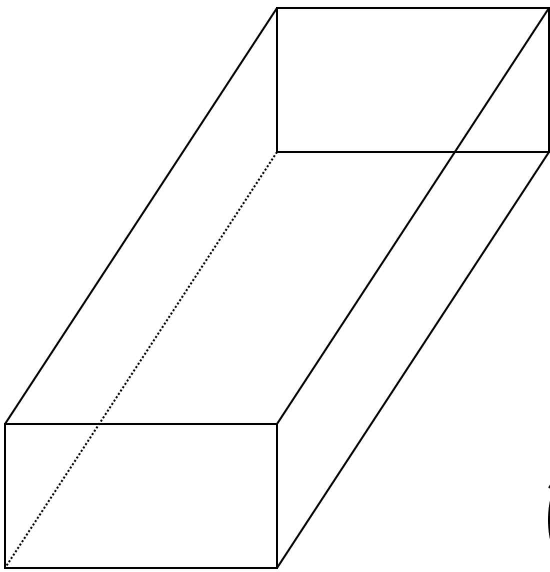
# EEC 603
# MICROWAVE ENGINEERING

## **UNIT-1**

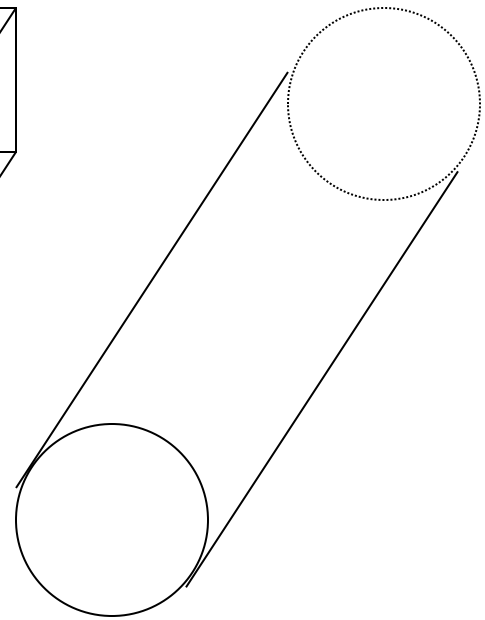
# Syllabus

- Introduction
- Rectangular Wave Guide: Field Components, TE, TM Modes, Dominant TE10 mode,
- Field Distribution, Power, Attenuation.
- Circular Waveguides: TE, TM modes.
- Wave Velocities, Micro strip Transmission line (TL),
- Coupled TL, Strip TL, Coupled Strip Line, Coplanar TL, Microwave Cavities.

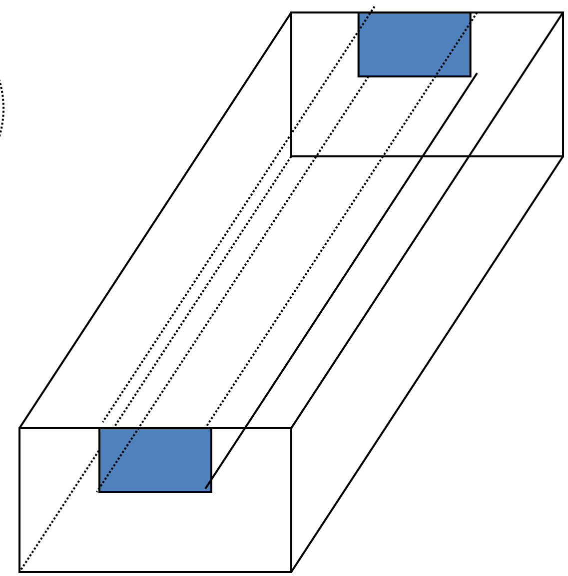
# Common Hollow-pipe waveguides



Rectangular guide

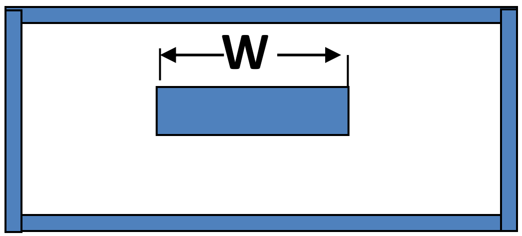


Circular guide

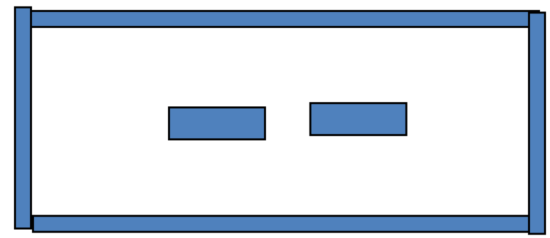


Ridge guide

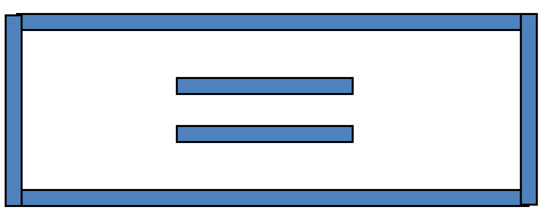
# STRIP LINE CONFIGURATIONS



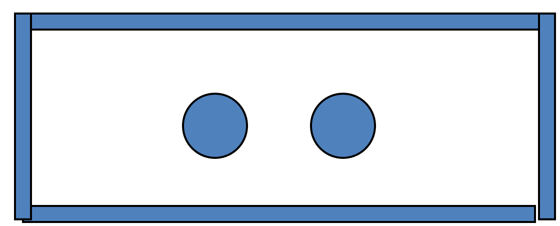

**SINGLE STRIP LINE**



**COUPLED LINES**

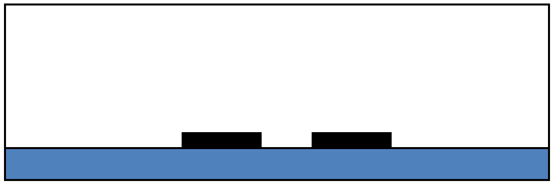


**COUPLED STRIPS**
**TOP & BOTTOM**

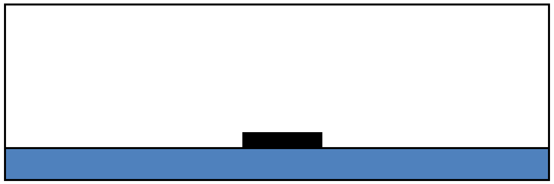


**COUPLED ROUND BARS**

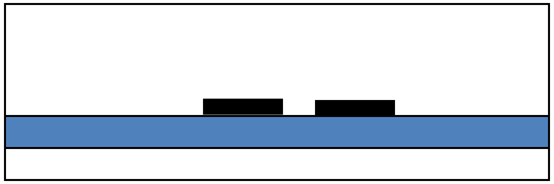
# MICROSTRIP LINE CONFIGURATIONS



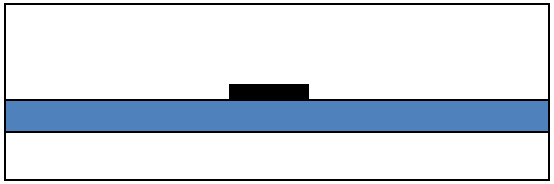
**TWO COUPLED MICROSTRIPS**



**SINGLE MICROSTRIP**



**TWO SUSPENDED SUBSTRATE LINES**



**SUSPENDED SUBSTRATE LINE**

# TRANSMISSION MEDIA

- TRANSVERSE ELECTROMAGNETIC (TEM):
  - COAXIAL LINES
  - MICROSTRIP LINES (Quasi TEM)
  - STRIP LINES AND SUSPENDED SUBSTRATE
- METALLIC WAVEGUIDES:
  - RECTANGULAR WAVEGUIDES
  - CIRCULAR WAVEGUIDES
- DIELECTRIC LOADED WAVEGUIDES

ANALYSIS OF WAVE PROPAGATION ON THESE TRANSMISSION MEDIA THROUGH MAXWELL'S EQUATIONS

## **Electromagnetic Theory** Maxwell's Equations

$$\nabla \times \overline{E} = -\frac{\partial \overline{B}}{\partial t} - \overline{\mathrm{M}} \quad ; \quad \nabla \times \overline{H} = \frac{\partial \overline{D}}{\partial t} + \overline{J}$$

$$\nabla \bullet \overline{D} = \rho \quad ; \quad \nabla \bullet \overline{B} = 0$$

$$\text{Continuity Equation :} \quad \nabla \bullet \overline{J} = -\frac{\partial \rho}{\partial t}$$

$\overline{E} = \text{Electric Filed Intensity V/m}$

$\overline{D} = \text{Electric Flux Density C/m}^2$

$\overline{B} = \text{Magnetic Flux Density T (Telsa or V - Sec./m}^2)$

$\overline{H} = \text{Magnetic Field Intensity A/m}$

$\overline{\mathrm{J}} = \text{Electric current density A/m}^2$

$\overline{M} = \text{Magnetic (fictitious) current density V/m}^2$

## Maxwell's Equations in Large Scale Form

$$\oint_S \overline{D} \bullet \overline{d}\overline{S} = \int_V \rho dv$$

$$\oint_S \overline{B} \bullet \overline{d}\overline{S} = 0$$

$$\oint_l \overline{E} \bullet \overline{d}\overline{l} = -\frac{\partial}{\partial t}\int_S \overline{B} \bullet \overline{d}\overline{S} - \int_S \overline{M} \bullet d\overline{S}$$

$$\oint_l \overline{H} \bullet \overline{d}\overline{l} = \int_S \overline{J} \bullet \overline{d}\overline{S} + \frac{\partial}{\partial t}\int_S \overline{D} \bullet \overline{d}\overline{S}$$

## Maxwell's Equations for the Time - Harmonic Case

Assume $\mathrm{e}^{j\omega t}$ variations, then:

$$\overline{E}(x,y,z,t) = \mathrm{Re}[\overline{E}(x,y,z)e^{j\omega t}]$$

$$\overline{E}(x,y,z) = \overline{a}_x(E_{xr} + jE_{xi}) + \overline{a}_y(E_{yr} + jE_{yi}) + \overline{a}_z(E_{zr} + jE_{zi})$$

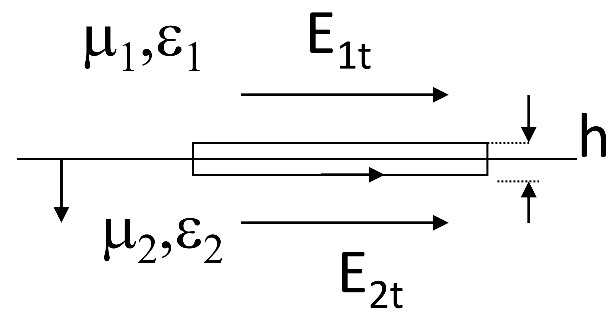
$$E_x = \mathrm{Re}[(E_{xr} + jE_{xi})e^{j\omega t}] = \mathrm{Re}[\sqrt{E_{xr}^2 + E_{xi}^2}\, e^{j\omega t + j\phi}]$$

$$= \sqrt{E^2{}_{xr} + E^2{}_{xi}}\cos(\omega t + \phi) \quad , \phi = \tan^{-1}(E_{xi}/E_{xr})$$

$$\nabla \bullet \overline{D} = \rho \qquad , \nabla \bullet \overline{B} = 0$$

$$\nabla \times \overline{E} = -j\omega\overline{B} - \overline{M} \qquad , \nabla \times \overline{H} = \overline{J} + j\omega\overline{D}$$

# Boundary Conditions at a General Material Interface




$$E_{t_1} - E_{t_2} = -M_s$$

$$D_{n_1} - D_{n_2} = \rho_s$$

$$\rho_s \equiv \text{Surface Charge Density}$$

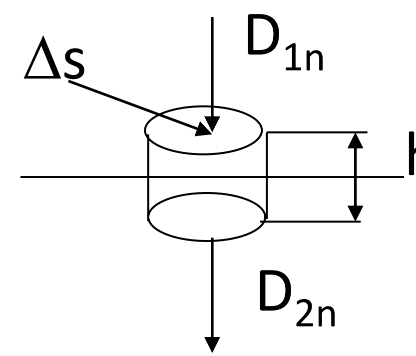
$$B_{n_1} = B_{n_2} \qquad ; \qquad H_{t_1} - H_{t_2} = J_s$$

$$\hat{n} \bullet (\overline{D}_1 - \overline{D}_2) = \rho_s$$

$$\hat{n} \bullet (\overline{B}_1 - \overline{B}_2) = 0$$

$$\hat{n} \times (\overline{E}_1 - \overline{E}_2) = -\overline{M}_s$$

$$\hat{n} \times (\overline{H}_1 - \overline{H}_2) = \overline{J}_s$$



# Wave Equation

$$\nabla \times \nabla \times \overline{E} = -\nabla^2 \overline{E} + \nabla(\nabla \bullet \overline{E}) = -j\omega\mu\nabla \times \overline{H} =$$

$$-j\omega\mu(\overline{J} + j\omega\varepsilon\overline{E})$$

For a Source free medium :

$$\nabla^2 \overline{E} + k^2 \overline{E} = 0 \qquad ; \qquad k^2 = \omega^2 \mu\varepsilon$$

$$\nabla^2 \overline{H} + k^2 \overline{H} = 0 \qquad ; \qquad k = \omega / v = \frac{2\pi}{\lambda}$$

# Plane Waves

$$\nabla^2 \overline{E} + k_0^2 \overline{E} = 0 = \frac{\partial^2 \overline{E}}{\partial x^2} + \frac{\partial^2 \overline{E}}{\partial y^2} + \frac{\partial^2 \overline{E}}{\partial z^2} + k_0^2 \overline{E}$$

$$\frac{\partial^2 E_i}{\partial x^2} + \frac{\partial^2 E_i}{\partial y^2} + \frac{\partial^2 E_i}{\partial z^2} + k_0^2 E_i = 0 \qquad , i = x, y, z$$

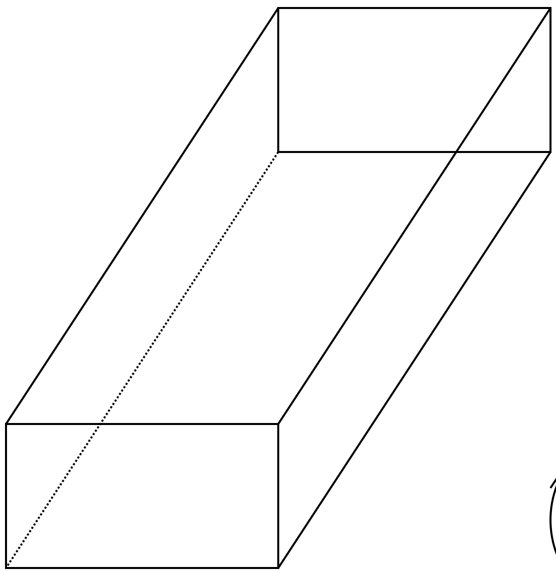
Solve for $E_x(x, y, z)$, Using separation of variables $\Rightarrow$

$$\mathrm{k}_{\mathrm{x}}^2 + k_y^2 + k_z^2 = k_0^2$$

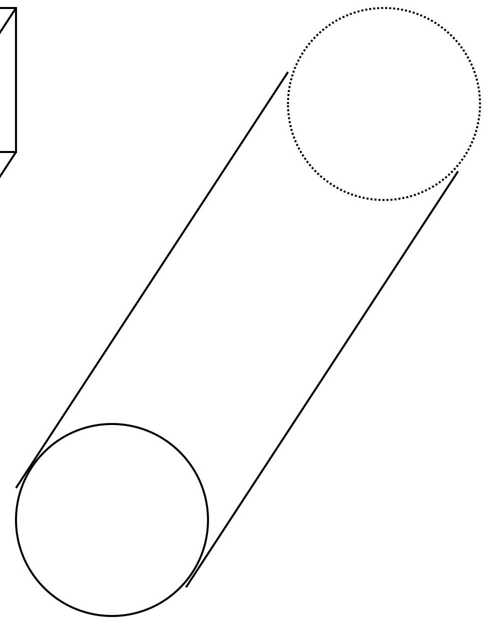
$$E_x = Ae^{-jk_s x - jk_y y - jk_z z} \qquad , \text{Let } \vec{k} = \widehat{a}_x k_x + \widehat{a}_y k_y + \widehat{a}_z k_z$$

$$\vec{r} = \widehat{a}_x x + \widehat{a}_y y + \widehat{a}_z z$$

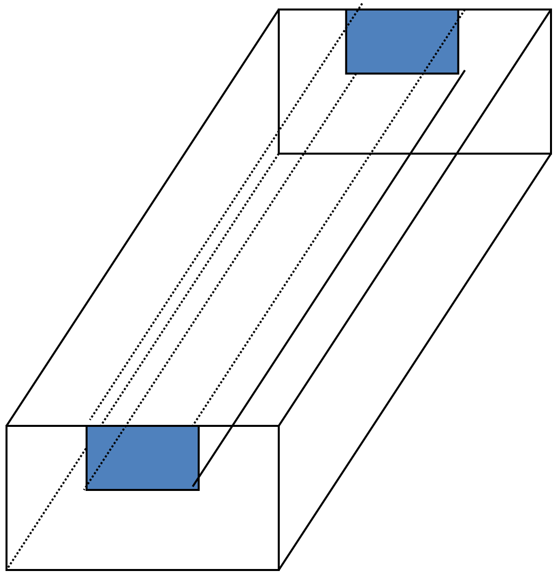
# Common Hollow-pipe waveguides



Rectangular guide



Circular guide



Ridge guide

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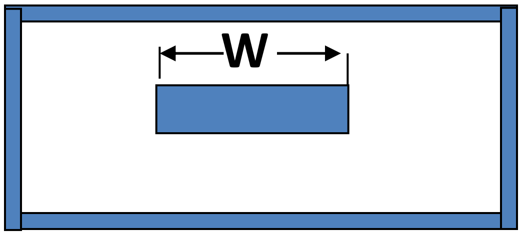
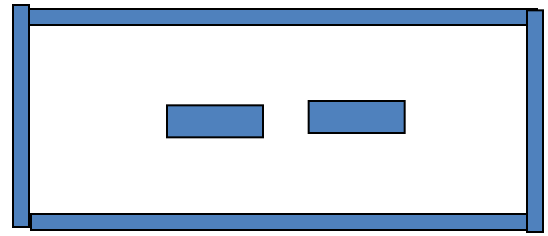
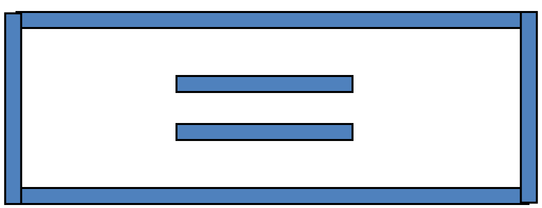



SINGLE STRIP LINE



COUPLED LINES



COUPLED STRIPS
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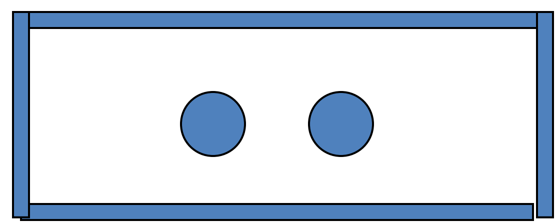

COUPLED ROUND BARS

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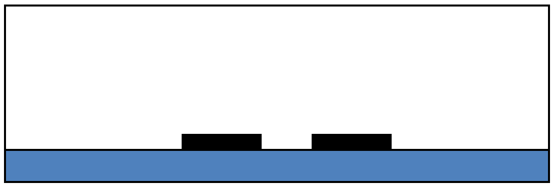

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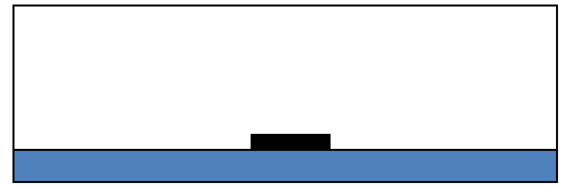

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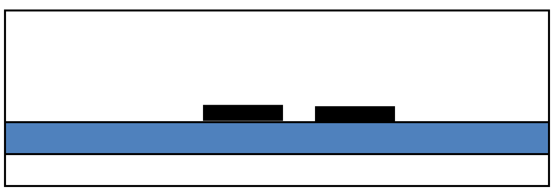

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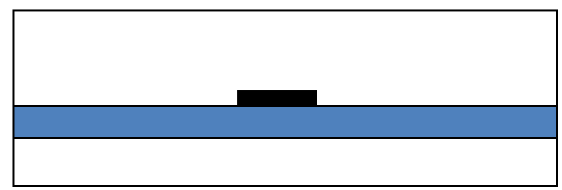

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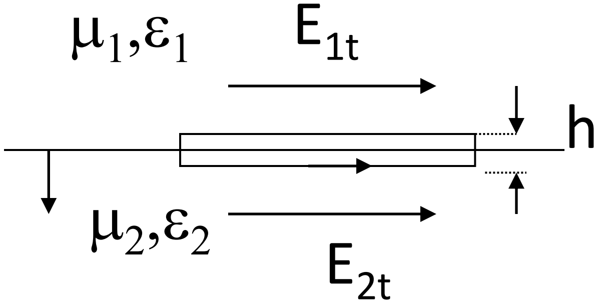


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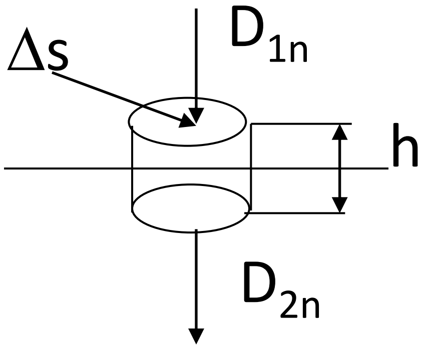

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