







	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











	Category 3 Class C	Category 5 Class D	Category 5E	Category 6 Class E	Category 7 Class F
Bandwidth	16 MHz	100 MHz	100 MHz	200 MHz	600 MHz
Cable Type	UTP	UTP/FTP	UTP/FTP	UTP/FTP	SSTP
Link Cost (Cat 5 =1)	0.7	1	1.2	1.5	2.2
					11

## Comparison of Shielded and Unshielded Twisted Pair

	Attenuation (dB per 100 m)			Near-end Crosstalk (dB)		
Frequency (MHz)	Category 3 UTP	Category 5 UTP	150-ohm STP	Category 3 UTP	Category 5 UTP	150-ohm STP
1	2.6	2.0	1.1	41	62	58
4	5.6	4.1	2.2	32	53	58
16	13.1	8.2	4.4	23	44	50.4
25		10.4	6.2	—	41	47.5
100		22.0	12.3	_	32	38.5
300		_	21.4		_	31.3
						12

















FREQUEN APPLICAT	CY UTILIZA IONS	ATION F	FOR FIBER	
Wavelength (in vacuum) range (nm)	Frequency Range (THz)	Band Label	Fiber Type	Application
820 to 900	366 to 333		Multimode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	С	Single mode	WDM
1561 to 1620	192 to 185	L	Single mode	WDM
				21



































## REFRACTION

- velocity of electromagnetic wave is a function of the density of the medium through which it travels
  - ~3 x 10<sup>8</sup> m/s in vacuum, less in anything else
- o speed changes with movement between media
- o index of refraction (refractive index) is
  - sine(incidence)/sine(refraction)
  - varies with wavelength

## o gradual bending

 density of atmosphere decreases with height, resulting in bending of radio waves towards earth





FREE SPACE LOSS  

$$\frac{P_{t}}{P_{r}} = \frac{(4\pi d)^{2}}{\lambda^{2}} = \frac{(4\pi f d)^{2}}{c^{2}}$$

$$L_{dB} = 10\log \frac{P_{t}}{P_{r}}$$

$$= 20\log \frac{4\pi d}{\lambda} = -20\log \lambda + 20\log d + 21.98dB$$

$$= 20\log \frac{4\pi f d}{c} = 20\log f + 20\log d - 147.56dB^{-42}$$







SUMMARY	
• transmission Media	
• physical path between transmi	itter and receiver
<ul> <li>bandwidth, transmission impa receivers</li> </ul>	irments, interference, number of
oguided Media	
• twisted pair, coaxial cable, opti	ical fiber
• wireless Transmission	
• microwave frequencies	
<ul> <li>antennas, terrestrial microway radio</li> </ul>	ve, satellite microwave, broadcast
• wireless Propagation	
• ground wave, sky wave, line of	sight
	46