Fundamentos de Redes de Computadores

Tema 6 – Meios de Transmissão

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Slides gerados à partir do Cap. Transmission Media do livro Data and Computer Communications (Stallings) & Computer Networks do Tanenbaum (Caps 2 e 4).

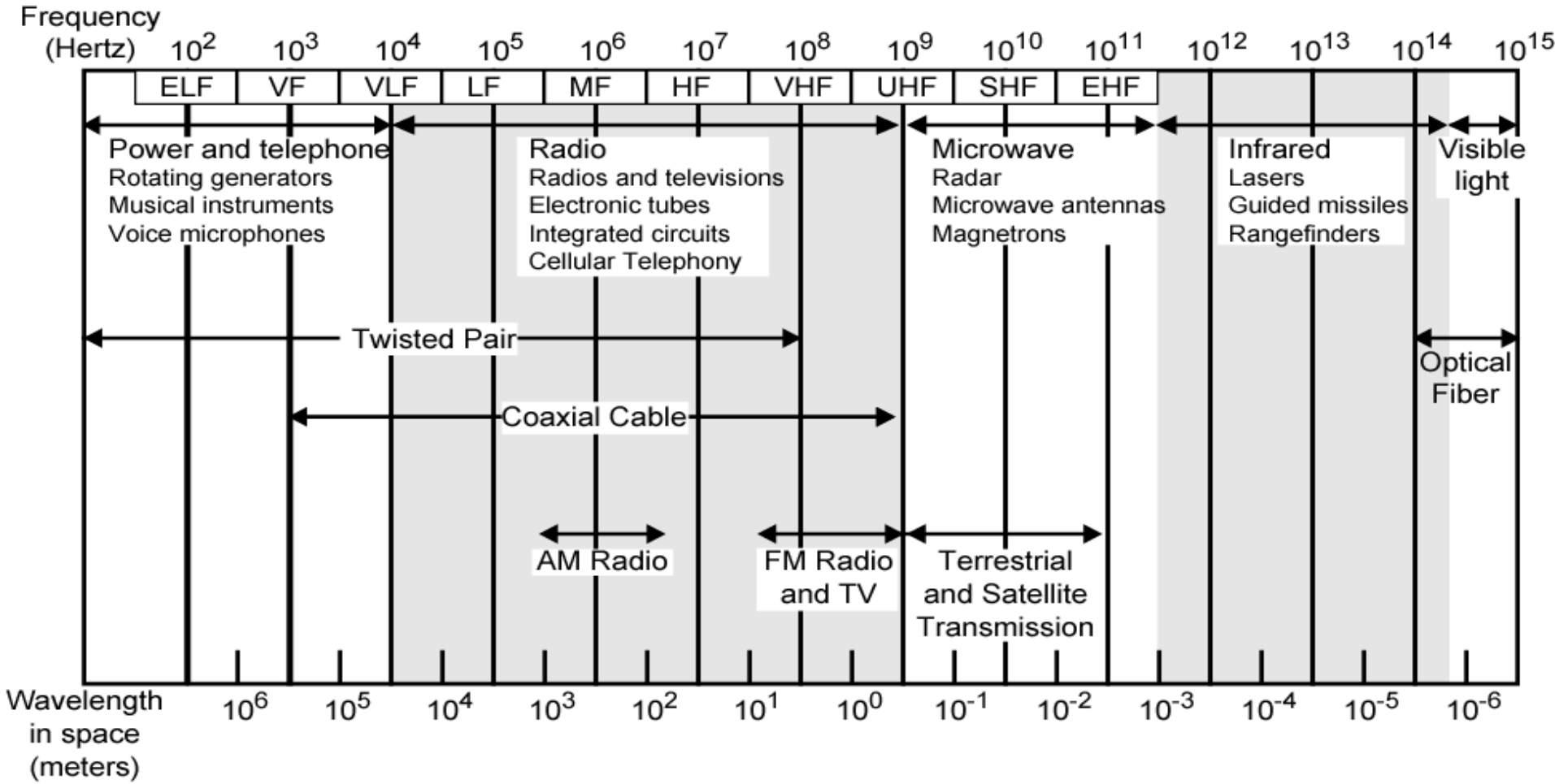
Overview

- Guiados – uso de cabos
- Não guiados – meio livre (wireless)
- Características e qualidade determinadas pelo meio e pelo sinal que trafega no meio
- Para meios guiados, o meio é o mais importante
- Para meios não guiados, a largura de banda produzida pela antena é mais importante
- As questões-chave relacionam-se à taxa de dados desejada e a distância que se quer alcançar

Questões de Projeto

- Largura de Banda (Bandwidth)
  - Quanto maior a largura de banda, maior a taxa de dados
- Deve-se considerar as imperfeições na tranmissão
  - Atenuação
- Interferências
- Número de receptores
  - No meio guiado
  - Mais receptores (multi-point) introduzem mais atenuação

Espectro Electromagnético



ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

Meios de Transmissão Guiados

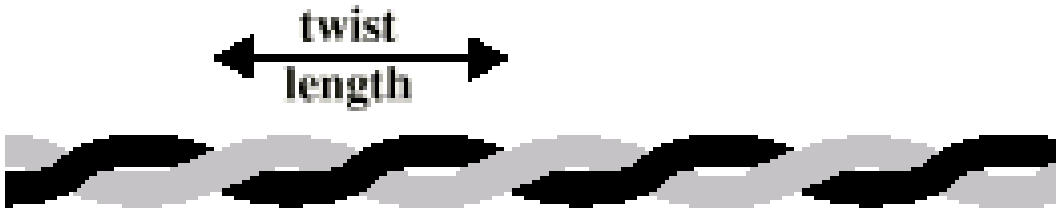
- Par Trançado
- Cabo Coaxial
- Fibra Ótica

Características de Transmissão de Meios Guiados

	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 μs/km	40 km

Twisted Pair

—Separately insulated
—Twisted together
—Often "bundled" into cables
—Usually installed in building during construction



(a) Twisted pair

Par Trançado - Aplicações

- Meio mais comum
- Usado na rede de telefonia
  - Entre a residência e o escritório da operadora (loop local)
- Dentro de prédios
  - Para ligar ramais a centrais de PBX (private branch exchange)
- Em redes locais (LAN's)
  - Aqui taxas de 10Mbps, 100Mbps e acima (gigabit Ethernet por exemplo)

Par Trançado - Prós e Contras

- Barato
- Fácil de trabalhar
- Baixa taxa de dados (dependendo do contexto)
- Usado em distâncias curtas

Par Trançado – Características de Transmissão

- Analógico
  - Amplificadores a cada 5km ou 6km
- Digital
  - Uso de sinais analógicos ou sinais digitais
  - Repetidores a cada 2 ou 3km
- Distância limitada
- Largura de banda limitada (1MHz)
- Taxa de dados limitada (depende da categoria)
- Suscetível a interferências e ruídos

Unshielded and Shielded TP

- Unshielded Twisted Pair (UTP)
  - Cabo de telefone simples
  - Mais barato
  - Fácil de instalar
  - Sofre de interferências externas
- Shielded Twisted Pair (STP)
  - Proteção que reduz a interferência (Metal braid or sheathing)
  - Mais caro
  - Mais difícil de manusear (mais denso, peso maior)

UTP Categorias

- Cat 3
  - Vai até 16MHz
  - Linhas de voz encontrada em escritórios de um modo geral
  - Comprimento do trançado entre 7.5 cm e 10 cm
- Cat 4
  - Limite de 20 MHz
- Cat 5
  - Limite de 100MHz
  - Comumente pre-instalado em prédios mais novos
  - Comprimento do trançado entre 0.6 cm e 0.85 cm
- Cat 5E (Enhanced) – see tables (Stallings)
- Cat 6
- Cat 7

Tipos de Par Trançado

(a)

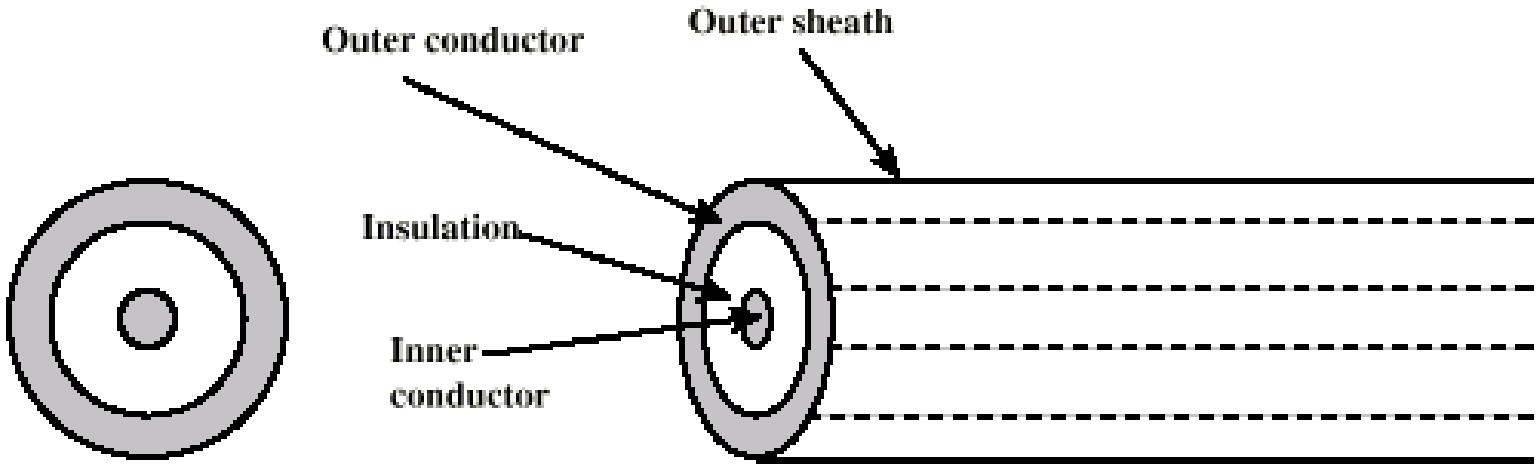
(b)

(a) Categoria 3 UTP.

(b) Categoria 5 UTP.

Obs.: Uso de conector RJ-11 em telefonia e RJ-45 em LAN's

Cabo Coaxial



—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

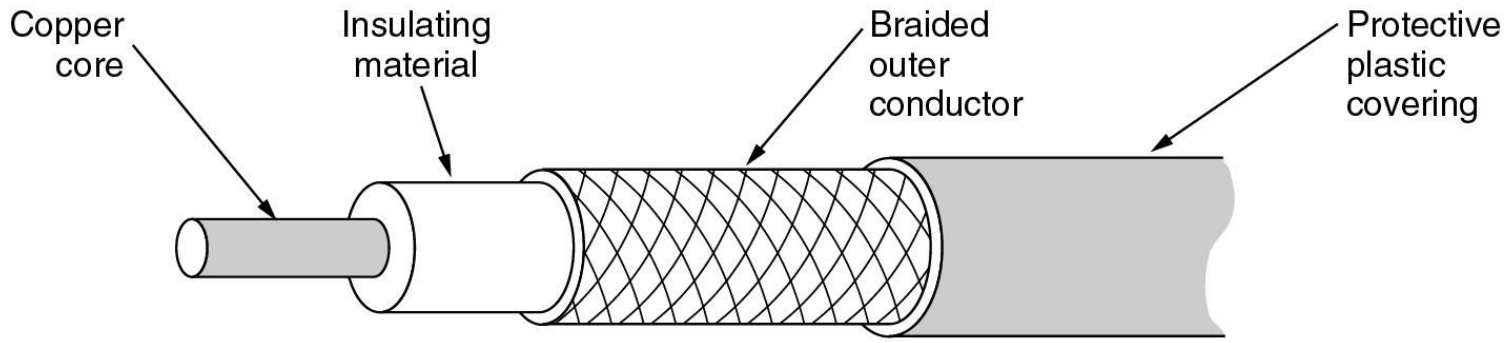
Aplicações de Cabo Coaxial

- Meio mais versátil
- Distribuição de sinais de Televisão
- Transmissão de telefonia em enlaces de longa distância
  - Pode carregar 10.000 chamadas de voz simultaneamente
  - Obs.: Esses enlaces têm sido trocados por fibra ótica
- Em distâncias curtas, interliga computadores (LAN's)

Cabo Coaxial – Características de Transmissão

- Analógico
  - Amplificadores a cada poucos kilômetros (4/5 Km)
  - Bom para frequências altas
  - Largura de banda na faixa dos 500MHz
- Digital
  - Repetidores a cada 1km
  - Bom para altas taxas de dados

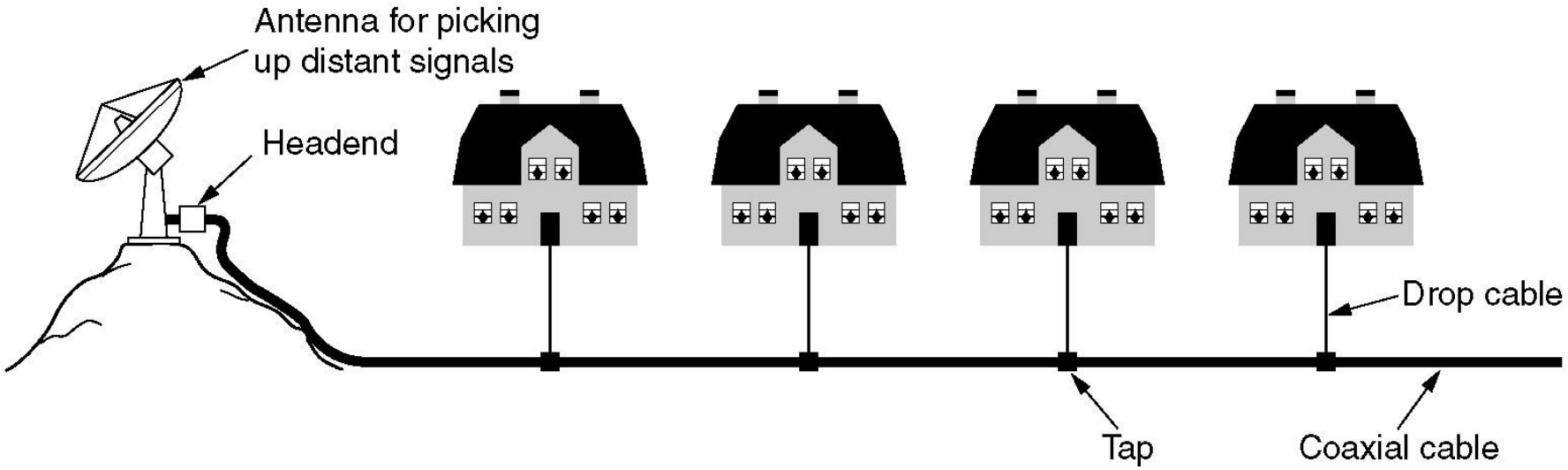
Visão interna de um Cabo Coaxial



- Em redes de TV a cabo, terminadores de 75 OHM's
- Em redes locais, cabo com terminação 50 OHM's

Obs.: Uso de conectores BNC em redes locais

Community Antenna Television



Uso de Cabo Coaxial 75 Ohms para distribuição de sinais de TV.

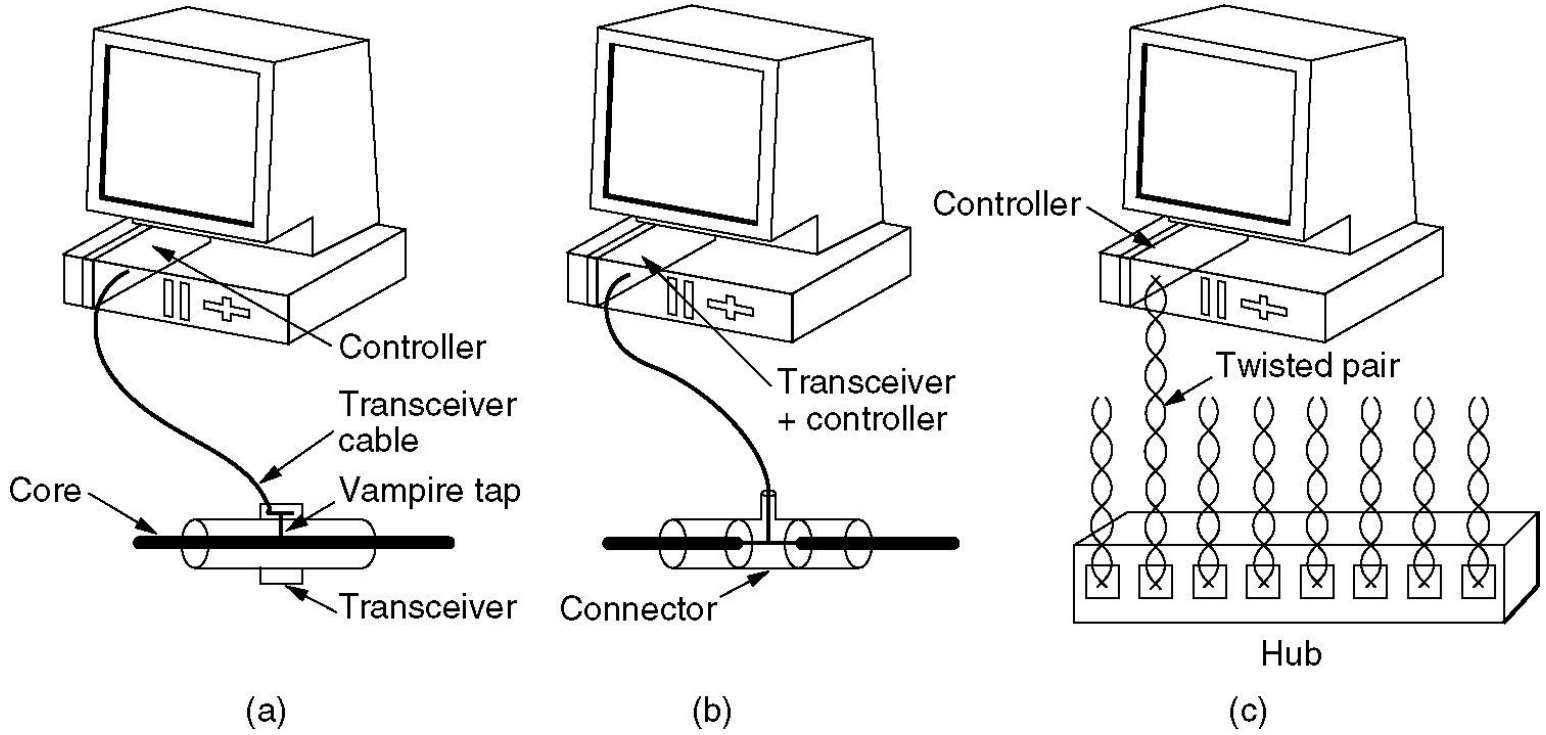
Obs.: Para Internet, necessidade de amplificadores bidirecionais para garantir tráfego up/down

Cabeamento em Redes Locais Ethernet e Fast Ethernet

Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

Cabeamento em LAN's Ethernet (2)



Três tipos de cabeamento mais comuns

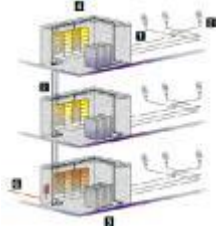
(a) 10Base5, (b) 10Base2, (c) 10Base-T.

Cabeamento em LAN's Gigabit Ethernet (2)

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

Cabeamento em LAN's (Gigabit Ethernet) feito com uso de par trançado e fibra ótica (visto mais adiante)

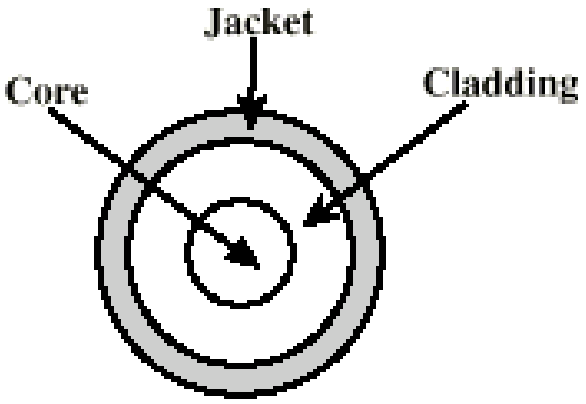
Cabeamento Estruturado em LAN's



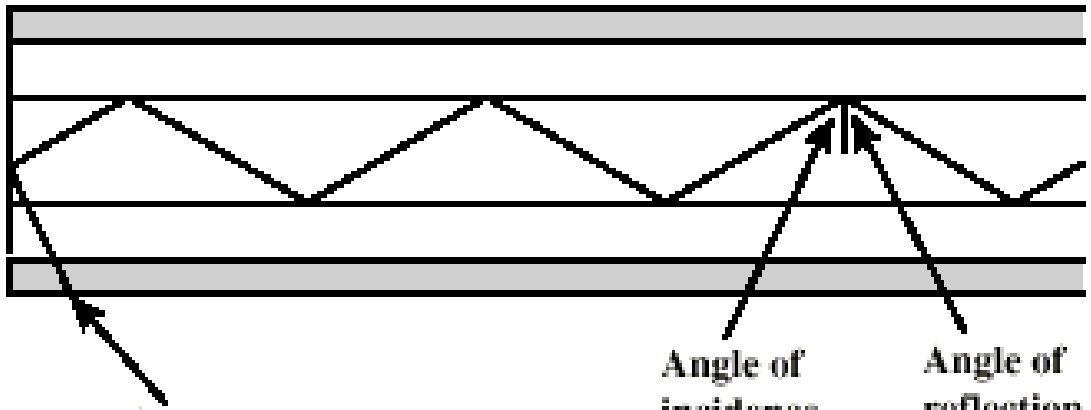
- Estratégia para facilitar a manutenção da estrutura de ligação das estações
  - Em princípio, assume-se uma capilarização de cabos com tomadas distribuídas em pontos estratégicos do prédio.
  - Normalmente esses cabos convergem para um patch panel instalado em um rack que facilita a codificação/organização dos cabos e tomadas de rede
  - Existem recomendações específicas para instalação de cabos

Tomadas RJ-45

Optical Fiber



—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight



Light at less than ciritical angle is absorbed in jacket

Optical Fiber - Benefits

- Greater capacity
  - —Data rates of hundreds of Gbps
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
- Greater repeater spacing
  - —10s of km at least

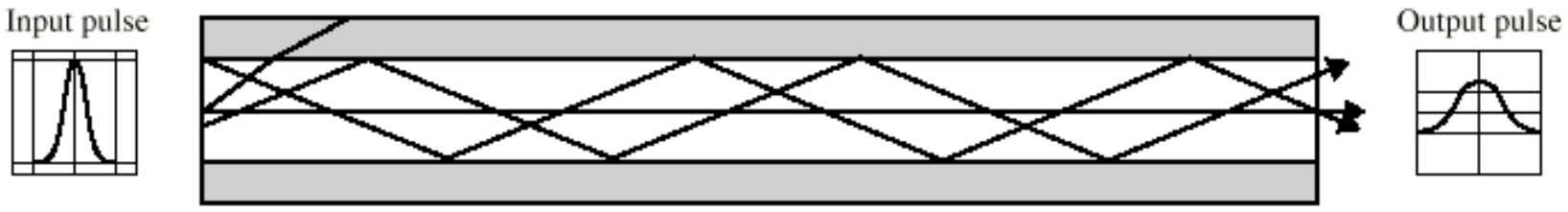
Optical Fiber - Applications

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs

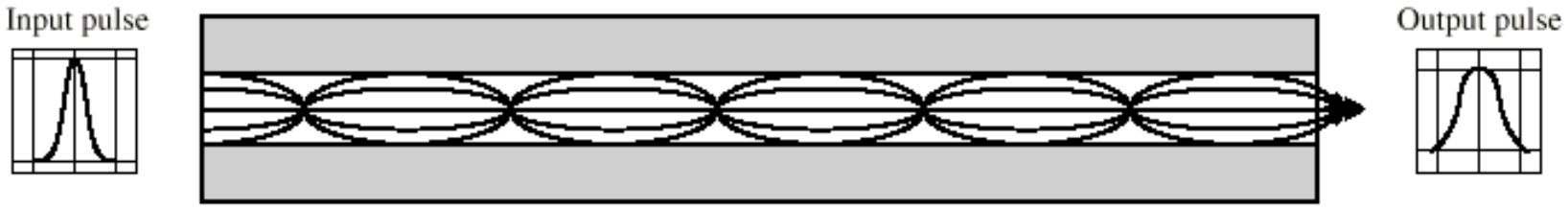
Optical Fiber - Transmission Characteristics

- Act as wave guide for 10^{14} to 10^{15} Hz
  - —Portions of infrared and visible spectrum
- Light Emitting Diode (LED)
  - —Cheaper
  - —Wider operating temp range
  - —Last longer
- Injection Laser Diode (ILD)
  - —More efficient
  - —Greater data rate
- Wavelength Division Multiplexing

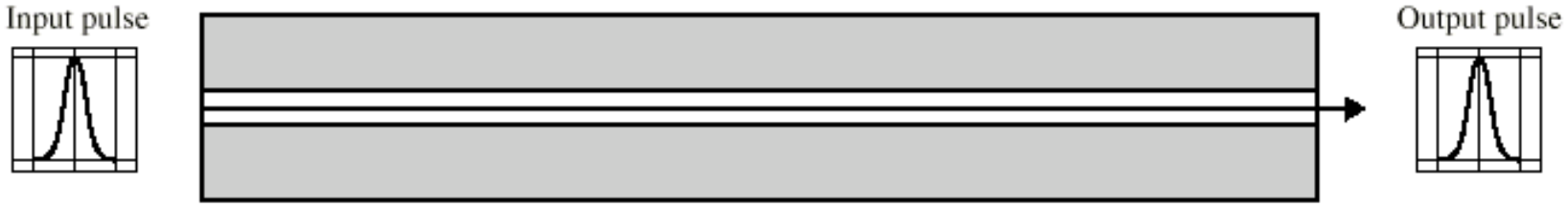
Optical Fiber Transmission Modes



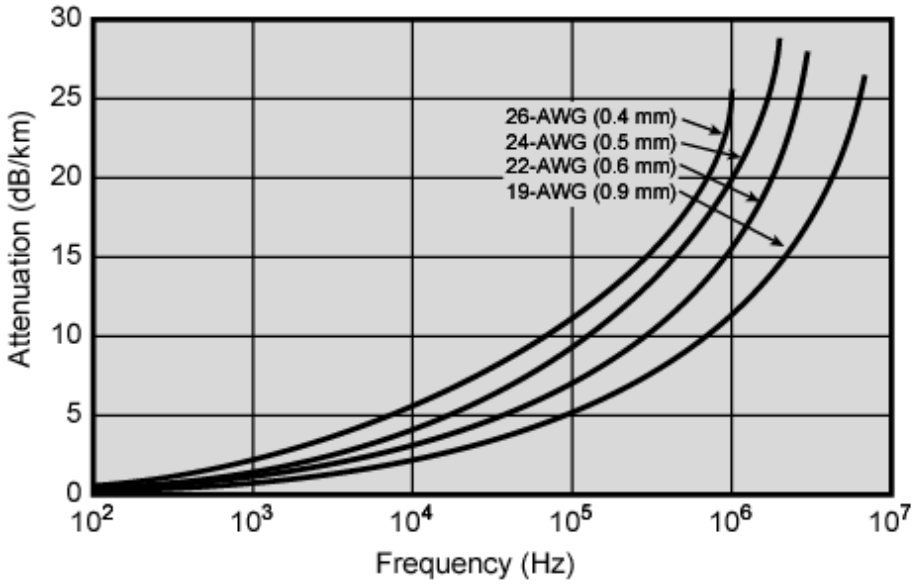
(a) Step-index multimode



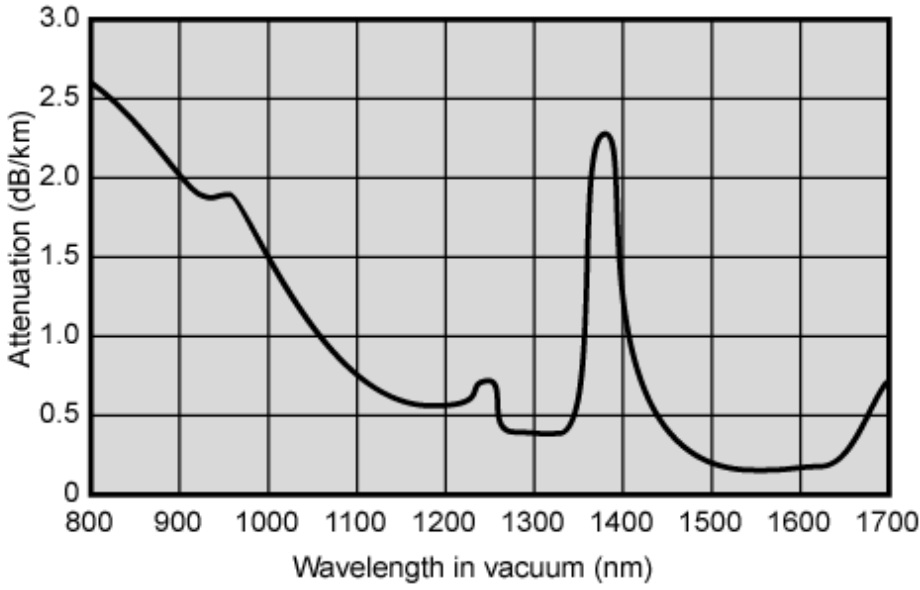
(b) Graded-index multimode



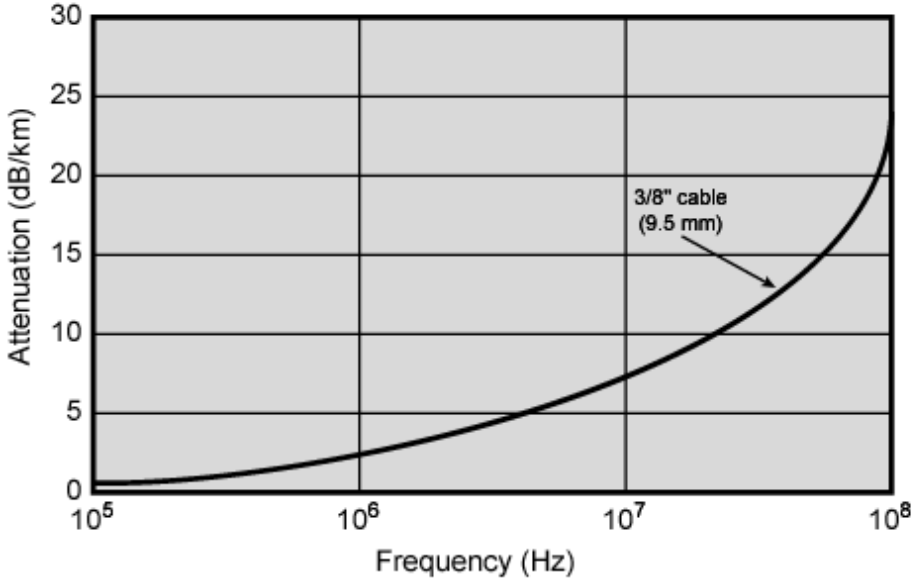
(c) Single mode



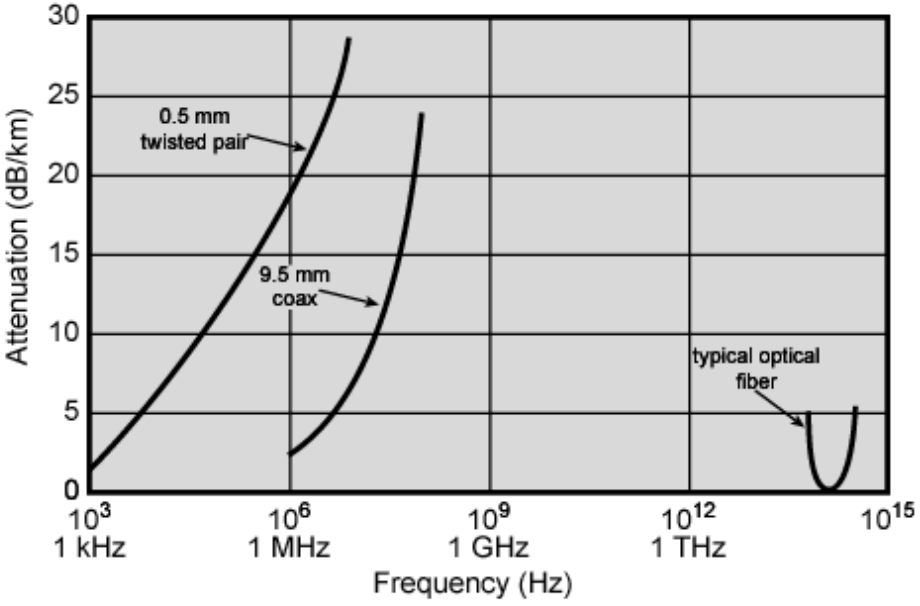
(a) Twisted pair (based on [REEV95])



(c) Optical fiber (based on [FREE02])



(b) Coaxial cable (based on [BELL90])



(d) Composite graph

Wireless Transmission Frequencies

- 2GHz to 40GHz
  - Microwave
  - Highly directional
  - Point to point
  - Satellite
- 30MHz to 1GHz
  - Omnidirectional
  - Broadcast radio
- 3×10^{11} to 2×10^{14}
  - Infrared
  - Local

Antennas

- Electrical conductor (or system of..) used to radiate electromagnetic energy or collect electromagnetic energy
- Transmission
  - Radio frequency energy from transmitter
  - Converted to electromagnetic energy
  - By antenna
  - Radiated into surrounding environment
- Reception
  - Electromagnetic energy impinging on antenna
  - Converted to radio frequency electrical energy
  - Fed to receiver
- Same antenna often used for both

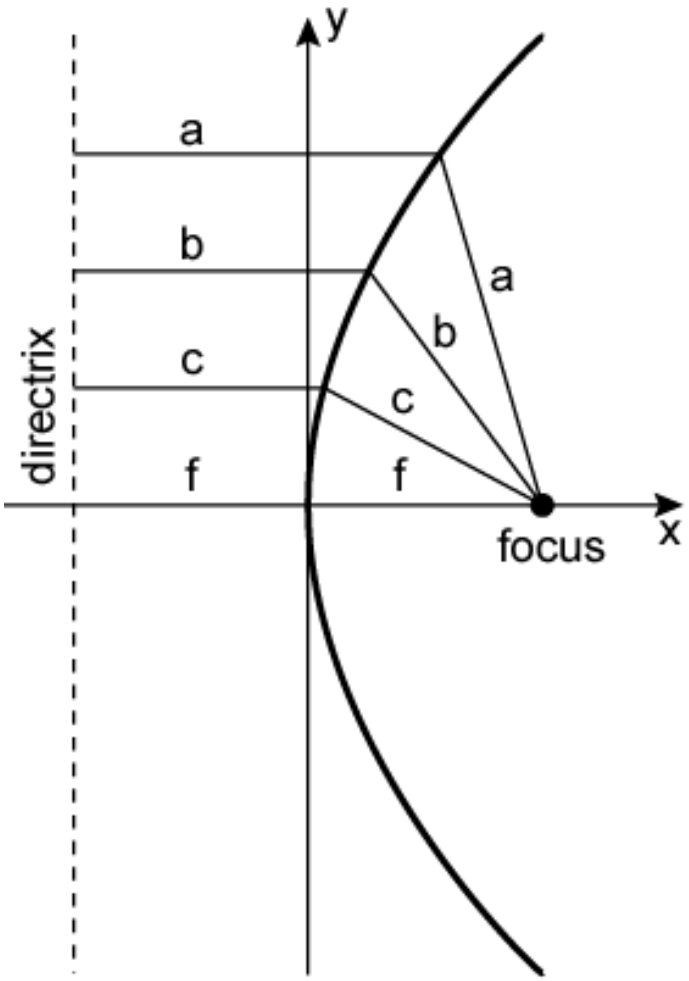
Radiation Pattern

- Power radiated in all directions
- Not same performance in all directions
- Isotropic antenna is (theoretical) point in space
  - Radiates in all directions equally
  - Gives spherical radiation pattern

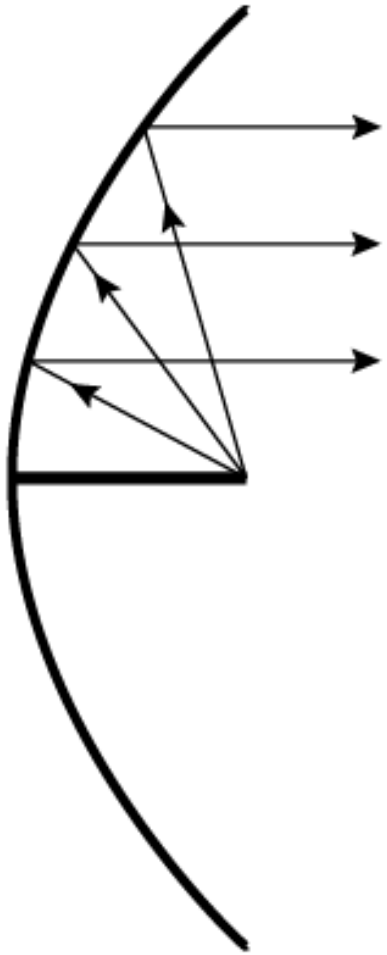
Parabolic Reflective Antenna

- Used for terrestrial and satellite microwave
- Parabola is locus of point equidistant from a line and a point not on that line
  - Fixed point is focus
  - Line is directrix
- Revolve parabola about axis to get paraboloid
  - Cross section parallel to axis gives parabola
  - Cross section perpendicular to axis gives circle
- Source placed at focus will produce waves reflected from parabola in parallel to axis
  - Creates (theoretical) parallel beam of light/sound/radio
- On reception, signal is concentrated at focus, where detector is placed

Parabolic Reflective Antenna



(a) Parabola



(b) Cross-section of parabolic antenna showing reflective property

Antenna Gain

- Measure of directionality of antenna
- Power output in particular direction compared with that produced by isotropic antenna
- Measured in decibels (dB)
- Results in loss in power in another direction
- Effective area relates to size and shape
  - Related to gain

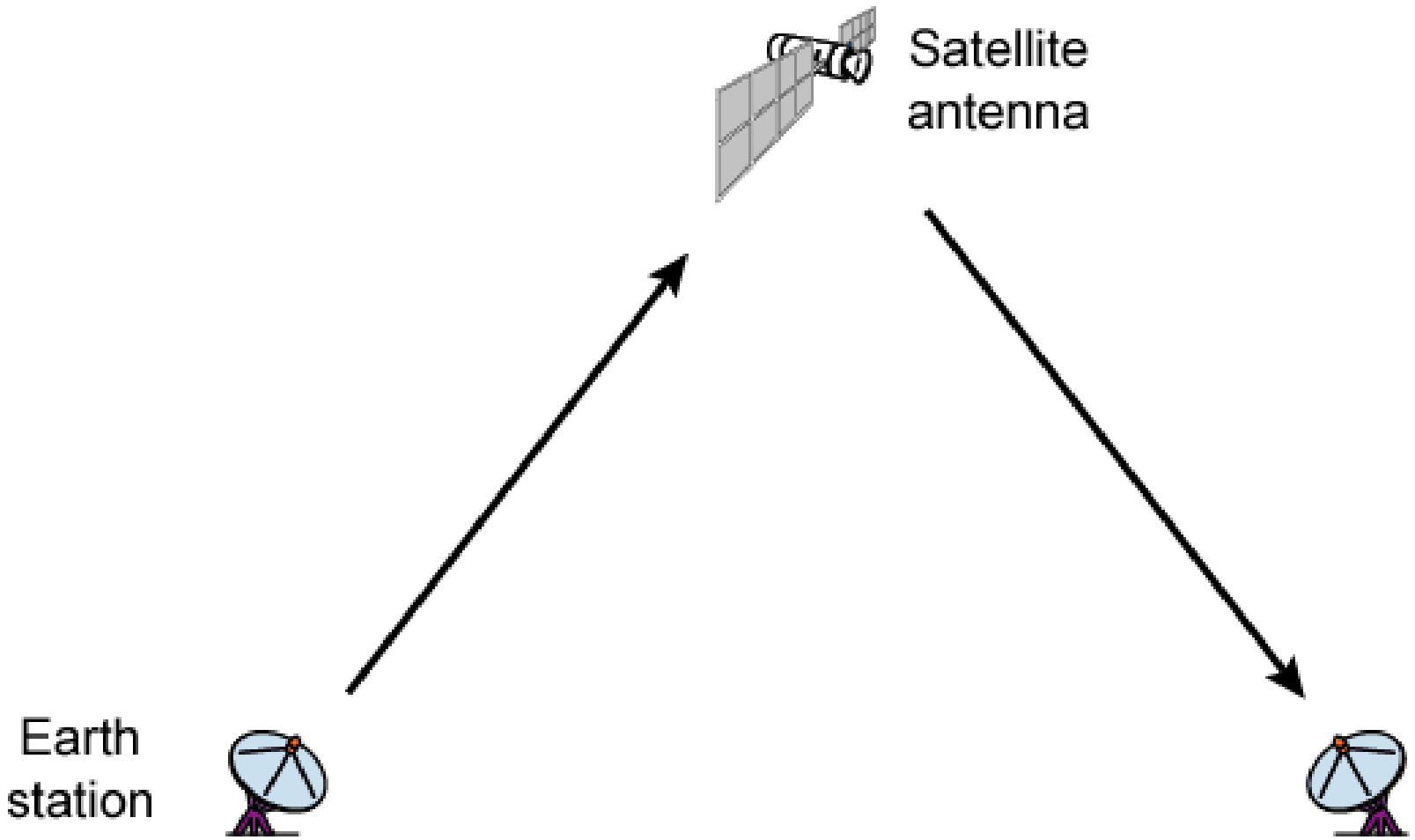
Terrestrial Microwave

- Parabolic dish
- Focused beam
- Line of sight
- Long haul telecommunications
- Higher frequencies give higher data rates

Satellite Microwave

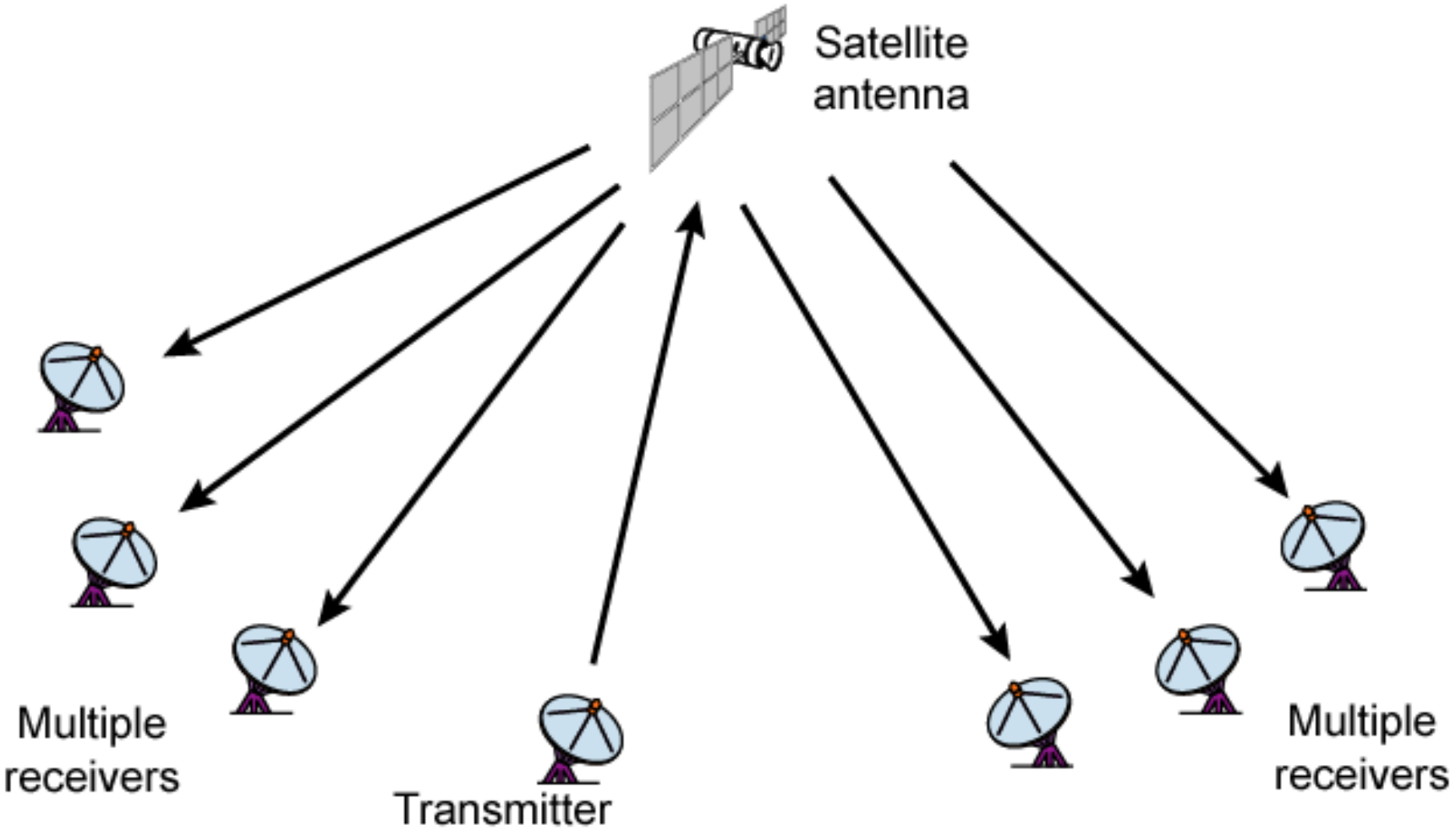
- Satellite is relay station
- Satellite receives on one frequency, amplifies or repeats signal and transmits on another frequency
- Requires geo-stationary orbit
  - Height of 35,784km
- Television
- Long distance telephone
- Private business networks

Satellite Point to Point Link



(a) Point-to-point link

Satellite Broadcast Link



(b) Broadcast link

Broadcast Radio

- Omnidirectional
- FM radio
- UHF and VHF television
- Line of sight
- Suffers from multipath interference
  - Reflections

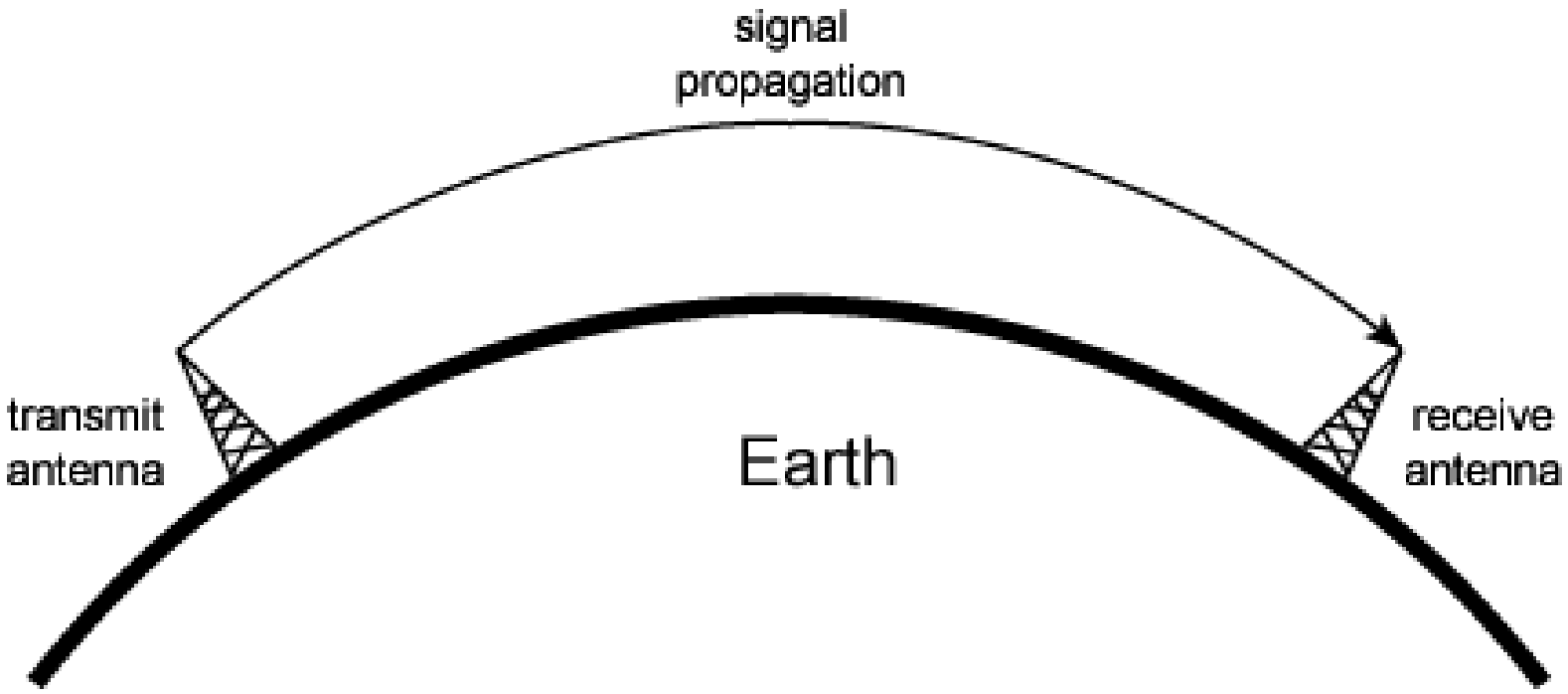
Infrared

- Modulate noncoherent infrared light
- Line of sight (or reflection)
- Blocked by walls
- e.g. TV remote control, IRD port

Wireless Propagation

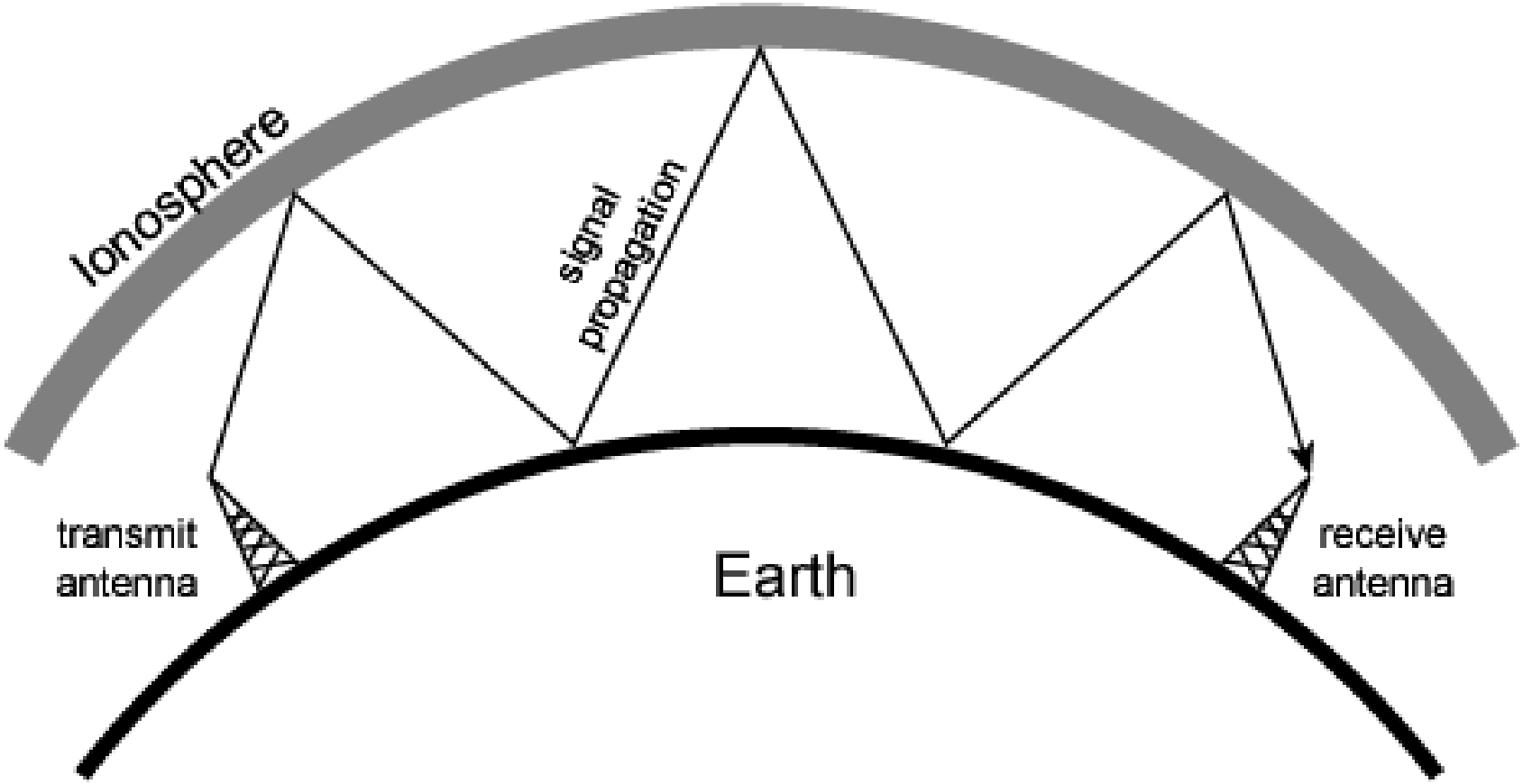
- Signal travels along three routes
  - Ground wave
    - Follows contour of earth
    - Up to 2MHz
    - AM radio
  - Sky wave
    - Amateur radio, BBC world service, Voice of America
    - Signal reflected from ionosphere layer of upper atmosphere
    - (Actually refracted)
  - Line of sight
    - Above 30Mhz
    - May be further than optical line of sight due to refraction
    - More later…

Ground Wave Propagation



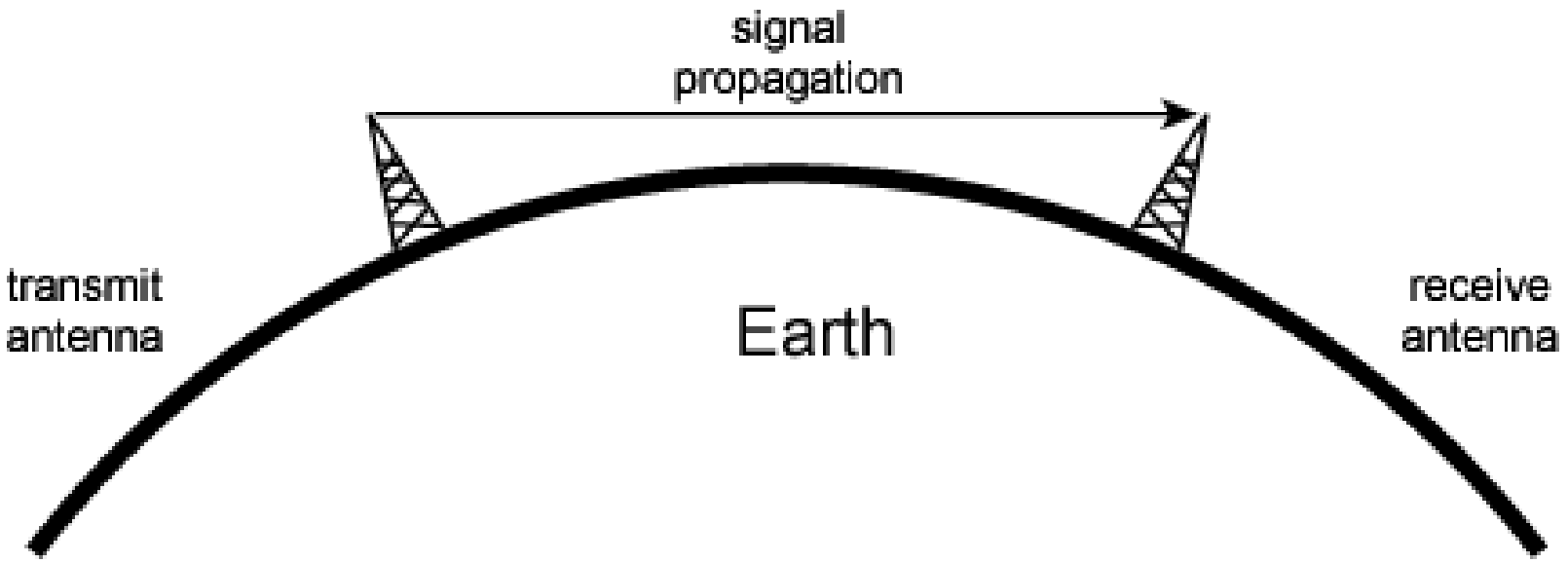
(a) Ground-wave propagation (below 2 MHz)

Sky Wave Propagation



(b) Sky-wave propagation (2 to 30 MHz)

Line of Sight Propagation

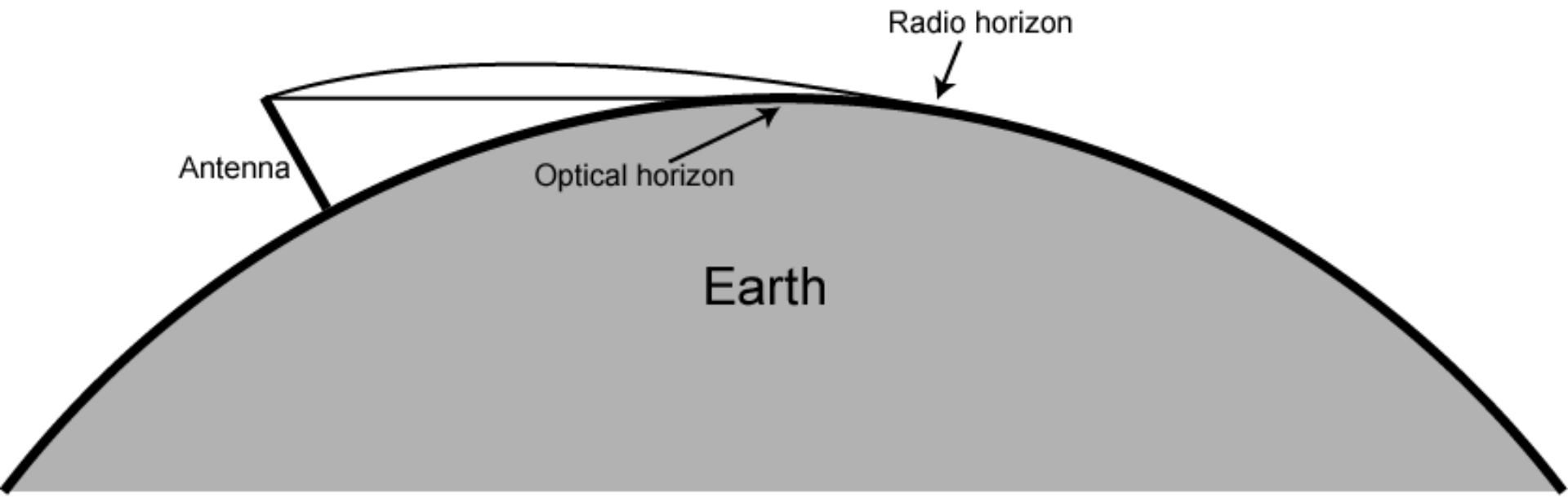


(c) Line-of-sight (LOS) propagation (above 30 MHz)

Refraction

- Velocity of electromagnetic wave is a function of density of material
  - ~3 x 10^8 m/s in vacuum, less in anything else
- As wave moves from one medium to another, its speed changes
  - Causes bending of direction of wave at boundary
  - Towards more dense medium
- Index of refraction (refractive index) is
  - Sin(angle of incidence)/sin(angle of refraction)
  - Varies with wavelength
- May cause sudden change of direction at transition between media
- May cause gradual bending if medium density is varying
  - Density of atmosphere decreases with height
  - Results in bending towards earth of radio waves

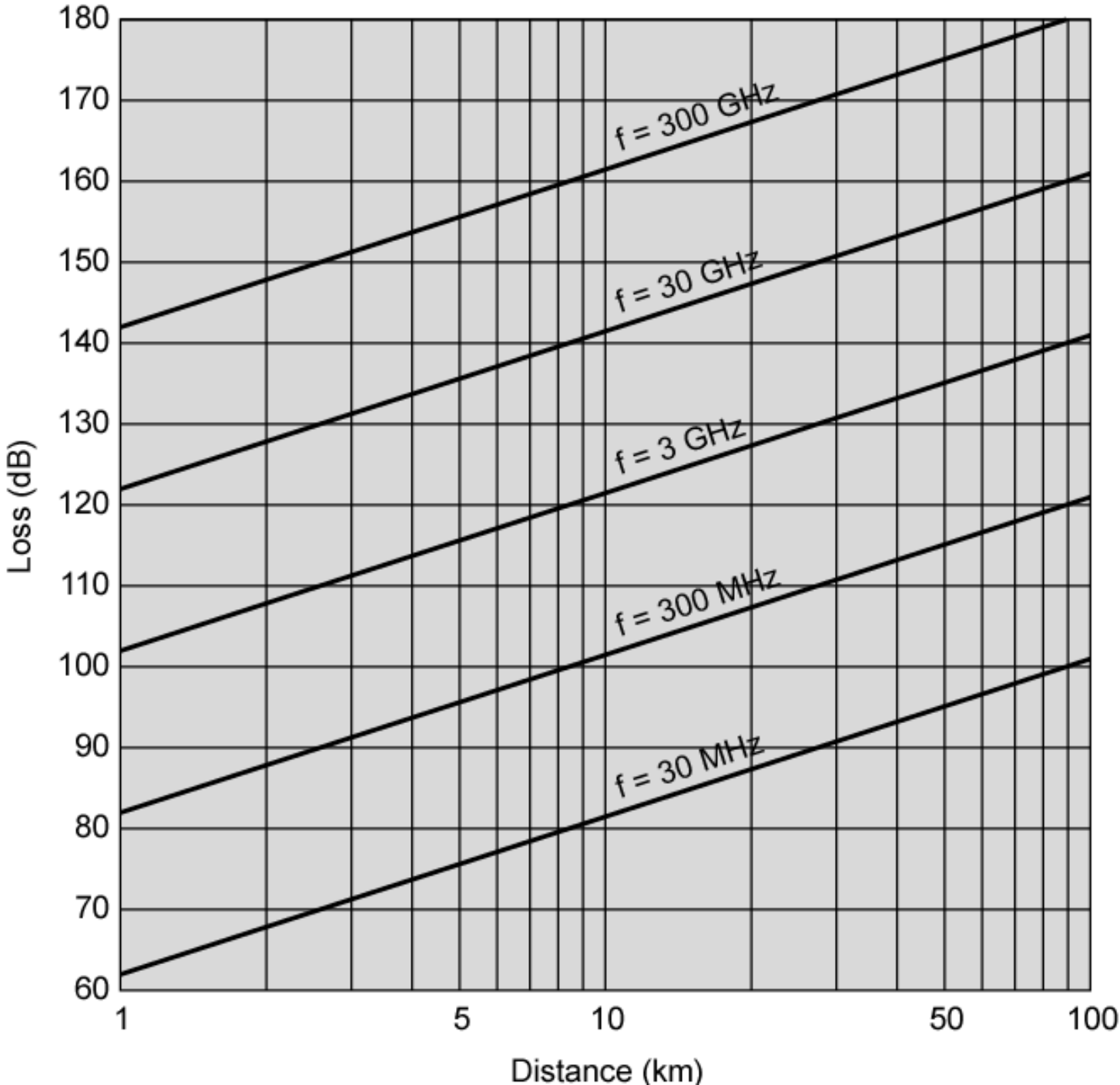
Optical and Radio Horizons



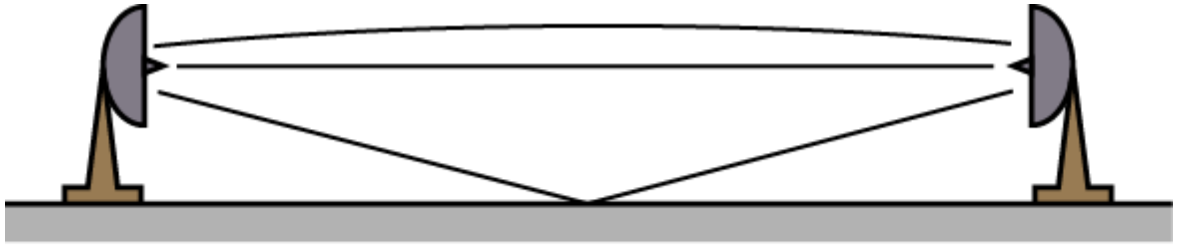
Line of Sight Transmission

- Free space loss
  - Signal disperses with distance
  - Greater for lower frequencies (longer wavelengths)
- Atmospheric Absorption
  - Water vapour and oxygen absorb radio signals
  - Water greatest at 22GHz, less below 15GHz
  - Oxygen greater at 60GHz, less below 30GHz
  - Rain and fog scatter radio waves
- Multipath
  - Better to get line of sight if possible
  - Signal can be reflected causing multiple copies to be received
  - May be no direct signal at all
  - May reinforce or cancel direct signal
- Refraction
  - May result in partial or total loss of signal at receiver

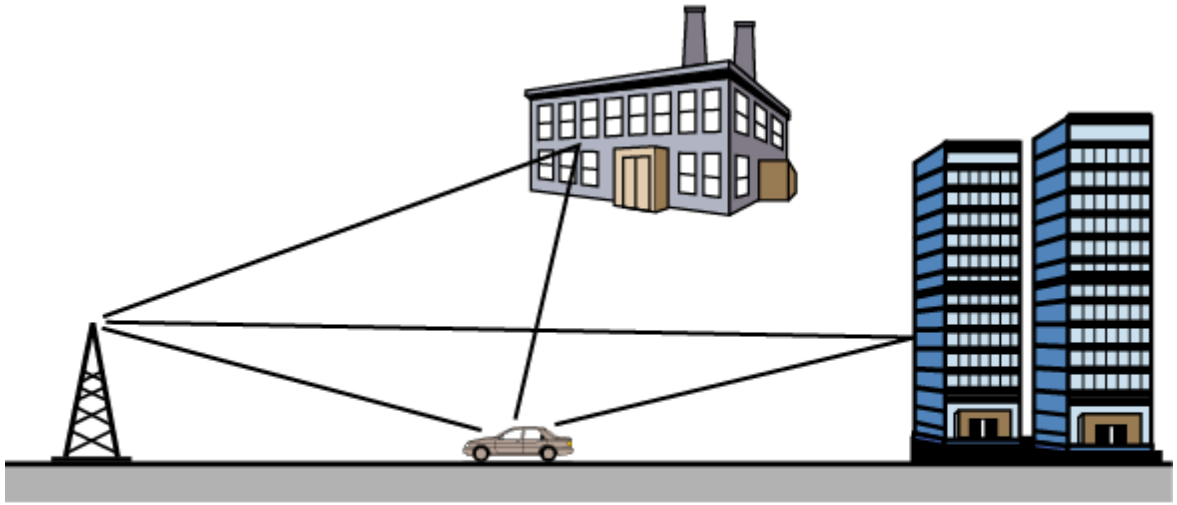
Free Space Loss



Multipath Interference



(a) Microwave line of sight



(b) Mobile radio

Required Reading

- Stallings Chapter 4