

Principles of Electronic Communication (313326)

MSBTE K-Scheme · Model Question Paper — Set C · Model Answers

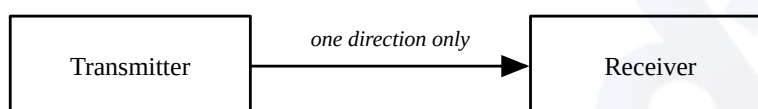
Answers are written point-wise as expected in MSBTE model answers. Marks scheme lines in blue italics are indicative. All numerical values were calculated by program.

Q.1

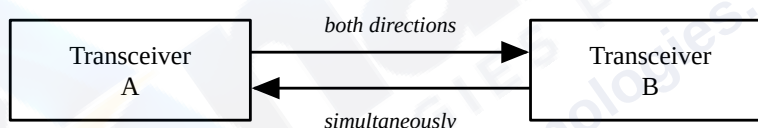
a) Simplex and full duplex.

2 M

- **Simplex:** communication takes place in **one direction only**; one station only transmits and the other only receives. Example: radio and TV broadcasting, pager.
- **Full duplex:** communication in **both directions simultaneously**. Example: telephone, mobile phone.



Simplex (e.g. radio / TV broadcasting)



Full duplex (e.g. telephone, mobile)

(1 M each)

b) EM wave is transverse.

2 M

- In an electromagnetic wave the electric field (E) and magnetic field (H) oscillate **perpendicular to each other** and both are **perpendicular to the direction of propagation**.
- Since the oscillations are at right angles to the direction of travel, the EM wave is a transverse (TEM) wave. Direction of travel is given by $E \times H$ (Poynting vector).

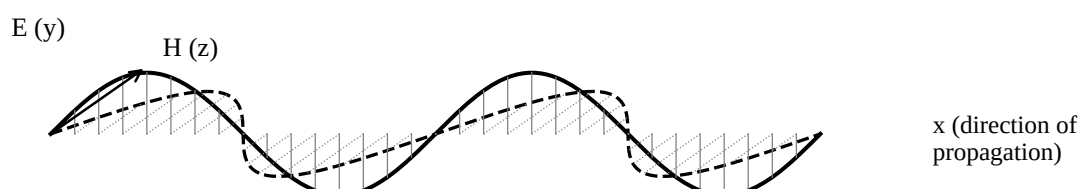


Fig.: Electromagnetic wave — E and H are perpendicular to each other and to the direction of propagation

(Justification 1 M, sketch 1 M)

c) Phase modulation.

2 M

Phase modulation (PM): the **phase** of the carrier is varied in accordance with the instantaneous amplitude of the modulating signal, keeping the amplitude of the carrier constant. $e_{PM} = V_c \sin(\omega_c t + m_p \sin \omega_m t)$.

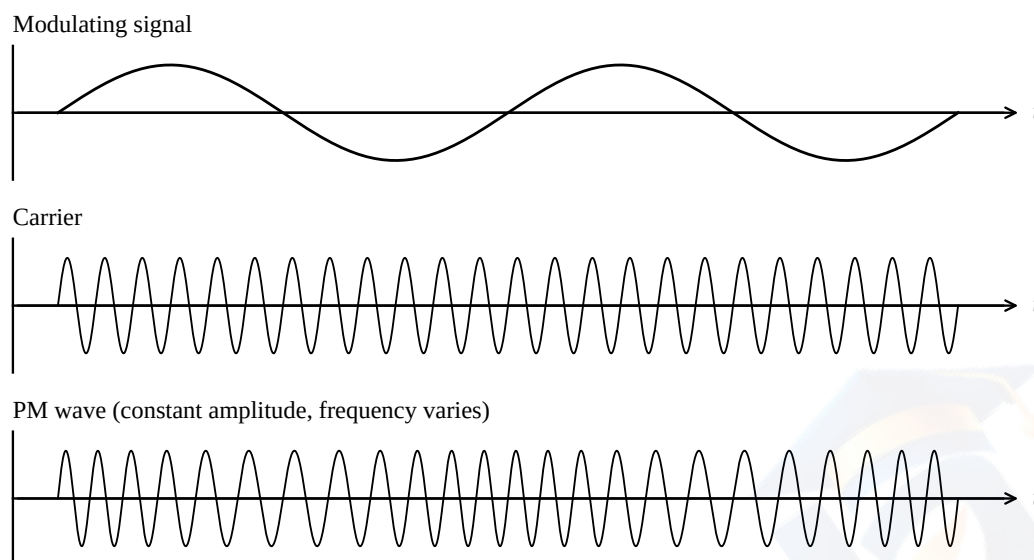


Fig.: PM wave — frequency is maximum where the slope of the modulating signal is maximum

(Definition 1 M, waveform 1 M)

d) Sideband frequencies and bandwidth.

2 M

$$f_c = 2 \text{ MHz} = 2000 \text{ kHz}, f_m = 3 \text{ kHz}$$

$$\text{USB} = f_c + f_m = \mathbf{2003 \text{ kHz}}$$

$$\text{LSB} = f_c - f_m = \mathbf{1997 \text{ kHz}}$$

$$\text{Bandwidth} = 2f_m = \mathbf{6 \text{ kHz}}$$

(Sidebands 1 M, BW 1 M)

e) Image frequency.

2 M

Image frequency: an unwanted signal frequency f_{si} which also produces the same IF at the mixer output ($f_{si} - f_o = \text{IF}$). It is separated from the wanted signal by $2 \times \text{IF}$: $f_{si} = f_s + 2 \text{ IF}$.

$$f_o = f_s + \text{IF} = 1000 + 455 = 1455 \text{ kHz}$$

$$f_{si} = f_s + 2 \text{ IF} = 1000 + 2 \times 455 = \mathbf{1910 \text{ kHz}}$$

(Definition 1 M, calculation 1 M)

f) Fading and polarization.

2 M

- **Fading:** random variation (rise and fall) of the received signal strength with time, caused by interference of waves arriving through different paths and by changes in the ionosphere.
- **Polarization:** the direction of the electric field vector of an EM wave with respect to the earth surface. If E is vertical → vertical polarization; horizontal → horizontal polarization (also circular / elliptical).

(1 M each)

g) Radiation pattern and beam width.

2 M

- **Radiation pattern:** graphical representation of the radiation (field strength or power) of an antenna as a function of direction (θ , ϕ). It shows major lobe, minor lobes and nulls.
- **Beam width (HPBW):** the angular width of the major lobe between the two half power (-3 dB) points.

(1 M each)

Q.2

a) Synchronous vs asynchronous transmission.

4 M

Synchronous transmission	Asynchronous transmission
Data sent as blocks (frames) of characters.	Data sent one character at a time.
Sync characters / flags at start of block; no start/stop bits.	Each character framed by start bit and stop bit(s).
Common clock — transmitter and receiver synchronized.	No common clock; receiver resynchronizes on each start bit.
No gap between characters; high speed and efficiency.	Idle gaps between characters; lower speed and efficiency.
Complex, costly. e.g. Ethernet, HDLC links.	Simple, cheap. e.g. keyboard, RS-232.

(Any four points 1 M each)

b) Comparison of three AM transmitters.

4 M

$P_t = P_c (1 + m^2/2)$; sideband power $P_{sb} = P_c m^2/2$; $\eta = m^2/(2 + m^2)$

T _x	P _c	m	Total power P _t	Sideband power	Efficiency η
A	1500 W	0.4	$1500 (1 + 0.4^2/2) = 1620$ W	120 W	7.41 %
B	1200 W	0.7	$1200 (1 + 0.7^2/2) = 1494$ W	294 W	19.68 %
C	1000 W	0.9	$1000 (1 + 0.9^2/2) = 1405$ W	405 W	28.83 %

Justification: The information is carried only by the sidebands. Transmitter **C** has the highest modulation index, so it gives the largest sideband (useful) power (405 W) and the highest efficiency (28.83 %), even though its total power is the smallest. Hence transmitter **C** is the best; A is the poorest (most power wasted in carrier).

(Powers 2 M, justification 2 M)

c) NBFM vs WBFM.

4 M

Parameter	Narrow band FM (NBFM)	Wide band FM (WBFM)
Modulation index	Small, less than 1 ($m_f < 1$)	Large, greater than 1 (5 to 2500)
Maximum deviation	5 kHz	75 kHz
Range of modulating frequency	30 Hz – 3 kHz	30 Hz – 15 kHz
Noise immunity	Less (noise suppression poorer)	Better (noise is suppressed more)

(1 M each)

d) Ground wave propagation.

4 M

In ground (surface) wave propagation, the wave travels from the transmitting antenna to the receiving antenna along the surface of the earth, following its curvature (diffraction).

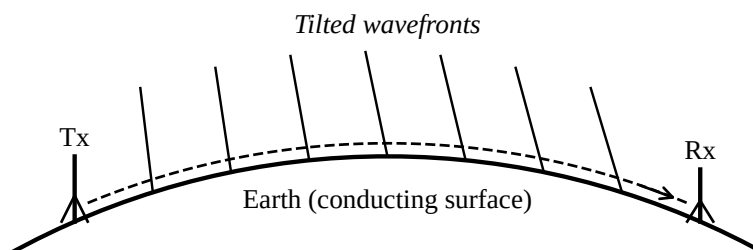


Fig.: Ground (surface) wave propagation — wavefront tilts and follows earth curvature

1. Used for frequencies up to about 2 – 3 MHz (VLF, LF, MF bands).
2. Wave travels along (glides over) the surface of the earth and follows its curvature due to diffraction.
3. Must be **vertically polarized**; horizontal polarization is short-circuited by the earth.
4. Attenuation (ground losses) increases with frequency; the wavefront tilts more and more as it travels.
5. Range depends on transmitted power and conductivity of the ground — best over sea water.
6. Not affected by day/night or ionospheric changes → stable, no fading.
7. Needs high power and large (tall) antennas. Used for MW broadcasting, ship-to-shore and navigation.

(Sketch 2 M, description 2 M)

Q.3

a) Practical AM diode detector.

4 M

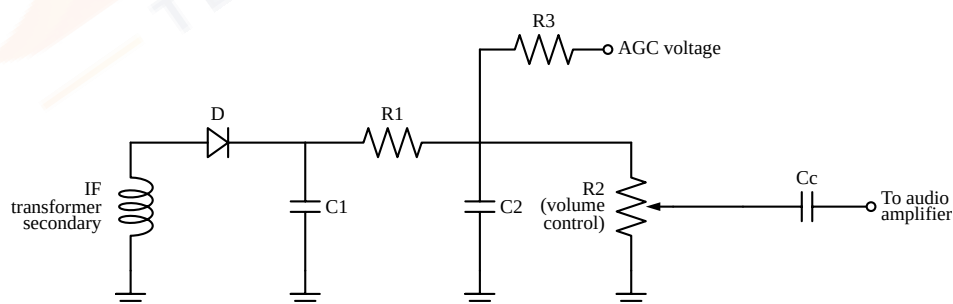


Fig.: Practical AM diode detector circuit

- The diode D conducts on positive half cycles of the IF signal and charges C1 to the peak value; between peaks C1 discharges slowly through the load, so the voltage follows the **envelope**.
- R1–C2 form an RC filter that removes the remaining IF ripple; R2 (potentiometer) is the volume control.

- C_c blocks the DC component and passes only audio to the audio amplifier; the DC component is filtered by R_3 and used as **AGC** voltage.
- Time constant RC must satisfy $1/f_c \ll RC < 1/f_m$ (max) to avoid ripple and diagonal clipping.

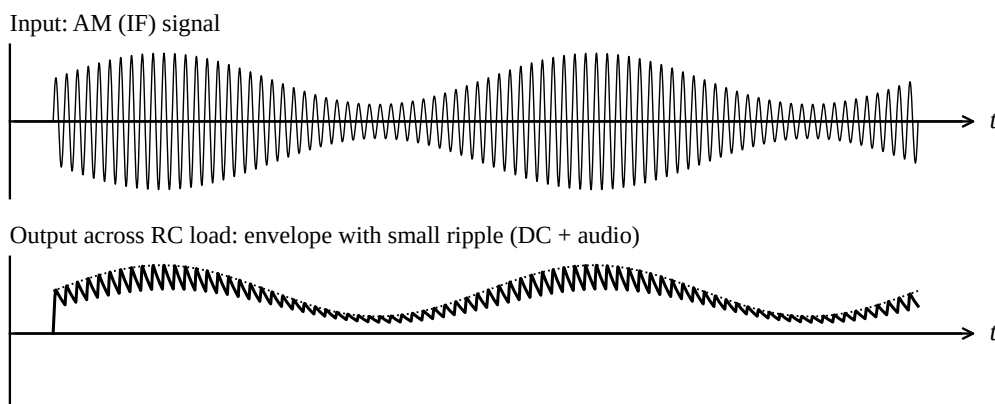


Fig.: Input and output waveforms of AM diode detector (computed RC envelope detector response)

(Circuit 2 M, waveforms 2 M)

b) Deviation ratio and bandwidth.

4 M

Deviation ratio $\delta = \Delta f / f_m = 75 / 15 = 5$

Bandwidth (Carson's rule) = $2(\Delta f + f_m) = 2(75 + 15) = 180 \text{ kHz}$

(2 M each)

c) Ionospheric layers for given conditions.

4 M

Condition	Layer
(i) Exists only in day time, lowest layer	D layer
(ii) Absorbs HF waves yet allows them to reach upper layer	F1 layer
(iii) Efficiently reflects HF, especially at night	F2 layer (F layer at night)
(iv) At about 100 km, reflects some HF in day time	E layer

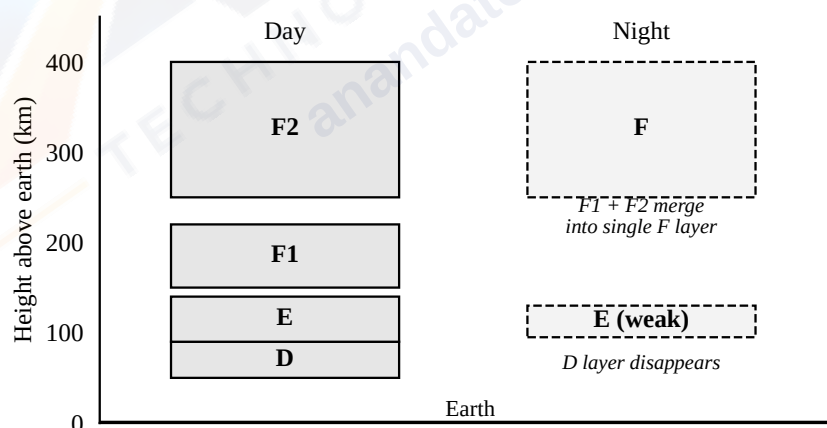


Fig.: Layers of ionosphere during day and night (typical heights)

(1 M each)

d) Loop antenna vs ferrite rod antenna.

4 M

Point	Loop antenna	Ferrite rod antenna
Working principle	Magnetic field of the wave links the loop area and induces EMF ($\propto$ number of turns $\times$ area).	Same principle, but the high permeability ferrite core concentrates the magnetic flux, giving large effective area in small size.
Construction	One or more turns of wire on a large air-cored frame (square / circular).	Many turns of wire wound on a small ferrite rod (few cm long).
Radiation pattern	Figure of eight; maximum in the plane of the loop, null perpendicular to the plane.	Figure of eight; maximum broadside to the rod, null along the rod axis.
Application	Direction finding (RDF), navigation, RFID.	Portable AM (MW/LW) radio receivers.

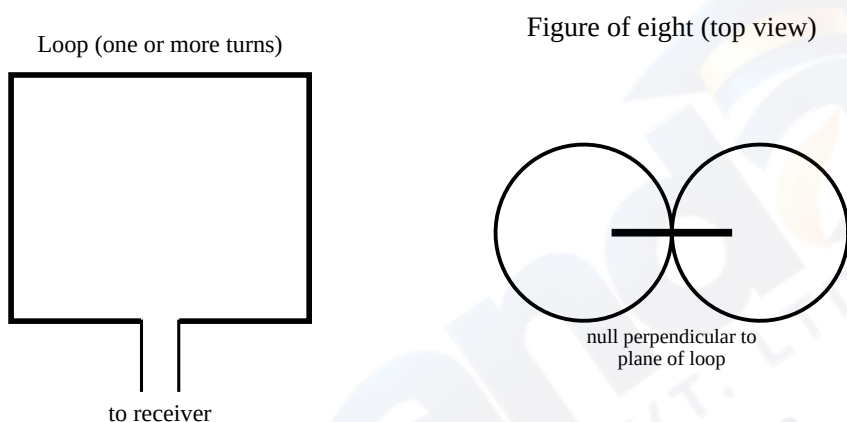


Fig.: Loop antenna and its radiation pattern

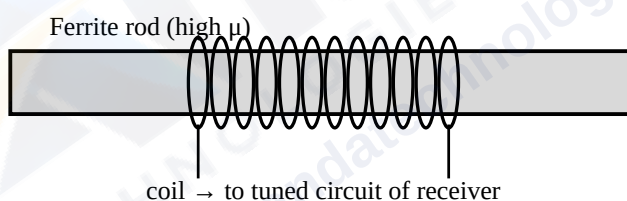


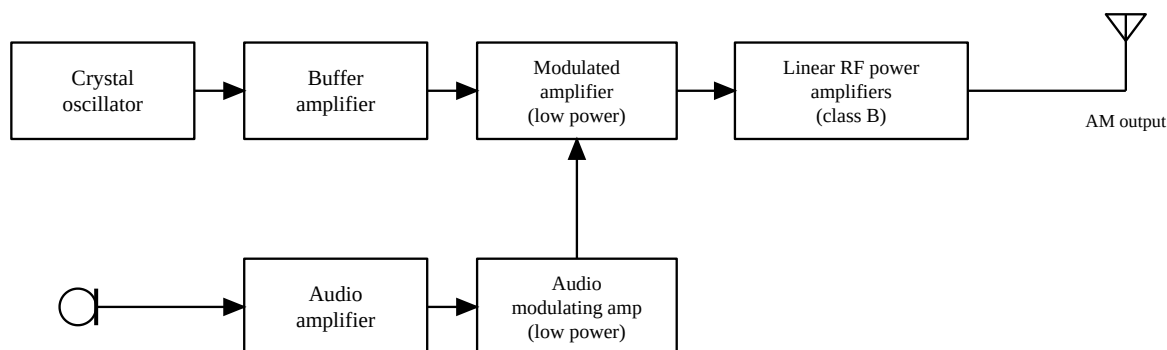
Fig.: Ferrite rod antenna (used in portable MW radio receivers)

(1 M each point)

Q.4

a) Low level AM transmitter; low vs high level.

4 M



Modulation is done at low power; AM wave is then amplified linearly

Fig.: Block diagram of low level AM transmitter

- **Crystal oscillator + buffer:** generate a stable carrier and isolate the oscillator.
- **Modulated amplifier:** modulation is done at a **low power level**; only a small audio power is needed.
- **Audio chain:** microphone → audio amplifier → low-power modulating amplifier.
- **Linear RF power amplifiers (class A / AB / B):** the AM wave is amplified to the required power without distortion of the envelope, then fed to the antenna.

Features: less audio power needed, but linear amplifiers have low efficiency. Used in TV (video) transmitters and SSB transmitters.

Low level modulation	High level modulation
Modulation done at low power stage.	Modulation done at final (high power) stage.
Needs small audio power.	Needs large audio power.
Linear (class A/B) amplifiers after modulation → low efficiency.	Class C amplifiers can be used → high efficiency.

(Diagram 2 M, two differences 2 M)

b) PLL as FM demodulator.

4 M

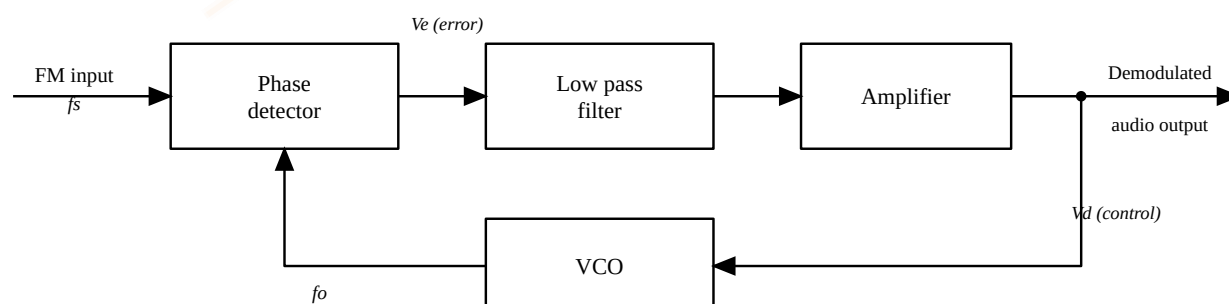


Fig.: PLL as FM demodulator

- **Phase detector:** compares the phase/frequency of the FM input (f_s) with the VCO output (f_o) and gives an error voltage V_e proportional to the difference.
- **Low pass filter:** removes high frequency components and passes the slowly varying error (control) voltage.
- **Amplifier:** amplifies the control voltage V_d ; this voltage is the demodulated output.
- **VCO:** its frequency is changed by V_d so that f_o follows (locks to) the input frequency f_s .

Working: When the loop is locked, $f_o = f_s$. As the FM input frequency deviates with the modulating signal, the error voltage changes and the control voltage forces the VCO to follow. Hence the control voltage V_d varies exactly as the frequency deviation, i.e. as the original modulating signal → **V_d is the demodulated audio output.** IC 565 is commonly used.

Advantages: linear, no tuned circuits/coils, good noise performance.

(Diagram 2 M, functions 2 M)

c) Type of propagation.

4 M

Application	Type of propagation
FM radio broadcasting	Space wave (line of sight) — VHF band
Ship-to-shore communication	Ground wave (VLF/LF/MF); sky wave for long distance (HF)
Satellite communication	Space wave (line of sight, wave passes through ionosphere)
Amateur (HAM) radio over long distance	Sky wave — HF band

(1 M each)

d) Radiation patterns of resonant dipoles.

4 M

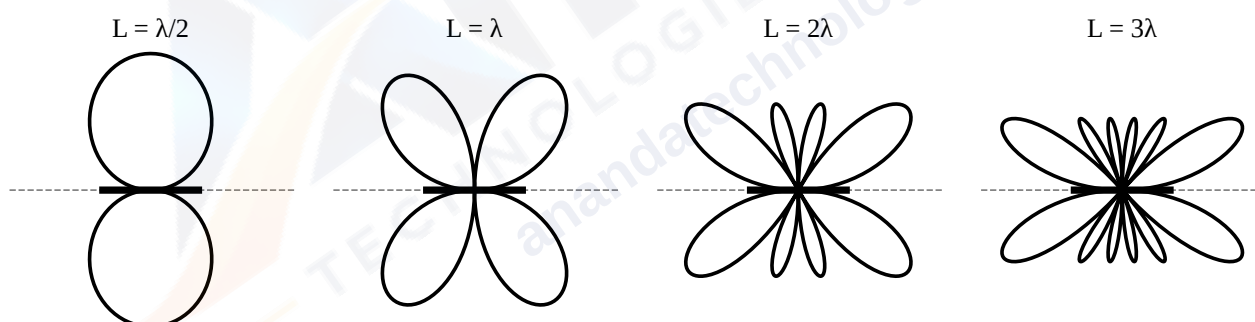


Fig.: Radiation patterns of resonant (standing wave) dipoles — wire along the horizontal axis

Length	No. of half waves (n)	No. of lobes ($2n$)	Major lobe angle from wire axis
$L = \lambda/2$	1	2	90° (broadside)
$L = \lambda$	2	4	54°
$L = 2\lambda$	4	8	36°
$L = 3\lambda$	6	12	29°

As the length of the resonant antenna increases, the number of lobes increases ($2n$ lobes for $L = n\lambda/2$) and the major lobes move closer to the antenna axis. There is no radiation along the axis of

the wire. (Patterns plotted from the standing-wave current distribution of a resonant wire.)

(Each pattern 1 M)

e) Resonant vs non-resonant antenna.

4 M

Point	Resonant antenna	Non-resonant antenna
Definition	Antenna whose length is an exact multiple of $\lambda/2$ and which is open at the far end; it resonates at the operating frequency.	Antenna whose length is not a multiple of $\lambda/2$ (usually several λ) and which is terminated in its characteristic impedance.
Circuit / termination	Open circuited (not terminated) at the end	Terminated in a resistance $R = Z_0$ at the far end
Reflection	Total reflection at open end (reflection coefficient = 1) $\rightarrow$ standing waves	No reflection (reflection coefficient = 0) $\rightarrow$ only travelling (forward) waves
Radiation pattern	Bidirectional (lobes on both sides)	Unidirectional (towards the terminated end)

Resonant: open ends, standing waves

Non-resonant: terminated in R, travelling waves

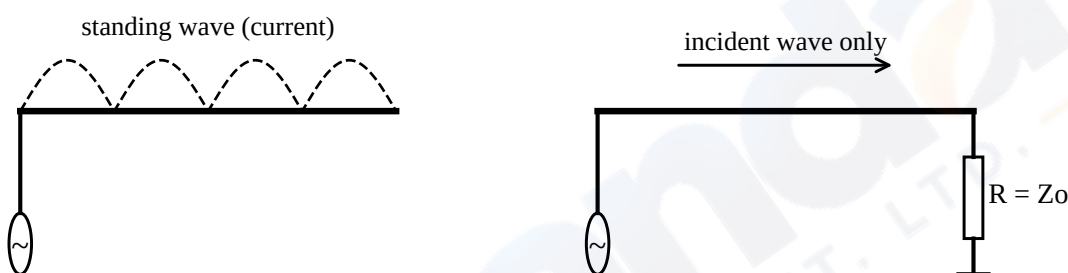


Fig.: Resonant and non-resonant antennas

Terminated wire, $L = 2\lambda$

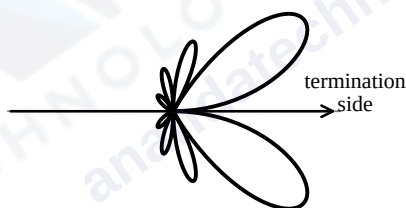


Fig.: Non-resonant (terminated) antenna — unidirectional pattern

(1 M each)

Q.5

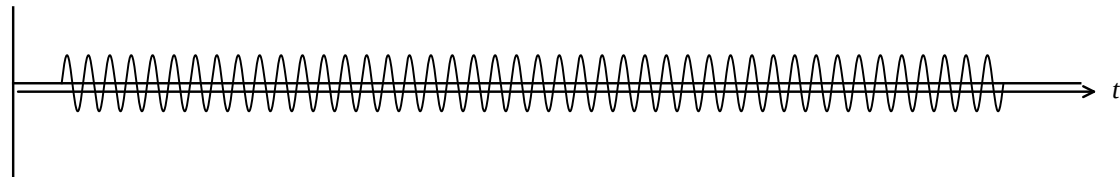
a) Amplitude modulation and effect of modulation index.

6 M

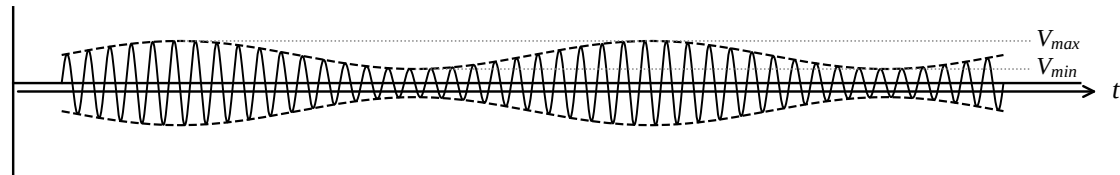
Amplitude modulation: the amplitude of the high frequency carrier is varied in accordance with the instantaneous amplitude of the modulating signal, keeping frequency and phase constant.

Modulation index: $m = V_m / V_c = (V_{\max} - V_{\min}) / (V_{\max} + V_{\min})$.

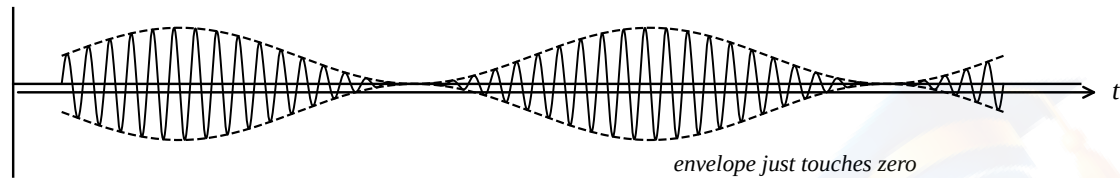
$m = 0$ (unmodulated carrier)



$m = 0.5$ ($m < 1$, under-modulation)



$m = 1$ (100 % modulation)



$m = 1.5$ ($m > 1$, over-modulation)

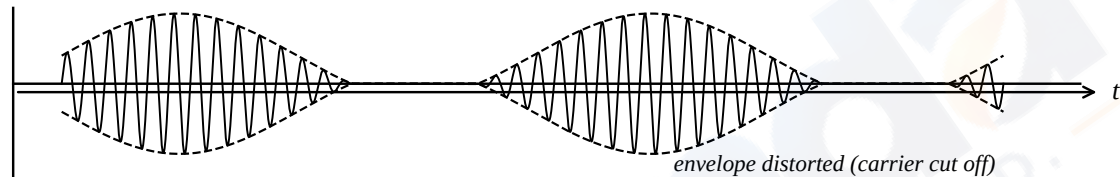


Fig.: Effect of modulation index on AM wave (dotted line = envelope)

- **$m = 0$** : no modulation — only the carrier is transmitted.
- **$m < 1$** : under-modulation; envelope is a true copy of the modulating signal; distortion-free.
- **$m = 1$** : 100 % modulation; envelope touches zero; maximum useful sideband power without distortion.
- **$m > 1$** : over-modulation; carrier is cut off for some time, envelope distorted, causes distortion and adjacent channel interference (splatter).

$$m = (15 - 5) / (15 + 5) = 10/20 = 0.5 \rightarrow \text{50 \% modulation}$$

(Definitions 1 M, waveforms 2 M, effects 1 M, numerical 2 M)

b) Frequency ranges with applications.

6 M

Band	Frequency range	One application
(i) Voice frequency (VF)	300 Hz – 3 kHz	Telephone voice channel
(ii) Medium frequency (MF)	300 kHz – 3 MHz	AM (MW) radio broadcasting
(iii) Very high frequency (VHF)	30 MHz – 300 MHz	FM radio broadcasting (88 – 108 MHz)
(iv) Super high frequency (SHF)	3 GHz – 30 GHz	Satellite communication / RADAR
(v) Infrared	$\approx 3 \times 10^{11}$ Hz – 4×10^{14} Hz (1 mm – 0.75 μ m)	TV remote control, optical fibre communication
(vi) Visible light	$\approx 4 \times 10^{14}$ Hz – 7.5×10^{14} Hz (750 nm – 400 nm)	Optical (Li-Fi) communication, human vision

(1 M each)

c) Microstrip patch antenna.

6 M

Microstrip patch antenna consists of a very thin metallic **patch** (copper, rectangular / circular) placed on one side of a **dielectric substrate** ($\epsilon_r \approx 2.2 - 12$, thickness $h \ll \lambda$) whose other side is a metallic **ground plane**. Length of rectangular patch $L \approx \lambda/2$ in the dielectric ($\lambda_g/2$).

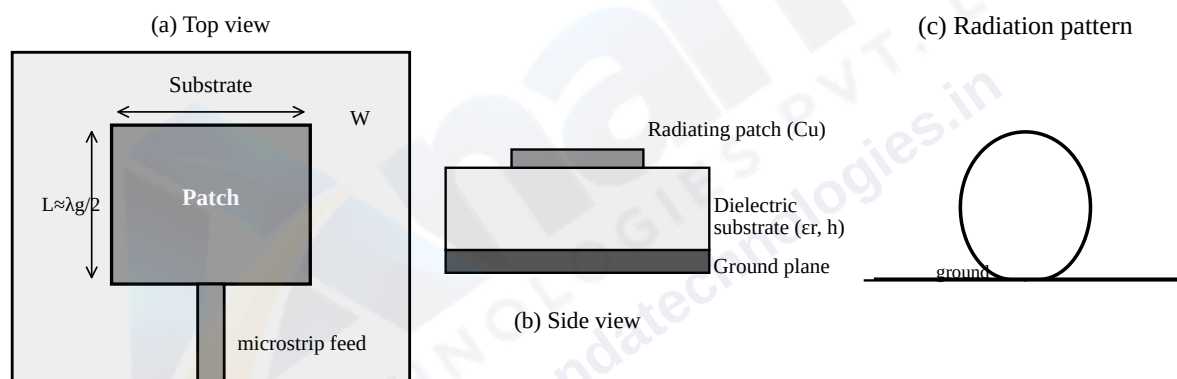


Fig.: Rectangular microstrip patch antenna — (c) broadside pattern, maximum normal to patch, no radiation below ground plane

- **Feeding:** microstrip line feed (shown), coaxial probe feed, aperture coupled or proximity coupled feed.
- **Working:** the fringing fields at the two open edges of the patch (separated by $\approx \lambda_g/2$) act as two radiating slots whose fields add in the direction normal to the patch.
- **Radiation pattern:** broadside — maximum radiation perpendicular to the patch; ground plane prevents radiation below; beamwidth wide ($\approx 70^\circ - 90^\circ$).

Advantages: low profile and light weight; low cost (made by PCB technology); can be made conformal to the surface of aircraft/missiles; easily integrated with microwave circuits; dual frequency / dual polarization possible. **Disadvantages:** narrow bandwidth, low gain, low power handling.

Applications: mobile phones, GPS receivers, WLAN/Bluetooth, satellite communication, aircraft and missiles (radar, fuzing, telemetry), RFID.

(Diagram 2 M, pattern 1 M, advantages 2 M, applications 1 M)

Q.6

a) Superheterodyne receiver.

6 M

Principle of superheterodyne receiver: The incoming RF signal (f_s) is mixed with the signal of a local oscillator (f_o) to convert it into a **fixed, lower intermediate frequency (IF)**, $IF = f_o - f_s$. Most of the gain and selectivity is then obtained at this fixed IF. For AM (MW band) $IF = 455 \text{ kHz}$; local oscillator is kept above the signal: $f_o = f_s + IF$.

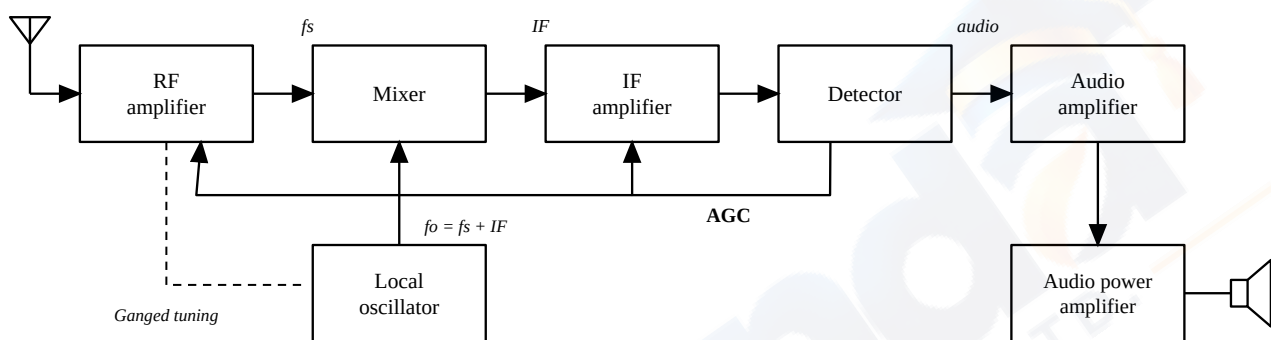


Fig.: Block diagram of AM superheterodyne receiver

Working / function of each block:

- **RF amplifier:** tuned amplifier; selects the desired station, amplifies the weak signal from the antenna, improves SNR and rejects the image frequency.
- **Local oscillator:** generates $f_o = f_s + IF$; its tuning is ganged with the RF stage so the difference is always 455 kHz.
- **Mixer (frequency changer):** non-linear stage; produces f_o , f_s , $(f_o + f_s)$ and $(f_o - f_s)$. The tuned output selects the difference frequency = IF. Modulation (envelope) is unchanged.
- **IF amplifier:** fixed-tuned (455 kHz) multistage amplifier; provides most of the gain and selectivity (adjacent channel rejection) of the receiver.
- **Detector:** diode envelope detector recovers the audio signal from the IF; it also gives a DC voltage proportional to signal strength for AGC.
- **AGC:** automatically controls the gain of RF and IF amplifiers so that the output stays nearly constant for strong and weak stations.
- **Audio amplifier and power amplifier:** amplify the audio signal to the power level needed to drive the loudspeaker.

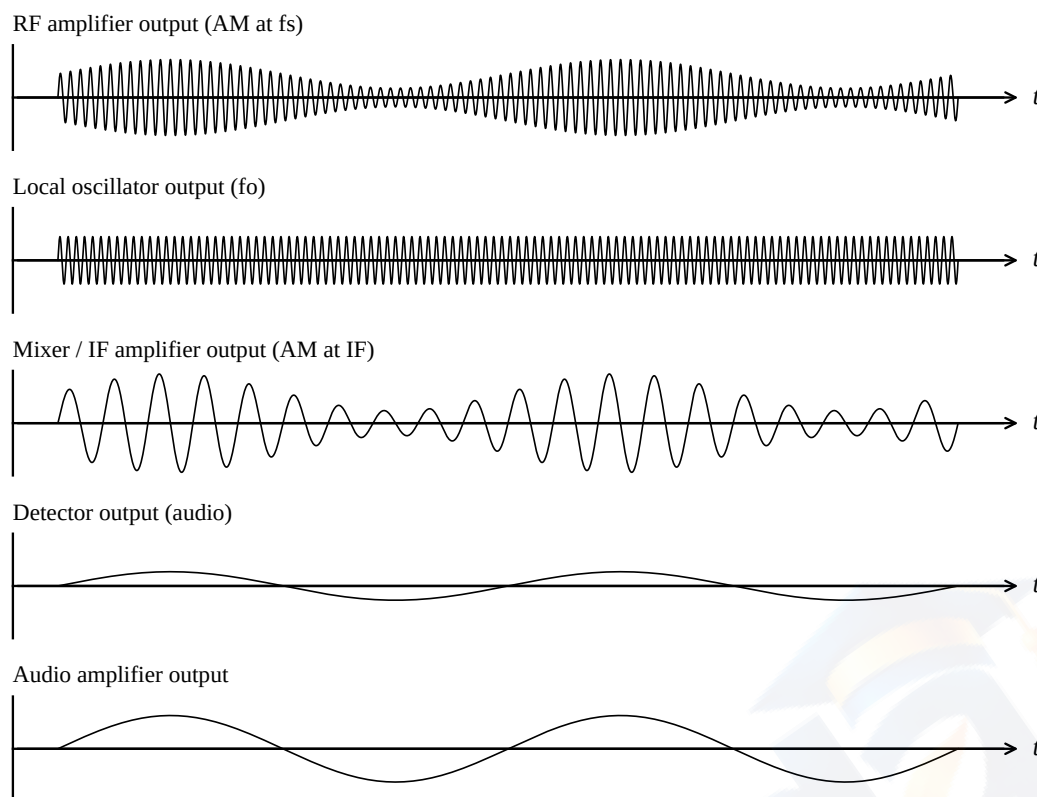


Fig.: Waveforms at different stages of superheterodyne receiver

(Principle 1 M, diagram 2 M, working 2 M, waveforms 1 M)

b) Sky wave vs space wave; MUF numerical.

6 M

(i)

Point	Sky wave propagation	Space wave propagation
Frequency range	3 MHz – 30 MHz (HF)	Above 30 MHz (VHF, UHF, microwave)
Polarization	Changes (rotates) after ionospheric reflection	Remains as transmitted (horizontal or vertical)
Service range	Very long (thousands of km, multi-hop)	Limited to line of sight (about 40 – 80 km), $d = 4.12(\sqrt{h_t} + \sqrt{h_r})$ km
Application	Short wave broadcasting, amateur radio, long distance ship communication	FM / TV broadcasting, mobile, microwave links, satellite

(ii)

- **Maximum usable frequency (MUF)**: the highest frequency that is returned to the earth for a given angle of incidence θ between two points. $MUF = f_c / \cos \theta = f_c \sec \theta$ (secant law).

$$MUF = f_c / \cos \theta = 9 / \cos 60^\circ = 9 / 0.5 = \mathbf{18 \text{ MHz}}$$

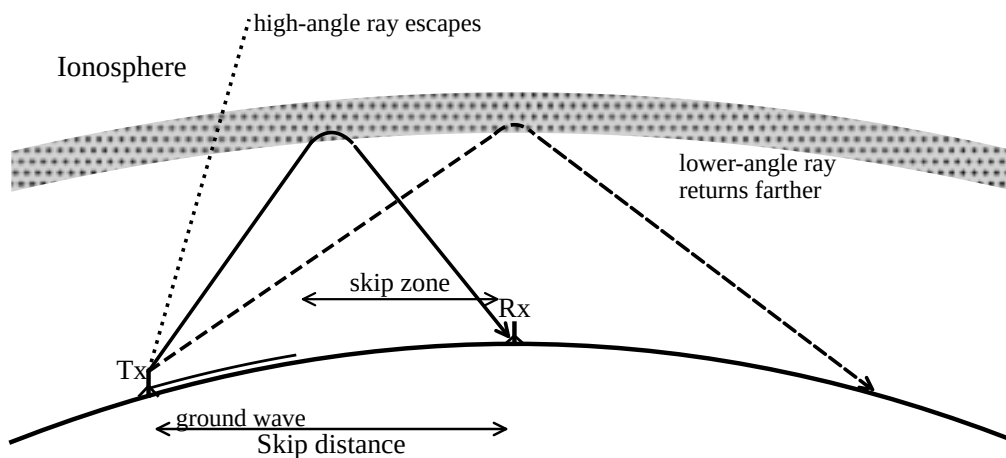


Fig.: Sky wave propagation (ionospheric refraction, skip distance, skip zone)

((i) 4 M, (ii) definition 1 M + numerical 1 M)

c) Applications of antennas.

6 M

Antenna	Applications (any two)
Loop antenna	Direction finding (RDF), portable MW receivers, navigation, RFID
Yagi-Uda antenna	TV reception (VHF/UHF), amateur radio, point-to-point VHF links
Telescopic antenna	Portable FM radio, walkie-talkie, cordless phones
Dish (parabolic) antenna	Satellite communication / DTH, RADAR, microwave links, radio astronomy
Flexible antenna	Wearable devices, mobile phones, RFID tags, body-area networks
Smart antenna	Mobile base stations (4G/5G), MIMO / Wi-Fi, interference reduction

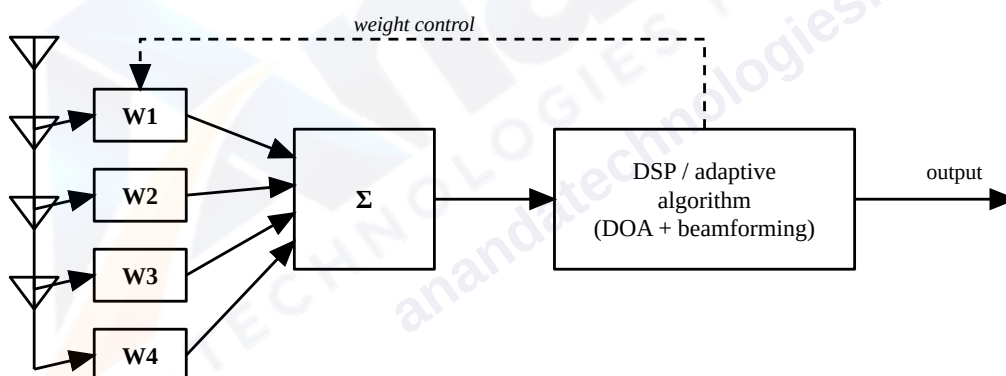


Fig.: Smart (adaptive array) antenna — beam steered towards wanted user, null towards interferer

(1 M each)

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