INDEX
Subject: RADIATION & MICROWAVE TECHNIQUES

ROLL NO.: 42428 DIV. BE - 8 YEAR: 2020-2021 SEMESTER: I

List of Laboratory Experiments

Sr. No	Title of Experiments	Performance Date	Submission Date	Sign
1	To measure and compare radiation pattern, return loss, impedance, gain, beam width of Dipole antenna and folded dipole antenna at microwave frequency.	10-08-2020	17-08-2020	
2	Design, simulate and compare performance of microwave dipole antennas of length 2λ, λ, λ/2 and λ/4.	24-08-2020	27-08-2020	
3	To measure and plot mode characteristics of reflex klystron.	03-09-2020	10-09-2020	
4	To measure and verify port characteristics of microwave tees (E, H, E-H or magic planes).	17-09-2020	24-09-2020	
5	To measure and verify port characteristics of directional coupler and calculate coupling factor, insertion loss and directivity.	08-10-2020	15-10-2020	
6	To measure and verify port characteristics of isolator and circulator and calculate insertion loss and isolation in dB.	22-10-2020	29-10-2020	
7	To plot standing wave pattern and measure SWR for open, short and matched termination at microwave frequency using slotted section with probe carriage.	05-11-2020	12-11-2020	
8	To measure VI characteristics of Gunn Diode and study of PIN modulator.	28-11-2020	03-12-2020	
9	Study the network analyzer and carry out the measurements of s-parameters.	03-12-2020	10-12-2020	

This is to certify that Shri / kum. Kapadne Chandan Jitendra has carried out the above mentioned 9 experiments in **RADIATION & MICROWAVE TECHNIQUES** laboratory of the institute.

For PUNE INSTITUTE OF COMPUTER TECHNOLOGY, Pune: 43

Date: 17-12-2020

Staff In charge **PRIINCIPAL**

CLASS: B.E. E &TC **SUBJECT: RMT**
EXPT. NO.: 1(a) **DATE:** 10-08-2020

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)
W_{rad} = 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,

$$D = U/U_0 = (4\prod U)/P_{rad}$$

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

$$D_{max} = D_0 = U_{max}/U_0 = (4\prod U_{max})/P_{rad}$$

D = directivity (dimensionless)
D_0 = 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

$$Z_A = R_A + jX_A$$

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)
$= (4\pi U(\theta,\varphi)) / (P_{in})$
(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

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

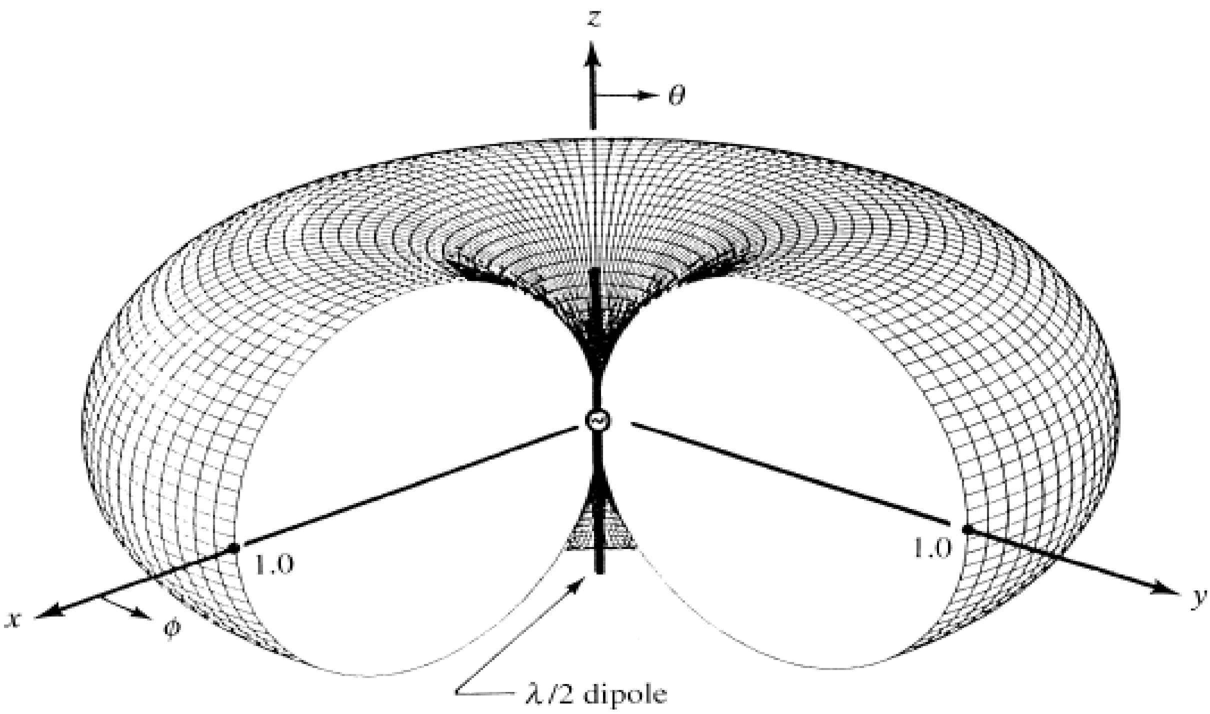
$$H_\phi \simeq j \frac{I_0 e^{-jkr}}{2\pi r}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

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
360^o	-

For Elevation:

HPBW	FNBW
60^o	180^o

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. $G_R = \frac{1}{G_T} \frac{P_{recieved}}{P_{accepted}} \left[\frac{4\pi R}{\lambda} \right]^2$
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

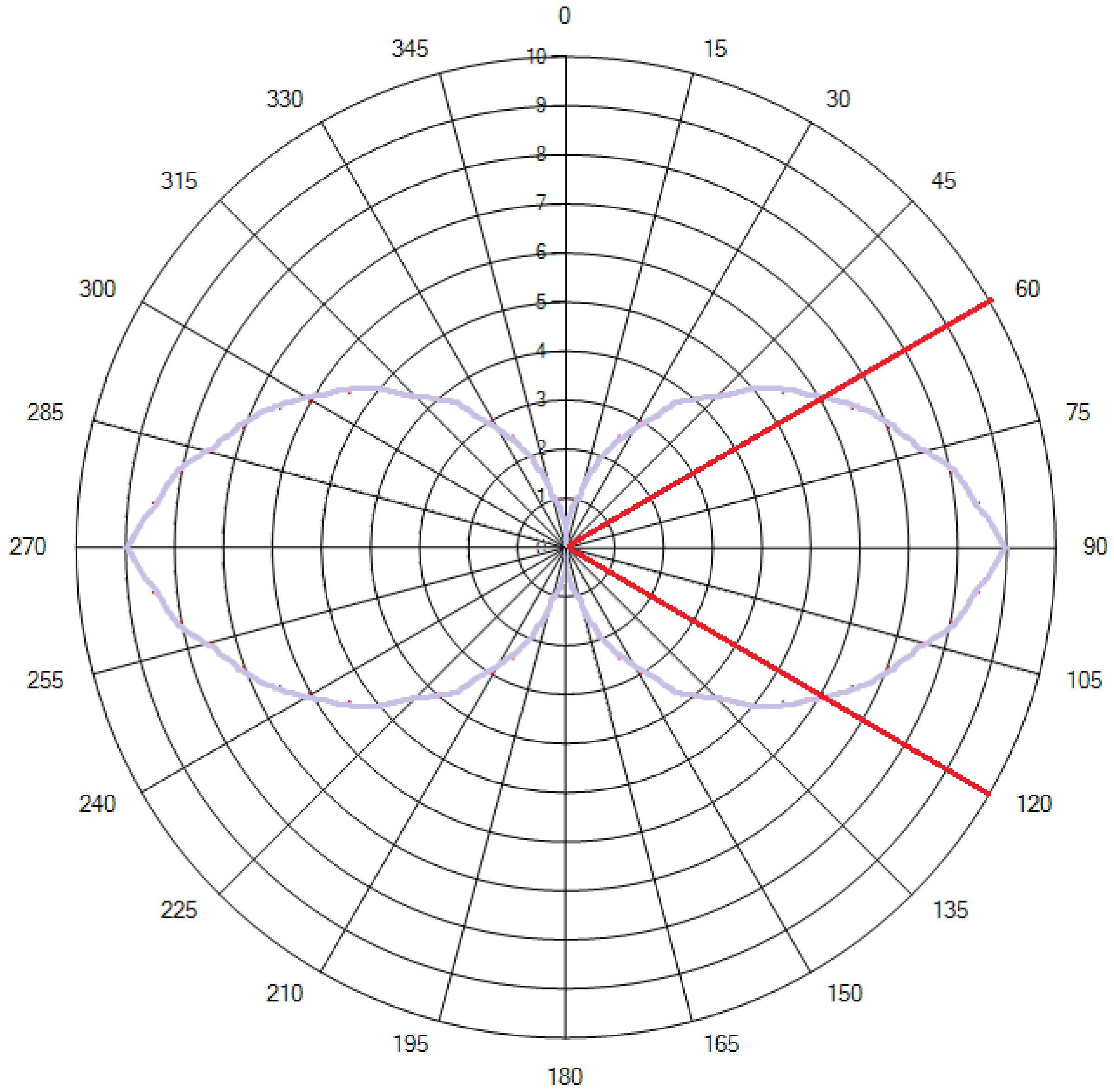
5. **Impedance:**

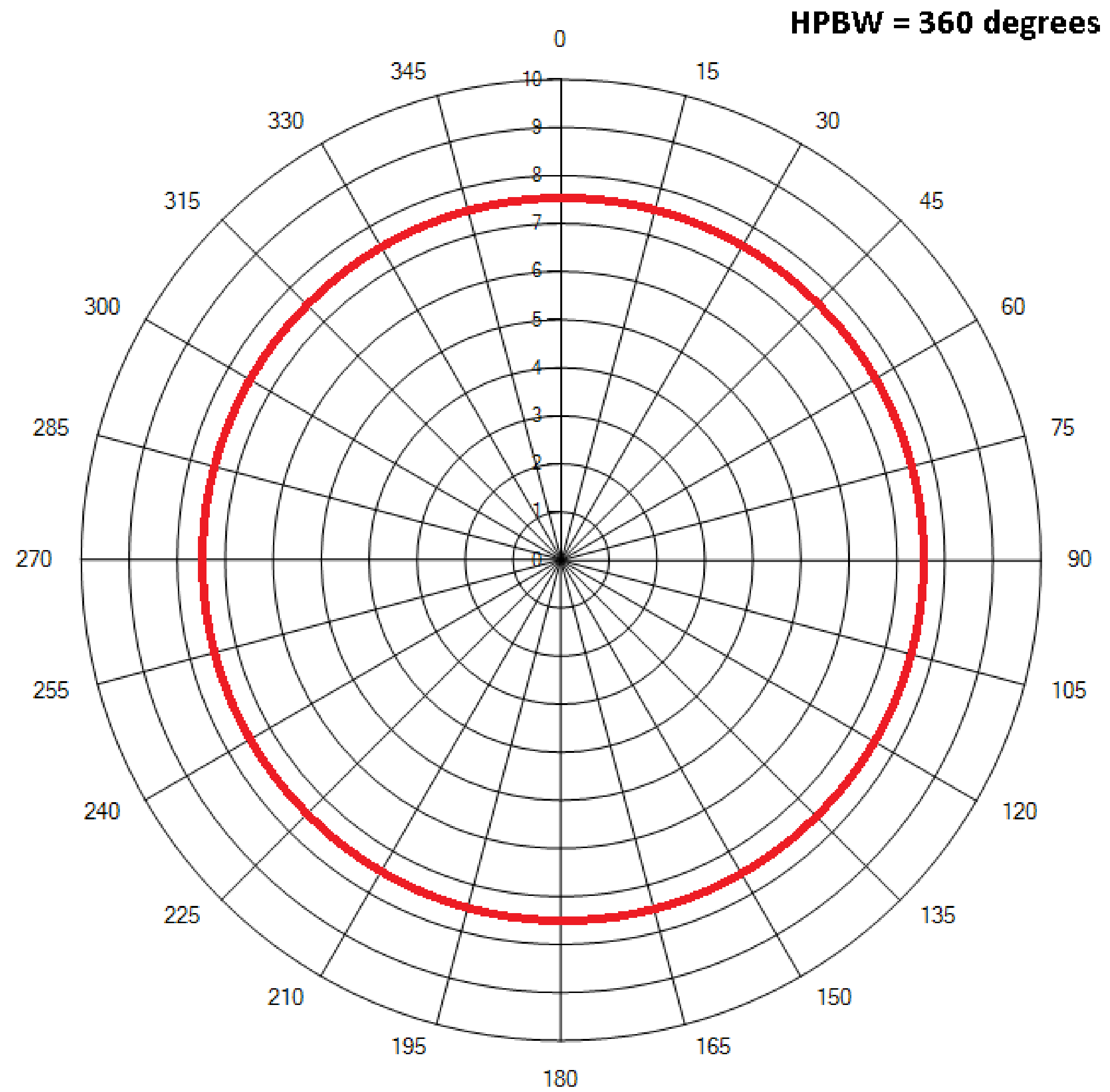
Return loss = -20log(tau) = 22.6
tau = 10 pow (-1.13) = 0.07413102413

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

Zl = 58.00664305 ohm

GRAPHS:





H-Plane Pattern

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.

CLASS: B.E. E &TC **SUBJECT: RMT**

EXPT. NO.: 1(b) **DATE:** 10-08-2020

TITLE : **To measure and compare radiation pattern, return loss, impedance, gain, beam width of folded 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 Amtec	0-2Ghz
2	Simple Dipole Antenna	
3	Folded Dipole Antenna	

THEORY :

Basic Characteristics:

In order to provide good matching characteristics, variations of the single dipole element must be used. One simple geometry that can achieve this is folded wire which forms a very thin (s<<lamda) rectangular loop.

A Folded dipole operates basically as an unbalanced transmission line and it can be analyzed by assuming that its current is decomposed into two distinct modes; a Transmission line mode and antenna mode.

Properties :

- It is basically a single antenna consisting two or three elements. The first element is fed directly while second and or third elements are coupled inductively at the ends.
- In a straight dipole, the total current is I but in folded dipole if current fed is I. Then the current in each arm is I/2 with condition that both arms are of same dimension.
- The radiation pattern of folded dipole antenna is same as that of straight dipole.
- The input impedance of folded dipole is 4 times that of straight dipole

- Rrad=4(73)=292ohm
- The spacing between arms of the folded dipole is very small and it is of the order of lamda/100.
- By using different diameters of two arms of folded dipole, the impedance can be transformed by factor ranging from 1.5 to 25.
- In yagi -uda antenna the folded dipole is used extensively as an active element.

Applications:

- Feed element of TV antennas such as Yagi-auDA ANTENNAS.
- As the terminal impedance of the folded dipole antenna can be adjusted over a wide range of impedances using different techniques it can be used as feed element for the antennas with very low and very high terminal impedances so that no impedance matching is required .

Advantages:

- It has high input impedance
- It has greater bandwidth
- It acts as built in reactance compensation network.
- It has better impedance matching characteristics.
- Its construction is simple and is cheaper.

PROCEDURE :

For Beam Width Calculations:

1. Connect the trainer kit with folded 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 folded 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: Folded Dipole Antenna

Resonant Frequency: 600 MHz

Length of antenna element: 25 cm

Beam-width:

For Azimuthal:

HPBW	FNBW
360	-

For Elevation:

HPBW	FNBW
71	180

Gain of an Antenna:

Sr no.	Accepted power	Received Power	Gain
1.	338.85 nW	97.73 nW	111.08

Return Loss, VSWR and impedance:

Forward Power = -34.5 dBm

Reverse Power = -77.1 dBm

VSWR = 1.014936934

Return Loss = 42.6 dBm

Z_0 = 50 ohm

Reflection coefficient = 0.007413102413

Impedance = 50.74684669 ohm

Formulae:

1. **D**= 41000/(Half Power Azimuthal Beam width * Half Power Elevation Beam width)
2. $G_R = \frac{1}{G_T} \frac{\mathrm{P}_{recieved}}{P_{accepted}} \left[\frac{4\pi R}{\lambda} \right]^2$
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 of max E-field is 4.85 V/m

Angles corresponding to this value are $\theta = 36^o$ and $\theta = 325^o = -35^o$

E-field HPBW = 36 – (-35)

E-field HPBW = 71^o

As H-field pattern is covering whole 360^o

H-field HPBW = 360^o

2. **Gain:**

Pt = 338.85 nW
Pr = 97.73 nW
R=1m
Gt=1.64
lambda=0.5

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

97.73n = 338.85n * 1.64 * Gr * (0.5/(4*pi*1)) * (0.5/(4*pi*1))

Gr = 111.08522

3. **Directivity:**

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

D = 41000 / ((HPBW-E) * (HPBW-H)) = 41000 / ((71) * (360)) = 1.604068858

D= 1.604068858

4. **Return Loss**

Forward power = -34.5 dBm
Reverse power = -77.1 dBm

Return loss = Forward power - Reverse Power = (-34.5) - (- 77.1) = 42.6 dBm

Return loss = 42.6 dBm

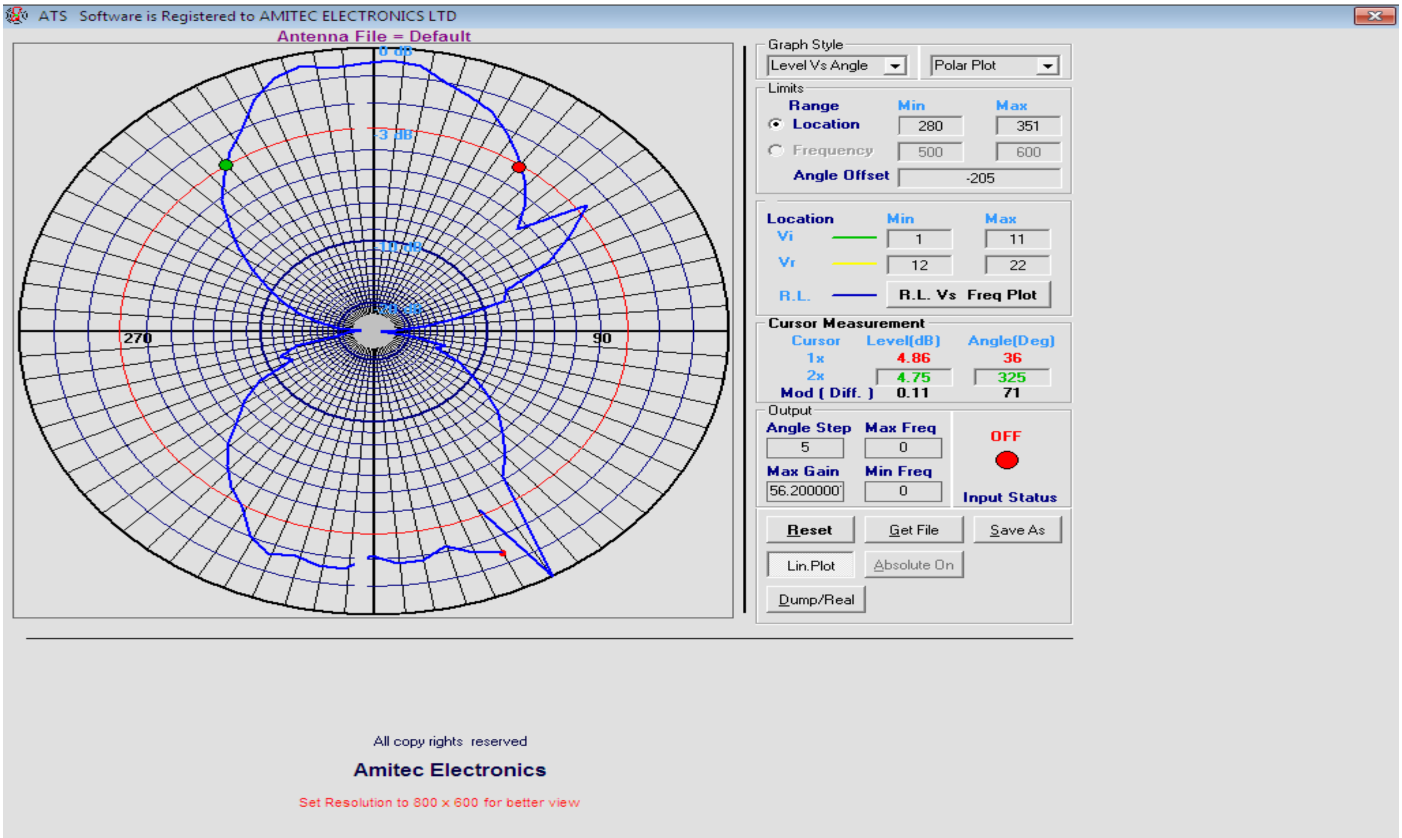
5. **Impedance:**

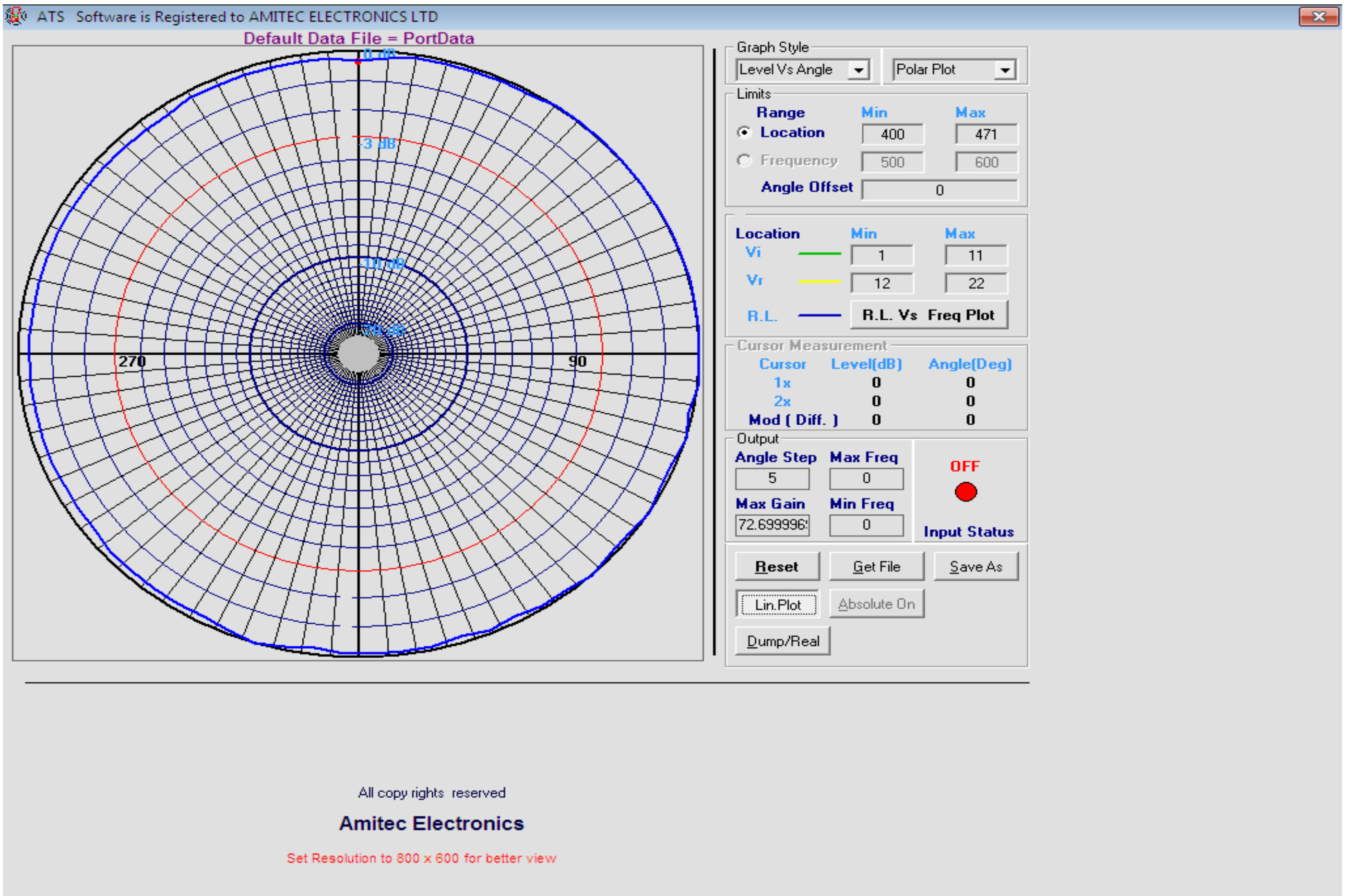
Return loss = -20log(tau) = 42.6
tau = 10 pow (-2.13) = 0.007413102413

tau = (Zl - Zo)/(Zl + Zo) = (Zl - 50)/(Zl + 50) = 0.007413102413

Zl = 50.74684669 ohm

GRAPHS:





CONCLUSION:

We studied various parameters for folded dipole antenna and variation of electric field over different theta values i.e. for vertical elevation values, HPBW = 60^{o}. It exhibits apple shaped electric field pattern for different elevation and circular shaped for different azimuthal angles. The gain was 111.08 and directivity = 1.604 which is close to expected value of 1.64. Return loss was found to be 42.6dB 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.

Comparison of an Antennas

Antenna Length / Antenna Parameters	Half wavelength dipole antenna (L= Lambda/2)	Folded dipole antenna
Structure	Wire Antenna	Wire Antenna
Return Loss	22.6 dB	42.6 dB
VSWR	1.160	1.015
Impedance	58 ohm	50.746 ohm
Directivity	1.89	1.604
Gain	0.157	111.2
Radiation Pattern	Apple shaped	Apple shaped

Conclusion:

- Both the antennae are wire structure antennae with the folded dipole having an extra lambda/2 wire connected in parallel with the HWDA with the help of metallic arcs.
- The return loss was found to be better in case of folded dipole antenna as compared to HWDA.
- The VSWR for both the antennae was found to be very close to the ideal value of unity. VSWR value for folded dipole was closer to 1 than HWDA.

- The impedance for folded dipole was expected to be in the range of 300 ohm but was calculated to be 50ohm i.e. perfectly matched with the Tx line this happened as a balun transformer was used for impedance matching. The HWDA gave a impedance of 58 ohm.
- The HWDA was found to be more directive with D=1.89 as compared to folded dipole antenna with D=1.604.
- The gain value for HWDA was found very low as compared to that of Folded dipole antenna
- The radiation pattern for both was found to be apple shaped.

CLASS: B.E. E &TC **SUBJECT: RMT**
EXPT. NO.: 2 **DATE:** 24-08-2020
Roll No.: 42428

TITLE : Design, simulate and compare performance of microwave dipole antennas of length 2λ, λ, λ/2 and λ/4.

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.

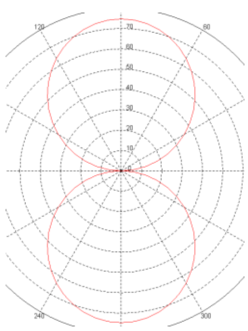
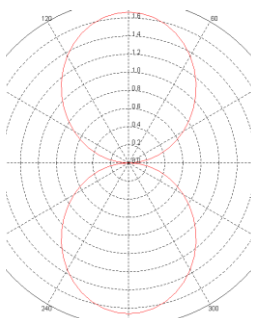
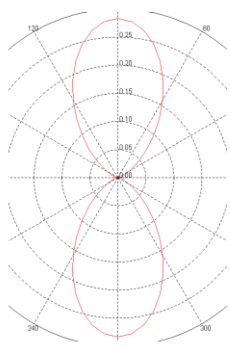
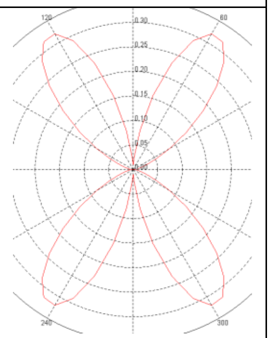
APPARATUS : Any EM Software

SPECIFICATION : f=600*10^6 Hz

OBSERVATIONS :

Structure (Length of an antenna)
Return Loss
VSWR
Impedance
Directivity
Gain
Radiation Pattern
HPBW of E-Plane
HPBW of H-Plane

COMPARISON:

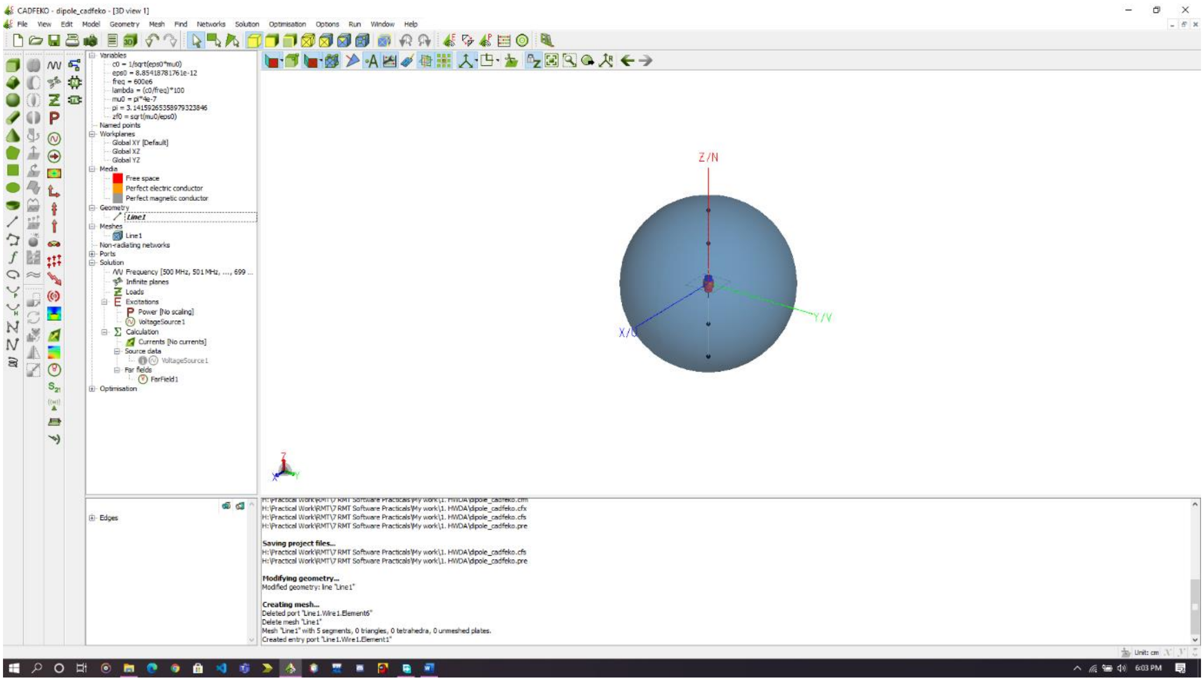
Antenna Length / Antenna Parameters	λ/4	λ /2	λ	2* λ
Structure(Dipole)	Quarter Wavelength	Half Wavelength	Wavelength	Double Wavelength
Return Loss	-0.1126 dB	-15.2798 dB	-0.2372 dB	-0.2981 dB
VSWR	660.57	1.41721	73.4107	58.3372
Impedance	15.3077-j709.123 ohm	70.8354-j0.942188 ohm	3040.72-j1383.71 ohm	2549.18 -j967.975 ohm
Directivity	1.52	1.64	2.45	2.48
Gain	1.52	1.64	2.45	2.48
Radiation Pattern	 Apple Shaped (0.07454 V)	 Apple Shaped (1.6607 V)	 Apple Shaped (0.2806 V)	 Hour Glass Shaped (0.3204 V)
HPBW of E-Plane	86.809 degrees	78.36383 degrees	48.4957 degrees	26.25065 degrees
HPBW of H-Plane	360 degrees	360 degrees	360 degrees	360 degrees

GRAPHS OF ALL ANTENNAS:

Plot the graphs of all parameters by using CAD-FEKO software and compare **dipole antennas of length λ/4, λ/2, λ and 2λ.** antenna with respect to all parameters.

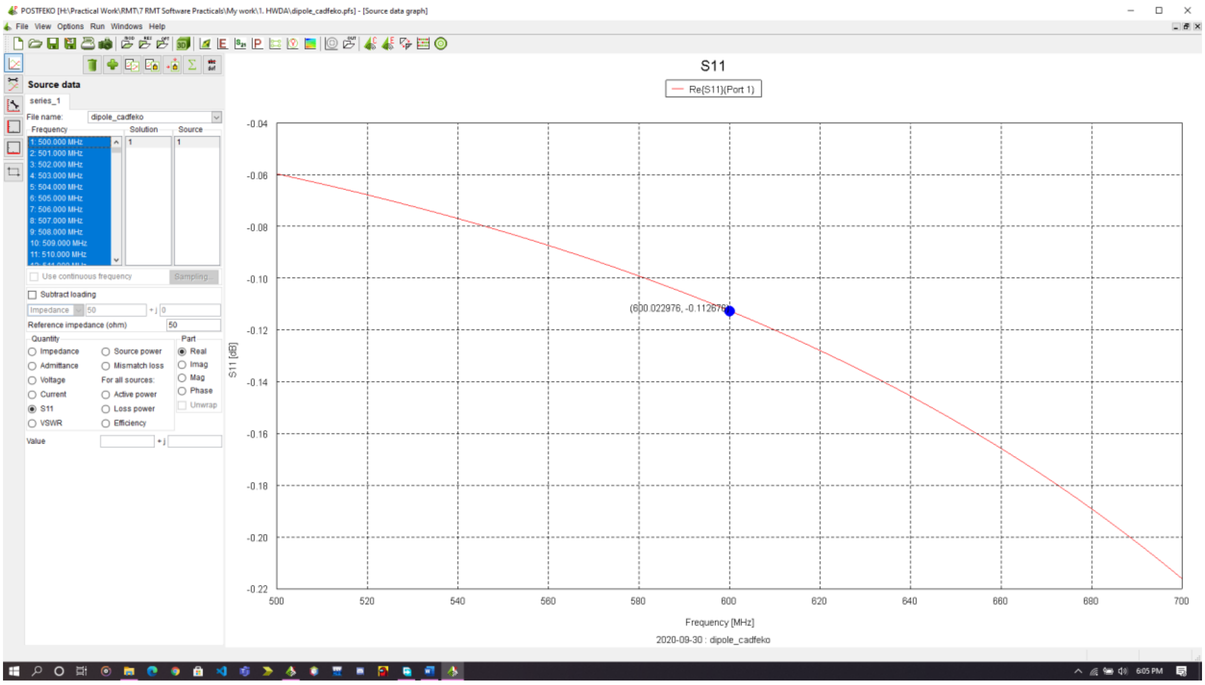
λ/4 antenna

Structure of Lambda by 4 antenna (λ/4)



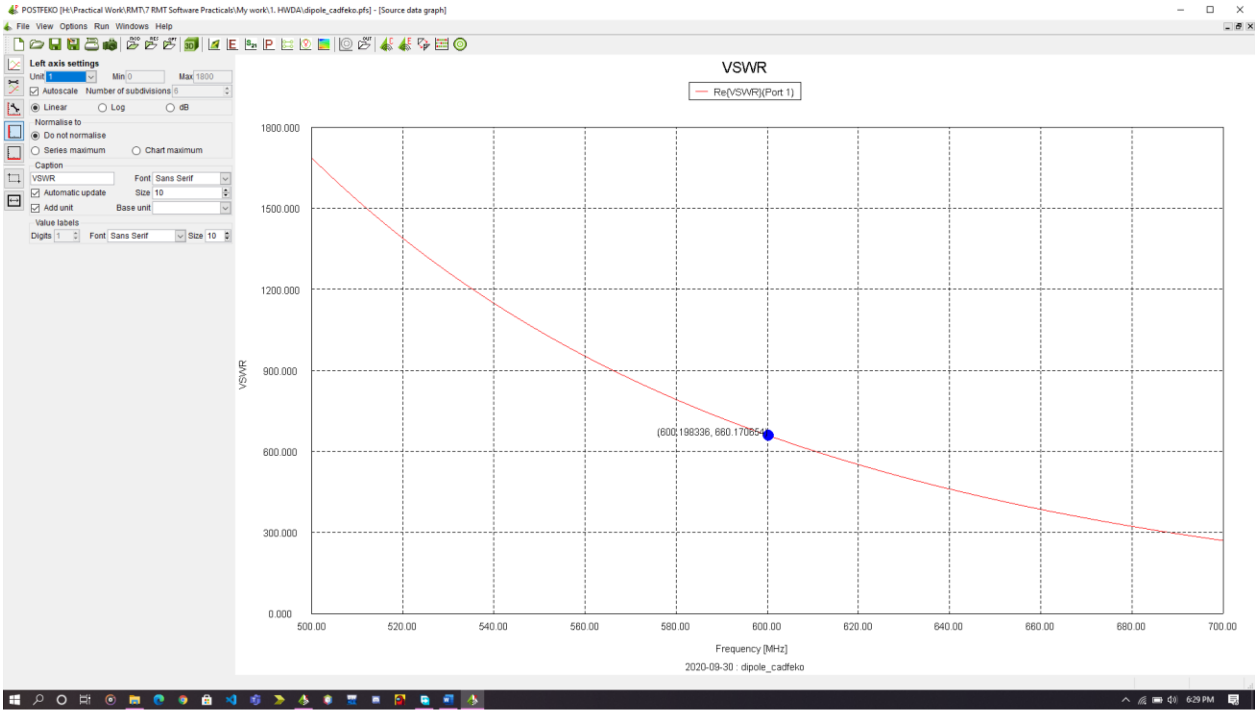
Return Loss of Lambda by 4 antenna (λ/4)

At freq=600MHz,s11=0.987122-j0.139833



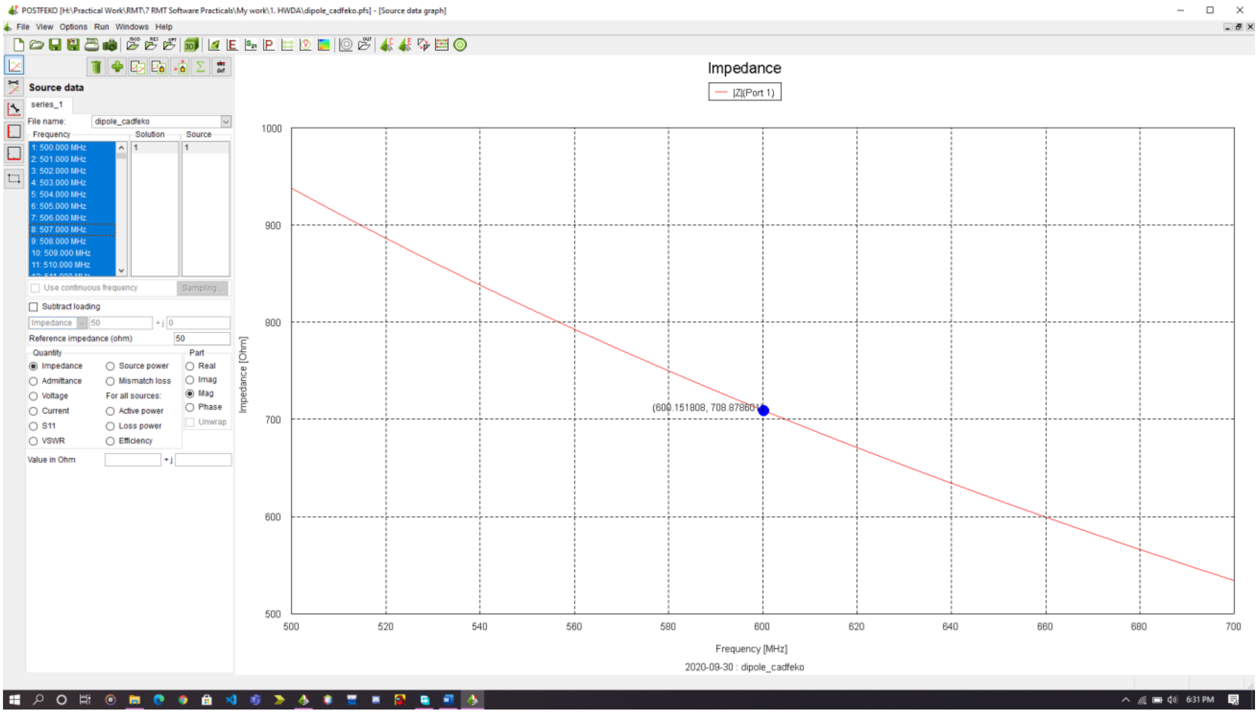
VSWR of Lambda by 4 antenna (λ /4)

At freq=600MHz,VSWR=660.57

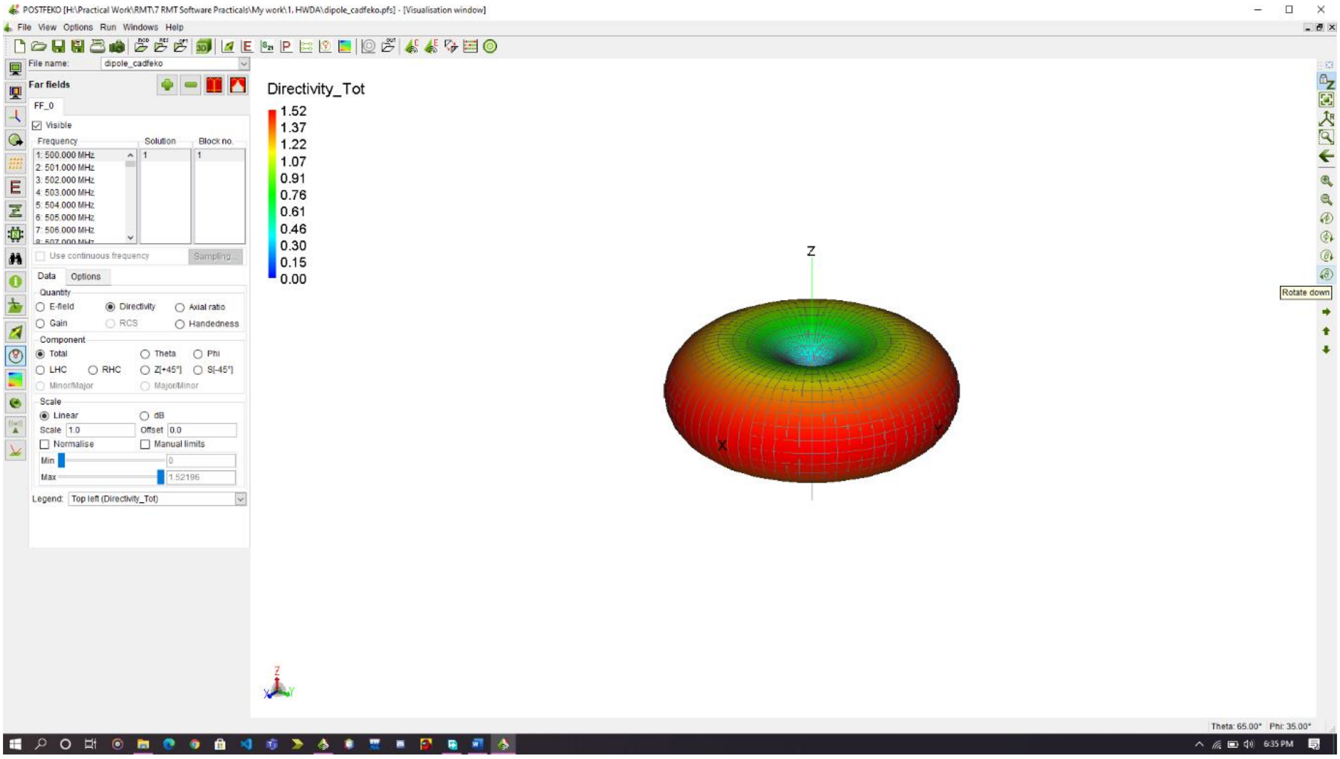


Impedance of Lambda by 4 antenna (λ /4)

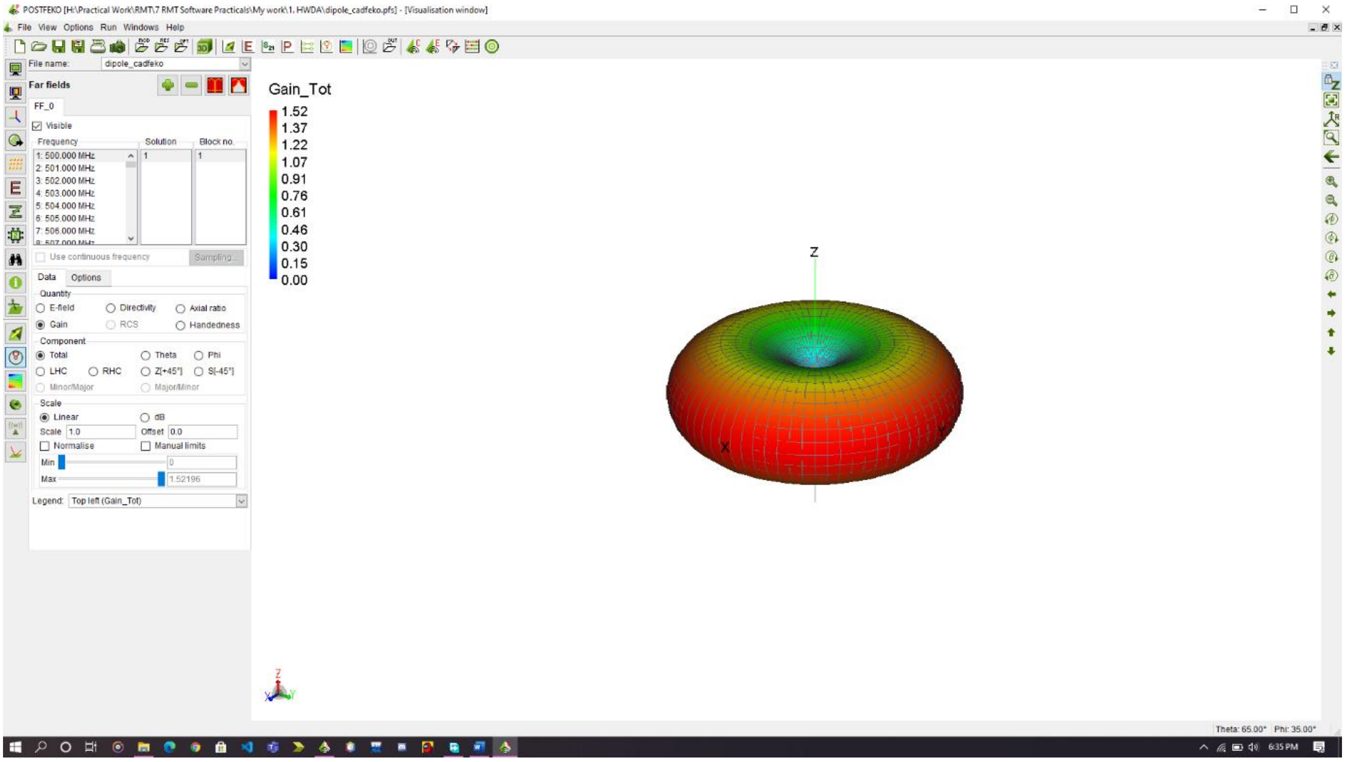
At freq=600MHz,Z=15.3077-j709.123 ohm



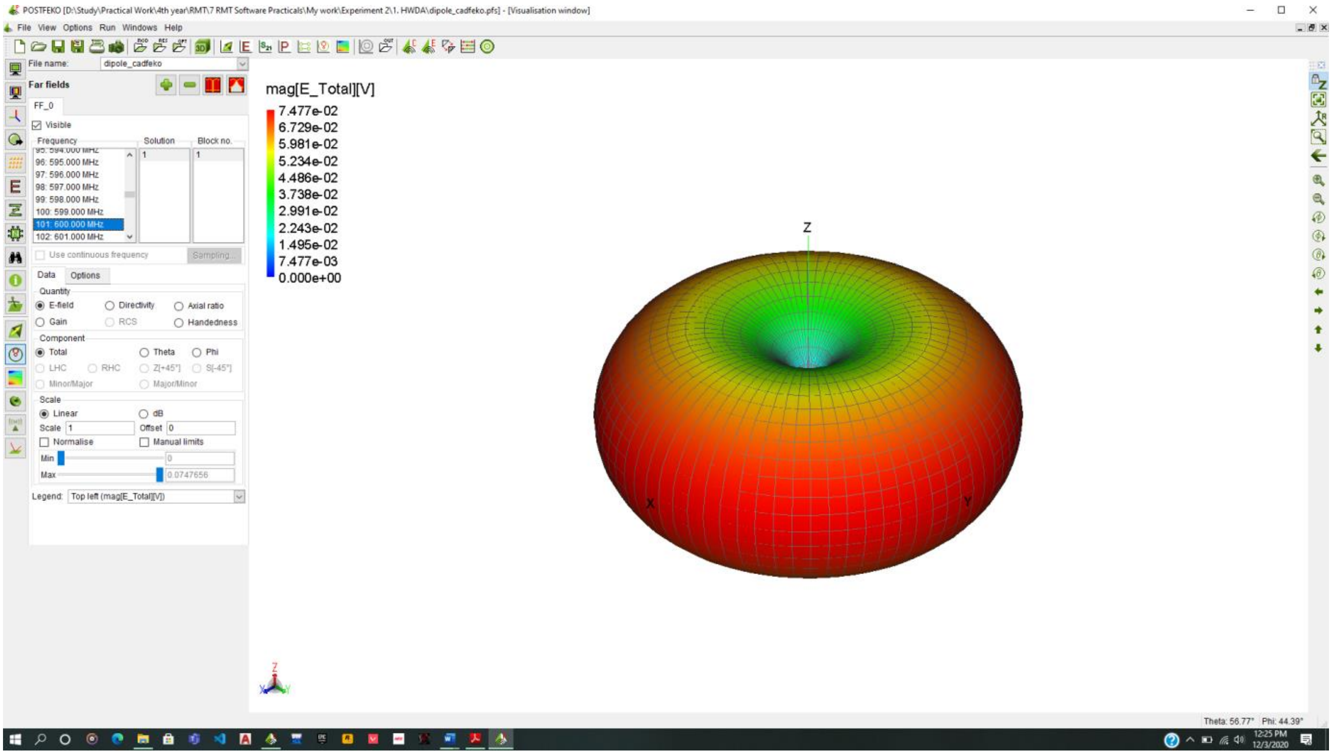
Directivity of Lambda by 4 antenna (λ /4)



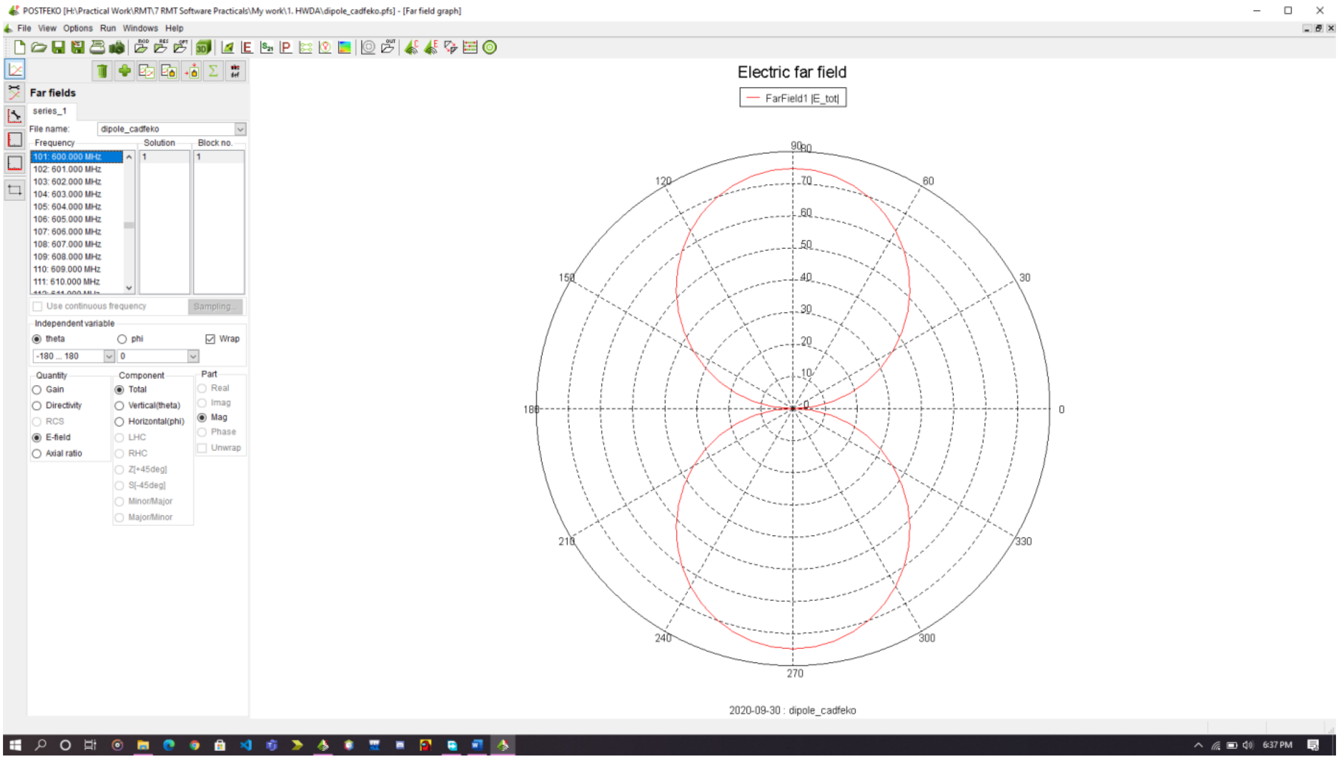
Gain of Lambda by 4 antenna (λ /4)



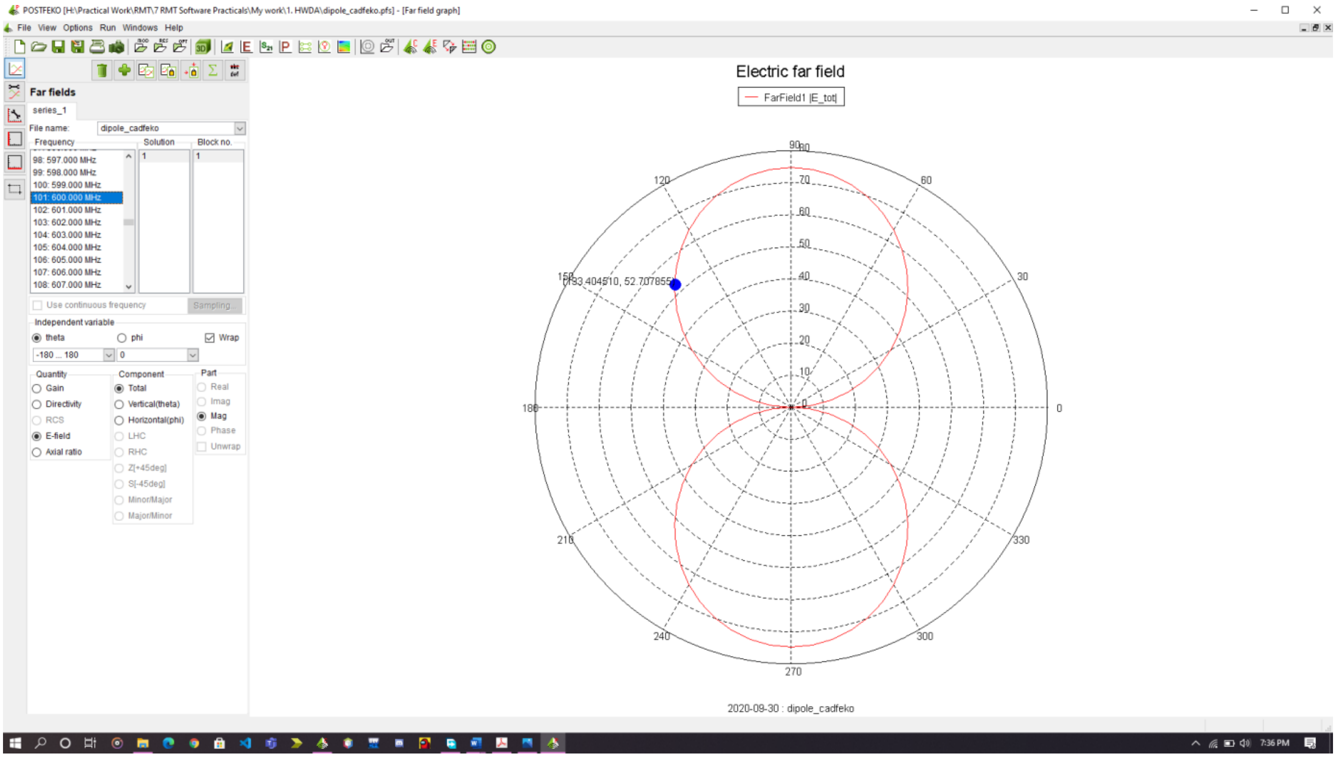
3-D Radiation Pattern of λ /4 antenna



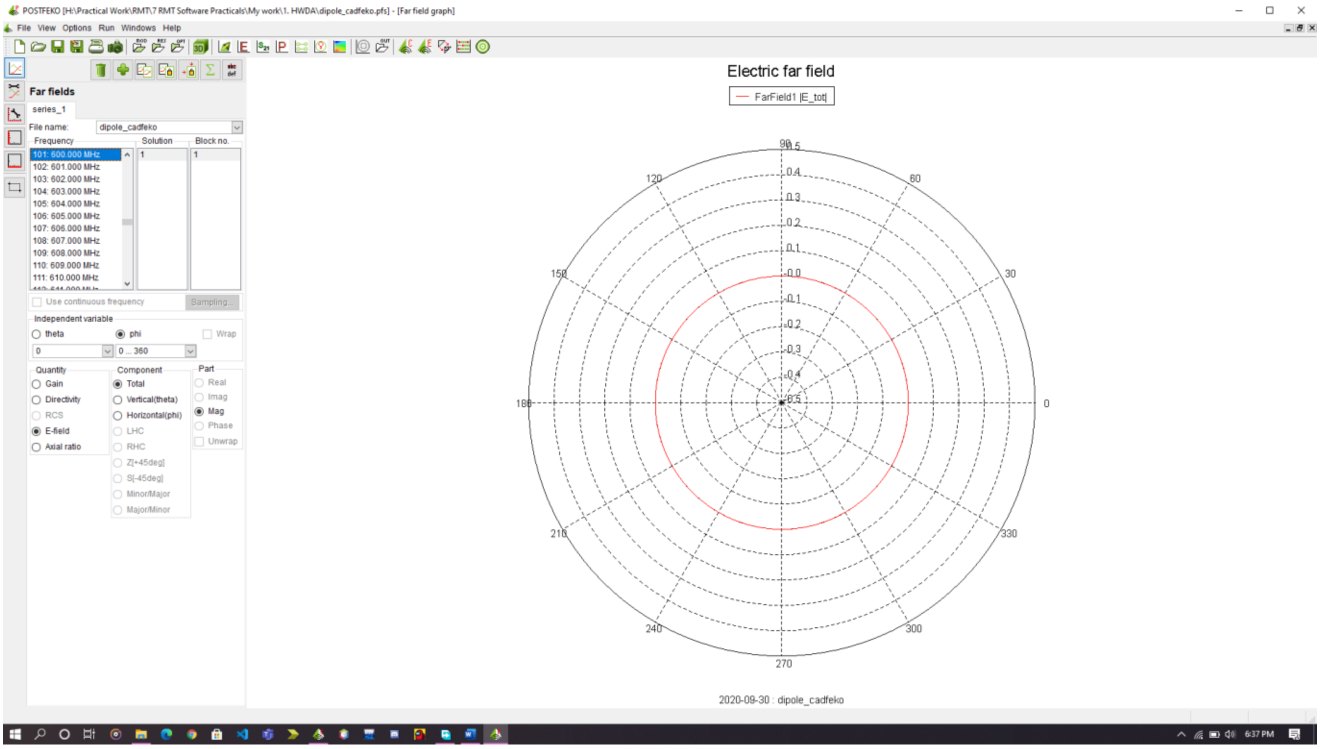
2-D(E-Plane Radiation Pattern) of (λ /4)



Beamwidth (E-Plane Radiation Pattern) of (λ /4)

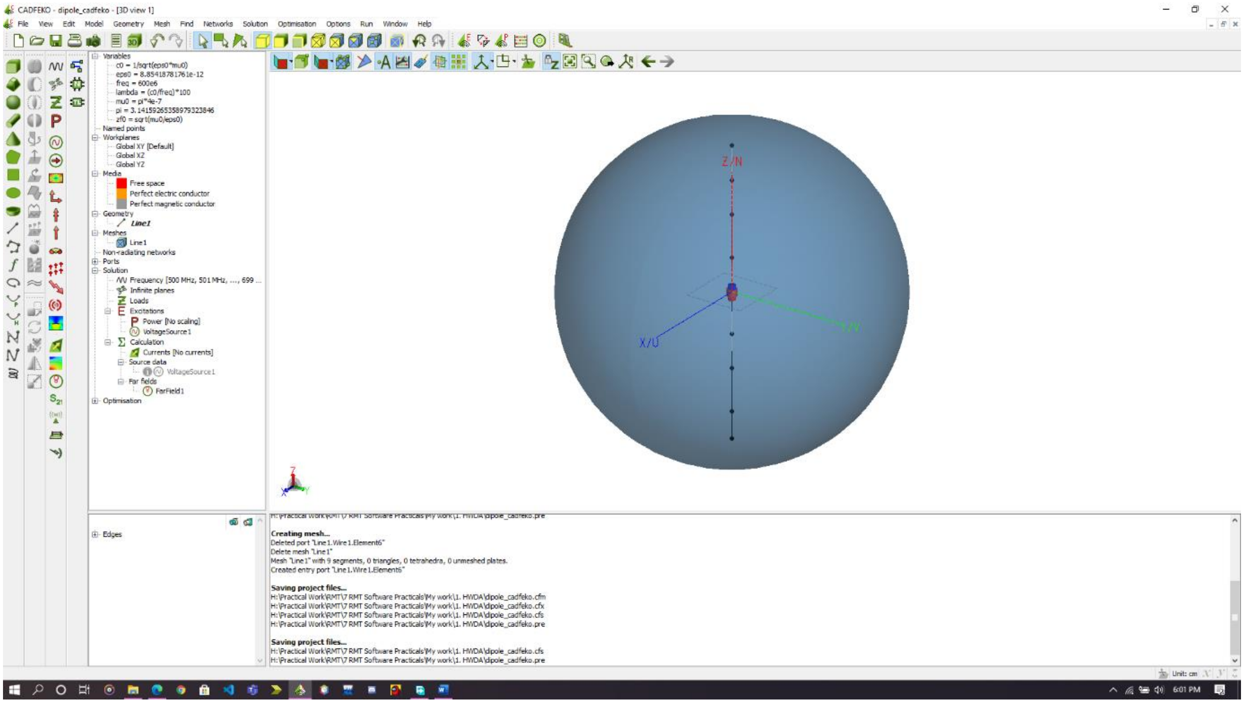


2-D(H-Plane Radiation Pattern) of (λ /4)



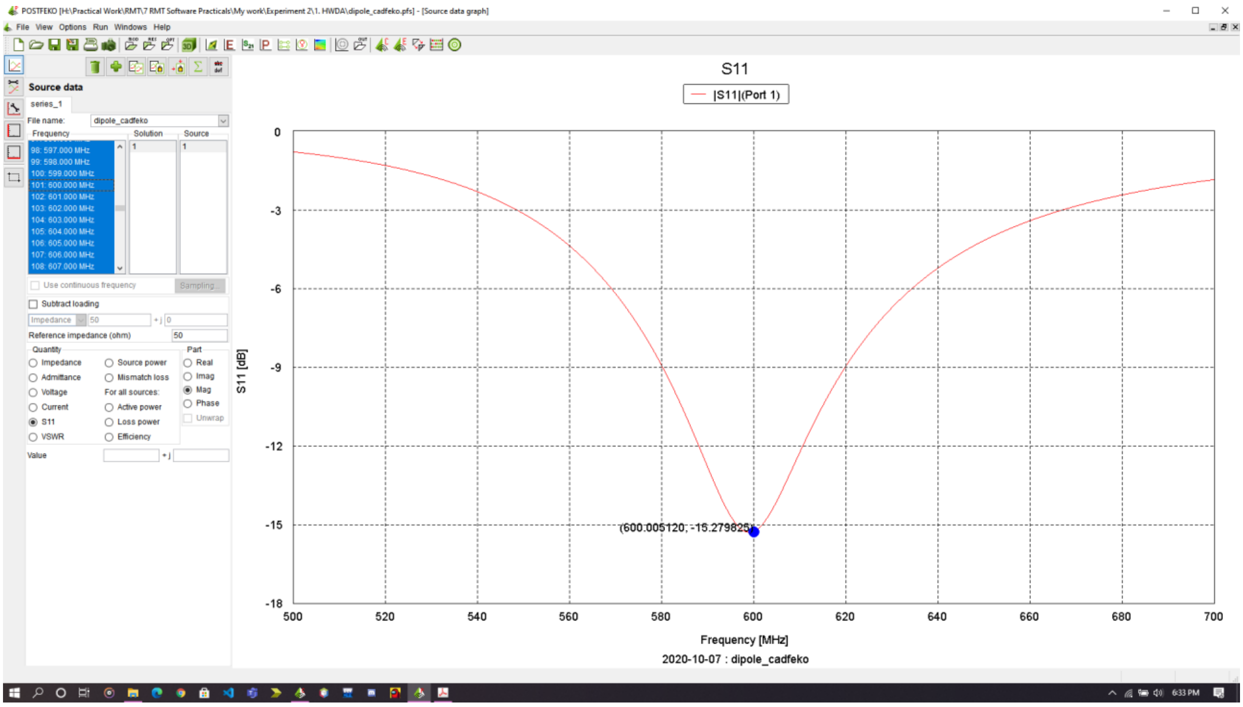
Half wavelength dipole antenna(HWDA)

Structure of HWDA (λ /2)



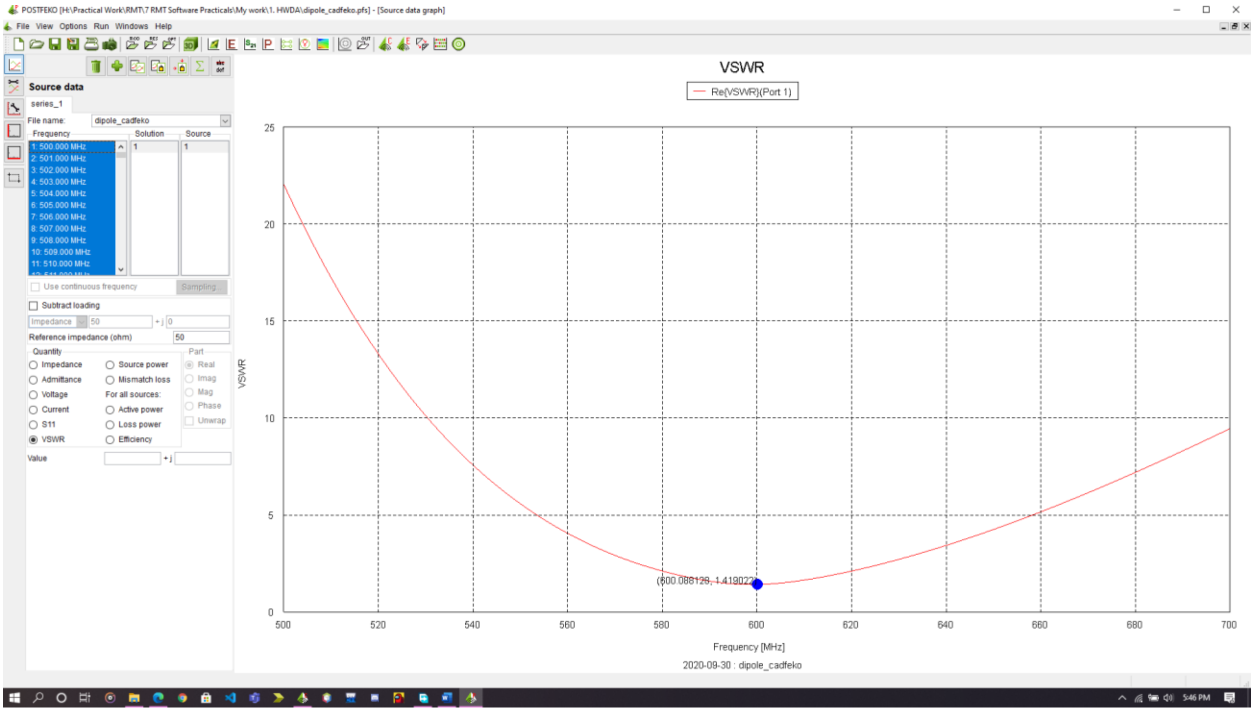
Return Loss of HWDA (λ /2)

At freq=600MHz,s11=0.172479-j0.00645242



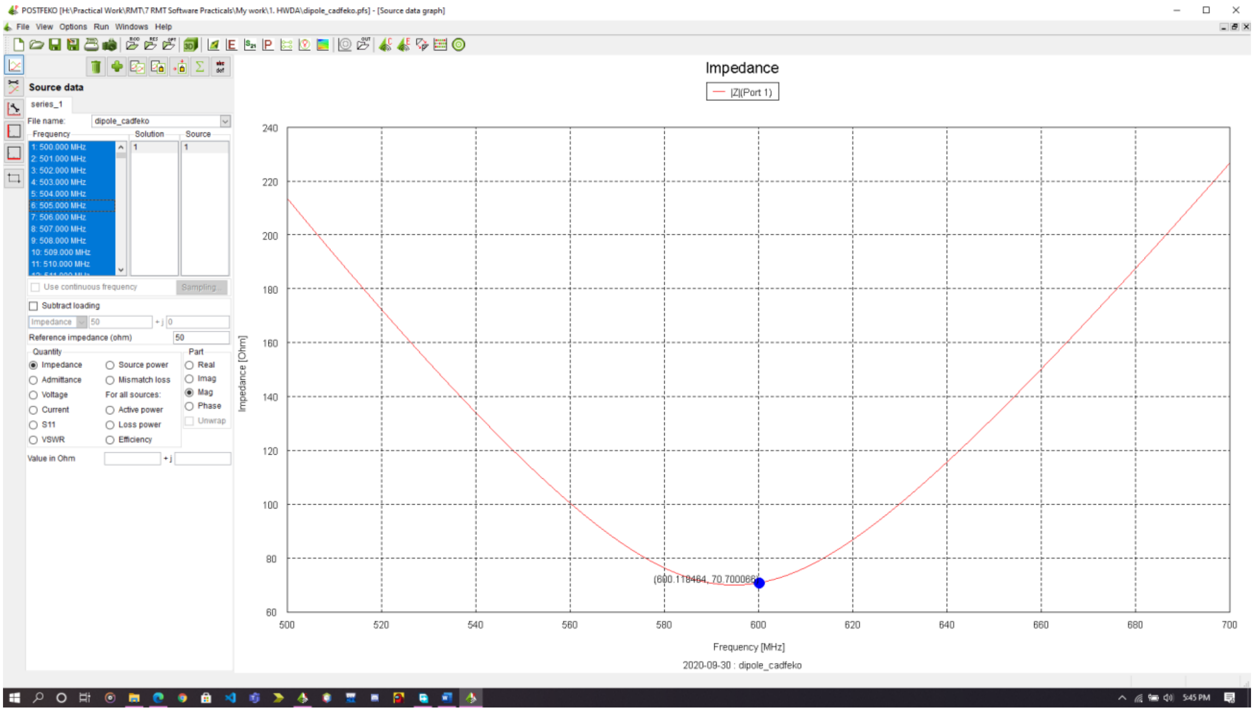
VSWR of HWDA (λ /2)

At freq=600MHz,VSWR=1.41721

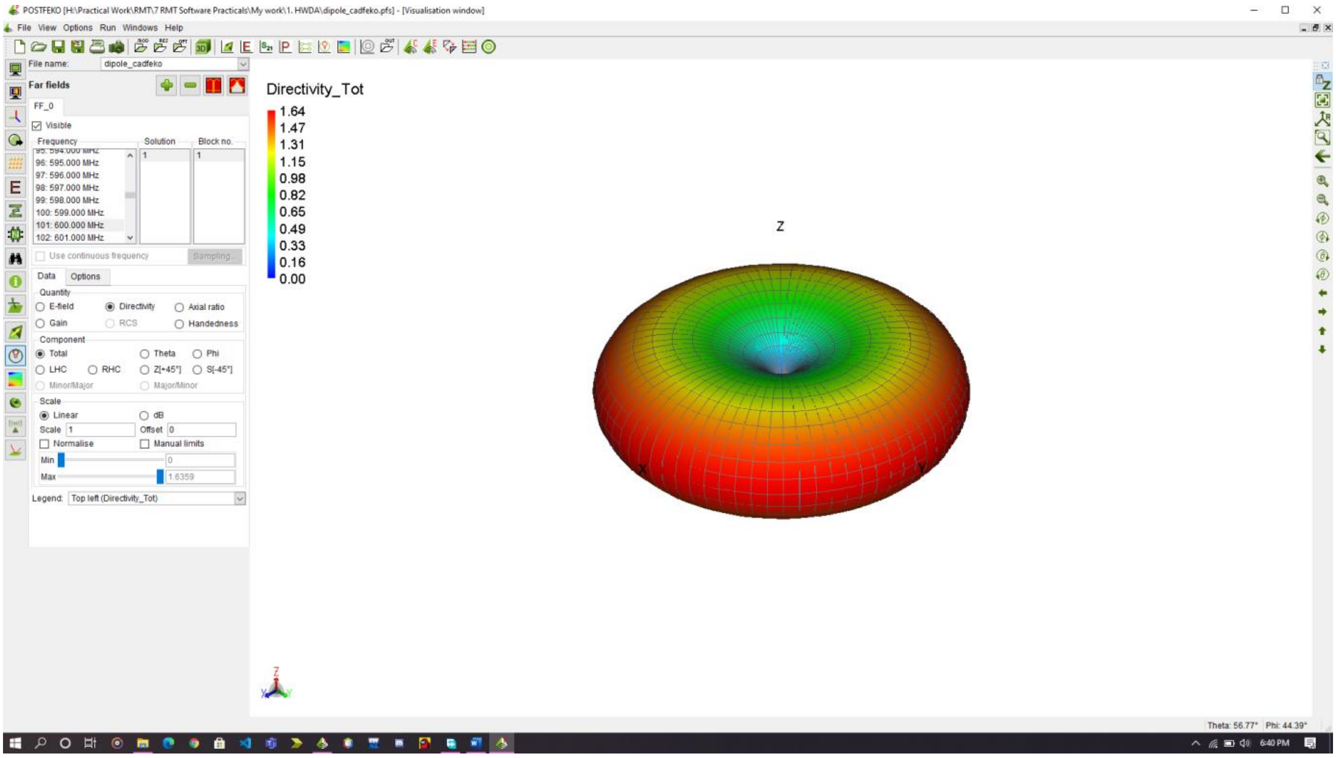


Impedance of HWDA (λ /2)

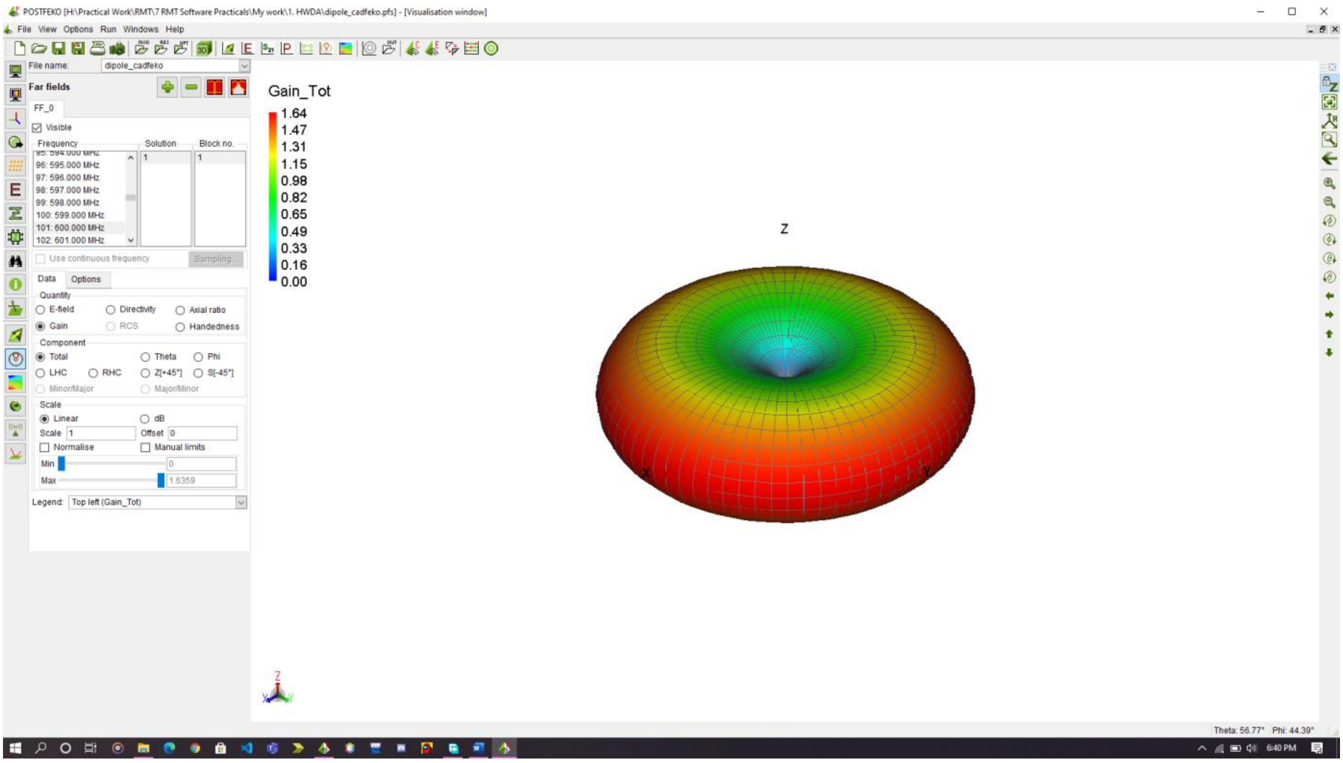
At freq=600MHz,Z=70.8354-j0.942188 ohm



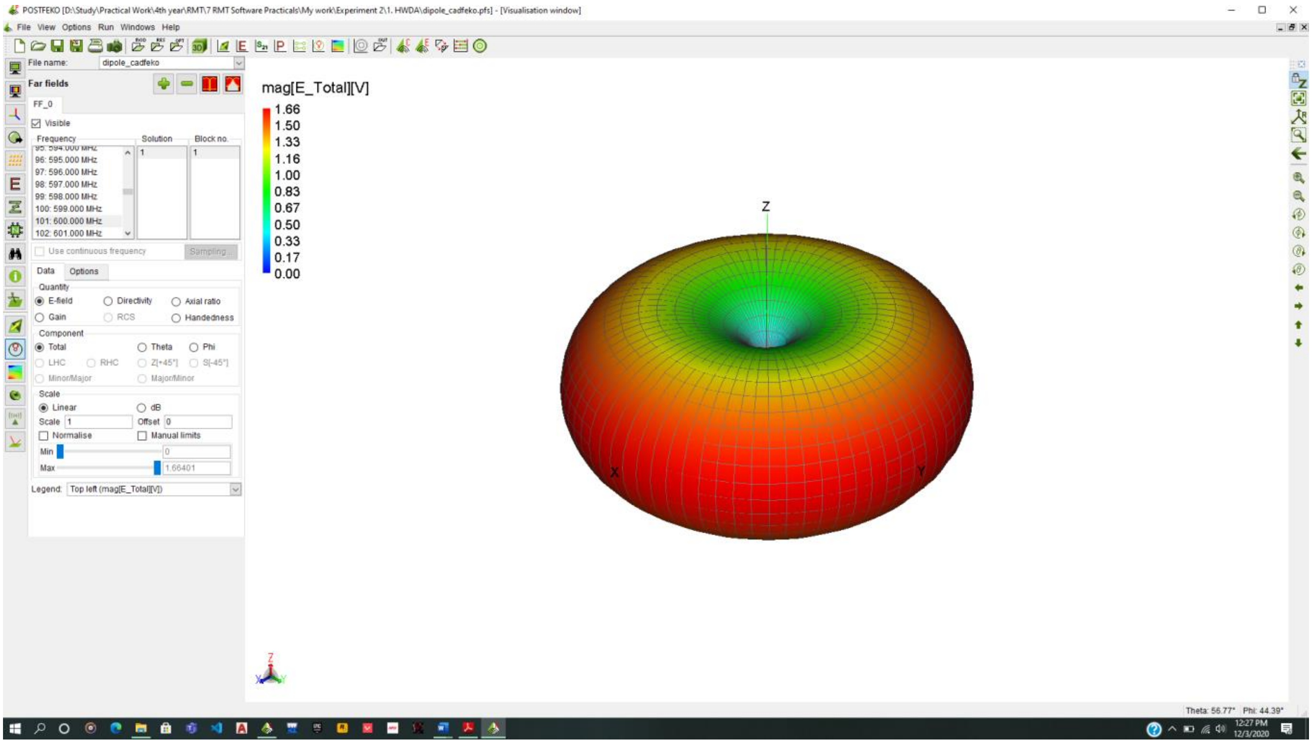
Directivity of HWDA (λ /2)



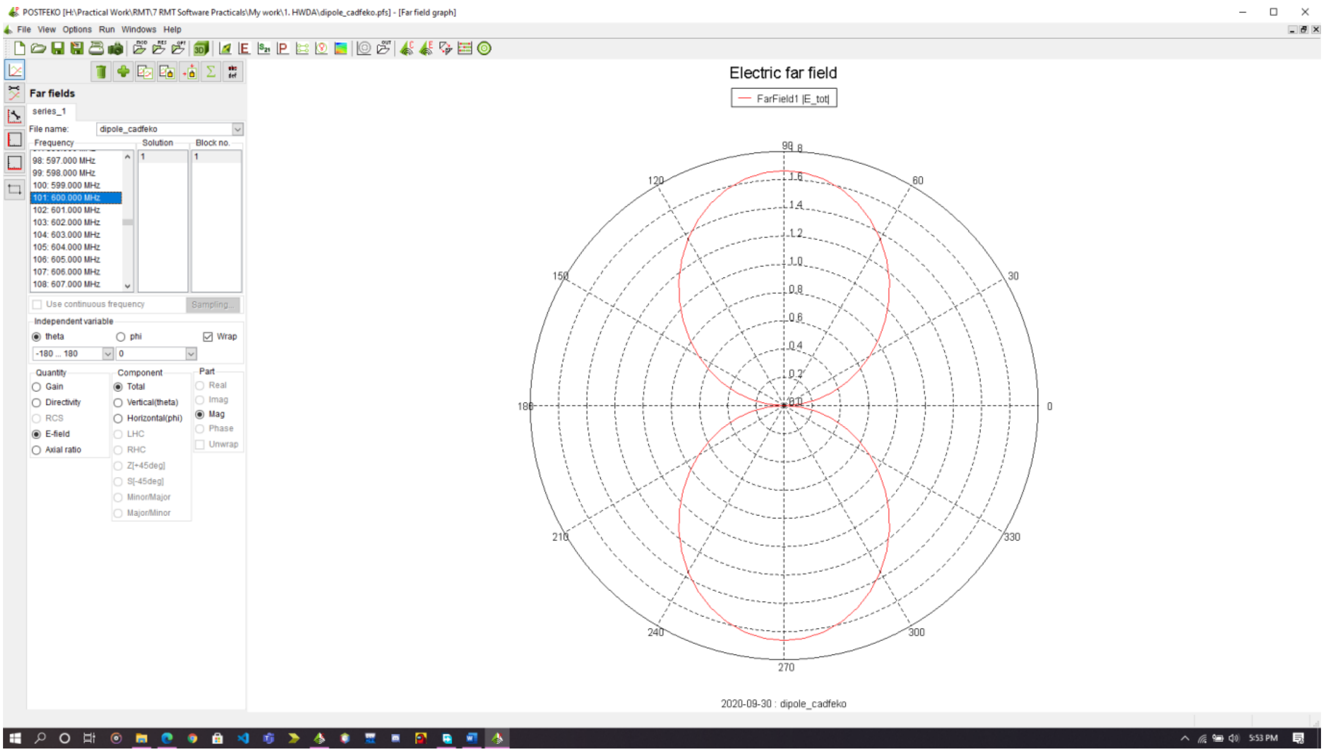
Gain of HWDA (λ /2)



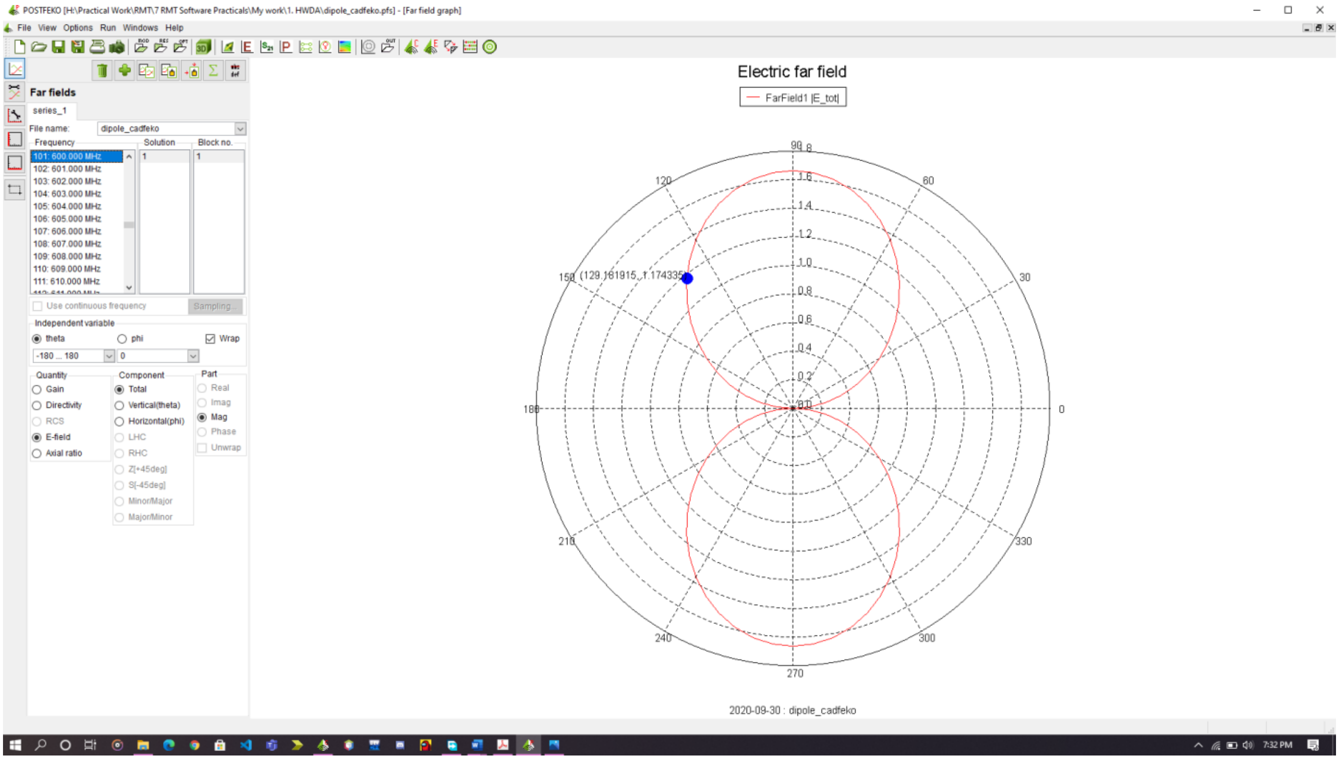
3-D Radiation Pattern of HWDA



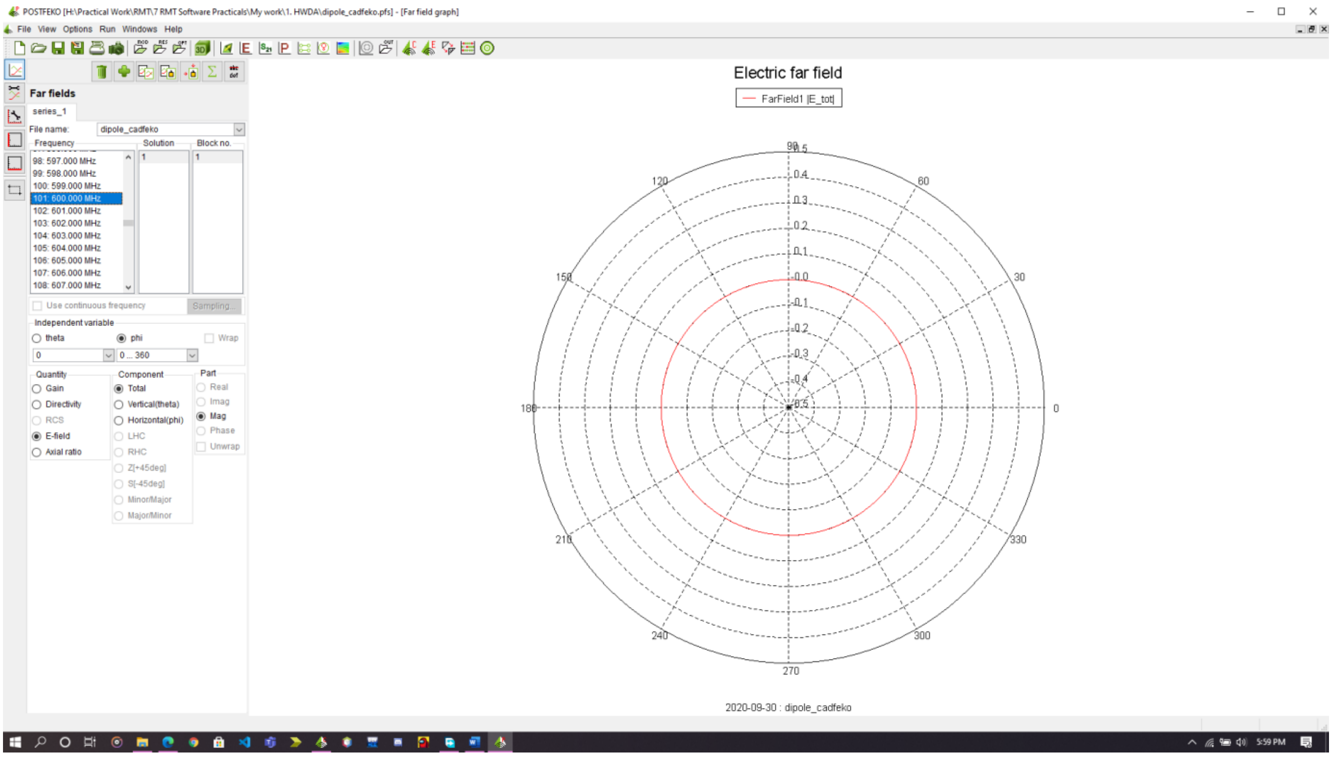
2-D(E-Plane Radiation Pattern) of (λ /2)



Beamwidth (E-Plane Radiation Pattern) of (λ /2)

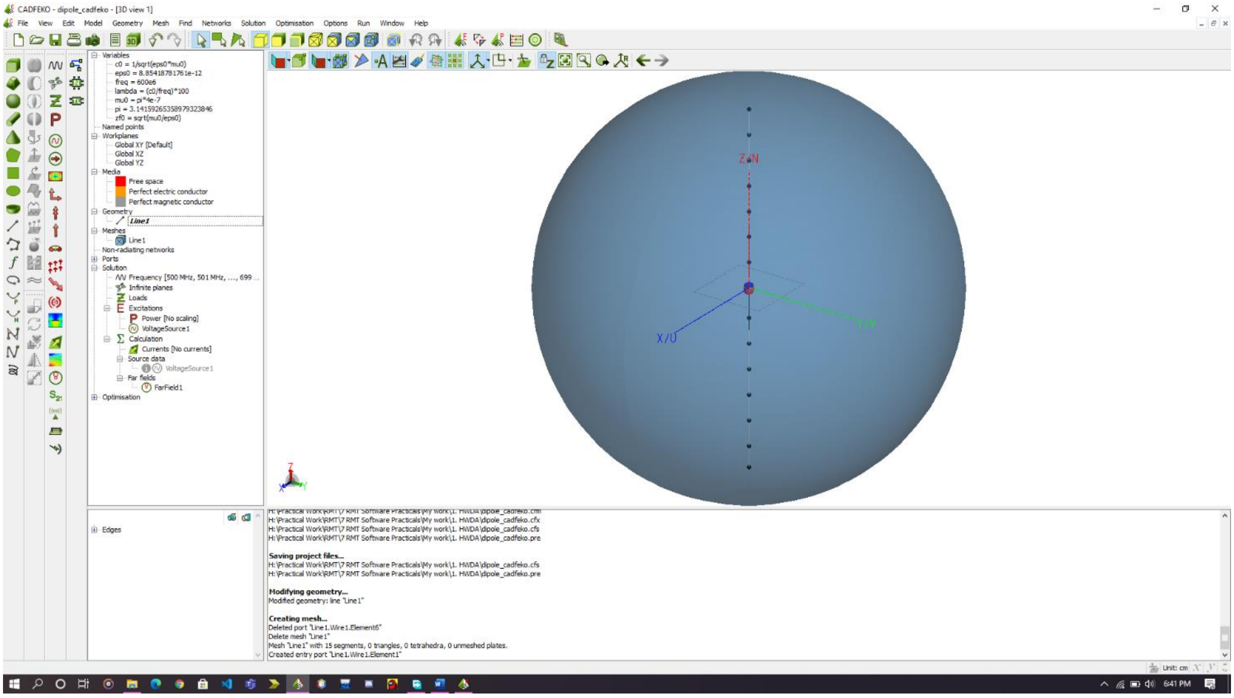


2-D(H-Plane Radiation Pattern) of (λ /2)



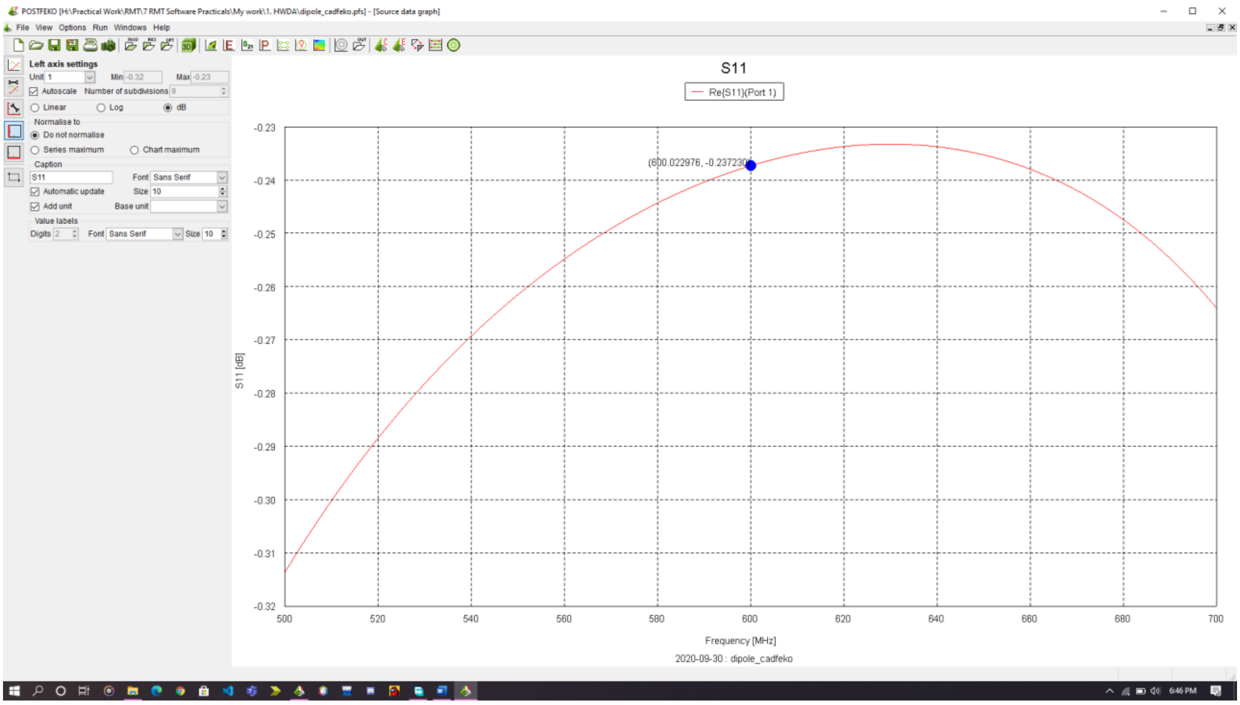
λ antenna

Structure of Lambda antenna (λ)



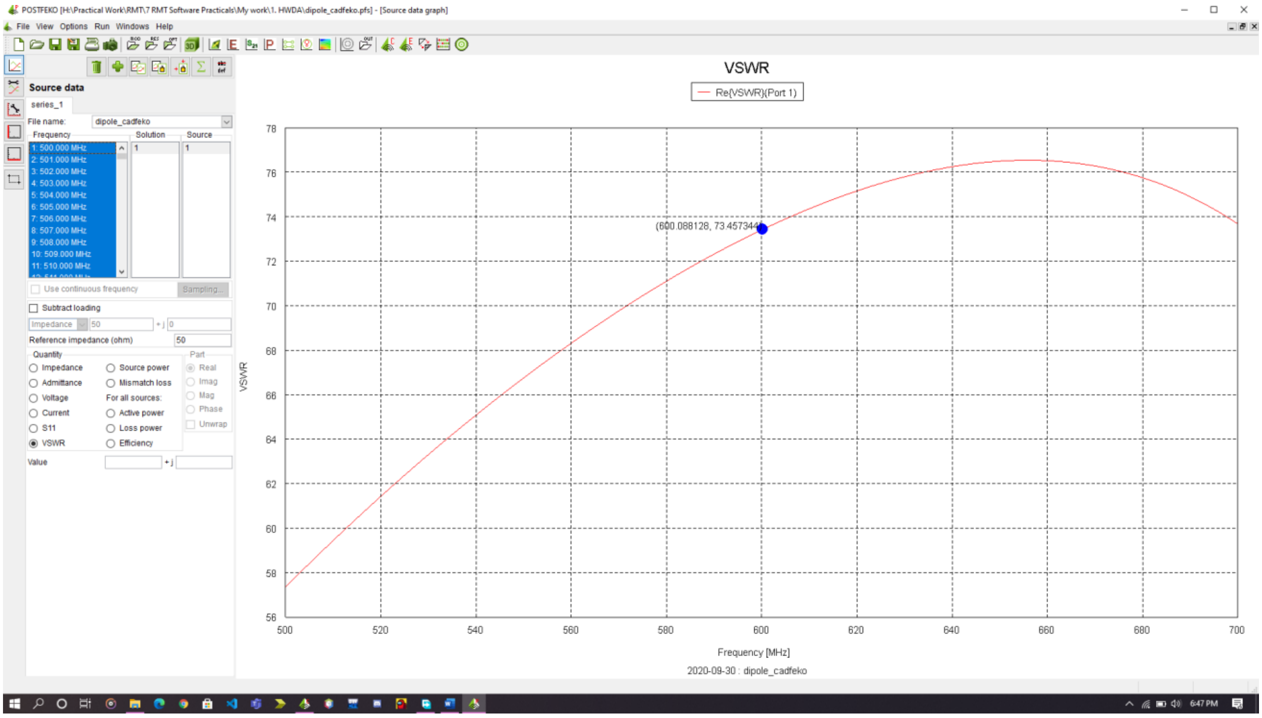
Return Loss of Lambda antenna (λ)

At freq=600MHz,s11=0.973047-j0.0120667



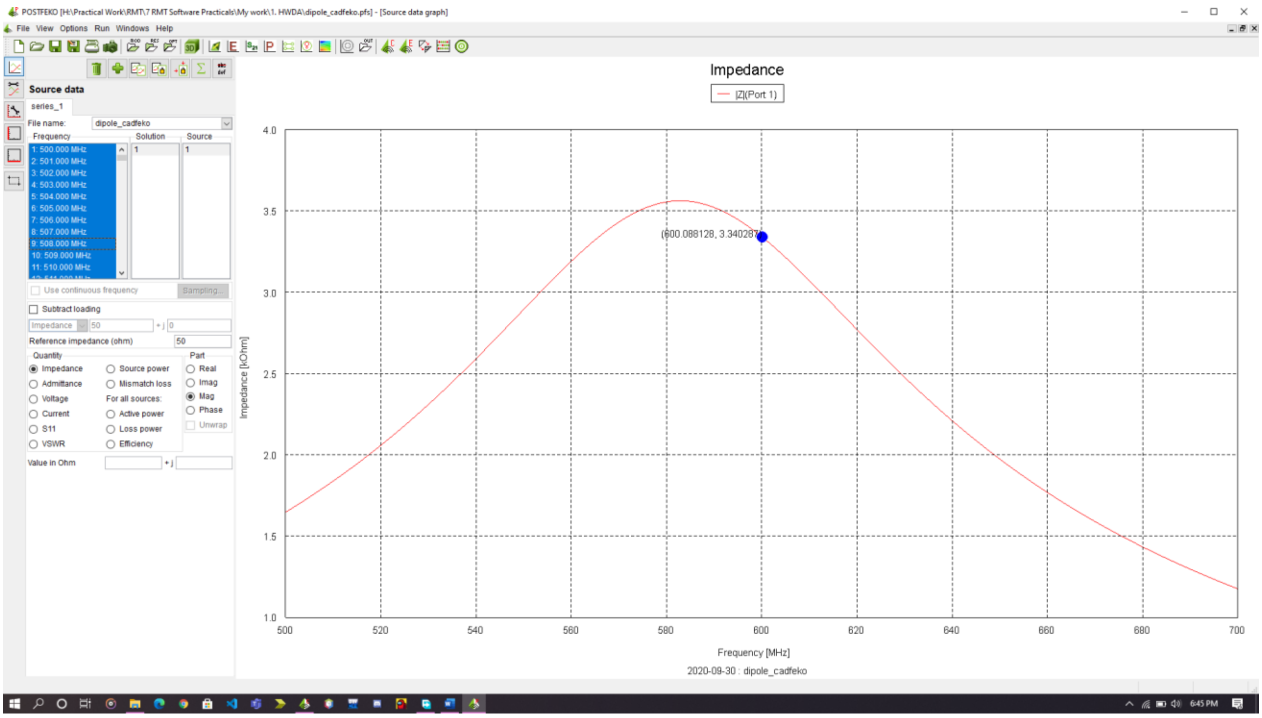
VSWR of Lambda antenna (λ)

At freq=600MHz,VSWR=73.4107

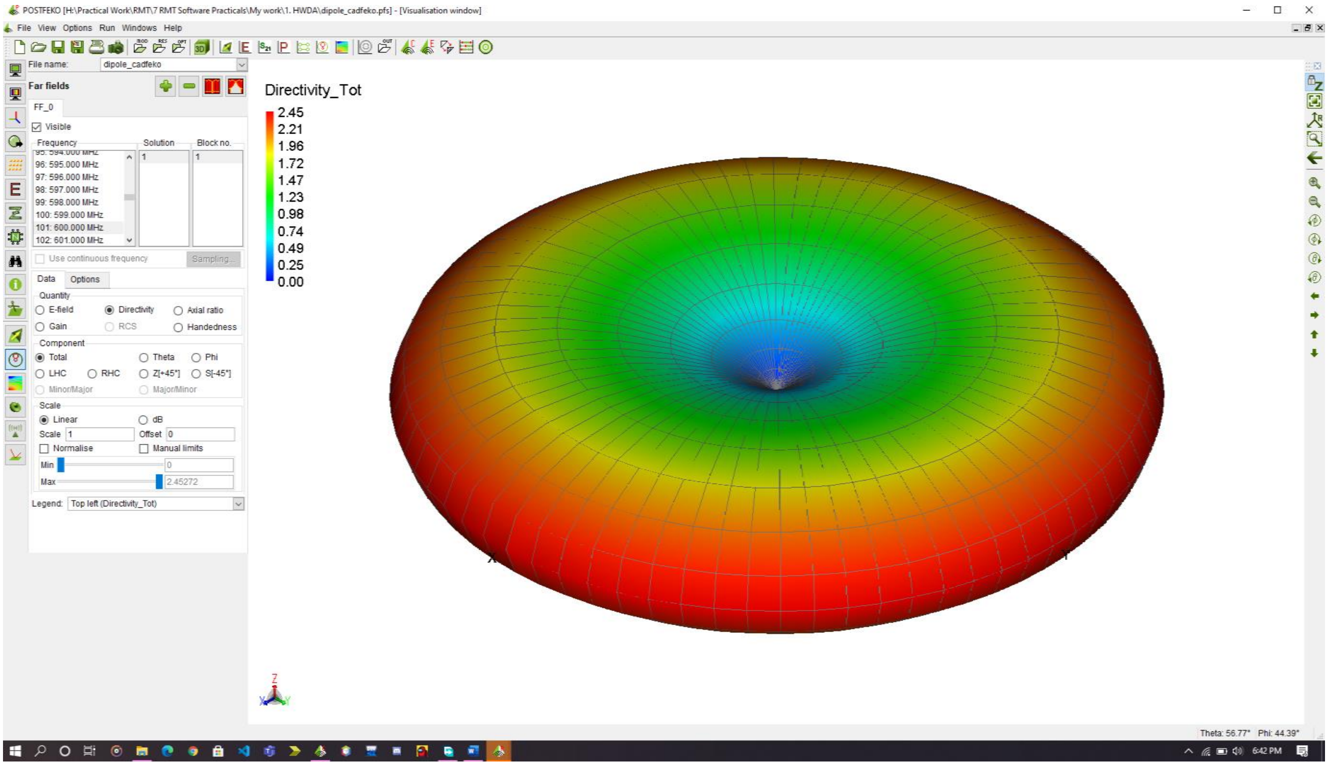


Impedance of Lambda antenna (λ)

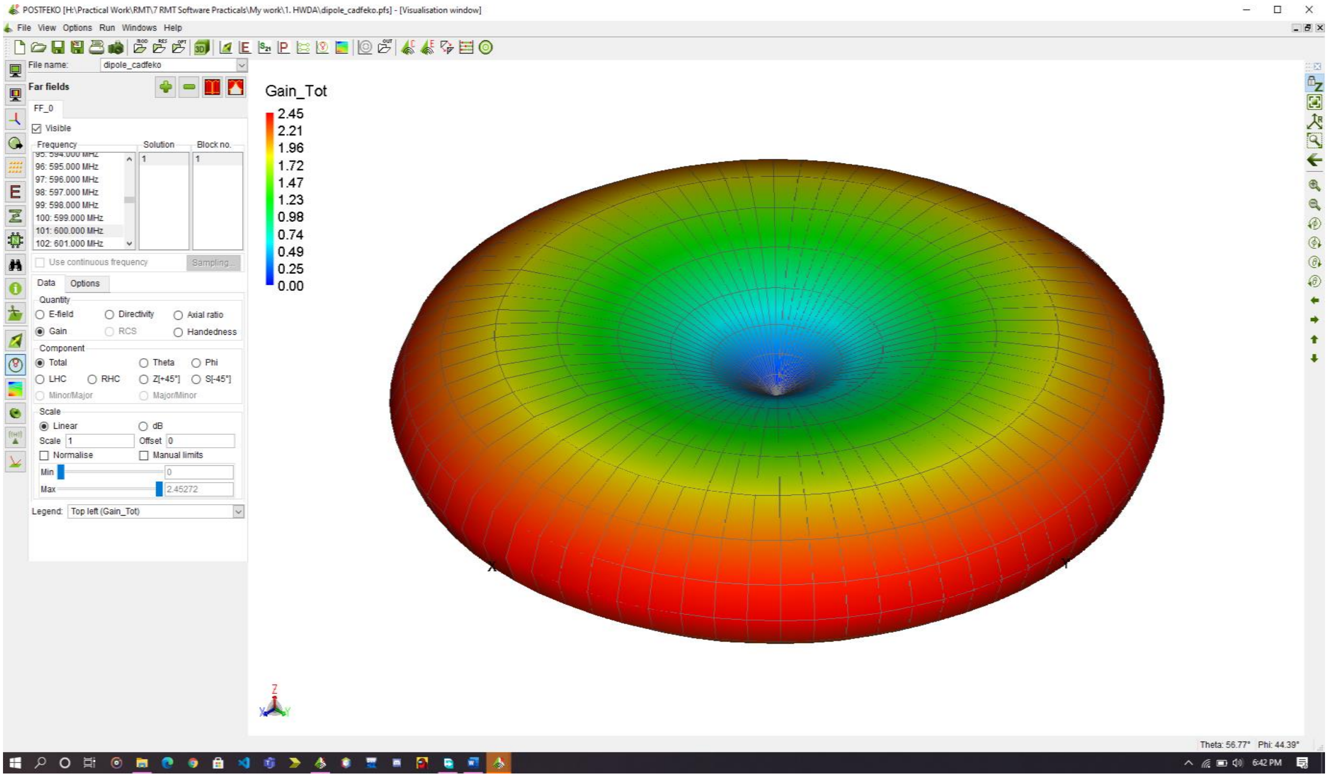
At freq=600MHz,Z=3040.72-j1383.71 ohm



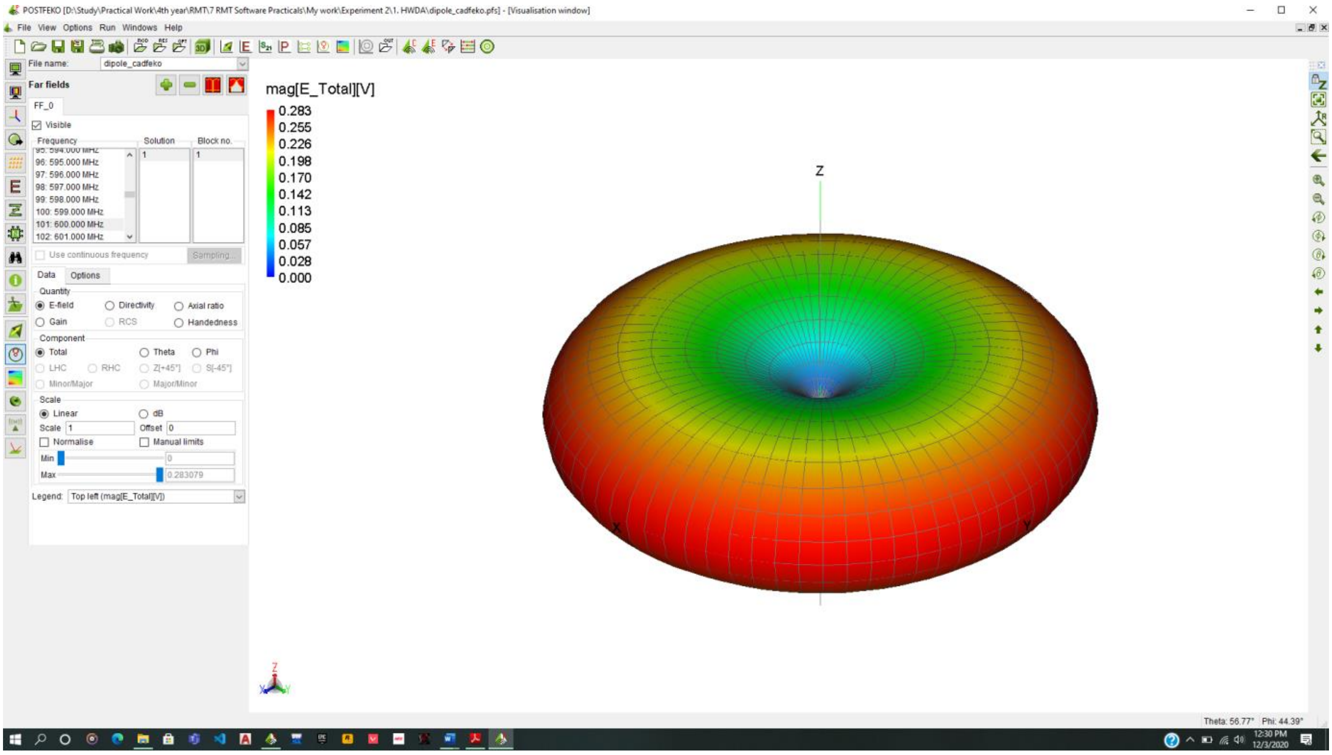
Directivity of Lambda antenna (λ)



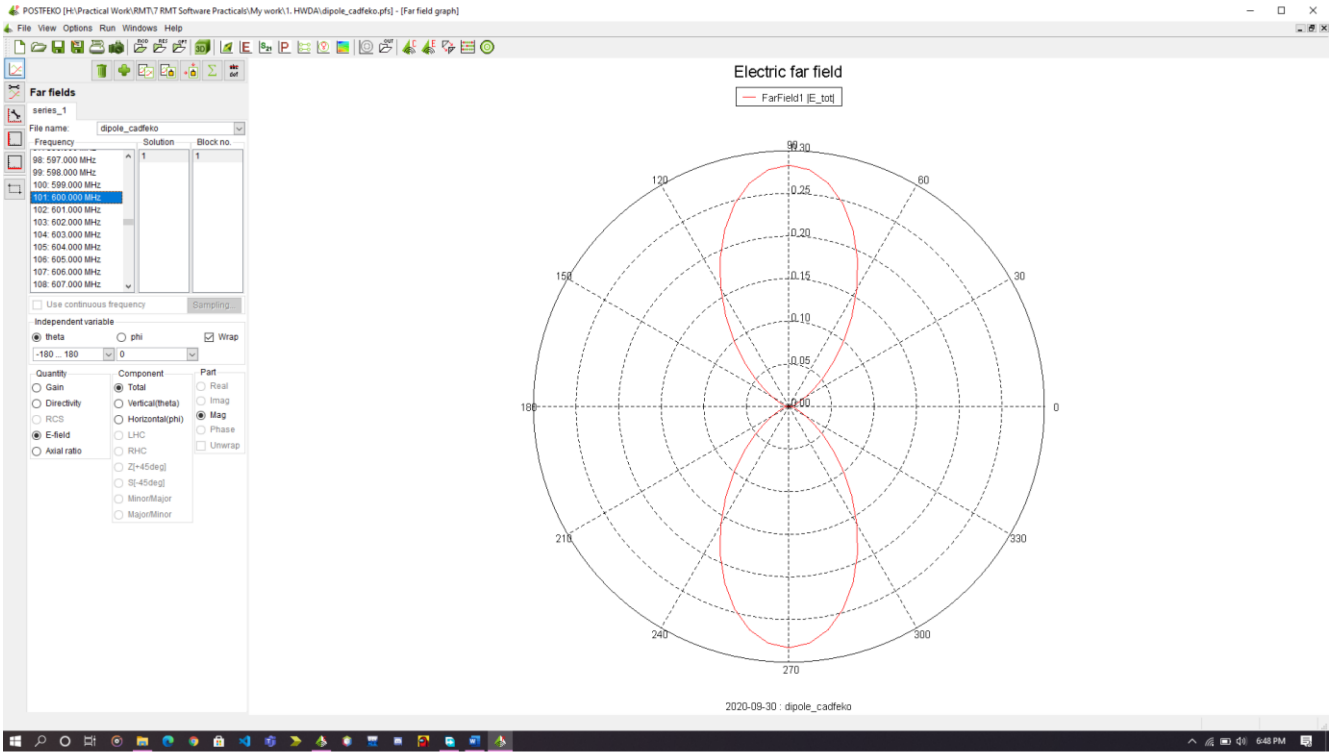
Gain of Lambda antenna (λ)



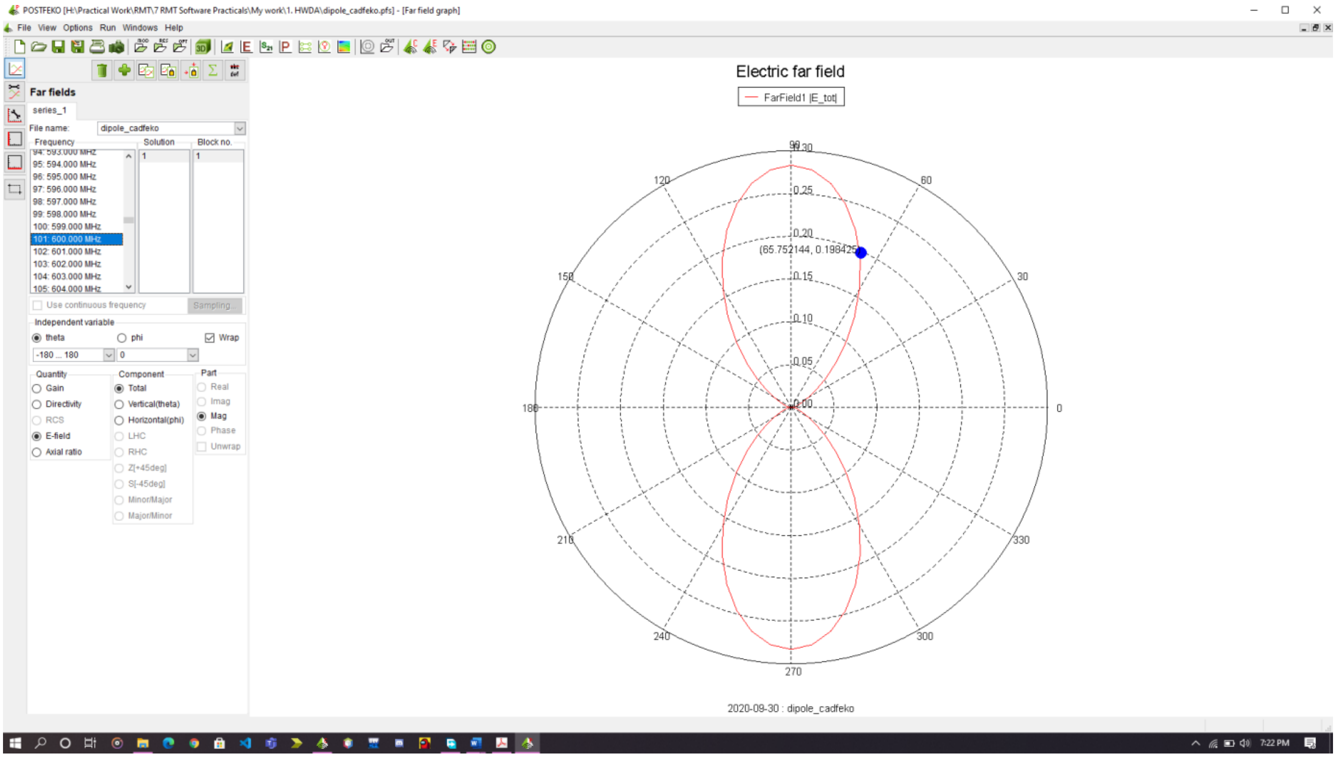
3-D Radiation Pattern of λ antenna



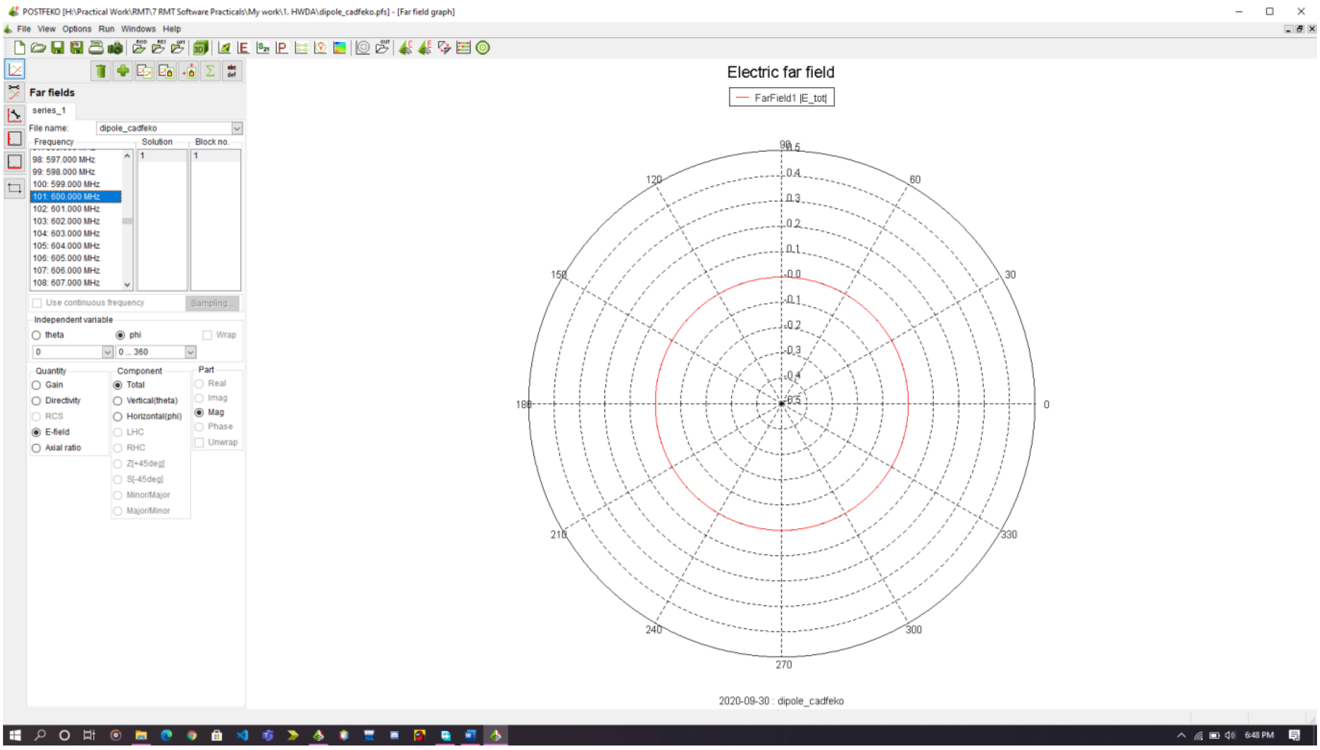
2-D(E-Plane Radiation Pattern) of (λ)



Beamwidth (E-Plane Radiation Pattern) of (λ)

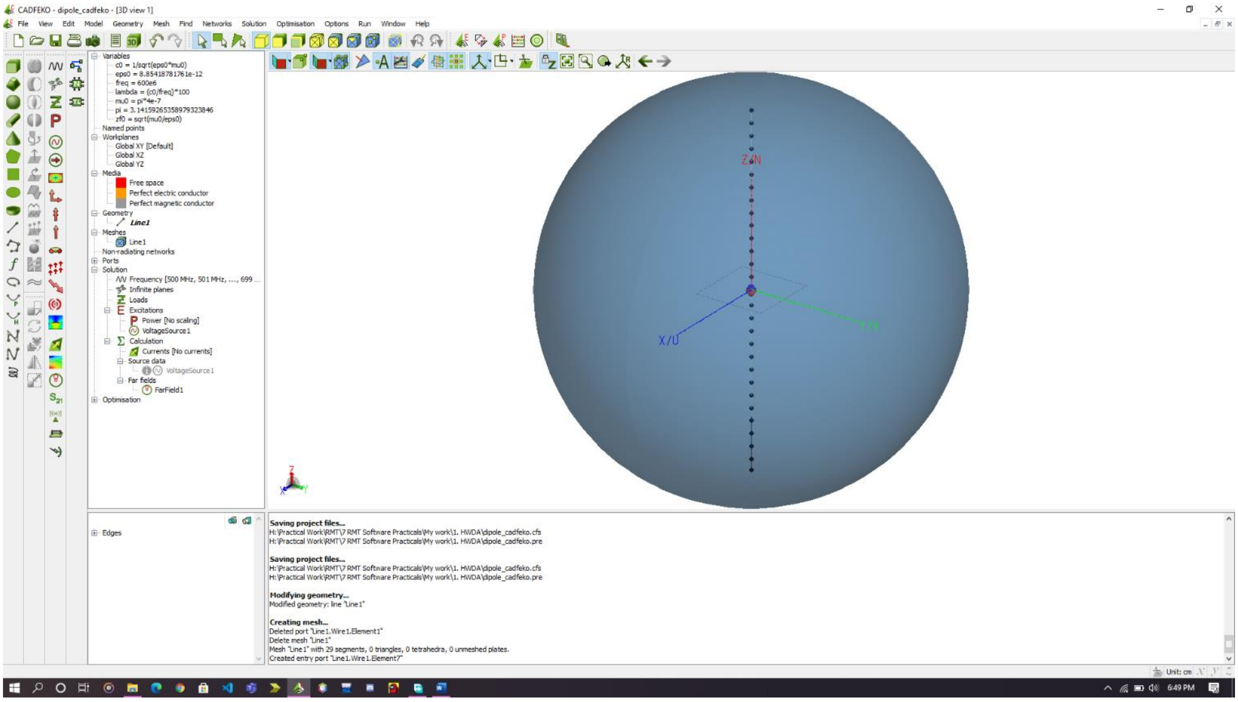


2-D(H-Plane Radiation Pattern) of (λ)



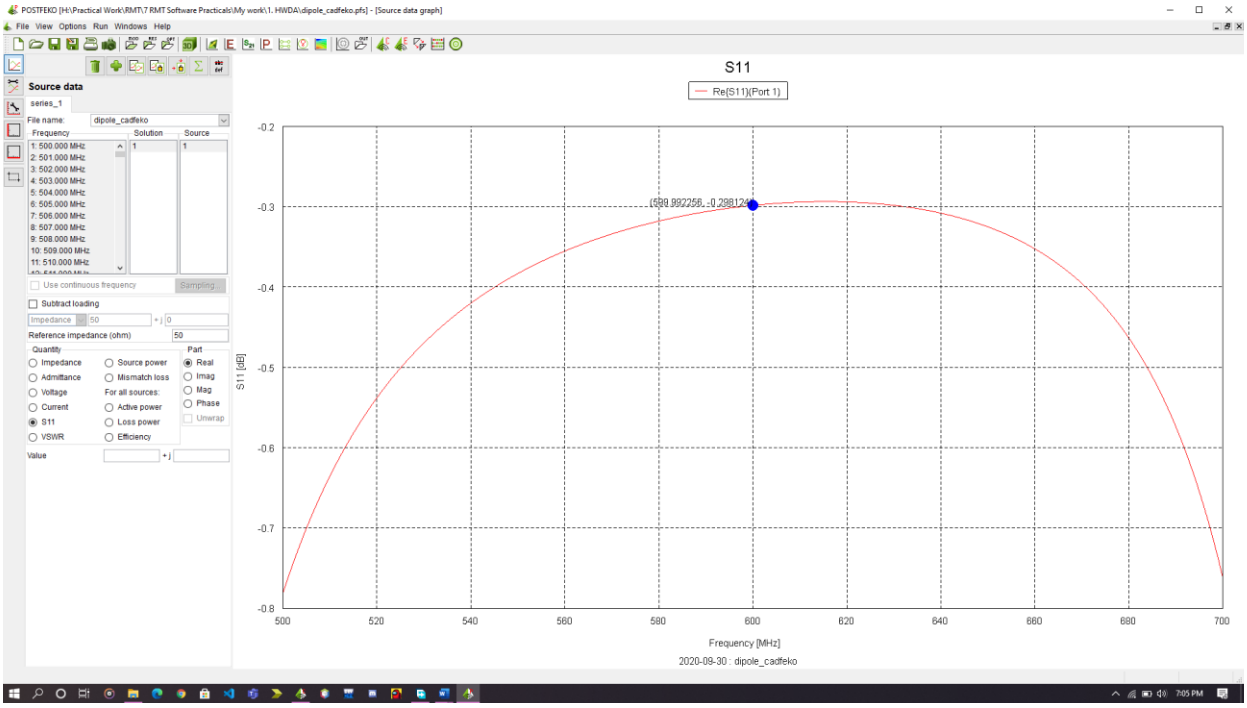
2* λ antenna

Structure of 2*Lambda antenna (2* λ)



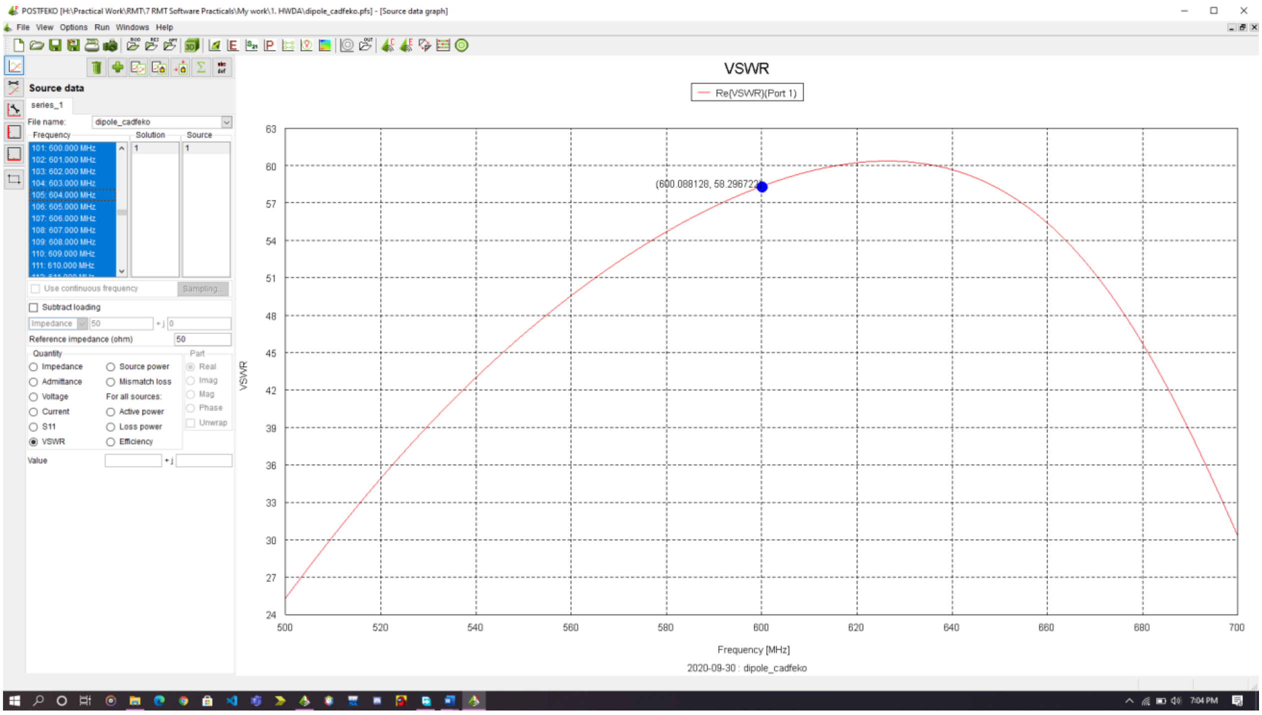
Return Loss of 2*Lambda antenna (2* λ)

At freq=600MHz, s11=0.966212-j0.012583



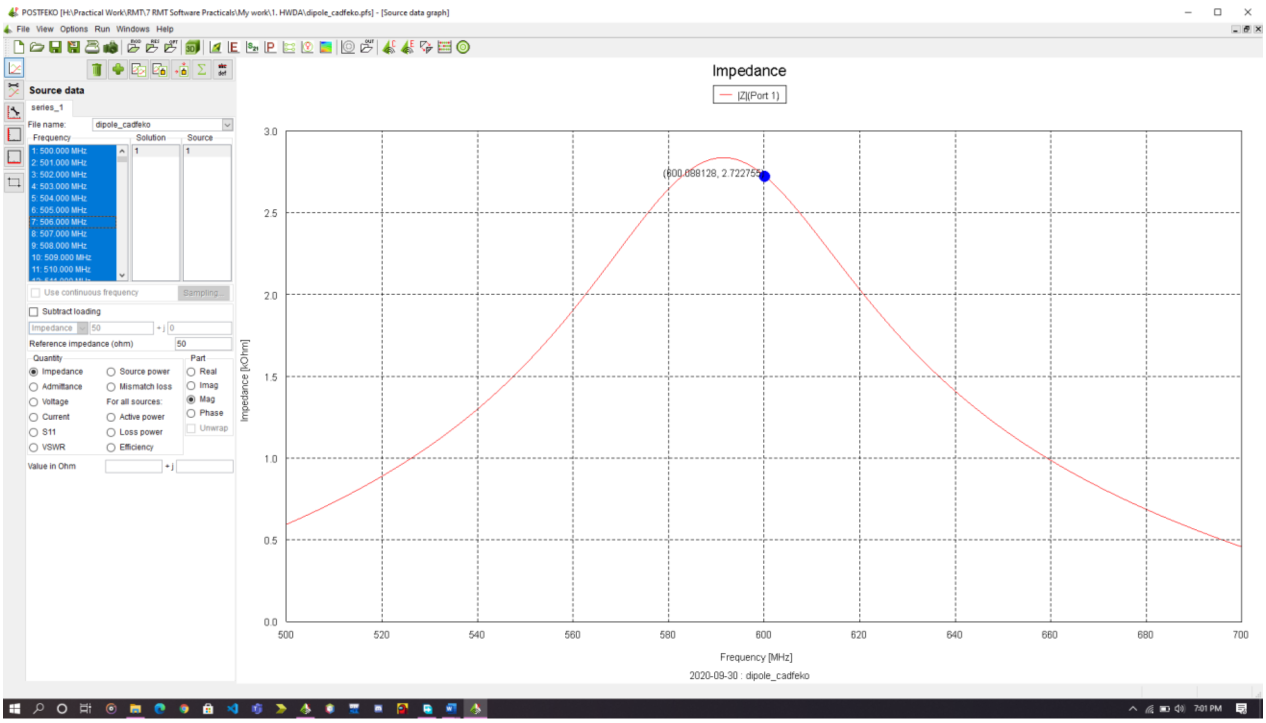
VSWR of 2*Lambda antenna (2* λ)

At freq=600MHz,VSWR=58.3372

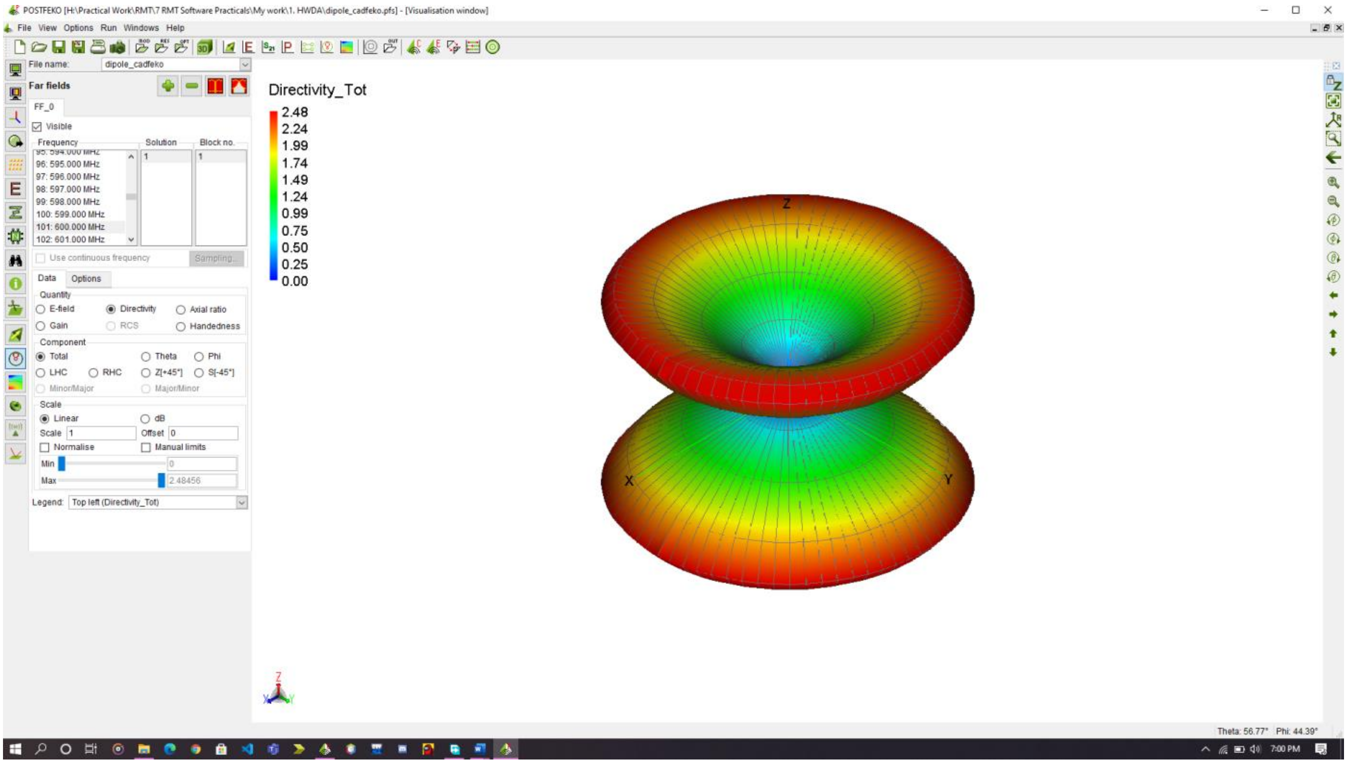


Impedance of 2*Lambda antenna (2* λ)

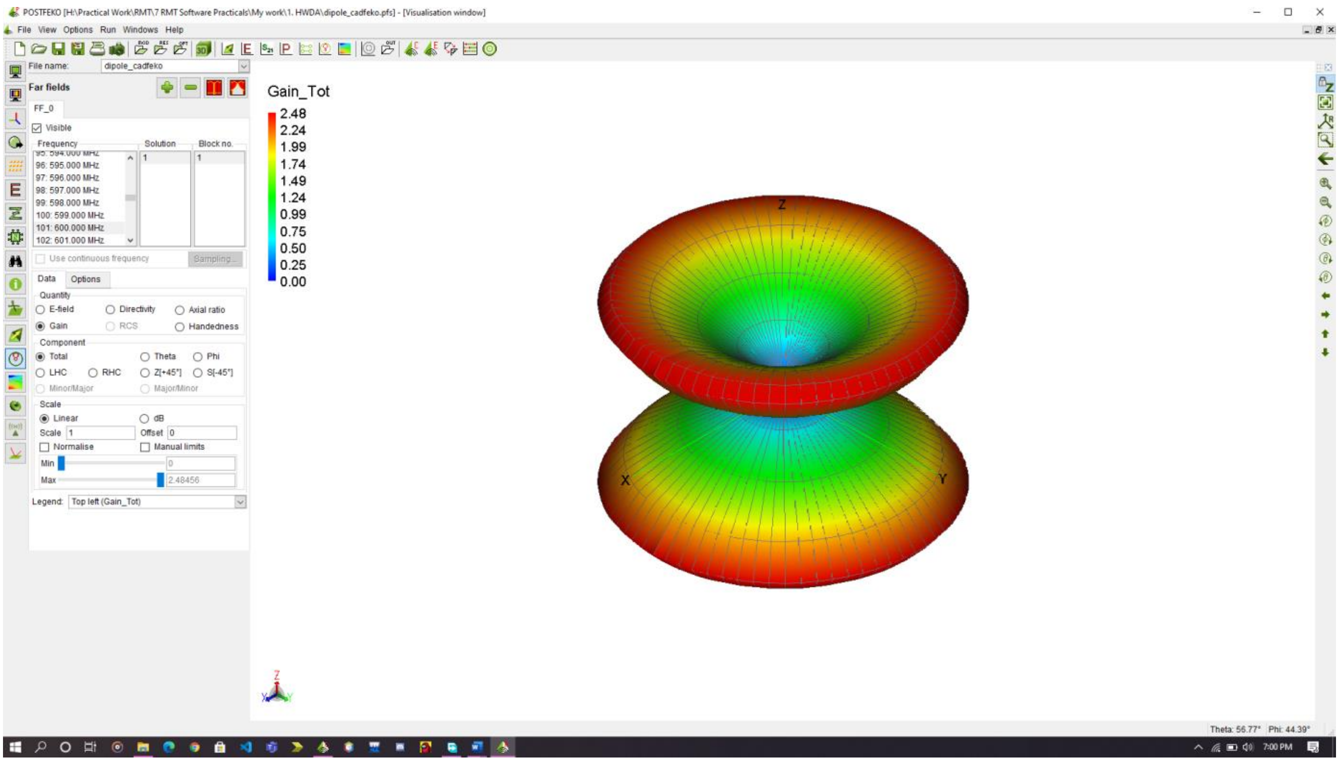
At freq=600MHz,Z= 2549.18 -j967.975 ohm



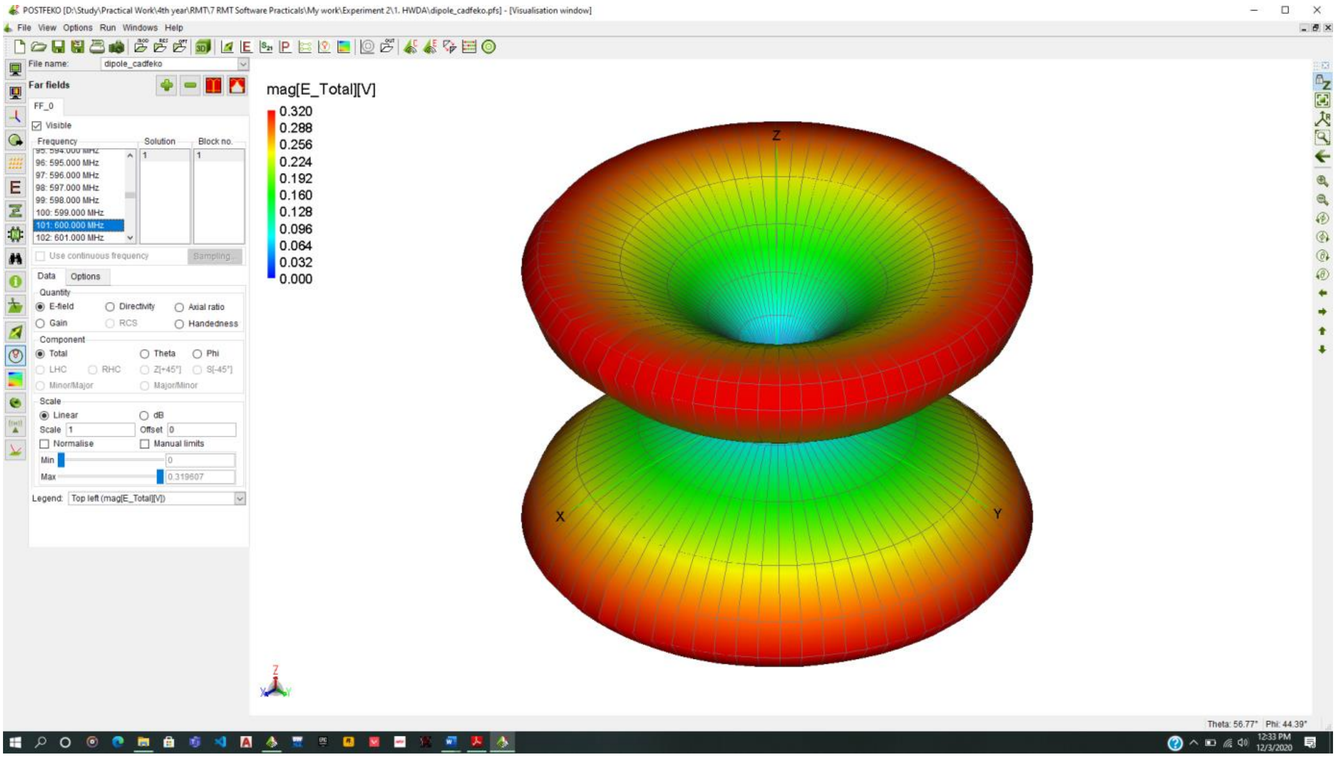
Directivity of 2*Lambda antenna (2* λ)



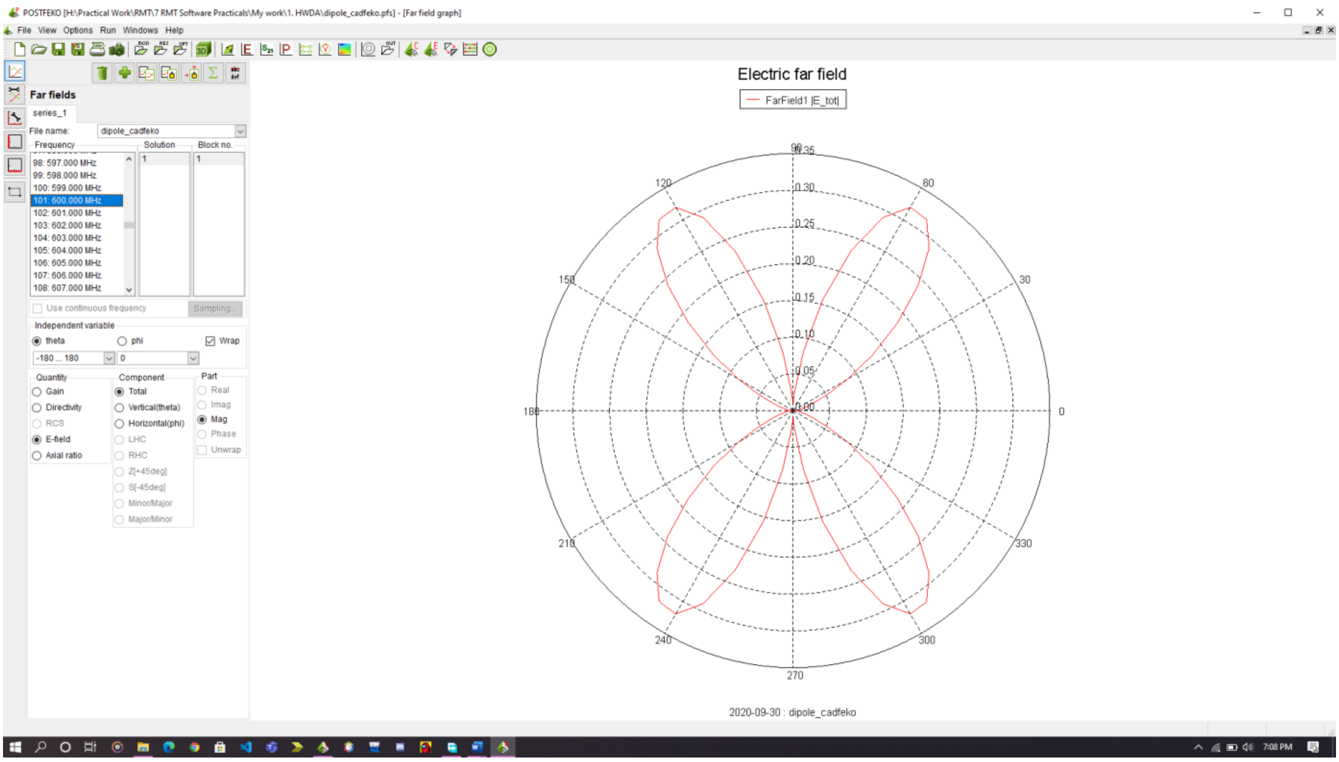
Gain of 2*Lambda antenna (2* λ)



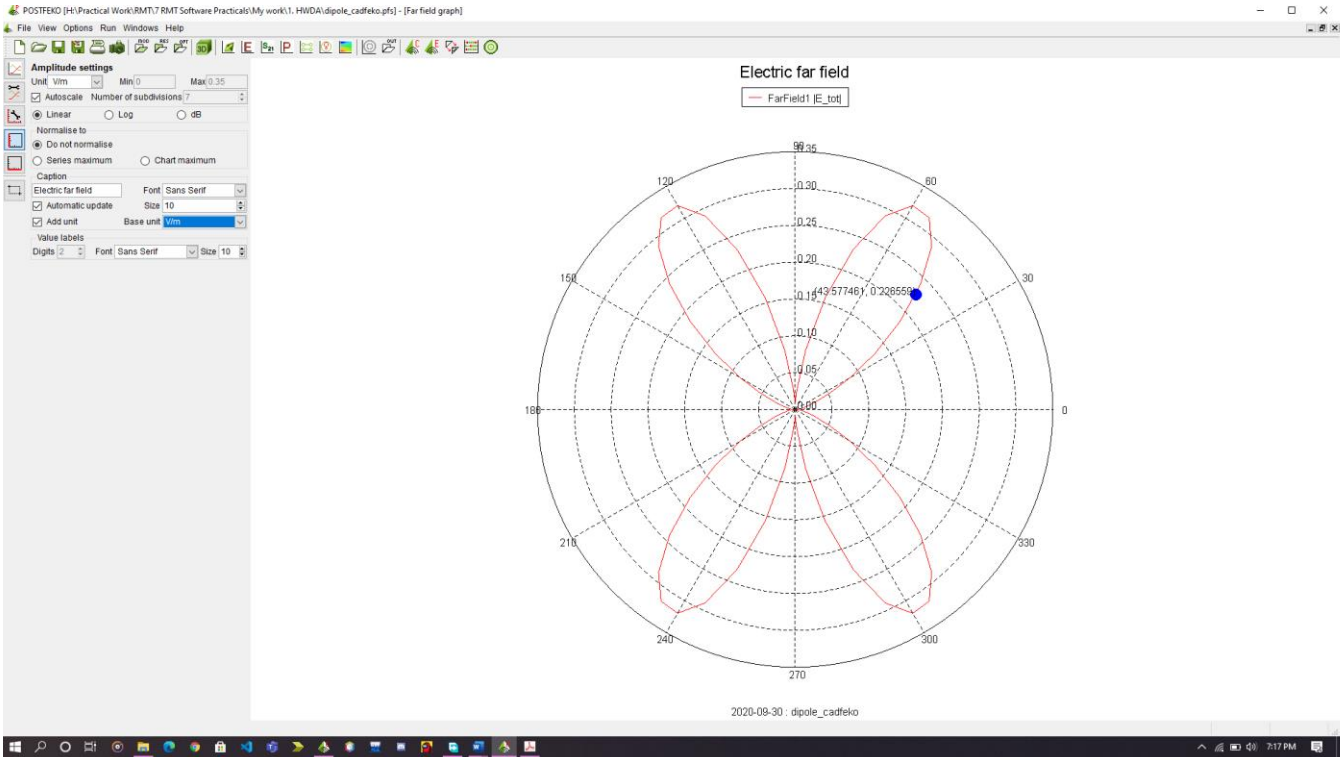
3-D Radiation Pattern of 2* λ antenna



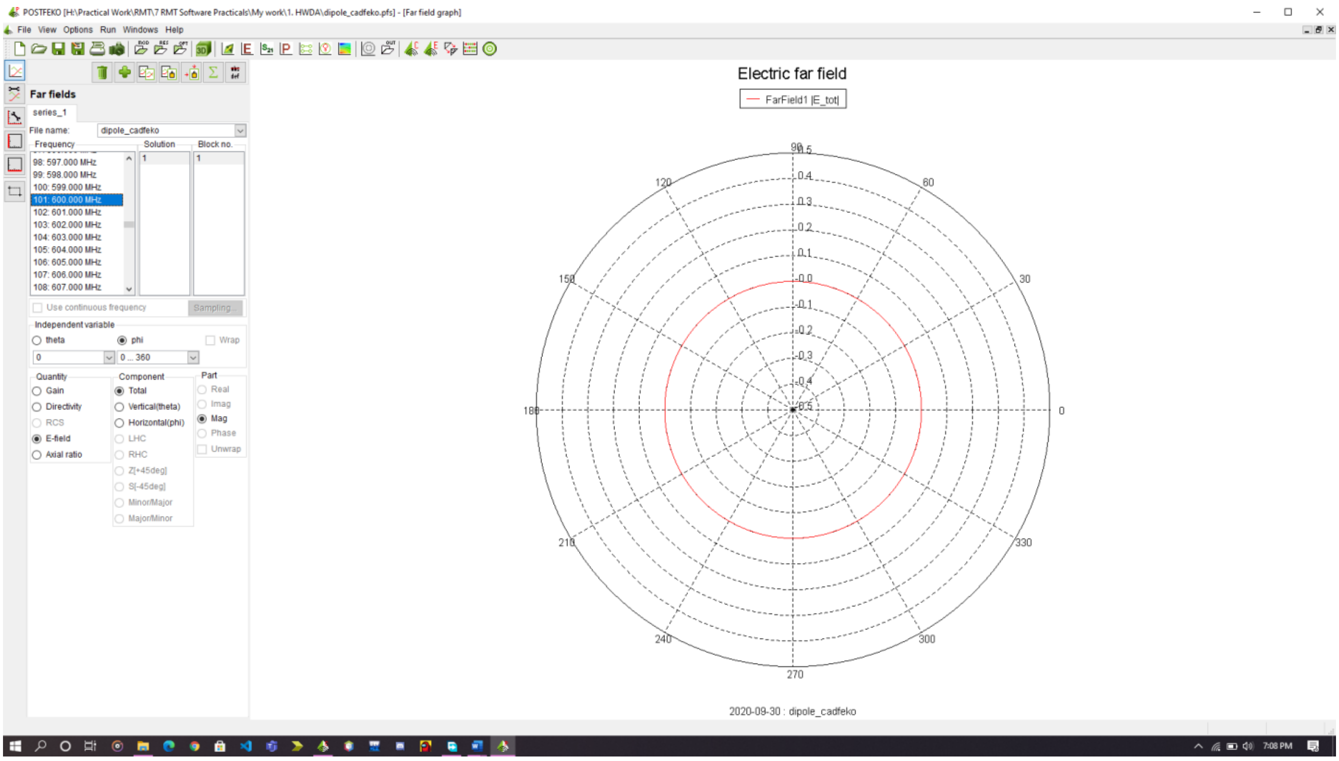
2-D(E-Plane Radiation Pattern) of (2* λ)



Beamwidth (E-Plane Radiation Pattern) of (2* λ)



2-D(H-Plane Radiation Pattern) of (2* λ)



CONCLUSION:

1. Radiation pattern is like 8 shaped pattern i.e. with two lobes perpendicular to antenna axis in case of lengths λ /4, λ /4 and λ. Radiation pattern for length 2* λ has 4 lobes.
2. Return loss should be as low as possible i.e. it should be as negative as possible in dB which we observe in case of length λ /2 (-15.2798 dB).
3. VSWR is close to ideal (= 1) in case of length λ /2 (= 1.41721) and has highest value in case of length λ /4 (= 660.57). After length λ /2, lowest VSWR is in case of length 2* λ (= 58.3372) and then length λ (= 73.4107).
4. Impedance is near to 73 ohms in case of length λ/2. It is large in case of length λ /4 and is very large in case of lengths λ and 2* λ.
5. Gain is lowest in case of length λ /4 and is increasing as length increases. Highest in case of length 2* λ.
6. Half Power Beam Width is highest in case length λ /4 which makes it less directive and is highest in case of length 2* λ.
7. All had the H-pattern of circle making the H-plane HPBW 360 degrees.

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.

CLASS: B.E. E &TC VIII **SUBJECT: RMT**

EXPT. NO.: 3 **DATE:** 03-09-2020

Roll No.: 42428

TITLE: To measure and plot mode characteristics of reflex klystron.

OBJECTIVE: 1. To study the characteristics of the reflex Klystron tube

2. To determine the it's electronic tuning range and Sensitivity

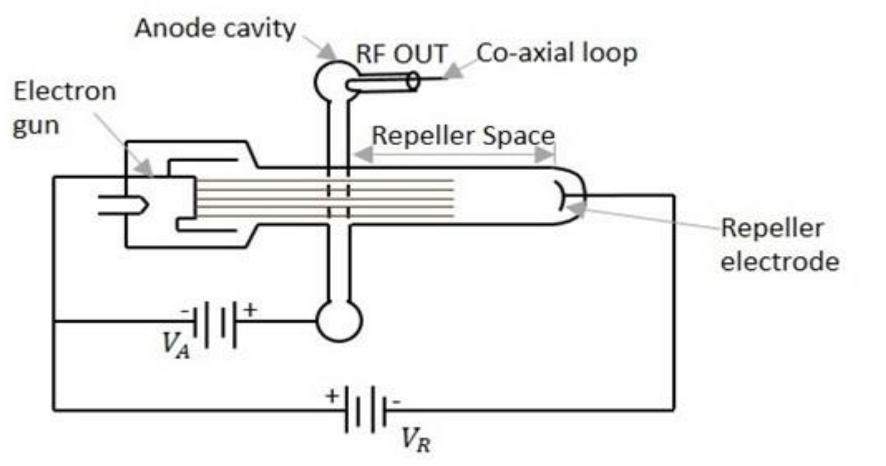
EQUIPMENTS:-

1. Klystron Power Supply
2. Klystron with mount
3. Cooling Fan
4. Isolator
5. Variable Attenuator
6. Frequency meter
7. X-Band detector
8. BNC-to-BNC cable
9. Oscilloscope

THEORY:

In the reflex klystron (also known as a 'Sutton' klystron after its inventor, Robert Sutton), the electron beam passes through a single resonant cavity. The electrons are fired into one end of the tube by an electron gun. After passing through the resonant cavity they are reflected by a negatively charged reflector electrode for another pass through the cavity, where they are then collected. The electron beam is velocity modulated when it first passes through the cavity. The formation of electron bunches takes place in the drift space between the reflector and the cavity. The voltage on the reflector must be adjusted so that the bunching is at a maximum as the electron beam re-enters the resonant cavity, thus ensuring a maximum of energy is transferred from the electron beam to the RF oscillations in the cavity. The voltage should always be switched on before providing the input to the reflex klystron as the whole function of the reflex klystron would be destroyed if the supply is provided after the input. The reflector voltage may be varied slightly from the optimum value, which results in some loss of output power, but also in a variation in frequency. This effect is used to good advantage for automatic frequency control in receivers, and in frequency modulation for transmitters. The level of modulation applied for transmission is small enough that the power output essentially remains constant. At regions far from the optimum voltage, no oscillations are obtained at all. This tube is called a reflex klystron because it repels the input supply or performs the opposite function of a klystron.

There are often several regions of reflector voltage where the reflex klystron will oscillate; these are referred to as modes. The electronic tuning range of the reflex klystron is usually referred to as the variation in frequency between half power points—the points in the oscillating mode where the power output is half the maximum output in the mode. The frequency of oscillation is dependent on the reflector voltage, and varying this provides a crude method of frequency modulating the oscillation frequency, albeit with accompanying amplitude modulation as well.



Constructional details of Reflex Klystron

PROCEDURE:

Power Supply Setting:

1. Connect the 3-pin main power cord provided with instrument to the socket located at back panel of the instrument.
2. Check the power point of the lab, there should be proper earthing of mains connection.
3. Connect the power cord to the main socket and switch 'ON' the instrument keeping meter switch at 'V' position and switch ON the H.T. supply.
4. Rotate the beam voltage knob and observe the voltage variation at the meter, it should vary from 200 V to 450V approx.
5. Put the meter switch to Reflector Voltage position variation in the meter with the help of reflector knob, it should vary from -10V to -270V approx.
6. Make sure H.T. switch should be at "OFF" position and put 'OFF' the main power switch.
7. It shows instrument is working satisfactorily.

Operating Procedure for power supply:

1. Connect the Klystron Mount to output socket of power supply.
2. Keep the beam voltage knob fully anti-clockwise position.
3. Keep the reflector voltage knob fully clockwise position.
4. Keep the H.T. switch at 'OFF'position.
5. **H.T. switch should be ON after warm up of klystron tube by switching ON PWR**.

Points to be remember always

1. **During operation of klystron, repeller does not carry any current and as such it may severely be damaged by electron bombardment. To protect repeller from such damage, the repeller negative voltage is always applied before anode voltage. Further,**

while modulating, repeller should never become positive with respect to the cavity. Also the repeller voltage should be varied in one direction only to avoid hysteresis in klystrons.

2. The heater voltage should be applied first and cooling should be provided simultaneously. After some time other voltages should be applied taking above precaution.

3. While measuring power, the frequency meter should be detuned each time because there is a dip in the output power when frequency meter is tuned.

4. To avoid loading of klystron, an isolator or alternatively some 3 db pad or attenuator should invariably be used between klystron and rest the set up.

SETUP_DIAGRAM:-

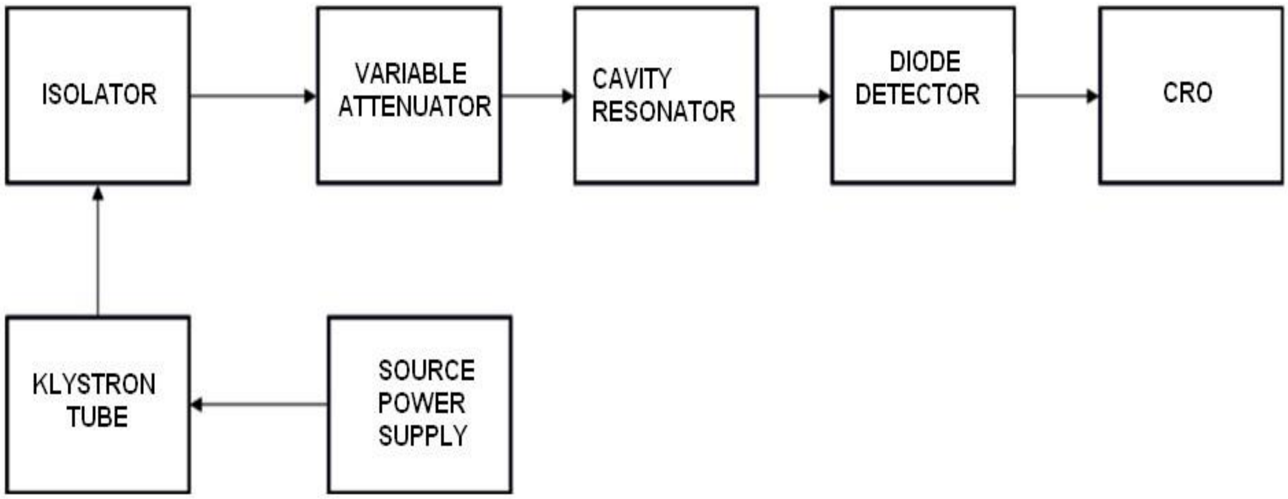


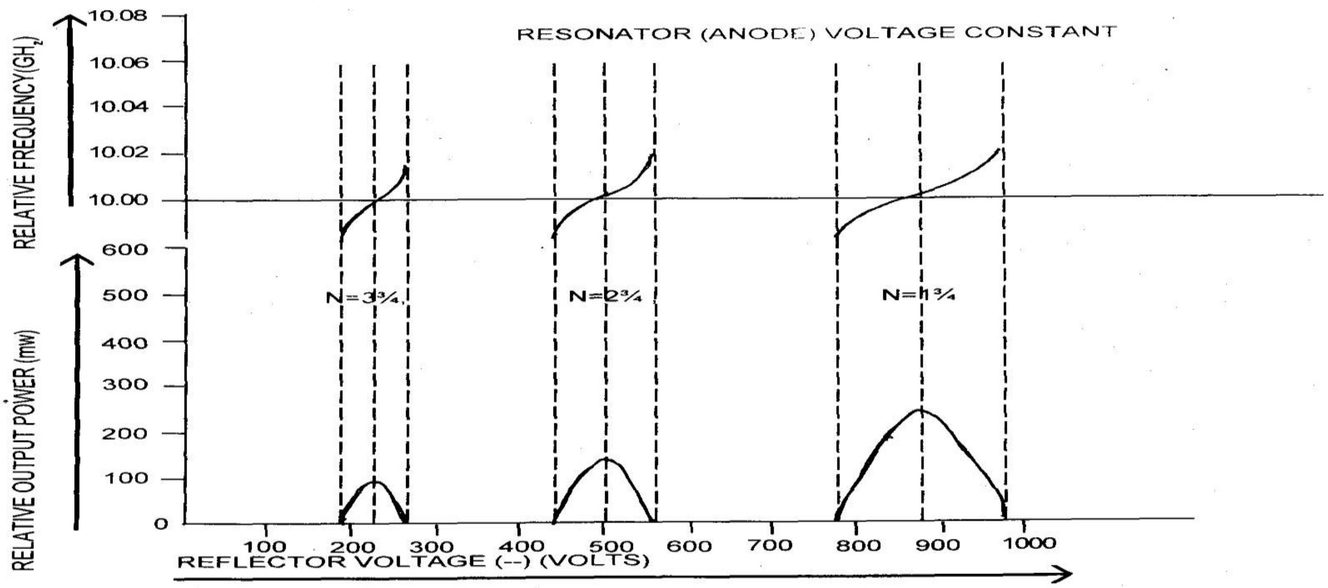
FIG1. Setup for Reflex Kylstron

PROCEDURE: CHARACTERISTICS OF REFLEX KLYSTRON

Square wave operation:

1. Connect the components and equipments as per set up
2. Set micrometer of variable attenuator around some position.
3. Set Mod selector switch to AM MOD position. Keep modulating frequency and amplitude knob somewhere at mid-position.
4. Beam voltage control knob to fully anticlockwise and reflector voltage control knob to fully clockwise and meter switch off position.
5. Rotate the knob of frequency meter at one side only.
6. Switch on the Klystron power supply, cooling fan and CRO.
7. Switch on the HT supply. Put on beam voltage switch and rotate the beam voltage knob clockwise slowly upto 250 V meter reading and observe beam current position, "The beam current should not increase more than 20 mA"
8. Change the reflector / repeller voltage and observe the maximum output. Tune the plunger of klystron mount ands detector for maximum output. Adjust AM modulating amplitude for undistorted output.
9. Note down output and frequency at this repeller voltage.
10. Read frequency on frequency meter: - rotate the knob of frequency meter slowly and stop at that position, where there is lowest output on CRO. Read directly the frequency meter between two horizontal line and vertical marker. If micrometer type frequency meter is used, read the micrometer reading and use the frequency chart.
11. Change the reflector voltage on both sides i.e. positive and negative side slightly and note down the output and frequency. His is one set of reading for one mode.
12. Repeat the steps from 8 to 11 by changing repeller voltage to observe different modes of klystron.
13. Plot the mode characteristics on a graph paper giving reflector voltage versus power output and frequency.

14. Calculate the mode number n for each mode.



SHOWS THE EFFECT OF REFLECTOR VOLTAGE ON BOTH THE LEVEL & THE FREQUENCY OF THE OUTPUT OF A REFLEX KLYSTRON.

OBSERVATION TABLE:-

Beam Current= 14mA

Beam Voltage= 240V

Sr.	Repeller Voltage (V)	Output Voltage (V)	Frequency (GHz)
1	-221	1.07	11.110
2	-210	2.14	11.075
3	-192	1.07	11.030
4	-171	1.05	11.105
5	-163	2.10	11.075
6	-158	1.05	11.065
7	-150	0.99	11.090
8	-146	1.98	11.075
9	-140	0.99	11.070

CALCULATIONS:-

i. Knowing mode top voltage of two adjacent modes, mode number of the modes may be computed from equation below:-

$$\frac{N_2}{N_1} = \frac{V_1}{V_2} = \frac{(n+1)+\frac{3}{4}}{n+\frac{3}{4}}$$

Mode number $N_n = n + 3/4$

$N_1 = 2.723+0.75=3.473$
$N_2 = 2.723+1.75=4.473$
$N_3 = 2.723+2.75=5.473$

ii. Knowing mode number, transmit time of each mode may be calculated from equation below:

$$t_1 = \frac{n+\frac{3}{4}}{f_{01}} = \frac{N_1}{f_{01}} sec$$

$t_1 = 0.3135$ns
$t_2 = 0.4038$ns
$t_3 = 0.4941$ns

iii. Calculate electronic tuning range, i.e. the frequency band from one end of the mode to the another
ETR for N_1 =0.08GHz
ETR for N_2 =0.04GHz
ETR for N_3 =0.02GHz

iv. ETS may be calculated from equation below:

$$ETS = \frac{f_2 - f_1}{V_2 - V_1}\ {MHz}/{V}$$

F_2 and F_1 being half power frequencies in GHz and V_2 and V_1 are corresponding voltage for a particular mode. [Note half power point is 0.5 i.e. 50% of maximum value]

ETS for N_1 =2.758MHz/V
ETS for N_2 =3.078MHz/V

ETS for N_3 =2MHz/V

CONCLUSION:-

In this experiment, we have studied about the characteristics of reflex Klystron tube. Considering beam current and beam voltage as 14mA And 240V respectively we have calculated the number the tuning range, tuning sensitivity also the mode characteristics of reflex Klystron tube were observed.

REFERENCES:-

1. Microwave and Radar Engineering—M.Kulkarni
2. Basic Microwave Lab Manual—Sisodia

CLASS: B.E. E &TC **SUBJECT: RMT**

EXPT. NO.: 4 **DATE:** 17-09-2020

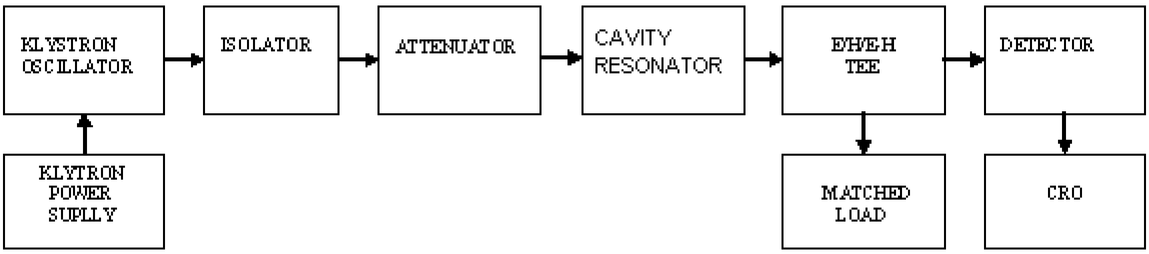
Roll No.: 42428

TITLE: To measure and verify port characteristics of microwave tees (E, H, E-H or magic planes).

OBJECTIVE:- To Verify the performance of E-plane Tee, H-plane Tee and E-H plane (Magic) tee

EQUIPMENTS:- Microwave oscillator,
Attenuator,
Isolator,
Frequency meter
E, H and E-H plane (magic) tees,
Detector mounts,
CRO
Matched loads.

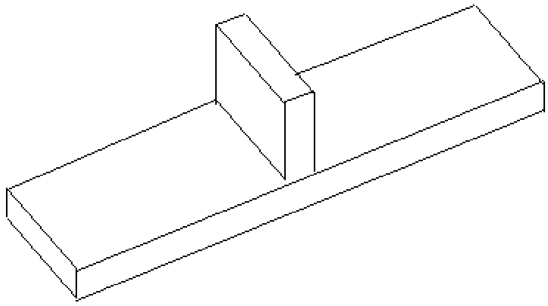
SETUP_DIAGRAM:-



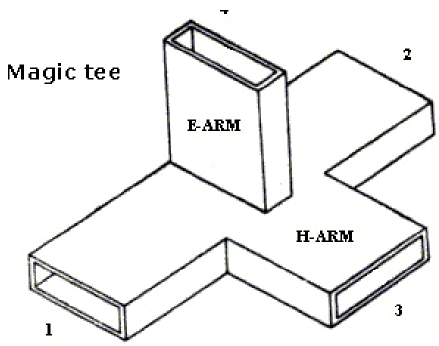
PROCEDURE:

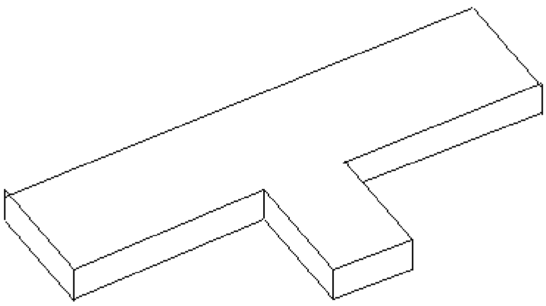
1. Energize the microwave source for particular operation. Adjust the repeller voltage to get maximum signal voltage at the output. Tune the detector mount for maximum output. [Without any TEE connected]
2. Now feed this power to port 1. of E plane tee.

3. Connect a matched load at port 2 and then measure the voltage at port 3 by connecting the detector.
4. Then measure the voltage at port 2 by interchanging the detector and matched load. Tabulate the readings.
5. Repeat the steps 2 to 4 for all orientation of tee i. e 2 and then 3
6. Verify their port characteristics. Determine coupling and isolation by knowing input and output
7. Repeat steps 2 to 6 for H-plane.
8. Similarly, verify the port characteristics of E-H plane (magic) Tee also.



E-Plane Tee





H-Plane Tee

OBSERVATION TABLE:

Beam Voltage = 238 V

Beam Current = 14 mA

Repeller voltage = -241 V

Frequency = 11.75 GHz

E plane tee

Input arm Voltage (V)	Output arm Voltage (V)	Matched Arm	Isolation / Attenuation $\alpha = 20\log_{10}(\frac{input-voltage}{output-voltage})db$	Coupling factor C $C = 10^{-\alpha/20}$
1=1.26	2= 1.20	3	0.423785	0.95238
1=1.26	3=686m	2	5.280928	0.54444
2=1.26	1=1.03	3	1.750666	0.81746
2=1.26	3=668m	1	5.511881	0.53015
3=1.26	1=645m	2	5.816216	0.51190
3=1.26	2=743m	1	4.587634	0.58968

H plane

Input arm Voltage (V)	Output arm Voltage (V)	Matched Arm	Isolation / Attenuation $\alpha = 20\log_{10}(\frac{input-voltage}{output-voltage})db$	Coupling factor C $C = 10^{-\alpha/20}$
1=5.52	2=4.39	3	1.989491	0.79528
1=5.52	3=3.60	2	3.712731	0.65217
2=5.52	1=3.88	3	3.062147	0.70289
2=5.52	3=3.72	1	3.427922	0.67391
3=5.52	1=2.77	2	5.989186	0.50181
3=5.52	2=2.29	1	7.642071	0.41485

Magic tee

Input arm Voltage (V)	Output arm Voltage (V)	Matched Arm	Isolation / Attenuation $\alpha = 20\log_{10}(\frac{input-voltage}{output-voltage})db$	Coupling factor C $C = 10^{-\alpha/20}$
1=1.26	2=402m	3, 4	9.922889	0.31904
1=1.26	3=1.26	2, 4	0	1
1=1.26	4=1.21	2, 3	0.351703	0.96031
2=1.26	1=350m	3, 4	11.126050	0.27777
2=1.26	3=1.21	1, 4	0.351703	0.96031
2=1.26	4=1.23	1, 3	0.209308	0.97619
3=1.26	1=1.02	2, 4	1.835407	0.80952
3=1.26	2=1.10	1, 4	1.179557	0.87301
3=1.26	4=686m	2, 1	5.280928	0.54444
4=1.26	1=1.31	2, 3	-0.338015	1.03968
4=1.26	2=1.27	1, 3	-0.068663	1.00793
4=1.26	3=100m	1, 2	22.007411	0.07936

CALCULATIONS:-

For E-plane Tee

$\alpha = 20\log_{10}(1.26/1.20) = 20\log_{10}(1.05) = 0.4237859\text{dB}$

$c = 10^{-0.4237859/20} = 10^{-0.0211893} = 0.95238$

For H-plane Tee

$\alpha = 20\log_{10}(5.52/4.39) = 20\log_{10}(1.2574032) = 1.98949115\text{dB}$

$c = 10^{-1.98949115/20} = 10^{-0.09947456} = 0.795289$

For Magic Tee

$\alpha = 20\log_{10}(1.26/0.402) = 20\log_{10}(3.13432) = 9.9228898\text{dB}$

$c = 10^{-9.922889/20} = 10^{-0.4961445} = 0.31904$

CONCLUSION:-

In this experiment we verified the performance of E-plane Tee, H-plane Tee and E-H plane (Magic) tee. For each Tee we applied input voltage at one port and observed the output voltages at other ports and according to the output voltages, we verified the functionality. For E-plane Tee when the input is applied at port 1 it appears at port 2 and port 3 gets isolated. Similarly, with other 2 ports. In the magic Tee when input is applied at port 1, it appears at ports 3 and 4 and port 2 gets isolated. Similarly, we can observe with other ports.

REFERENCES:-

1. Microwave and Radar Engineering—M.Kulkarni
2. Basic Microwave Lab Manual—Sisodia

CLASS: B.E. E &TC **SUBJECT: RMT**

EXPT. NO.: 5 **DATE:** 08-10-2020

Roll No.: 42428

TITLE: - To measure and verify port characteristics of directional coupler and calculate coupling factor, insertion loss and directivity.

OBJECTIVE:-

1. To study the function of multi-hole directional coupler.
2. To measure Coupling factor, Directivity, Insertion Loss

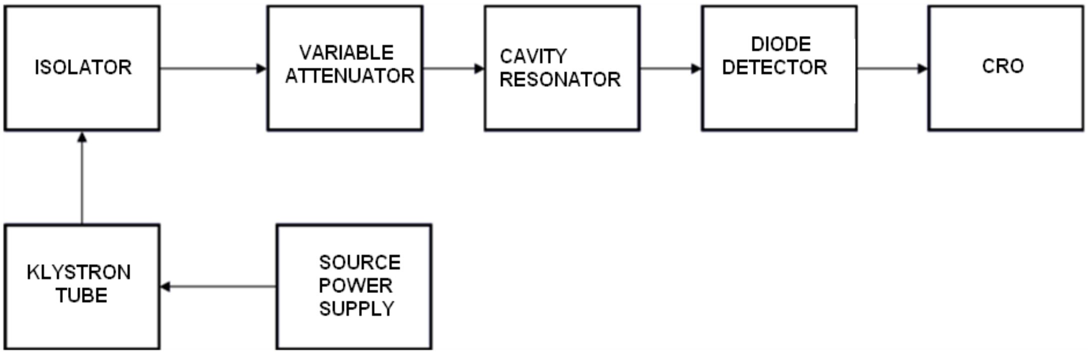
EQUIPMENTS:-

Microwave power source
Source power supply
Cooling fan
Variable calibrated attenuator
Frequency meter
Tuned detector
C.R.O.
Cables and accessories.
Matched termination
Directional coupler

PROCEDURE and SETUP_DIAGRAMS:-

Measurement of coupling and insertion loss and directivity

i. Assemble the setup as shown



ii. Energize the microwave source for particular operation of frequency.

iii. Determine power P_i, the reference power or the input power, fed to the main line input port of the directional coupler and record the observations in observation table. This is V_{in}.

iv. Insert the directional coupler as shown in fig:2 with detector to auxiliary port 3 and matched termination to port 2. & measure power P_f i.e. the power coupled in auxiliary line. This is V_f.

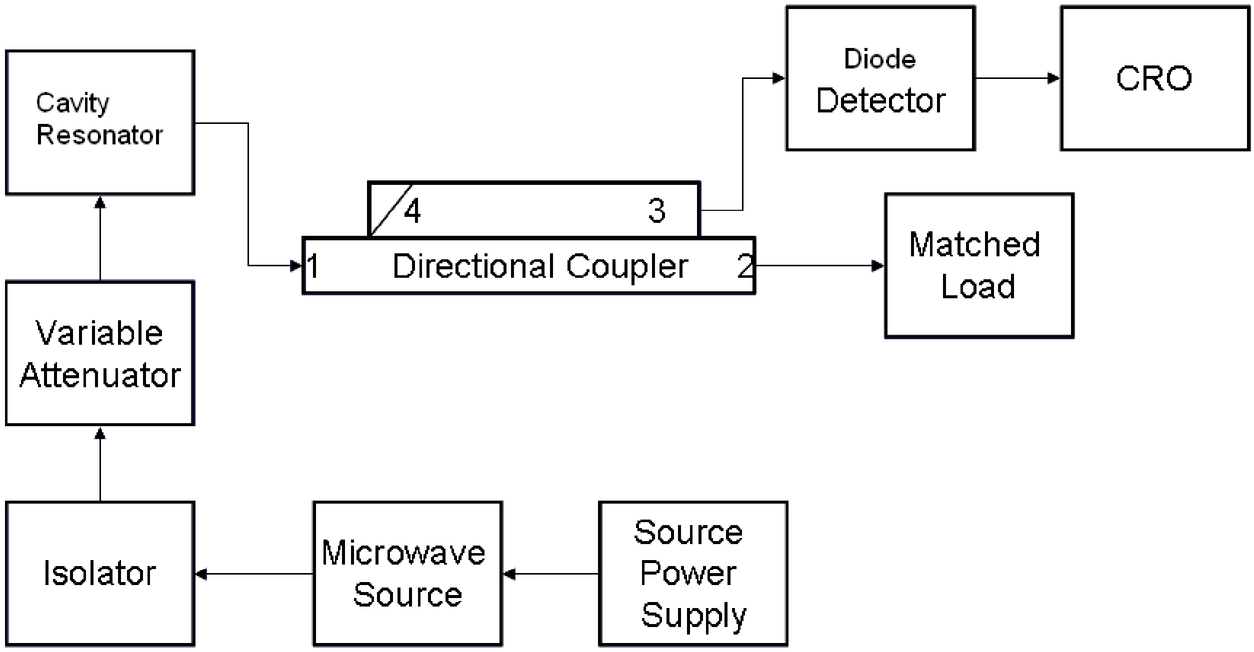


Fig 2- Output at port 3

v. Coupling is calculated using equation.

vi. Now carefully disconnect the detector from the auxiliary line output port 3 and matched termination from the main line output port 2 without disturbing the set up.

vii. Connect the matched termination at auxiliary line output port 3 and detector to main line output port 2 as shown in fig:3 . Measure the power P_r at main line output port the same in observation table. This is V_r.

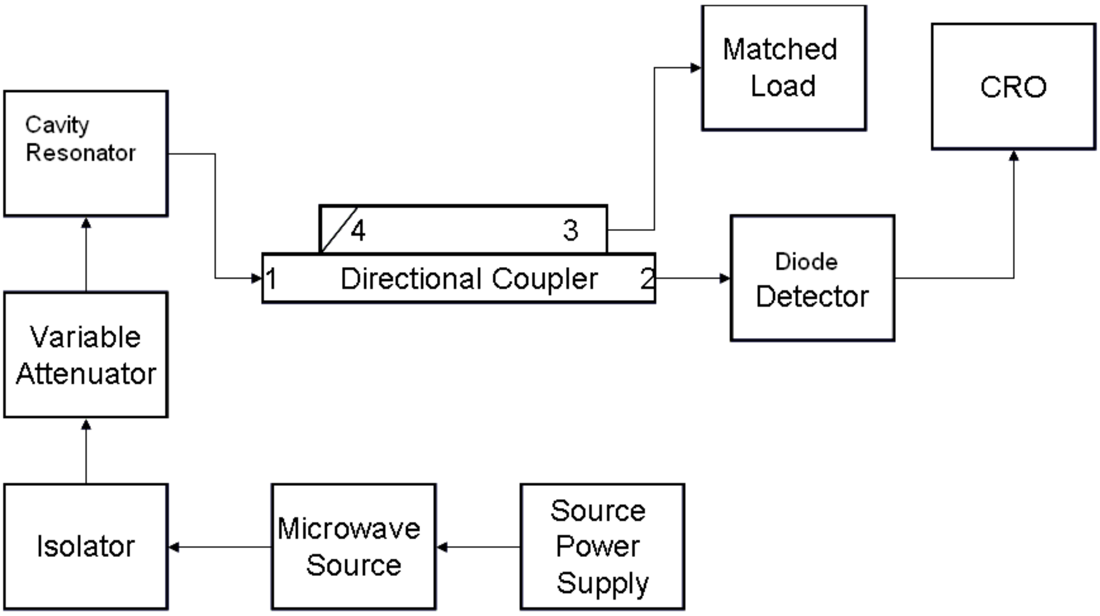


Fig 3-Output at port 2

viii. The insertion loss is calculated using equation.

ix. Connect directional coupler in reverse direction as shown in Fig.4 i.e. port 2 to frequency meter side, matched termination to port 1 and detector to port 3 without disturbing settings.

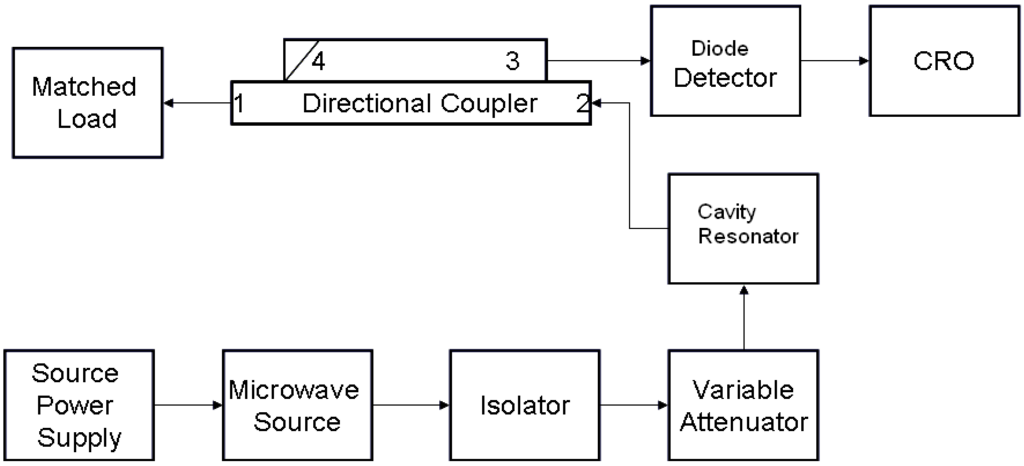


Fig 4- Output at port 3 with input at port 2

x. Measure the back power (P_b) output with the coupler reversed. This is V_b.

xi. The directivity is calculated using equation

OBSERVATION TABLE:

Beam voltage = 247 V

Beam current= 14 mA

Repeller Voltage = 198 mV

Frequency = 11.75 GHz

Voltages	10 dB	20 dB
V_{in}	2.84V	982mV
V_r (main line)	2.7V	796mV
V_f (auxiliary line)	920mV	141mV
V_b (auxiliary line)	6.64mV	5mV

CALCULATIONS

i. Coupling factor

$$C = 20\log\frac{V_{in}}{V_f}$$

C_{10dB} = 20log(2.84/0.920) = 20log(3.08695) = **9.79061** dB

C_{20dB} = 20log(0.982/0.141) = 20log(6.964539) = **16.85784** dB

ii. Insertion loss

$$L = 20\log\frac{V_{in}}{V_r}$$

L_{10dB} = 20log(2.84/2.7) = 20log(1.05185) = **0.4390915** dB

L_{20dB} = 20log(0.982/0.796) = 20log(1.233668) = **1.823968** dB

iii. Directivity

$$D = 20\log\frac{V_f}{V_b}$$

D_{10dB} = 20log(920/6.64) = 20log(138.5542) = **42.832395** dB

D_{20dB} = 20log(141/5) = 20log(28.2) = **29.0049822** dB

iv. Isolation

$$I = 20\log\frac{V_{in}}{V_b}$$

I_{10dB} = 20log(2.84/0.00664) = 20log(427.71084) = **52.623** dB

I_{20dB} = 20log(0.982/0.005) = 20log(196.4) = **45.86283** dB

CONCLUSION:-

In this experiment, we observed functionality of multi-hole directional coupler and measured Coupling factor, Directivity, Insertion Loss, and Isolation by applying the source from klystron oscillator. The coupling factor for 10dB and 20dB was found to be 9.79061 dB and 16.85784 dB respectively. The insertion loss for 10dB and 20dB was found to be 0.4390915 dB and 1.823968 dB respectively. The Directivity for 10dB and 20dB was found to be 42.832395 dB and 29.0049822 dB respectively. The

Isolation for 10dB and 20dB was found to be 52.623 dB and 45.86283 dB respectively.

REFERENCES:-

1. Microwave and Radar Engineering—M.Kulkarni
2. Basic Microwave Lab Manual—Sisodia

CLASS: B.E. E &TC **SUBJECT: RMT**
EXPT. NO.: 6 **DATE:** 22-10-2020
Roll No.: 42428

TITLE: To measure and verify port characteristics of isolator and circulator and calculate insertion loss and isolation in dB.

OBJECTIVE:

1. To study the characteristics of Circulator/ Isolator.
2. To measure Insertion Loss, Isolation.

EQUIPMENTS: Microwave oscillator with power supply,
Attenuator,
Isolator,
Circulator,
Detector mounts,
Frequency meter,
Matched loads,
CRO

THEORY:

ISOLATOR:

An **isolator** is a two-port device that transmits microwave or radio frequency power in one direction only. It is used to shield equipment on its input side, from the effects of conditions on its output side; for example, to prevent a microwave source being detuned by a mismatched load.

An isolator is a non-reciprocal device with a non-symmetric scattering matrix. An ideal isolator transmits all the power entering port 1 to port 2, while absorbing all the power entering port 2, so that to within a phase-factor its S-matrix is

$$S = \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix}$$

To achieve non-reciprocity, an isolator must necessarily incorporate a non-reciprocal material. At microwave frequencies this material is invariably a ferrite which is biased by a static magnetic field. The ferrite is positioned within the isolator such that the microwave signal presents it with a rotating magnetic field, with the rotation axis aligned with the direction of the static bias field. The behavior of the ferrite depends on the sense of rotation with respect to the bias field, and hence is different for microwave signals travelling in opposite directions. Depending on the exact operating conditions, the signal travelling in one direction may either be phase-shifted, displaced from the ferrite or absorbed.

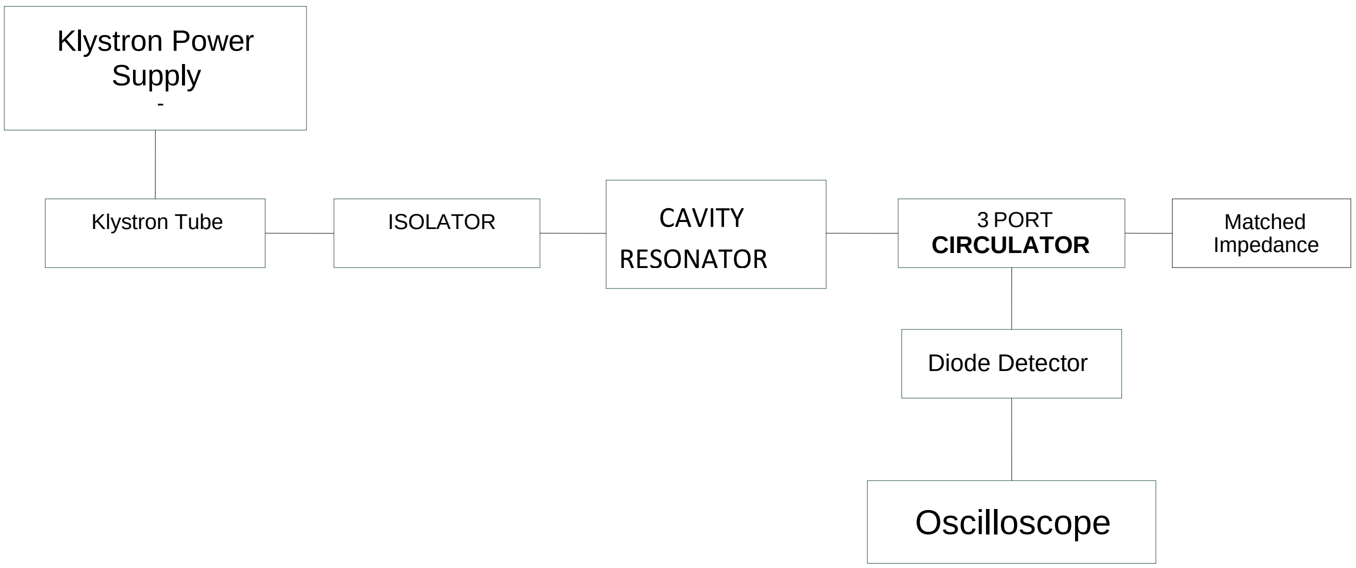
CIRCULATOR:

A **circulator** is a non-reciprocal three- or four-port device, in which power entering any port is transmitted to the next port in rotation (only). So to within a phase-factor, the scattering matrix for a three-port circulator is

$$S = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

A two-port isolator is obtained simply by terminating one of the three ports with a matched load, which absorbs all the power entering it. The biased ferrite is part of the circulator. The bias field is lower than that needed for resonance absorption, and so this type of isolator does not require such a heavy permanent magnet. Because the power is absorbed in an external load, cooling is less of a problem than with a resonance absorption isolator.

SETUP_DIAGRAM:



PROCEDURE:

1. Energize the microwave source for particular operation. Adjust the repeller voltage to get maximum signal voltage at the output. Tune the detector mount for maximum output. [Without circulator connected in set up]
2. Feed this known power to port 1 of 3 ports circulator.
3. Connect a matched load at port 3 and then measure the voltage at port 2, by connecting the diode detector.
4. Then measure the voltage at port 3 by interchanging the detector and matched load.
5. Repeat the procedure by applying the inputs at port 2 and then to port-3. Tabulate the readings. Verify their port characteristics.
6. Similarly, verify the port characteristics of Isolator also. (When port which is not coupled to input port is terminated by matched termination, it makes an isolator)

OBSERVATION TABLE:

CIRCULATOR:

Input	Output	Output	Insertion Loss(dB) $L = 20\log_{10}(\frac{i/p_{-nport}}{o/p_{-n+1port}})db$	Isolation (dB) $I = 20\log_{10}(\frac{i/p_{-nport}}{o/p_{-n+2port}})db$
Port 1 =2.20V	Port 2 =1.92V	Port 3 =31mV	1.182429	37.021219
Port 2 =2.20V	Port 3 =1.90V	Port 1 =14.8mV	1.273381	43.443219
Port 3 =2.20V	Port 1 =1.91V	Port 2 =22.9mV	1.227786	39.651743

ISOLATOR:

Input	Output	Insertion Loss(dB) $L = 20\log_{10}(\frac{i/p_{-nport}}{o/p_{-n+1port}})db$	Isolation (dB) $I = 20\log_{10}(\frac{i/p_{-nport}}{o/p_{-n+2port}})db$
Port 1 =2.20V	Port 2 =1.96V	1.003332	-
Port 2 =2.20V	Port 1 =44mV	-	33.979400

CALCULATIONS:-

For Circulator:

For input at port 1

$L = 20\log_{10}(2.2/1.92) = 20\log_{10}(1.14583) = 1.182429dB$

$I = 20\log_{10}(2.2/0.031) = 20\log_{10}(70.967742) = 37.021219dB$

For input at port 2

$L = 20\log_{10}(2.2/1.90) = 20\log_{10}(1.1578947) = 1.273381dB$

$I = 20\log_{10}(2.2/0.0148) = 20\log_{10}(148.64864) = 43.443219dB$

For input at port 1

$L = 20\log_{10}(2.2/1.91) = 20\log_{10}(1.151832461) = 1.227786dB$

$I = 20\log_{10}(2.2/0.0229) = 20\log_{10}(96.069869) = 39.651743dB$

For Isolator:

$L = 20\log_{10}(2.2/1.96) = 20\log_{10}(1.12244898) = 1.003332dB$

$I = 20\log_{10}(2.2/0.044) = 20\log_{10}(50) = 33.979400dB$

CONCLUSION:-

In this experiment we studied the characteristics of Circulator and Isolator and measured Insertion Loss and Isolation for both. In case of circulator, when we apply input at port 1, we observe output at port 2 and port 3 gets isolated. When we apply input at port 2, we observe output at port 3 and port 1 gets isolated. When we apply input at port 3, we observe output at port 1 and port 2 gets isolated. In case of isolator when we apply input at port 1 then we observe full output at port 2 but in case of vice versa we observe negligible output. From this we can say that both are following their working principles.

REFERENCES:-

1. Microwave and Radar Engineering—M.Kulkarni
2. Basic Microwave Lab Manual—Sisodia

CLASS: B.E. E &TC **SUBJECT: RMT**
EXPT. NO.: 7 **DATE: 5/11/2020**
Roll No.: 42428

TITLE: To plot standing wave pattern and measure SWR for open, short and matched termination at microwave frequency using slotted section with probe carriage.

OBJECTIVE: To determine V_{max} and V_{min} at open, short and match termination.

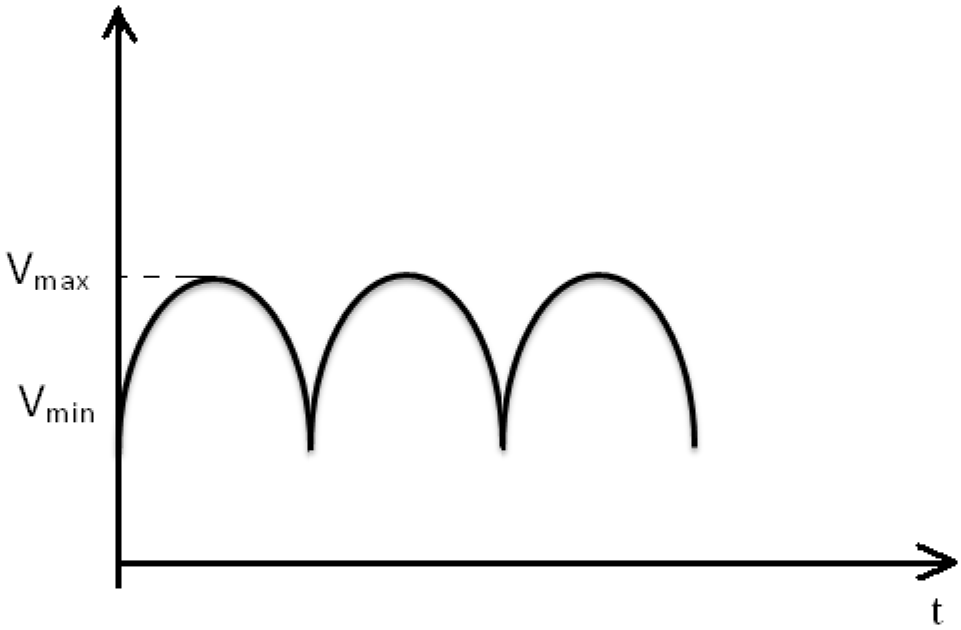
EQUIPMENTS:

1. Klystron Power Supply
2. Reflex Klystron with mount
3. Cooling Fan
4. Isolator
5. Variable Attenuator
6. Cavity Resonator
7. X-Band diode detector
8. BNC-to-BNC cable
9. Cathode Ray Oscilloscope
10. Slotted waveguide
11. Tunable Probe
12. Waveguid Stand
13. Matched Termination

THEORY:

Voltage standing wave ratio (VSWR) is define as the ratio of V_{max} and $V_{min.}$

$$VSWR = V_{max} / V_{min}$$



Rflection coefficient:

In term of reflection coefficient we can define VSWR as

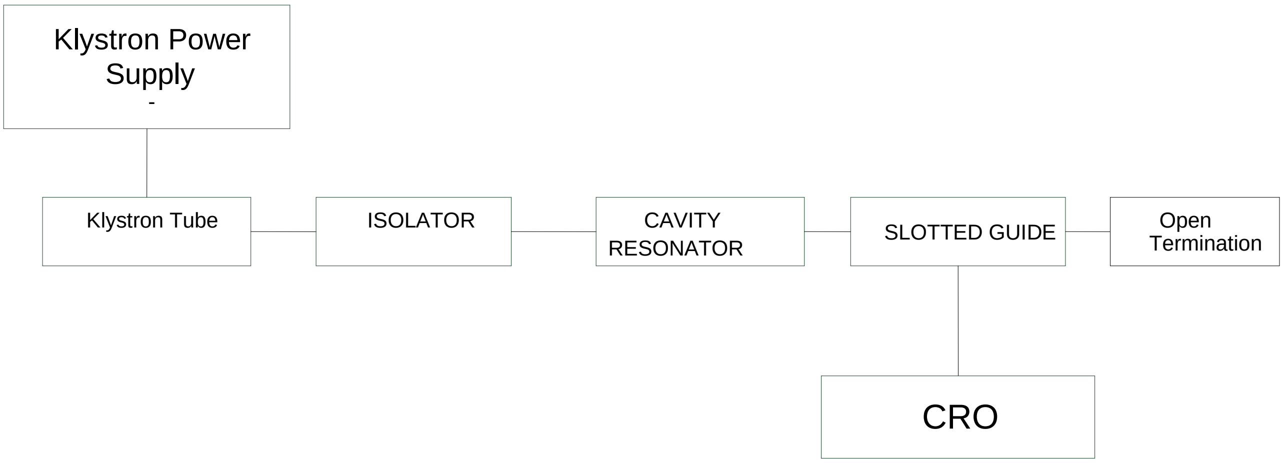
$$\text{VSWR}= \frac{1+|\Gamma|}{1-|\Gamma|}$$

The amplitude of reflected and incident waves are equals thus VSWR is infinite i.e. al energy is reflected.

The standing wave ratio (SWR) is dimensionless and value of VSWR lies in the range $1 \le S \le \infty$.

PROCEDURE:

1. Set up the components and equipments as shown in fig below.



<u>Fig. 1</u> Measurement of VSWR with open termination

2. Keep the control knobs of klystron power supply as bellow :

Meter Switch	'OFF'
Mod-Switch	AM
Beam Voltage	Fully anti-clockwise
Reflector voltage	Fully clockwise
AM-Amplitude Knob	Around fully clockwise
AM-Frequency Knob	Around Mid position

3. 'ON' the Klystron Power Supply, VSWR Meter and Cooling Fan.

4. Turn the meter switch of Power Supply to beam voltage position and set beam voltage at 300V with the help of beam voltage knob.

5. Adjust the reflector voltage to get some deflection in VSWR Meter.

6. Tune the reflector voltage knob for maximum deflection.

7. Tune the probe in slotted line section for maximum deflection, keep slotted section open.

8. Tune the frequency meter knob to get the 'dip' on the CRO scale and note down the frequency directly from frequency meter.

9. Detune the Frequency Meter

10. Move the probe to next minimum position and record the probe position again.

11. Do the above procedure for short and match termination.

OBSERVATION AND CALCULATIONS:

Beam Voltage: 246 V

Beam Current: 14 mA

Repeller Voltage: 246 V

Frequency: 11.75 GHz

Observation Table:

Termination	V_{max}	V_{min}	VSWR
Match	162 mV	106 mV	1.52
Open	164 mV	44 mV	3.72
Short	168 mV	6 mV	28

CONCLUSION:

In this experiment, we studied practical method to calculate VSWR. For matched termination VSWR was found to be 1.52 which is close to ideal value. For open and short termination, we found the value of VSWR to be 3.72 and 28 respectively which ideally should be infinite.

REFERENCES:

1. Microwave and Radar Engineering — M.Kulkarni
2. Basic Microwave Lab Manual — Sisodia

CLASS: B.E. E &TC **SUBJECT: RMT**
EXPT. NO.: 8 **DATE:** 28-11-2020
Roll No.: 42428

TITLE: To measure VI characteristics of Gunn Diode and study of PIN modulator.

OBJECTIVE:

1. To study the Gunn Diode as a source of microwave power.
2. To draw the characteristics on the effect of variation of bias voltage on frequency/power.

EQUIPMENTS: Gunn diode power supply, Gunn diode, Attenuator, Detector, Frequency meter, CRO.

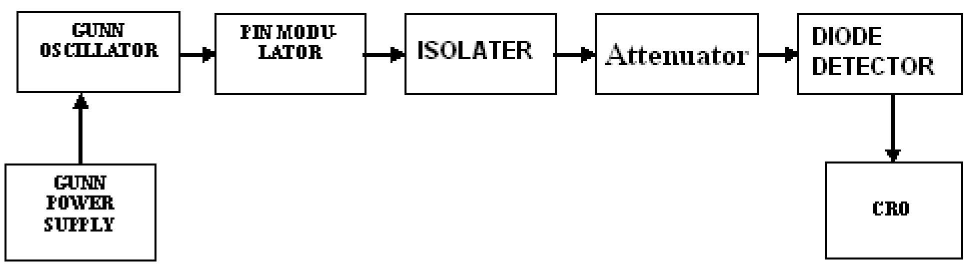
THEORY:

A Gunn diode, also known as a transferred electron device (TED), is a form of diode used in high-frequency electronics. It is somewhat unusual in that it consists only of N-doped semiconductor material, whereas most diodes consist of both P and N-doped regions. In the Gunn diode, three regions exist: two of them are heavily N-doped on each terminal, with a thin layer of lightly doped material in between. When a voltage is applied to the device, the electrical gradient will be largest across the thin middle layer. Conduction will take place as in any conductive material with current being proportional to the applied voltage. Eventually, at higher field values, the conductive properties of the middle layer will be altered, increasing its resistivity and reducing the gradient across it, preventing further conduction and current actually starts to fall down. In practice, this means a Gunn diode has a region of negative differential resistance.

The negative differential resistance, combined with the timing properties of the intermediate layer, allows construction of an RF relaxation oscillator simply by applying a suitable direct current through the device. In effect, the negative differential resistance created by the diode will negate the real and positive resistance of an actual load and thus create a "zero" resistance circuit which will sustain oscillations indefinitely. The oscillation frequency is determined partly by the properties of the thin middle layer, but can be tuned by external factors. Gunn diodes are therefore used to build oscillators in the 10 GHz and higher (THz) frequency range, where a resonator is usually added to control frequency. This resonator can take the form of a waveguide or microwave cavity. Tuning is done mechanically, by adjusting the parameters of the resonator.

Gallium arsenide Gunn diodes are made for frequencies up to 200 GHz, gallium nitride materials can reach up to 3 terahertz.

SETUP_DIAGRAM:



PROCEDURE:

1. Connect microwave bench set-up & components as shown in figure.
2. Keep the control knobs of Gunn power supply as below:
   Meter switch – off
   Gunn bias knob – fully anticlockwise
   PIN bias knob – mid position

PIN mode frequency – mid position

3. Set the micrometer of Gunn oscillator for required frequency of operation (say, 9GHz) using calibration chart.
4. Switch on the Gunn power supply.
5. Measure the Gunn diode current corresponding to the various Gunn bias voltages through the digital panel meter and meter switch. Increase the Gunn bias voltage in steps of 0.5 up to 10 volts and note down the corresponding output current. Do not exceed the bias voltage more than 10 volts.
6. Draw the curve of Gunn bias voltage Vs output current.
7. Also, while increasing the Gunn bias voltage in steps, measure the output power using CRO and its corresponding frequency using a frequency meter. Plot the graphs as function of Gunn bias voltage.
8. Measure threshold voltage which corresponds to maximum current.

Note: **DO NOT KEEP GUNN BIAS KNOB POSITION AT THRESHOLD POSTION FOR MORE THAN 10-15 SECONDS. READING SHOULD BE OBTAINED AS FAST AS POSSIBLE. OTHERWISE DUE TO EXCESSIVE HEATING, GUNN DIODE MAY BURN**

MODEL GRAPH:

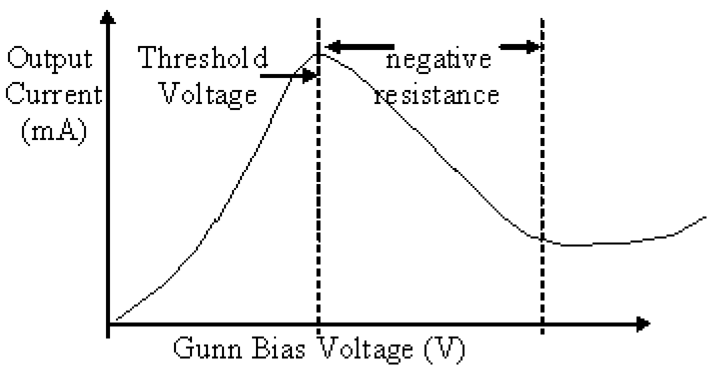


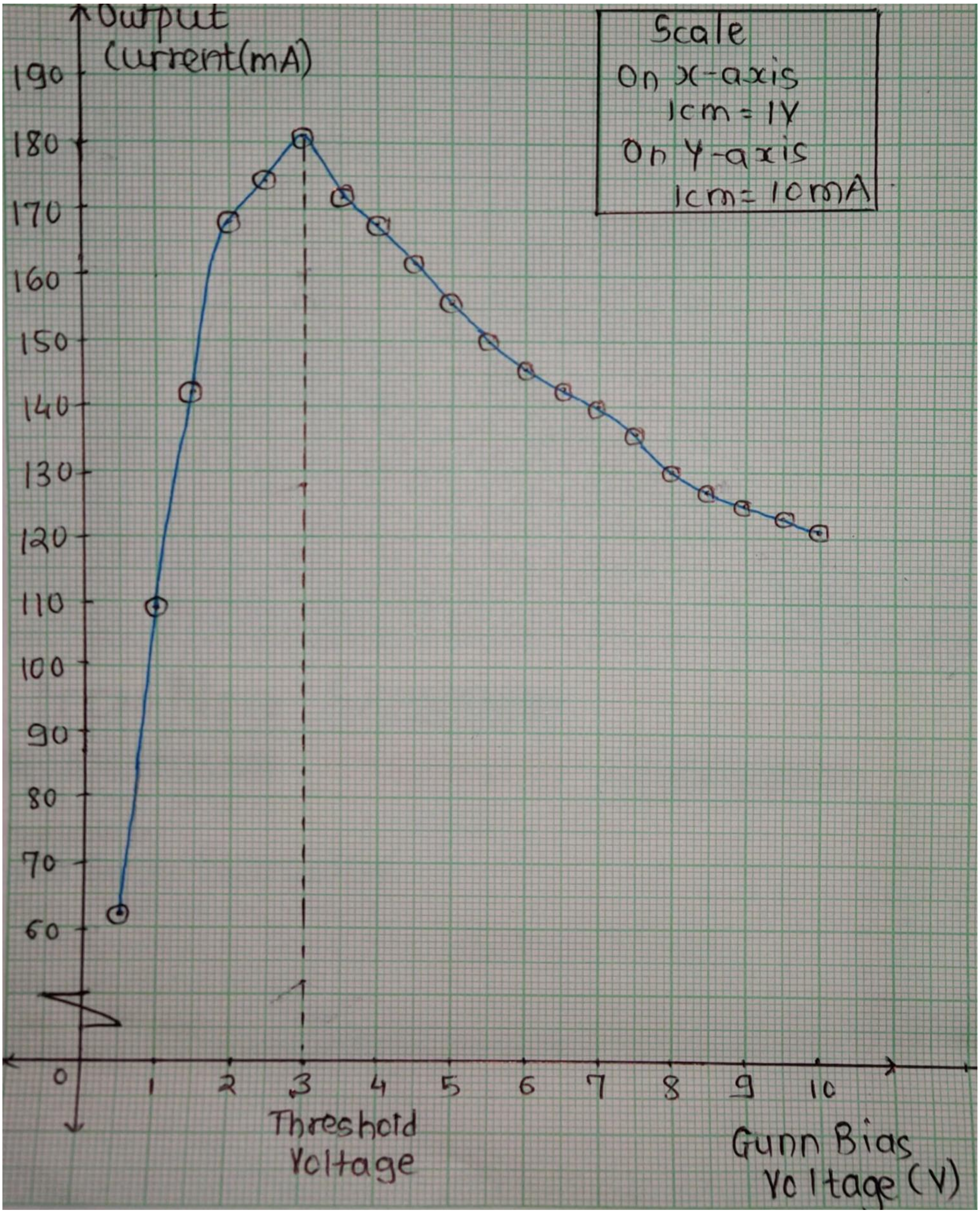
Fig. An approximation of the VI curve for a Gunn diode.

OBSERVATION TABLE:

Micrometer setting = 5.28 mm   Frequency = 11.4 GHz

SR NO	GUNN BIAS VOLTAGE (V)	OUTPUT CURRENT (mA)	OUTPUT POWER (mW)
1	0.5	62	31
2	1.0	109	109
3	1.5	142	213
4	2.0	168	336
5	2.5	174	435
6	3.0	181	543
7	3.5	172	602
8	4.0	168	672
9	4.5	162	729
10	5.0	156	780
11	5.5	150	825
12	6.0	146	876
13	6.5	143	929.5
14	7.0	140	980
15	7.5	136	1020
16	8.0	130	1040
17	8.5	127	1079.5
18	9.0	125	1125
19	9.5	123	1168.5
20	10.0	121	1210

GRAPH:


Output
Current(mA)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
0
1
2
3
4
5
6
7
8
9
10
Threshold
Voltage
Gunn Bias
Voltage (V)
Scale
On x-axis
1cm = 1V
On Y-axis
1cm = 10mA

CONCLUSION:

In this experiment we studied the Gunn Diode as a source of microwave power. We observed the effect of variation of bias voltage on frequency/power and found the threshold voltage to be 3V where we get the peak current. From the observations and drawn characteristics we can say that the observed characteristics resembles the ideal one.

REFERENCES:-

1. Microwave and Radar Engineering—M.Kulkarni
2. Basic Microwave Lab Manual—Sisodia

CALIBRATION CHART OF X-BAND GUNN-OSCILLATOR (10mW)

FREQUENCY (GHz)	MICROMETER READING (mm)
8.2	20.05
8.4	18.15
8.6	16.53
8.8	14.80
9.0	13.65
9.2	12.51
9.4	11.92
9.6	11.35
9.8	10.70
10.0	10.06
10.2	9.02
10.4	7.99
10.6	7.11
10.8	6.25
11.0	5.95
11.2	5.60
11.4	5.28
11.6	4.78
11.8	4.30
12.0	3.53
12.2	3.18

CLASS: B.E. E &TC SUBJECT: RMT

EXPT. NO.: 09 DATE: 03-12-2020

Roll No. : 42428

TITLE: Study the network analyzer and carry out the measurements of s-parameters.

OBJECTIVE: 1. Study of front panel & rear panel controls, accessories, and calibration methods of R&S®ZVA Vector Network Analyzer.

THEORY:

A network analyzer is an instrument that measures the network parameters of electrical networks. Today, network analyzers commonly measure s–parameters because reflection and transmission of electrical networks are easy to measure at high frequencies, but there are other network parameter sets such as y-parameters, z-parameters, and h-parameters. Network analyzers are often used to characterize two-port networks such as amplifiers and filters, but they can be used on networks with an arbitrary number of ports.

Network analyzers are used mostly at high frequencies; operating frequencies can range from 9 kHz to 110 GHz. Special types of network analyzers can also cover lower frequency ranges down to 1 Hz. These network analyzers can be used for example for the stability analysis of open loops or for the measurement of audio and ultrasonic components.

The two main types of network analyzers are

* **Scalar Network Analyzer** (SNA) — measures amplitude properties

* **Vector Network Analyzer** (VNA) — measures both amplitude and phase properties

A VNA may also be called a gain-phase meter or an Automatic Network Analyzer. An SNA is functionally identical to a spectrum analyzer in combination with a tracking generator. The three biggest VNA manufacturers are Agilent, Anritsu, and Rohde & Schwarz.

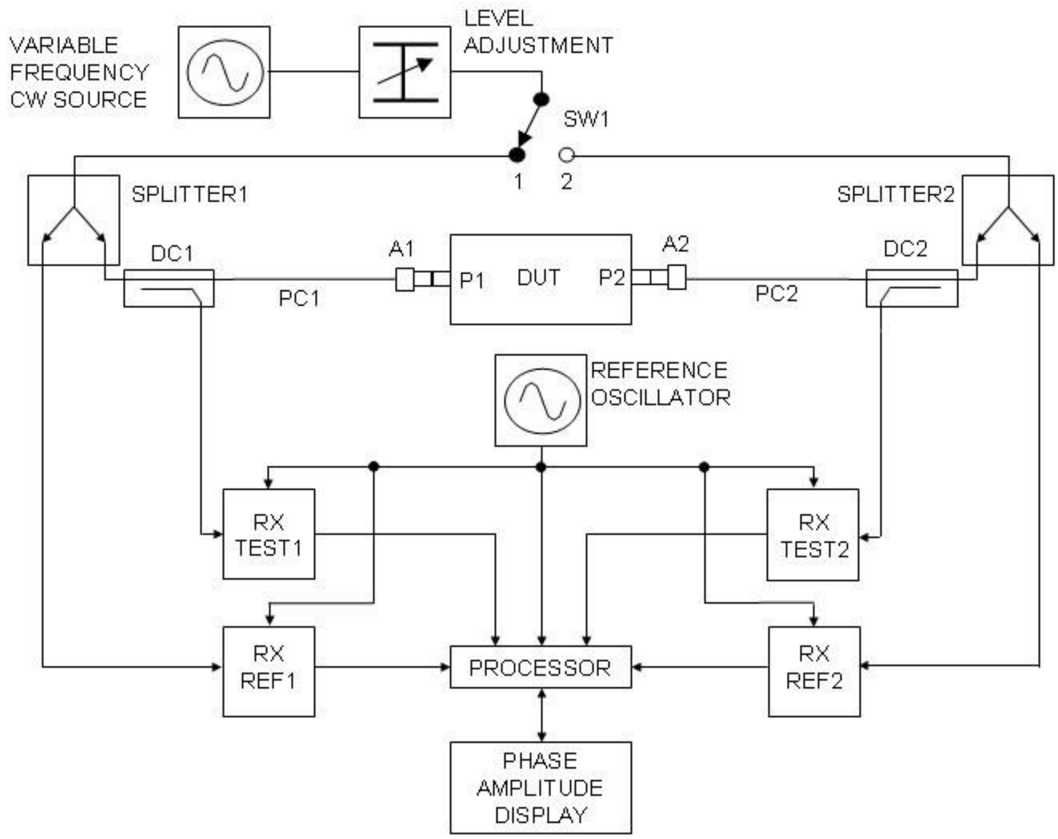


Fig1. Basic Parts of a Vector Network Analyser

Architecture

The basic architecture of a network analyzer involves a **signal generator, a test set, and one or more receivers**.

Signal generator

The network analyzer needs a test signal, and a signal generator or signal source will provide one. Older network analyzers did not have their own signal generator but had the ability to control a standalone signal generator using. Nearly all modern network analyzers have a built-in signal generator. High-performance network analyzers have two built-in sources. Two built-in sources are useful for applications such as mixer test, where one source provides the RF signal, another the LO, or amplifier intermodulation testing, where two tones are required for the test

Test set

The test set takes the signal generator output and routes it to the device under test, and it routes the signal to be measured to the receivers. It often splits off a reference channel for the incident wave. In a SNA, the reference channel may go to a diode detector (receiver) whose output is sent to the signal generator's automatic level control. The result is better control of the signal generator's output and better measurement accuracy. In a VNA, the reference channel goes to the receivers; it is needed to serve as a phase reference.

Receiver

The receivers make the measurements. A network analyzer will have one or more receivers connected to its test ports. The reference test port is usually labeled R, and the primary test ports are A, B, C,.... Some analyzers will dedicate a separate receiver to each test port, but others share one or two receivers among the ports. The R receiver may be less sensitive than the receivers used on the test ports.

For the SNA, the receiver only measures the magnitude of the signal. A receiver can be a detector diode that operates at the test frequency. The simplest SNA will have a single test port, but more accurate measurements are made when a reference port is also used. The reference port will compensate for amplitude variations in the test signal at the measurement plane. It is possible to share a single detector and use it for both the reference port and the test port by making two measurement passes.

For the VNA, the receiver measures both the magnitude and the phase of the signal. It needs a reference channel (R) to determine the phase, so a VNA needs at least two receivers. The usual method down converts the reference and test channels to make the measurements at a lower frequency. The phase may be measured with a quadrature detector. A VNA requires at least two receivers, but some will have three or four receivers to permit simultaneous measurement of different parameters.

Calibration

The accuracy and repeatability of measurements can be improved with calibration. Calibration involves measuring known standards and using those measurements to compensate for systematic errors. After making these measurements, the network analyzer can compute some correction values to produce the expected answer. For answers that are supposed to be zero, the analyzer can subtract the residual. For non-zero values, the analyzer could calculate complex factors that will compensate for both phase and amplitude errors. Calibrations can be simple (such as compensating for transmission line length) or involved methods that compensate for losses, mismatches, and feed through.

A network analyzer (or its test set) will have connectors on its front panel, but the measurements are seldom made at the front panel. Usually, some test cables will go from the front panel to the device under test (DUT) such as a two-port filter or amplifier. The length of those cables will introduce a time delay and corresponding phase shift (affecting VNA measurements); the cables may also introduce some attenuation (affecting SNA and VNA measurements).

S-parameter measurements have a notion of a reference plane. The goal is to refer all measurements to the reference plane.

Using ideal shorts, opens, and loads makes calibration easy, but ideal standards are difficult to make. Modern network analyzers will account for the imperfections in the standards.

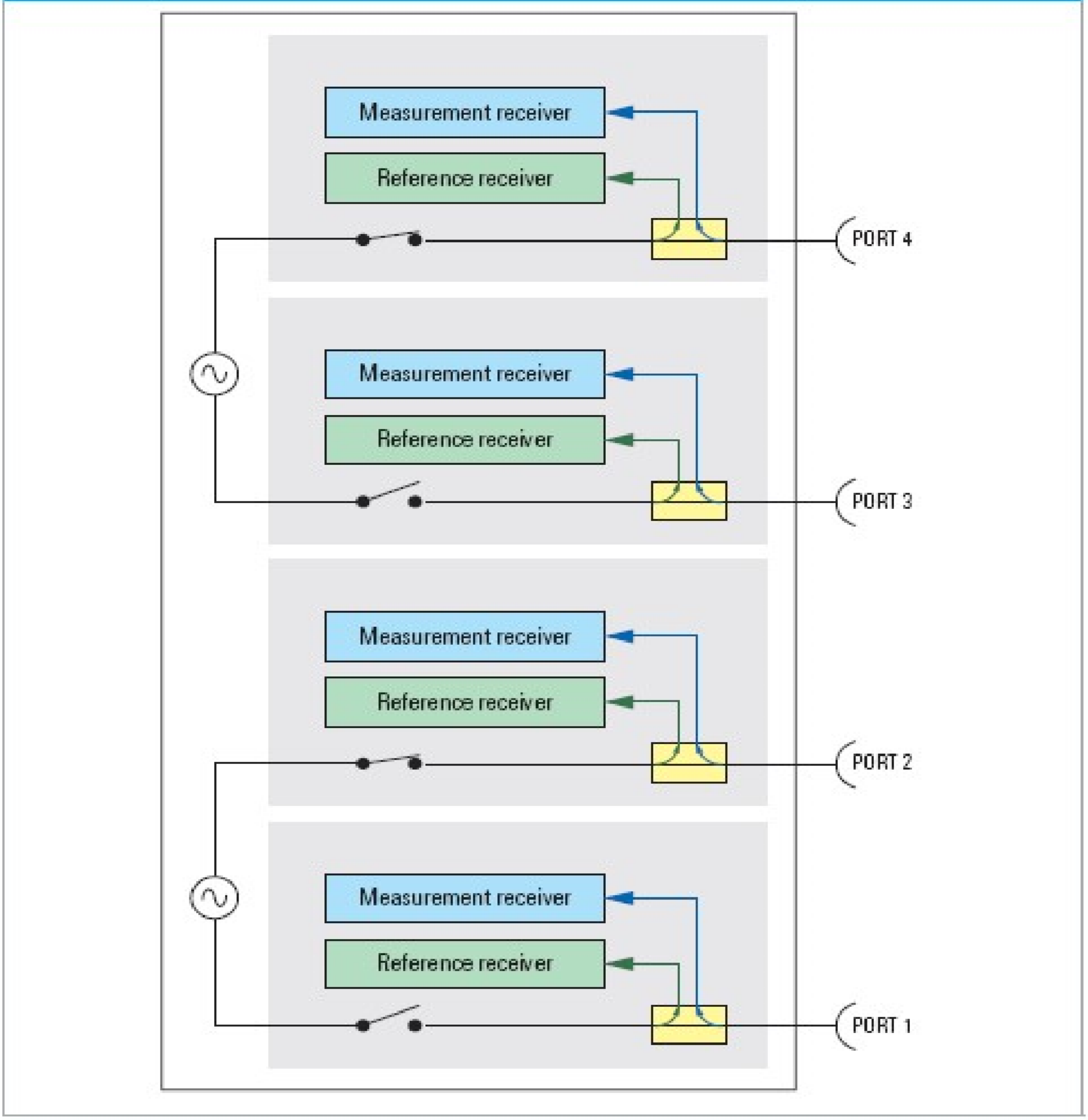
R&S®ZVA Vector Network Analyzer

Key features

- Linear and nonlinear amplifier and mixer measurements
- Noise figure measurements
- Pulse profile measurements with 12.5 ns resolution
- True differential measurements for reliable characterization of active devices with balanced ports
- High output power typ. > 15 dBm
- Wide dynamic range typ. > 140 dB
- High measurement speed < 3.5 μs per test point
- Wide IF bandwidth: 1/5/30 MHz
- Versatile calibration techniques: TOSM, TRL/LRL, TOM, TRM, TNA, UOSM
- Automatic calibration units
- Phase and group delay measurements on mixers with
- and without LO access
- Frequency range: 300 kHz to 8 GHz (R&S®ZVA8), 10 MHz to 24/40/50/67/80/110 GHz (R&S®ZVA24/40/50/67/80/110)

Test Port Cable: The **R&S®ZV-Z198** is a 1.00 mm female to 1.00 mm male cable of length 160 mm that has an operating frequency range from **0Hz to 110 GHz**

Block diagram of the R&S®ZVA8/24/40/50 four-port models



Calibration Features:

The R&S®ZVA not only offers classic TOSM calibration (Through, Open, Short, Match), but also a variety of other calibration techniques. Since each test port of the R&S®ZVA is equipped with a reference receiver of its own, modern seven-term calibration techniques can be used. These include TRL/LRL (Through, Reflect, Line/Line, Reflect, Line), TOM (Through, Open, Match), TNA (Through, Network, Attenuator), and TRM (Through, Reflect, Match), which are suitable for calibration in test fixtures or on wafers. Since calibration is performed directly on the DUT plane, any effects from the test fixture are eliminated.

Automatic calibration – fast, error-free, and with high precision

While all manual calibration techniques such as TOSM, TRM, and TRL can be used for multiport measurements, they are time-consuming, error-prone, and lead to excessive wear of the calibration standard. Rohde & Schwarz offers an automatic calibration unit for coaxial one-port and multiport calibration. The unit is ready to operate immediately after being connected and performs complete four-port calibration covering 201 test points in less than 30 seconds.

The R&S®ZVA allows for any combination between the analyzer ‘s test port connectors and the connectors of the calibration unit. The analyzer detects the connections automatically. Errors due to wrong connections are a thing of the past. The R&S®ZVA ‘s firmware also allows the characterization of calibration units by the user. Moreover, it is possible to characterize a calibration unit together with an adapter of any type. By treating the adapter as part of the calibration unit, the R&S®ZVA supports any combination of any connector types, which means that the calibration unit itself can be equipped with up to four different connectors. User-specific adapters can also be placed on the connectors of the calibration unit, which protects the connectors against wear.

OBSERVATIONS:-

For Rectangular Patch Antenna connected at Port 1 :

For Frequency = 2.315500 GHz

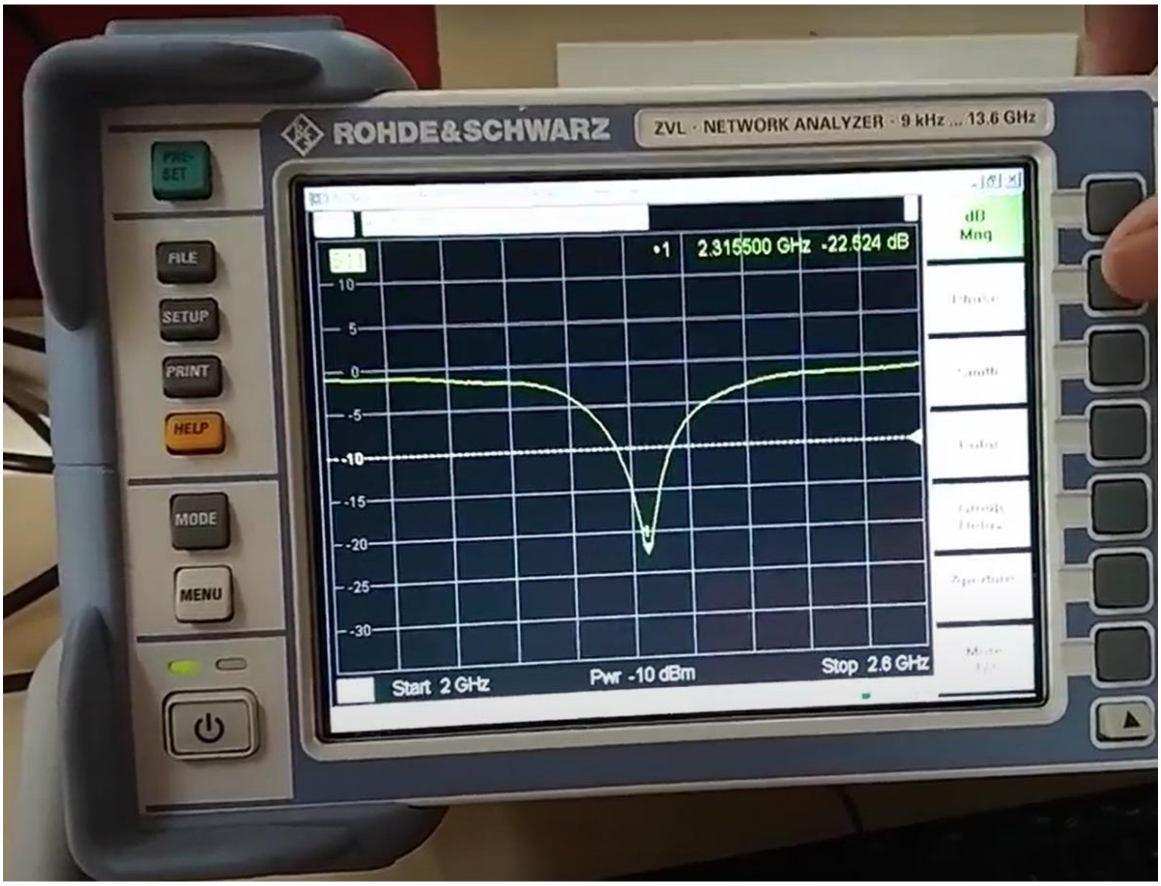
Return Loss(S11) = **-22.524** dB

VSWR = **1.160**

Impedance = **56.789 – j4.173** Ω

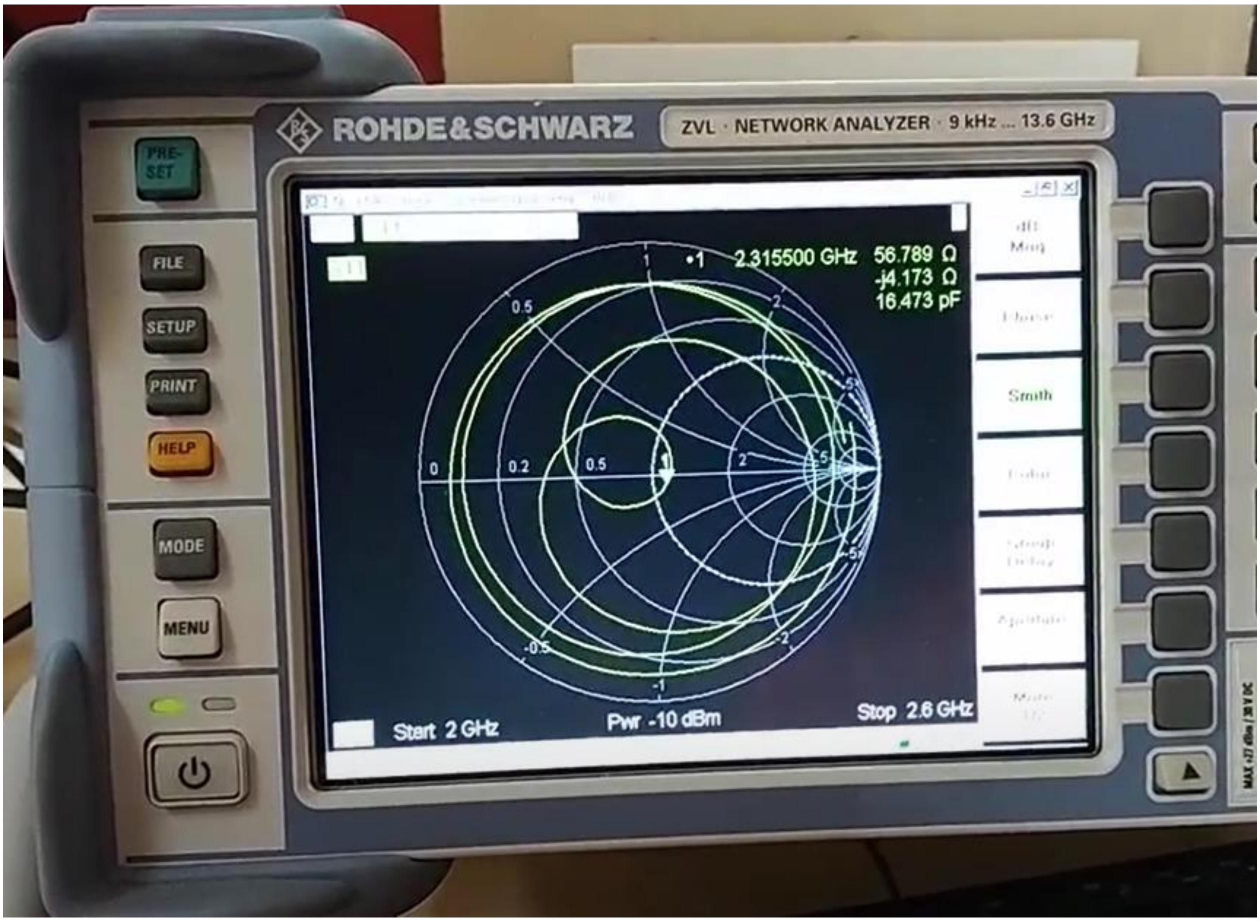
Phase = **-30.719º**

Return Loss(S11) Measurement :

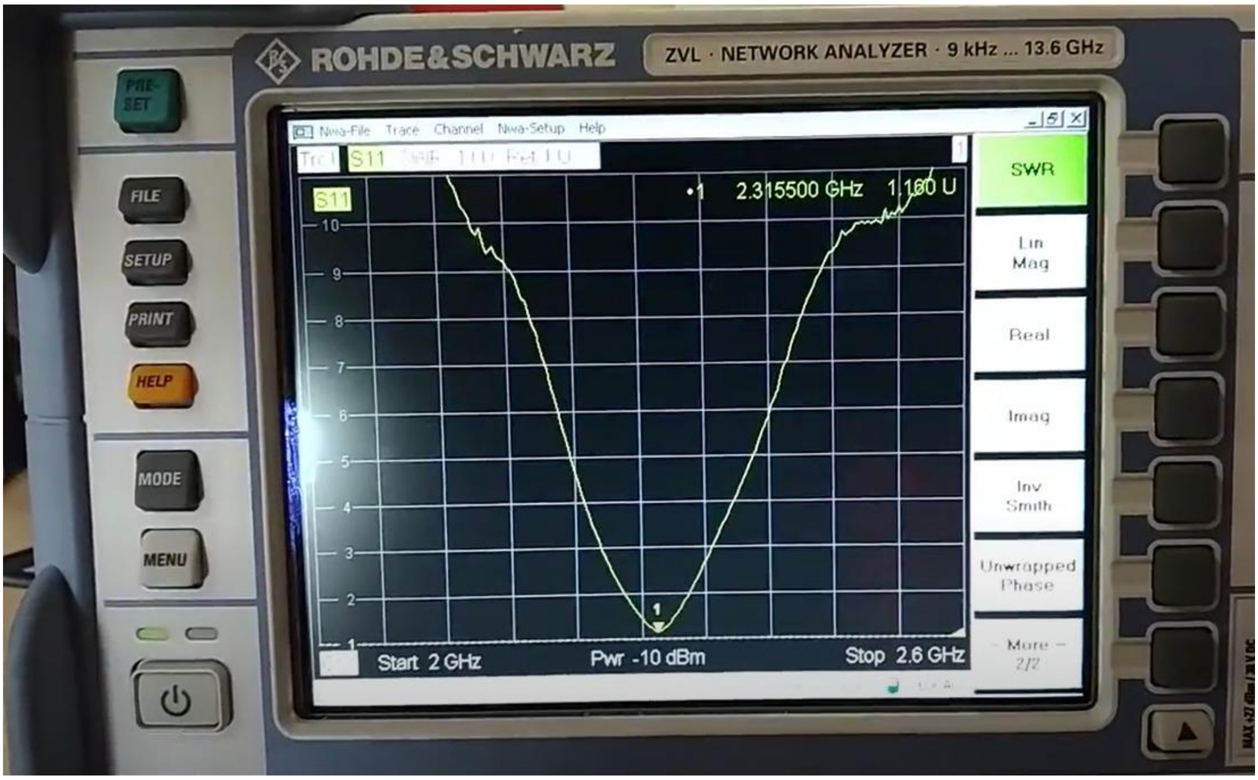


Phase Measurement :

Smith Chart :


ROHDE&SCHWARZ
ZVL · NETWORK ANALYZER · 9 kHz ... 13.6 GHz
PRE-SET
FILE
SETUP
PRINT
HELP
MODE
MENU
•1 2.315500 GHz 56.789 Ω
-j4.173 Ω
16.473 pF
Smith
Start 2 GHz
Pwr -10 dBm
Stop 2.6 GHz

VSWR Measurement :



CONCLUSION:-

In this experiment we studied about the Vector Network Analyzer, front panel & rear panel controls, accessories, and calibration methods of R&S®ZVA Vector Network Analyzer. We understood how we can access the functionality of VNA through the OS installed i.e., Windows XP. We understood and observed how we can measure different antenna parameters using the VNA and observed their respective plots on the screen. We also saw how we can observe multiple plots at a same time.

REFERENCES:-

1. R&S®ZVA Vector Network Analyzer Product Brochure, Datasheet
2. Network Analyzer Basics from Agilent.