1 CONTENTS

2 PART #1

2.1 BASIC CONCEPT OF FREQUENCY METER

In this part we intend to provide some basic notes about the Microwave frequency meter and how it works as well as we supposed!

A frequency meter is an instrument that determines the frequency of a periodic communication wave. Various types of mechanical frequency meters were used in the past, but since the 1970s these have almost universally been replaced by digital frequency counters but in this case we are supposed to analyse a mechanical and also Microwave-based one to show how it can be implemented in HFSS and how it can be track the power-flow among different their ports which are located at the side of rectangular waveguide and also through cylinder cavity!

The most popular topology which is used in industrial cased during the years can be shown below:

Figure 1: Representation of Frequency Meter

In most cases it could be located as part of trasmission line and in touch with wave power flow, when the wave with special band frequancy passes from waveguide and reaches to the frequency meter it's time to excite the topology using hole which is provided to join the cylander cavity and rectangular waveguide, furthermore there is a screw controller which can adjust the height of cavity and in this way it can be calculated the frequncy of unknown passed wave.

3 PART #2

3.1 REPORTING THEORETICAL APPROACH

Scattering Matrix: in this part we want to calculate the S parameters based on symmetry and also based on the direct of power-flow:

$S_{13} = S_{23}$

$S_{11} = S_{22}$

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{12} & S_{22} & S_{13} \\ S_{13} & S_{13} & 0 \end{bmatrix}$$

As you can see the above matrix has been made to show the symmetry and also equality of power-flow.

Now based on unit-rule and other notes which mentioned in class we are going to calculate the S parameters, Let's dive into calculations:

$$|S_{13}|^2 + |S_{13}|^2 = 1 \quad \xrightarrow{yields} \quad |S_{13}| = \frac{1}{\sqrt{2}}$$

$$|S_{11}| = \frac{1}{2} \quad \xrightarrow{yields} \quad |S_{12}| = \frac{-1}{2}$$

So going through this regard we can reach to the following matrix as of our case:

$$\begin{bmatrix} \frac{1}{2} & -\frac{1}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \end{bmatrix}$$

Design is done for X band so we take middle point 10GHz as our resonant frequency.

For dominant mode TE111 in our cylindrical resonator we have:

$$f_{nmp} = \frac{C_0}{2*pi*\sqrt{\mu\varepsilon}} * \sqrt{\left(\frac{P'_{nm}}{a}\right)^2 + \left(\frac{P*pi}{L}\right)^2} \xrightarrow{yields} 10 * \ 10^9 = \frac{3*10^8}{2*pi} * \sqrt{\left(\frac{1.8}{\frac{22.86}{2}*10^{-3}}\right)^2 + \left(\frac{1*pi}{L}\right)^2}$$

Which yields: L = 2*10^-2 j m therefore the radius of cylinder is not enough for detecting 10GHz

If we keep the ratio the same and multiply the lengths by 10 we will have:

$10 * \ 10^9 \ = \frac{3*10^8}{2*pi} * \sqrt{\left(\frac{1.8}{\frac{22.86}{2}*10^{-2}}\right)^2 + \left(\frac{1*pi}{L}\right)^2}$ which yields: L = 0.015 m = 15mm

As you can see further we use a standard rectangular waveguide which is implemented in band X (8-12 GHz) afterward we have tried to obtain the height of cavity based on the equations which discussed in class about resonator cavity , the most important one is the relation between the radius and height of cavity which I have used that to obtain the height in above calculation.

4 PART #3

4.1 INDUSTRIAL APPLICATION

Industrial frequency meters are used in radio frequency (RF) and microwave applications to tune transmitters and otherwise display rapidly-changing frequencies; in audio applications to determine exact pitch; and in power applications to tune AC motors and other AC devices.

Important specifications for frequency meters include units of measure, frequency accuracy, and estimated weight. Battery- powered devices are suitable for field measurements. Temperature-compensated devices include programming or electrical components designed to counteract known errors caused by temperature changes. Frequency meters with mirrored scales improve readability by enabling users to avoid parallax errors. Devices with a range switch allow users to select the range of units to measure. Frequency meters with overload protection and diode testing are also available.

APPLICATIONS:

Frequency meters are used in a variety of applications and industries, some of which are listed below.

- Heavy equipment vibration monitoring
- Parasitic harmonics and cross-modulation detection within RF signals
- RF signal calibration
- AC motor tuning
- Audio frequency pitch tuning

Direct Reading Frequency Meter (DRF):

It is constructed from cylindrical cavity resonator with a variable short circuit termination. The shorting plunger is used to change the resonance frequency of the cavity by changing the cavity length. DRF measures the frequency directly. It is particularly useful when measuring frequency differences of small changes.

Specifications

Model	Band	Freq. Range(GHz)	Waveguide	Calibration	VSWR
XFM-139	X	8.20-12.40	WR-90	+/-2	1.02
KuFM-139	Ku	12.40-18.00	WR-62	+/-2	1.02
KFM-139	K	18.00-26.50	WR-42	+/-2	1.02

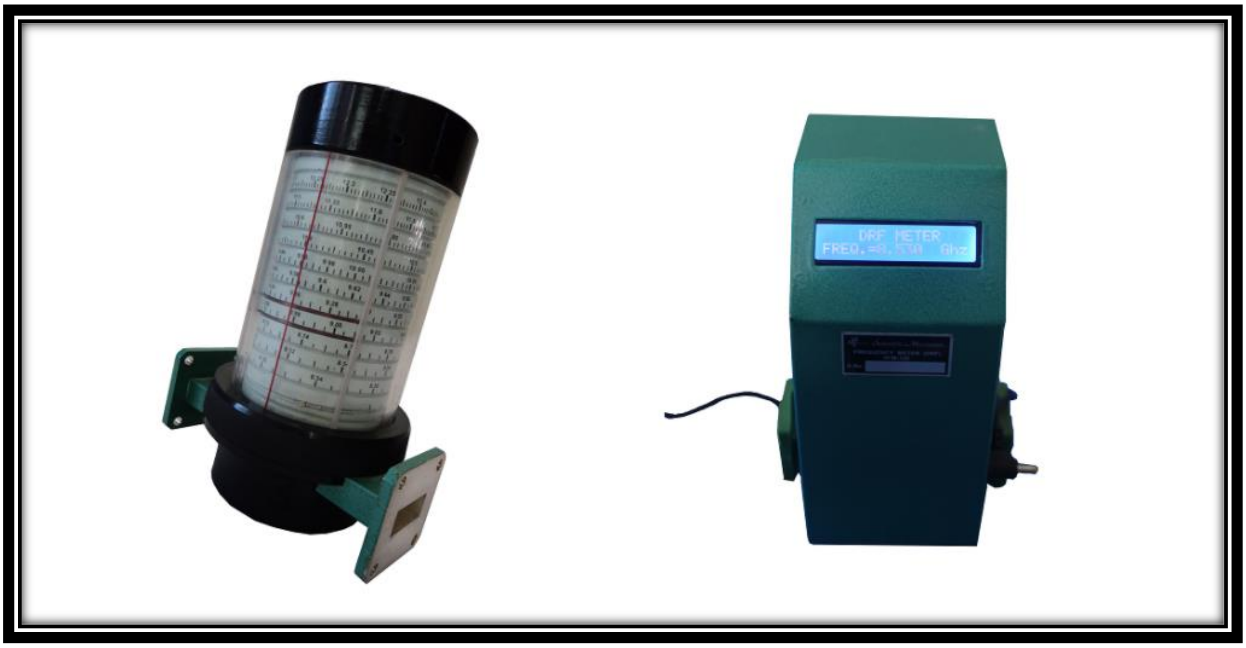


Figure 2: Representation of DRF Type

Frequency Meter (Micrometer type):

These frequency meters are intended for moderate accuracy application in microwave measurement and are usually best for this purpose. These permit full power flow down the transmission line except at the turned frequency. It consists of a cavity, plunger and the section of standard waveguide. The plunger ensures precise control of its position enabling frequency measurement with high accuracy.

Specifications

Model	Band	Freq. Range(GHz)	Waveguide	Calibration (MHz)	VSWR
SFM-125	S	2.60-3.95	WR-284	10	1.03
CFM-125	C	3.95-5.85	WR-229	10	1.03
JFM-125	J	5.85-8.20	WR-137	10	1.03
XFM-125	X	8.20-12.40	WR-90	10	1.03
KuFM-125	Ku	12.40-18.00	WR-62	10	1.03
KFM-125	K	18.00-26.50	WR-42	10	1.03

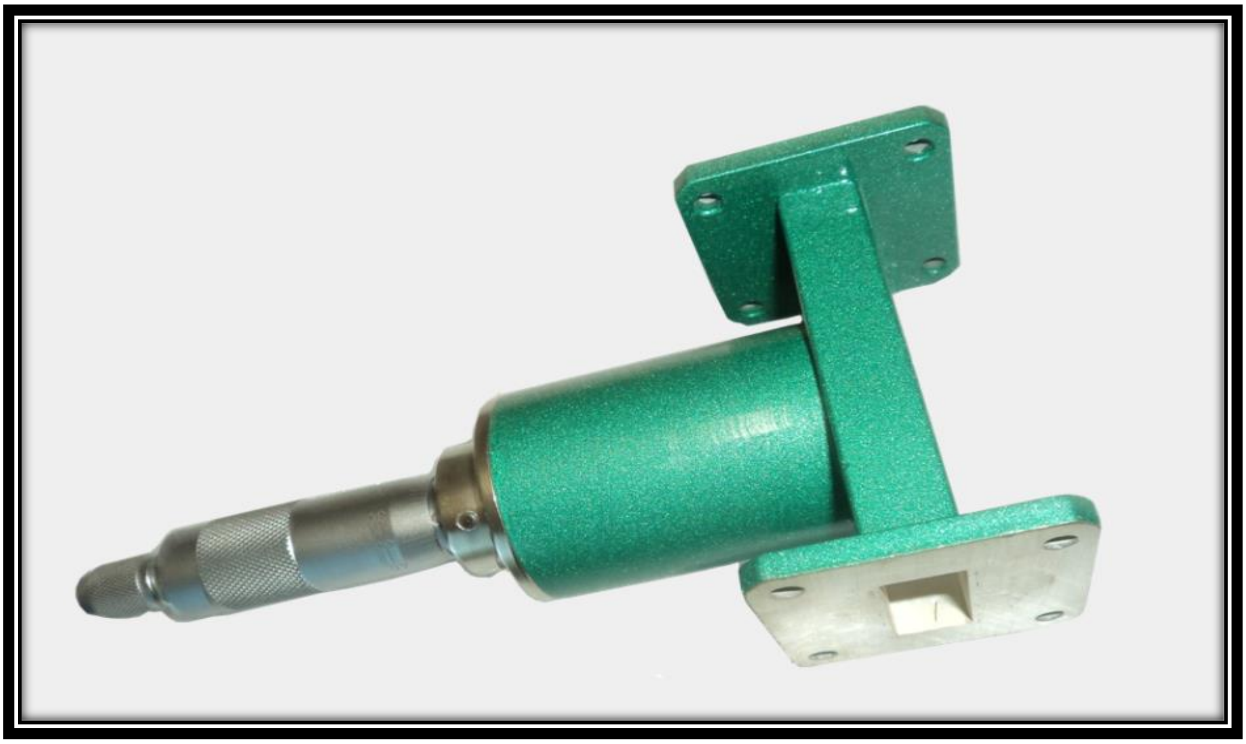


Figure 3: Representation of Micrometer type

Further you can find many types of industrial frequency meter which work base on microwave concepts:

You will get a new waveguide FREQUENCY METER type P532A manufactured by HP which can be used for Ku-Band measurements and applications. Ideal for laboraty and outdoor measurements due to its mechanically turned waveguide cavity adjustment. Unit will be shipped in its original HP package.

Specifications:

Frequency:	12.4 to 18.0 GHZ
Waveguide:	WR-62
Size:	6.3 x 4.7 x 3.1 in or 16 x 12 x 8 cm
Weight:	1.2 kg

For other microwave products please look at our other auctions at EBAY and feel free to contact us for additional questions.

MicroLab FXR

Model: C410B

Microwave Waveguide Precision Frequency Meter

J-Band

WR-137

Type-N(f) port

5.85 GHz - 8.2 GHz

S/N: 156

<u>Specifications:</u>

Frequency: 40 to 60.0 GHZ

Waveguide: WR-62

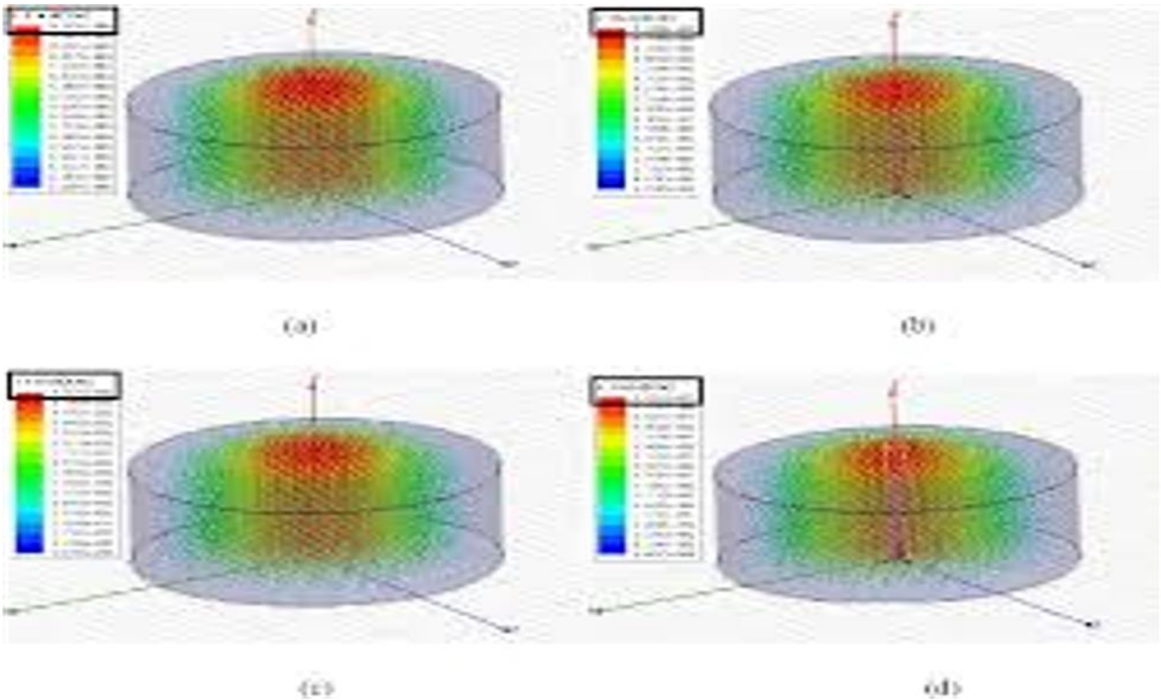
Size: 6.3 x 4.7 x 3.1 in or 16 x 12 x 8 cm

Weight: 1.5 kg

5 PART #4

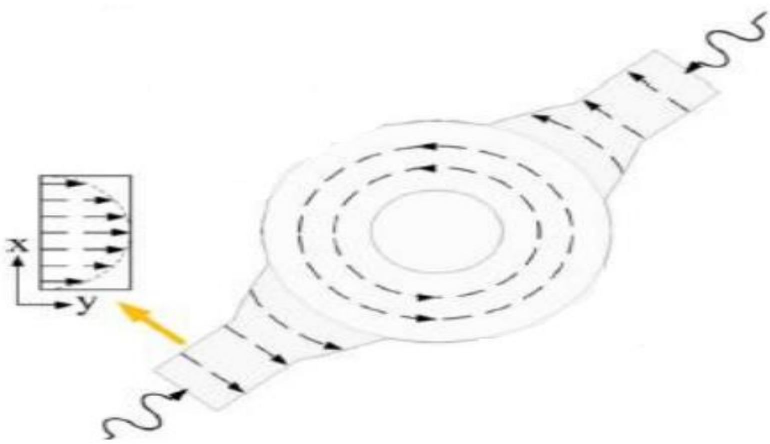
5.1 ELECTROMEGNATIC

We have electromagnetic wave carry like figure below for circular waveguide:



(a) (b) (c) (d)

So fields transition alongside radius should change in order to get an ability of transformation in square waveguide. The way that wave transforms is such as below figure:



6 PART #5

6.1 DESIGN & SIMULATION IN HFSS

In this part we tent to construct the model in HFSS using following steps in implementing:

First of all, we make a rectangular waveguide according to theoretical result.

After we subtract the waveguide from an another one to make a desired shape and afterward we make a hole in the waveguide upper surface to put the cylinder on it.

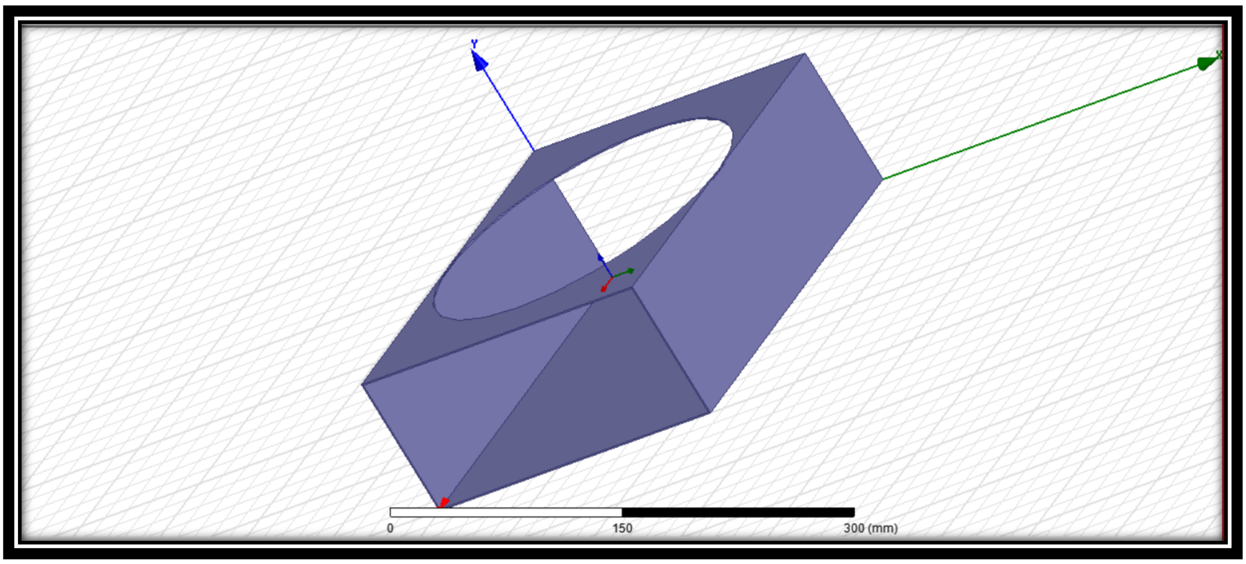


Figure 4: Construction Step 1

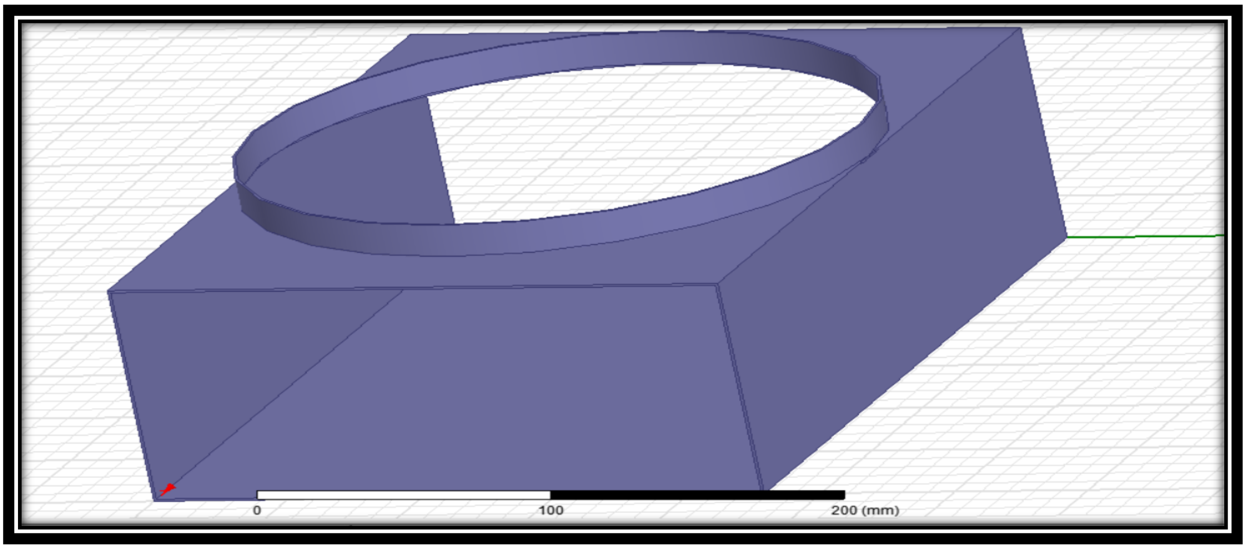


Figure 5: Construction Step 2

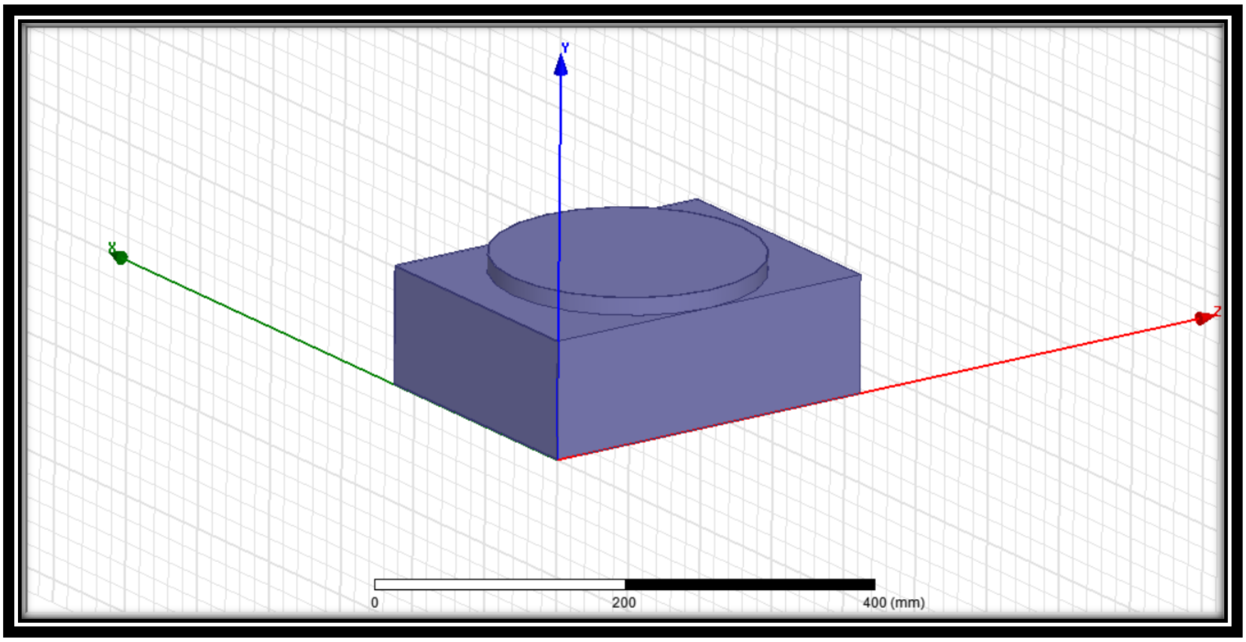


Figure 6: Construction Step 3

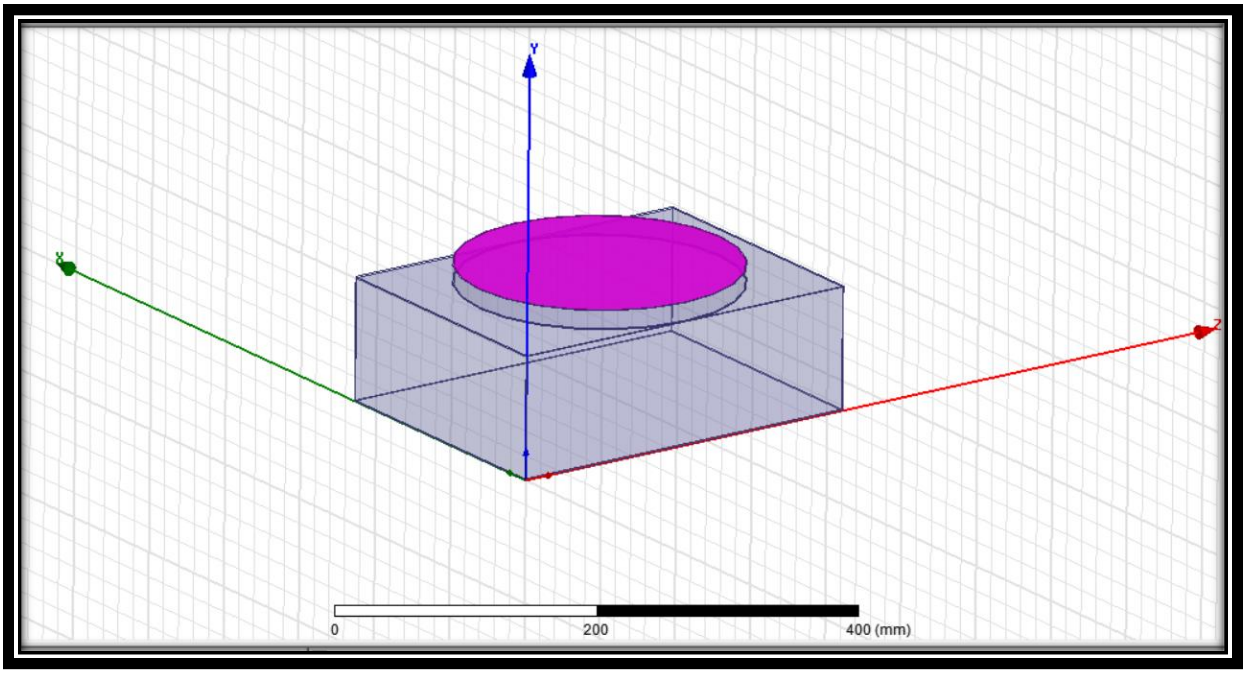


Figure 7: Construction Step 4

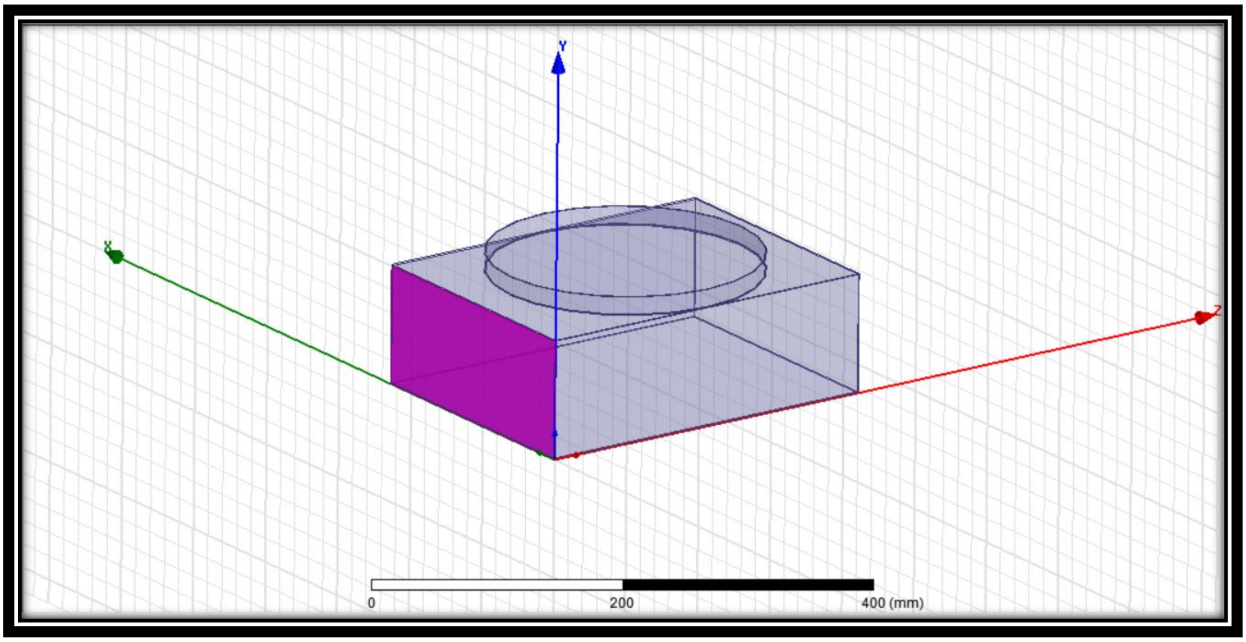


Figure 8: Construction Step 5

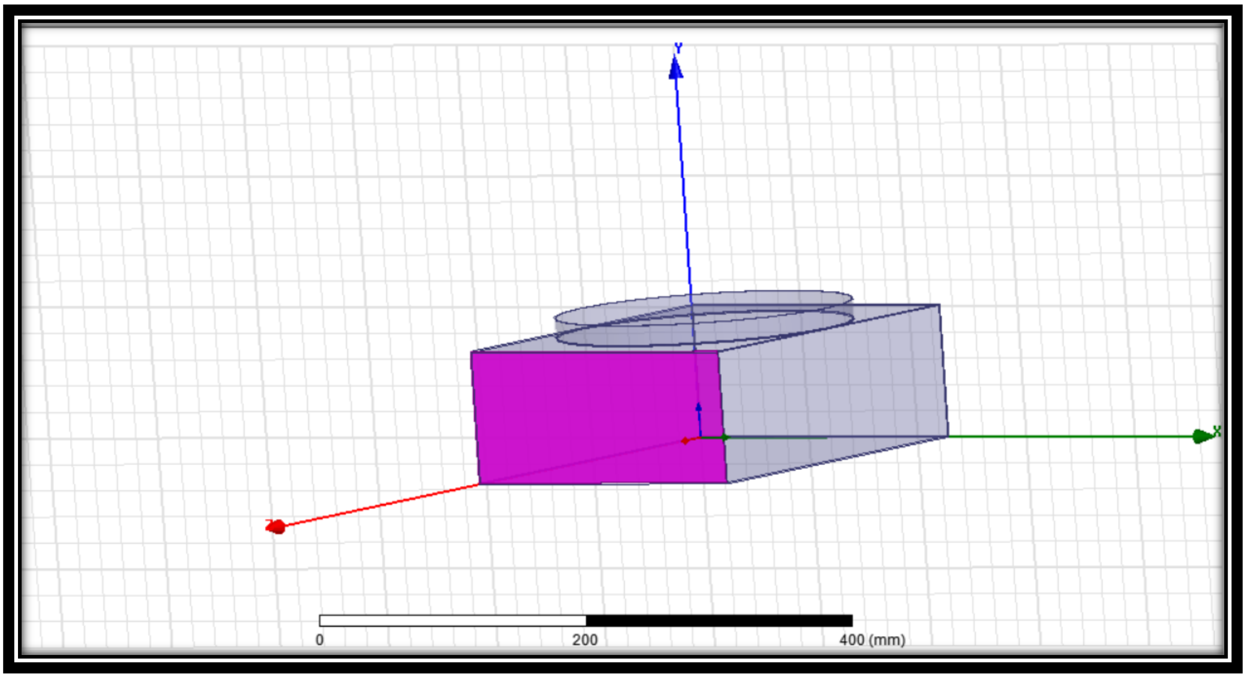


Figure 9: Construction Step 6

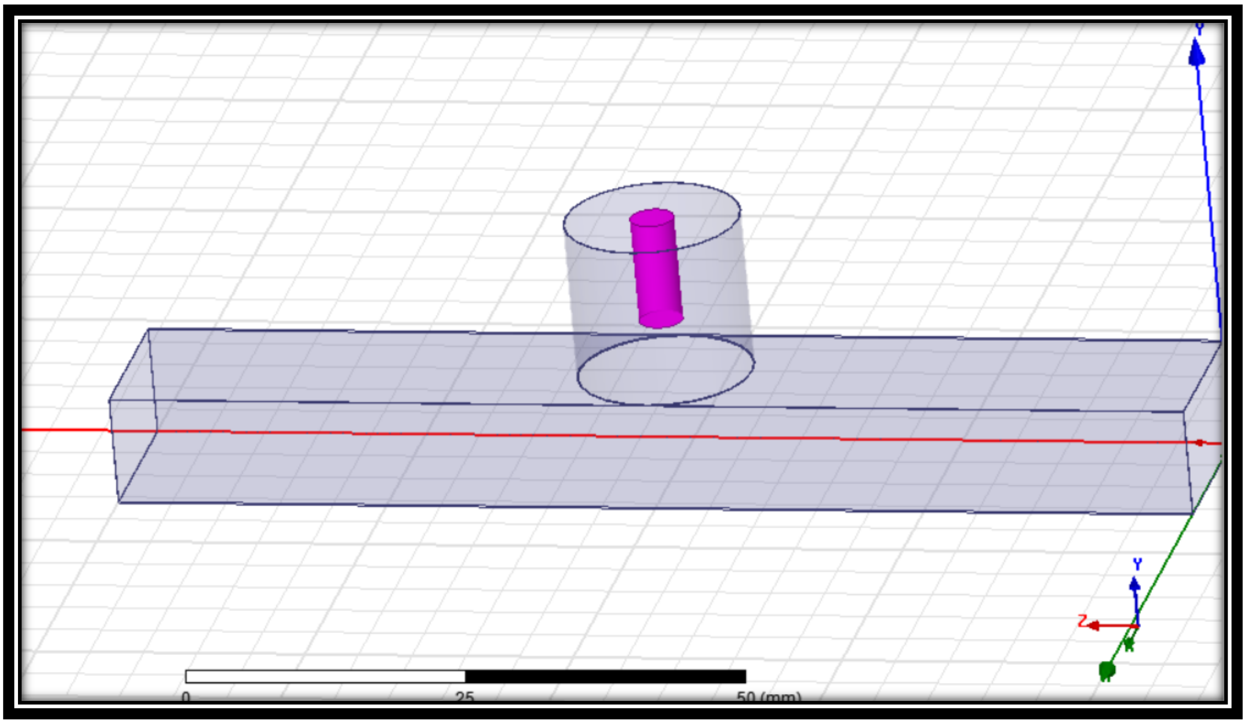


Figure 10: Construction Step 7

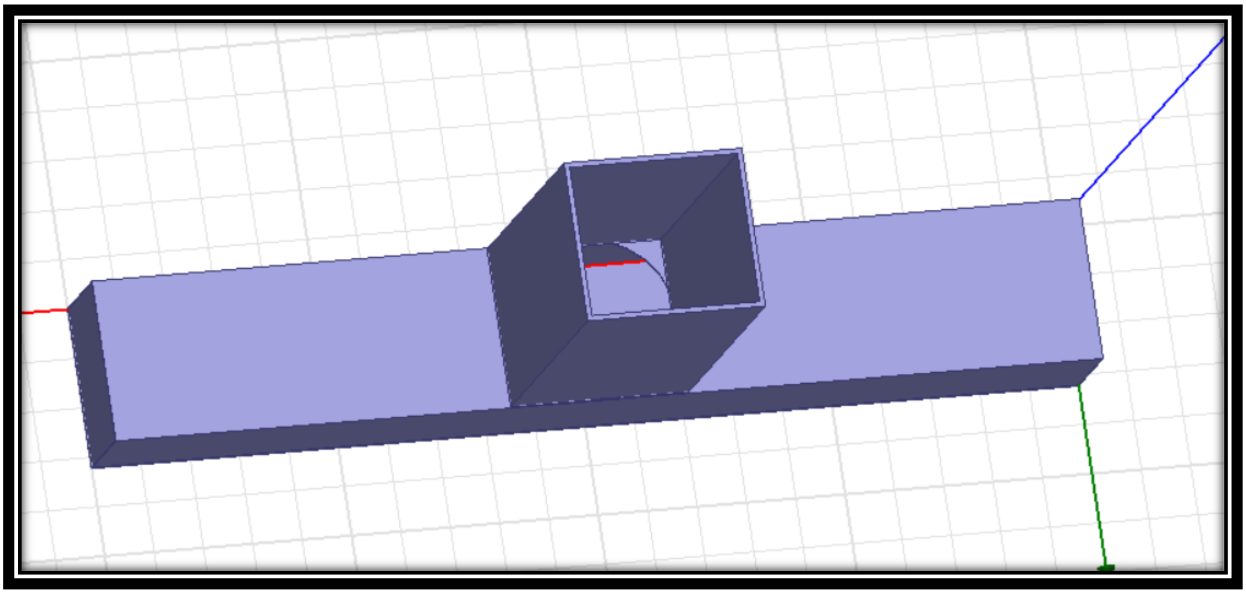


Figure 11: Construction Step 8

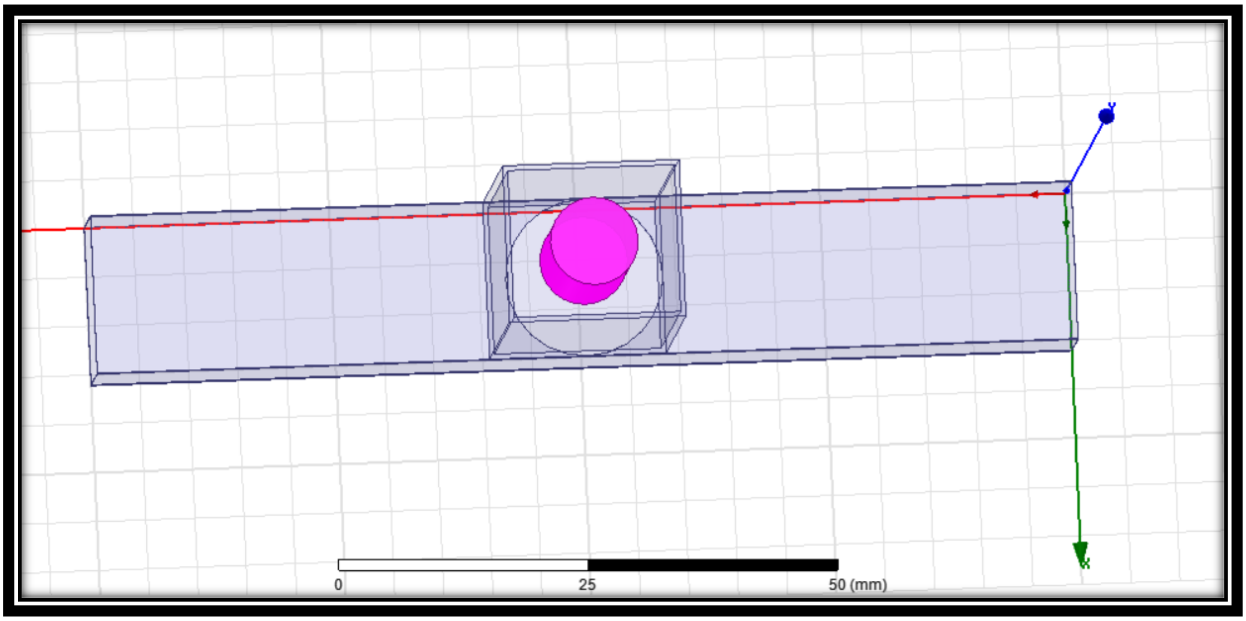


Figure 12: Construction Step 9

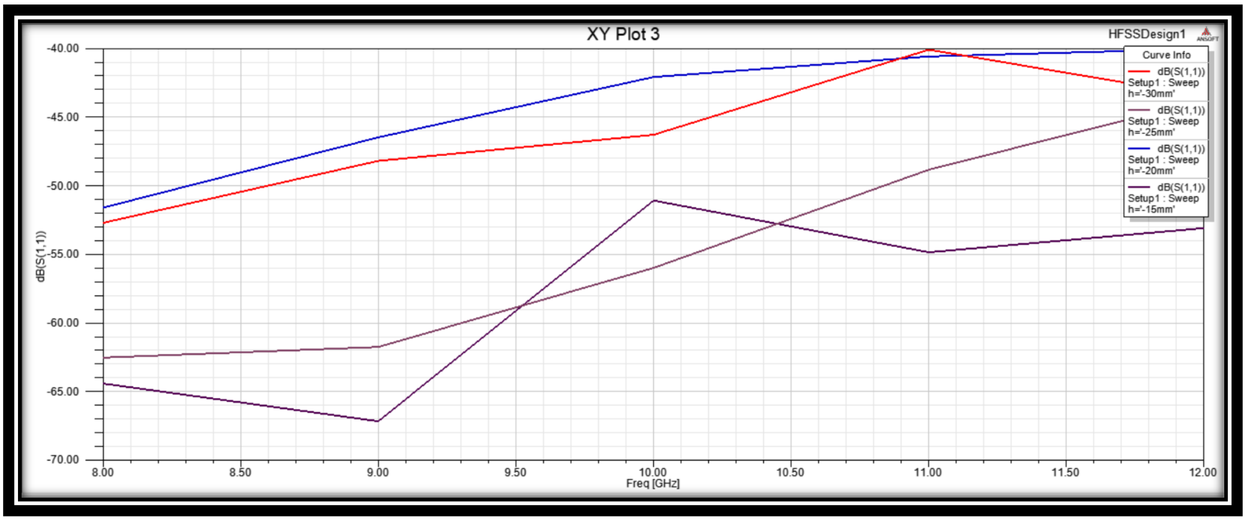


Figure 12: testing our result

7 Part #5

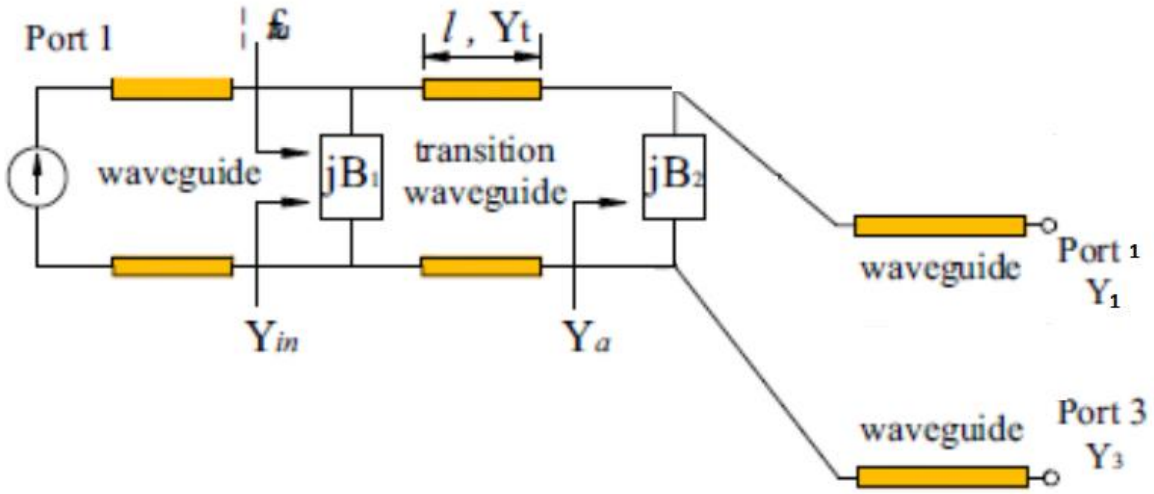
7.1 Port Matching AND Height parameter

If we simulate circuit similar for this Structure, we have:

If we assume transition waveguide as the space filling the gap between circular waveguide and square waveguides we can have an equivalent circuit for this structure such as above. Because of symmetry we should have all output admittance as one single equal admittance.

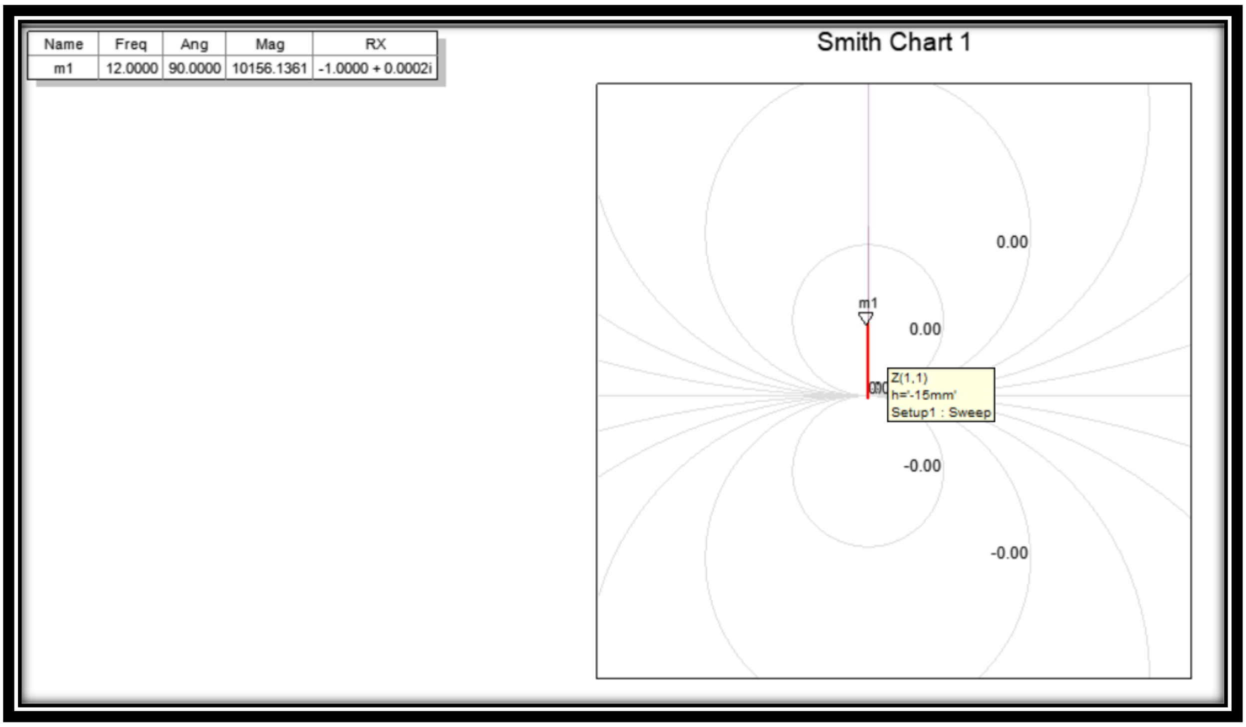
As we are going to match admittances of output and input we should make a little change in transition waveguide gap, we put a matching cylinder in there to have the least loss in waveguide duty to power dividing. We assume this cylinder admittance as $jB2$. The calculation for return coefficient of Γ:

$$\Gamma_{in} = \frac{(Y_w - jB_1)[Y_t + (jY_w - B_2)tan\beta l] - Y_t(Y_w + jB_2 + jY_t \tan\beta l)}{(Y_w + jB_1)[Y_t + (jY_w - B_2)tan\beta l] + Y_t(Y_w + jB_2 + jY_t \tan\beta l)}$$



Reference: Based on a paper in RF engineering basic concept from RF journal collection of CERN research company!

In order to achieve impedance matching we first need to observe input impedance in smith chart of target port.

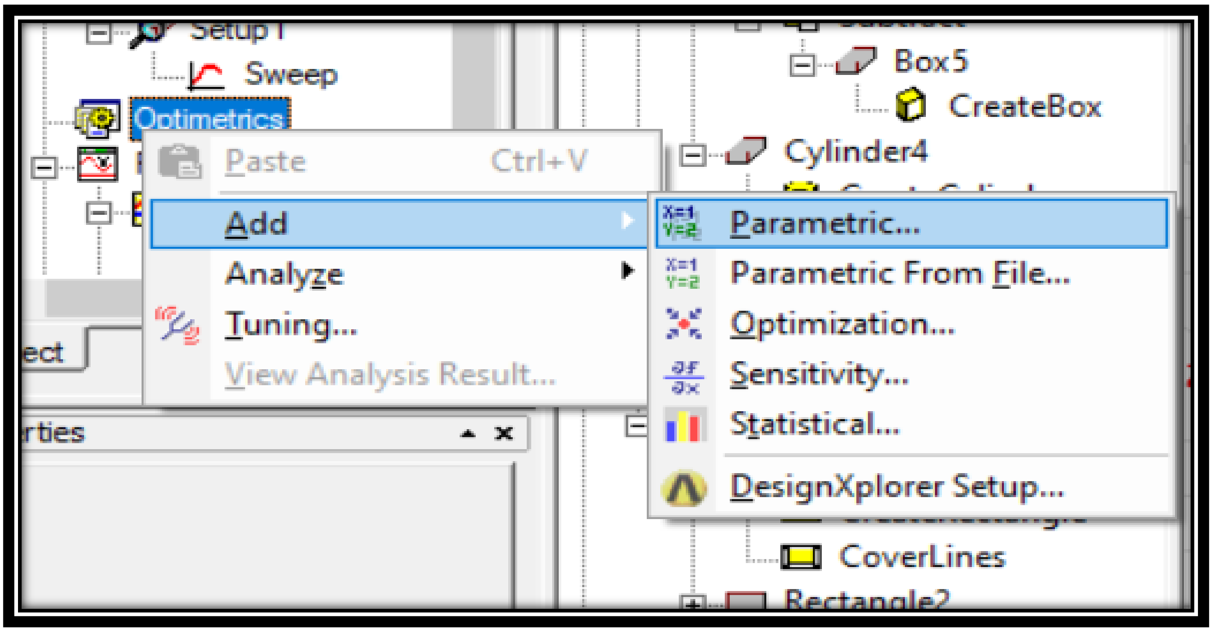


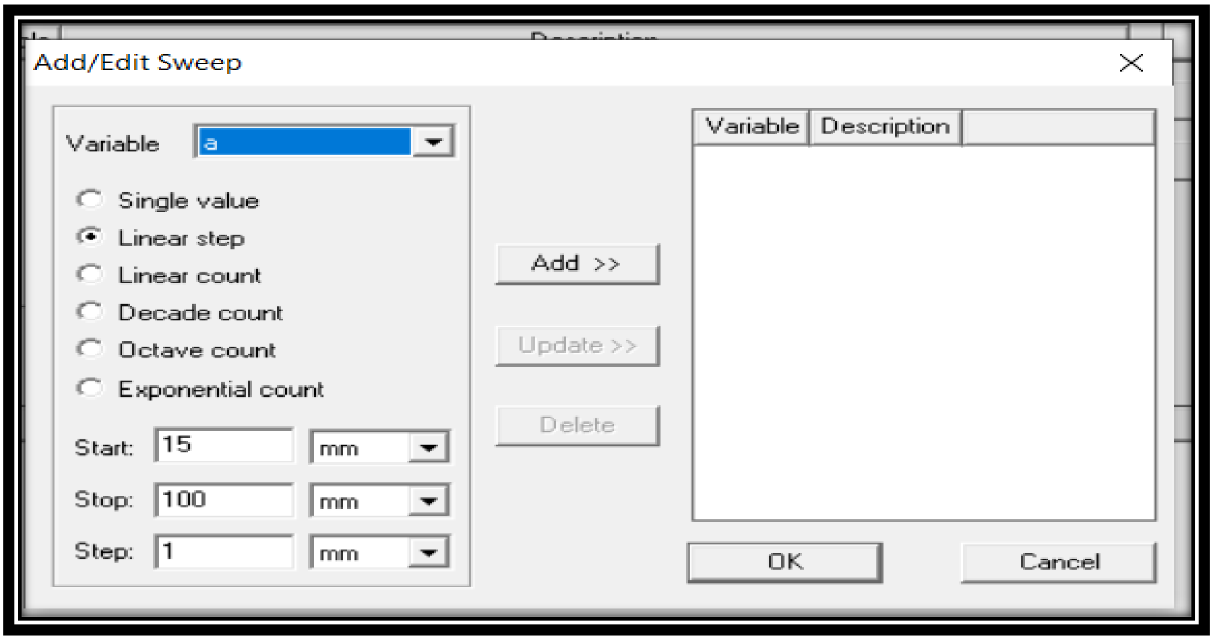
Then we can achieve so by conjugate matching and proper selection of resistor, inductor and capacitor impedance matching can be achieved.

In order to change the input impedance, we can add some lumped circuit parts to the input of the circuit or if we have some design parameter which we can manipulate to modify the input impedance that is the first step.

Height parameter sweep:

In this part I put the height parameter as of our variable parameter in our analyses and afterward using below Tabs I set the parameter as the sweep variable to change the height.



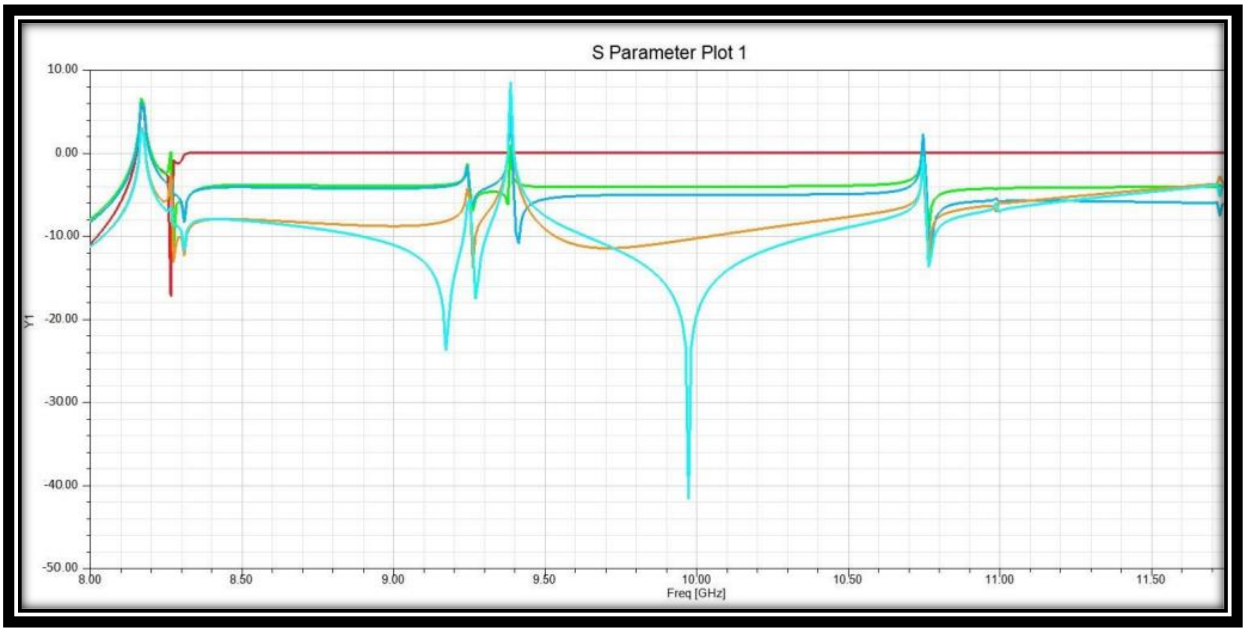


8 Part #6

8.1 Simulation Results In HFSS

8.1.1 Plotting Scattering Parameters:

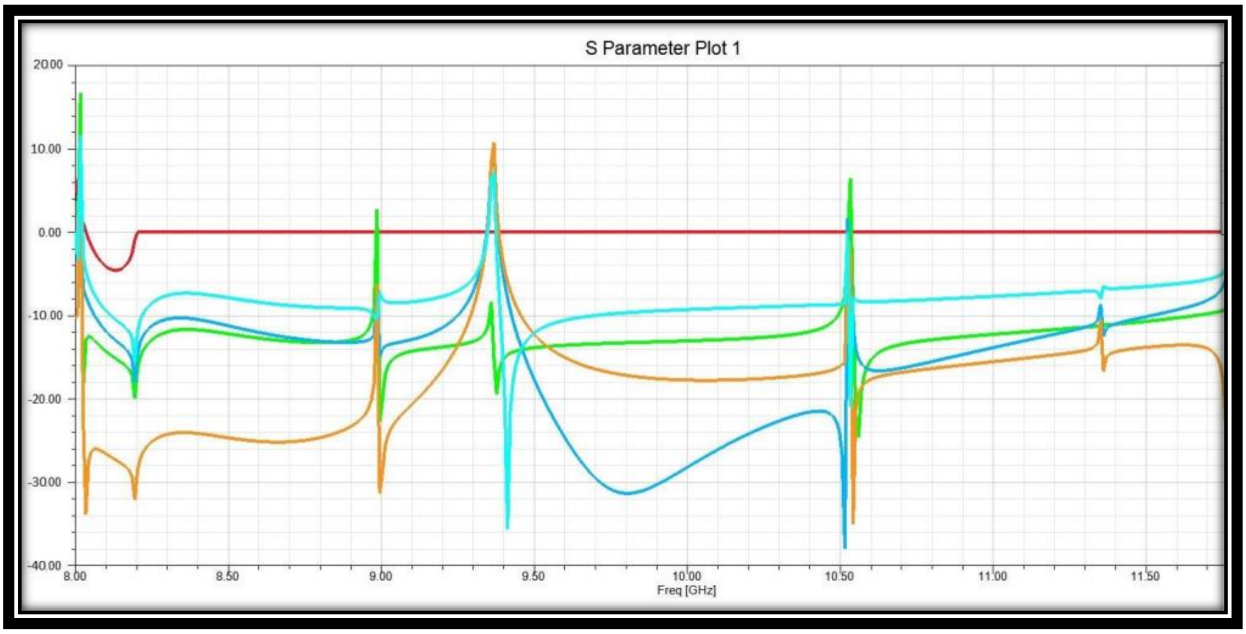
Here you can easily find the figure of scattering matrix for our case:



8.1.2 Sensitivity Analysis

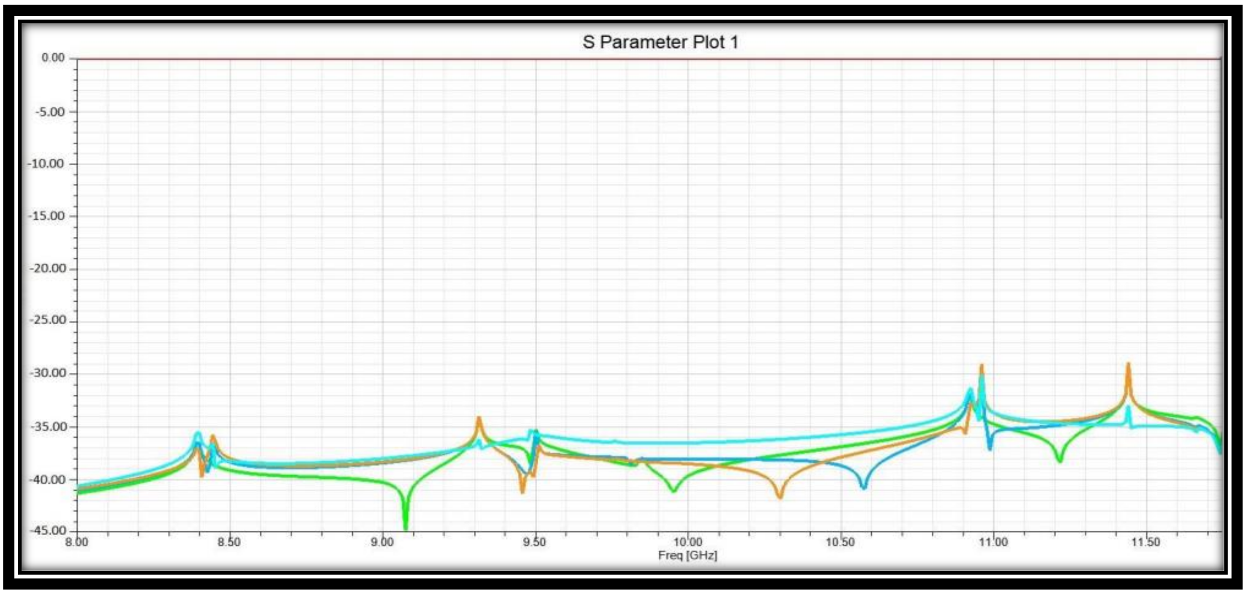
In This part we change the size of the topology in each cases and also investigate the Scattering parameters as you can see the results are as below:

(increasing in height & length & Radius & Width of the model)



In This part we decrease the size of the topology in each cases and also investigate the Scattering parameters as you can see the results are as below:

(decreasing in height & length & Radius & Width of the model)



9 ACKNOWLEDGEMENT

I am really grateful for Mr MohammadReza Tavakoli (810197477) because in some part of this project we had a nice and effective discussion which highly helped us to have a better analyse and also have more adequate results!

Afterwards, I am thankful to all of course teaching assistants: **JammalKazazi**(jamal.kazazi@gmail.com) who designed this project with high quality.

10 REFERENCES

[1] https://www.youtube.com/watch?v=CxTk7_M5Nhg

[2] https://www.youtube.com/watch?v=oFJygeBr-sI

[3] https://www.youtube.com/watch?v=ES3HObniA5s

[4] https://www.youtube.com/watch?v=5AOB1mbyHNk