DESIGN OF BASIC ANTENNAS & ANALYSIS OF VARIOUS ANTENNA PARAMETERS USING MATLAB

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Abstract : A person who needs to convey thoughts, ideas, or a doubt can do so through voice communication. Here, communication takes place through sound waves. However, if two people want to communicate who are at long distances, then these sound waves are to be converted into electromagnetic waves. The device which converts required information signal into electromagnetic waves is called "antenna" or "aerial". It is a transducer which converts electrical signals into electromagnetic signals and vice-versa. Whenever wireless communications occur there arises necessity of an antenna. There are several critical parameters affecting an antenna's performance that can be adjusted during the design process. They are field patterns, power pattern, resonant frequency, impedance, gain, polarization, directivity, efficiency and beam width. Out of these, parameters like radiation pattern, directivity, VSWR, impedance ,axial ratio, return loss are studied using MATLAB(MATrix LABoratory) antenna toolbox. It provides the library of antennas and arrays, analysis, and visualization tools for using in these applications. It can also integrate with other toolboxes

***IndexTerms* - Axial ratio, Return loss, Radiation pattern**

I. INTRODUCTION

Antenna parameters like gain, directivity, radiation pattern play a very important role in the analysis of an antenna. This paper mainly focuses on the design of various antennas such as dipole, loop, slot, reflector, helical antenna, micro-strip patch, yagi-uda and generating radiation patterns which provide us the antenna parameters such as directivity, gain, elevation and azimuth angles. Firstly, a literary survey of basic and existing antenna types was done. The basic antenna types included the dipole, aperture, various types of horn, helical, micro-strip. The next step was to perform the theoretical analysis of these types of antennas to match with the existing operating values. Here, outputs were verified theoretically. As mentioned earlier, MATLAB consists of Antenna Toolbox which enables to design and perform analysis on various antennas using various built-in commands. It defines various classes for this purpose. They are given as follows: Dipole antennas, Monopole antennas, Loop antennas, Spiral antennas, Patch antennas, and Other antennas which include cavity, helix, reflector, slot, vivaldi, yagi-Uda. Various classes for the design include:

Table-1:Classes of various antennas

Dipole Antennas

bowtieRounded	Create rounded bowtie dipole antenna
bowtieTriangular	Create planar bowtie dipole antenna
biquad	Create biquad antenna
dipole	Create strip dipole antenna
dipoleFolded	Create folded dipole antenna
dipoleMeander	Create meander dipole antenna
dipoleVee	Create V-dipole antenna
dipoleHelix	Create helical dipole antenna
dipolehelixMultifilar	Create balanced bifilar or quadrafilar dipole helix antenna without circular ground plane
dipoleBlade	Create blade dipole antenna
dipoleCycloid	Create cycloid dipole antenna
dipoleJ	Create J-dipole antenna
dipoleCrossed	Crossed dipole or turnstile antenna

Monopole Antennas

invertedF	Create inverted-F antenna over rectangular ground plane
invertedL	Create inverted-L antenna over rectangular ground plane
invertedFcoplanar	Create inverted-F antenna in same plane as rectangular ground plane
invertedLcoplanar	Create inverted-L antenna in same plane as rectangular ground plane
monopole	Create monopole antenna over rectangular ground plane
monopoleTopHat	Create capacitively loaded monopole antenna over rectangular ground plane

Loop Antennas

loopCircular	Create circular loop antenna
loopRectangular	Create rectangular loop antenna

Spiral Antennas

spiralArchimedean	Create Archimedean spiral antenna
spiralEquiangular	Create equiangular spiral antenna

Patch Antennas

patchMicrostrip	Create microstrip patch antenna
patchMicrostripCircular	Create probe-fed circular microstrip patch antenna
patchMicrostripInsetfed	Create inset-fed microstrip patch antenna
pifa	Create planar inverted-F antenna
patchMicrostripEnotch	Create probe-fed E-shaped microstrip patch antenna
patchMicrostripHnotch	H-shaped microstrip patch antenna
patchMicrostripTriangular	Create triangular microstrip patch antenna

Slot Antennas

slot	Create rectangular slot antenna on ground plane
vivaldi	Create Vivaldi notch antenna on ground plane

Helix Antennas

helix	Create helix or conical helix antenna on ground plane
dipoleHelix	Create helical dipole antenna
helixMultifilar	Creates bifilar or quadrafilar helix or conical helix antenna on circular ground plane
dipolehelixMultifilar	Create balanced bifilar or quadrafilar dipole helix antenna without circular ground plane

Fractal Antennas

fractalKoch	Create Koch curve fractal dipole or loop antenna on X-Y plane
fractalGasket	Create Sierpinski's Gasket fractal antenna on X-Y plane
fractalCarpet	Create Sierpinski's carpet fractal antenna
fractalIsland	Minkowski's loop fractal antenna

Waveguides

waveguide	Create rectangular waveguide
horn	Create horn antenna

II ANTENNA PARAMETERS

Other antenna parameters discussed in this paper includes axial ratio, radiation pattern, return loss.

2.1Radiation pattern

Radiation is the term used to represent the emission or reception of wave front at the antenna, specifying its strength. In any illustration, the sketch drawn to represent the radiation of an antenna is its radiation pattern. One can simply understand the function and directivity of an antenna by having a look at its radiation pattern. Note that 3-D radiation pattern of an antenna or array object over a specified range can obtained as follows:

Pattern(object, frequency)

This command returns radiation pattern of an antenna or array object

2.2 Axial ratio

The polarization state of an EM wave can also be indicated by Axial Ratio (AR). It is defined as

$$AR=OA/OB,\ 1 \leq AR \leq \infty \text{ or } 0(dB)\leq AR \leq \infty(dB)$$

where OA and OB are the major and minor axes of the polarization ellipse respectively. Note that axial ratio gives the type of polarisation.

AR=1-> Circular polarisation

1<AR<∞->Elliptical polarisation

AR=∞->Linear polarisation

Also, very often, we use the AR bandwidth and the AR beamwidth to characterize the polarization of an antenna. The AR bandwidth is the frequency bandwidth in which the AR of an antenna changes less than 3-dB from its minimum value. The AR beamwidth is the angle span over which the AR of an antenna changes less than 3-dB from its minimum value. Axial ratio can be obtained for any antenna as follows: `ar =` **`axialRatio(antenna, frequency, azimuth, elevation).`** This command returns the axial ratio of an antenna, over the specified frequency, and in the direction specified by, `azimuth` and `elevation`.

2.3 Return loss(Db)

RF energy travels through transmission lines (co-ax cables or PCB traces) just like sound travels through an empty room. It is susceptible to reflections and bounces. When we send RF down a co-ax or PCB trace , we want it to go into the antenna (then radiate out into the world). We do not want it to bounce back at us like sound in an empty room. This bounce back is called “return”. Return loss is the measure of how small the “return” or reflection is. We want a small return, so a large loss on the return “echo” is good. Smaller return is bad, and means less energy is going into our antenna. Return loss can be obtained for an antenna as follows: **returnLoss(antenna, frequency range)**.This command returns the plot between return loss in Db and frequency.

III ALGORITHM TO OBTAIN DESIGN OF AN ANTENNA USING MATLAB

In this section, algorithm for the design of an antenna is presented. From the above data mentioned in the introduction part, it is clear that to design an antenna, firstly two things are to be taken into consideration

3.1 If an antenna has only one word as a keyword , then command is given by initiating with lower case letter (eg: dipole of dipole class)

3.2 If antenna has two words in it, first word is to be initiated with lower case letter and second word with upper case letter.(eg: yagiUda of other antennas class)The same is applicable to the three word antenna.(eg: monopoleTopHat antenna of monopole class).

3.3 Now, assign a variable to the desired name of the antenna.

3.4 Press ‘enter’ in the MATLAB command window, then specifications of all the properties of antenna such as length, width, feed offset, tilt, tilt axis will be displayed.

3.5 These specifications can further be changed as follows:

3.5.1 Give the variable of an antenna with a dot extension and specify the property that is to be changed and assign it with desired value using ‘=’ symbol.

Eg:

Consider a case of dipole antenna

d = dipole with properties:

Length: 2

Width: 0.1000

FeedOffset: 0

Tilt: 0

TiltAxis: [1 0 0]

Note that these properties are obtained by default using Antenna toolbox. These properties can be altered. For this consider an above example.

If length is to be changed to 5 instead of 2, it can be done as follows:

d**.**Length=5 (here, d specifies variable that is assigned to dipole class, length is the property of an antenna, 5 is the desired value for the design).

3.6 Now, to display the design use a command called ‘show(variable)’,where variable in the above example considered is ’d’. In this way antenna design with the required specifications can be obtained.

IV DESIGN OF VARIOUS ANTENNAS AND CALCULATION OF ANTENNA PARAMETERS

4.1 DIPOLE ANTENNA

Wires of half wavelengths are termed as dipoles. A thin-wire can act as a dipole. It is a flared up version of a transmission line. Flaring is done in-order to avoid mismatch between a guided wave and a free-space wave. It’s operating frequency range is from 20 MHz to 2.2GHz.It’s radiation resistance is theoretically 73 ohms.

Design of a dipole antenna can be obtained by using Matlab command window as follows:

d=dipole

d = dipole with properties:

Length: 2

Width: 0.1000

FeedOffset: 0

Tilt: 0

TiltAxis: [1 0 0]

>> show(d)

Radiation pattern for the frequency of 1.6GHz is obtained as follows:
pattern(d,1.6e9)

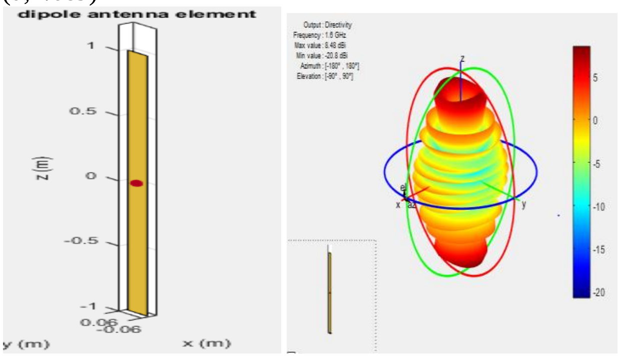


Fig-4.1.1 Design and radiation pattern of dipole antenna

From the above fig-1, it is clear that for a dipole with the frequency of 1.6MHz, Maximum value of directivity: **8.48 dBi ,** Minimum value of directivity : **-20dBi,** Azimuth angle: [-180,180], Elevation angle: [-90,90], Here , elevation angle is of 180,azimuthal angle is of 90

Axial Ratio for the frequency of 1.6GHz is obtained as follows:
>>axialRatio(d,1.6e9,180,90)
321.3055

Return loss for the frequency range from 200MHz-700MHz is obtained as follows:
returnLoss(d,200e6:1e6:700e6)

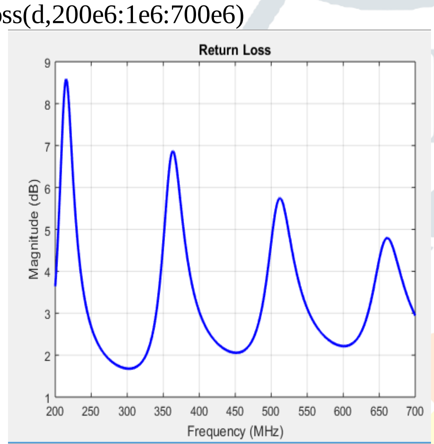


Fig-4.1.2 Magnitude v/s Frequency

4.2. LOOP ANTENNA

An RF current carrying coil is given a single turn into a loop, can be used as an antenna called as loop antenna .The frequency range of operation of loop antenna is around 300MHz to 3GHz. This antenna works in UHF range. It may be in any shape such as circular, rectangular, triangular, square or hexagonal according to the designer's convenience. It is mostly used as a receiving antenna.

Design of a circular loop antenna can be obtained by using Matlab command window as follows:
l=loopCircular
l = loop Circular with properties:
Radius: 0.6366
Thickness: 0.0200
Tilt: 0
TiltAxis: [1 0 0]
>> show(l)

Radiation pattern for the frequency of 2GHz is obtained as follows:
pattern(l,2e9)

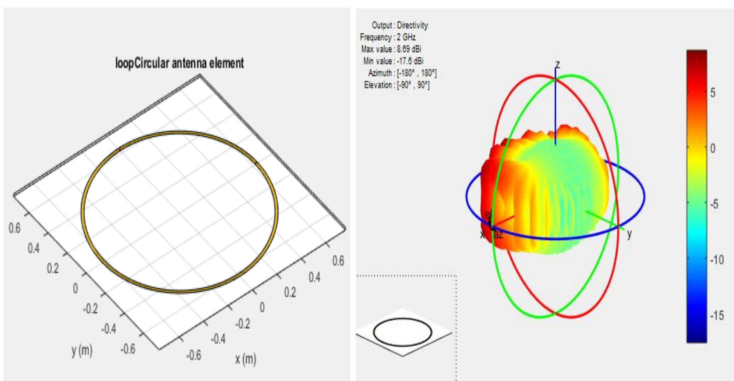


Fig-4.2.1 Design and radiation pattern of loop antenna

From the above fig-2, it is clear that for a loop antenna with the frequency of 2GHz, Maximum value of directivity: **8.69dBi,** Minimum value of directivity : **-17.6dBi,** Azimuth angle: [-180,180], Elevation angle: [-90,90]

Axial Ratio for the frequency of 2GHz can be obtained as follows:

```
>> axialRatio(l,2e9,180,90)
   27.9538
```

Also, radius specified here in the above properties is 0.6366.Now this radius can be changed as follows:

```
l.Radius=0.05
l =  loop Circular with properties:
Radius: 0.6366
Thickness: 0.0200
Tilt: 0
TiltAxis: [1 0 0]

>> show(l)
```

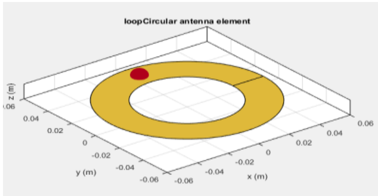


Fig-4.2.2 Loop antenna with varied radius

Return loss for the frequency range from 300MHz-600MHz is obtained as follows:

```
returnLoss(l,300e6:1e6:600e6)
```

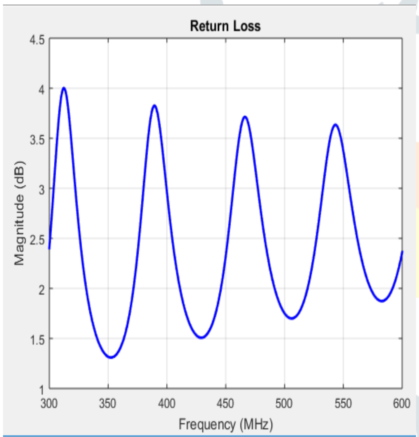


Fig-4.2.3 Magnitude v/s frequency

4.3 SLOT ANTENNA

Frequency range is from 300MHz to 30GHz.Practically,slot antenna can be obtained by removing a small portion in the large metallic sheet. It is said to be a 'complementary dipole' due to the fact that decrease in width of the small portion(slot) resembles like a thin wire.

Design of a slot antenna can be obtained by using Matlab command window as follows:

```
s=slot
s = slot with properties:
Length: 1
Width: 0.1000
SlotCenter: [0 0 0]
GroundPlaneLength: 1.5000
GroundPlaneWidth: 1.5000
FeedOffset: 0
Tilt: 0
TiltAxis: [1 0 0]
>> show(s)
```

Radiation pattern for the frequency of 350MHz can be obtained as follows:
pattern(s,350e6)

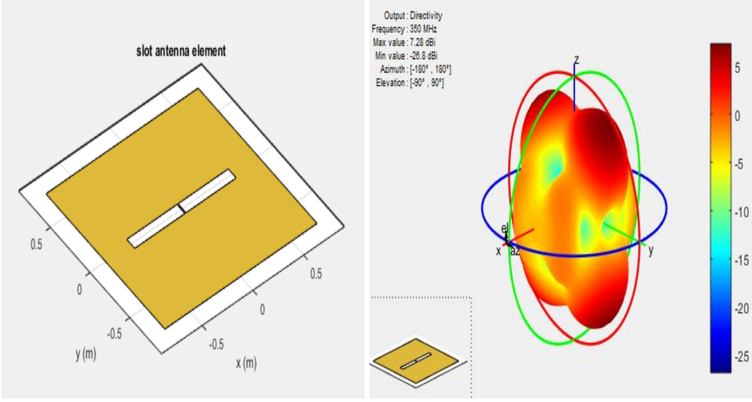


Fig-4.3.1 Design and radiation pattern of slot antenna

From the above fig-3, it is clear that for the slot antenna with the frequency of 350MHz, Maximum value of directivity : **7.28 dBi,**Minimum value of directivity : **-26.8dBi,** Azimuth angle: [-180,180], Elevation angle: [-90,90]

Axial Ratio for the frequency of 350MHz can be obtained as follows:
>>axialRatio(s,350e6,180,90)
  47.2346

Return loss for the frequency range from 350MHz -450MHz is obtained as follows:
returnLoss(s,350e6:1e6:450e6)

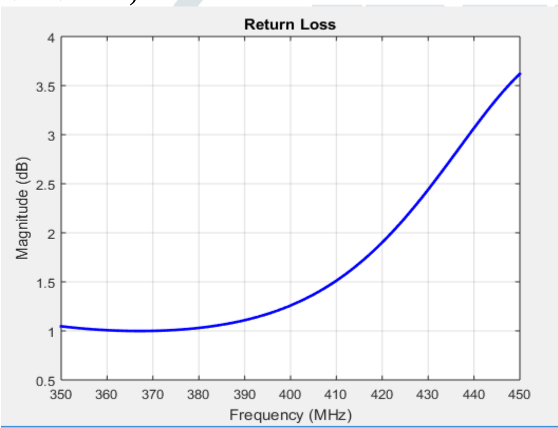


Fig-4.3.2 Magnitude v/s frequency

4.4. REFLECTOR(PLANE) ANTENNA

Frequency range of reflector antenna is in the order of microwaves. Hence, it is also called as microwave antenna. Practically, it is designed with the help of metallic sheet. Dipole is used as feeder. Spacing between feeder and reflector should be as less as possible to have more gain.
i.e, Spacing α 1/gain

Design of a plane reflector antenna can be obtained by using Matlab command window as follows:
r=reflector
r = reflector with properties:
Exciter: [1x1 dipole]
GroundPlaneLength: 0.2000
GroundPlaneWidth: 0.2000
Spacing: 0.0750
Tilt: 0
TiltAxis: [1 0 0]
>> show(r)

Radiation pattern for the frequency of 450MHz is obtained as follows:
pattern(r,450e6)

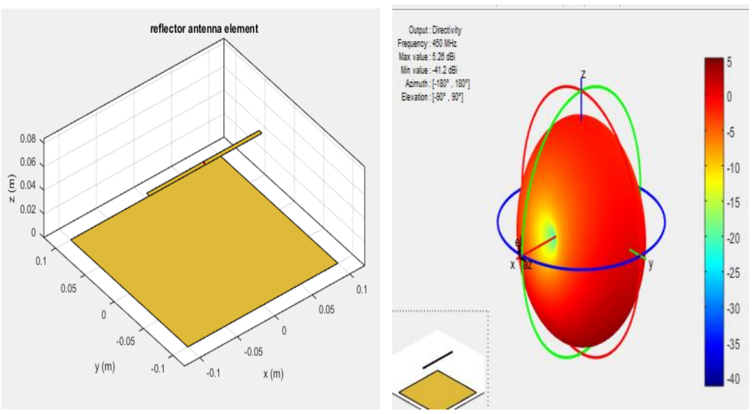


Fig-4 Design and radiation pattern of reflector antenna

From the above fig-4, it is clear that for the reflector antenna with the frequency of 450MHz, Maximum value of directivity : **5.26 dBi,** Minimum value of directivity : **-41.2dBi,** Azimuth angle: [-180,180],Elevation angle: [-90,90]

Axial ratio for the frequency of 450MHz can be obtained as follows:
>>axialRatio(r,450e6,180,90)
59.3943

Return loss for the frequency range from 350MHz-450MHz can be obtained as follows:
returnLoss(r,350e6:1e6:450e6)

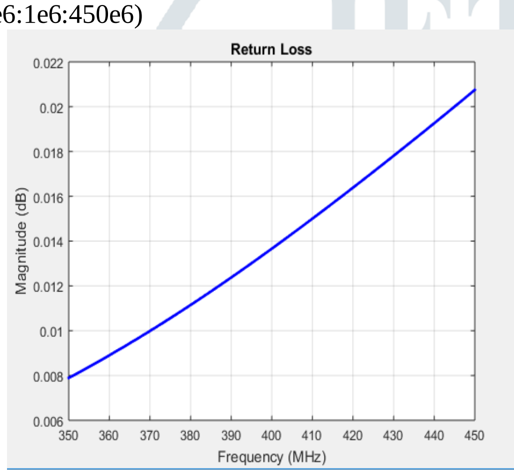


Fig-4.1 Magnitude v/s frequency

4.5 HELICAL ANTENNA(HELIX)

It supports UHF and VHF frequency bands. It is a broad band antenna. Practically, it is made up of two conductors. i.e, inner & outer conductors. Outer conductor is with reference to ground plane. Inner conductor is made up of copper wire. Two parameters play a major role in operation of helical antenna. They are spacing between the turns of copper wire(S) &diameter of helical antenna (D).When S->0, loop antenna is obtained out of helix &
when D->0,dipole antenna is obtained.

Design of Helical antenna can be obtained by using Matlab command window as follows:

h=helix
h = helix with properties:
Radius: 0.0220
Width: 1.0000e-03
Turns: 3
Spacing: 0.0350
GroundPlaneRadius: 0.0750
Tilt: 0
TiltAxis: [1 0 0]
>> show(h)

Radiation pattern for the frequency of 350MHz is obtained as follows:
pattern(h,350e6)

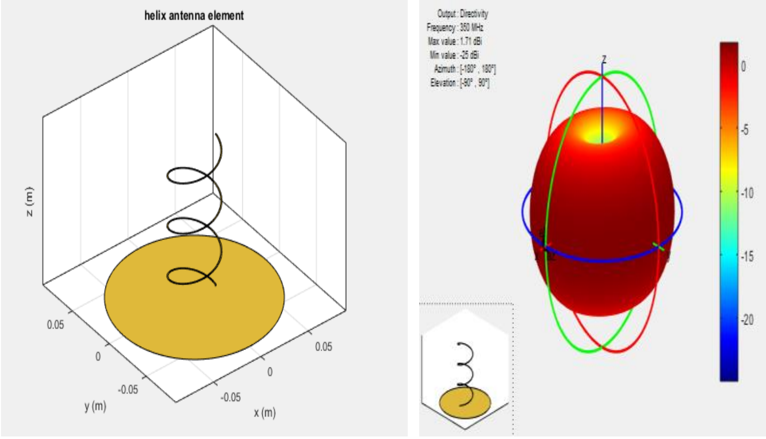


Fig-5 Design and radiation pattern of helical antenna

From the above fig-5, it is clear that for the helical antenna with the frequency of 350MHz, Maximum value of directivity : **1.71 dBi,** Minimum value of directivity : **-25dBi,** Azimuth angle: [-180,180], Elevation angle: [-90,90]

Axial ratio for the frequency of 350MHz can be obtained as follows:
>>axialRatio(h,350e6,180,90)
28.1041

Return loss for the frequency range of 350MHz - 450MHz can be obtained as follows:
returnLoss(h,350e6:1e6:450e6)

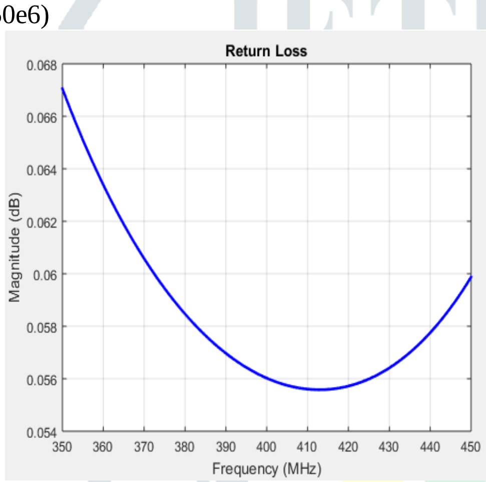
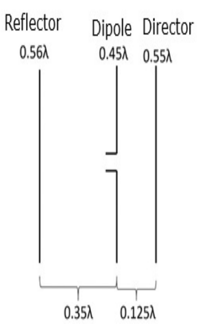


Fig-5.1 Magnitude v/s frequency

4.6 YAGI-UDA ANTENNA

The frequency range in which the Yagi-Uda antennas operate is around 30 MHz to 3GHz which belong to the VHF and UHF bands. It is seen that there are many directors placed to increase the directivity of the antenna. The feeder is the folded dipole. The reflector is the lengthy element, which is at the end of the structure. The center rod like structure on which the elements are mounted is called as boom. The single element present at the back of the driven element is the reflector, which reflects all the energy towards the direction of the radiation pattern. The other elements, before the driven element, are the directors, which direct the beam towards the desired angle. Practically, design is as follows:



Design of Yagi-uda antenna can be obtained by using Matlab command window as follows:
y=yagiUda
y = yagiUda with properties:
Exciter: [1x1 dipoleFolded]
NumDirectors: 3
DirectorLength: 0.4080
DirectorSpacing: 0.3400
ReflectorLength: 0.5000
ReflectorSpacing: 0.2500

Tilt: 0
TiltAxis: [1 0 0]
>> show(y)

Radiation pattern for the frequency of 1GHz is obtained as follows:
pattern(y, 1e9)

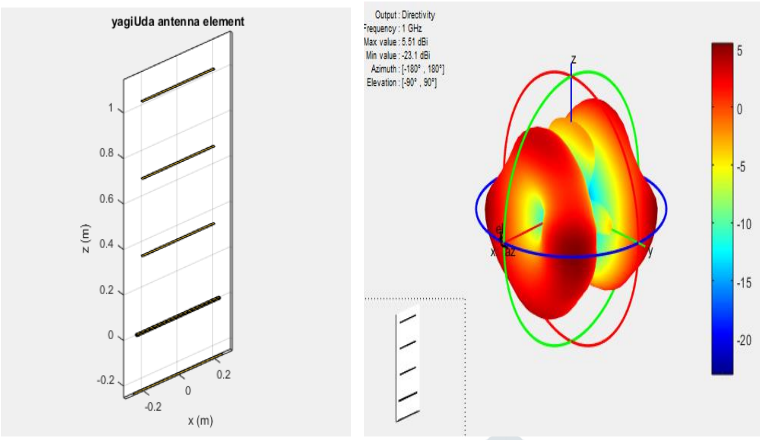


Fig-6 Design and radiation pattern of Yagi-uda antenna

From the above fig-6, it is clear that for the yagi-uda antenna with the frequency of 1GHz, Maximum value of directivity : **5.51 dBi,** Minimum value of directivity : **-23.1dBi,** Azimuth angle: [-180,180], Elevation angle: [-90,90]

Axial Ratio for the frequency of 1GHz is obtained as follows:
>>axialRatio(y,1e9,180,90)
53.5940

Return loss for the frequency range from 850MHz-950MHz is obtained as follows:
returnLoss(y,850e6:1e6:950e6)

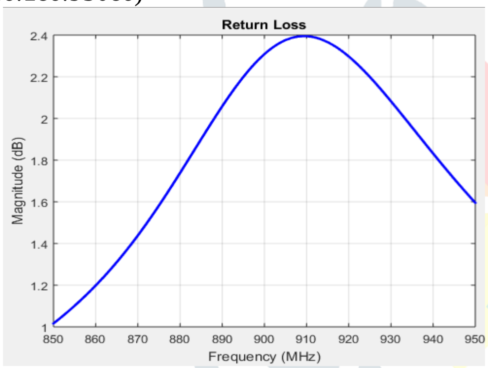


Fig-6.1 Magnitude v/s frequency

V. CONCLUSION

This paper successfully demonstrates a novel method of using MATLAB Antenna toolbox for designing and analyzing antenna & its parameters. The main advantage of using antenna toolbox in MATLAB is that the design & analysis is easier compared to HFSS(High-Frequency Structure Simulator) design of antennas. Also, This software finds its vast application in the research field. It is of great use for the RF engineers. By using this software we can find out which antenna will work better in a particular geographical area and which antenna will work with clusters. One can also perform comparisons with different types of antennas that are designed in this project. The results that I have got is based on the calculations and software only, these results can be checked with implementing hardware for a particular antenna. We can also create a whole system for communication by the help of this software. We can transmit a wave, receive it and check errors. The comparison of the antenna for a particular application can be done in future to select the best one out of the designed antennas.

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