UE22EC351B

TRANSMISSION LINES, WAVEGUIDES, AND ANTENNAS

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UNIT 2: Waveguides, cavities, and radiation from point source

Introduction: Waveguide propagation

- **1893:** Oliver Heaviside proposed wave propagation in a hollow tube, but he rejected his idea.

- **1897:** Lord Rayleigh mathematically proved waveguide propagation and modes (TE & TM) but had no experimental proof.

- **1932-1936:** Independently rediscovered; experiments by George C. Southworth (AT&T) and W. L. Barrow (MIT) confirmed waveguide propagation.

- **Impact:** Enabled low-loss high-frequency power transmission, revolutionizing microwave engineering.

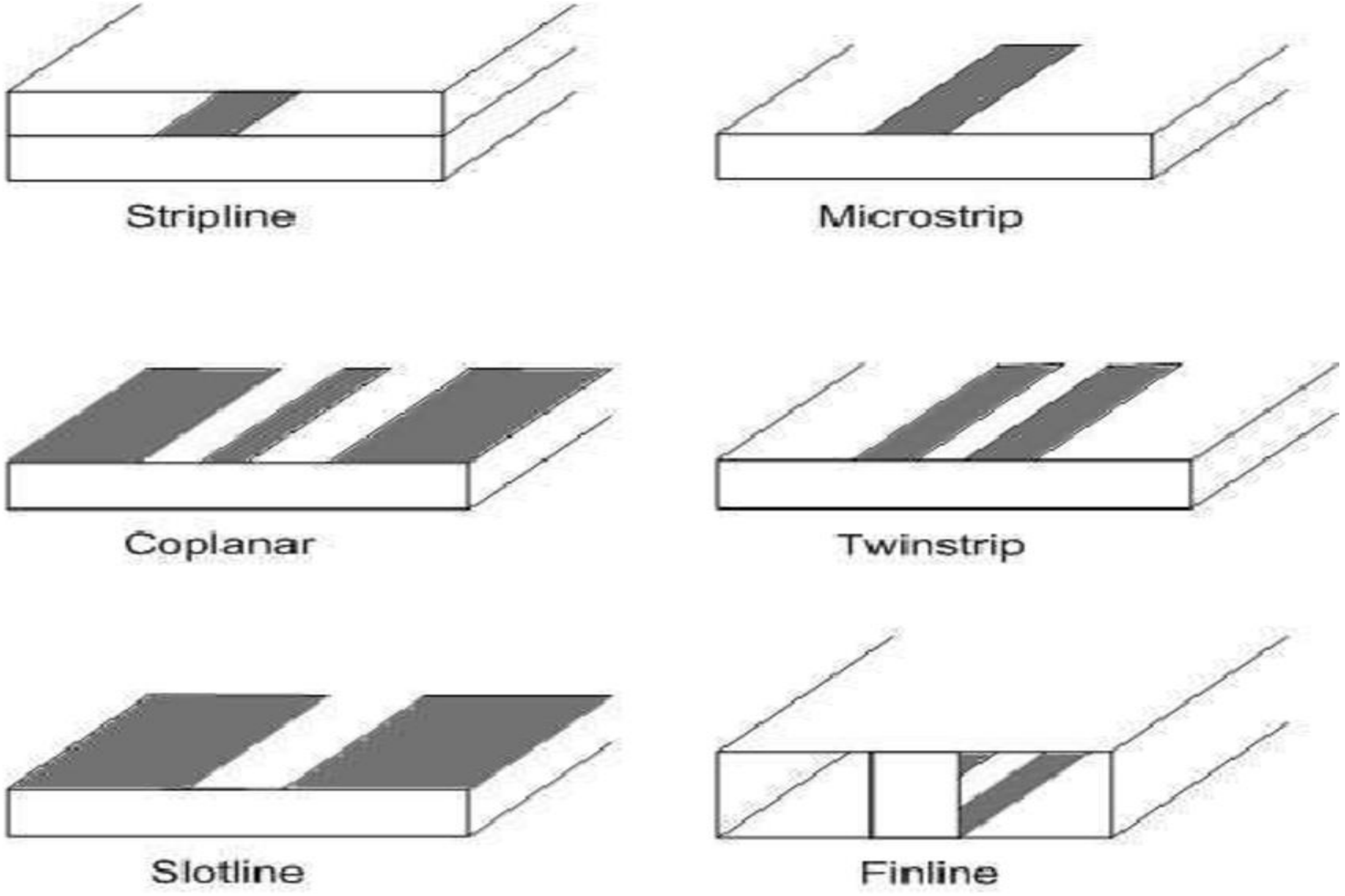
Introduction: Waveguide propagation

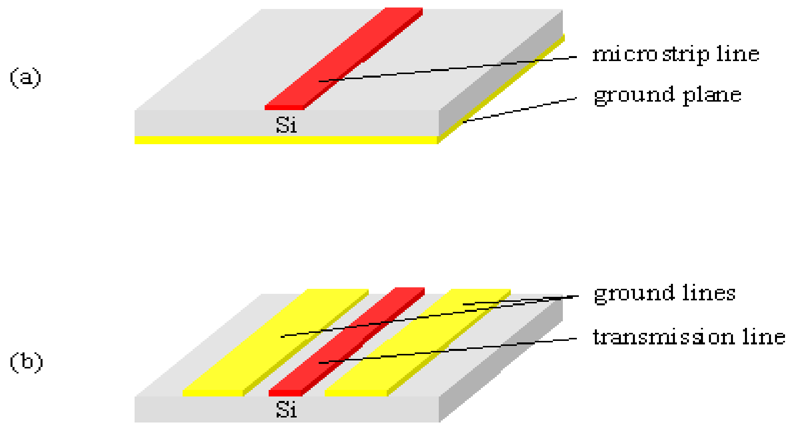
- **Early Systems:** Used waveguides, two-wire lines, and coaxial lines.
- **Waveguides**: High power handling, low loss, but bulky & expensive.
- **Two-Wire Lines:** Cheap but unshielded.
- **Coaxial Lines:** Shielded but hard to integrate.
- **Planar Transmission Lines:** Compact, low-cost, and integrate well with circuits (e.g., stripline, microstrip, slotline).

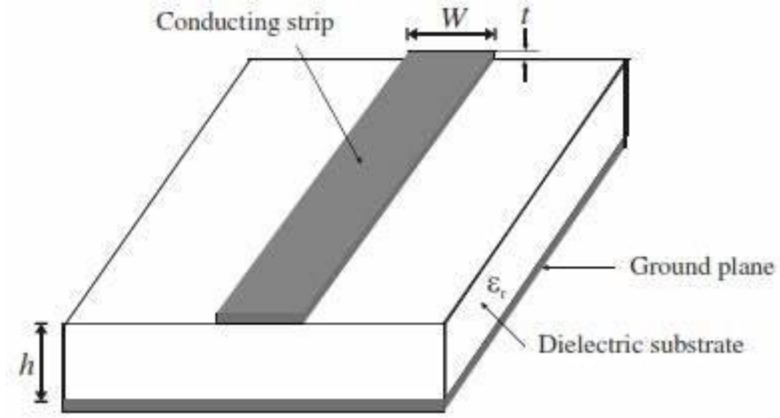
Key Developments:

- **WWII:** Early planar lines (flat-strip coaxial).
- **1950s:** Intensive research on planar lines.
- **1960s:** Thin-substrate microstrip lines improved performance, becoming a preferred choice.
- **Impact:** Enabled microwave integrated circuits, advancing RF technology.

Planar Transmission Lines:







Introduction: Waveguide propagation

- The different types of wave propagation and modes that can exist on general transmission lines and waveguides will be discussed in this unit.

- Transmission lines that consist of two or more conductors may support transverse electromagnetic (TEM) waves, characterized by the lack of longitudinal field components.

- Such lines have a uniquely defined voltage, current, and characteristic impedance.

- Waveguides, often consisting of a single conductor, support transverse electric (TE) and/or transverse magnetic (TM) waves, characterized by the presence of longitudinal magnetic or electric field components.

Introduction: Waveguide propagation

Why Waveguides?

At high frequencies, waveguides are preferred over transmission lines because:

1. **Lower Losses** – Transmission lines (coaxial cables) suffer from high resistive and dielectric losses at high frequencies, whereas waveguides minimize these losses.
2. **Higher Power Handling** – Waveguides can carry more power without breakdown or excessive heating.
3. **Reduced Dispersion** – Waveguides support specific propagation modes, reducing signal distortion over long distances.
4. **No Radiation Losses** – Unlike transmission lines, waveguides confine energy within their structure, preventing radiation losses.

This makes waveguides ideal for applications like microwave communication, radar, and satellite systems.

Introduction: Waveguide propagation

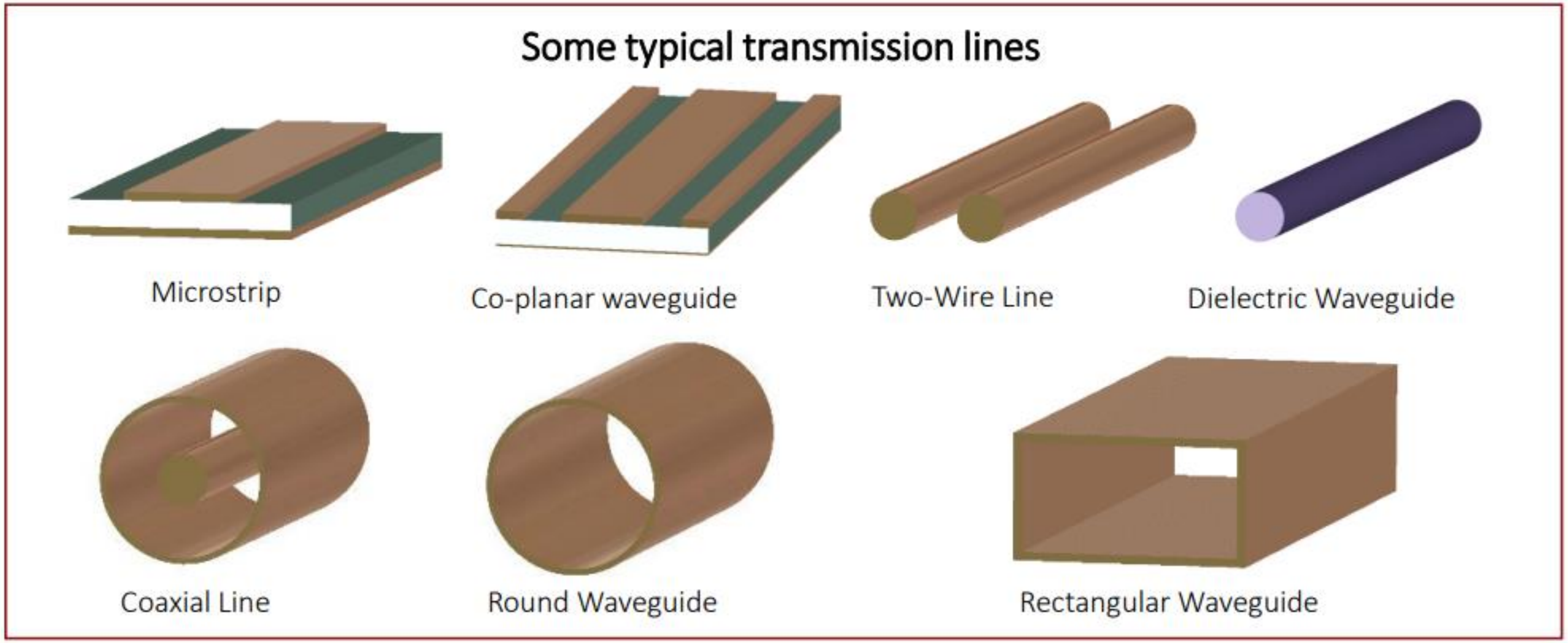
- Transmission lines and waveguides are utilized to transfer electromagnetic waves carrying energy and information from a source to a receiver

- For an efficient transport one likes to guide the energy inside a line instead of spreading it out in space

- Choice of the line technology depends on the purpose, e.g. operating frequency range, the transmitted power level, and what power losses one can tolerate

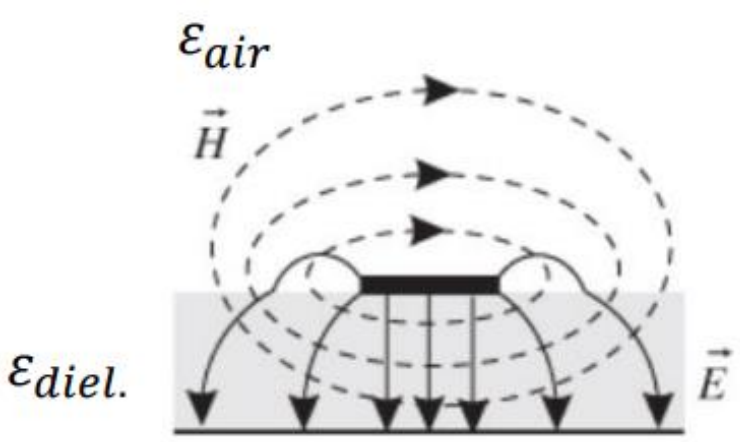
Introduction: Waveguide propagation

Some typical transmission lines are shown in this figure



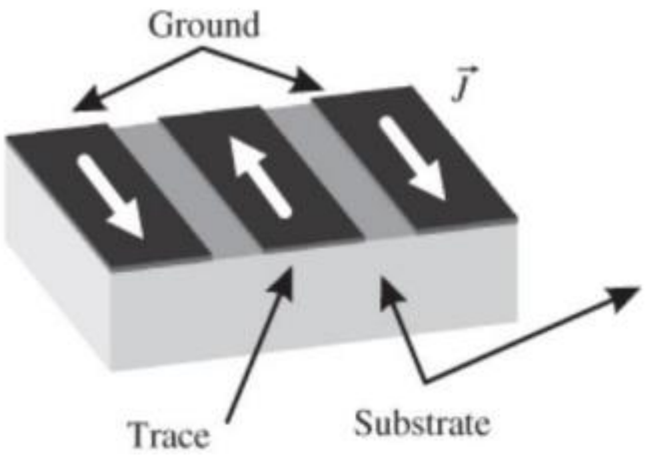
Microstrip lines

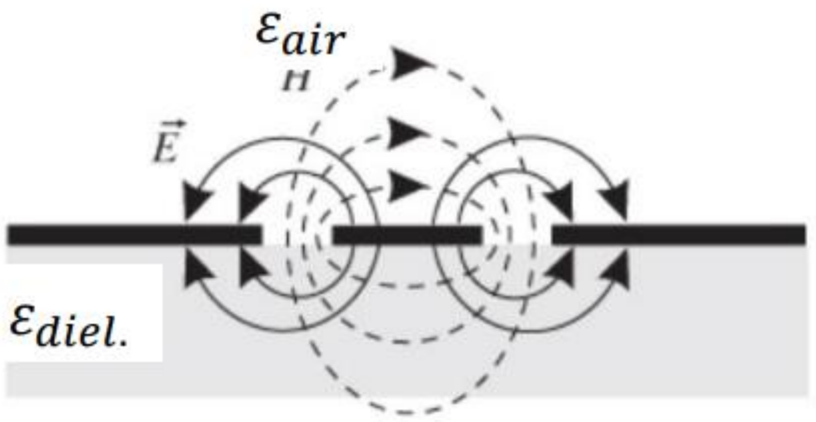
- Microstrip lines are types of planar transmission lines widely used in printed circuit boards (PCBs)
- Made by a strip conductor, dielectric substrate, and a groun d plate
- Used in the microwave range with typical maximum frequency of 110 GHz
- Comparably lossy
- Not shielded, may radiate parasitically and is vulnerable to cross-talk



Coplanar waveguides (CPWs)

- are similar to microstrip lines and also used for PCBs
- Invented later than microstrips (1969 versus 1952)
- Easier to fabricate since having the return and main conductors in the same plane
- May or may not be grounded at the bottom
- Also operate in a quasi-TEM mode at a typical maximum frequency of 110 GHz.





Introduction: Waveguide propagation

Optical Fibers

- Dielectric waveguides can be optical fibers that have a circular cross-section
- Consist of a dielectric material surrounded by another dielectric material
- Allows transmitting optical and infrared signals with small losses (~0.2 dB per 1 km)
- Power transmitted is in the mW range.

Coaxial cables are widely used in laboratories and carry signals in the TEM mode.

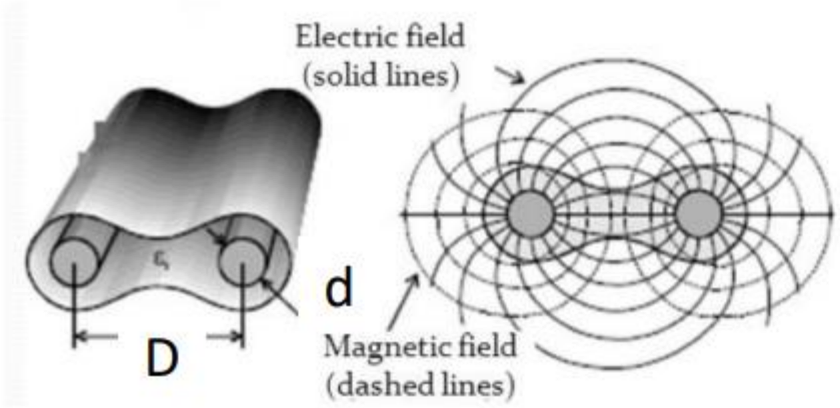
- At higher frequencies, the dimensions of the cables should be however limited as higher order modes (with a cutoff) can propagates
- This in turn limits the power capability
- Coaxial cables are typically utilized below 3 GHz

with attenuation losses of a few dB/100m in the UHF range (around 100 MHz)

Introduction: Waveguide propagation

Two-wire (twin-lead) lines are used for telecommunication to transport RF wave

- Used e.g. for antenna lines to TV
- Separation of the wire is small compared to the wavelength (at 30 MHz wavelength is 100 m)
- Wave is transported in a TEM mode
- May offer smaller losses in the VHF band than miniature coaxial cables, e.g. 0.55 dB/100m versus 6.6 dB/100m for RG-58 • However, more vulnerable to interference even if shielded.



$$\boxed{Z \approx 276\,\Omega\, Log\left(\frac{2D}{d}\right)}$$

For D >> d

Source: Electromagnetic Waves and Applications Part III, Y. MA

Introduction: Waveguide propagation

- The geometry of an arbitrary transmission line or waveguide is shown in Figure 3.1 and is characterized by conductor boundaries that are parallel to the z-axis.

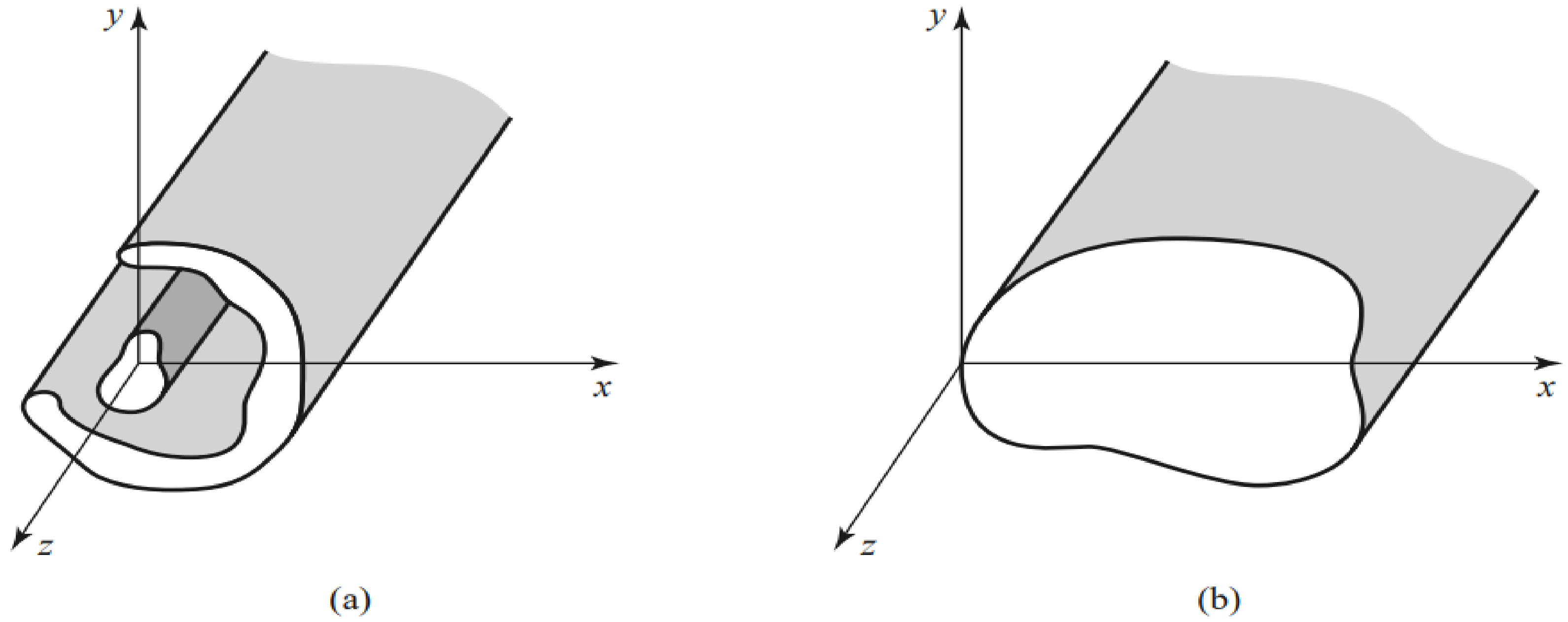


FIGURE 3.1 (a) General two-conductor transmission line and (b) closed waveguide.

- These structures are assumed to be uniform in shape and dimension in the z direction and infinitely long.
- The conductors will initially be assumed to be perfectly conducting.

THANK YOU

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