INTRODUCTION TO MICROWAVE ENGINEERING

EEEN 566– Microwave Engineering

Friday, 6 February 2026

EEEN 566 - SYLLABUS

- **Wave guiding Systems:** Types of waveguides. Excitation of waveguides, mode coupling and mode suppression.
- **Power transmission and attenuation**. Pertubation method. Circuit Theory for Waveguiding Systems;
- **N-port network analysis** using Z,H,Y, ABCD parameters. Forsters reactance theorem.
- **Scattering parameters**, definitions and relationship with other parameters. Passive
- **Microwave Devices:** Phase changers. Directional couplers. Hybrid junction.
- **Microwave propagation in gyrotropic media**,
- **Faraday rotation**. Ferrite devices employing Faraday rotation.
- **Circulators**. Other ferrite devices.

EEEN 566- DETAILED SYLLABUS /01

Prerequisites

Electromagnetics I, Electromagnetics II, Engineering Mathematics II, Transmission Lines

Purpose

To enable the student to understand the fundamental concepts of microwave, waveguide characteristics, analysis of microwave circuits and devices and applications.

EEEN 566- DETAILED SYLLABUS /02

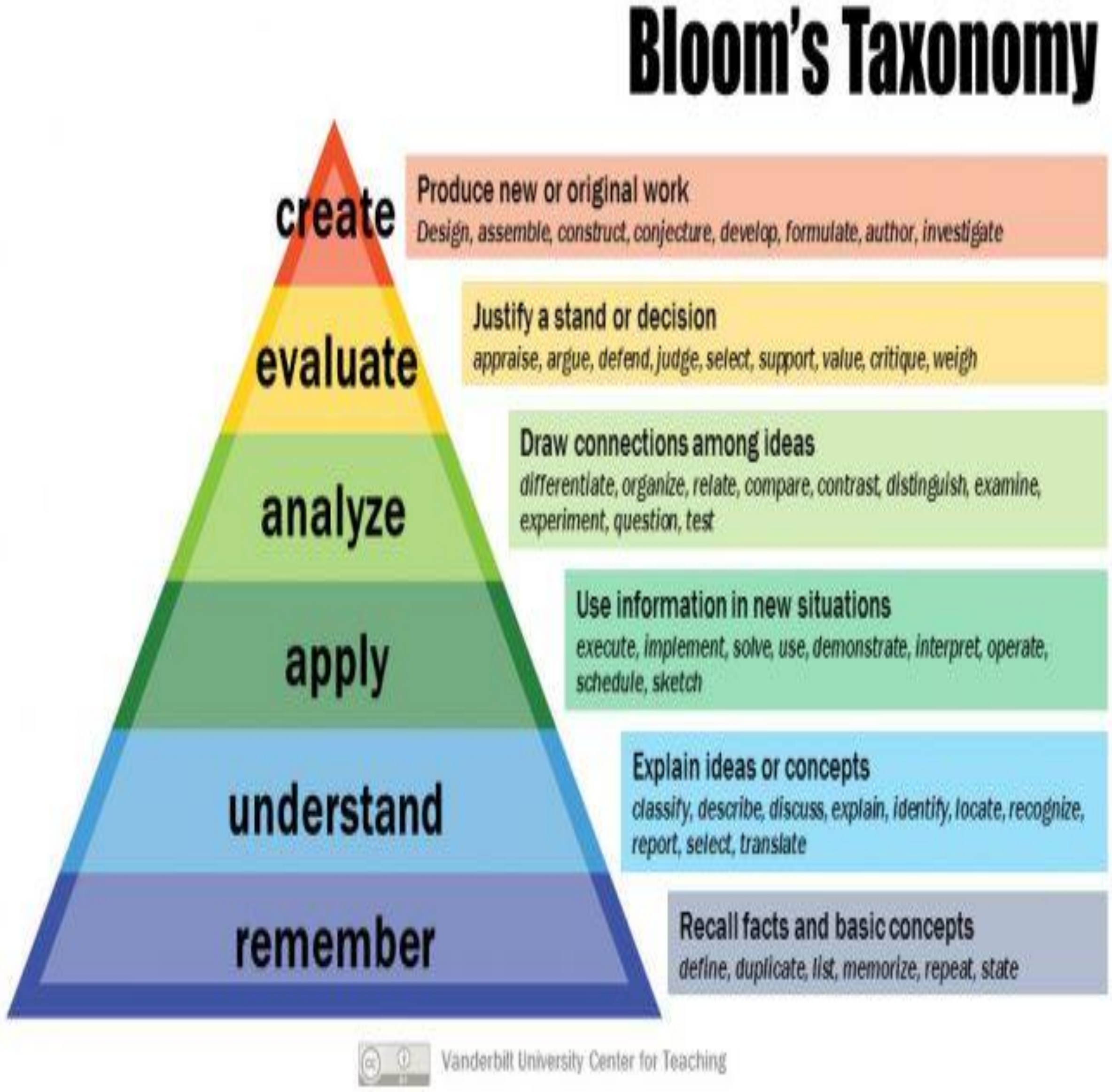
Course Objectives

1. Discuss components and devices used in RF & Microwave systems.
2. Analyze microwave systems
3. Demonstrate understanding of different RF & Microwave circuits.
4. To design microwave circuits and devices

Expected Learning Outcomes

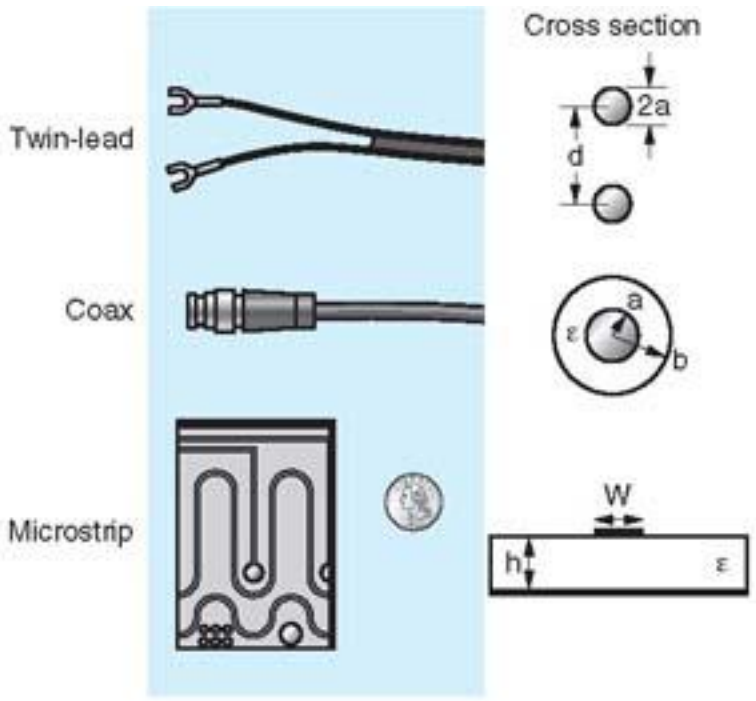
At the end of this course, the student should be able to:

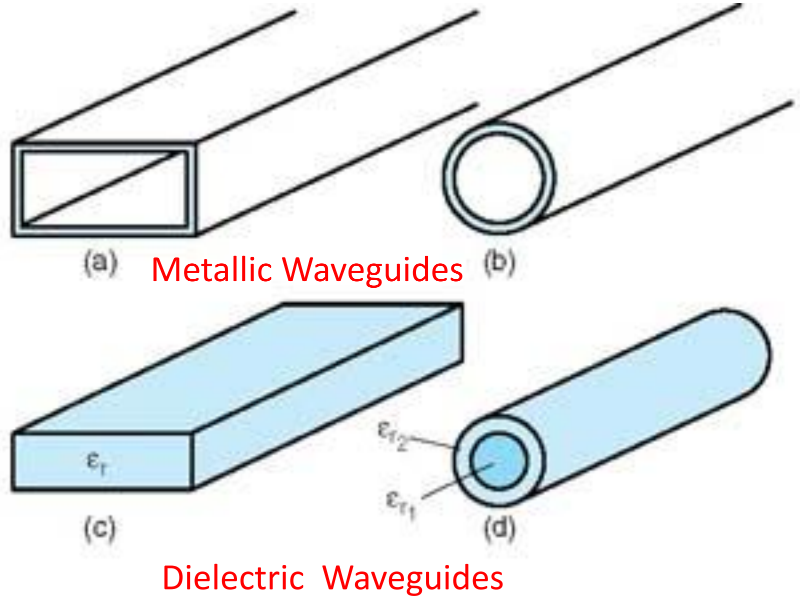
1. **Appreciate** the operation and **analyze** the performance of components and devices used in RF & Microwave systems.
2. **Analyze** microwave systems and assess the impact of microwave component performances on overall system performance.
3. **Design and implement** different RF & Microwave circuits to meet set requirements.



EEEN 566-COURSE DESCRIPTION (1)

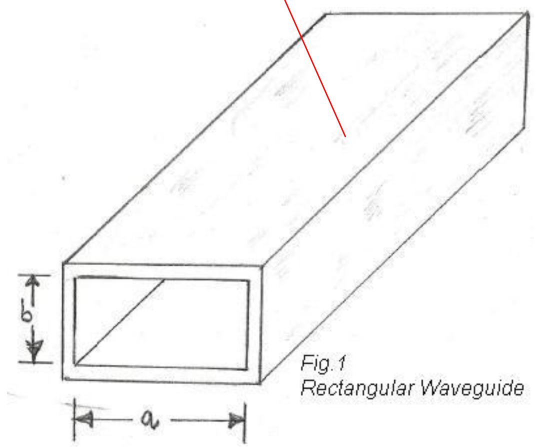
1. **Introduction:** Components of RF and microwave design, Behaviour of passive components, Propagation of guided waves. Micro-stripline circuits; Evaluation of attenuation constant for the rectangular waveguide.





EEEN 566-COURSE DESCRIPTION (2)

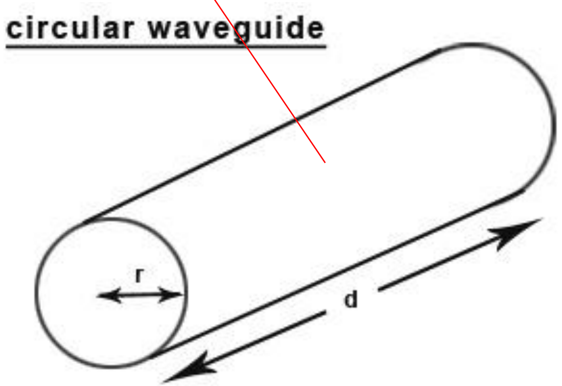
2. Waveguides and Components: Review of electromagnetic (EM) spectrum. Rectangular waveguides, Circular Waveguides, Microwave cavities.



(a) Rectangular Waveguide

A hollow metallic tube with a rectangular cross section. The conducting walls of the waveguide confine the electromagnetic fields and thereby guide the electromagnetic wave.

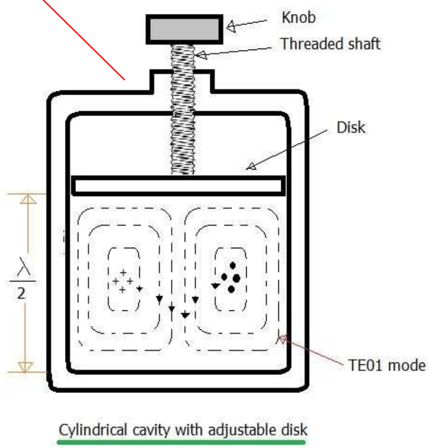
In the inner air-filled volume of the tube, electromagnetic waves can propagate above mode-specific cut-off frequencies



(b) Circular Waveguide:

A hollow metallic cylinder with an inner radius R.

In the inner air-filled volume of the cylinder electromagnetic waves can propagate above mode-specific cut-off frequencies



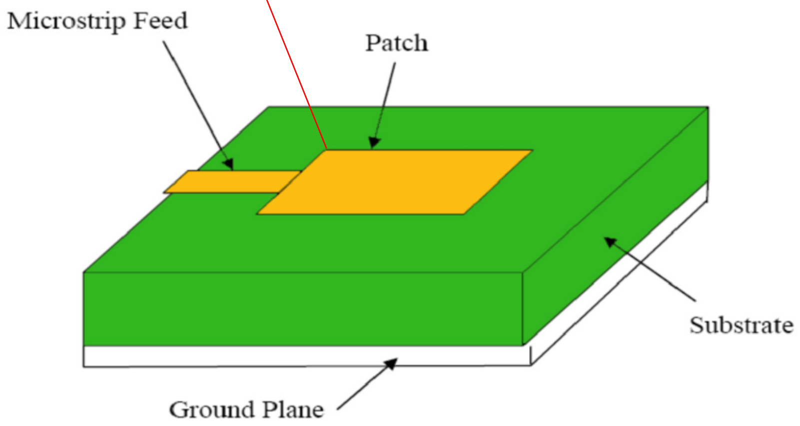
(c) A microwave cavity

A special type of resonator, consisting of a closed (or largely closed) metal structure that confines electromagnetic fields in the microwave region of the spectrum.

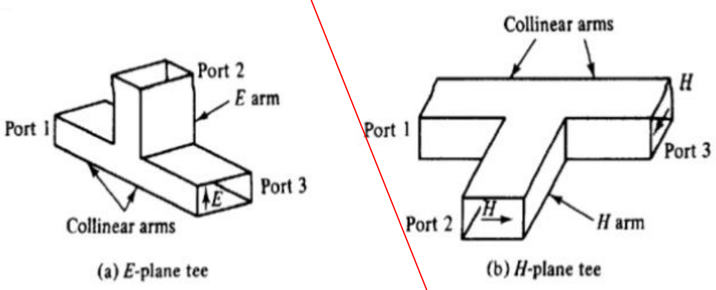
EEEN 566- COURSE DESCRIPTION (3)

3. Microwave antennas: electromagnetic horns; reflector antennas; micro-strip antennas; phased arrays.

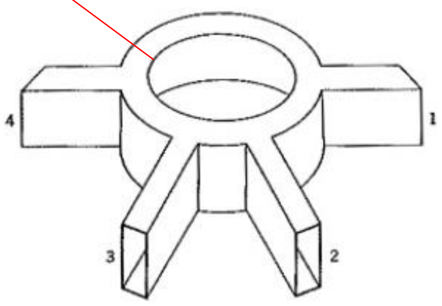
Directional couplers. Circulators, isolators. Wave guide couplings, bends and twists, Transitions, hybrid couplers, Matched load, Attenuators and phase shifters, E-plane, H-plane and Hybrid Tees, Hybrid ring.



(a) <u>Microstrip antenna</u>
An antenna fabricated using microstrip techniques on a printed circuit board (PCB).



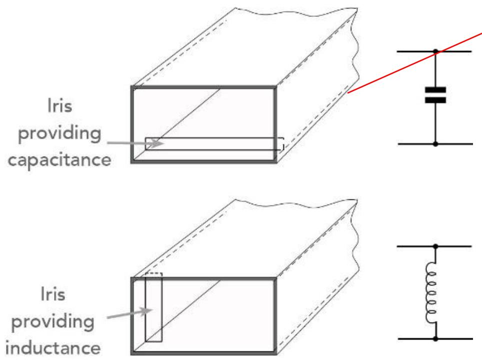
(b) Waveguide Hybrid Tee
A 3-port device that can be used to either divide or combine power in a waveguide system.



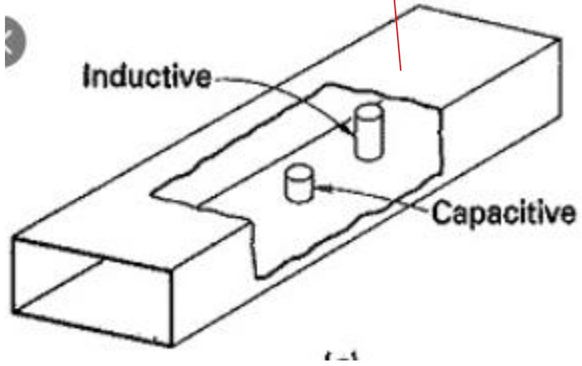
(c) Hybrid ring
A type of coupler used in RF and microwave systems. In its simplest form, it is a 3 dB coupler

EEEN 566 - COURSE DESCRIPTION (4)

4. Waveguide discontinuities: Windows, Irises and Tuning screws, Detectors, wave meters.



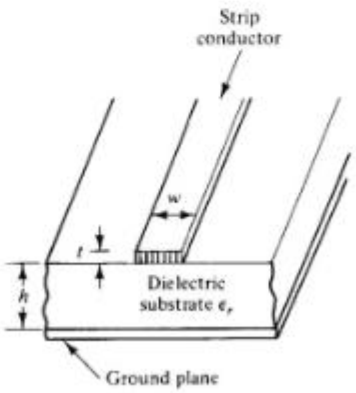
(a) Waveguide iris
Used to places a shunt capacitance or inductance across the waveguide.



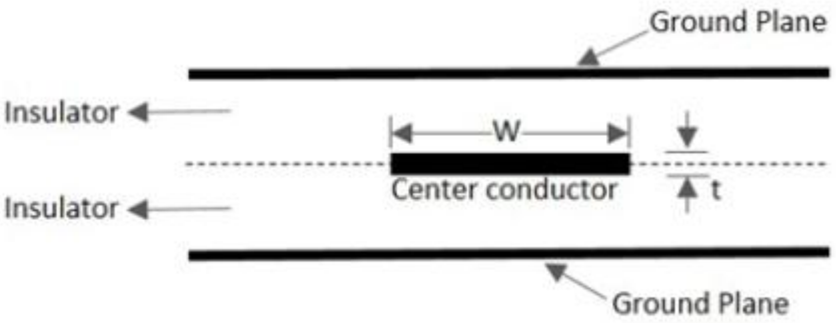
Tuning screws
Screws inserted into resonant cavities which can be adjusted externally to the waveguide.

EEEN 566--COURSE DESCRIPTION (4)

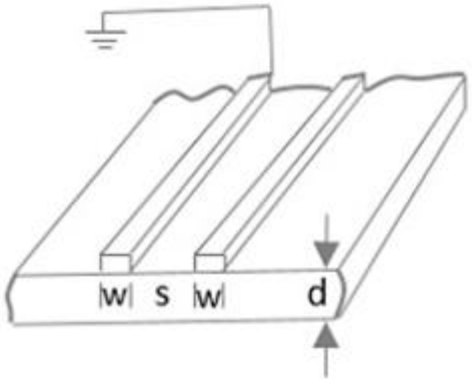
5. Strip Lines: Microstrip lines. Parallel strip lines. Coplanar strip lines. Shielded strip lines.



(a) Stripline
A form of printed circuit transmission line where the signal trace is sandwiched between upper and lower ground planes,



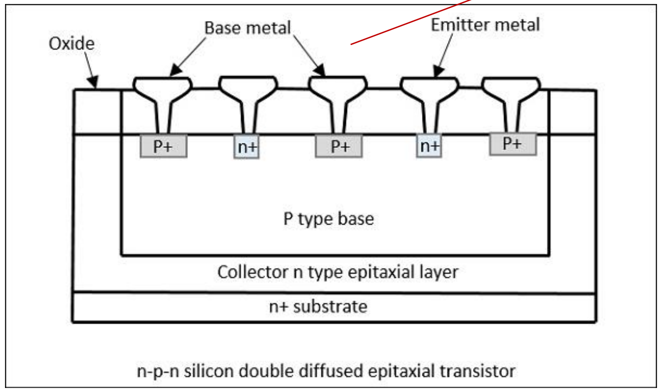
(b) Shielded stripline has its strip conductor embedded in a dialectric media between two ground planes.



(c) Coplanar stripline is formed by two conducting strips with one strip grounded, both being placed on the same substrate surface, for convenient connections.

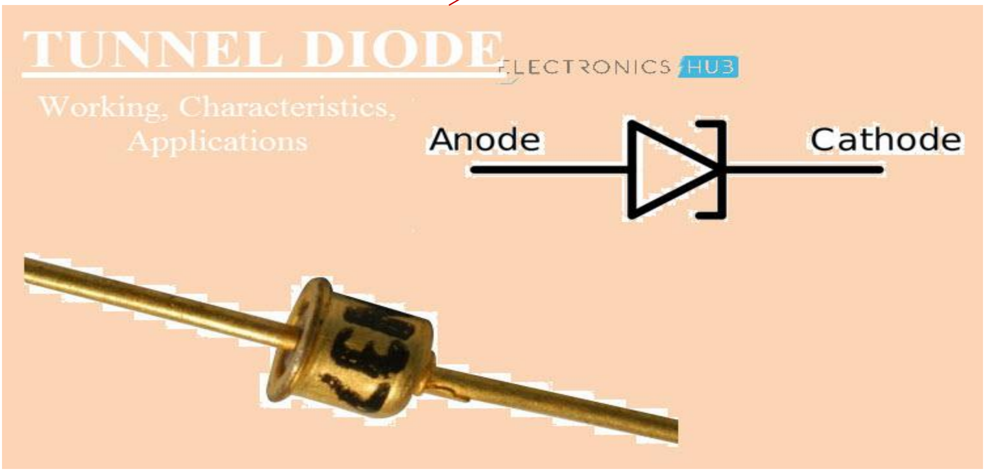
EEEN 566--COURSE DESCRIPTION (6)

6. Microwave Active circuits: Microwave transistors and tunnel diodes; Microwave FETs.



(a) Microwave Transistors

Silicon n-p-n transistors that can provide adequate powers at microwave frequencies have been developed. They are with typically up to 5 watts at a frequency of 3GHz with a gain of 5dB.



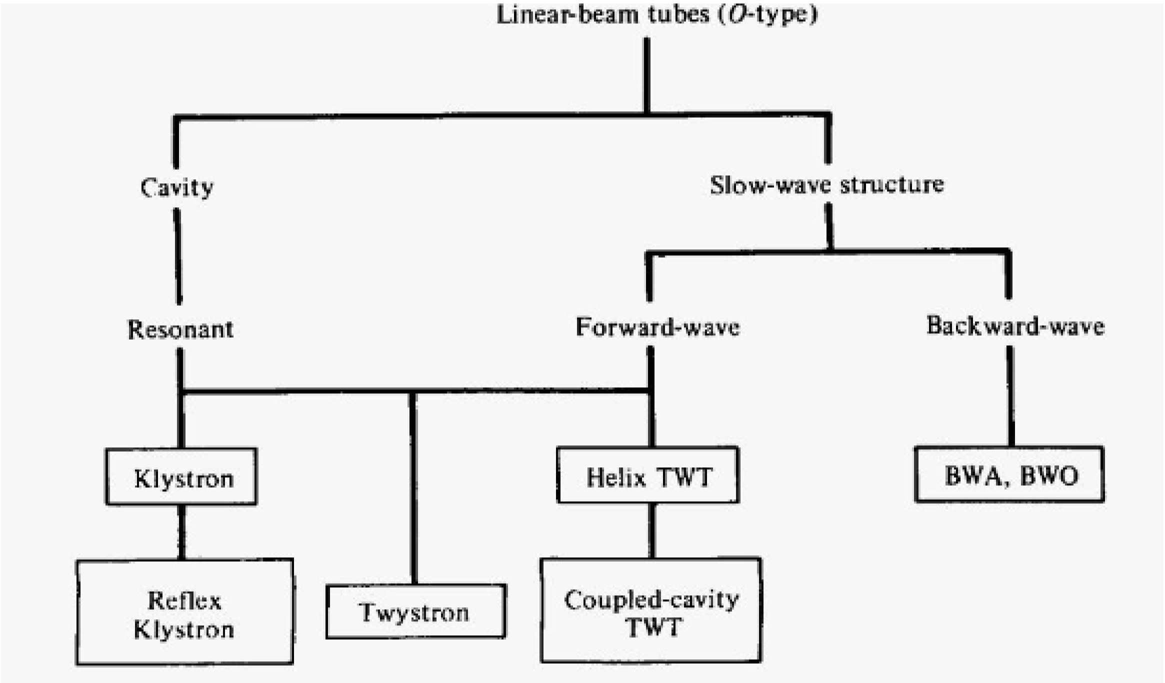
(b) Tunnel diode

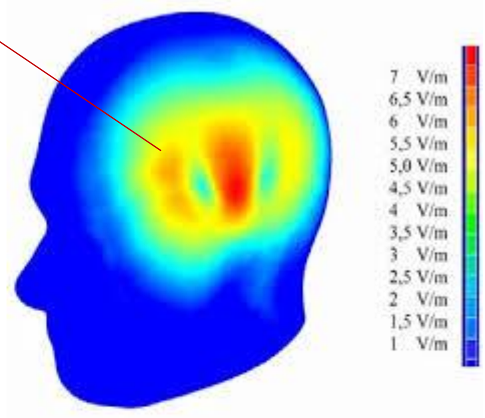
A semiconductor diode that exhibits negative resistance, meaning the current decreases with an increase in voltage.

Tunnel diode can be used as a switch, amplifier, and oscillator.

EEEN 566--COURSE DESCRIPTION (7)

7. Transferred electron devices: Avalanche transit time devices. Microwave linear beam tubes. Microwave crossed-field tubes. Microwave Communication Systems. Effect of Biological Exposure to microwave radiation.





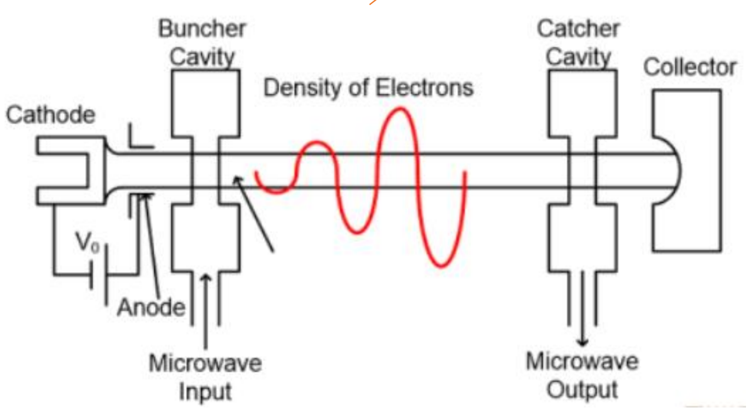
Biological Exposure to Microwave Radiation

Microwave radiation can heat body tissue the same way it heats food. Exposure to high levels of microwaves can cause a painful burn.

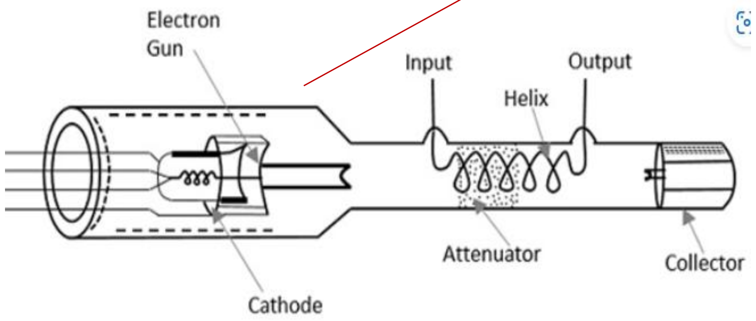
Two areas of the body, the eyes and the testes, are particularly vulnerable to RF heating because there is relatively little blood flow in them to carry away excess heat.

EEEN 566--COURSE DESCRIPTION (8)

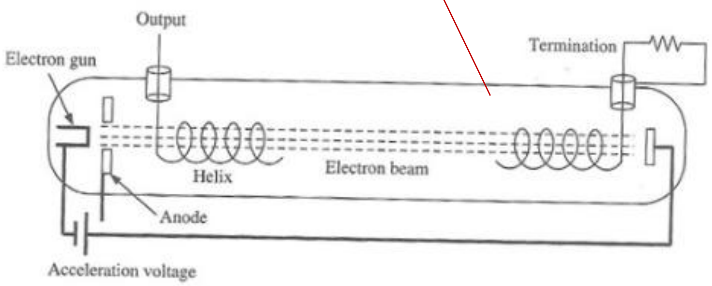
8. Microwave tubes: Klystron, Reflex Klystron, Magnetron, TWT, BWO. Their schematic, Principle of operation, performance characteristics and application.



(a) Klystron
A Klystron (also known as a Klystron Tube or Klystron Amplifier) is a vacuum tube that is used to oscillate and amplify microwave frequency signals.



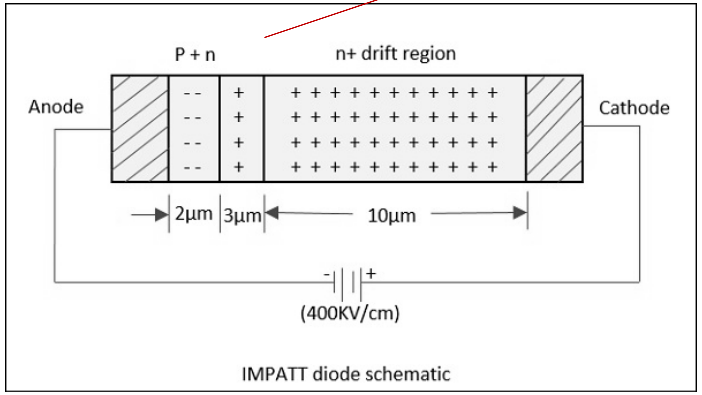
(b) Travelling Wave Tube
Broadband microwave amplifiers which have no cavity resonators like Klystrons. Amplification is done through the prolonged interaction between an electron beam and Radio Frequency



(c) Backward Oscillator
RF wave travelling backwards in opposite direction to the electron beam in helix structure. Frequency of oscillation depends on voltage between cathode and helix.

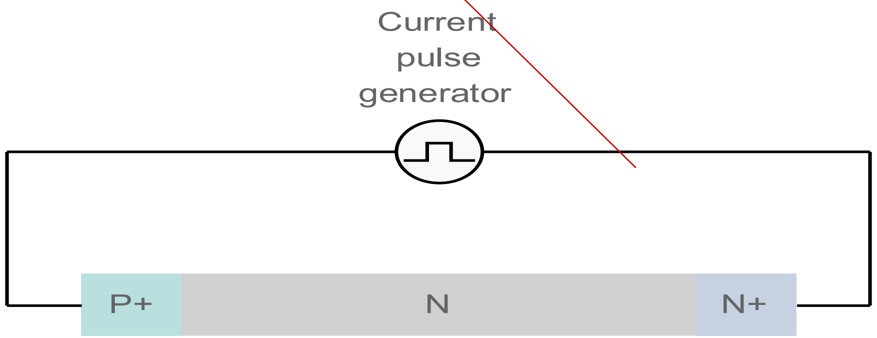
EEEN 566--COURSE DESCRIPTION (9-1)

9. Microwave semiconductor devices: PIN diode, Tunnel diode, LSA diode, varactor diode, Gunn Devices, IMPATT and TRAPATT, their Principal of operation, characteristics and applications.



IMPATT diode (IMPact ionization Avalanche Transit-Time diode)

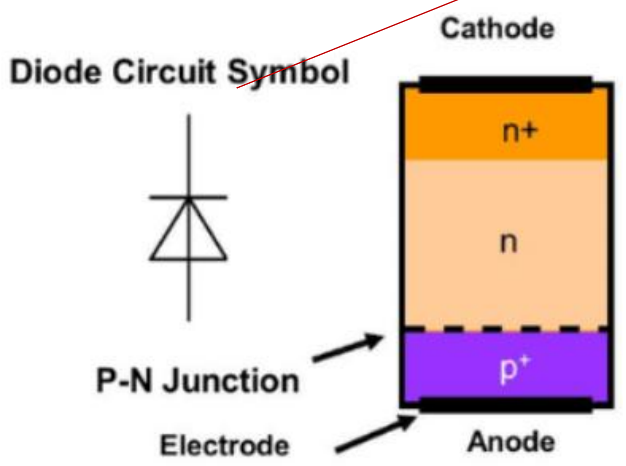
A form of high-power semiconductor diode used in high-frequency microwave electronics devices. They have negative resistance and are used as oscillators and amplifiers at microwave frequencies.

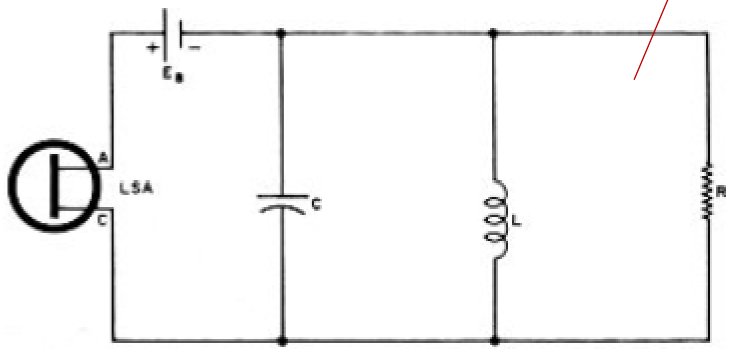


TRAPATT or TRApped, Plasma Avalanche Triggered Transit diode

The TRAPATT diode is based around the initial concept of the IMPATT but it has been enhanced by increasing the doping level between the junction and the anode

9. Microwave semiconductor devices: PIN diode, Tunnel diode, LSA diode, varactor diode, Gunn Devices, IMPATT and TRAPATT, their Principal of operation, characteristics and applications.





PIN Diode

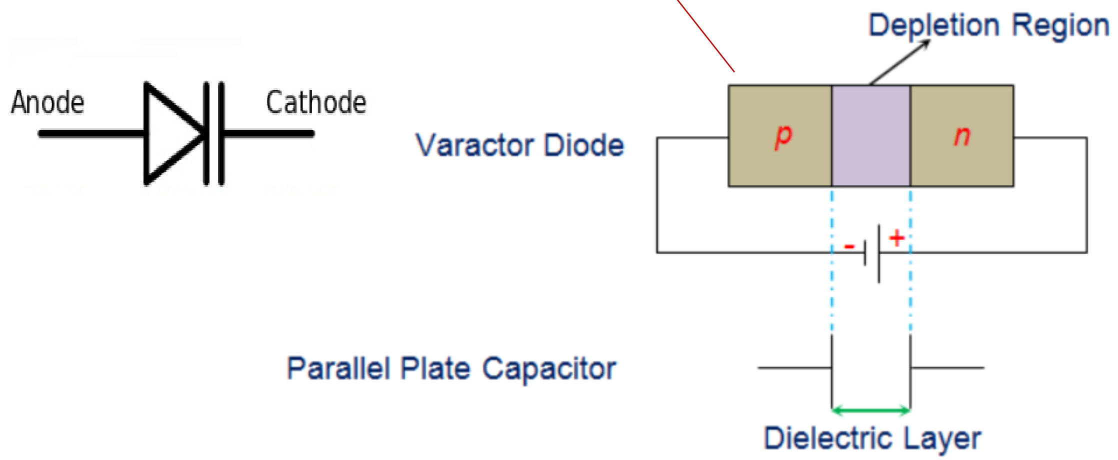
A special type of diode that contains an undoped intrinsic semiconductor between the p-type semiconductor and n-type semiconductor regions.

LSA (Limited Space-charge Accumulation) diode

A transferred-electron diode similar to the Gunn diode except that it is intended to operate at frequencies that are determined by the microwave cavity in which the diode is mounted and that are several times higher than the transit-time frequency so that the formation of charge packets (or domains) is limited.

EEEN 566--COURSE DESCRIPTION (9-3)

9. Microwave semiconductor devices: PIN diode, Tunnel diode, LSA diode, Varactor diode, Gunn Devices, IMPATT and TRAPATT, their Principal of operation, characteristics and applications.



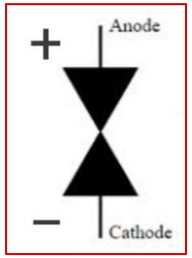
Varactor Diode

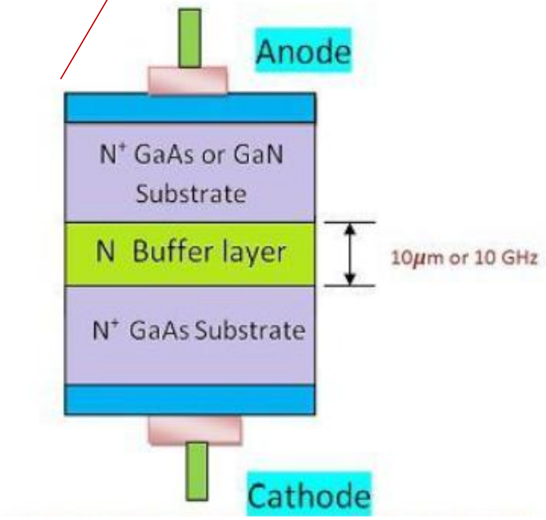
A type of diode whose internal capacitance varies with respect to the reverse voltage. It always works in reverse bias ...

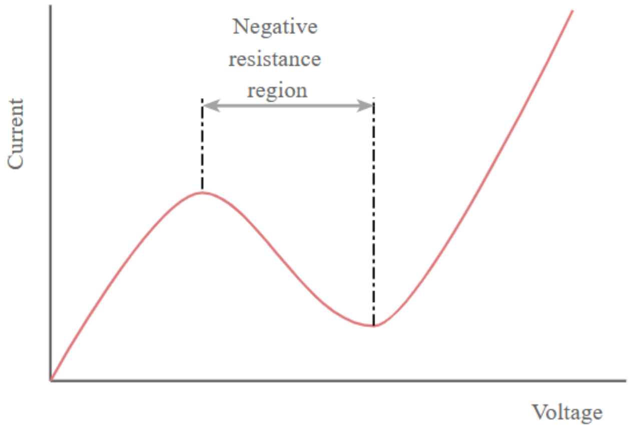
1. **Varactor diodes** are compact in size, economical, reliable and less noisy compared to other diodes.
2. Hence, they are used in the following applications:
   a) **Tuning circuits** to replace the old-style variable capacitor tuning of FM radio
   b) Tank circuits of receiver or transmitter for auto-tuning as in case of TV
   c) Signal modulation and demodulation.
   d) Microwave frequency multipliers as a component of LC resonant circuit
   e) Very low noise microwave parametric amplifiers

EEEN 566--COURSE DESCRIPTION (9-4)

9. Microwave semiconductor devices: PIN diode, Tunnel diode, LSA diode, varactor diode, Gunn Devices, IMPATT and TRAPATT, their Principal of operation, characteristics and applications.





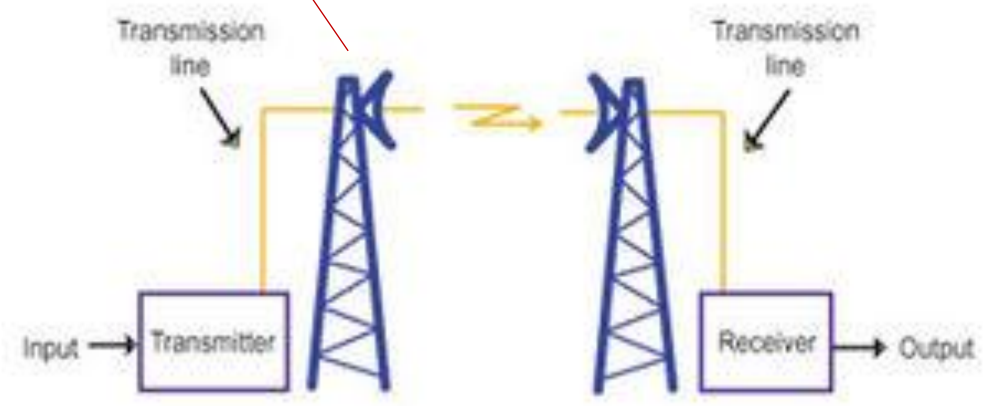


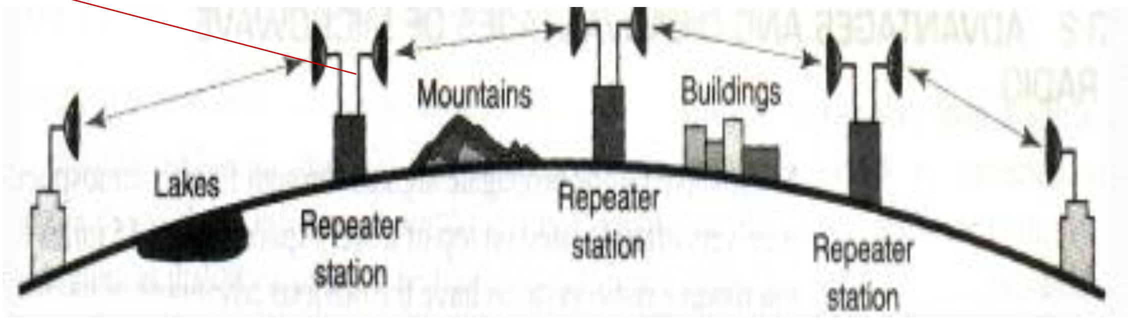
Gunn Diode

A passive semiconductor device with two terminals, which composes of only an n-doped semiconductor material, unlike other diodes which consist of a p-n junction. Gunn diodes can be made from the materials which consist of multiple, initially-empty, closely-spaced energy valleys in their conduction band like Gallium Arsenide (GaAs), Indium Phosphide (InP), Gallium Nitride (GaN), Cadmium Telluride (CdTe), Cadmium Sulfide (CdS), Indium Arsenide (InAs), Indium Antimonide (InSb) and Zinc Selenide (ZnSe).

EEEN 566-COURSE DESCRIPTION (10)

- **10. Microwave Relays:** Line-of-site path characteristics, Microwave radio stations and repeaters.





Microwave radio relay

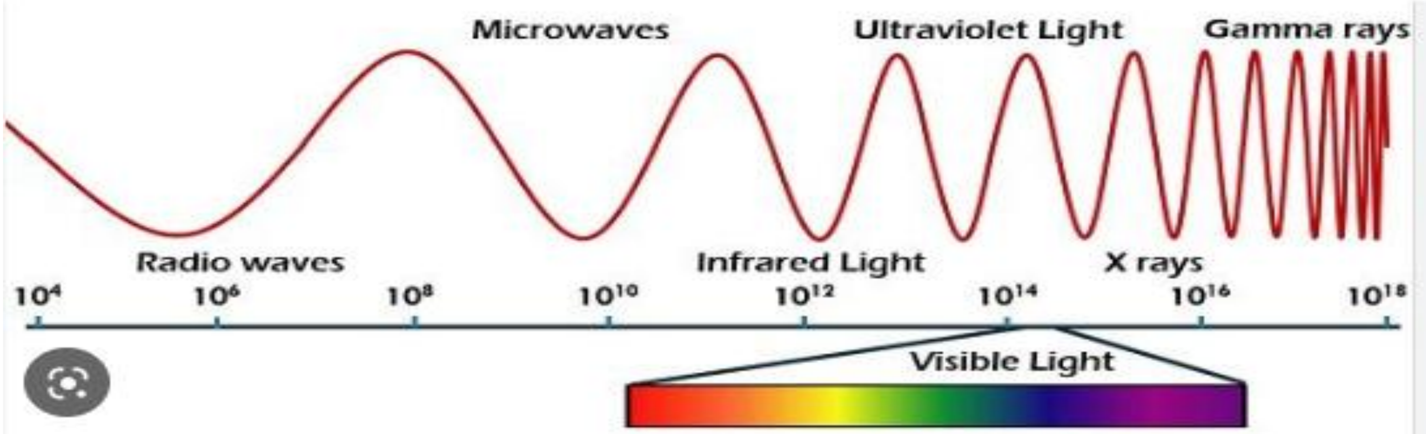
A technology widely used for transmitting signals, such as long-distance telephone and video between two terrestrial points on a narrow beam of microwaves

Microwave repeater Stations

Microwave RF repeaters are designed to transfer signals from one radio link to another without loss of quality, data, or traffic, while compensating for multipath and fading loss

WHAT ARE MICROWAVES

1. Microwaves are a form of electromagnetic radiation with Microwaves are a form of electromagnetic radiation with frequencies between **300 MHz (1 m) and 300 GHz (1 mm)**
2. The prefix **micro- in microwave is not meant** to suggest a wavelength in the micrometer range. Rather, it indicates that microwaves are "small" (having shorter wavelengths), compared to the radio waves used prior to microwave technology.
3. The **boundaries between infrared, terahertz radiation, microwaves, and UHF waves** are fairly arbitrary and vary in different fields of study.



STANDARD RADAR FREQUENCY LETTER-BAND NOMENCLATURE (IEEE STANDARD 521-2002)

BAND DESIGNATOR	FREQUENCY (GHZ)	WAVELENGTH IN FREE SPACE (CENTIMETERS)
HF	0.003 to 0.030	10000 to 1000
VHF	0.030 to 0.300	1000 to 100
UHF	0.300 to 1	100 to 30.0
L band	1 to 2	30.0 to 15.0
S band	2 to 4	15 to 7.5
C band	4 to 8	7.5 to 3.8
X band	8 to 12	3.8 to 2.5
Ku band	12 to 18	2.5 to 1.7
K band	18 to 27	1.7 to 1.1
Ka band	27 to 40	1.1 to 0.75
V band	40 to 75	0.75 to 0.40
W band	75 to 110	0.40 to 0.27
mm	110 to 300	0.27 to 0.10

Microwaves

Microwave does not relate to micrometer/micron

$$f = \frac{c}{\lambda}$$

If $\lambda = 1 \times 10^{-6}$

Then $f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{10^{-6}} = 3 \times 10^{14}$

= 300 Terahertz

RECENT DEVELOPMENTS IN MICROWAVE ENGINEERING

Core Journals

- *Microwave and Wireless Components Letters, IEEE*
- *Microwave Theory and Techniques, IEEE Transactions on*

Others in Related Fields

- *IEEE Transactions on Antennas and Propagation,*
- *Antennas and Wireless Propagation Letters, IEEE*
- *Communications, IEEE Transactions on*