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Electromagnetics:

Electromagnetic Field Theory

TE and TM Analysis Setup for Waveguides

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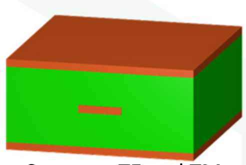
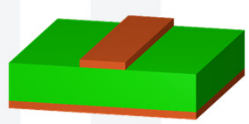
Existence Conditions for TE and TM Modes

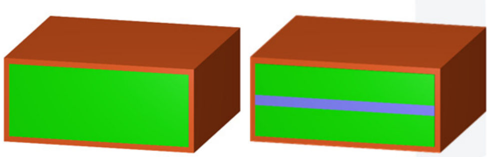
TE and TM modes only exist in waveguides with a homogeneous fill or in waveguides with a uniform axis like slabs and circularly symmetric guides.



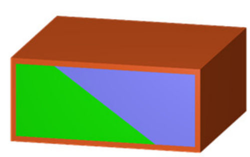
Supports TE and TM



Does Not Support TE or TM



Supports TE and TM



Does Not Support TE or TM

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TE Analysis in LHI Media

Choose to set $E_{0,z} = 0$ and $H_{0,z} \neq 0$. This means it is only necessary to solve for $H_{0,z}$.

$$\cancel{\nabla^2 E_{0,z} + k_c^2 E_{0,z} = 0} \qquad \boxed{\nabla^2 H_{0,z} + k_c^2 H_{0,z} = 0}$$

An added benefit of this solution approach is that $H_{0,z}$ is tangential to all boundaries in a waveguide.

For TE analysis, the other field components are calculated just from $H_{0,z}$.

$$H_{0,x} = -\frac{j\beta}{k_c^2}\frac{\partial H_{0,z}}{\partial x} \qquad E_{0,x} = -\frac{j\omega\mu}{k_c^2}\frac{\partial H_{0,z}}{\partial y}$$

$$H_{0,y} = -\frac{j\beta}{k_c^2}\frac{\partial H_{0,z}}{\partial y} \qquad E_{0,y} = \frac{j\omega\mu}{k_c^2}\frac{\partial H_{0,z}}{\partial x}$$

From this, the characteristic impedance Z_{TE} is

$$Z_{TE} = \frac{E_{0,x}}{H_{0,y}} = \frac{-\frac{j\omega\mu}{k_c^2}\frac{\partial H_{0,z}}{\partial y}}{-\frac{j\beta}{k_c^2}\frac{\partial H_{0,z}}{\partial y}} = \frac{\omega\mu}{\beta} = \eta\frac{k}{\beta}$$

β is found by solving the wave equation.

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TM Analysis in LHI Media

Choose to set $E_{0,z} \neq 0$ and $H_{0,z} = 0$. This means it is only necessary to solve for $E_{0,z}$.

$$\boxed{\nabla^2 E_{0,z} + k_c^2 E_{0,z} = 0} \qquad \cancel{\nabla^2 H_{0,z} + k_c^2 H_{0,z} = 0}$$

An added benefit of this solution approach is that $E_{0,z}$ is tangential to all boundaries in a waveguide.

For TM analysis, the other field components are calculated just from $E_{0,z}$.

$$H_{0,x} = \frac{j\omega\varepsilon}{k_c^2}\frac{\partial E_{0,z}}{\partial y} \qquad E_{0,x} = -\frac{j\beta}{k_c^2}\frac{\partial E_{0,z}}{\partial x}$$

$$H_{0,y} = -\frac{j\omega\varepsilon}{k_c^2}\frac{\partial E_{0,z}}{\partial x} \qquad E_{0,y} = -\frac{j\beta}{k_c^2}\frac{\partial E_{0,z}}{\partial y}$$

From this, the characteristic impedance Z_{TM} is

$$Z_{TM} = \frac{E_{0,x}}{H_{0,y}} = \frac{-\frac{j\beta}{k_c^2}\frac{\partial E_{0,z}}{\partial x}}{-\frac{j\omega\varepsilon}{k_c^2}\frac{\partial E_{0,z}}{\partial x}} = \frac{\beta}{\omega\varepsilon} = \eta\frac{\beta}{k}$$

β is found by solving the wave equation.

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