Design of Slotted Waveguide Antennas with Low Sidelobes for High Power Microwave Applications

B.E. Dissertation

Submitted in partial fulfillment of the requirement of

University of Mumbai

For the Degree of

Bachelor of Engineering
(Electronics and Telecommunication Engineering)

by

Ansari Abu Talha (14ET13)
Khan Sakib (14ET26)
Shaikh Shiraj Mohammed (14ET40)

Under the guidance of

Prof. Riyaz Pathan

Department of Electronics and Telecommunication Engineering
Anjuman-I-Islam's Kalsekar Technical Campus,
Sector 16, New Panvel , Navi Mumbai
(Affiliated to University of Mumbai)
April 2018

Anjuman-I-Islam's
Kalsekar Technical Campus
(Affiliated to the University of Mumbai)
Plot 2 and 3,Sector 16, Khandagaon, Near Thana Naka, New Panvel, Navi Mumbai 410206.

Certificate

This is to certify that, the dissertation titled

"Design of Slotted Waveguide Antennas with Low Sidelobes for High Power Microwave Applications "

is a bonafide work done by

Ansari Abu Talha (14ET13)
Khan Sakib (14ET26)
Shaikh Shiraj Mohammed (14ET40)

and is submitted in the partial fulfillment of the requirement for the degree of

Bachelor of Engineering
in
Electronics and Telecomunication Engineering
to the
University of Mumbai.

Guide

Project Coordinator

Head of Department

Principal

Certificate of Approval by Examiners

This is to certify that the dissertation entitled **"Design of Slotted Waveguide Antennas with Low Sidelobes for High Power Microwave Applications"** is a bonafide work done by **Ansari Abu Talha, Khan Sakib, Shaikh Shiraj Mohammed** under the guidance of **Mr. Riyaz Pathan**. This dissertation has been approved for the award of **Bachelor's Degree in Electronics and Telecommunication Engineering**, University of Mumbai.

Examiners:

Name:

Name:

Acknowledgments

I would like to take the opportunity to express my sincere thanks to my guide **Asst Prof. Riyaz Pathan**, Department of Electronics and Telecommunication Engineering, AIKTC, School of Engineering, Panvel for his invaluable support and guidance throughout my project research work. Without his kind guidance and support this was not possible. I am grateful to him for his timely feedback which helped me track and schedule the process effectively. His time, ideas and encouragement that he gave is help me to complete my project efficiently.

I am thankful to **Prof.Afzal Shaikh**, HOD, Department of Electronics and Telecommunication Engineering, AIKTC, School of Engineering, Panvel and all my B.E. teachers for providing advice and valuable guidance.

I would also like to thank **Dr.Abdul Razak Honnutagi**, AIKTC, Panvel, for his encouragement and for providing an outstanding academic environment, also for providing the adequate facilities.

I also extend my sincere thanks to all the faculty members and the non-teaching staff and friends for their cooperation.

Last but not the least, I am thankful to all my family members whose constant support and encouragement in every aspect helped me to complete my project.

Abstract

Slotted waveguide antenna (SWA) arrays offer clear advantages in terms of their design, weight, volume, power handling, directivity, and efficiency. Slotted waveguide antennas (SWA) are often employed in radar applications where design specifications commonly require high gains and mechanical robustness. Since the peak power transmitted by radar antennas is usually very high, waveguide antennas present a practical alternative to planar arrays. While numerous design references and guidelines exist for planar arrays, they are far fewer for slotted waveguide antennas. In this report there is a complete workflow for the analysis and design of a slotted waveguide antenna with slots placed on the narrow wall of the waveguide. The platform use for design the model and simulate is HFSS Software

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Introduction

A slotted waveguide is waveguide that used as an antenna in microwave radar applications. Prior to its use in surface search radar, such systems used a parabolic segment reflector. The slotted waveguide antenna was the result of collaborative radar research carried on by McGill University and the National Research Council of Canada during World War II. The co-inventors, W.H. Watson and E.W. Guptill of McGill, were granted a United States patent for the device, described as a ”directive antenna for microwaves”, in 1951. For comparison, in the parabolic type of antenna a feedhorn at the end of a waveguide directs a conical beam of output energy toward the reflector, whence it is focused into a narrow collimated beam. Reflected energy from the environment follows the reverse path and is focused by the reflector onto the feed horn where it travels back to the receiver. The reflector must be built to a precision determined by the wavelength used. For a one centimeter wavelength, a reflector precision of one or two millimeters would be adequate.

1.2 Basics of waveguide

- A waveguide is a structure that guides waves, such as electromagnetic waves
- Most efficient way to transfer electromagnetic energy.
- Essentially coaxial lines without the centre conductors
- Constructed from conductive material and may be rectangular, circular, or elliptical in shape.

- According to waveguide theory there are a number of different types of electromagnetic wave that can propagate within the waveguide.
- Since energy is transferred through waveguides by electromagnetic fields, you need a basic understanding of field theory.
- Both electric (E FIELD) and magnetic fields (H FIELD) are present in waveguides, and the interaction of these fields causes energy to travel through the waveguide

. In general, a waveguide is one type of transmission line(Tx), capable of guiding Electro Magnetic (EM) Waves at high frequency with minimum amount of power loss. So if dimension (side) of waveguide is greater than half wavelength, the waves propagate through it with extremely low loss.

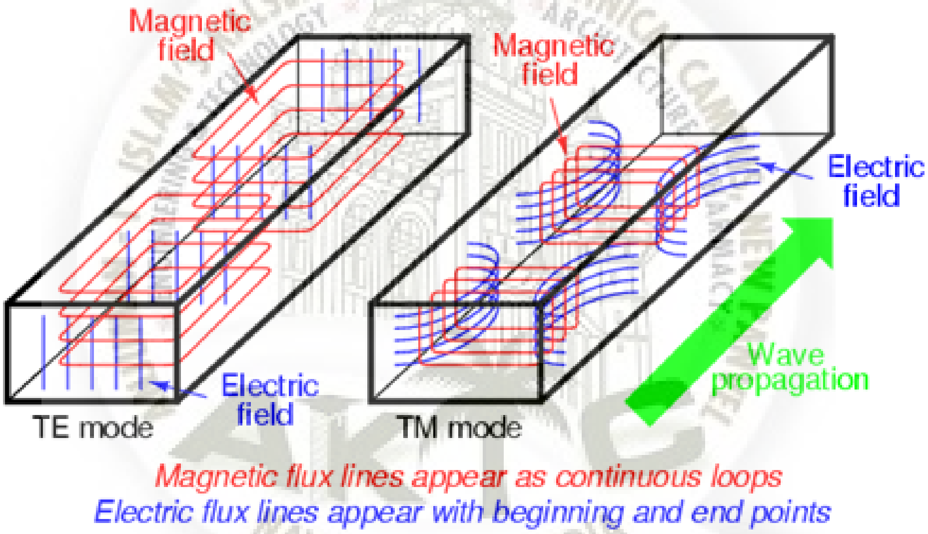


Figure 1.1: Waveguide

At the same time, if the end of the waveguide is simply left open, the wave will radiate out from the open end. It also offers radiation into open space if it is fed at one end and the other end is kept open like an opened Tx line. In this process a small portion of the incident wave is radiated and the remaining portion is reflected back by open circuit. This is due to discontinuities at the edges, which matches the waveguide to free space very poorly. These discontinuities could be reduced by flaring of waveguide and the entire energy incident in forward direction radiated subject to proper impedance matching.

1.3 Modes of operation

- When the waveguide yields an electric field configuration known as the half-sine electric distribution, the configuration is called as the mode of operation.

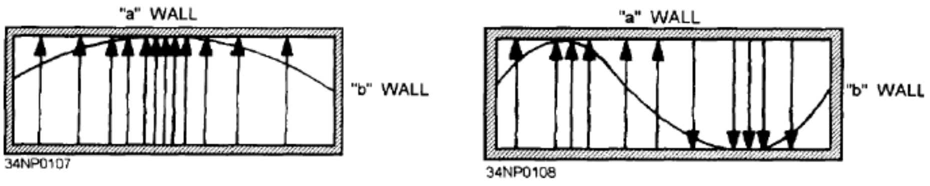


Figure 1.2: Half Sin E field and Full Sin E field

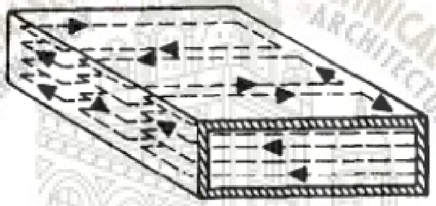


Figure 1.3: Magnetic Field cause by Half Sinn

- **TEM waves:** waves with no electric or magnetic field in the direction of propagation (Hz = Ez= 0). Plane waves and transmission-line waves are common examples.
- **TM waves:** waves with an electric field but no magnetic field in the direction of propagation (Hz =0, Ezis not 0). These are sometimes referred to as E waves.
- **TE waves:** waves with a magnetic field but no electric field in the direction of propagation (Hz is not 0, Ez= 0). These are sometimes referred to as H waves.
- **Hybrid waves:** Sometimes the boundary conditions require all field components. These waves can be considered as a coupling of TE and TM modes by the boundary.

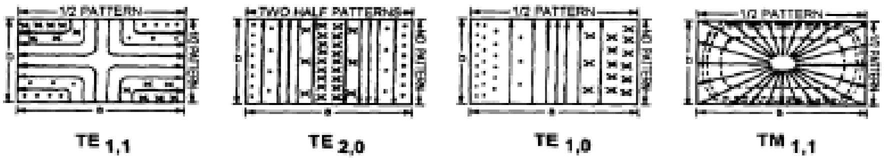


Figure 1.4: Transverse Electric(TE) Modes

1.4 Cutoff Frequency

Cutoff frequency : lowest frequency for which a mode will propagate in it.

- The cutoff frequency is found with the characteristic equation of the Helmholtz equation for electromagnetic waves.
- Any exciting frequency lower than the cutoff frequency will attenuate, rather than propagate
- The modes that can exist inside a waveguide depends on the
  1. Dimensions of the waveguide.
  2. Medium inside it.
  3. Excitation.
  4. Coupling of energy from the source.

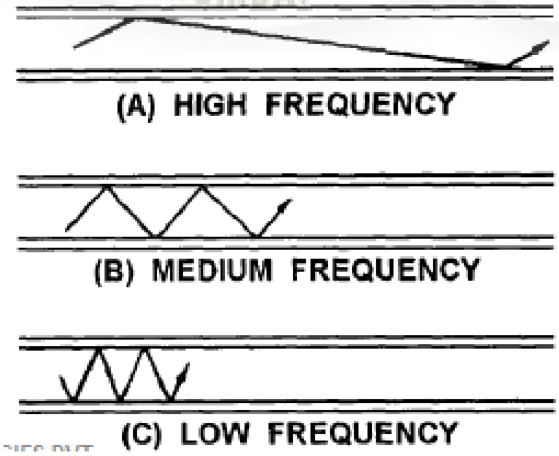
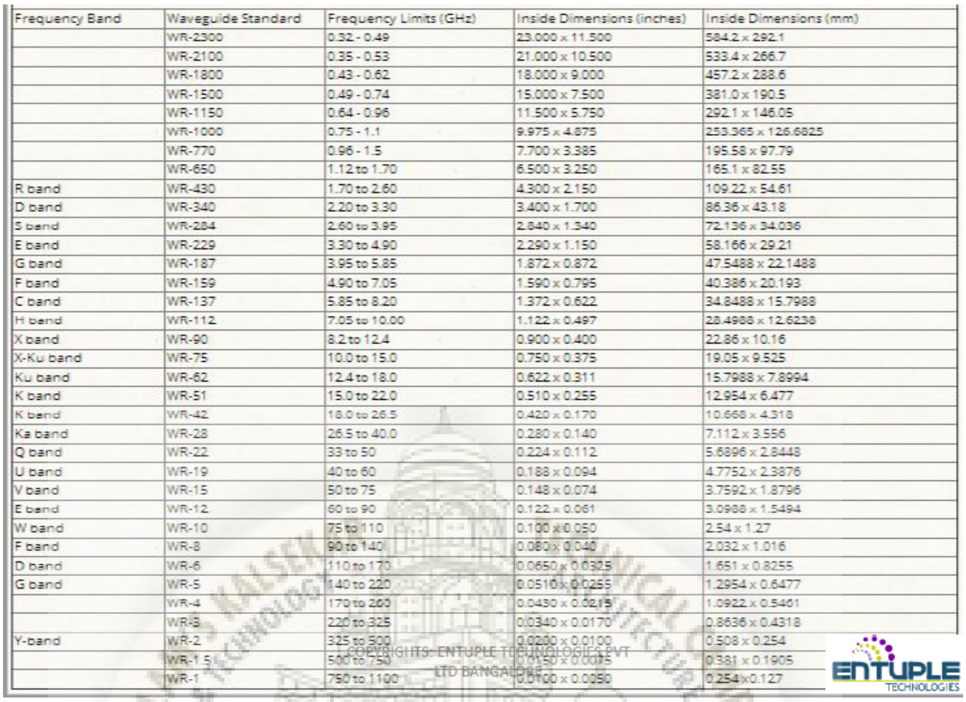


Figure 1.5: Reflection angle at various frequency

1.4.1 Dimension Required For Waveguide



Frequency Band	Waveguide Standard	Frequency Limits (GHz)	Inside Dimensions (inches)	Inside Dimensions (mm)
	WR-2300	0.32 - 0.49	23.000 x 11.500	584.2 x 292.1
	WR-2100	0.35 - 0.53	21.000 x 10.500	533.4 x 266.7
	WR-1800	0.43 - 0.62	18.000 x 9.000	457.2 x 288.6
	WR-1500	0.49 - 0.74	15.000 x 7.500	381.0 x 190.5
	WR-1150	0.64 - 0.96	11.500 x 5.750	292.1 x 146.05
	WR-1000	0.75 - 1.1	9.975 x 4.875	253.365 x 126.6825
	WR-770	0.96 - 1.5	7.700 x 3.385	195.58 x 97.79
	WR-650	1.12 to 1.70	6.500 x 3.250	165.1 x 82.55
R band	WR-430	1.70 to 2.60	4.300 x 2.150	109.22 x 54.61
D band	WR-340	2.20 to 3.30	3.400 x 1.700	86.36 x 43.18
S band	WR-284	2.60 to 3.95	2.840 x 1.340	72.136 x 34.036
E band	WR-229	3.30 to 4.90	2.290 x 1.150	58.166 x 29.21
G band	WR-187	3.95 to 5.85	1.872 x 0.872	47.5488 x 22.1488
F band	WR-159	4.90 to 7.05	1.590 x 0.795	40.386 x 20.193
C band	WR-137	5.85 to 8.20	1.372 x 0.622	34.8488 x 15.7988
H band	WR-112	7.05 to 10.00	1.122 x 0.497	28.4988 x 12.6238
X band	WR-90	8.2 to 12.4	0.900 x 0.400	22.86 x 10.16
X-Ku band	WR-75	10.0 to 15.0	0.750 x 0.375	19.05 x 9.525
Ku band	WR-62	12.4 to 18.0	0.622 x 0.311	15.7988 x 7.8994
K band	WR-51	15.0 to 22.0	0.510 x 0.255	12.954 x 6.477
K band	WR-42	18.0 to 26.5	0.420 x 0.170	10.668 x 4.318
Ka band	WR-28	26.5 to 40.0	0.280 x 0.140	7.112 x 3.556
Q band	WR-22	33 to 50	0.224 x 0.112	5.6896 x 2.8448
U band	WR-19	40 to 60	0.188 x 0.094	4.7752 x 2.3876
V band	WR-15	50 to 75	0.148 x 0.074	3.7592 x 1.8796
E band	WR-12	60 to 90	0.122 x 0.061	3.0988 x 1.5494
W band	WR-10	75 to 110	0.100 x 0.050	2.54 x 1.27
F band	WR-8	90 to 140	0.080 x 0.040	2.032 x 1.016
D band	WR-6	110 to 170	0.0650 x 0.0325	1.651 x 0.8255
G band	WR-5	140 to 220	0.0510 x 0.0255	1.2954 x 0.6477
	WR-4	170 to 260	0.0430 x 0.0215	1.0922 x 0.5461
	WR-3	220 to 325	0.0340 x 0.0170	0.8636 x 0.4318
Y-band	WR-2	325 to 500	0.0200 x 0.0100	0.508 x 0.254
	WR-1.5	500 to 750	0.0150 x 0.0075	0.381 x 0.1905
	WR-1	750 to 1100	0.0100 x 0.0050	0.254x0.127

Figure 1.6: Dimension Table for Required Waveguide

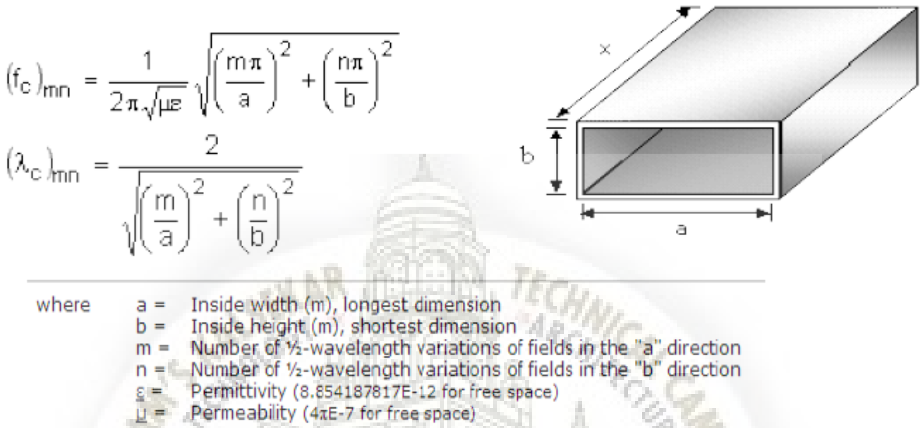
1.5 Dominant mode

- Dominant mode: The mode with the lowest cutoff frequency
- The dominant mode is the most efficient mode.
- Waveguides are normally designed so that only the dominant mode will be used.
- To operate in the dominant mode, a waveguide must have an a (wide) dimension of at least one half-wave length of the frequency to be propagated.
- The a dimension of the waveguide must be kept near the minimum allow able value to ensure that only the dominant mode will exist.
- Of the possible modes of operation available for a given waveguide, the dominant mode has the lowest cutoff frequency

1.6 Types of waveguide

Rectangular Waveguide:

The lower cutoff frequency (or wavelength)for a particular mode in rectangular waveguide is determined by the following equations (note that the length, x, has no bearing on the cutoff frequency)



$$(f_c)_{mn} = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$$

$$(\lambda_c)_{mn} = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

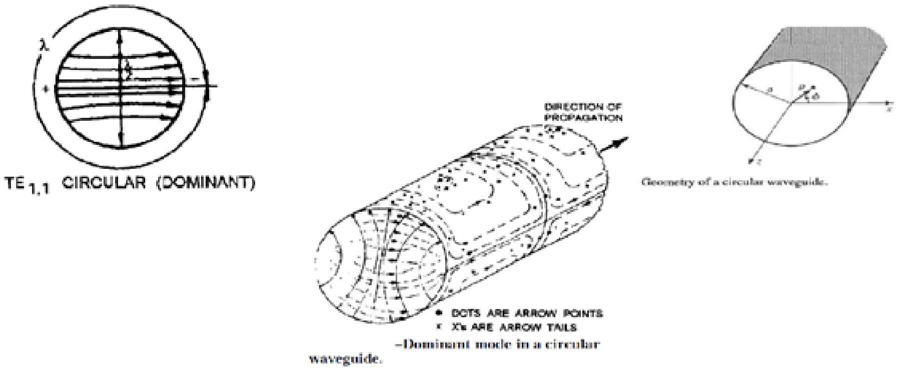
where a = Inside width (m), longest dimension
b = Inside height (m), shortest dimension
m = Number of ½-wavelength variations of fields in the "a" direction
n = Number of ½-wavelength variations of fields in the "b" direction
ε = Permittivity (8.854187817E-12 for free space)
μ = Permeability (4πE-7 for free space)

Figure 1.7: Rectangular Waveguide

- The TE10mode has the lowest cutoff frequency and is called the dominant mode.
- All other modes have higher cutoff frequencies
- Guides are usually designed so that at the frequency of operation only the dominant mode is propagating, while all higher-order modes are ”cutoff.

Figure 1.8: Different Field patterns for Rectangular Waveguide

Circular Waveguide:



–Dominant mode in a circular waveguide.

Geometry of a circular waveguide.

Figure 1.9: Circular waveguide

- Attractive because of its ease of manufacturing and low attenuation of TE0N Modes used in specific areas of radar and communications systems, such as rotating joints used at the mechanical point where the antennas rotate.
- Drawback is its fixed bandwidth between modes.
- The cutoff wavelength is 1.71 times the diameter of the waveguide.

1.7 Rectangular Slotted Waveguide Antenna

Rectangular Slotted Waveguide Antennas (SWAs) [1] radiate energy through slots cut from the broad or narrow wall of a rectangular waveguide. This means the radiating elements are an integral part of the feed system, which is the waveguide itself, leading to a simple design not requiring baluns or matching networks. The other main advantages of SWAs include relatively low weight and small volume, their high power handling, high efficiency, and good reflection coefficient [2]. For this, they have been ideal solutions for many radar, communications, navigation, and high power microwave applications [3].

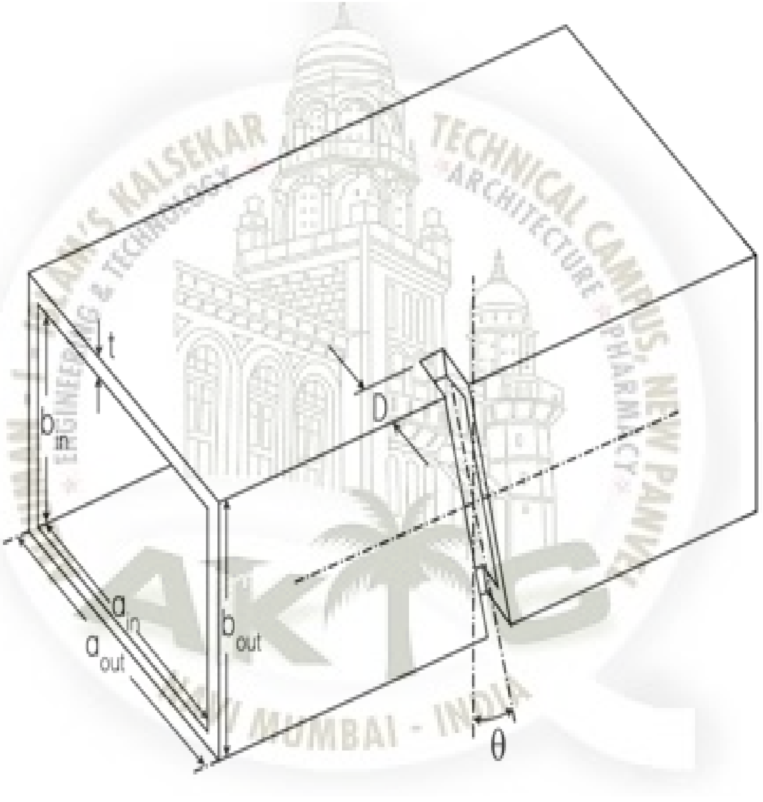


Figure 1.10: Rectangular Slotted Waveguide Antenna

SWAs can be resonant or non-resonant depending on the way the wave propagates inside the waveguide, which is a standing wave in the former case and a traveling-wave in the latter [4, 5]. The traveling-wave SWA has a larger bandwidth, but it requires a matched terminating load to absorb the wave and prevent it from being reflected, which reduces its efficiency. It also has the shortcoming of the dependency of the main beam direction on the operating frequency. Resonant SWAs, on the other hand, have the end of the waveguide terminated with a short circuit, which results in a higher efficiency due to no power loss at the waveguide end. In addition, the main beam is normal to the array independently of the frequency, but these advantages come at the cost of a narrower operation band. The design of a resonant SWA is generally based on the procedure described by Stevenson and Elliot [4, 69], by which the waveguide end is short-circuited at a distance of a quarter-guide wavelength from the center of the last slot, and the inter-slot distance is one-half the guide wavelength. For rectangular slots, the slot length should be about half the free-space wavelength.

Chapter 2

Literature Survey

- **A Survey on Accurate synthesis of linear non-resonant narrow wall inclined slotted waveguide arrays:**

  In this paper M. Lkke1 A. stergaard2 1TERMA, Radar Systems, Hovmarken 4, DK-8520 Lystrup, Denmark 2ESA, ESTEC, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands designed an efficient and highly accurate network model for analysing and synthesising large but finite slotted waveguides (SWGs) is presented. The network model is tailored for arrays of linear end-fed narrow wall inclined slots. The network model accurately predicts, as function of frequency, the key electrical antenna parameters such as antenna-radiation pattern (beamwidth, inner and spurious side lobes down to the 240 dB level, main beam squint), waveguide loss, power dissipated in the load and return loss. The network model explicitly takes mechanical tolerances into account.

  The model is based upon S parameter measurements of a number of test-SWGs. The network model has been proven to be scalable from X-band to S band waveguides and can be extrapolated to slot parameters far beyond the range of the slots of the test SWGs. The comparison between predicted and measured results has shown that the network model is highly accurate, providing a significant improvement over full wave commercial tools in terms of prediction of the antenna parameters of interest as well as in computational speed. A network model for designing SWGs has been presented. This model can be used to predict a number of antenna parameters such as radiation pattern, power dissipated into the load, return loss etc., as function of frequency. Furthermore, a fundamental behaviour across waveguide bands relating to the slot inclination angle and the slot shunt conductance of narrow wall inclined slots has been presented. Hence, the network model can be scaled to other waveguide sizes without having to manufacture new sets of test-SWGs.

Review in this paper he worked on the beamwidth inner and suprious side lobe down to 240 dB level main beam squint.The model is based upon S parameter measurements of a number of test-SWGs.The antenna have high side lobe and it is not sufficient to transmit the signal.

- **A Survey on Slotted Waveguide Antenna Design Using 3D EM Simulation:**

  In this paper Rodrigo Kenji Enjiu CST AG, Darmstadt, Germany Marcelo Bender Perotoni UFABC, Santo Andr, Brazil designed a slotted wave guide antenna are of ten employed in radar applications where design specifications commonly require high gains and mechanical robustness. Since the peak power transmitted by radar antennas is usually very high, waveguide antennas present a practical alternative to planar arrays. While numerous design references and guidelines exist for planar arrays, there are far fewer for slotted waveguide antennas. This article presents a comprehensive workflow for the analysis and design of a slotted waveguide antenna with slots placed on the narrow wall of the waveguide. The virtual design is modelled and simulated using two different numerical methods and different mesh types.

  This simulation is compared to the analytical solution for array antennas and to the performance of a physical prototype. Edge-slotted waveguide antennas are widely used in radar applications where they outperform other types of antennas such as printed arrays. Despite the ubiquity of SWAs, we were unable to find any previous literature describing comprehensive analytical formulations or computer-aided design programs for SWA synthesis. In the absence of design curves or suitable measurement data, the designer usually resorts to empirical methods to optimize the design.

  The use of modern computer simulation software offers an alternative approach to SWA design. The workflow proposed in this paper covers the entire antenna project, from slot characterization to physical prototyping of the antenna, and shows how simulation can be used at every step to improve antenna performance. The antenna described in this article has 12 slots. It achieved optimum performance, verified numerically, without any changes needed to further improve the final design. The measurement of a prototype validates the accuracy of the simulation.

- **Parallel Higher-Order MoM Simulation for Narrow-Wall Slotted Waveguide Array:**

  Sio-Weng Ting, Xun-Wang Zhao, Hui Zhao(4), Yu Zhang ,Tapan K. Sarkar designed a A traveling waveguide array with 108 narrow-wall slots is analysed using the parallel method of moments with higher-order polynomial basis functions on a distributed memory cluster. The concept of the perfectly matched layer in differential-equation methods is introduced to design the matched load terminating the waveguide. The simulated data is compared with the commercial softwareANSYS HFSSs result to validate the proposed method. The results demonstrate that the parallel method of moments is able to accurately and efficiently solve complex electromagnetic radiation problems. A 108-slot traveling waveguide array is analysed by using a new parallel computational electromagnetics (CEM) codeHigher-Order Basis based Integral Equation Solver (HOBIES). The matched load designed according to the principle of perfectly matched layer works very well for terminating the waveguide. The comparison with ANSYS HFSS commercial software demonstrates that HOBIES is a more efficient method.

Chapter 3

Technical Detalis

3.1 Methodology

Depending upon the desired field polarization, the slots can be placed on either the narrow or broad wall of the waveguide, as shown in Figure 3.1. At the fundamental TE10 mode, longitudinal slots on the broad wall will produce a field with vertical polarization, while transverse slots on the narrow wall result in a horizontal field polarization. For each design, the polarization depends on the specific antenna use.

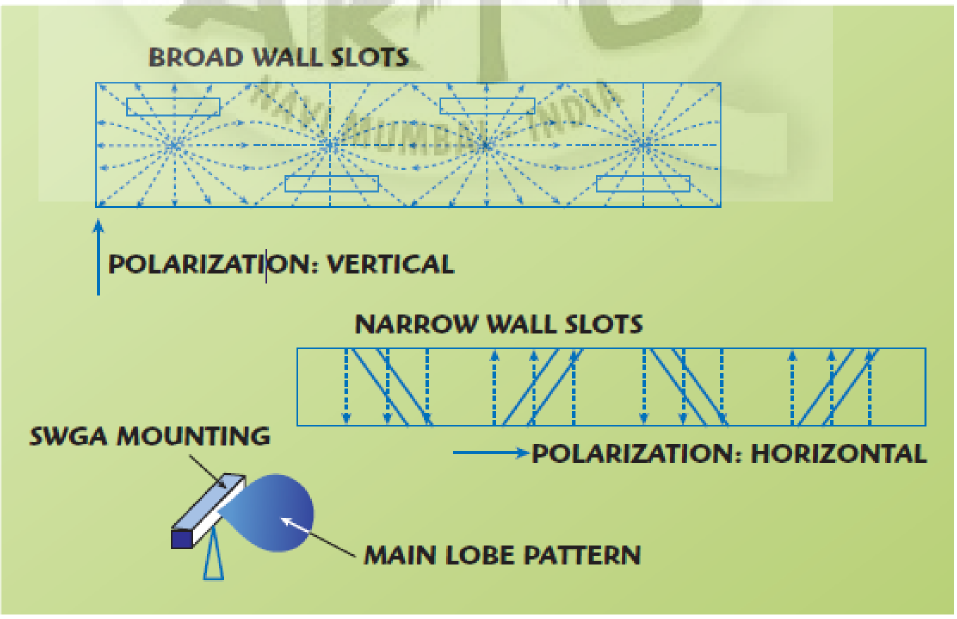


Figure 3.1: The choice of slot position.

Table 3.1: Parameters of the SWGs antenna

Parameters	**Specifications**
Gain	15 dB
Polarization	Horizontal
Frequency	9.375 GHz
Side lobe level (SLL)	30 dB

To demonstrate the applicability of 3D simulation to SWAs, this article describes the design of a naval radar antenna. The specification requires that the antenna operate in X-Band (8 to 12 GHz). The scanning beam must have a narrow beamwidth in the azimuth plane and a wider beamwidth in the elevation plane to compensate for the roll of the ship. Other parameters are specified in Table 3.1

These requirements can be fulfilled by the arrays in Figure 3.1, with the horizontal polarization requirement determining the use of the narrow wall slots. In order to achieve a resonant length, narrow wall slots must penetrate into the upper and bottom broad walls. These slots are known as edge-slots. Figure 3.1 shows these slots running diagonally between the broad walls. If they were perfectly perpendicular, they would not radiate, since the slots would run parallel to the current lines and therefore would not interrupt the current flow. By tilting the slots, a fraction of the current lines are interrupted, causing the slots to radiate.

The slots are distributed along the waveguide so that they form an array; the choice of array type and its setup allow the engineer to specify the gain, side lobe level (SLL) and beam steering. The discrete Taylor distribution was chosen for the array, since it produces a good theoretical match to the SLL requirement as well as providing a smooth variation between the excitations of adjacent elements a useful characteristic when mutual coupling is a concern. Because this is an SWA, the waveguide hosts a standing wave, in which slots are placed at the antinodes locations where the electric field reaches its maximum. They are therefore separated by half of the guided wavelength (g/2). Since a half wavelength on the Smith chart corresponds to a complete rotation, the individual slot admittances are summed at the waveguide input as if they were at the same position. SWA designs do not usually take into account mutual coupling between slots. Since mutual coupling and waveguide thickness have a significant influence on the admittances of the edge-slots, an accurate analysis of the antenna should take their effects into account. Electromagnetic (EM) simulation can model both these effects, as well as the effects due to coaxial transitions and flanges. With EM simulation, the traditional empirical trial-and-error method is replaced by a computational evaluation. The procedure assigns a theoretical excitation distribution to the array, where each element coefficient corresponds to a slot conductance (at the central frequency where the susceptance is zero) ensuring the length of each slot corresponds to a resonance at the operational frequency. The first step characterizes the individual slots. Figure 3.2 shows the important parameters. The choice of waveguide (WR-90) and milling equipment

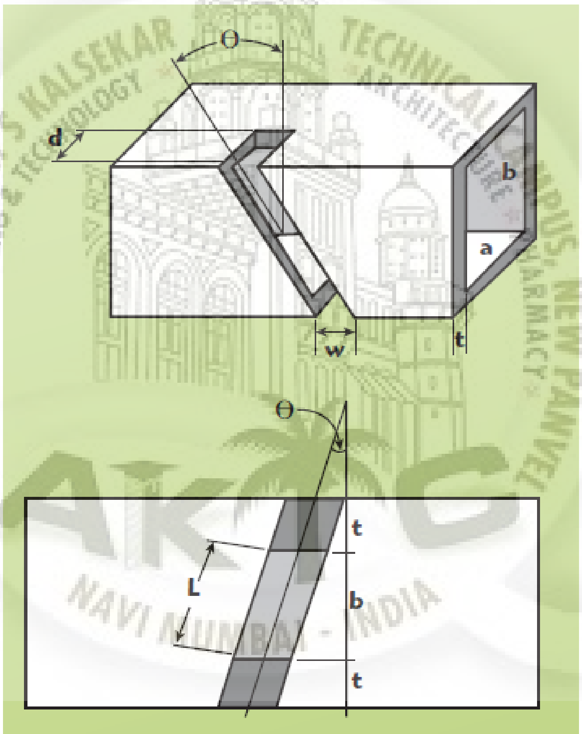


Figure 3.2: Geometric parameters for the edge slots.

determines the parameters a = 22.86 mm, b =10.16 mm, w = 1.59 mm and t = 1.27 mm. This leaves only two independent parameters to optimize: (slot inclination angle) and d (depth of the slot). The complete slot length is assumed to be the one measured on the internal face of the waveguide, parameter Lr, with a resonant length Lr = 0.4625 g.

3.2 Problem Statement

It is seen that due to the increase in the main lobe, the side lobe and cross polarization are also getting increased and there are so many losses occurring due to this.

3.3 Software Requirement

High Frequency Structural Simulation (HFSS) Version 13.0.

Chapter 4

Antenna Design

4.1 Introduction to HFSS

HFSS is an interactive software package for calculating the electromagnetic behavior of a structure.The software includes post-processing commands for analyzing this behavior in detail. The work window of HFSS software is shown.
Using HFSS, we can compute:

- Basic electromagnetic field quantities and,for open boundary problems,radiated near and far fields.
- Characteristic port impedance and propagation constants.
- Generalized S-parameters and S-parameters re-normalized to specific port impedance.
- The eigen modes, or resonances, of a structure.
  We are expected to draw the structure, specify material characteristics for each object, and identify ports and special surface characteristics. HFSS then generates the necessary field solutions and associated port characteristics and S-parameters.

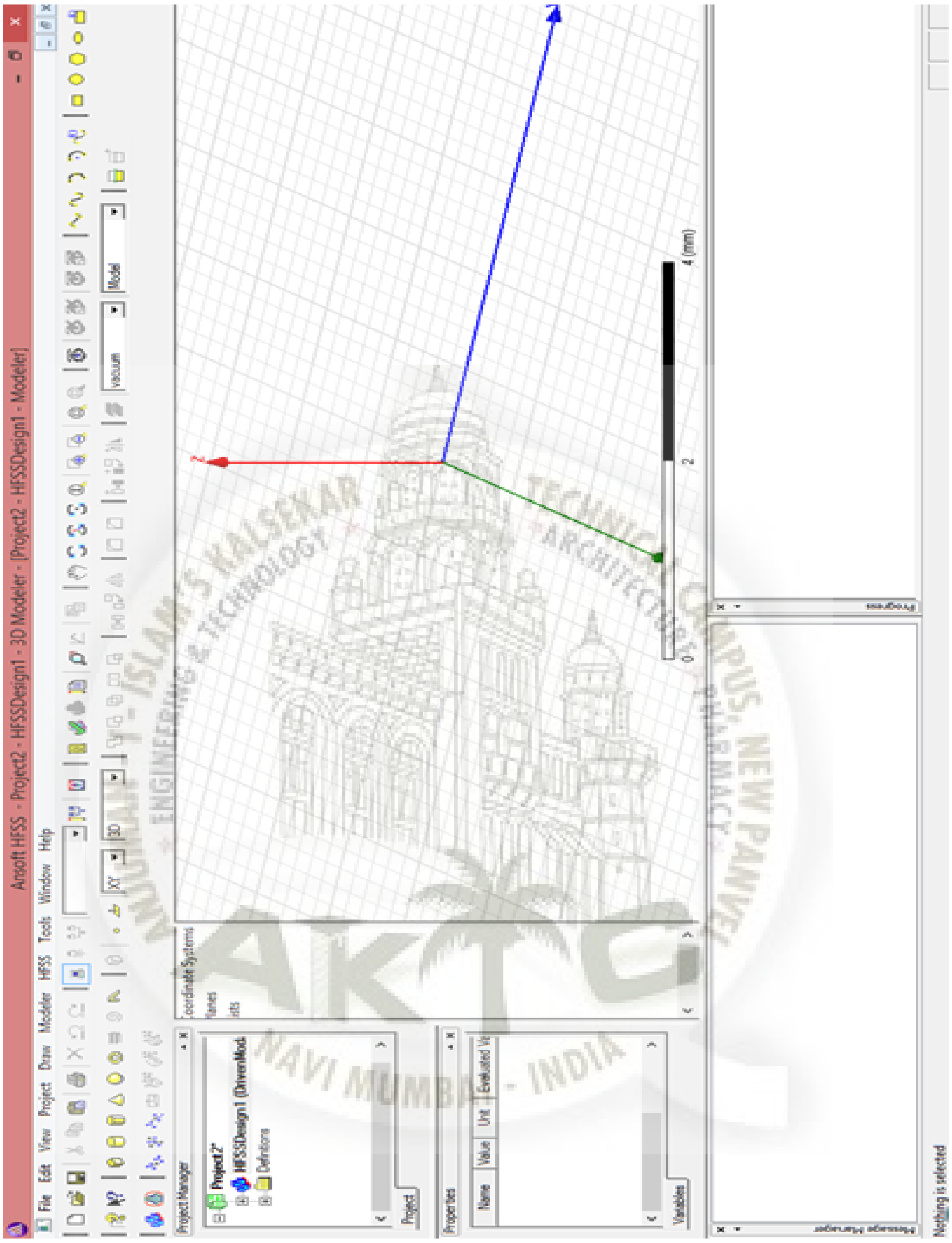
  HFSS uses a numerical technique called the Finite Element Method (FEM). This is a procedure where a structure is subdivided in to many smaller subsections called finite elements. The finite elements used by HFSS are tetrahedra,and the entire collection of tetrahedra is called a mesh. A solution is found for the fields within the finite elements, and these fields are interrelated so that Maxwells equations are satisfied across inter-element boundaries.Yielding a field solution for the entire, original, structure. Once the field solution has been found, the generalized S-matrix solution is determined.

There are six main steps to creating and solving a proper HFSS simulation. They are:

1. Create model/geometry
2. Assign boundaries
3. Assign excitations
4. Set up the solution
5. Solve
6. Post-process the results

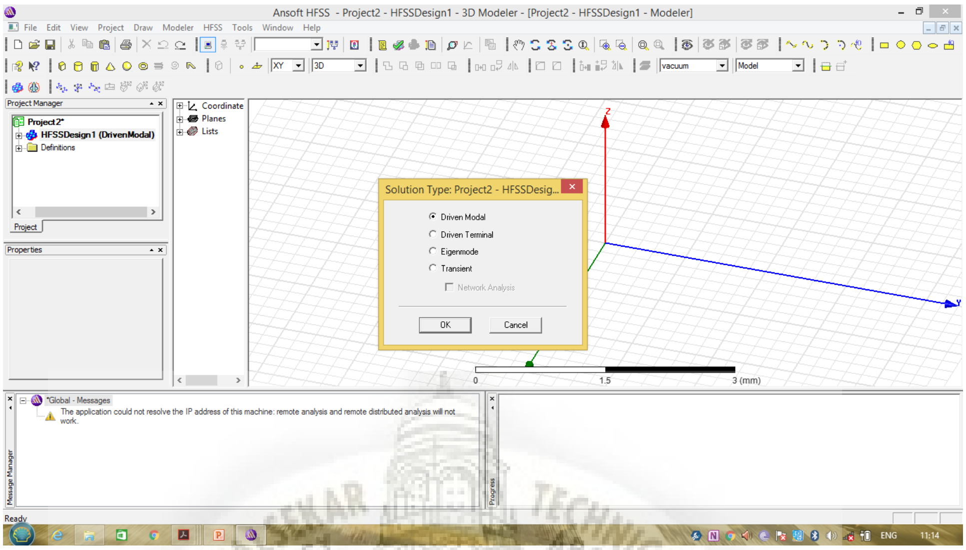
Simulation steps for slotted waveguide antenna

Step 1 : Create Model/Geometry Before creating model we have to select insert HFSS design, which opens the window in which model is to drawn:



Now we have to select solution type for our project

i.e Driven Modal $GotoHFSS \rightarrow Solutiontype \rightarrow SelectDrivenModal \rightarrow OK$


Ansoft HFSS - Project2 - HFSSDesign1 - 3D Modeler - [Project2 - HFSSDesign1 - Modeler]

Solution Type: Project2 - HFSSDesig...

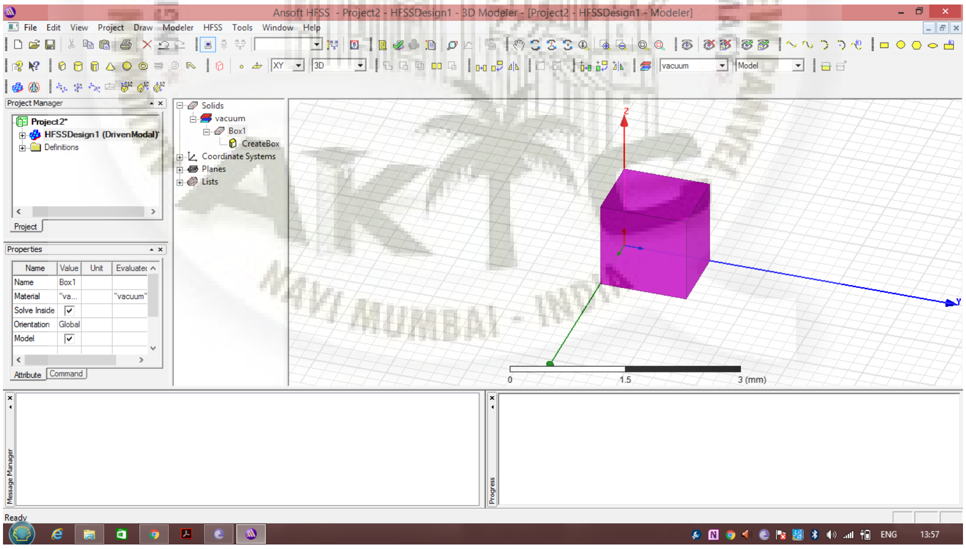
● Driven Modal
○ Driven Terminal
○ Eigenmode
○ Transient
☐ Network Analysis

OK Cancel

The application could not resolve the IP address of this machine: remote analysis and remote distributed analysis will not work.

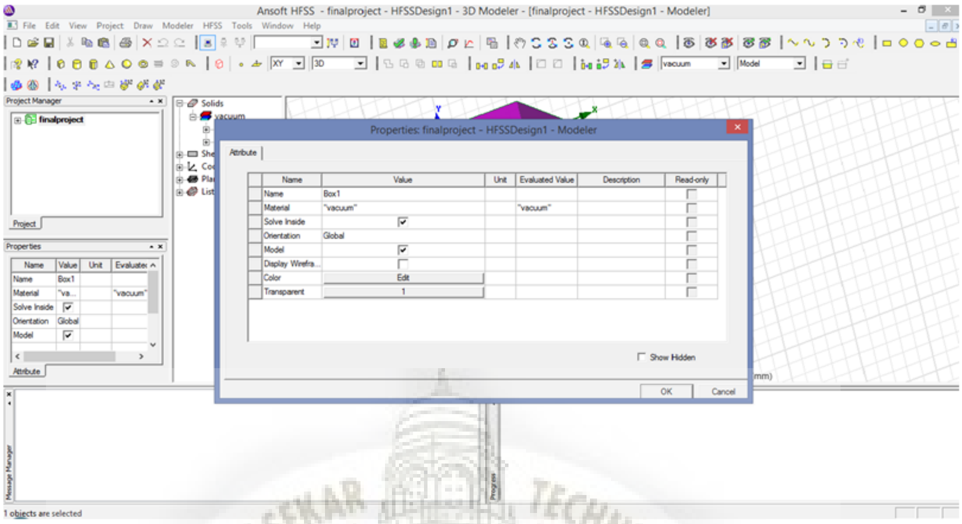
Placing Vacuum Box in the drawing window.

$SelectDrawbox \rightarrow Placeinthedrawingwindow$


Ansoft HFSS - Project2 - HFSSDesign1 - 3D Modeler - [Project2 - HFSSDesign1 - Modeler]

Name	Value	Unit	Evaluated
Name	Box1		
Material	"va...		"vacuum"
Solve Inside	☑		
Orientation	Global		
Model	☑		

Setting box properties (Name,Material, Colour and transparency) $RightclickonBox1 \rightarrow Properties \rightarrow Material \rightarrow Vacuum \rightarrow Ok.$



Properties: finalproject - HFSSDesign1 - Modeler

Attribute

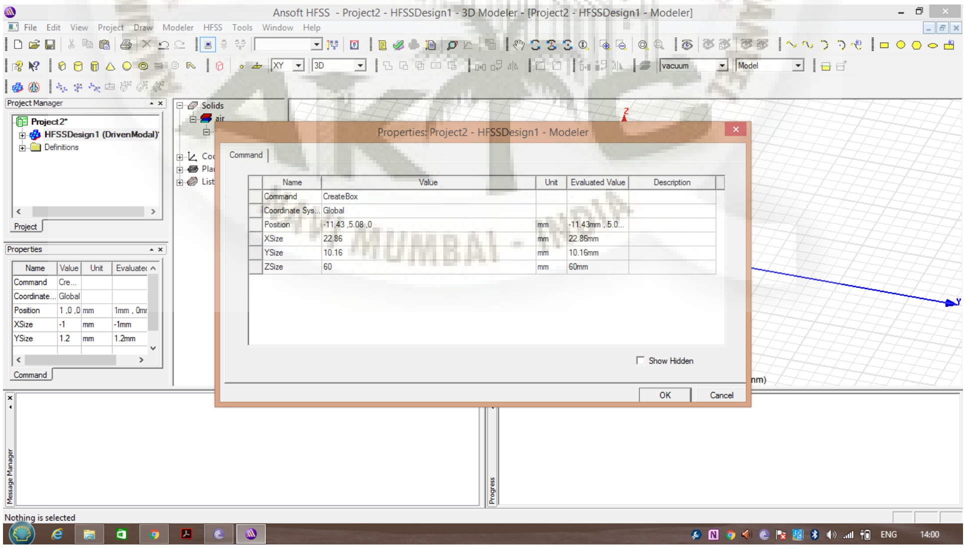
Name	Value	Unit	Evaluated Value	Description	Read-only
Name	Box1				☐
Material	"vacuum"		"vacuum"		☐
Solve Inside	☑				☐
Orientation	Global				☐
Model	☑				☐
Display Wirefra...	☐				☐
Color	Edit				☐
Transparent	1				☐

☐ Show Hidden

1 objects are selected

After setting Name, Color and transparency the size and position of the Vacuum Box is edited.

$RightclickonCreatebox \rightarrow Properties \rightarrow editx, y, zposition \rightarrow editX, Y, Zsize \rightarrow Ok.$



Properties: Project2 - HFSSDesign1 - Modeler

Command

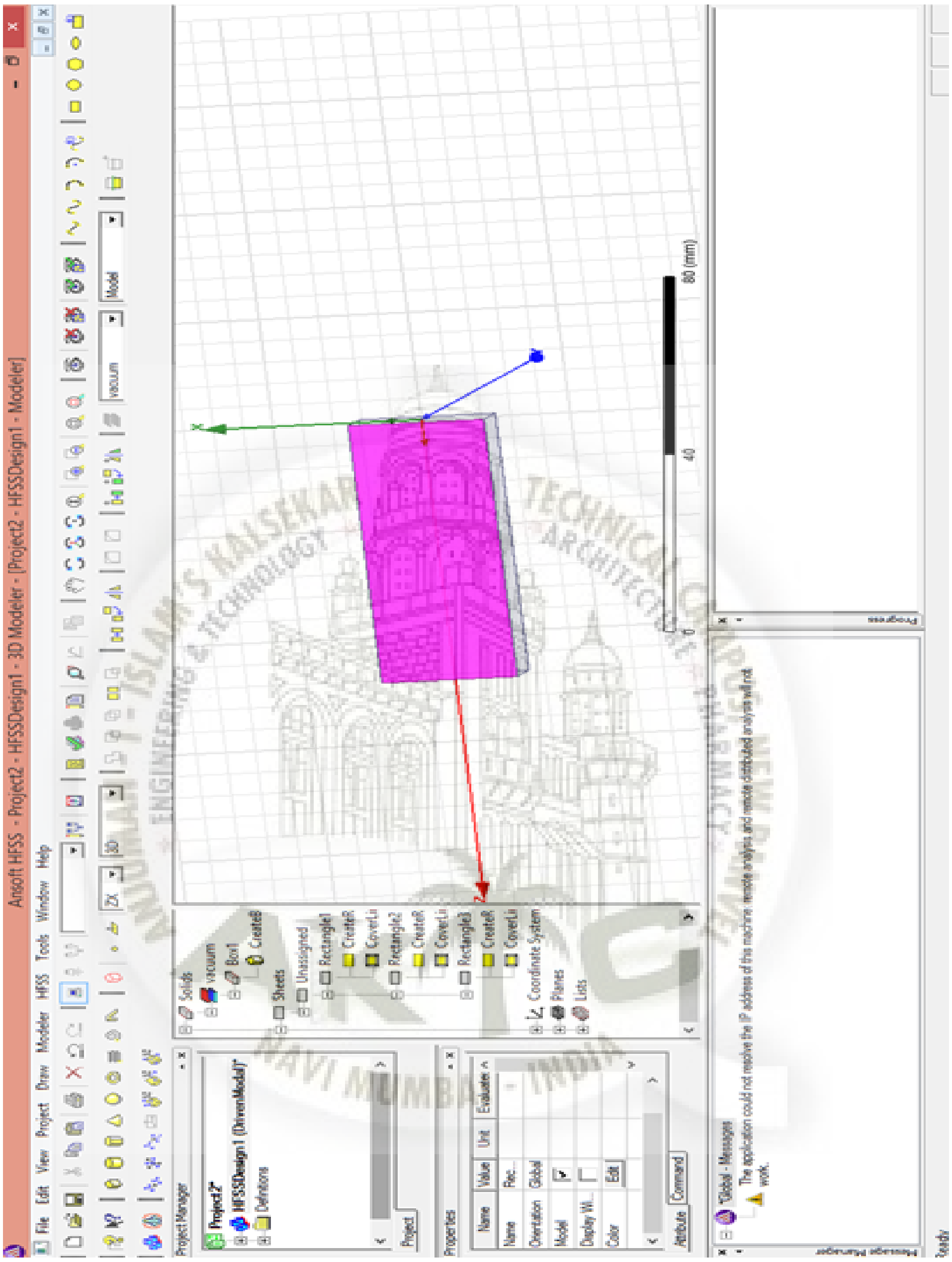
Name	Value	Unit	Evaluated Value	Description
Command	CreateBox			
Coordinate Sys...	Global			
Position	-11.43 ,5.08 ,0	mm	-11.43mm , 5.0...	
XSize	22.86	mm	22.86mm	
YSize	10.16	mm	10.16mm	
ZSize	60	mm	60mm	

☐ Show Hidden

Nothing is selected

Now we have to place walls of waveguide, in the window.

$Fromtoolbar, SelectDrawRectangle \rightarrow Placeinthewindow.$

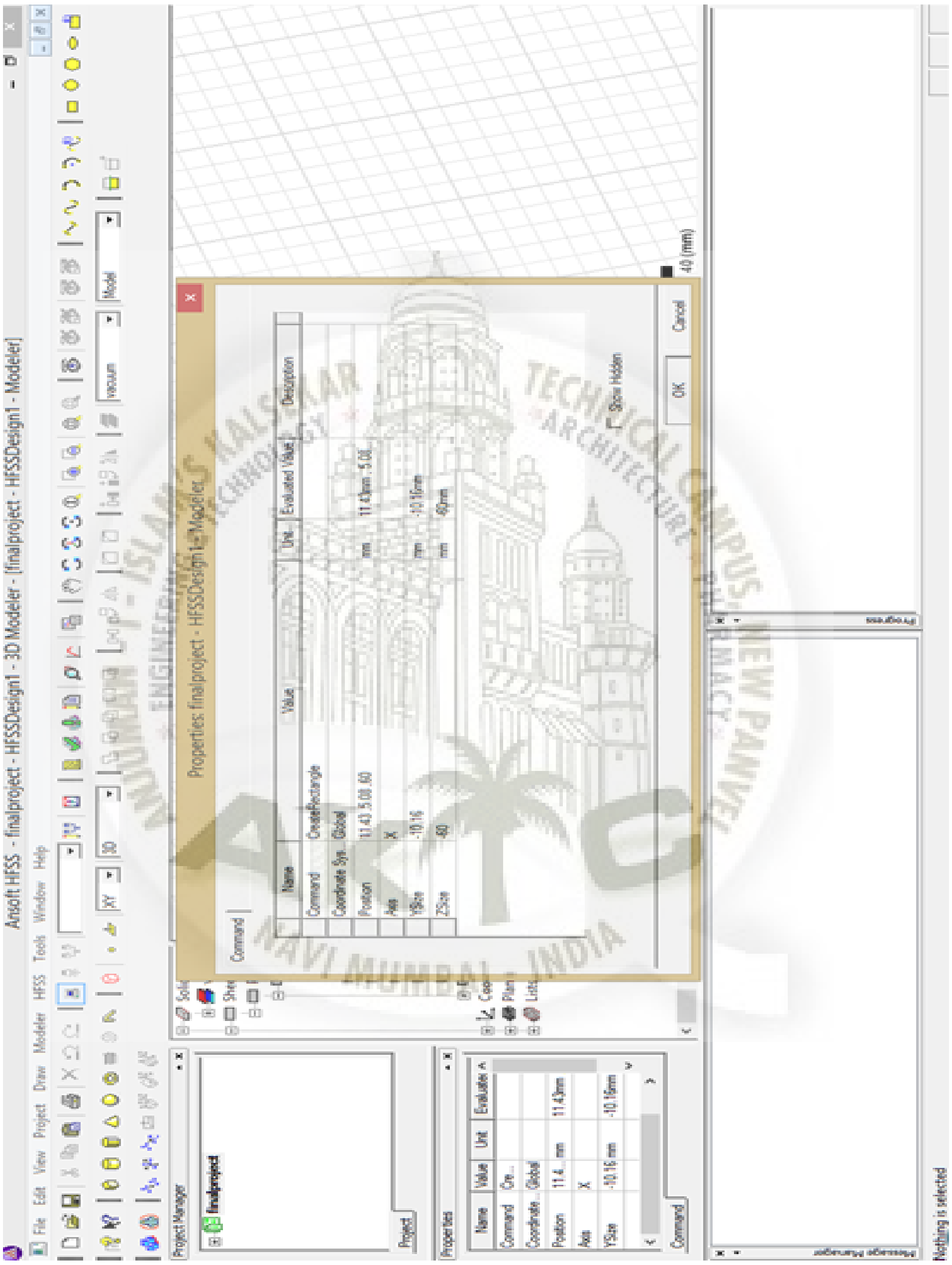


The application could not resolve the IP address of this machine; remote analysis and remote distributed analysis will not work.

Now edit properties of the rectangle drawn (Name, Color, and Transparency) and then its size and position.

$Rightclick on Rectangle1 \rightarrow Properties \rightarrow Edit Name, Color and Transparency.$

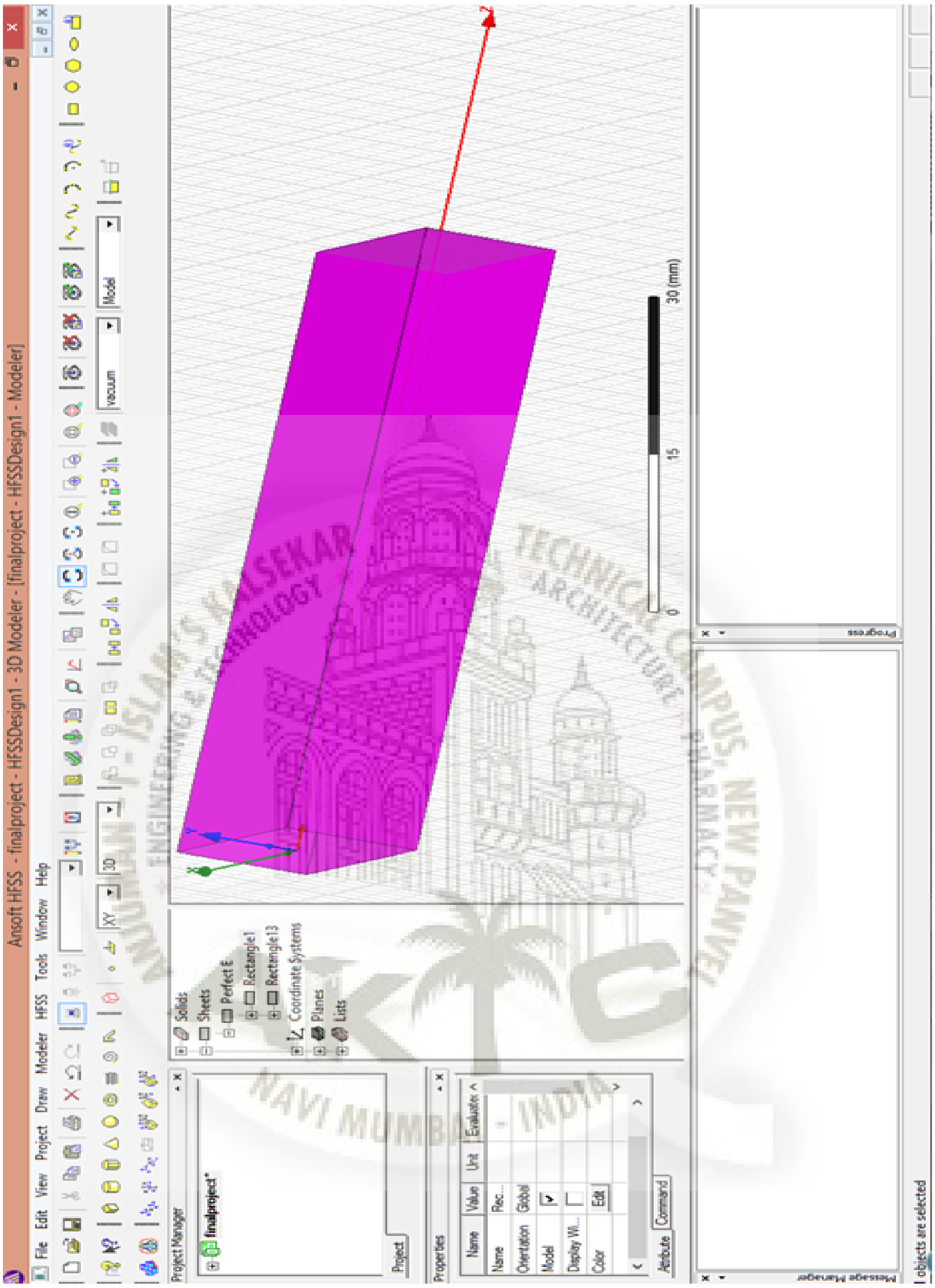
$Rightclick on Create Rectangle \rightarrow Properties \rightarrow Edit Size \& Position$



Properties: finalproject - HFSSDesign1 - Modeler

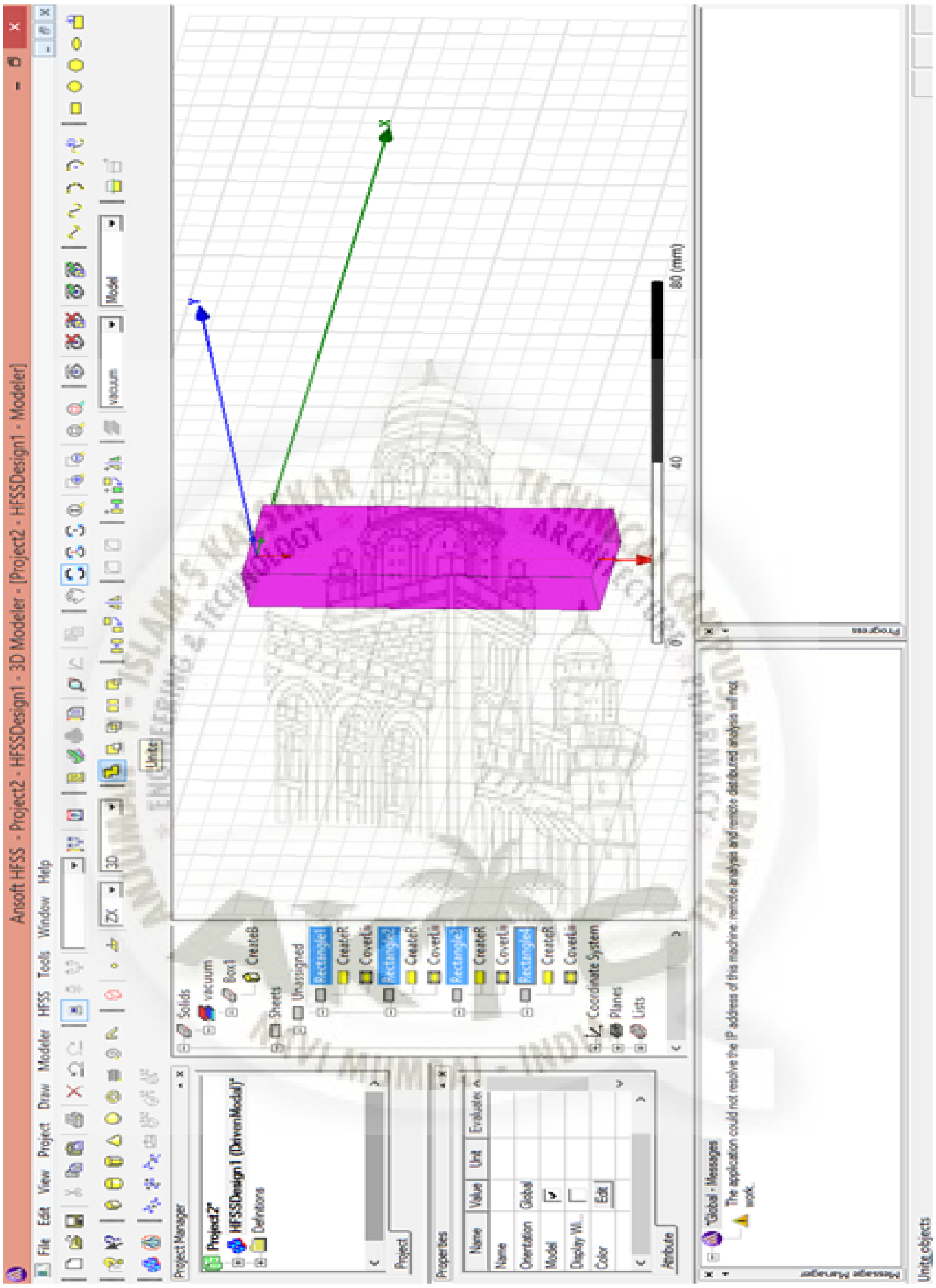
Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate Sys...	Global			
Position	11.43 ,5.08 ,60	mm	11.43mm , 5.08...	
Axis	X			
YSize	-10.16	mm	-10.16mm	
ZSize	40	mm	40mm	

Making Remaining walls of waveguide



Unite All the wall of waveguide

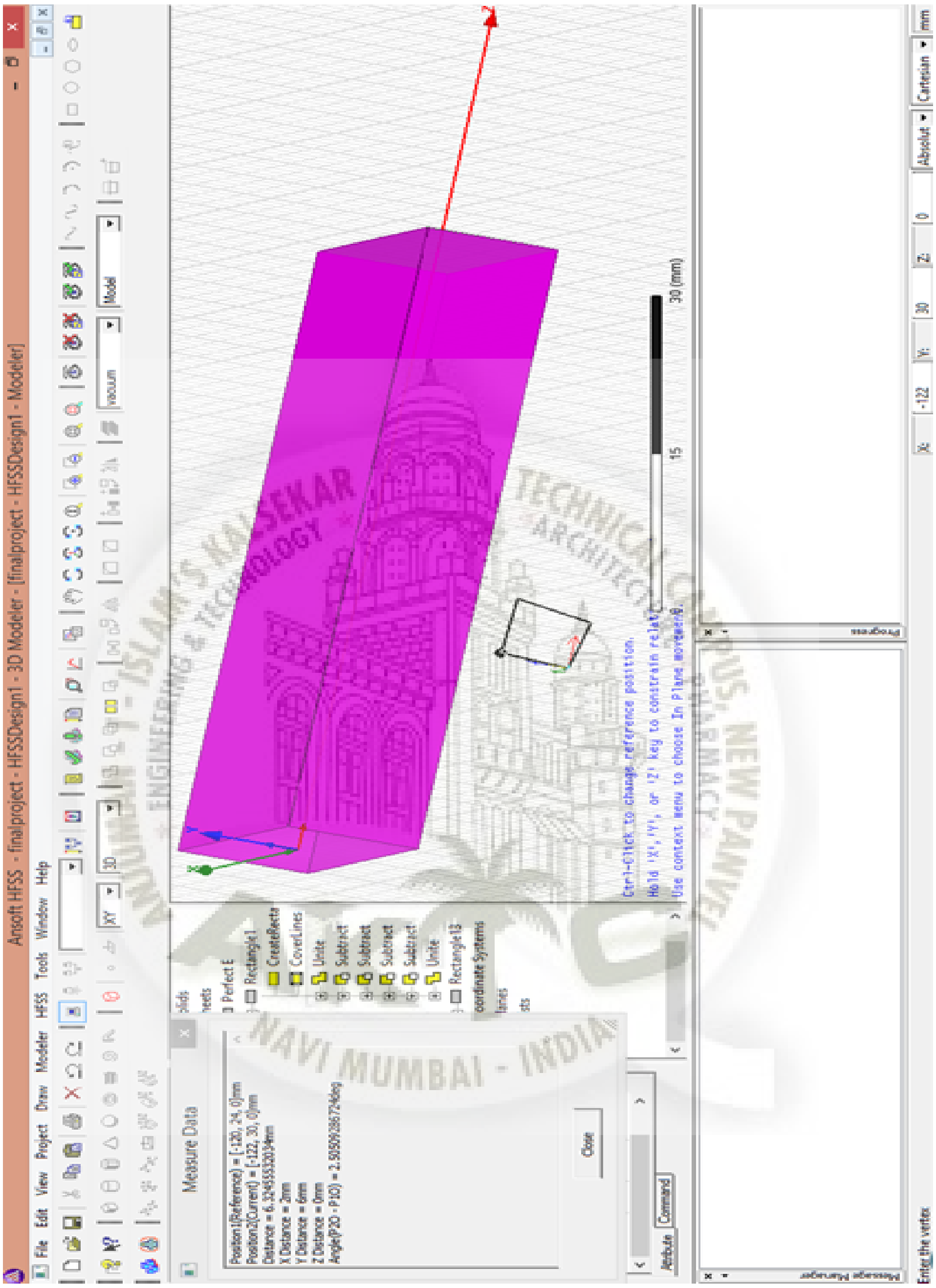
$Selectallthewallofwaveguide \rightarrow ClickonUnite$



Global - Messages
The application could not resolve the IP address of this machine; remote analysis and remote distributed analysis will not work.

Making of slots on waveguide

$ClickonPolyline \rightarrow MakeRandomsizeTriangle \rightarrow Doubleclickonlastpoint$

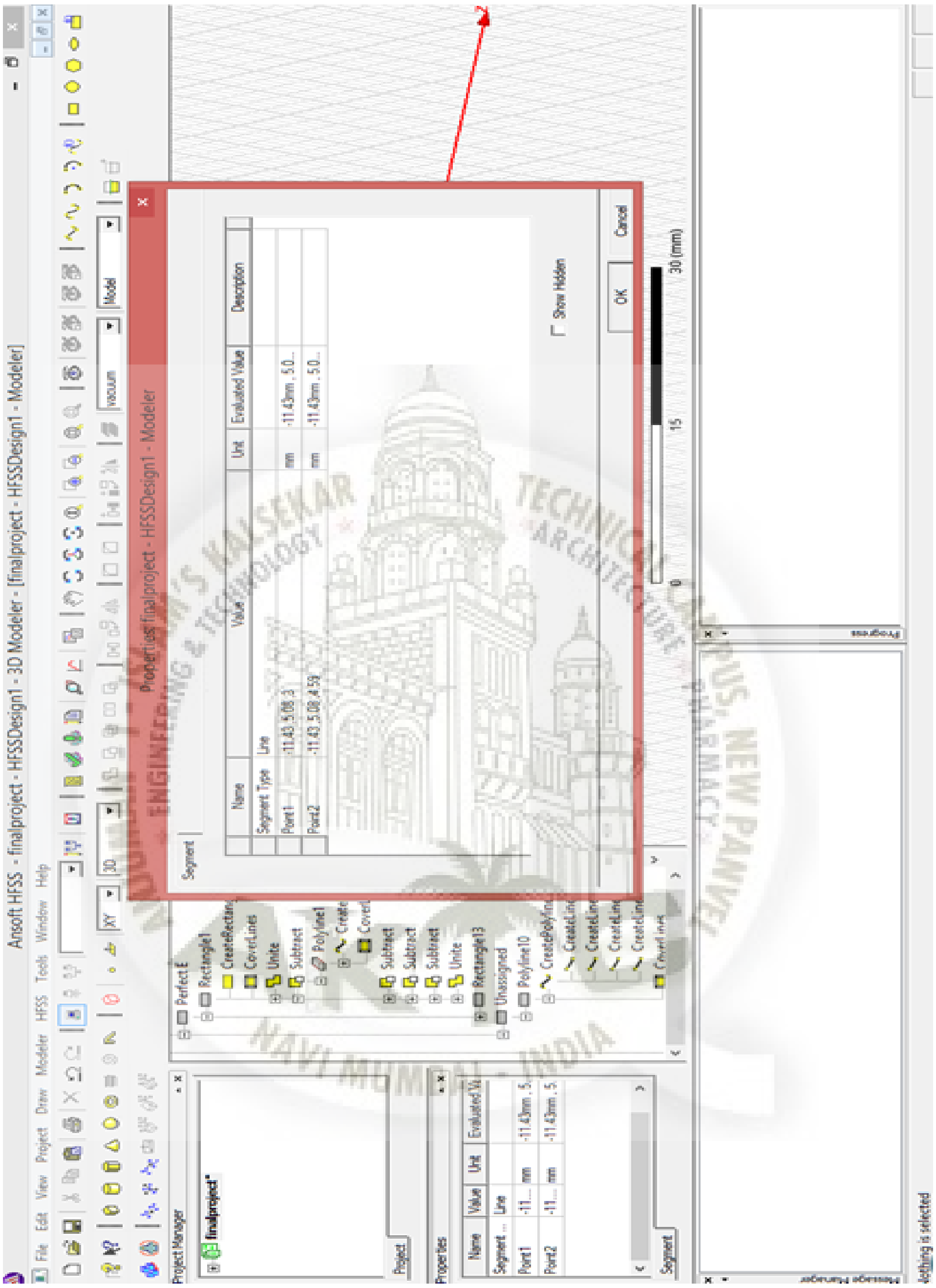


Position1(Reference) = [-120, 24, 0]mm
Position2(Current) = [-122, 30, 0]mm
Distance = 6.32455532034mm
X Distance = 2mm
Y Distance = 6mm
Z Distance = 0mm
Angle(P2O - P1O) = 2.50509285734deg

Ctrl+Click to change reference position.
Hold 'X', 'Y', or 'Z' key to constrain relat...
Use context menu to choose In Plane movement.

Enter the vertex

$Clickonunassigned \rightarrow CreatePolyline \rightarrow CreateLine \rightarrow editx, y, zpositionofEachCreateLin$

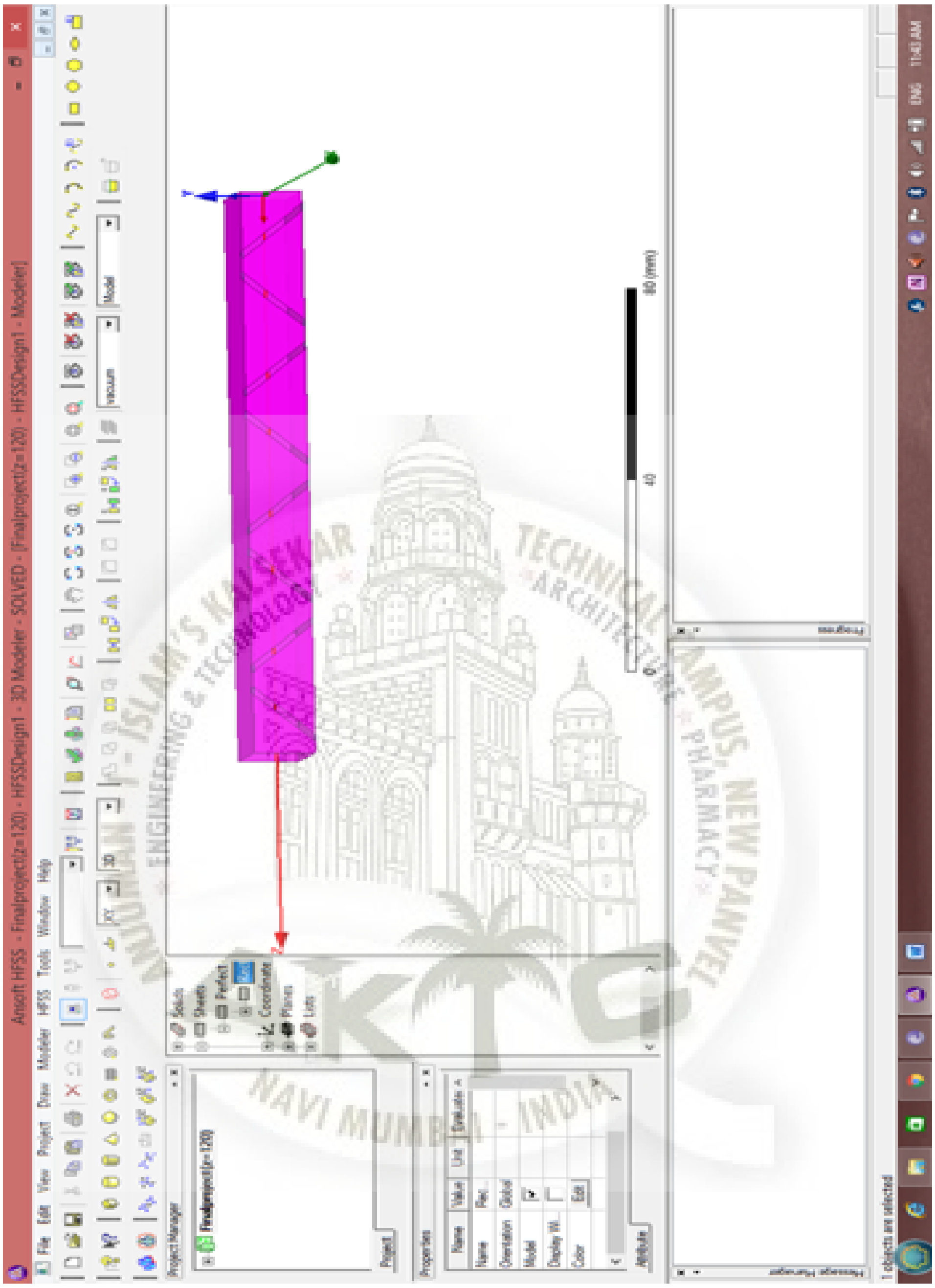


Ansoft HFSS - finalproject - HFSSDesign1 - 3D Modeler - [finalproject - HFSSDesign1 - Modeler]

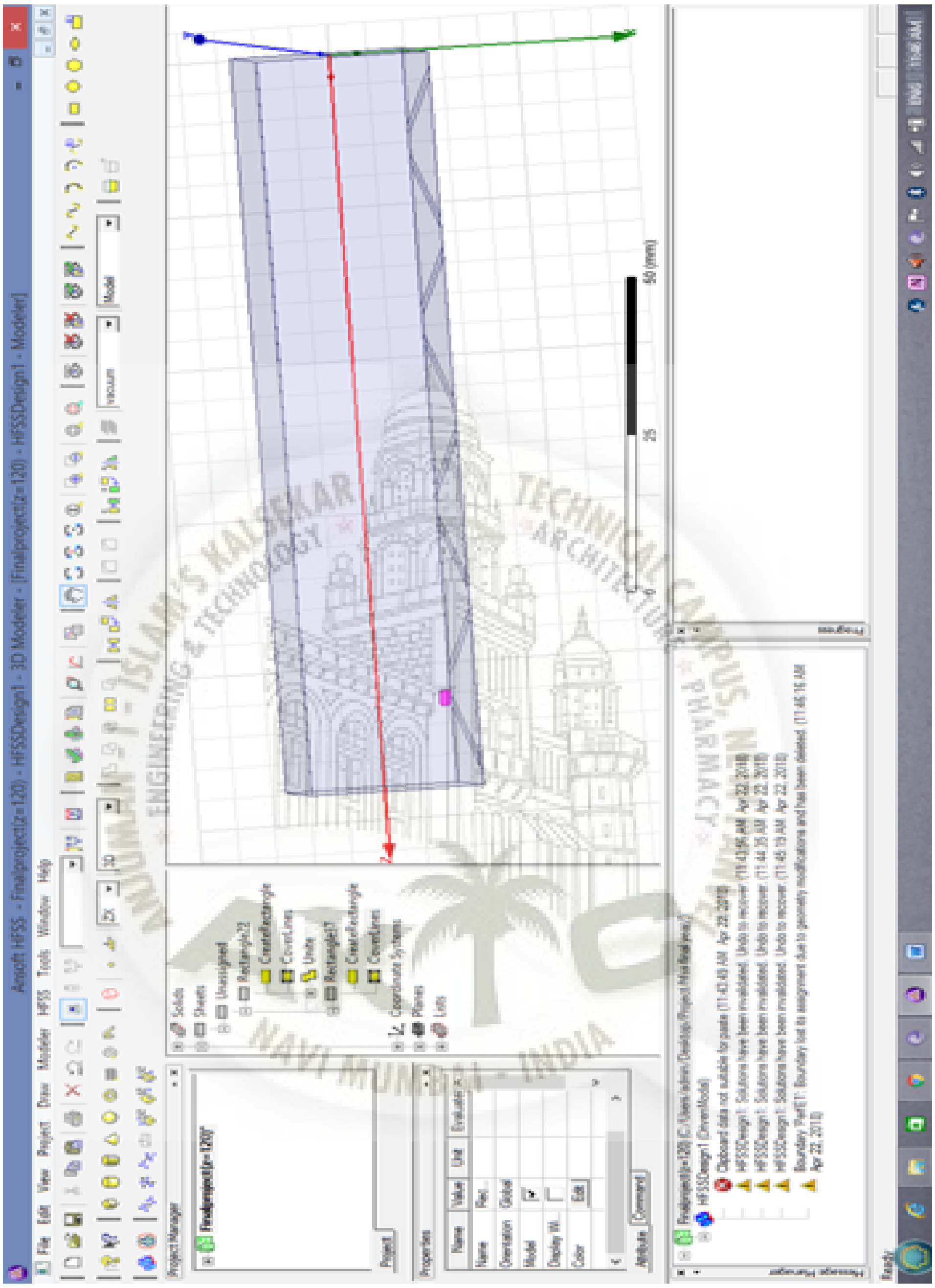
Properties: finalproject - HFSSDesign1 - Modeler

Name	Value	Unit	Evaluated Value	Description
Segment Type	Line			
Point1	-11.43 ,5.08 ,3	mm	-11.43mm , 5.0...	
Point2	-11.43 ,5.08 ,4.59	mm	-11.43mm , 5.0...	

Making all Slots at an angle of 45 Degree opposite to each other

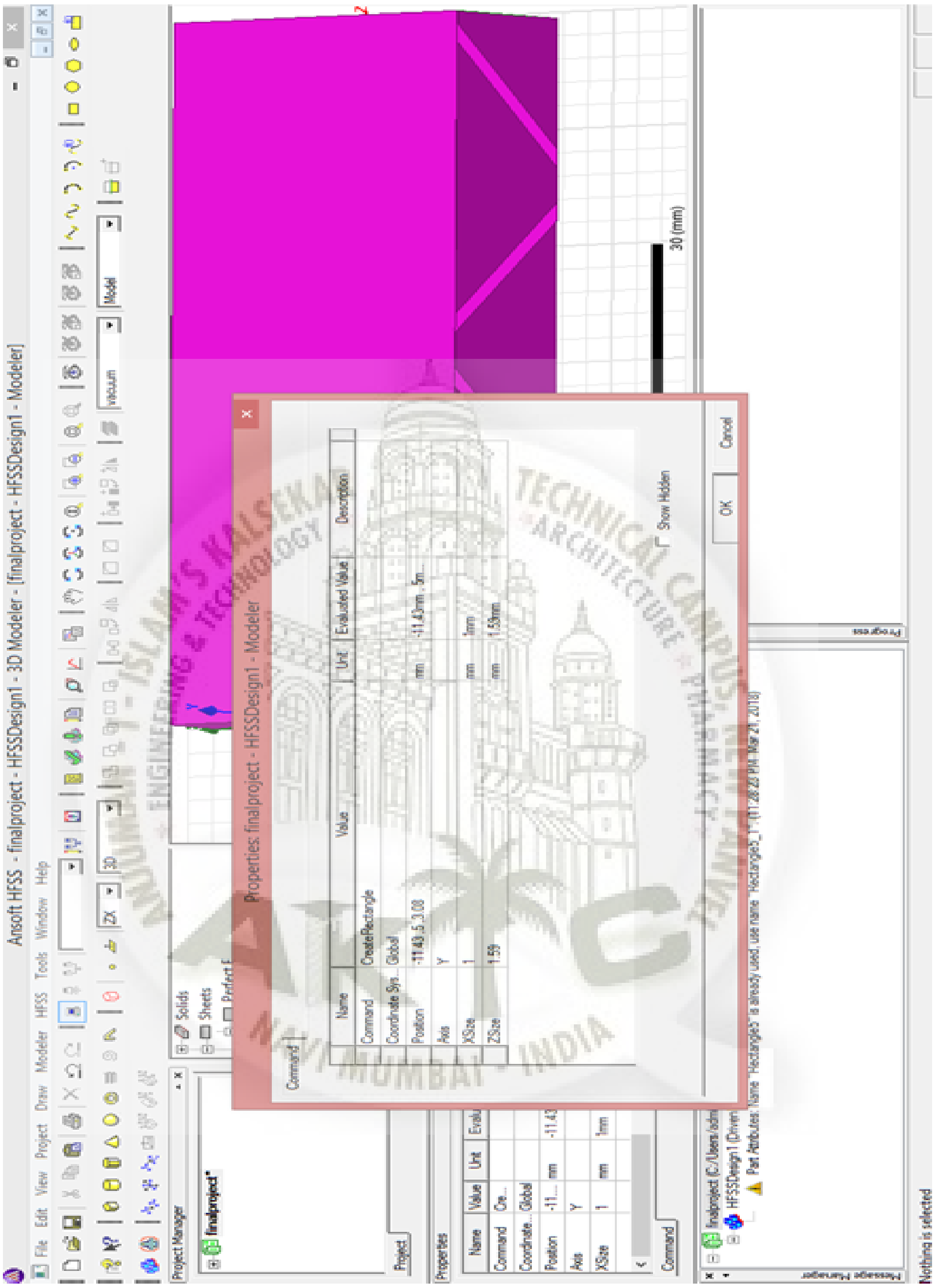


Making slots on top and bottom side of inclined slots $ClickonDrawRectangle \rightarrow Placeinthewindow$



Now edit properties of the rectangle drawn

RightclickonRectangle → Properties → EditSize&Position

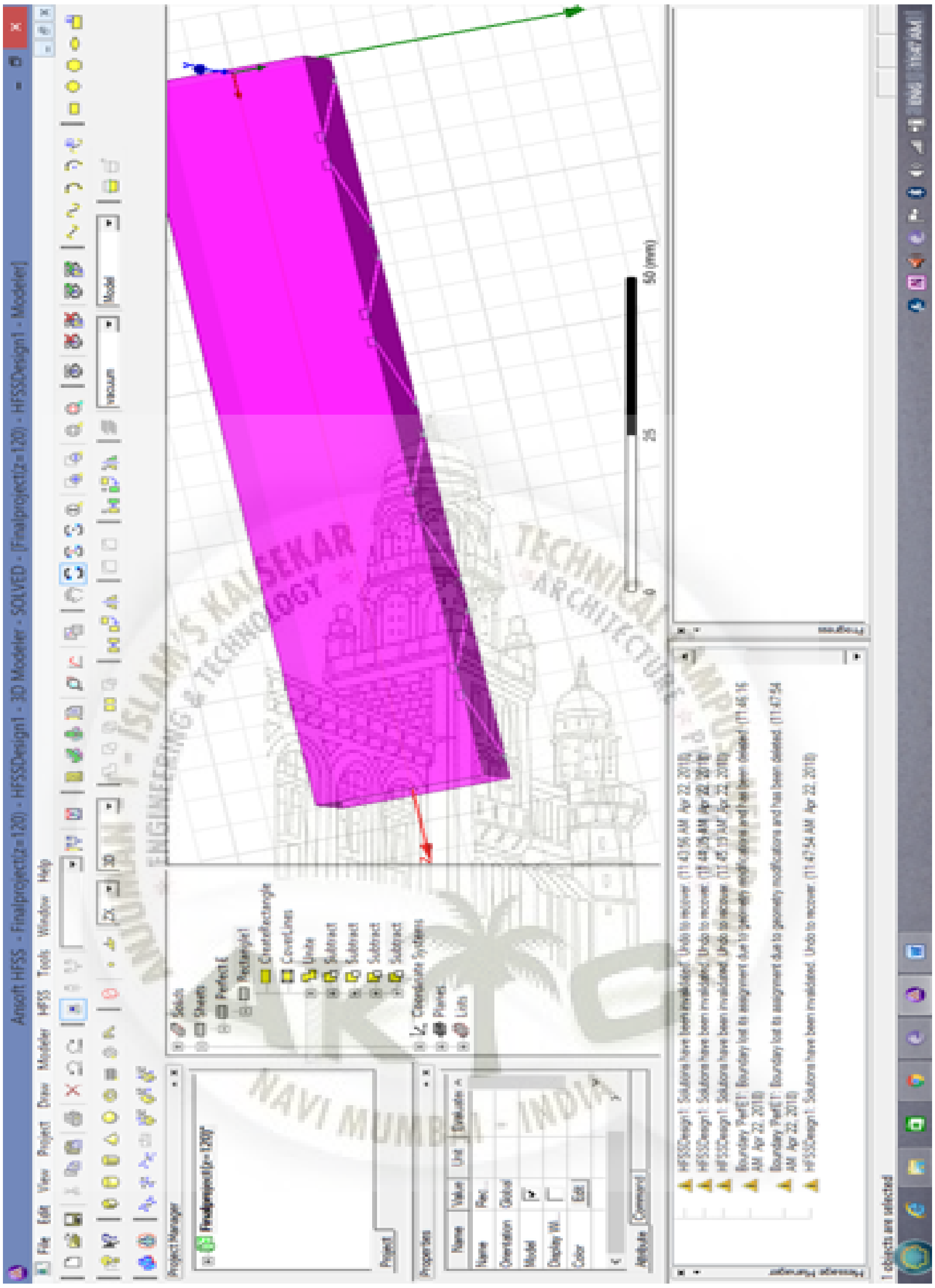


Properties: finalproject - HFSSDesign1 - Modeler

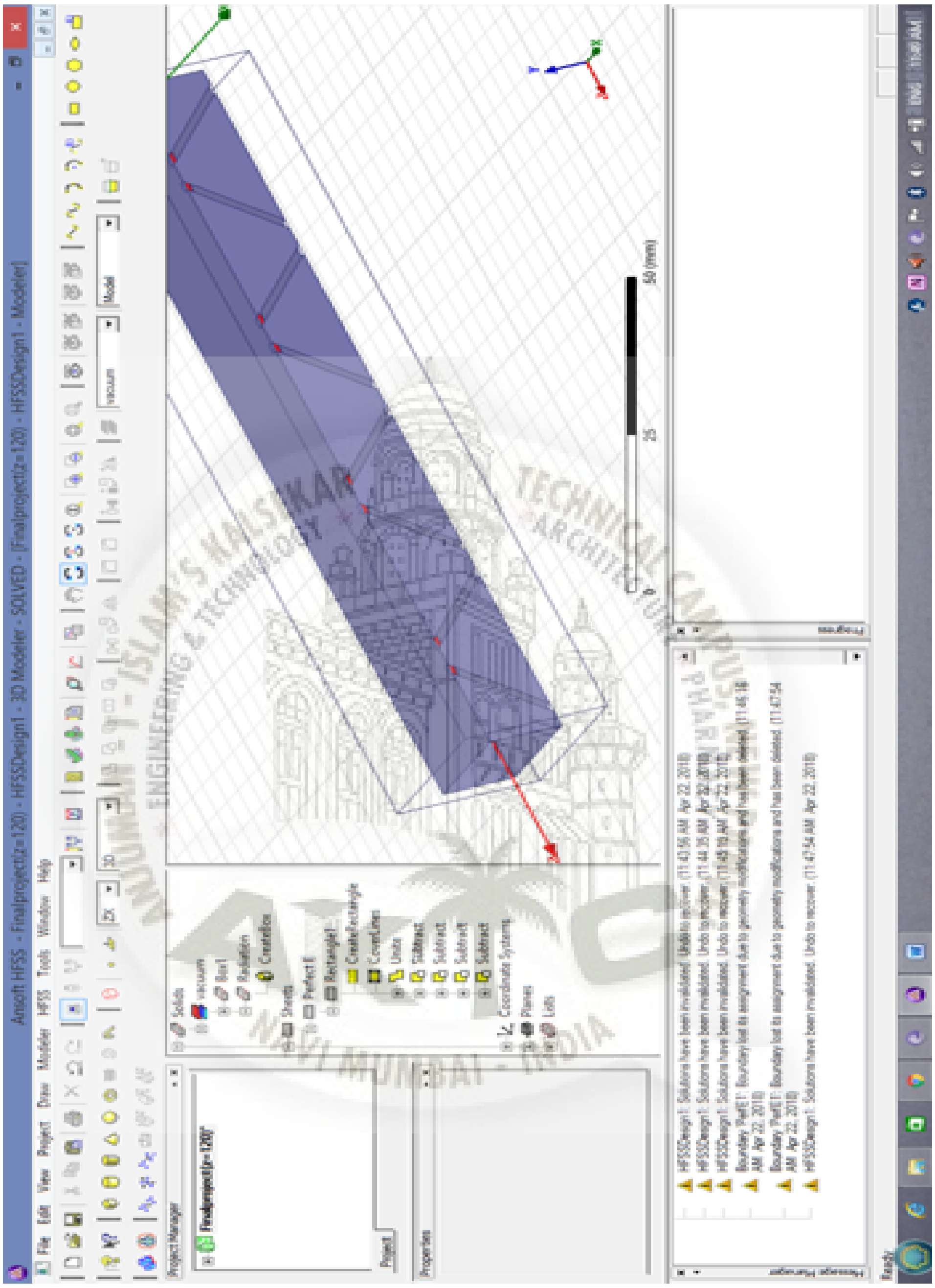
Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate Sys...	Global			
Position	-11.43 ,-5 ,3.08	mm	-11.43mm , -5m...	
Axis	Y			
XSize	1	mm	1mm	
ZSize	1.59	mm	1.59mm	

Part Attributes: Name 'Rectangle5' is already used, use name 'Rectangle5_1' (11:28:20 PM Mar 21, 2018)

Make all required slots

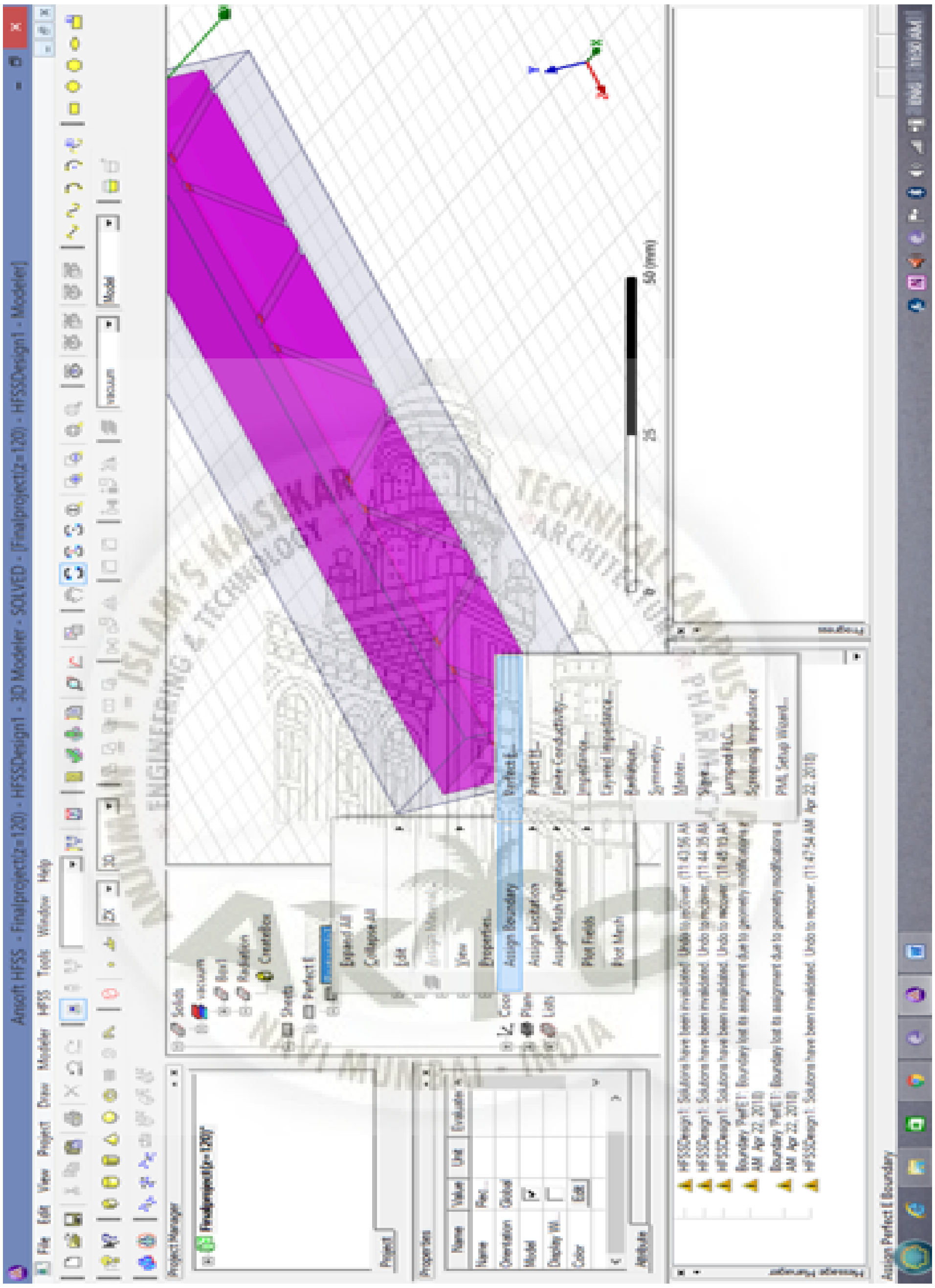


Drawing Radiation box by selecting Draw box and assigning it Material vacuum. And editing its properties (Name, Color, and Transparency).

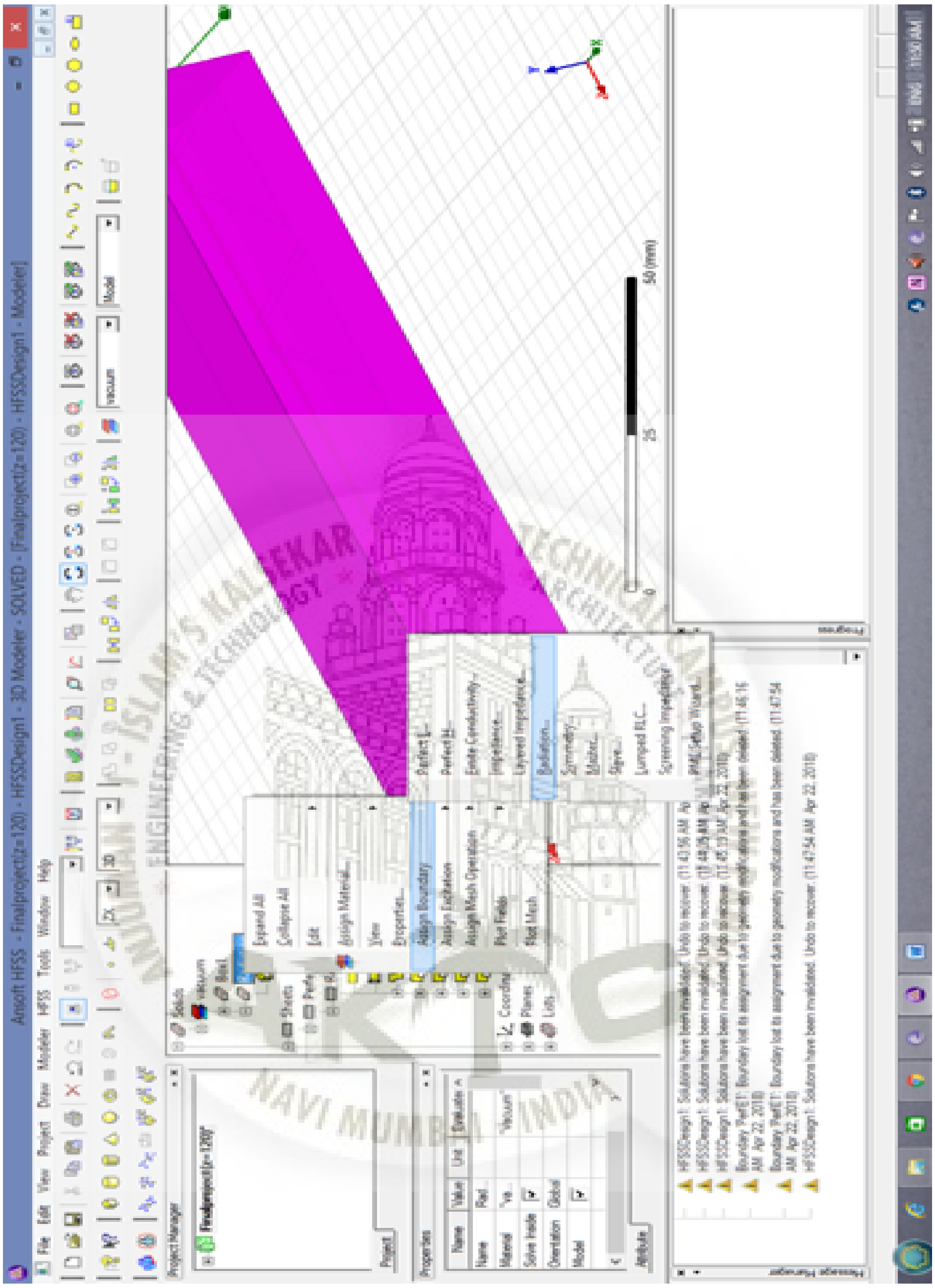


Step 2 : Assign boundaries

We had to assign boundary condition to wall of waveguide

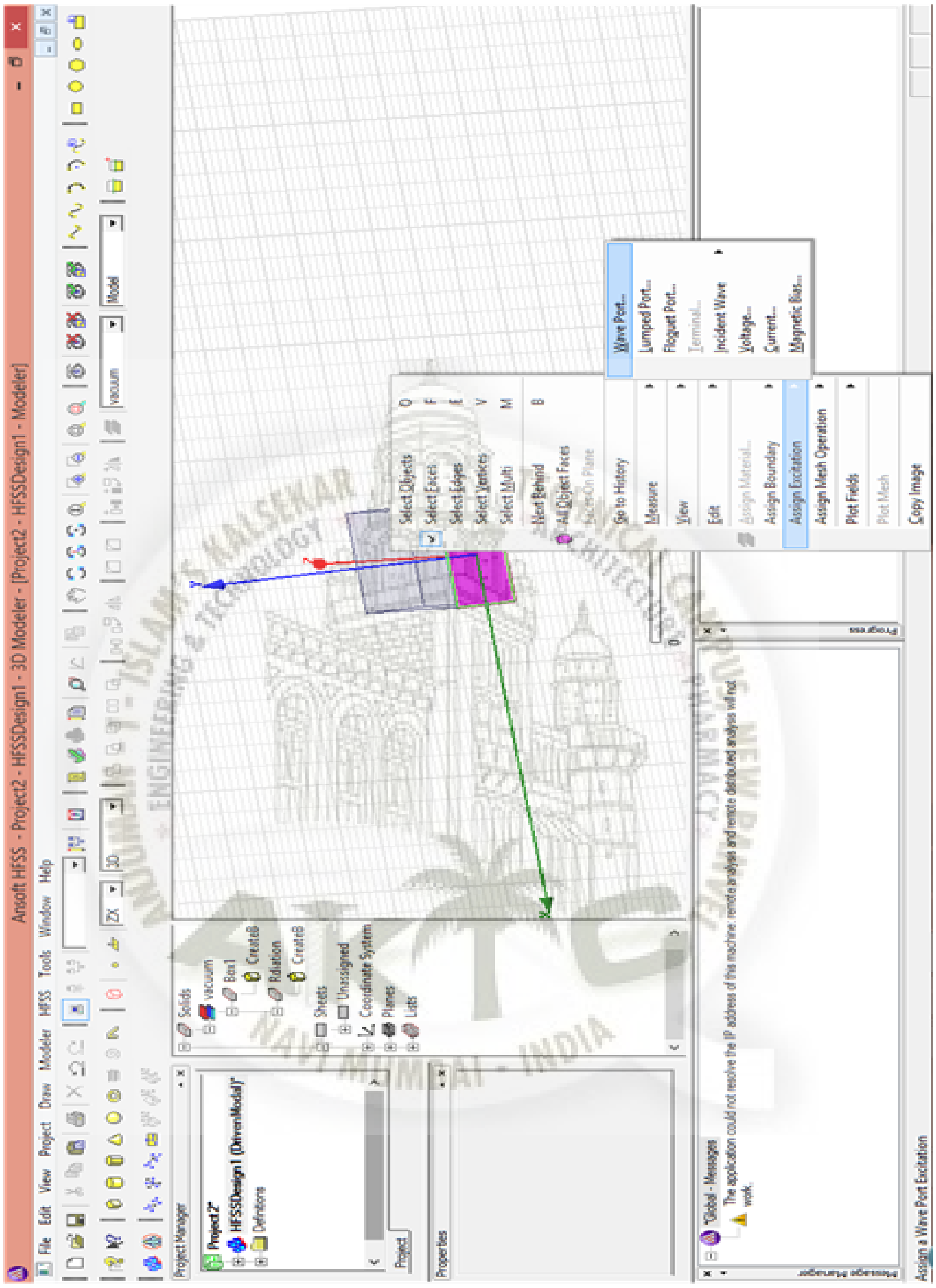


Similarly we have to assign boundary condition to Radiation box



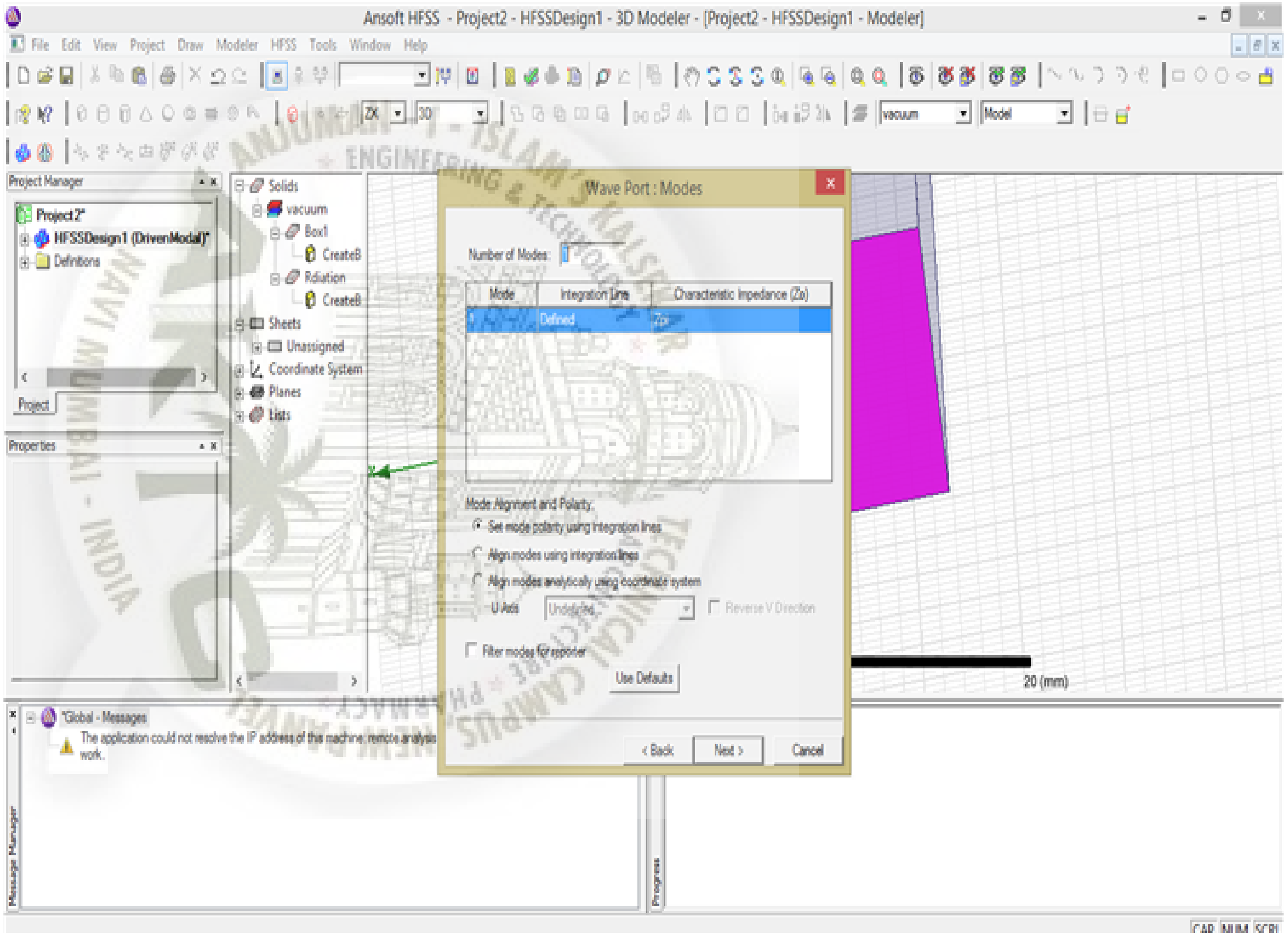
Step 3 : Assign excitation

The Excitation is assign to the Hollow side of waveguide



The application could not resolve the IP address of this machine; remote analysis and remote distributed analysis will not work.

Assign a Wave Port Excitation



Number of Modes: 1

Mode	Integration Line	Characteristic Impedance (Zo)
1	Defined	Zpi

Mode Alignment and Polarity:

● Set mode polarity using integration lines

○ Align modes using integration lines

○ Align modes analytically using coordinate system

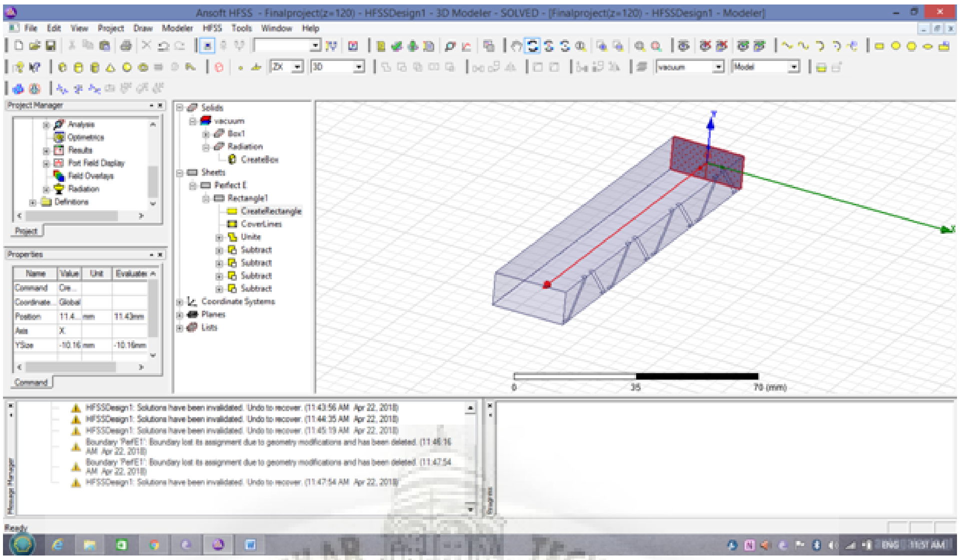
U Axis: Undefined ☐ Reverse V Direction

☐ Filter modes for reporter

*Global - Messages

The application could not resolve the IP address of this machine; remote analysis work.

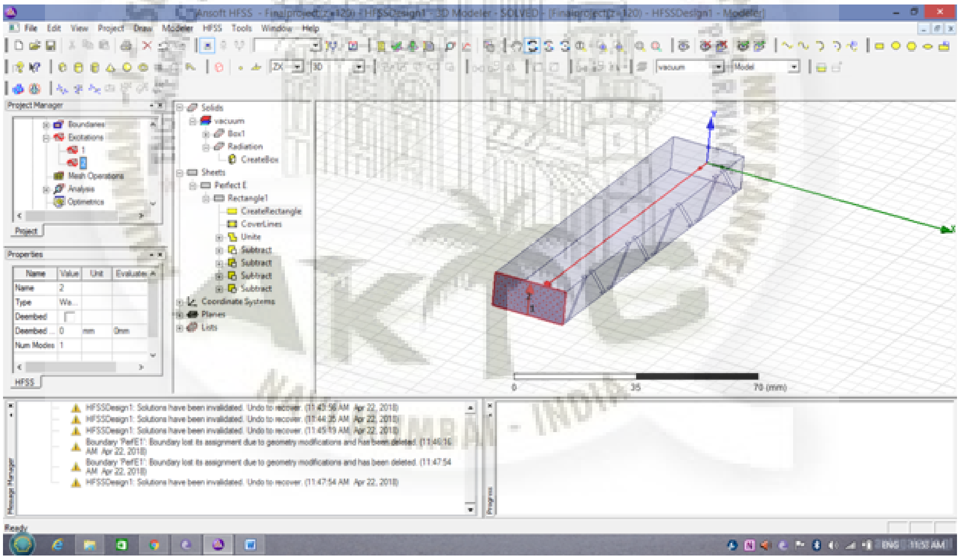
Similarly assign excitation to another side of wave guide



Name	Value	Unit	Evaluated
Command	Cre...		
Coordinate...	Global		
Position	11.4...	mm	11.43mm
Axis	X		
YSize	-10.16	mm	-10.16mm

```
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:43:56 AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:44:35 AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:45:19 AM  Apr 22, 2018)
Boundary 'PerfE1': Boundary lost its assignment due to geometry modifications and has been deleted. (11:46:16
AM  Apr 22, 2018)
Boundary 'PerfE1': Boundary lost its assignment due to geometry modifications and has been deleted. (11:47:54
AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:47:54 AM  Apr 22, 2018)
```

Now excitation is assigned

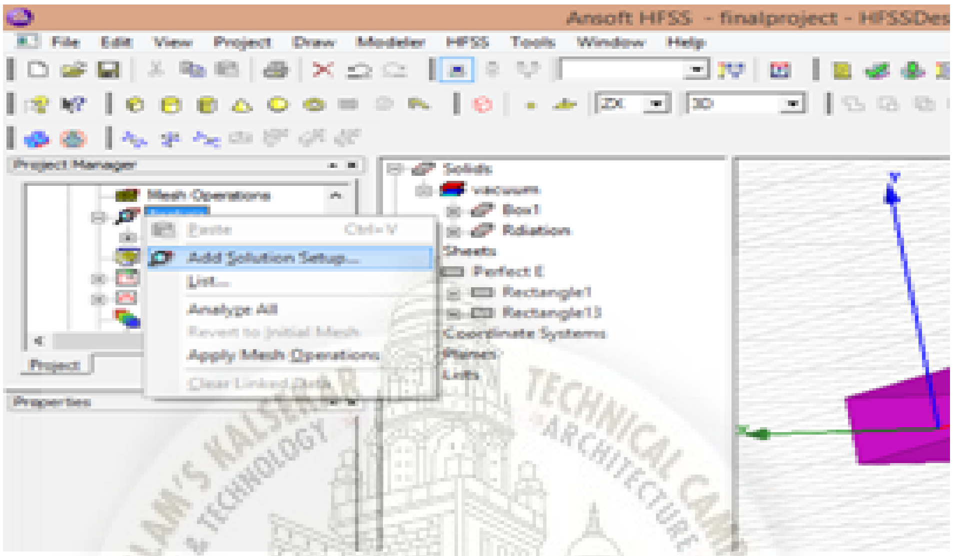


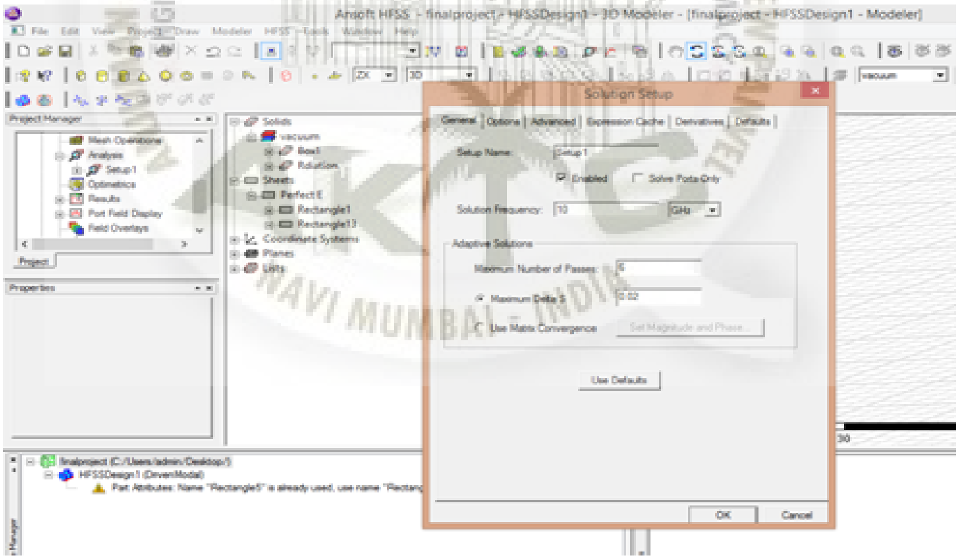
Name	Value	Unit	Evaluated
Name	2		
Type	Wa...		
Deembed	☐		
Deembed	0	mm	0mm
Num Modes	1		

HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:43:56 AM Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:44:35 AM Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:45:19 AM Apr 22, 2018)
Boundary 'PerfE1': Boundary lost its assignment due to geometry modifications and has been deleted. (11:46:16 AM Apr 22, 2018)
Boundary 'PerfE1': Boundary lost its assignment due to geometry modifications and has been deleted. (11:47:54 AM Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:47:54 AM Apr 22, 2018)

Step 4 : Setup the solution In this step a solution setup and sweep frequency is added.

$Inprojectmanagerwindow, Rightclickon \rightarrow AnalysisAddSolutionSetup \rightarrow Entersolutionfre$





Setup Name: Setup1

☑ Enabled ☐ Solve Ports Only

Solution Frequency: 10 GHz

Maximum Number of Passes: 6

● Maximum Delta S: 0.02

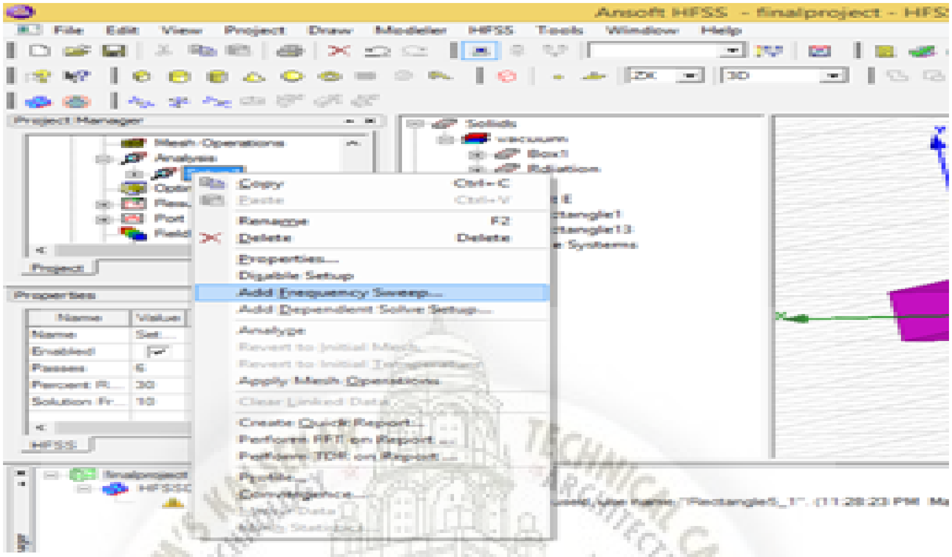
finalproject (C:/Users/admin/Desktop/)

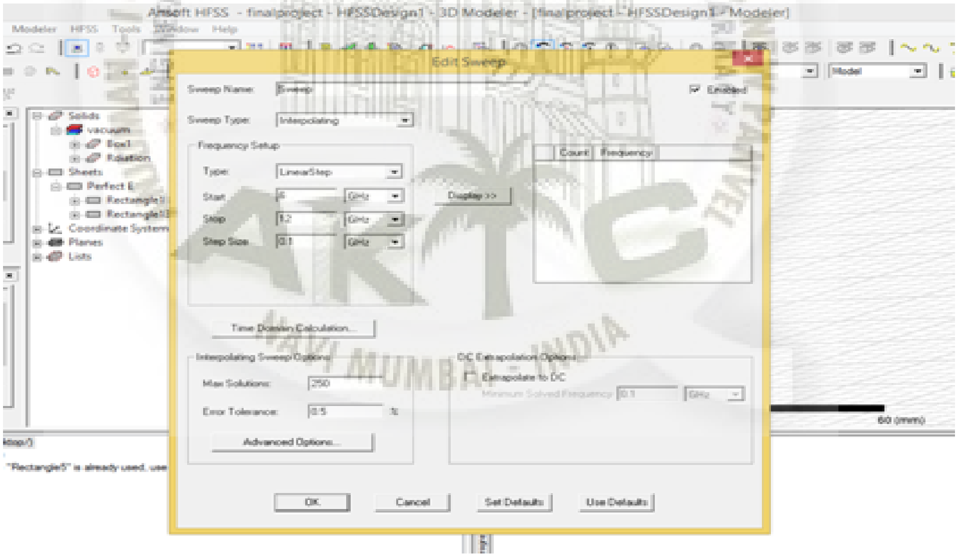
HFSSDesign1 (DrivenModal)

Part Attributes: Name "Rectangle5" is already used, use name "Rectang

Now include sweep frequency.

$$ExpandAnalysis \rightarrow RightclickonSetup1 \rightarrow AddFrequencySweep \rightarrow$$
$$EnterStart\&EndFrequency, andStepsize$$





Sweep Name: Sweep

☑ Enabled

Sweep Type: Interpolating

Type: LinearStep

Start: 6 GHz

Stop: 12 GHz

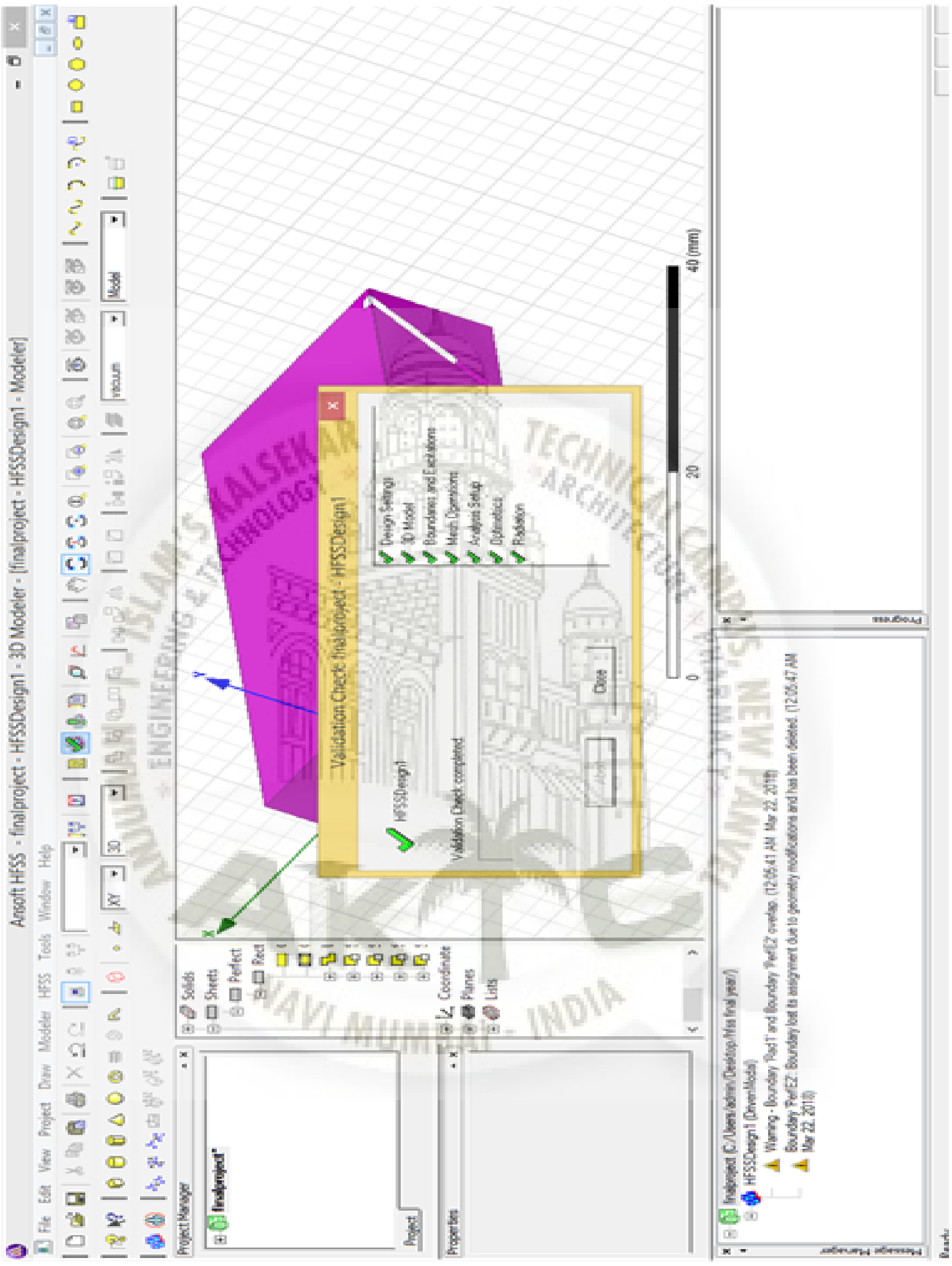
Step Size: 0.1 GHz

Max Solutions: 250

Error Tolerance: 0.5 %

Step 5 : Solve

After adding solution setup we will do validation & execute our model by clicking on Analyze



Ansoft HFSS - finalproject - HFSSDesign1 - 3D Modeler - [finalproject - HFSSDesign1 - Modeler]

Validation Check: finalproject - HFSSDesign1

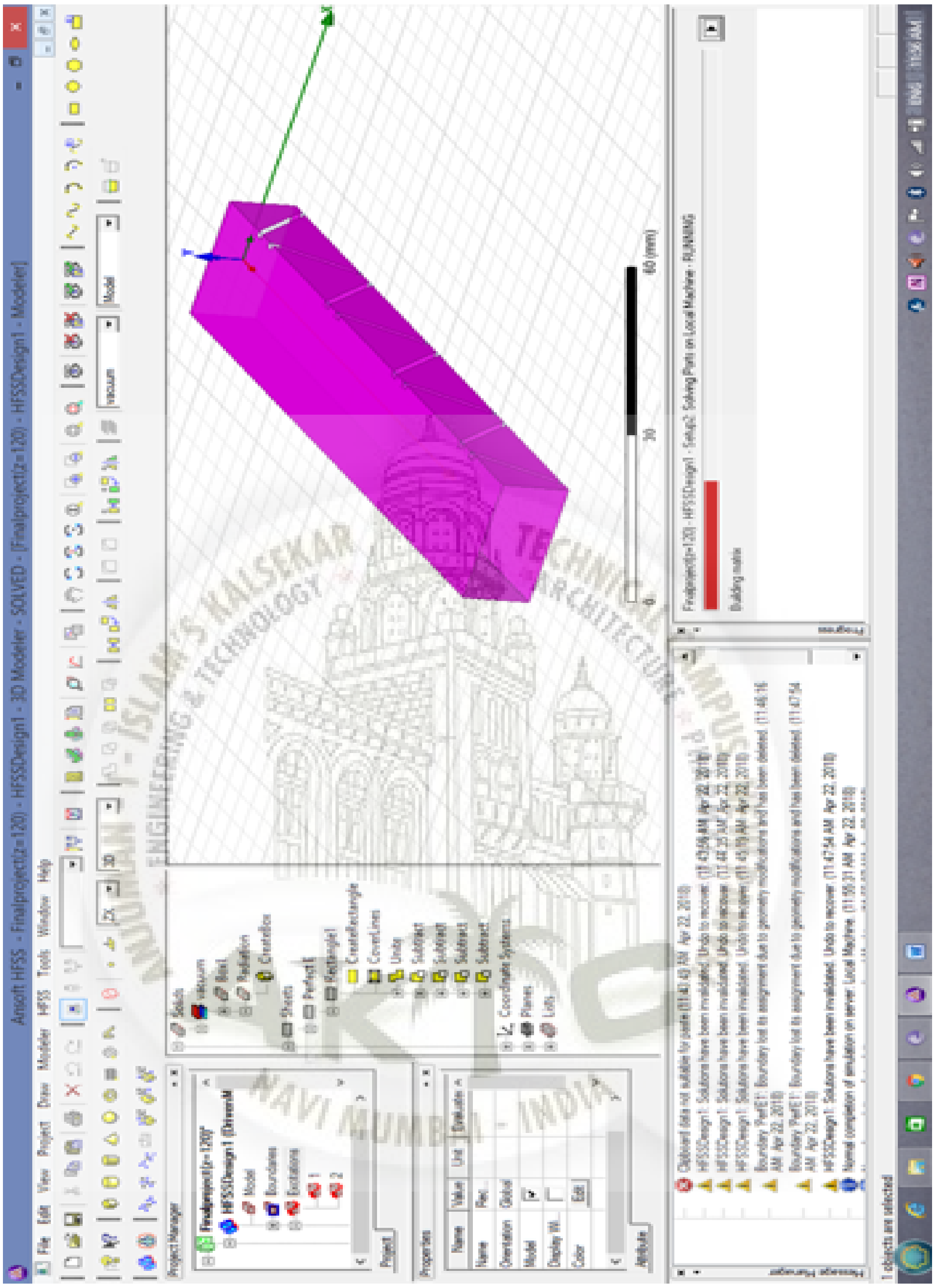
HFSSDesign1

Validation Check completed

- ✓ Design Settings
- ✓ 3D Model
- ✓ Boundaries and Excitations
- ✓ Mesh Operations
- ✓ Analysis Setup
- ✓ Optimetrics
- ✓ Radiation

finalproject (C:/Users/admin/Desktop/hfss final year/)
HFSSDesign1 (DrivenModal)
Warning - Boundary 'Rad1' and Boundary 'PerfE2' overlap. (12:05:41 AM Mar 22, 2018)
Boundary 'PerfE2': Boundary lost its assignment due to geometry modifications and has been deleted. (12:05:47 AM Mar 22, 2018)

Analyzing model



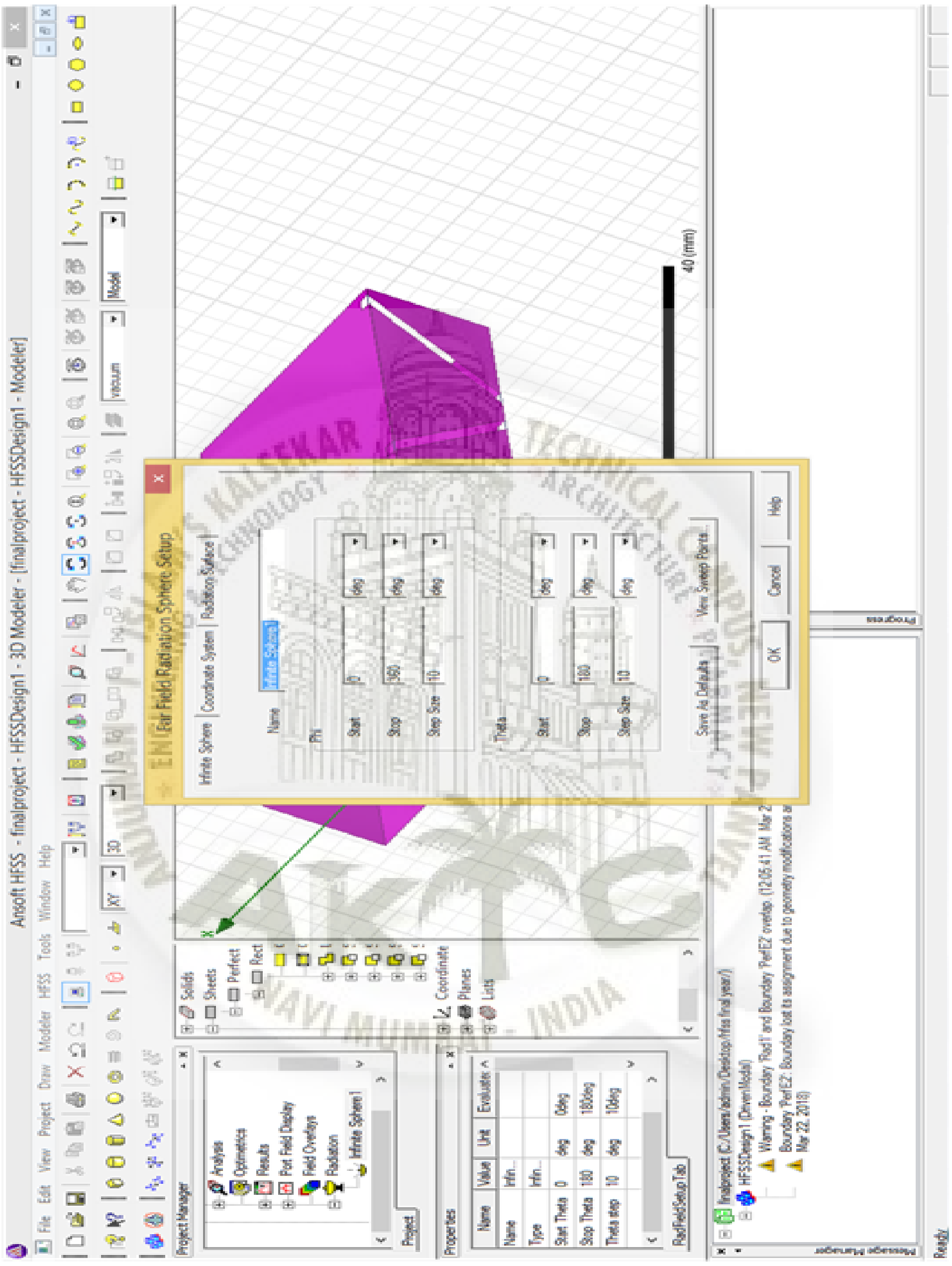
```
Clipboard data not suitable for paste (11:43:43 AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:43:56 AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:44:35 AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:45:19 AM  Apr 22, 2018)
Boundary 'PerfE1': Boundary lost its assignment due to geometry modifications and has been deleted. (11:46:16
AM  Apr 22, 2018)
Boundary 'PerfE1': Boundary lost its assignment due to geometry modifications and has been deleted. (11:47:54
AM  Apr 22, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (11:47:54 AM  Apr 22, 2018)
Normal completion of simulation on server: Local Machine. (11:55:31 AM  Apr 22, 2018)
```

```
Finalproject(z=120) - HFSSDesign1 - Setup2: Solving Ports on Local Machine - RUNNING
Building matrix
```

1 objects are selected

Step 6 : Post processing the Results

Far field Radiation sphere setup



Name: Infinite Sphere1

Phi

- Start: 0 deg
- Stop: 360 deg
- Step Size: 10 deg

Theta

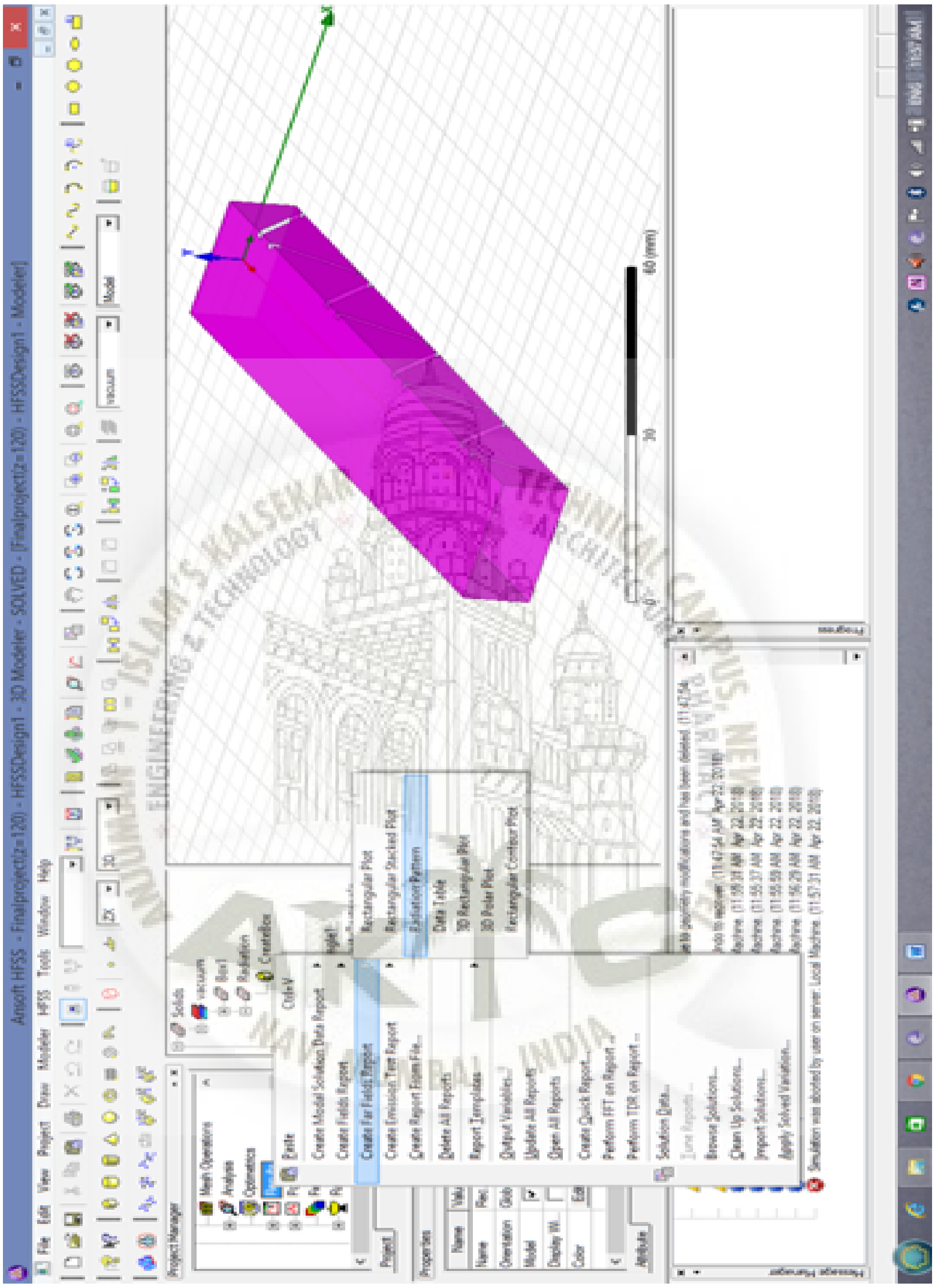
- Start: 0 deg
- Stop: 180 deg
- Step Size: 10 deg

Name	Value	Unit	Evaluated ...
Name	Infin...		
Type	Infin...		
Start Theta	0	deg	0deg
Stop Theta	180	deg	180deg
Theta step	10	deg	10deg

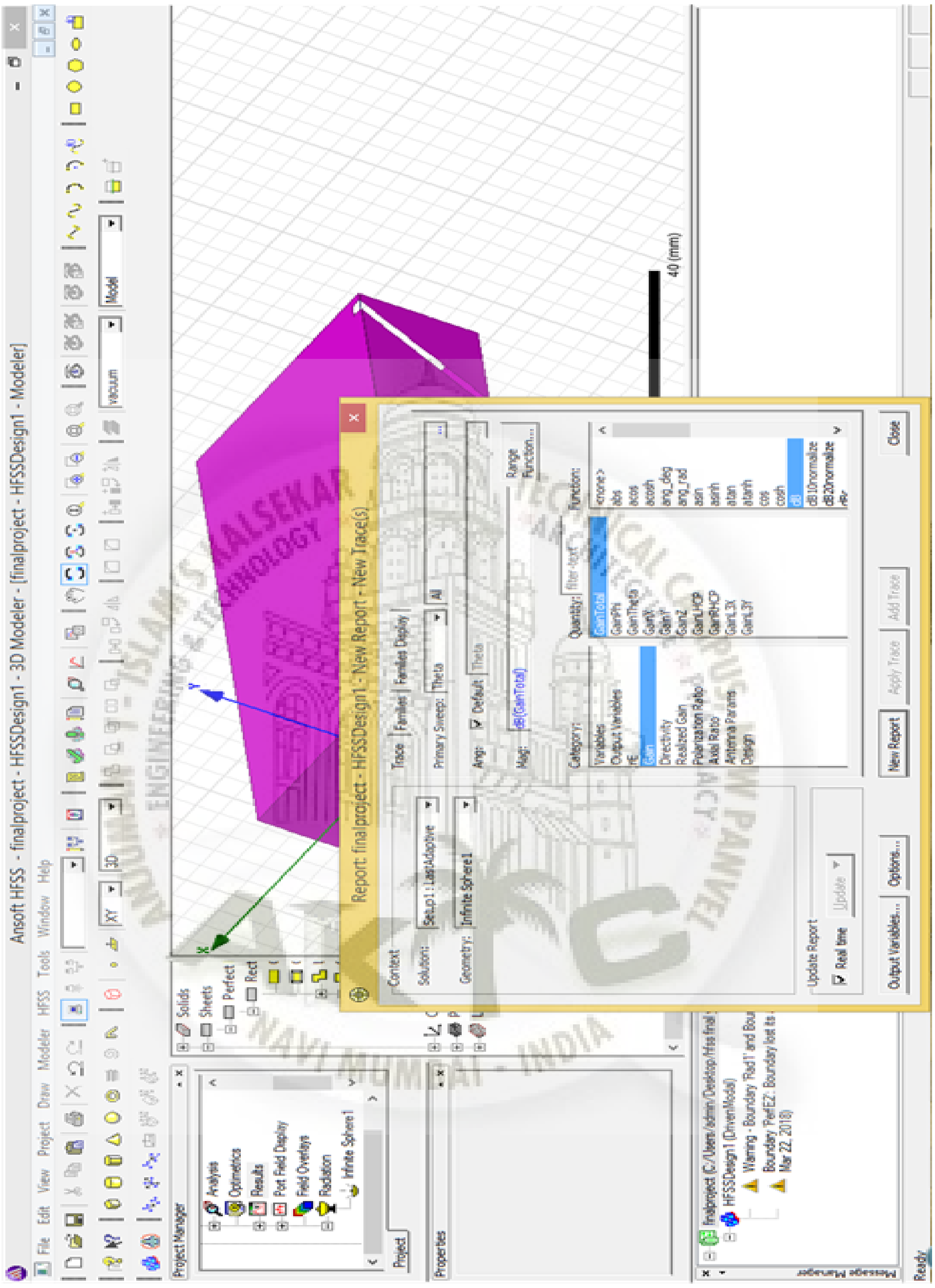
finalproject (C:/Users/admin/Desktop/hfss final year/)
HFSSDesign1 (DrivenModal)
Warning - Boundary 'Rad1' and Boundary 'PerfE2' overlap. (12:05:41 AM Mar 2
Boundary 'PerfE2': Boundary lost its assignment due to geometry modifications a
Mar 22, 2018)

$ForRadiationPattern$

$Rightclickonresult \rightarrow selectcreatefarfieldreport \rightarrow selectradiationpattern$



$SelectGaininCategory \rightarrow selectGainTotalinQuantity \rightarrow selectdBinFunction \rightarrow Clickonthenewreport$



Ansoft HFSS - finalproject - HFSSDesign1 - 3D Modeler - [finalproject - HFSSDesign1 - Modeler]

Report: finalproject - HFSSDesign1 - New Report - New Trace(s)

Solution: Setup1 : LastAdaptive

Geometry: Infinite Sphere1

Primary Sweep: Theta

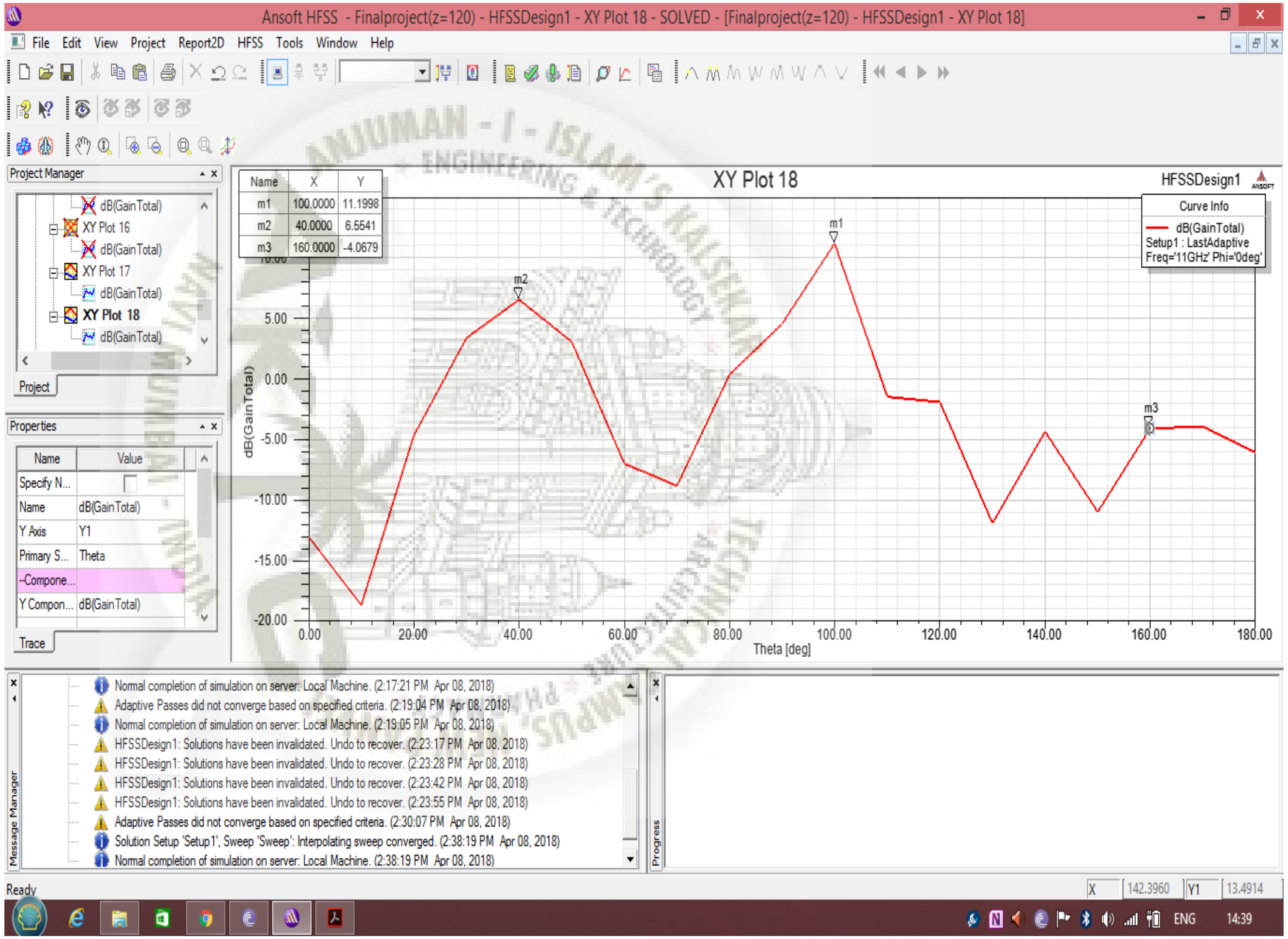
Mag: dB(GainTotal)

Category: Gain

Quantity: GainTotal

Function: dB

Rectangular plot

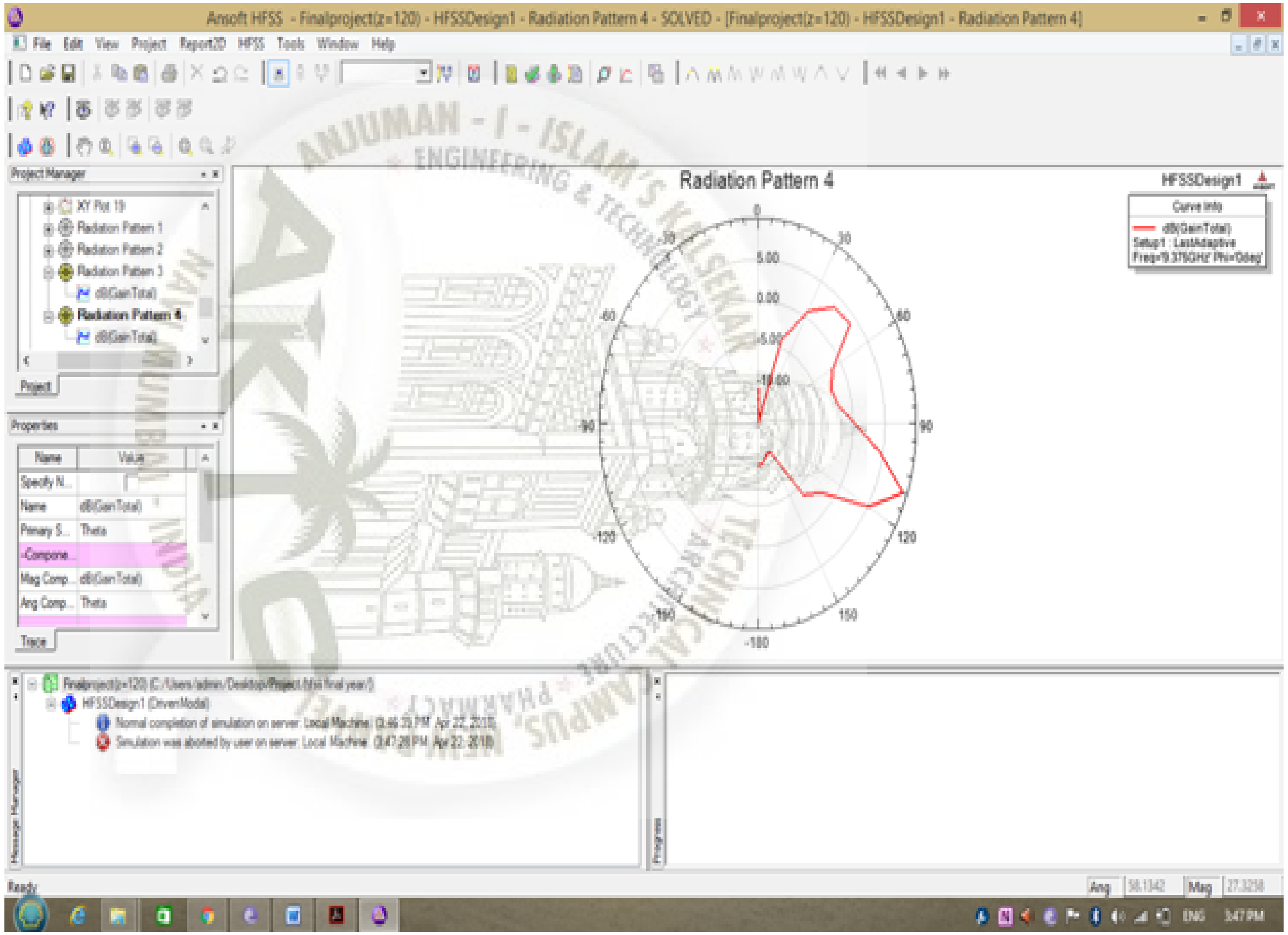


Name	X	Y
m1	100.0000	11.1998
m2	40.0000	6.5541
m3	160.0000	-4.0679

Name	Value
Specify N...	☐
Name	dB(GainTotal)
Y Axis	Y1
Primary S...	Theta
-Compone...	
Y Compon...	dB(GainTotal)

```
Normal completion of simulation on server: Local Machine. (2:17:21 PM  Apr 08, 2018)
Adaptive Passes did not converge based on specified criteria. (2:19:04 PM  Apr 08, 2018)
Normal completion of simulation on server: Local Machine. (2:19:05 PM  Apr 08, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (2:23:17 PM  Apr 08, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (2:23:28 PM  Apr 08, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (2:23:42 PM  Apr 08, 2018)
HFSSDesign1: Solutions have been invalidated. Undo to recover. (2:23:55 PM  Apr 08, 2018)
Adaptive Passes did not converge based on specified criteria. (2:30:07 PM  Apr 08, 2018)
Solution Setup 'Setup1', Sweep 'Sweep': Interpolating sweep converged. (2:38:19 PM  Apr 08, 2018)
Normal completion of simulation on server: Local Machine. (2:38:19 PM  Apr 08, 2018)
```

Radiation Pattern



Name	Value
Specify N...	
Name	dB(GainTotal)
Primary S...	Theta
-Compone...	
Mag Comp...	dB(GainTotal)
Ang Comp...	Theta

Finalproject(z=120) (C:/Users/admin/Desktop/Project (Nsit final year)/)
HFSSDesign1 (DrivenModal)
Normal completion of simulation on server: Local Machine. (3:46:35 PM Apr 22, 2018)
Simulation was aborted by user on server: Local Machine. (3:47:28 PM Apr 22, 2018)

Chapter 5

Conclusion

5.1 Conclusion

The workflow proposed in this report covers the entire antenna project, from slot characterization and simulation of the antenna using HFSS software and show how simulation can be used at every step to improve antenna performance.The antenna described in this article has 4 slots on the narrow wall of the antenna and the slots are inclined at 45 degree. It achieved optimum performance, verified numerically. The measurement of a prototype validates the accuracy of the simulation.The accuracy of the network model has been demonstrated on a number of SWG designs. The network model predicts sidelobes within the range of-4dB to +6 dB peak-to-peak at a 11.93 dB main lobe level(Gain)across the operating frequency band of 8.2 to 12.4 GHz.

5.2 Future Scope

In future the slots can be increase for desire gain and for minimum side lobe to avoid false detection in radar application. Through Waveguide IRIS Structure side lobe level can be decrease to minimum. This antenna can be use with advance technology for precision analysis.

5.3 Reference

1. Gilbert, R. A., *Antenna Engineering Handbook, Chapter :* Waveguide Slot*Antenna Arrays,* McGraw-Hill, 2007.

2. Mailloux, R. J., *Phased Array Antenna Handbook*, Artech House, 2005.

3. Rueggeberg, W., A multislotted waveguide antenna for high-powered microwave heating systems, *IEEE Trans. Ind. Applicant.,*Vol. 16, No. 6, 809813, 1980.

4. Elliott, R. S. and L. A. Kurtz, The design of small slot arrays, *IEEE Trans. Antennas Propagate.* Vol. 26, 214219, March 1978.

5. Elliott, R. S., The design of traveling wave fed longitudinal shunt slot arrays, IEEE Trans.

6. J. L. Volakis, Antenna Engineering Handbook (Fourth Edition). McGraw-Hill Professional, June 2007.

7. Y. Zhang, Parallel Computation in Electro magnetics. Xian, China: Xidian University Press, 2006.

8. Press, W.H., Flannery, B.P., Teukolsky, S.A., Vetterling, W.T.: Numerical recipes in Fortran (Cambridge University Press, 1992, 2nd edn.), Ch. 10.4

9. Chernin, M.G.: Slot admittance data at Ka band, IEEE Trans. Antennas Propagate., 1956, 4, pp. 632636

Chapter 6

Certificates

Universal College of Engineering

DTE Code: 3460

(Permanently Unaided | Approved by AICTE, DTE & Affiliated to University of Mumbai)
Near Bhajansons and Pinyadham, Kaman Bhiwandi Road, Vasai
in association with **I.E.T.E. - I.S.F., C.S.I. & I.S.A.**

4th National Level Project Exhibition Cum Poster Presentation

Certificate of Participation

Awarded to Ms./Mr. ANSARI ABU TALHA

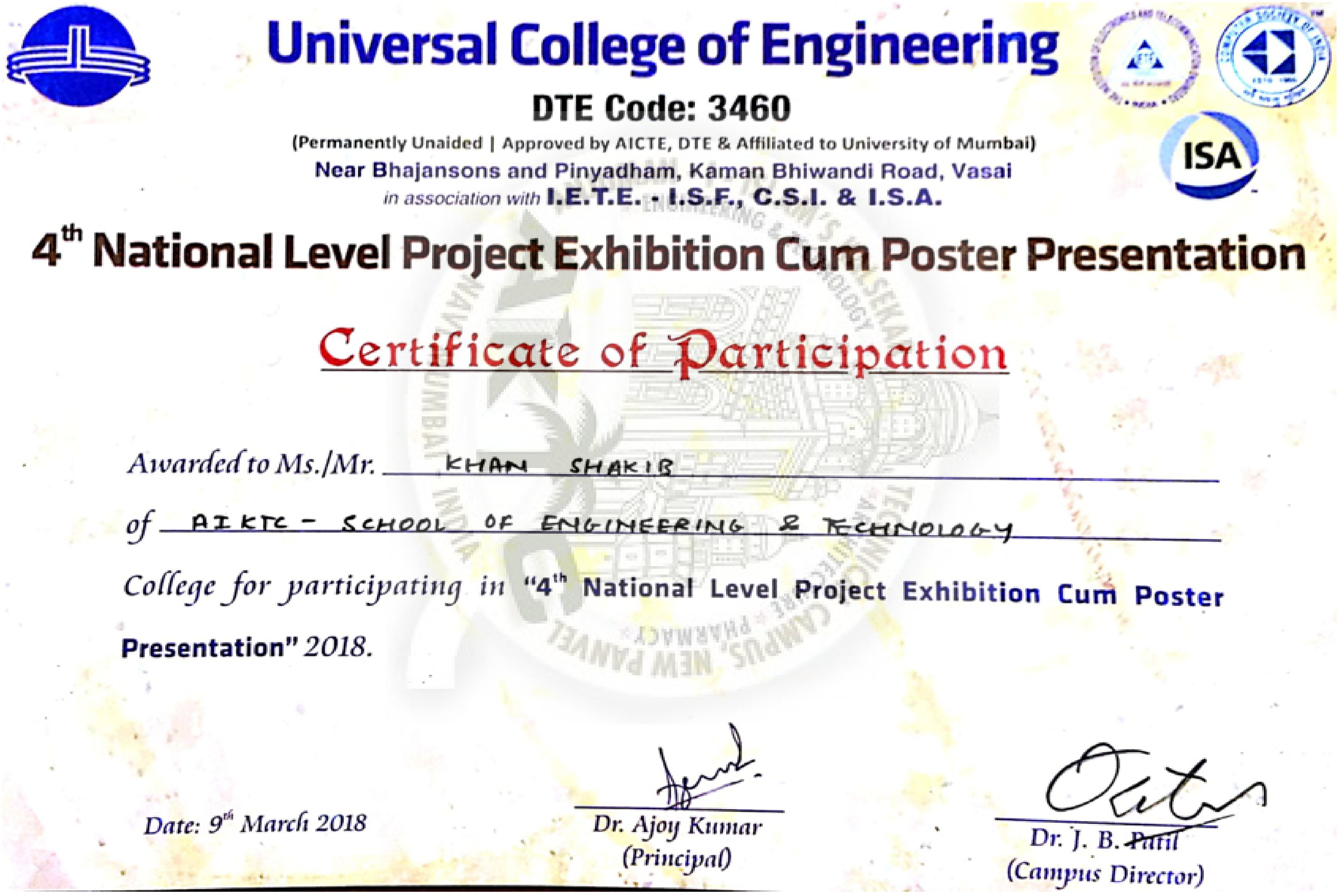
of AIKTC - SCHOOL OF ENGINEERING & TECHNOLOGY

College for participating in **"4th National Level Project Exhibition Cum Poster Presentation"** *2018.*

Date: 9th March 2018

Dr. Ajoy Kumar
(Principal)

Dr. J. B. Patil
(Campus Director)



Universal College of Engineering

DTE Code: 3460

(Permanently Unaided | Approved by AICTE, DTE & Affiliated to University of Mumbai)
Near Bhajansons and Pinyadham, Kaman Bhiwandi Road, Vasai
in association with **I.E.T.E. - I.S.F., C.S.I. & I.S.A.**

4th National Level Project Exhibition Cum Poster Presentation

Certificate of Participation

Awarded to Ms./Mr. KHAN SHAKIB

of AIKTC - SCHOOL OF ENGINEERING & TECHNOLOGY

College for participating in "4th National Level Project Exhibition Cum Poster Presentation" *2018.*

Date: 9th March 2018

Dr. Ajoy Kumar
(Principal)

Dr. J. B. Patil
(Campus Director)

Universal College of Engineering

DTE Code: 3460

(Permanently Unaided | Approved by AICTE, DTE & Affiliated to University of Mumbai)
Near Bhajansons and Pinyadham, Kaman Bhiwandi Road, Vasai
in association with **I.E.T.E., I.S.F., C.S.I. & I.S.A.**

4th National Level Project Exhibition Cum Poster Presentation

Certificate of Participation

Awarded to Ms./Mr. SHAIKH SHIRAJ MOHAMMED

of AIKTC - SCHOOL OF ENGINEERING

College for participating in **"4th National Level Project Exhibition Cum Poster Presentation"** *2018.*

Date: 9th March 2018

Dr. Ajoy Kumar
(Principal)

Dr. J. B. Patil
(Campus Director)