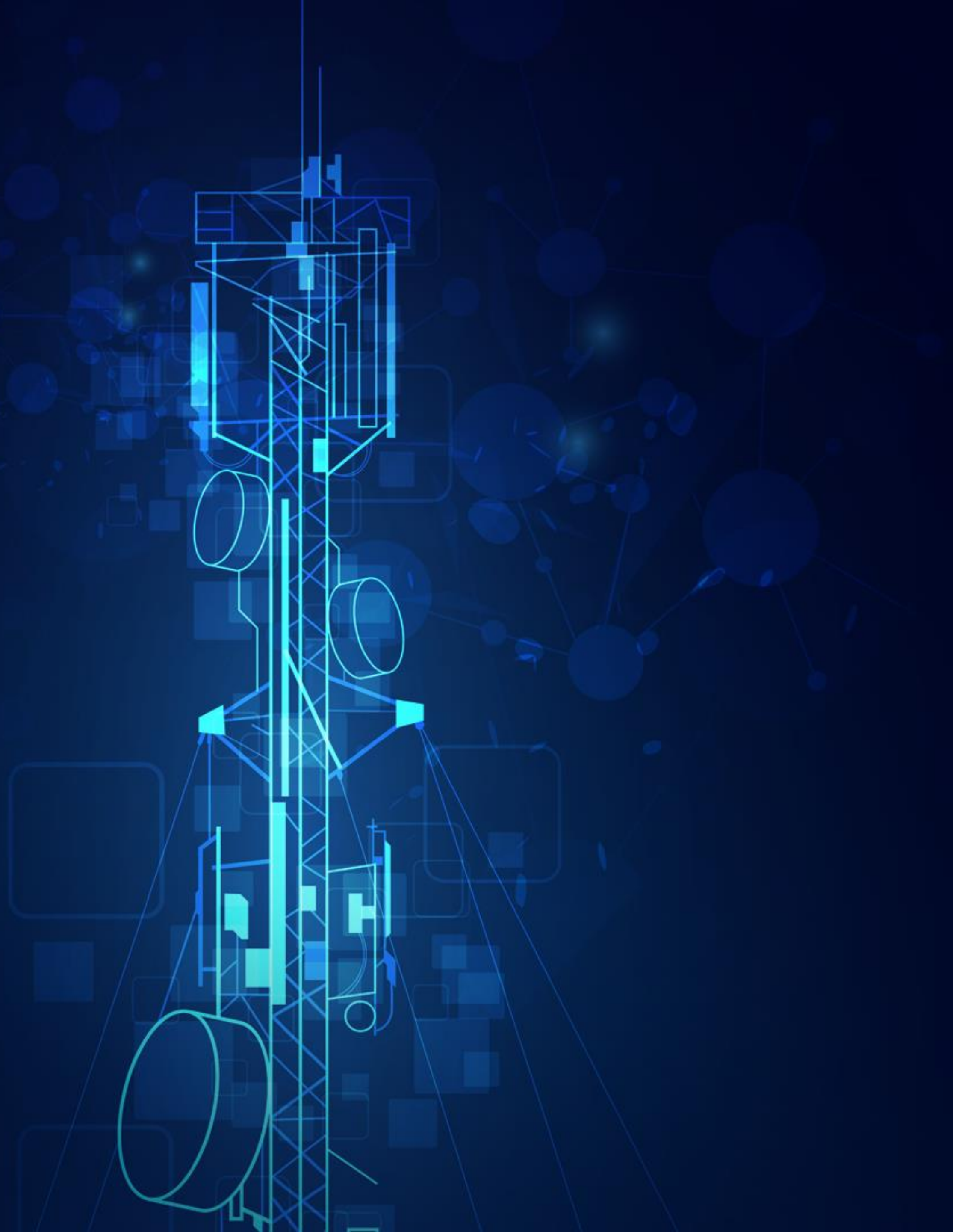
Welcome to

Aakash + BYJU'S NOTES

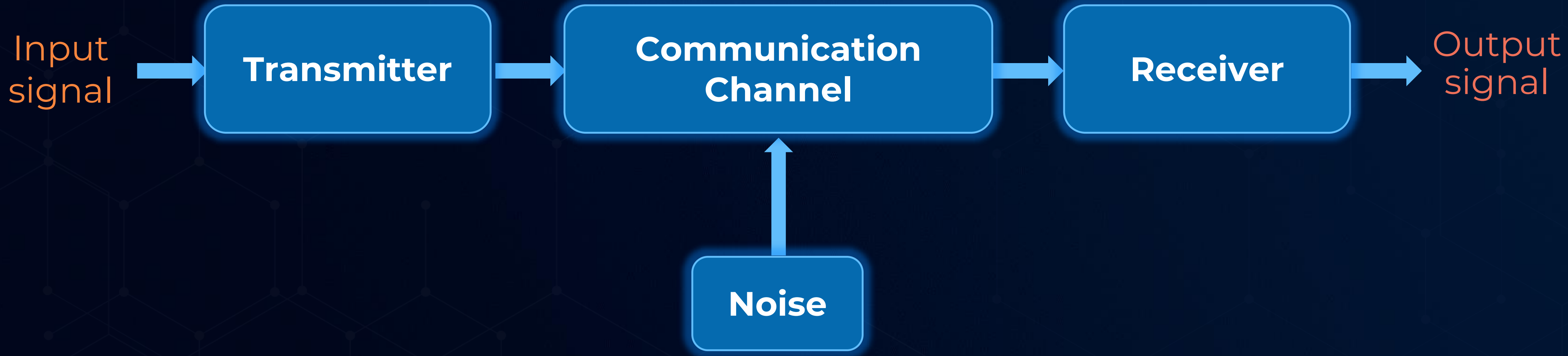
Communication Systems



Communication System

Communication system: A set-up used in transmission of information from one place to another.

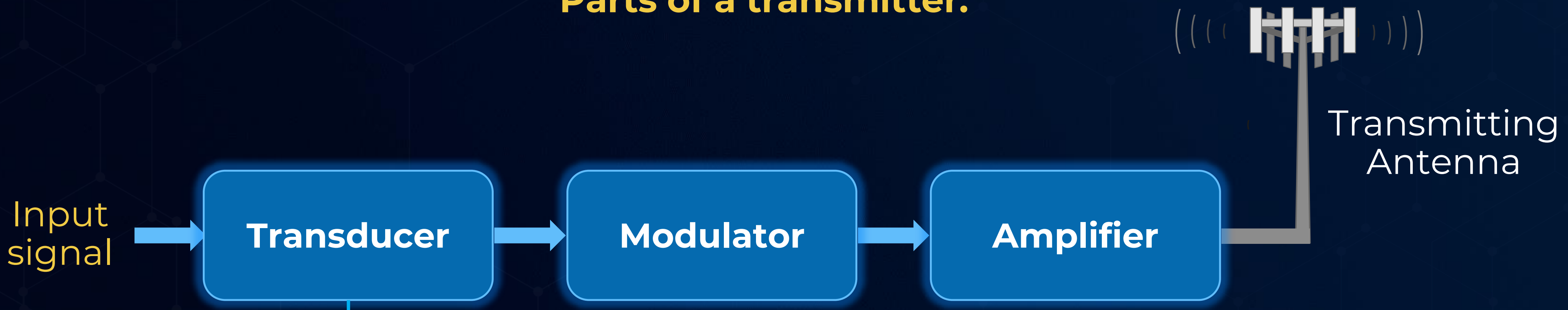
Irrespective of its nature, every communication system has three essential elements:



Communication System

Transmitter: It processes the incoming message signal so as to make it suitable for transmission through channel and subsequent reception.

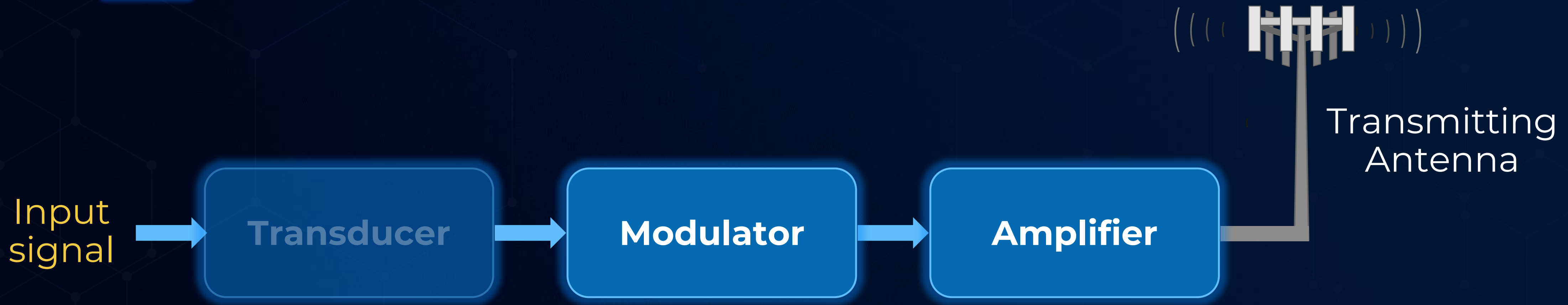
Parts of a transmitter:



A device which convert signal of various physical form into electrical signal, and vice versa.

Example: Microphone, photo detectors etc.

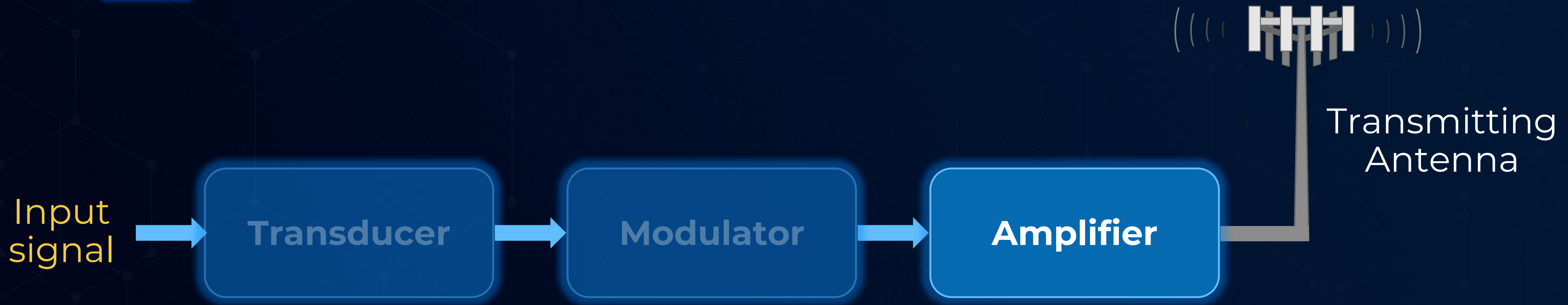
Communication System



Modulator: It modulates the output signal of transducer by superimposing it on high frequency carrier wave so that the signal can be transmitted to long distance. This process is known as "**Modulation**".

Attenuation: It is the loss of strength of a signal while propagating through a medium.

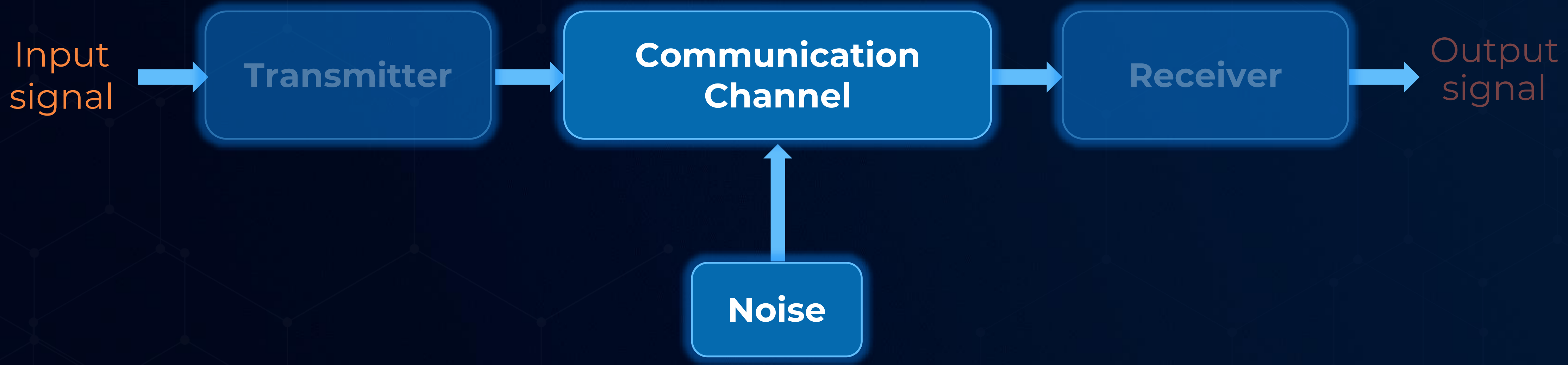
Communication System



Amplifier: To compensate the attenuation of the signal, the amplification (i.e., the increase of amplitude and hence the increase of strength) of the signal is required to be done and it is done by using **amplifier**.

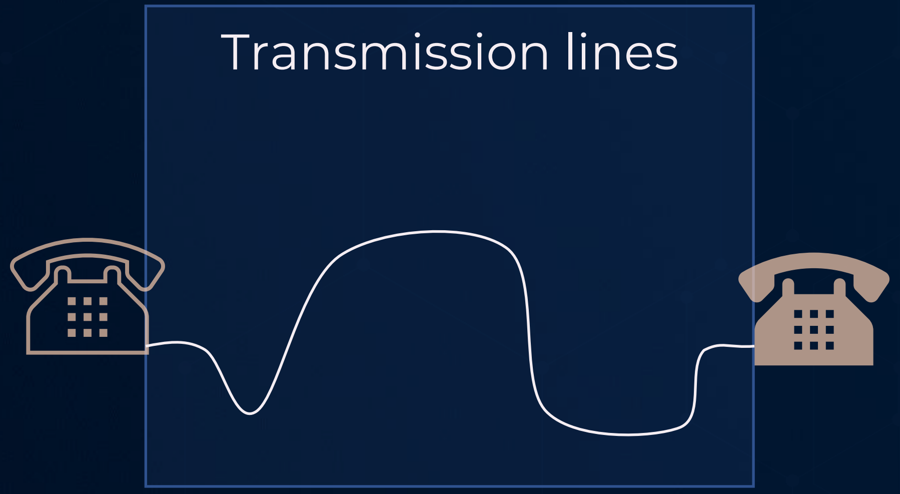
Transmitting antenna: The modulated and amplified signal is then radiated into space with the help of an antenna called "**Transmitting antenna**".

Communication System

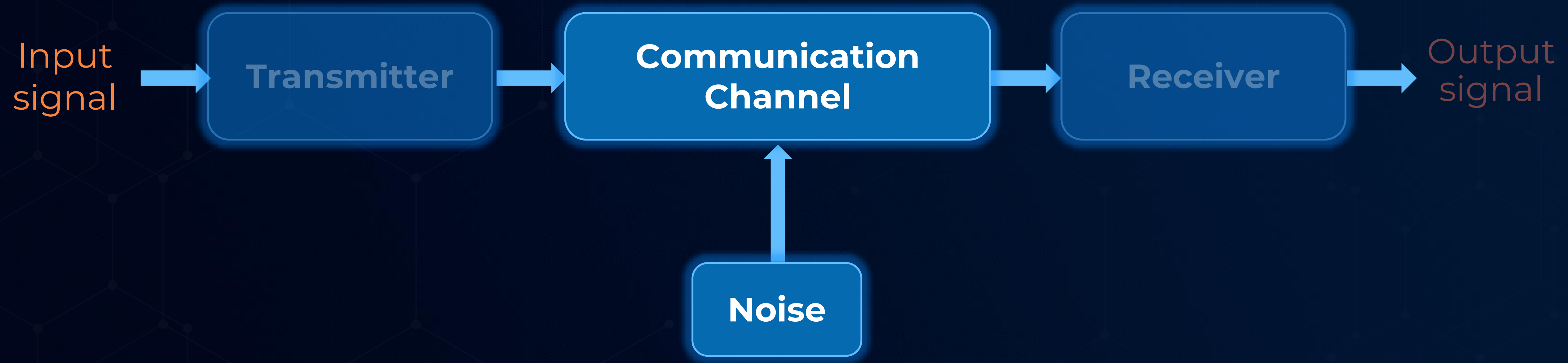


Communication System

- The communication channel carries the modulated wave from the transmitter to the receiver.



Communication System

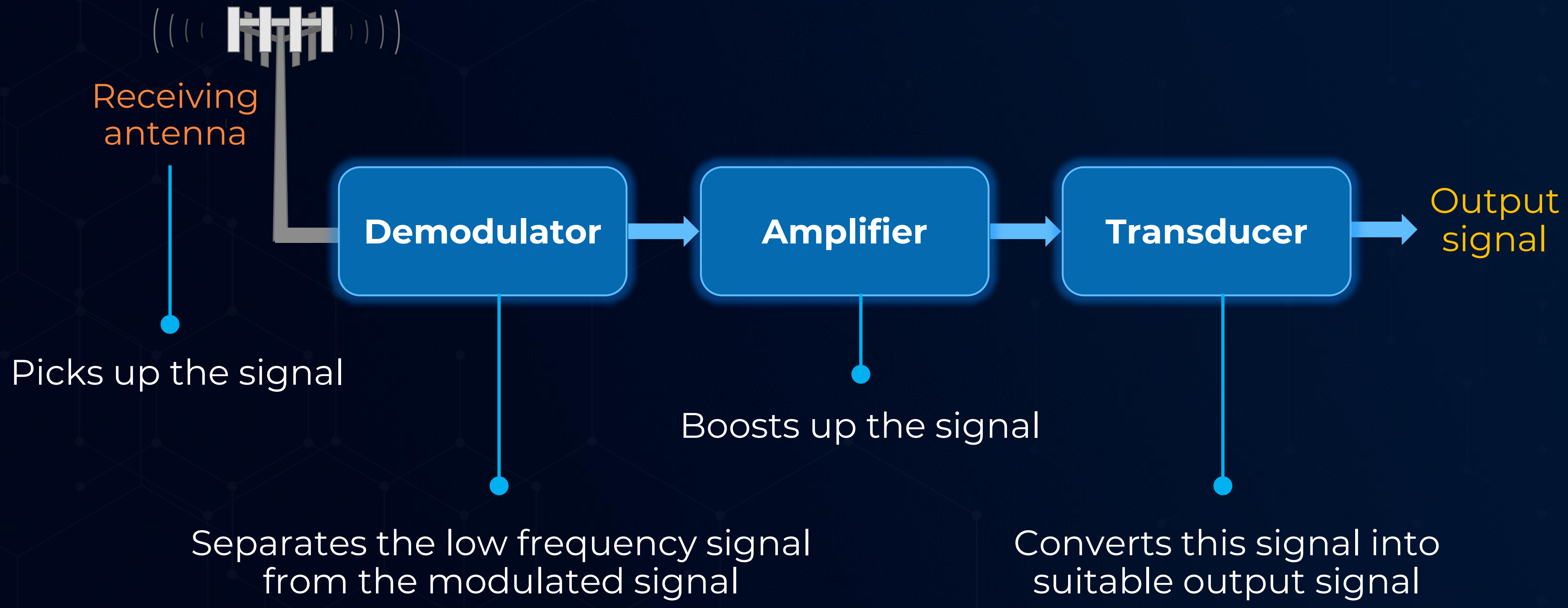


- Noise: It refers to the unwanted signals that tend to disturb the transmission and processing of signals in a communication system.

Communication System

The receiver receives the signal at receiving antenna and modifies it to a recognizable form of output signal.

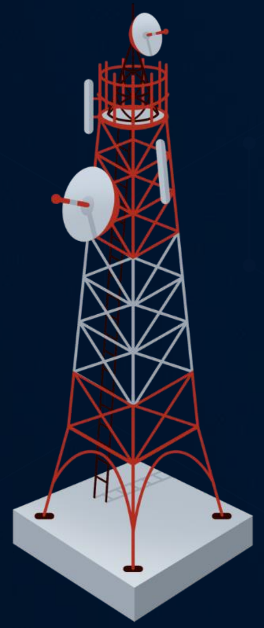
Parts of a receiver:



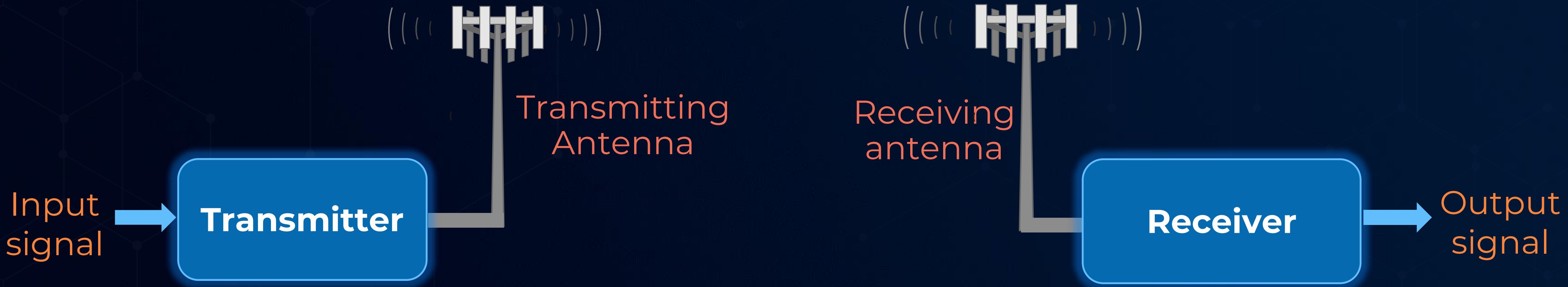
Antenna

- An antenna is a structure that is capable of transmitting or receiving electromagnetic waves.
- Transmitting antenna: It converts high frequency current into electromagnetic waves.
- Receiving antenna: It converts electromagnetic waves into high frequency current.
- To transmit a signal of wavelength λ, the required length of the antenna is:

$$l \geq \frac{\lambda}{4}$$



Transmission Medium

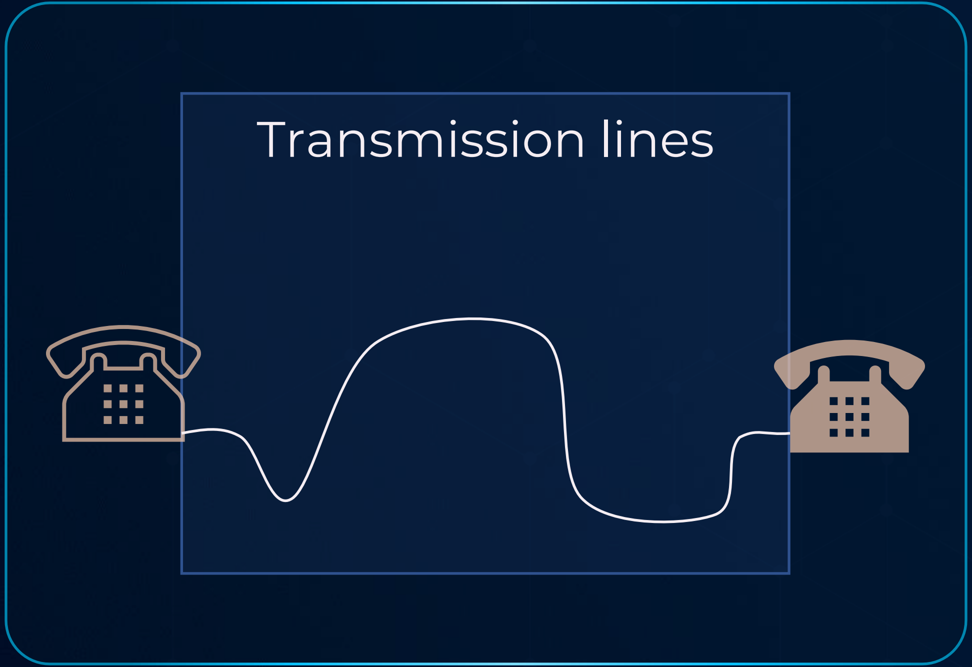


- A transmission medium (communication channel) is required to send a signal from transmitting antenna to receiving antenna.

Guided Transmission Medium

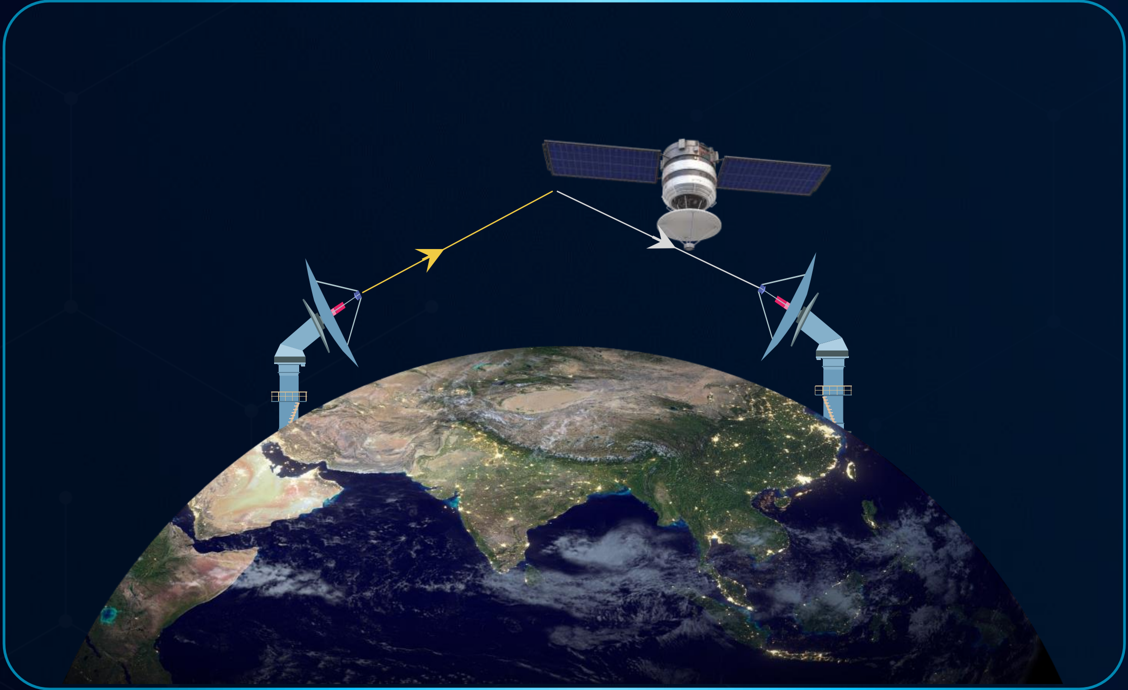
- This communication medium or channel is used in point-to-point communication between a single transmitter and a receiver.

- Guided transmission medium is used in line communication:
  - Two wire transmission line
  - Co-axial cable transmission
  - Optical fiber cable communication



Unguided Transmission Medium

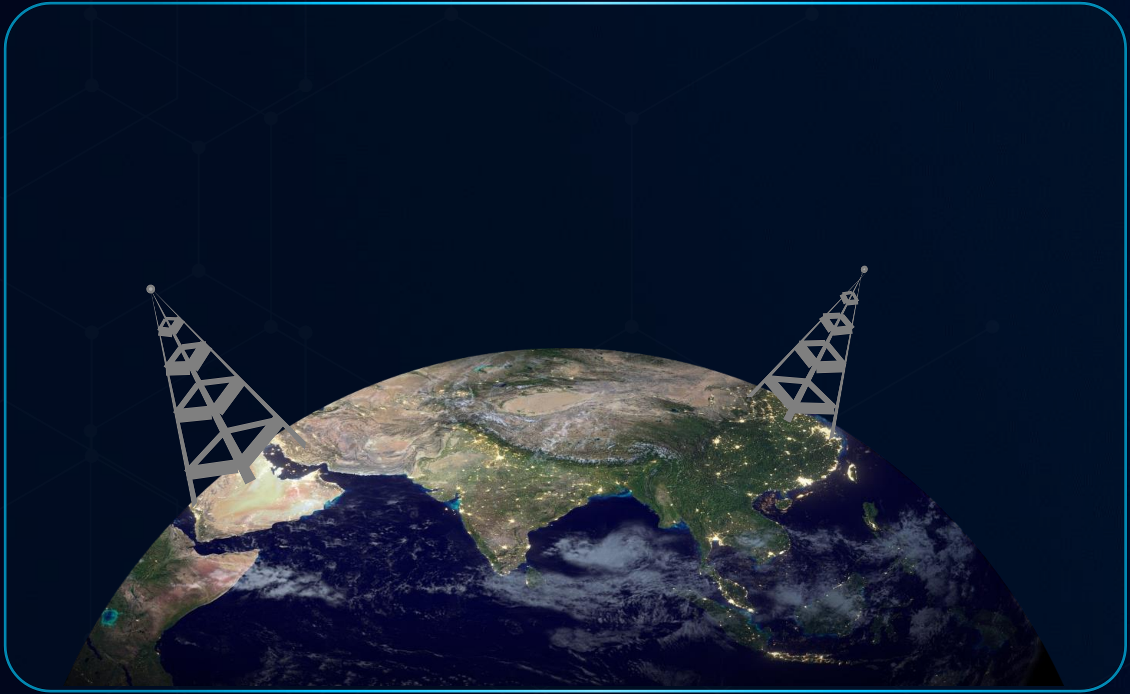
- It is that communication medium which is used, where there is no point-to-point communication between transmitter and receiver.
- A large number of receiver is present corresponding to a single transmitter.



- It is used in space communication and satellite communication.

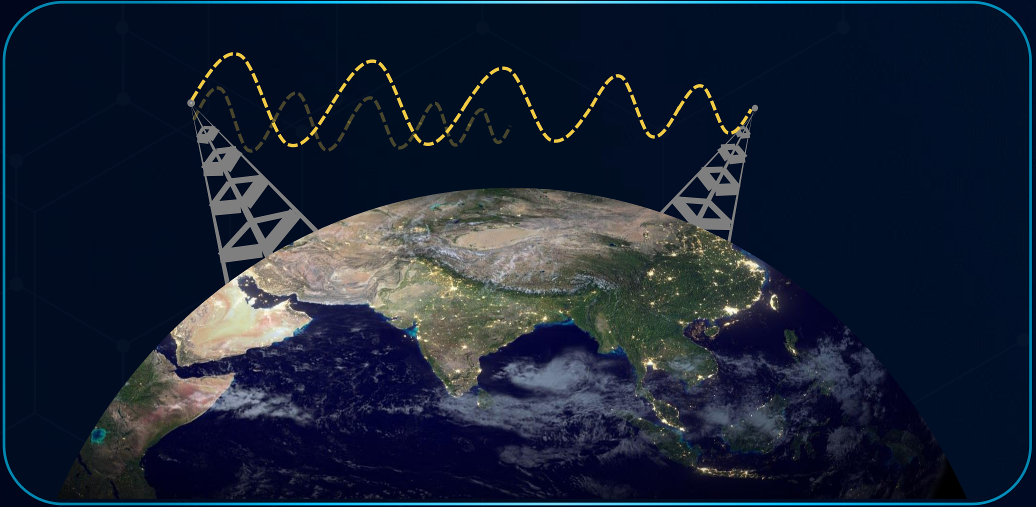
Propagation of Electromagnetic Wave

- Depending on the distance between transmitting antenna and receiving antenna, the electromagnetic wave radiated by transmitter can be classified into three categories:



  - Ground waves
  - Sky waves
  - Space waves

Ground Wave



- For transmitting the signals of longer wavelengths (i.e., lower frequencies), the antennas have large physical size, and they are located on or very near to the ground.
- For such antennas, the wave glides over the surface of Earth. This mode of propagation is called **surface wave propagation** or **Ground wave propagation**.
- The ground has a strong influence on the propagation of the signal. The wave induces current in the ground over which it passes, and it is attenuated as a result of absorption of energy by the Earth.
- The attenuation of surface waves increases very rapidly with increase in frequency.
- The maximum range of coverage depends on the transmitted power and frequency (up to few MHz).
- In standard AM broadcast, ground based vertical towers are generally used as transmitting antennas.

Advantage: due to large wavelength, it bends over the obstacle easily (diffraction)

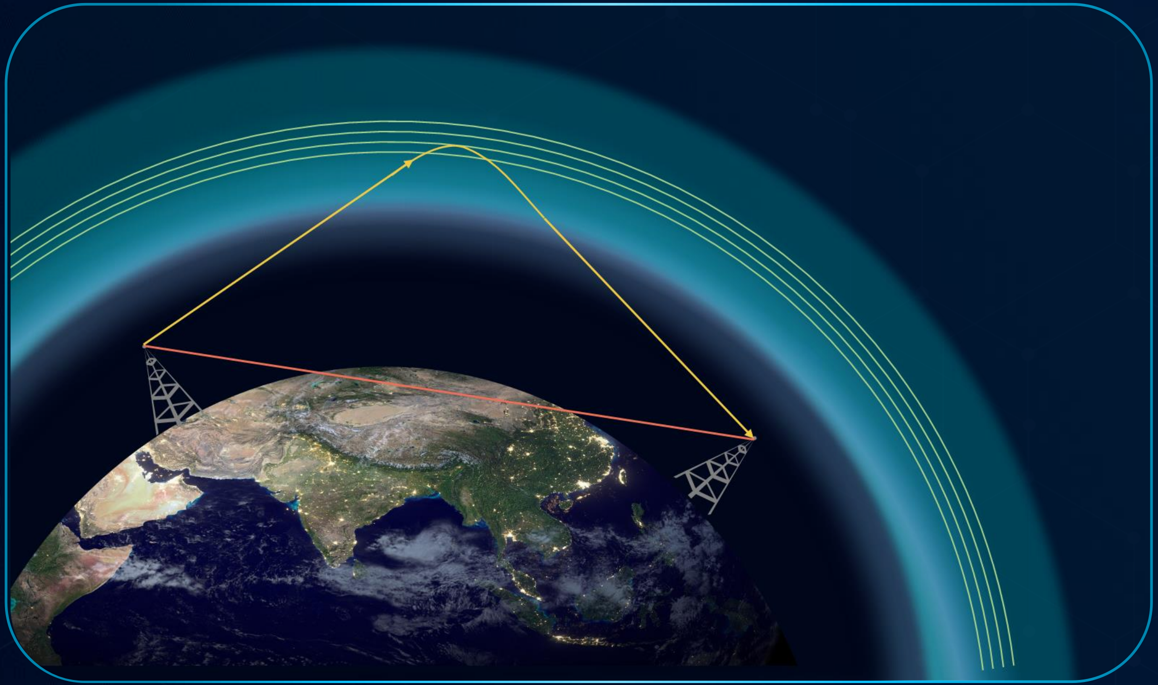
Sky Wave

- For ground wave propagation, the attenuation increases rapidly with increase in frequency. Thus, it is not suitable for transmitting high frequencies.

- Sky wave propagation is used to overcome this difficulty.

- Sky wave propagation:

  A mode of propagation of EM wave of high frequency (range: few MHz to $40\ MHz$) by which long distance communication can be achieved by ionospheric reflection of electromagnetic waves back towards the Earth.



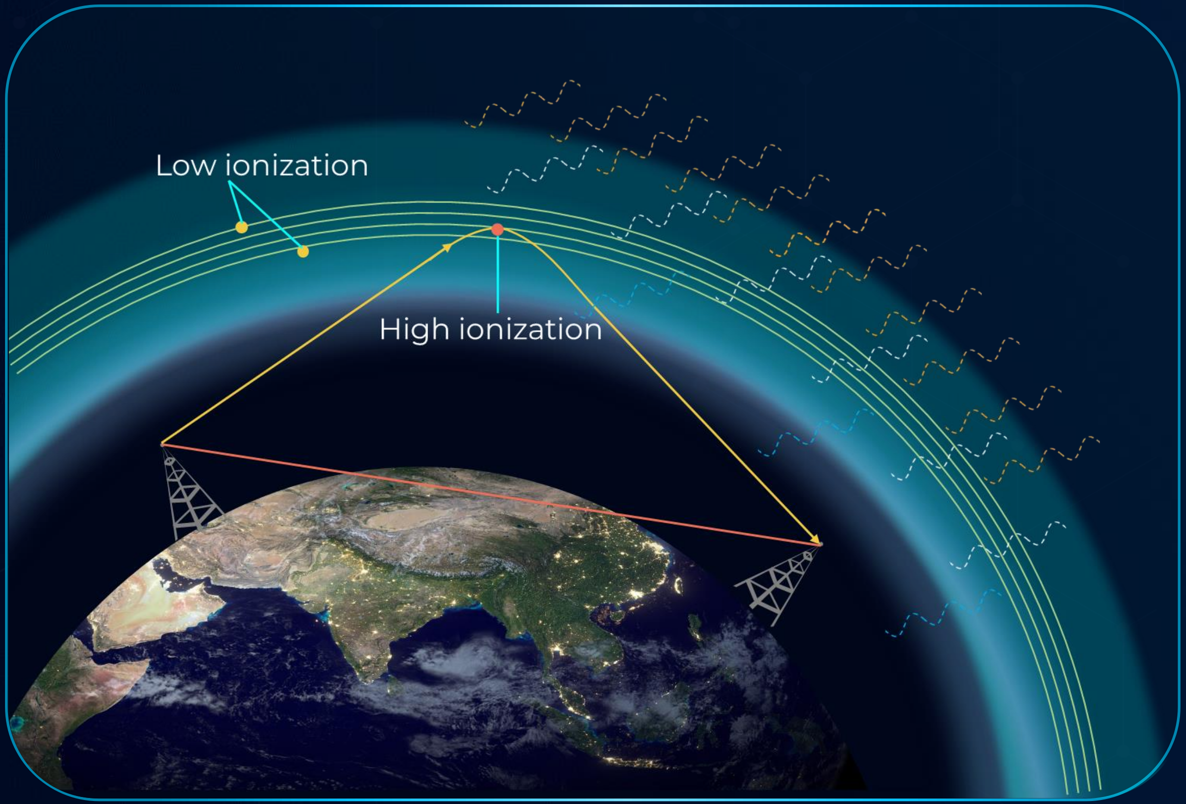
Summary

- Ionization occurs due to the absorption of the ultraviolet and other high-energy radiation coming from the sun by air molecules.
- At upper layers, air density is low → Low absorption of radiation → Low ionization.
- At lower layers, air density is high, but intensity of radiation is low → Low ionization.
- Higher the ionization lower will be the refractive index of layer.

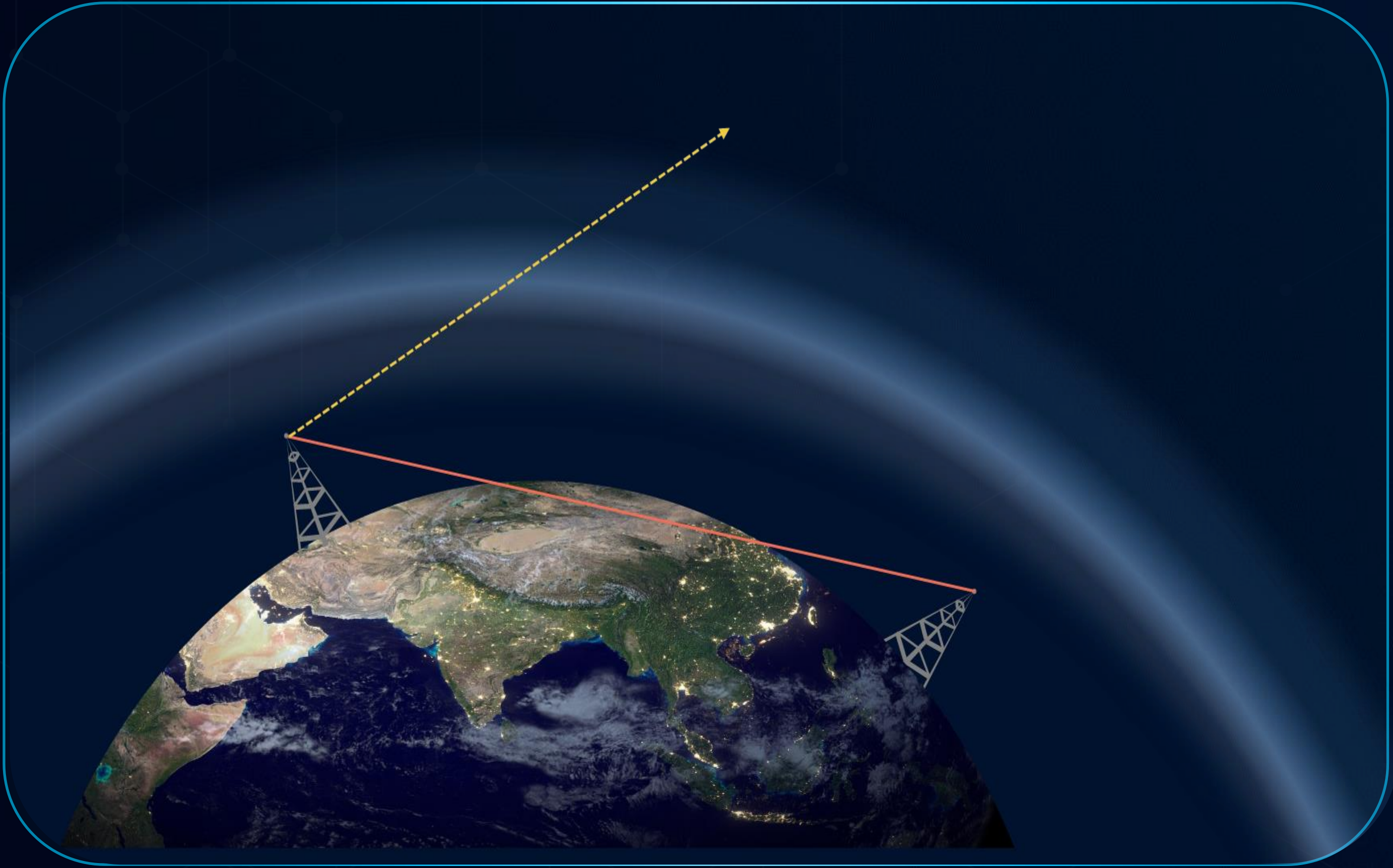
⬇

So, the signal travels from denser to rarer medium and suffers TIR at a certain layer.

Hence, TIR of signal at ionosphere is the main reason of "Ionospheric reflection".



Space Wave

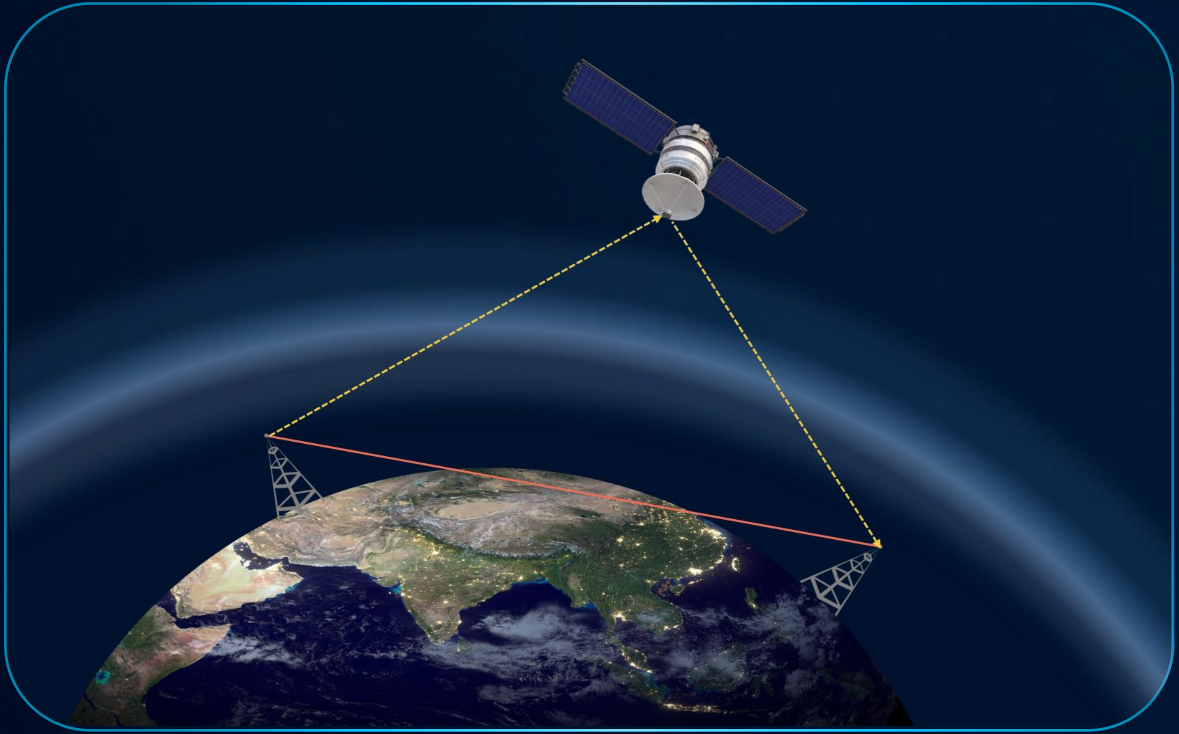


- For signals of frequencies above $40\ MHz$, the waves passes through ionosphere and communication is essentially limited to line-of-sight paths.

- Because of line-of-sight nature of propagation, direct waves get blocked at some point by the curvature of the Earth.

Summary

- To send the signal beyond the horizon, satellites are used.
- Therefore, the space waves are used for the line-of-sight communication as well as for the satellite communication.

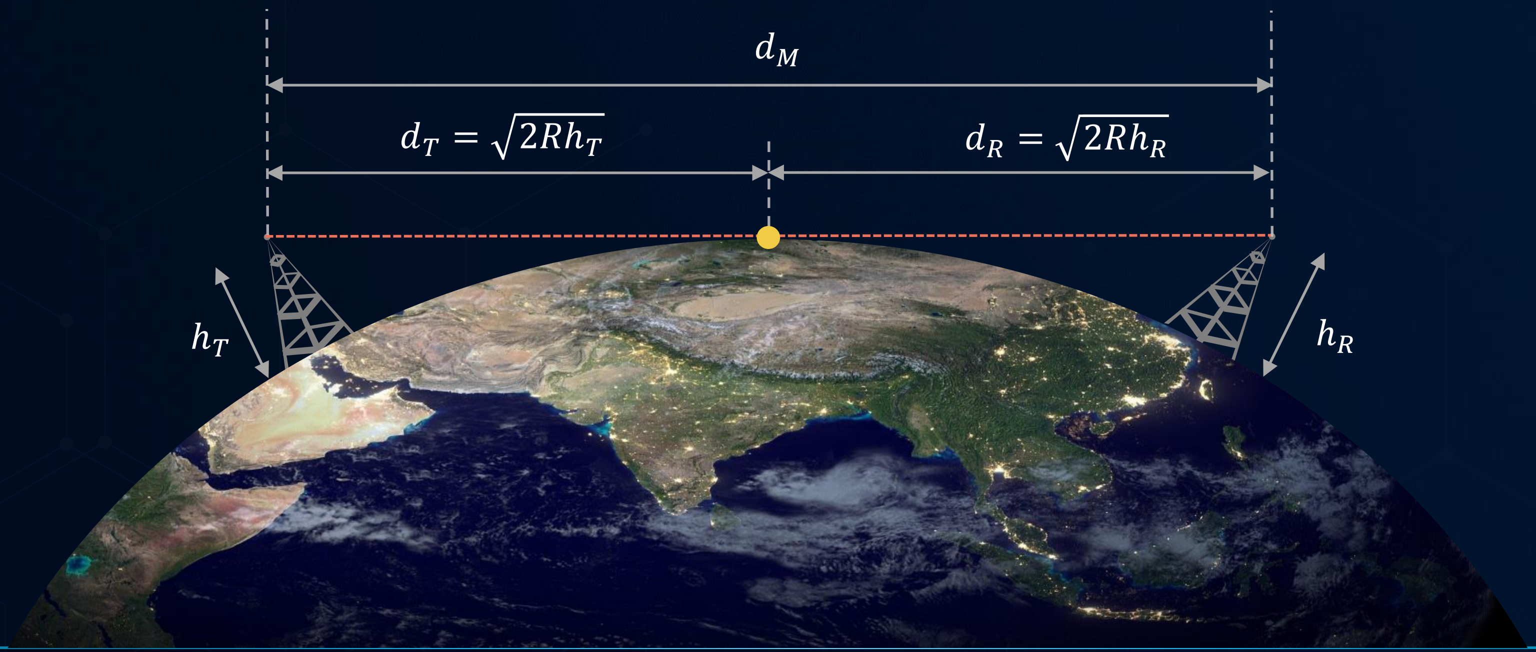


Summary

Maximum distance for line of sight communication:

$$\boxed{d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}}$$

R = Radius of Earth



If a carrier wave of $1000\ kHz$ is used to carry the signal, the length of transmitting antenna will be equal to:

Given: $f = 1000\ Hz$

To find: The length of antenna

Solution:

To transmit or receive a signal of wavelength λ, the minimum required height of the antenna is:

$$l = \frac{\lambda}{4}$$

$$l = \frac{c}{4\nu}$$

$$l = \frac{3 \times 10^8}{4 \times 1000 \times 10^3}\ m$$

$$l = 75\ m$$

A $3\ m$

B $7500\ m$

C $75\ m$

D $3000\ m$

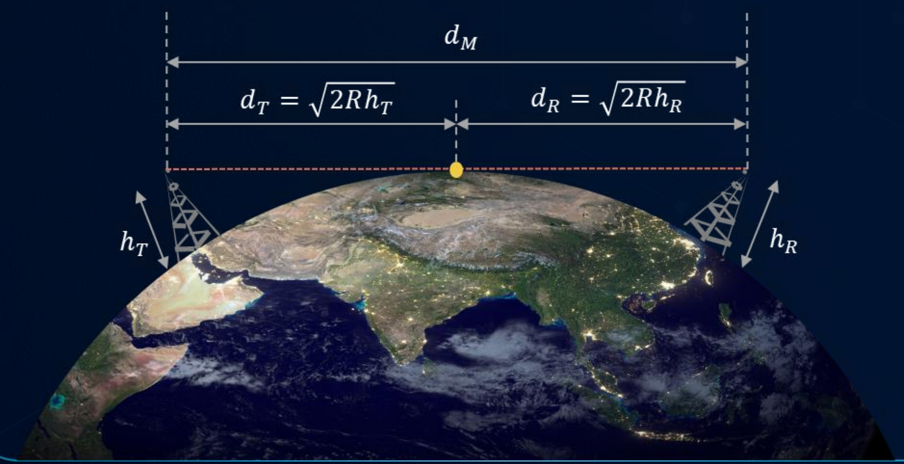
In a line of sight communication, a distance of about $50\ km$ is kept between the transmitting and receiving antennas. If the height of the receiving antenna is $70\ m$. Find the minimum height of the transmitting antenna. (Given: Radius of the Earth $= 6.4 \times 10^6\ m$)

Given: $h_R = 70\ m$

$d_M = 50\ km = 50 \times 10^3 m$

$R = 6.4 \times 10^6\ m$

To find: $h_T = ?$



Solution:

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

$$d_M = \sqrt{2R}\left(\sqrt{h_T} + \sqrt{h_R}\right)$$

$$50 \times 10^3 = \sqrt{2 \times 6.4 \times 10^6}\left(\sqrt{h_T} + \sqrt{70}\right)$$

$$50 \times 10^3 = 8 \times 10^{\frac{5}{2}} \times \sqrt{2}\left(\sqrt{h_T} + \sqrt{70}\right)$$

$$\frac{50}{8\sqrt{2}} \times 10^{\frac{1}{2}} = \left(\sqrt{h_T} + \sqrt{70}\right)$$

$$\frac{50\sqrt{5}}{8} = \left(\sqrt{h_T} + \sqrt{70}\right)$$

$$\frac{50\sqrt{5}}{8} = \left(\sqrt{h_T} + \sqrt{70}\right)$$

$$14 - 8.36 = \sqrt{h_T}$$

$$\sqrt{h_T} = 5.64$$

$$h_T = 31.8 \approx 32\ m$$

$$h_T = 32\ m$$

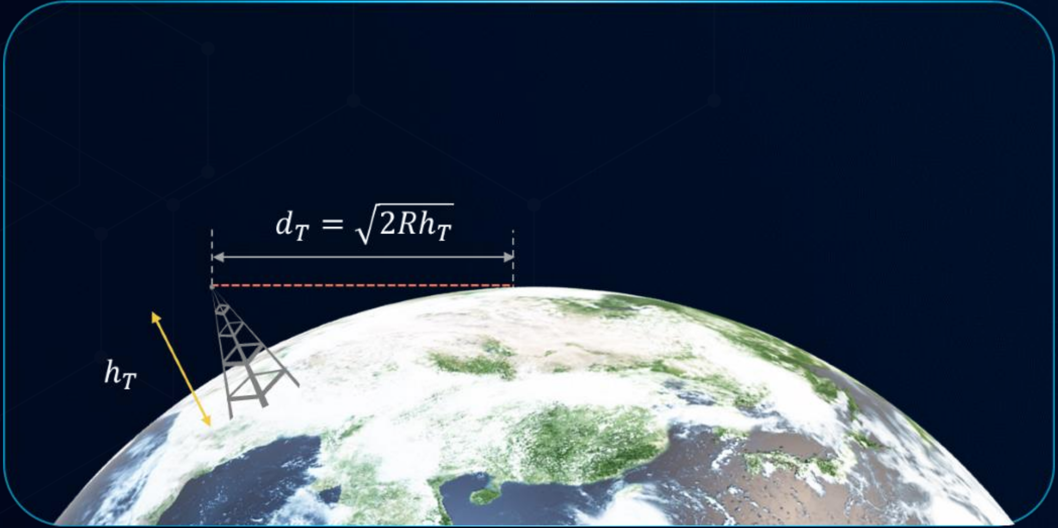
A $20\ m$

B $51\ m$

C $32\ m$

D $40\ m$

To double the covering range of a TV transmission tower, its height should be multiplied by:



The range of a TV transmission tower, $d = \sqrt{2Rh_T}$

For $d \rightarrow 2d$, the required condition is: $h_T \rightarrow 4h_T$

So, to double the covering range of a TV transmission tower, its height should be multiplied by 4.

A $1/\sqrt{2}$

B 4

C 2

D $\sqrt{2}$

Message Signals

Message signals are electrical signals generated from the original information to be transmitted using an appropriate transducer.

A message signal is a single valued function of time that conveys the information.

Message Signals

- **Analog Signals**
- **Digital Signals**

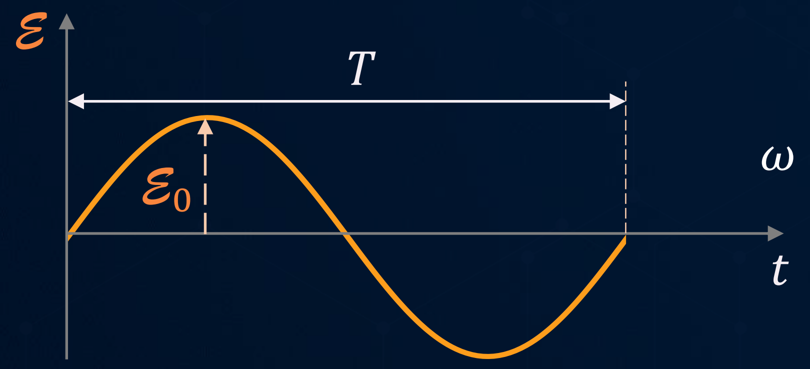
Analog Signals

- Current or voltage value varies continuously with time.

Examples:

Speech, music, sound produced by a vibrating tuning fork, variations in light intensity etc.

$$\mathcal{E} = \mathcal{E}_0 \sin(\omega t + \phi)$$



$$\omega = \frac{2\pi}{T}$$

Sinusoidal signal

- These are converted into current/ voltage variations using suitable transducers.
- The information bearing signals are called base band signals.

Digital Signals

- Current or voltage value varies discontinuously with time.

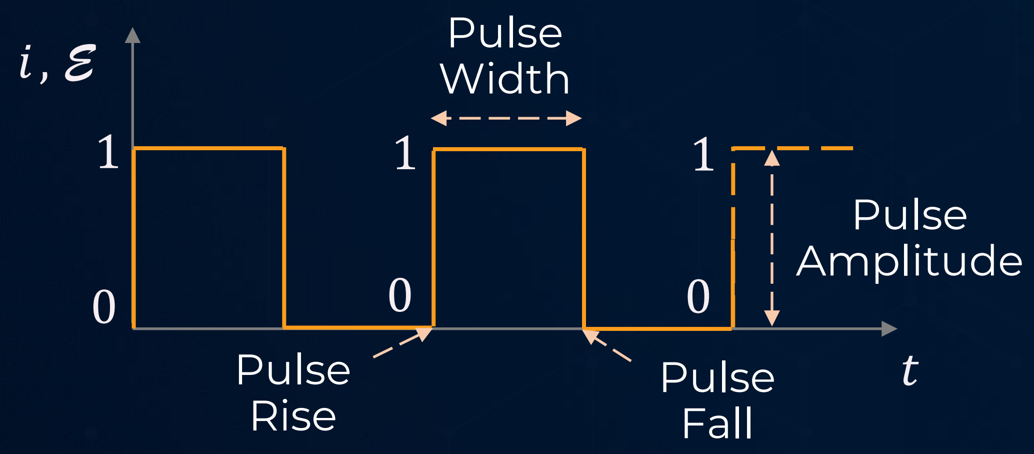
- The signal is usually represented in the form of pulses. Each pulse has two levels of current or voltage, represented by 0 (low) and 1 (High).

Examples:

- Output of a digital computer
- Electronic transmission of a document at a distant place via telephone line i.e., FAX etc.

- Both 0 and 1 are called "bits".

- A collection of 8 bits is called a "byte".



Digital Signal

Summary

- **Bandwidth** refers to the frequency range over which an equipment operates, or the portion of the frequency spectrum occupied by the signal.

Bandwidth of signals:

Message Signal	Frequency range	Bandwidth
Speech signals	$300\ Hz$ to $3100\ Hz$	$2800\ Hz$
Music signals	$20\ Hz$ to $20\ kHz$	$\sim 20\ kHz$
Video signals		$4.2\ MHz$
T.V. signals		$6\ MHz$

Bandwidth of transmission medium:

Transmission media	Frequency range	Bandwidth
Coaxial cable	$5\ MHz$ to $1.2\ GHz$	$750\ MHz$
Radio wave	$540\ kHz$ to $4.2\ GHz$	$\sim 4.1\ GHz$
Optical fibre	$1\ THz$ to $1000\ THz$	$> 100\ GHz$

Need of Modulation

- Suppose we wish to transmit an electrical signal in the audio frequency (AF) range $(20\ Hz\ to\ 20\ kHz)$ over a long distance. We cannot do it, because of:
- **Size of Antenna or Aerial:**

For an audio frequency signal of frequency, $f = 15\ kHz$

Wavelength of signal, $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{15 \times 10^3} = 20000\ m$

Length of a vertical antenna, $l = \frac{\lambda}{4} = 5000\ m$

- To setup an antenna of vertical height $5000\ m$ is impossible. Thus, we need to use high frequencies for transmission (because $f \uparrow \implies \lambda \downarrow \implies l \downarrow$), and for this purpose, we need modulation.

Need of Modulation

- **Effective Power radiated by antenna:**

Power of signal, $P \propto \left(\frac{l}{\lambda}\right)^2$

For same value of l, higher value of λ produces lower value of P.

As high power signals are needed for good transmission, wavelength λ should be small, and for this purpose, frequency should be high.

- **Mixing up of signals from different transmitters:**

To distinguish between the signals from each user, communication at high frequencies and allotting a band of frequencies to each user is needed. This is what is being done for different radio and T.V. broadcast stations.

Definition of Modulation

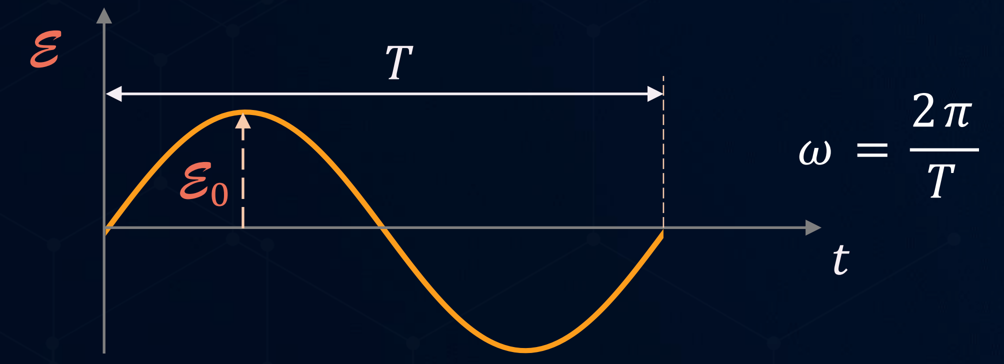
- **Modulation** is the phenomenon of superimposing the low frequency baseband message or information signals (called the modulating signals) on a high frequency wave (called the carrier wave).
- The resultant wave is known as "**Modulated wave**".

Carrier wave

- Continuous (sinusoidal) wave
- Discontinuous (Pulsed) wave

Types of Modulation

Continuous (sinusoidal) wave:



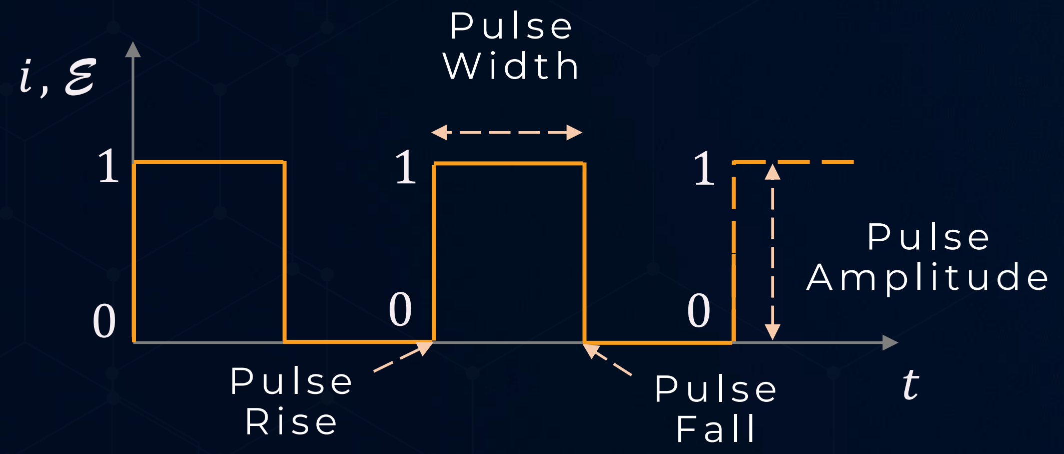
$$\mathcal{E} = \mathcal{E}_0 \sin(\omega t + \phi)$$

Any one of three characteristics ($\mathcal{E}_0$, ω, ϕ) can be varied in accordance with modulating baseband signal, giving rise to:

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM)

Types of Modulation

Discontinuous (Pulsed) wave:



The significant characteristics of a pulse can be varied in accordance with the modulating baseband signal, giving rise to:

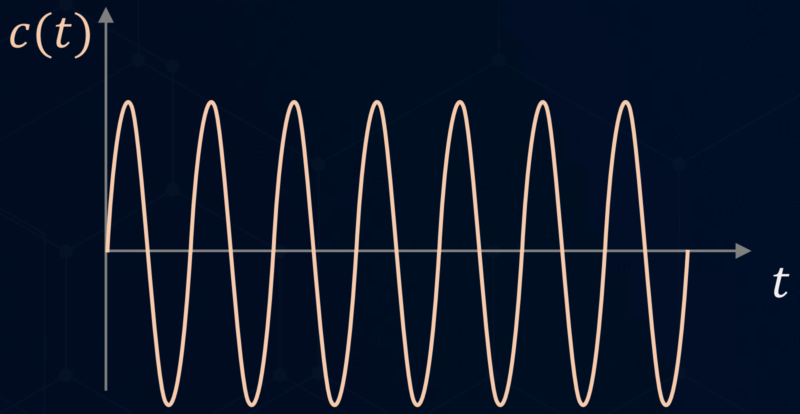
- Pulse Amplitude Modulation (PAM)
- Pulse Width Modulation (PWM)
- Pulse Position Modulation (PPM)

Summary

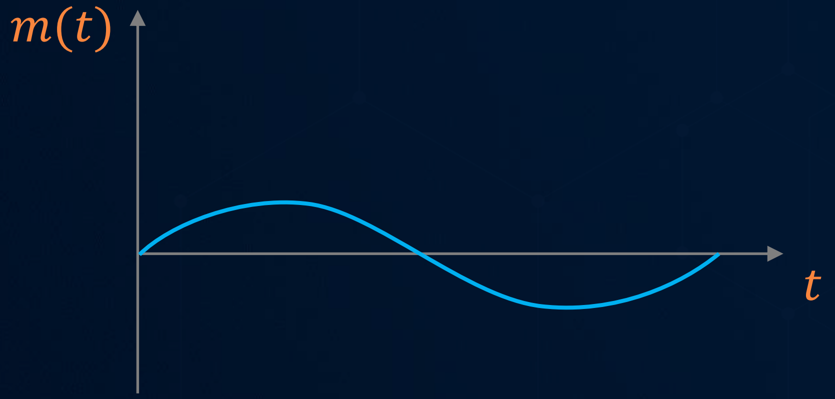
- When a modulating audio frequency (AF) wave is superimposed on a high frequency carrier wave in a manner that the frequency of modulated wave is same as that of the carrier wave, but its amplitude is made proportional to the instantaneous amplitude of the AF modulating signal, the process is called **Amplitude Modulation** (AM).

$$c(t) = A_c \sin \omega_c t$$

$$m(t) = A_m \sin \omega_m t$$



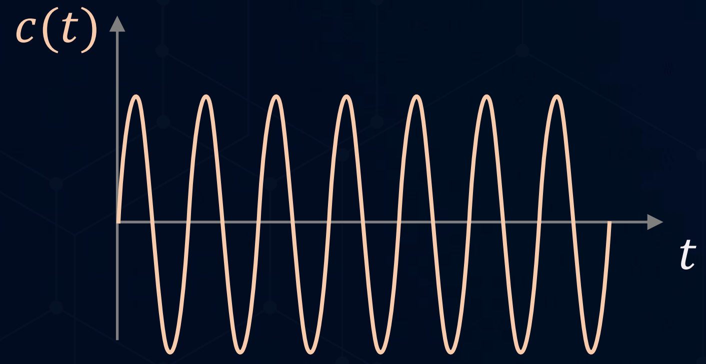
Carrier wave



Modulating signal

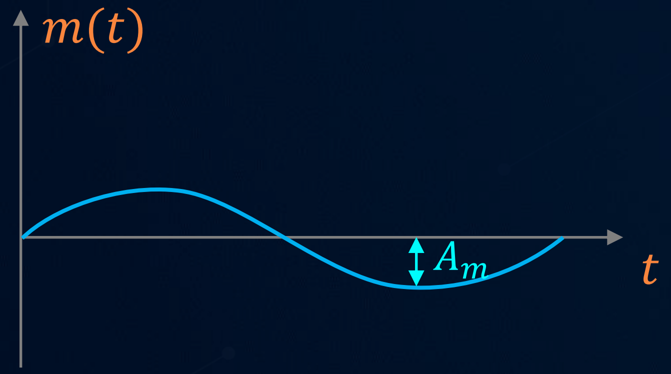
Summary

Carrier wave



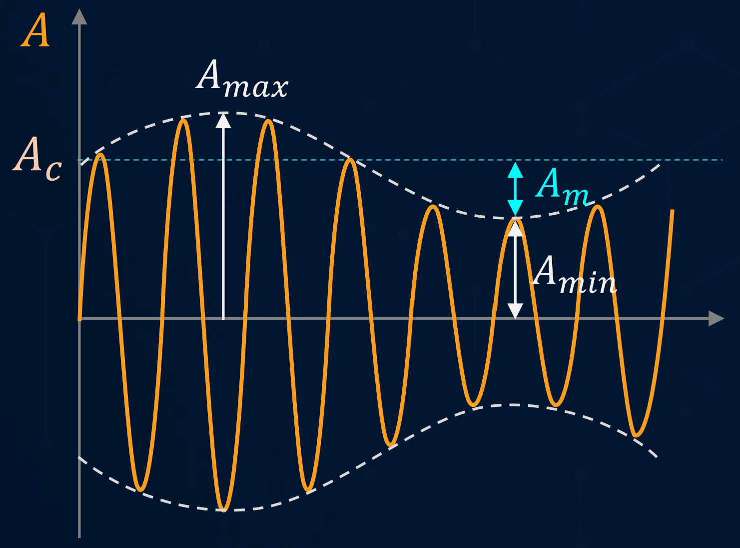
$$c(t) = A_c \sin \omega_c t$$

Modulating signal



$$m(t) = A_m \sin \omega_m t$$

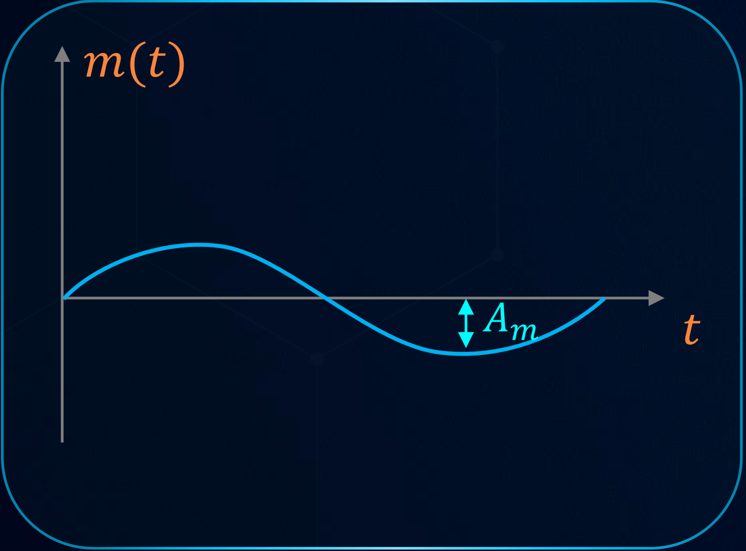
Amplitude Modulated wave

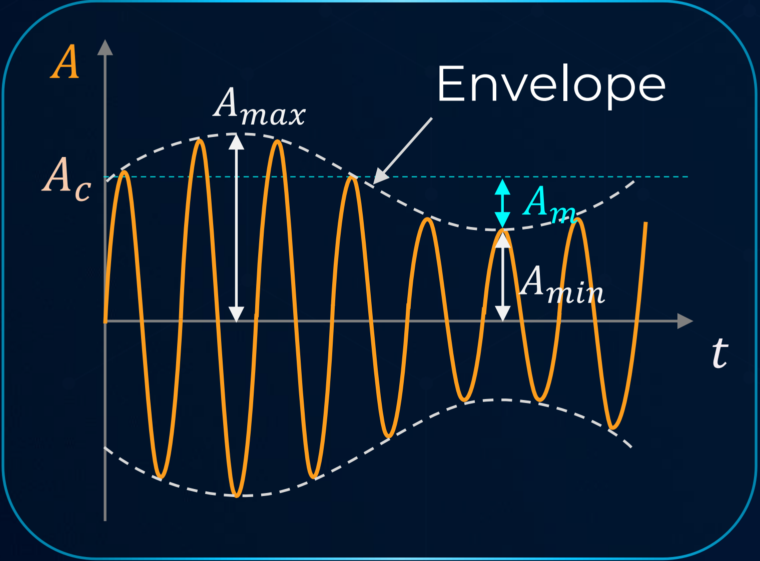


$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

Frequency of AM wave is equal to the frequency of carrier wave.

Summary

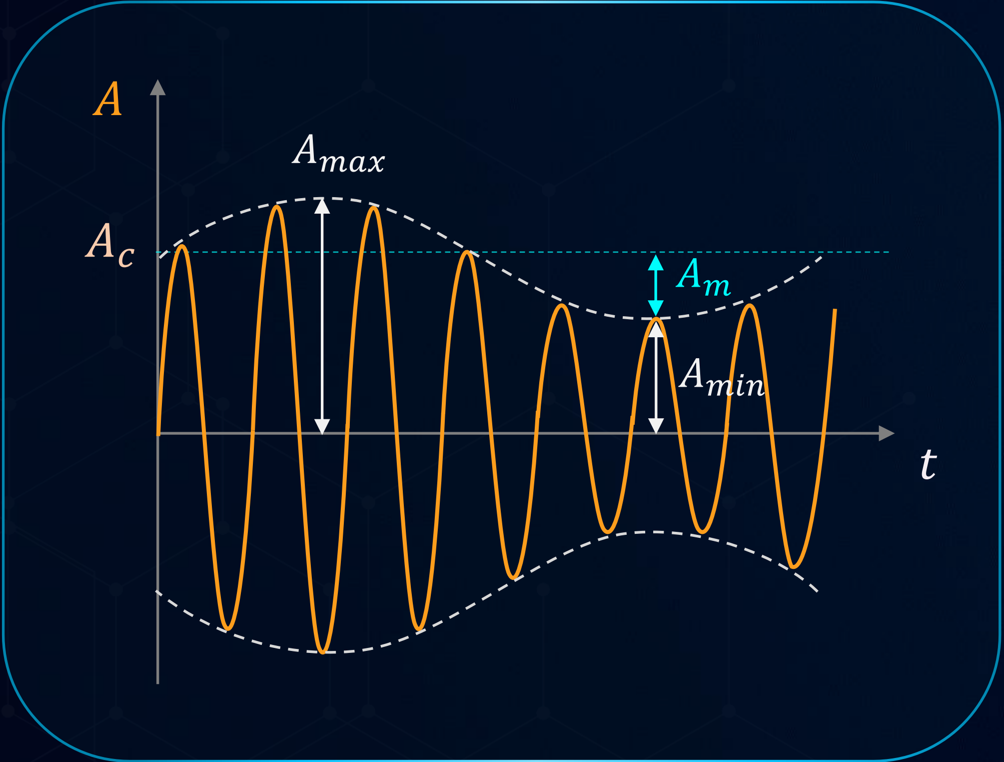




$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t = A \sin \omega_c t$$

- Variation of amplitude takes place with angular frequency ω_m.
- The envelope represents the frequency of the modulated signal.

Maximum and Minimum Amplitude of AM Wave



$$A_{max} = A_c + A_m$$

$$A_{min} = A_c - A_m$$

$$A_m = \frac{A_{max} - A_{min}}{2}$$

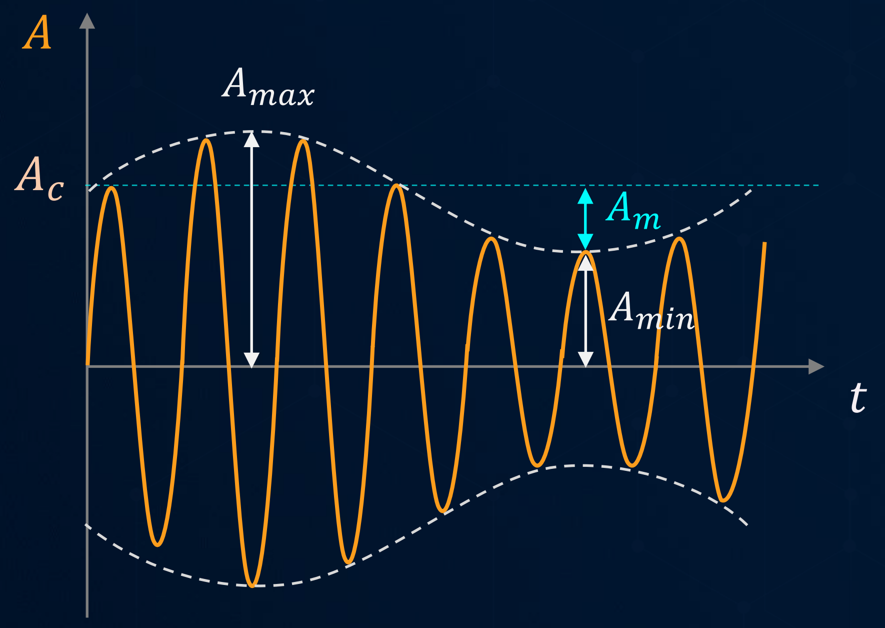
$$A_c = \frac{A_{max} + A_{min}}{2}$$

Modulation Index

- Modulation index:

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

- In practice μ is kept ≤ 1 to avoid distortion.
- Modulation index determines the quality of the transmitted signal.
- As the modulation index increases, the audio signal on reception becomes clearer.



An amplitude modulated wave is represented by the expression $v_m = 5(1 + 0.6 \sin 6280t) \sin(211 \times 10^4 t)\ V$. The minimum and maximum amplitudes of the amplitude modulated waves are, respectively:

Given: $v_m = 5(1 + 0.6 \sin 6280t) \sin(211 \times 10^4 t)\ V$

Solution:

We know: $c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$

Comparing this general equation with the given equation, we get,

$A_c = 5\ V$ $\quad$ $A_m = 3\ V$

We also know that:

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

$$5 = \frac{(A_{max} + A_{min})}{2}$$

$$(A_{max} + A_{min}) = 10\ V \qquad (1)$$

$$A_m = \frac{(A_{max} - A_{min})}{2}$$

$$3 = \frac{(A_{max} - A_{min})}{2}$$

$$(A_{max} - A_{min}) = 6\ V \qquad (2)$$

Adding equation (1) and equation (2), we get,

$$2A_{max} = 16\ V$$

$$\boxed{A_{max} = 8\ V}$$

Substituting this value of A_{max} in equation (1), we get,

$$A_{min} = 10\ V - A_{max}$$

$$\boxed{A_{min} = 2\ V}$$

A. $3/2\ V, 5V$

C. $5/2\ V, 8V$

B. $2V, 8V$

D. $3\ V, 5V$

Frequency Spectrum of AM Wave

The modulated signal $(c_m(t))$ can be written as:

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

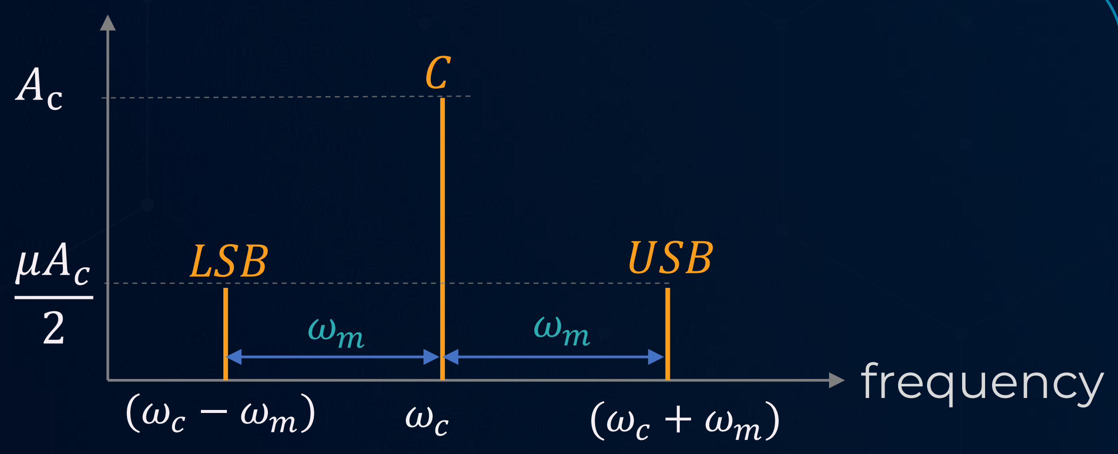
$$c_m(t) = A_c \left[1 + \frac{A_m}{A_c} \sin \omega_m t\right] \sin \omega_c t$$

$$c_m(t) = A_c \sin \omega_c t + A_c \mu \sin \omega_m t \sin \omega_c t$$

$$c_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} [\cos(\omega_c - \omega_m)\, t - \cos(\omega_c + \omega_m)\, t]$$

$$\boxed{c_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} [\cos(\omega_c - \omega_m)\, t] - \frac{\mu A_c}{2} [\cos(\omega_c + \omega_m)\, t]}$$

Summary



LSB = Lower side band $\quad$ USB = Upper side band

$$c_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2}[\cos(\omega_c - \omega_m)\, t] - \frac{\mu A_c}{2}[\cos(\omega_c + \omega_m)\, t]$$

Bandwidth of AM wave $= f_{USB} - f_{LSB} = (f_c + f_m) - (f_c - f_m) = 2f_m$

Bandwidth of AM wave = 2 × Frequency of modulating signal

A signal of $5\ kHz$ frequency is amplitude modulated on a carrier wave of frequency $2\ MHz$. The frequencies of the resultant signal is/are :

Given: Modulating frequency, $f_m = 5\ kHz$

Carrier wave frequency, $f_c = 2\ MHz$

To find: Frequencies of resultant signal

Solution:

Frequency spectrum of a AM signal is given by,

$$c_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2}[\cos(\omega_c - \omega_m)\, t] - \frac{\mu A_c}{2}[\cos(\omega_c + \omega_m)\, t]$$

Therefore, frequencies of resultant signal are:

$f_c = 2\ MHz = 2000\ kHz$

$f_c + f_m = (2000 + 5)\ kHz = 2005\ kHz$

$f_c - f_m = (2000 - 5)\ kHz = 1995\ kHz$

A. $2005\ kHz, 2000\ kHz$ and $1995\ kHz$

B. $2000\ kHz$ and $1995\ kHz$

C. $2\ MHz$ only

D. $2005\ kHz$ and $1995\ kHz$

Power and Current Relation in AM Wave

Average power dissipated per cycle in the unmodulated carrier wave is:

$$P_c = \frac{1}{T}\int_0^T \frac{V_c^2}{R}\,dt = \frac{1}{R}\left[\frac{1}{T}\int_0^T A_c^2 \sin^2 \omega_c t\, dt\right]$$

$$\boxed{P_c = \frac{A_c^2}{2R}}$$

Where R = Resistance of the antenna

Total power dissipated per cycle in the modulated wave is:

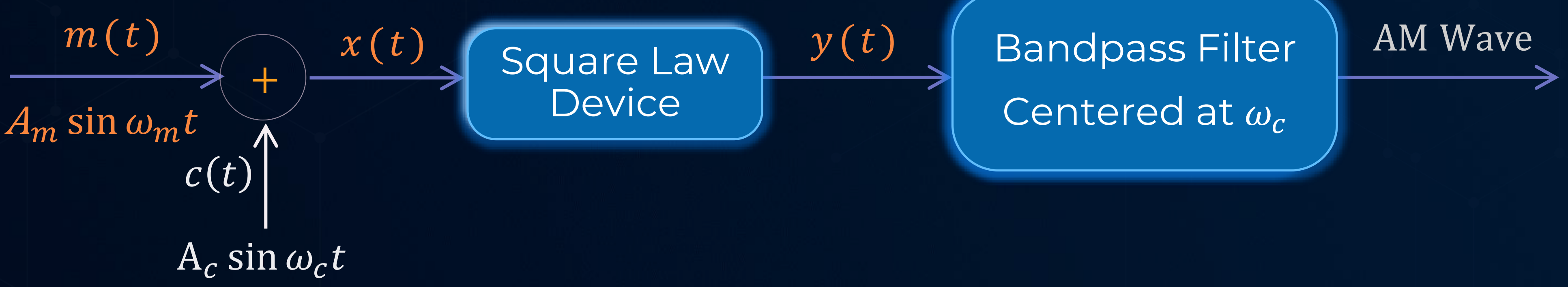
$$\boxed{P_t = P_c\left(1+\frac{\mu^2}{2}\right)}$$

If I_t and I_c is rms value of modulated current and unmodulated carrier current, respectively, then,

$$\frac{P_t}{P_c} = \left(1+\frac{\mu^2}{2}\right) = \frac{I_t^2 R}{I_c^2 R} \Rightarrow \boxed{\frac{I_t}{I_c} = \sqrt{1+\frac{\mu^2}{2}}}$$

Summary

$$x(t) = m(t) + c(t) \qquad y(t) = Bx(t) + Cx^2(t)$$



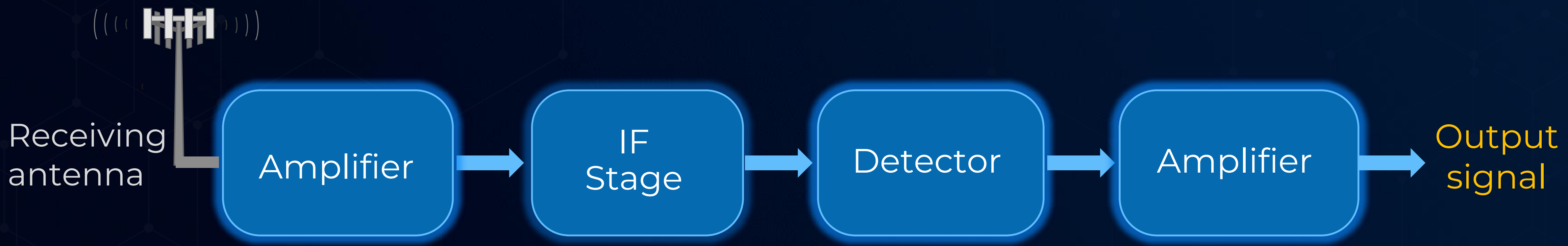
$$y(t) = BA_m \sin \omega_m t + BA_c \sin \omega_c t + C\frac{(A_m^2 + A_c^2)}{2} - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t$$

$$+ CA_m A_c \cos(\omega_c - \omega_m)\, t + CA_m A_c \cos(\omega_c + \omega_m)\, t$$

- The band pass filter rejects DC and the sinusoids of frequencies ω_m, $2\omega_m$ and $2\omega_c$ and retains the frequencies ω_c, $\omega_c - \omega_m$ and $\omega_c + \omega_m$.
- The output of the band pass filter is therefore an AM wave.

Detection of AM Wave

- Detection is the process of recovering the modulating signal from the modulated carrier wave.



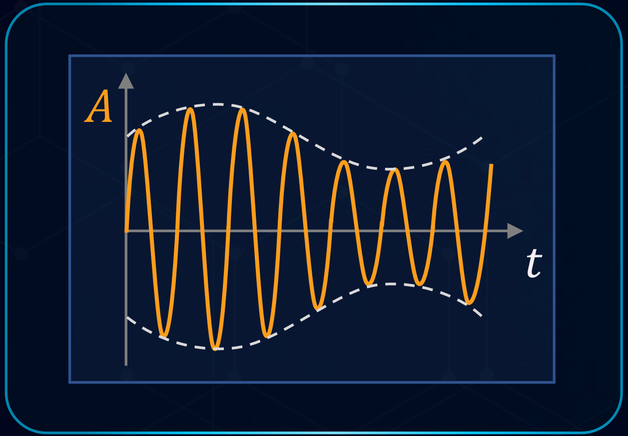
- Signal received from the receiving antenna is first passed through an amplifier because the signal becomes weak in travelling from transmitting antenna to receiving antenna.

- For further processing, the signal is passed through intermediate frequency (IF) stage preceding the detection. At this stage, the carrier frequency is changed to a lower frequency.

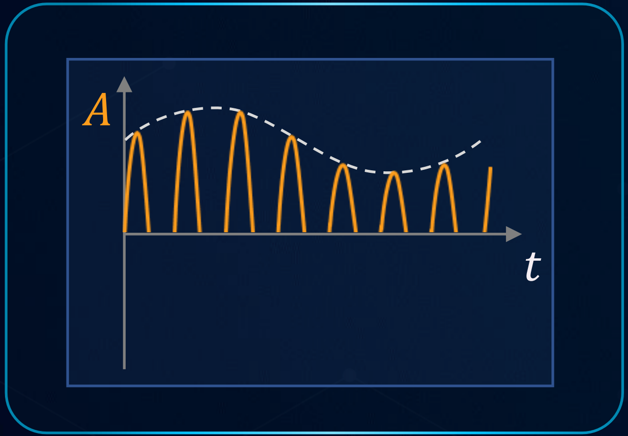
- The output signal from the detector may not be strong enough to be made use of and hence is required to be amplified.

Detection of AM Wave

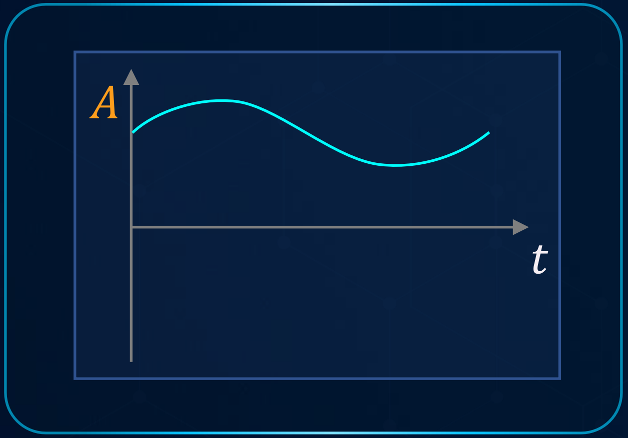
Internal structure of detector:



AM input wave



Rectified wave



Output

?

The modulation frequency of an AM radio station is $250\ kHz$, which is 10% of the carrier wave. If another AM station approaches you for license, what broadcast frequency will you allot?

Given: Modulation frequency, $f_m = 250\ kHz$

$f_m = 10\%\ of\ f_c$

Solution:

The frequency of carrier wave:

$$250 = \frac{10}{100} \times f_c \quad \Rightarrow \quad f_c = 2500\ kHz$$

For a given carrier wave of frequency f_c with modulation frequency f_m, the bandwidth is:

$f_{upper} = f_c + f_m \qquad f_{lower} = f_c + f_m$

To avoid overlapping of bandwidths, next broadcast frequencies can be:

$f_1 = f_c \pm 2f_m$

$f_2 = f_c \pm 3f_m$ and so on.

So, immediate next available broadcast frequency is:

$f_{1,upper} = f_c + 2f_m$

$f_{1,upper} = 2500 + 500\ kHz$

$f_{1,upper} = 3000\ kHz$

$f_{1,lower} = f_c - 2f_m$

$f_{1,lower} = 2500 - 500\ kHz$

$f_{1,lower} = 2000\ kHz$

Therefore, if another AM station approaches us for license, the broadcast frequency which we can allot is $2000\ kHz$.

A $2750\ kHz$

C $2250\ kHz$

B $2900\ kHz$

D $2000\ kHz$