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Advanced Computation:
Computational Electromagnetics

Alternative Grids

Outline

- Drawbacks of the Standard Yee Grid
- Alternative grids

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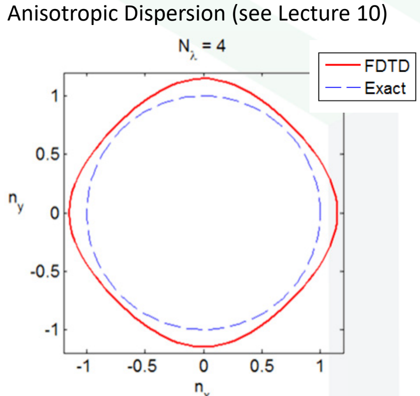
Slide 2

Drawbacks of the Standard Yee Grid

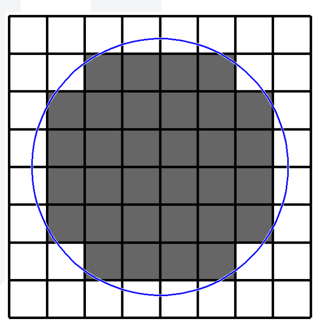
Drawbacks of Uniform Grids

Uniform grids are the easiest to implement, but do not conform well to arbitrary structures and exhibit high anisotropic dispersion.

Anisotropic Dispersion (see Lecture 10)

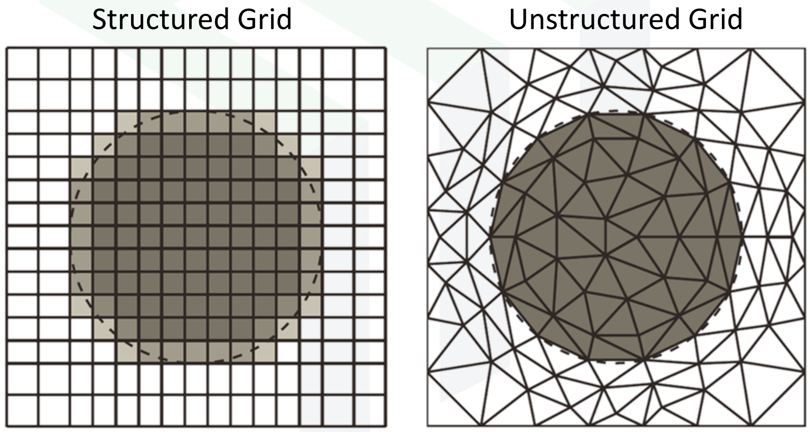


Staircase Approximation (see Lecture 18)



Drawbacks of Structured Grids

Structured grids are the easiest to implement, but do not conform well to arbitrary geometries.



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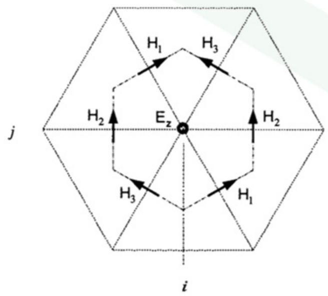
Alternative Grids

Slide 6

Hexagonal Grids

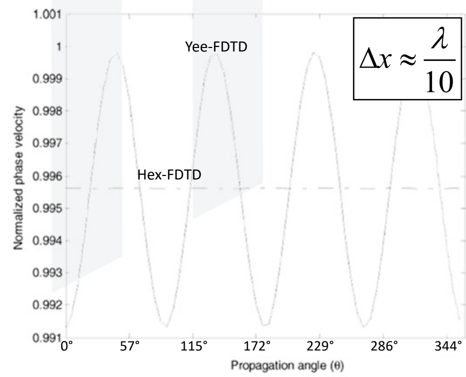
Hexagonal grids are good for minimizing anisotropic dispersion suffered on Cartesian grids. This is very useful when extracting phase information.



(b) Staggered, uncollocated grid and its associated dual grid

See Text, pp. 101-103.

Phase Velocity as a Function of Propagation Angle



$$\Delta x \approx \frac{\lambda}{10}$$

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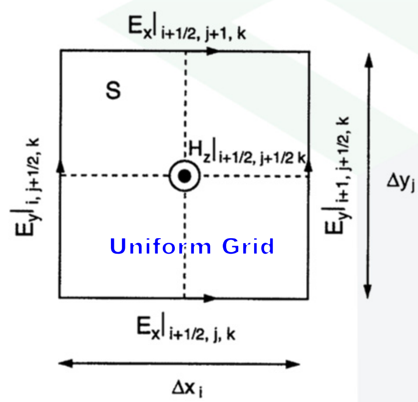
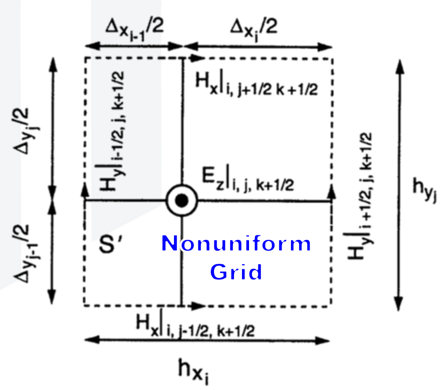
Nonuniform Orthogonal Grids (1 of 2)

Nonuniform orthogonal grids are still relatively simple to implement and provide some ability to refine the grid at localized regions.





See Text, pp. 464-471.

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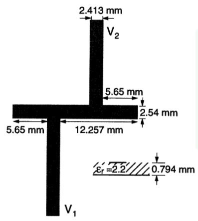
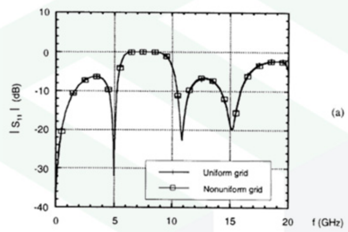
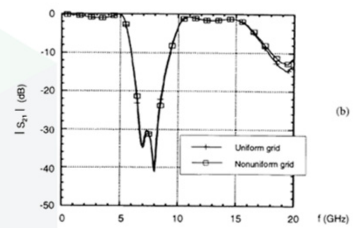
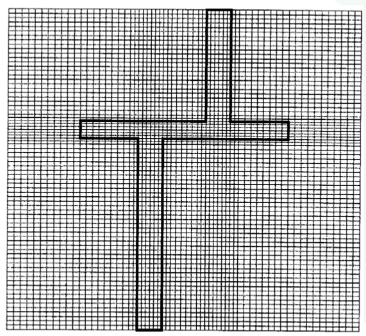
Nonuniform Orthogonal Grids (2 of 2)









Uniform Grid Simulation
- 80×110×16 cells
- 140,800 cells

Nonuniform Grid Simulation
- 64×76×16 cells
- 77,824 cells

Conclusion: Roughly 50% memory and time savings.

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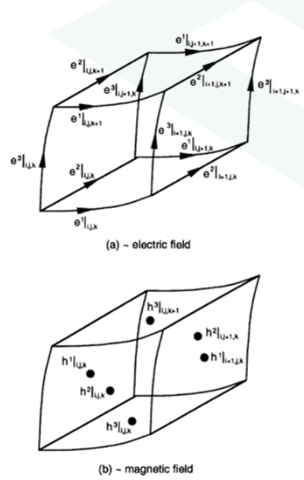
Curvilinear Coordinates

Maxwell's equations can be transformed from curvilinear coordinates to Cartesian coordinates to conform to curved boundaries of a device.



See Text, pp. 484-492.

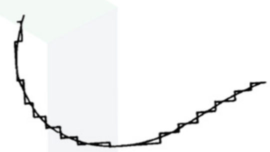


Fig. 2. Staircasing approximation to a curved boundary.

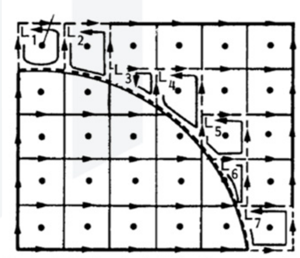


Fig. 3. Cell deformation in vicinity of a curved boundary.

M. Fusco, "FDTD Algorithm in Curvilinear Coordinates," IEEE Trans. Ant. and Prop., vol. 38, no. 1, pp. 76-89, 1990.

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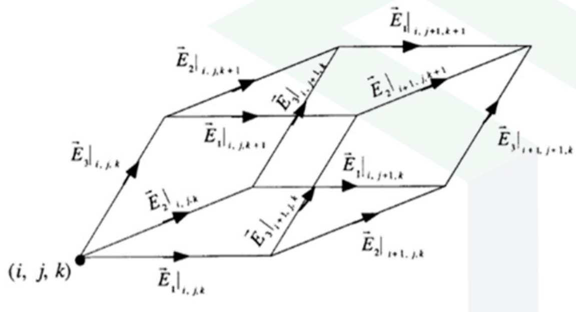
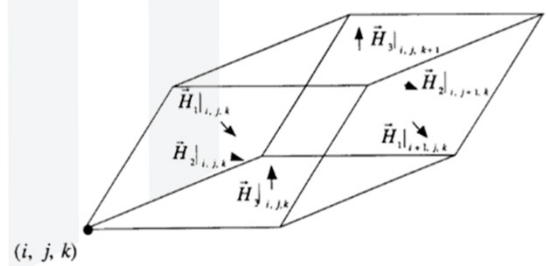
Structured Nonorthogonal Grids

This is a particularly powerful approach for simulating periodic structures with oblique symmetries.



(a) Covariant electric fields.



(b) Covariant magnetic fields.

M. Fusco, "FDTD Algorithm in Curvilinear Coordinates," IEEE Trans. Ant. and Prop., vol. 38, no. 1, pp. 76-89, 1990.

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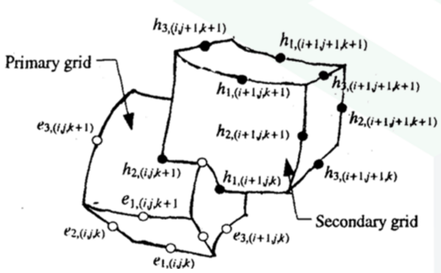
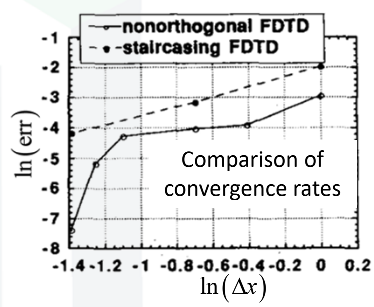
Irregular Nonorthogonal Unstructured Grids

Unstructured grids are more tedious to implement, but can conform to highly complex shapes while maintaining good cell aspect ratios and global uniformity.





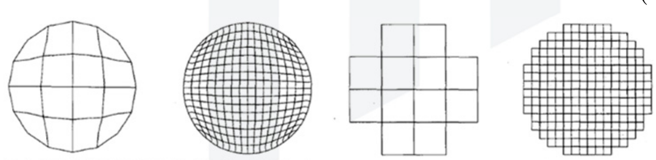


Fig. 2. Sparse and dense nonorthogonal grids for the cylindrical cavity.

Fig. 3. Sparse and dense staircase grids for the cylindrical cavity.

P. Harms, J. Lee, R. Mittra, "A Study of the Nonorthogonal FDTD Method Versus the Conventional FDTD Technique for Computing Resonant Frequencies of Cylindrical Cavities," IEEE Trans. Microwave Theory and Techniq., vol. 40, no. 4, pp. 741-746, 1992.

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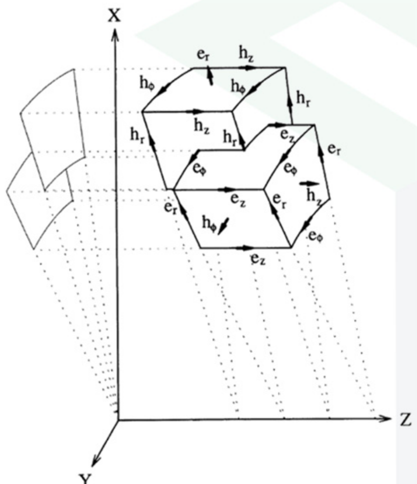
Bodies of Revolution (Cylindrical Symmetry)

Three-dimensional devices with cylindrical symmetry can be very efficiently modeled using cylindrical coordinates.



See Text, Chapter 12

Devices with cylindrical symmetry have fields that are periodic around their axis. Therefore, the fields can be expanded into a Fourier series in ϕ.

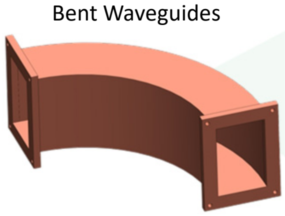
$$\vec{E}(\rho,\theta,\phi)=\sum_{m=0}^{\infty}\vec{e}_{\text{even}}(\rho,\theta)\cdot\cos(m\phi)+\vec{e}_{\text{odd}}(\rho,\theta)\cdot\sin(m\phi)$$

$$\vec{H}(\rho,\theta,\phi)=\sum_{m=0}^{\infty}\vec{h}_{\text{even}}(\rho,\theta)\cdot\cos(m\phi)+\vec{h}_{\text{odd}}(\rho,\theta)\cdot\sin(m\phi)$$

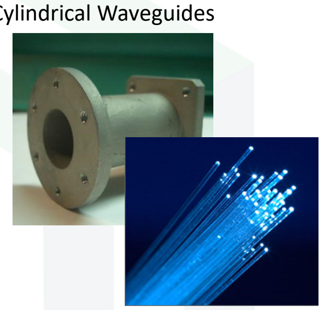
Due to a singularity at $r=0$, update equations for fields on the z axis are derived differently.

Some Devices with Cylindrical Symmetry

Bent Waveguides



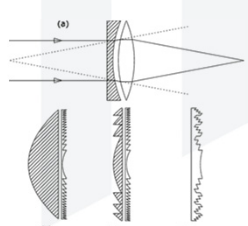
Cylindrical Waveguides



Dipole Antennas

Conical Horn Antenna

Diffractive Lenses



Focusing Antennas