SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

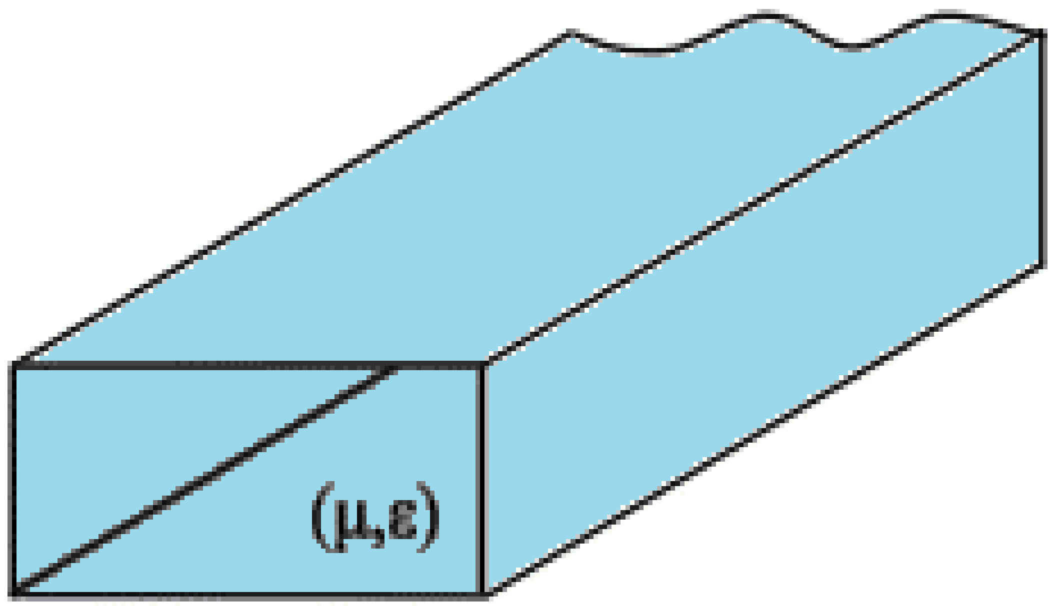
19ECT302 – TRANSMISSION LINES AND ANTENNAS

III YEAR/ V SEMESTER

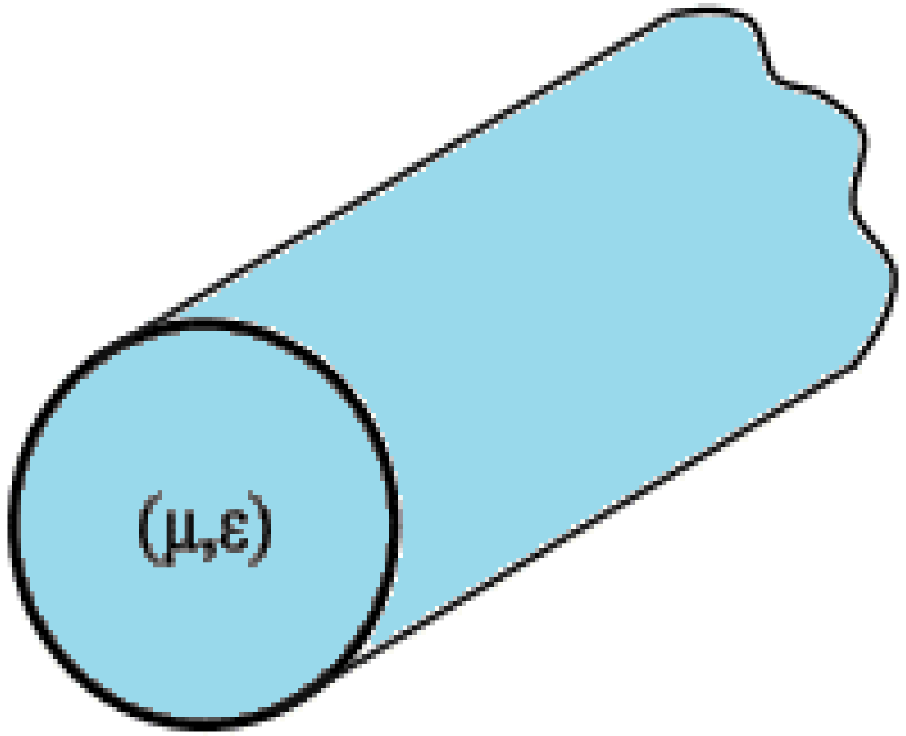
UNIT 2 – GUIDED WAVES

TOPIC – TM & TE WAVES IN CIRCULAR WAVEGUIDES

WHAT DO YOU INFER FROM THESE DIAGRAMS ?



Rectangular Waveguide



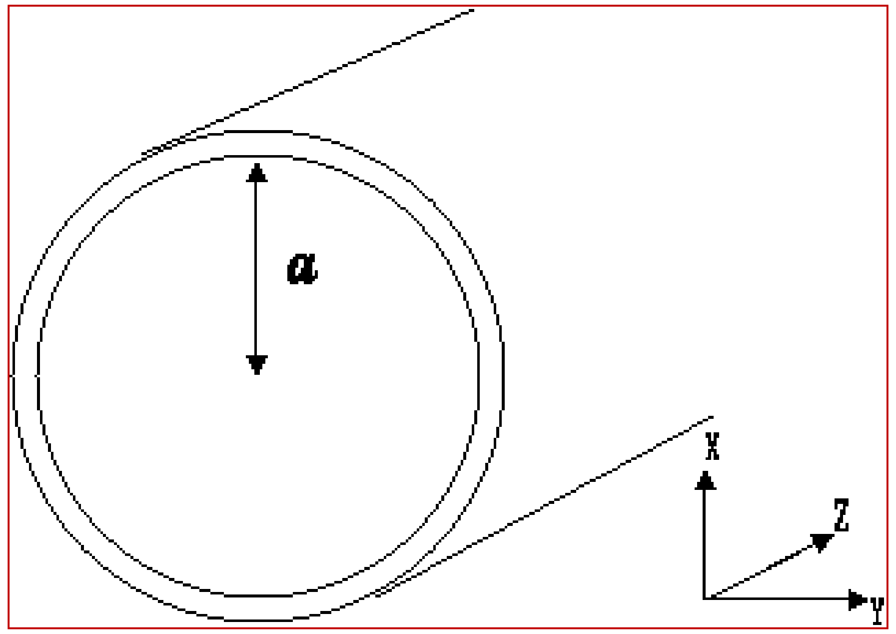
Circular Waveguide

CIRCULAR WAVEGUIDES -ADVANTAGES

- The circular waveguide are easier to manufacture than rectangular waveguides and are easier to join.
- The TM01 modes are rotationally symmetrical and hence rotation of polarization can be overcome.
- TE01 mode in circular for long distance waveguide transmission.

CIRCULAR WAVEGUIDES –TE & TM MODES

- Figure shows a cylindrical waveguide which is simply a hollow tube with circular cross section of radius ***a*** and extending along the Z direction
- There are two sets of modes, TE and TM modes, which can propagate in a cylindrical waveguide.



From Maxwell's Equations

$\hat{z}$

$$\frac{1}{\rho}\frac{\partial E_z}{\partial \phi} \pm j\beta_z E_\phi = -j\omega\mu H_\rho$$

$$\mp j\beta_z E_\rho - \frac{\partial E_z}{\partial \rho} = -j\omega\mu H_\phi$$

$$\frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho \overline{E}_\phi\right) - \frac{1}{\rho}\frac{\partial E_\rho}{\partial \phi} = -j\omega\mu H_z$$

$$\frac{1}{\rho}\frac{\partial H_z}{\partial \phi} \pm j\beta_z H_\phi = j\omega\varepsilon E_\rho$$

$$\mp j\beta_z H_\rho - \frac{\partial H_z}{\partial \rho} = j\omega\varepsilon E_\phi$$

$$\frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho H_\phi\right) - \frac{1}{\rho}\frac{\partial H_z}{\partial \phi} = j\omega\varepsilon E_z$$

TE & TM MODE – FIELD ANALYSIS

The ρ and ϕ components can be expressed in terms of Ez and Hz as

$\hat{z}$

$$E_\rho = \frac{1}{\beta_z^2 - \beta^2}\left[\pm j\beta_z \frac{\partial E_z}{\partial \rho} + \frac{j\omega\mu}{\rho}\frac{\partial H_z}{\partial \phi}\right]$$

$$E_\phi = -\frac{1}{\beta_z^2 - \beta^2}\left[\mp j\frac{\beta_z}{\rho}\frac{\partial E_z}{\partial \phi} + j\omega\mu\frac{\partial H_z}{\partial \rho}\right]$$

$$H_\rho = -\frac{1}{\beta_z^2 - \beta^2}\left[\frac{j\omega\varepsilon}{\rho}\frac{\partial E_z}{\partial \phi} \mp j\beta_z\frac{\partial H_z}{\partial \rho}\right]$$

$$H_\phi = \frac{1}{\beta_z^2 - \beta^2}\left[j\omega\varepsilon\frac{\partial E_z}{\partial \rho} \pm j\frac{\beta_z}{\rho}\frac{\partial H_z}{\partial \phi}\right]$$

TE & TM MODE – FIELD ANALYSIS

For TE waves, $E_z = 0$ and H_z satisfies the equation

$$H_z = R(\rho)\Phi(\phi)e^{\mp j\beta_z z}$$

$$\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial H_z}{\partial\rho}\right)+\frac{1}{\rho^2}\frac{\partial^2 H_z}{\partial\phi^2}-\left(\beta_z^2-\beta^2\right)H_z=0$$

CIRCULAR WAVEGUIDES -APPLICATIONS

- Rotating joints in radars to connect the horn antenna feeding a paraboloid reflector (which must rotate for tracking).
- TE01 mode is suitable for long distance waveguide transmission above 10GHz.
- Short and medium distance broad band communication (cold replace/share coaxial and microwave links).
- radar.

CIRCULAR WAVEGUIDES -APPLICATIONS

- It is used where the transmission or reception is in the range of microwave frequencies.
- It is also used for handling the high power of energy. It is mostly used in the airborne

HOW TO STORE EM ENERGY ?

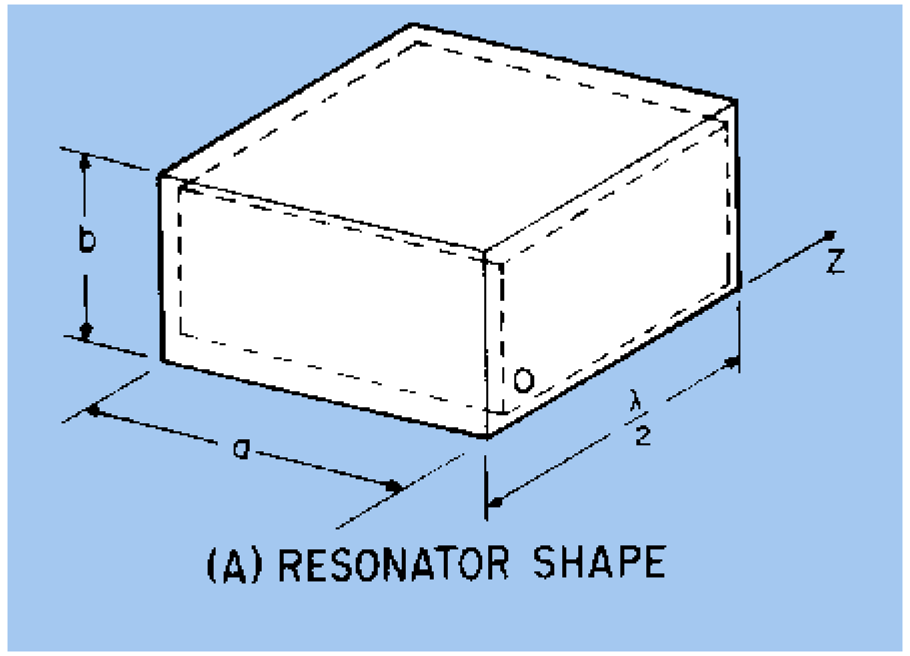
With the help of cavity resonators.

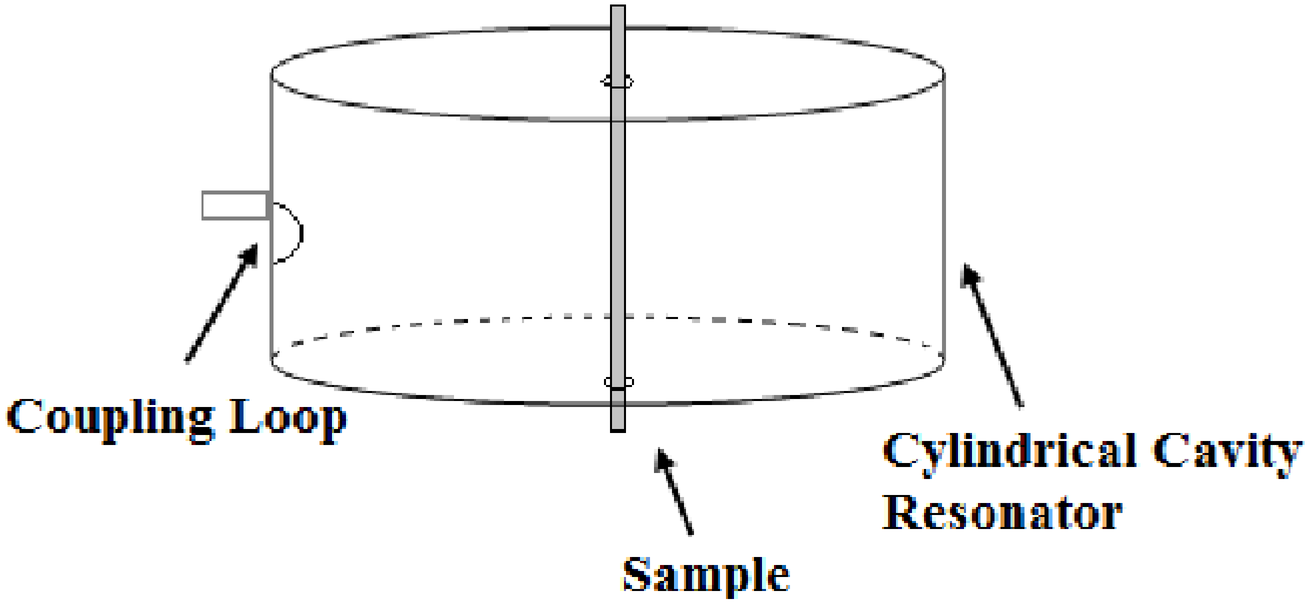
Definition:

An electronic device consisting of a space usually enclosed by metallic walls within which resonant electromagnetic fields may be excited and extracted for use in microwave systems

CAVITY RESONATORS - INTRODUCTION

- Cavities, or resonators, are used for storing energy
- Used in klystron tubes, band-pass filters and frequency meters
- It’s equivalent to a RLC circuit at high frequency
- Their shape is that of a cavity, either rectangular or cylindrical.





CAVITY RESONATORS - INTRODUCTION

- To provide a resonant circuit at UHF and higher frequencies, an enclosure completely surrounded by conducting walls is required.
- Such a shielded enclosure confines electromagnetic fields inside and furnishes large areas for current flow.
- Thus eliminating radiation and high-resistance effects.
- These enclosures have natural resonant frequencies and a very high Q (Quality factor), and are called cavity resonator.

CAVITY RESONATORS – TE & TM MODES

- Designation of TE and TM modes in resonator cavity is not unique because we are free to choose x or y or z as the “direction of propagation”. That is, there is no unique "longitudinal direction.“
- A three-symbol (mnp) subscript is needed to designate a TM or TE standing wave pattern in a cavity resonator.

DEGENERATE AND DOMINANT MODES

- Like waveguides, different modes having the same resonant frequency are called degenerate modes.
- TM_{mnp} and TE_{mnp} are always degenerate if none of the mode indices is zero.
- The mode with lowest resonant frequency for a given cavity size is referred as the dominant mode.

RESONANT FREQUENCY

- Resonant frequency of the cavity can be defined as:

$$\omega_{mnp} = (1/\sqrt{\mu\varepsilon}) * \sqrt{[(m*\pi/a)^2 + (n*\pi/b)^2 + (p*\pi/d)^2]}$$

$$f_{mnp} = u/2*\sqrt{[(m/a)^2 + (n/b)^2 + (p/d)^2]} \quad \text{(Hz)}$$

where integers m,n,p denote the number of half-wave variations in the x, y, and z direction, respectively.

RESONANT FREQUENCY

- Resonant frequency of the cavity can be defined as:

$$\omega_{mnp} = (1/\sqrt{\mu\varepsilon})* \sqrt{[(m*\pi/a)^2 + (n*\pi/b)^2 + (p*\pi/d)^2]}$$

$$f_{mnp} = u/2*\sqrt{[(m/a)^2 + (n/b)^2 + (p/d)^2]} \quad (Hz)$$

where integers m,n,p denote the number of half-wave variations in the x, y, and z direction, respectively.

QUALITY FACTOR

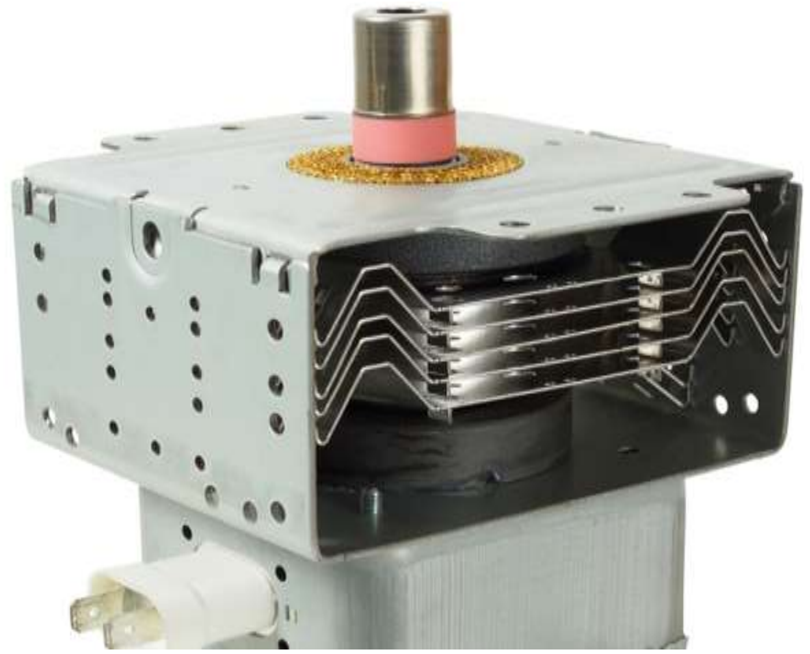
Quality factor, Q of a resonator, is associated with the loss factor of the cavity resonator and is defined as:

Q=2π * (Time average energy stored at a resonant frequency)/(Energy dissipated in one period of this frequency)

$$Q = fr/\Delta f$$

CAVITY RESONATOR - FUNCTIONALITY

- The majority of resonant cavities are made from closed or short-circuited sections of a waveguide or high-permittivity dielectric material.
- In terms of functionality, the storing of electric and magnetic energy takes place within the resonant cavity itself.
- Furthermore, the only loss of energy is due to the finite conductivity of the cavity walls and dielectric losses of the material filling the cavity.



CAVITY RESONATOR - FUNCTIONALITY

- In every cavity, there will be multiple resonant frequencies that correlate to EM field modes, maintaining the needed boundary conditions on the walls of the cavity.
- Due to these boundary conditions that must be met at resonance (tangential electric fields must be zero at cavity walls), as it follows that cavity length, it must be an integer multiple of half-wavelength at resonance.
- Therefore, a resonant cavity can be considered a waveguide equivalent of a short-circuited half-wavelength transmission line resonator.

CAVITY RESONATOR - FUNCTIONALITY

- The electromagnetic fields in the cavity are excited via an exterior connection.
- An outside power source is usually coupled to the cavity by a small aperture, a small wire probe, or a loop.
- The outer or external coupling structure affects cavity performance, and this is a consideration one must take during the overall analysis.

CAVITY RESONATOR - APPLICATIONS

- Used in Tuned cicuits
- Also used in UMF Tubes, Klystron Amplifiers, Oscillators and Duplexers of RADAR.
- They are also used in microwave frequency meters.
- An outside power source is usually coupled to the cavity by a small aperture, a small wire probe, or a loop.
- The outer or external coupling structure affects cavity performance, and this is a consideration one must take during the overall analysis.

ASSESSMENT

1. What is the need for cavity resonators?
2. What are the types of resonators?
3. Mention the applications of Microwave resonant cavities
4. Define resonance frequency.
5. What is quality factor of microwave cavities.
6. How a cavity is formed

THANK YOU