CLASS: B.E. E &TC **SUBJECT: RMT**
EXPT. NO.: 1(a) **DATE:**

TITLE: To measure and compare radiation pattern, return loss, impedance, gain, beam width of Dipole antenna at microwave frequency.

PREREQUISITES :

1. Half Power Beam Width
2. First Null Beam width
3. Reflection coefficient
4. Standing wave ratio

OBJECTIVE **:** To study various antenna parameters like radiation pattern, return loss, impedance, Directivity, gain and beam width so as to get a thorough understanding of an antenna.

APPARATUS **:**

Sr. No.	Apparatus	Range
1	Antenna Trainer Kit Amitec	0-2Ghz
2	Simple dipole antenna	

THEORY **:**

Fundamental Parameters of Antenna

1) Radiation Pattern :

An antenna *radiation pattern* or *antenna pattern* is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization."

The radiation property of most concern is the two- or three dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius. Often the *field* and *power* patterns are normalized with respect to their maximum value, yielding *normalized field* and *power patterns*.

2) RADIATION INTENSITY :

Radiation intensity in a given directions defined as "the power radiated from an antenna per unit solid angle." The radiation intensity is a far-field parameter, and it can be obtained by simply multiplying the radiation density by the square of the distance. In mathematical form it is expressed as

$$U = r^2 \, W_{rad}$$

where

U = radiation intensity (W/unit solid angle)
Wrad = radiation density (W/m2)
Ω = element of solid angle = sin$\theta\ d\theta\ d\varphi$.

3) BEAMWIDTH :

Associated with the pattern of an antenna is a parameter designated as *beamwidth*. The *beamwidth* of a pattern is defined as the angular separation between two identical points on opposite side of the pattern maximum. In an antenna pattern, there are a number of beamwidths. One of the most widely used beamwidths is the *Half-Power Beamwidth* (*HPBW*), which is defined by IEEE as: "In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half value of the beam."

3) Directivity of an antenna:

It 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 power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied." Stated more
Simply, the directivity of a non isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source. In mathematical form,

D = U⁄U0 = (4∏U) ⁄Prad

If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity) expressed as

Dmax = D0 = Umax/U0 = (4∏Umax)/Prad
D = directivity (dimensionless)
D0 = maximum directivity (dimensionless)

4) INPUT IMPEDANCE:

Input impedance is defined as "the impedance presented 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." In this section we are primarily interested in the input impedance at a pair of terminals which are the input terminals of the antenna. The ratio of the voltage to current at these terminals, with no load attached, defines the impedance of the antenna as

ZA = RA + jXA

5) *Antenna Gain:*

Gain of an antenna **(in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π." Inequation form this can be expressed as**

Gain = (4π radiation intensity) ⁄ (*total* input (accepted) power)
= (4$\pi U(\theta,\varphi)$) ⁄ (*Pin)*
*(*Dimensionless*)*

Inmost cases we deal with *relative gain*, which is defined as "the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction." The power input must be the same for both antennas. The reference antenna is usually a dipole, horn, or any other antenna whose gain can be calculated or it is known. In most cases, however, the reference antenna is a *lossless isotropic source*. Thus

$G = 4\pi U(\theta,\varphi)/P_{in}$ (lossless isotropic source) -----------(dimensionless)

When the direction is not stated, the power gain is usually taken in the direction of maximum radiation, we can write that the total radiated power (P_{rad}) is related to the total input power (P_{in}) by

$P_{rad} = e_{cd} * P_{in}$

Where e_{cd} is the antenna radiation efficiency (dimensionless)

According to the IEEE Standards, "gain does not include losses arising from impedance mismatches (reflection losses) and polarization
mismatches (losses)."

In this edition of the book we define two gains; one, referred to as *gain* (*G*), and the other, referred to as *absolute gain (Gabs)*.

6) Antenna Efficiency:

It is the measure of the power radiated by the antenna when source is applied at the input of the antenna. It is given by the formula as given below:

$\eta = (P_{rad})/(P_{rad} + P_{loss}) = (R_{rad})/(R_{rad} + R_{loss})$

Where,

η=Antenna Efficiency

Prad=Toal power radiated by antenna

Ploss=Power loss in Antenna

Rrad=Radiation Resistance

Rloss=Resistance Causing Power loss

Dipole Antenna:

One of the most commonly used antennas is the half-wavelength ($l = \lambda/2$) dipole. Because its radiation resistance is 73 ohms, which is very near the 50-ohm or 75-ohm characteristic impedances of some transmission lines, its matching to the line is simplified especially at resonance. Because of its wide acceptance in practice, we will examine in a little more detail its radiation characteristics.

The electric and magnetic field components of a half-wavelength dipole can be given as

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

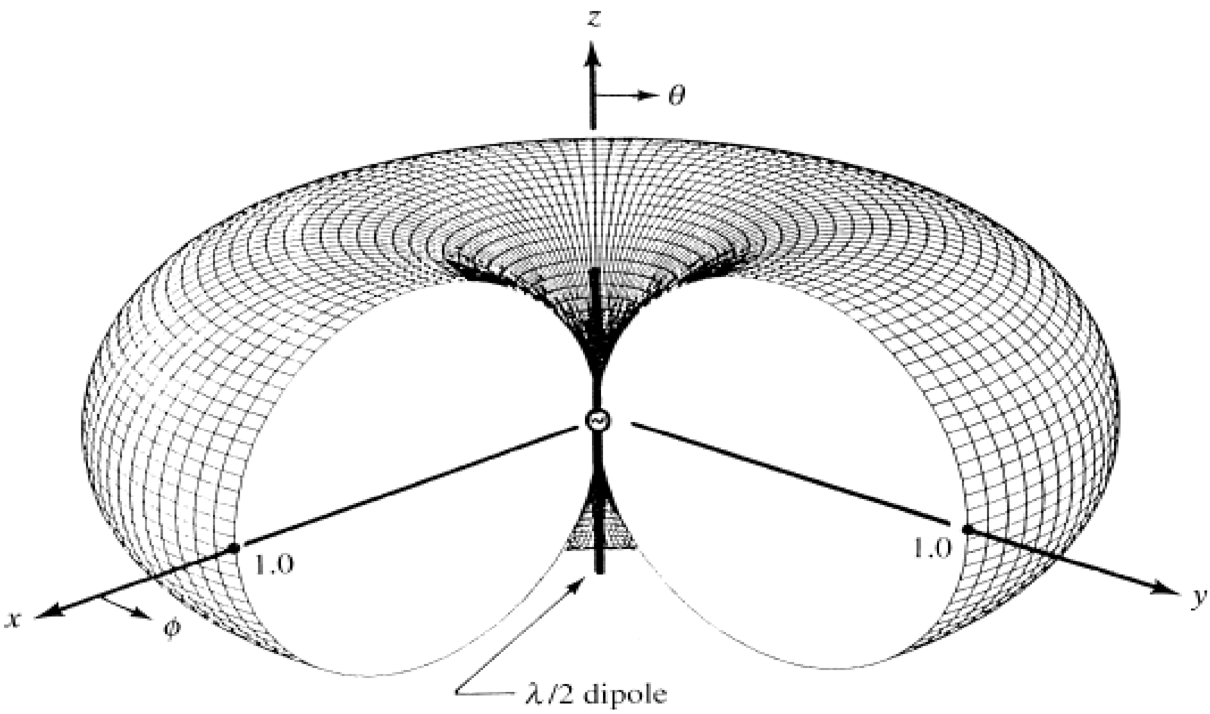
$$H_\phi \simeq j \frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

In turn, the time-average power density and radiation intensity can be written, respectively,

$$W_{av} = \eta \frac{|I_0|^2}{8\pi^2 r^2} \left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \right]^2 \simeq \eta \frac{|I_0|^2}{8\pi^2 r^2} \sin^3\theta$$

$$U = r^2\ W_{av} = \eta \frac{|I_0|^2}{8\pi^2} \left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \right]^2 \simeq \eta \frac{|I_0|^2}{8\pi^2} \sin^3\theta$$

Whose two-dimensional pattern is shown plotted in while the three dimensional pattern is depicted in fig. For the three-dimensional pattern of a 90◦ angular sector has been removed to illustrate the figure-eight elevation plane pattern variations.



PROCEDURE :

For Beam Width Calculations:

1. Connect the trainer kit with simple dipole antenna as the receiver and a dipole as the transmitter
2. Set the frequency of operation in the transmitter and receiver
3. Set the receiver to automatic mode
4. Mount the receiver on the stepper motor
5. Set the desired memory location on the receiver
6. Set the step size of motor as 5 units
7. Observe that the receiver power should be more than 40dBμ and less than 72dBμ.
8. Set the stepper motor on auto mode and let it rotate 360˚
9. Connect the receiver to the plot software and see the log plot.
10. Calculate the Beam-width of an antenna and print the radiation pattern.

For Gain Measurement:

1. Connect the trainer kit with dipole antenna as the receiver and a dipole as the transmitter
2. Set the frequency of operation in the transmitter and receiver
3. Set the receiver to automatic mode
4. Use a power splitter and measure input power to the transmitter in dBμ
5. Now measure the received power.
6. Observe that the receiver power should be more than 40dBμ and less than 72dBμ. Use attenuator if necessary. (Each Attenuator attenuates by 20dBμ)
7. Note the readings.
8. Calculate the Gain of an antenna.

For Directivity measurement

1. Follow the procedure of beam width calculation for horizontal orientation and vertical orientation of an antenna under test.
2. Calculate the half power beam width for vertical (elevation) and horizontal (azimuthal) antenna.
3. Calculate directivity using formula given below.

For Impedance Measurement

1. Connect the IN terminal of directional coupler to the transmitter output.
2. Connect the OUT terminal of directional coupler to an antenna under test.
3. Connect the SAMPLE terminal to the receiver section
4. Note down the forward power seen on receiver screen.
5. Reverse the connections for IN and OUT terminals
6. Note down the reverse power on receiver screen
7. Calculate return loss and impedance of antenna using formulae and the chart given below .

OBSERVATIONS:

Type of Receiving antenna: Half Wave Dipole Antenna

Resonant Frequency: 600 MHz

Length of antenna element: 25 cm

Beam-width:

For Azimuthal:

HPBW	FNBW
360º	**-**

For Elevation:

HPBW	FNBW
60º	**180º**

Gain of an Antenna:

Sr no.	Accepted power	Received Power	Gain
1.	**338.85 nW**	**138.04 nW**	**0.1569**

Return Loss, VSWR and impedance:

Forward Power = -50 dBm

Reverse Power = -72.6 dBm

VSWR = 1.16013

Return Loss = 22.6 dBm

Z_0 = 50 ohm

Reflection coefficient = 0.07413

Impedance = 58.00664 ohm

Formulae:

1. **D**= 41000/(Half Power Azimuthal Beam width * Half Power Elevation Beam width)
2. $G_R = \frac{1}{G_T} \frac{P_{\text{recieved}}}{P_{accepted}} \left[\frac{4\pi R}{\lambda} \right]^2$
3. C=f*λ

CALCULATIONS:

1. **Beam width**

   Electric field is maximum at $\theta = 90^o$ with value 9 V/m

   3 dB scaled down value is 6.36396 V/m

   Angles corresponding to this value are $\theta = 60^o$ and $\theta = 120^o$

   E-field HPBW = 120 - 60

   E-field HPBW = 60º

   As H-field pattern is covering whole 360º

   H-field HPBW = 360º

2. **Gain:**

   Pt = 338.85 nW
   Pr = 138.04 pW
   R=1m
   Gt=1.64
   lambda=0.5

   Pr = Pt Gt Gr sq(lambda / 4 pi R)

   138.04p = 338.85n * 1.64 * Gr * (0.5/(4*pi*1)) * (0.5/(4*pi*1))

   Gr = 0.1569037526

3. **Directivity:**

   E-plane HPBW = 71 degrees
   H-plane HPBW = 360 degrees

   D = 41000 / ((HPBW-E) * (HPBW-H)) = 41000 / ((60) * (360)) = 1.89

   D= 1.89

4. **Return Loss**

   Forward power = -50 dBm
   Reverse power = -72.6 dBm

   Return loss = Forward power - Reverse Power = (-50) - (- 72.6) = 22.6 dBm

Return loss = 22.6 dBm

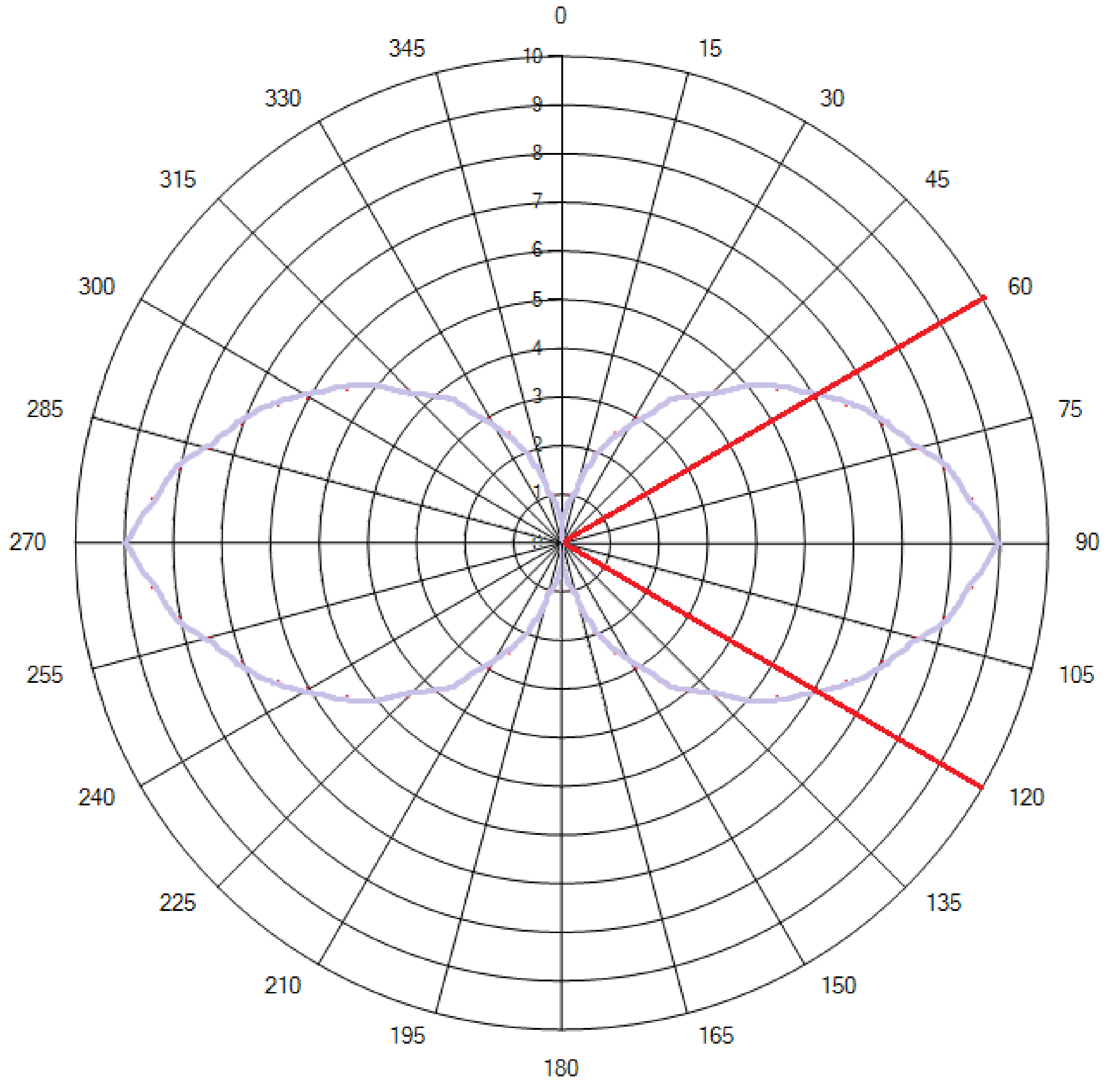
5. **Impedance:**

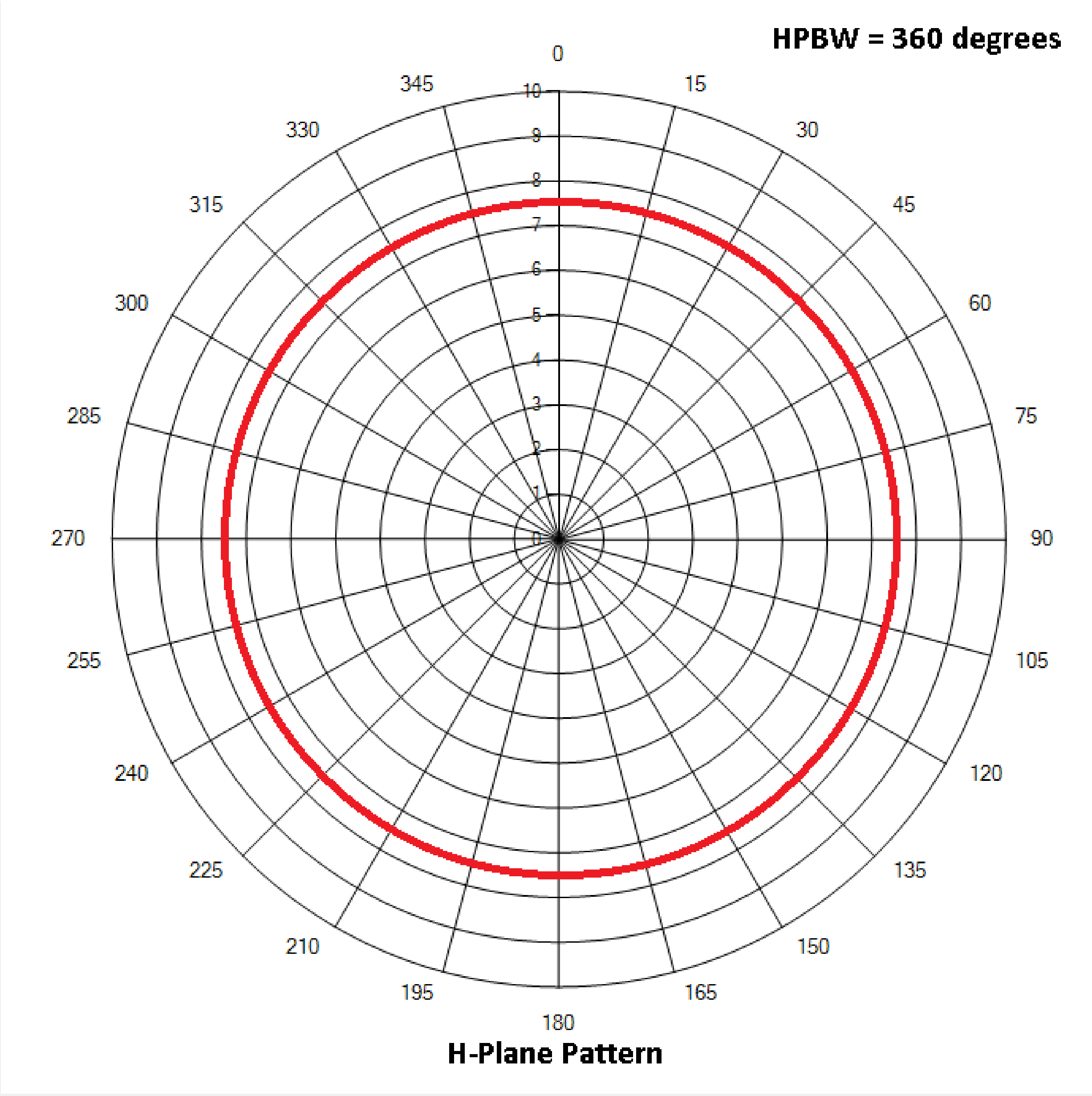
Return loss = -20log(tau) = 22.6
tau = 10 pow (-1.13) = 0.07413102413

tau = (Zl - Zo)/(Zl + Zo) = (Zl - 50)/(Zl + 50) = 0.07413102413

Zl = 58.00664305 ohm

GRAPHS:





CONCLUSION:

We studied various parameters for simple dipole antenna and variation of electric field over different theta values i.e. for vertical elevation values. Electric field varies between the value 0 to 9 with HPBW = 60^o. It exhibits apple shaped electric field pattern for different elevation and circular shape for different phi values. The gain was 0.157 and directivity = 1.89 which is close to expected value of 1.64. Return loss was found to be 22.6dB and we expect to be as small as possible.

RERFERENCES:

1. Antenna Theory: Analysis and design, Constantine A. Balanis, 3rd Edition, John Wiley & Sons Ltd.
2. Principles of Antenna Theory, Kai Fong Lee, 1984, John Wiley and Sons Ltd. ISBN 0 471 90167 9.