METHODIST
COLLEGE OF ENGINEERING AND TECHNOLOGY
Approved by AICTE New Delhi | Affiliated to Osmania University, Hyderabad
Abids, Hyderabad, Telangana, 500001

Estd : 2008

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

MICROWAVE LABORATORY

STUDENT LABORATORY MANUAL

(As per 2019-2020 Academic Regulations)

B.E VII SEMISTER ECE

SUBJECT CODE: PC 751 EC

Name:_____

Roll No.:_____

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Prepared by

Mr. B Indrababu, Assistant Professor
Mr. T Sravan Kumar , Associate Professor

Methodist College of Engineering & Technology

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Experiment No.	Title of the Experiment	Date	Page No.	Marks				Remarks/ Signature
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E: Experiment (10 Marks)   O: Observation (10 Marks)   R: Record (5Marks)   T: Total (25 Marks)

Experiment No.	Title of the Experiment	Date	Page No.	Marks				Remarks/ Signature
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E: Experiment (10 Marks)   O: Observation (10 Marks)   R: Record (5Marks)   T: Total (25 Marks)

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Vision of the Institute:

To produce ethical, socially conscious and innovative professionals who would contribute to sustainable technological development of the society.

Mission of the Institute:

To impart quality engineering education with latest technological developments and interdisciplinary skills to make students succeed in professional practice

To encourage research culture among faculty and students by establishing state of art laboratories and exposing them to modern industrial and organizational practices

To inculcate humane qualities like environmental consciousness, leadership, social values, professional ethics and engage in independent and lifelong learning for sustainable contribution to the society

Vision of the Department:

To strive to become centre of excellence in Education, Research with moral, ethical values and serve society

Mission of the Department:

M1: To provide Electronics & Communication Engineering knowledge for successful career either in industry or research

M2: To develop Industry-Interaction for innovation, product oriented research and development.

M3: To facilitate value added education combined with hands-on trainings

Program Educational Objectives:

PEO 1: Apply the knowledge of Basic sciences and Engineering in designing and implementing the solutions in emerging areas of Electronics and Communication Engineering.

PEO 2: Pursue the research or higher education and practise profession.

PEO 3: Adapt to the technological advancements for providing the sustainable Engineering solutions to meet organisation/society needs

PEO 4: Work as an individual or in a team with professional ethics and values.

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Program Outcomes:

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs):

PSO1: Professional Competence: Apply the knowledge of Electronics & Communication Engineering principles in different domains like VLSI, Signal processing, Communication, Embedded system & Control Engineering.

PSO2: **Technical Skills**: Able to design and implement products using the cutting- edge software and hardware tools and hence provide simple solutions to complex problems.

PSO3: Social consciousness: Graduates will be able to demonstrate the leadership qualities and strive for the betterment of organization, environment and society

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LAB INSTRUCTIONS
Lab Rule of conduct, DO's & DON'Ts

Conduct yourself in a responsible manner at all times in the laboratory. Don't talk aloud or crack jokes in lab.

A lab coat should be worn during laboratory experiments.

Dress properly during a laboratory activity. Long hair, dangling jewellery and loose or baggy clothing are a hazard in the laboratory.

Observe good housekeeping practices. Replace the materials in proper place after work to keep the lab area tidy.

Do not wander around the room, distract other students, startle other students or interfere with the laboratory experiments of others.

Do not eat food, drink beverages or chew gum in the laboratory and do not use laboratory glassware as containers for food or beverages.

Rules & Guidelines for conducting Lab-Work

Students are not allowed to touch any equipment, in the laboratory area until you are instructed by Teacher or Technician.

Before starting Laboratory work follow all written and verbal instructions carefully. If you do not understand a direction or part of a procedure, ASK YOUR CONCERNED TEACHER BEFORE PROCEEDING WITH THE ACTIVITY.

Before use equipment must be read carefully Labels and instructions. Set up and use the equipment as directed by your teacher. If you do not understand how to use a piece of equipment, ASK THE TEACHER FOR HELP!

Perform only those experiments authorized by your teacher. Carefully follow all instructions, both written and oral. Unauthorized experiments are not allowed in the Laboratory. Students are not allowed to work in Laboratory alone or without presence of the teacher. Any failure / break-down of equipment must be reported to the teacher. Protect yourself from getting electric shock.

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Course Code	Course Title						Core/ Elective
PC751EC	**MICROWAVE LAB**						Core
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P	25	50	1
	-	-	-	2			

Course Objectives:
1. Understand the characteristics of RKO and Gunn oscillator.
2. Measurement of frequency and wavelengths would be learnt by the student.
3. VSWR various TEES would be understood by the student.
4. Radiation pattern would be learnt by the student for horn antenna.
5. How to Create, Simulate and analyse the different types of Microstrip Antennas by using EM simulation software.

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PART- A

1. Characteristics of Reflex Klystron oscillator, finding the mode numbers and efficiencies of different modes.
2. Characteristics of Gunn diode oscillator, Power Output Vs Frequency, Power Output Vs Bias Voltage.
3. Measurement of frequency and Guide wavelength calculation: a. Verification of the relation between Guide wavelength, free space wavelength and cut-off Wavelength of X-band rectangular waveguide.

4. Measurement of low and high VSWRs: VSWR of different components like matched terminals, capacitive and inductive windows, slide screw tuner for different heights of the tuning posts etc.
5. Measurement of impedance for horn antenna, Matched load and slide screw tuner.
6. To find the S-parameters of Directional coupler.

PART - B

1. To find the S-parameters of Tees: E plane, H plane and Magic Tee.
2. To find the S-parameters of Circulator
3. Measurement of radiation patterns for basic microwave antennas like horn and parabolic reflectors in E-plane and H-plane. Also to finding the gain, bandwidth and beamwidth these antennas.
4. How to Create, Simulate and Analyse the Dipole Antenna Structure by using EM simulation software
5. How to Create, Simulate and Analyse a Microstrip Rectangular Patch Antenna by using EM simulation software
6. How to Create, Simulate and Analyse a Probe Feed Patch Antenna by using EM simulation software

Note: At least 10 experiments to be carried out during the semester

Suggested Readings:
1. Paul B. Zbar, Albert P. Malvino, *Micheal A. Miller, Basic Electronics, A text – Lab Manual*, 7th Edition, TMH 2001. .

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PART A

EXPERIMENTS

I. INTRODUCTION TO MICROWAVE COMPONENTS

RECTANGULAR WAVE GUIDE

Wave guides are manufactured to the highest mechanical and electrical standards and mechanical tolerances. L and S band wave guides are fabricated by precision brazing of brass-plates and all other wave guides are in extrusion quality. W.G. sections of specified length can be supplied with flanges, painted outside and silver or gold plated in side.

SPECIFICATIONS

EIA No. : WR - 90

X Band frequency: 8.2 - 12.4 GHZ

Waveguide slot width: 2.286cm   Waveguide slot Height: 1.1016cm

Total Component width: 2.54 cm   Total Component height: 1.27cm

Material: Brass/Copper.

FIXED ATTENUATORS

Series 5000 fixed Attenuators are meant for inserting a known attenuation in a wave guide system. These consist of a lossy vane inserted in a section of wave guide, flanged on both ends. These are useful for isolation of wave guide circuits, padding and extending the range of measuring equipments.

Fixed Attenuators are available for 3, 6 or 10 dB attenuation values, but any attenuation valve between 0 and 30dB can be provided.

SPECIFICATIONS

Model No: X-5000

Frequency : 8.12 - 12.4 GHZ

Attenuation (dB) : 3,6,10

Calibration Accuracy : ± 0.2dB

Avg Power : 2W/Max   VSWR : 1.10 Max Insertion Loss (dB) : 0.2/W.G.

Type: WG – 90 / Flange Type (UG/U) : 39.

A precision built probe carriage has a centimeter scale with a vernier reading of 0.1mm least count and a dial gauge can be mounted easily if precise readings are required.

Model No. : X - 6051

Freq (Ghz) : 8.2 - 12.4   Max Residual VSWR : 1.01

WG type (WR-) : 90   Flange Type (UG-/U) : 39

TUNABLE PROBE

Model 6055 Tunable probe is designed for use with model 6051 slotted sections. These are meant for exploring the energy of the EF in a suitably fabricated section of wave guide.

The depth of penetration into a wave guide - section is adjustable by the knob of the probe. The tip pick up the RF power from the line and this power is rectified by crystal detector, which is then fed to the VSWR meter or indicating instrument.

Model No. : X6055   Freq (Ghz) : 8.2 - 12.4

output Connector : BNC(F)   Detector : IN23.

WAVEGUIDE DETECTOR

MOUNT (TUNABLE)

Model 4051 Tunable Detector Mount is simple and easy to use instrument for detecting microwave power through suitable detector. It consists of a detector crystal mounted in a section of a Wave guide and shorting plunger for matching purpose. The output from the crystal may be fed to an indicating instrument. In K and R bands detector mounts the plunger is driven by a micrometer.

Model No. : X - 4051   Freq. Range (Ghz) : 8.2 - 12.4

O/P Connector : BNC (F)   Wave guide type (WR-) : 90

Flange Type (UG/U) : 39   Detector : IN23

KLYSTRON MOUNT

Model 2051 Klystron mounts are meant for mounting corresponding Klystrons such as 2K25, 723A/B, 726A or RK - 5976 etc. These consists of a section of wave guide flanged on one end and terminatedwith a movable short on the other end. An octalbase with cable is provided for Klystron.
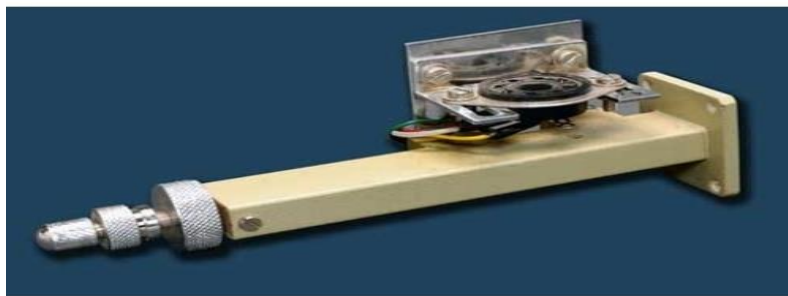
KLYSTRON MOUNT

Klyston tube

Model No. : X – 2051   Freq. Range (GHz) 8.2 - 12.4

WG Type (WR-) : 90   Flange Type (UG-/U): 39

CIRCULATORS

Model 6021 and 6022 are T and Y types of three port circulators respectively. These are precisely machined and assembled to get the desired specifications. Circulators are matched three port devices and these are meant for allowing Microwave energy to flow in clockwise direction with negligible loss but almost no transmission in the anti-clockwise direction.

T type and Y type Circulator

Model No. : X - 6021   Frequency Range (Ghz) : 8.6 - 10.6 or 10.2 - 12.2

Min. Isolation (dB) : 20   Max. Insertion Loss (dB) : 0.4

Max. VSWR : 1.20

SLIDE SCREW TUNERS

Model 4041 slide screw tuners are used for matching purposes by changing the penetration and position of a screw in the slot provided in the centre of the wave guide.

These consists of a section of wave guide flanged on both ends and a thin slot is provided in the broad wall of the Wave guide. A carriage carrying the screw, is provided over the slot. A VSWR upto 20 can be tuned to a value less than 1.02 at certain frequency.
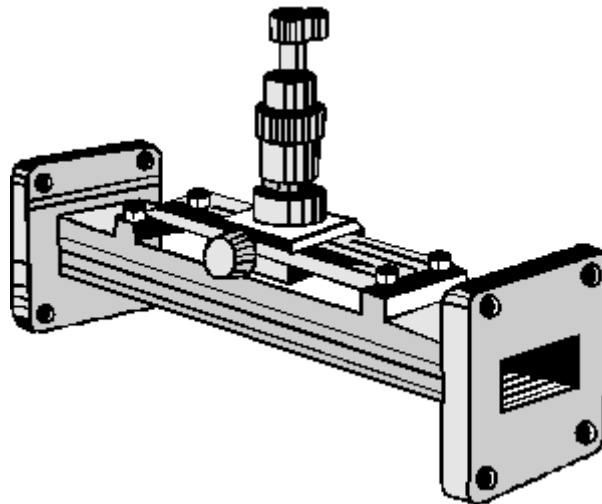
Model No. : X – 4041   Freq. Range (Ghz) : 8.2 - 12.4

WG Type (WR-) : 90   Flange type (UG/U) : 39

MULTIHOLE DIRECTIONAL COUPLERS

Model 6000 series Multi hole directional couplers are useful for sampling a part of Microwave energy for monitoring purposes and for measuring reflections and impedance. These consist of a section of Wave guide with addition of a second parallel section of wave guide thus making it a four port network. However the fourth port is terminated with a matched load. These two parallel sections are coupled to each other through many holes, almost to give uniform coupling; minimum frequency sensitivity and high directivity. These are available in 3, 6, 10, 20 and 40dB coupling.

Model No. : X - 6003   Frequency Range (Ghz) : 8.2 - 12.4

Coupling (dB) : 3,10,20,40   Directivity (dB) : 35

Wave guide type (WR-): 90   Flange type (UG/U) : 39

E PLANE TEE

Model 3061 E - plane tee are series type T - junction and consists of three section of wave guide joined together in order to divide or compare power levels. The signal entering the first port of this T - junction will be equally dividing at second and third ports of the same magnitude but in opp. Phase

Model No. : X - 3061   Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90   Flange Type (UG/U) : 39

H - PLANE TEE

Model 3065 H - Plane Tee are shunt type T - junction for use in conjunction with VSWR meters, frequency - meters and other detector devices. Like in E-plane tee, the signal fed through first port of H - plane Tee will be equally divided in magnitude at second and third ports but in same phase.

Model No. : X - 3065   Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90   Flange Type (UG-/U) : 39

MAGIC TEE

Model 3045 E - H Tee consists of a section of wave guide in both series and shunt wave guide arms, mounted at the exact midpoint of main arm. Both ends of the section of wave guide and both arms are flanged on their ends. These Tees are employed in balanced mixers, AFC circuits and impedance measurement circuits etc. This becomes a four terminal device where one terminal is isolated from the input terminal.

Model No. : X - 3045   Frequency Range (GHz): 8.2 - 12.4

WG Type (WR-) : 90   Flange Type (UR-/U) : 39

MOVABLE SHORT

Model 4081 movable shorts consists of a section of waveguide, flanged on one end and terminated with a movable shorting plunger on the other end. By means of this non contacting type plunger, a reflection co-efficient of almost unity may be obtained.

Model No. : X - 4081   Frequency Range (GHz) : 8.2 - 12.4

WG Type (WR-) : 90   Flange Type (UG-/U) : 39

MATCHED TERMINATION

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Model 4000 are low power and non-reflective type of terminations. It consists of a small and highly dissipative taper flap mounted inside the centre of a section of wave guide. Matched Terminations are useful for USWR measurement of various waveguide components. These are also employed as dummy and as a precise reference loads with Tee junctions, directional couplers and other similar dividing devices.

Model No. : X - 4000, Freq. Range (GHz) : 8.2 - 12.4 Max VSWR : 1.04

AV Power: 2W, WG Type (WR-) 90, Flange Type (UG-/U) : 39

PYRAMIDAL WAVEGUIDE HORN ANTENNA

Model 5041 pyramidal Wave guide Horn antenna consists of waveguide joined to pyramidal section fabricated from brass sheet. The pyramidal section shapes the energy to concentrate in a specified beam. Wave guide horns are used as feed horns as radiators for reflectors and lenses and as a pickup antenna for receiving microwave power.
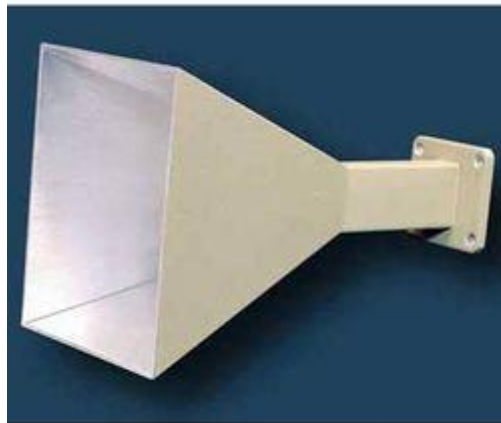
Model No. : X - 5041   Frequency Range (GHz) : 8.2 - 12.4

Max VSWR: 1.20   WG Type (WR-) : 90

Flange Type (UG-/U) : 39

GUNN OSCILLATORS

Model 2151 Gunn Oscillators are solid state microwave energy generators. These consist of waveguide cavity flanged on one end and micrometer driven plunger fitted on the other end. A Gunn-diode is mounted inside the Wave guide with BNC (F) connector for DC bias. Each

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Gunn oscillator is supplied with calibration certificate giving frequency vs micrometer reading.

Model No. : X – 2152   Freq : 8.2 - 12.4 GHz

Min output power: 10 MW   WG Type (WR-) : 90 Flange Type (UG-/U) : 39

PIN MODULATORS

Model 451 pin modulators are designed to modulate the cw output of Gunn Oscillators. It is operated by the square pulses derived from the UHF (F) connector of the Gunn power supply. These consists of a pin diode mounted inside a section of Wave guide flanged on it's both end. A fixed attenuation vane is mounted inside at the input to protect the oscillator.

Model No. : X - 451   Frequency Range (GHz) : 8.3 - 12.4

Max RF Power: 1W   WG Type (WR-) : 90 Flange Type (GHz) : 39

GUNN POWER SUPPLY

Model X-110 Gunn Power supply comprises of an regulated DC power supply and a square wave generator, designed to operate Gunn-Oscillator model 2151 or 2152, and pin modulators model 451 respectively. The DC voltage is variable from 0 - 10V. The front panel meter monitors the Gunn voltage and the current drawn by the Gunn diode. The square wave of generator is variable from 0 - 10V. in amplitude and 900 - 1100 Hz in frequency. The power supply has been so designed to protect Gunn diode from reverse voltage application over transient and low frequency oscillations by the negative resistance of the Gunn-diode.

ISOLATORS

The three port circulators Model 6021 may be converted into isolators by terminating one of its port into matched load. These will work over the frequency range of circulators. These are well matched devices offering low forward insertion loss and high reverse isolation.
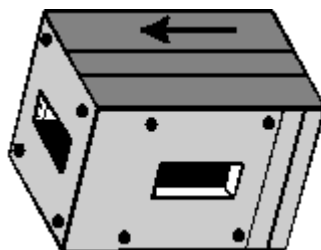
Model No. : X - 6022   Frequency Range (GHz) : 8.6 - 12.2

Min Isolation (dB): 20   Max Insertion Loss (dB) : 0.4 Max VSWR : 1.20 .

Thus all the microwave components were studied in detail.

REVIEW QUESTIONS

1. What is microwave?

2. Mention the frequency band for a millimetre wave.

3. List some of IEEE microwave frequency bands.

4. List some of characteristic feature of microwave.

5. List some of the application of microwave technology.

6. Draw a simple microwave system.

7. What are waveguide `Tees'?

8. List the basic type of waveguide tees.

9. What is an isolator?

10. What is a circulator?

11. What is a directional coupler?

12. What is velocity modulation?

13. Mention the Principle used in Klystron?

14. When the o/p power of reflex klystron maximum?

15. What is meant by attenuator?

1. MODE CHARACTERISTICS OF REFLEX KLYSTRON

AIM: To study the Mode Characteristics of Reflex Klystron.

APPARATUS REQUIRED:

Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Variable Attenuator, Slotted section with Probe carriage, CRO, Movable Short.

THEORY:

Klystron is a microwave vacuum tube employing velocity modulation. These electrons move towards the repeller (ie) the electrons leaving the cavity during the positive half cycle are accelerated while those during negative half cycle are decelerated. The faster ones penetrate further while slower ones penetrate lesser in the field of repeller voltage. But, faster electrons leaving the cavity take longer time to return and hence catch up with slower ones. In the cavity the electrons bunch and intract with the voltage between the cavity grids. It consists of an electron gun producing a collimated electron beam. It bunches pass through grids at time the grid potentials is such that electrons are decelerated they give by energy. The electrons are then collected by positive cavity wall near cathode. To protect repeller from damage, repeller voltage is applied before accelerating voltage.

```
┌──────────┐    ┌──────────┐    ┌──────────┐    ┌──────────┐    ┌──────────┐
│ Klystron │    │  Reflex  │    │          │    │ Variable │    │Frequency │
│  Power   │───▶│ Klystron │───▶│ Isolator │───▶│Attenuator│───▶│  Meter   │
│  Supply  │    │Oscillator│    │          │    │          │    │          │
└──────────┘    └──────────┘    └──────────┘    └──────────┘    └──────────┘
                                                                      │
                                                                      ▼
                                  ┌──────────┐    ┌──────────┐
                                  │  Output  │    │Wave guide│
                                  │  Meter   │◀───│ Detector │
                                  │  (CRO)   │    │  Mount   │
                                  └──────────┘    └──────────┘
```
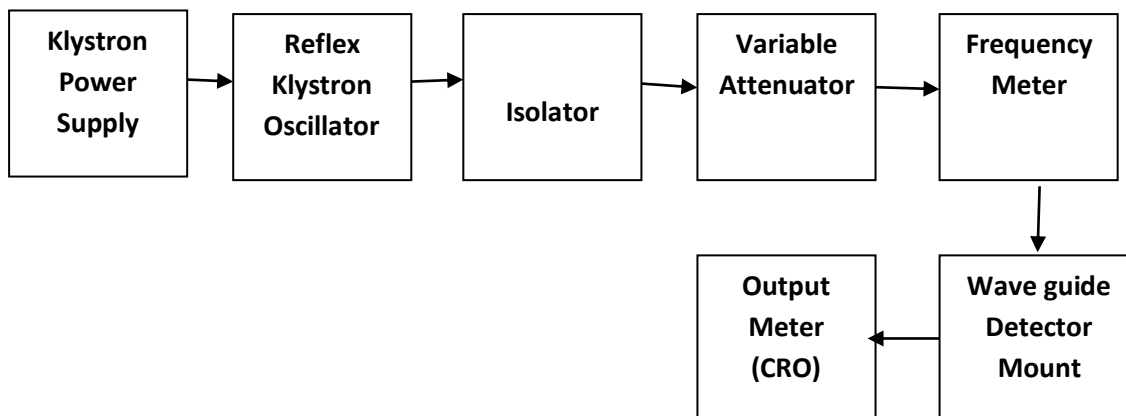
Fig: Set up for Klystron Tube Characteristics

PROCEDURE:

1) Assemble the components as shown in fig.
2) After following the necessary precautions, the Klystron Power Supply is switched ON.
3) To obtain peak voltage, the attenuator is positioned at it's minimum attenuation.
4) Vary the repeller voltage from it's maximum negative value and increase it in steps on N and record output power and frequency.
5) The frequency is measured by tuning the basic frequency meter to have a dip in the output voltage each time.
6) The frequency meter is detuned before measuring the output power each time.

7) The mode characteristics of Reflex Klystron is plotted. (i.e. Output Voltage Vs Repeller voltage and Frequency Vs Repeller voltage)

BASIC PRECAUTIONS:

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.

2) The repeller voltage should be varied in one direction to avoid hysteresis in klystrons .

3) The heater voltage should be applied first and cooling should be provided simultaneously after some time other voltages should be applied taking precaution

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

5) To avoid loading of the klystron an isolator/attenuation should invariably be used between klystron and the rest of the set-up.

CALCULATIONS:

(i) ETR – Electronic tuning range i.e, the frequency band from one end of the mode to another is calculated by
ETR = $f_1$max – $f_1$min for N_1 mode (GHz)

$f_1$max, $f_1$min → half power frequencies

(ii) ETS – Electronic tuning sensitivity
ETS = = $f_1$max – $f_1$min/V_1max- V_1min (MHz/V)

$f_1$max, $f_1$min → half power frequency

V_1max, V_1min→ corresponding repeller voltages for a particular mode.

(iii) Knowing mode top voltages of two adjacent modes, mode numbers of the modes is computed from the equation,

N_2/ N_1= V_1/ V_2= (n+1) +3/4/n+3/4
OR
N_2/ N_1= V_1/ V_2= (n+1.75)/(n+0.75)

Where V_1 and V_2 are the values of repeller voltages required to operate the klystron in mode numbers N_1 and N_2.

(iv) Transit time of each mode is calculated from

t_1 = (n+3/4)/f_1= N1/f_1

Where f1=frequency of microwave operation in one mode.

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TABULAR COLUMN:

1) **Table 1**

Repeller Voltage(V_R)	Output Voltage(V)

2) **Table 2**

Beam Voltage=_ _ _ _ _ _ _ _ _   Beam Current=_ _ _ _ _ _ _ _ _

S.NO	Mode	Repeller Voltage(V_R)	Output Voltage (V)	Frequency(GHz)

EXPECTED GRAPH:
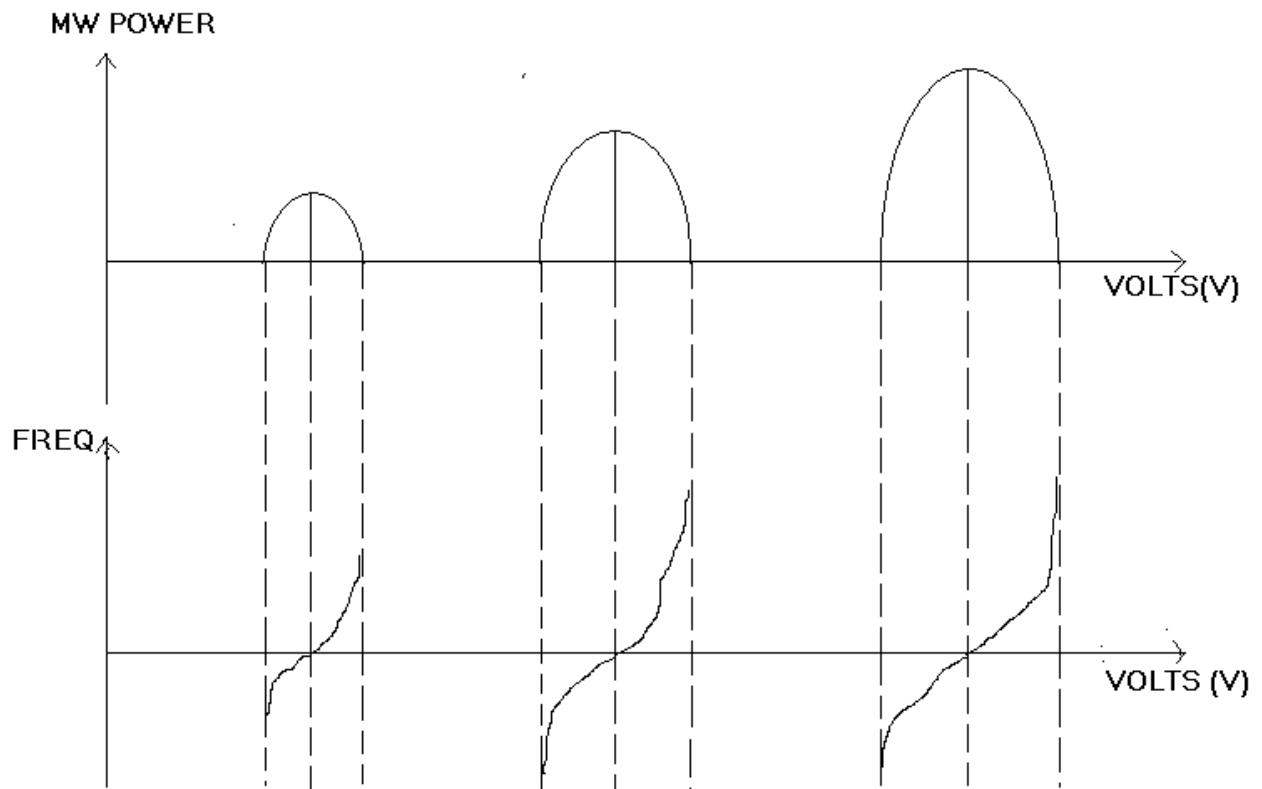
RESULT: The characteristics of Klystron Oscillator are verified and modes are calculated.

REVIEW QUESTIONS

1. List two basic configurations of Klystron tubes.
2. What is velocity modulation?
3. List down the characteristic of two cavity klystron amplifier.
4. Write a note on mode of oscillations.
5. Draw the reflex klystron modes.
6. Higher order mode occurs at _____ repeller voltage.
7. When the o/p power of reflex klystron maximum?
8. List the application of reflex klystron.
9. What is transit time?
10. Which mode number is most frequently used? Why?

2. STUDY OF VI CHARACTERISTICS OF GUNN DIODE

AIM: Study of VI characteristics of Gunn diode.

APPARATUS:

X-Band Gunn Oscillator, Microwave bench, PIN modulator, Isolator, Frequency meter, Variable attenuator, Slotted section, Tunable probe, Detector Mount, Matched termination, Gunn power supply, Wave guide stand, BNC cable,

Cooling fan.
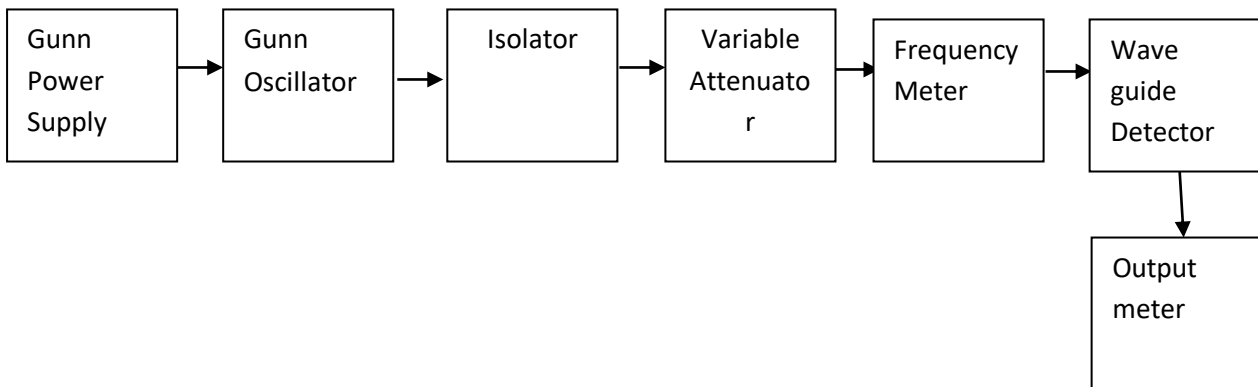
Fig: Bench Set up Diagram

THEORY:

Some bulk semiconductor materials such as Gallium arsenide (GA As), Indium phosphide (InP) and Cadmium Telluride (CdTe) have two closely spaced energy bands in the conduction band. At lower electric field strengths in the material, most of the electrons will be transmitted into higher energy band. In the higher energy band the effective electron mass is longer and hence the electron mobility is lower than what it is in the lower energy band. Since the conductivity is directly proportional to the mobility there is an immediate range of electric field strengths for which the fraction of electrons that are transferred into higher energy low mobility conduction is such that the average mobility and hence conductivity decreases with an increase in the electric field strength. Thus there is a range of voltage over which the current decreases with the increasing voltage and a negative instrumental of resistance is displayed by the device. A Gunn device is also called a transferred electronic device since the negative resistance arises from the transfer of electrons from the lower to higher energy band. The oscillations that occur in the material with energy band structure noted above was discovered by J.B.GUNN. The probability of obtaining negative differential resistance had been predicted earlier by Ridley and Watkins.

PROCEDURE;

1. First connect the Gunn test bench as shown in block diagram.

2. Keep the control knobs of power supply as detailed below:

        ON/OFF switch   : OFF
        Gunn diode bias knob : fully anti-clockwise to keep the bias voltage to
                      zero to start with.
        PIN bias knob   : fully anti-clockwise to keep the bias voltage to zero to start
        with
        PIN mode frequency   : middle position to keep frequency approx. to 1 kHz.

3. Do not apply any bias to PIN diode throughout the experiment.

4. Set the micrometer on the wave guide cavity Gunn oscillator to approximately 10.9mm (approximate 9.5GHz)

5. Increase the voltage in steps of 0.5V up to l0V and record the corresponding current from the meter on the Gunn power supply by switching alternately to current and voltage position.

6. Reset the Gunn power supply and at each bias voltage tune the frequency meter to observe the dip. Note the frequency reading.

7. Reset the Gunn power supply and vary the micrometer of the Gunn oscillator and observe the dip in CRO.

8. Note down the micrometer reading of the Gunn and corresponding frequency from frequency meter.

9. Draw the following graphs between a) V-I characteristics as observed in the power supply panel (b) Bias voltage Vs Frequency (c) Frequency & micrometer reading of Gunn.

TABULAR COLUMN:

S.No	Voltage (Volts)	Current (mA)	Frequency (GHz)

EXPECTED GRAPHS:
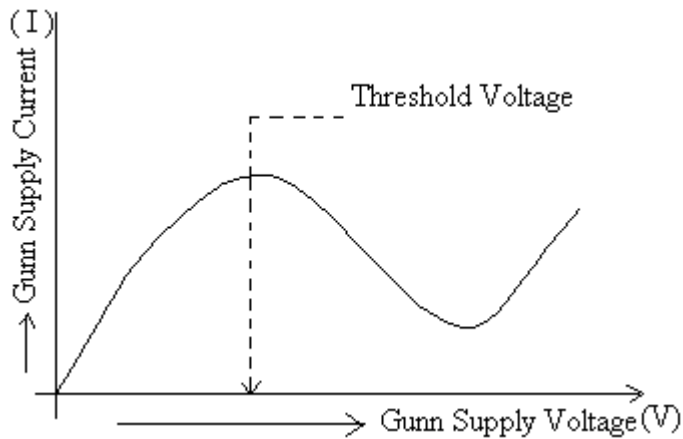
RESULT: The Characteristics of Gunn diode are verified and plotted

REVIEW QUESTIONS

1. What is Gunn effect?

2. GaAs is used in the fabrication of GUNN diodes because.......................

3. The gunn diode is................................

4. When the applied electric field exceeds the threshold value, electrons absorb more energy from the field and become..............................

5. The electrodes of a Gunn diode are made of...........................

6. When either a voltage or current is applied to the terminals of bulk solid state compound GaAs, a differential _____ is developed in that bulk device.

7. The frequency of oscillation in Gunn diode is given by................................

8. The modes of operation of a Gunn diode are illustrated in a plot of voltage applied to the Gunn diode v/s frequency of operation of Gunn diode.
a) true
b) false

9. The Gunn diode is used in the range of.......................

10. Silicon and germanium are called _____ semiconductors.

11. What is the another name of Gunn diode?

12. Draw the equivalent Circuit for GUNN?

13. What are the different modes in GUNN diode oscillator?

14. How many junctions are there in GUNN?

15. Explain the transferred electron effect in GUNN?

16. What are applications of GUNN?

3. WAVELENGTH & FREQUENCY MEASUREMENT

AIM: To determine the guide wavelength of rectangular wave guide in a dominant mode propagation.

COMPONENTS REQUIRED:

1. Microwave source (klystron power supply)

2. Klystron Mount

3. Isolator

4. Variable Attenuator

5. Frequency meter

6. Slotted section

6. Matched Termination

7. VSWR meter (or) CRO

BLOCK DIAGRAM:
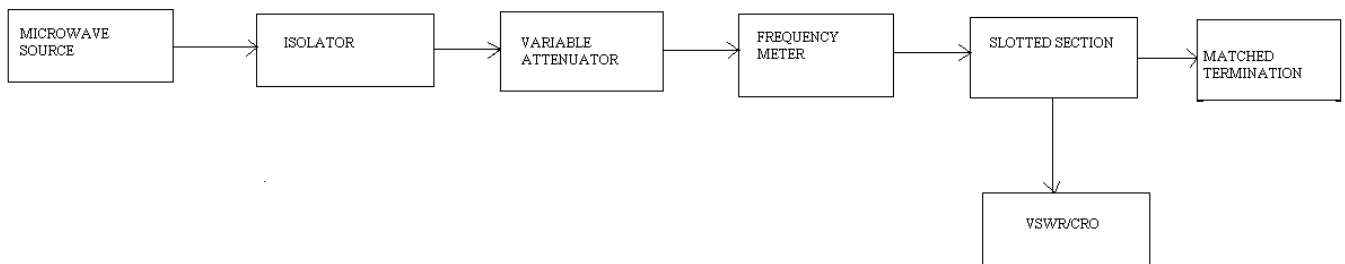
PROCEDURE:

1. Arrange the bench setup as shown in figure.
2. Switch on the microwave source and adjust the attenuator, frequency meter, etc to get maximum power.
3. Move the carriage probe in the slotted section in particular direction until there is a minimum deflection in the indic0ting meter is obtained note this distance as d1.

4. Once again move the carriage probe from its position d1 in particular direction in order to get minimum deflection on the indication meter. Note this distance as d2.

5. Calculate the guide wave length using formula, also find frequency of the wave using formula and verify it with frequency meter.

OBSERVATIONS AND CALCULATIONS:

I) USING DETECTOR MOUNT AT THE LOAD

Beam Voltage   = _____   Beam Current = _____

Repeller Voltage = _____   Dip Frequency= _____

II) USING SLOTTED SECTION WITH MATCHED TERMINATION:

Guide wavelength (λg) = 2(d2 ~ d1)

Where d1 , d2 are two successive minimums (or) maximum.

Cut-off wavelength (λc) =2a,

a = 22 .86mm for X band.

Free space wavelength (λo) by using

$1/ \lambda o^2 = 1/ \lambda g^2 + 1/ \lambda c^2$

Frequency (f) = C/ λo

RESULT: Thus the wavelength & frequency of the wave is determined.

REVIEW QUESTIONS

1) How are wavelength measured?

2) How do you measure wavelength in a compression wave?

3) What are the units of measure for wavelength?

4) What is frequency and how is it measured?

5) How is a sound's frequency measured?

6) What is the frequency of waves measure in?

7) What is the cut off wave length?

8) What is the dominant mode of rectangular waveguide? Explain.

9) Indicate the frequency Vs wave length for X-band?

10) Explain the principle of frequency meter?

11) What type of frequency meter used in microwave test bench?

12) What is the microwave frequency range?

4. VSWR MEASUREMENT

AIM: To determine the standing wave ratio and reflection coefficient.

EQUIPMENTS:

1. Klystron tube   2. Klystron power supply   3. VSWR meter   4. Klystron Mount

5. Isolator   6. Frequency meter   7. Variable attenuator   8. Slotted line

9. Tunable probe   10. Wave guide stand   11. S-S tuner   12. Movable short 13. BNC Cable

THEORY:

The electromagnetic field at any point of transmission line, may be considered
as a travelling waves: 'Incident Wave' propagates from generator and the reflected wave
propagates towards the generator. The reflected wave is set up by reflection of incident wave
from a discontinuity on the line or from the load impedance. The magnitude and phase of
reflected wave depends upon amplitude and phase of the reflecting impedance. The presence
of two travelling waves, gives rise to standing wave along with the line. The maximum field
strength is found where two waves are in phase and minimum where the two waves adds in
opposite phase. The distance between two successive minimum (or maximum) is half the
guide wave – length on the line. The ratio of electrical field strength of reflected and incident
wave is called reflection coefficient. The voltage standing ratio (VSWR) is defined as ratio
between maximum and minimum field strength along the line.

Hence VSWR, $S = Emax/Emin = (|Ei|+|Er|)/ (|Ei| -|Er|)$

Reflection Coefficient, $\rho = Er/Ei = \{Z – Zo\}/ \{Z + Zo\}$

Where Z is the impedance at a point on line, Zo is characteristic impedance.
The above equation gives following equation:

$|\rho| = [S-1]/[S+1]$

BLOCK DIAGRAM:

PROCEDURE:

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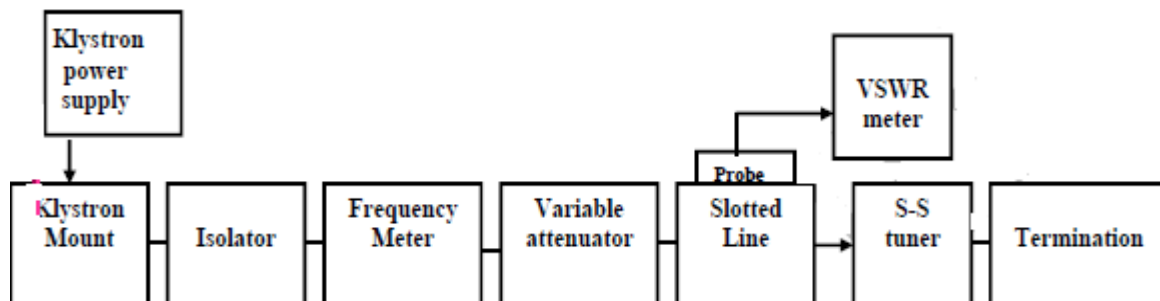
I. GENERAL:

1. The equipments is set as shown in block diagram.

2. The variable attenuator is set to maximum position.

3. The control knobs of VSWR meter is set as below:

> a. Range db – 40db/50db position
>
> b. Input Switch – Crystal low impedance
>
> c. Meter Switch – Normal position
>
> d. Gain (Coarse and fine) – Mid position

4. The control knobs of klystron power supply is set as below:

> Meter switch – 'OFF'
>
> Mod – switch – AM
>
> Beam voltage knob – fully anticlockwise
>
> Reflector voltage – fully clockwise.
>
> AM amplitude knob – around fully clock wise.
>
> AM frequency knob – around mid position.

5. The klystron power supply, VSWR meter and cooling fan are switched on.

6. The meter switch of power supply is turned to beam voltage position and beam voltage is set to 300V with help of beam voltage knob.

7. The reflector voltage is adjusted to get some deflection in VSWR meter.

8. The output is tuned by tuning reflector voltage, AM amplitude and frequency control knob of power supply.
9. The plunger of klystron mount is tuned for maximum deflection.
10. The probe is also tuned for maximum deflection in VSWR meter.
11. To get deflection in the scale of VSWR the range db – switch, variable attenuator position and gain control knob is adjusted if necessary.
12. The deflection in VSWR can be varied by moving the probe along the slotted line.

II. MEASUREMENT OF LOW AND MEDIUM VSWR:

1. The probe is moved along the slotted line to get maximum deflection in VSWR meter.

2. VSWR meter gain control knob or variable attenuator is adjusted until the meter indicates 1.0 on the normal upper SWR scale.

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3. The probe is moved to next minima point without disturbing all the control knobs and corresponding VSWR is recorded.

4. The above step is repeated for change of S-S tuner probe depth and corresponding VSWR is recorded.

5. If the VSWR is between 3.2 and 10, then range dB switch is changed to next higher position and VSWR is read from this second scale ranging from 3 t0 10.

III. MEASUREMENT OF HIGH VSWR (Double Minimum Method):

1. The depth of S-S tuner is set slightly more for maximum deflection.

2. The probe is moved along the slotted line till a minimum is indicated.

3. The VSWR meter gain control knob and variable attenuator is adjusted to obtain a reading of 3db of normal db of VSWR Meter.

4. The probe is moved to the left on slotted line, until full scale deflection is obtained, i.e. 0db on 0-10db scale. The corresponding probe position is noted. Let it be d1.

5. The step 3 and 4 are repeated and then the probe is moved to right along with slotted line until full scale deflection is obtained on 0- 10 db normal db scale. Let it be d2.

6. The S-S tuner and terminator is replaced by movable short.

7. The distance between two successive minima position of probe is measured. Twice this distance gives guide wavelength λg.

8. VSWR is computed by following equation: S = λg/[π(d1-d2)].

OBSERVATIONS:

With S-S tuner and Termination:

      First minima position d1 = _____cm.

      Second minima position d2 = _____cm.

With Movable Short:

      First minima position d3 = _____cm.

      Second minima position d4 = _____cm.

      Guide wavelength, λg = 2(d3-d4) = _____cm

VSWR is computed as follows:

      VSWR = λg/π(d1-d2) =_____.

RESULT:

Thus The VSWR is measured.

Measured value of VSWR = _____.

Viva Questions

1) Does VSWR vary with line length?

2) Can the magnitude of the reflection coefficient (ρ) be greater than 1?

3) Can VSWR be negative?

4) Is there a the minimum length of transmission line required on either side of the VSWR meter for valid readings?

5) Is the characteristic impedance of the sampler line section important?

6) What is standing wave?

7) What is reflection coefficient?

8) When do standing waves form?

9) How they are useful in microwave engineering?

10) What is min. value of VSWR?

11) What is range of reflection coefficient?

5. RADIATION PATTERN OF HORN ANTENNA

AIM: To obtain directional pattern of a Horn Antenna.

APPARATUS REQUIRED

Klystron Power Supply, Klystron with mount, Isolator, Frequency meter, Fixed Attenuator Detector, Parabolic Reflector, CRO.

RADIATION PATTERN
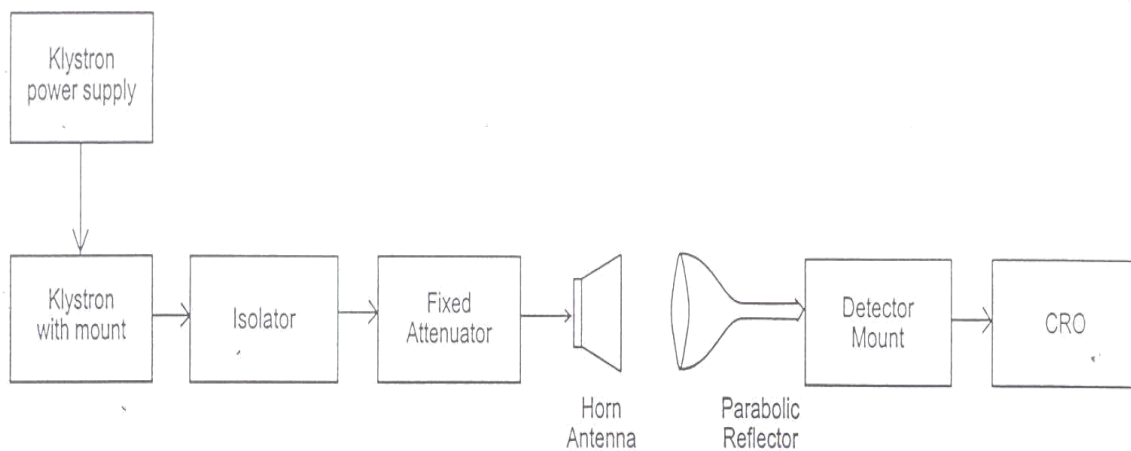
THEORY

A horn antenna may be regarded as a flared out or opened out wave guide. A wave guide is capable of radiating radiation into open space provided the same is excited at one end and opened at the other end. However, the radiation is much greater through wave guide than the 2 wire transmission line. To overcome reflection and diffraction in the wave guide, the mouth of the waveguide is opened out which assumes the shape of a electromagnetic horn. If the wave guide is terminated by any type of horn, the abrupt discontinuity existed is replaced by a gradual transformation, then all the energy incident in forward direction in the waveguide will now be radiated, provided the impedance matching is proper. This improves directivity and reduces diffraction. If flaring is done only in one direction, then sartorial horn is produced. If flaring is done along both the walls, then pyramidal horn is obtained. By flaring the walls of the circular waveguide, a conical horn is formed. The fields inside the waveguide propagate in the same manner as in free space, but on reaching the mouth of the waveguide, these propagating fields continue to propagate in the same general direction but also starts spreading laterally and the wave front eventually becomes spherical. However this may be treated as transition region where the change over from the guided propagation to free space propagation occurs. Since the waveguide impedance & free space impedance are not equal, hence to avoid standing wave ratio, flaring of walls of waveguide is done which besides matching of impedance also provide concentrated radiation pattern (ie) greater directivity and narrower beam width. It is the flared structure that is given the name electromagnetic horn radiator. The function is to produce a uniform phase front with a larger aperture in

comparison to waveguide and thus directivity is greater. If flare angle is very large, the wave front on the mouth of the horn will be curved rather than plane. This will result in non-uniform phase distribution over the aperture, resulting in increased beam width and reduced directivity, and vice versa occurs if the flare angle is very small. The directivity of the horn antenna is given as $D = 7.5\ A/\lambda^2$ where A area of horn mouth opening. Horn antennas are extensively used at microwave frequencies under the condition that power gain needed is moderate.

Precaution-Power flowing out of horns may damage retina of the eye so do not see directly inside the horn antenna

DIRECTIONAL PATTERN OF HORN ANTENNA
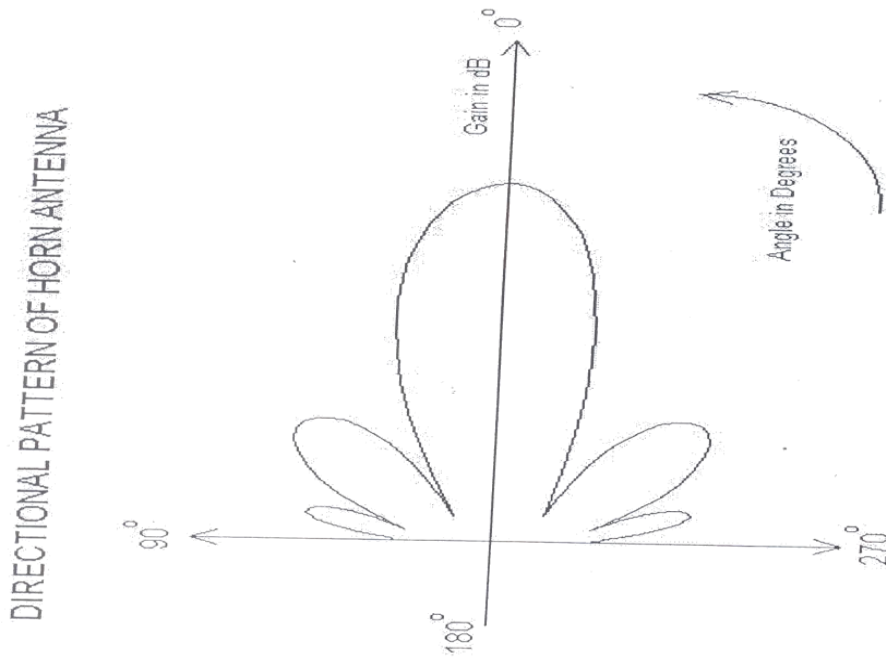
INPUT VOLTAGE V_T = 330mv

Angle (degree s)	V_R (mv)		Gain (dB) = 20 log (V_R/V_T)	
	Clock wise	Anticlock wise	Clock wise	Anticlock wise
0				
5				
10				
15				
20				
25				
30				
35				
40				
45				
50				
55				
60				
65				
70				
75				

PROCEDURE

1. Setup the equipments as shown in fig. Keeping the axis of both antennas in same axis line
2. Energize the microwave source, and set mode 3 determines input power at transmitting antenna end by connecting detector mount.
3. Connect the transmitting antenna back. Turn the receiving horn to the left in 5° steps upto at least 60° and note the corresponding voltage.
4. Repeat the above step but this time turning the receiver to the right and note down the readings.
5. Draw a relative power pattern ie, o/p vs angle.
6. From diagram 3 dB beam width is determined.

RESULT

Thus the directional pattern of the Horn antenna was obtained and the corresponding graph was drawn.

Viva Questions

1) What is horn?

2) In order to function properly, a horn antenna must be a certain minimum size .What is it?

3) Where are Horn antennas commonly used ?

4)-------- is basic building block for any practical antenna

5) Which is a non-resonant antenna?

6)_____ is the measurement of a unilateral antenna properties of directivity

7) Top loading is used in an antenna in order to increase its _____.

8) All elements in a beam _____ antennas are in line

9) Which antenna with very high gain and very narrow beamwidth.

10)_____ is the horizontal pointing angle of an antenna

6. DIRECTIONAL COUPLER

AIM : To study the function of multi hole directional coupler by measuring the following parameters.

1. Coupling factor   2. Insertion loss   3. Directivity   4. Isolation Loss

APPARATUS:

Microwave source (Klystron or Gunn diode), Isolator, Frequency meter, Variable attenuator, Slotted line, Tunable probe, Detector mount, Matched termination, MHD coupler, Waveguide Stand, Cables and Accessories, VSWR meter/CRO.
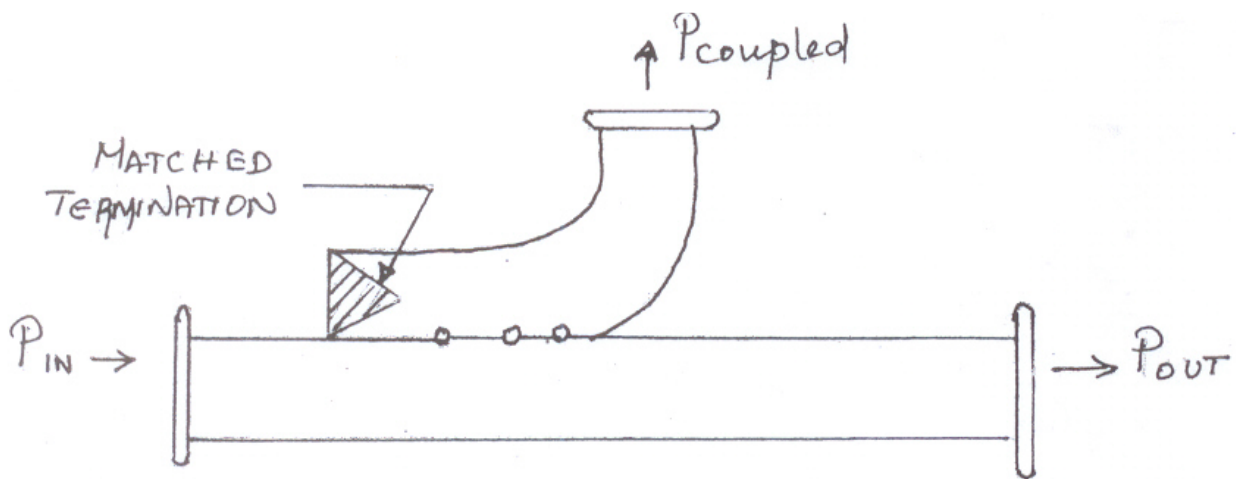
BENCH SETUP DIAGRAM OF DIRECTIONAL COUPLER CHARACTERISTICS:
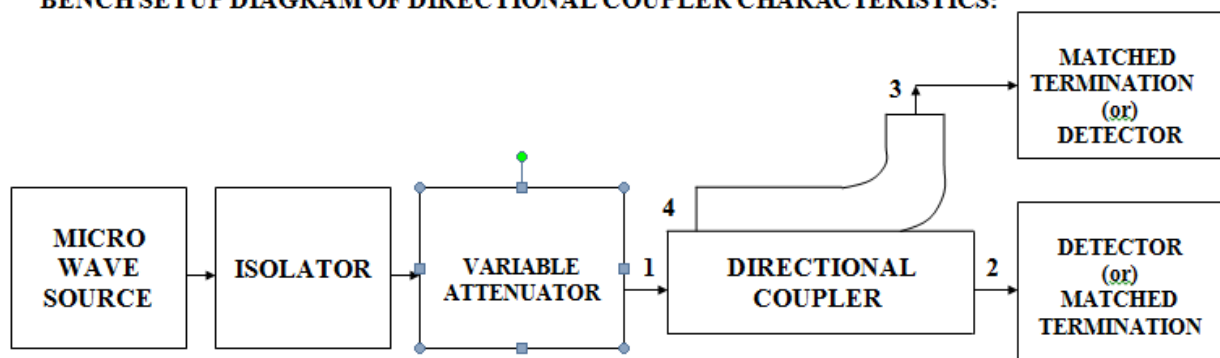
THEORY:

A directional coupler is a useful hybrid waveguide joint, which coules power in an auxiliary waveguide arm in one direction. It is a four-port device but one of the ports is terminated into a matched load. Ref figure 1.

Characteristics of a Directional Coupler
An ideal directional coupler has the following characteristics

i) If power is fed into port (1) the power is coupled in ports (2) and (3) i.e., power flows   in the forward direction of the auxiliary arm port (3) but no power couples in port (4)   i.e., in backward direction similarly power fed in (2) couples into ports (1) and (4) and   not in (3).

ii) All the four ports are matched, i.e. if three of them are terminated in matched loads, the fourth is automatically terminated in a matched load.

iii) If power couples in reverse direction, power fed in (1) appears in ports (2) and nothing in (3), then such type of coupler is known as backward directional coupler.

The conclusion is that in the auxiliary section the power is coupled in only one Direction.

PROCEDURE:

1. Connect the components and equipment as shown in fig. 2

2. Keep the control knob of klystron power supply as below:

Modulation selection: AM

Beam voltage knob: Fully anti-clockwise

Reflector voltage knob: Fully clockwise

Selector switch: Beam voltage

3. Keep the AM modulation control knob of amplitude &frequency at mid position.

4. Switch on the klystron power supply.

5. Now vary the Beam voltage knob to 280 V. Next change the selector knob to Beam

Current. Observe the BEAM CURRENT. [The beam current should not be more

than 20 mA].

6. Now change the selector switch to Reflector voltage position.

7. Now decrease the Reflector voltage to minimum position.

8. Now observe the square wave form in CRO by varying either reflector voltage or

adjusting the amplitude knob of AM.

9. Set the equipment by connecting detector mount to the input end (without directional coupler),
now measure the input Power(P1) i.e. P_i. Do not alter till the end of the experiment.

10. Now Insert the directional coupler connect the detector mount at port2, Terminate the port4 with matched termination. Now measure the Power at port 2 i.e. P2 or P_r(received power).

11. Then connect detector mount to port 4 terminate port 2 with matched termination. Now measures the power at port 4 i.e. P4 or P_f(forward power).

12. Connect the directional coupler in reverse direction. ie, port 2 – input, port 1 – matched termination, port 3 – detector mount. Now measure the power at port 3 i.e. P3 or P_b (backward power)

CALCULATIONS:

1) Coupling Factor (C) = 10 log (pi/pf) db=20 log (Vi/Vf) db

2) Directivity (D)= 10 log (pf/pb) db = 20 log (Vf/Vb) db

3) Isolation (I) =10 log (pi/pb) db = 20 log (Vi/Vb) db

4) Insertion loss (L)=10 log (pi/pr) db = 20 log (Vi/Vr) db

RESULT: The performance characteristics of directional coupler were determined.

Viva Questions

 1) What is the primary purpose of a directional coupler?

2) How far apart are the two holes in a simple directional coupler?

3) What is the purpose of the absorbent material in a directional coupler?

4) In a directional coupler that is designed to sample the incident energy, what happens to the two portions of the wave front when they arrive at the pickup probe?

5) What happens to reflected energy that enters a directional coupler that is designed to sample incident energy?

6) What is directional coupler?

7) How many ports does it have?

8) What is the difference between dc to magic tee?

9) What is Directivity?

10) What is Insertion Loss?

11) What is Coupling Factor?

12) What is the relation between coupling factor and insertion loss?

PART B

EXPERIMENTS

7. A) S - MATRIX CHARACTERIZATION OF E-Plane Tee and H-Plane Tee

AIM: To Measure the power division in the E-Plane Tee, H-Plane Tee and Magic Tee.

EQUIPMENTS REQUIRED:

> Klystron power supply
>
> Klystron Tube
>
> Klystron Mount
>
> Isolator
>
> Frequency Meter
>
> Variable Attenuator
>
> Slotted section
>
> Detector Mount
>
> Wave guide Stands
>
> VSWR Meter
>
> BNC Cable
>
> CRO
>
> H-Plane Tee
>
> E-Plane Tee

GENERAL EXPERIMENTAL SETUP:
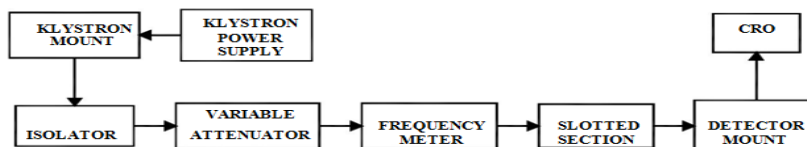
H-PLANE TEE:
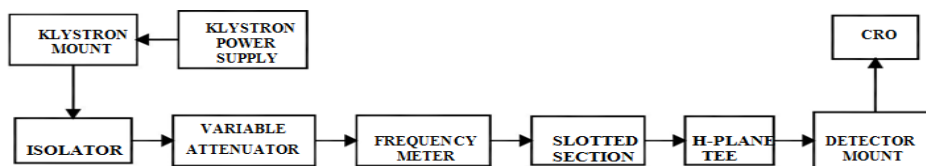
TABULATION:

PORT1	PORT2	PORT 3

E-PLANE TEE:
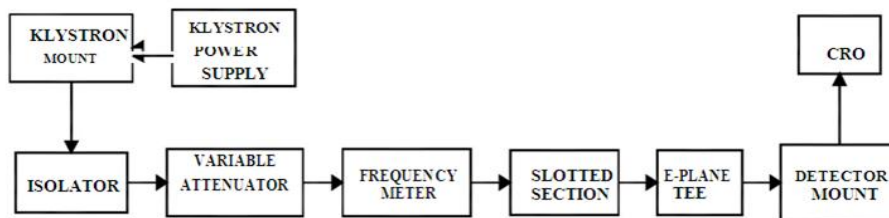
PROCEDURE:

1. Connect the components and equipment as shown in fig. 2
2. Keep the control knob of klystron power supply as below:

        Modulation selection   : AM

        Beam voltage knob   : Fully anti-clockwise

        Reflector voltage knob   : Fully clockwise

        Selector switch   : Beam voltage

3. Keep the AM modulation control knob of amplitude &frequency at mid Position.

4. Switch on the klystron power supply.

5. Now vary the Beam voltage knob to 295V. Next change the selector knob to Beam Current. Observe the BEAM CURRENT

6. Now change the selector switch to Reflector voltage position.

7. Now decrease the Reflector voltage to minimum position.

8. Now observe the square wave form in CRO by varying either reflector voltage or adjusting the amplitude knob of AM.

9. Connect the slotted section output to detector mount , now measure the power (or) Voltage using CRO (or) power meter

10. Now remove the detector mount from slotted section connect the H Plane Tee Port1 to slotted section. Terminate the Port 3, with matched termination. Now measure the power or voltage at Port 2 (P2) using CRO (or) power meter.

11. Then remove the detector mount from Port 2, and connect to port 3, terminate the Port 2, with matched termination. Now measure the power or voltage at Port 3(P3) using CRO meter

TABULATION:

P1 dB	P2 dB	P3 dB

RESULT:

Viva Questions

1) What are the two basic types of T junctions?

2) Why is the H-type T junction so named?

3) The magic-T is composed of what two basic types of T junctions?

4) What are the primary disadvantages of the magic-T?

5) What type of junctions are formed where the arms of a hybrid ring meet the main ring?

6) Hybrid rings are used primarily for what purpose?

7. B) S – MATRIX CHARACTERIZATION OF MAGIC TEE

AIM: To Measure Isolation between E and Harms of the magic tee & Demonstrate 3dB Power Division in side arm the magic tee.

EQUIPMENTS REQUIRED:

- Klystron power supply
- Klystron Tube
- Klystron Mount
- Isolator
- Frequency Meter
- Variable Attenuator
- Slotted section
- Detector Mount
- Wave guide Stands
- VSWR Meter
- BNC Cable
- CRO
- Magic Tee

EXPERIMENTAL SETUP:
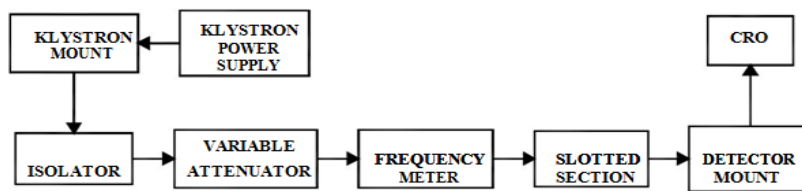
Fig 1: For Input Power Measurement
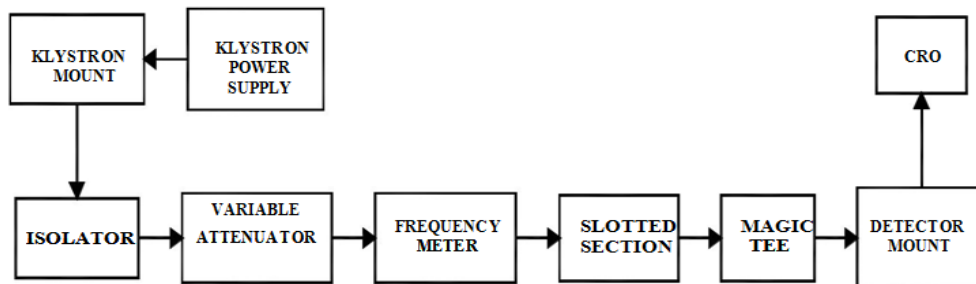
Fig 2: For Coupled /Isolated Power Measurement

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PROCEDURE:

1. Connect the components and equipment as shown in fig. 2
2. Keep the control knob of klystron power supply as below:

Modulation selection	: AM
Beam voltage knob	: Fully anti-clockwise
Reflector voltage knob	: Fully clockwise
Selector switch	: Beam voltage

3. Keep the AM modulation control knob of amplitude &frequency at
   mid position.

4. Switch on the klystron power supply.
5. Now vary the Beam voltage knob to 295V. Next change the selector knob to Beam
   Current. Observe the BEAM CURRENT. [The beam current should not be more than
   30 m amps].
6. Now change the selector switch to Reflector voltage position.
7. Now decrease the Reflector voltage to minimum position.
8. Now observe the square wave form in CRO by varying either reflector voltage or
    adjusting the amplitude knob of AM.
9. Connect the slotted section output to detector mount now measure the power from the
    Detector mount P1 (or) voltage using CRO or power meter. Remove the detector mount
    from the slotted section then connect the magic tee collinear arm 1 to slotted section
    output connect the detector mount to collinear arm 2.
10. Terminate the port 4 and port 3 with matched termination. Now measure the power or

    Voltage at port 2 using CRO or power meter.

11. Now remove the detector mount from the collinear arm 2 connect the detector
     Mount to port 3 terminate the collinear arm 2 and port 4 with matched termination.

     Now measure the power or voltage at port 3(P3) using CRO or power meter.

12. Now remove the detector mount from the port3, and connect to port 4 then
     terminate the collinear arm and port 3, with matched termination. Now measure
     the power (or) voltage port (P4) using CRO or power meter.

FORMULA:

$$Coupling\,(dB) = -10 \log \frac{P_1}{P_3} = -10 \log \frac{P_2}{P_3}$$

$$Isolation\,(dB) = -10 \log \frac{P_3}{P_4}$$

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RESULT:

Viva Questions

1) What are the two basic types of T junctions?

2) Why is the H-type T junction so named?

3) The magic-T is composed of what two basic types of T junctions?

4) What are the primary disadvantages of the magic-T?

5) What is magic tee?

6) How many ports does it have?

7) Difference between magic tee to directional coupler?

8) What is magic behind this?

9) A magic tee is nothing but a modification of.....................

10) What are the applications of magic T

8. S-PARAMETERS OF CIRCULATOR

AIM: To find the S-parameters and characteristics of circulator.

EQUIPMENT:

    1. Microwave source (klystron power supply)

    2. Klystron Mount

    3. Isolator

    4. Variable Attenuator

    5. Frequency meter

    6. Circulator

    7. Power Detector

    8. Matched termination ----- 1 No

TEST SETUP:

Gunn / Klystron	Reflex Klystron	Isolator	Variable attenuator	Frequency Meter	circulator	waveguide	Output meter

Matched Termination
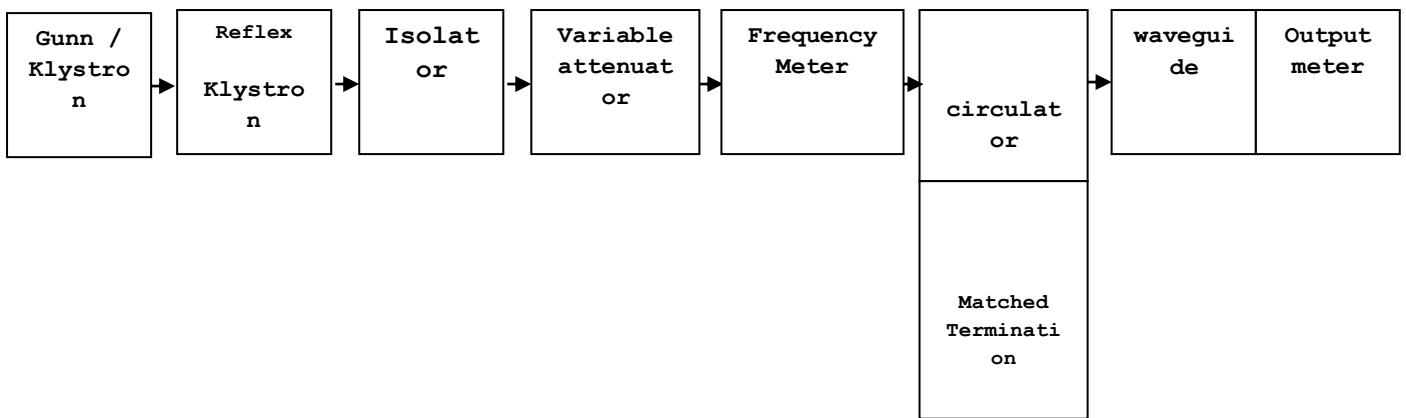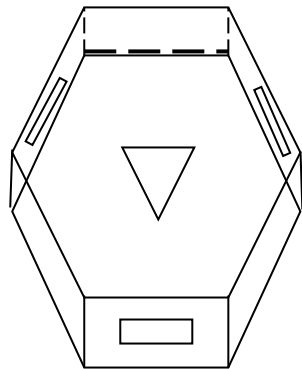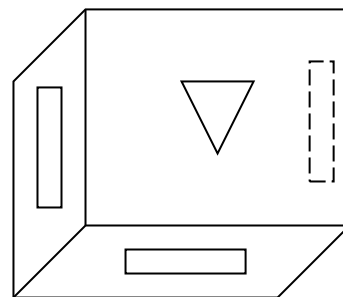
Circulators:

        Y – Type   **T – Type**

$$[S] = \begin{pmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

PROCEDURE:

1. Arrange the bench setup without connecting circulator and measure the input power.

2. Now connect the circulator and note down the output power at port 2 & port 3.

3. Substitute the values to estimate the S – matrix of circulator.

Measurement of insertion loss:

4. Remove the circulator from slotted line and connect the detector mount to the slotted section. The output of the detector mount should be connected with CRO.

5. Set any reference level of output in CRO with the help of variable attenuator, Let it be V1.

6. Carefully remove the detector mount from slotted line without disturbing the position of set up. Insert the circulator between slotted line and detector mount. Keep input port to slotted line and detector its output port. A matched termination should be placed at third port.

7. Record the output in CRO, Let it be V2.

8. Compute Insertion loss given as V1-V2 in db.

Measurement of Isolation:

9. The circulator has to be connected in reverse i.e. output port to slotted line and detector to input port with other port terminated by matched termination.

10. Record the output in CRO. Let it be V3.

11. Compute Isolation as V1-V3 in db.

12. The same experiment can be done for other ports of circulator.

RESULT: The S-parameters and performance characteristics of circulator were determined.

Viva Questions

1. _____ is a three-port microwave device that can be lossless and matched at all spots.
2. The total number of ones in the scattering matrix of an ideal circulator is............
3. In the scattering matrix representation of a non-ideal circulator, the diagonal elements of the matrix are....................
4. Practically, opposite circulatory in a ferrite circulator can be obtained by.....................
5. What is a common mechanical analog of ferrimagnetic resonance?
6. What explains nonreciprocal action in ferrites?
7. What explains nonreciprocal action in semiconductors?
8. What are ferrites?
9. In which resonance region do most waveguide circulators operate?
10. Which type of circulator typically has the highest power handling capability?

11. What is the primary difference between a circulator and an isolator?
12. How important is the microwave transmission medium (waveguide, stripline, coaxial line) in ferrite selection?
13. What is the primary characteristic of a circulator?

II. Introduction to HFSS

what is HFSS?

HFSS is a high-performance full-wave electromagnetic(EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained.

Ansoft HFSS employs the Finite Element Method(FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

Typical uses include:

- Package Modeling – BGA, QFP, Flip-Chip
- PCB Board Modeling – Power/Ground planes, Mesh Grid Grounds, Backplanes.
- Silicon/GaAs - Spiral Inductors, Transformers
- EMC/EMI – Shield Enclosures, Coupling, Near- or Far-Field Radiation
- Antennas/Mobile Communications – Patches, Dipoles, Horns, Con formal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate(SAR), Infinite Arrays, Radar Cross Section(RCS), Frequency Selective Surfaces(FSS)
- Connectors – Coax, SFP/XFP, Backplane, Transitions
- Wave guide – Filters, Resonators, Transitions, Couplers
- Filters – Cavity Filters, Microstrip, Dielectric
- HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques.
- The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method(FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos-Pade Sweep(ALPS). Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full-Wave Spice™.

● Ansoft HFSS has evolved over a period of years with input from many users and industries.

● In industry, Ansoft HFSS is the tool of choice for high-productivity research, development, and virtual prototyping.

System Requirements

● Microsoft Windows XP(32/64), Windows 7 or above Server. For upto-date information, refer to the HFSS Release Notes.

● Pentium –based computer

● 128MB RAM minimum

● 8MB Video Card minimum

● Mouse or other pointing device

● CD-ROM drive

Starting Ansoft HFSS

1. Click the Microsoft Start button, select Programs, and select the Ansoft, HFSS 15.

program group. Click HFSS 15.

2.   Or Double click on the HFSS 15 icon on the Windows Desktop
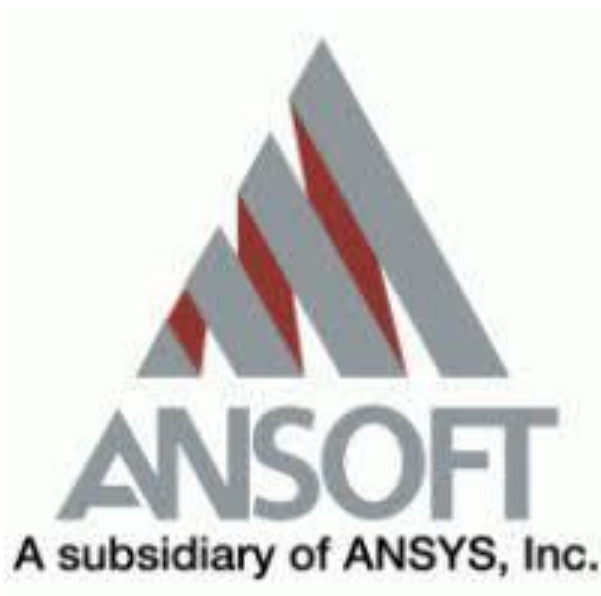
Getting Help:

If you have any questions while you are using Ansoft HFSS you can find answers in several ways:

i.   Ansoft HFSS Online Help provides assistance while you are working.

ii. To get help about a specific, active dialog box, click the Help button in the dialog box or press the F1 key.

iii. Select the menu itemHelp > Contents to access the online help system.

iv. Tooltips are available to provide information about tools on the toolbars or dialog boxes. When you hold the pointer over a tool for a brief time, a tooltip appears to display the name of the tool.

v.   As you move the pointer over a tool or click a menu item, the Status Bar at the bottom of the Ansoft HFSS window provides a brief description of the function of the tool or menu item.

vi. The Ansoft HFSS Getting Started guide provides detailed information about using HFSS to create and solve 3D EM projects.

Ansoft Technical Support:

I.   To contact Ansoft technical support staff in your geographical area, please log on to the Ansoft corporate website, www.ansoft.com and select Contact.

II. Your Ansoft sales engineer may also be contacted in order to obtain this information.

Ansoft Terms

The Ansoft HFSS window has several optional panels:

● A Project Manager which contains a design tree which lists the structure of the project.

● A Message Manager that allows you to view any errors or warnings that occur before you begin a simulation.

● A Property Window that displays and allows you to change model parameters or attributes.

● A Progress Window that displays solution progress.

● A 3D Modeler Window which contains the model and model tree for the active design.

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Menu bar → Toolbars → 3D Modeler Window

Project Manager with project tree

Message Manager

Status bar

Coordinate Entry Fields

Property Window

Progress Window

Project Manager:

Project Manager Window

Project

Design

Design Setup

Design Automation
•Parametric
•Optimization
•Sensitivity
•Statistical

Design Results
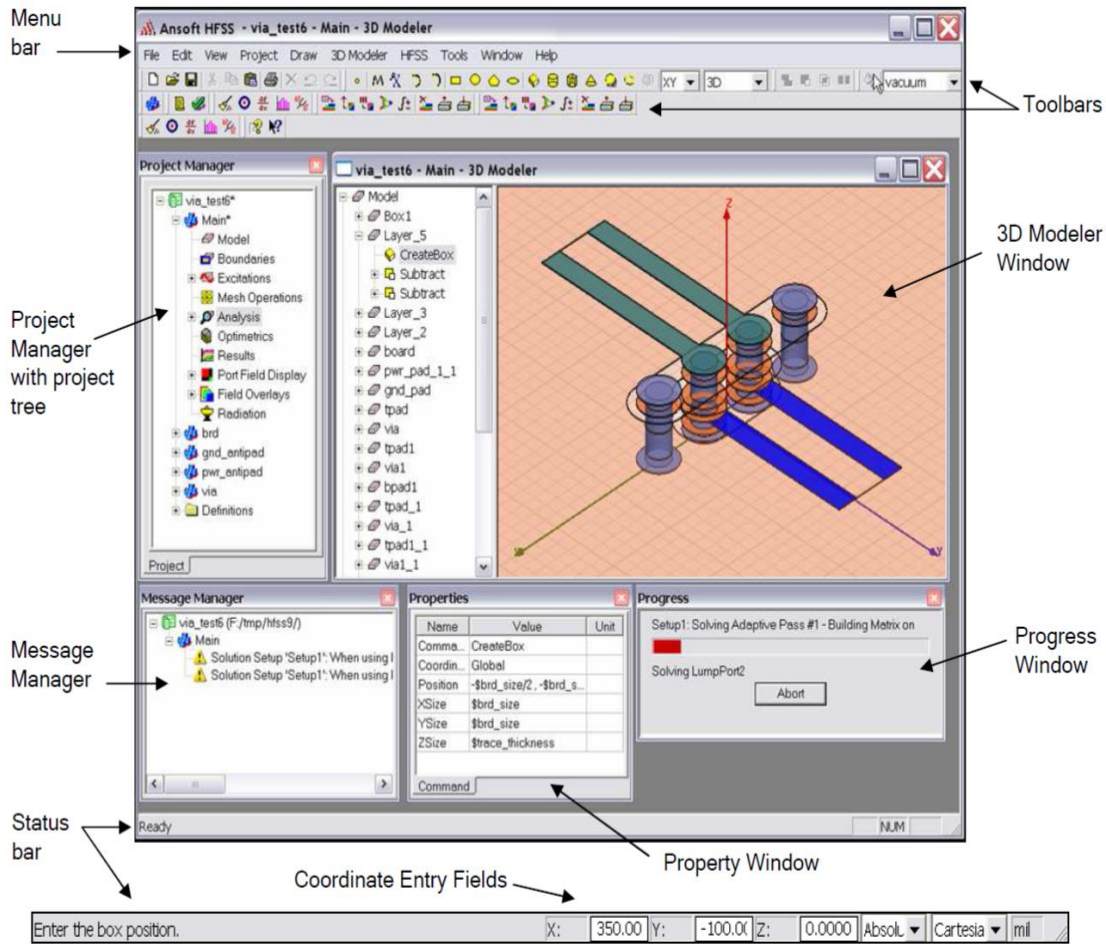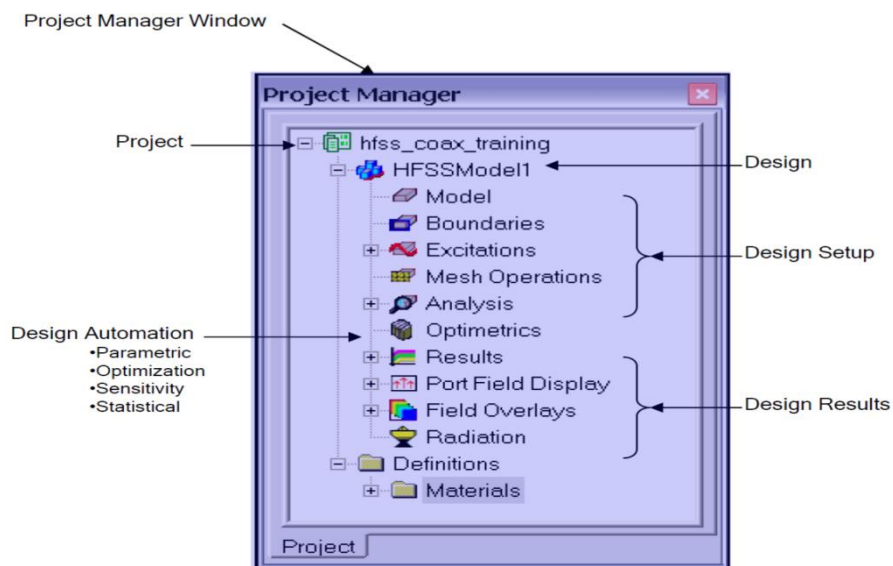
Property Window:
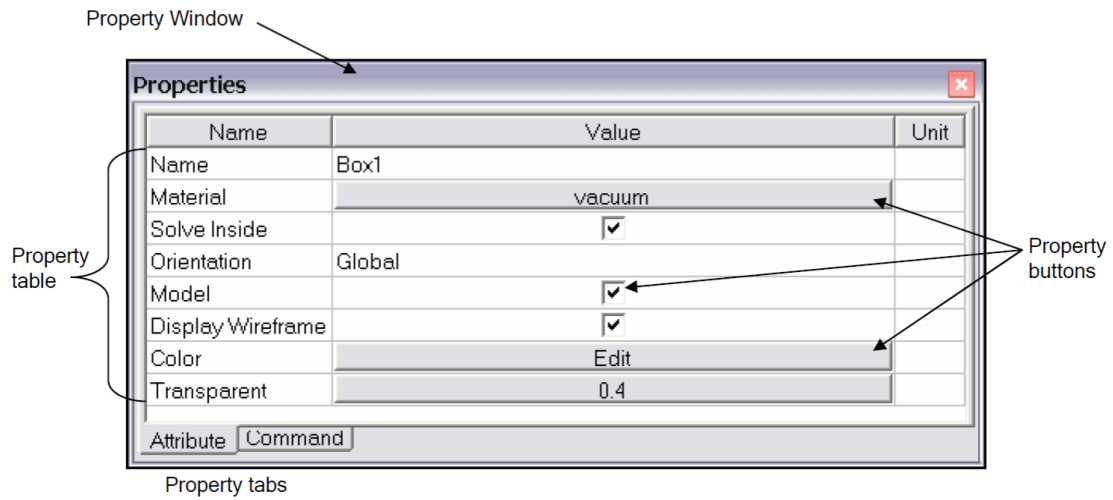
Ansoft 3D Modeler:

3D Modeler Design Tree:

Grouped by Material

Object View
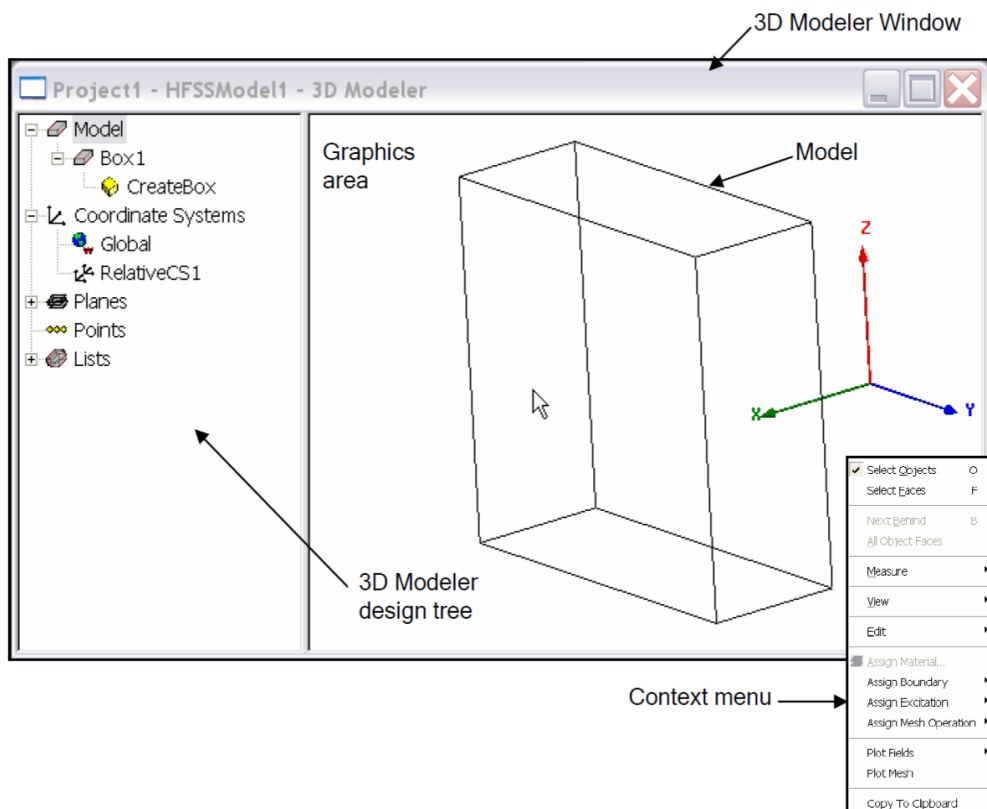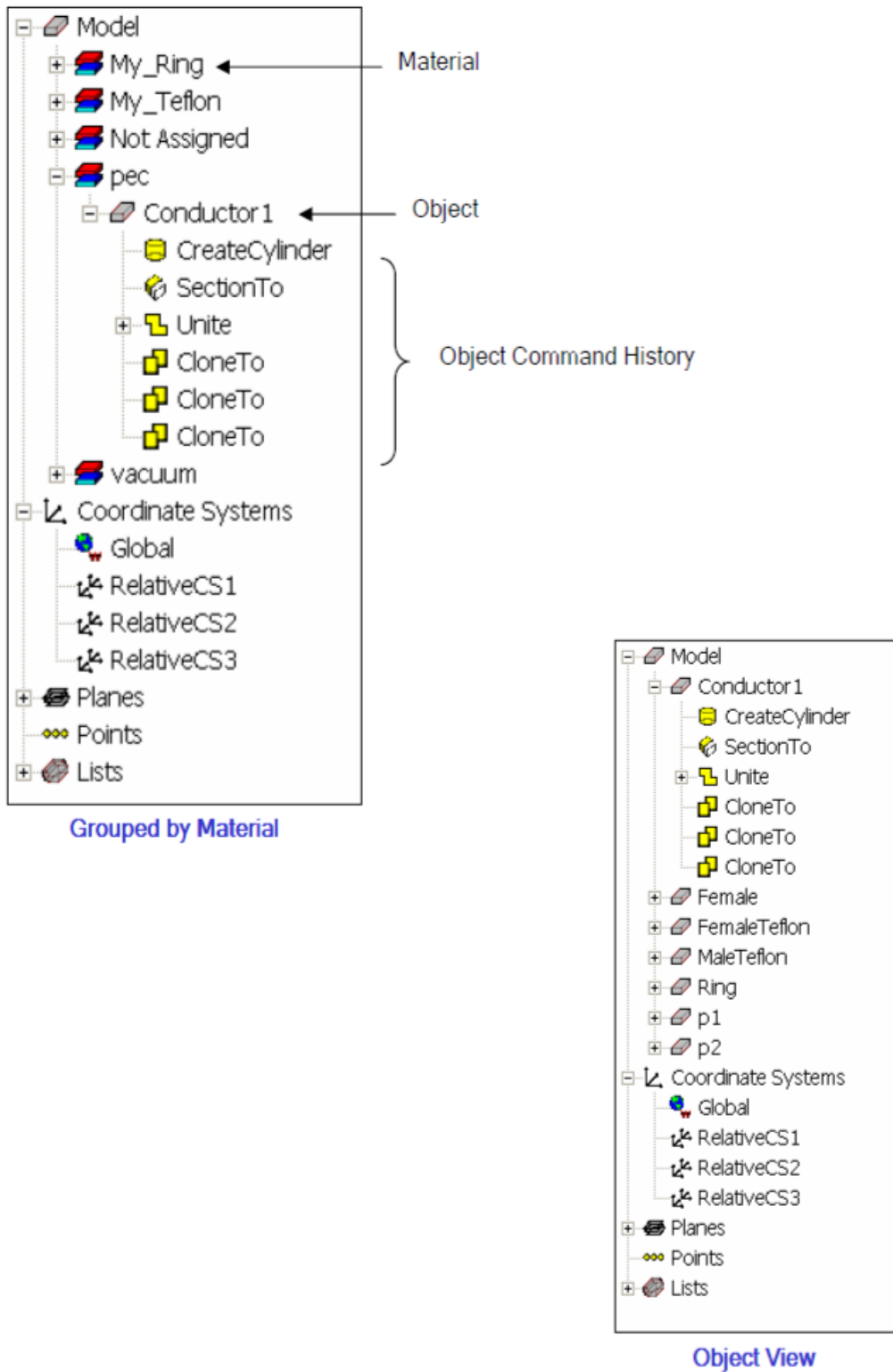
Design Windows

i. In the Ansoft HFSS Desktop, each project can have multiple designs and each design is displayed in a separate window.

ii. You can have multiple projects and design windows open at the same time.

iii. Also, you can have multiple views of the same design visible at the same time.

iv. To arrange the windows, you can drag them by the title bar, and resize them by dragging a corner or border. Also, you can select one of the following menu options:

v. Window >Cascade, Window >Tile Vertically, or Window > Tile Horizontally.

vi. To organize your Ansoft HFSS window, you can iconize open designs. Click the Iconize ** symbol in the upper right corner of the document border.

vii. An icon appears in the lower part of the Ansoft HFSS window. If the icon is not visible, it may be behind another open document. Resize any open documents as necessary.

viii. Select the menu item Window > Arrange Icons to arrange them at

the bottom of the Ansoft HFSS window.

ix. Select the menu item Window > Close All to close all open design. You are prompted to Save unsaved designs.

Toolbars:

The toolbar buttons are shortcuts for frequently used commands. Most of the available toolbars are displayed in this illustration of the Ansoft HFSS initial screen, but your Ansoft HFSS window probably will not be arranged this way.

You can customize your toolbar display in a way that is convenient for you.

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To display or hide individual toolbars:

i.   Right-click the Ansoft HFSS window frame.

ii. A list of all the toolbars is displayed. The toolbars with a check mark

iii. beside them are visible; the toolbars without a check mark are hidden.

iv. Click the toolbar name to turn its display on or off

v. To make changes to the toolbars, select the menu item **Tools > Customize.**

vi. See Customize and Arrange Toolbars on the next page.

Ansoft HFSS Desktop:

The Ansoft HFSS Desktop provides an intuitive, easy-to-use interface for

developing passive RF device models. Creating designs, involves the following:

1. Parametric Model Generation – creating the geometry, boundaries and

Excitations.

2. Analysis Setup – defining solution setup and frequency sweeps

3. Results – creating 2D reports and field plots

4. Solve Loop - the solution process is fully automated

To understand how these processes co-exist, examine the illustration shown below.
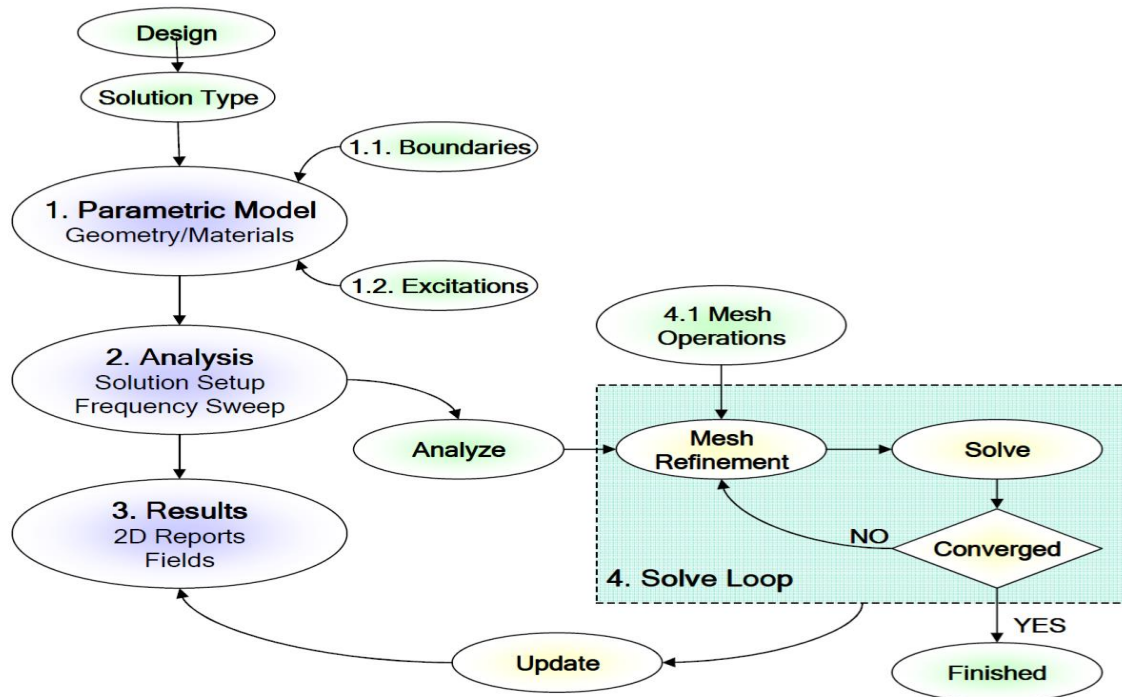
Opening a HFSS project:

This section describes how to open a new or existing project. Opening a New project

To open a new project:

1. In an Ansoft HFSS window, select the menu item File > New.

2. Select the menu Project > Insert HFSS Design.

Opening an Existing HFSS project

To open an existing project:

1. In an Ansoft HFSS window,select the menu File > Open.

Use the Open dialog to select the project.

2. Click Open to open the project

Opening an Existing Project from Explorer:

You can open a project directly from the Microsoft Windows Explorer.

1.   To open a project from Windows Explorer, do one of the following:

2.   Double-click on the name of the project in Windows Explorer.

3. Right-click the name of the project in Windows Explorer and select

4. Open from the shortcut menu.
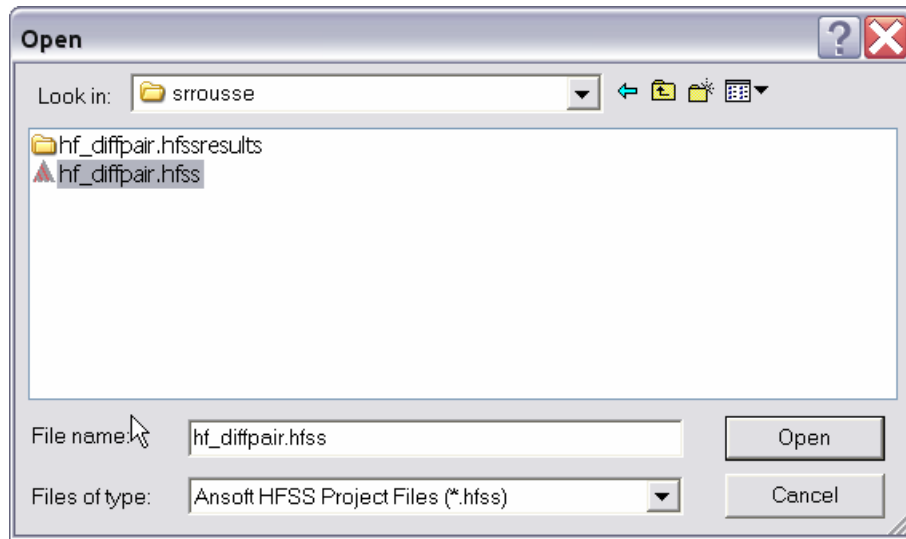
Set Solution Type

This section describes how to set the Solution Type. The Solution Type defines the type of results, how the excitations are defined, and the convergence. The following Solution Types are available:

1. Driven Modal - calculates the modal-based S-parameters. The S-matrix solutions will be expressed in terms of the incident and reflected powers of waveguide modes.

2. Driven Terminal - calculates the terminal-based S-parameters of

    transmission line ports. The S-matrix solutions will be expressed

    in terms of terminal voltages and currents.

3.Eignemode – calculate the eigenmodes, or resonances, of a structure. The Eigenmode solver finds the resonant frequencies of the structure and the fields at those resonant frequencies.

Convergence

Driven Modal – Delta S for modal S-Parameters. This was the only convergence method available for Driven Solutions in previous versions.

Driven Terminal – Delta S for the single-ended or differential nodal SParameters.

Eigenmode - Delta F
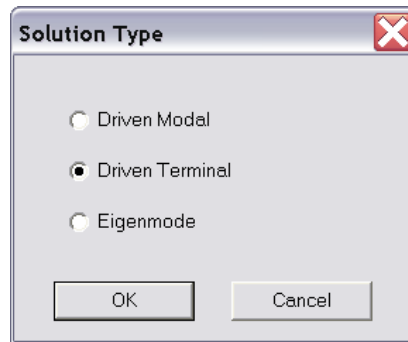
To set the solution type:

1. Select the menu item HFSS > Solution Type

2. Solution Type Window:

3. Choose one of the following:

a)   Driven Modal
b)   Driven Terminal
c)   Eigenmode
5.   Click the OK button.

Parametric Model Creation

●   The Ansoft HFSS 3D Modeler is designed for ease of use and flexibility. The power of the 3D Modeler is in its unique ability to create fully parametric designs without editing complex macros/model history.

●   The purpose of this chapter is to provide an overview of the 3D Modeling capabilities. By understanding the basic concepts outlined here you will be able to quickly take advantage of the full feature set offered by the 3D Parametric Modeler.

Overview of the 3D Modeler User Interface

The following picture shows the 3D Modeler window.

- 3D Modeler Design Tree – The 3D Modeler Design Tree is an essential part of the user interface. From here you may access the structural elements in addition to any object dependencies and attributes.
- Context Menus – Context menus are a flexible way of accessing frequently used menu commands for the current context. The contents of these menus change dynamically and are available throughout the interface by clicking the right mouse button.
- Graphics Area – The graphics area is used to interact with the structural elements.
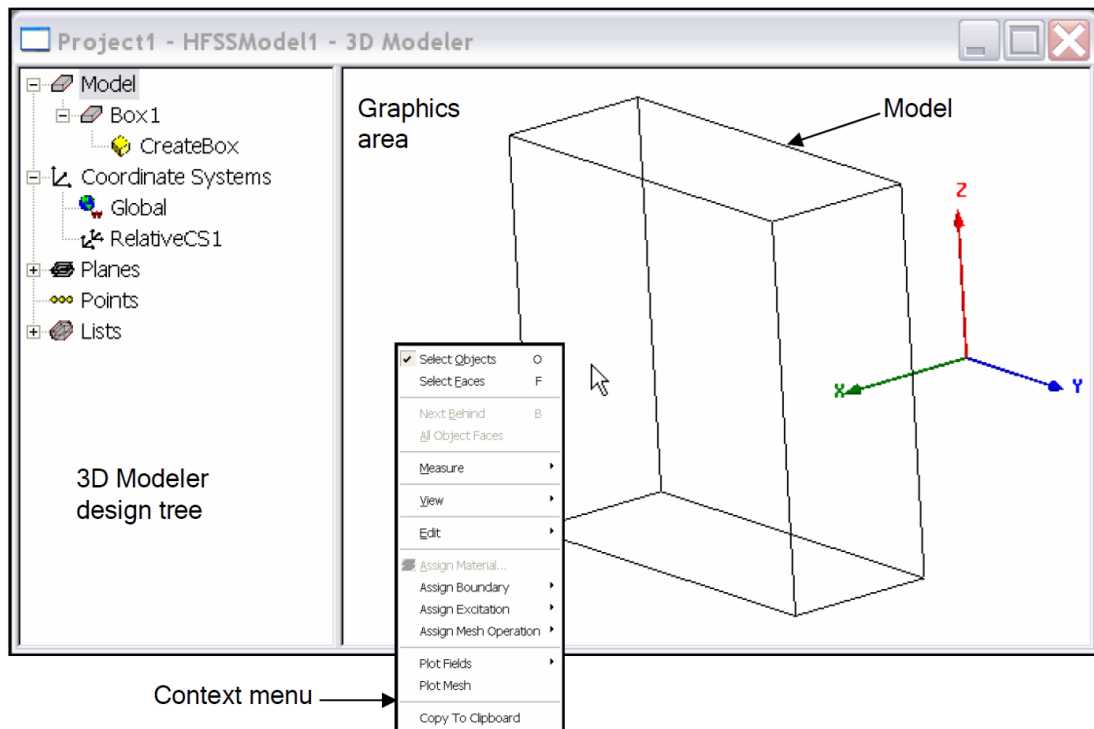
When using the 3D Modeler interface you will also interact with two additional interfaces:

Property Window – The Property Window is used to view or modify the attributes and dimensions of structural objects

Status Bar/Coordinate Entry – The Status Bar on the Ansoft HFSS Desktop Window displays the Coordinate Entry fields that can be used to define points or offsets during the creation of structural objects.
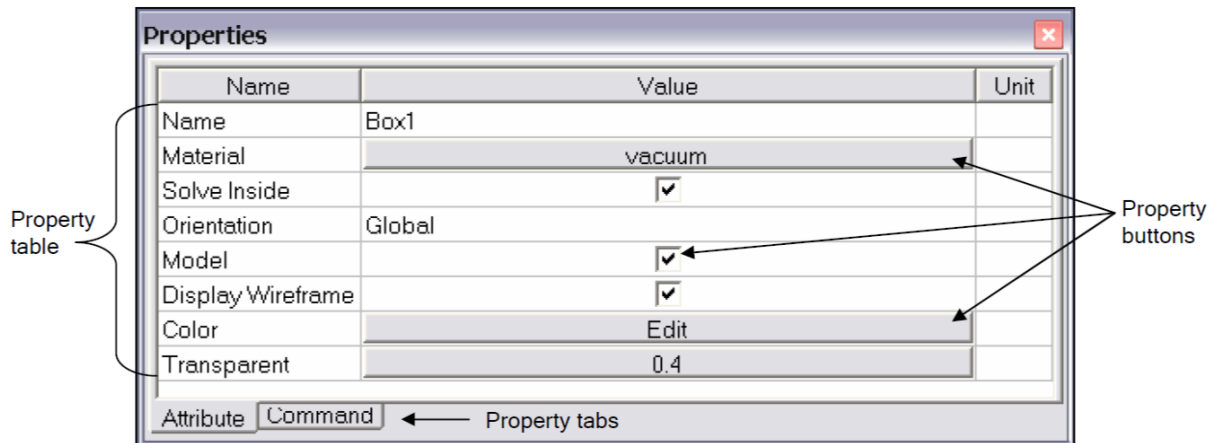
Grid Plane

- To simplify the creation of structural primitives, a grid or drawing plane is used.
- The drawing plane does not in any way limit the user to two dimensional coordinates but instead is used as a guide to simplify the creation of structural primitives. The drawing plane is represented by the active grid plane (The grid does not have to be visible). To demonstrate how drawing planes are used, review the following section: **Creating and Viewing Simple Structures**.

Active Cursor

- The active cursor refers to the cursor that is available during object creation. The cursor allows you to graphically change the current position. The position is displayed on the status bar of the Ansoft HFSS Desktop Window.
- When objects are not being constructed, the cursor remains passive and is set for dynamic selection. See the Overview of Selecting Objects for more details.

Creating and Viewing a Simple Structure

Creating 3D structural objects is accomplished by performing the following steps:

1. Set the grid plane

2. Create the base shape of the object

3. Set the Height

Create a Box

We will investigate creating a box to demonstrate these steps. These steps assume that project and a HFSS design have already been created. Thre points are required to create the box. The first two form the base rectangle and the third sets the height.

Point 1: Defines the start point of the base rectangle.

Point 2: Defines the size of the base rectangle.

Point 3: Defines the height of the Box.
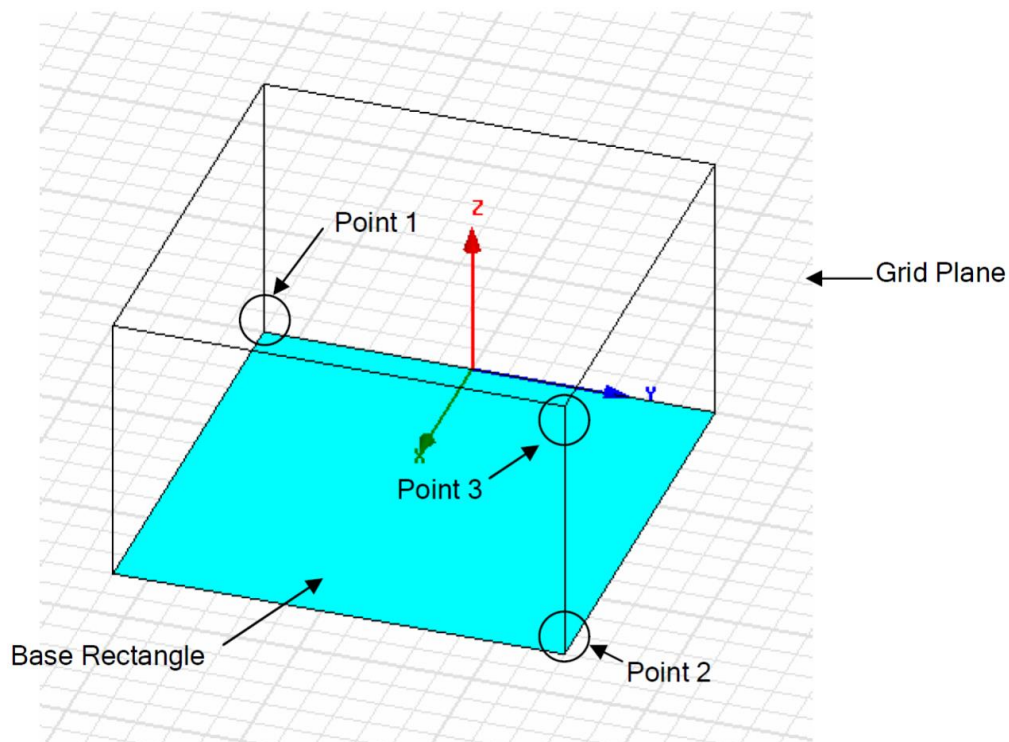
1. Select the menu item 3D Modeler > Grid Plane > XY

2. Use the mouse to create the base shape

a) Set the start point by positioning the active cursor and click the left
    mouse button.
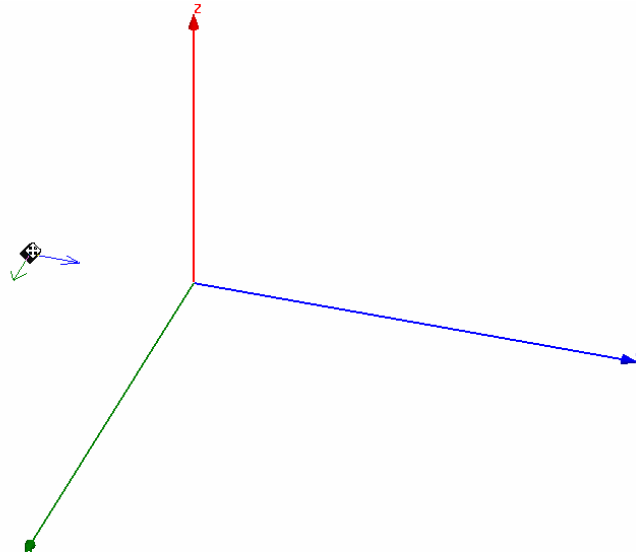
b)   Position the active cursor and click the left mouse button to set the second point that forms the base rectangle.
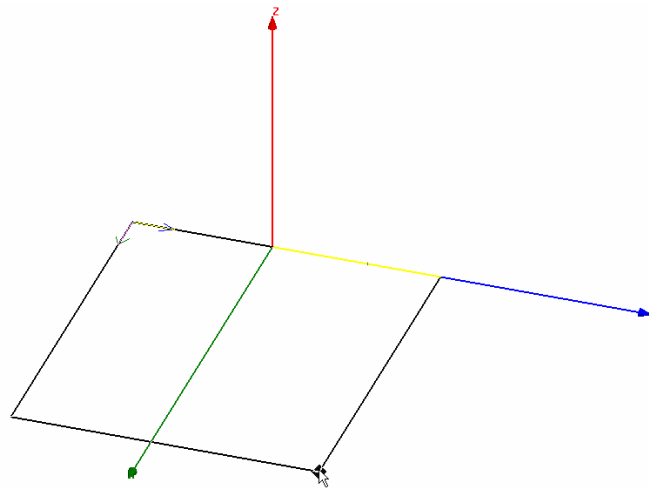
c)   Set the Height by positioning the active cursor and clicking left mouse button.
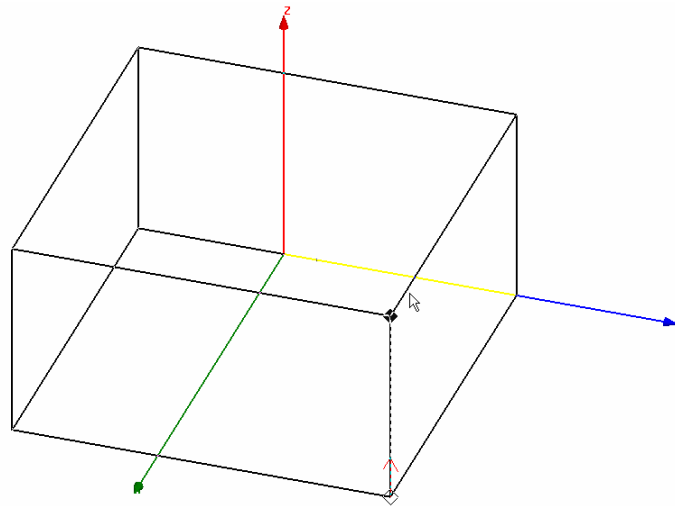
Specifying Points

Grid

- From the example, we saw that the simplest way to set a point is by clicking its position on the grid plane. To set the precision of the grid plane,select the menu item View > Grid Settings. From here you may specify the Grid Type, Style, Visibility, and Precision.

- By pressing the Save As Default button, you can set the default behavior for future HFSS Designs.

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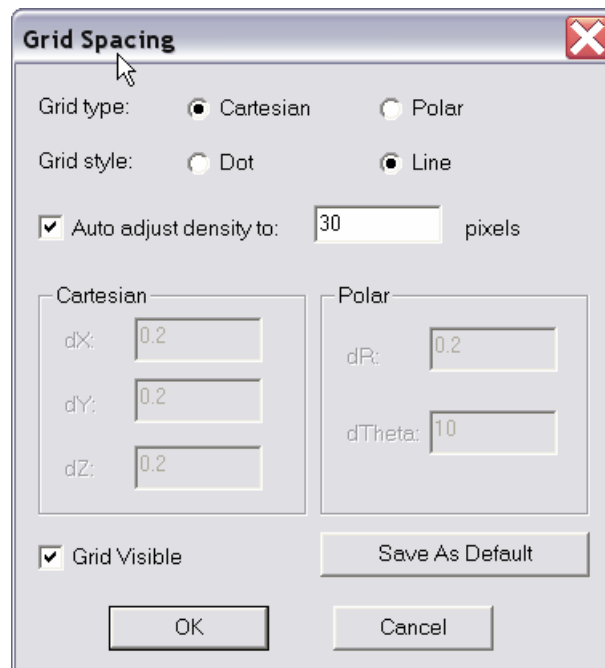
Coordinate Entry

Another way to specify a coordinate is to use the Coordinate Entry fields which are located on the status bar of the Ansoft HFSS Desktop. The position may be specified in Cartesian, Cylindrical, or Spherical coordinates. Once the first point is set, the Coordinate Entry will default to Relative coordinates. In Relative mode the coordinates are no longer absolute (measured from the origin of the working coordinate system), but relative to the last point entered.

Equations

The Coordinate Entry fields allow equations to be entered for position values. Examples: 2*5, 2+6+8, 2*cos(10*(pi/180)). Variables are not allowed in the Coordinate Entry Field.

Note: Trig functions are in radians

Object Properties

By default the Properties dialog will appear after you have finished sketching an object. The position and size of objects can be modified from the dialog. This method allows you to create objects by clicking the estimated values using the mouse and then correcting the values in the final dialog.

The Property dialog accepts equations, variables, and units. See the Overview of Entering Parameters for more detail.

Every object has two types of properties

1.   Command – Defines the structural primitive
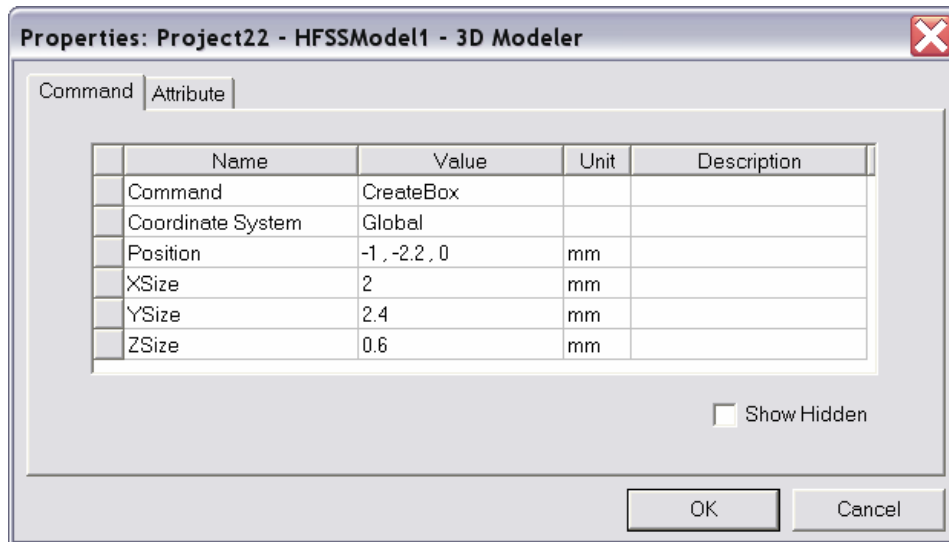
2.   Attributes – Defines the material, display, and solve properties
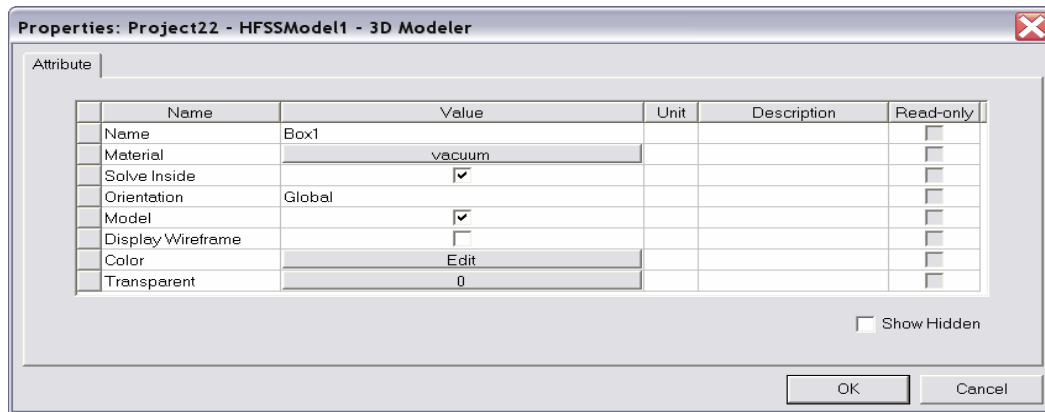
Overview of Draw

Primitives:

In solid modeling, the basic element or object is often called a primitive.

Examples of primitives are boxes, cylinders, rectangles, circles, etc. There are two types of primitives:

1.   3D primitives or solids
2.   2D primitives or surfaces.
● By placing a collection of primitives in the correct location and of the correct size we can create a represent complex structural objects.

- To create complex objects, primitives can be used as "tools" to cut holes, carve away, or join. The operations that are performed with these "tools" are often referred to as Boolean operations.
- 2D primitives can be swept to create arbitrarily shaped solid primitives.

2D Draw Objects:

The following 2D Draw objects are available:

a) Rectangle, Circle, Line, Point, Spline, Ellipse, Regular Polygon (v8.5 circle)

3D Draw Objects:

The following 3D Draw objects are available:

a) Box, Cylinder, Sphere, Torus, Helix, Bond Wire, Cone, Regular Polyhedron (v8.5 cylinder)

True Surfaces:

Circles, Cylinders, Spheres, etc are represented as true surfaces. In versions prior to release 9, these primitives would be represented as faceted objects. If you wish to use the faceted primitives (Cylinders or Circles), select the Regular Polyhedron or Regular Polygon. To control the mesh generation of true surfaces objects, see the section on Mesh Control.

Snap Mode:

As an aid for graphical selection, the modeler provides Snap options. The default is to snaps are shown here. The shape of the active cursor will dynamically change as the cursor is moved over the snap positions.

Moving:

By default all active cursor movement is in three dimensions. The modeler can also be set to allow the active cursor to only move in a plane or out of plane. These are set from the menu item 3D Modeler > Movement Mode. In addition, the movement can be limited to a specific direction (x, y, or z) by holding down the x, y, or z key. This prevents movement in the other directions.

Pressing the CTRL+Enter key sets a local reference point. This can be useful for creating geometry graphically that is based on an existing objects. This is outlined on the next page:
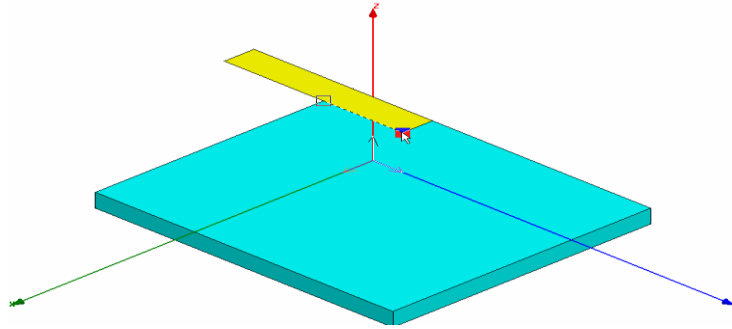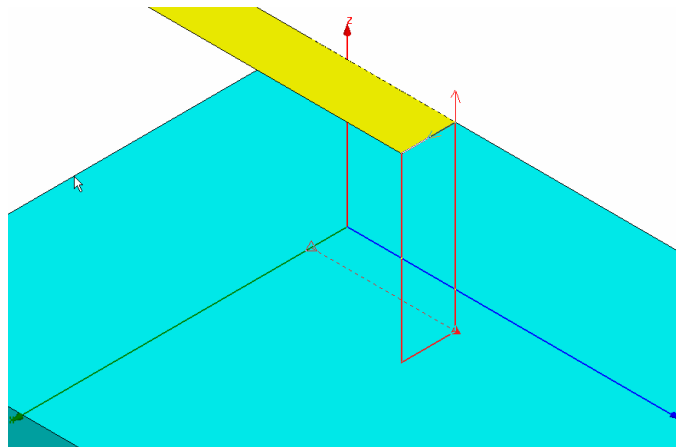

Step 1: Start Point
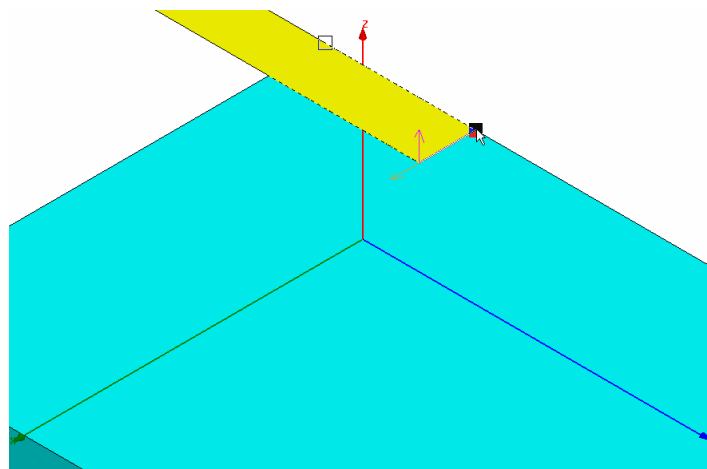
Step 2: Hold X key and select vertex point
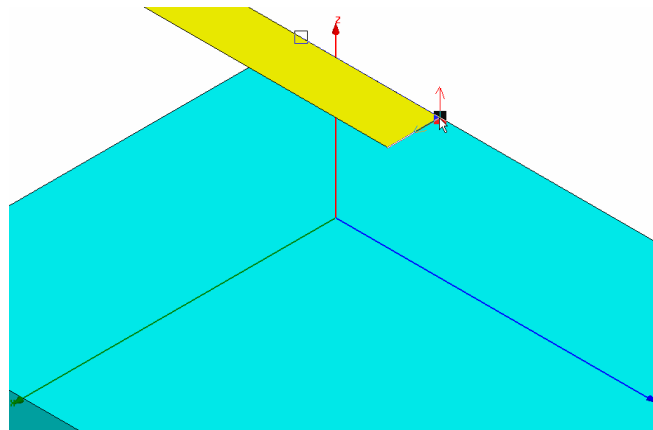
Step 3: CTRL+Enter Keys set a local reference.

Step 4: Hold Z key and set height. Overview of Draw:

Import:

In 3D modeler you can import a drawing file from outside.

Choose option 3D Modeler -> Import . Here is the list of import files that we support. For some of these import option you will need an add-on translator feature in your license file.

Healing:

Automated healing for imported solid models ,Post-translation user controlled healing

3D Model Analysis – 3D Modeler/Analyze:

Face, Object , Area analysis based on user inputs

List of problems (faces, edges, vertices)

a) Auto Zoom In into region where problem exists
b) Remove Face
c) Remove Edge
d) Remove Sliver
e) Remove Vertices

Selecting Previously Defined Shapes You may select an object by moving the mouse over the object in the graphics area and clicking on it. The default mode is Dynamic selection which will display the object to be selected with a unique outline color. Please note that after selecting (Clicking on the object) the object it will be displayed solid pink while all other objects are drawn transparent.

Types of Selection

The default is to select objects. Sometimes is necessary to select faces, edges, or vertices. To change the selection mode, select the menu item Edit > Select and choose the appropriate selection mode. The shortcut keys o (Object selection) and f (face selection) are useful for quickly switching between the most common selection modes.

Multiple Select or Toggle Selection

Multiple objects can be selected graphically by holding down the CTRL key while selecting. In addition, with the CTRL key pressed, the selection of an object can be toggled between selected or unselected.

Blocked Objects

If the object you wish to select is located behind another object, select the object that is blocking the desired object and press the b key or right-click and select Next Behind from the context menu. You may repeat this as many times as needed to select the correct object.Select All Visible You can select all visible objects by pressing the CTRL+a key or by selecting the menu item Edit > Select All Visible. Select by Name

To select objects by Name you can use anyone of the following:

● Select the menu item Edit > Select > By Name.
● Select the menu item HFSS > List.

- Select the Model tab.
- Select objects from the list.
- Use the Model Tree. See the next page.

Model Tree

After an object has been created, it is automatically added to the Model Tree. All objects can be found in the Model Tree. If you open the Model folder you will find the objects sorted by Object or by Material. You can toggle between the views by toggling the menu item 3D Modeler > Group Object by Material.

As stated previously, every object has two types of properties:

Attributes:

You may select an object by clicking on the corresponding item in the Model Tree.

When the object is selected the attributes will be displayed in the Property Window. Double-clicking on the object will open a properties dialog. Use the Property Window or properties dialog to modify the attributes.

Commands:

From the Model Tree, the Command Properties can be selected by expanding the object folder to display the command list. Using the mouse, select the corresponding command from the tree. The properties will be displayed in the Property Window. Double-clicking on the command will open a properties dialog. Use the Property Window or properties dialog to modify the command.

When the command is selected, the object will be outlined with bold lines in the 3D Model Window. Since an object can be a combination of several primitives, the command list may

contain several objects. Anyone of these commands can be selected to visualize or modify the object.
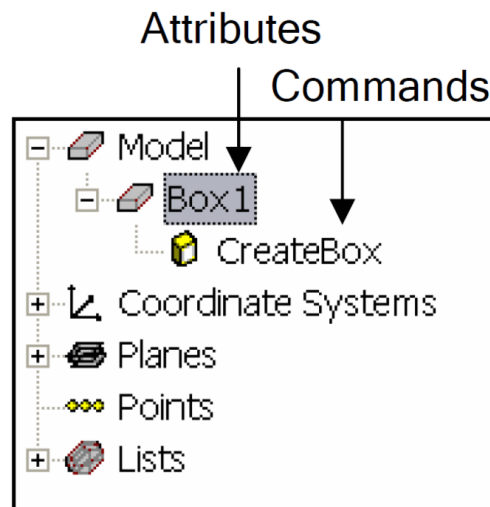
Model Tree:

Geometry in the 3D modeler is also grouped according to their model definition. Objects, Sheets, Lines, and Points are all separated so that they can be easily identified in the model tree.
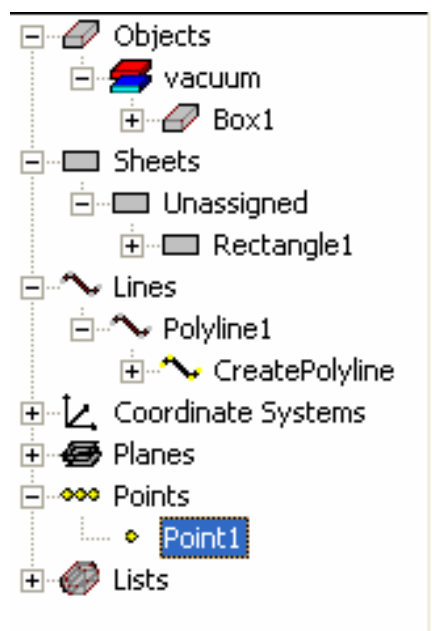
If a boundary condition or an excitation is defined on a sheet object, then those 2D objects will be further separated according to their assignment.
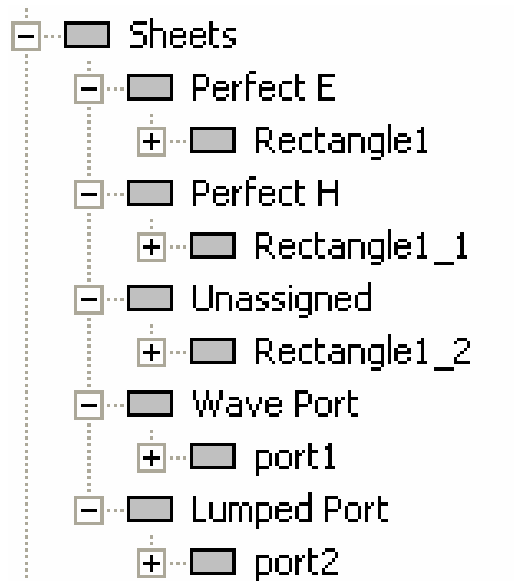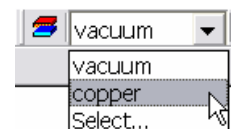

Object Attributes:

An objects attributes set the following user defined properties:

Name – User defined name. Default names start with the primitive type followed by an increasing number: Box1, Box2, etc.

Material – User defined material property. The default property is vacuum. This can be changed by using the material toolbar.

Solve Inside – By default HFSS only solves for fields inside

dielectrics. To force HFSS to solve inside conductors, check

solve inside.

Orientation

Model Object – Controls if the object is included in the solve

Display Wireframe – Forces the object to always be displayed as wireframe

Color – Set object color

Transparency – Set the transparency of an object. 0–Solid, 1-Wireframe

Note: Visibility is not an object property.

| Name	Value	Unit
Name	Box1	
Material	vacuum	
Solve Inside	☑	
Orientation	Global	
Model	☑	
Display Wireframe	☐	
Color	Edit	
Transparent	0	

Attribute
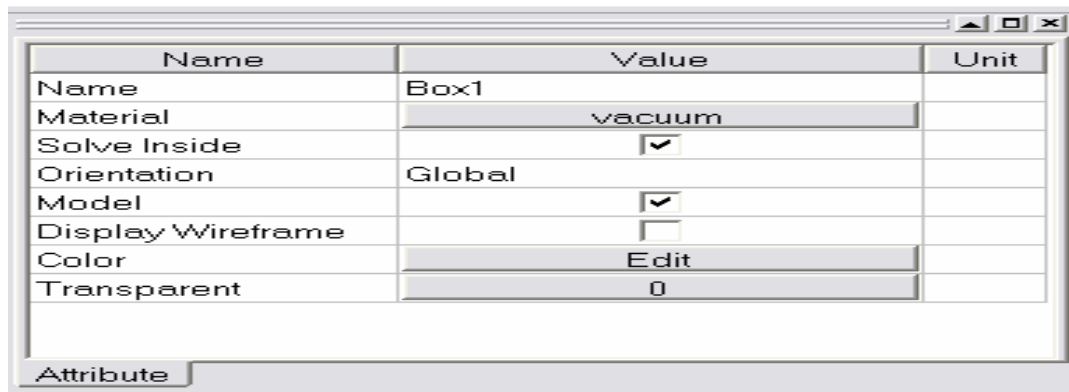
Materials

By clicking on the property button for the material name, the material definition window will appear. You can select from the existing database or define a custom project material.
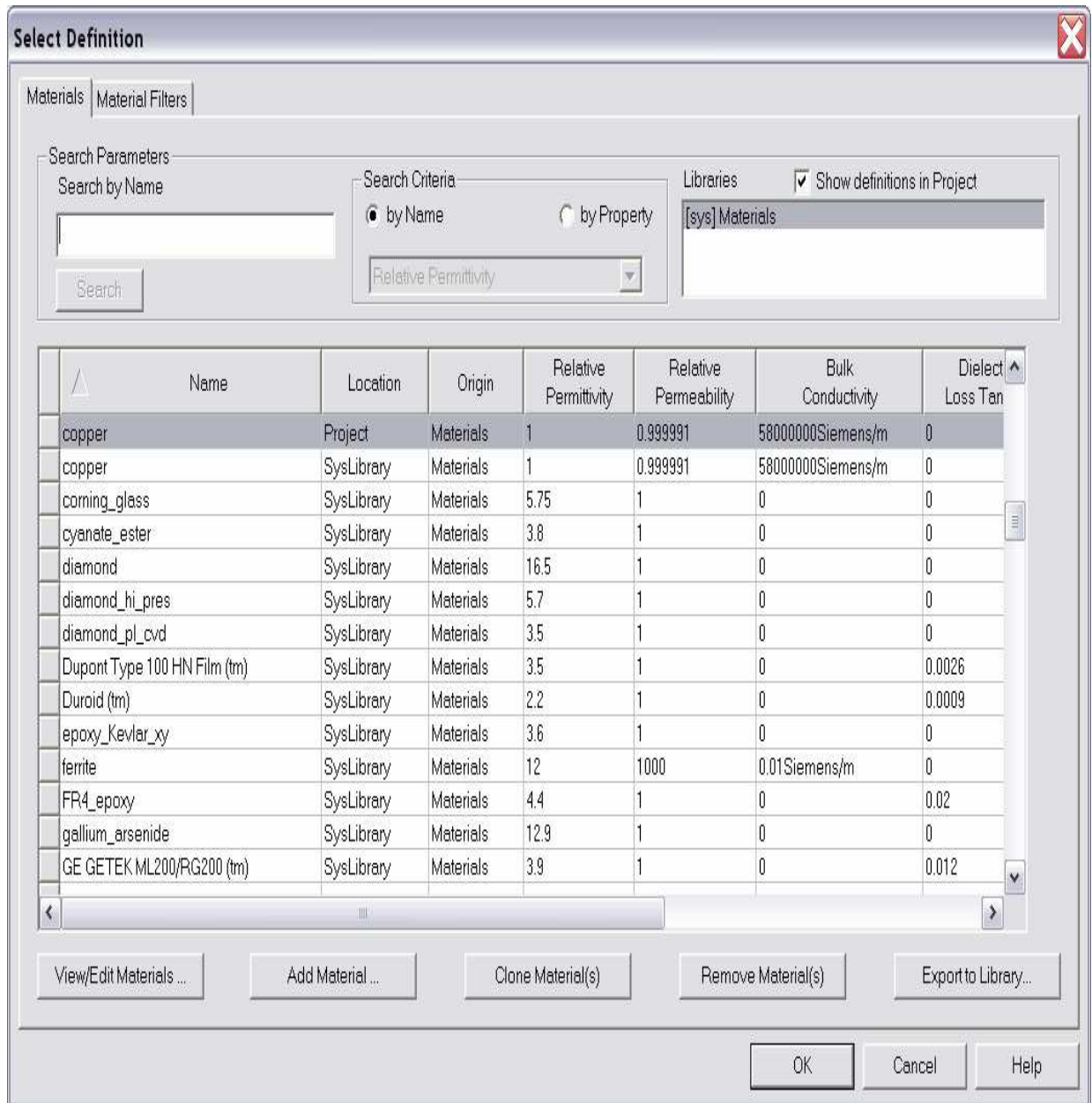
User Defined Project Material

To define a custom material click the Add Material button from the material definition window. The following dialog will appear. Enter the material definitions and click the OK button.
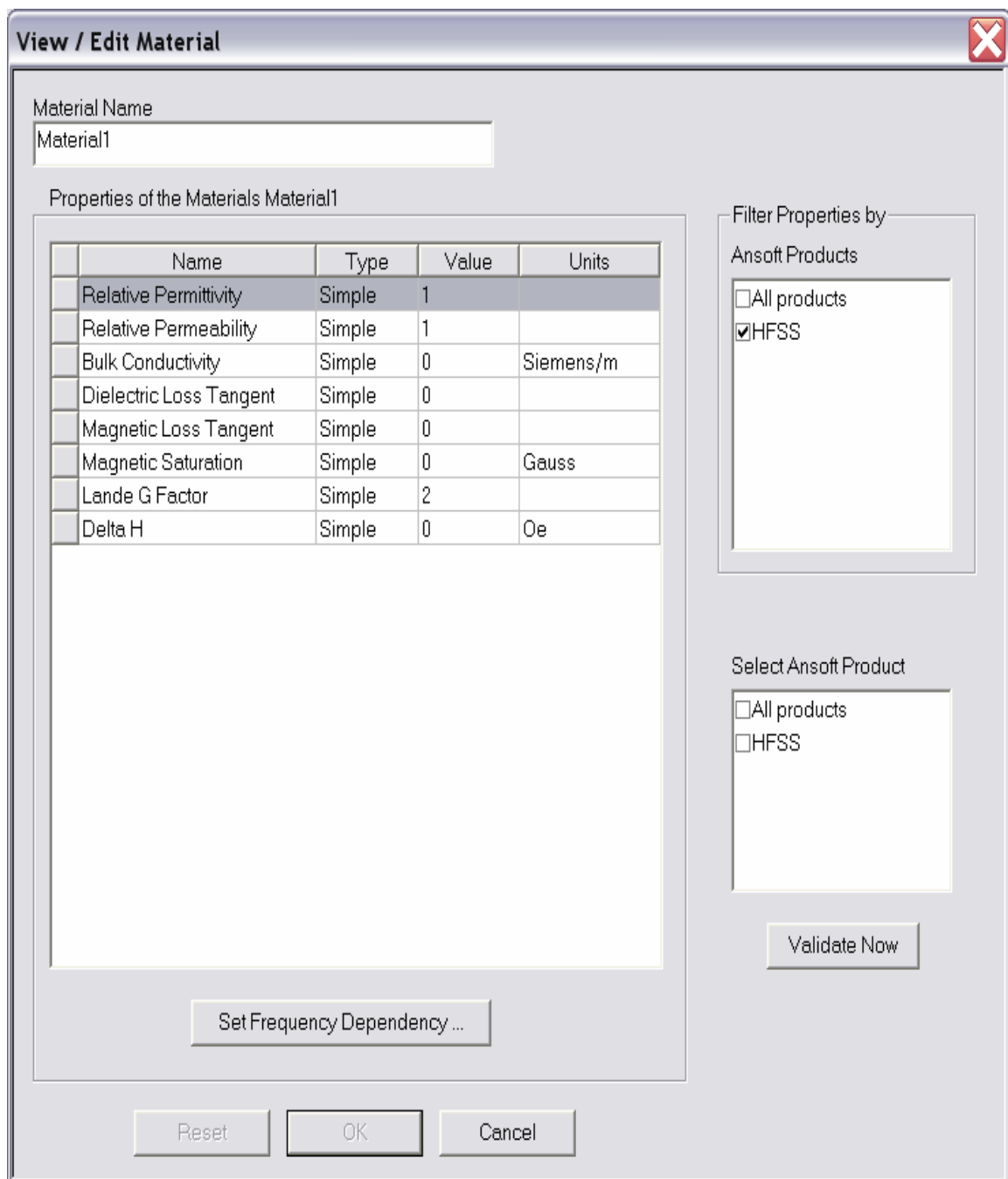
Changing the View

You can change the view at any time (even during shape generation) by using the following commands:

Toolbar

- Rotate – The structure will be rotated around the coordinate system

- Pan – The structure will be translated in the graphical area
- Dynamic Zoom – Moving the mouse upwards will increase the zoom factor while moving the mouse downwards will decrease the zoom factor
- Zoom In/Out – In this mode a rubber band rectangle will be defined by dragging the mouse. After releasing the mouse button the zoom factor will be applied.
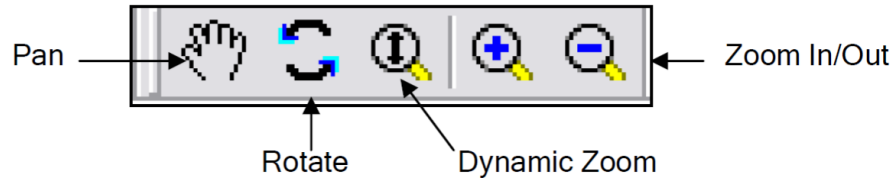
Context Menu

Right click in the graphics area and select the menu item View and choose from the options outlined in the Toolbar section. The context menu also offers the following:

Fit All – This will zoom the defined structure to a point where it fits in the drawing area

Fit Selection – This fits only the selected objects into the drawing area.

Spin – Drag the mouse and release the mouse button to start the object spinning. The speed of the dragging prior to releasing the mouse controls the speed of the spin.

Animate – Create or display the animation of parametric geometry

Shortcuts:

Since changing the view is a frequently used operation, some useful shortcut keys exist. Press the appropriate keys and drag the mouse with the left button pressed:

ALT + Drag – Rotate

In addition, there are 9 pre-defined view angles that can be selected by holding the ALT key and double clicking on the locations shown.

Shift + Drag - Pan

ALT + Shift + Drag – Dynamic Zoom

Predefined View Angles
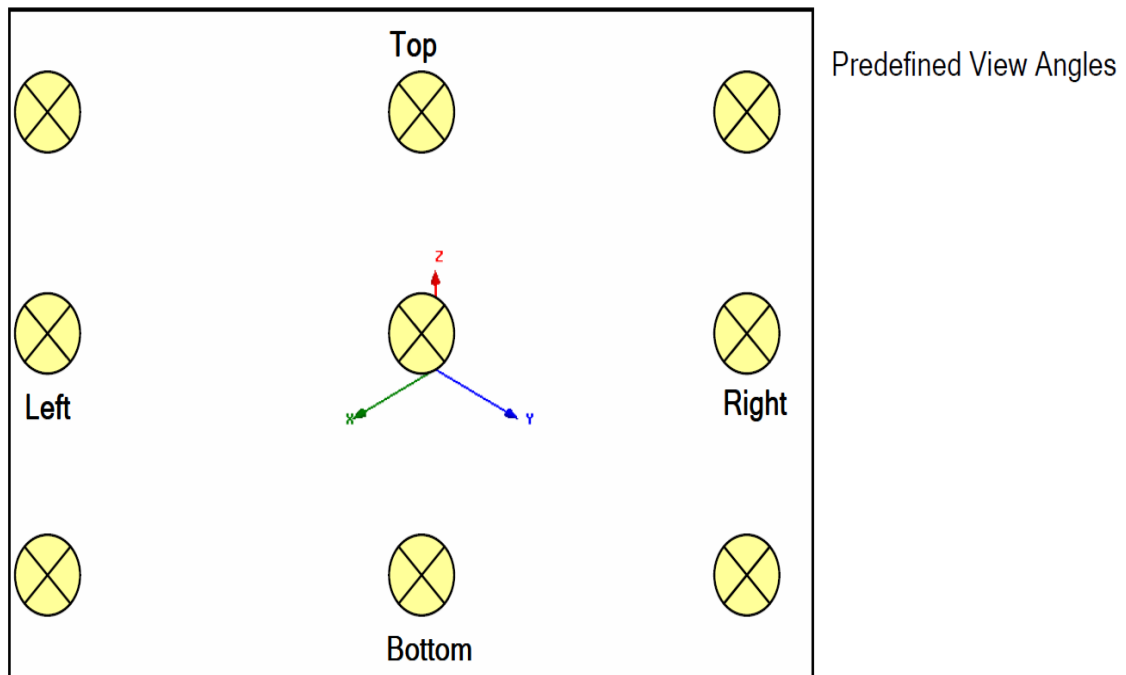
Visibility:

The visibility of objects, Boundaries, Excitations, and Field Reports can be controlled from the menu item View > Visibility

Hide Selection:

The visibility of selected objects can be set hidden by selecting the object(s) and choosing the menu View > Hide Selection > All Views.

Rendering:

To change the rendering select the menu item View > Render > Wireframe or View > Render > Smooth Shaded

Coordinate System:

To control the view of the coordinate system, select the menu item:

Visibility:

Toggle the menu item View > Coordinate System > Hide(Show)

Size:

Toggle the menu item View > Coordinate System > Small

(Large)

Background Color:

To set the background color, select the menu item View > Modify

Attributes> Background Color

Addition View Settings:

Additional attributes of the view such as the projection, orientation, and lighting can be set from the menu item View > Modify Attributes.

Enhancements and New Features

Selection:

Select Connected **Vertices**

Select Connected **Faces**

Select Connected **Edges**

Select **Edge Chain**

Select **Face Chain**

Select **Uncovered Loops**

Healing:

Purge History – makes an object appear as an imported entity so that healing can be performed on it

Remove **Faces**

Remove **Edges**

Remove **Vertices**

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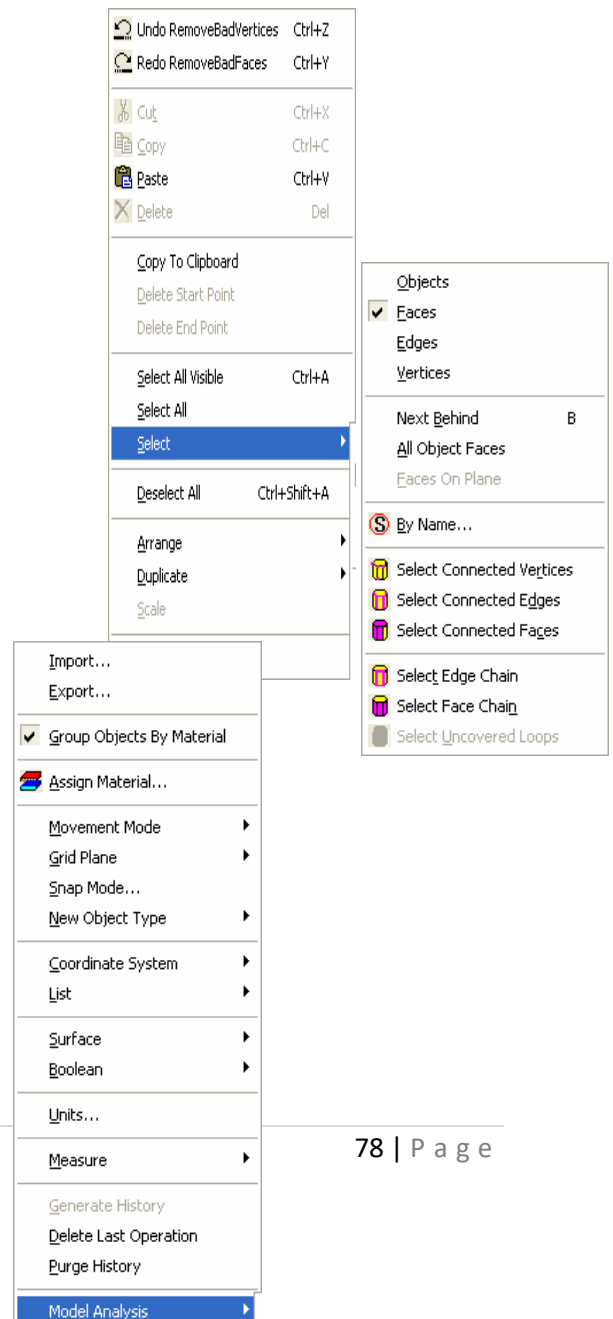
Align Faces Enhancements and New Features

Visibility

- Hide selected objects in Active View
- Hide selected objects in All Views
- Show selected objects in Active View
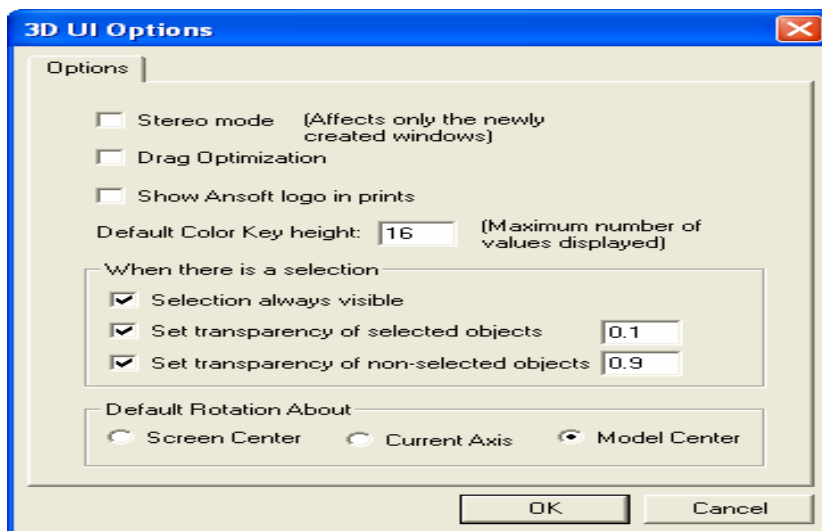- Show selected objects in All Views

3D User Interface Options

- When there is a selection
- Selection is always visible
- Set transparency of selected objects
- Set transparency of non-selected objects
- Default Rotation About
- Screen Center
- Current Axis
- Model Center

3D Modeler Options

Visualize history of objects

Applying Structural Transformations

So far we have investigated hot to model simple shapes and how to change the view of the model. To create more complicated models or reduce the number of objects that need to be created manually we can apply various transformations.

The following examples assume that you have already selected the object(s) that you wish to apply a transformation.

You can select the transformation options from the menu item:

Edit >

Arrange >

- **Move** – Translates the structure along a vector
- **Rotate** – Rotates the shape around a coordinate axis by an angle
- **Mirror** – Mirrors the shape around a specified plane
- **Offset** – Performs a uniform scale in x, y, and z.

Duplicate >

- **Along Lines** – Create multiple copies of an object along a vector
- **Around Axis** – Create multiple copies of an object rotated by a fixed angle around the x, y, or z axis
- **Mirror** - Mirrors the shape around a specified plane and creates a duplicate
- **Scale** – Allows non-uniform scaling in the x, y, or z direction
  The faces of an object can also be moved to alter the shape of an existing object.

To move the faces of an object select the menu item **3D Modeler > Surfaces >Move Faces** and select Along Normal or Along Vector.

Combine Objects by Using Boolean Operations:

Most complex structures can be reduced to combinations of simple primitives. Even the solid primitives can be reduced to simple 2D primitives that are swept along a vector or around an axis(Box is a square that is swept along a vector to give it thickness). The solid modeler supports the following Boolean operations:

- **Unite** – combine multiple primitives
a) Unite disjoint objects

b) Separate Bodies to separate

- **Subtract** – remove part of a primitive from another

- **Split** – break primitives into multiple parts

- **Intersect**– keep only the parts of primitives that overlap

- **Sweep** – turn a 2D primitive into a solid by sweeping: Along a Vector, Around an Axis, Along a Path

- **Connect** – connect 2D primitives. Use Cover Surfaces to turn the connected object into a solid

- **Section** – generate 2D cross-sections of a 3D object

- Most Boolean operations require a base primitive in which the Boolean operation is performed. Only the base object will be preserved.

- The Boolean functions provide the option to Clone objects.

- **Split Crossing Objects** – When a group of objects are selected, a Boolean split is performed on ANY objects that overlap.

Local Coordinate Systems

The ability to create local coordinate systems adds a great deal of flexibility to the creations of structural objects. In previous sections we have only discussed objects that are aligned to the global coordinate system. The local coordinate system simplifies the definition of objects that do not align with the global coordinate system. In addition, the object history is defined relative to a coordinate system. If the coordinate system is moved, the geometry will automatically move with it. The definition of coordinate systems are maintained in the Model Tree.

Working Coordinate System

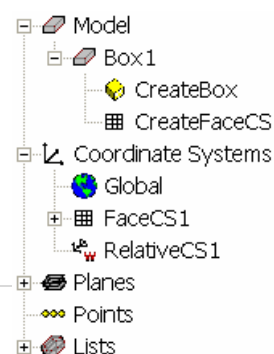The working coordinate system is the currently selected CS. This can be a local or global CS

Global CS

- The default fixed coordinate system

Relative CS

- User defined local coordinate system.

a) Offset

b)   Rotated

c)   Both

Face CS

     User defined local coordinate system. It is tied to the location of the object face it was created on. If the size of the base object changes, all objects created relative to the face CS will be updated automatically.
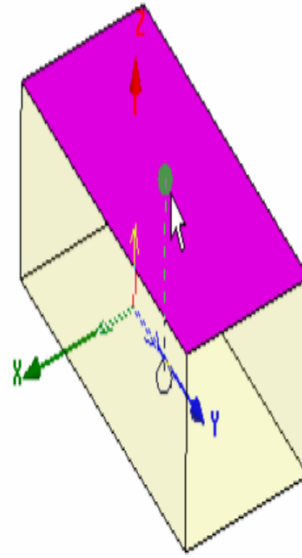
    To create a face CS, select the menu item 3D Modeler > Coordinate
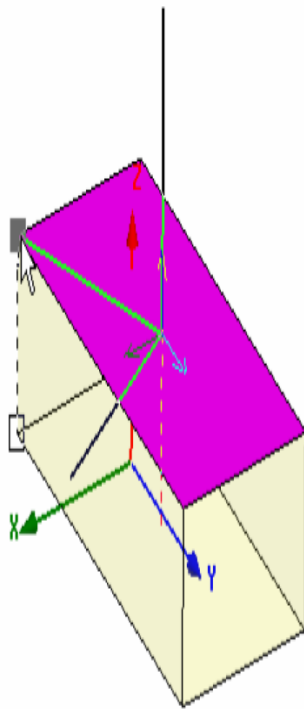
    System > Face

1. Graphically select Face (Highlighted in model)

2. Select Origin for Face CS

3. Set X-Axis
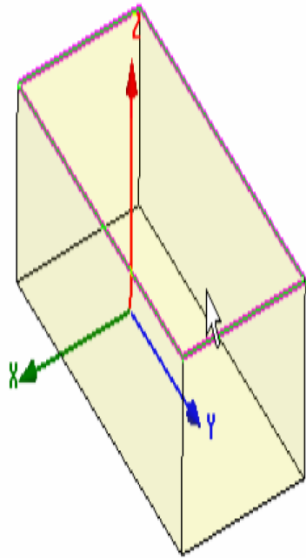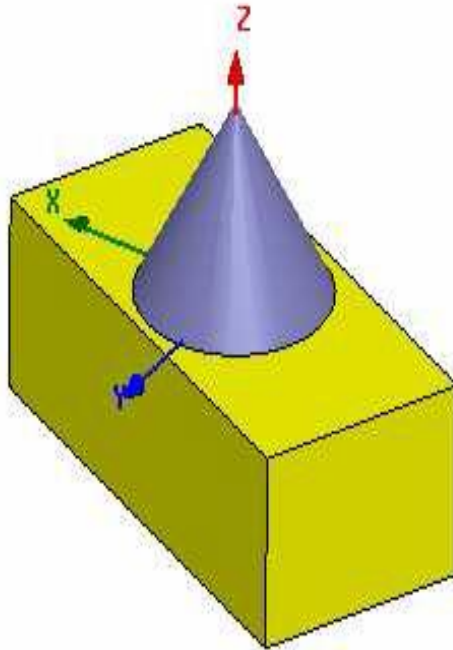
Step 1: Select Face

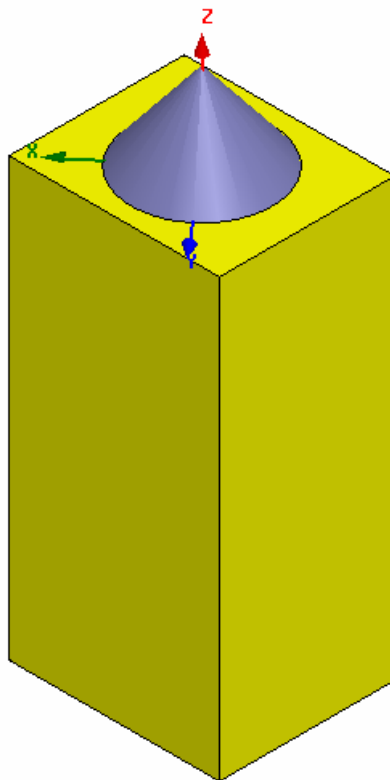Step 2: Select Origin

Step 3: Set X-Axis

New Working CS

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Example of Face CS:
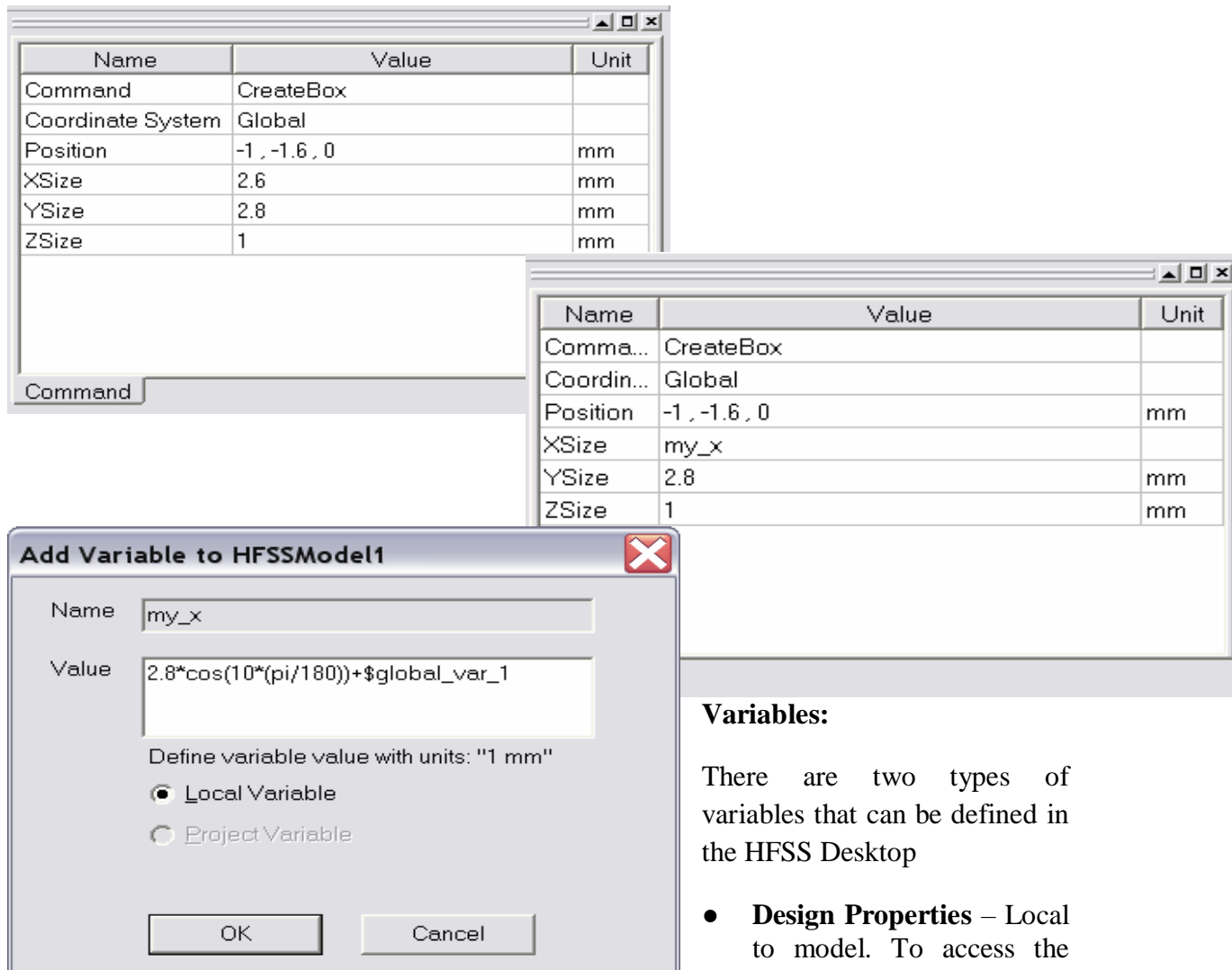

Cone is created with Face CS

Change the size of the box and the Cone is automatically moved with the Face CS Parametric Geometry

The parametric modeler capability allows us to define variables in replace of a fixed position or size. Once this has been defined the variable can be changed by the user or by Optimetrics. Optimetrics can then be used to perform automatic Optimization, Parametric Sweeps, Statistical, or Sensitivity Analysis.

Defining Parameters

- Select the command to parameterized
- Choose the value to change
- Enter a variable in replace of the fixed value
- Define the variable using any combination of math functions or design variables.

The model will automatically be updated.

Name	Value	Unit
Command	CreateBox	
Coordinate System	Global	
Position	-1 , -1.6 , 0	mm
XSize	2.6	mm
YSize	2.8	mm
ZSize	1	mm

Command

Name	Value	Unit
Comma...	CreateBox	
Coordin...	Global	
Position	-1 , -1.6 , 0	mm
XSize	my_x	
YSize	2.8	mm
ZSize	1	mm

Add Variable to HFSSModel1

Name: my_x

Value: 2.8*cos(10*(pi/180))+$global_var_1

Define variable value with units: "1 mm"

- Local Variable
- Project Variable

OK   Cancel

Variables:

There are two types of variables that can be defined in the HFSS Desktop

- **Design Properties** – Local to model. To access the local variables select the menu item HFSS > Design Properties.
- **Project Variables** – Global to all models in project. Start with $. To access the global or project variables, select the menu item Project >Project Variables

Units:

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When defining variables they must contain units. The default units for variables is meters.

Equations:

The variables can contain complex equations. See the Online Help for a complete list of math functions

Equation based Curves and Surfaces:

Any curve/surface that can be described by an equation in three dimensions can bedrawn.
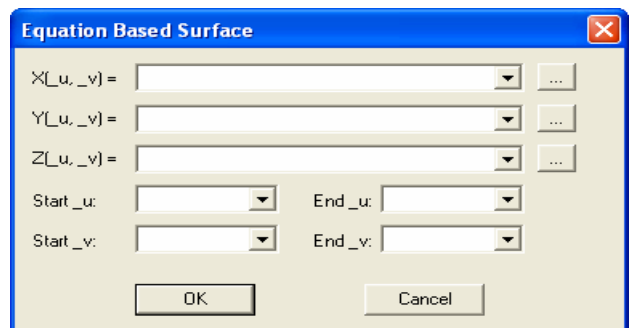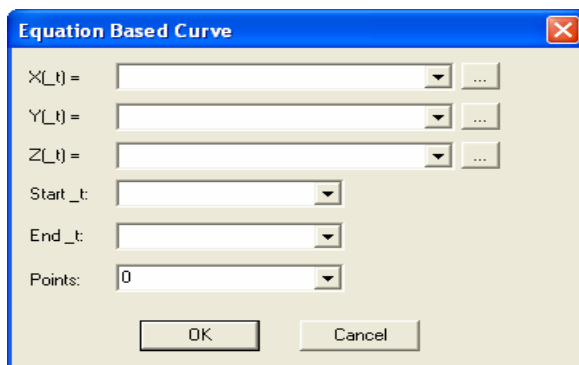
Animation:

Right-Click in the 3D Model Window & Choose Animate to preview the parameterization

Note: depending on the quality of your graphics card you have the option of exporting ether AVI or GIF animation files.

METHODIST COLLEGE OF ENGINEERING AND TECHN0LOGY

EXPERIMENT-9

DESIGN AND SIMULATE A HALFWAVE DIPOLE ANTENNA

Aim: To design a Halfwave dipole antenna at a frequency of 1GHz and simulate its behaviour.

Software Used: HFSS

Procedure:

1. Initially after deciding the operating frequency calculate the wavelength using $\lambda = \dfrac{c}{f}$ where f is the operating frequency.
2. Now calculate the half wavelength to assign it as the length of the dipole antenna.
3. Excluding the port the dipole has two segments each of Quarter wavelength that combined gives total length of antenna to be $\dfrac{\lambda}{2}$.
4. Select the shape of the segment i.e. cylinder and define the dimensions (Frequently used measurements can be declared as parameters).
5. Now select the material of the dipole and construct it using the preset dimensions.
6. Create a component called gap with an approximate dimension of 1~2mm exactly at the center of the dipole with material as vacuum and perform subtract operation from the tool bar there by creating a gap.
7. Now select the gap component and go to Modeller →Surface → Section in tool box and select the axis this will create a cross section between two quarterwave parts acting as a port.
8. Define a lumped port with a default resistance of 50 ohms and define a new integration line by choosing the bottom and top edge of rectangular section at the gap.
9. Create a PML open region to set a dielectric and vacuum simulation atmosphere and designate the frequency.
10. Analyse the designed dipole by assigning a frequency sweep around the frequency of operation.
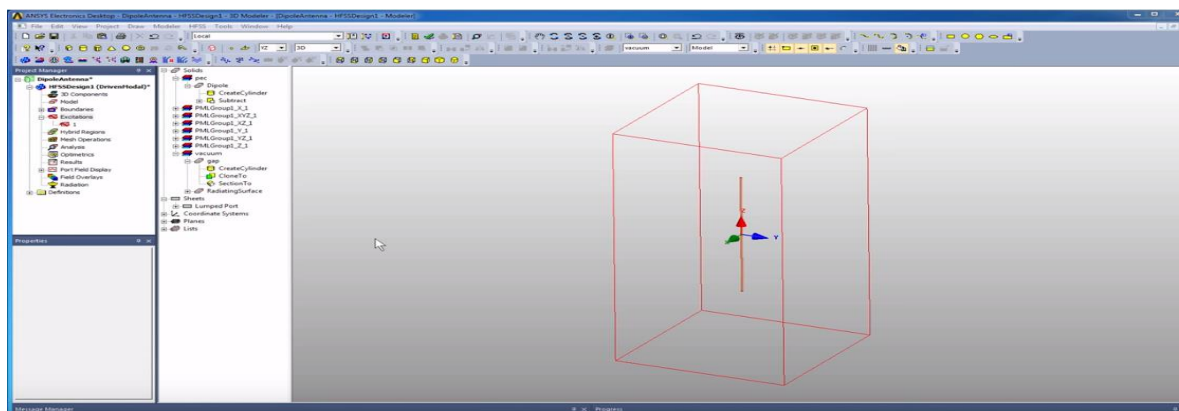
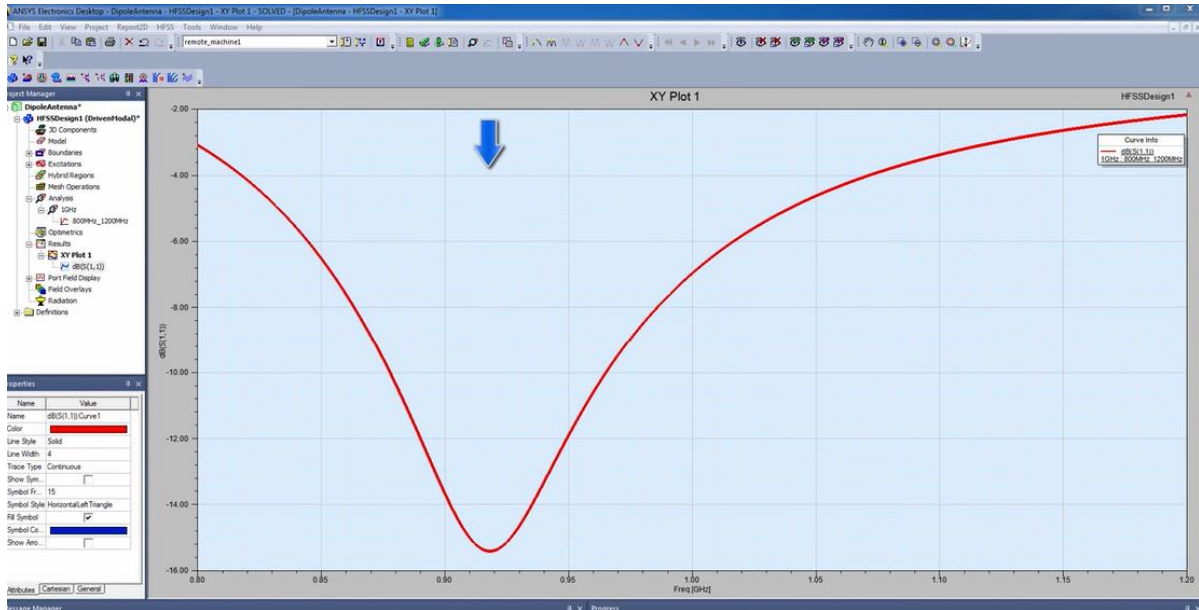**Model Figures:**

Fig 1: Halfwave Dipole

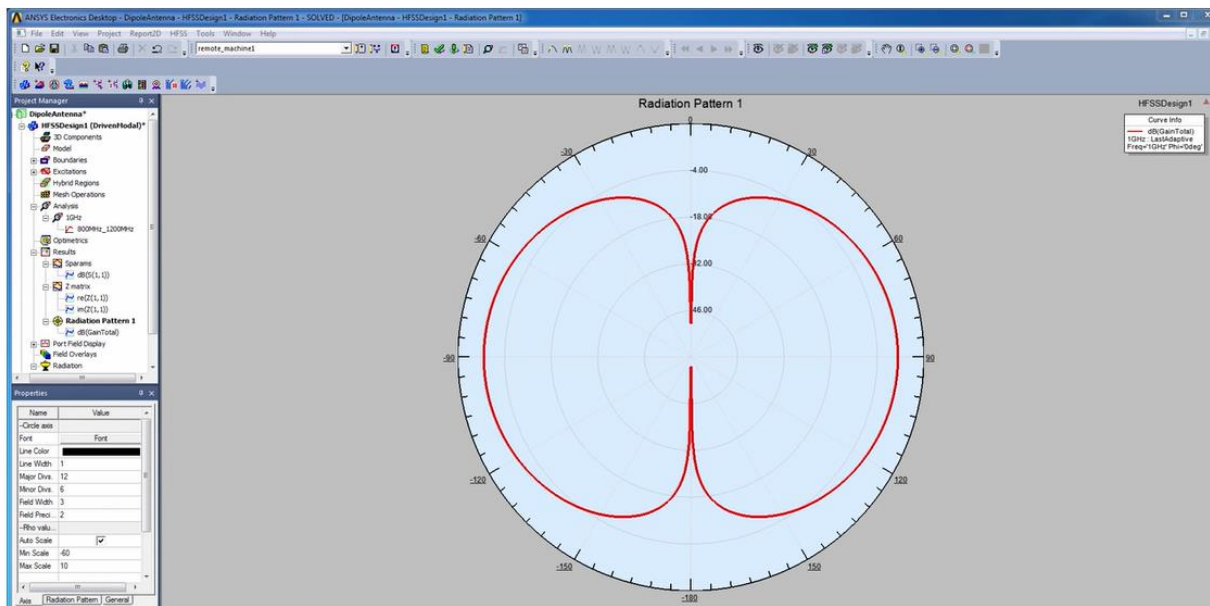**BE CBCS VII SEM MW LAB MANUAL (E&CE)**

FIG2: Return loss at 1GHz

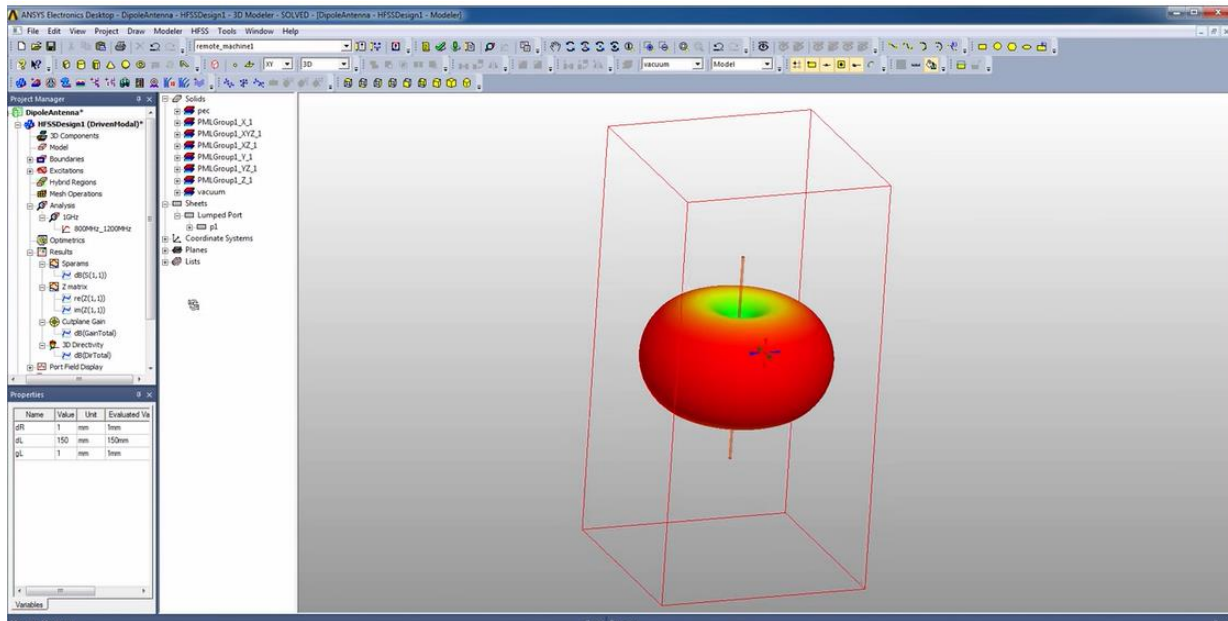FIG3: Polar Graph of Radiation Pattern

FIG4: 3D Farfield plot at 1GHz

Calculations:

Wavelength= $\lambda = \dfrac{c}{f}$

Half wavelength= $\dfrac{\lambda}{2}$

Gap=1~2mm

Results: Halfwave dipole antenna has been successfully designed in HFSS and the results have been simulated at 1GHz.

Viva Questions

1. What is the range of frequency in half dipole antenna?
2. What are the advantages of half dipole antenna
3. Explain the radiation pattern of half dipole antenna
4. The impedance at the center of the antenna is known as?
5. The type of dipole antenna that has a higher band width is called as?
6. The radiation pattern of a half-wave dipole has the shape of a _____
7. What is the beam width for a half wave dipole antenna?
8. What does the beam width of an antenna tell us?
9. What is the power radiated by the antenna with gain called as?
10. What is the impedance of the folded dipole antenna?
11. A dipole antenna is also called as?

EXPERIMENT 11

DESIGN AND SIMULATION OF MICROWAVE PATCH ANTENNA AT 2.4GHZ

Aim: To design and simulate a microwave patch antenna at a frequency of 2.5GHz in HFSS.

Software used: HFSS

Procedure:

1. Initially after deciding the operating frequency and the material being used for substrate calculate the Length and Width of the patch .
2. Now calculate the length and width of the antenna feed line depending on the dielectric constant and electric angle.
3. Calculate the feed depth for an Inset feed type patch antenna.
4. After declaring these as standard parameters in the software start designing the patch antenna as layers.
5. Select the Substrate as FR-4 Lossy and set the thickness to 1.6mm and the length and width should be considerably greater than the dimensions of the patch($\frac{\lambda}{2}$ difference on all sides is recommended)
6. Create a component called patch and give it the dimensions as calculated earlier and set the thickness of the patch to a maximum of $\frac{1}{10}$ th of the substrate thickness.
7. Now create a ground plane using the same dimensions as substrate for length and width but the thickness should be equal to that of patch.

8. Define a component called feed line and design it with pre calculated dimensions(see to it that the length of the feed is sufficient enough to extend till lower end of substrate plane).
9. Now using the ADD feature in the transform toolbox combine the patch and the feed line with each other.
10. Now select the gap component and go to Modeller →Surface → Section in tool box and select the axis this will create a cross section between two quarterwave parts acting as a port.
11. Define a lumped port with a default resistance of 50 ohms and define a new integration line by choosing the bottom and top edge of rectangular section at the end of feed.
12. Create a PML open region to set a dielectric and vacuum simulation atmosphere and designate the frequency.
13. Analyse the designed patch antenna by assigning a frequency sweep around the frequency of operation.
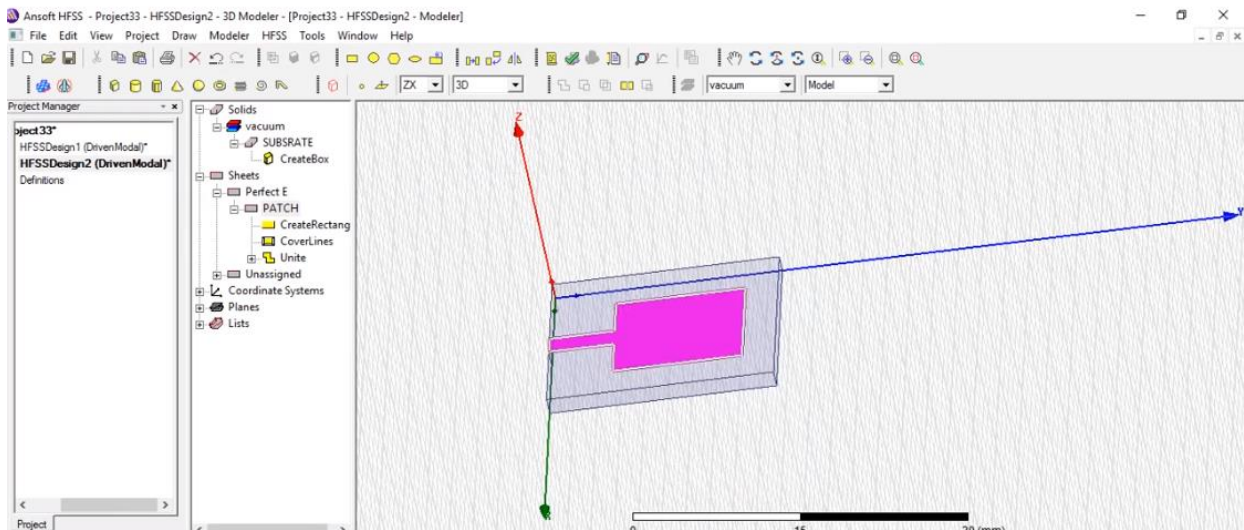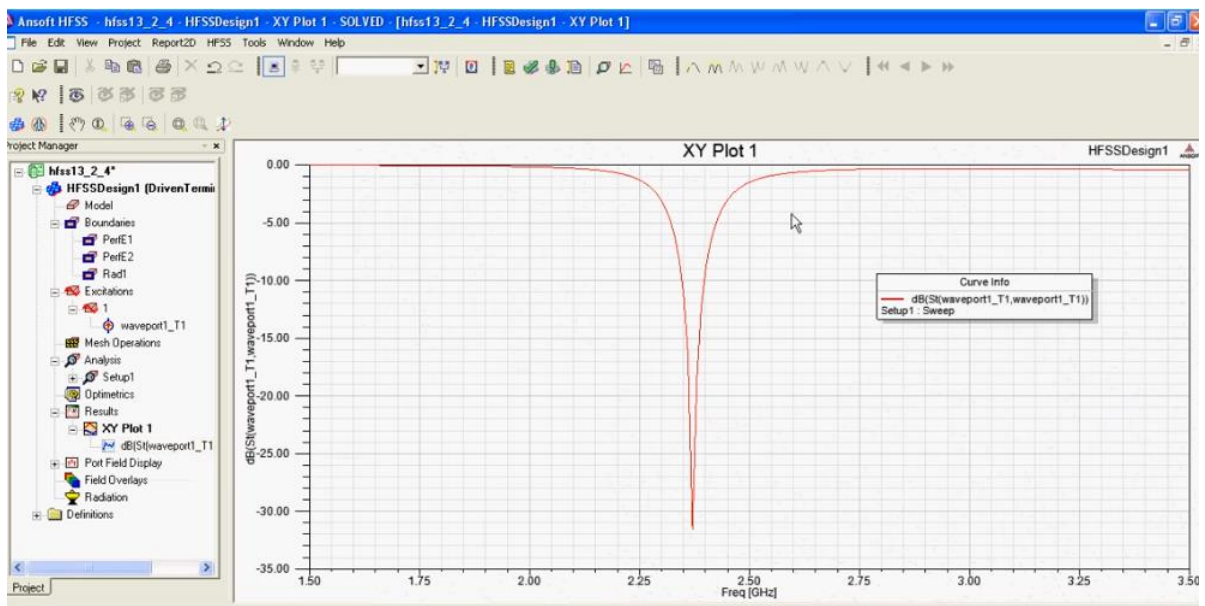
Model Figures :
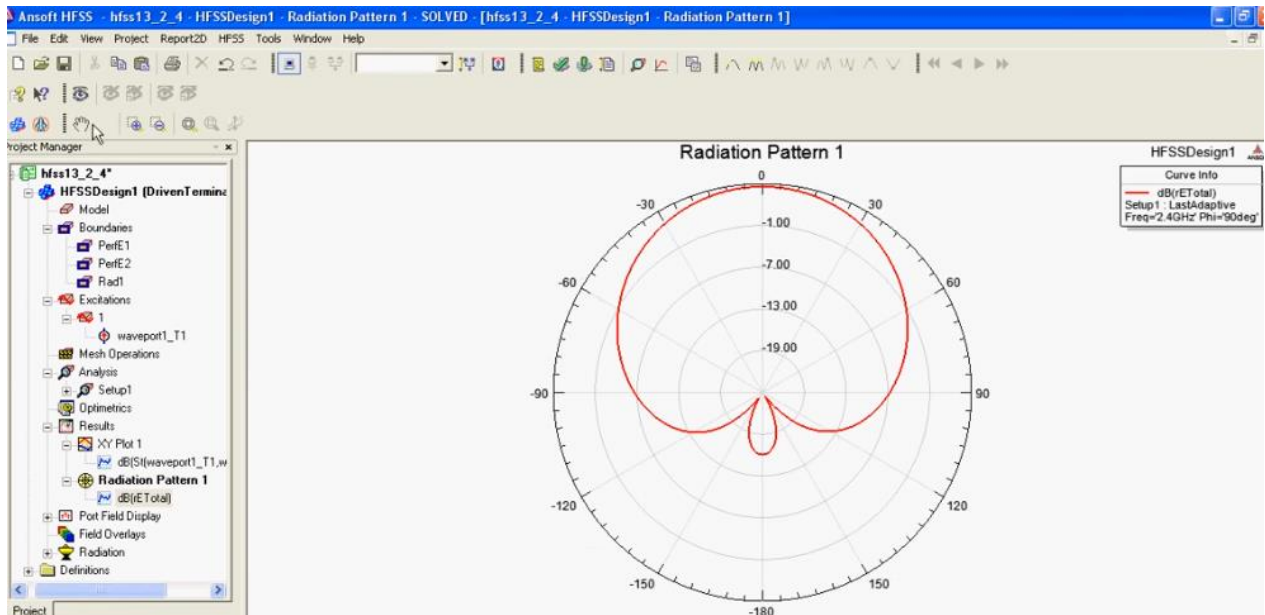

FIG1: Patch antenna

FIG 2: Return loss at 2.5GHz

FIG 3: Polar Radiation patter on antenna

Calculations:

Width of patch(w)= $\dfrac{c}{2f}\sqrt{\dfrac{2}{\varepsilon_r+1}}$

Where ε_r is relative permittivity of substrate

Length of patch(l)= $L = L_{eff} - 2\Delta L$

$$\varepsilon_{reff} = \dfrac{\varepsilon_r+1}{2} + \dfrac{\varepsilon_r-1}{2}\left[1+12\dfrac{h}{w}\right]^{\frac{-1}{2}}$$

Where $L_{eff} = \dfrac{c}{2f\sqrt{\varepsilon_{reff}}}$

And normalized length extension ΔL is given by

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$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$

Feed Length $= \dfrac{\lambda_g}{4}$

Where guided wavelength(λ_g) $= \dfrac{\lambda}{\sqrt{\varepsilon_{reff}}}$

Lg=L+6h

Wg=W+6h

If Radiation box is to be manually created:

Axis Position$= \dfrac{-\lambda_g}{6} + \dfrac{-\lambda_g}{6} + \dfrac{-\lambda_g}{6}$

Length $= \dfrac{\lambda_g}{6} + \dfrac{\lambda_g}{6} + L_g$

Width $= \dfrac{\lambda_g}{6} + \dfrac{\lambda_g}{6} + W_g$

Height $= \dfrac{\lambda_g}{6} + \dfrac{\lambda_g}{6} + h$

Results: Microwave Patch antenna antenna has been successfully designed in HFSS and the results have been simulated at 2.5GHz.

Viva Questions

1. Patch antennas are the antennas of small size and are made of _____
2. An antenna source that radiates energy uniformly in all the directions is called_____-
3. Microstrip feeding of the microstrip antenna ……………………..

4. In the moment method analysis of the patch antenna …………………….
5. How to reduce beawidth for a single patch antenna?
6. What is the possible range of height for the occurrence of sporadic E-region with respect to normal E-region?
7. How does patch antenna work?
8. What type of antenna is patch antenna?
9. What would happen if the rms value of induced emf in loop acquires an angle $\theta = 90°$?
10. If the elements of a binomial array are separated by $\lambda/4$, how many shape patterns are generated with no minor lobes?

BEYOND SYLLABUS

1. To study the phase shifter

AIM : - To study the phase shifter.

APPARATUS REQUIRED :- Microwave source, Isolator, Variable attenuator, Frequency meter, Slotted line, Tunable probe, Phase shifter, Movable short, VSWR meter, Cables and Accessories

THEORY: - A phase shifter consists of a piece of waveguide and a dielectric material inside the waveguide placed parallel to Electric vector of TElO mode. The phase changes, as a piece of dielectric material is moved from edge of waveguide towards the centre of the waveguide.

BLOCK DIAGRAM: -
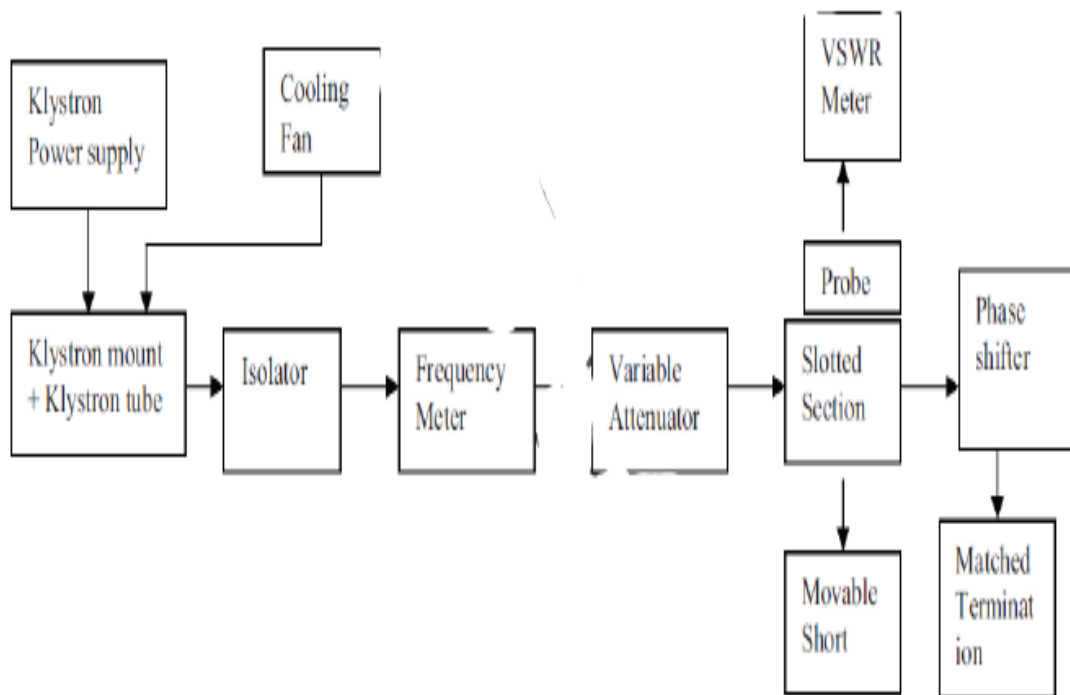
PROCEDURE: - 1. Set up the equipment as shown in the Fig.

2. First movable short is placed at the end of slotted line.

3. Energize the microwave source for maximum output at particular frequency of operation.

4. Find out the !g with the help of tunable probe slotted line and VSWR meter. It is the twice the distance between two minima on the slotted line.

5. Find out the operating frequency for frequency meter or by relation of λg

6. Find out λ as

   $\lambda = c/f$ $1/\lambda^2 = 1/\lambda g^2 + 1/\lambda c^2$

7. Note and record a reference minima position on the slotted line. Let it is X.

 8. Remove carefully the movable short from the slotted line without disturbing any position on the set up, place the phase shifter to the slotted line with its micrometer reading zero and then place the movable short to the other port of phase shifter.

9. Find out a new minima position let it is Y.

10. Change the position of micrometer of phase shifter and find out the corresponding position of new minima, let it is Yi.

CALCULATION : Since new minima is multiple of half wave-length from the short, it should be possible to calculate the exact electrical length of phase shifter. For example suppose at 10 GHz a reference minima is found at X = 16.08 cm. Now suppose that phase shifter is two wave-lengths long and placed on the line as in step 8, the new minima y = 14.90 cm is obtained. Hence, short has apparently moved 16.08 - 14.90 = 1.18 cm. This can be written in form of as ! (.393) = (1.18) !/3 Since the apparent movement is in the direction the short actually moved, it is added to the approximate number of half wave length in the phase shifter. The total electrical length is 2.393 wave lengths. The phase shift in radians is found as below: Multiply by 2 $ to give phase shift in radius or by 3600 to give phase shift in degrees. Phase shift in above example = 2 $ x 2.393 radians = 360 x 2.393 degrees The phase shift for other micrometer reading position can be found as above.

RESULTS:

Viva Questions

1.Phase shifters are used in _____ where the antenna beam can be steered in space by electronically controlled phase shifters.

2. The scattering matrix of a gyrator is.............................

3. Is Ferrite phase shifters have more advantages over FETs and diodes in using them in microwave integrated circuits?

4.What is Faraday's rotation law?