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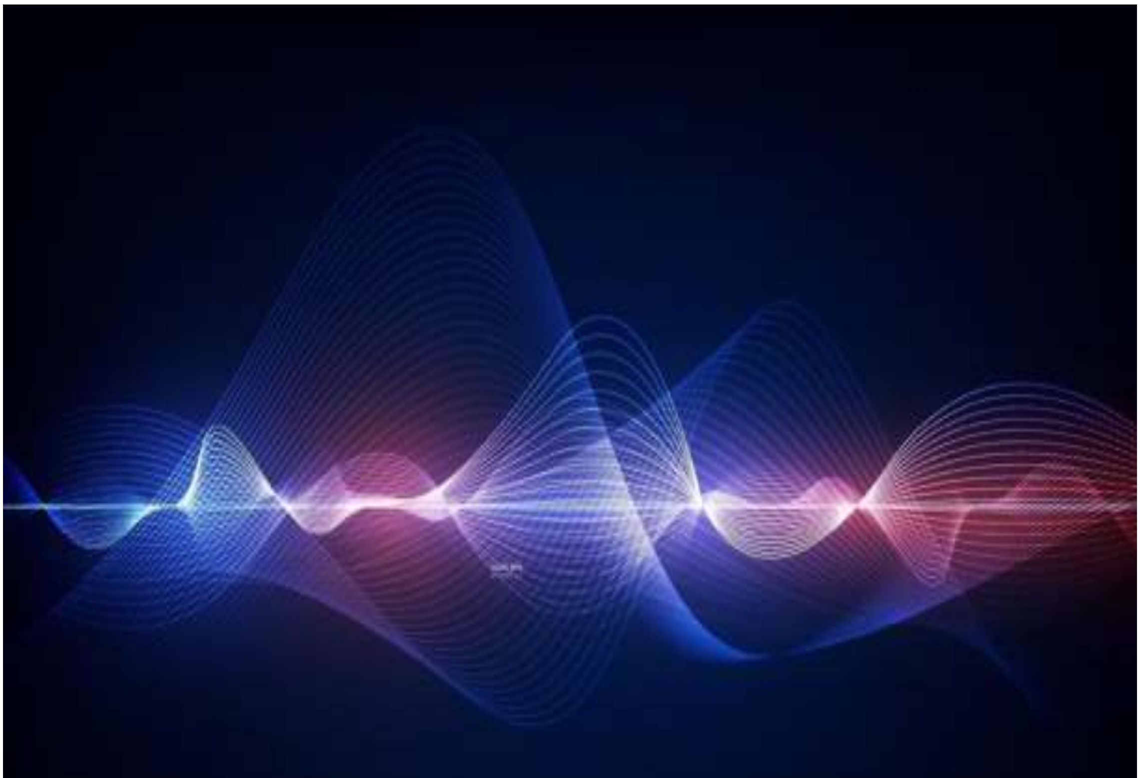
SULTAN MIZAN ZAINAL ABIDIN



MICROWAVE DEVICES
DEP50043

POLYTECHNIC OF SULTAN MIZAN ZAINAL ABIDIN
DEPARTMENT OF ELECTRICAL ENGINEERING
(COMMUNICATION)

ACKNOWLEDGEMENT

Alhamdulillah, all praise to Almighty Allah who made this possible for team to complete this book entitled “Microwave Devices”. We wish to express our deep and sincere gratitude for those who have guided and given full cooperation and commitment in completing this book.

This book is structured to meet the need of theoritically in course of Microwave Devices. This book can be used as a guidance for all the students and lecturers who are involved in Electrical Engineering (Communication) for course DEP50043 programme in Sultan Mizan Zainal Abidin Polytechnic (PSMZA).

We realize that this book is far from perfect, therefore constructive criticism and suggestions are welcomed to improve this book.

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CHAPTER/CONTENTS

SYNOPSIS

MICROWAVE DEVICES introduces the existence, characteristic and the effect of electromagnetic wave to the surrounding. This course also focuses on the devices used in microwave communication system such as waveguide (transmission lines), basic accessories, sources, microwave antennas as well as the techniques of measurement used in microwave system.

COURSE LEARNING OUTCOMES (CLO)

Upon completion of this course, students should be able to:

1. Investigate microwave propagation problems using mathematical concept and design tools by implementing the knowledge of electromagnetic field to the operation of devices used in microwave system. (C4, PLO4)

2. Assemble the related microwave communication equipment in performing the measurement of appropriate output variable. (P4, PLO5)

3. Demonstrate appropriate good social interaction and responsibility while handling microwave equipment or transmission system. (A3, PLO6)

KEMENTERIAN PENDIDIKAN TINGGI

SOARING UPWARDS

POLITEKNIK MALAYSIA

DEP50043
MICROWAVE DEVICES

COURSE LEARNING OUTCOME

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KEMENTERIAN PENDIDIKAN TINGGI

SOARING UPWARDS

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CHAPTER 1

MICROWAVE COMPONENTS AND SOURCES

LEARNING OUTCOMES

Upon completion of this chapter, the students would be able to:

1.1 Remember the principle of electromagnetic wave

1.2 Understand the propagation of electromagnetic wave

1.3 Understand the microwave propagation system

1.4 Remember the following components in waveguide system

1.5 Remember type of microwave sources

1.6 Understand the differences between microwave sources

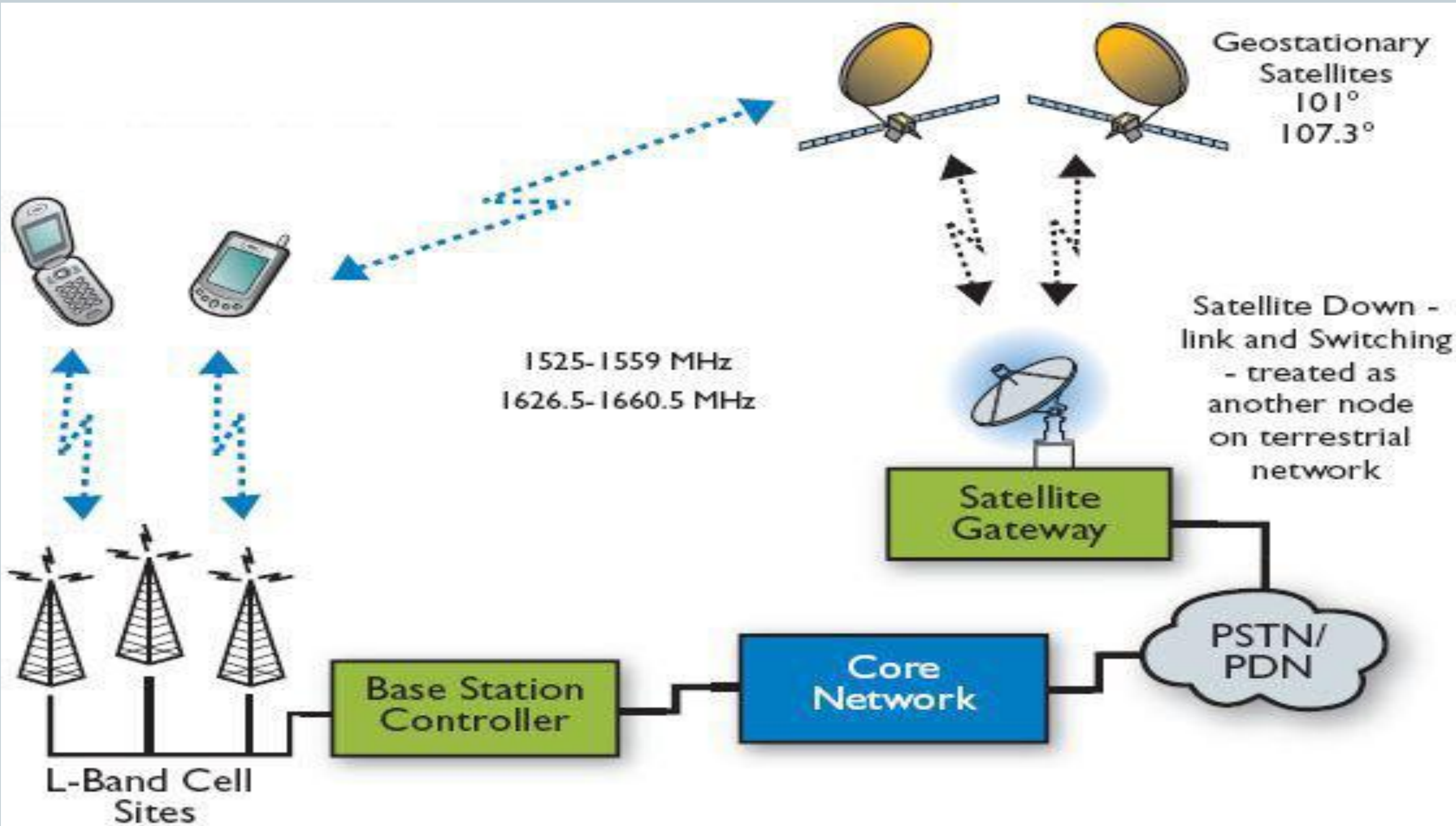
1.1
Remember the principle of electromagnetic wave

Introduction of Electromagnetic Wave

Electromagnetic wave is used to carry signal and uses Earth's atmosphere as a medium of transmission (Figure 1.1), because:

- For long range wired communication (metallic cables, fiber optics) is not suitable
→when equipments are separated by large span terrain or communicating with satellite 23 000 mile above earth atmosphere. (impossible, impractical)

- Or when the equipment are mobile, i.e. mobile phones, two-way radio.



(Figure 1.1 Earth's atmosphere as a medium of transmission)

- Electrical energy that has escaped into free space is called electromagnetic wave.

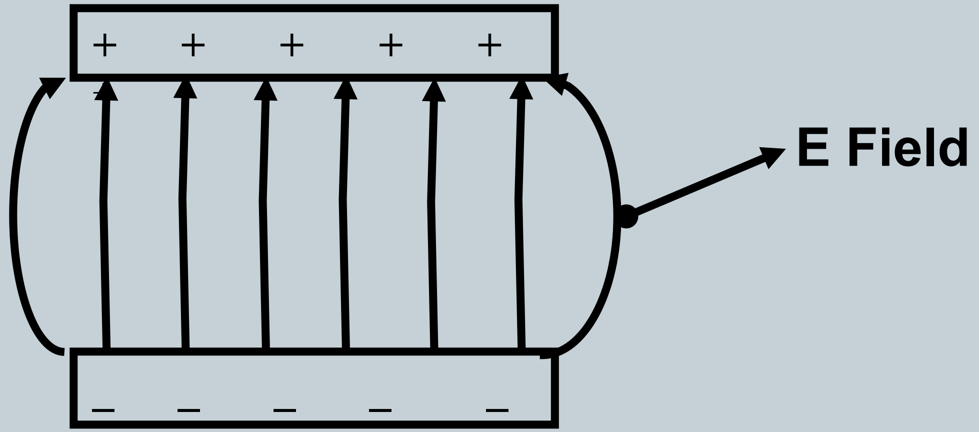
- This electrical energy is generated by a.c. current.

- Thus, the electromagnetic wave consists of oscillating Electrical field and oscillating Magnetic field

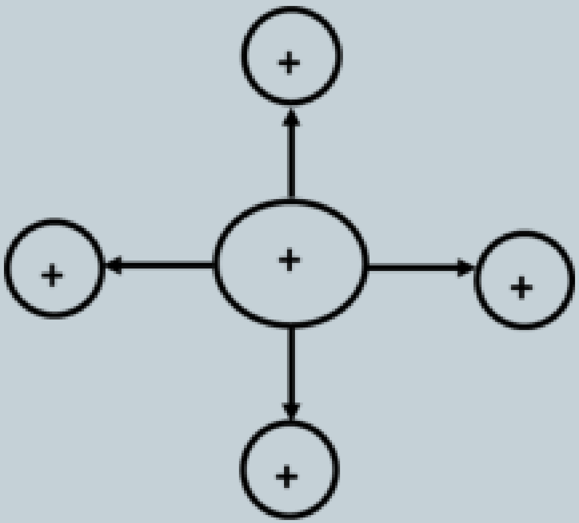
- The electrical energy is evenly divided between the magnetic and electric field.

Electric field (E)

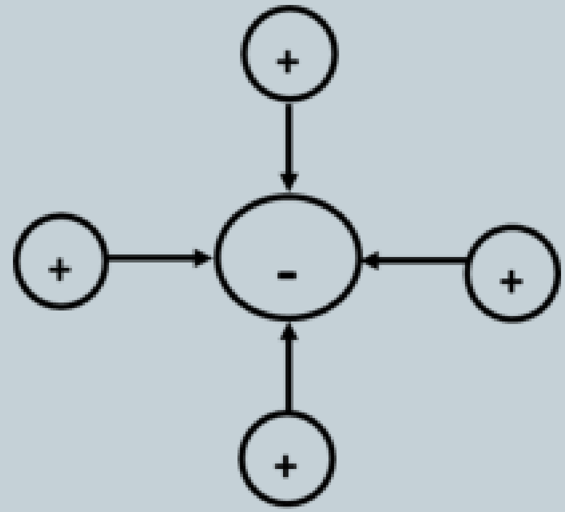
The existing of E field is due to the flow of electric current which is cause by the movement of electrons in a conductor starting with a negative charge and ends with a positive charge.



The characteristics of E field



i) Fixed positive charge repels the positive charges nearby



ii) Fixed negative charge attracts the positive charges nearby

Magnetic field (H)

H field lines have no starting or ending point.

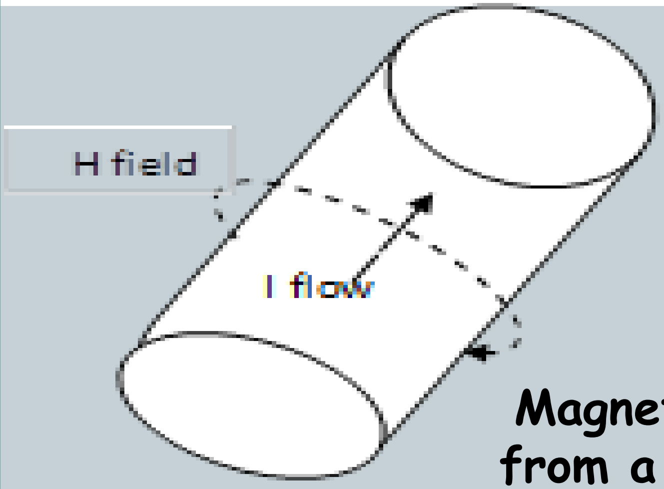
Magnetic line must be continuous; start as a point circle and expand from the center in circular form.

H field direction around a current can be identified by using:
Right Hand Rule (RHR)
- It states that if the right hand thumb points in the direction of the current, the direction of magnetic field is in the direction towards the curved of the fingers.

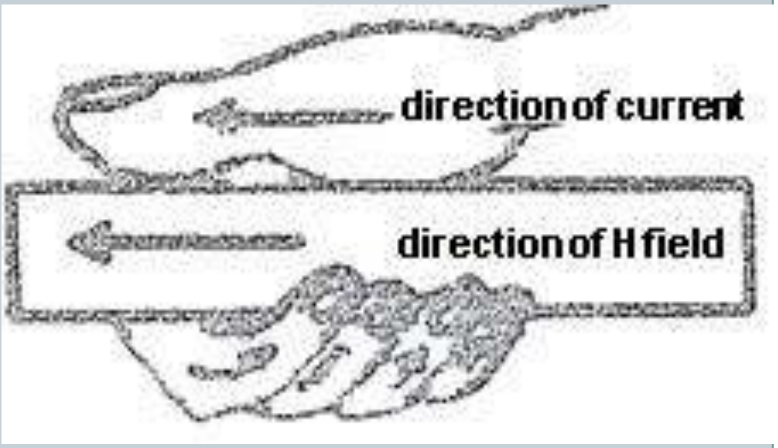
The characteristics of H field

- Formed a close loop (no starting or ending point).
- Possess specific direction based on right hand rule.
- The fields does not crossed each other.
- Repels each other.
- The fields possess a tension along its distant (it trys to shorten the route).

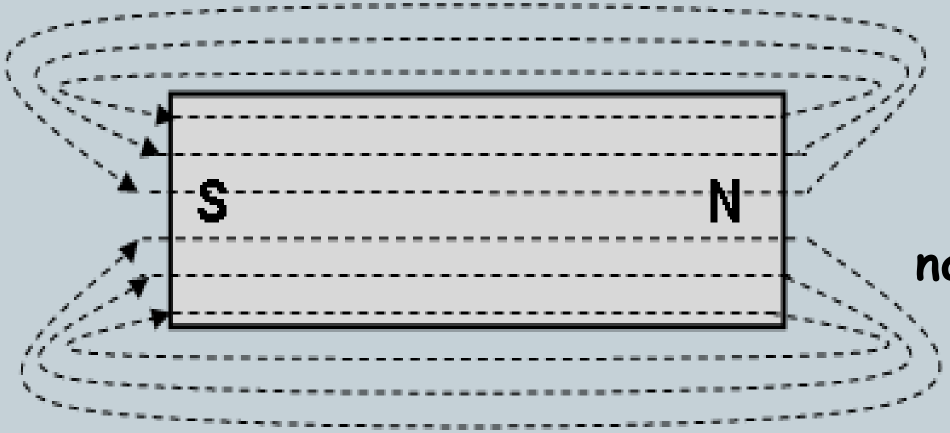
The strength of magnetic field depends on the electric strength and its distant from the conductor.



Magnetic result from a charge in motion



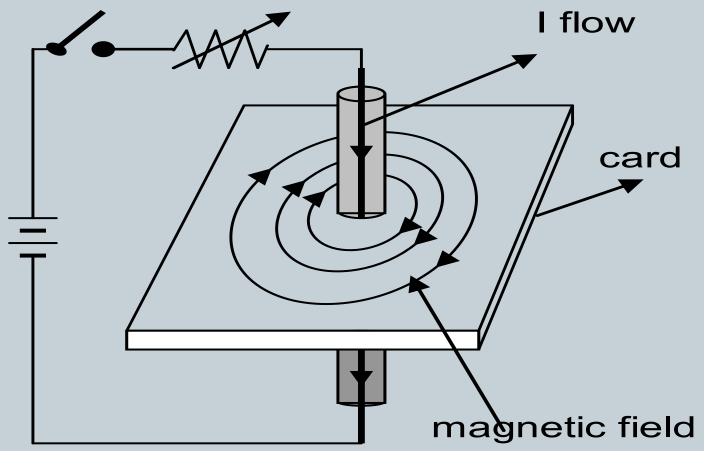
Direction of H field by right-hand rule



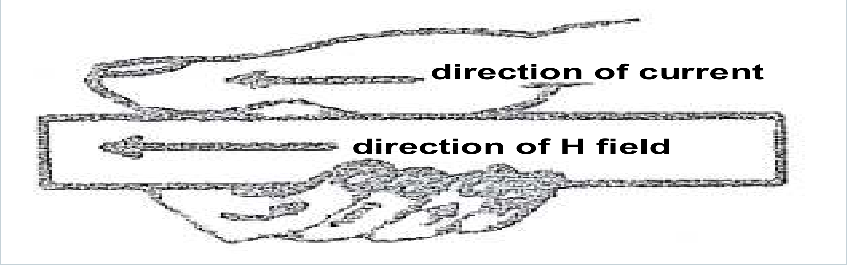
Continuous nature H lines

Methods to identify H field direction:

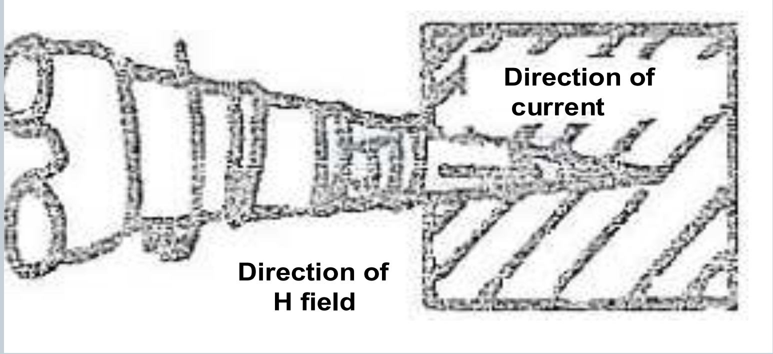
i) Using compass



Right Hand Rule



iii) Screw rule

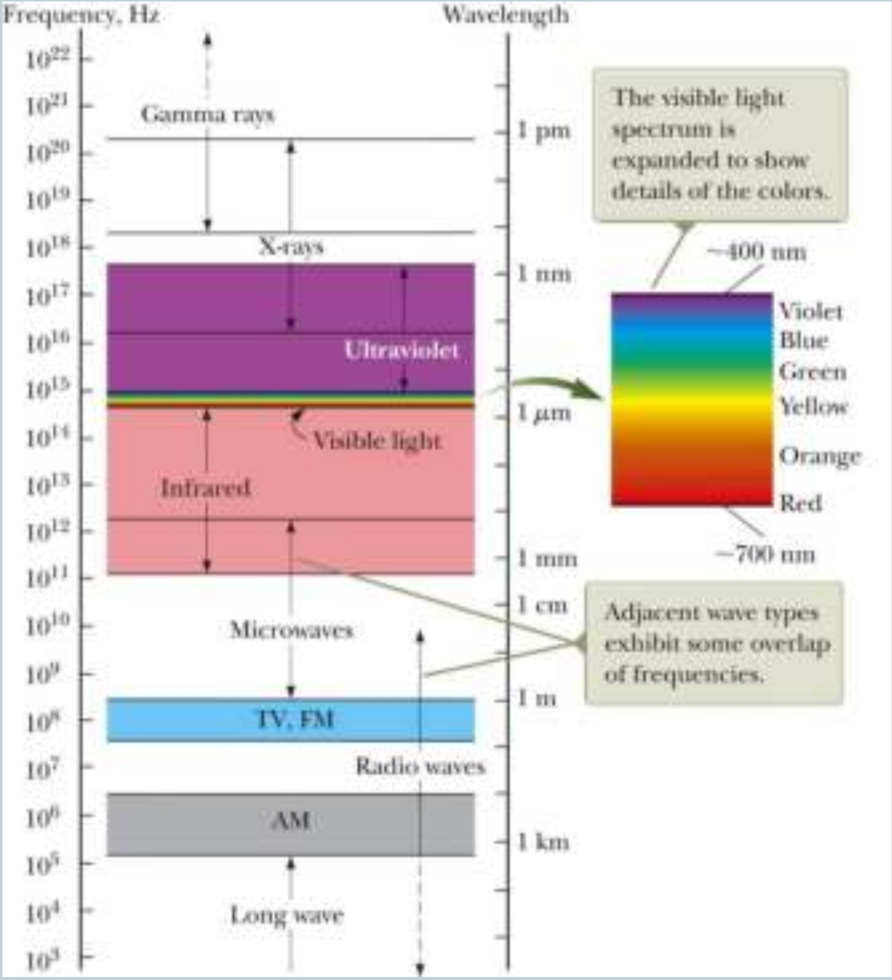


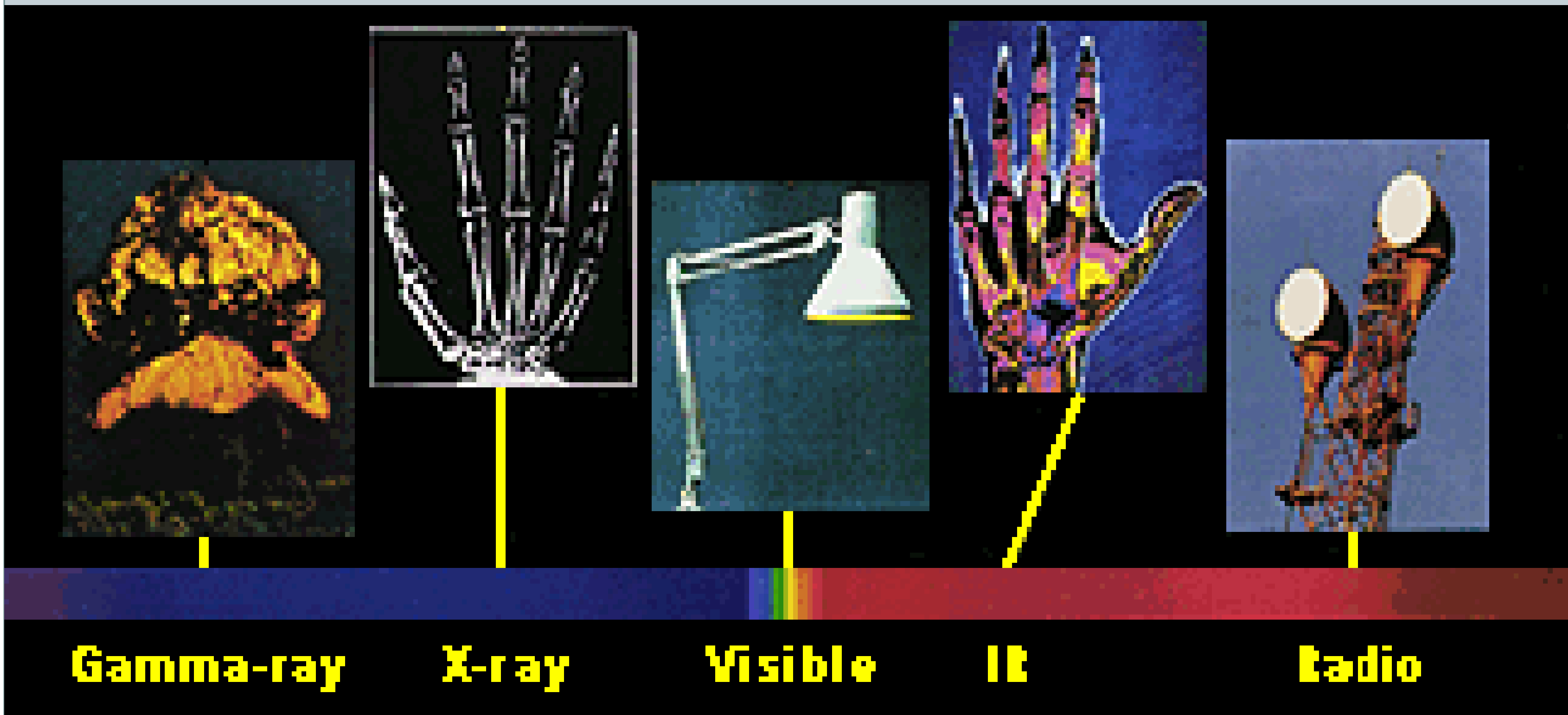
Radiation of Electromagnetic

Electromagnetic radiation is a form of energy that is produced by oscillating elec tric and magnetic disturbance and takes many forms, such as radio waves, micro waves, Xrays and gamma rays.

These electric and magnetic waves travel perpendicular to each other at the spe ed of light through a vacuum having different wavelengths.

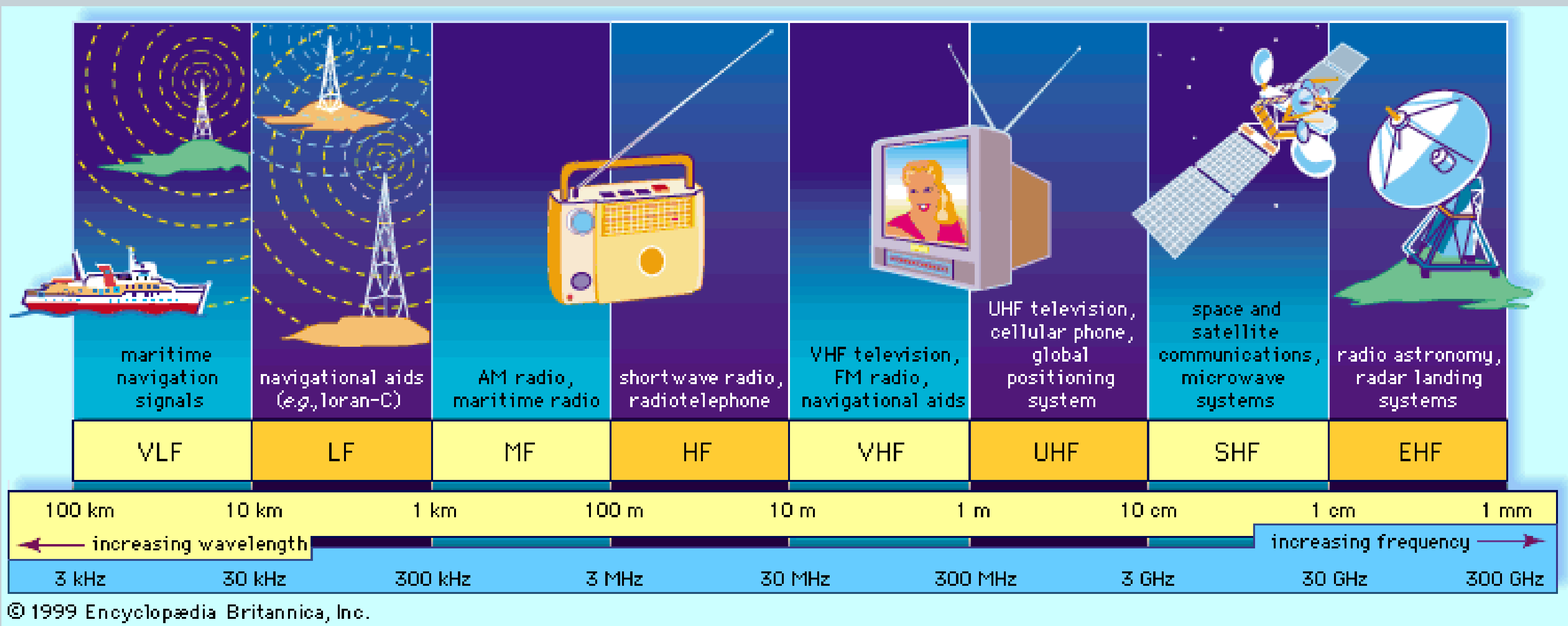
Light, radio waves, x-rays, ultra-violet radiation are all forms of a type of wave composed of oscillating electric and magnetic fields with different wavelength (or frequency).




Gamma-ray
X-ray
Visible
IR
Radio

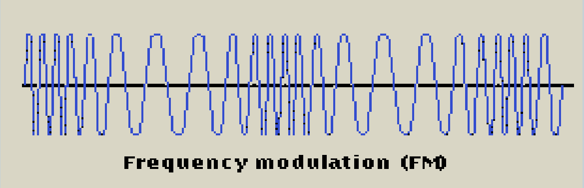
Radio waves

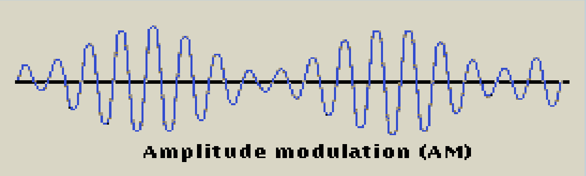
lowest energy EM radiation



FM - frequency modulation

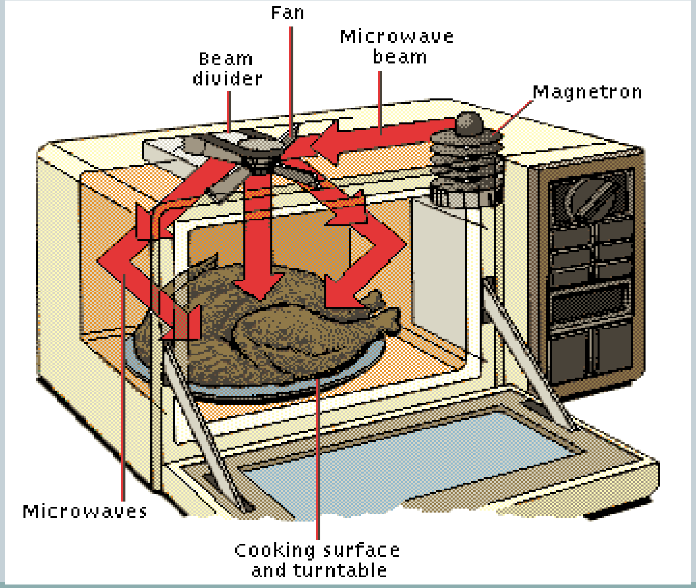
AM - amplitude modulation





Microwaves

- penetrate food and vibrate water & fat molecules to produce thermal energy

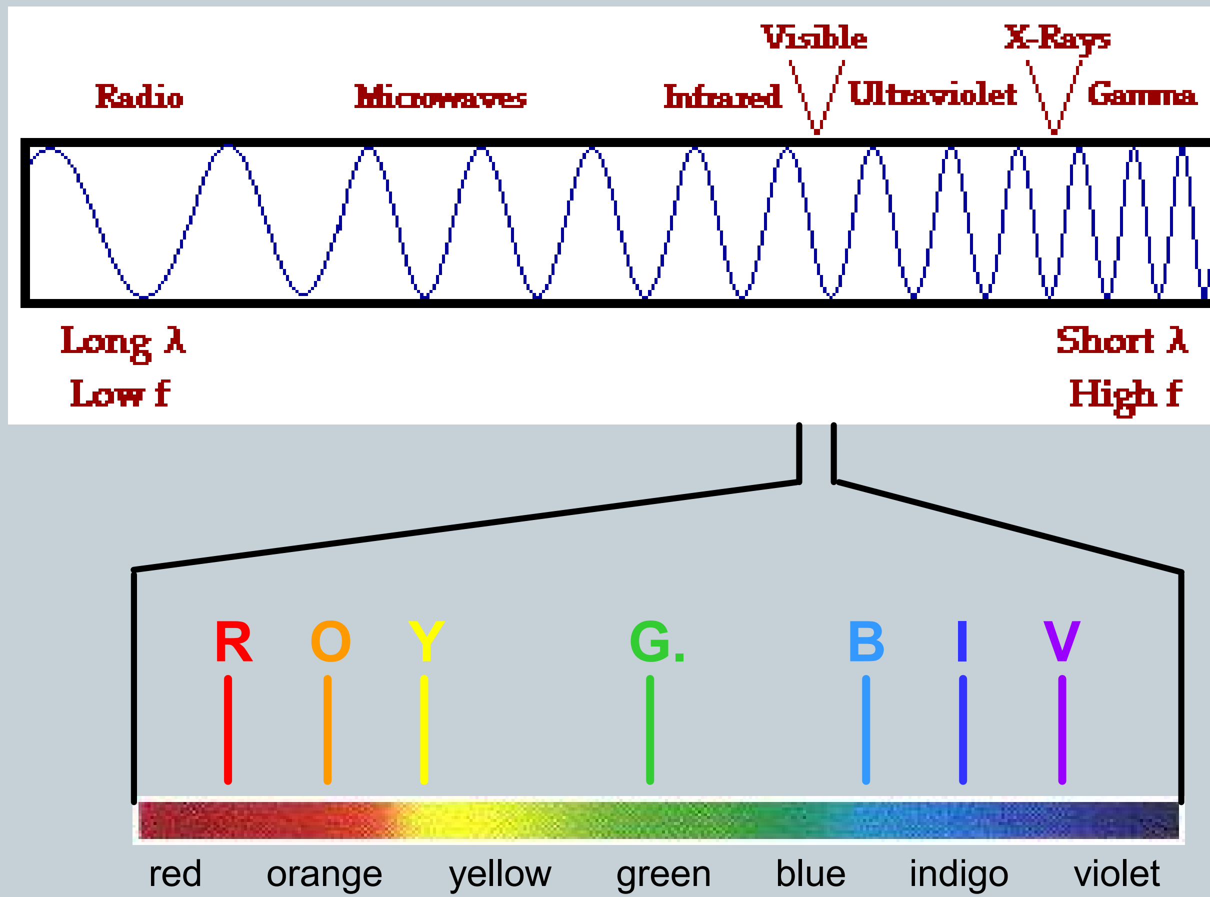


Infrared Radiation (IR)

- Slightly lower energy than visible light
- Can raise the thermal energy of objects
- Thermogram - image made by detecting IR radiation

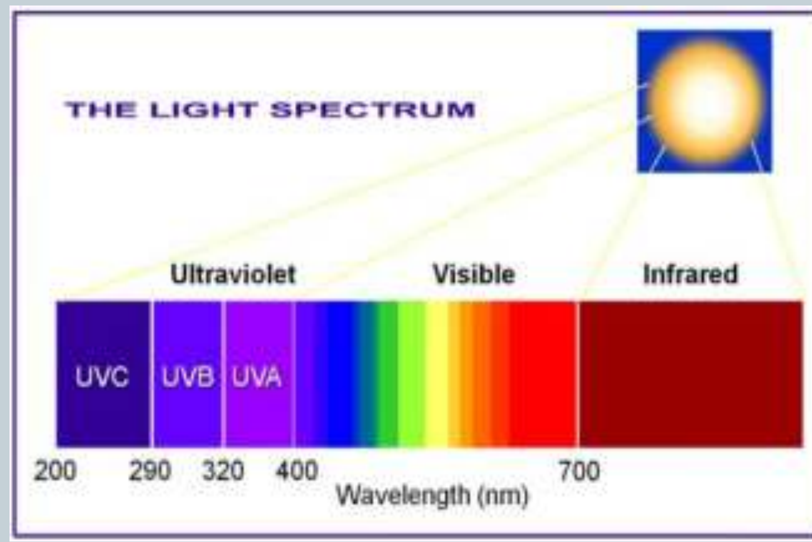
Visible Light

- small part of the spectrum we can see
- **ROY G. BIV** - colors in order of increasing energy

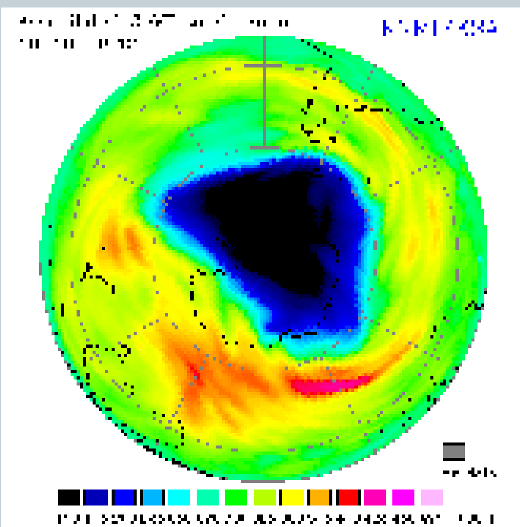


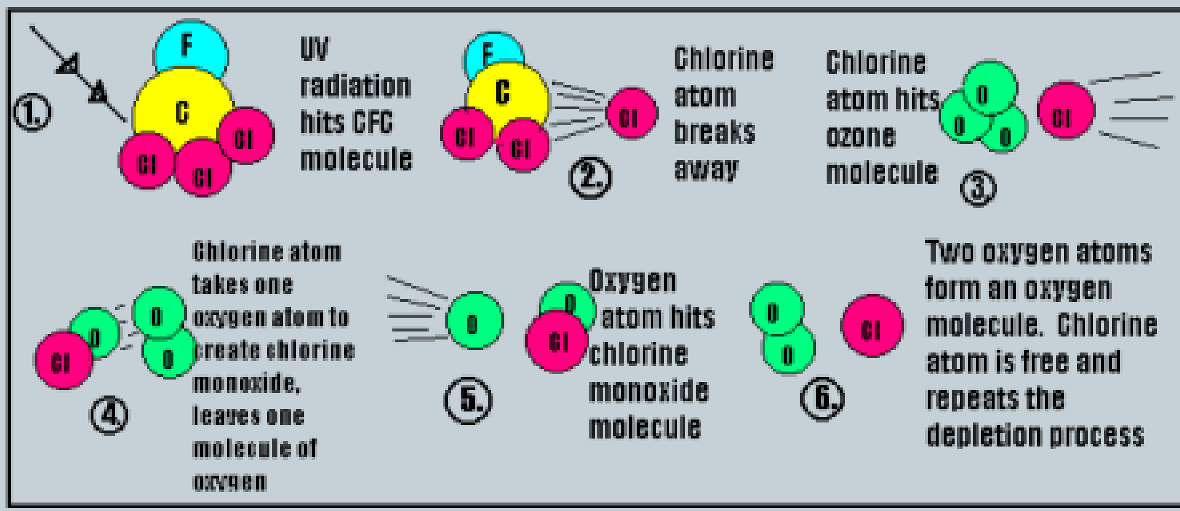
Ultraviolet Radiation (UV)

- Slightly higher energy than visible light
- <u>Types</u>:
  1. UVA - tanning, wrinkles
  2. UVB - sunburn, cancer
  3. UVC - most harmful, sterilization



zone layer depletion = UV exposure!





X rays

- higher energy than UV
- can penetrate soft tissue, but not bones

Gamma Rays

- highest energy EM radiation
- emitted by radioactive atoms
- used to kill cancerous cells

Radiation treatment using radioactive cobalt-60.

1.2
Understand the propagation of electromagnetic wave

Electromagnetic Wave

DEFINITION –

Is an oscillations of the electric and magnetic fields which is perpendicular to each other and propagates with the speed of light (3×10^8 m/s) in free space.

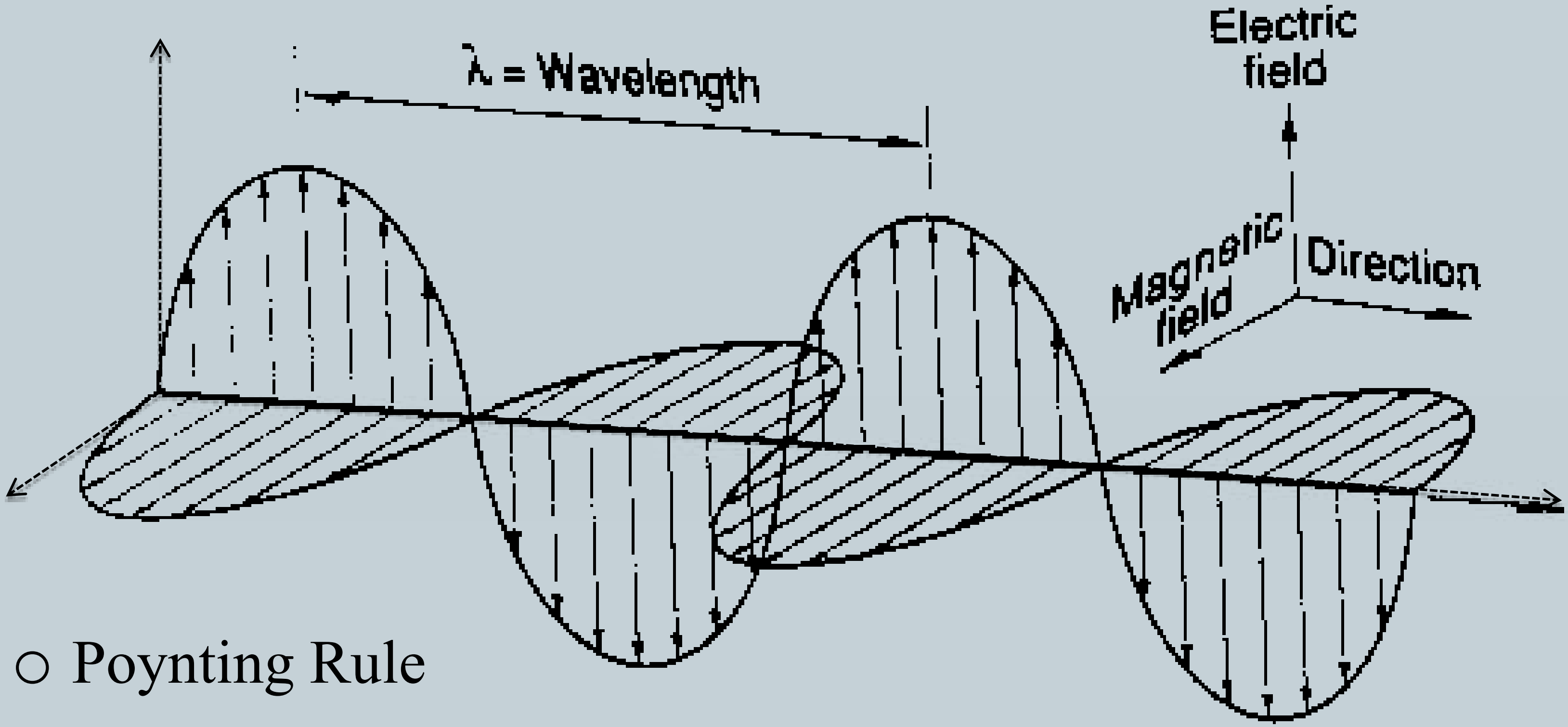
3 CATEGORIES :

- Transverse Electromagnetic Wave (TEM) occurs in free space, coaxial cable and microstrip.
- Transverse Electric (TE) occurs in wave guide.
- Transverse Magnetic (TM) occurs in wave guide.

Transverse Electromagnetic Wave (TEM)

- both electric and magnetic field oscillate in the direction perpendicular to the direction of wave propagation.

- The relationship of the both E and H field orientation with direction of propagation is shown by Poynting vector, **P = E x H** (Figure 1.2a)



- Poynting Rule

  P = **E** x **H**.

(Figure 1.2a Electromagnetic Wave)

The orientation of the E and H fields with respect to the direction of wave propagated will determine the type of EM waves.

i) ***Transverse Electromagnetic* (TEM)** waves - E field and H field transverse to the direction of propagation.(Figure 1.2b).

ii) ***Transverse Electric*, TE** waves - E field is transverse to the direction of propagation and H field has components in the direction of the wave,(Figure 1.2c).

iii) ***Transverse Magnetic*, TM** waves - H field is transverse to the direction of propagation and the E field has components in the direction of the wave,(Figure 1.2d).

Electromagnetic Wave using Vector Diagram

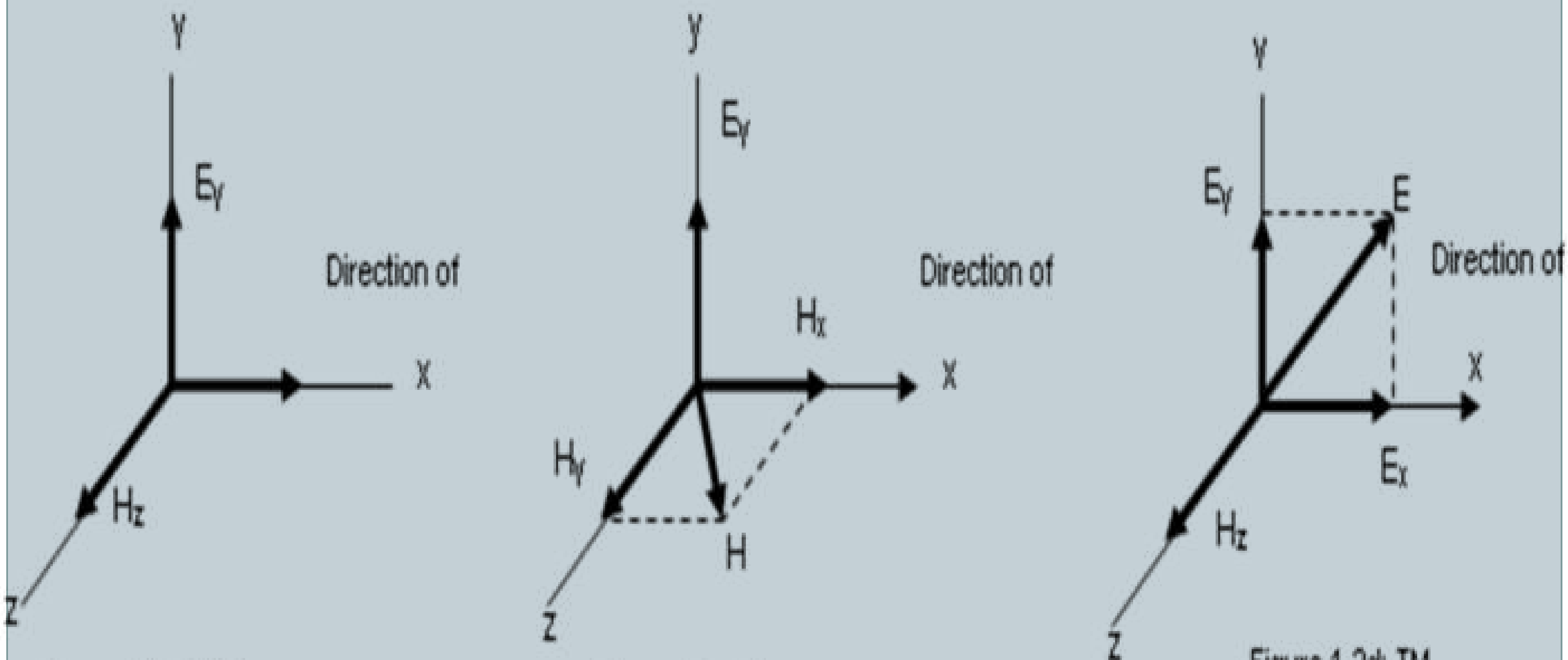


Figure 1.2b: TEM

Figure 1.2c: TE

Figure 1.2d: TM

1.3
Understand the microwave propag ation system

Microwave Transmission System

- MICROWAVE is define as part of an electromagnetic wave that has very high frequency (300 MHz-300GHz) and very short wavelength (1mm-1m).
- Microwave or radio wave propagates at the speed of light ($3x10^8$ ms^{-1}) in vacuum / free space.
- Point to point (sending and receiving antennas need to be **in the same orientation**).
- Easily interfere with other signals sent at the same frequency range.

Microwave Propagation System

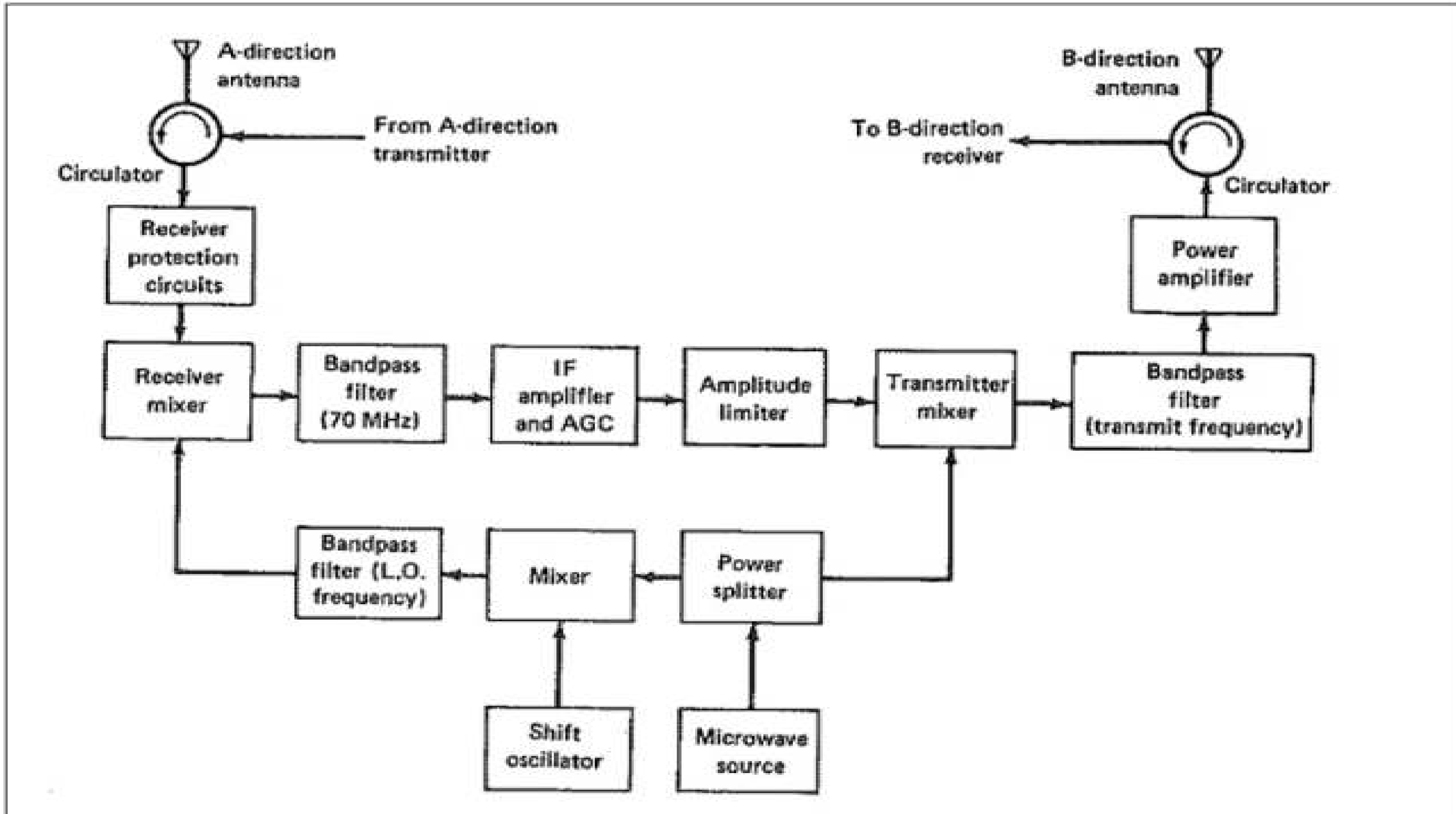


Figure 1.3 : Microwave Communication Link from location A to location B.

Microwave Propagation System

1.	**Antenna**	**Mostly a parabolic refractor types of antenna are used which is used to transmit and receive the signal.**
2.	Circulator	A circulator is used to isolate transmitter with the receiver input and to couple transmitter to antenna and antenna to receiver input.
3.	Protection Circuitry	It provides safety to the mixer from overloads.
4.	Mixer (Receiver)	It has two outputs. One is the incoming signal and other is the signal from lower band pass filter (BPF).The mixer gives an IF signal of 70Mhz.
5.	Band pass filter (BPF)	It provides the necessary selectivity to the receiver and it prevents the interference.
6.	IF amplifier and AGC	It amplifies the signal up to a intermediate frequency of 70Mhz. and its gain is controlled through AGC (automatic gain control)
7.	Amplitude limiter	As the signal is frequency modulated one so as amplitude limiter is used to avoid unwanted amplitude variations.

8.	Mixer (Transmitter)	It is used to convert IF frequency to transmitting microwave frequency band to pass through it and hence prevent interference.
9.	Power Amplifier	This amplifier amplifies the transmitted power from a repeater section in the range of 0.2W to 10W.
10.	Microwave Source	Klystron & Gunn Oscillators were used as microwave source. Now, V H F transistor crystal oscillators are used for microwave source.
11.	Power Splitter	It divides the output power from a microwave source and feeds a large portion to the transmitter mixer, which converts it into transmitting microwave frequency.
12.	Shift Oscilator	It provides one of the inputs to the balanced mixer so that it produces 70MHz IF at the output of receiver mixer.
This microwave link communicates with 600 to 2700 channels per carrier. Thus the number of carriers in each direction can be four to twelve.		

1.4

Remember the following compone nts in waveguide system

Waveguide Components

- CONNECTORS/JOINT (PLANE, CHOKE, ROTARY)
- ATTENUATORS
- COUPLER
- BASIC ACCESSORIES (BENDS, CORNER, TAPERED, TWIST)
- T-JUNCTION (E-PLANE AND H-PLANE) AND HYBRID-T
- SLOTTED SECTION
- ISOLATOR
- CIRCULATOR
- FREQUENCY MIXERS
- FILTER: LOW PASS FILTER, HIGH PASS FILTER, BAND PASS FILTER

Connectors / Joint

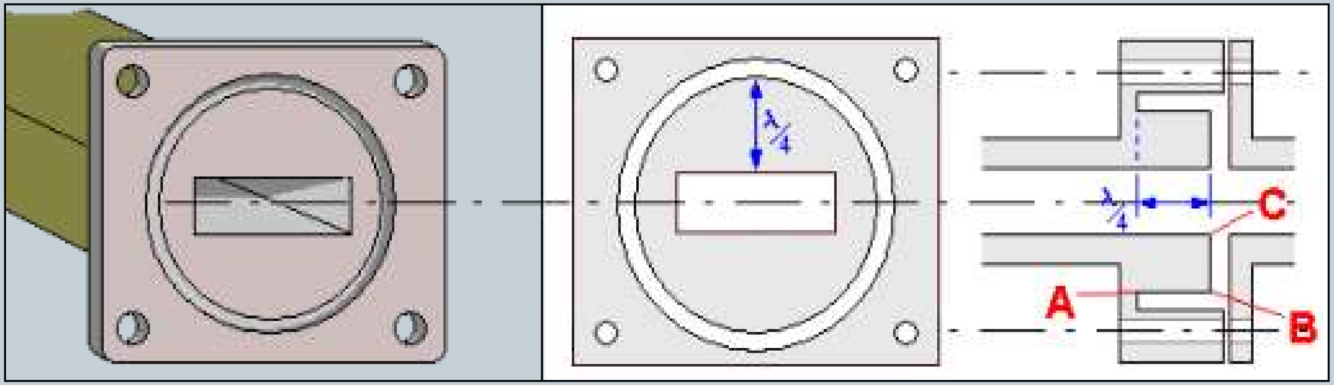
- Plane
- Choke
- Rotary

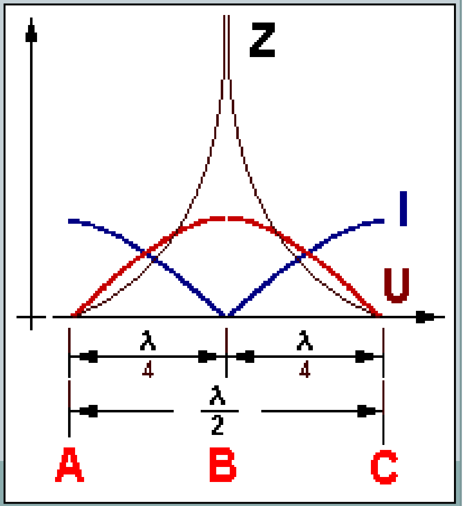
Plane Connector

- Formed by the union of any combination of gasket and cover flanges, and ideally creates a continuous inner su rface from one waveguide to the other, with no crack at the join to interrupt the surface currents.

Choke Connector

- Most commonly used for maintenance and repair at the sections of waveguide.
- Provides good electromagnetic continuity between sections of waveguide with very little power loss.





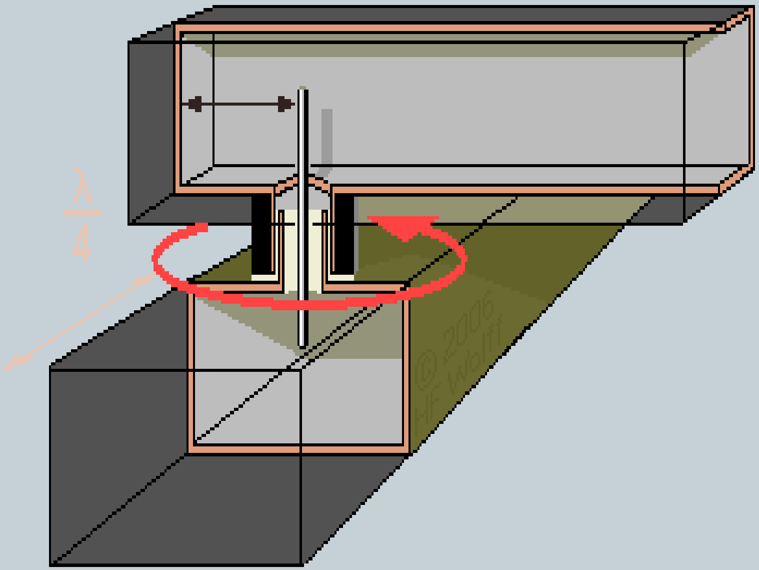
Rotary Joint

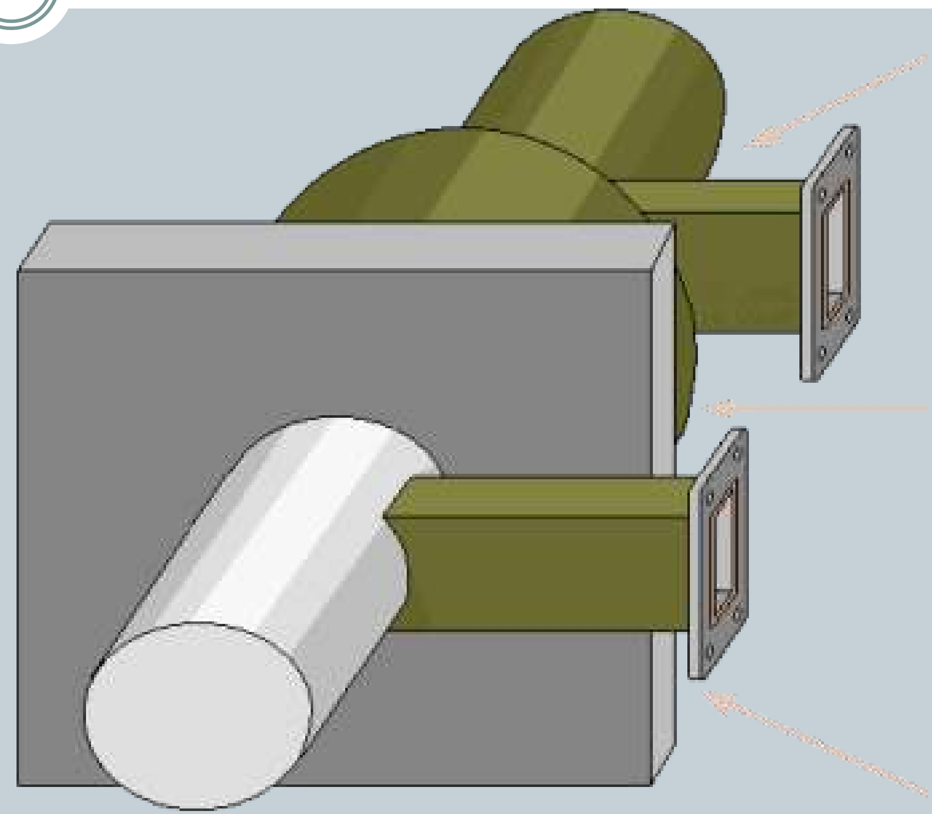
-Must be used whenever a stationary rectangular waveguide is to be connected to a rotating antenna.

-A circular waveguide is normally used in a rotating joint.

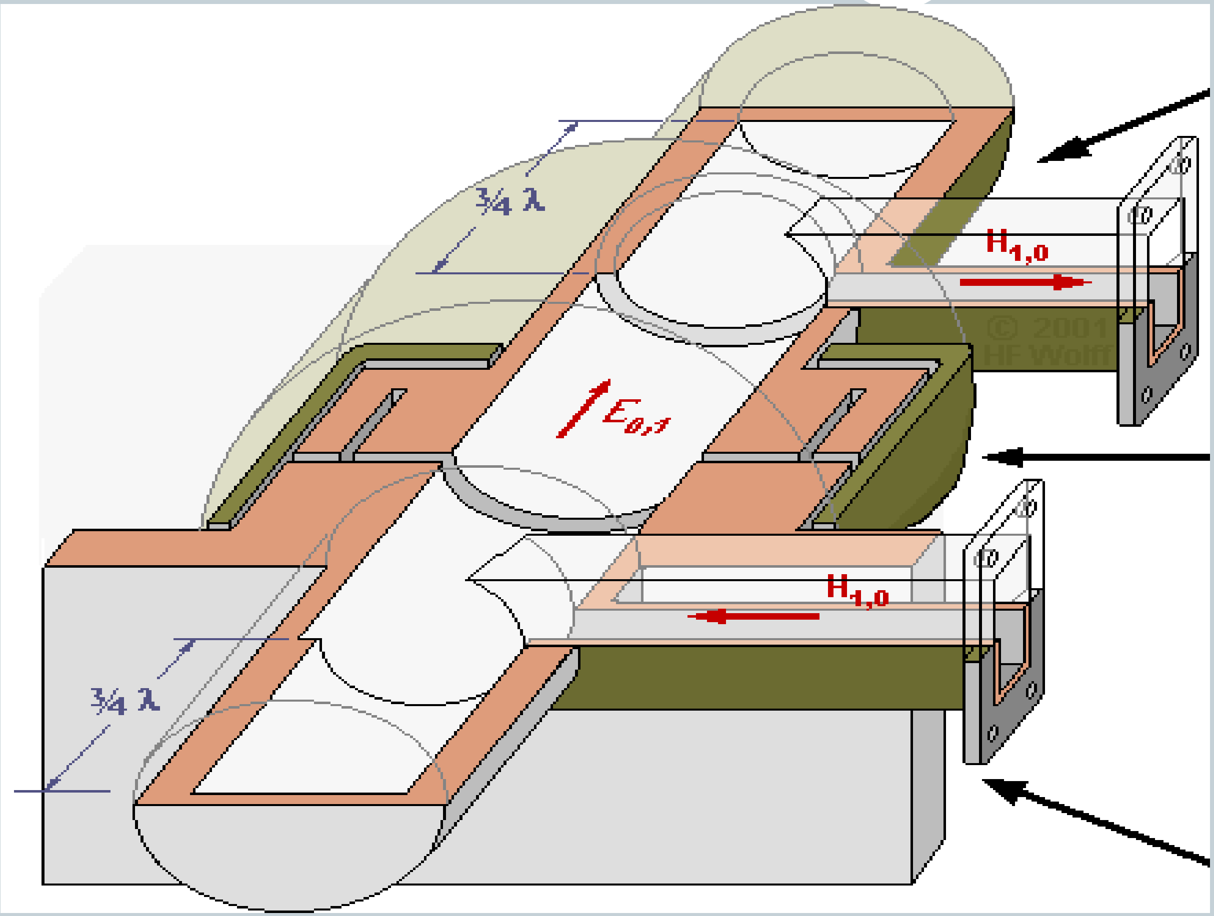
-The rotating section of the joint also uses a choke joint to complete the electrical connection with the stationary section.

ROTARY JOINT





ROTARY JOINT



Rotating section

The rotating section of the joint uses a choke joint to complete the electrical connection with the stationary section.

Stationary section

Attenuators

- Are components that reduce the amount of power a fixed amount, a variable amount or in series of fixed steps from the input to the output of the device.
- The power loss is absorbed by the attenuator.
- Attenuators operate on the interference with the electric or magnetic field, or both.
- It is important that attenuators reduce power through the device without reflecting energy or affecting the mode of transmission.

ATTENUATORS

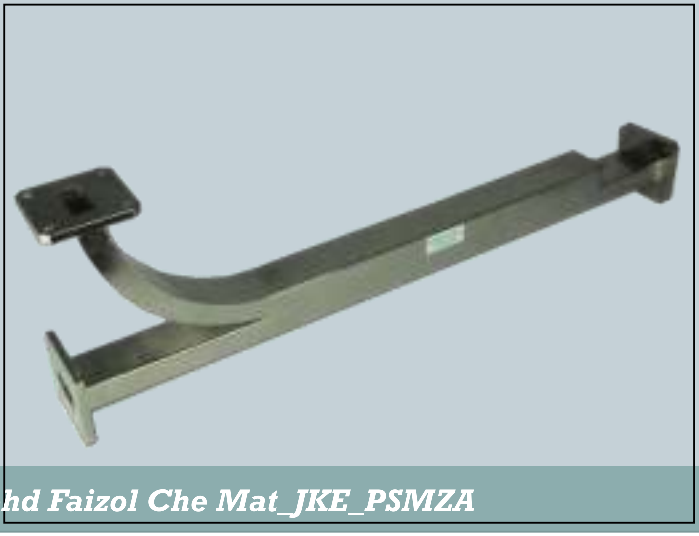
TYPES OF ATTENUATORS:-

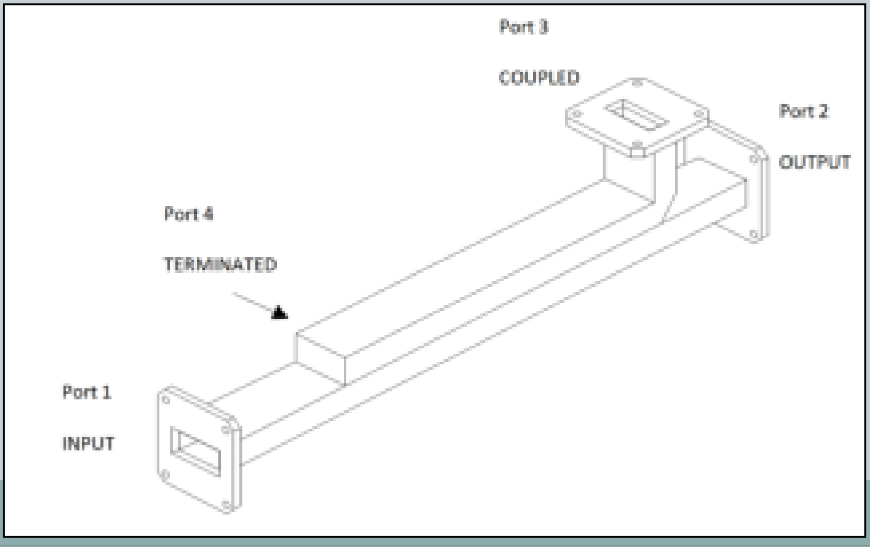
- Slide-vane
- Flap-vane
- Rotary-vane

Coupler

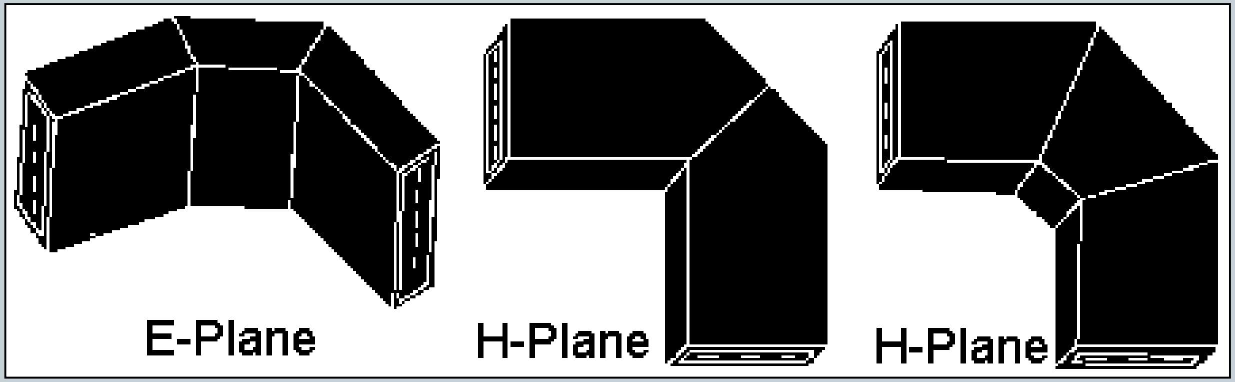
DIRECTIONAL COUPLER

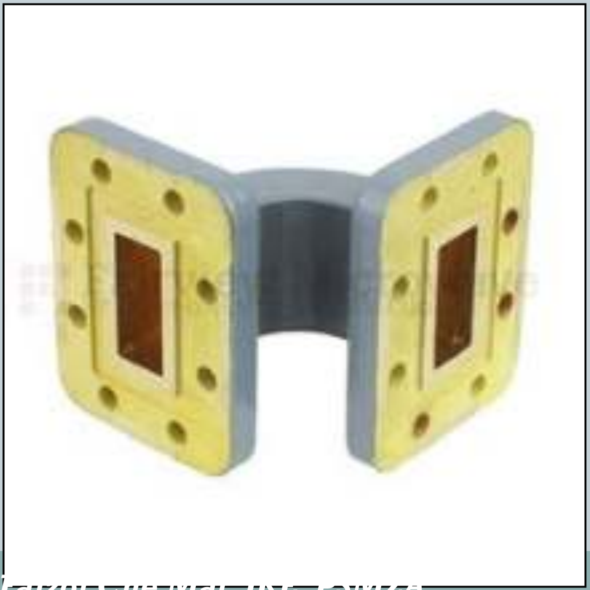
- Launches or receives power in only 1 direction
- **Used to split some of power into a second guide**
- Can use probes or holes.
- The action of the coupler is such that a fraction of the forward energy passing through the main arm will be coupled to the auxiliary arm.

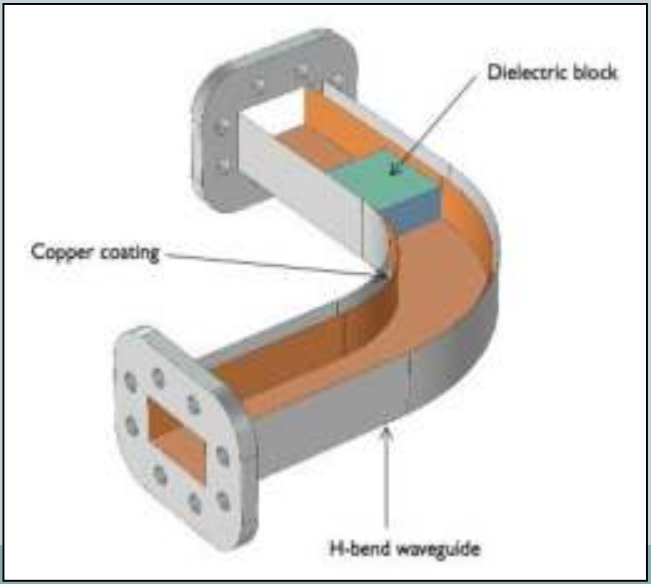




Basic Accessories (Bends)

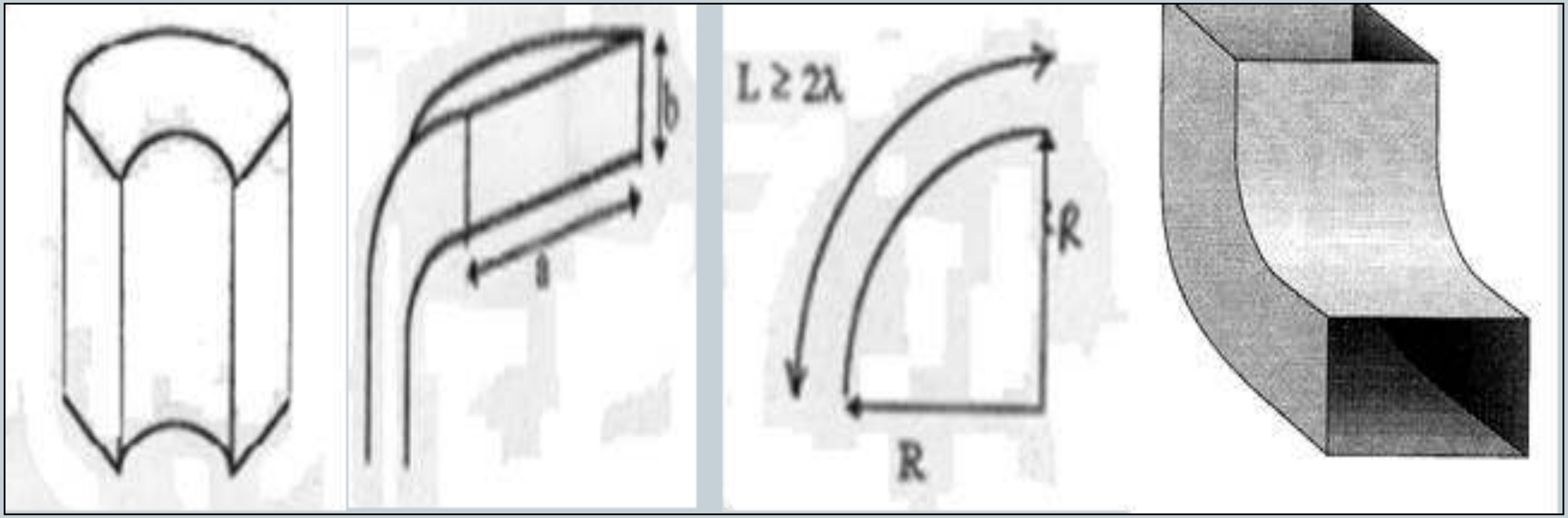




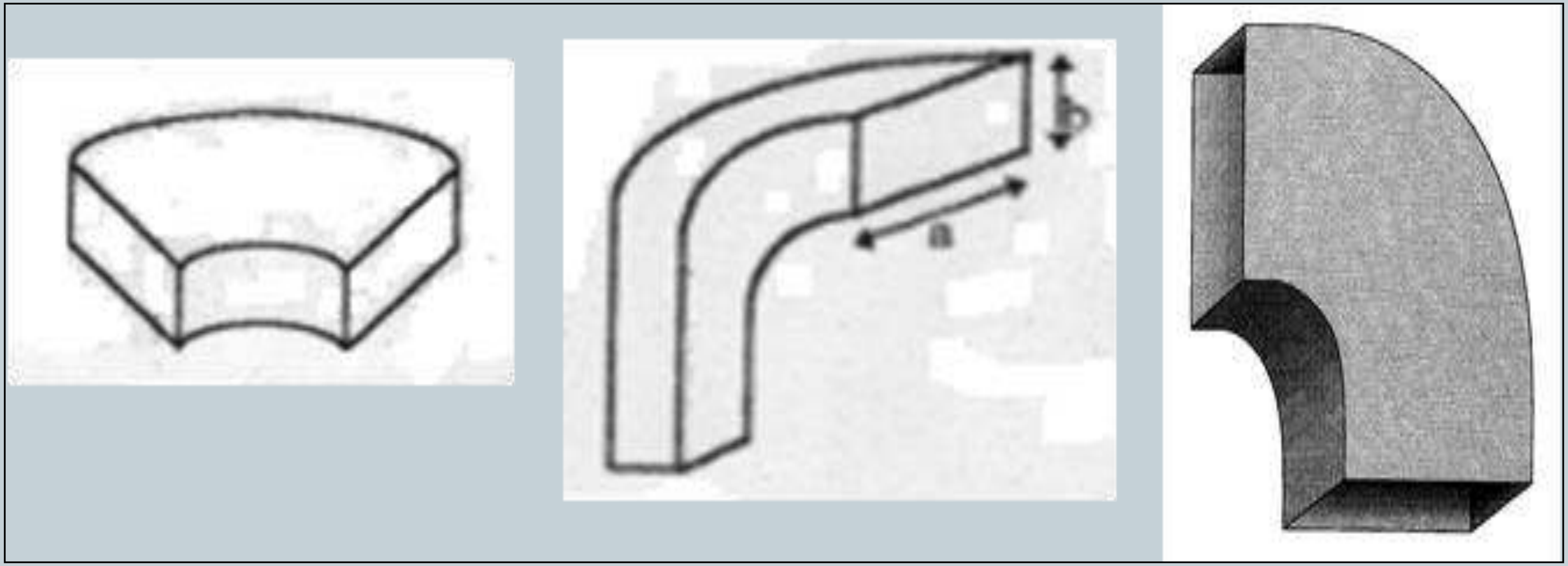


E-plane or **H-Plane** bends depending on the direction of bending.

E-PLANE BEND – used to extend waveguide from one place to another, such as a corner

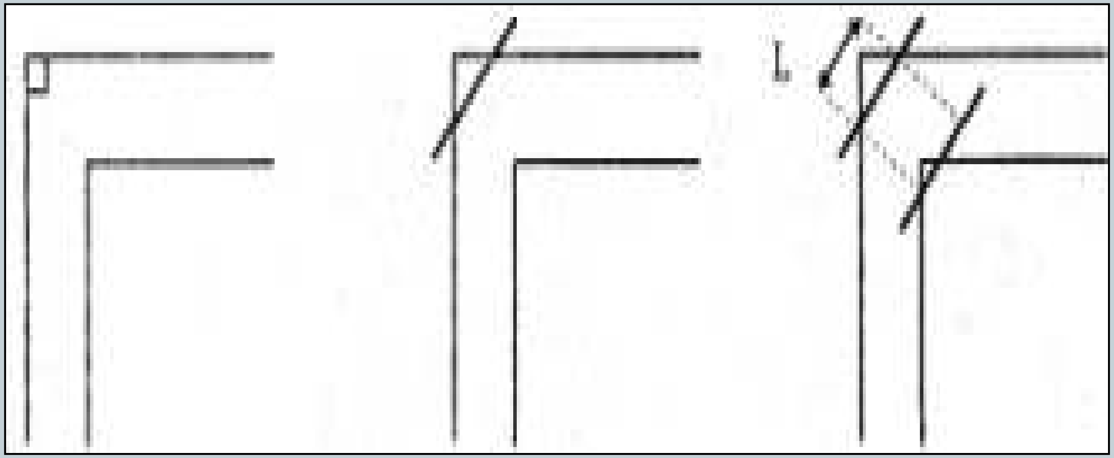


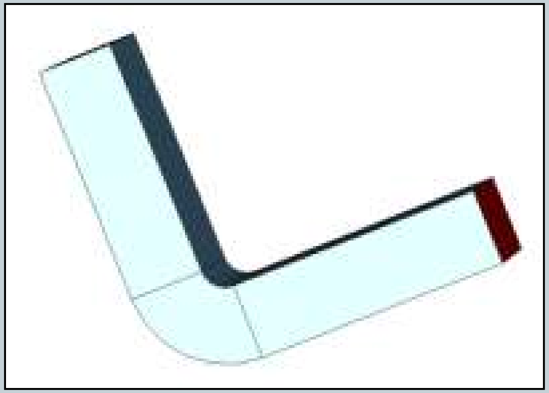
H-PLANE BEND- used to extend waveguide from one place to another, such as a corner

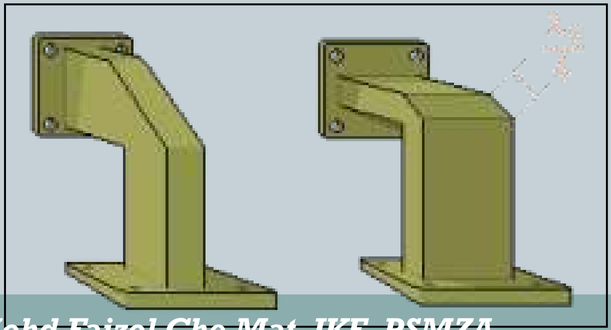


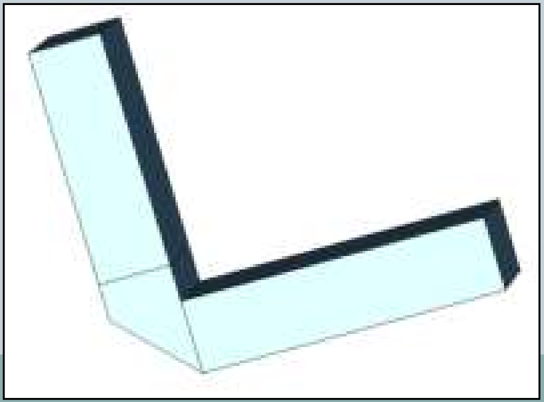
Basic Accessories (Corner)

CORNERED - to change the direction of the guide through the desired angle.





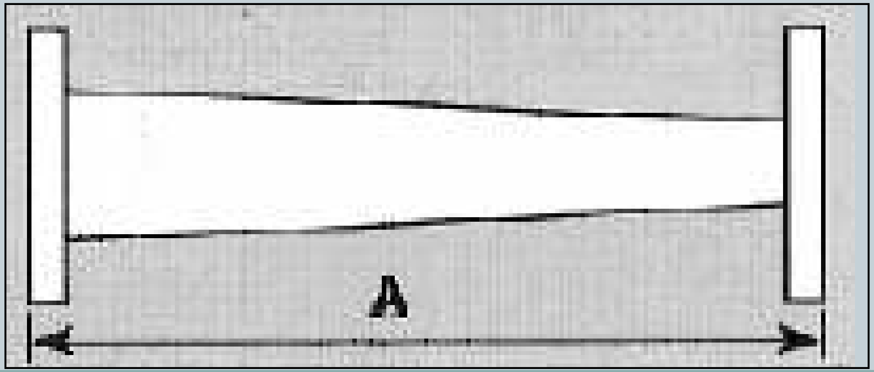




Basic Accessories (Tapered)

TAPERED - Provide a gradual dimensional change between two sizes of waveguide

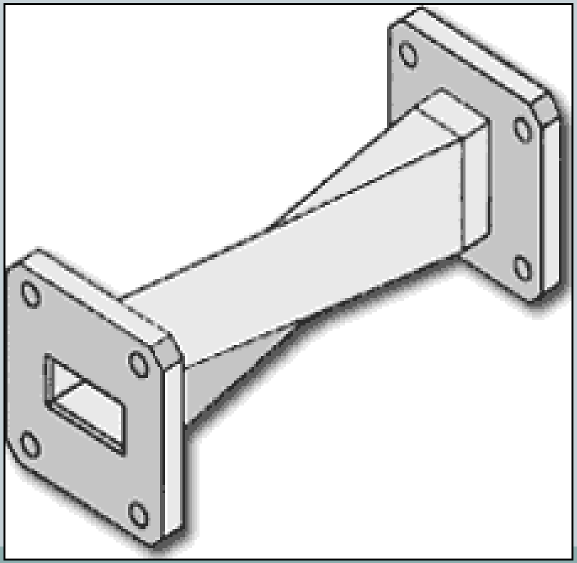
- Often necessary when making a transition between two different types of waveguide transmission lines, such as single ridge waveguide and double-ridge waveguide



Basic Accessories (Twisted)

TWISTED - A section of waveguide in which there is progressive rotation of the transverse cross section about the longitudinal axis.

-A gradual twist in the waveguide is used to turn the polarisation of the waveguide and hence the waveform.



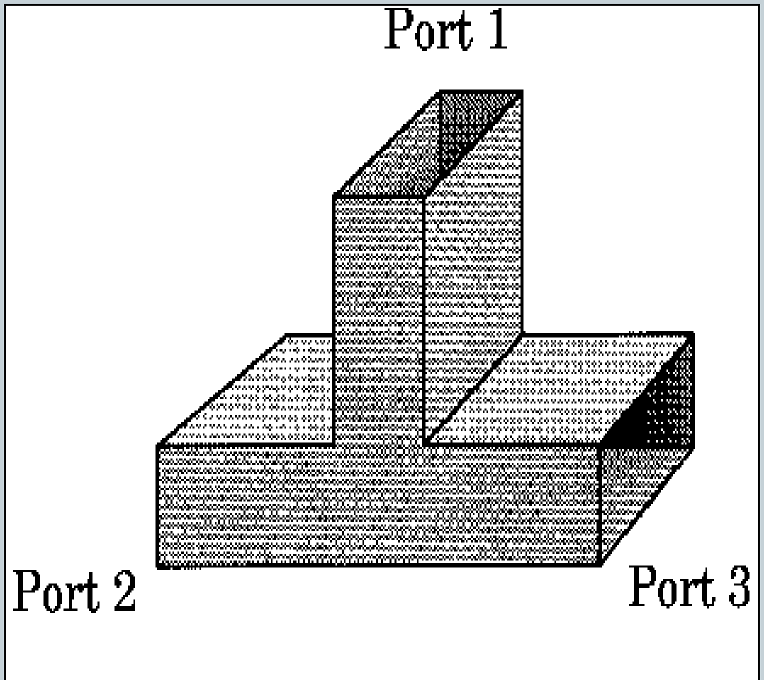
T-Junction (E-plane and H-plane)

E-PLANE TEE

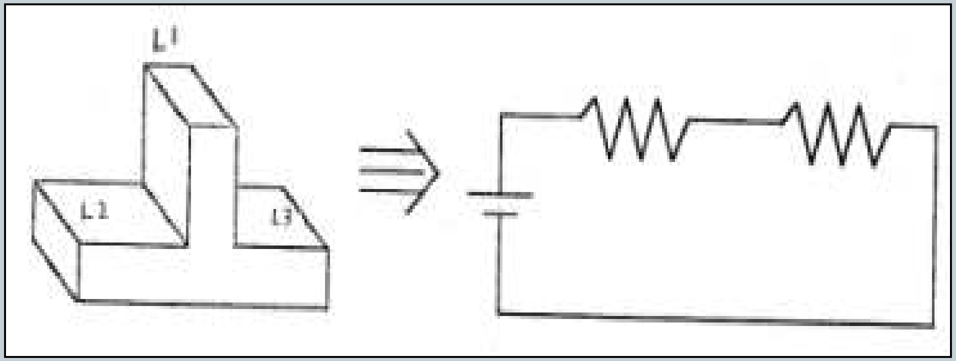
The electrical equivalent of connecting the arm in **series.** Consider an E-plane tee with a dominant TE_{10} traveling down Arm 1 to the intersection of Arms 2 and 3.

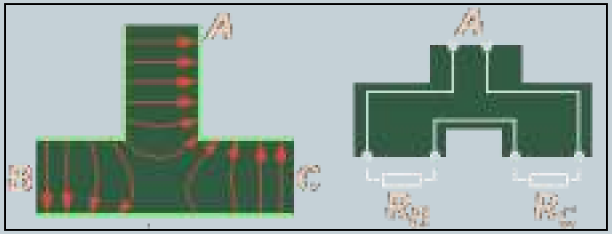
The E fields originates and terminates on charges in the waveguide walls.

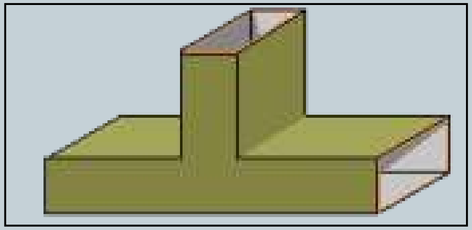
T-Junction (E-plane)



(a) E–Plane Tee







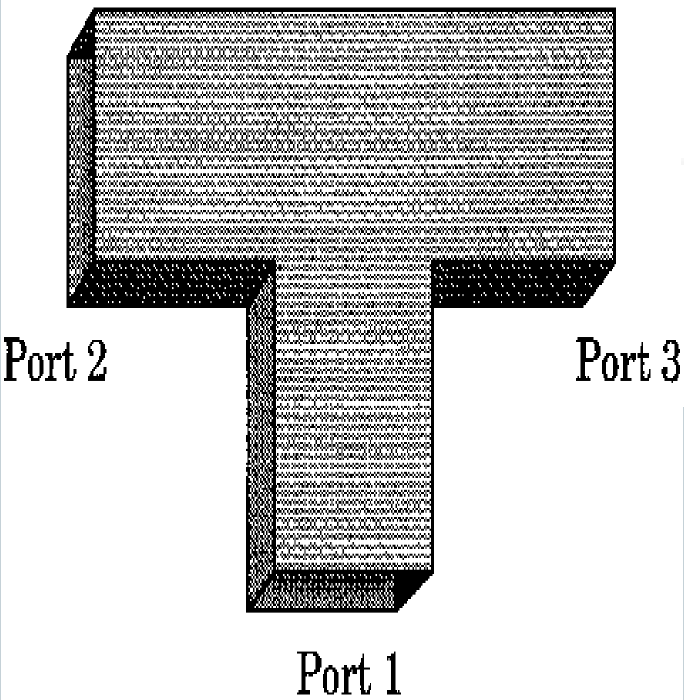
T-Junction (H-plane)

- This type of waveguide junction is called an H-type T junction because the long axis of the main top of the "T" arm is **parallel** to the plane of the magnetic lines of force in the waveguide.

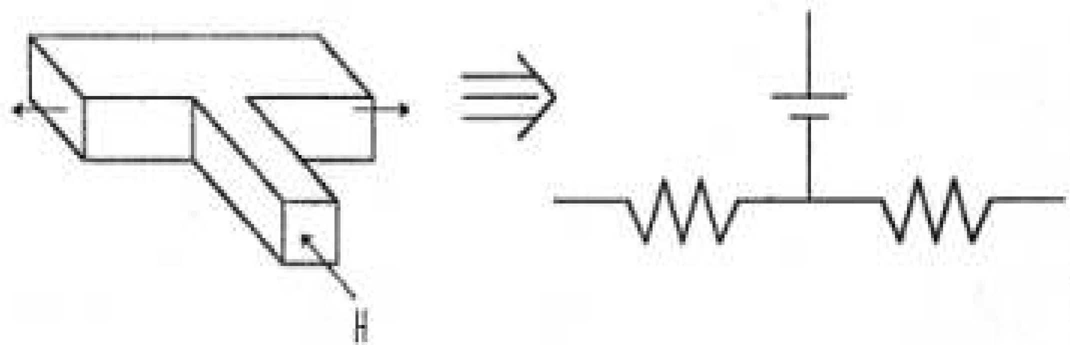
- It is characterized by the fact that the two outputs from the top of the "T" section in the waveguide are in phase with each other.

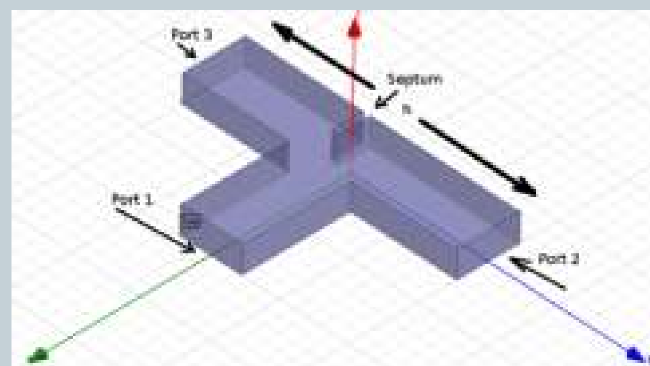
JUNCTION-T (H-PLANE TEE)

H-PLANE TEE



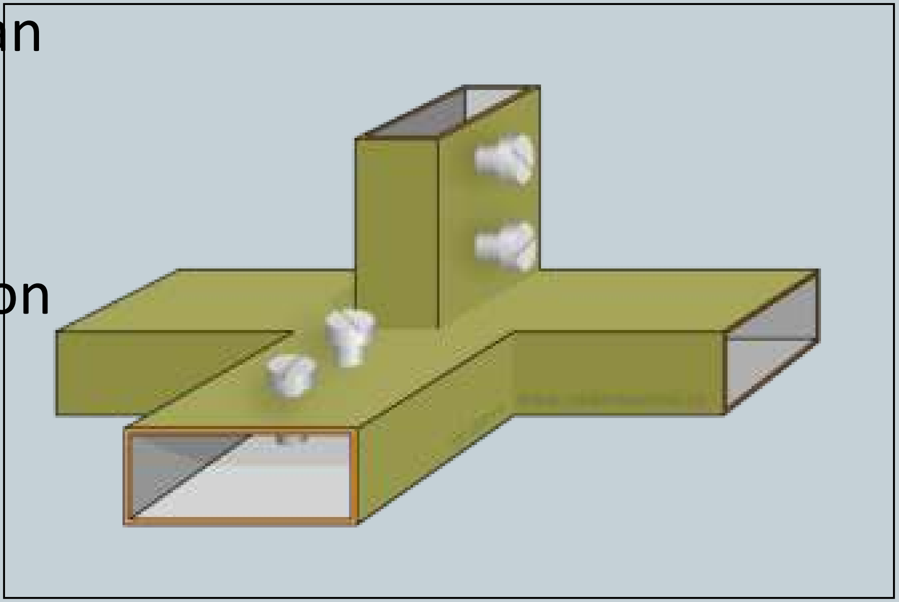
(b) H–Plane Tee





Hybrid-T

- Used as a power combiner, or a divider. It is ideally lossless, so that all power into one port can be assumed to exit the remaining ports.
- The magic T waveguide junction is effectively a combination of the E-type and H-type waveguide junctions.



Hybrid-T Junction

It combines E-plane and H-plane junctions.

P_{in} at port 1 or 2 will divide between ports 3 and 4.

P_{in} at port 3 or 4 will divide between ports 1 and 2.

H. Chan; MohawkCollege

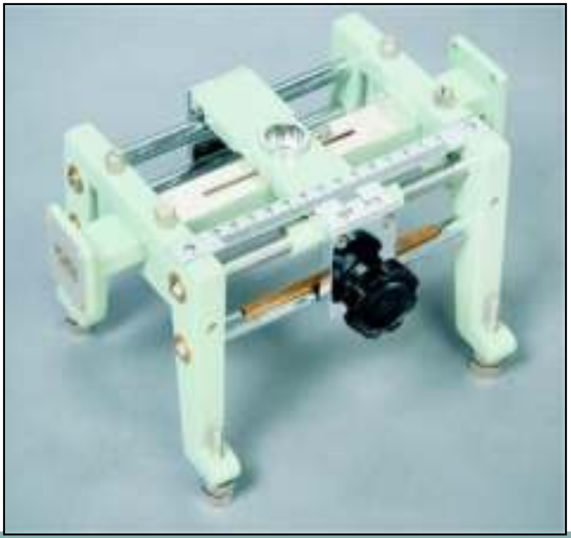
Hybrid-T Junction (cont'd)

- If input power of the same phase is applied simultaneously at ports 1 and 2, the combined power exits from port 4. If the input is out-of-phase, the output is at port 3.
- Applications:
  - Combining power from two transmitters.
  - TX and a RX sharing a common antenna.
  - Low noise mixer circuit.

Slotted Section

- A device used for **measuring the variation in field strength along a waveguide.**
- Generally **used to measure standing wave.**
- Slotted line section with tunable detectors is used to measure:

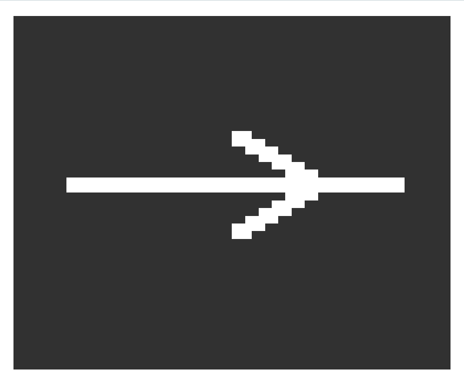
- Impedance
- Reflection coefficient
- Return loss
- VSWR
- Standing wave pattern
- Frequency of the microwave generator



Isolator

- An isolator is a ferrite device that can be constructed so that it **allows microwave energy to pass in one direction but blocks energy in the other direction.**
- Generally used between the source and rest of the setup to avoid overloading of the source due to reflected power.
- **<u>2 types</u>**: Faraday-rotation and resonance isolator.

ISOLATOR



Isolator (Symbol)

input-plug

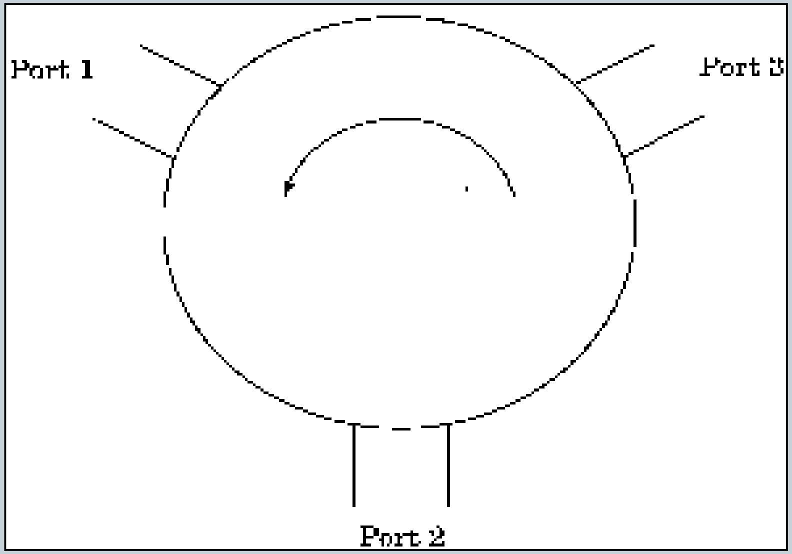
output-jack

dummy-load

Real isolator for 18 GHz

Circulator

Circulator passes input from each port to the next around the circle, not to any other port.

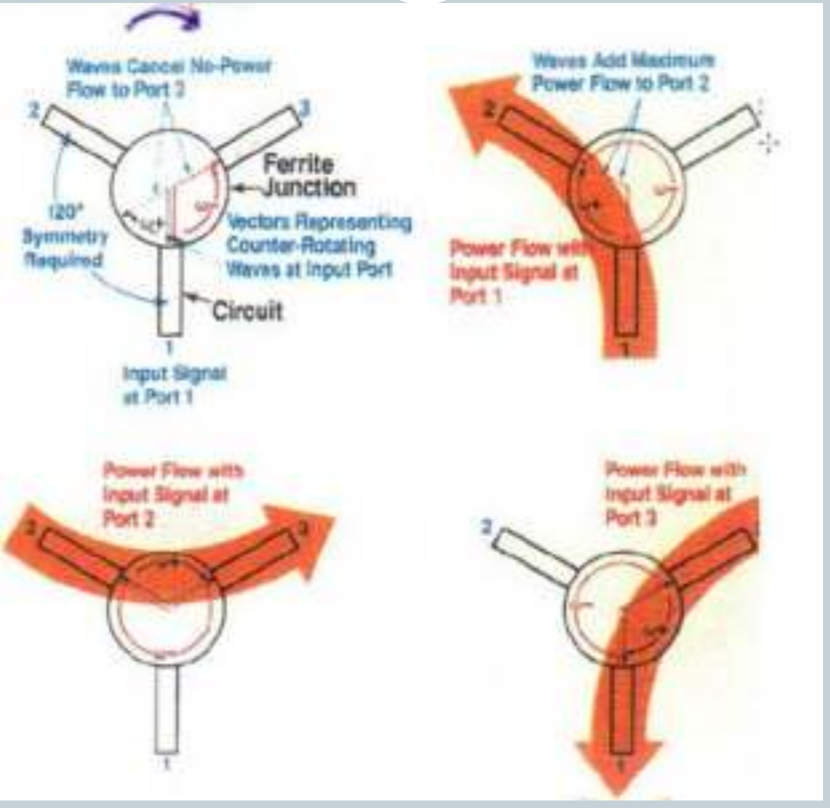


Circulator Top View

Circulator

- A multiport device in which power is circulated from n^{th} port to $(n+1)^{th}$ port only in one direction.
- 2 types: four-port (commonly used) and three-port circulators.
- All of the ports are matched.
- Transmission of power takes place in cyclic order only.
- An ideal circulator is perfectly lossless.

CIRCULATOR



Ferrite circulator: principle of operation

CIRCULATOR

Ferrite circulators are often used as a duplexer.

The operation of a circulator can be compared to a revolving door with three entrances and one mandatory rotating sense.

This rotation is based on the interaction of the electromagnetic wave with magnetised ferrite.

CIRCULATOR

A microwave signal entering via one specific entrance follows the prescribed rotating sense and has to leave the circulator via the next exit.

Energy from the transmitter rotates anticlockwise to the antenna port.

Virtually all circulators used in radar applications contain ferrite.

CIRCULATOR

In Ferrite circulators the energy will divides into two equal parts at the entrance (1), but with different propagation speed due to the influence of the ferrite.

At the **port 3** both signal parts are on **in opposition**, thus cancellation occurs.

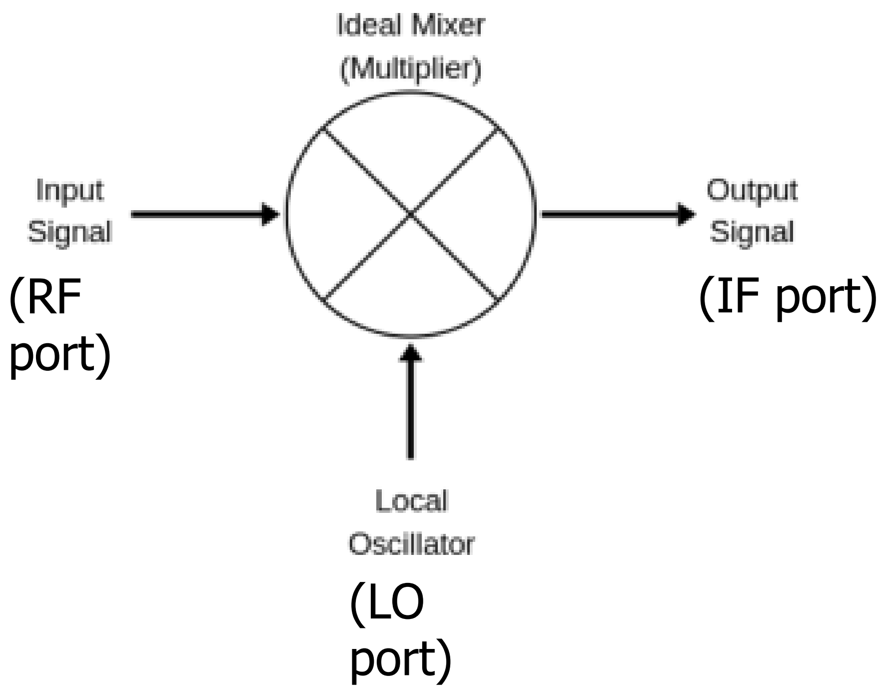
At **port 2** both signal parts are **in-phase**, thus adding themselves up to the complete signal again.

The symmetric construction of the ferrite circulator, make it possible to determine a defined way direction by the choice of the connection.

If an antenna is in a connection, transmitting energy is always escorted to the antenna while the echo signals always find the way to the receiver.

Frequency Mixers

- Takes two signals and combines them to create new signal.
- **Used to translate microwave signals into much lower frequencies and vice versa (translating them back into the microwave range)**.
- Mixers are needed in most microwave systems because RF signal is way too high to process.
- Consist of 3 ports: radio frequency (RF), local oscillator (LO), and intermediate frequency (IF).
- RF port: where the high frequency signal is applied.
- LO port: effectively reverses the path of the RF to the IF.
- IF port: where RF signal that was modified by the LO signal is passed, and its waveform is filtered to become the IF signal.


Ideal Mixer
(Multiplier)
Input
Signal
(RF
port)
Output
Signal
(IF port)
Local
Oscillator
(LO
port)


IF
RF
LO
MAGNUM
MICROWAVE
MC54PL-5
101-101925-005

Filters

Types of filter:

- Low Pass Filter
- High Pass Filter
- Band Pass Filter

Low Pass Filter

- A Lowpass filter **provides good signal transmission at frequencies below the cutoff frequency.**

High Pass Filter

- Highpass filters operate as a reverse of the lowpass filter.

- Highpass filters are **used to reject or attenuate frequencies below the frequency band.**

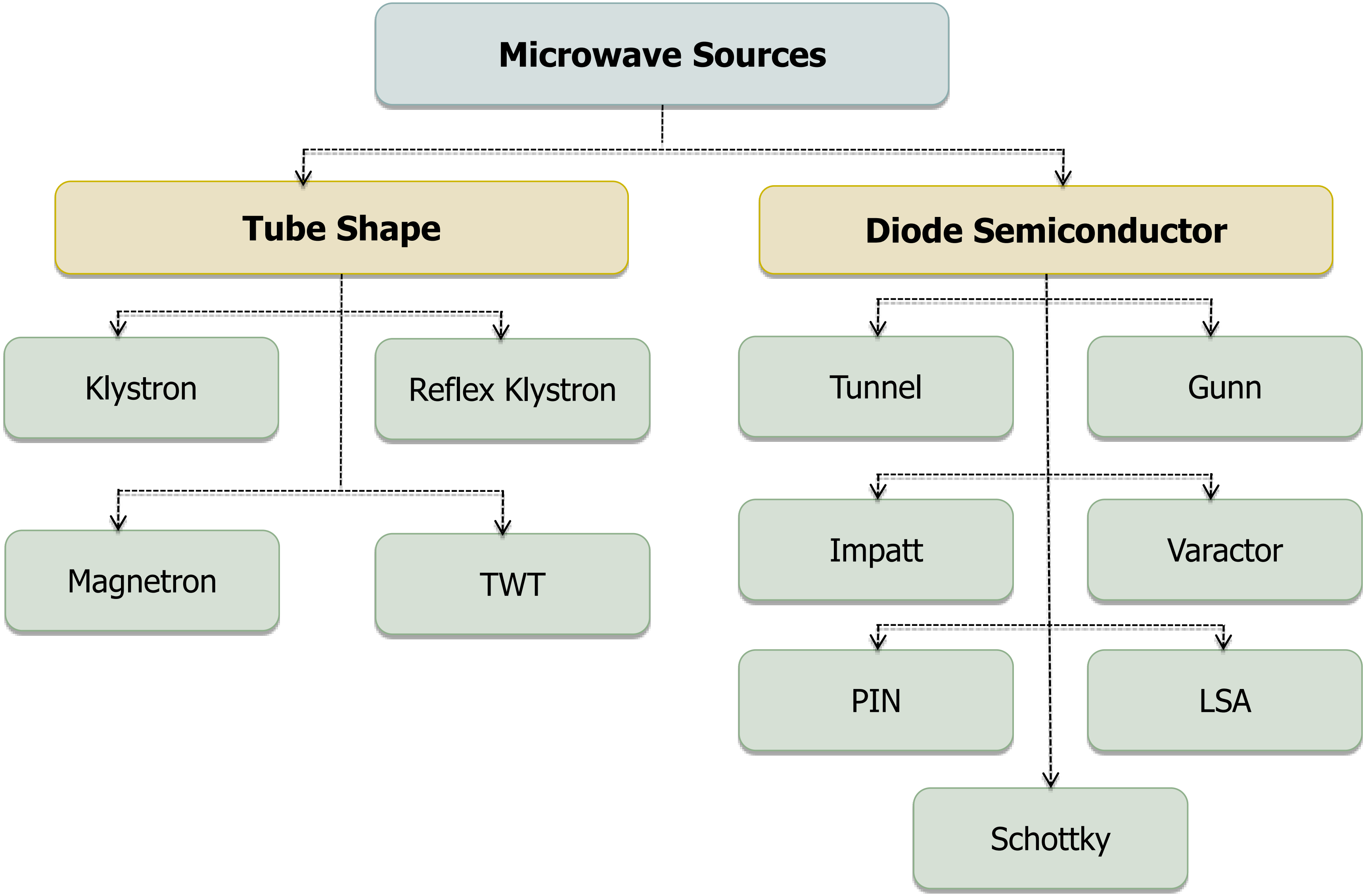
- Similar to the lowpass filter, they are typically used to suppress the signal of nearby transmitters.

Band Pass Filter

- A Bandpass filter provides a good signal transmission within its passband and rejects lower and higher frequencies

1.5

Remember type of microwave sour ces


Microwave Sources
Tube Shape
Diode Semiconductor
Klystron
Reflex Klystron
Magnetron
TWT
Tunnel
Gunn
Impatt
Varactor
PIN
LSA
Schottky

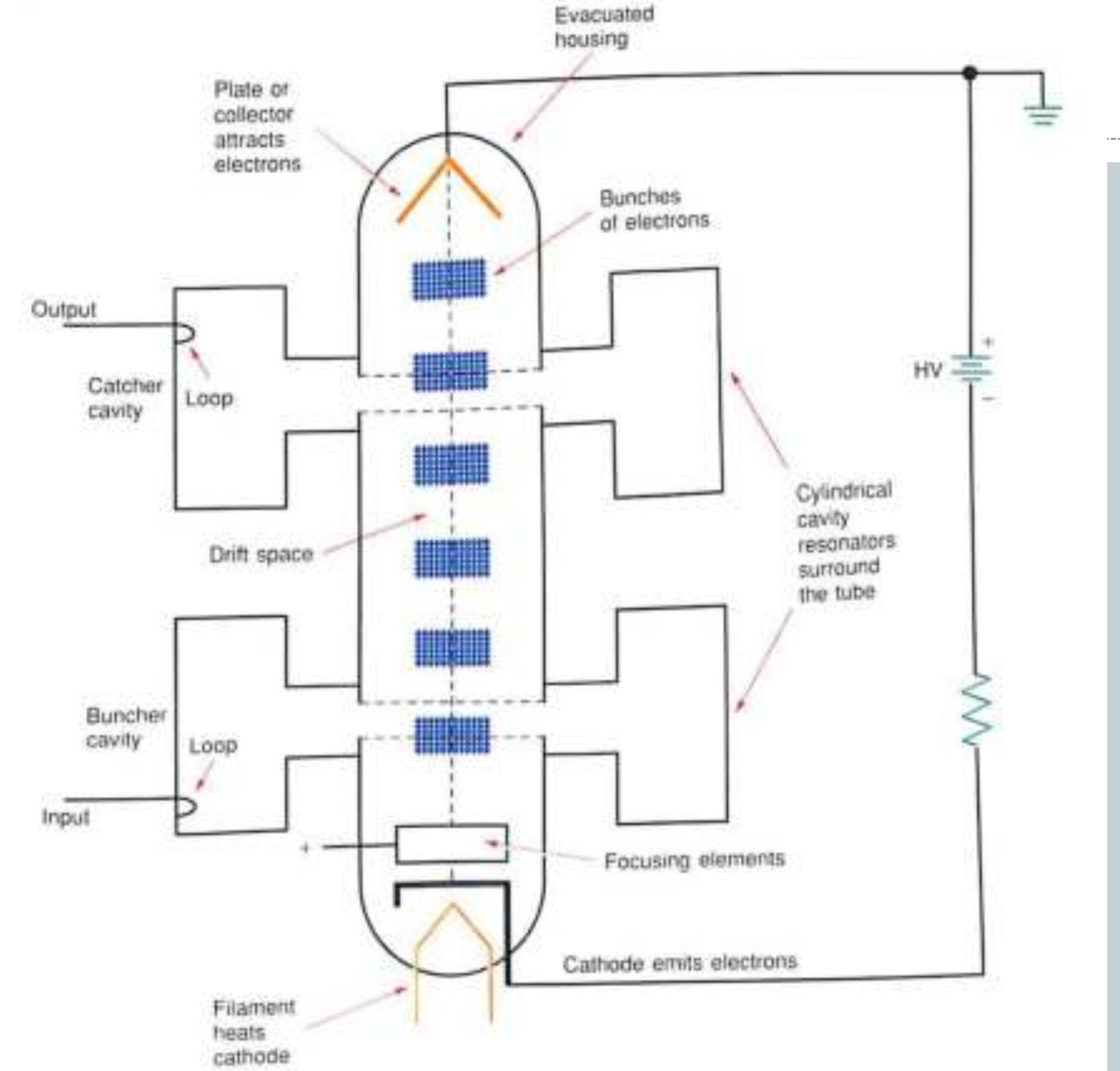
Microwave Sources of Vacuum Tube

a. Klystron

→The klystron is a linear-beam tube that can be used as either an amplifier or an oscillator. In a klystron amplifier, the electron beam passes through two or more resonant cavities.

→The first cavity accepts an RF input and modulates the electron beam by bunching it intoThe microwave tube, klystron is basically a vaccum tube designed with cavity resonators to produce velocity modulation of electron beam for amplification purpose.

- As shown in the figure 1.5a, cathode in a vacuum tube is heated by a filament, this cathode at high temperatur e, emits electrons,which are attracted by collector. This causes current to be established between cathode and collector.
- **Klystrons** are available in wide range of sizes. Small s ize units produce mwatts of power while large size unit s produce thousand watts of power. They are used at U HF as well as 100 GHz frequency band of operation.



(Figure 1.5a Operation of klystron)

- Special variation to the basic klystron tube is called as **reflex klystron**. It is used as microwave oscillator. The difference between normal klystron and reflex klystron is that reflex klystron uses single cavity.
- Reflex klystron devices are targetted for low power and are small in sizes. Power ranges from 100mwatt to several watts.
- Output of reflex klystron can easily be Freq-Modulated with the addition of AC modulating signal in the series with repeller voltage. Gunn diodes have replaced this type of klystrons.

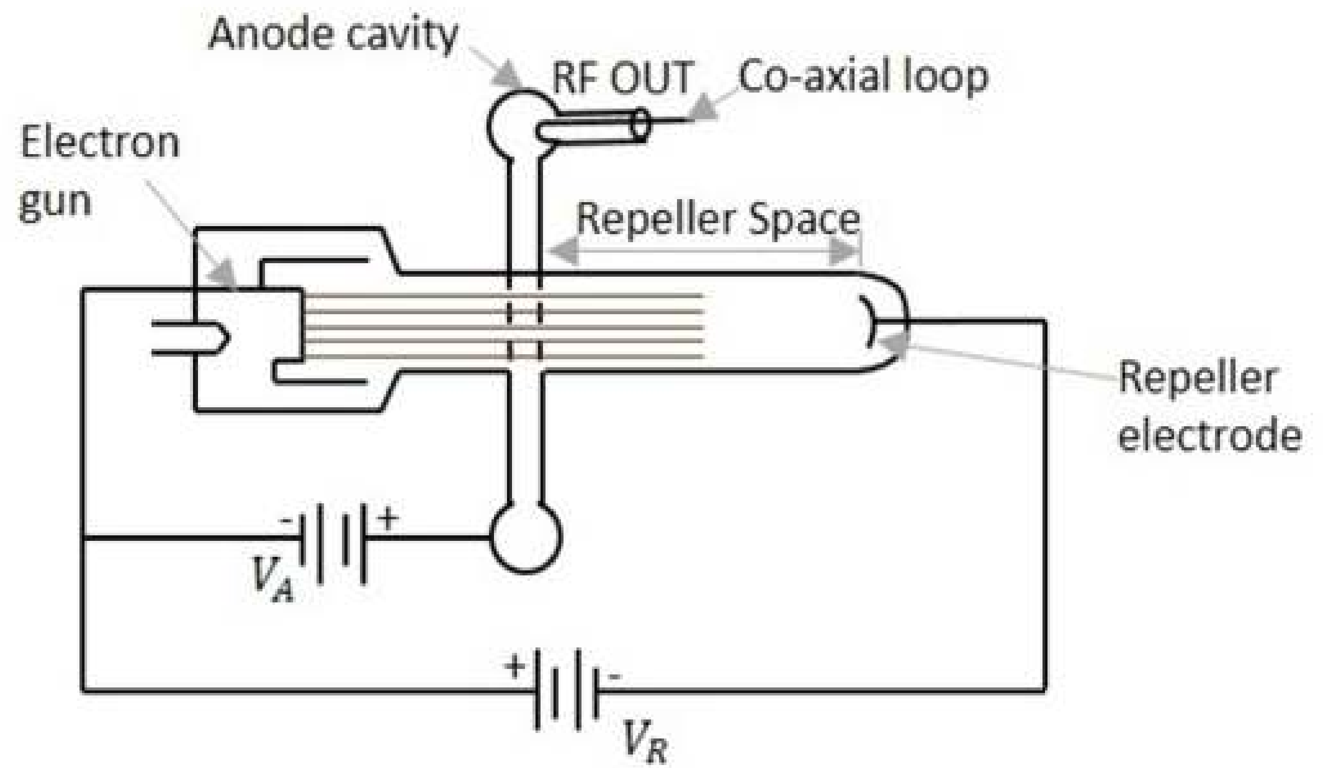
Reflex Klystron

- This microwave generator, is a Klystron that works on reflections and oscillations in a single cavity, which has a variable frequency.

- Reflex Klystron consists of an electron gun, a cathode filament, an anode cavity, and an electrode at the cathode potential. It provides low power and has low efficiency.

- The electron gun emits the electron beam, which passes through the gap in the anode cavity. These electrons travel towards the Repeller electrode, which is at high negative potential.

- Due to the high negative field, the electrons repel back to the anode cavity. In their return journey, the electrons give more energy to the gap and these oscillations are sustained. The constructional details of this reflex klystron is as shown in the following figure 1.5b.

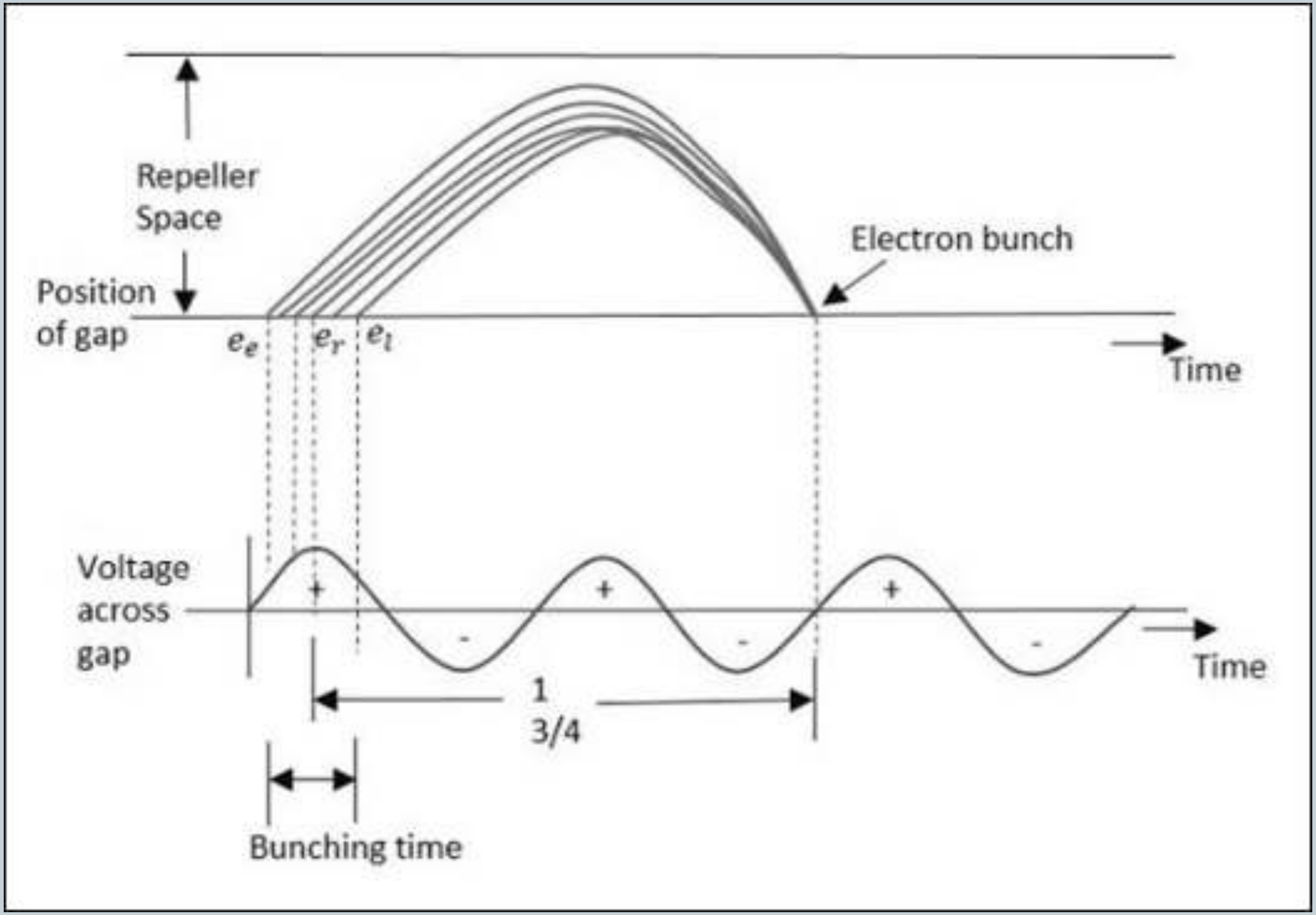


(Figure 1.5b)

Constructional details of Reflex Klystron

Operation of Reflex Klystron

- The operation of Reflex Klystron is understood by s ome assumptions. The electron beam is accelerate d towards the anode cavity. (Figure 1.5c)
- Let us assume that a reference electron er crosses t he anode cavity but has no extra velocity and it rep els back after reaching the Repeller electrode, with the same velocity. Another electron, let's say ee whi ch has started earlier than this reference electron, r eaches the Repeller first, but returns slowly, reachi ng at the same time as the reference electron.



(Figure 1.3c Electron beam waveform of reflex klystron)

- We have another electron, the late electron el, which star ts later than both er and ee, however, it moves with great er velocity while returning back, reaching at the same tim e as er and ee.

- Now, these three electrons, namely er, ee and el reach th e gap at the same time, forming an electron bunch. This tr avel time is called as transit time, which should have an o ptimum value. The following figure illustrates this.

- The anode cavity accelerates the electrons while going and gains their energy by retarding them during the return journey. When the gap voltage is at maximum positive, this lets the maximum negative electrons to retard.

- The optimum transit time is represented as

$$T = n + \frac{3}{4} \quad where\ n\ is\ an\ integer$$

Applications of Reflex Klystron

- Reflex Klystron is used in applications where varia ble frequency is desirable, such as −
  - Radio receivers
  - Portable microwave links
  - Parametric amplifiers
  - Local oscillators of microwave receivers
  - As a signal source where variable frequency is d esirable in microwave generators.

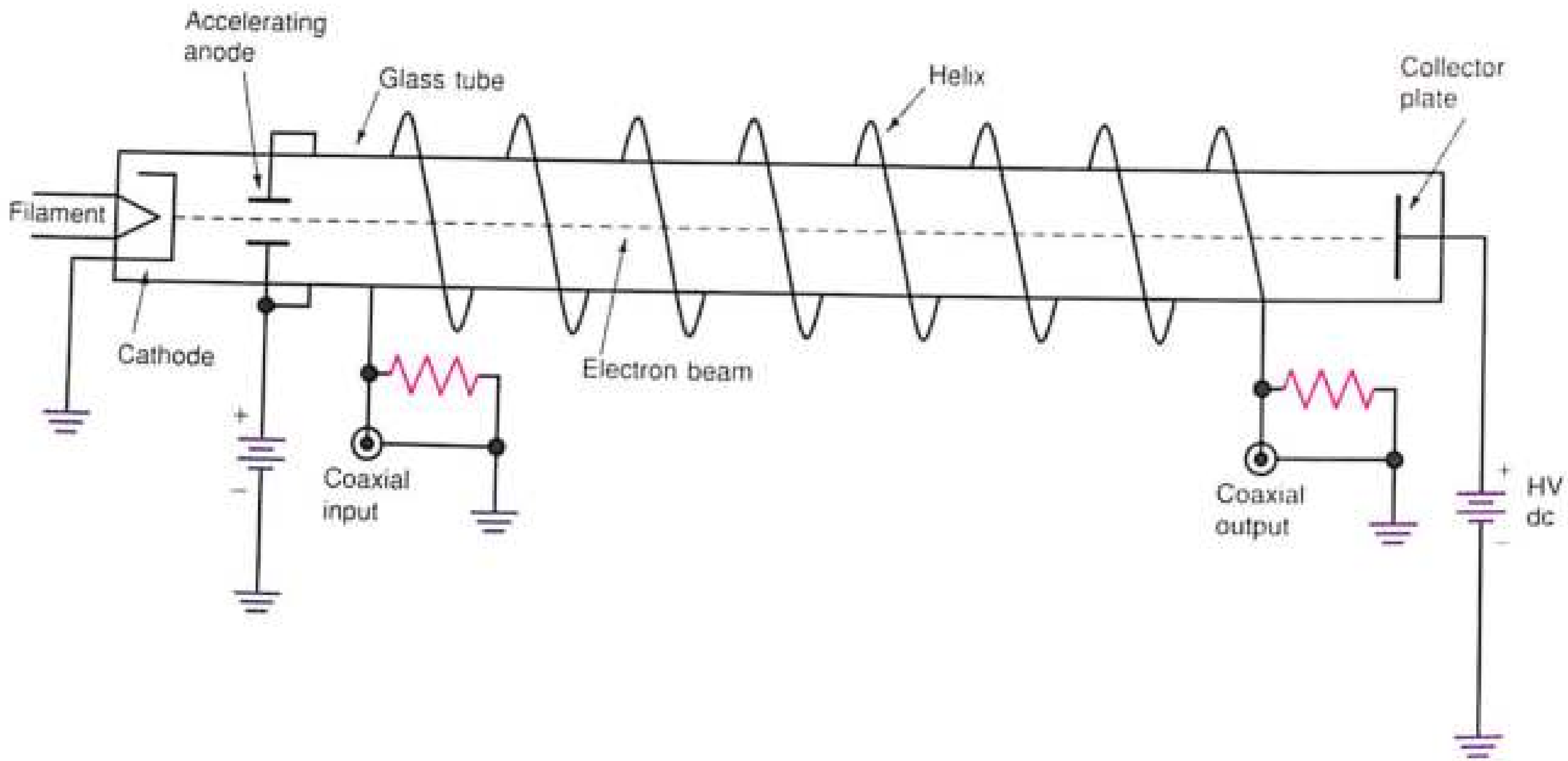
b. Travelling Wave Tube (TWT)

→This microwave tube is used as microwave RF power amplifier. (Figure 1.5d)

→The main benefits of Traveling Wave Tube(TWT) is wid e bandwidth of operation and can generate hundreds an d even thousands of watts. TWTs can also be used as b oth continuous and pulsed mode of operation. Length of this tube is about 1 ft to few feet, many wavelengths to th e operating frequency.

→Let's see how it works. There is a coil surrounding the t ube. Electron beam passes through the center of the heli x due to magnets and they are tightly coupled.

→The microwave signal need to be amplified is applied a t the cathode end of helix. The amplified output is taken f rom the collector end of the helix.



 (Figure 1.5d Structure of TWT)

Basic Principle of TWT (Amplifier)

- <u>Electron gun</u>: to form and accelerate a beam of electrons.
- <u>Focusing magnet</u>: to focus the beam of electrons through the interaction structure.
- <u>Collector</u>: to collect the electron beam after the μwave power has been generated.
- <u>I/P</u>: where the small μwave signal to be amplified is introduced to the interaction structure.
- <u>Interaction structure</u>: where the electron beam interacts with the μwave signal to be amplified.
- <u>O/P</u>: where the μwave power is taken out of the tube.
- <u>Internal attenuator</u>: to absorb the power reflected back into the tube from mismatches in the O/P Tx line.
- TWT uses the same basic velocity modulation process as Klystron.

Operation of TWT (Amplifier)

- The process starts with the formation of a beam of electrons with same velocity by electron gun.
- The electron beam is then shot into the interaction structure.
- The µwave signal to be amplified is put into the I/P.
- Electrons in the electron beam and the µwave signal interact as they travel at the same velocity through the structure.
- If electron enters the +ve phase of an RF cycle, it stays in the +ve phase and continuously accelerates.
- If electron enters the -ve phase of an RF cycle, it stays in the -ve phase and continuously decelerates.
- As electrons progress along the TWT, the fast electrons begin to catch the slower electrons, and a bunched beam is formed that excites an increasing µwave signal.

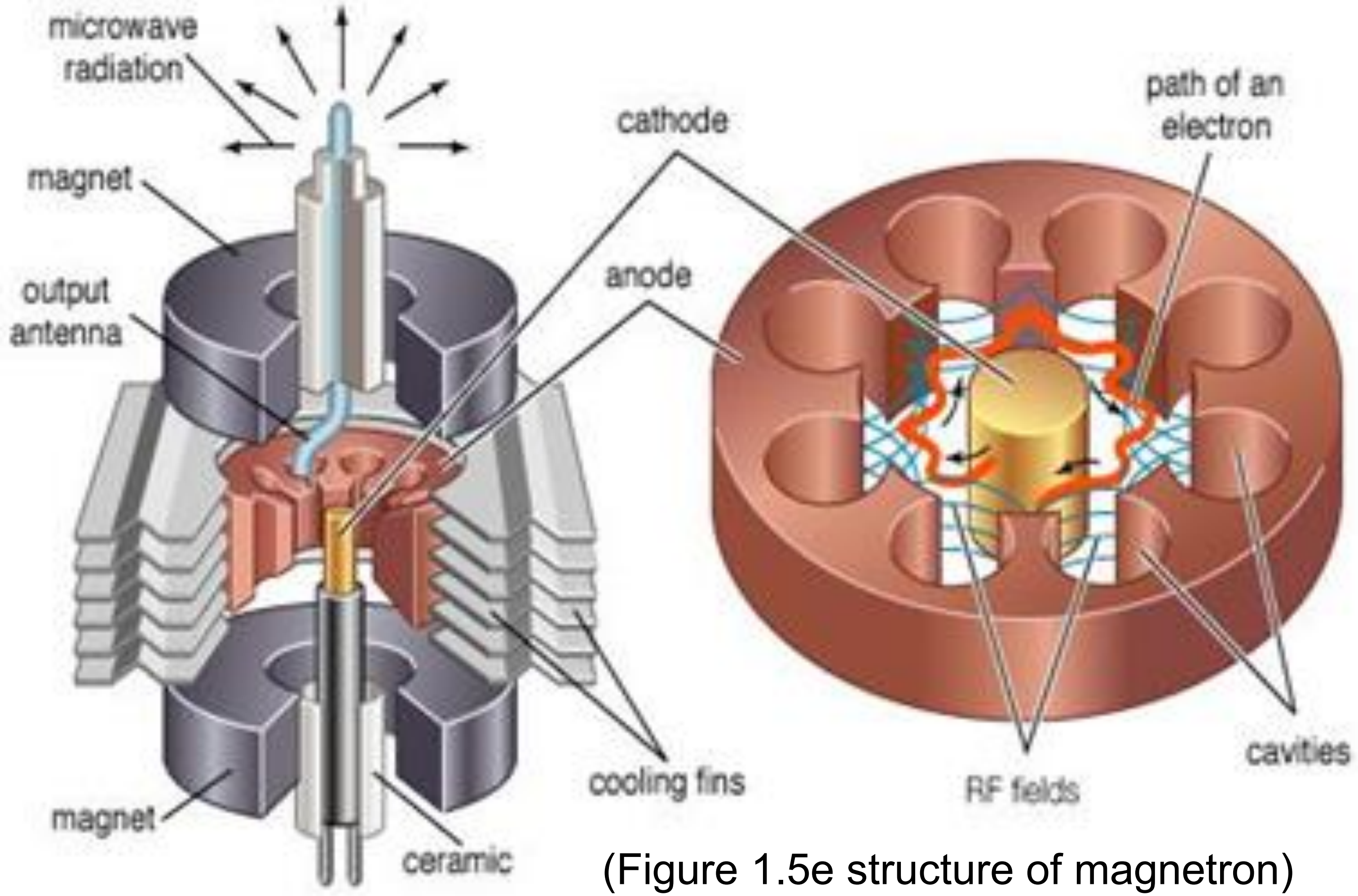
c. Magnetron

→Combination of simple diode vacuum tube with cavity r esonators and extremely powerful permanent magnet is called magnetron. (Figure 1.5e)

→This microwave tube assembly is depicted in the figure . The magnetron consists of circular anode made of copp er and connected with high voltage +ve DC. Even no. of resonant cavities having diameter equal to one half wave length of the operating frequency is placed in this circular anode.

→In the center there is a interaction chamber which acts as cathode and emits electrons when heated up.

- Here direction of electrons is not as in normal diode, but changed by application of strong magnetic field with the use of C shaped magnet.
- Magnetron help generate power in millions of watts.
- In pulsed mode, it can even generate mega watts of power.
- There are two main types of magnetrons viz. pulsed magnetron and CW magnetron. Pulsed magnetrons are used in radar and Continuous Wave(CW) magnetrons are used in microwave ovens.

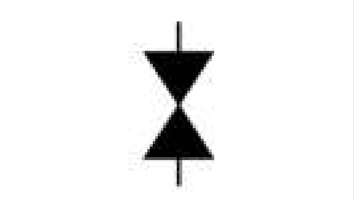
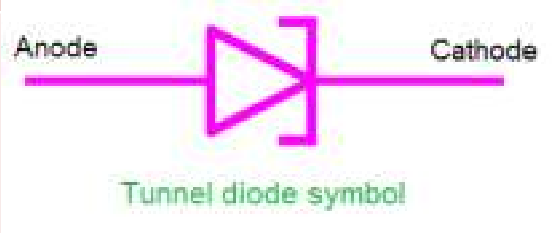


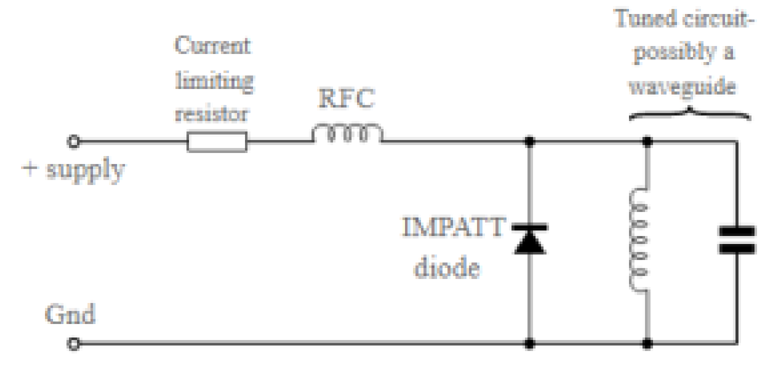
(Figure 1.5e structure of magnetron)

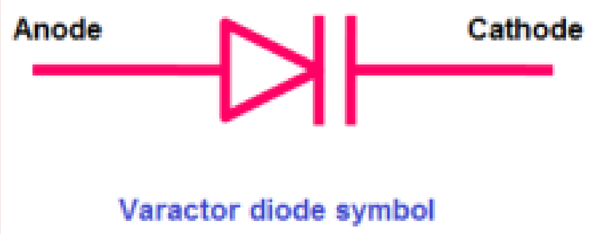
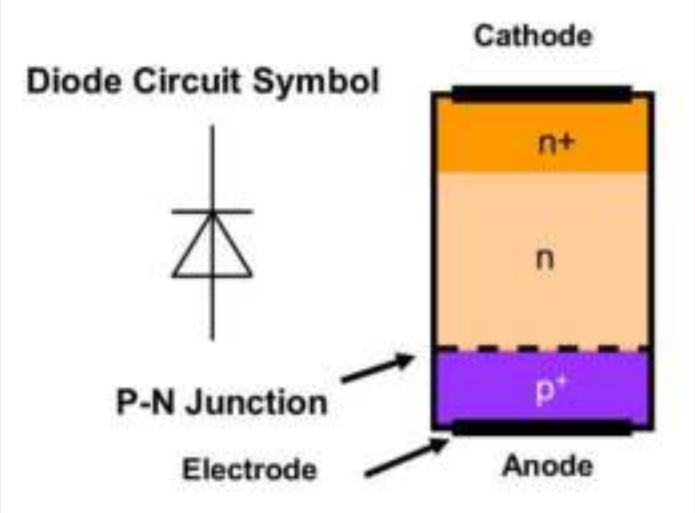
Basic Principle of Magnetron (Oscillator)

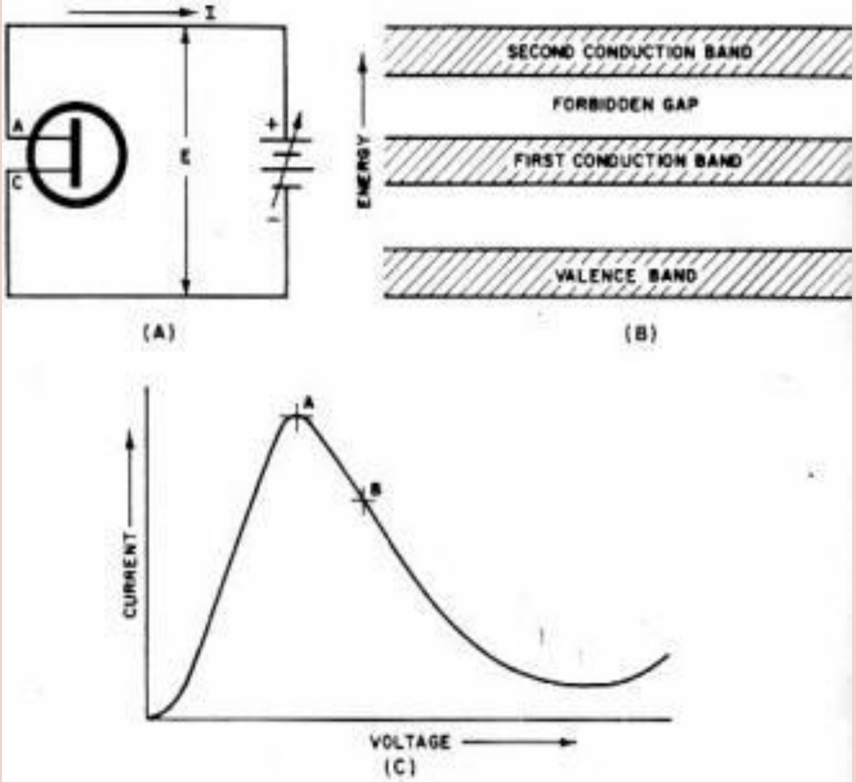
- Cylindrical cathode: emits electrons.
- Anode: where µwave signal is propagated.
- O/P: where the µwave signal generated in the magnetron is taken out into an external Tx line.
- Magnet: provides the magnetic field needed for the crossed-field interaction.
- Magnetron has no I/P because it is an oscillator.
- µwave signal travels along the anode, which is a coupled-cavity type of interaction structure, with the vanes forming the cavities.
- Electrons emitted from the cathode are bent by the combined effect of the electric and magnetic fields to move around the cathode.

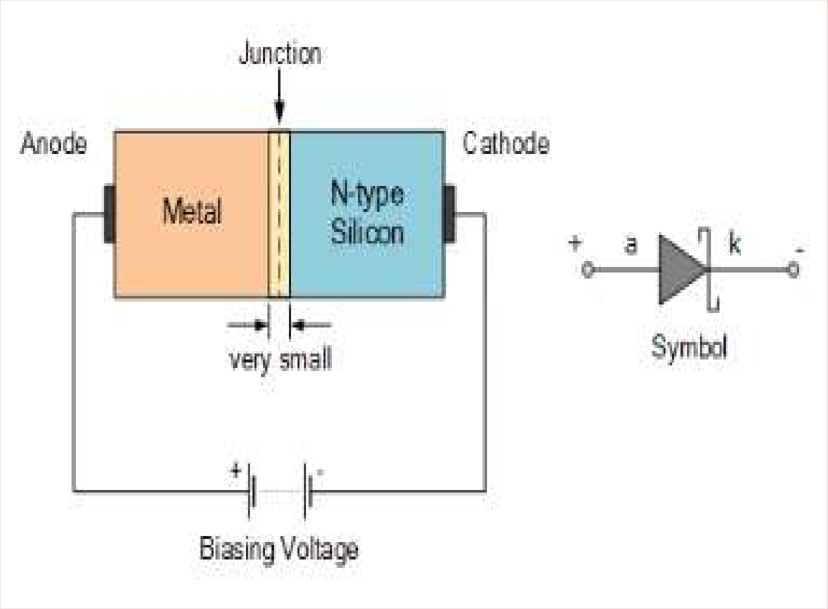
Semiconductor Sources

Semiconductor Sources	Symbol
Gunn Diode ▪The Gunn diode is a unique component - even though it is called a diode, it does not contain a PN diode junction. ▪The Gunn diode or transferred electron device can be termed a diode because it has two electrodes.	
Tunnel Diode •The operation of tunnel diode depends on the quantum mechanics principle known as "Tunneling".	

Semiconductor Sources	Symbol
Impatt Diode •The structure of an IMPATT diode is very similar to a standard Schottky or PIN diode but when looking at how an IMPATT diode works, it can be seen to be very different. •The IMPATT microwave diode uses avalanche breakdown combined and the charge carrier transit time to create a negative resistance region which enables it to act as an oscillator.	The diode is driven by a supply source through a current-limiting resistor and an RF choke to provide DC isolation from the radio-frequency signal. In order to sustain oscillations at a specified frequency, the IMPATT diode is typically integrated into a tuned resonator circuit, such as a waveguide cavity.  Typical IMPATT diode oscillator circuit

Semiconductor Sources	Symbol
Varactor diodes •Varactor diode is a p-n junction diode whose capacitance is varied by varying the reverse voltage	
PIN Diode •The PIN diode is a one type of photo detector, used to convert optical signal into an electrical signal. The PIN diode comprises of three regions, namely P-region, I-region and N-region. •Typically, both the P and N regions are heavily doped due to they are utilized for Ohmic contacts.The intrinsic region in the diode is in contrast to a PN junction diode. This region makes the PIN diode an lower rectifier, but it makes it appropriate for fast switches, attenuators, photo detectors and applications of high voltage power electronics.	

Semiconductor Sources	Symbol
LSA •LSA is a Limited Space Charge Accumulation diode used as an oscillator. •It is a –ve resistance device. •Its bias volt. is in the center of –ve region. •It will not permit formation of high field domain. •Its freq. of oscillation depends only on the external circuit. •It provides high power output.	

Semiconductor Sources	Symbol
Schottky Barrier diode •The Schottky Diode is another type of semiconductor diode but have the advantage that their forward voltage drop is substantially less than that of the conventional silicon pn-junction diode.	

1.6

Understand the differences betwee n microwave sources

DEVICE	FEATURES	FREQ/POWER	EFFICIENCY	PRINCIPLE APPLICATION
Magnetron	Compact, low cost, simple & reliable	Up to 95GHz Up to 10MW,	50-60% High power oscillator as one frequency	High power oscillator at one frequency Radar transmitters (pulse wave), Microwave oven (continous wave) with low power.
Reflex-klystron	Low cost, wide tuning, voltage tuning, long life	4-200 GHz Up tp 3W	<10%	Oscillator and Amplifier Local oscillators relays, signal generator, preamplifier generator, telemetry
TWT	Octave bandwidth, high gain, long life low noise	Up to 95GHZ Up to 1MW	20 – 40% Amplification up to 50dB	Wide band low noise voltage amplifier Radar transmitters, relays,

Gunn	**Small in size** **rugged**	**1-100GHz** **100-200W (pulsed)**		**Oscillator** **Radar Gun (speed of moving vehicle-police)**
Impatt	Rugged Small in size	0.5 to 100GHz 1 W(continuous) 400 W(pulsed)	3% in CW 60% in pulsed mode	Amplifier Oscillator Low power radar system
Semiconductor devices	Low cost Smaller size	Lower power consumption Higer bandwidth	High reliability	Compatible with integrated circuits