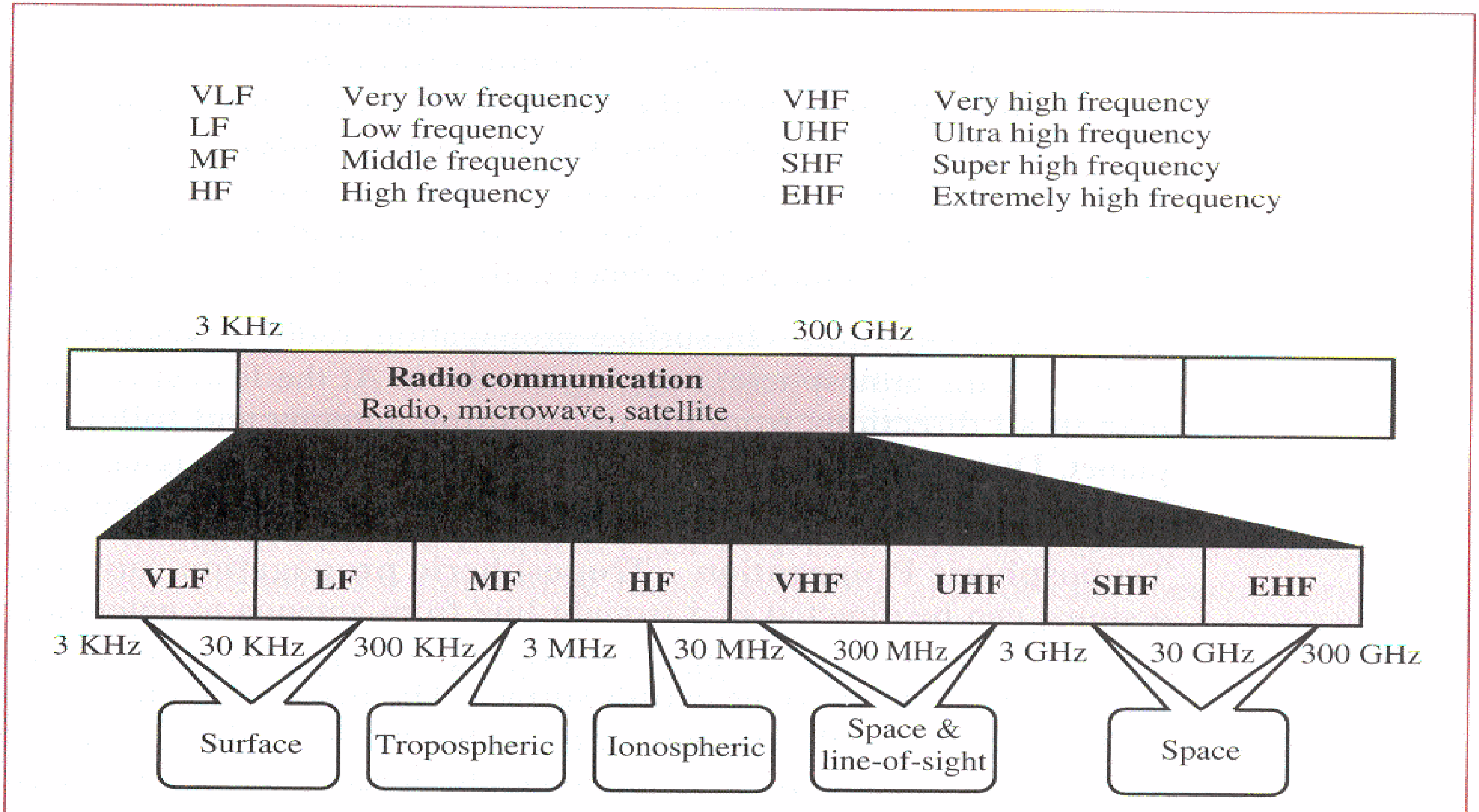
Unbounded Transmission Media

Unbounded Media

- The three main types of wireless media are
- Radio
- Microwave
- infrared

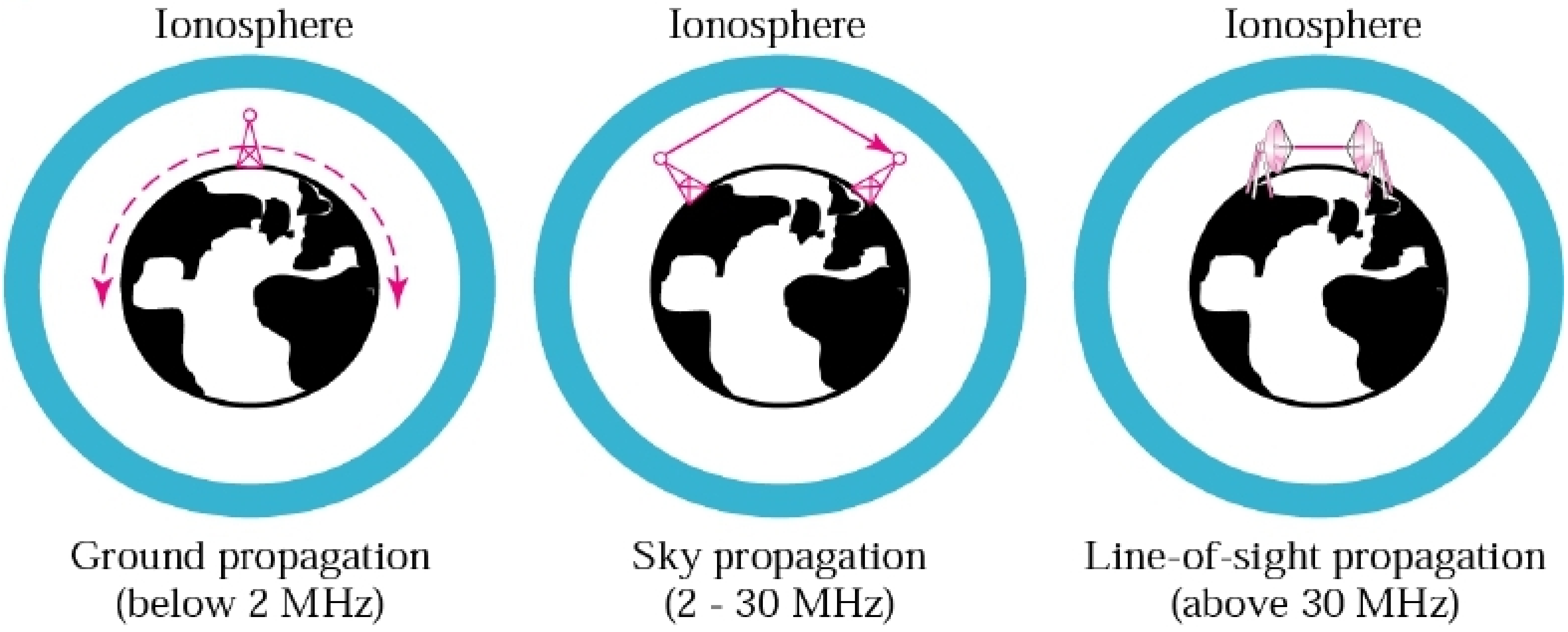
Electromagnetic spectrum for wireless communication

Figure 7.21 *Radio communication band*



Unguided waves can travel from source to destination in several ways.

Propagation methods



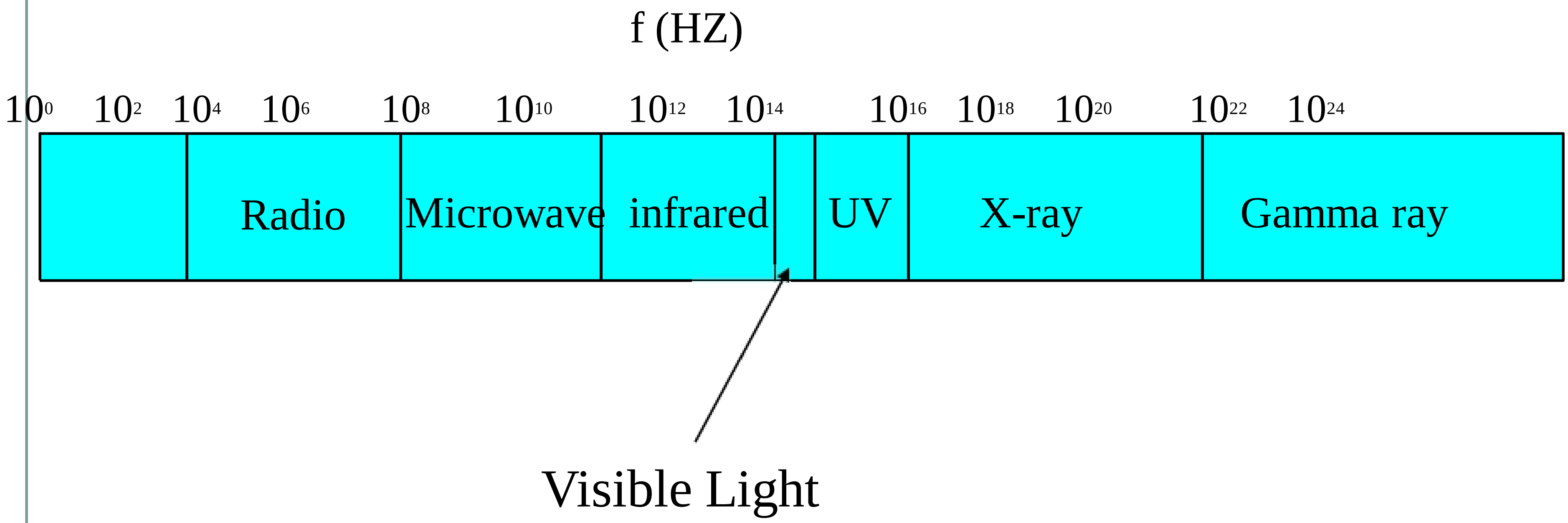
Ground propagation : Radio waves travel through the lowest portion of the atmosphere.

Sky propagation: Radio waves radiate upwards into ionosphere, they are reflected back to earth.

Line of sight propagation: very high frequency signals are transmitted in straight line directly from antenna to antenna.

Bands

Band	Range	Propagation	Application
VLF	3–30KHz	Ground	Long-range radio navigation
LF	30–300KHz	Ground	Radio beacons and Navigation allocators
MF	300KHz–3MHz	Sky	AM radio
HF	3–30MHz	Sky	Citizens band(CB), ship/air craft communication
VHF	30–300MHz	Sky and line-of-sight	VHF TV, FM radio
UHF	300MHz–3GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF	3–30GHz	Line-of-sight	Satellite communication
EHF	30–300GHz	Line-of-sight	Long-range radio navigation



f (HZ)

10^0 10^2 10^4 10^6 10^8 10^{10} 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{22} 10^{24}

Radio

Microwave

infrared

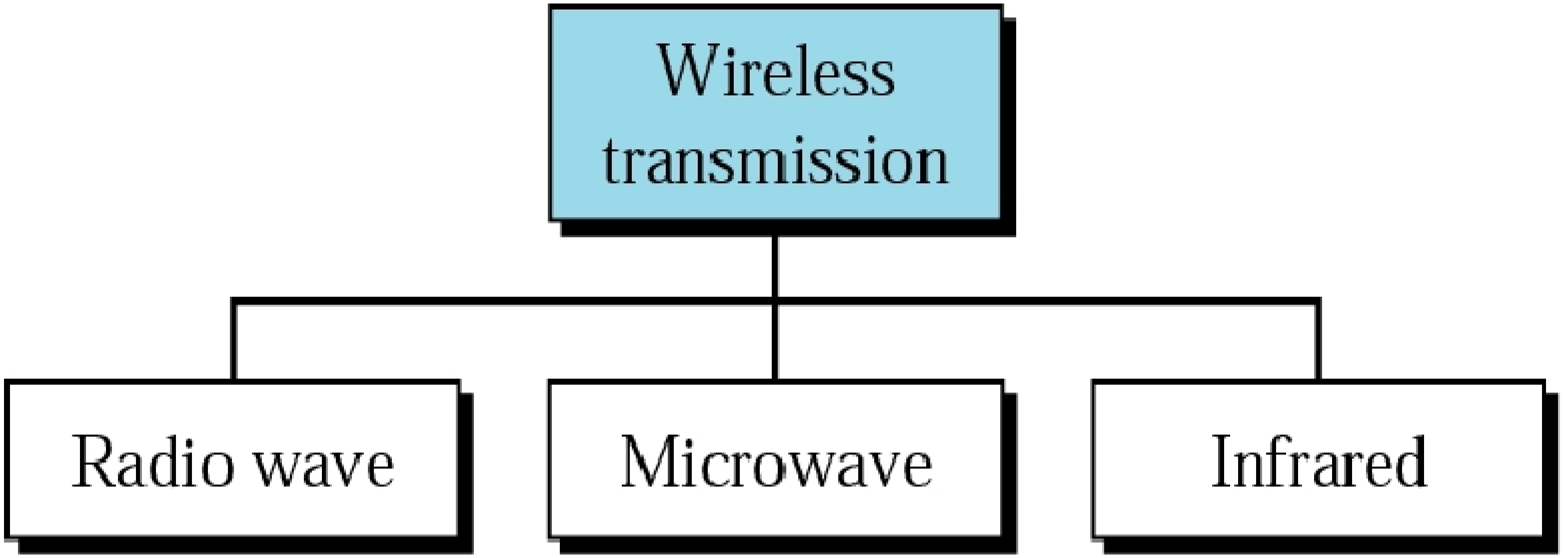
UV

X-ray

Gamma ray

Visible Light

Wireless transmission waves



Wireless transmission

Radio wave

Microwave

Infrared

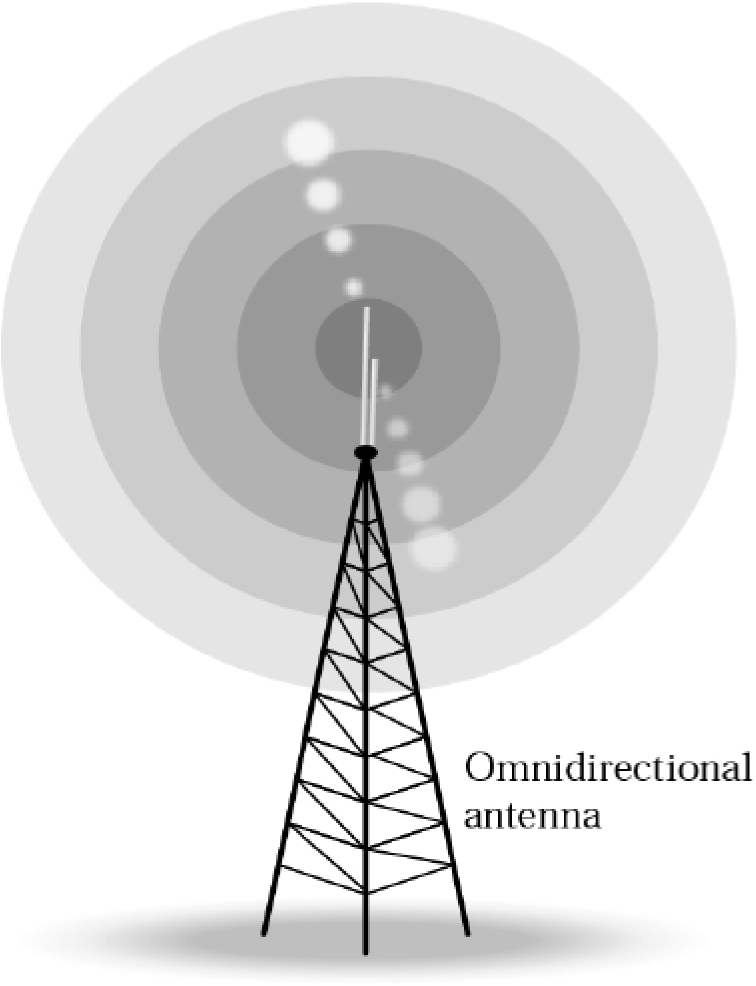
Radio Waves

- This is the the cheapest wireless media(although the price can increase if more complicated and advanced equipment is needed)
- Are easy to generate and can travel long distance
- As they can penetrate buildings, they are widely used for communications both indoors and outdoors
- Radio waves are omni directional i.e. they can travel in all the directions from the source, so the transmitter and the receiver do not have to be aligned.

Radio Waves

- Radio waves are frequency dependent
- At low frequencies, radio wave pass through obstacles very well
- At all the frequencies , radio waves are subject to interference with other devices that operate on the same frequencies
- To avoid interference between users, government tightly license the use of radio transmission.

Omni directional antennas



Note:

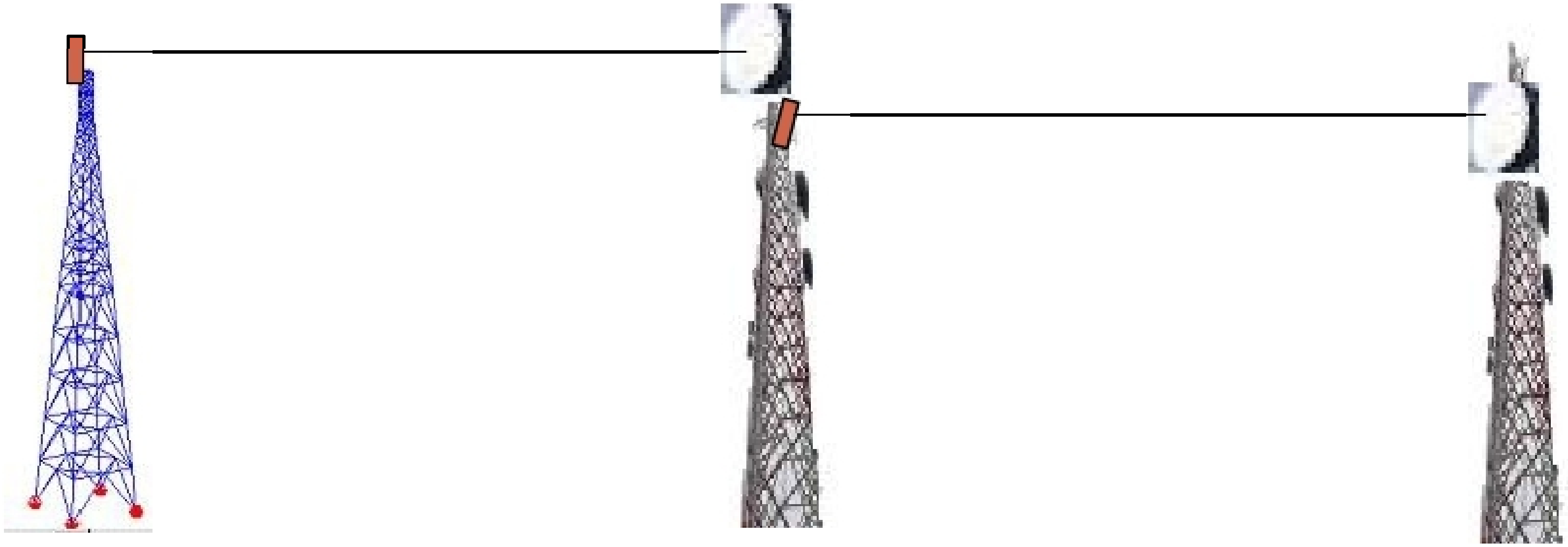
Radio waves are used for multicast communications, such as radio and television, and paging systems.

Microwave

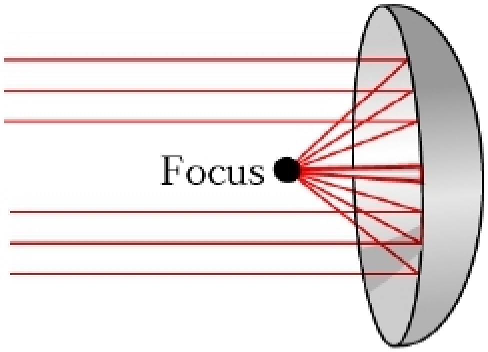
- The wave travel in straight line
- requires unobstructed line of sight between source and receiver i.e. the transmitter and the receiver must be aligned.
- transmitter is a parabolic dish, mounted as high as possible
- Microwave signals propagate in one direction at a time, which means that two frequencies are necessary for two-way communication such as telephone conversation.
- One frequency is reserved for microwave transmission in one direction and other for transmission in the other direction.
- Today , both piece of equipment are combines into one piece called as transceiver which allow a single antenna to serve both frequencies.

Microwave

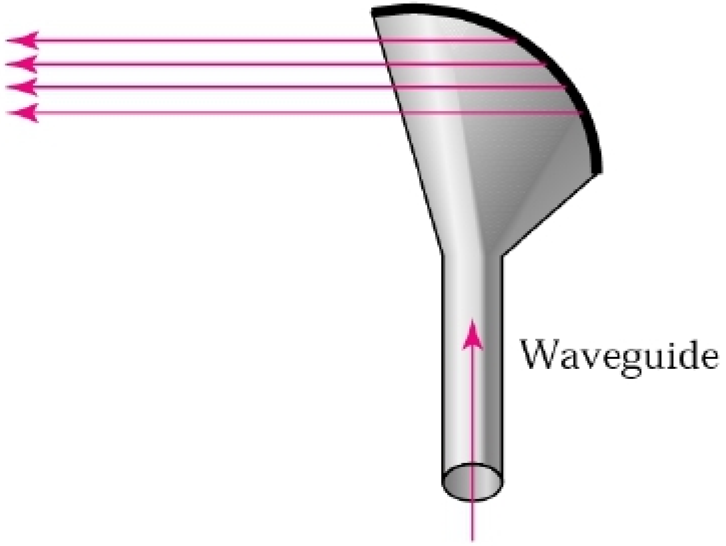
- Each frequency require its own transmitter and receiver.
- The higher the tower , the farther apart they can be i.e. more the height of the tower, more the distance covered.
- used by common carriers as well as by private networks
- Unlike radio waves, microwave do not pass through obstacles.



Unidirectional antennas



a. Dish antenna



b. Horn antenna

Microwave Transmission

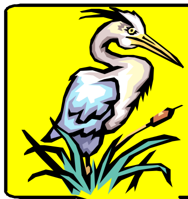
- Used for long distance communicationse.g. telephone communications, mobile phones, television distribution.
- It is expensive(putting two simple towers with antennas on each is much cheaper than burying a wire through a congested urban or over a mountain)

Microwave Transmission Advantages

- no cabling needed between sites
- wide bandwidth
- multichannel transmissions

Microwave Transmission Disadvantages

- line of sight requirement
- Expensive towers and repeaters
- subject to interference such as passing airplanes and rain



Note:

Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Infrared

- They are widely used for short-range communications
- They are cheap and easy to build
- The remote controls used on television VCRs, and Stereos all use infrared communications.
- You do not need to have a license for using infrared.
- The major drawback is that they do not pass obstacles

Note:

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

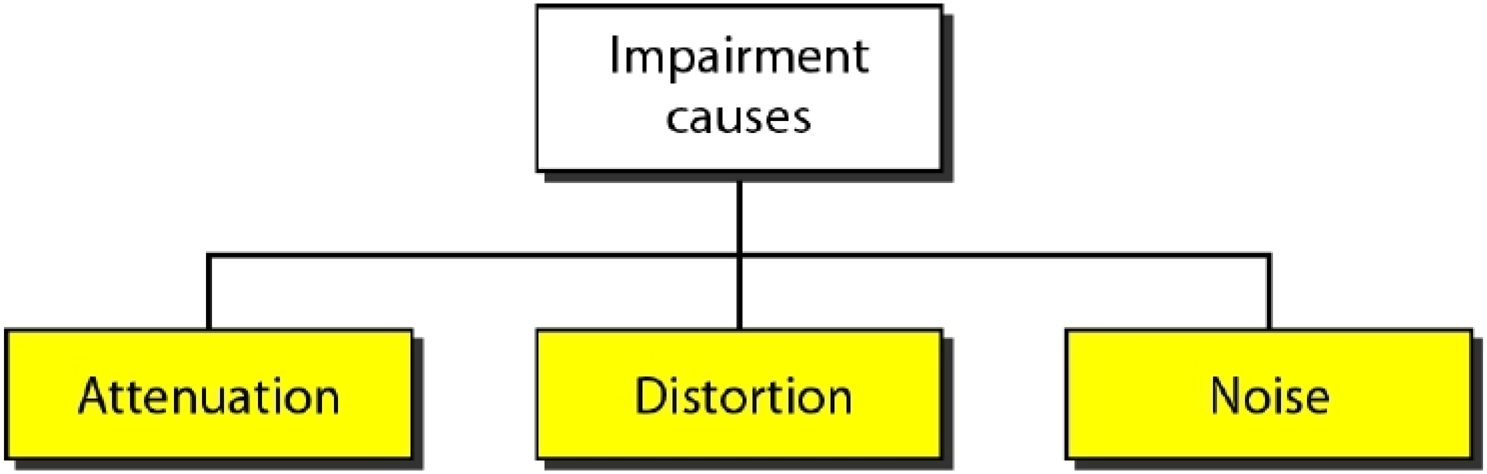
TRANSMISSION IMPAIRMENT

Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment. This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium. What is sent is not what is received. Three causes of impairment are attenuation, distortion, and noise.

Topics discussed in this section:

- **Attenuation**
- **Distortion**
- **Noise**

Causes of impairment


Impairment causes

Attenuation

Distortion

Noise

Attenuation

- Means loss of energy → weaker signal
- When a signal travels through a medium it loses energy overcoming the resistance of the medium
- Amplifiers are used to compensate for this loss of energy by amplifying the signal.

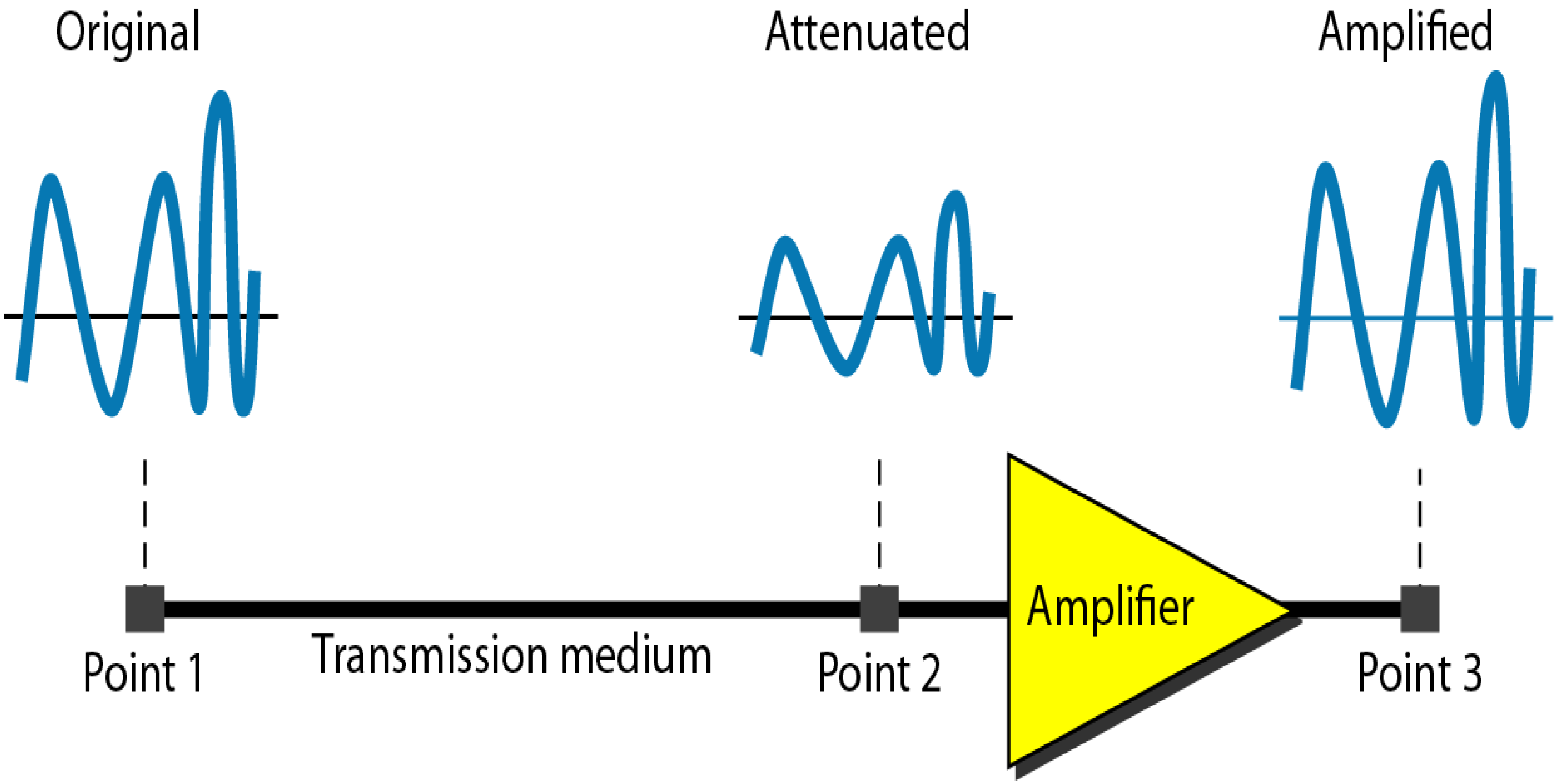
Measurement of Attenuation

- To show the loss or gain of energy the unit “decibel” is used.

$$dB = 10\log_{10} P_2/P_1$$

P_1 - input signal

P_2 - output signal


Original
Attenuated
Amplified
Amplifier
Point 1
Transmission medium
Point 2
Point 3

Example

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P_2 is (1/2)P_1. In this case, the attenuation (loss of power) can be calculated as

$$\boxed{10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5 P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}}$$

A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.

Example

A signal travels through an amplifier, and its power is increased 10 times. This means that $P_2 = 10P_1$. In this case, the amplification (gain of power) can be calculated as

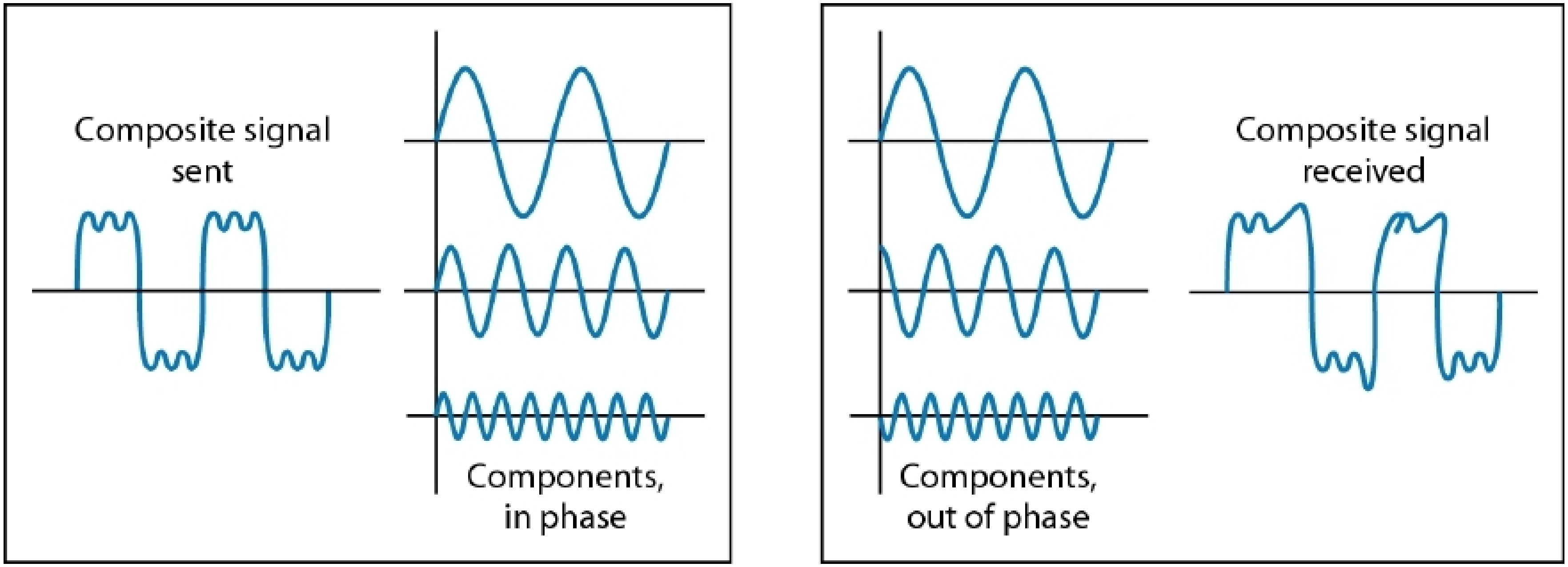
$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{10P_1}{P_1}$$

$$= 10 \log_{10} 10 = 10(1) = 10 \text{ dB}$$

Distortion

- Means that the signal changes its form or shape
- Distortion occurs in composite signals
- Each frequency component has its own propagation speed traveling through a medium.
- The different components therefore arrive with different delays at the receiver.
- That means that the signals have different phases at the receiver than they did at the source.

Distortion



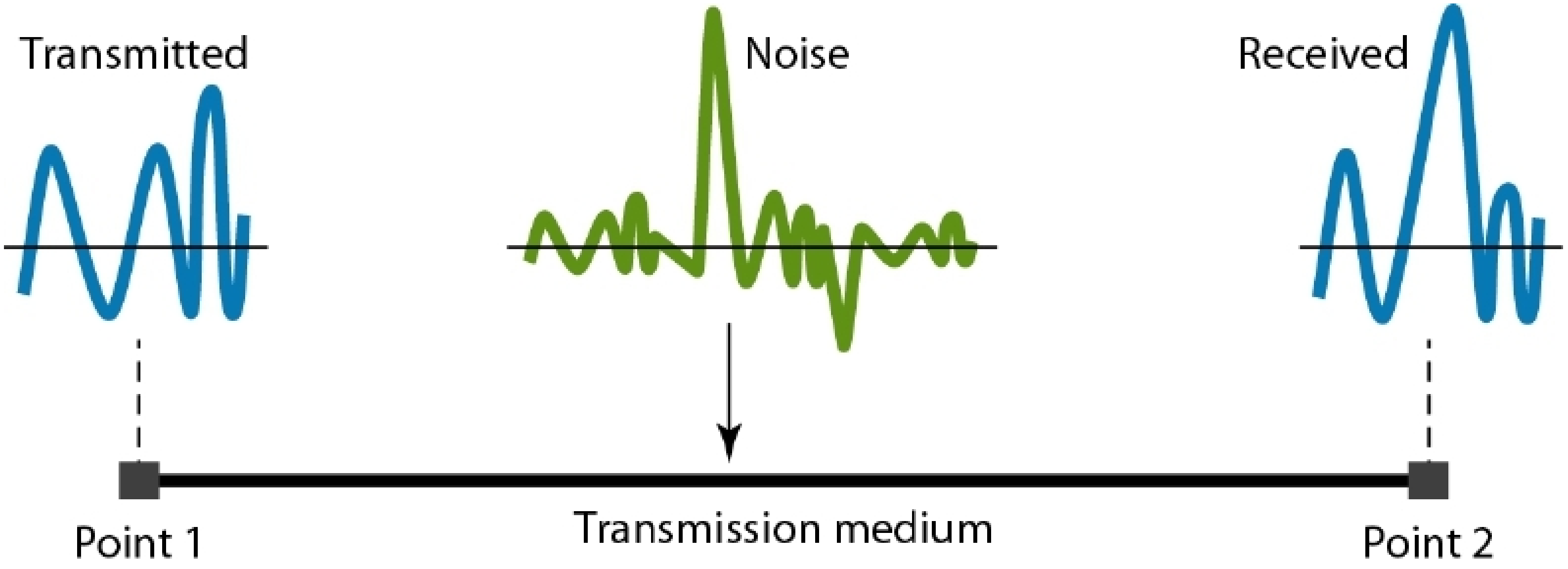
At the sender

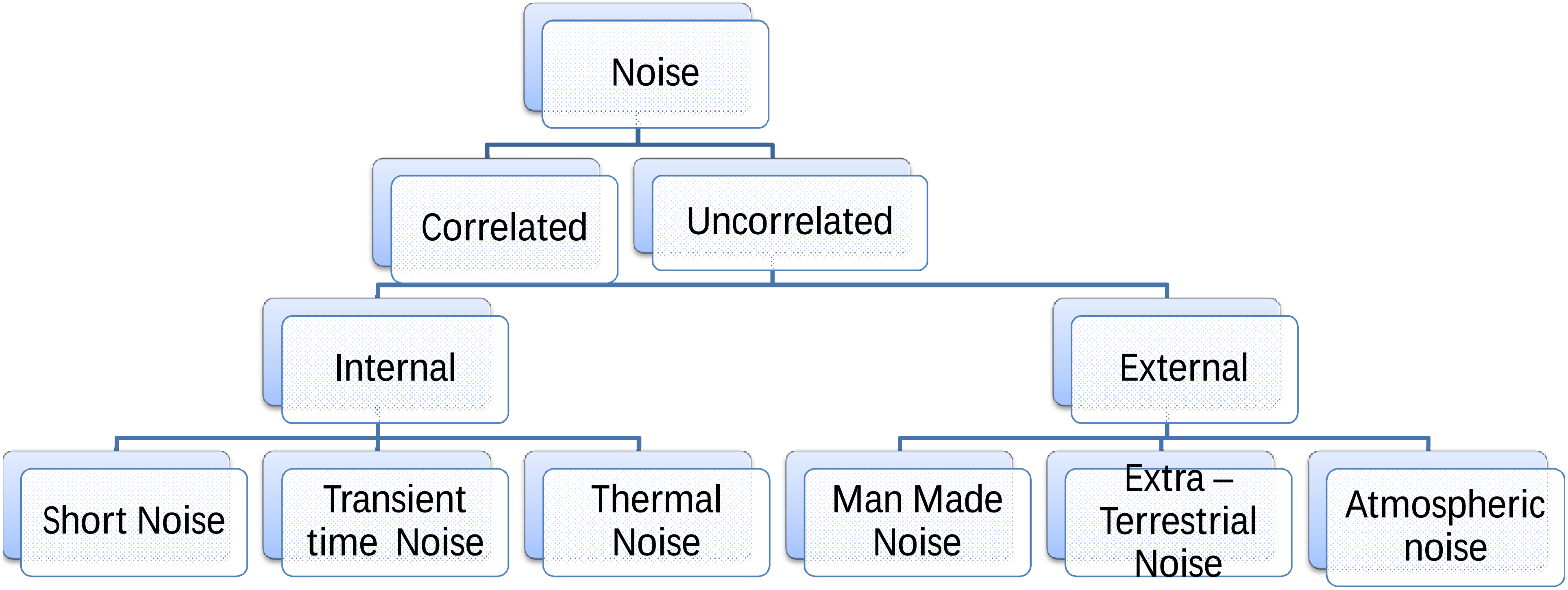
At the receiver

Noise

- There are different types of noise
  - Thermal - random motion of electrons in the wire creates an extra signal
  - Induced - from motors and appliances, devices act are transmitter antenna and medium as receiving antenna.
  - Crosstalk - same as above but between two wires.
  - Impulse - Spikes that result from power lines, lightning, etc.

Noise


Transmitted
Noise
Received
Point 1
Transmission medium
Point 2



Noise

Correlated

Uncorrelated

Internal

External

Short Noise

Transient time Noise

Thermal Noise

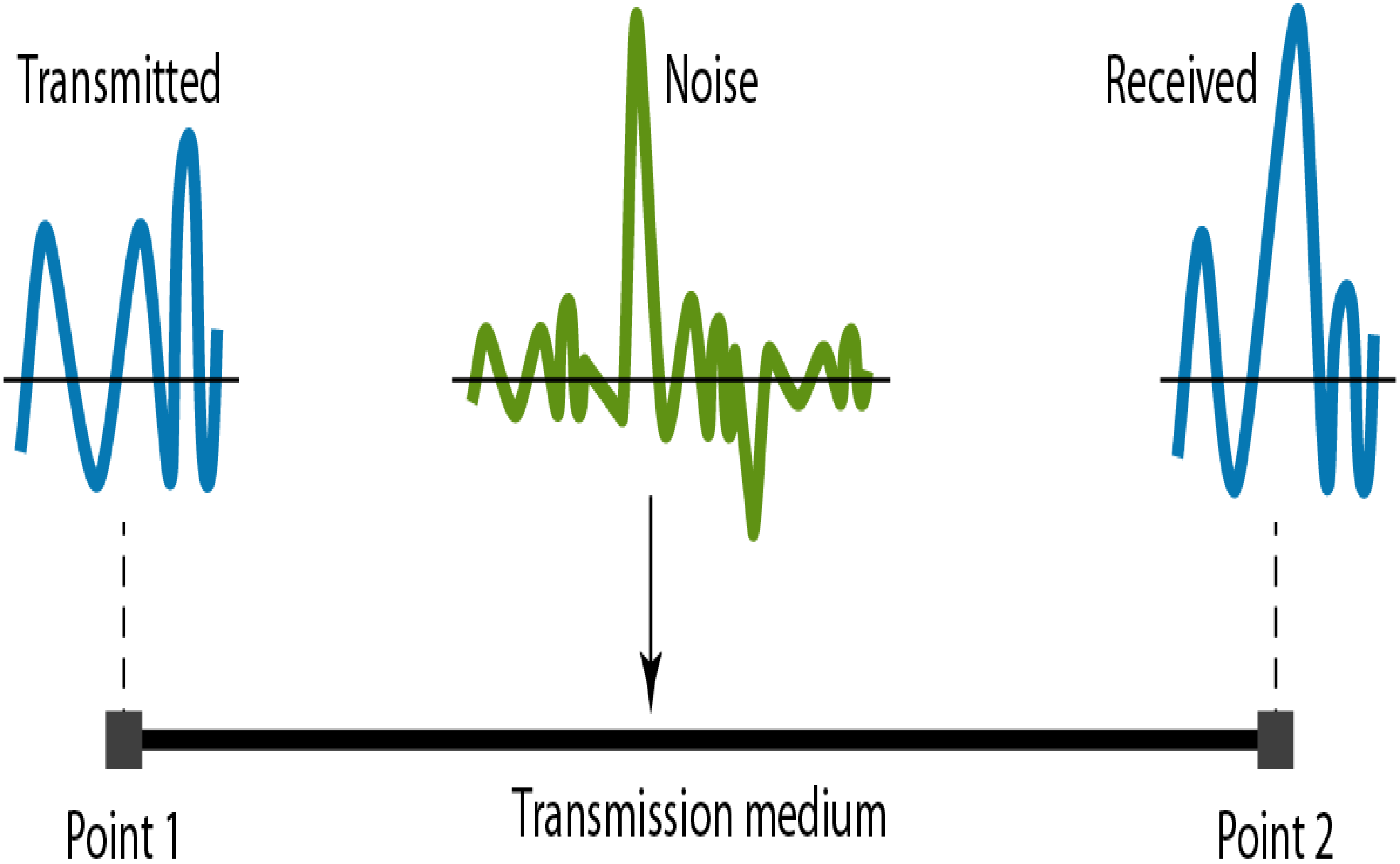
Man Made Noise

Extra – Terrestrial Noise

Atmospheric noise

Correlated and uncorrelated noise

- Correlation implies a relationship between the signal and the noise. Hence the correlated signal exits only, when a signal is present.
- Uncorrelated noise is present all the time whether there is signal or not.


Transmitted
Noise
Received
Point 1
Transmission medium
Point 2

External and internal noise

- External noise is the noise that is generated outside the device.
- Internal noise is electrical interference generated within the device.

Atmospheric noise

- It is naturally occurring electrical disturbances that originate within earth’s atmosphere. It is also called static electricity. This noise is unpredictable in nature. These are less serves as 30 M Hz.
- Field strength is inversely proportional to frequency, so this noise interfere more with reception of radio then that of television.
- Sources are lightening discharge, thunderstorm, cracking etc

Extra terrestrial noise

- Such noise consist of electrical signals that originate from outside earth’s atmosphere & also called deep space noise. Such noise originates from the galaxies & the Sun.

Man Made Noise

- This noise is because of undesired pick ups from electrical appliance Such as motor, automobile, Switch gears. This is effective in frequency range 1MHz to 500MHz.
- It is produced by Mankind.
- It is under human control & can be eliminated by removing the source of the noise.
- It contain a wide range of frequency that are propagated through space in the same manner as radio waves.

Shot noise

- It is caused by the random arrival of carriers at the output element of an electrical device, such as diode, FET.
- It is randomly varying & is superimposed on to any signal present.

Transit time noise

- Any modification to a stream of carriers as they pass from input to the output of a device produces an irregular random variations categorized as transit noise.
- Transit time noise in transistors is determined by carrier mobility, bias voltage and transitor constructions.

Thermal noise

- It is associated with the rapid & random movement of electron within a conductor due to thermal agitation

Signal to Noise Ratio (SNR)

- To measure the quality of a system the SNR is often used. It indicates the strength of the signal w.r.t. the noise power in the system.
- It is the ratio between two powers.
- It is usually given in dB and referred to as SNR_{dB}.

Example

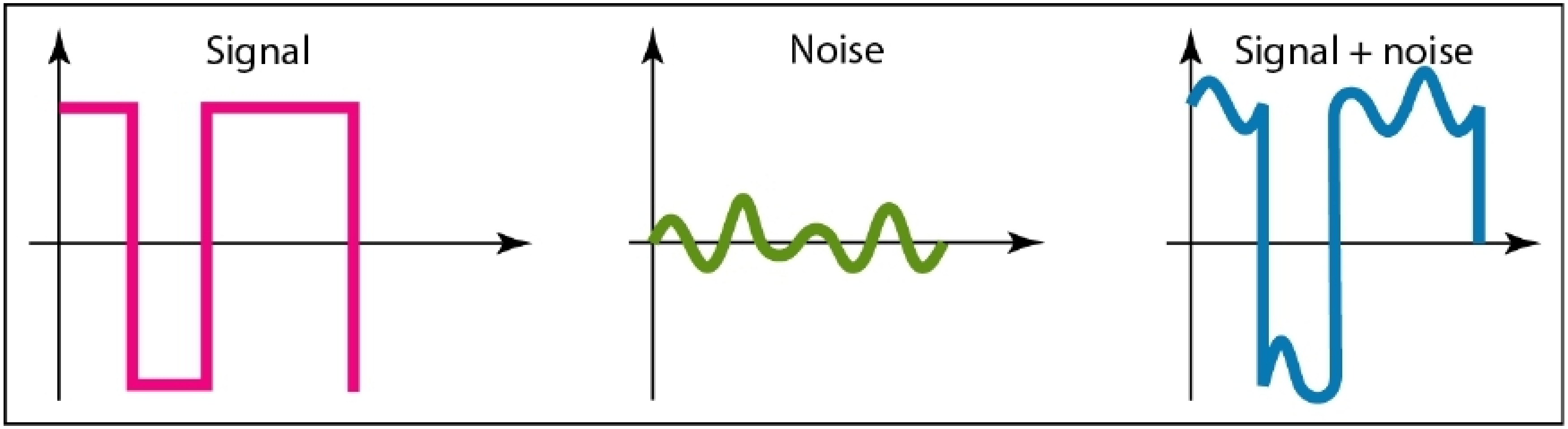
The values of SNR and SNR

$$\mathrm{SNR} = \frac{\text{signal power}}{0} = \infty$$

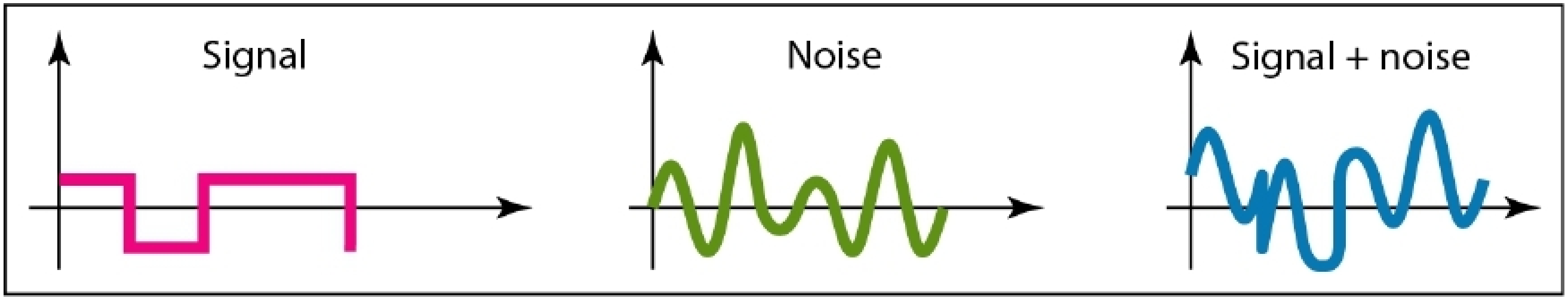
$$\mathrm{SNR}_{\mathrm{dB}} = 10 \log_{10} \infty = \infty$$

We can never achieve this ratio in real life; it is an ideal.

Two cases of SNR: a high SNR and a low SNR



a. Large SNR



b. Small SNR

DATA RATE LIMITS

A very important consideration in data communications is how fast we can send data, in bits per second, over a channel. Data rate depends on three factors:

1. ***The bandwidth available***
2. ***The level of the signals we use***
3. ***The quality of the channel (the level of noise)***

Topics discussed in this section:

- **Noiseless Channel: Nyquist Bit Rate**
- **Noisy Channel: Shannon Capacity**
- **Using Both Limits**

Note

Increasing the levels of a signal increases the probability of an error occurring, in other words it reduces the reliability of the system. Why??

Capacity of a System

- The bit rate of a system increases with an increase in the number of signal levels we use to denote a symbol.
- A symbol can consist of a single bit or “n” bits.
- The number of signal levels = 2^n.
- As the number of levels goes up, the spacing between level decreases → increasing the probability of an error occurring in the presence of transmission impairments.

NYQUIST Theorem(Sampling theorem)

- Sampling is a process to convert a continuous message signal in to digital, the signal is first converted into discrete time signal.
- For conversion sufficient number of samples must be taken .
- These number of samples to be taken depends on maximum signal frequency present.
  - Instantaneous sampling
  - Flat top Sampling

- A Band limited signal of finite energy, which has no frequency components higher that B Hz , is completely recovered from the knowledge of its samples taken at the rate of 2B samples per second, where B is Bandwidth of signal. 2B is commonly known as sampling rate or Nyquist data rate.
- A band limited signal of finite energy, which has no frequency components higher than B Hz is completely described by specifying the values of the signal at instants of time separated by 1/2B seconds.
- First part is in frequency domain while second part is in time domain.

- After sampling it will goes under the process of quantization, coding and we will get digital waveform.
- In communication after the process of modulation when it transmitted and received by the receiver, there is need to convert again it into its original form, that is analog continuous time signal.

Nyquist Theorem

- Nyquist gives the upper bound for the bit rate of a transmission system by calculating the bit rate directly from the number of bits in a symbol (or signal levels) and the bandwidth of the system (assuming 2 symbols/per cycle and first harmonic).
- Nyquist theorem states that for a noiseless channel:

$$C = 2\ B \log_2 2^n$$

C= capacity in bps

B = bandwidth in Hz

Shannon’s Theorem

- Shannon’s theorem gives the capacity of a system in the presence of noise.

$$C = B \log_2(1 + SNR)$$

Note

The Shannon capacity gives us the upper limit; the Nyquist formula tells us how many signal levels we need.

Example 1

Does the Nyquist theorem bit rate agree with the intuitive bit rate described in baseband transmission?

Solution

They match when we have only two levels. We said, in baseband transmission, the bit rate is 2 times the bandwidth if we use only the first harmonic in the worst case. However, the Nyquist formula is more general than what we derived intuitively; it can be applied to baseband transmission and modulation. Also, it can be applied when we have two or more levels of signals.

Example 2

Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\boxed{\text{BitRate} = 2 \times 3000 \times \log_2 2 = 6000 \text{ bps}}$$

Example 3

Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 4 = 12{,}000 \text{ bps}$$

Example 4

We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

Solution

We can use the Nyquist formula as shown:

$$265{,}000 = 2 \times 20{,}000 \times \log_2 L$$

$$\log_2 L = 6.625 \qquad L = 2^{6.625} = 98.7 \text{ levels}$$

Since this result is not a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

Example 5

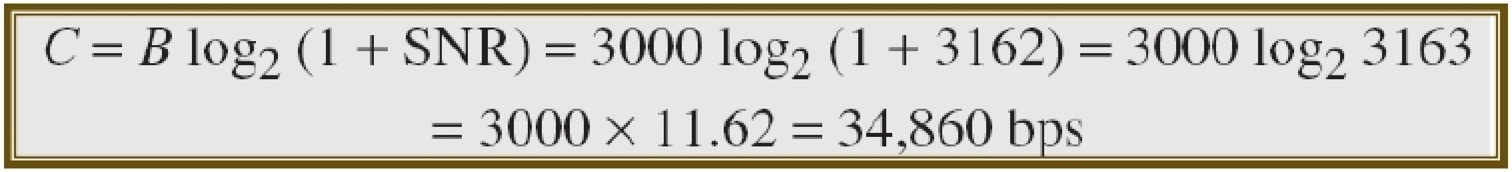
Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$C = B \log_2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log_2 1 = B \times 0 = 0$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

Example 6

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

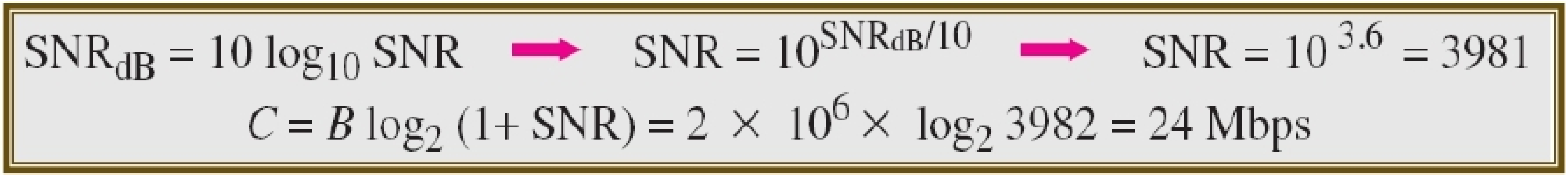


$$C = B \log_2(1 + \mathrm{SNR}) = 3000 \log_2(1 + 3162) = 3000 \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

Example 7

The signal-to-noise ratio is often given in decibels. Assume that $\text{SNR}_{\text{dB}} = 36$ and the channel bandwidth is 2 MHz. The theoretical channel capacity can be calculated as



$$\text{SNR}_{\text{dB}} = 10 \log_{10} \text{SNR} \rightarrow \text{SNR} = 10^{\text{SNR}_{\text{dB}}/10} \rightarrow \text{SNR} = 10^{3.6} = 3981$$

$$C = B \log_2 (1 + \text{SNR}) = 2 \times 10^6 \times \log_2 3982 = 24 \text{ Mbps}$$

Example 8

For practical purposes, when the SNR is very high, we can assume that SNR + 1 is almost the same as SNR. In these cases, the theoretical channel capacity can be simplified to

$$\boxed{C = B \times \frac{\text{SNR}_{\text{dB}}}{3}}$$

For example, we can calculate the theoretical capacity of the previous example as

$$\boxed{C = 2\ \text{MHz} \times \frac{36}{3} = 24\ \text{Mbps}}$$

Example 9

We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate and signal level?

Solution

First, we use the Shannon formula to find the upper limit.

$$\boxed{C = B \log_2 (1 + \text{SNR}) = 10^6 \log_2 (1 + 63) = 10^6 \log_2 64 = 6 \text{ Mbps}}$$

Example 9 (continued)

The Shannon formula gives us 6 Mbps, the upper limit. For better performance we choose something lower, 4 Mbps, for example. Then we use the Nyquist formula to find the number of signal levels.

$$\boxed{4\ \text{Mbps} = 2 \times 1\ \text{MHz} \times \log_2 L \quad \longrightarrow \quad L = 4}$$

Bandwidth

- Bandwidth of an information signal
- Bandwidth of communication channel
- The bandwidth of communication channel must be large enough to pass all significant information frequency . In other words the bandwidth of communication channel must be equal to or greater than the bandwidth of the information
-

- Information capacity is a measure of how much information can be transferred through a communication system.
- The amount of information that can be propagated through a transmission system is a function of bandwidth & transmission.

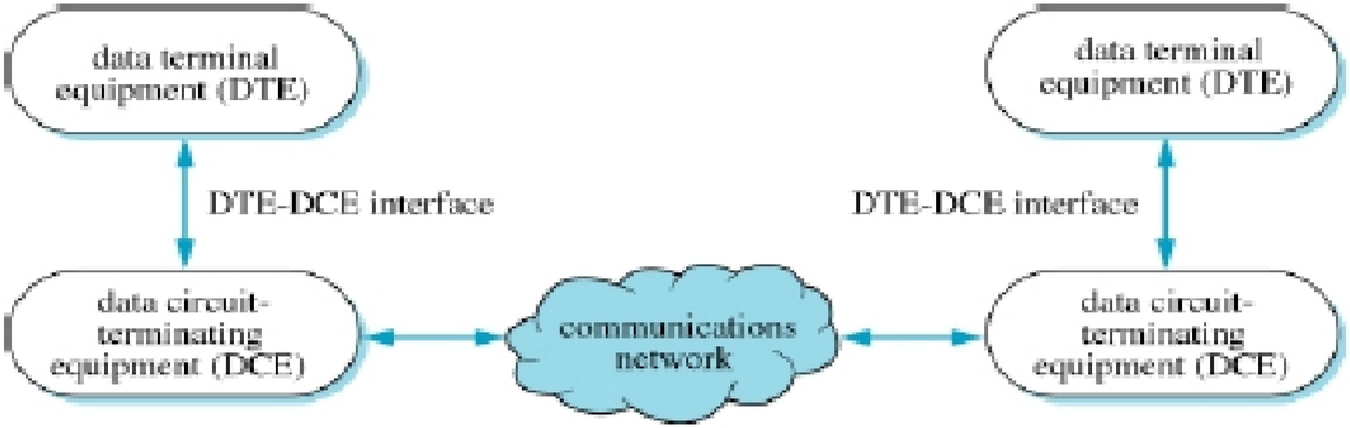
$$C \propto B * t$$

- Which indicate that if wider bandwidth and longer time of transmission, then more information can be transmitted.
- In general, more complex the information, the more bandwidth is required to transport it in a given period of time.

Interface Standard

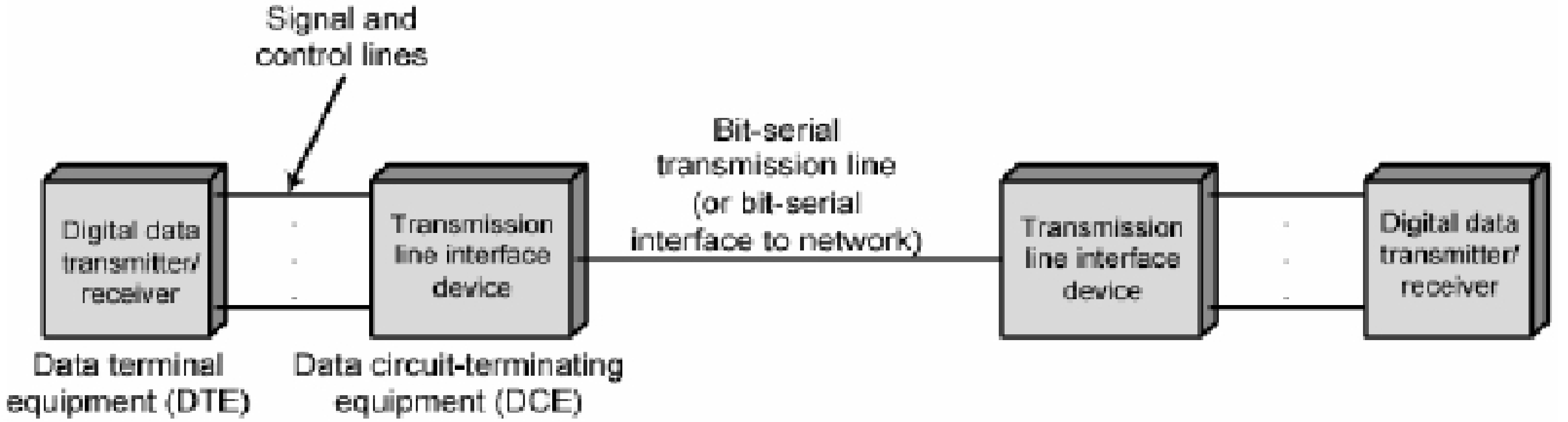
PC

Modem



Phone line

Data Communications Interfacing



(a) Generic interface to transmission medium

(b) Typical configuration

Interface Standards

Many different groups contribute to interface standards:

International Telecommunications Union (ITU) (formerly CCITT)

Electronics Industries Association (EIA)

Institute for Electrical and Electronics Engineers (IEEE)

International Organization for Standards (ISO)

American National Standards Institute (ANSI)

Characteristics of Interface

- Mechanical
    - Connection plugs
- Electrical
    - Voltage, timing, encoding
- Functional
    - Data, control, etc.
- Procedural
    - Sequence of events

Interface Standards

Interface standards can consist of four components:

1. The electrical component

2. The mechanical component

3. The functional component

4. The procedural component

Interface Standards

The **electrical component** deals with voltages, line capacitance, and other electrical characteristics.

The **mechanical component** deals with items such as the connector or plug description. A standard connector is the ISO 2110 connector, also known as DB-25.

The DB-9 connector has grown in popularity due to its smaller size.

Interface Standards

The **functional component** describes the function of each pin or circuit that is used in a particular interface.

The **procedural component** describes how the particular circuits are used to perform an operation.

For example, the functional component may describe two circuits, Request to Send and Clear to Send.

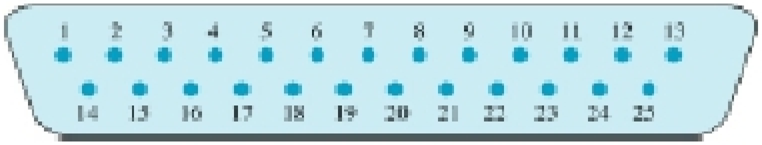
The procedural component describes how those two circuits are used so that the DTE can transfer data to the DCE.

RS-232 and EIA-232F

- An older interface standard designed to connect a device such as a modem to a computer or terminal.
- Originally RS-232 but has gone through many revisions.
- The electrical component is defined by V.28, the mechanical component is defined by ISO 2110, and the functional and procedural components are defined by V.24.

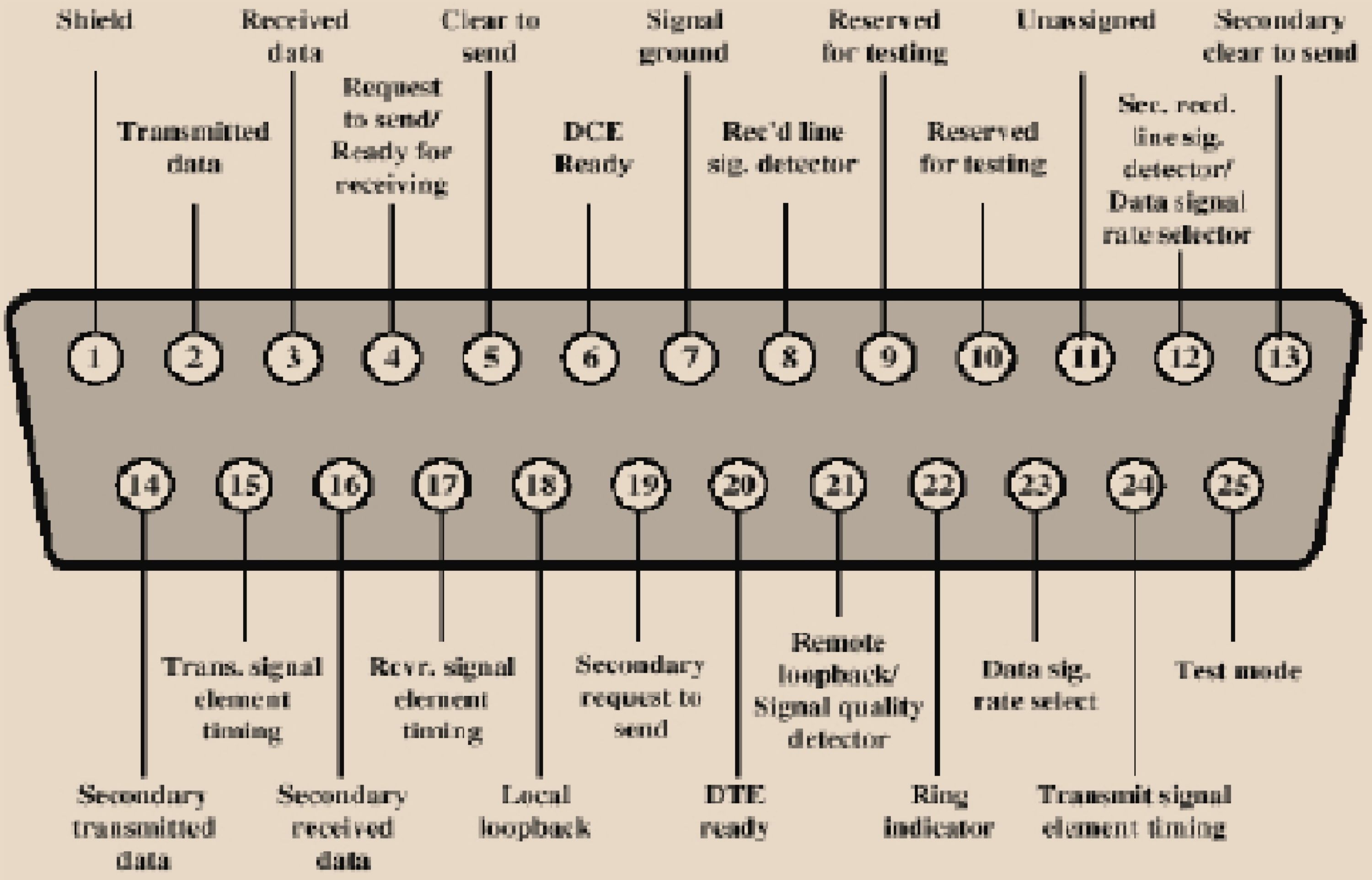
RS-232 interface

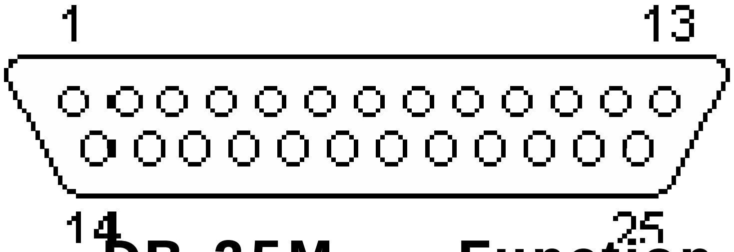
- RS-232 (EIA-232)
    - EIA: Electronic industrial association
- 25-line cable with 25-pin connector
    - Pin 2: Transmit Data (TD)
    - Pin 3: Receive Data (RD)
    - Pin 4: Request To Send (RTS)
    - Pin 5: Clear To Send (CTS)
    - Pin 6: Data Set Ready (DSR)
    - Pin 8: Data Carrier Detect (DCT)
    - Pin 20: Data Terminal Ready (DTR)
    - Pin 7: Electrical Ground
- A typical cable
    - 25-pin connector connected to the modem (versatility)
    - 9-pin connector connected to the PC (Cheaper, no need to use full range of capabilities)



Each line has a specific Function in establishing communication between the devices

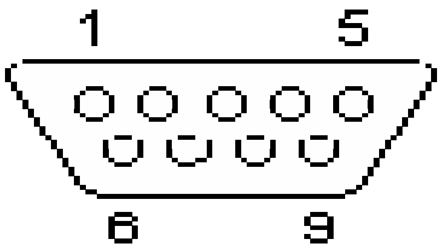
A closer look





RS-232 DB25 Pin Out

DB-25M	**Function**	**Abbreviation**
Pin #1	Chassis/Frame Ground	GND
Pin #2	Transmitted Data	TD
Pin #3	Receive Data	RD
Pin #4	Request To Send	RTS
Pin #5	Clear To Send	CTS
Pin #6	Data Set Ready	DSR
Pin #7	Signal Ground	GND
Pin #8	Data Carrier Detect	DCD or CD
Pin #9	Transmit + (Current Loop)	TD+
Pin #11	Transmit - (Current Loop)	TD-
Pin #18	Receive + (Current Loop)	RD+
Pin #20	Data Terminal Ready	DTR
Pin #22	Ring Indicator	RI
Pin #25	Receive - (Current Loop)	RD-

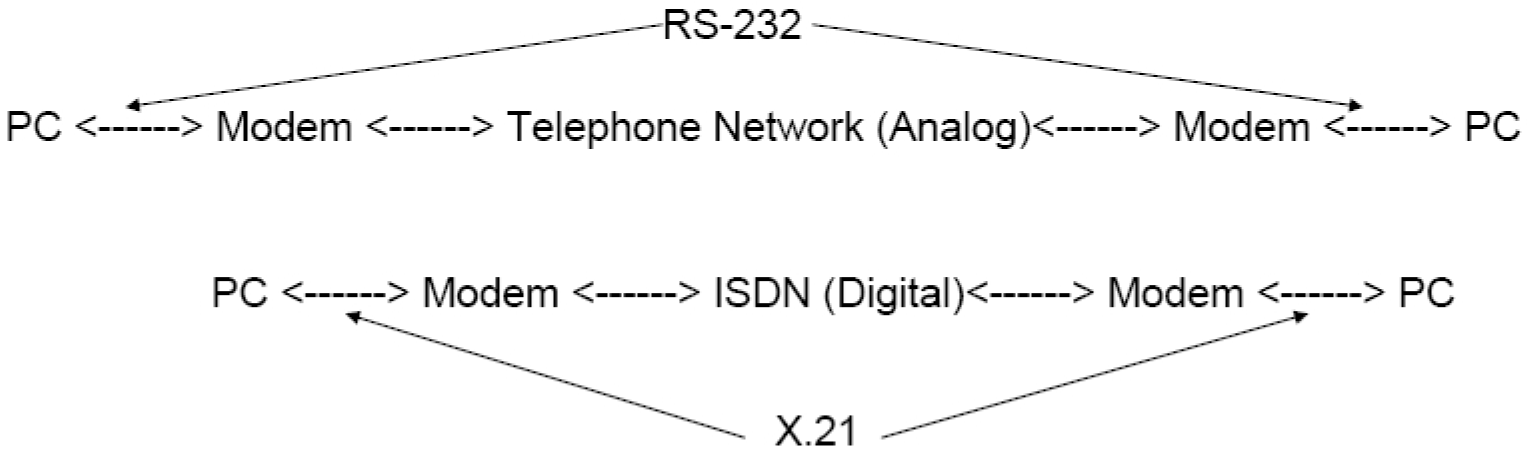


RS-232 DB9 Pin Out

DB-9M	**Function**	**Abbreviation**
Pin #1	Data Carrier Detect	CD
Pin #2	Receive Data	RD or RX or RXD
Pin #3	Transmitted Data	TD or TX or TXD
Pin #4	Data Terminal Ready	DTR
Pin #5	Signal Ground	GND
Pin #6	Data Set Ready	DSR
Pin #7	Request To Send	RTS
Pin #8	Clear To Send	CTS
Pin #9	Ring Indicator	RI

X.21 Interface

- ITU (CCITT) standard
- Balanced circuit
- Digital signaling interface
- Put more logic in DTE/DCE to interpret control sequences
- C (control) & I (indication) state info
- T (trans.) & R (rcv.) data or control info.



RS-232

PC <------> Modem <------> Telephone Network (Analog)<------> Modem <------> PC

PC <------> Modem <------> ISDN (Digital)<------> Modem <------> PC

X.21

X.21 Interface

- X.21 includes specifications for receiving and placing calls as well as for sending and receiving data using synchronous full duplex transmission.

- X.21 is direct digital connection hence all data transmission must be synchronous and equipments will need to provide both bit and character synchronization.

- Minimum data rate is 64kbps.Because this is the bit rate currently used to encode voice in digital form on the telephone lines.

- Advantage is signals are encoded in serial digital form ,which sets the stage for providing special new services in computer communication.

Signal

Interchange circuit	Name	Direction
T	Transmit	DTE to DCE
R	Receive	DCE to DTE
C	Control	DTE to DCE
I	Indication	DCE o DTE
S	Signal Element Timing	DCE to DTE
B	Byte Timing	DCE to DTE

X.21 provides eight signals:

Signal Ground (G) -
This provides reference for the logic states against the other circuits. This signal may be connected to the protective ground (earth).

DTE Common Return (Ga) -
Used only in unbalanced-type configurations (X.26), this signal provides reference ground for receivers in the DCE interface.

Transmit (T) -
This carries the binary signals which carry data from the DTE to the DCE. This circuit can be used in data-transfer phases or in call-control phases from the DTE to DCE (during Call Connect or Call Disconnect).

Receive (R) -
This carries the binary signals from DCE to DTE. It is used during the data-transfer or Call Connect/Call Disconnect phases.

Control (C) -

Controlled by the DTE to indicate to the DCE the meaning of the data sent on the transmit circuit. This circuit must be ON during data-transfer phase and can be ON or OFF during call-control phases, as defined by the protocol.

Indication (I) -

The DCE controls this circuit to indicate to the DTE the type of data sent on the Receive line. During data phase, this circuit must be ON and it can be ON or OFF during call control, as defined by the protocol.

Signal Element Timing (S) -

This provides the DTE or DCE with timing information for sampling the Receive line or Transmit line. The DTE samples at the correct instant to determine if a binary 1 or 0 is being sent by the DCE. The DCE samples to accurately recover signals at the correct instant. This signal is always ON.

Byte Timing (B) –

This circuit is normally ON and provides the DTE with 8-bit byte element timing. The circuit transitions to OFF when the Signal Element Timing circuit samples the last bit of an 8-bit byte. Call-control characters must align with the B lead during call-control phases. During data- transfer phase, the communicating devices bilaterally agree to use the B lead to define the end of each transmitted or received byte. The C and I leads then only monitor and record changes in this condition when the B lead changes from OFF to ON, although the C and I leads may be altered by the transitions on the S lead. This lead is frequently not used.