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ECE Dept.
MW&A
V IISem
2018-19

Department of Electronics & Communication Engg.

Course : Microwave and Antennas -15EC71. **Sem.: 7th (2018-19)**

Course Coordinator:

Prof. M M Gadag

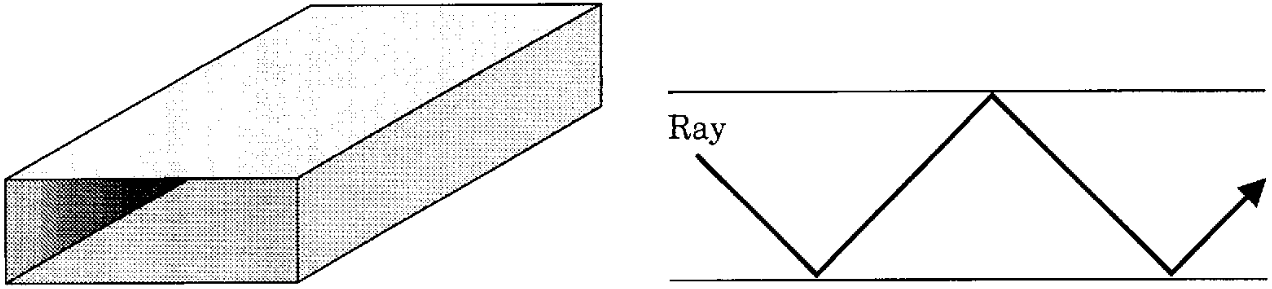
Introduction

- Microwaves have frequencies > 1 GHz approx.
- Stray reactances are more important as frequency increases
- Transmission line techniques must be applied to short conductors like circuit board traces
- Device capacitance and transit time are important
- Cable losses increase: waveguides often used instead

Waveguides

- Pipe through which waves propagate
- Can have various cross sections
  - Rectangular
  - Circular
  - Elliptical
- Can be rigid or flexible
- Waveguides have very low loss

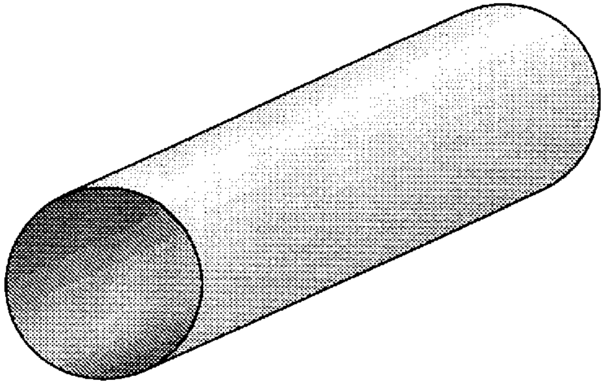
Waveguides



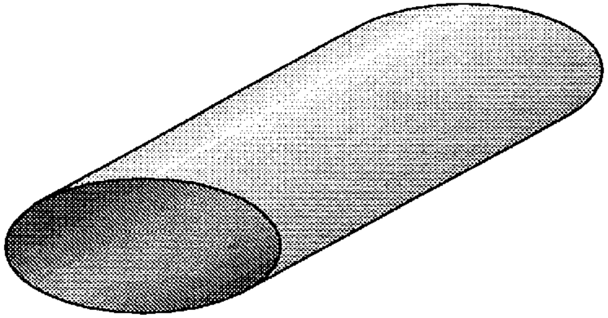
Structure

Propagation

(a) Rectangular Waveguide



(b) Circular Waveguide



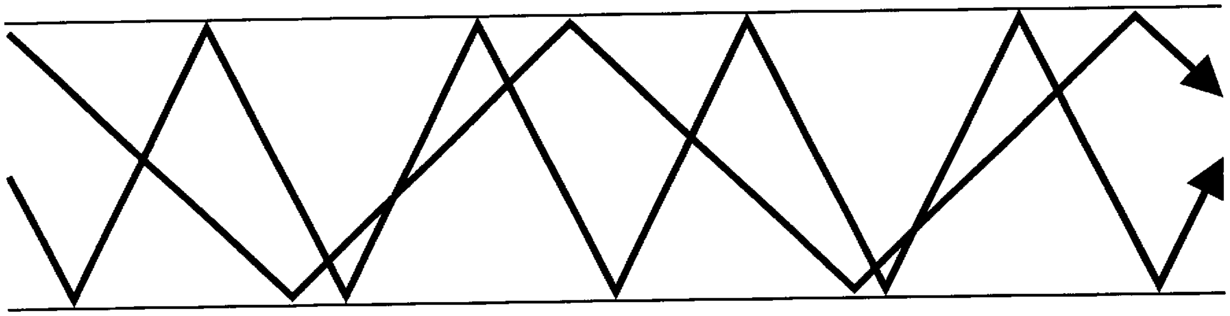
(c) Elliptical Waveguide

Transparency 250 (Figure 19.1)

Modes

- Waves can propagate in various ways
- Time taken to move down the guide varies with the mode
- Each mode has a cutoff frequency below which it won’t propagate
- Mode with lowest cutoff frequency is **dominant mode**

Multimode Propagation



——— Low-Order Mode: Faster Propagation

——— High-Order Mode: Slower Propagation

Transparency 251 (Figure 19.2)

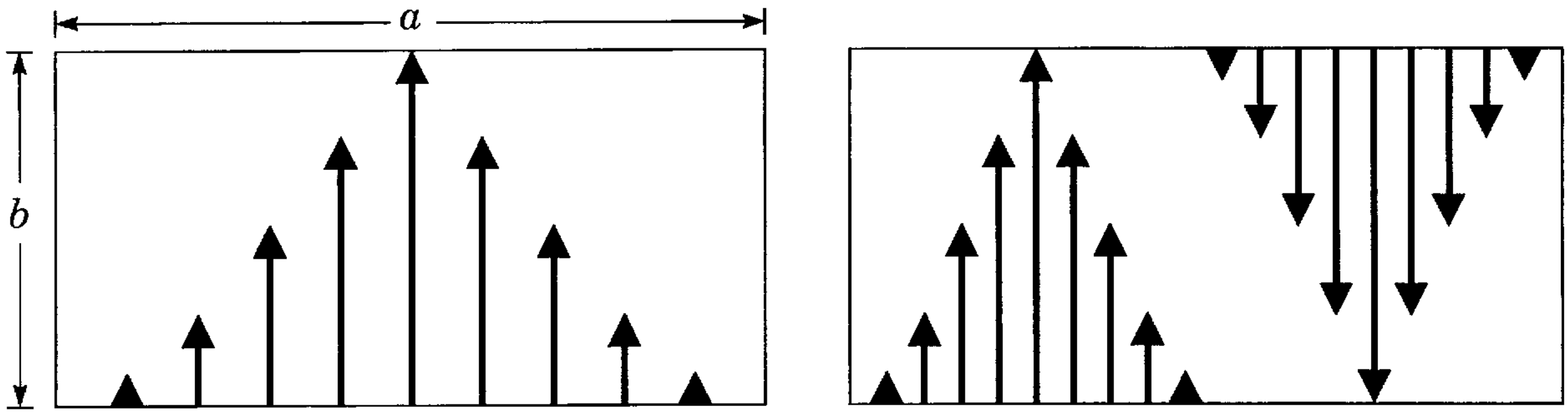
Mode Designations

- TE: transverse electric
  - Electric field is at right angles to direction of travel
- TM: transverse magnetic
  - Magnetic field is at right angles to direction of travel
- TEM: transverse electromagnetic
  - Waves in free space are TEM

Rectangular Waveguides

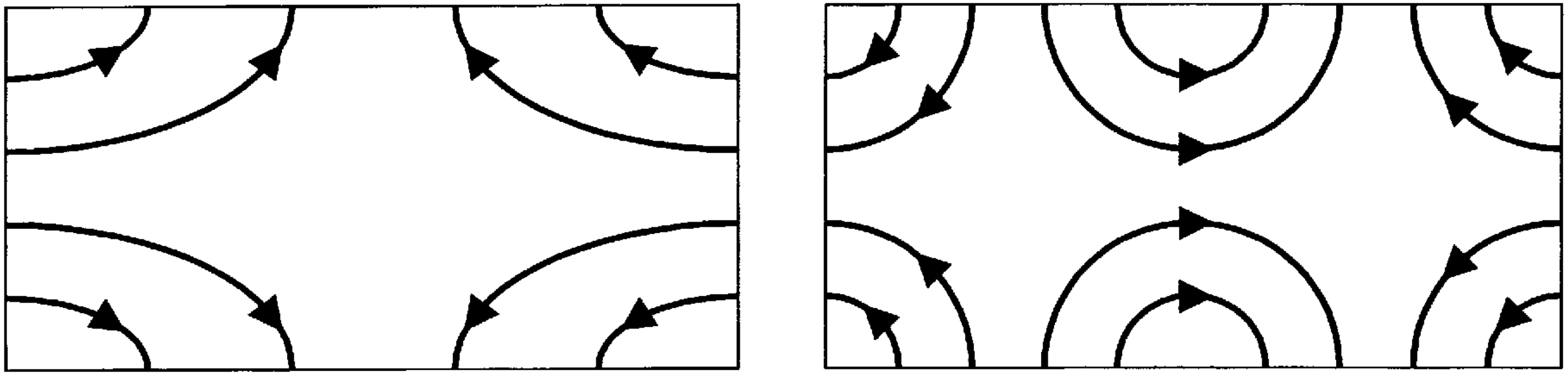
- Dominant mode is TE_{10}
  - 1 half cycle along long dimension (a)
  - No half cycles along short dimension (b)
  - Cutoff for *a* = $\lambda c/2$
- Modes with next higher cutoff frequency are TE_{01} and TE_{20}
  - Both have cutoff frequency twice that for TE_{10}

TE Modes in Rectangular Waveguide



(a) TE_{10}

(b) TE_{20}



(c) TE_{11}

(d) TE_{21}

Transparency 252 (Figure 19.3)

Cutoff Frequency

- For TE_{10} mmode in rectangular waveguide with $a = 2b$

Usable Frequency Range

- Single mode propagation is highly desirable to reduce dispersion
- This occurs between cutoff frequency for TE_{10} mode and twice that frequency
- It’s not good to use guide at the extremes of this range

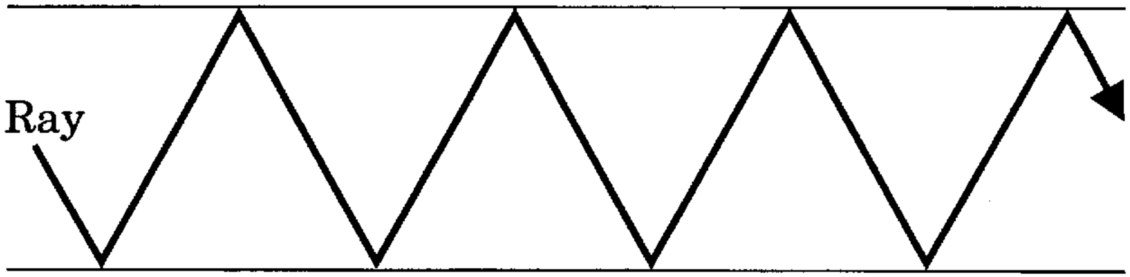
Example Waveguide

- RG-52/U
- Internal dimensions 22.9 by 10.2 mm
- Cutoff at 6.56 GHz
- Use from 8.2-12.5 GHz

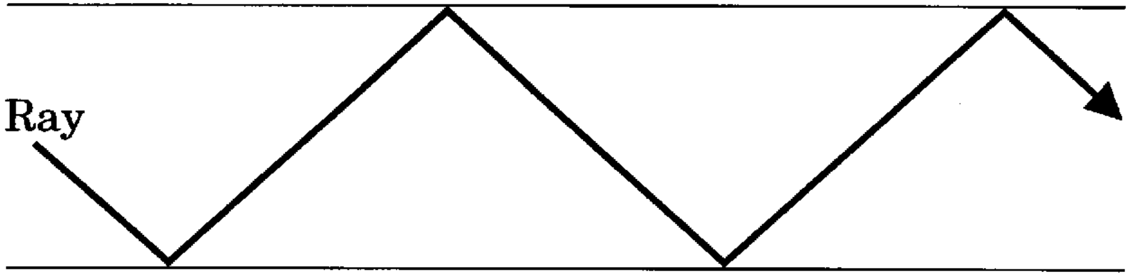
Group Velocity

- Waves propagate at speed of light *c* in guide
- Waves don’t travel straight down guide
- Speed at which signal moves down guide is the group velocity and is always less than *c*

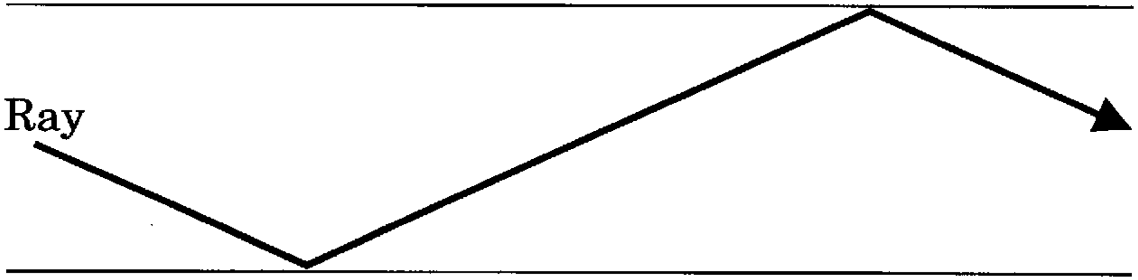
Variation of Group Velocity with Frequency



(a) Frequency Just Above Cutoff



(b) Higher Frequency

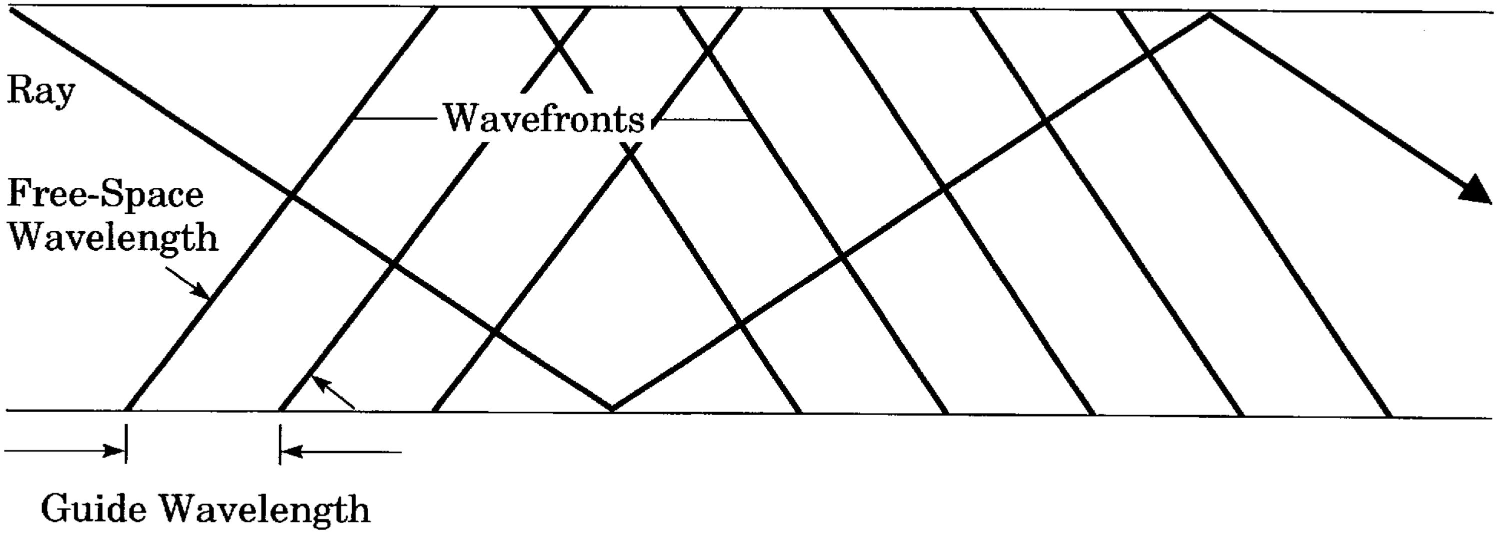


(c) Still Higher Frequency

Phase Velocity

- Not a real velocity (>*c*)
- Apparent velocity of wave along wall
- Used for calculating wavelength in guide
  - For impedance matching etc.

Variation of Phase Angle along a Waveguide



Transparency 254 (Figure 19.7)

Characteristic Impedance

- Z_0 varies with frequency

$$Z_0 = \frac{377}{\sqrt{1 - \left(\frac{f_c}{f} \right)^2}} \Omega$$

Guide Wavelength

- Longer than free-space wavelength at same frequency

$$\lambda_g = \frac{\lambda}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

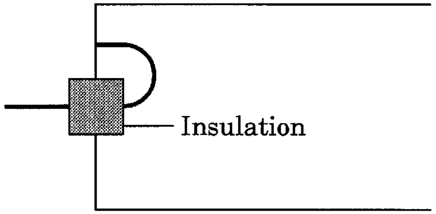
Impedance Matching

- Same techniques as for coax can be used
- Tuning screw can add capacitance or inductance

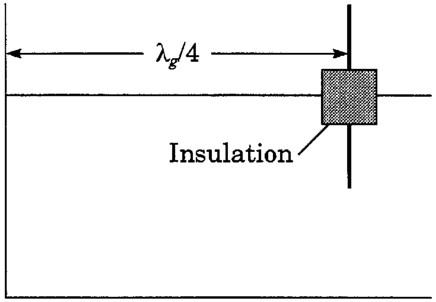
Coupling Power to Guides

- 3 common methods
  - Probe: at an E-field maximum
  - Loop: at an H-field maximum
  - Hole: at an E-field maximum

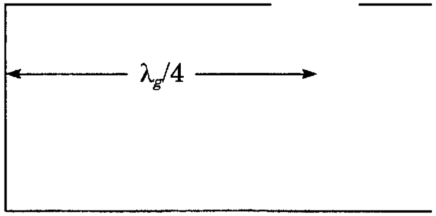
Coupling Power to a Waveguide



(a) Probe



(b) Loop



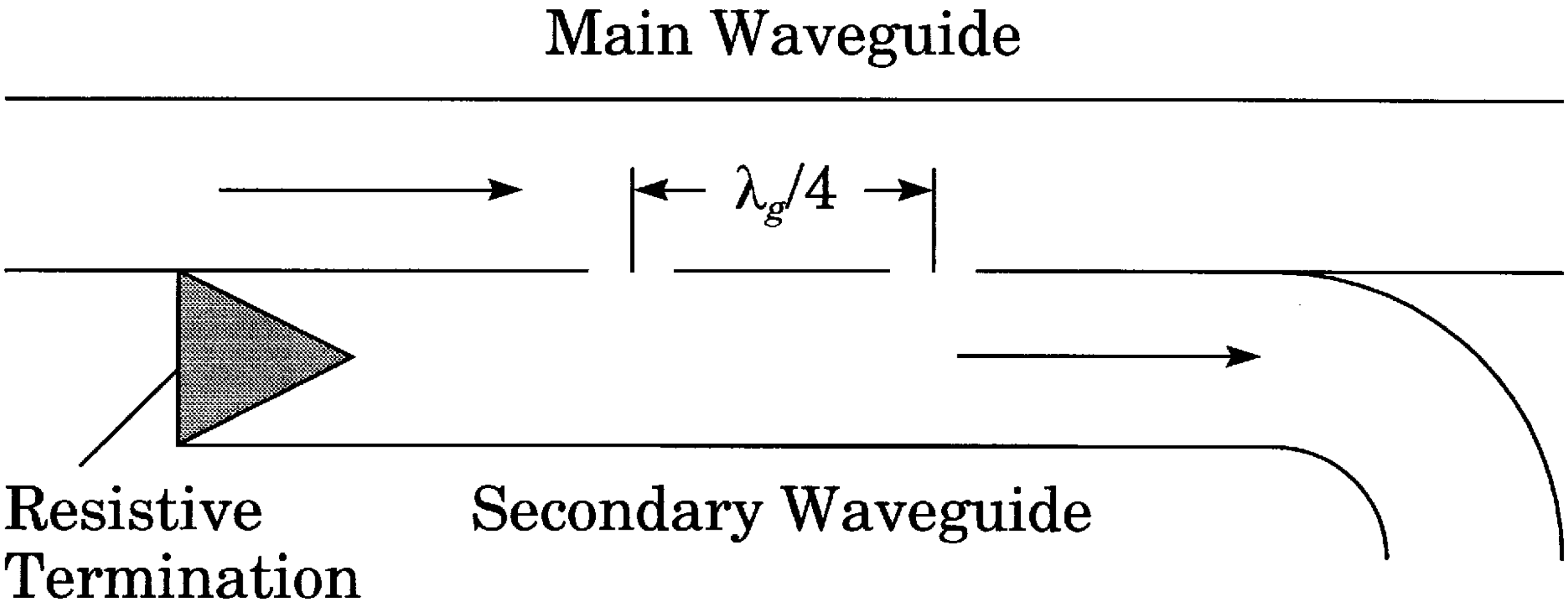
(c) Hole

Transparency 255 (Figure 19.10)

Directional Coupler

- Launches or receives power in only 1 direction
- Used to split some of power into a second guide
- Can use probes or holes

Two-Hole Directional Coupler

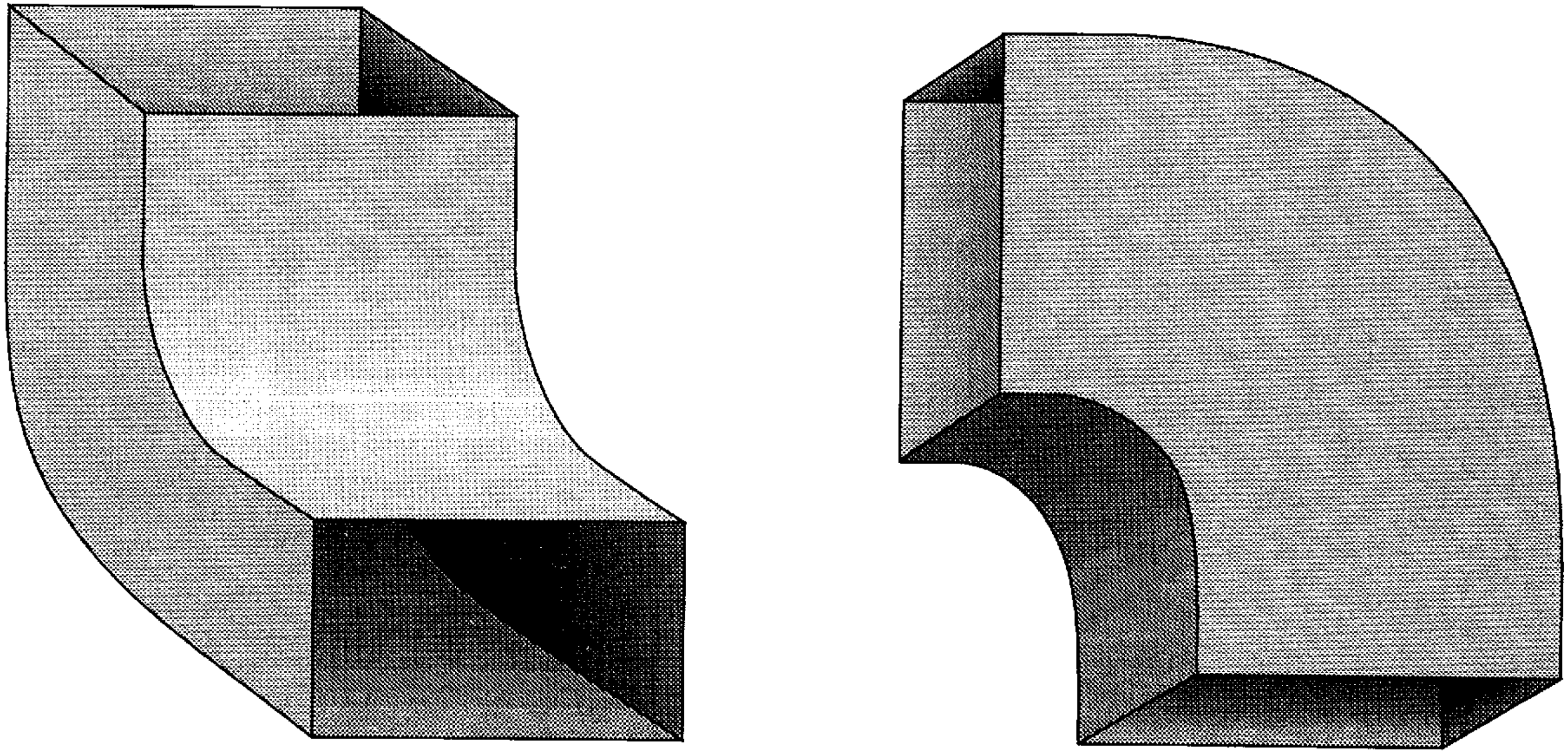


Transparency 256 (Figure 19.12)

Passive Components

- Bends
  - Called E-plane or H-Plane bends depending on the direction of bending
- Tees
  - Also have E and H-plane varieties
  - Hybrid or magic tee combines both and can be used for isolation

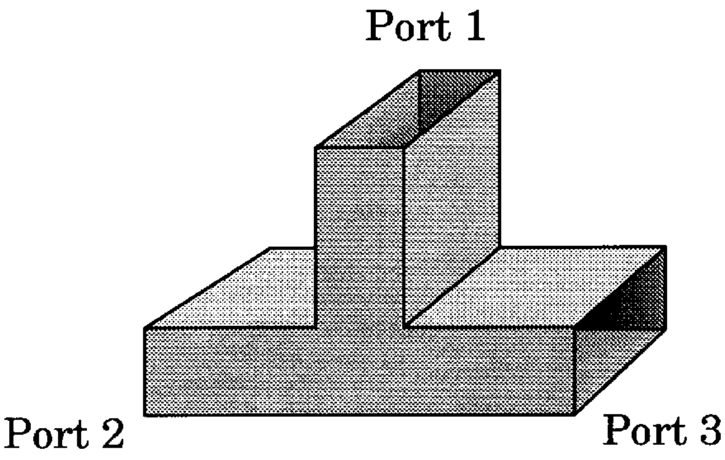
Waveguide Bends



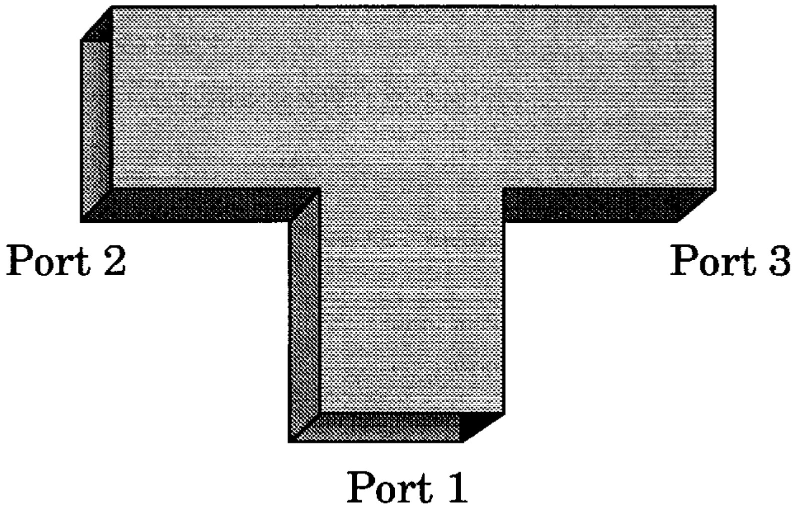
(a) E–Plane Bend

(b) H–Plane Bend

Waveguide Tees



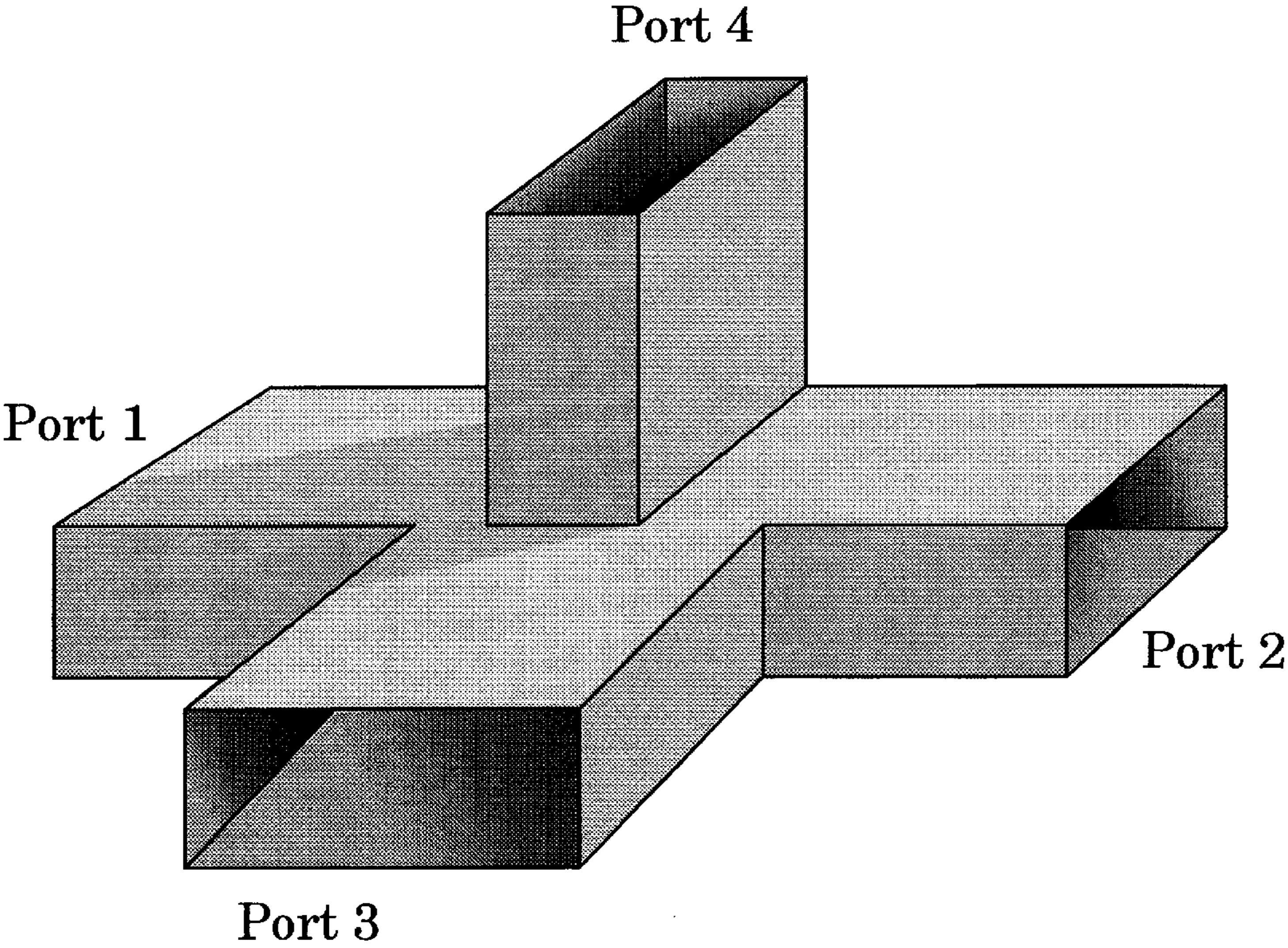
(a) E–Plane Tee



(b) H–Plane Tee

Transparency 259 (Figure 19.17)

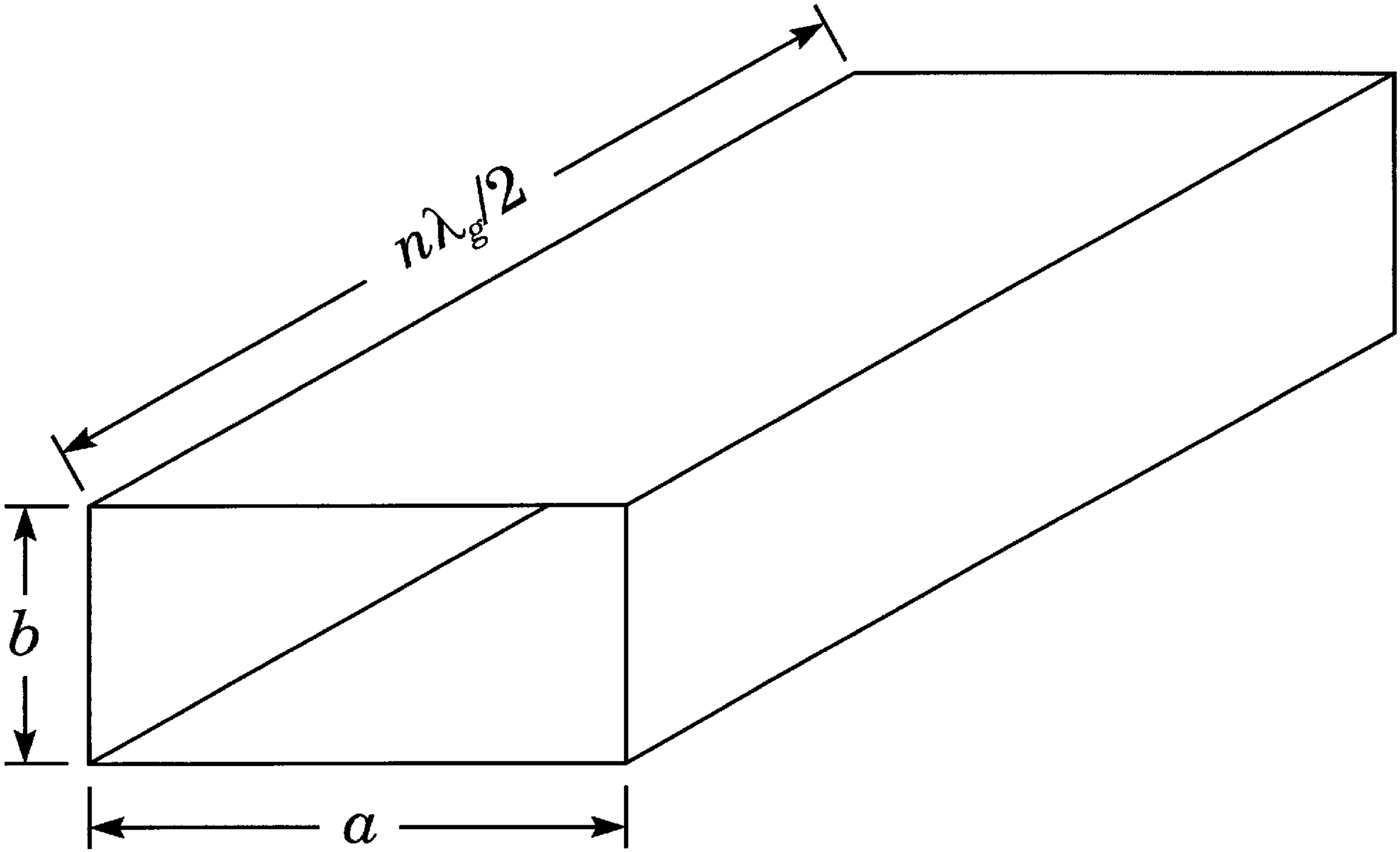
Hybrid Tee



Resonant Cavity

- Use instead of a tuned circuit
- Very high Q

Rectangular Cavity

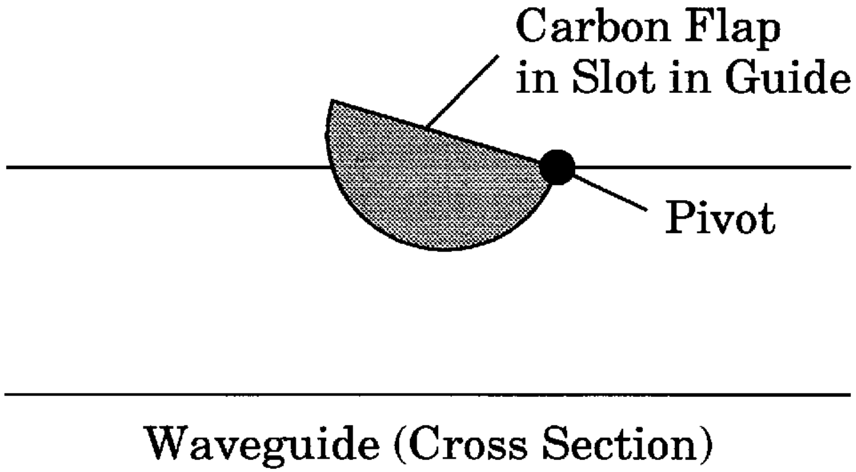


Transparency 261 (Figure 19.20)

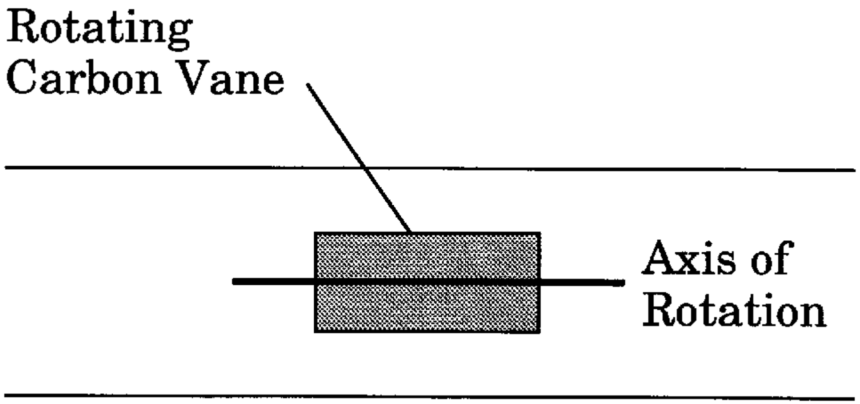
Attenuators and Loads

- Attenuator works by putting carbon vane or flap into the waveguide
- Currents induced in the carbon cause loss
- Load is similar but at end of guide

Waveguide Atttenuators



(a) Flap

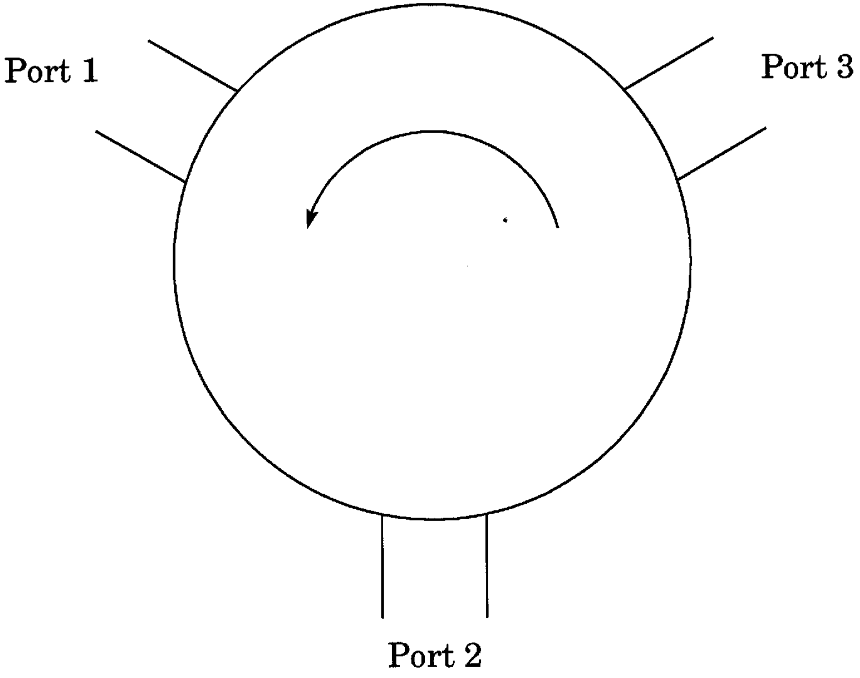


(b) Rotating Vane

Circulator and Isolator

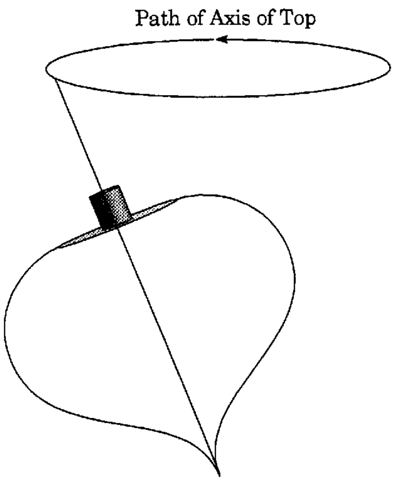
- Both use the unique properties of ferrites in a magnetic field
- Isolator passes signals in one direction, attenuates in the other
- Circulator passes input from each port to the next around the circle, not to any other port

Circulator (Top View)

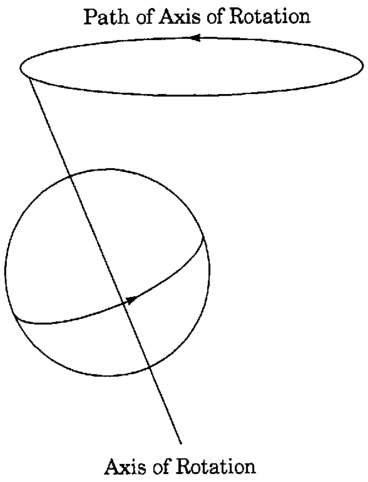


Transparency 263 (Figure 19.26)

Precession

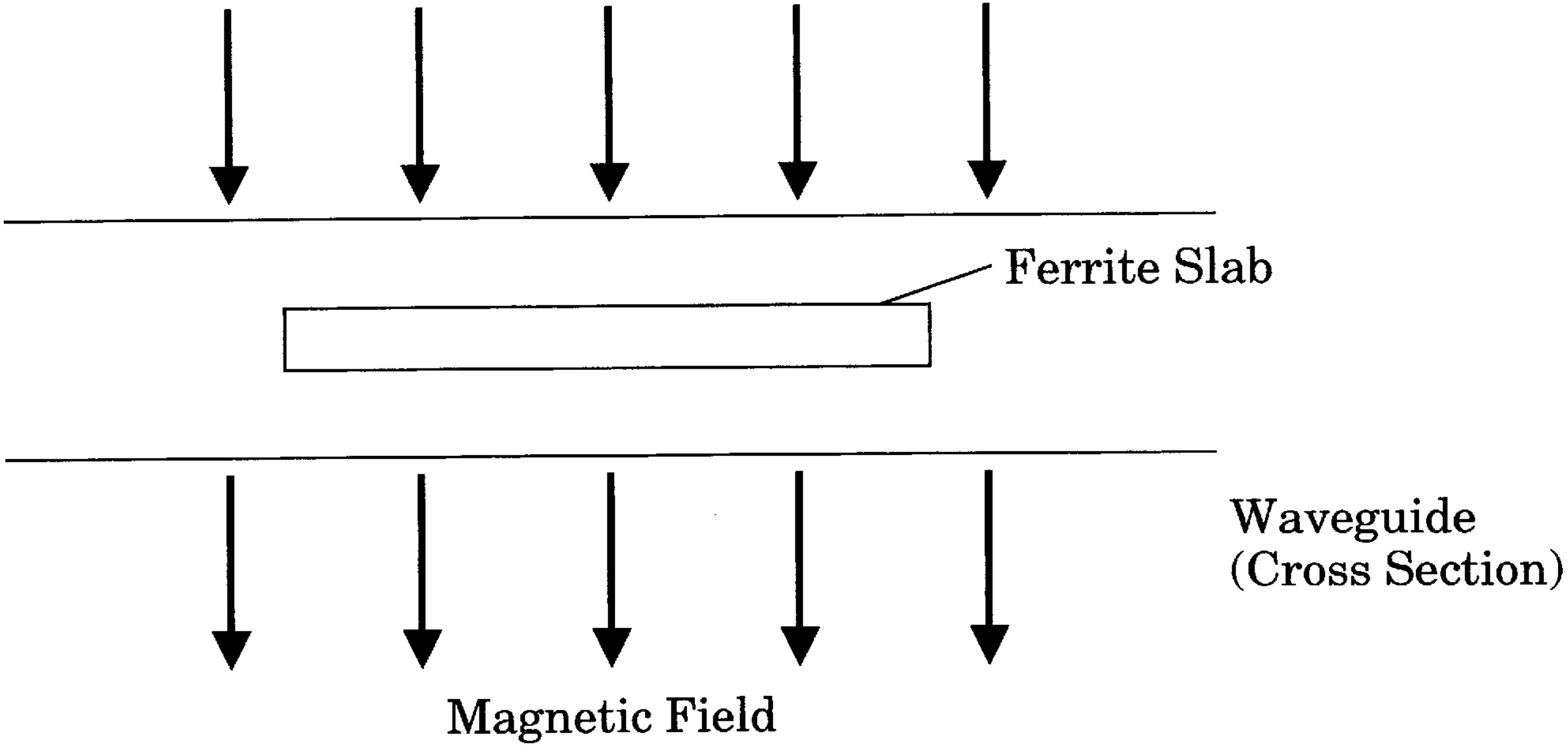


(a) Child's Top



(b) Electron

Ferrite Isolator

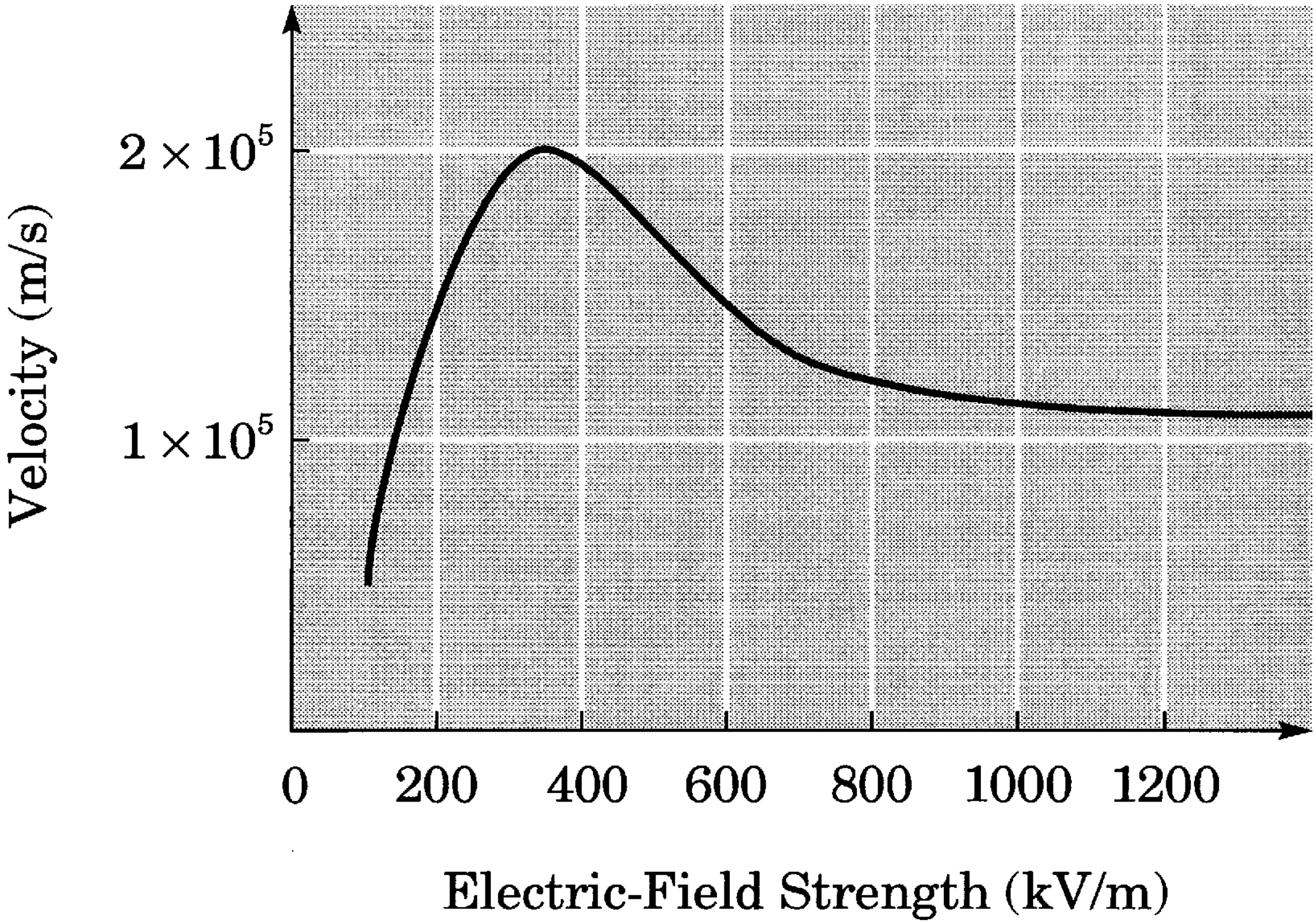


Transparency 265 (Figure 19.29)

Gunn Device

- Slab of N-type GaAs (gallium arsenide)
- Sometimes called Gunn diode but has no junctions
- Has a negative-resistance region where drift velocity decreases with increased voltage
- This causes a concentration of free electrons called a domain

Drift Velocity in Gallium Arsenide

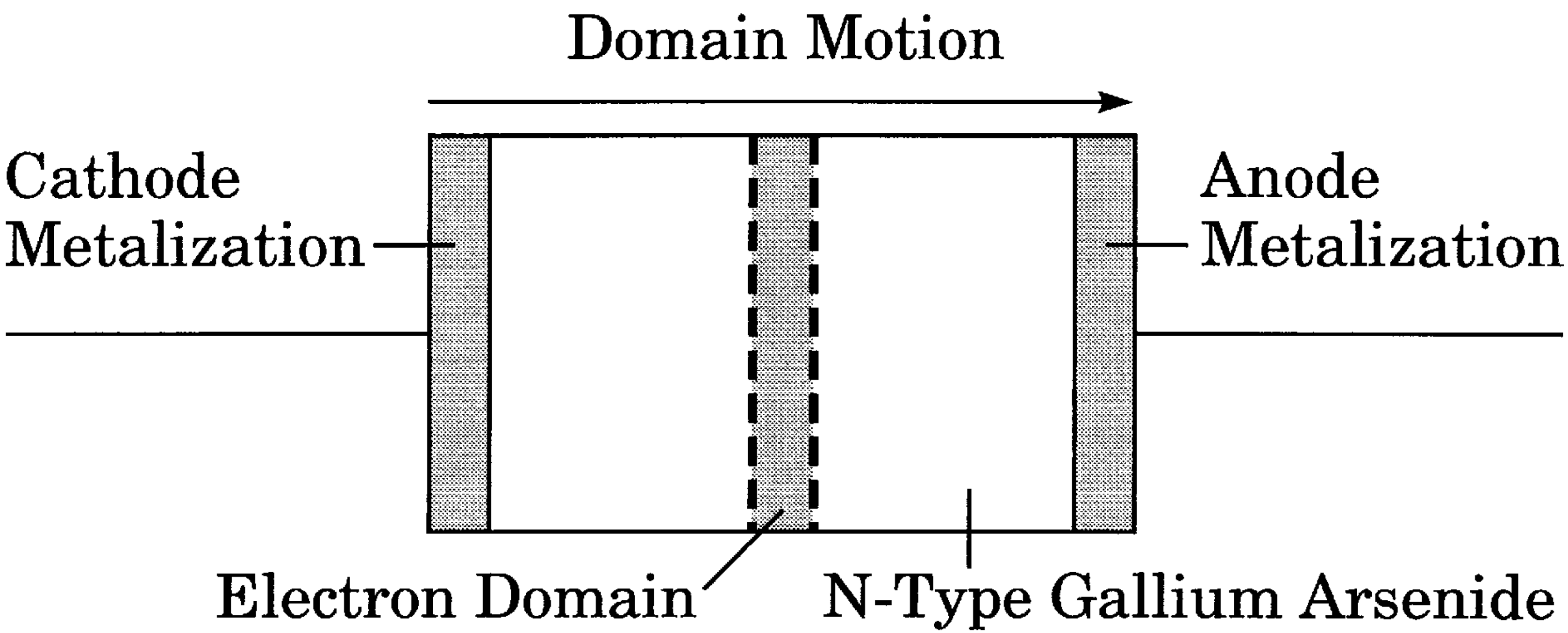


Transparency 267 (Figure 19.33)

Transit-time Mode

- Domains move through the GaAs till they reach the positive terminal
- When domain reaches positive terminal it disappears and a new domain forms
- Pulse of current flows when domain disappears
- Period of pulses = transit time in device

Gunn Device (Cross Section)



Transparency 266 (Figure 19.32)

Gunn Oscillator Frequency

- $T = d/v$

  T = period of oscillation

  d = thickness of device

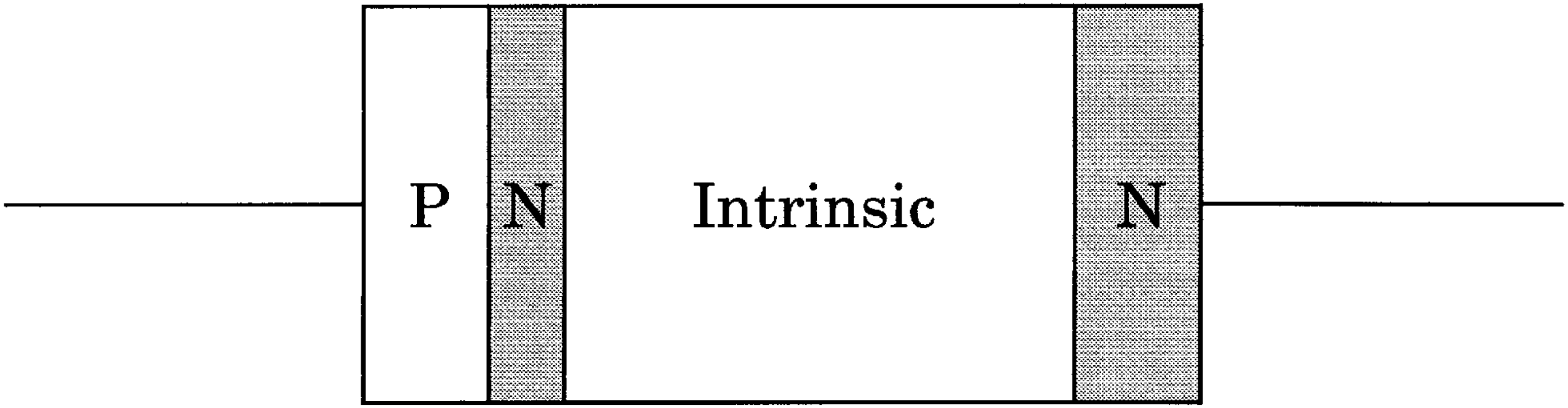
  v = drift velocity, about 1×10^5 m/s

- $f = 1/T$

IMPATT Diode

- IMPATT stands for Impact Avalanche And Transit Time
- Operates in reverse-breakdown (avalanche) region
- Applied voltage causes momentary breakdown once per cycle
- This starts a pulse of current moving through the device
- Frequency depends on device thickness

IMPATT Diode

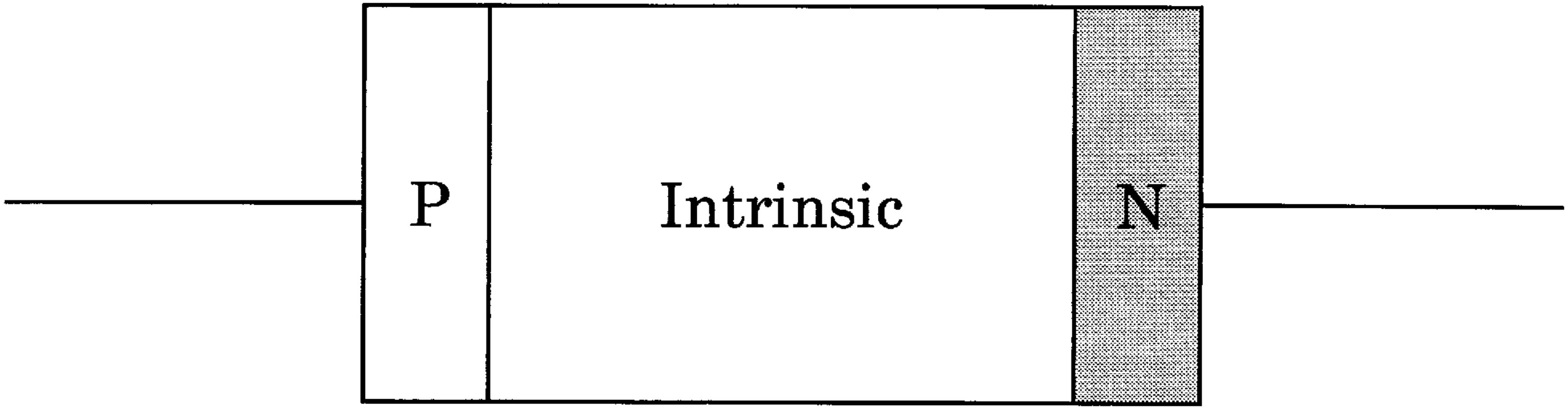


Gallium Arsenide

PIN Diode

- P-type --- Intrinsic --- N-type
- Used as switch and attenuator
- Reverse biased - off
- Forward biased - partly on to on depending on the bias

PIN Diode



Gallium Arsenide

Transparency 269 (Figure 19.37)

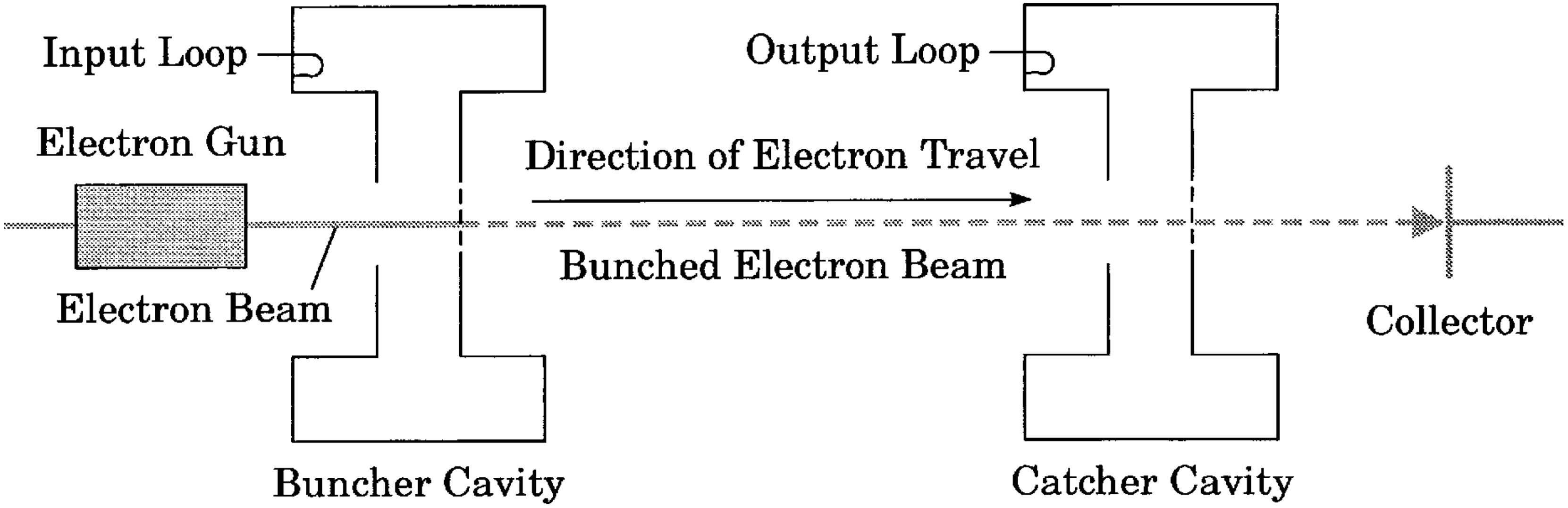
Microwave Tubes

- Used for high power/high frequency combination
- Tubes generate and amplify high levels of microwave power more cheaply than solid state devices
- Conventional tubes can be modified for low capacitance but specialized microwave tubes are also used

Klystron

- Used in high-power amplifiers
- Electron beam moves down tube past several cavities.
- Input cavity is the *buncher*, output cavity is the *catcher.*
- *Buncher* modulates the velocity of the electron beam

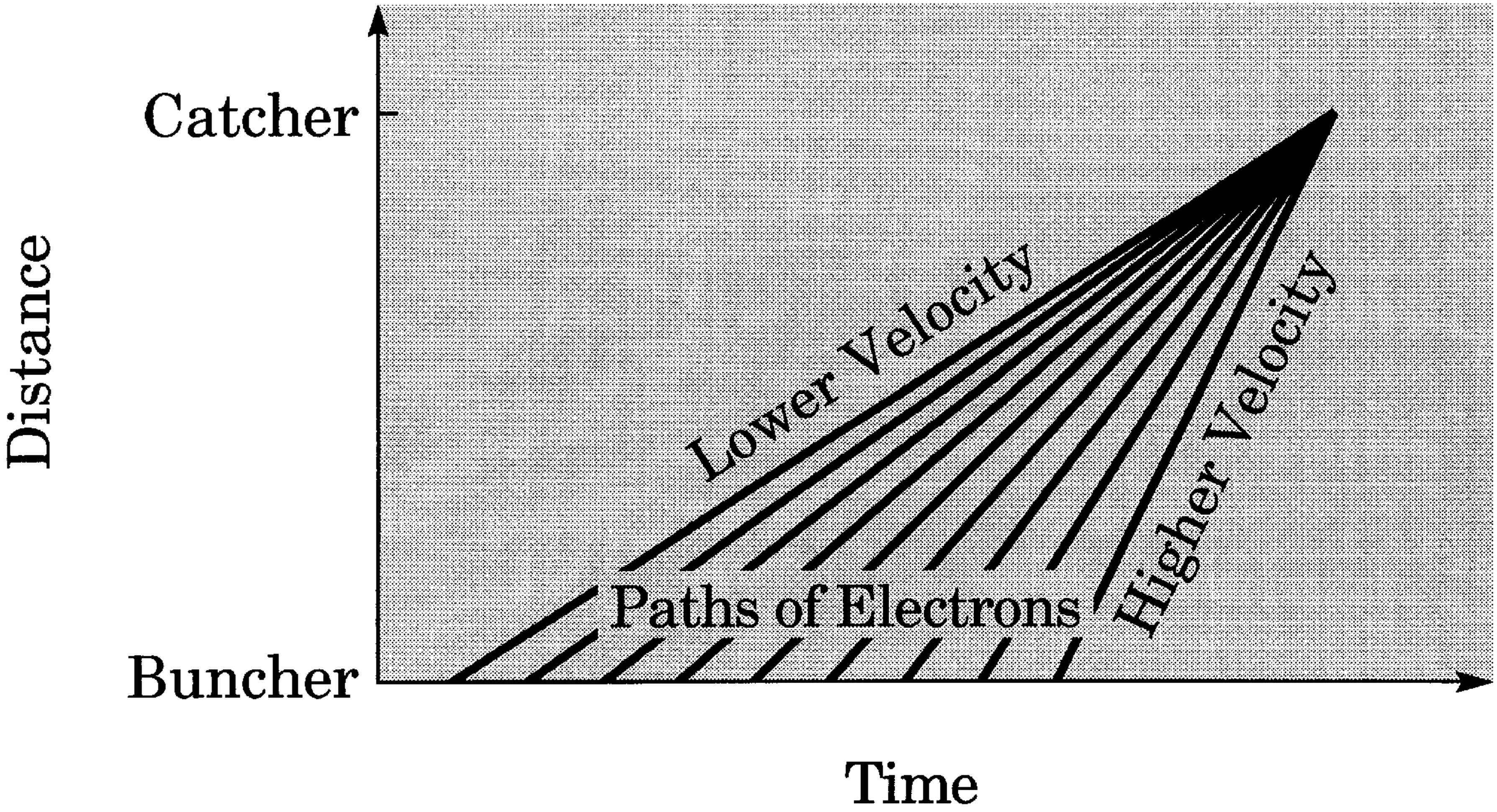
Klystron Cross Section



Velocity Modulation

- Electric field from microwaves at buncher alternately speeds and slows electron beam
- This causes electrons to bunch up
- Electron bunches at catcher induce microwaves with more energy
- The cavities form a slow-wave structure

Velocity Modulation



Transparency 272 (Figure 19.40)

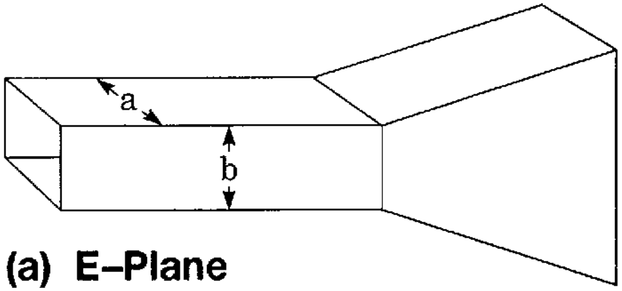
Microwave Antennas

- Conventional antennas can be adapted to microwave use
- The small wavelength of microwaves allows for additional antenna types
- The parabolic dish already studied is a reflector not an antenna but we saw that it is most practical for microwaves

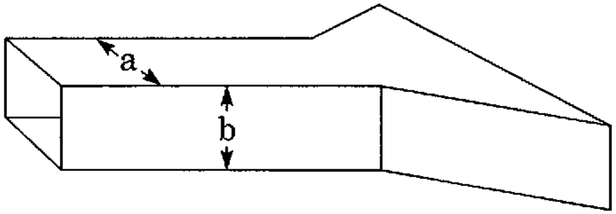
Horn Antennas

- Not practical at low frequencies because of size
- Can be E-plane, H-plane, pyramidal or conical
- Moderate gain, about 20 dBi
- Common as feed antennas for dishes

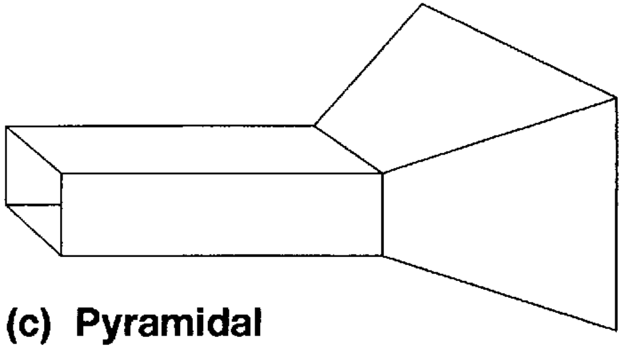
Horn Antennas



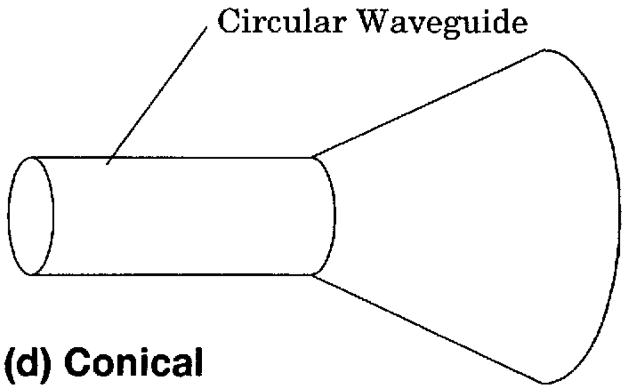
(a) E–Plane



(b) H–Plane



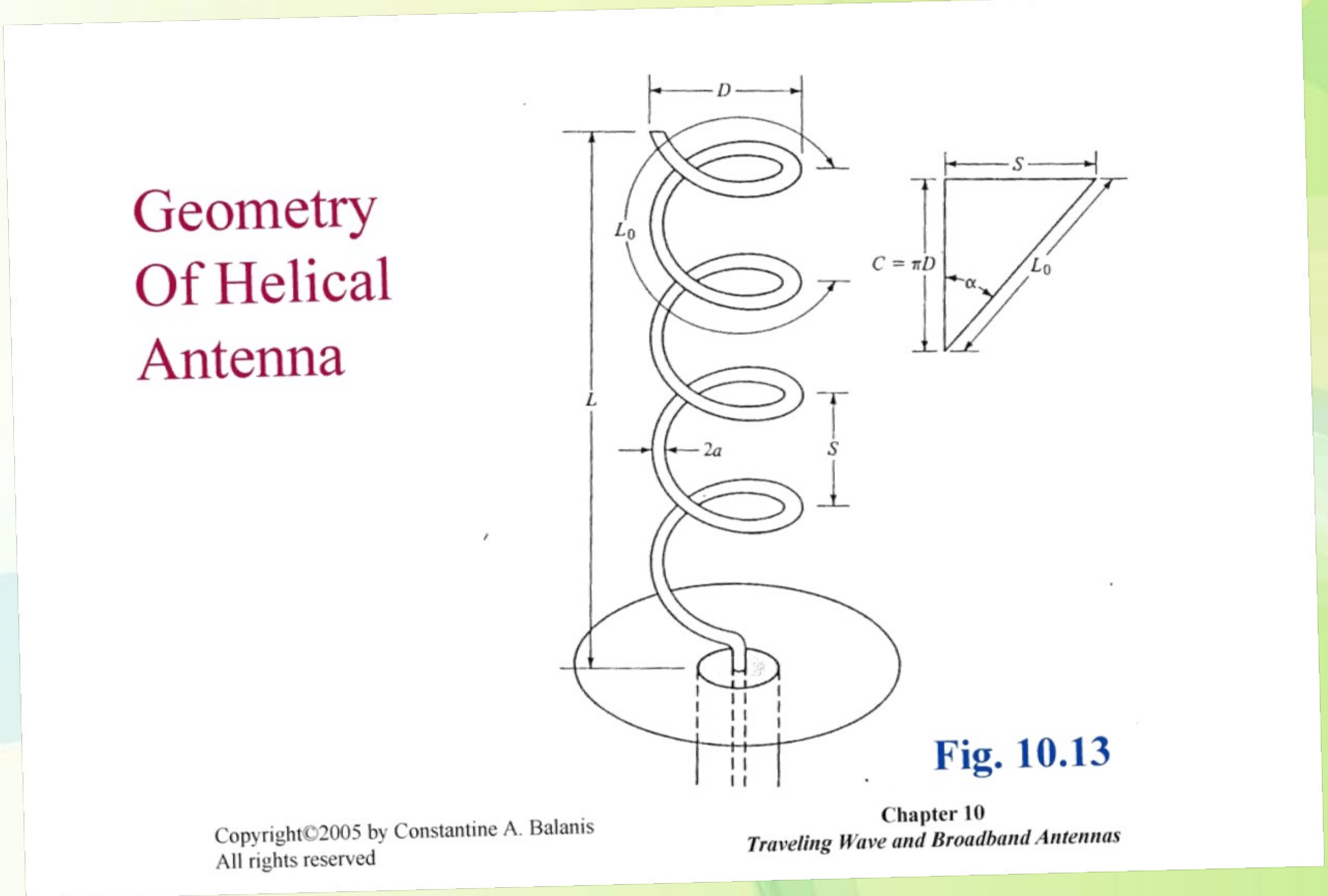
(c) Pyramidal



(d) Conical

3.2 Helical Antennas

Geometry of Helical Antennas



Geometry Of Helical Antenna

Fig. 10.13

Chapter 10
Traveling Wave and Broadband Antennas

Modes of Operation:

- Normal (Broadside)
- Axial (End-fire) – Most practical
  - Circular polarization can be achieved over a wider bandwidth (usually 2:1)
  - More efficient

Normal Mode

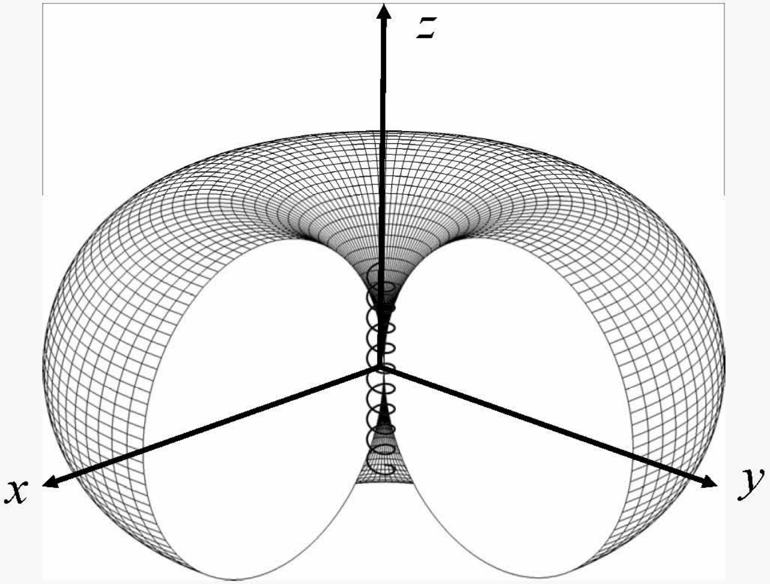


Fig. 10.14(a)

End-fire Mode

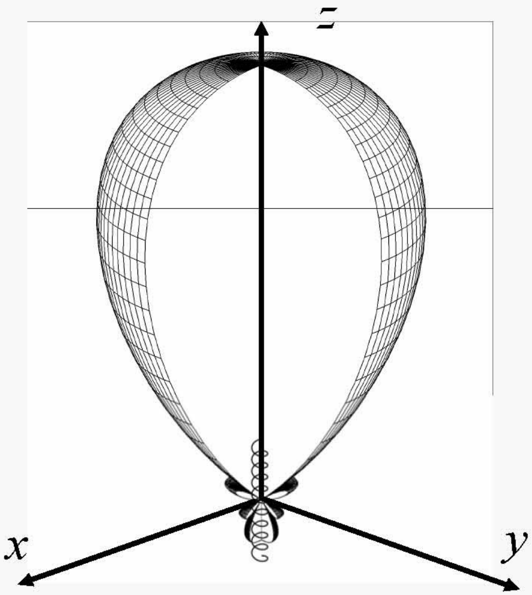


Fig. 10.14(b)

Important Parameters

$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right) = \tan^{-1}\left(\frac{S}{C}\right)$$

$\alpha = 0^{o}$ (flat loop)

$\alpha = 90^{o}$ (linear wire)

$$L_0 = \sqrt{S^2 + C^2}$$

$$L_n = N L_0 = N\sqrt{S^2 + C^2}$$

Parameters for End-fire Mode

$$R \approx 140\left(\frac{C}{\lambda_0}\right)$$

$$HPBW \approx \frac{52\lambda_0^{3/2}}{C\sqrt{NS}}$$

$$FNBW(\text{deg}) \approx \frac{115\lambda_0^{3/2}}{C\sqrt{NS}}$$

$$D_o \approx 15N\frac{C^2S}{\lambda_0^3}$$

$$AR = \frac{2N+1}{2N}$$

Queries ...?