# ASSINGNMENT - I.



Q. 1. Derive fundamental Equation for free space Propagation / Friss Transmission equation.

→ Isotropic Radiation → $P_{avg} = \frac{P_{rad}}{4\pi r^2}$

$$G_{dmax} = \frac{P_{dmax}}{P_{avg}}$$

$$\therefore P_{dmax} = (G_{dmax}) \cdot P_{avg}$$

$$P_{dmax} = (G_{dmax})_t \cdot \frac{P_{rad}}{4\pi r^2}$$

$$P_{rec} = P_{dmax} (A_e)_r$$

$$\therefore P_{rec} = (G_{dmax})_r \cdot \frac{P_{rad}}{4\pi r^2} \cdot (A_e)_r$$

$$(A_e)_r = (G_{dmax})_r \cdot \frac{\lambda^2}{4\pi}$$

$$P_{rec} = (G_{dmax})_t \frac{P_{rad}}{4\pi r^2} \cdot (G_{dmax})_r \frac{\lambda^2}{4\pi}$$

$$\therefore \frac{P_{rec}}{P_{rad}} = (G_{dmax})_t \cdot (G_{dmax})_r \left(\frac{\lambda}{4\pi r}\right)^2.$$

$$\frac{\lambda}{4\pi r} \Rightarrow \text{Path Loss.}$$

Q. 2] Define Antenna? Explain Radiation Mechanism of Antenna.

→ Antenna is known as Transducer. When electric current pass through an antenna It converts into radio waves which are transmitted to free space.

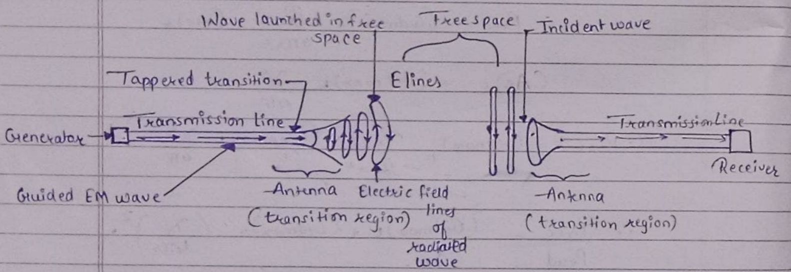
- A radio antenna is defined as the structure associated with the region of transition between a guided wave and free-space or vice-versa.

All involve the same basic principle that radiation is produced by accelerated charge. The basic equation of radiation is expressed as,

$$il = Qv \; .... \text{ in } (Am/s)$$

where,

$l$ = Length of current elements,
$i$ = Current changing with time in (Ampere/second),
$Q$ = charge,




Transmitting antenna Receiving antenna

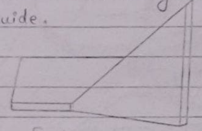
(a) Open ended transmission line as Transmitting Antenna
(b) Open ended Transmission line as Receiving Antenna

Q.3] What are different types of Antenna? Explain following antenna with construction working principle advantages and applications
1. Horn Antenna 2. Parabolic dish Antenna
3. Micro strip Patch Antenna.



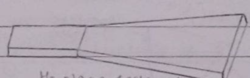
→ 1] Horn Antenna.

(i) E-plane Horn:
- In case of E-plane horn, flaring is done in the direction of E-field within waveguide.



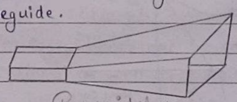
E-plane sectoral horn

(ii) H-plane Horn:
- In case of H-plane horn, flaring is done in the direction of H-field within waveguide.



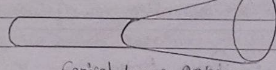
H-plane sectoral horn

(iii) Pyramidal Horn:
- In case of pyramidal horn, flaring is done in the direction of E and H field within waveguide.



Pyramidal Horn

(iv) Conical Horn:-



Conical horn antenna

2] Parabolic reflector antenna:
- For microwave and communication systems like satellite and Radar antenna having high gain and large bandwidth is required. To satisfy these requirement Parabolic Reflector Antennas are used. Construction of Parabolic reflector is shown is below Fig.

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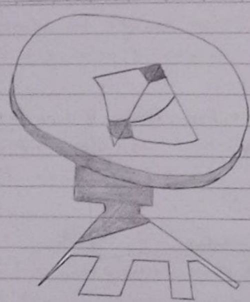

Fig :- Construction of Parabolic Reflector

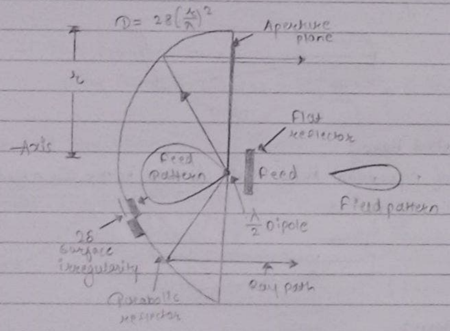


Fig :- Various elements of Parabolic reflector

## 3] Microstrip Patch Antenna

- In its most basic form, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in fig. The patch is generally made of conducting material such as copper or gold and can take any possible shape.

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- The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

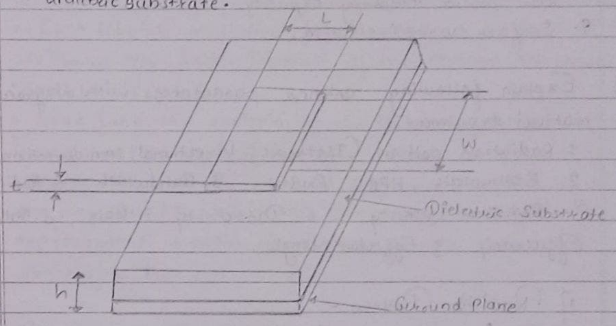


Fig :- Structure of Microstrip Antenna

Advantages -

1. Lightweight and low volume.
2. Low profile planar configuration that can be easily made conformal to host surface.
3. Low fabrication cost, hence can be manufactured in large quanti
4. Supports both, linear as well as circular polarization.
5. Can be easily integrated with Microwave Integrated Circuits (MI
6. Capable of dual and triple frequency operations.
7. Mechanically robust when mounted on rigid surfaces.
8. However microstrip patch antennas suffer from a number of disadvantages as compared to conventional antennas.

Disadvantages -

1. Narrow bandwidth
2. Low efficiency.
3. Low gain.
4. Extraneous radiation from feeds and junctions.

5. Poor and fire radiator except tapered slot antennas.
6. Low power handling capacity.
7. Surface wave excitation.

Q. 4] Explain following antenna parameters with diagram / mathematical treatment

1. Radiation pattern (Isotropic, Directional, omnidirectional).
2. Beamwidth, HPBW, FNBW 3. Bandwidth 4. Radiation Density
5. Radiation Intensity 6. Directivity 7. Gain, 8. Antenna Efficiency 9. Effective length.

→ 1] Radiation Pattern -

—An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates.

Following are the major parts of radiation pattern and shown in fig.

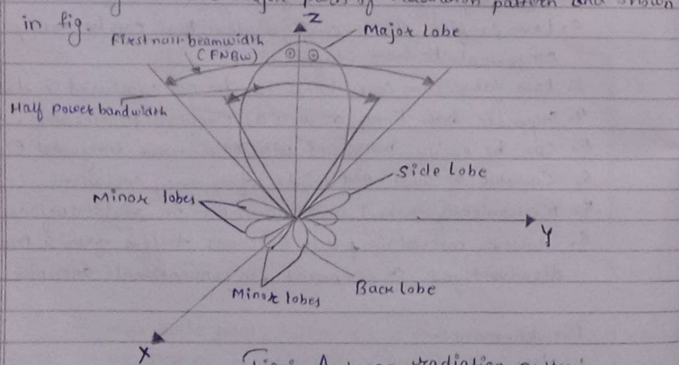


Fig: Antenna radiation pattern

• Major lobe is defined as "the radiation lobe containing the direction of maximum radiation". In fig, main lobe or main beam is directed along +Z direction which can be considered as $\theta = 0°$ in spherical co-ordinate system. This is broadside direction of radiation.

• Back lobe is radiation from an antenna which is at an angle of 180° w.r.t Main lobe. In most of the antenna minimum energy in Back lobe is preferred.

• Side lobe are radiation in the direction of main lobe having power much less than that of the main lobe.

• Minor lobes usually represent radiation in undesired directions, and they should be minimized. The level of minor lobes is usually expressed as a ratio of the power density in the lobe to that of the major lobe.

2] Antenna Beamwidth -

—A directional antenna can be said to direct a beam of radiation in one or more directions. The width of this beam is defined as the angle between its half-power points.

Half Power Beamwidth (HPBW) - "In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half value of the beam."

Another beamwidth is the angular separation between the first nulls of the pattern and it is referred to as the First-Null Beamwidth (FNBW).

3] Antenna Bandwidth -

"The range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard" is known as the bandwidth of a antenna.

4] Radiation ~~Density~~ Directivity -

Directivity of an antenna is defined as " the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

$$\text{Directivity (D)} = \frac{\text{Radiation intensity of given antenna}}{\text{Radiation intensity of isotropic source}}$$

5] Antenna Gain -

Gain of antenna (in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotopically.

$$G = \frac{U_{A} 4\pi}{U_{REF}}$$ — Radiation Intensity

6] - Antenna Efficiency -

Efficiency is defined as ratio of radiated power to Power fed to antenna. Due to various losses which are taking place at various terminals, antenna efficiency are less than 100%. Various losses which are taking place are:

1. Losses due to Reflection
2. Power loss due to conductor ($I^2R$ Loss)
3. Dielectric Losses

7] Effective Length -

Effective length of an antenna is a quantity that is use to determine the voltage induced on the open-circuit terminals of the antenna when a wave impinges upon it.

8] Radiation Density -

Radiation density is the amount of radient energy (or radiation) present per unit volume of space. It is usually expressed in joule per cubic meter ($J/m^3$).

Mathematically is given by:

$$u = \frac{4\sigma}{c} T^4$$

Where:

$u$ = radiation energy density ($J/m^3$)
$\sigma$ = Stefan-Boltzman constant
$c$ = speed of light in vaccum
$T$ = absolute temperature (in Kelvin)

9] Radiation Intensity :-

- Radiation Intensity is the power of electromagnetic radiation emitted per unit area per unit solid angle in a given direction. It quantifies how much energy flows through a surface in a particular direction

Mathematically -

$$I = \frac{dP}{dA\ \cos\theta\ d\Omega}$$

Where:

$I$ = radiation intensity ($W \cdot m^{-2} \cdot sr^{-1}$)
$dP$ = differential radiant power (W)
$dA$ = differential area ($m^2$)
$\theta$ = angle between surface normal and radiation direction
$d\Omega$ = differential solid angle (sr)

Q.5] Define Polarization? Explain different types of Polarization.

→ Polarization of an antenna in a given direction is defined as "the polarization of the wave transmitted (radiated) by the antenna. Antenna can be linearly, Elliptically or circularly polarized.

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i] Linear polarization (Vertical and horizontal polarization)

- A time-harmonic wave is linearly polarized at a given point in space if the electric-field (or magnetic-field) vector at that point is always oriented along the same straight line at every instant of time.
- If the resultant field vector is oriented along horizontal axis, the polarization is known as Horizontal polarization.

ii] Elliptical polarization.

- A time-harmonic wave is elliptically polarized if the tip of the field vector (electric or magnetic) traces an elliptical locus in space. At various instants of time the field vector changes continuously with time at such a manner as to describe an elliptical locus.
- It is right-hand (clockwise) elliptically polarized if the field vector rotates clockwise, and it is left-hand (counter clockwise) elliptically polarized if the field vector of the ellipse rotates counter clockwise.

iii] Circular polarization (special case of elliptical polarization)

- A time-harmonic wave is circularly polarized at a given point in space if the electric (or magnetic) field vector at that point traces a circle as a function of time.
- The necessary and sufficient conditions to accomplish this are if the field vector (electric or magnetic) possesses all of the following:

a] The field must have two orthogonal linear components, and
b] The two components must have the same magnitude, and
c] The two components must have a time-phase difference of odd multiples of $90°$.

Q.6] A free space microwave link consisting of tx and Rx each of 30dB gain operate at 10GHz. The distance between tx and Rx is 20Km, Transmitter radiate 15w power calculate power received by receiver and path loss of link in dB.

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→ Given -

$$G_T = G_R = 30\,dB$$
$$F = 10\,GHz = 10 \times 10^9\,Hz$$
$$r = 20\,Km = 20 \times 10^3\,m$$
$$P_t = 15\,w \text{ Power}$$

$$G_T = 30\,dB$$
$$30 = 10 \log G_T$$
$$G_T = 10^{30/10}$$
$$G_T = 1000$$

$$G_T = G_R = 1000$$

$$\lambda = \frac{C}{F} = \frac{3 \times 10^8}{10 \times 10^9} = 0.03\,m$$

$$P_r = P_t\, G_T\, G_R \left(\frac{\lambda}{4\pi r}\right)^2$$
$$= 15 \times 1000 \times 1000 \left(\frac{0.03}{4\pi \times 20 \times 10^3}\right)^2$$
$$= 2.1372 \times 10^{-7}\,w$$
$$= 0.2137\,\mu w$$

$$\text{Path loss} = 10 \log 10 \left(\frac{4\pi r}{\lambda}\right)^2$$
$$= 20 \log 10 \left(\frac{4\pi \times 20 \times 10^3}{0.03}\right)$$
$$\text{Path loss} = 138.4623\,dB$$

Q.7. An antenna has radiation resistance of 72 Ω a loss resistance of 8 Ω and power gain of 12dB. Determine antenna efficiency and its directivity.

→ Given: Radiation Resistance ($R_r$) = 72 Ω
Loss Resistance ($R_L$) = 8 Ω
$G_p$ = 12 dB

$G_p = 12\ dB$
$12 = 10 \log G_p$
$G_p = 10^{\frac{12}{10}}$
$G_p = 15.84$

— Antenna efficiency $(\eta) = \frac{R_r}{R_r + R_L} = \frac{72}{72+8} = 0.9$

$\eta = 90\%$

$D = \frac{G_p}{\eta} = \frac{15.84}{0.9} = 17.6$

$D$ in dB $= 10 \log 17.6$

$\boxed{D = 12.4551\ dB}$

ASSINGNMENT - 2.

Que. 1] What is microwave Frequency range? What are advantages & application of microwaves.

→ Microwaves occupy the frequency range of 1 GHz to 300 GHz, corresponding to wavelength between 30cm and 1mm.

Microwaves are a part of the electromagnet spectrum that lie between radio waves and infrared waves.

Frequency Range -
- Frequency Range : 300 MHz (0.3 GHz) to 300 GHz.
  corresponding wavelength range : 1m to 1mm

Advantages of Microwaves
1. Large Bandwidth - Supports high data transmission rates.
2. Line of sight Propagation - Useful for satellite and radar communication
3. Smaller Antenna Size - Due to short wavelength, antennas can be compact
4. High Penetration - Can pass through atmosphere, clouds, and rain with minimal attenuation.
5. Low Interference - Less affected by external noise compared to lower frequencies.

Application of Microwaves :-
1. Communication Systems
   - Satellite Communication
   - Mobile networks (3G uses mmwave, part of microwave spectrum)
   - Wi-fi, Bluetooth
2. Radar & Navigation
   - Air traffic control radar
   - Weather radar
   - Military surveillance and missile guidance

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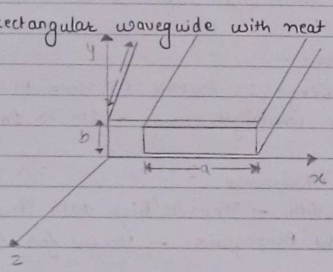
3. Medical Application
   - Microwave diathermy (deep tissue heating for therapy)
   - ~~Non de~~ Cancer treatment (hyperthermia therapy)

4. Industrial Applications
   - Microwave heating and drying in industries
   - Non- destructive testing.

Que. 2] Explain rectangular waveguide with neat diagram.
→




A rectangular waveguide is a hollow metallic tube with a rectangular cross-section used to guide electromagnetic waves typically in the microwave frequency range. The most common configuration has the width ('a') greater than the height ('b') and only specific field arrangements, known as modes, can propagate within the guide.

STRUCTURE & DIAGRAM
- A rectangular waveguide consist of four conducting walls forming a hollow pipe with width a and height b (typically $a = 2b$).
- The internal dimensions determine the cutoff frequencies for various modes. a key aspect for efficient wave propagation.
- The dominant propagating mode is usually the transverse electric ($TE_{10}$) mode, where the electric field is perpendicular to the electric field is perpendicular to the direction of wave propagation.

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Key features
- Low Loss :- Minimal resistive losses, especially at microwave frequencies and above.
- Mode dependence :- Only specific modes (TE, TM, TEM) can exists, determined by guide dimensions and frequency
- No power leakage :- The structure confines waves, minimizing unwanted energy loss.

Que.3] Explain following waveguide Parameters - a] Cut-off wavelength
→ b] Dominant Mode c] Guide wavelength d] Group Velocity e] Phase velocity f] wave impedance.

→ ⓐ Cut-off Wavelength ($\lambda_c$)
- It is the maximum length (or minimum frequency) at which a particular mode can propagate in the wave guide.
- formula (For rectangular wavelength TE/TM mode)

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

where,
$a$ = broad dimension of waveguide
$b$ = narrow dimension,
$m, n$ = mode indices

ⓑ Dominant Mode
- The mode with the lowest cut-off frequency that can propagate in a waveguide.
- For rectangular waveguide : Dominant mode is $TE_{10}$
- For circular waveguide : Dominant mode is $TE_{11}$
- Importance : This mode is usually used for transmission since it Propagates with least attenuation.

ⓒ Guide Wavelength ($\lambda_g$)

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- The wavelength of the signal inside the waveguide different from free-space wavelength ($\lambda$).
- It represents the distance over which the phase of the wave repeats inside the guide.
- Formula.

$$\lambda_g = \frac{\lambda}{\sqrt{1 - \left(\frac{F_c}{F}\right)^2}}$$

ⓓ Group Velocity ($V_g$)

- The velocity at which energy or information is transmitted along the waveguide.

Formula – $V_g = c\sqrt{1 - \left(\frac{F_c}{F}\right)^2}$

where $c$ = speed of light in free space.

ⓔ Phase Velocity ($V_p$)

- The ratio of transverse electric field (E) to transverse magnetic field (H) in a waveguide.
- Different for TE and TM modes:

for TE modes :-

$$Z_{TE} = \frac{Z_0}{\sqrt{1 - \left(\frac{F_c}{F}\right)^2}}$$

for TM modes :-

$$Z_{TM} = Z_0\sqrt{1 - \left(\frac{F_c}{F}\right)^2}.$$

- where $Z_0 \approx 377\Omega$.

Que. 4] A rectangular waveguide is filled by dielectric material of $\epsilon_r = 9$ and has internal dimensions of 7cm x 3.5cm for dominant TE 10 mode then

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ⓐ Determine the cutoff frequency
ⓑ Phase velocity in guide at frequency of 2GHz
ⓒ Guided wavelength $\lambda_g$ at 2GHz

→ Given data –

Dielectric relative permittivity : $\epsilon_r = 9$

$a = 7\,cm = 0.07\,m$

$b = 3.5\,cm = 0.035\,m$

$f = 2\,GHz = 2 \times 10^9\,Hz$

effective velocity in dielectric $v = \frac{c}{\sqrt{\epsilon_r}} = \frac{3 \times 10^8}{3} = 1 \times 10^8\,m/s$

ⓐ cut off frequency for $TE_{10}$

$$f_c = \frac{v}{2a} = \frac{1 \times 10^8}{2 \times 0.07} = 714.3\,MHz$$

ⓑ Phase velocity in the guide at 2GHz

$$V_p = \frac{v}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

substitute values

$$\frac{f_c}{f} = \frac{714.3 \times 10^6}{2 \times 10^9} \approx 0.357$$

$$1 - \left(\frac{f_c}{f}\right)^2 = 1 - (0.357)^2 = 1 - 0.127 = 0.873$$

$$V_p = \frac{1 \times 10^8}{\sqrt{0.873}} = \frac{1 \times 10^8}{0.934} \approx 1.071 \times 10^8\,m/s$$

ⓒ Guided wavelength

$$\lambda = \frac{v}{f} = \frac{1 \times 10^8}{2 \times 10^9} = 0.05\,m = 5\,cm$$

$$\lambda_g = \frac{\lambda}{\sqrt{1 - \left(\frac{F_c}{F}\right)^2}}$$

where cut-off wavelength

$$\lambda_c = \frac{v}{f_c} = \frac{1 \times 10^8}{714.3 \times 10^6} \approx 0.14\,m = 14\,cm$$

Now,

$$\frac{\lambda}{\lambda_c} = \frac{0.05}{0.14} = 0.357 \qquad 1-(0.357)^2 = 0.873$$

$$\lambda_g = \frac{0.05}{\sqrt{0.873}} = \frac{0.05}{0.934} = 0.0536\,m = 5.36\,cm.$$

Que. 5] Give difference between (a) waveguide & co-axial Cable.
→

| Aspect | Waveguide | Co-axial Cable |
|---|---|---|
| Structure | Hollow metallic tube (rectangular or circular) | Central conductor with outer conductor separated by dielectric |
| Frequency range | Suitable for microwave & millimeter waves above ~1 GHz) | works well upto a few GHz, limited at higher frequencies due to losses. |
| Mode of Propagation | Supports TE and TM modes (not TEM) | Supports TEM mode. |
| Size | Bulky and rigid | Flexible and compact. |

| Aspect | TE Mode | TM mode |
|---|---|---|
| Definition | Electric field is transverse to direction of propagation | Magnetic field is transverse to direction of propagation. |
| Longitudinal components | $H_z \neq 0$, $E_z = 0$ | $E_z \neq 0$, $H_z = 0$ |
| Existance in waveguide | Most common mode in rectangular waveguides | Exits but less frequently used. |
| Applications | Used in waveguides, dominant mode in rectangular waveguide. | Used in certain cavity resonators and circular guides. |

| Aspect | Waveguide | Co-axial Cable |
|---|---|---|
| Structure | Hollow metallic tube (rectangular or circular) | Co-axial cable, stripline or microstrips. |
| Mode Supported | supports TE and TM modes | Mostly TEM mode |
| Frequency use | Microwave & millimeter-wave | Works well at low & RF frequencies. |
| Losses | Low at high frequency | Loss increases with frequency. |
| Size & Cost | Bulky, expensive | Compact, cheaper. |

| Aspect | Stripline | Microstripline |
|---|---|---|
| Structure | Conductor, sandwiched between two ground planes with dielectric on both side | Conductor on top of a dielectric substrate with a single ground plane at the bottom. |
| Mode of Propagation | Supports pure TEM mode. | Supports quasi TEM mode |
| Field confinement | Electric field is completely inside dielectric | Fields partly in dielectric and partly in air |
| Losses | Lower radiation loss, better shielding | Higher radiation on loss |
| Fabrication | more complex, harder to make | Easy to fabricate on PCB. |

Que. 6] Explain Rectangular Cavity Resonator. Derive Q factor of Cavity resonator. Explain applications of Cavity Resonator.

→ Rectangular Cavity Resonator

- A cavity resonator is a closed hollow metallic structure made from a section of waveguide where ends are short-circuited with perfectly conducting walls.
- In a rectangular cavity resonator, the structure is a rectangular box with dimensions :
  - a → width (along x-axis)
  - b → height (along y-axis)

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- The field inside are confirmed, and standing waves are established.
- The resonant frequencies are determined by cavity dimension and the mode of operation.

Resonant frequency (for TE / TM modes)

The general resonant frequency for a rectangular cavity:

$$f_r = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}$$

where,

m, n, p = mode of indices (integer ≥0, but not all zero)

c = velocity of light medium

for TE modes : $H_c = 0$, and m, n, p must be non zero

Q - Factor of a Cavity Resonator

The quality factor (Q) is a measure of how effectively the resonator stores energy compared to how much it loses per cycle.

$$Q = 2\pi \frac{\text{Energy stored in cavity}}{\text{Energy lost per cycle}}$$

- Stored energy (w) : Mainly stored in electric and magnetic fields

$$w = \frac{1}{4}\iiint_V \left(\epsilon |E|^2 + \mu |H|^2\right) dv$$

- Power loss (P) : occurs due to surface existence of cavity walls

$$P = \frac{1}{2} R_s \iint_S |H_t|^2 \, ds$$

where, $R_s = \sqrt{\frac{\pi f \mu}{\sigma}}$ (surface resistance of wall $\sigma$ = conductivity)

Thus, $Q = \frac{\omega W}{P}$

- A high Q means narrow bandwidth and low losses.

- APPLICATIONS OF CAVITY RESONATORS

1] Microwave Oscillators (Klystron, magnetron, cavity oscillator)

2] Microwave Filters.

3] Frequency stabilization.

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Que. 7] A metal box is 3x4x5 cm in dimensions, filled with air. Calculate the resonant frequency of the cavity for $TE_{102}$

→ a = 4cm = 0.04 m

b = 3cm = 0.03 m

d = 5cm = 0.05 m

$c = 3 \times 10^8$ m/s

mode : $TE_{102}$

- m = 1, n = 0, P = 2

$$f_r = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}$$

$$f_r = \frac{3\times10^8}{2}\sqrt{\left(\frac{1}{0.04}\right)^2 + \left(\frac{0}{0.03}\right)^2 + \left(\frac{2}{0.05}\right)^2}$$

$$= 1.5 \times 10^8 \sqrt{(25)^2 + 0 + (40)^2}$$

$$= 1.5 \times 10^8 \sqrt{625 + 1600}$$

$$= 1.5 \times 10^8 \times 47.27$$

$$f_r \approx 7.09 \times 10^9 \text{ Hz}$$

$$\boxed{f_r \approx 7.09 \text{ GHz}}$$

Que. 8] What is strip line? Explain its operation and different types.

→ A strip line is a type of planar transmission line used for microwave frequencies.

- It consists of a flat conducting strip placed between two parallel ground planes, fully embedded inside a dielectric material.
- Because it is completely enclosed, the electromagnetic fields are confined within the dielectric.

OPERATION OF STRIPLINE

- When an RF / microwave signal is applied to the strip conductor, the electromagnetic fields are established between the strip and the ground planes.

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- The mode of propagation is pure TEM because both electric and magnetic fields are transverse to the direction of propagation.

TYPES OF STRIPLINE –

① SYMMETRIC STRIPLINE :–
- The strip conductor is exactly at the center between two ground planes.
- fields are evenly distributed by pure TDM mode.
- Provides excellent Performance.

② ASYMMETRIC STRIPLINE :–
- The strip conductor is placed off-center between the two ground planes.
- Used when fabrication or design constraints exist.
- fields are still TEM but not evenly distributed.

③ OFFSET STRIPLINE :-
- Similar to asymmetric but the offset is deliberately designed for specific impedance matching or performance.

④ MULTIPLE STRIPLINE / DUAL STRIPLINE
- Two or more strip conductors placed inside the dielectric between ground planes.
- Used for coupled-line circuits like directional coupler, filters, or balanced transmission lines.

Que. 9] Explain the operation of microstrip lines with its structure and quasi TEM mode field distribution.

→ MICROSTRIP LINE : STRUCTURE
A microstrip line is a type of planar transmission line widely used in microwave circuits (antennas, filters, couples, etc).
Its structure consists of :-

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1. Conducting strip – a thin metallic strip (usually copper) of width $w$.
2. Dielectric substrate – material of thickness $h$ and relative permitivity $\varepsilon_r$, placed between the strip and ground.
3. Ground plane – a conducting plane on the bottom surface of the substrate.

OPERATION OF MICROSTRIP LINE –
- When RF / microwave signal is applied, the current flows along the conducting strip.
- The return current flows along the ground plane
- The electric field (E) exists between the strip and the ground plane
- ~~The electric field~~ while the magnetic field (H) encircles the strip current.

QUASI – TEM Mode field Distribution.

1] Electric - field (E - field) :-
- Starts from the strip conductor and terminates at the ground plane
- Inside the substrate :- field lines are denser
- Above the substrate :- field lines are more spread out.

2] Magnetic field (H - field) :-
- Encircles the current flowing along the strip
- Magnetic field lines are concentrated closer to the strip.

3] Effective Dielectric Constant :-
- Because fields exist in two media (· dielectric). we define an effective dielectric constant.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12h\sqrt{w}}}\right)$$

This lies between 1 (air) and $\varepsilon_r$
- Propagation velocity is :-

$$v_p = \frac{c}{\sqrt{\varepsilon_{eff}}}$$

Que. 10] Write short note on Re-entrant Cavity. Explain different Coupling Methods.

→ - A re-entrant cavity resonator is a modified cavity where a metallic post projects from one of the cavity walls toward the opposite wall, leaving a narrow gap.
This structure creates a concentrated capacitance at the gap and inductance in the post, making the cavity behave like a lumped LC resonator at microwave frequencies.

## Coupling Methods in Cavity Resonators -

① Probe Coupling :-
- A co-axial cable (probe) penetrates into the cavity near the region of strong electric field.
- Couples electric energy from co-axial line to the cavity.

② Loop Coupling :-
- A small loop of wire is placed inside the cavity where the magnetic field is strong.
- Couples magnetic flux into the cavity.

③ Aperture / slot Coupling :-
- A slot or hole is cut in the cavity wall.
- Waveguide / microstrip on one side couples energy into cavity through the slot.
- Common in waveguide cavity filters.