

Principles of Electronic Communication (313326)

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

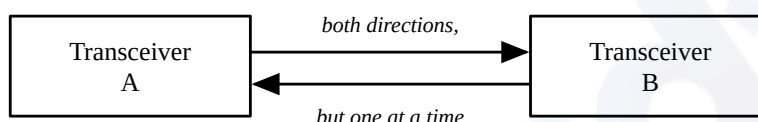
Answers are written point-wise as expected in MSBTE model answers. Marks scheme lines in blue italics are indicative. All numerical values were calculated by program.

Q.1

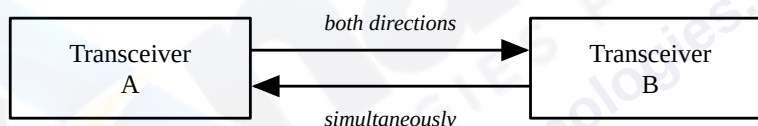
a) Half duplex and full duplex mode.

2 M

- **Half duplex:** communication is possible in **both directions but not at the same time**; one transmits while the other receives (press-to-talk). Example: walkie-talkie, police wireless.
- **Full duplex:** communication in **both directions simultaneously**. Example: telephone, mobile phone.



Half duplex (e.g. walkie-talkie)



Full duplex (e.g. telephone, mobile)

(Each definition with example 1 M)

b) SNR in dB.

2 M

$$\text{SNR} = 10 \log_{10}(\text{Ps} / \text{Pn})$$

$$\text{Ps} / \text{Pn} = 25 \text{ mW} / 0.2 \text{ mW} = 125$$

$$\text{SNR} = 10 \log(125) = \mathbf{20.97 \text{ dB}}$$

(Formula 1 M, answer 1 M)

c) Frequency components of AM wave.

2 M

$$\text{Carrier } f_c = 1500 \text{ kHz, } f_m = 8 \text{ kHz}$$

$$\text{Lower side band (LSB)} = f_c - f_m = 1492 \text{ kHz}$$

$$\text{Carrier} = 1500 \text{ kHz} = 1.5 \text{ MHz}$$

$$\text{Upper side band (USB)} = f_c + f_m = 1508 \text{ kHz}$$

$$\text{Bandwidth} = 2f_m = \mathbf{16 \text{ kHz}}$$

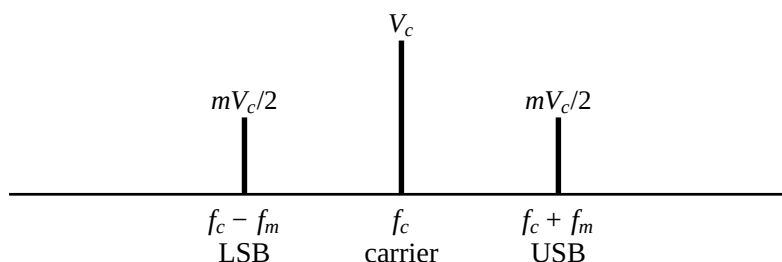


Fig.: Frequency spectrum of AM wave

(Components $1\frac{1}{2} M$, BW $\frac{1}{2} M$)

d) Types of FM detectors.

2 M

1. Slope detector (single / balanced)
2. Foster–Seeley discriminator
3. Ratio detector
4. Quadrature detector
5. PLL FM detector

(Any four, $\frac{1}{2} M$ each)

e) Skip distance and critical frequency.

2 M

- **Skip distance:** the shortest distance from the transmitter, measured along the earth surface, at which a sky wave of a given frequency (above f_c) returns to the earth.
- **Critical frequency (f_c):** the highest frequency that is returned to the earth by an ionospheric layer when the wave is sent **vertically upward** (angle of incidence 0°). $f_c = 9\sqrt{N_{\max}}$ ($N_{\max}$ = max. electron density per m^3).

(1 M each)

f) Ground wave propagation.

2 M

Ground (surface) wave propagation: the radio wave travels from transmitting to receiving antenna along (gliding over) the surface of the earth, following the curvature of the earth. The wave is vertically polarized.

Frequency range: up to about 2 – 3 MHz, i.e. VLF, LF and MF bands (30 kHz – 3 MHz).

(Definition 1 M, range 1 M)

g) Half wave dipole and radiation pattern.

2 M

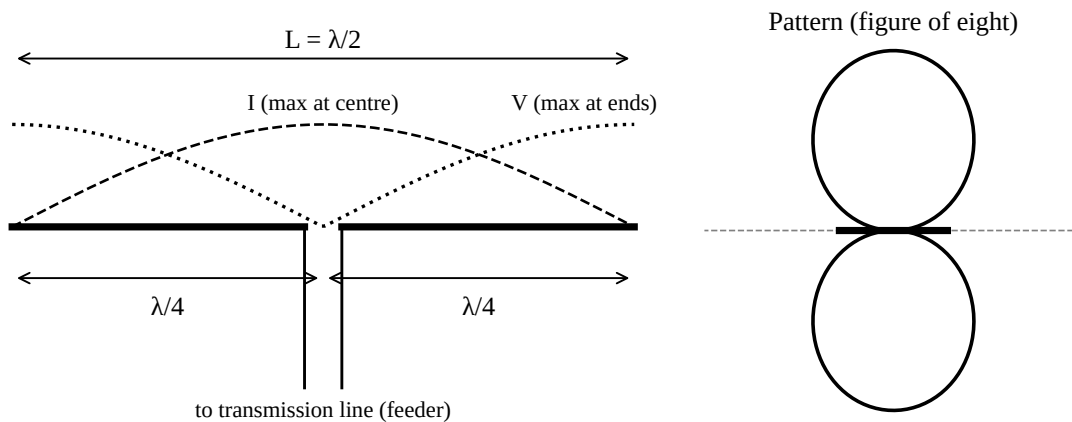


Fig.: Half wave dipole antenna, current / voltage distribution and radiation pattern

(Sketch 1 M, pattern 1 M)

Q.2

a) Basic electronic communication system.

4 M

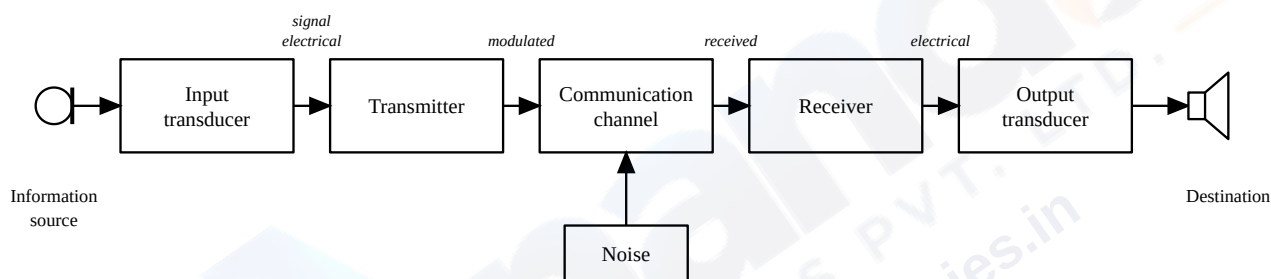


Fig.: Block diagram of basic electronic communication system

- **Information source:** produces the message — voice, music, picture or data.
- **Input transducer:** converts the non-electrical message into an electrical signal (e.g. microphone).
- **Transmitter:** processes the signal — amplification, modulation (puts information on a high frequency carrier) and power amplification — and feeds it to the antenna / line.
- **Communication channel:** the medium through which the signal travels — wire, coaxial cable, optical fibre or free space. Signal is attenuated here.
- **Noise:** unwanted random signal added mainly in the channel; it degrades the signal.
- **Receiver:** selects and amplifies the weak received signal and demodulates it to recover the original message signal.
- **Output transducer / destination:** converts the electrical signal back into original form (e.g. loudspeaker) for the user.

(Diagram 2 M, functions 2 M)

b) AM power calculation ($P_c = 800 \text{ W}$, $m = 0.75$).

4 M

Formulae: $P_t = P_c(1 + m^2/2)$; $P_{USB} = P_{LSB} = m^2P_c/4$; $\eta = m^2/(2 + m^2) \times 100 \%$

(i) $P_t = 800 (1 + 0.75^2/2) = 800 \times 1.28125 = \mathbf{1025 \text{ W}}$

(ii) Power in each sideband = $m^2 P_c / 4 = 0.5625 \times 800 / 4 = \mathbf{112.5 \text{ W}}$ (total sideband power = 225 W)

(iii) $\eta = 0.5625 / 2.5625 \times 100 = \mathbf{21.95 \%}$

(Each part with formula; total 4 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
Bandwidth	Small, $\approx 2f_m$ (same as AM)	Large, $\approx 2(\Delta f + f_m)$, about 15 times NBFM ($\approx 180 - 200 \text{ kHz}$)
Application	Mobile communication, police wireless, ambulance, two-way radio	FM broadcasting, TV sound, high quality music

(1 M each point)

d) Ionospheric layers for given conditions.

4 M

Condition	Layer
(i) Lowest layer, reflects VLF/LF, absorbs MF & HF to some degree	D layer (50 – 90 km, day only)
(ii) Present in day time at about 180 km, combines with F2 at night	F1 layer
(iii) Most important reflecting layer for HF, present day and night	F2 layer (F layer at night)
(iv) Aids MF surface wave, reflects some HF in day time	E layer ($\approx 100 \text{ km}$)

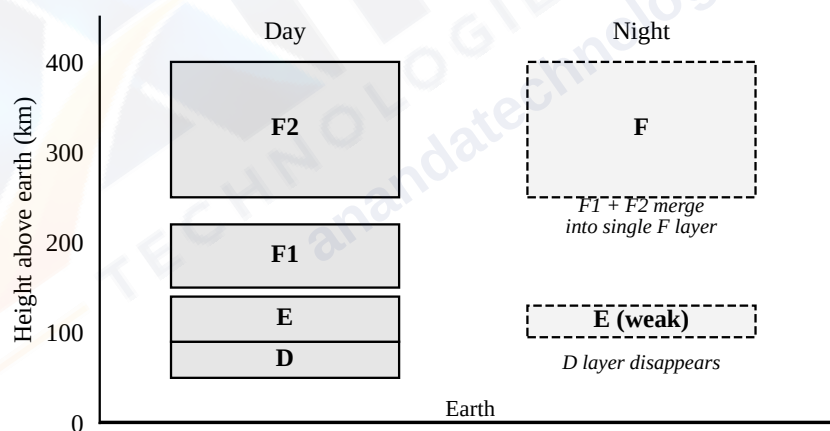


Fig.: Layers of ionosphere during day and night (typical heights)

(1 M each)

Q.3

a) Frequency range for applications.

4 M

Application	Frequency range
Voice communication	300 Hz – 3.4 kHz (VF band)
FM radio broadcasting	88 MHz – 108 MHz (VHF band)
Mobile (cellular) communication	800 MHz – 2.6 GHz (UHF band; e.g. 900 / 1800 MHz)
Satellite communication	3 GHz – 30 GHz (SHF band; C band 4/6 GHz, Ku band 12/14 GHz)

(1 M each)

b) Deviation ratio and bandwidth.

4 M

Deviation ratio $\delta = \Delta f(\text{max}) / f_m(\text{max}) = 50 / 15 = 3.33$

Bandwidth (Carson's rule) $BW = 2 (\Delta f + f_m) = 2 (50 + 15) = 130 \text{ kHz}$

(Deviation ratio 2 M, bandwidth 2 M)

c) Type of propagation for applications.

4 M

Application	Type of propagation
AM (MW) radio broadcasting	Ground wave (surface wave) — MF band; sky wave also at night
TV broadcasting	Space wave (line of sight) — VHF/UHF band
Short wave international broadcasting	Sky wave (ionospheric propagation) — HF band
GPS / satellite navigation	Space wave (line of sight from satellite)

(1 M each)

d) 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) → standing waves	No reflection (reflection coefficient = 0) → 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

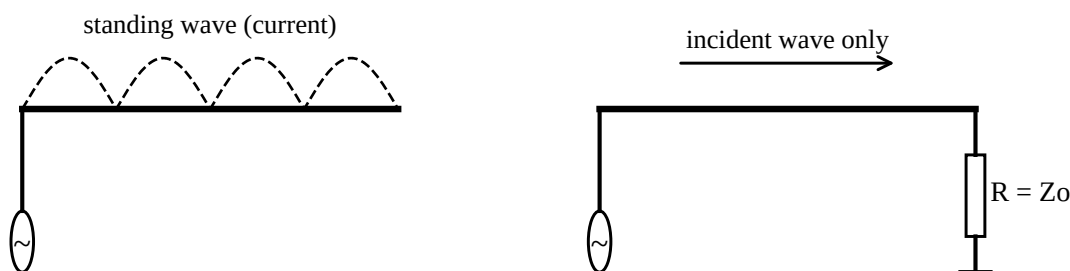


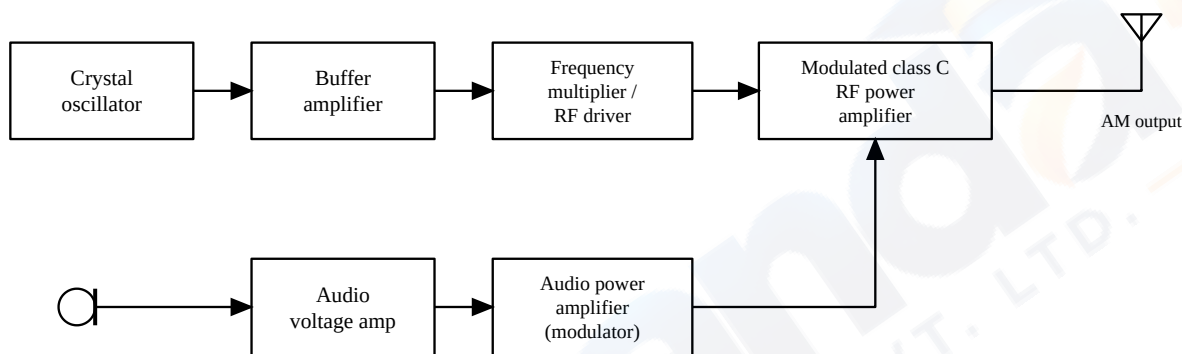
Fig.: Resonant and non-resonant antennas

(1 M each point)

Q.4

a) High level AM transmitter.

4 M



Modulation is done in the final (high power) stage

Fig.: Block diagram of high level AM transmitter

- **Crystal oscillator:** generates a stable carrier at the sub-multiple of the carrier frequency.
- **Buffer amplifier:** isolates the oscillator from the following stages so that load changes do not change the oscillator frequency.
- **Frequency multiplier / driver:** raises the frequency to the required carrier frequency and gives enough drive to the final stage.
- **Modulated class C RF power amplifier:** modulation takes place here (collector / plate modulation) at **high power level**; the output is the AM wave fed to the antenna.
- **Audio chain:** microphone → audio voltage amplifier → audio power amplifier (modulator) gives the large audio power needed for modulating the final stage.

Features: efficient class C amplifiers can be used for all RF stages → high overall efficiency; but a large audio power is needed. Used in AM broadcast transmitters.

(Diagram 2 M, explanation 2 M)

b) Pre-emphasis and de-emphasis.

4 M

In FM, noise affects the **higher modulating frequencies** more (noise output rises with frequency), while the amplitude of high audio frequencies in speech/music is small. So the SNR at high audio frequencies is poor.

- **Pre-emphasis:** at the transmitter, before modulation, the amplitude of higher audio frequencies (above ≈ 2.1 kHz) is artificially boosted using a high-pass RC network (time constant $75 \mu\text{s}$). This improves SNR at high frequencies.
- **De-emphasis:** at the receiver, after the FM detector, a low-pass RC network (same $75 \mu\text{s}$) attenuates the high frequencies by the same amount, so the original audio response is restored and the noise at high frequencies is also reduced.

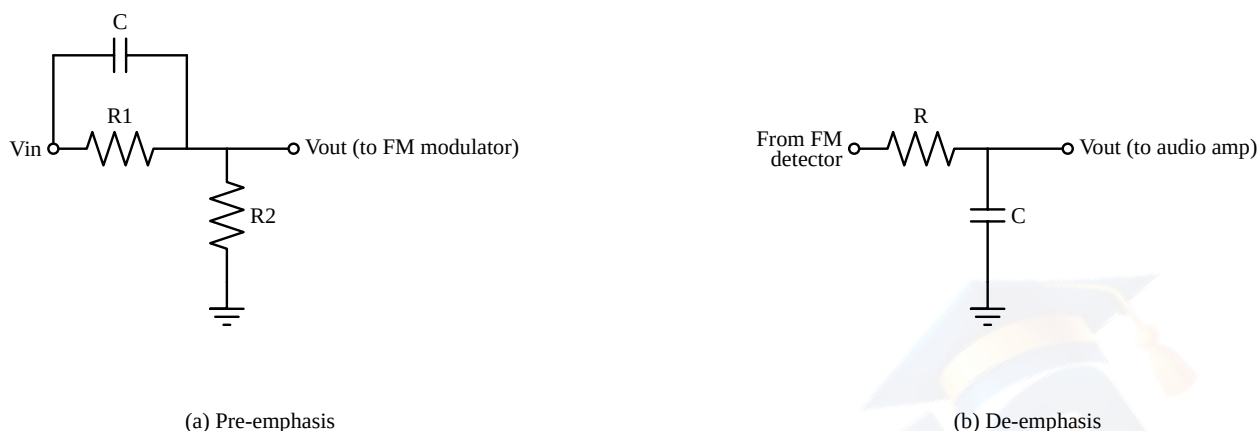


Fig.: (a) Pre-emphasis circuit (high pass) (b) De-emphasis circuit (low pass), $\tau = RC = 75 \mu\text{s}$

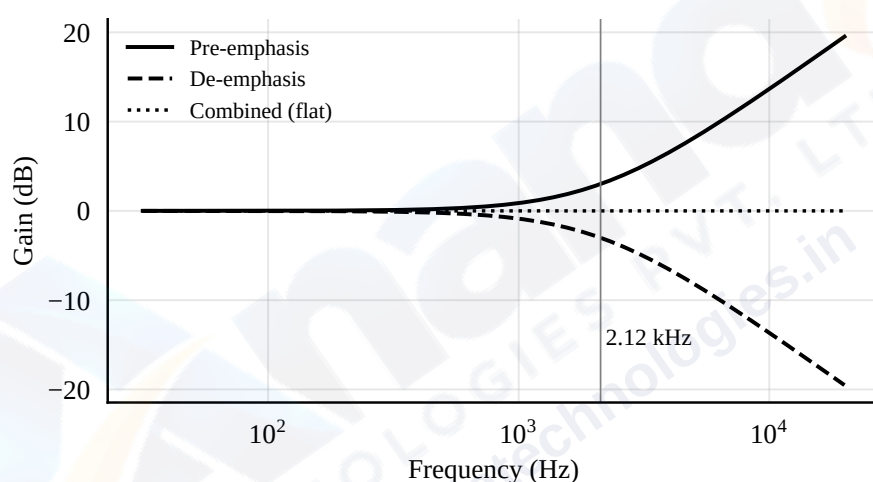


Fig.: Pre-emphasis and de-emphasis frequency response ($\tau = 75 \mu\text{s}$)

Corner frequency $f = 1/(2\pi RC) = 1/(2\pi \times 75 \mu\text{s}) = 2122 \text{ Hz} \approx 2.1 \text{ kHz}$.

(Concept 2 M, circuits/response 2 M)

c) Sky wave vs space wave.

4 M

Point	Sky wave propagation	Space wave propagation
Frequency range	3 MHz – 30 MHz (HF)	Above 30 MHz (VHF, UHF, microwave)
Effect of fading	Severe fading (ionosphere changes, multipath)	Less fading (mainly multipath / atmospheric)
Polarization	Changes (rotates) after ionospheric reflection	Remains as transmitted (horizontal or vertical)
Application	Short wave broadcasting, amateur radio, long distance ship communication	FM / TV broadcasting, mobile, microwave links, satellite

(1 M each point)

d) Radiation patterns of resonant dipoles.

4 M

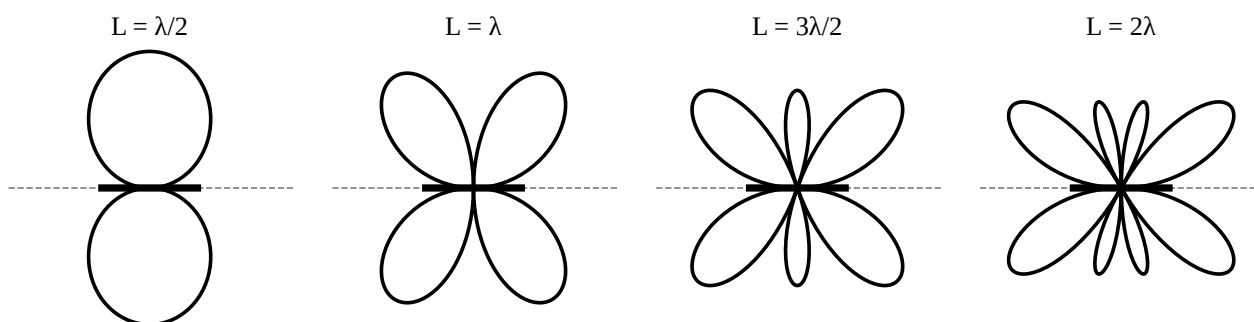


Fig.: Radiation patterns of resonant (standing wave) dipoles — wire along the horizontal axis

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°
$L = 3\lambda/2$	3	6	43°
$L = 2\lambda$	4	8	36°

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) Rectangular microstrip patch antenna.

4 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 ($\lambda_g/2$).

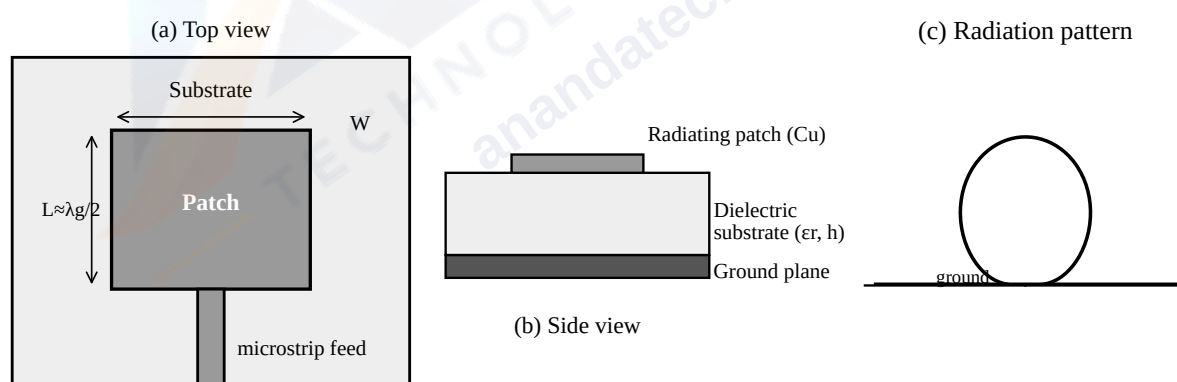


Fig.: Rectangular microstrip patch antenna — (c) broadside pattern, maximum normal to patch, no radiation below ground plane

- **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 ($\approx 70^\circ - 90^\circ$).

(Structure 2 M, pattern 2 M)

Q.5

a) Modulation index of AM and its effect.

6 M

Modulation index (m): the ratio of the amplitude of the modulating signal to the amplitude of the carrier: $m = V_m / V_c$. It shows the depth of modulation; % modulation = $m \times 100$. In terms of the envelope, $m = (V_{\max} - V_{\min}) / (V_{\max} + V_{\min})$.

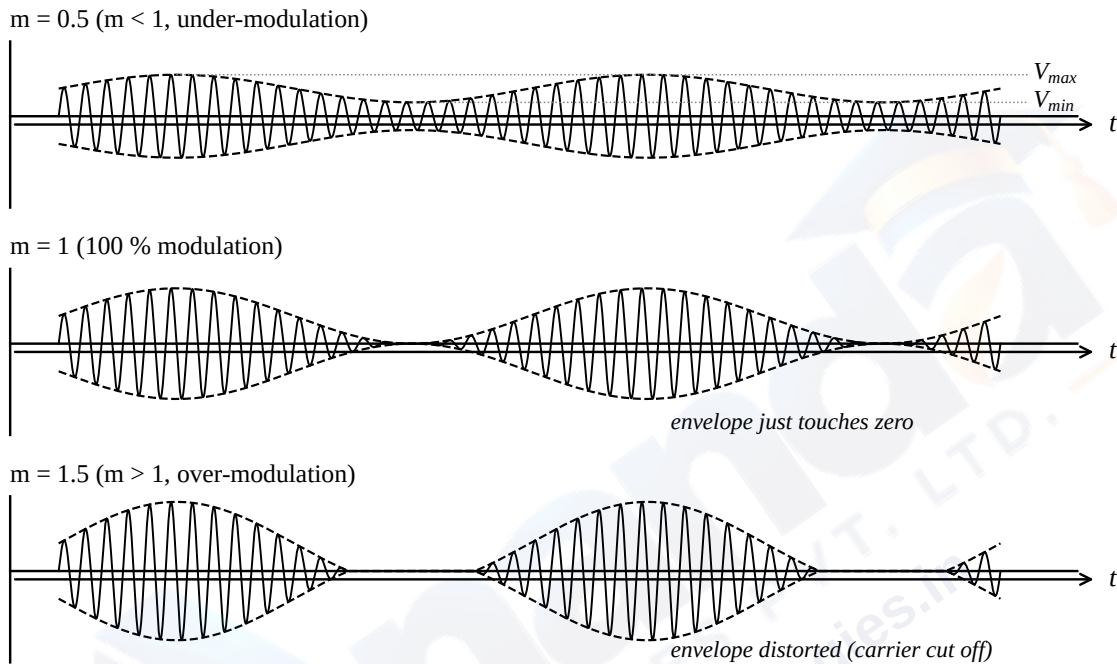


Fig.: Effect of modulation index on AM wave (dotted line = envelope)

- **$m < 1$ (under-modulation):** the envelope follows the modulating signal faithfully; $V_{\min} > 0$. Signal is recovered without distortion, but sideband power is less.
- **$m = 1$ (100 % modulation):** the envelope just touches zero ($V_{\min} = 0$); maximum sideband power without distortion — ideal condition.
- **$m > 1$ (over-modulation):** the carrier is cut off for part of the cycle, the envelope is distorted; the detector output is distorted and extra sidebands (splatter) cause interference. It must be avoided.

Numerical:

$$m = (V_{\max} - V_{\min}) / (V_{\max} + V_{\min}) = (18 - 6) / (18 + 6) = 12 / 24 = 0.50, \text{ i.e. } 50 \% \text{ modulation}$$

(Definition 1 M, waveforms & effects 3 M, numerical 2 M)

b) FM detectors and PLL FM demodulator.

6 M

Types of FM detectors:

1. Slope detector (single tuned)
2. Balanced slope detector
3. Foster–Seeley (phase) discriminator

4. Ratio detector
5. Quadrature detector
6. Phase locked loop (PLL) detector

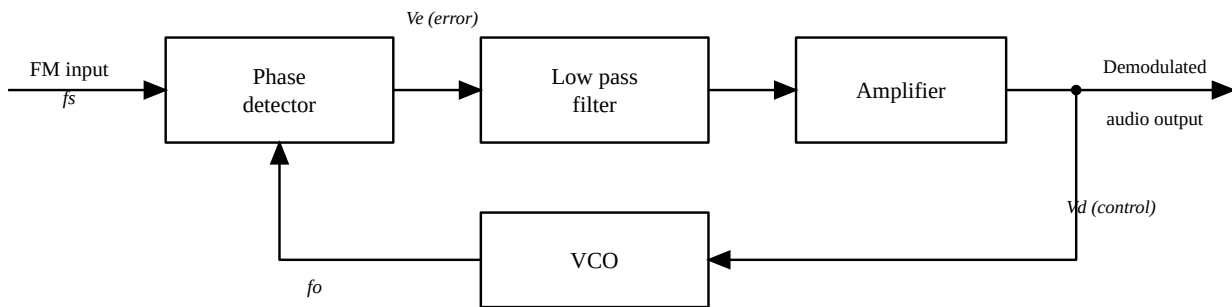


Fig.: PLL as FM demodulator

- **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.

(List 1 M, diagram 2 M, explanation 3 M)

c) Serial/parallel transmission and synchronous vs asynchronous.

6 M

(i) Serial transmission: data bits are sent **one after another** over a single line (channel). It needs fewer wires, is cheap and suitable for long distance, but slower. Example: USB, RS-232, Ethernet.

Parallel transmission: a group of bits (e.g. 8 bits) is sent **simultaneously** over separate lines; fast but costly, used for short distances (printer port, internal buses).

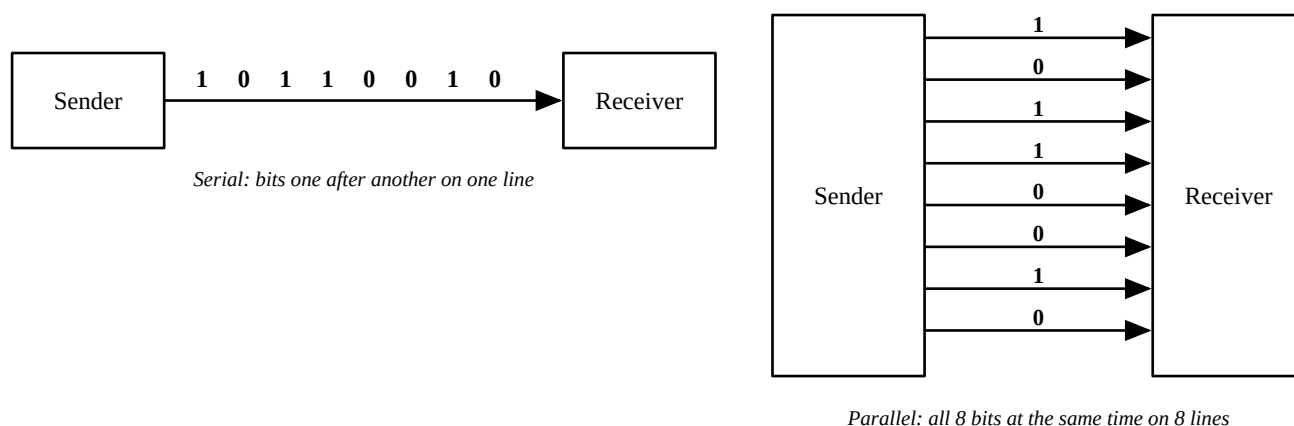


Fig.: Serial and parallel transmission

(ii) Synchronous vs asynchronous transmission:

Asynchronous transmission	Synchronous transmission
Data is sent one character at a time; each character has a start bit and stop bit(s).	Data is sent as a block (frame) of characters with sync characters at the start.
No common clock between transmitter and receiver.	Transmitter and receiver clocks are synchronized.
Gaps (idle time) can exist between characters.	No gaps between characters.
Lower speed and efficiency (extra start/stop bits).	Higher speed and efficiency.
Simple and cheap. Example: keyboard, RS-232 serial port.	Complex and costly. Example: Ethernet, video conferencing.

Idle (1)	Start 0	D0	D1	D2	D3	D4	D5	D6	D7	Stop 1	Idle (1)
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Asynchronous: each character is framed by start and stop bits

SYN	SYN	Char 1	Char 2	Char 3	...	Char n
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Synchronous: block of characters preceded by sync characters, no start/stop bits

Fig.: Character format in asynchronous and synchronous transmission

((i) 2 M, (ii) any four points 4 M)

Q.6

a) AM 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: $f_o = f_s + IF$.

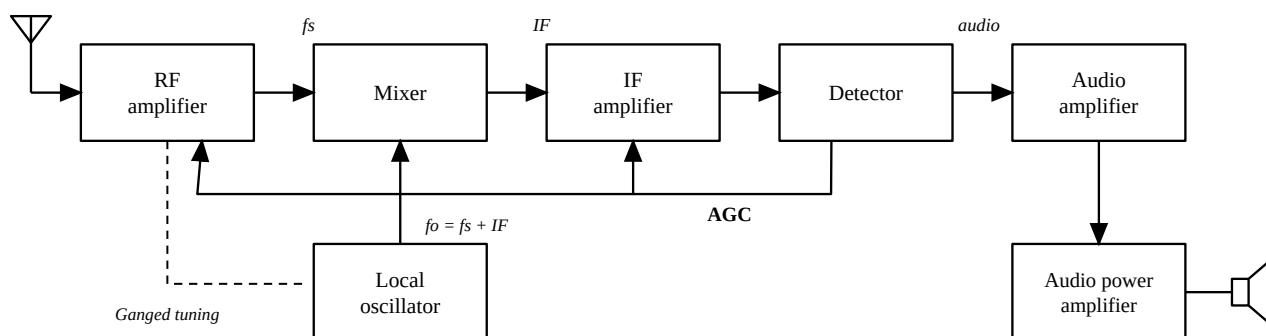


Fig.: Block diagram of AM superheterodyne receiver

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.

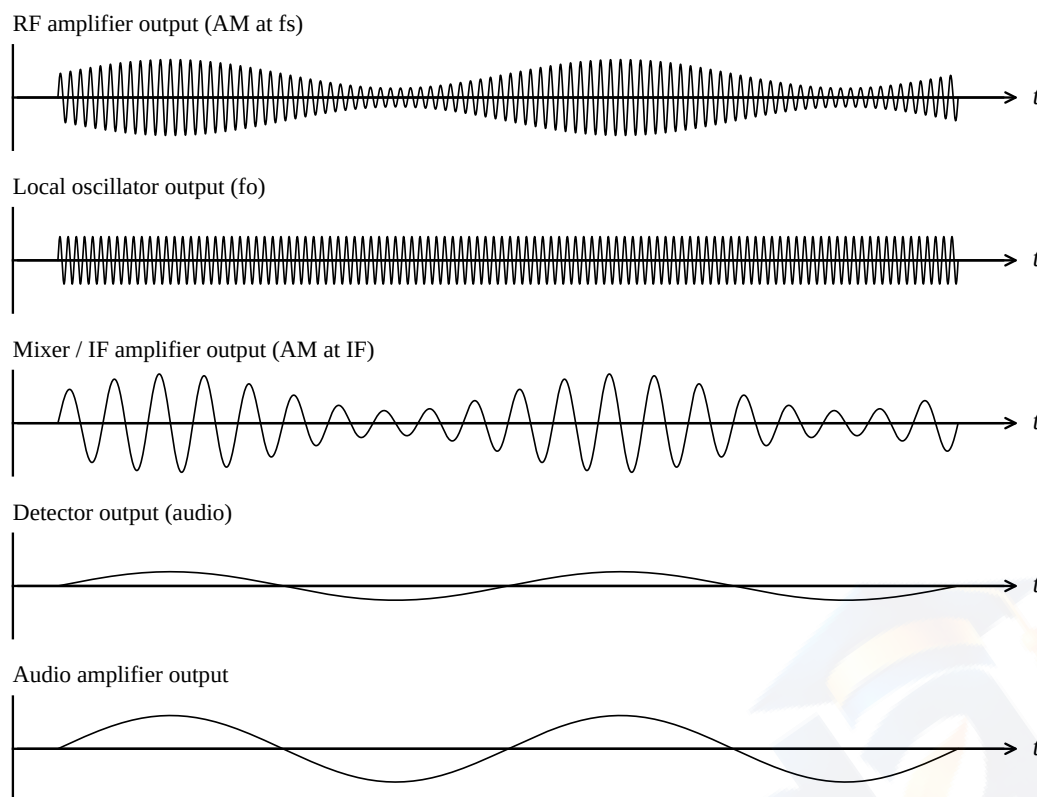


Fig.: Waveforms at different stages of superheterodyne receiver

(Principle 1 M, block diagram 2 M, explanation 2 M, waveforms 1 M)

b) FM wave and FM equation numerical.

6 M

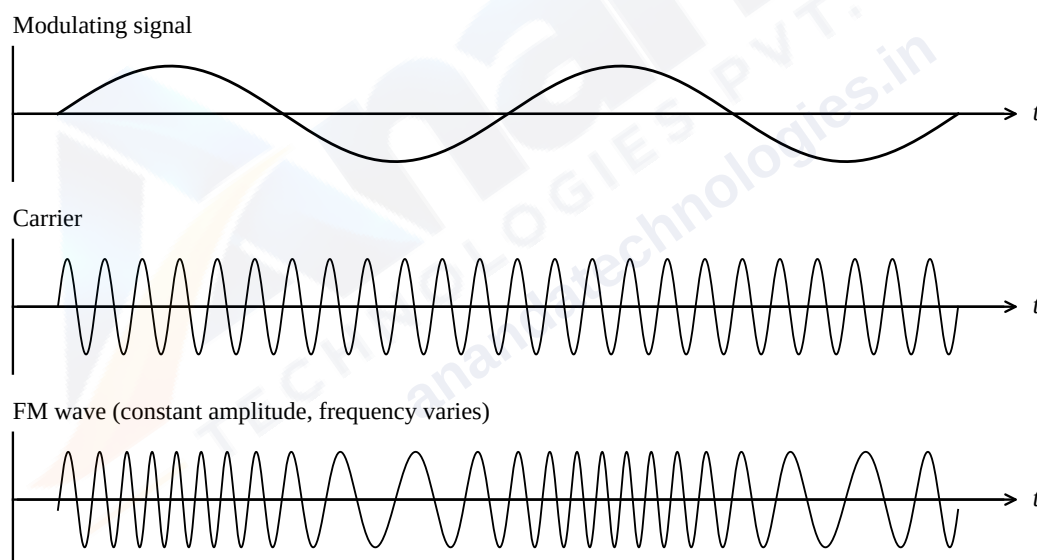


Fig.: (i) FM wave in time domain

(ii) Compare with $e_{FM} = A \sin (\omega_c t + m_f \sin \omega_m t)$: $A = 12 \text{ V}$, $\omega_c = 6 \times 10^8 \text{ rad/s}$, $m_f = 5$, $\omega_m = 1500 \text{ rad/s}$

Carrier frequency $f_c = \omega_c / 2\pi = 6 \times 10^8 / 2\pi = \mathbf{95.49 \text{ MHz}}$

Modulating frequency $f_m = \omega_m / 2\pi = 1500 / 2\pi = \mathbf{238.73 \text{ Hz}}$

Modulation index $m_f = 5$

Max. frequency deviation $\Delta f = m_f \times f_m = 5 \times 238.73 = \mathbf{1193.7 \text{ Hz}}$

$$\text{Bandwidth} = 2(\Delta f + f_m) = 2(1193.7 + 238.73) = \mathbf{2864.8 \text{ Hz}}$$

$$\text{Power } P = V_{\text{rms}}^2 / R = (12/\sqrt{2})^2 / 50 = 72 / 50 = \mathbf{1.44 \text{ W}}$$

(Waveform 1 M, each calculated value $\approx 1 \text{ M}$)

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
Dish (parabolic) antenna	Satellite communication / DTH, RADAR, microwave links, radio astronomy
Horn antenna	Feed for dish antennas, microwave measurements (standard gain), RADAR
Microstrip patch antenna	Mobile phones, GPS, WLAN, aircraft & missiles (radar, telemetry)
Ferrite rod antenna	Portable AM (MW/LW) radio receivers, RFID readers

(1 M each)

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