Introduction to Communications

SCHOOL ON RADIO USE FOR DIGITAL AND MULTIMEDIA COMMUNICATIONS

ICTP, February 2002

Ermanno Pietrosemoli

Ermanno@ula.ve

Latin American Networking School

University of Los Andes

Merida- Venezuela

Introduction to Communication

- Transmission Basic
- Guided Media
- Non Guided Media
- Spectrum Utilization Strategies
- Access Techniques
- Evolution of Communications
- Communication Standards

Transmission Media

- All based in electromagnetic waves
- Transmission speed comparable with that of light, $c = 300$ Mm/s
- Attenuation increases with distance
- Subjects to interference and Noise
- Limits on Bandwidth

Transmission Media

Ideal Channel:

- Constant Attenuation
- Constant Delay

Transmission Media

Real Channel:

- Variable Attenuation

(Amplitude Distorsion)

- Phase or delay Distorsion

Transmission Media

Crosstalk

- NEXT
- FEXT

NEXT:
Near End Cross Talk

Parasitic coupling of energy from one circuit to another

That originates in the same end

Attenuation

Any signal will diminish in strength while moving from the Tx to the Rx.

In logarithmic units the attenuation is given by:

$$dB = 10\log\left(\frac{\mathrm{Pr}}{Pt}\right)$$

Absolute Power

Absolute Power can be expressed logarithmically by comparing with a specified reference:

$$dBm = 10\log\left(\frac{\Pr}{1mW}\right)$$

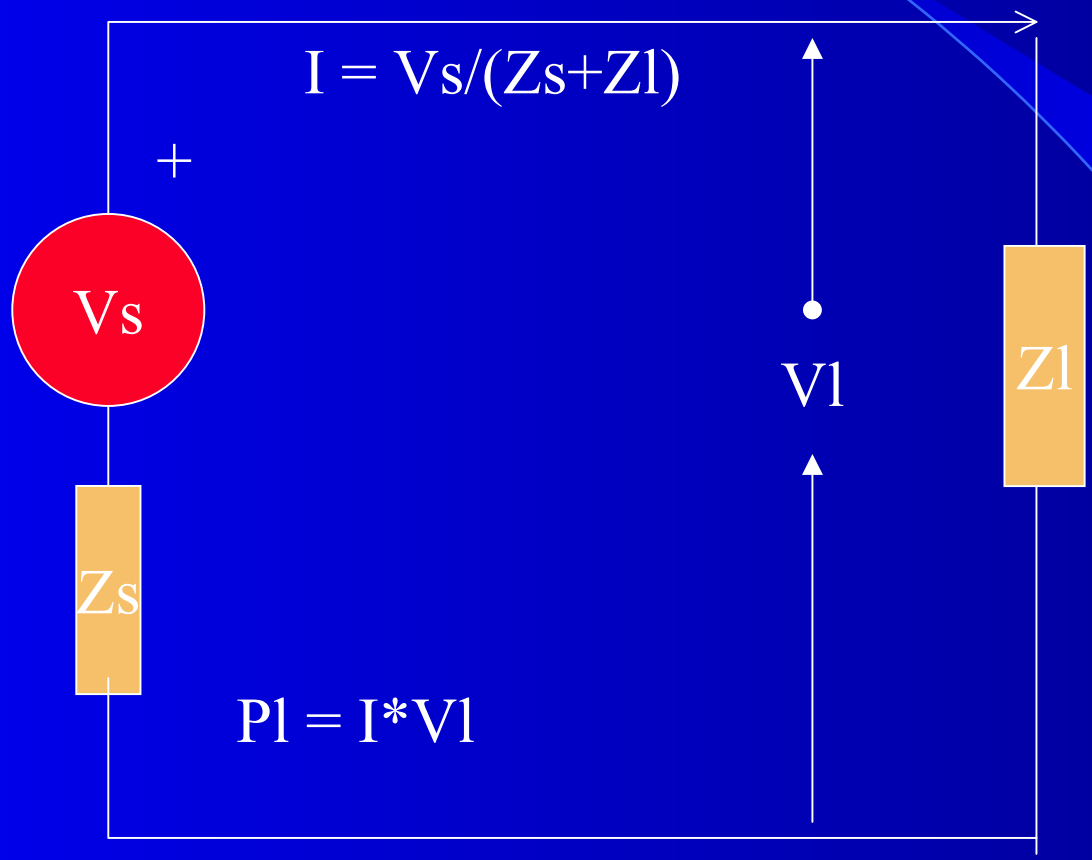
Power: mW or dBm

(mW)	dBm
1	0
10	10
20	13
100	20
1000	30
0.5	-3
0.1	-10
0.01	-20

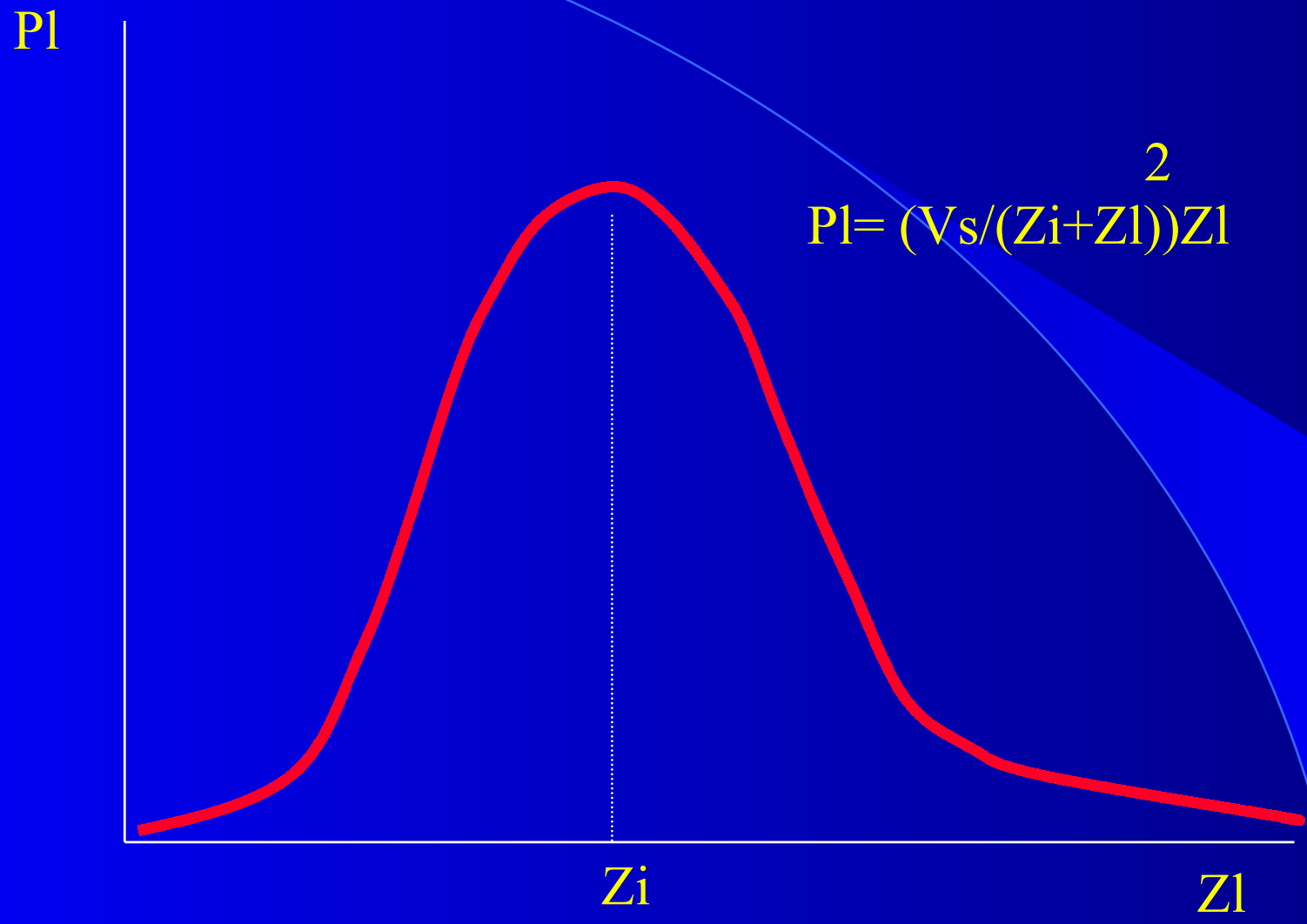
Bandwidth

- Transmission speed in bits/s is proportional to bandwidth in Hz
- The factor depends on the modulation technique employed (bandwidth efficiency)

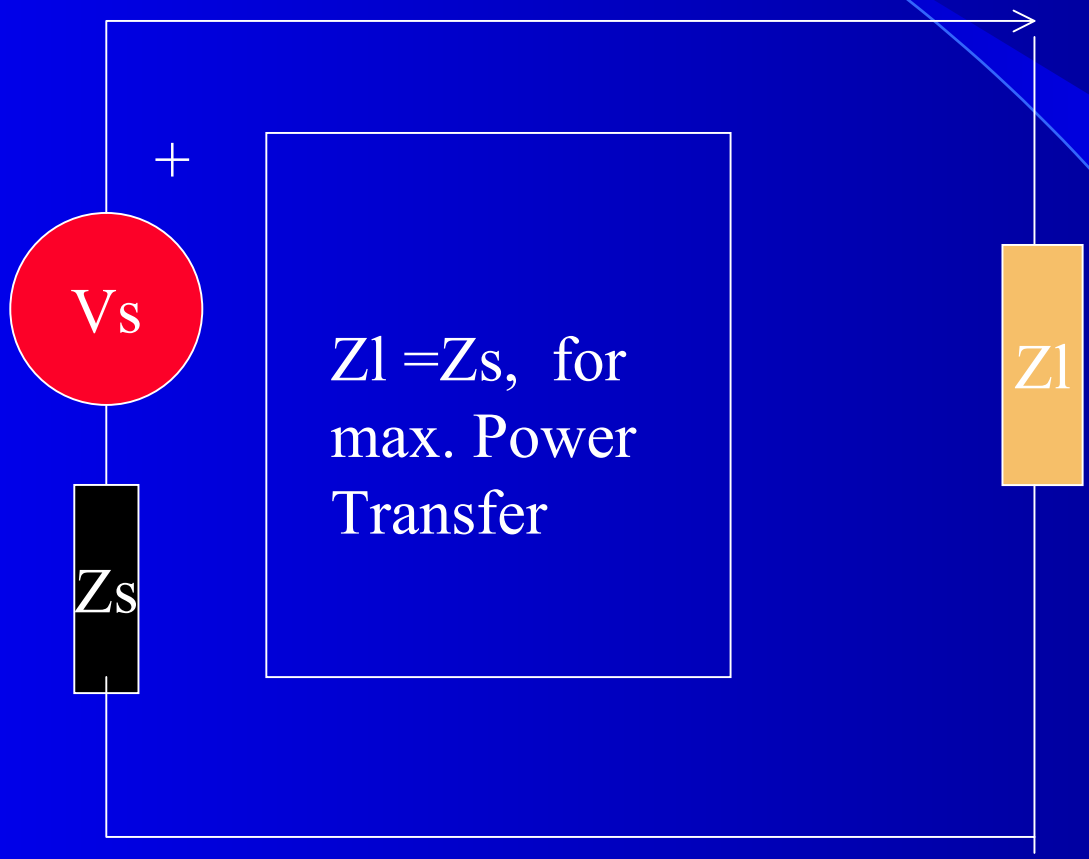
Maximum Power Transfer



Power delivered to a load



Impedance Matching



Impedance Matching

Impedance Matching is measured by VSWR (Voltage Standing Wave Ratio).

Ideally unit

When greater than 2, excessive reflected power.

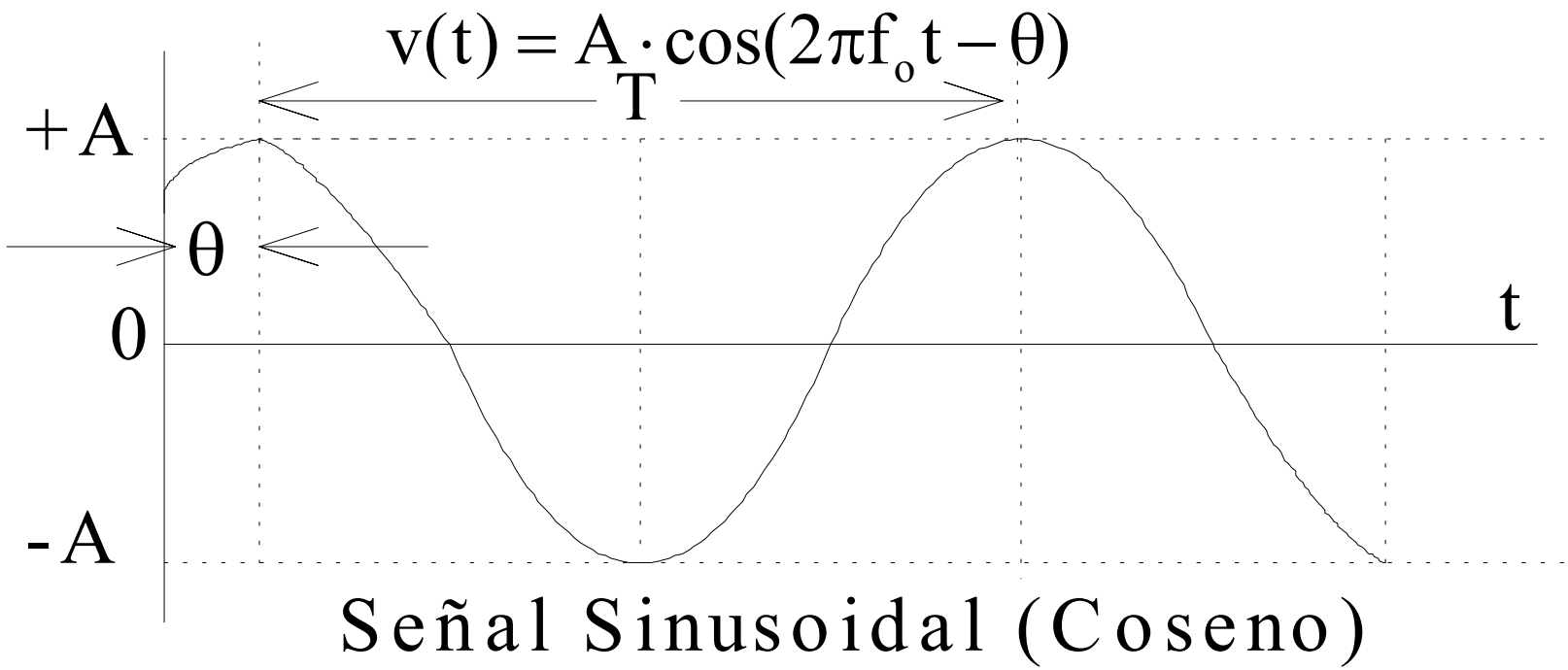
Impedance Matching

- Standing wave is measured by a Wattmeter.
- VSWR= (Pi+Pr)/(Pi-Pr)

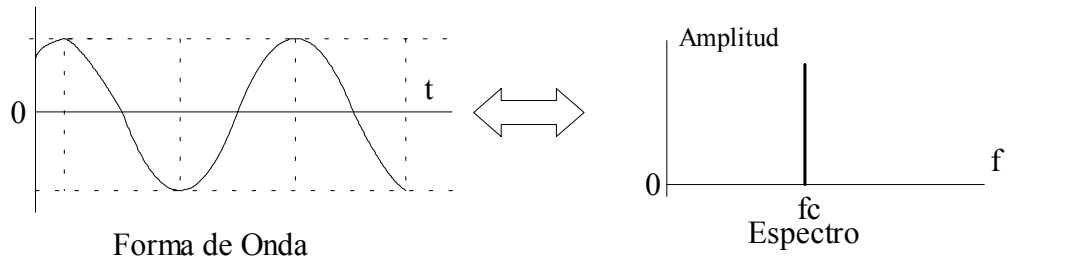
Fundamental Concepts

- Antennas physical dimension > $\lambda/10$
- Transmission Bandwidth proportional to carrier frequency B < fc/10

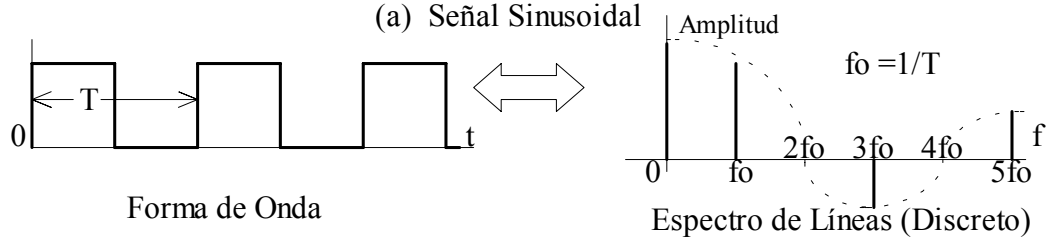
Sinusoidal Signal



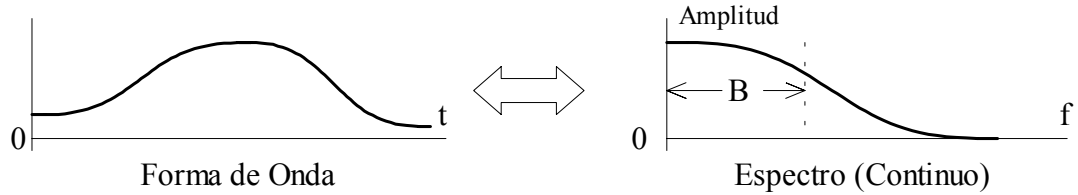
Waveshapes and spectrum



(a) Señal Sinusoidal



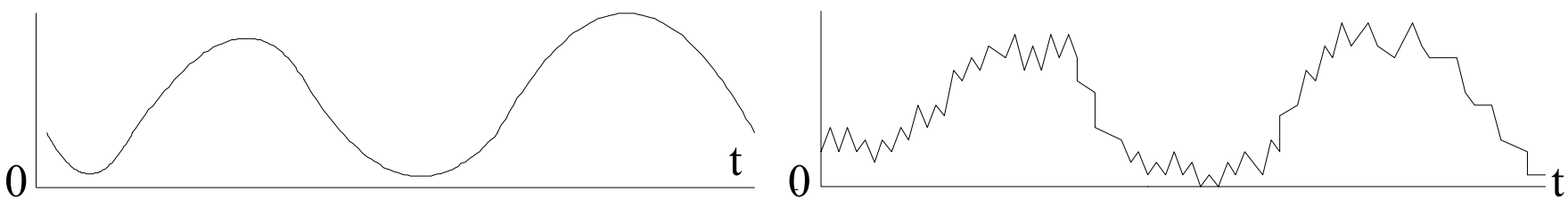
(b) Señal Periódica Rectangular (de Potencia)



(c) Señal Aperiódica (de Energía)

Electrical Noise

Random perturbation that impairs communication



(a) Señal sin Ruido (b) Señal con Ruido

Fig. 1.7. Efecto del Ruido sobre una Señal.

Signal to Noise Ratio

S/N= (Average Signal Power)/(Noise Power)

In dB,

$$\left[\frac{S}{N}\right](dB) = 10 \cdot \log_{10}\left(\frac{S}{N}\right) \quad dB$$

Transmission Media Types

Guided:

- Twisted pair
- Coaxial
- Optical Fibre

Non Guided:

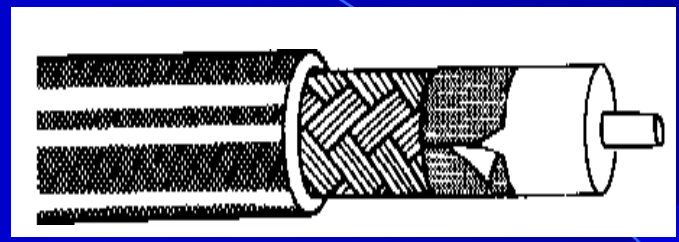
- Radio Frequencies
- Microwaves
- Infrared

How can one transmit a signal?

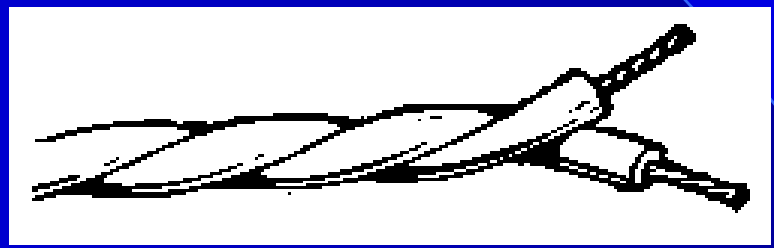
- One conducting wire, ground return, cheap but greatly affected by interference and noise. Used in the early telegraphic systems, it was soon replaced by two parallel wires.
- Two parallel wires, diminishes interference, but it is better if twisted, the more the twisting, the highest the frequency response

Guided Media

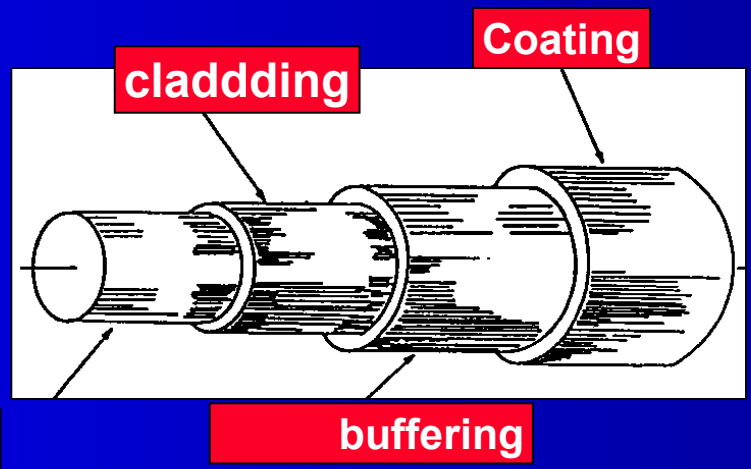
Coaxial Cable



Twisted Pair



Optical Fibre

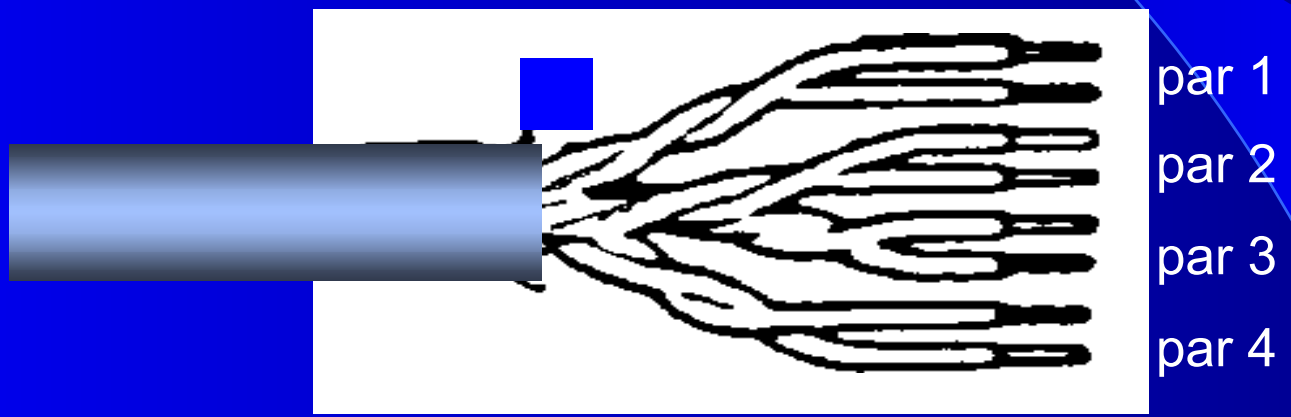


Twisted Pair

- Can be Shielded (STP) to further reduce interference, or Unshielded (UTP) for easier installation
- Most cost effective for short distances
- Easy to install and terminate
- Can support up to 250 Mbps at short distances

UTP Zo 100 Ω

- Unshielded Twisted Pair



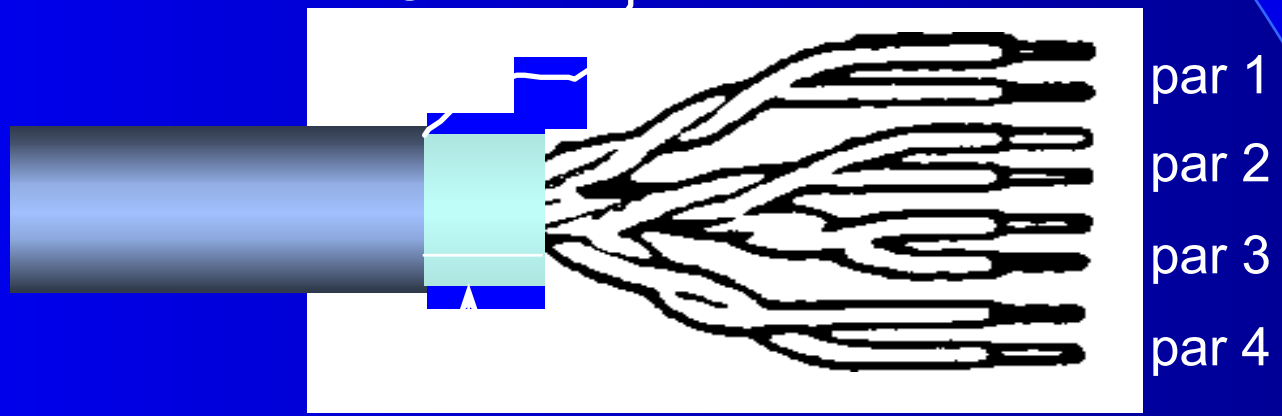
Horizontal UTP Cable Attenuation/Xtalk in dB (worst pair)

Frec. (MHz)	Cat. 3	Cat. 4	Cat. 5
0.064	0.9/-	0.8/-	0.8/-
0.150	-/53	-/68	-/74
0.256	1.3/-	1.1/-	1.1/-
0.512	1.8/-	1.5/-	1.5/-
0.772	2.2/43	1.9/58	1.9/64
1.0	2.6/41	2.1/56	2.1/62
4.0	5.6/32	4.3/47	4.3/53
8.0	8.5/27	6.2/42	5.9/48
10.0	9.8/26	7.2/41	6.6/47
16.0	13.1/23	8.9/38	8.2/44
20.0	-/-	10.2/36	9.2/42
25.0	-/-	-/-	10.5/41

Cable FTP de 100 Ω

- Foildeed Twisted Pair

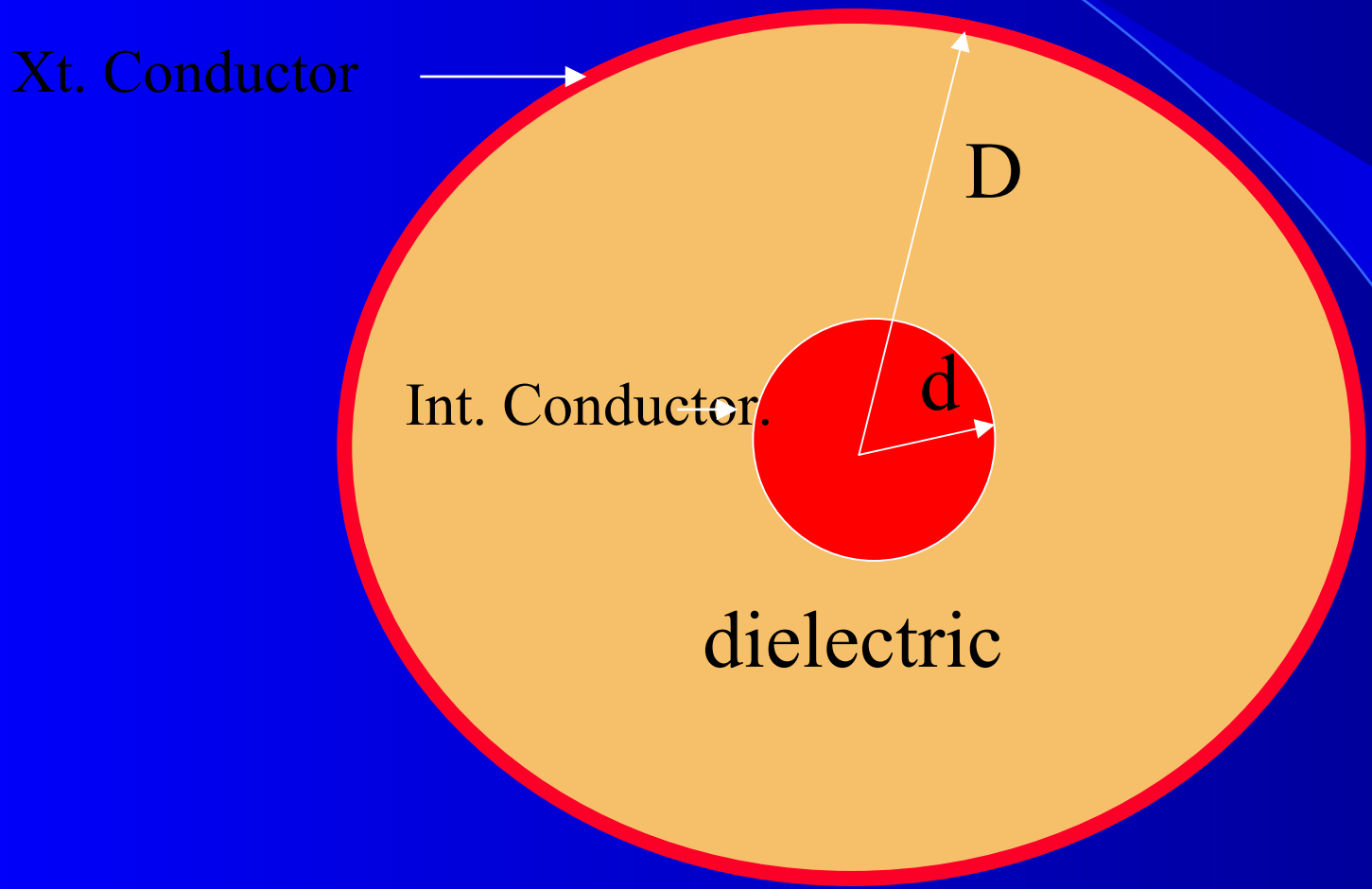
Conducting wire preserves continity of shield



Coaxial Cable

- Inner conductor inside a flexible metallic cover, separated by a dielectric
- External cover can be a mesh, and is always coated by a protective insulator.

Coaxial Cable



Attenuation of Coaxial Cable

$$at = k \frac{\sqrt{f}}{\log(D/d)} \left(1/D + 1/d\right)$$

k = Constant affected by dielectric material

f = frequency in Hz

D= Internal diameter of cover

d= internal conductor diameter

Coaxial Cable

- Attenuation proportional to square root of frequency and inversely proportional to diameter.
- The ratio between conductors diameters specifies characteristic impedance
- Propagation speed between 0.7c and 0.9c

Coaxial Cable

No longer recommended in local area networks, it is being substituted by UTP at short distances an Fibre at long distances

Still widely used in TV distribution and for connecting radios to antennas.

Attenuation of common coaxials in dB/ 100 ft (dB/ 100 m)

Tipo de Cable	144 MHz	220 MHz	450 MHz	915 MHz	1.2 GHz	2.4 GHz	5.8 GHz
RG-58	6.2 (20.3)	7.4 (24.3)	10.6 (34.8)	16.5 (54.1)	21.1 (69.2)	32.2 (105.6)	51.6 (169.2)
RG-8X	4.7 (15.4)	6.0 (19.7)	8.6 (28.2)	12.8 (42.0)	15.9 (52.8)	23.1 (75.8)	40.9 (134.2)
LMR-240	3.0 (9.8)	3.7 (12.1)	5.3 (17.4)	7.6 (24.9)	9.2 (30.2)	12.9 (42.3)	20.4 (66.9)
RG-213/214	2.8 (9.2)	3.5 (11.5)	5.2 (17.1)	8.0 (26.2)	10.1 (33.1)	15.2 (49.9)	28.6 (93.8)
9913	1.6 (5.2)	1.9 (6.2)	2.8 (9.2)	4.2 (13.8)	5.2 (17.1)	7.7 (25.3)	13.8 (45.3)

LMR-400	1.5 (4.9)	1.8 (5.9)	2.7 (8.9)	3.9 (12.8)	4.8 (15.7)	6.8 (22.3)	10.8 (35.4)
3/8" LDF	1.3 (4.3)	1.6 (5.2)	2.3 (7.5)	3.4 (11.2)	4.2 (13.8)	5.9 (19.4)	8.1 (26.6)
LMR-600	0.96 (3.1)	1.2 (3.9)	1.7 (5.6)	2.5 (8.2)	3.1 (10.2)	4.4 (14.4)	7.3 (23.9)
1/2" LDF	0.85 (2.8)	1.1 (3.6)	1.5 (4.9)	2.2 (7.2)	2.7 (8.9)	3.9 (12.8)	6.6 (21.6)
7/8" LDF	0.46 (1.5)	0.56 (2.1)	0.83 (2.7)	1.2 (3.9)	1.5 (4.9)	2.3 (7.5)	3.8 (12.5)
1 1/4" LDF	0.34 (1.1)	0.42 (1.4)	0.62 (2.0)	0.91 (3.0)	1.1 (3.6)	1.7 (5.6)	2.8 (9.2)
1 5/8" LDF	0.28 (0.92)	0.35 (1.1)	0.52 (1.7)	0.77 (2.5)	0.96 (3.1)	1.4 (4.6)	2.5 (8.2)

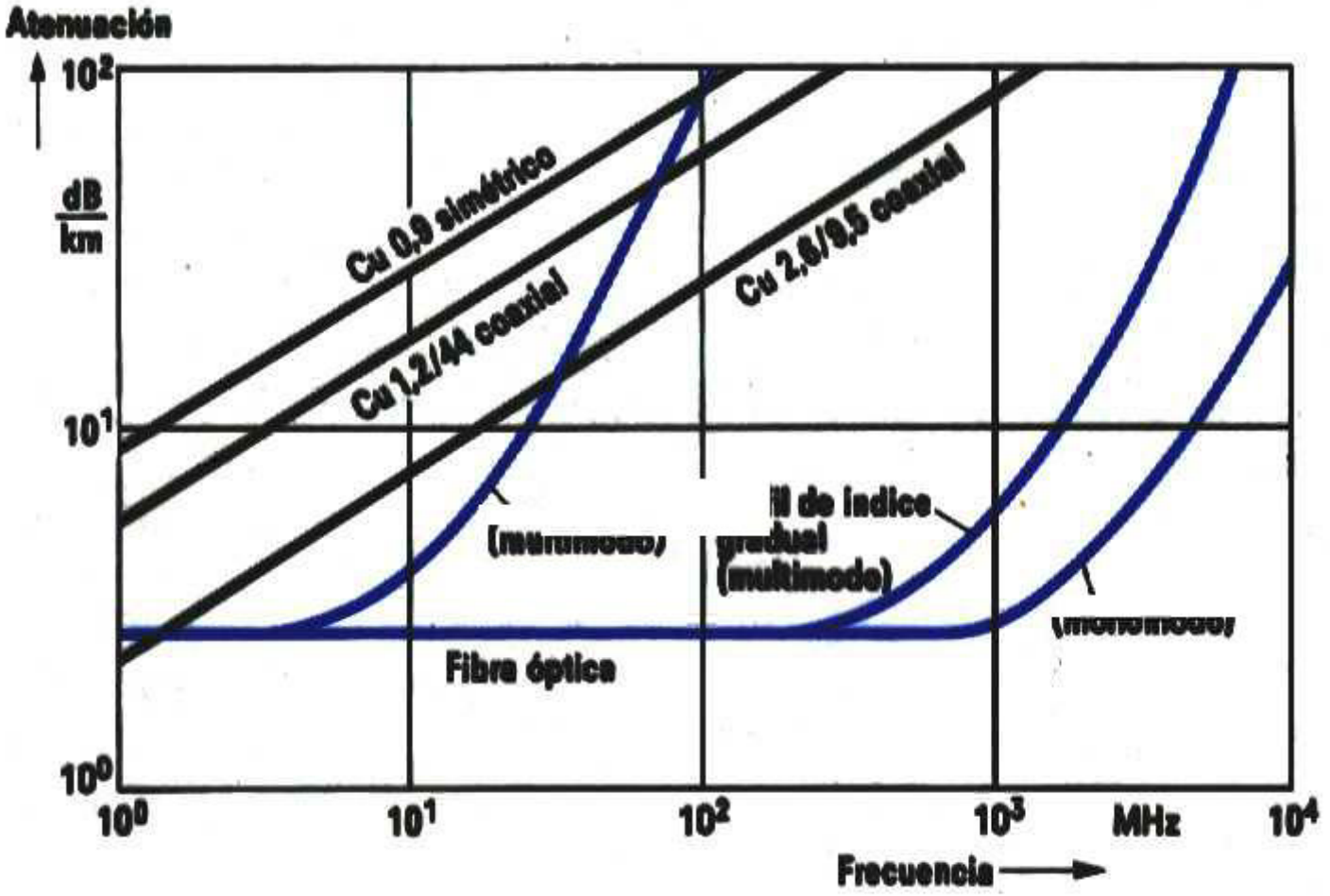
Coaxial Cable Connectors

- BNC, good for low frequencies, not waterproof, bayonet style
- TNC, similar, but waterproof and improved frequency response, widely used in cellular phone networks
- Type F, threaded, interior use up to 900 MHz
- Type UHF, (PL59), only VHF, bigger, threaded not weatherproof
- Type N, weatrherproof, threaded, useful for UHF
- SMA, threaded, low loss, interior only

Optical Fibre

- Greatest bandwidth (> 40 Gbps) and lowest attenuation (< 0.2 dB/km)
- Immune to interference and tapping
- Thinner and lighter than copper
- Needs right of way
- Special tools and techniques for installing

Transmission Media Comparison:

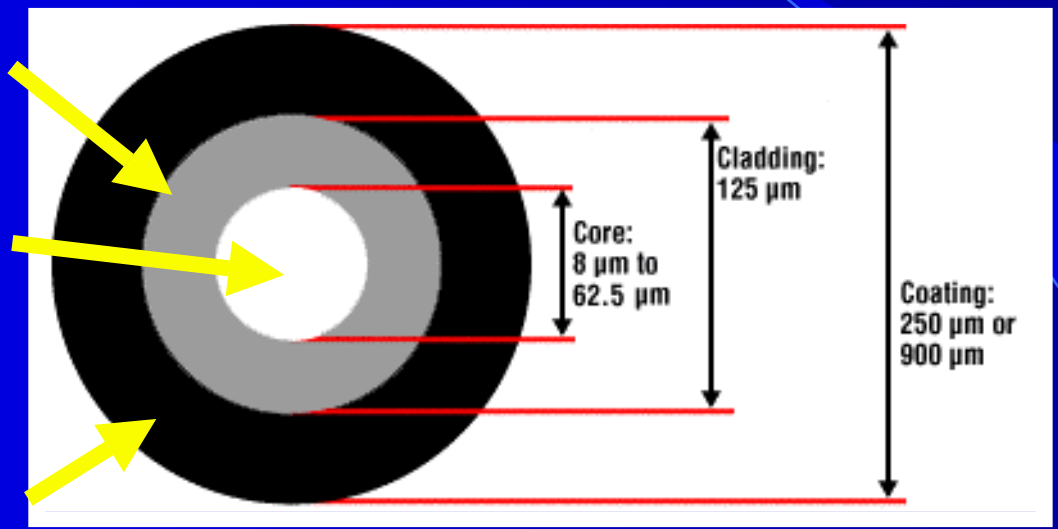


Optical Fibre Structure

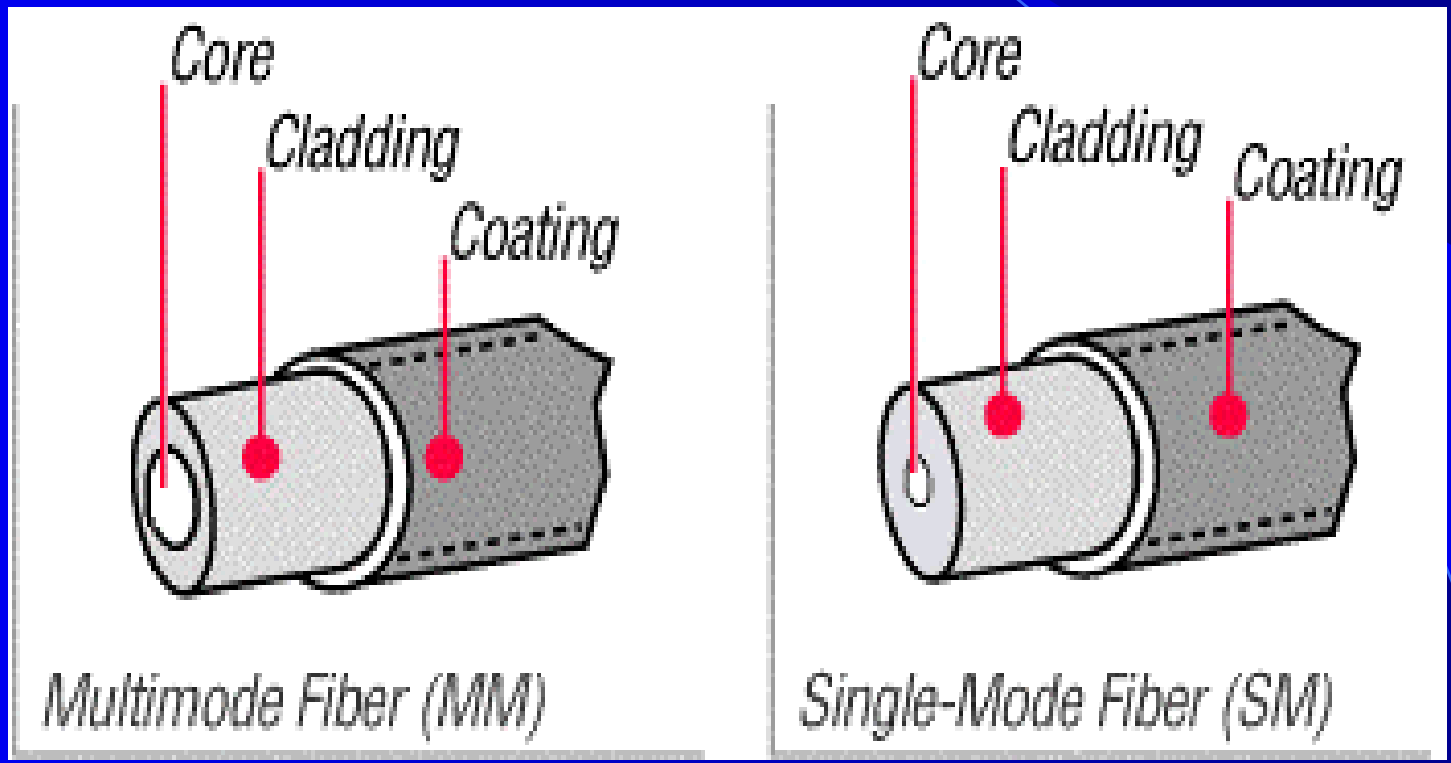
Cladding

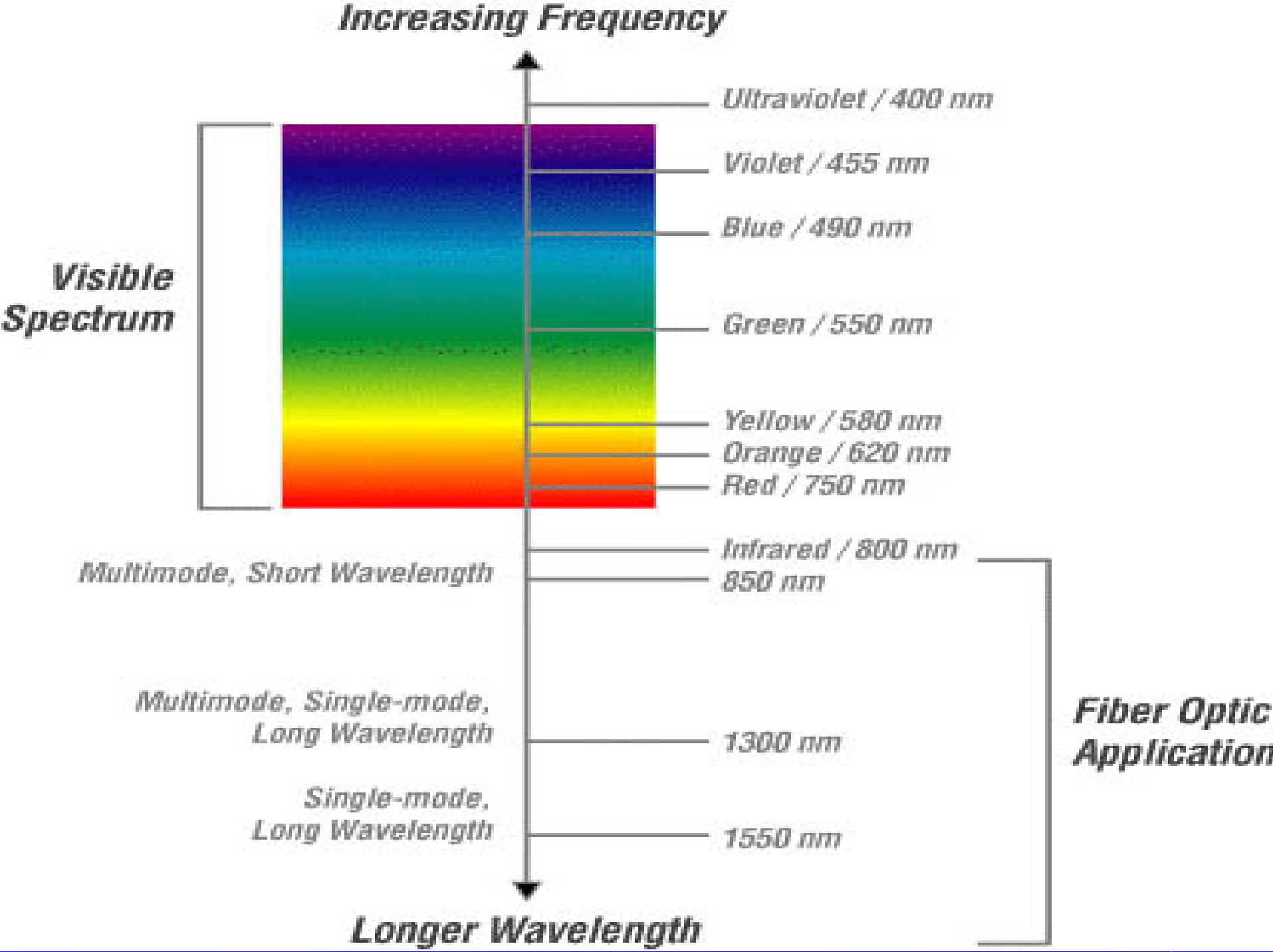
Core

Coating



Multimode and Single Mode Fibres




Increasing Frequency
Ultraviolet / 400 nm
Violet / 455 nm
Blue / 490 nm
Visible Spectrum
Green / 550 nm
Yellow / 580 nm
Orange / 620 nm
Red / 750 nm
Infrared / 800 nm
Multimode, Short Wavelength
850 nm
Multimode, Single-mode, Long Wavelength
1300 nm
Single-mode, Long Wavelength
1550 nm
Fiber Optic Application
Longer Wavelength

Role of Wiring in Networking

- 40% of emlpoyees move inside same building each year.
- 70% of faults cabling related.
- Cabling represents about 5% of the local network cost.
- Least subject to obsolescence.

Non Guided Media

- EM waves can be efficiently radiated by suitable antennas
- Since Marconi's 1898 demonstration of the feasibility of radio communications the spectrum availability in a given area has been steadily increasing

Non Guided Media

- AM, 75 m antenna, fc = 1 MHz, fm = 5 kHz
- FM, 2 m antenna, fc = 100 MHz, fm =15 kHz
- $f = c/\lambda$, c = 300 000 km/s
- The higher the carrier frequency, more bandwidth available but less range
- Lower frequencies guided by earth surface and reflected by ionosphere

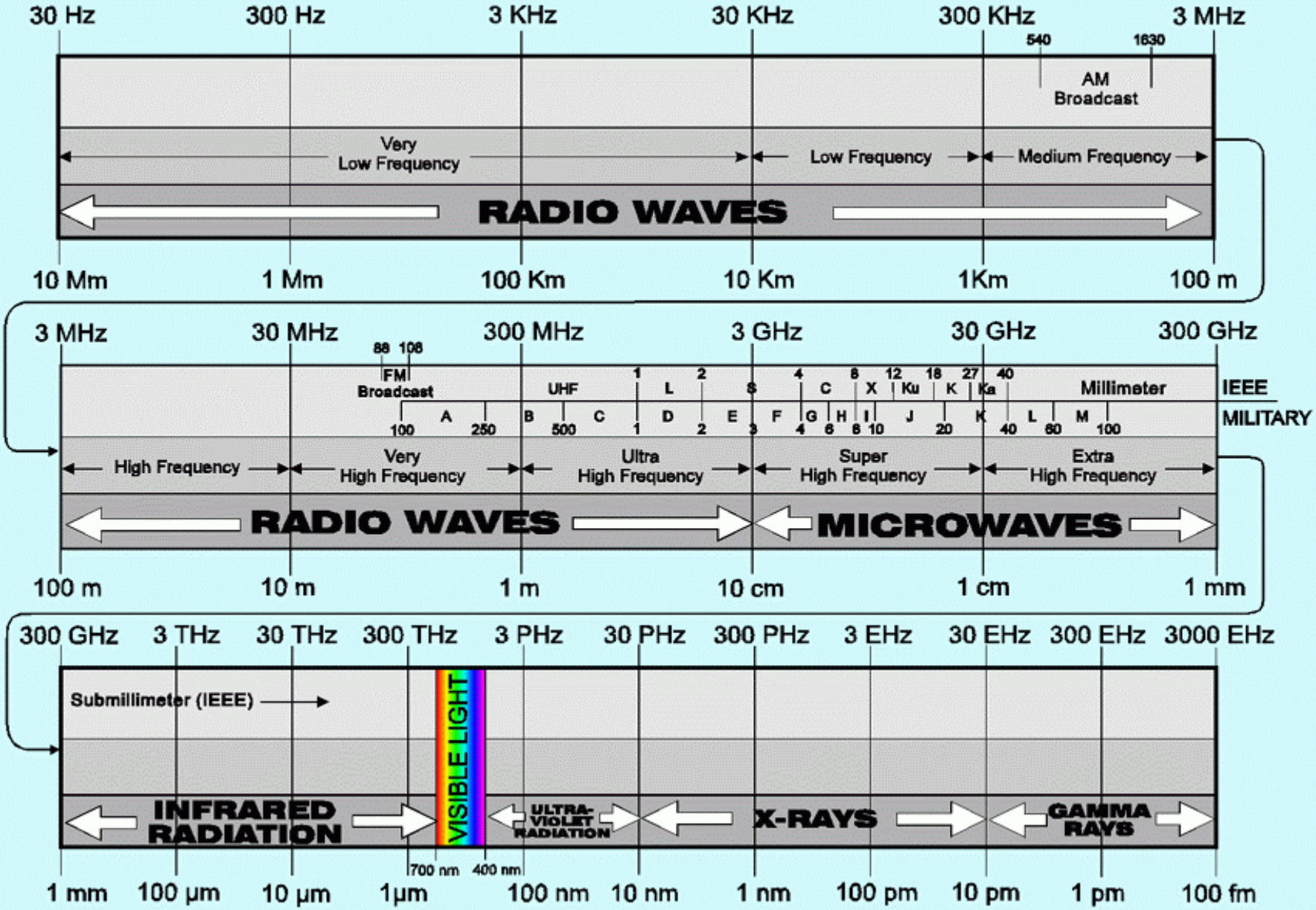
SI Units prefixes

Name	Symbol	Power of 10
atto	a	-18
femto	f	-15
pico	p	-12
nano	n	-9
micro	μ	-6
mili	m	-3
centi	c	-2
deci	d	-1

SI Units prefixes

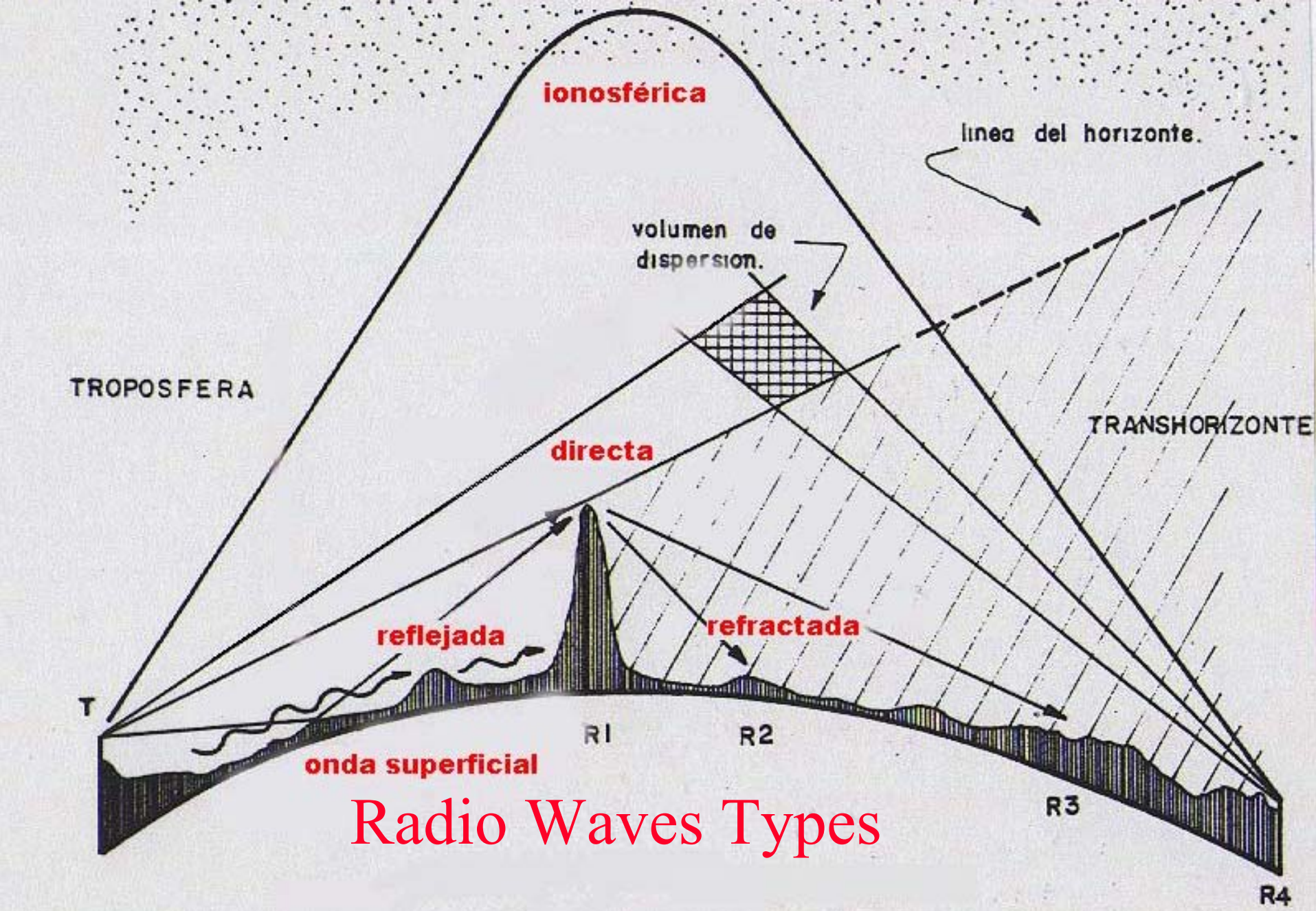
Name	Symbol	Power of 10
exa	E	18
peta	P	15
tera	T	12
giga	G	9
mega	M	6
kilo	k	3
hecto	h	2
deca	D	1

RADIO FREQUENCY SPECTRUM



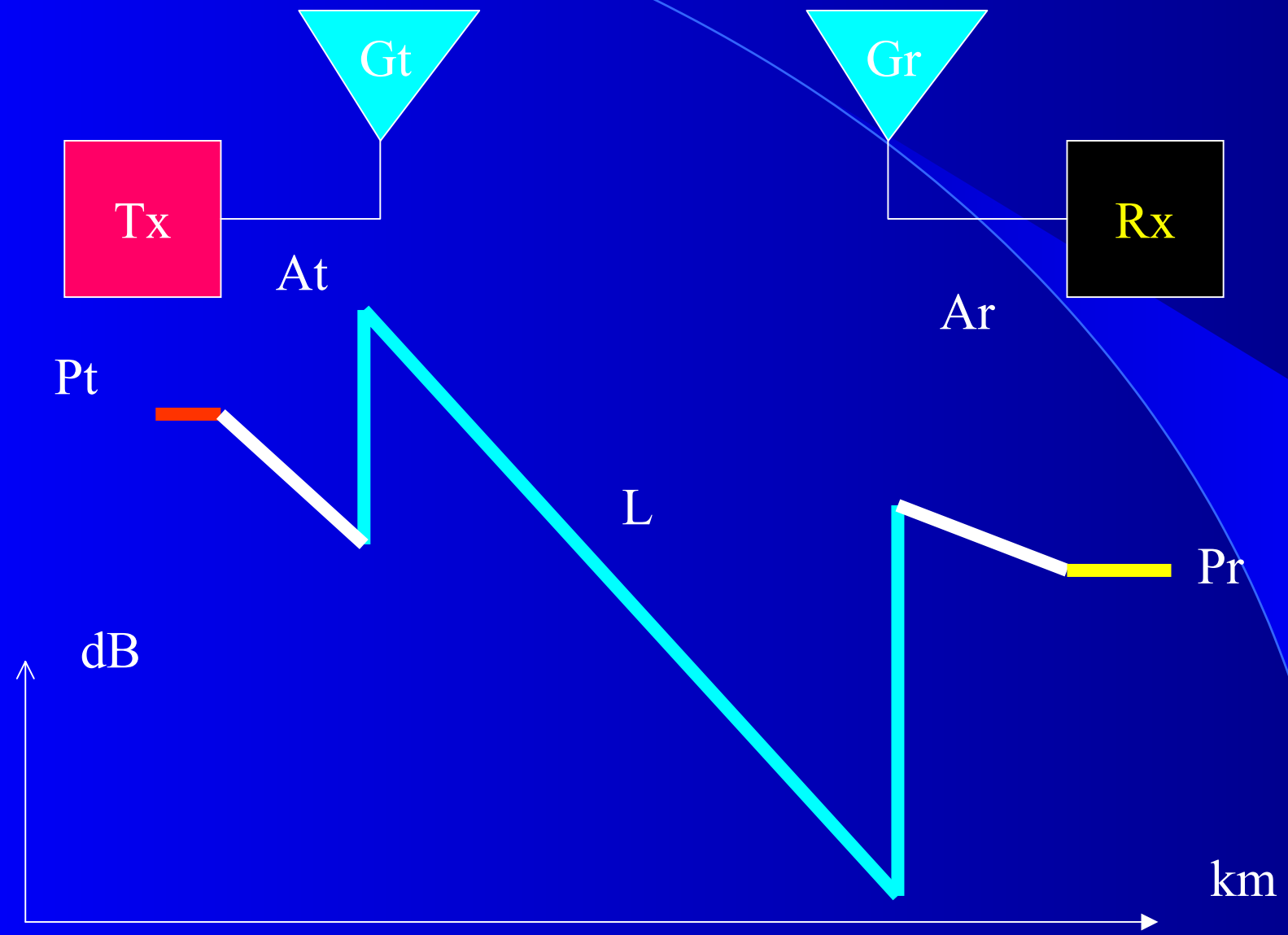
Radio Wave Propagation

- Direct wave
- Ground or Surface wave
- Reflected Wave
- Ionosferic Reflection
- Obstacle Refraction
- Earth Curvature
- Multipath



Radio Waves Types

Schematic Radio Transmission

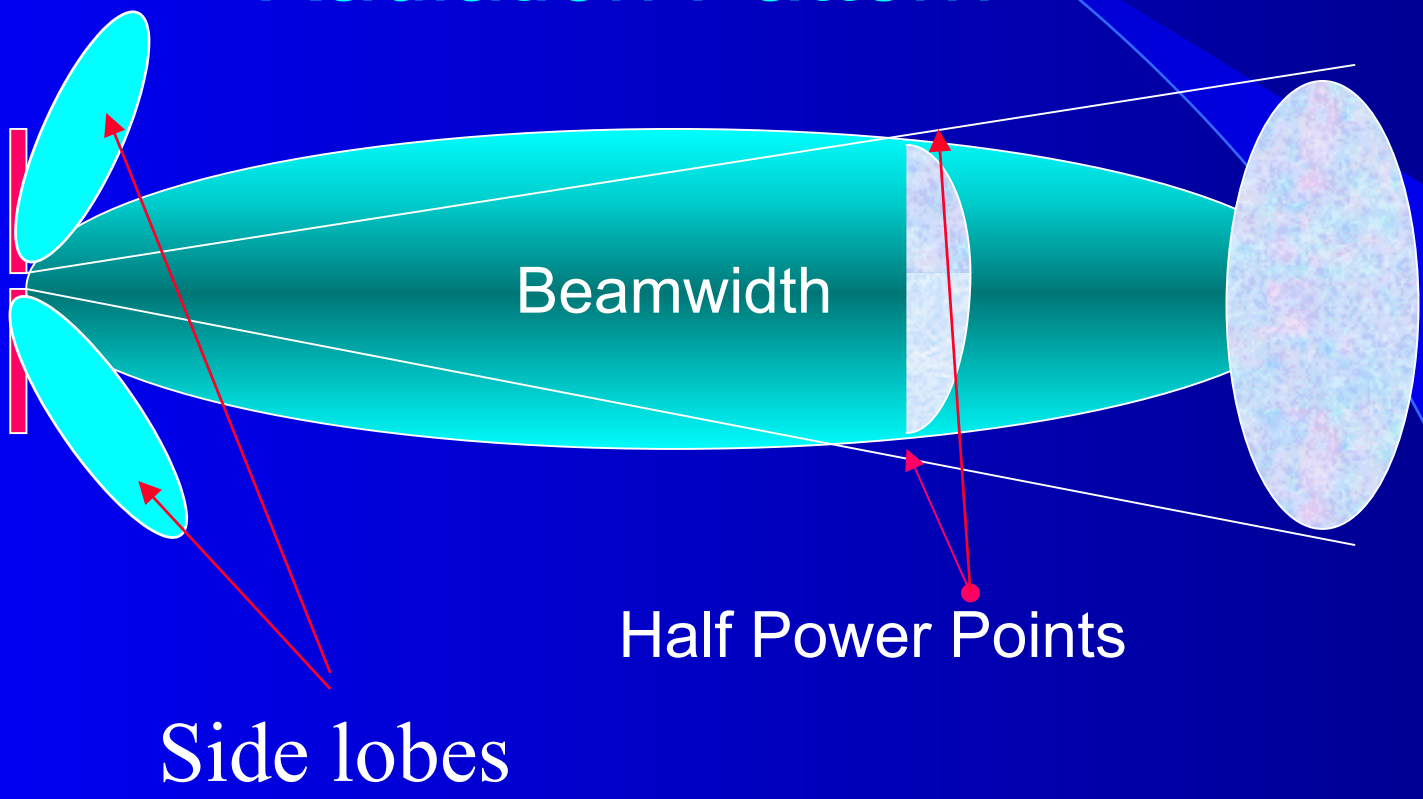


Elements of a Transmission System

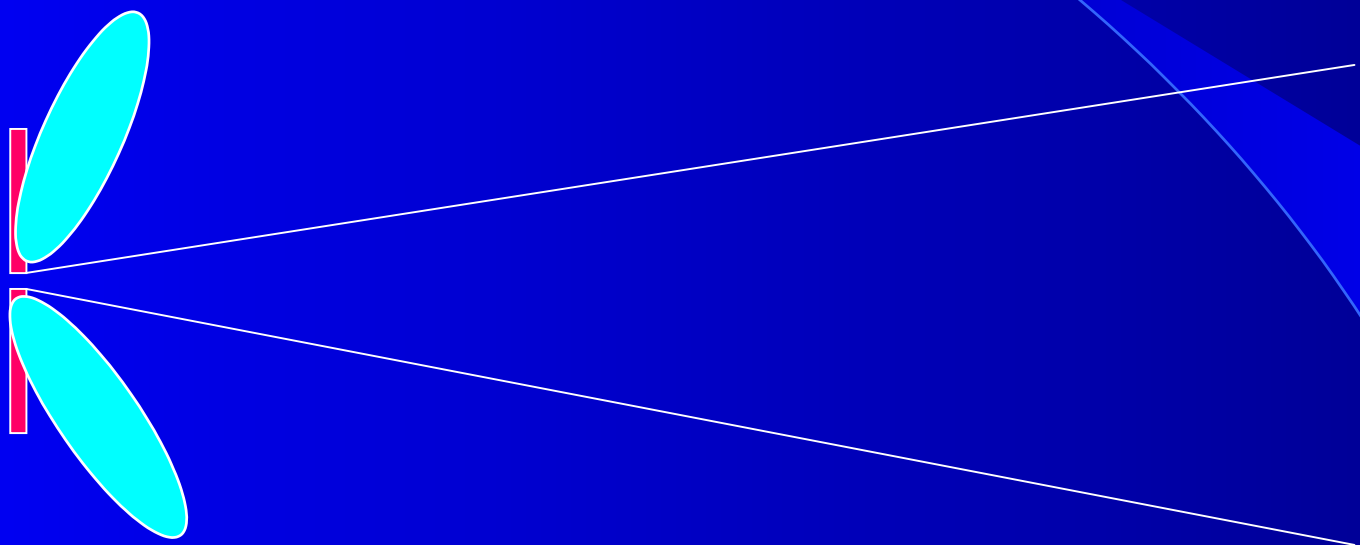
- Transmitter
- Connecting cable or waveguide
- Antennas
- Receiver
- Power Supply, Grounding and Lightning Protection

Antenna Features

Radiation Pattern



Antenna Features



Antenna Features

- Gain = Directivity X Efficiency
- Beam width
- Bandwidth (VSWR)
- Characteristic Impedance
- Effective Aperture
- “Bora” Resistance !

Antenna Polarization

Polarization corresponds to the direction of the electric field transmitted by the antenna

- Vertical
- Horizontal
- Elliptyc (RH or LH)

Polarization mismatch can induce up to 20 dB loss

Transmission Bandwidth

- Classical systems strive to use as little bandwidth as possible
- Alternative systems spread the signal over wide chunks of frequencies, but at a lower power so that the spectrum can be shared
- Either systems can yield high spectrum efficiency

Transmission Bandwidth

- Narrow Systems
- Spread Spectrum Systems
- Ultra Wide Band

Spread Spectrum

(*Pseudo Noise Sequence*) also called *Direct Sequence*

(*Frequency Hopping*)

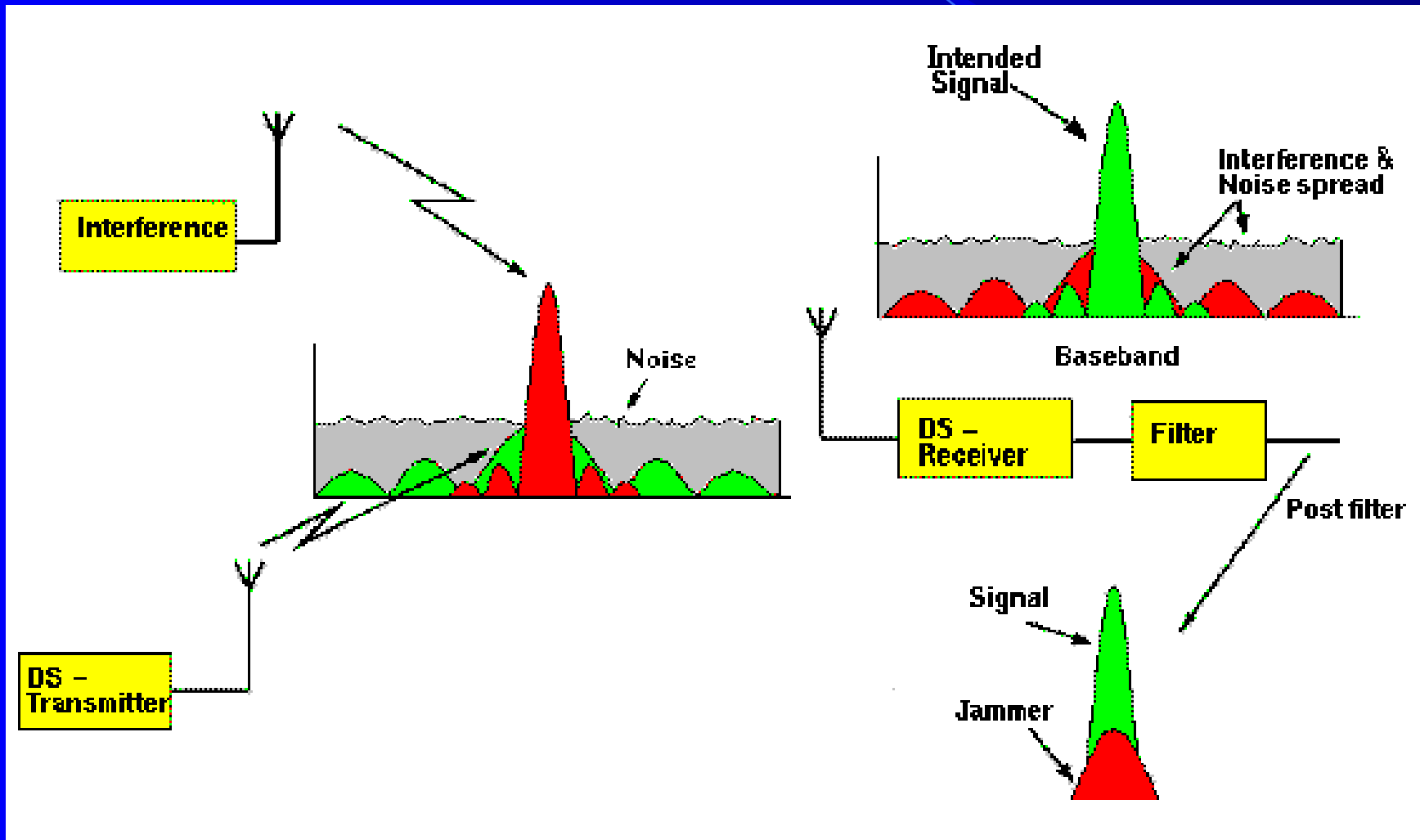
Spread Spectrum ISM Bands

902~928 MHz , USA only

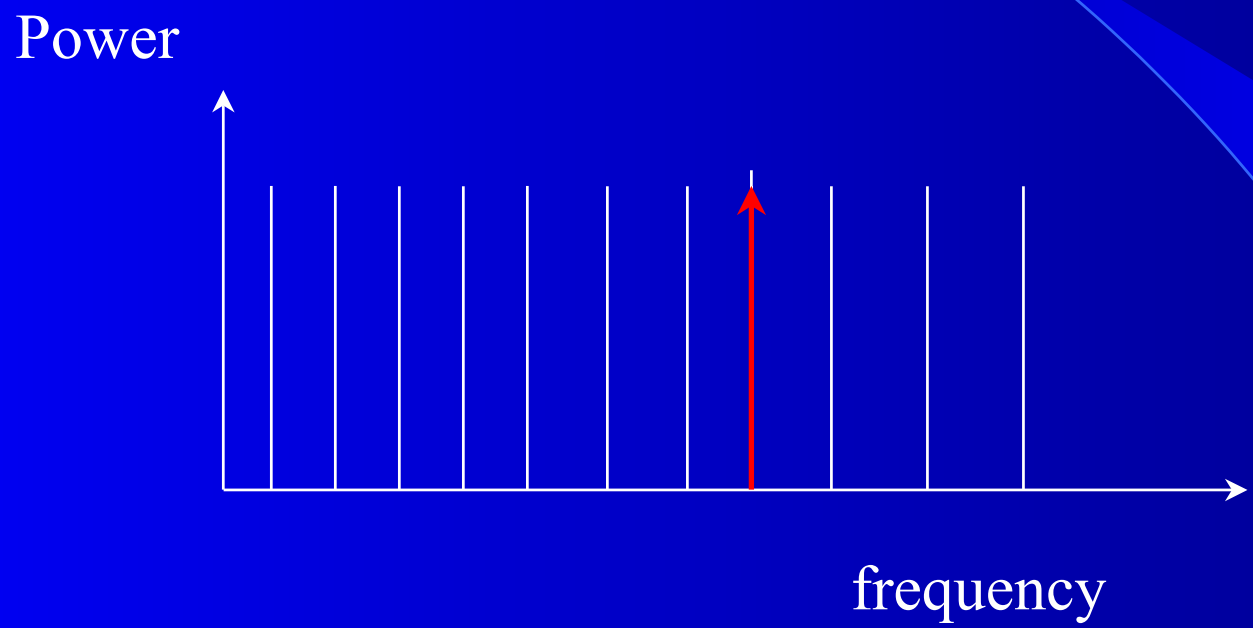
2.4 ~2.484 GHz, Worldwide

5.8 GHz, USA

DSSS Signals Spectrum



Frequency Hopping Spread Spectrum



ULTRA WIDE BAND

- Transmission technique employing very narrow pulses that occupy a very large bandwidth (greater than 25 % of the carrier frequency) but very little power (supposedly indistinguishable from ambient noise), capable of great transmission speed and with imaging and position capabilities

ULTRA WIDE BAND

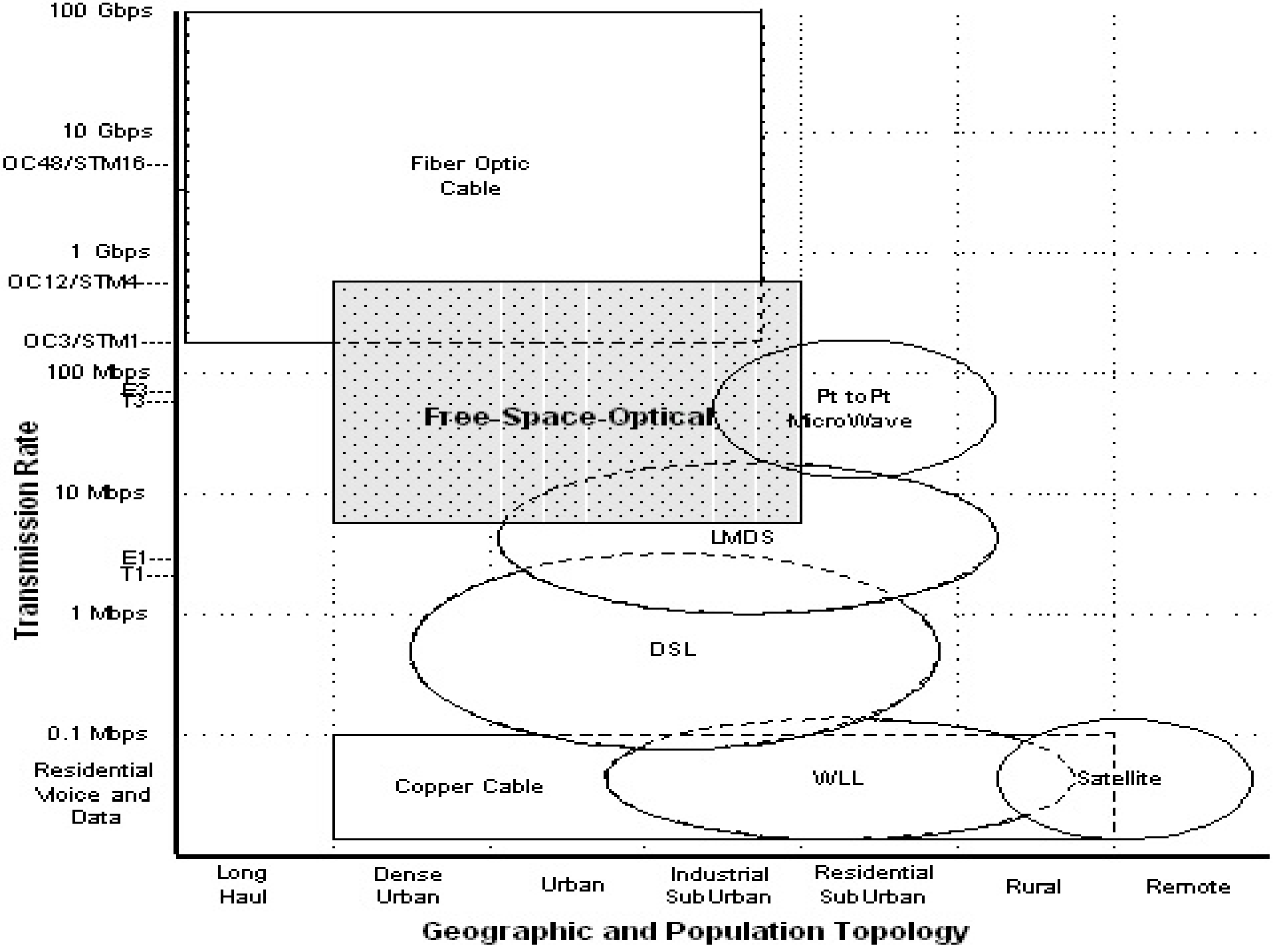
- ULTRAWIDEBAND GETS FCC NOD, DESPITE PROTESTS
- A growing spectrum shortage will not affect UWB because it shares spectrum with other technologies. The technology also offers easy signal encryption and can be used in small communications devices because of its low power requirements. The FCC plans to address interference concerns by prohibiting the use of UWB below the 3.1 GHz band, as well as restricting the power of UWB devices
- (Wall Street Journal, 15 February 2002)

Optical Space Transmission

- Light has been used since antiquity to transmit signals at a distance
- The first modern system was built by Chappe in France “Optical Telegraph”
- Current systems limited to few kilometers range, but offer speeds up to hundreds of Mbps

Optical Space Transmission

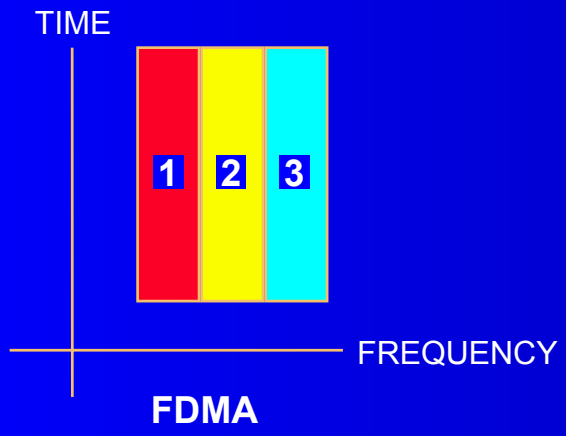
- Local Area Networks
- Point to Point Systems
- Outer Space Systems


100 Gbps
10 Gbps
OC48/STM16
Fiber Optic Cable
1 Gbps
OC12/STM4
OC3/STM1
100 Mbps
E3
T3
Free-Space-Optical
Pt to Pt MicroWave
10 Mbps
LMDS
E1
T1
1 Mbps
DSL
0.1 Mbps
Residential Voice and Data
Copper Cable
WLL
Satellite
Transmission Rate
Long Haul
Dense Urban
Urban
Industrial Sub Urban
Residential Sub Urban
Rural
Remote
Geographic and Population Topology

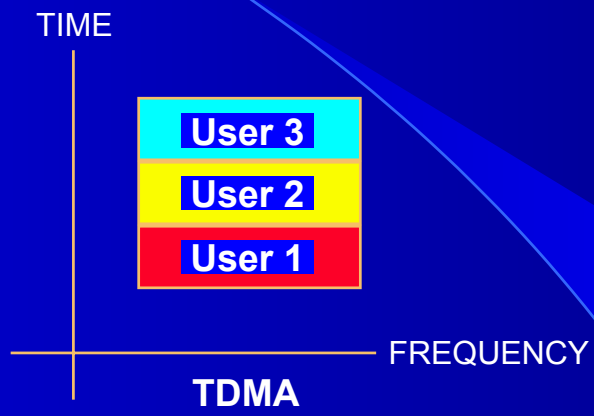
Access Techniques

- *FDMA: Frequency Division Multiple Access*
- *TDMA:Time Division Multiple Access*
- *CDMA: Code Division Multiple Access*
- *SDMA: Space Division Multiple Access*

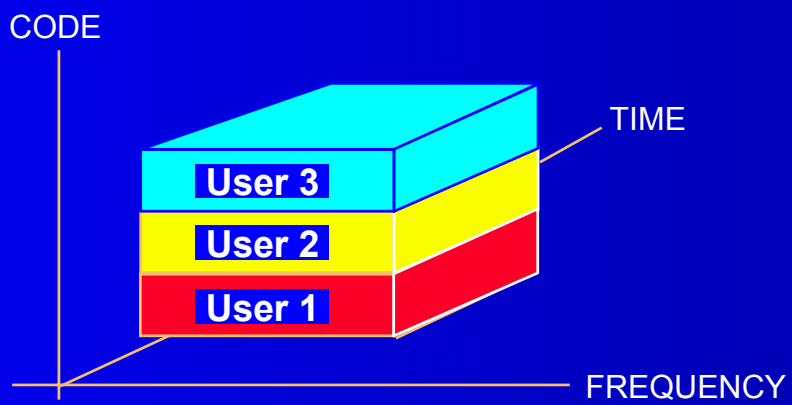
Access Techniques



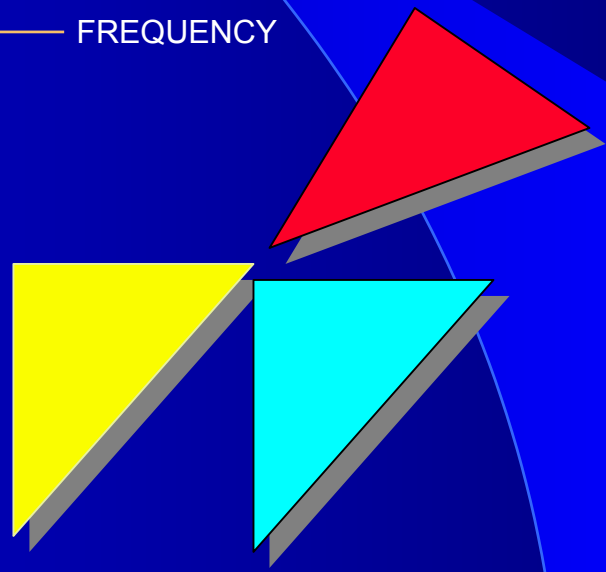
FDMA



TDMA



CDMA
o r "Spread Spectrum"



Spatial Diversity

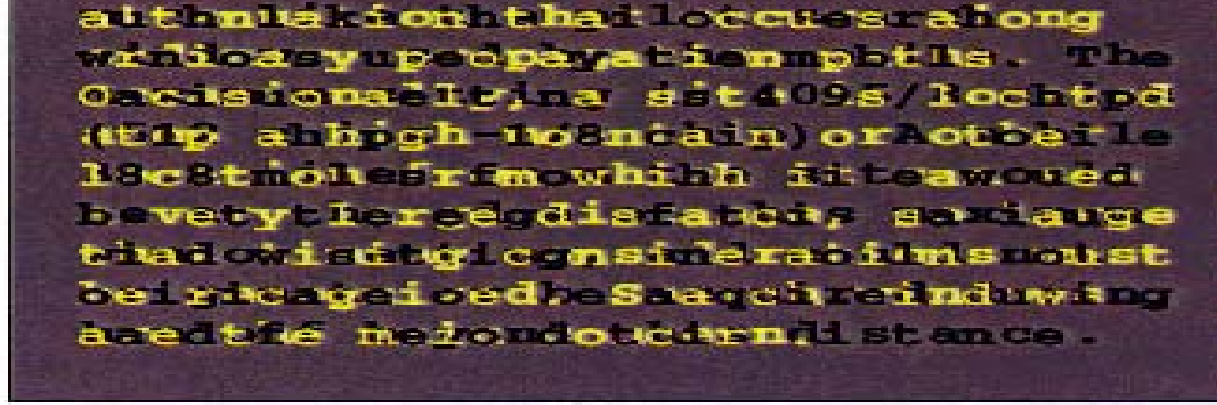
Duplexing Techniques

- *FDD: Frequency Division Duplexing*
- *TDD:Time Division Duplexing*
- *CDD: Code Division Duplexing*
- *SDD: Space Division Duplexing*

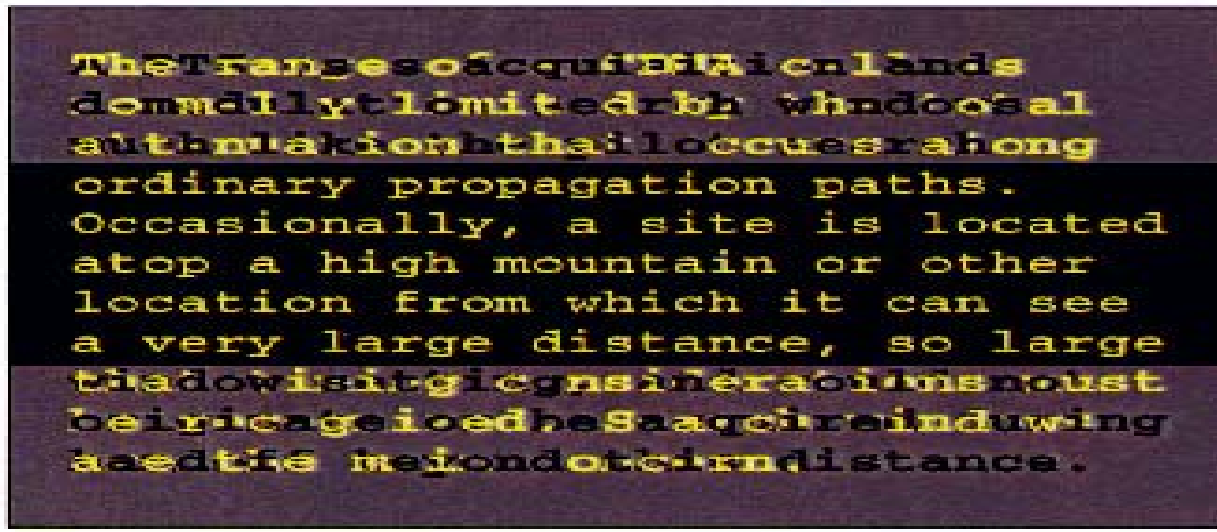
NORTEL NETWORKS

"Orthogonal" Inks

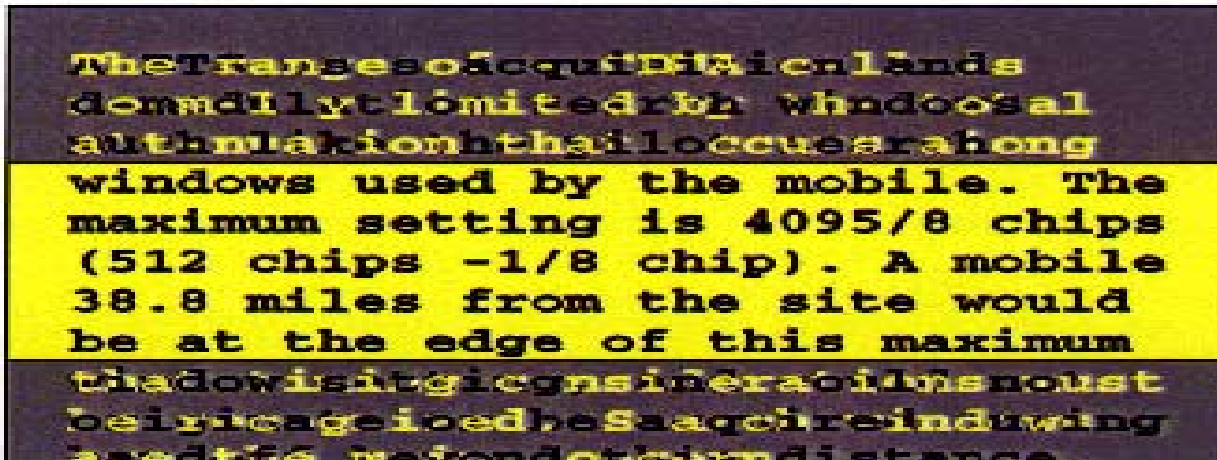
"CDMA-like" Page Containing Two Messages Printed Using Inks of "Orthogonal" Colors



Yellow Message Partially Decoded (Blue Message Becomes Transparent!)



Blue Message Partially Decoded (Yellow Message Becomes Transparent!)



Communications evolution

1919 Intercontinental telephone calls, tube amp.

1946 Multiplexing, of 1800 Ch. over coax

1978 Last coaxial installed in USA, 132 000 Ch.

- Micowaves, 2 400 circuits

1981 Microwaves, 61 800 circuits

1958 Coaxial Submarine Cable, 72 voice Ch.

1983 Coaxial Submarine Cable. 10 500 Ch.

1988 Optical Fibre submarine Cable 280 Mb/s

1999 80 Gps transmssion on Fibre

Communication Systems Growth

Compound annual growth rate over useful life

Terrestrial coax 14.4%

Terrestrial microwave 11%

Undersea fiber 67%

Terrestrial fiber similar to geo satellite, 35%

Telephonic rates have nt diminished with the same speed. AT&T marketing expenditures increased ten fold from 1983 to 1994.

ource:Rate Expectations, by Michael Noll Tele.com, March 6,2000

de jure Standards Organizations:

ITU-T International Telecommun. Union (former CCITT)

ISO International Standards Organization

IEC International Electrotechnical Commission

ETSI European Telecom. Std. Institute

CEN/CENELEC Com. Europeenne de Norm. Elect.

ANSI Amer. Nat. Standards Institute

NIST National Institute for Std. & Technology

de facto Standards Organizations

IEEE	**Int. Instit. of Electrical & Electronic Eng.**
ECSA	**Exchange Carriers Standards Assoc.**
EIA	**Electronic Industry Association**
TIA	**Telecom. Industry Association**
SPAG	**Standards Promotions & Appl. Group**
OSF	**Open Software Foundation**
IETF	**Internet Engineering Task Force**
ATM	**Forum**
BELLCORE	**Bell Communic. Research (Telcordia)**
ECMA	**European Computer Manufacturers Asso**
CEPT	**Conf. European of Posts et Telecomm.**