Communication System (CS)

Elements of CS

Info. S. → Transmitter   Channel   Receiver → User of Information

↑↑↑
Noise (unwanted signal)
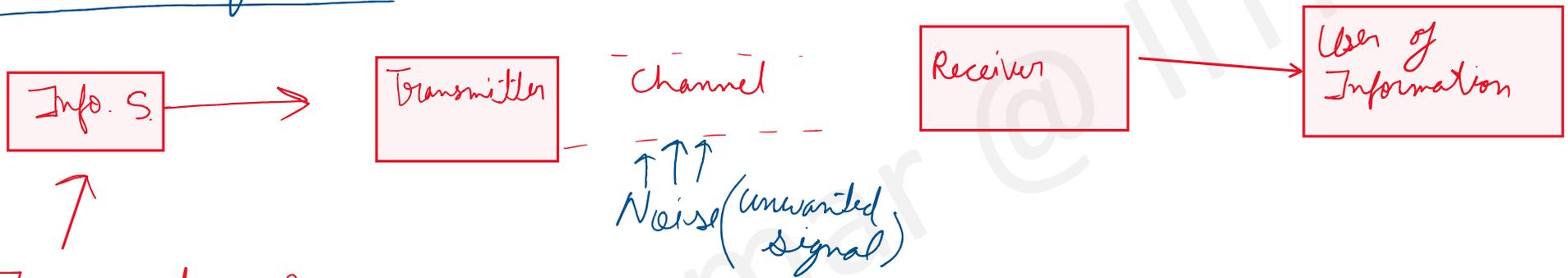
↑ Information source

There are two basic mode of communication :-

① Point to Point (PTP)

single Source → single receiver

Ex- Telephonic, Mobile network
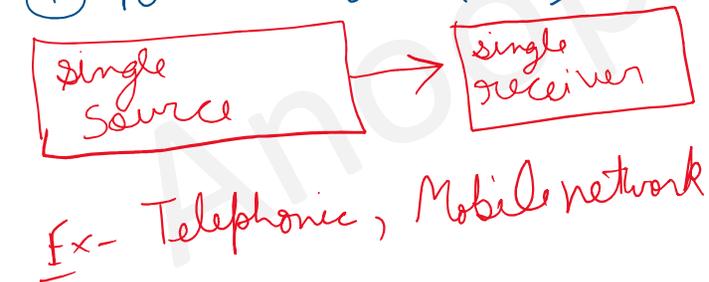
② Broadcast Communication

single source → Many receiver
→ Many receiver
→ Many receiver
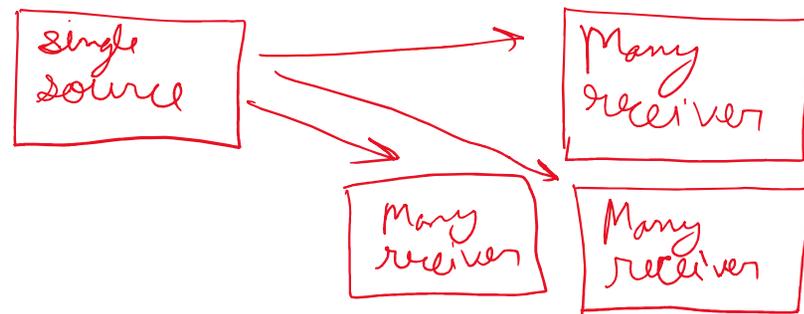
Ex-
Radio,
Television

Basic Terminology

- Message signal $\approx$ Low frequency signal $\approx$ Modulating signal $\approx$ Information signal

  Audio signal $\approx$

- Carrier wave $\approx$ high frequency wave $\approx$ EM wave $\approx$ High frequency wave generator

- <u>Transducer</u> — Any device that converts one form of energy into another form. <u>Ex</u>- Microphone (Mechanical $\longrightarrow$ electrical)

- <u>Signal</u> — Information converted in electrical form & suitable for transmission. They are of two type
  1. Analog
  2. Digital

- <u>Noise</u> — Unwanted signal that tend to disturb the transmission. It can be outside or Inside the system

- <u>Transmitter</u> - A transmitter process the incoming message signal so as to make it suitable for transmission through channel.

- Receiver — It receives the signal.

- <u>Attenuation</u> - The loss of strength of signal while propagating through channel (medium).

- <u>Amplification</u> — Process of increasing the amplitude or strength of signal using an electronic circuit.

- <u>Range</u> — Largest distance b/w source & point upto which strength of received signal is of sufficient strength.

- <u>Bandwidth</u> — frequency range over which any equipment operates or the portion of spectrum occupied by the signal.

- <u>Modulation</u> — Mixing of low frequency signal to high frequency signal.

- <u>Demodulation</u> — The process of retrival of information from the modulated wave at receiver.

- <u>Repeater</u> — Combination of receiver, transmitter & amplifier. It increases the range of communication & strength

Bandwidth of Signals

In Communication system message signals (voice , music, picture or Computer data) have different ranges of V. For example —

- speech signal has frequency range $\quad 300 Hz \underline{\quad\quad} 3100 Hz$

$$\text{so bandwidth of speech signal} = (3100 - 300) Hz$$
$$= 2800 Hz$$

- Music has range $20 Hz$ to $20,000 Hz$

$$\text{Bandwidth for music transmission} = (20000 - 20) Hz$$
$$= 19980 Hz$$
$$\approx 20 kHz$$

- Similarly Bandwidth of T.V. signal $\approx 6 MHz$

Bandwidth of Transmitting Medium

Commonly used transmission media are wire, freespace, optical fibre

- Coaxial cable — (750 MHz)
- Free space — (1 kHz to GHz)

*media is plural form of medium

Communication satellite

Ionosphere

LOS

Ground wave

Earth

LOS = Line of Sight

space wave $\left(\text{above } 40\,MHz\right)$

Sky wave $\left(5\,MHz \text{ to } 40\,MHz\right)$
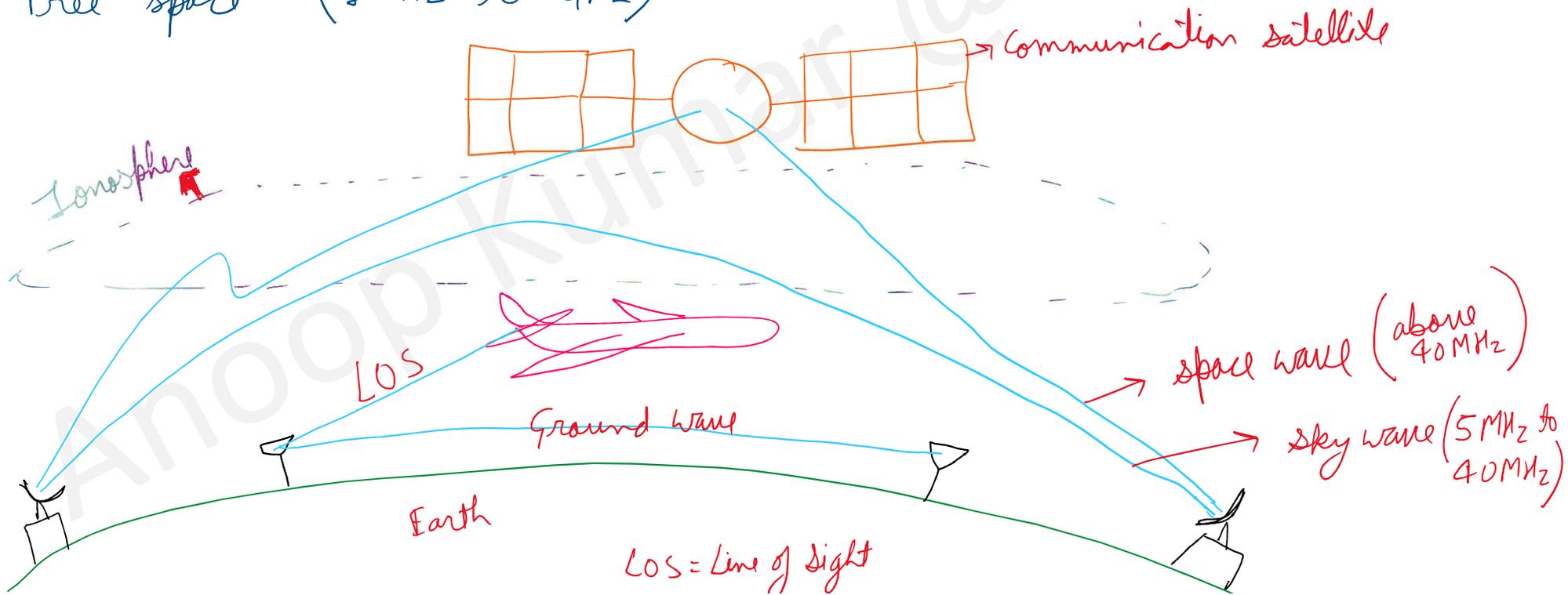
Ground Wave

length of wire $= \dfrac{\lambda}{4} = \dfrac{c}{4\nu}$ {where λ = wavelength of wave

ν (read as nu) = frequency of wave

this shows for lower frequency length should be large.

Sky wave

wave of range 5 MHz to 40 MHz is used because above 40MHz wave penetrates ionosphere and don't reflect back.

space wave propagation

frequency greater than 40MHz, as they penetrates the ionosphere

"therefore Satellites are used to reflect back to the earth"

How to find the range of a signal?

$$d_T^2 + R^2 = (R + h_T)^2$$

$$d_T^2 + R^2 = R^2 + h_T^2 + 2Rh_T$$

$$d_T^2 = h_T^2 + 2Rh_T$$

$$d_T^2 = h_T^2 \left(1 + \frac{2R}{h_T}\right)$$

$$d_T = h_T \left(1 + \frac{2R}{h_T}\right)^{\frac{1}{2}}$$

$$d_T = h_T \sqrt{\frac{2R}{h_T}} \qquad \frac{2R}{h_T} >> 1$$

$$\boxed{d_T = \sqrt{2Rh_T}} \longrightarrow \text{due to transmitting antenna}$$

similarly $\boxed{d_r = \sqrt{2Rh_r}} \longrightarrow$ due to receiver
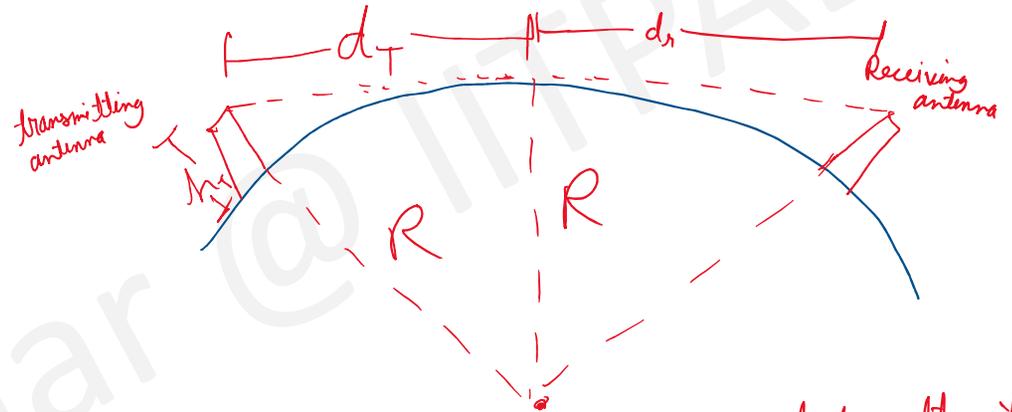
$d_T \rightarrow$ distance before attenuation

$R \rightarrow$ Radius of earth

$h_T \rightarrow$ height of tower

If transmitting & receiving antena both are working then

$$d = d_T + d_r$$

total range = $d = \sqrt{2Rh_T} + \sqrt{2Rh_r}$

Modulation and its Necessity :—

① To keep size of Antenna small

for low frequency signal $(\nu = 20kHz)$, size of antenna $l = \dfrac{c}{4\nu} = \dfrac{3\times10^8}{4\times2\times10^4}$

$$l = 3750m \approx 3.7km$$

- this show for low frequency signal it is very difficult to construct antenna, that's why it is modulated.

② Effective power radiated should be large to increase signal strength

effective power radiated by antenna $\propto (\nu)^2$

" " " " $\propto \left(\dfrac{l}{\lambda}\right)^2$

$\begin{cases} \text{where} \\ \nu = \text{frequency} \\ \lambda = \text{wavelength} \end{cases}$

- Therefore modulation is needed to increase signal strength.

③ To avoid mixing of frequency from different transmitter

* Therefore Modulation is necessary

There are mainly three type modulation

① Amplitude Modulation (AM)

$$C_m(t) = \left[(A_c + A_m \sin \omega_m t) \sin(\omega_c t + \phi)\right]$$

② Frequency Modulation (FM)

$$C_m(t) = A_c \sin\left((\omega_c + A_m \sin \omega_m t) t + \phi\right)$$

③ Phase Modulation

$$C_m(t) = A_c \sin\left(\omega_c t + (\phi + A_m \sin \omega_m t)\right)$$

where
A_c = Amplitude of carrier wave
A_m = Amplitude of message wave
ω_c = angular frequency of carrier wave
ω_m = angular frequency of message wave
ϕ = phase constant

Amplitude Modulation (AM)

In AM the amplitude of carrier wave is varried in accordance with signal.

Let carrier wave is given by $\quad C(t) = A_c \sin \omega_c t$

Message wave (signal) ———— $m(t) = A_m \sin \omega_m t$

So, AM wave

$$C_m(t) = (A_c + A_m \sin \omega_m t) \sin(\omega_c t)$$

$$= \left(A_c + \frac{A_m}{A_c} A_c \sin \omega_m t\right) \sin(\omega_c t)$$

$$\boxed{C_m(t) = (A_c + \mu A_c \sin \omega_m t) \sin(\omega_c t)}$$

Where $\mu = \dfrac{A_m}{A_c}$ is called modulation index

$\mu \leq 1$ To avoid distortion & To avoid overlaping

$$C_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2} \cos(\omega_c + \omega_m)$$

①

This is modulated wave

This wave is consist of three frequencies

$f_c \longrightarrow$ carrier wave frequency

$f_c + f_m \longrightarrow$ USB (upper side band) frequency

$f_c - f_m \longrightarrow$ LSB (lower side band) frequency
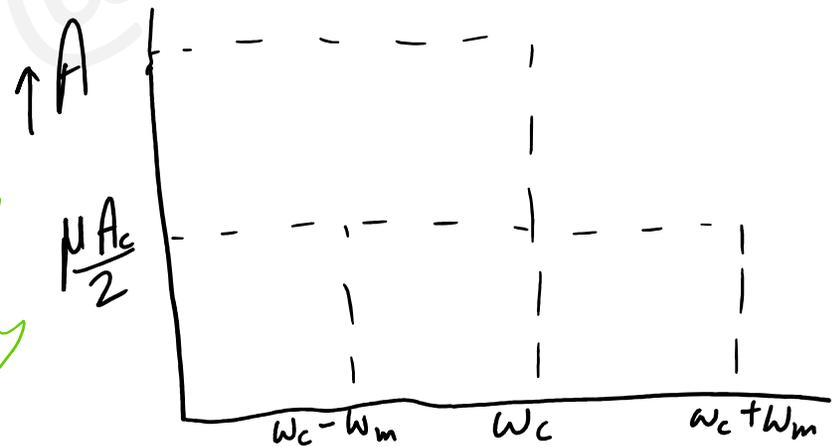
$\longrightarrow \omega$ = angular frequency

$\boxed{\omega = 2\pi f}$

From eqⁿ ① Amplitude of Modulation wave is

$$A = (A_c + \mu A_c \sin\omega_m t)$$

$$A_{max} = A_c + \mu A_c \qquad \{\text{when } \sin\omega_m t = 1\} \qquad ②$$

$$A_{min} = A_c - \mu A_c \qquad \{\text{when } \sin\omega_m t = -1\} \qquad ③$$

Adding eqⁿ ② & ③

$$\frac{A_{max} + A_{min}}{2} = A_c$$

$$A_{max} = \frac{A_{max} + A_{min}}{2} + \mu A_c$$

$$2A_{max} = A_{max} + A_{min} + 2\mu A_c$$

$$A_{max} - A_{min} = 2\mu A_c$$

$$\mu = \frac{A_{max} - A_{min}}{2A_c} \implies \boxed{\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}}$$
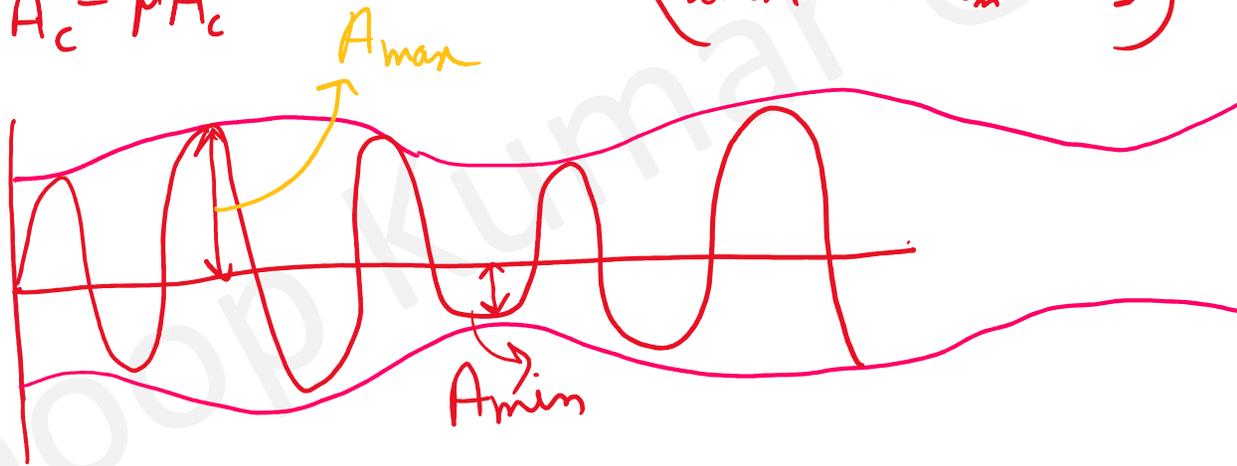
Modulation Index

Demodulation
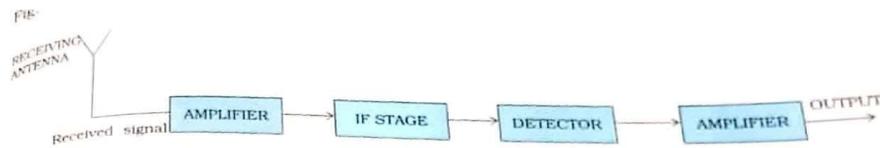
FIGURE 15.12 Block diagram of a receiver.
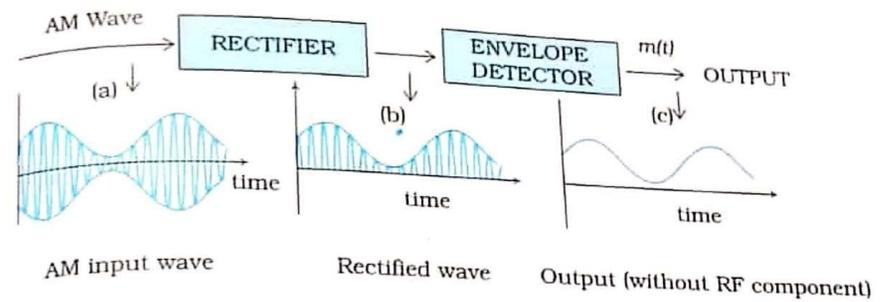
FIGURE 15.13 Block diagram of a detector for AM signal. The quantity on y-axis can be current or voltage.