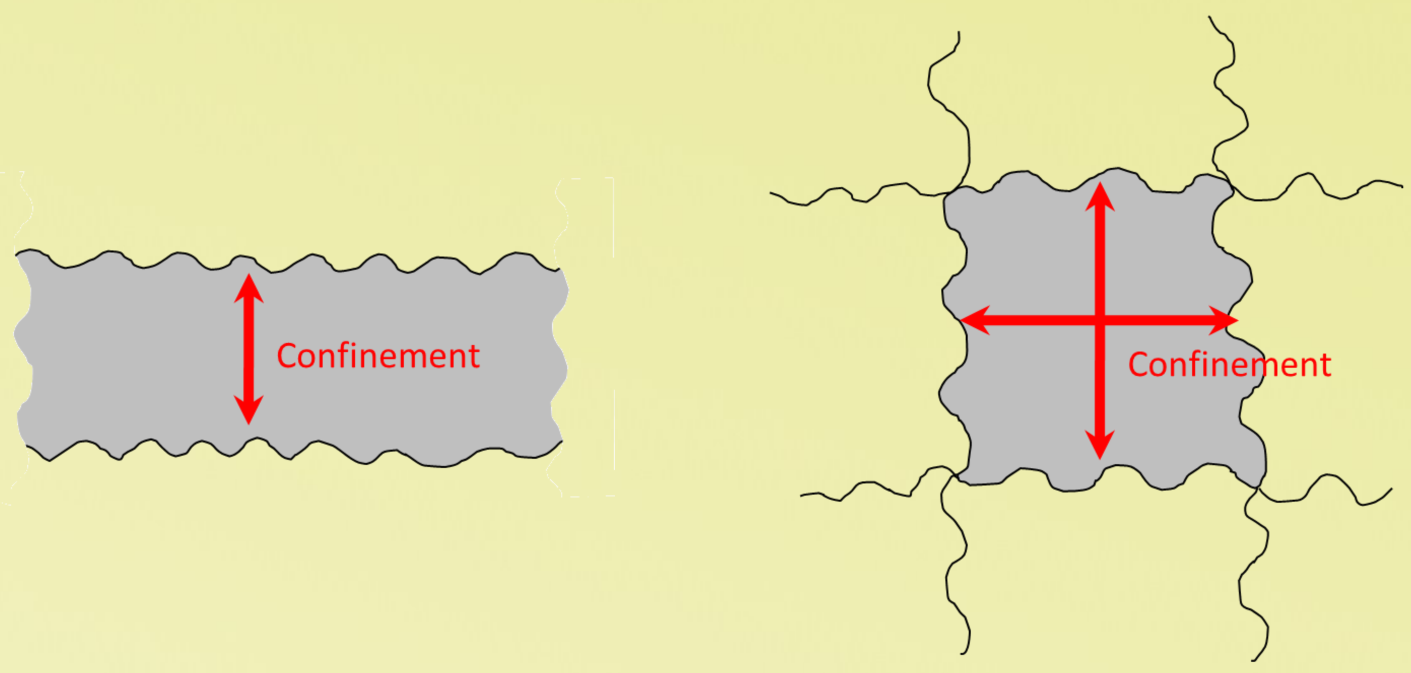
THE UNIVERSITY OF TEXAS AT EL PASO

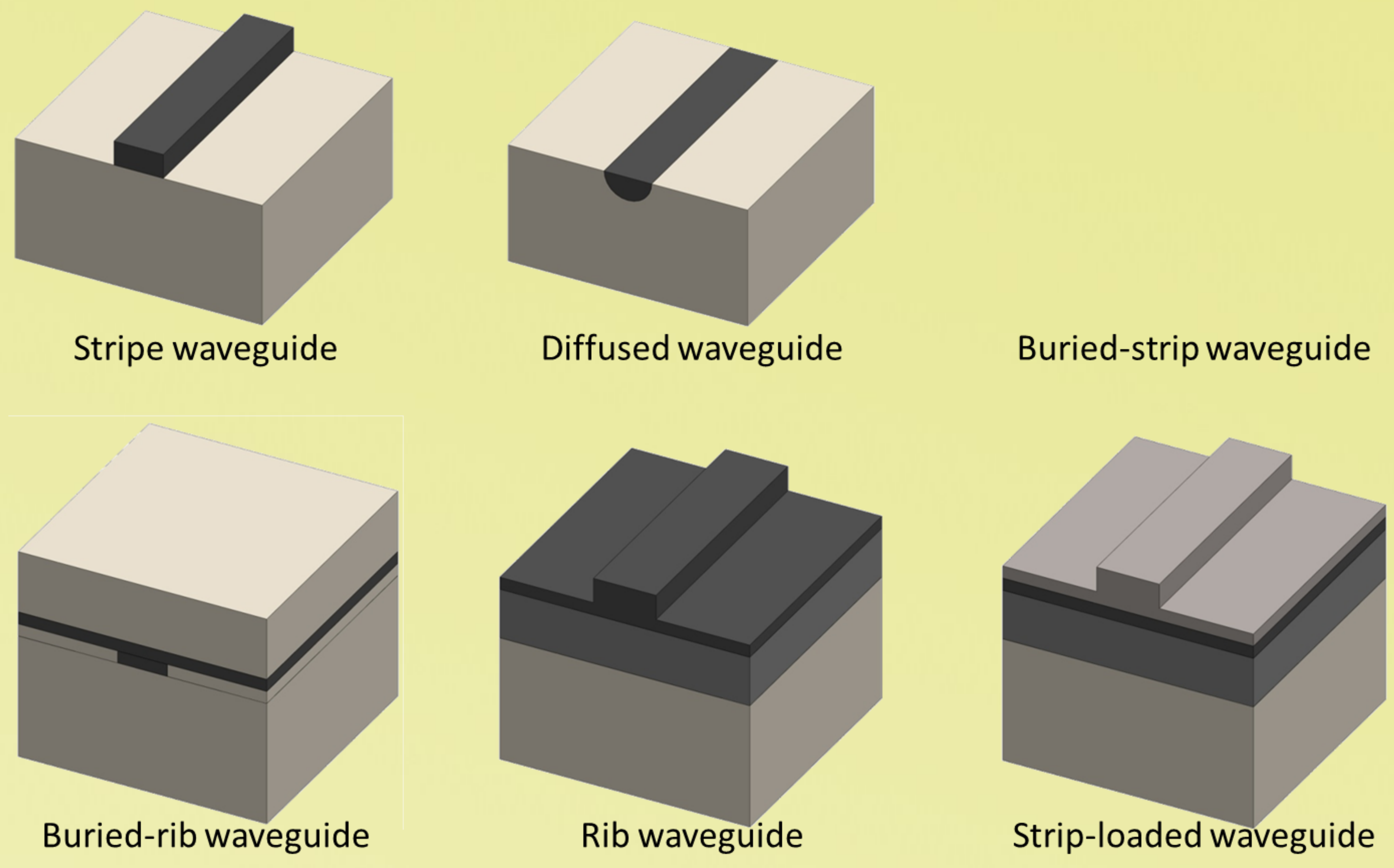
Finite-Difference Analysis of Waveguides

The finite-difference method (FDM) provides a simple way analyze all forms of waveguides. It is simple to formulate and easy to implement. The basis code uses a uniform grid so it is not has efficient as finite element methods that use more efficient unstructured grids.

SLAB VS. CHANNEL WAVEGUIDES

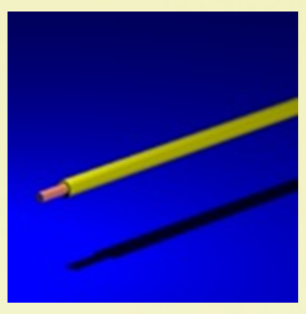


CHANNEL WAVEGUIDES FOR INTEGRATED

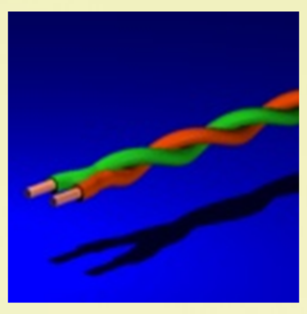


CHANNEL WAVEGUIDES FOR RADIO FREQUENCIES

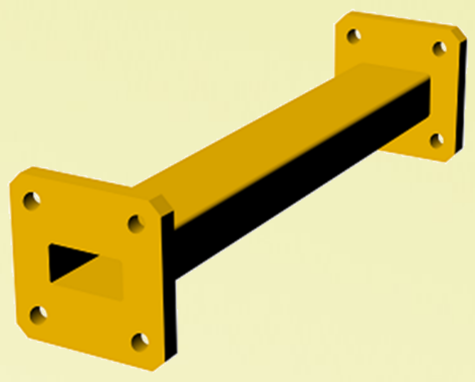
Isolated Wire



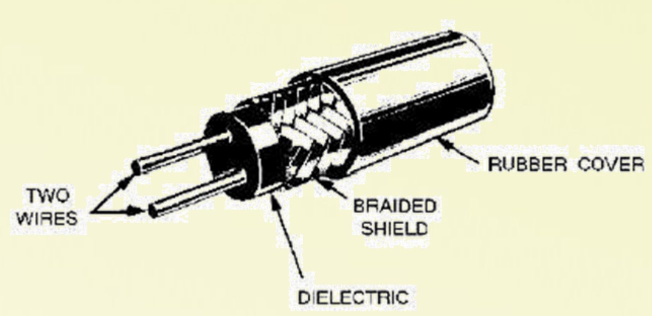
Twisted Pair Transmission Line



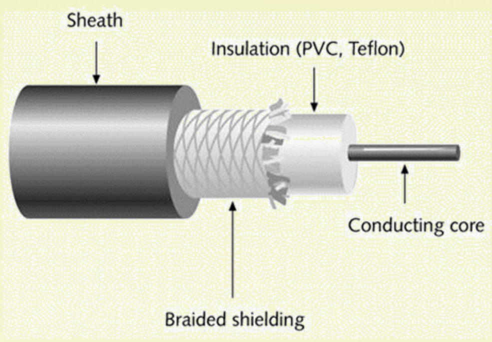
Rectangular Waveguide



Shielded-Pair Transmission Line

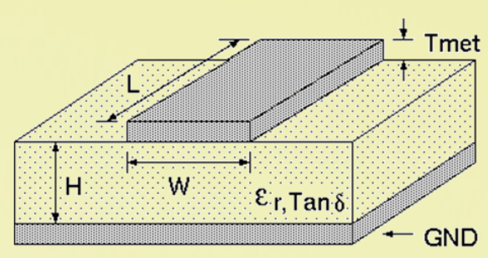


Coaxial Cable

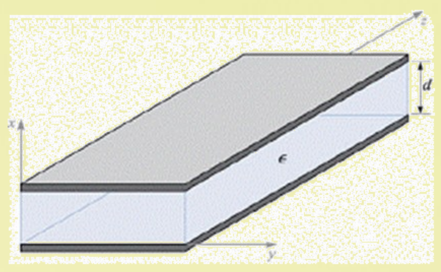


CHANNEL WAVEGUIDES FOR PRINTED CIRCUITS

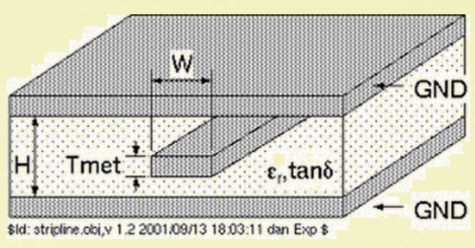
Microstrip



Parallel-Plate Transmission Line



Stripline



Slot Line

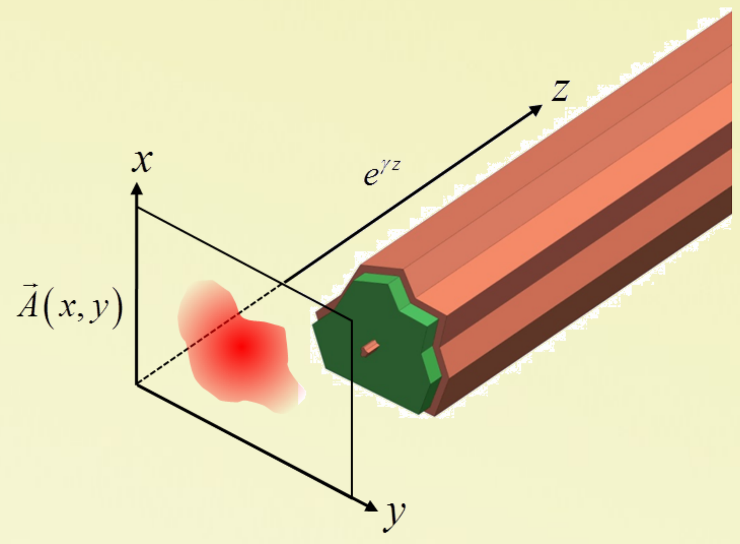
Coplanar Line

$$\vec{E}(x,y,z)=\vec{A}(x,y)e^{\gamma z}$$

complex amplitude, mode shape

accumulation of phase in z direction

$\gamma=\alpha+j\beta\equiv$ progation constant



RIGOROUS HYBRID MODE ANALYSIS

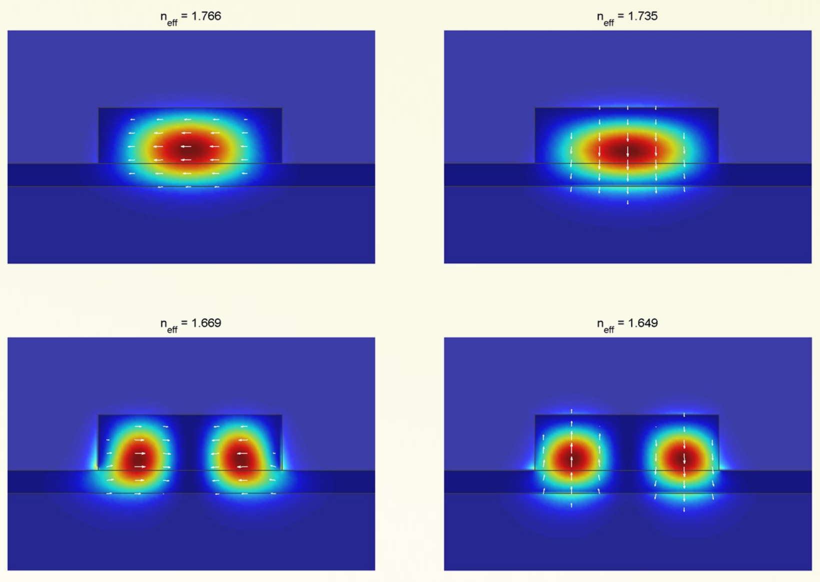
Standard eigen-value equation

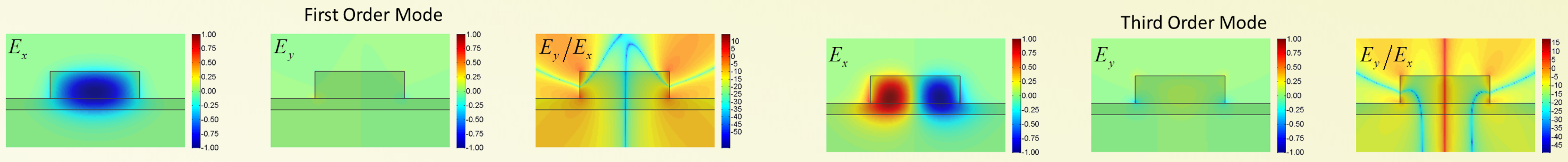
$$\mathbf{\Omega}^2\begin{bmatrix}\mathbf{a}_x\\ \mathbf{a}_y\end{bmatrix}=\tilde{\gamma}^2\begin{bmatrix}\mathbf{a}_x\\ \mathbf{a}_y\end{bmatrix}\qquad \mathbf{Ax}=\lambda\mathbf{x}\qquad \mathbf{A}=\mathbf{\Omega}^2\quad \lambda=\tilde{\gamma}^2$$

$$\mathbf{\Omega}^2=\mathbf{PQ}$$

$$\mathbf{P}=\begin{bmatrix}-\mathbf{D}_{x'}^{e}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{y'}^{h} & \mathbf{D}_{x'}^{e}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{x'}^{h}+\boldsymbol{\mu}_{yy}\\ -\left(\mathbf{D}_{y'}^{e}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{y'}^{h}+\boldsymbol{\mu}_{xx}\right) & \mathbf{D}_{y'}^{e}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{x'}^{h}\end{bmatrix}\qquad \mathbf{Q}=\begin{bmatrix}-\mathbf{D}_{x'}^{h}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{y'}^{e} & \mathbf{D}_{x'}^{h}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{x'}^{e}+\boldsymbol{\varepsilon}_{yy}\\ -\left(\mathbf{D}_{y'}^{h}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{y'}^{e}+\boldsymbol{\varepsilon}_{xx}\right) & \mathbf{D}_{y'}^{h}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{x'}^{E}\end{bmatrix}$$

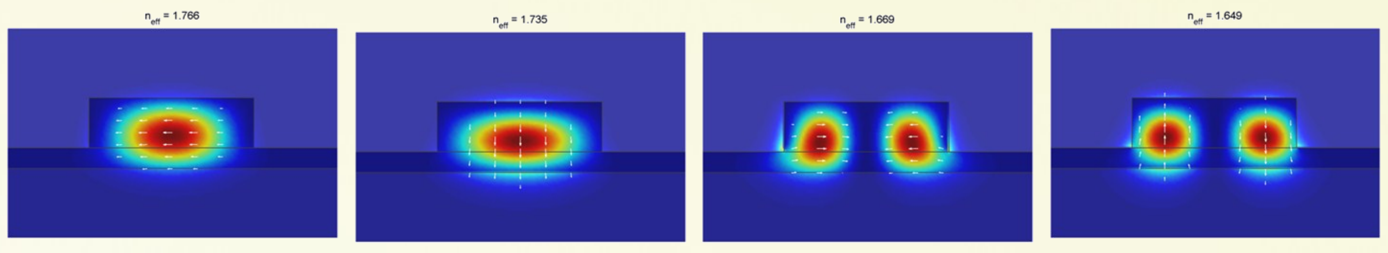
Rib waveguide analysis





We see that the modes tends to be strongly linearly polarized.

Full-Vector Analysis (12 second run time @ λ/30 resolution)



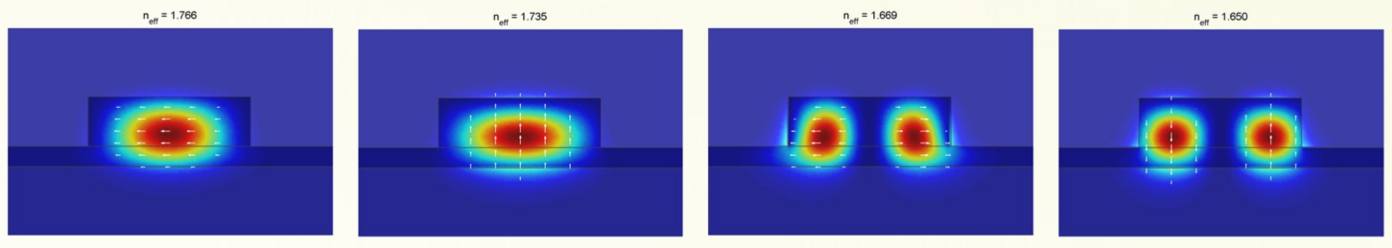
QUASI-TE/TM MODE ANALYSIS

Observing how strongly linearly polarized the hybrid modes are, we can approximate the smaller components to be zero. This simplifies the analysis and makes it more efficient.

E_x Mode: $\mathbf{\Omega}_{xx}^2\mathbf{a}_x=\tilde{\gamma}^2\mathbf{a}_x$ $\qquad \mathbf{\Omega}_{xx}^2=\mathbf{D}_{x'}^{E}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{y'}^{H}\mathbf{D}_{x'}^{H}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{y'}^{E}-\left(\mathbf{D}_{x'}^{E}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{x'}^{H}+\boldsymbol{\mu}_{yy}\right)\left(\mathbf{D}_{y'}^{H}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{y'}^{E}+\boldsymbol{\varepsilon}_{xx}\right)$

E_y Mode: $\mathbf{\Omega}_{yy}^2\mathbf{a}_y=\tilde{\gamma}^2\mathbf{a}_y$ $\qquad \mathbf{\Omega}_{yy}^2=\mathbf{D}_{y'}^{E}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{x'}^{H}\mathbf{D}_{y'}^{H}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{x'}^{E}-\left(\mathbf{D}_{y'}^{E}\boldsymbol{\varepsilon}_{zz}^{-1}\mathbf{D}_{y'}^{H}+\boldsymbol{\mu}_{xx}\right)\left(\mathbf{D}_{x'}^{H}\boldsymbol{\mu}_{zz}^{-1}\mathbf{D}_{x'}^{E}+\boldsymbol{\varepsilon}_{yy}\right)$

Quasi-Vectorial Analysis (7 second run time @ λ/30 resolution)



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