Dielectrics

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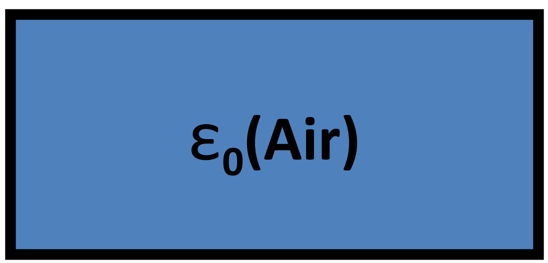
Historical Perspective

- 1910 : Hondros and Debye – Propagation of EM waves along cylindrical dielectric guides.
- 1930s : Waveguiding and attenuation characteristics were well established.
- 1940s : Investigations on finite length dielectric rod antennas
- 1950s : Development of dielectric guides for microwave and millimeter wave integrated circuits.
- 1960s: Dielectric and dielectric loaded antennas with desirable properties at microwave and millimeter wave frequencies.
- 1980s: Class of dielectric surface waveguides as H-guides for use in higher frequency range.

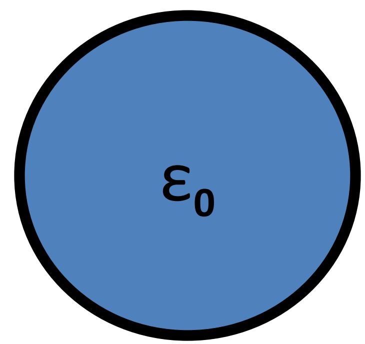
- mm wave frequencies : 30 to 300 GHz.
- 5 broad categories of waveguiding media:

1. Hollow metal waveguides.
2. Planar transmission lines.
3. Quasiplanar transmission lines.
4. Dielectric integrated guides.
5. H- and groove-guide structures.

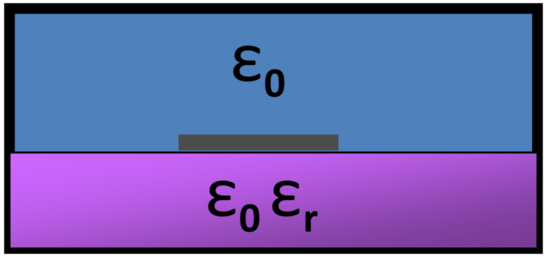
- TE_{10} mode rectangular waveguides – high power transmitting systems upto 100 Ghz
- TE_{01} mode circular waveguides – larger dimension, lower losses but not a dominant mode, not practical for realizing mm wave components



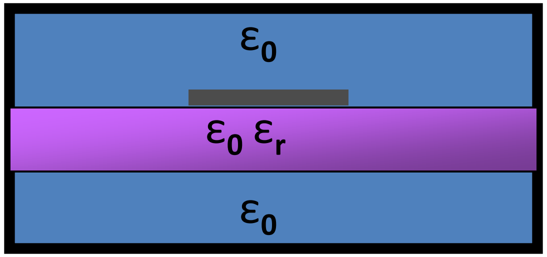
(a) Rectangular waveguide



(b) Circular waveguide

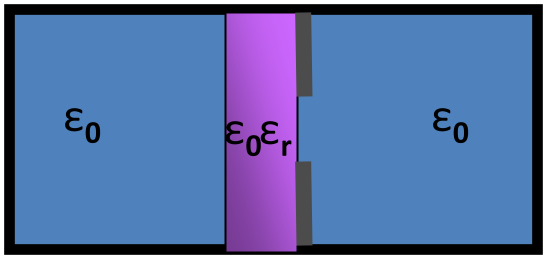


(c) Microstrip

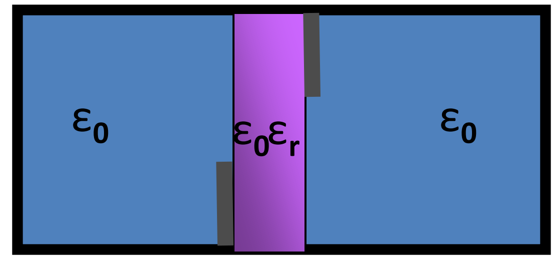


(d) Suspended stripline

- **Low & medium power applications – MIC technology**
- **µstripline, slotline, suspended stripline, inverted µstripline, coplanar line.**
- **Simple geometry, easy incorporation of active devices.**
- **mmwave applications require thinner substrates & lower dielectric constants.**
- **Freq. upto 100 to 140 GHz with careful fabrication.**



(e) Unilateral Fin line



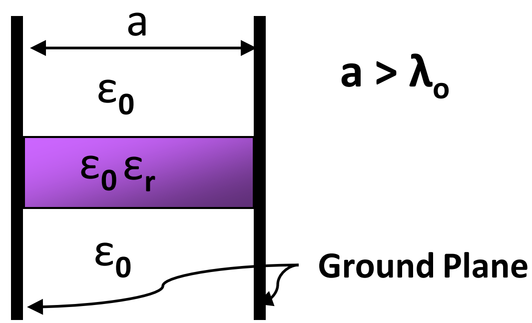
(f) Antipodal Fin line

- **Low loss & good integration in 30 to 120 GHz.**
- **Quasi-planar tx. line, formed by mounting dielectric substrate with printed fins on it in the E-plane of a standard rectangular waveguide.**
- **Eliminates need to maintain tight dimensional tolerances on inner walls.**
- **Planar technology and easy mounting of active devices.**

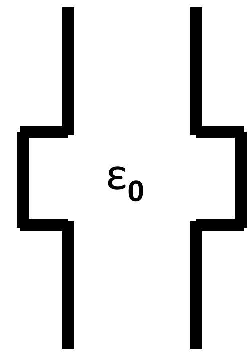
(g) Image guide

(h) Nonradiative guide

- **Previous 3 classes of tx. lines suffer from conductor loss.**
- **Dielectric guides backed by ground planes – suited for Integrated circuit applications.**
- **Image Guide – dielectric strip in intimate contact with a ground plane.**
- **Nonradiative Guide – undesirable radiation at bends & other discontinuities suppressed.**
- **Freq. 30 to 120 GHz, low loss, light weight.**



(i) H- guide

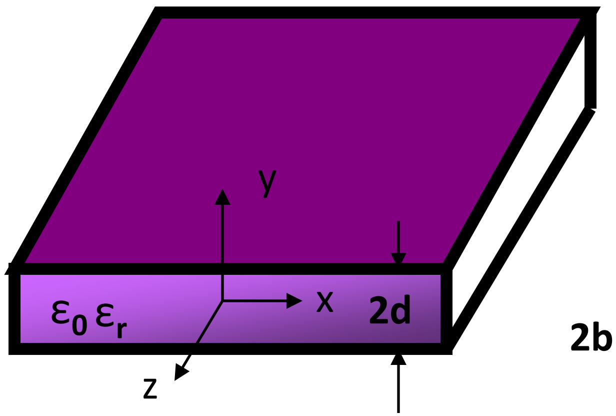


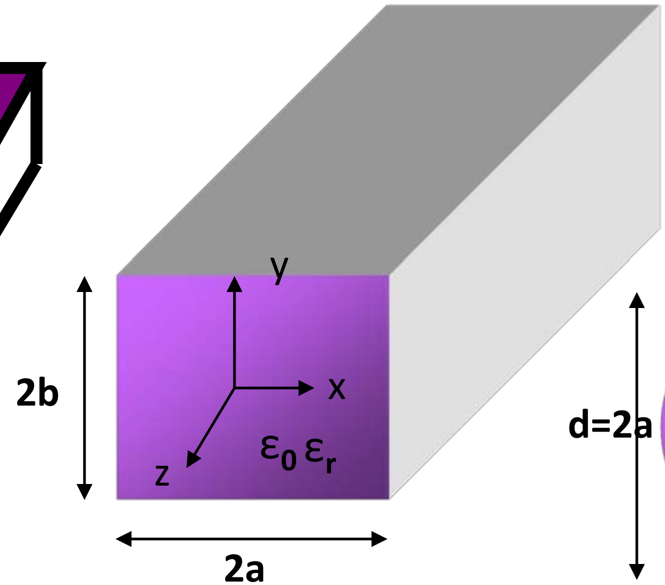
(j) Groove guide

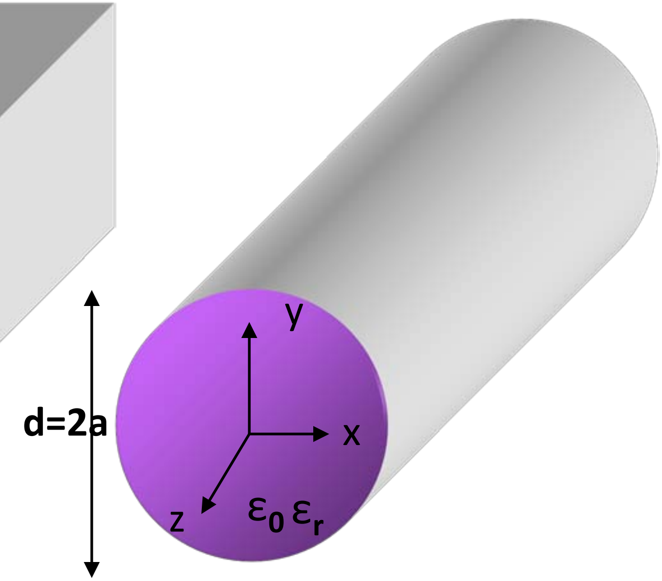
- Class of surface wave guiding structures.
- Basic H – guide resembles that of the nonradiative guide except that 'a' greater than a wavelength.
- It makes use of surface wave guidance at the dielectric interface in one transverse direction and field confinement by parallel plates in the other.
- Supports a hybrid mode, both E and H having a component in the direction of propagation.
- No longitudinal current flow on the metal walls.
- Low propagation loss.
- Freq. 100 to 200 GHz.

- **Operation of H – guides beyond 200GHz limited due to multimode propagation.**
- **Overcome in the groove guide**
- **Groove region creates a surface wave effect and supports a slow wave effect and supports slow wave propagation.**
- **Freq. 100 to 300 GHz**
- **Single mode operation with low propagation loss.**

A broad comparison of the different categories of tx. Lines for mm wave integrated circuit applications has been provided above in order to indicate the relative utility of the dielectric integrated guides with reference to other guides.



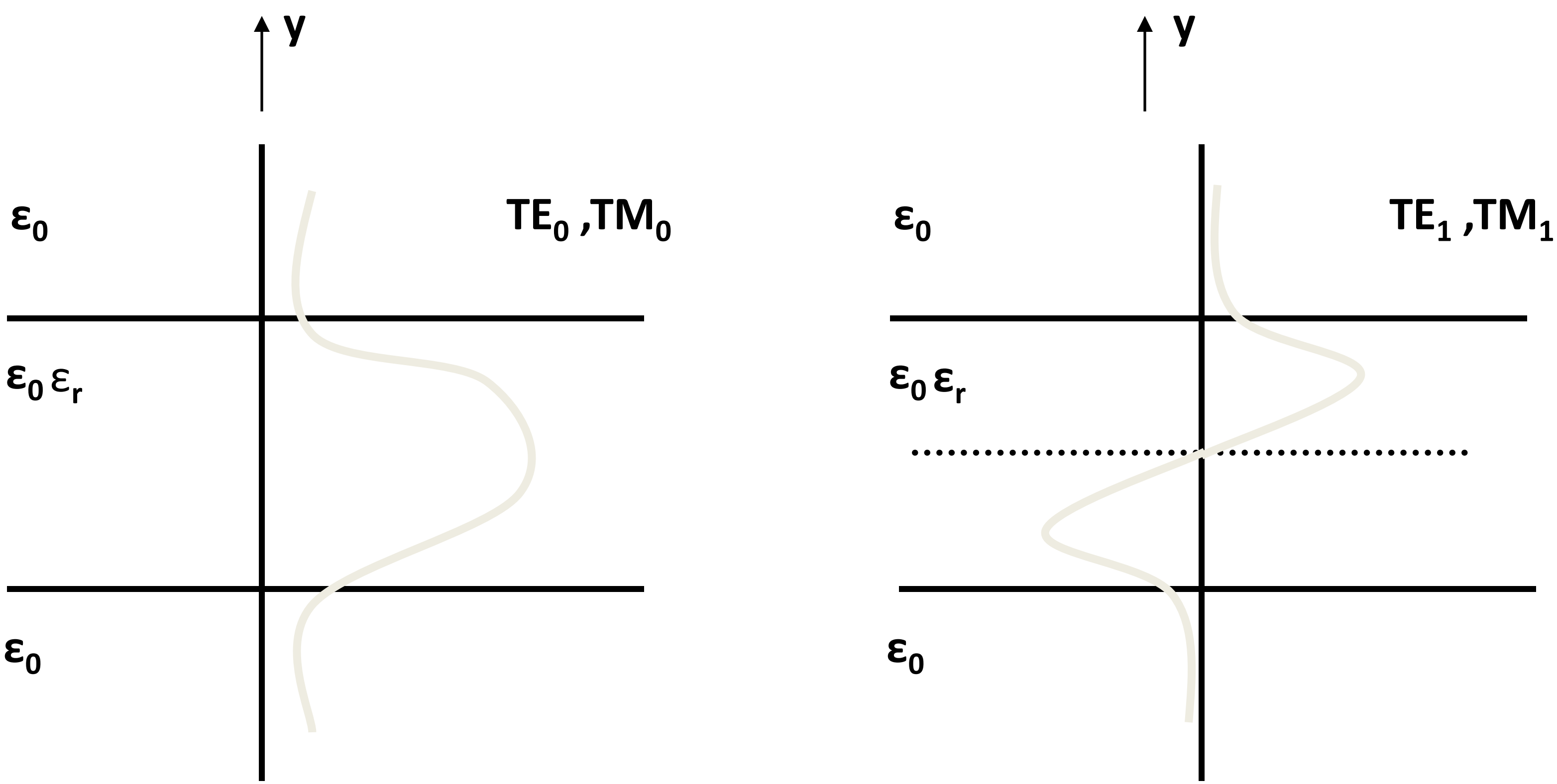




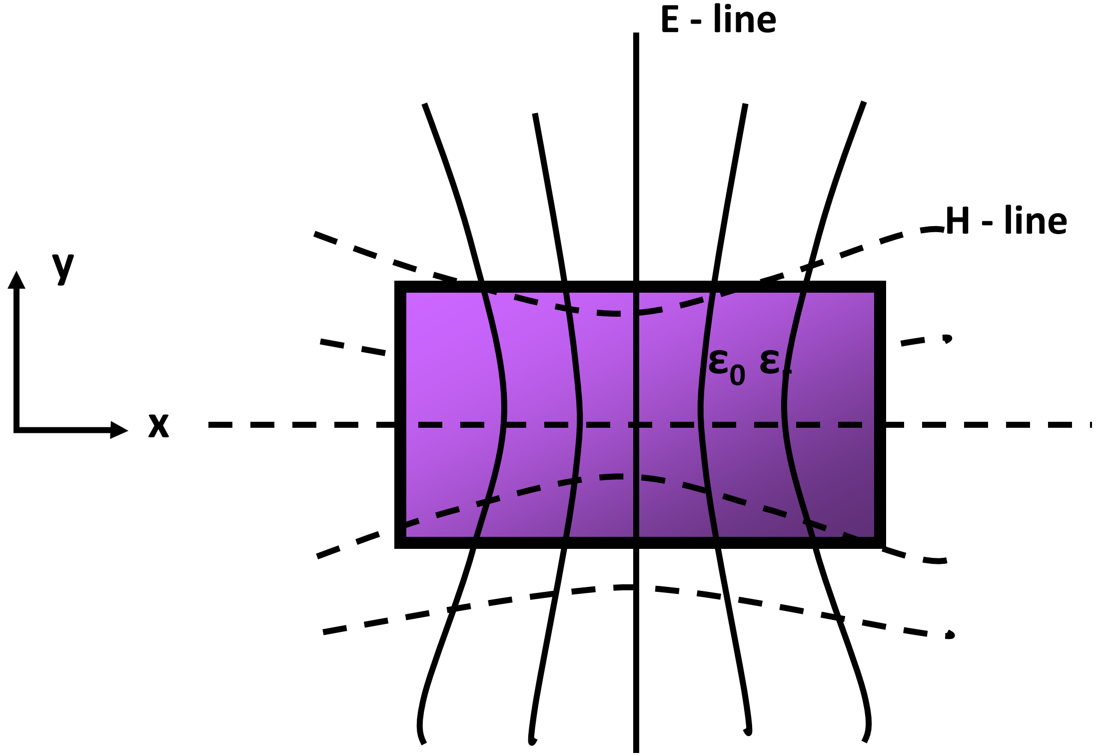
Slab dielectric guide

Rectangular dielectric guide

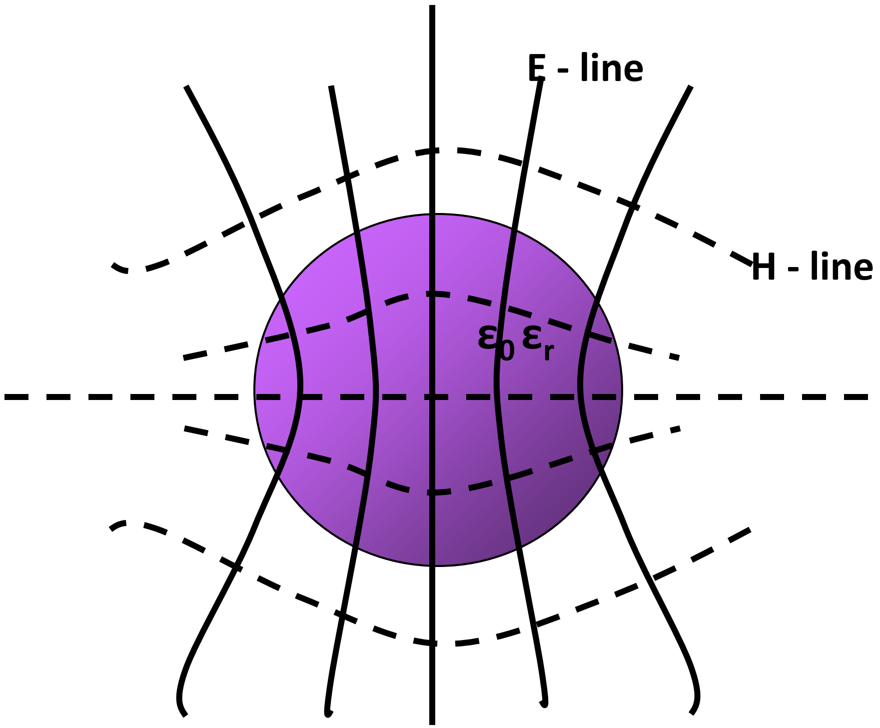
Circular dielectric guide



Transverse distribution of E_x component for TE modes and H_x component for TM modes in a slab dielectric guide.



E^{y}_{11} mode field distribution in rectangular dielectric guide



Dominant HE_{11} mode field distribution in cylindrical dielectric guide

- **Typical mm wave dielectric materials:**
  - Ceramic dielectrics
  - Polymer dielectrics
  - Castable dielectrics
  - Dielectric Pastes for Thick-Film Process
  - Semiconductor Dielectrics
  - Various Ferrites

- Most widely used guide structures in component development are image guides.
- Best potential at freq above 60GHz
- Use of dielectric H-guide and groove-guide structures at for freq. beyond 100GHz.
- Realizing high-performance antennas.
- Feed structures for array antennas.
- Incorporation of active devices in dielectric guides is more difficult than in suspended striplines or fin lines
- Realizing dynamically controlled devices such as switches, phase shifters and attentuators.