**Innovative Teaching through Simulation and Demonstration**
**for B.E-E.C.E-A-III Year- V SEM**

Course: Antennas and Wave Propagation

# Design Analysis of Microstrip Patch Antenna using RF Simulation Tools

**BY**

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# DESIGN AND ANALYSIS OF MICROSTRIP ANTENNA USING ADS

**OBJECTIVE**: To design and simulate microstrip patch antenna patch antenna

## Theory:

A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors usually made of copper or gold can be virtually assumed to be of any shape. However, conventional shapes are normally used to simplify analysis and performance prediction. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The basic configuration of a microstrip patch antenna is shown in figure1

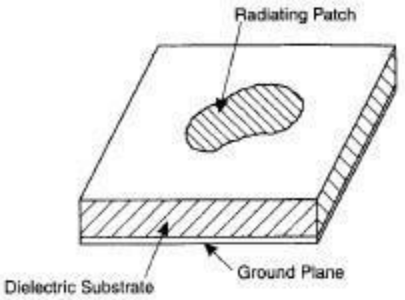


Fig. 1 Basic configuration of Microstrip Antenna

The radiating patch may be square, rectangular, circular elliptical or any other configuration. Square, rectangular and circular shapes are the most common because of ease of analysis and fabrication. Some of the advantages of the microstrip antennas compared to conventional microwave antennas are

- Low weight, low volume
- Low fabrication cost,
- Easy mass production,
- Linear and circular polarization are possible with simple feed,
- Easily integrated with MIC,
- Feed lines and matching networks can be fabricated simultaneously with antenna structures

Patch antennas find various applications stating from military to commercial, because of their ease of design and fabrication. Patch arrays are extensively used in phased array radar applications and in applications requiring high directivity and narrow beamwidth.

## *Design of a Patch Antenna at 2.4 GHz*

### Step1: Calculating Patch Antenna Dimensions

1. Select an appropriate substrate of thickness (h) and dielectric constant ($\varepsilon_r$) for the design of the patch antenna. In present case, we shall use following Dielectric for design:

    a. Height: 1.6 mm
    b. Metal Thickness: 1.4 mil (1 oz. Copper i.e. 35um)
    c. Er: 4.6
    d. TanD: 0.001
    e. Conductivity: 5.8E7 S/m

2. Calculate the physical parameters of the patch antenna as shown in the geometry in Figure 2 using the given formula.

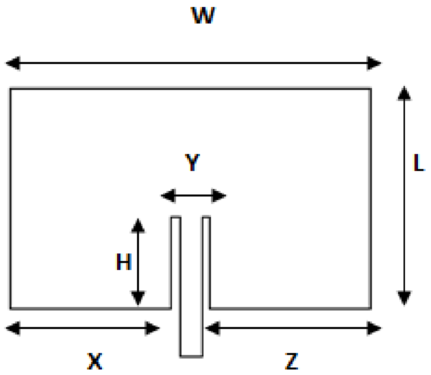


Fig. 2 Geometry of the Square Patch

Antenna The width and length of the radiating surface is given by,

$$W=L= \frac{c}{(2f\sqrt{\varepsilon_r})} = 29.2mm$$

where,

velocity of light $c = 3 \times 10^8$ m/s

Frequency, f = 2.4 GHz

Relative Permittivity $\varepsilon_r = 4.6$

The depth of the feed line in to the patch is given by,

$$H=0.822*L/2 = 12 \text{ mm}$$

The other dimensions are,

$$Y= W/5= 5.8 \text{ mm}$$

$$X = Z = 2W/5 = 11.7\text{mm}$$

### Step2: Creating Patch Antenna Geometry:

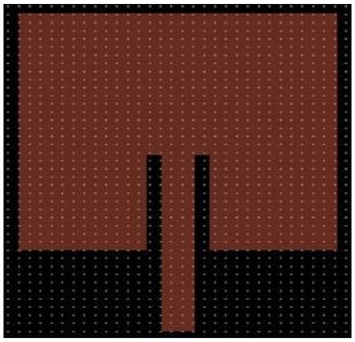
1. Create a new workspace, name it as **Lab5_PatchAntenna_wrk**
2. Open the new layout cell and name it as **Lab1_Patch**
3. Use Insert ->Polygon and use Select Insert -> Coordinate Entry and enter following coordinates one by one and keep on clicking Apply at each coordinate entry:

(0, 0)
(0, 29.2)
(29.2, 29.2)
(29.2, 0)
(17.5, 0)

(17.5, 12)

(16.1, 12)
(16.1, -10)
(13.1, -10)
(13.1, 12)
(11.7, 12)
(11.7, 0)

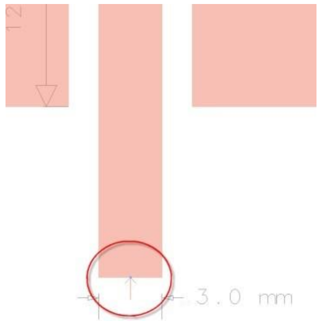
(0, 0)



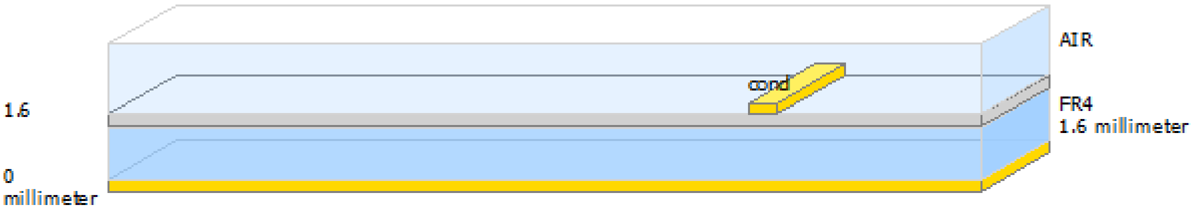
\Click OK and press Space Bar to end the polygon drawing command.

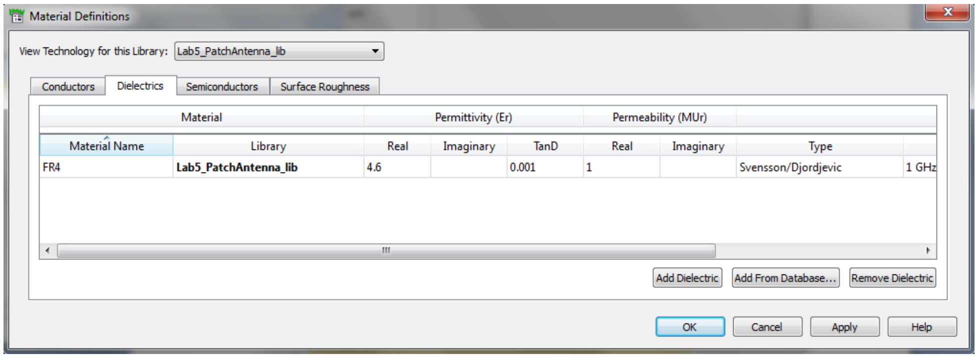
### Step3: Antenna Simulation

1. Connect a pin at the feed point of the antenna as shown below



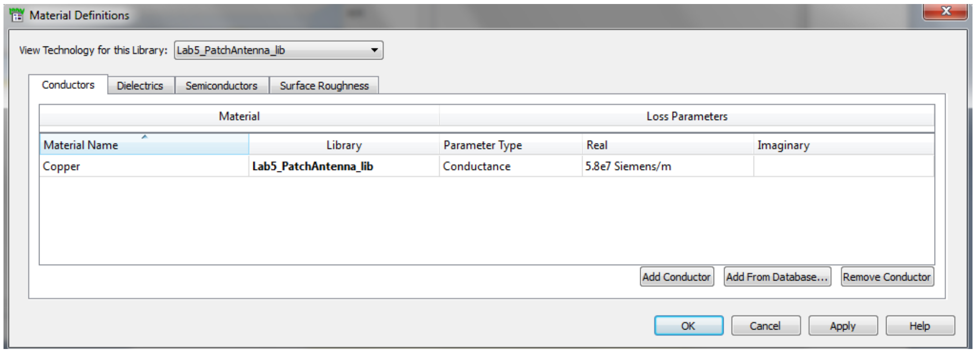
2. Go to the **EM setup** window and click on **Substrate** and click on **New** to accept the 25 mil Alumina template. Define the substrate as below, modify the default substrate height, Er, TanD and **conductor height and define it as Copper** (select it from Add from Database list). Changing name of the dielectric is optional as it has no bearing on the simulation. Click on cond and change it **"Intrude Into Substrate"** and enter the height as 35 micron.





View Technology for this Library: Lab5_PatchAntenna_lib

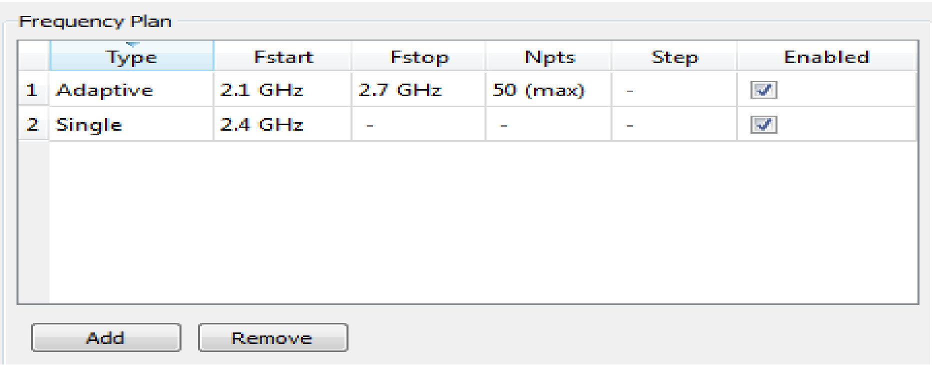
| Material | | Permittivity (Er) | | | Permeability (MUr) | | | |
|---|---|---|---|---|---|---|---|---|
| Material Name | Library | Real | Imaginary | TanD | Real | Imaginary | Type | |
| FR4 | **Lab5_PatchAntenna_lib** | 4.6 | | 0.001 | 1 | | Svensson/Djordjevic | 1 GHz |



View Technology for this Library: Lab5_PatchAntenna_lib

| Material | | Loss Parameters | | |
|---|---|---|---|---|
| Material Name | Library | Parameter Type | Real | Imaginary |
| Copper | **Lab5_PatchAntenna_lib** | Conductance | 5.8e7 Siemens/m | |

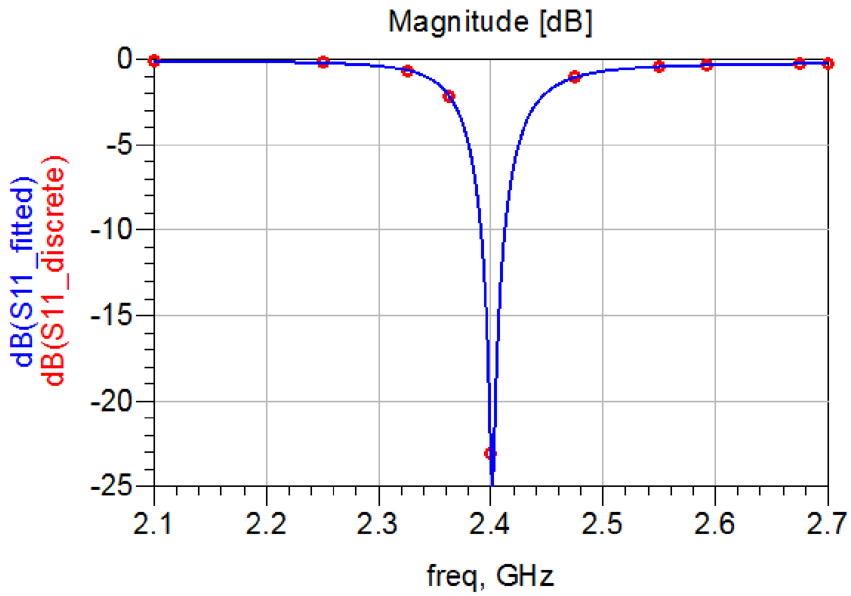
3. Set the **Simulation Frequency range** as 2.1GHz – 2.7GHz (adaptive sweep) and Add a new Single Point of 2.4GHz as shown below



Frequency Plan

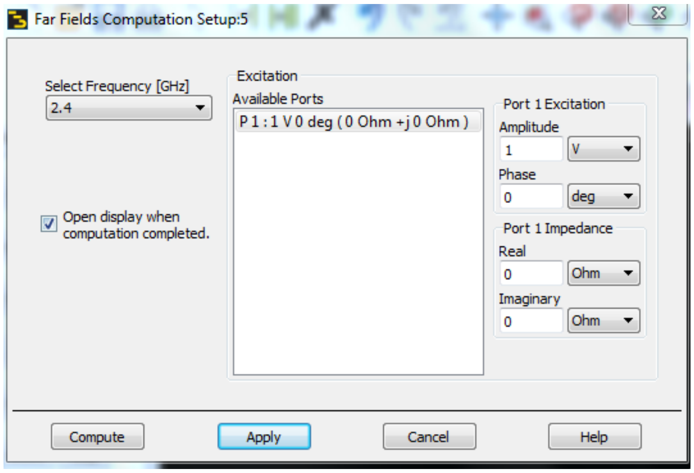
| | Type | Fstart | Fstop | Npts | Step | Enabled |
|---|---|---|---|---|---|---|
| 1 | Adaptive | 2.1 GHz | 2.7 GHz | 50 (max) | - | ☑ |
| 2 | Single | 2.4 GHz | - | - | - | ☑ |

4. Click on Simulate and observe the simulation results in data display



## Step4: Antenna Radiation Pattern

1. For Far-Field Antenna Pattern, go to **EM->Post Processing->Far Field** and select the desired frequency (e.g. 2.4 GHz) and click on Compute.


Far Fields Computation Setup:5

Select Frequency [GHz]: 2.4

☑ Open display when computation completed.

Excitation

Available Ports: P 1 : 1 V 0 deg ( 0 Ohm +j 0 Ohm )

Port 1 Excitation

Amplitude: 1 V

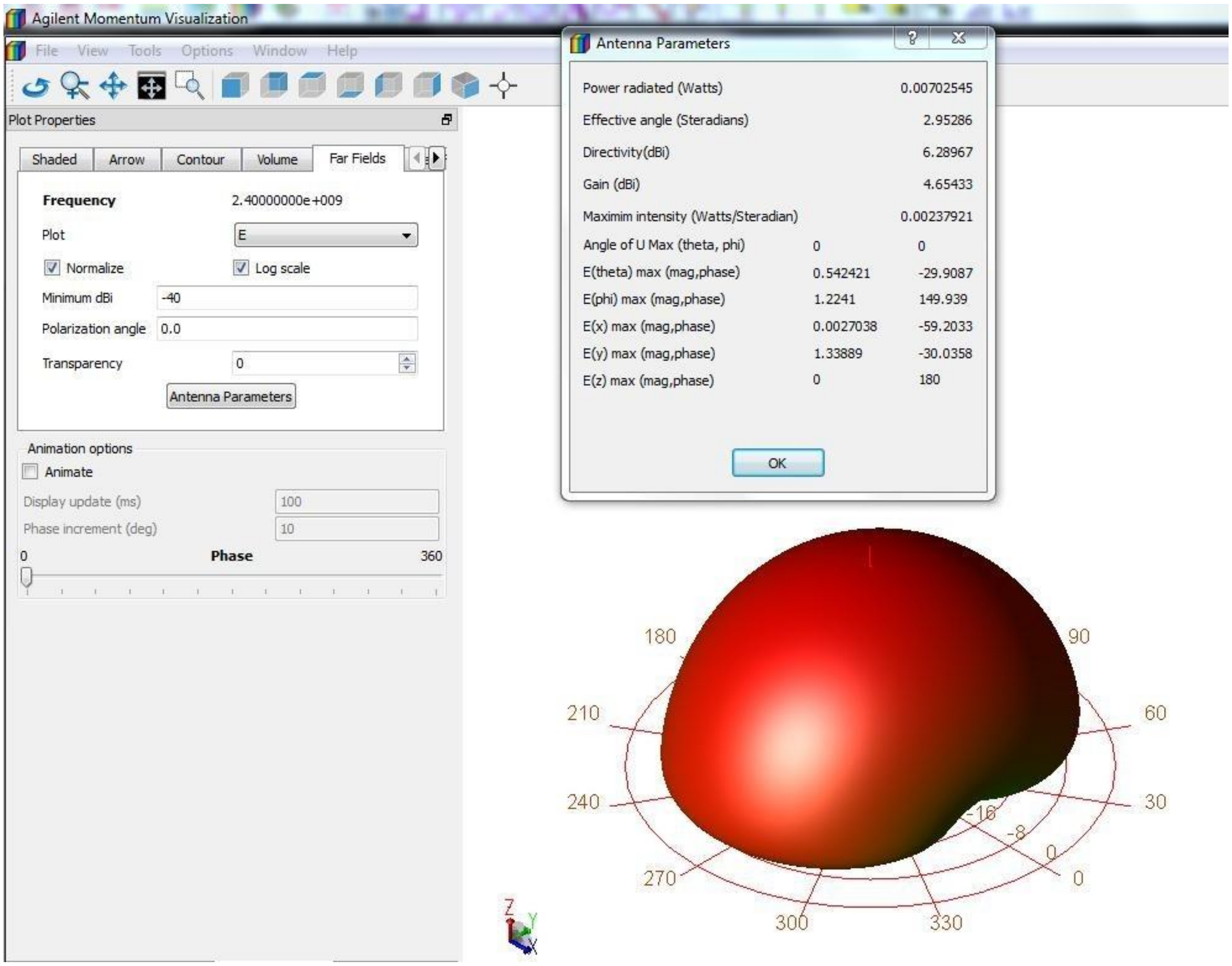
Phase: 0 deg

Port 1 Impedance

Real: 0 Ohm

Imaginary: 0 Ohm

2. Far field computation will be done and results will be displayed in the post processing window as shown below. We can use **Window->Tile** and then go to **Plot Properties** (from the bottom tabs) and then select **Far Field->Antenna Parameters** to see all the required data.



Frequency 2.40000000e+009

Plot E

☑ Normalize ☑ Log scale

Minimum dBi -40

Polarization angle 0.0

Transparency 0

☐ Animate

Display update (ms) 100

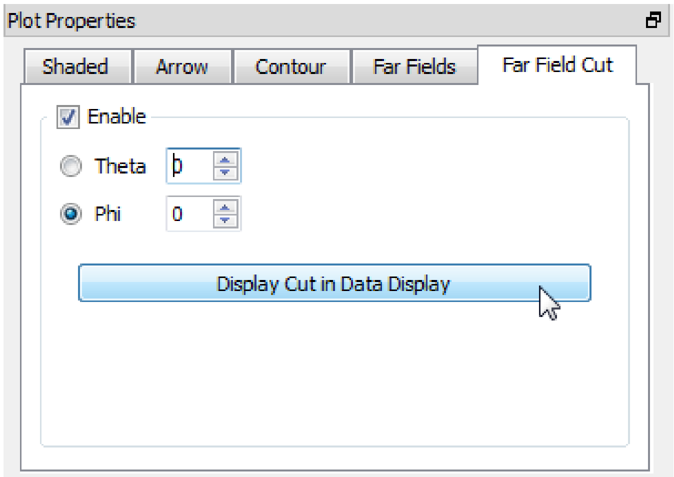
Phase increment (deg) 10

Phase 0 360

Antenna Parameters

| | | |
|---|---|---|
| Power radiated (Watts) | | 0.00702545 |
| Effective angle (Steradians) | | 2.95286 |
| Directivity(dBi) | | 6.28967 |
| Gain (dBi) | | 4.65433 |
| Maximim intensity (Watts/Steradian) | | 0.00237921 |
| Angle of U Max (theta, phi) | 0 | 0 |
| E(theta) max (mag,phase) | 0.542421 | -29.9087 |
| E(phi) max (mag,phase) | 1.2241 | 149.939 |
| E(x) max (mag,phase) | 0.0027038 | -59.2033 |
| E(y) max (mag,phase) | 1.33889 | -30.0358 |
| E(z) max (mag,phase) | 0 | 180 |

3. Goto **Far Field Cut** tab and select the Phi and click on **Display Cut in data display** button

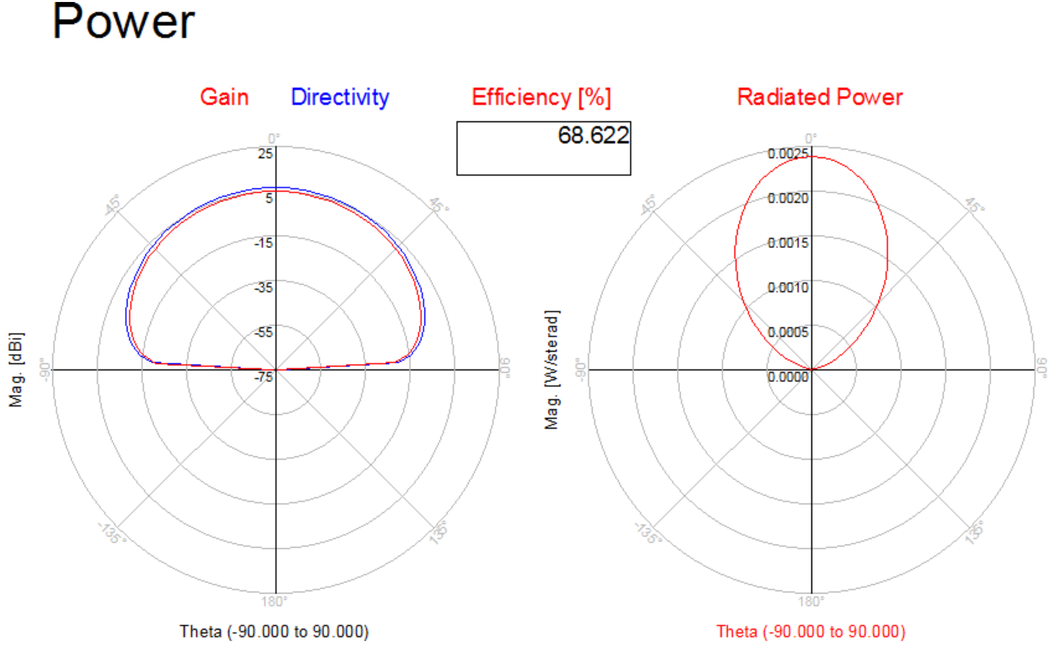


☑ Enable

○ Theta 0

● Phi 0

4. Once done, we will be able to see far field cut in the ADS data display as shown below



Efficiency [%]

68.622

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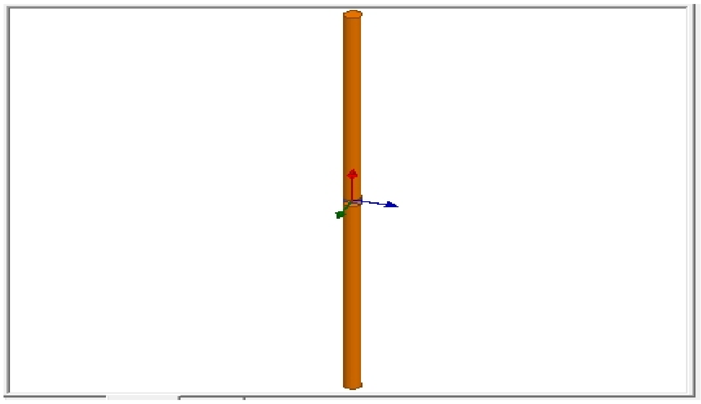
# DESIGN AND ANALYSIS OF HALF WAVE DIPOLE ANTENNA

**Objective:** To design and verify the design parameters of Half wave dipole

## DESIGN DIAGRAM:



**Theory:** In radio and telecommunications a **dipole antenna** or **doublet** is the simplest and most widely used class of antenna. The most common form of dipole is two straight rods or wires oriented end to end on the same axis, with the feed line connected to the two adjacent ends, but dipoles may be fed anywhere along their length. This is the simplest type of antenna from a theoretical point of view. Dipoles are resonant antennas, meaning that the elements serve as resonators, with standing waves of radio current flowing back and forth between their ends. So the length of the dipole elements is determined by the wavelength of the radio waves used. The most common form is the **half-wave dipole**, in which each of the two rod elements is approximately 1/4 wavelength long, so the whole antenna is a half-wavelength long. The radiation pattern of a vertical dipole is omnidirectional; it radiates equal power in all azimuthal directions perpendicular to the axis of the antenna. For a half-wave dipole the radiation is maximum, 2.15 dBi perpendicular to the antenna axis, falling monotonically with elevation angle to zero on the axis, off the ends of the antenna.

A general purpose dipole antenna (long thin wire antenna) with height h1 = h2 = L/2, where L is the total length of the antenna is shown in Figure 1.

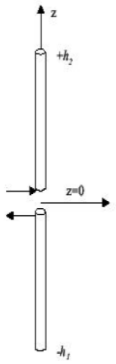


Figure 1. Thin Linear Antenna of Total Length $h_2 + h_1$

The dipole antenna is constructed with two thin linear elements that are symmetrically fed at thecenter by a balanced two-wire transmission line. The antennas may be of any length, but it isassumed that the current distribution is sinusoidal. Current-distribution measurements indicatethat this is a good assumption provided that the antenna is thin: That is, when the conductordiameter is less than □/100.

The current of the center fed antenna of length $L$ at any point $z$ on the antenna is:

$$I(z) = I_o \sin\left[\frac{2\pi}{\lambda}\left(\frac{L}{2}-|z|\right)\right] \quad .$$

The far-field electric and magnetic field of a dipole antenna is determined by integrating thefields for an infinitesimal dipole of length $dz$ at a distance $r$ from the antenna.

$$dE_\theta = \frac{jZ_o I_o \sin\theta dz}{2\pi r \lambda}$$

$$\text{and} \quad dH_\phi = \frac{jI_o \sin\theta dz}{2\pi r \lambda} \quad .$$

The value of the magnitude for the magnetic field H□□for the entire length of the antenna is theintegral Equation (3) over the length of the entire antenna:

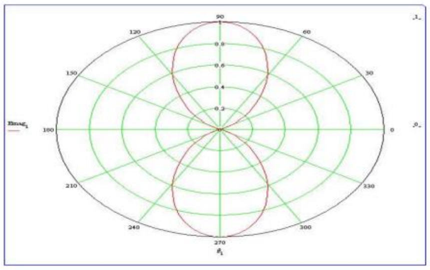
$$dH_\phi = \int_{-L/2}^{L/2} dH_\phi \ .$$

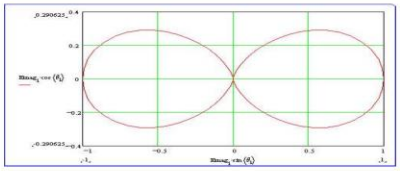
This yields the magnetic field for an arbitrary length dipole antennas in the far-field:

$$H_\phi = \frac{jI_o e^{-j\beta r} e^{j\omega t}}{2\pi r}\left\{\frac{\cos\left[\frac{(\beta L \cos\theta)}{2}\right] - \cos\left(\frac{\beta L}{2}\right)}{\sin\theta}\right\} \quad .$$

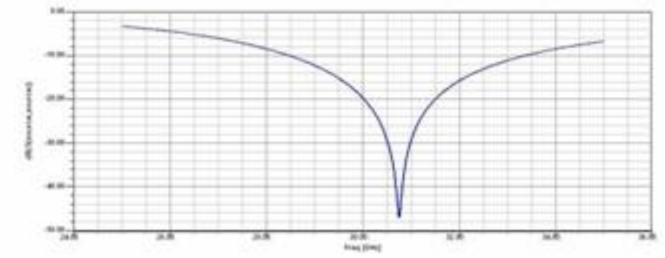
The corresponding electric field for an arbitrary length dipole antennas in the far-field is:

$$E_{\theta} = \frac{jZ_oI_oe^{-j\beta r}e^{j\omega t}}{2\pi r}\left\{\frac{cos\left[\frac{(\beta Lcos\,\theta)}{2}\right]-cos\left(\frac{\beta L}{2}\right)}{sin\theta}\right\}\ .$$





Results:



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# DESIGN AND ANALYSIS OF HORN ANTENNA

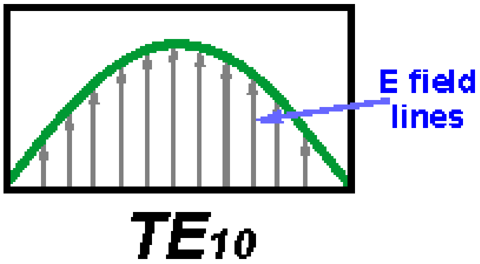
## OBJECTIVE:

To Design & Analyze the performance characteristics of Horn Antenna operating at 10GHz.

## THEORY:

A horn antenna is used to transmit radio waves from a waveguide (a metal pipe used to carry radio waves) out into space, or collect radio waves into a waveguide for reception. It typically consists of a short length of rectangular or cylindrical metal tube (the waveguide), closed at one end, flaring into an open-ended conical or pyramidal shaped horn on the other end. The radio waves are usually introduced into the waveguide by a coaxial cable attached to the side, with the central conductor projecting into the waveguide to form a quarter-wave monopole antenna. The waves then radiate out the horn end in a narrow beam. In some equipment the radio waves are conducted between the transmitter or receiver and the antenna by a waveguide; in this case the horn is attached to the end of the waveguide. In outdoor horns, such as the feed horns of satellite dishes, the open mouth of the horn is often covered by a plastic sheet transparent to radio waves, to exclude moisture.

The horn antenna is essentially a section of waveguide where the open end is flared to provide a transition to the areas of free space.Waveguides are generally one of two shapes: rectangular or circular. By far the most widely used of these two is the rectangular form.Waveguide theory indicates that there are several modes of propagation that can occur within a waveguide. The most widely used is the TE10 mode and this is indicated in the diagram below.



**Field in TE10 waveguide**

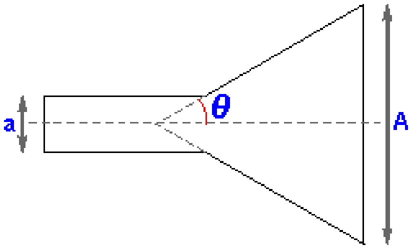
As the waveguide is rectangular it will have different dimensions for each side. For the horn antenna theory and calculations these will be taken that it has a width b and height a, with b>a.

The horn antenna is a simple development of the waveguide transmission line. Using some simple theory, it is quite possible to see how the horn antenna works. It is quite possible to leave a waveguide open and let signal radiate from this. However this is not particularly efficient. Signals passing along the waveguide see a sudden transition from the waveguide to free space which has an impedance of around 377Ω.

The result of this sudden transition is to cause signals to be reflected back long the waveguide as standing waves - theory shows that this is exactly the same as for poor matches at the end of coaxial or other forms of wire based transmission lines. To overcome this issue, the waveguide can be tapered out or flared. This has the effect of providing a gradual transition from the impedance of the waveguide to that of free space. In effect it acts like a progressive matching transformer. The flare functions similarly to a tapered transmission line, or an optical medium with a smoothly varying refractive index. In addition, the wide aperture of the horn projects the waves in a narrow beam. The horn type that provides the most effective match is the exponential horn. However pyramid or conical horns give a sufficiently good match for most applications, and they are far easier and much cheaper to fabricate.

**CALCULATIONS**:

One of the key properties of the horn antenna is the angle at which the horn flares out. This affects many areas of the performance including the gain and directivity as described below.The angle of flare is defined in the diagram below and there can be a different angle for both the E-plane (E field) and the H-plane (H field. These are referred to as $\theta_E$ and $\theta_H$.



For a rectangular horn antenna the formulas are:

$$\boxed{aperture_E = \sqrt{2\lambda L_E}}$$

$$\boxed{aperture_H = \sqrt{3\lambda L_H}}$$

Then for a conical horn antenna the formula is:

$$\boxed{diameter = \sqrt{3\lambda L}}$$

**Where:**

Aperture$_E$ is the width of the aperture in the E-field direction.
Aperture$_H$ is the width of the aperture in the H-field direction.
$L_E$ is the slant length of the side in the E-field direction.
$L_H$ is the slant length of the side in the H-field direction.

diameter is the diameter of the cylindrical horn aperture.
L is the slant length of the cone from the apex.
λ is the wavelength of the signal.

Conical horn the gain formula can be shown to be:

$$Gain = \left(\frac{\pi d}{\lambda}\right)^2 e_A$$

**Where**
A is the physical area of the aperture
d is the physical diameter of a conical horn aperture
λ is the wavelength
eA is the aperture efficiency and is a figure between 0 and 1