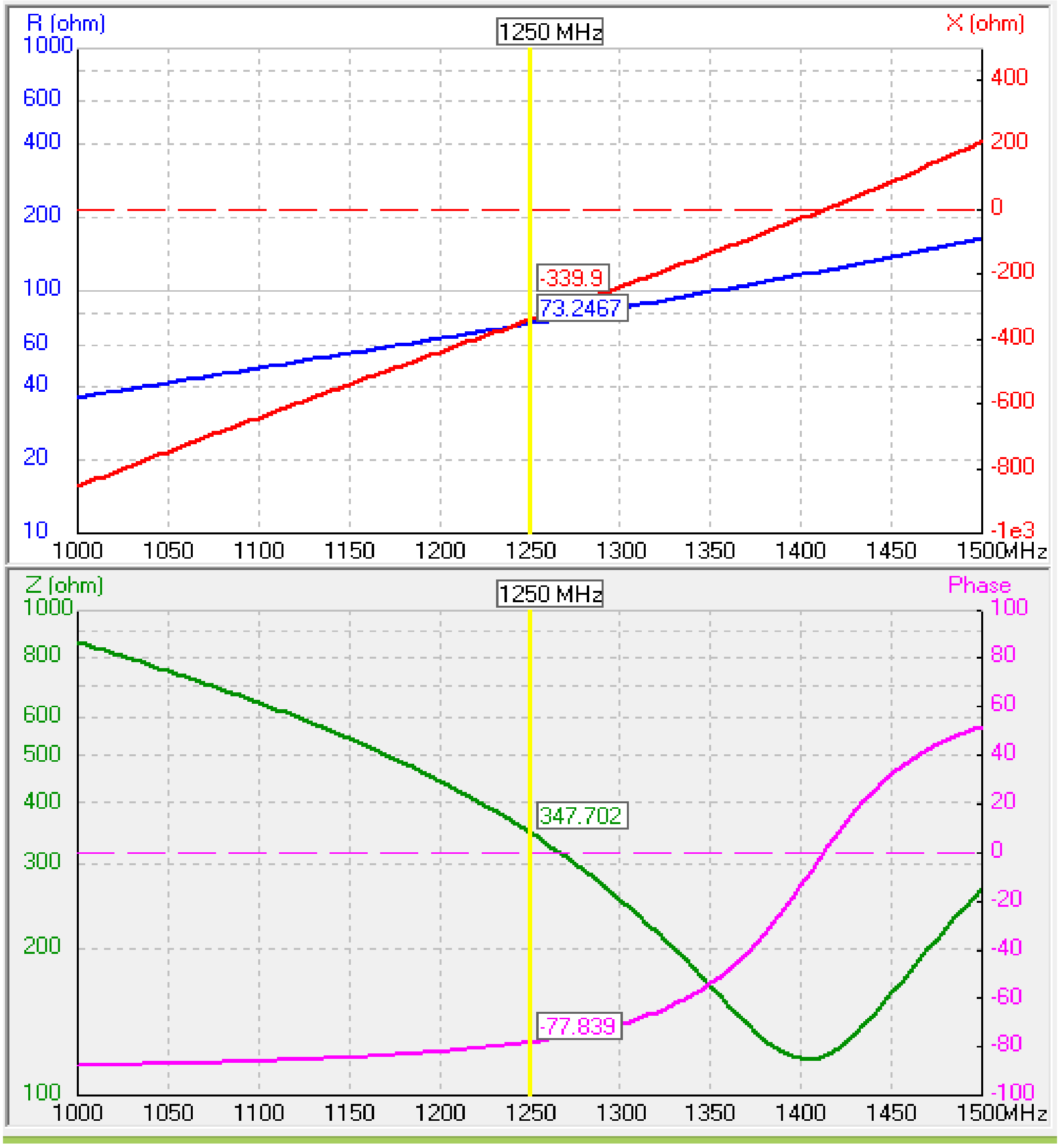


Fig 6.1: Impedance diagram with $R_{rad} = 73\Omega$

6.2 Half-wavelength dipole antenna radiation pattern under free space Vs. Under Ground effect

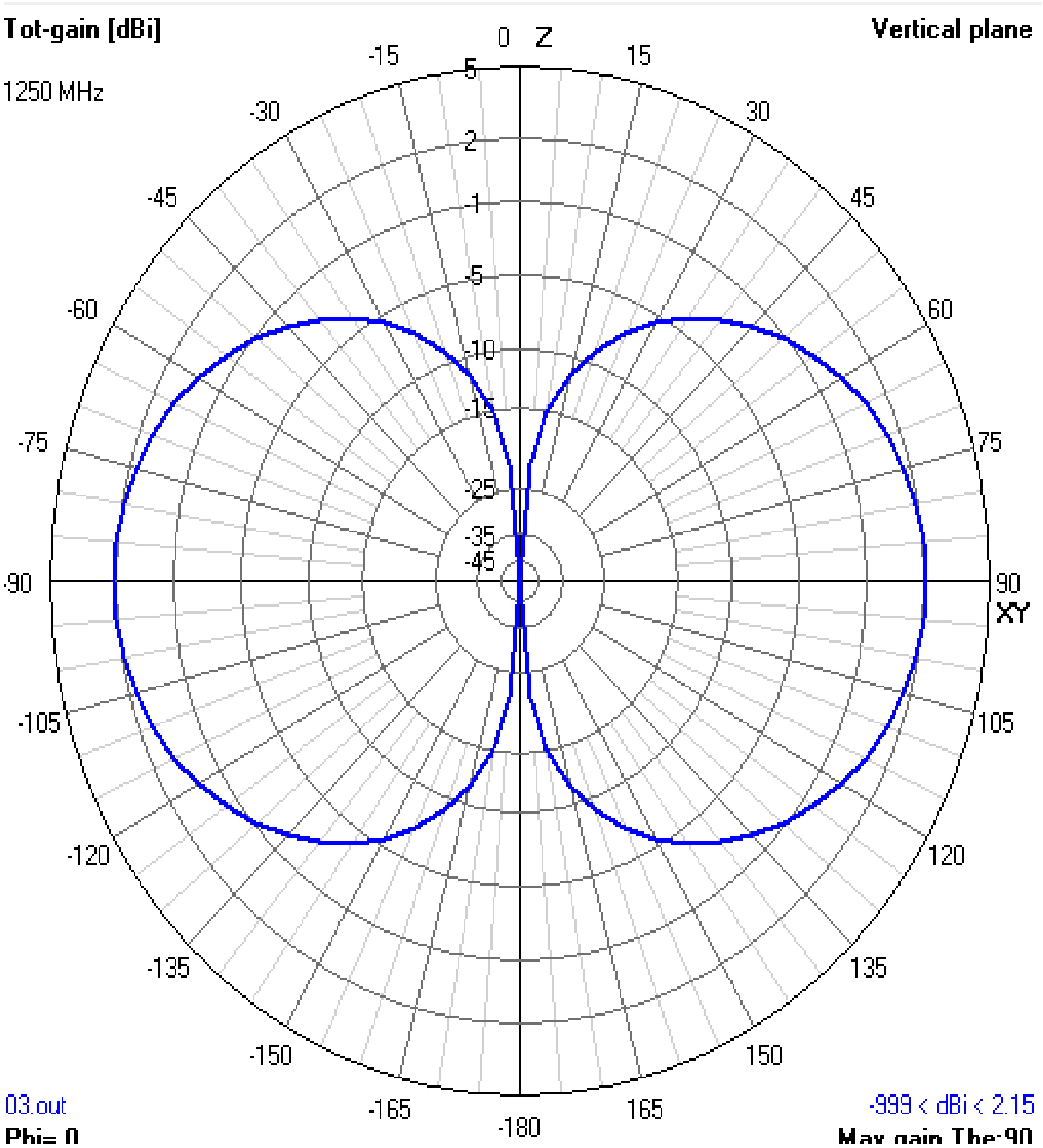


Fig 6.2: Radiation Pattern Under Free Space(dipole)

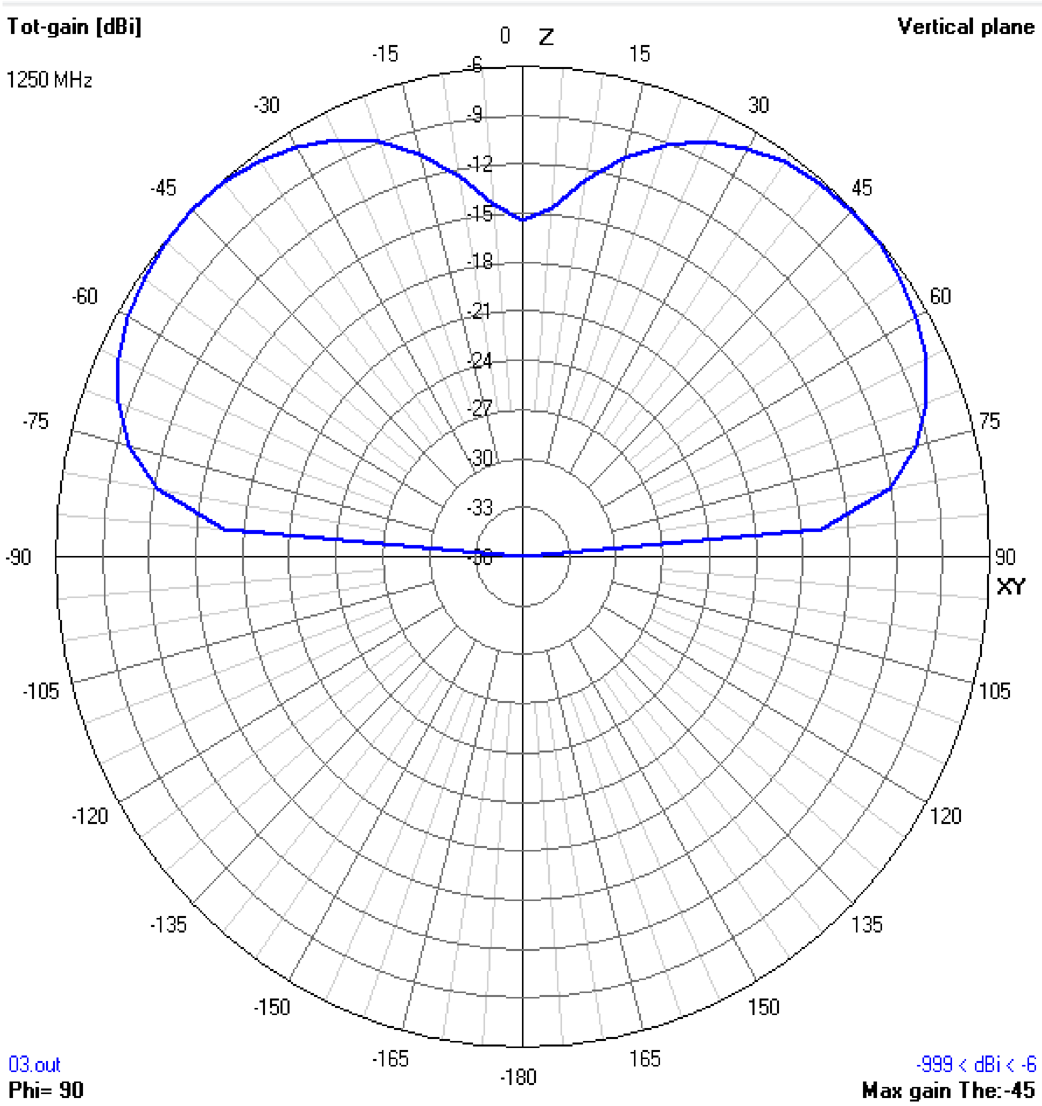


Fig 6.3: Radiation Pattern Under Ground Effect(dipole)

So, the difference between these two effects is noticeable. In case of free space effect there are two sided lobes but under ground effect the antenna has a radiation pattern consisting of upper half portion only.

6.3 Comparison Of Radiation Pattern Of Yagi-Uda Antenna

We have design the Yagi-Uda antenna via 4NEC2 and also simulate the antenna's different parameters. We have also used a MATLAB coding for the simulation of Yagi-Uda Array Antenna. Thus we can easily compare these two results.

6.3.1 Simulation By 4NEC2

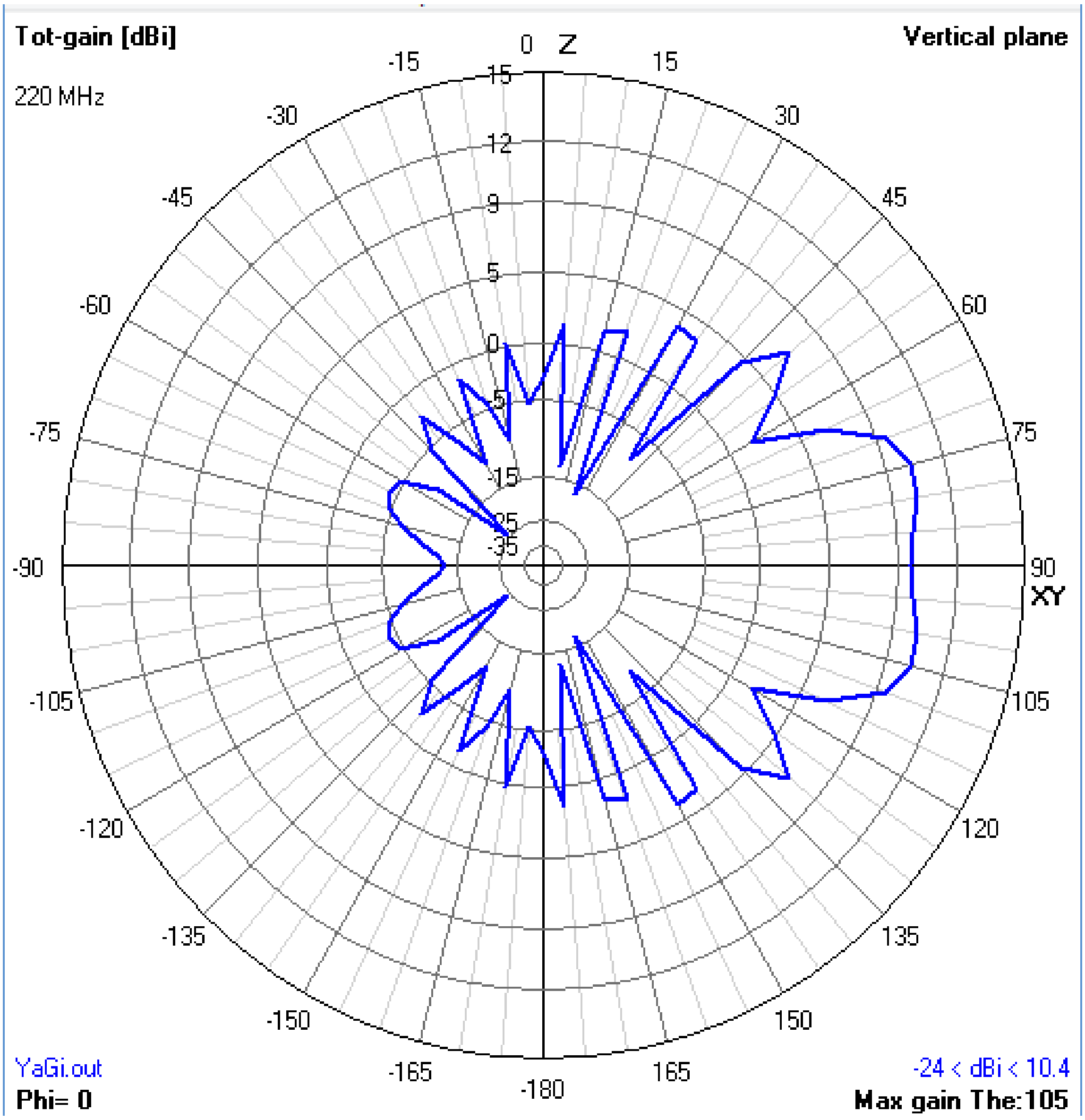


Fig 6.4: Radiation Pattern Via 4NEC2(Yagi-Uda)

6.3.2 Simulation via MATLAB

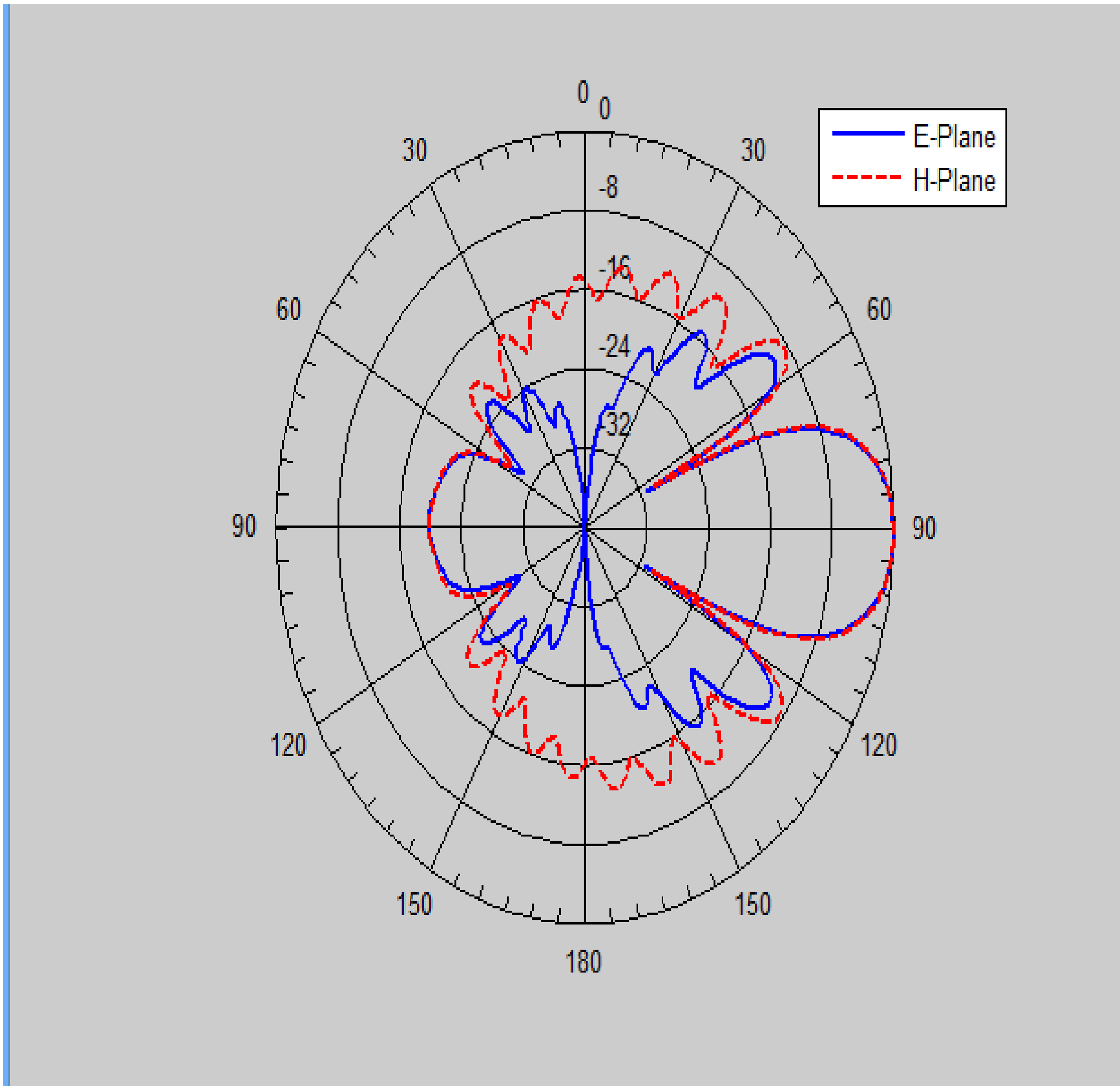


Fig 6.5: Radiation Pattern Simulation Via MATLAB(Yagi-Uda)

CHAPTER-7

CONCLUSION AND FUTURE WORK

This project is concluding the entire project thesis and propose/recommend some enhancement work to bring the research work more interesting and effective.

7.1 Conclusion

The dipole antennas are mostly used in mobile telecommunications system [17],[18]. The Yagi-Uda array antennas are widely used in broadband communications, T.V. applications and other RF applications. In our project we have tried to design a half-wavelength dipole antenna and 15 elements Yagi-Uda Array Antenna via 4NEC2 software. We have also tried to observe different parameters of antenna after designing these antennas and simulating it. In every case we have modified design modifications, design measurements, operating frequency, required environment for proper design.
We have specified every antenna parameters with their formulas and design equations for designing the antennas.
Directivity is an important parameter of antenna designing. We have also used a MATLAB code for simulating this parameter with the change of antenna height and radiation resistance.
We have also used some MATLAB code for simulation of various antenna parameters and then compared them with the 4NEC2 outputs.
From the 4NEC2 outputs we have seen that the simulation results are nearly similar to the simulation via MATLAB coding. So, in this project

we have also succeeded to show the relationship between 4NEC2 software designing and MATLAB coding .

7.2 Future Work

So far we have designed Linear Wire Antennas and Yagi-Uda Array Antenna and simulate them via 4NEC2 and MATLAB with a particular frequency. The frequency selected for designing half-wavelength dipole was 1250 MHZ and the Yagi-Uda Array antenna was designed under the VHF (very high frequency) range (30-300MHZ) . The resonant frequency selected for designing Yagi-Uda Array antenna was 220 MHz These frequencies are a little bit more but they are not applicable to WiMax technology or UHF(Ultra High Frequency) technologies. These technologies operate at a very high resonant frequency. UHF region lies in the frequency range of (300-3000 MHz). The resonant frequency of Yagi-Uda Array antenna for WiMax operation is about 1GHz.We have not designed yet any antenna operating at such a very high frequencies. Our future work is to design a practical Yagi-Uda antenna for WiMax applications under a very high frequency of about 1GHz and simulate various parameters of the corresponding antenna.

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