EEE 315

Communication Engineering-I

Topic 3: Communication Channels

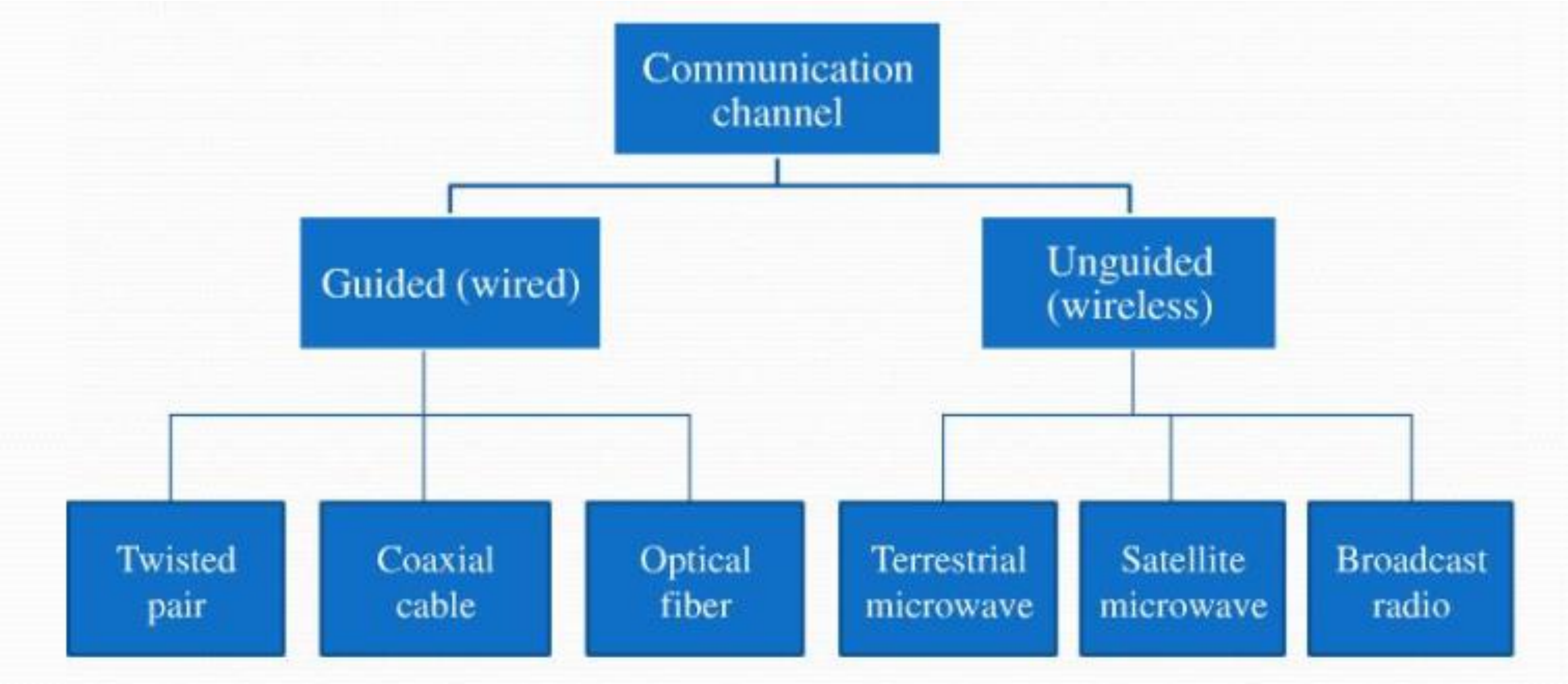
(Ref: Modern Digital and Analog Communication Systems – B. P. Lathi - Chapter 1)

Purpose of Communication Channel

Transmitting data from transmitter output to receiver input.

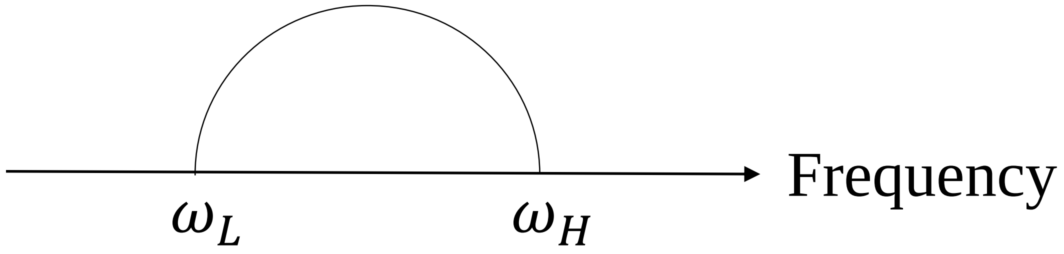
Also known as communication media.

Classification of Communication Channel



Common Terms Related to Channels

Signal Bandwidth: The difference between the upper frequency boundary and the lower frequency boundary is called the bandwidth of a signal.



Bandwidth = $\omega_H - \omega_L$

Channel Bandwidth: The bandwidth of a channel is the range of frequencies that it can transmit with reasonable fidelity.

- A signal can be successfully sent over a channel if the channel bandwidth exceeds the signal bandwidth.

Common Terms Related to Channels

Signal to Noise Ratio (SNR): The ratio of signal power to noise power is called Signal to Noise Ratio.

$$\text{SNR} = \frac{Signal\ Power}{Noise\ Power}$$

Not all channel can transmit all bandwidths, nor is the SNR same for every channel.

- The quality of communication systems varies with the Signal-to-Noise ratio (SNR).
- A certain minimum SNR at the receiver is necessary for successful communication.

SNR can also be expressed in dB unit: $\text{SNR}_{(\text{dB})} = 10 \log_{10} \text{SNR} = 10 \log_{10} \frac{Signal\ Power}{Noise\ Power}$

Signal to Noise Ratio Example

- **Find Signal to Noise Ratio in dB if the signal power is 100W and noise power is 0.1W.**

Here, Signal Power, P_s = 100 W
Noise Power, P_n = 0.1 W

$$SNR_{dB} = 10\ log_{10}\ SNR$$

$$SNR_{dB} = 10\ log_{10} \frac{Signal\ Power}{Noise\ Power}$$

$$SNR_{dB} = 10\ log_{10} \frac{P_s}{P_n}$$

$$SNR_{dB} = 10\ log_{10} \frac{100}{0.1}$$

$$SNR_{dB} = 10\ log_{10} \frac{100}{0.1} = \ 10\ log_{10}(1000) = 30\ dB$$

- H.W.: Find SNR(dB) if the signal power is 14W and noise power is 2W.

Signal to Noise Ratio Example

- **Find noise power if Signal to Noise Ratio is 20 dB and signal power is 10W.**

  Here, SNR = 20 dB, Signal Power, P_s = 10 W

$$SNR_{dB} = 10\ log_{10}\ SNR$$

$$or, \frac{SNR_{dB}}{10} = log_{10}\ SNR$$

$$\text{So, } SNR = 10^{SNR_{dB}/10}$$

$$\frac{P_s}{P_n} = 10^{SNR_{dB}/10}$$

$$\frac{10W}{P_n} = 10^{20/10}$$

$$\frac{10W}{P_n} = 100$$

$$Noise\ Power = P_n = \frac{10W}{100} = 0.1W$$

Bandwidths of Some Common Channels

Copper wire: 1 MHz

Coaxial cable: 100 MHz

Microwave/RF: GHz

Optical fiber: THz

Channel bandwidth MUST be larger than the bandwidth of the signal needed to be transmitted.

Capacity of a Channel

- ❑ Two primary resources in communications:

1. **Channel bandwidth:** Limits the bandwidth of signals that can successfully pass through.
2. **Transmitted power:** Signal SNR at the receiver determines the recoverability of the transmitted signals.

- ❑ Shannon's Capacity Theorem, $C = B \log_2 (1 + SNR)$ bits/second

  C = Channel Capacity (bits/second or bps)

  B = Channel Bandwidth (Hz)

  SNR = Signal-to-Noise ratio = Signal Power/ Noise Power

- ❑ Channel capacity is the maximum number of bits that can be transmitted per second with a probability of error arbitrarily close to zero.

Capacity of a Channel

Channel Capacity, $C = B \log_2 (1 + SNR)$ bits/second

$= 3.32\ B \log_{10} (1 + SNR)$ bits/second

- ❑ Capacity increases linearly with bandwidth, but only logarithmically with signal strength.
- ❑ Shannon's limit tells us what we can achieve; it tells us nothing about how to do it.

Example: Shannon's Capacity Theorem

- A baseband signal with 10 kHz bandwidth has average power of 14W. If it is transmitted by a channel which has noise power=2W , what will be the capacity of that channel?

Here, Bandwidth, $B = 10kHz$

$$SNR = \frac{14W}{2W} = 7$$

Channel Capacity, $C = \text{B} \log_2 (1 + \text{SNR})$

$$= (10x10^3)\ log_2(1+7)$$
$$= 30000\ bits/second$$
$$= 30\ kbit/second$$
=30 kbps

Alternatively, $C = 3.32 \text{ B} \log_{10} (1 + \text{SNR})$

$$= 3.32\ (10x10^3)\ log_{10}(1+7)$$
$$= 29983\ bits/second$$
$$= 29.98\ kbit/second$$
$$\approx 30\ kbit/second$$

Example: Shannon's Capacity Theorem

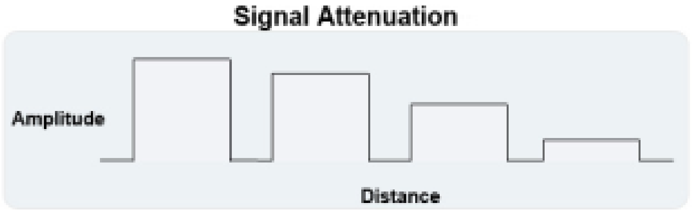
- H.W.: A baseband signal with 12 kHz bandwidth has Signal to Noise ratio 20 dB, what will be the capacity of that channel?

Hints: Change SNR_{dB} to SNR

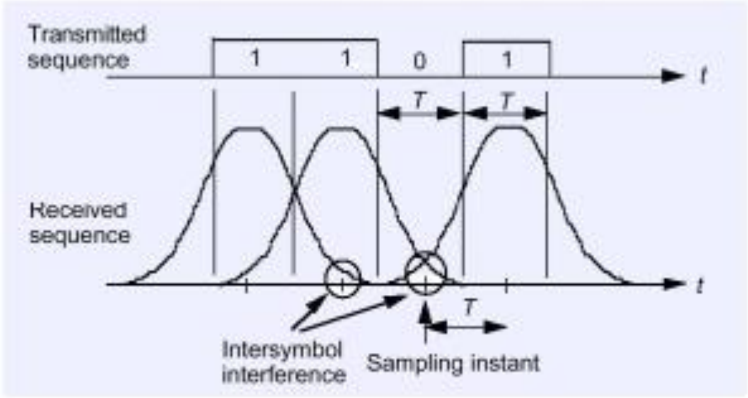
$$C = B \log_2 (1 + SNR) \text{ bits/second}$$

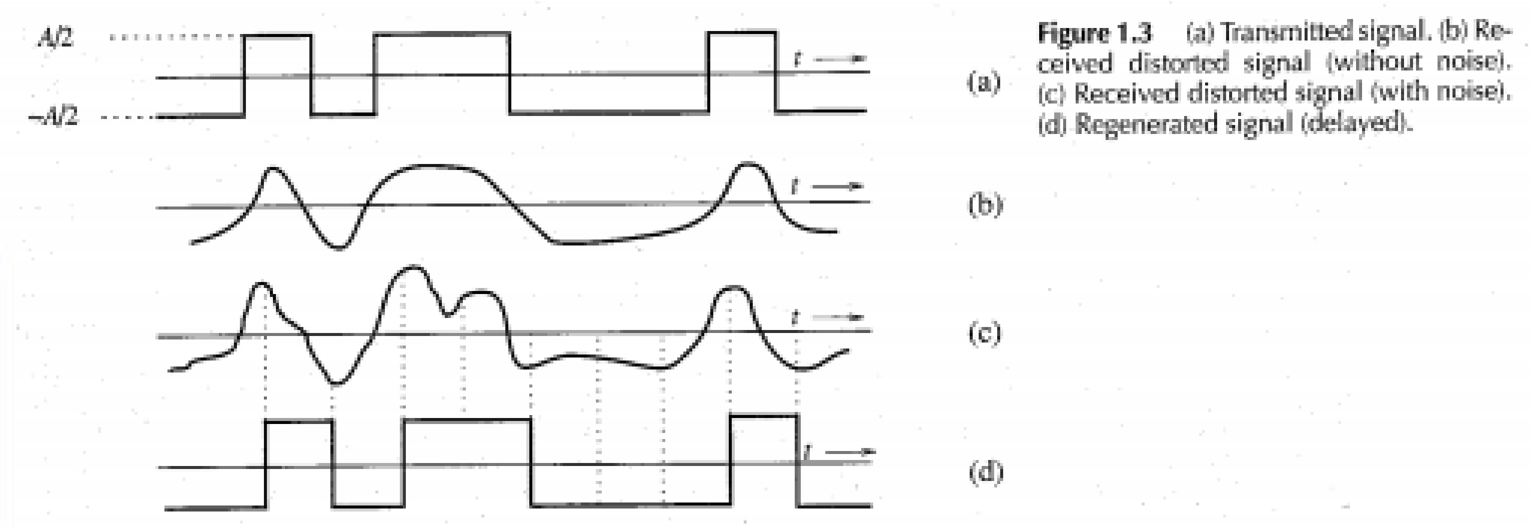
Challenges in Communication Link

1. **Attenuation:** Reduction in signal power or intensity.
2. **Distortion:** Signal shape gets changed.
3. **Noise:** Random signals that manipulate messages.
4. **Multi-User Interference:** Collision or interference among two or more messages.



Attenuation





Effect of Distortion and Noise

Types of Transmission

1. Baseband Transmission

- The message signal is transmitted directly.
- Messages are generally low frequency signals.
- Can be transmitted through cables.
- Has severe interference due to overlapping bands.

2. Carrier Modulation/Passband Transmission

- The message signal is used to modify a carrier signal.
- Carriers are generally high frequency signals.
- Can be transmitted wireless.