

Principles of Electronic Communication (313326)

MSBTE K-Scheme · Model Question Paper — Set B · 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.

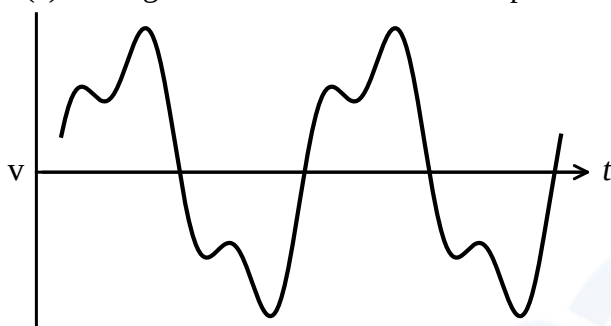
Q.1

a) Analog and digital signal.

2 M

- **Analog signal:** a signal that varies continuously with time and can take any (infinite) value of amplitude within a range. e.g. voice, temperature sensor output.
- **Digital signal:** a signal that is discrete in time and has only a finite number of levels (e.g. 0 and 1). e.g. computer data.

(a) Analog: continuous in time and amplitude



(b) Digital: discrete levels (0 and 1)

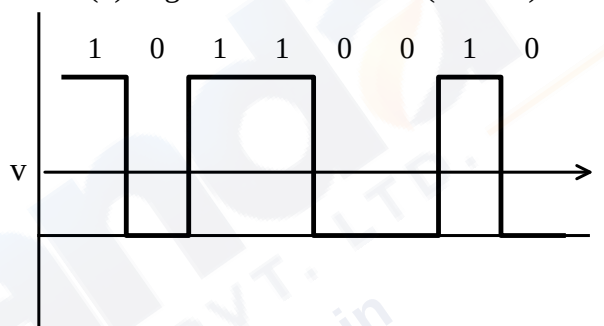


Fig.: (a) Analog signal (b) Digital signal

(Each definition with sketch 1 M)

b) Simplex vs half duplex.

2 M

Simplex	Half duplex
Communication in one direction only.	Communication in both directions, but one at a time.
Receiver cannot reply.	Each station can transmit and receive alternately (press-to-talk).
Example: radio / TV broadcasting.	Example: walkie-talkie, police wireless.

(Any two points 1 M each)

c) Sensitivity and selectivity.

2 M

- **Sensitivity:** ability of a receiver to receive and amplify **weak signals**. It is the minimum input signal (μV) required at the antenna to produce a specified output power (e.g. 50 mW) with a given SNR.
- **Selectivity:** ability of a receiver to **select the desired signal** and reject the unwanted adjacent channel signals. It mainly depends on the IF amplifier.

(1 M each)

d) Value of IF.

2 M

- (i) AM (MW band) receiver: **IF = 455 kHz** (range used $\approx 438 - 465$ kHz)
- (ii) FM broadcast receiver: **IF = 10.7 MHz**

(1 M each)

e) Characteristics of ground wave propagation.

2 M

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.

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

f) Ionospheric layers in day and night.

2 M

- (i) **Day time:** D, E, F1 and F2 layers.
- (ii) **Night time:** D layer disappears, E layer becomes weak, F1 and F2 combine to form a single **F layer** (so mainly E and F).

(1 M each)

g) Yagi-Uda antenna and radiation pattern.

2 M

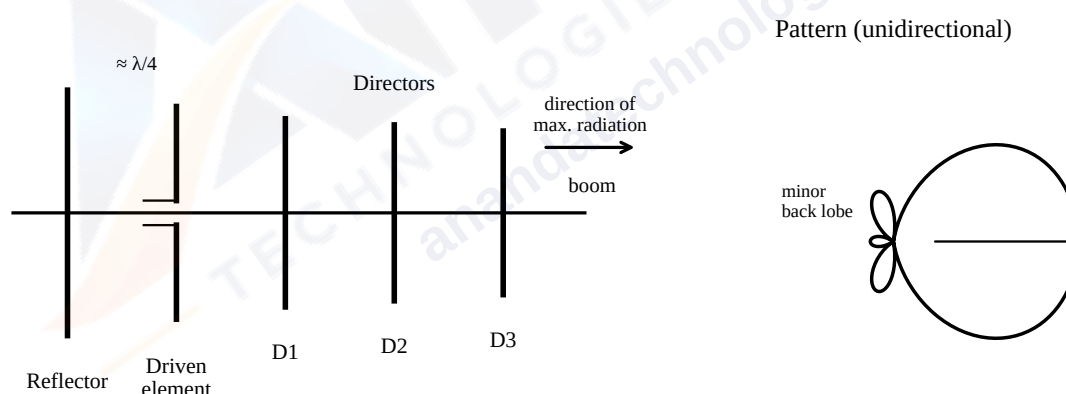


Fig.: Yagi-Uda antenna and its radiation pattern

(Sketch 1 M, pattern 1 M)

Q.2

a) Noise — definition and classification.

4 M

Noise: any unwanted, random electrical signal which gets added to the desired signal during transmission or reception and interferes with it, reducing the quality (SNR) of the received signal.

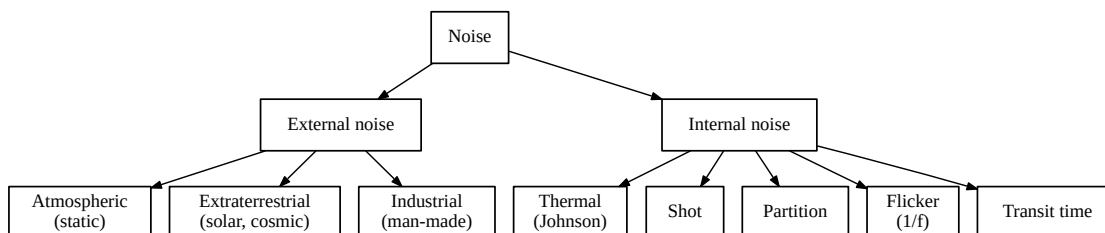


Fig.: Classification of noise

- **Atmospheric noise (static):** caused by natural disturbances such as lightning discharges in the atmosphere; heard as crackling; severe below about 30 MHz.
- **Extraterrestrial noise:** originates outside the earth — solar noise from the sun and cosmic (galactic) noise from distant stars; important at 8 MHz – 1.5 GHz.
- **Industrial (man-made) noise:** produced by automobile ignition, electric motors, switching gear, fluorescent lamps, welding machines, high-voltage lines (1 – 600 MHz).

(Definition 1 M, classification 1 M, two types 2 M)

b) Two-tone AM: total power and antenna current.

4 M

Formulae: $m_t = \sqrt{m_1^2 + m_2^2}$; $P_t = P_c(1 + m_t^2/2)$; $I_t = I_c \sqrt{1 + m_t^2/2}$

$$m_t = \sqrt{(0.4)^2 + (0.5)^2} = \sqrt{0.41} = \mathbf{0.6403}$$

$$P_t = 10 (1 + 0.41/2) = 10 \times 1.205 = \mathbf{12.05 \text{ kW}}$$

$$I_t = 8 \sqrt{1.205} = \mathbf{8.782 \text{ A}}$$

(mt 1 M, Pt 1½ M, It 1½ M)

c) NBFM vs WBFM.

4 M

Parameter	Narrow band FM (NBFM)	Wide band FM (WBFM)
Range of modulating frequency	30 Hz – 3 kHz	30 Hz – 15 kHz
Bandwidth	Small, $\approx 2f_m$ (same as AM)	Large, $\approx 2(\Delta f + f_m)$, about 15 times NBFM ($\approx 180 - 200 \text{ kHz}$)
Pre-emphasis / de-emphasis	Not needed	Needed
Application	Mobile communication, police wireless, ambulance, two-way radio	FM broadcasting, TV sound, high quality music

(1 M each)

d) Type of propagation.

4 M

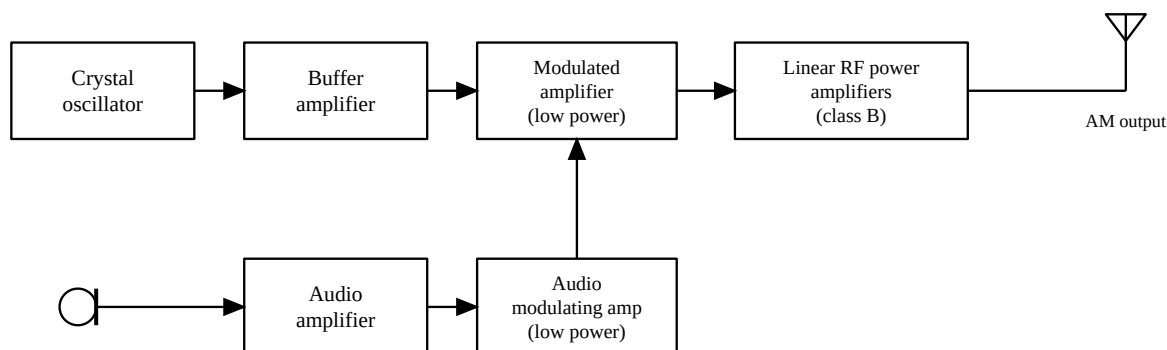
Application	Type of propagation
FM radio broadcasting	Space wave (line of sight) — VHF band
Ship-to-shore communication	Ground wave (VLF/LF/MF); sky wave for long distance (HF)
Microwave links	Space wave (line of sight)
Mobile (cellular) communication	Space wave (line of sight) — UHF band

(1 M each)

Q.3

a) Low level AM transmitter.

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.

(Diagram 2 M, explanation 2 M)

b) FM bandwidth by Bessel table and Carson's rule.

4 M

$$mf = \Delta f / f_m \rightarrow f_m = \Delta f / mf = 9 / 3 = 3 \text{ kHz}$$

Bessel function values for $mf = 3$ (a side frequency is significant if $|J_n| \geq 0.01$):

n	J _n (3)	Significant?
0	-0.2601	Yes
1	0.3391	Yes
2	0.4861	Yes
3	0.3091	Yes
4	0.1320	Yes
5	0.0430	Yes
6	0.0114	Yes
7	0.0025	No
8	0.0005	No

Highest significant sideband $n = 6 \rightarrow 6$ pairs of sidebands

$$BW = 2 \times n \times f_m = 2 \times 6 \times 3 = \mathbf{36 \text{ kHz}}$$

Carson's rule: $BW = 2(\Delta f + f_m) = 2(9 + 3) = 24 \text{ kHz}$ (approximate; contains $\approx 98\%$ of power)

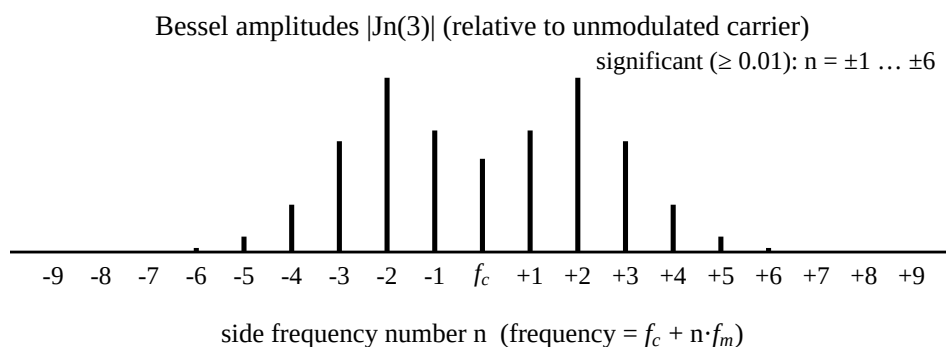


Fig.: FM spectrum for $m_f = 3$ (carrier and side frequencies spaced f_m apart)

(f_m 1 M, sidebands 1 M, BW 1 M, Carson 1 M)

c) Sky wave terms.

4 M

- **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).
- **Virtual height (h'):** the height to which a wave would have to rise if it were **reflected** from a perfect reflecting surface — point where the extended incident and returning rays meet. It is always greater than the actual height.
- **Actual height (h):** the real height in the ionosphere at which the wave actually turns back to the earth after gradual refraction.
- **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).

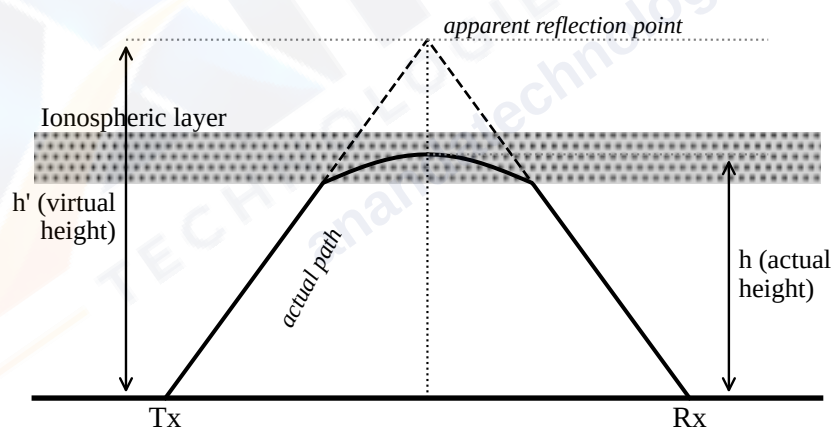


Fig.: Actual height (h) and virtual height (h') of ionospheric layer

(1 M each)

d) Radiation patterns of resonant dipoles.

4 M

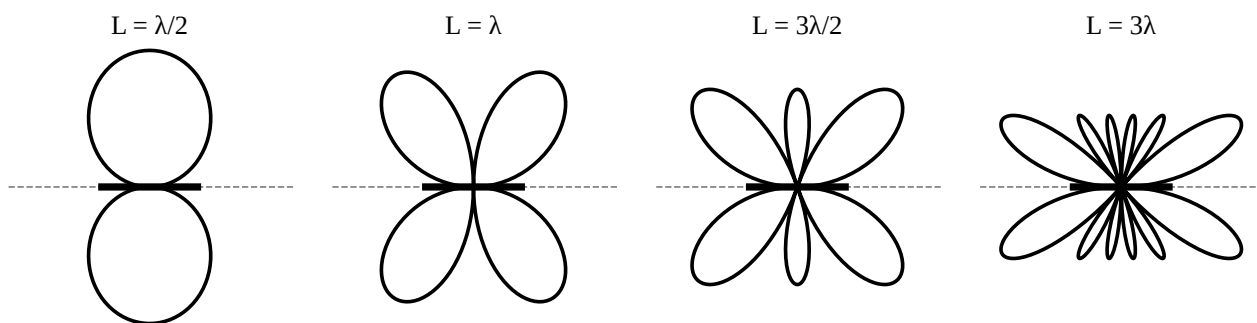


Fig.: Radiation patterns of resonant (standing wave) dipoles — wire along the horizontal axis

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°
$L = 3\lambda/2$	3	6	43°
$L = 3\lambda$	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)

Q.4

a) Varactor diode FM modulator.

4 M

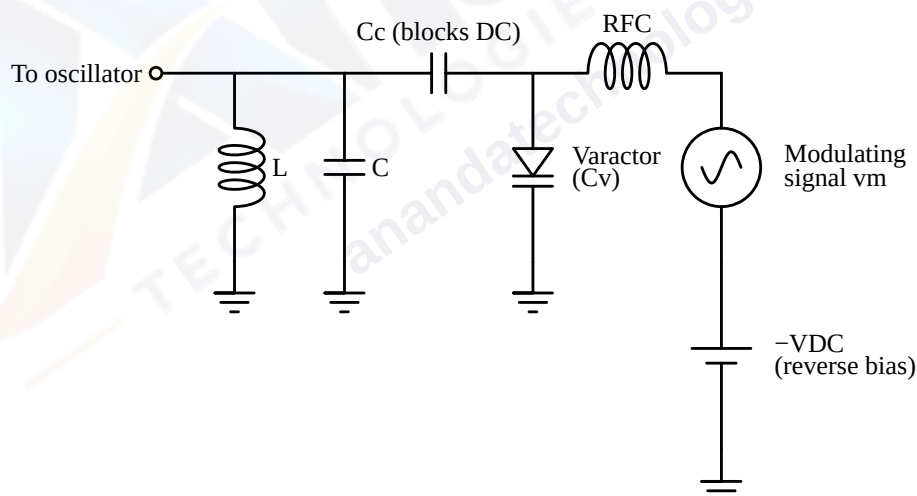


Fig.: Varactor diode FM modulator (varactor forms part of oscillator tank circuit)

- A **varactor diode** is a reverse biased diode whose junction capacitance C_v decreases as the reverse voltage increases ($C_v \propto 1/\sqrt{V}$).
- The varactor is connected (through C_c) across the tank circuit L – C of the carrier oscillator, so the oscillator frequency is $f = 1 / [2\pi \sqrt{L (C + C_v)}]$.
- The modulating signal is added to the fixed reverse bias. As the modulating voltage changes, the reverse bias and hence C_v change, so the oscillator frequency changes in proportion to the

modulating signal → **direct FM**.

- RFC prevents RF from entering the modulating source; Cc blocks DC bias from the tank coil.
- Simple circuit, but frequency stability is poor (crystal cannot be used directly) — AFC is needed.

(Circuit 2 M, working 2 M)

b) Sky wave vs space wave.

4 M

Point	Sky wave propagation	Space wave propagation
Principle	Reflection / refraction from ionosphere	Line-of-sight: direct wave + ground reflected wave through troposphere
Frequency range	3 MHz – 30 MHz (HF)	Above 30 MHz (VHF, UHF, microwave)
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
Effect of fading	Severe fading (ionosphere changes, multipath)	Less fading (mainly multipath / atmospheric)

(1 M each)

c) AM vs FM.

4 M

Parameter	AM	FM
Definition	Amplitude of carrier is varied in accordance with the instantaneous amplitude of the modulating signal; frequency and phase constant.	Frequency of carrier is varied in accordance with the instantaneous amplitude of the modulating signal; amplitude constant.
Modulation index	$m = V_m / V_c$; lies between 0 and 1	$m_f = \Delta f / f_m$; can be greater than 1
Bandwidth	$BW = 2f_m$ (small, e.g. 10 kHz)	$BW = 2(\Delta f + f_m)$ (large, e.g. 180 – 200 kHz)
Noise immunity	Poor — noise adds to amplitude	Better — amplitude noise removed by limiter

(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.
Reflection	Total reflection at open end (reflection coefficient = 1) $\rightarrow$ standing waves	No reflection (reflection coefficient = 0) $\rightarrow$ only travelling (forward) waves
Bandwidth	Narrow (frequency sensitive)	Wide
Example	Half wave dipole, Yagi-Uda, folded dipole	Rhombic antenna, terminated long wire (Beverage)

Resonant: open ends, standing waves

Non-resonant: terminated in R, travelling waves

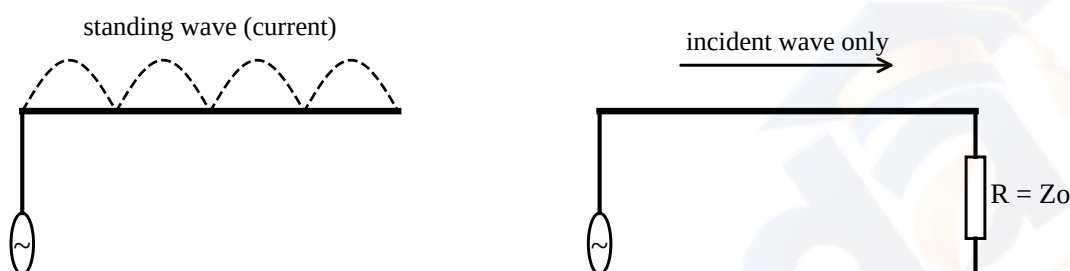


Fig.: Resonant and non-resonant antennas

(1 M each)

e) Proper antenna for applications.

4 M

Application	Proper antenna
(i) Portable MW radio receiver	Ferrite rod (loop) antenna
(ii) TV reception at VHF	Yagi-Uda antenna
(iii) DTH satellite TV reception	Parabolic dish antenna
(iv) GPS receiver in a mobile phone	Microstrip patch antenna

(1 M each)

Q.5

a) AM numerical with spectrum.

6 M

Given: $V_m = 6$ V, $f_m = 2$ kHz ; $V_c = 10$ V, $f_c = 200$ kHz (2×10^5 Hz)

Modulation index $m = V_m / V_c = 6/10 = 0.6$

Percentage modulation = **60 %**

LSB frequency = $f_c - f_m = 200 - 2 = 198$ kHz ; USB frequency = $f_c + f_m = 202$ kHz

Amplitude of each sideband = $mV_c/2 = 0.6 \times 10/2 = 3$ V

Bandwidth = $2f_m = 4$ kHz

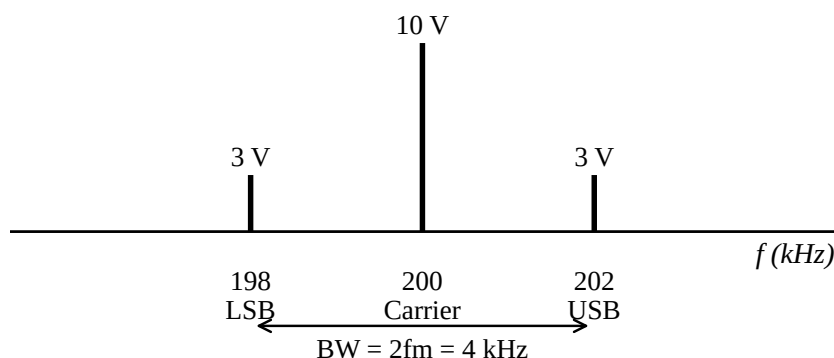


Fig.: Frequency spectrum of AM wave

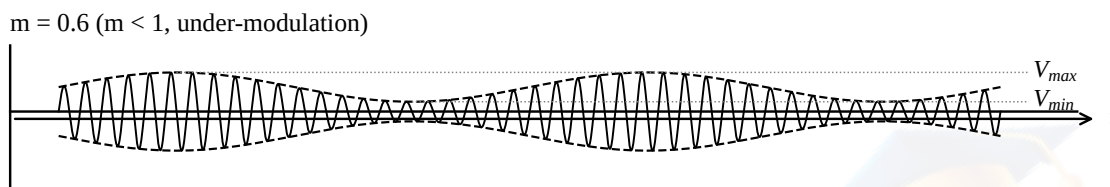


Fig.: AM wave for $m = 0.6$ ($V_{max} = 16 \text{ V}$, $V_{min} = 4 \text{ V}$)

(Calculations 4 M, spectrum 1 M, waveform 1 M)

b) DSB-FC vs DSB-SC vs SSB.

6 M

Point	DSB-FC (AM)	DSB-SC	SSB(-SC)
Carrier suppression	Not suppressed (full carrier)	Suppressed	Suppressed
Sideband suppression	Not suppressed (both sidebands)	Not suppressed (both sidebands)	One sideband suppressed
Bandwidth	$2f_m$	$2f_m$	f_m (half of AM)
Transmission efficiency	Low — max. 33.3 % (at $m = 1$)	100 % (all power in sidebands)	100 % (all power in one sideband)
Power requirement	High — $P_c(1 + m^2/2)$	Less — $m^2 P_c/2$	Least — $m^2 P_c/4$
Application	MW / SW radio broadcasting	FM stereo (L – R signal on 38 kHz subcarrier), colour TV chroma signal, QAM	Point-to-point HF radio, telephony (FDM), amateur radio

(1 M each point)

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 ($\lambda_g/2$).

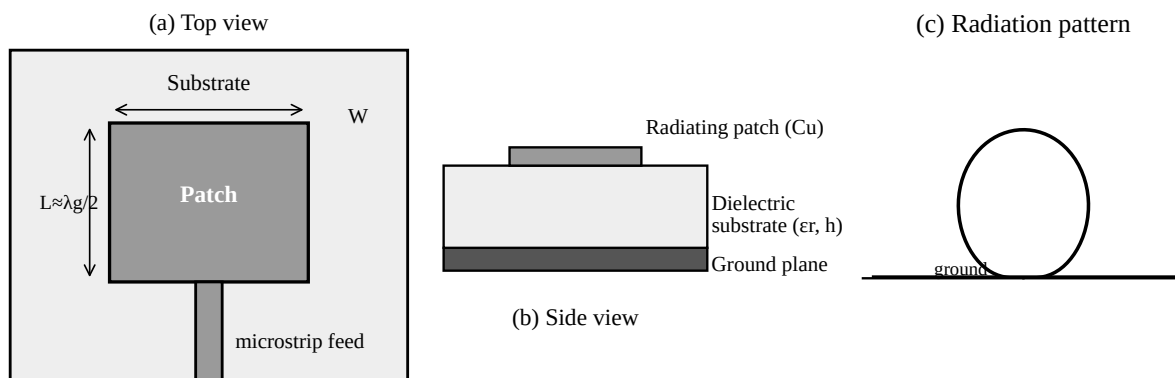


Fig.: Rectangular microstrip patch antenna — (c) broadside pattern, maximum normal to patch, no radiation below ground plane

- **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.

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

Q.6

a) Identify blank blocks of superheterodyne receiver.

6 M

Fig. 1 is the block diagram of an AM superheterodyne receiver. A = Mixer, B = Detector, C = Local oscillator.

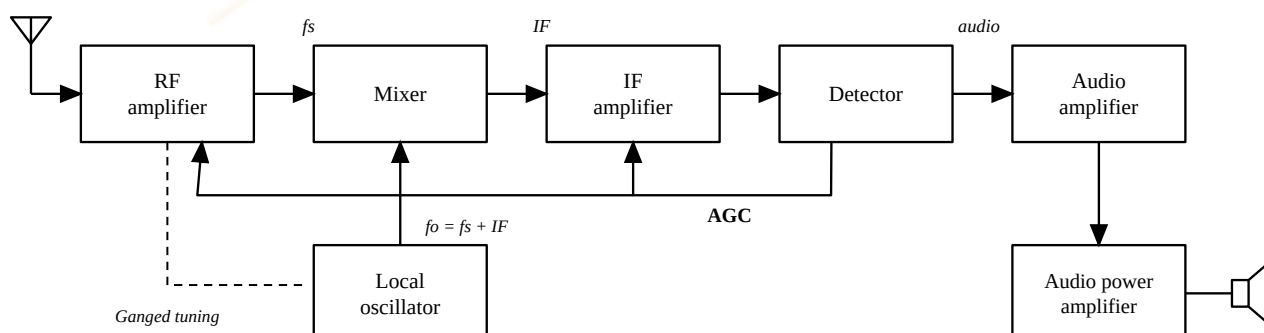


Fig.: Block diagram of AM superheterodyne receiver

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 $f_o = f_s + \text{IF}$; 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.

IF = $f_o - f_s = 455 \text{ kHz}$ is fixed for all stations, so the IF amplifier gives high, uniform gain and selectivity.

(Identification 1½ M, diagram 1½ M, functions 3 M)

b) FM detection methods and PLL 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

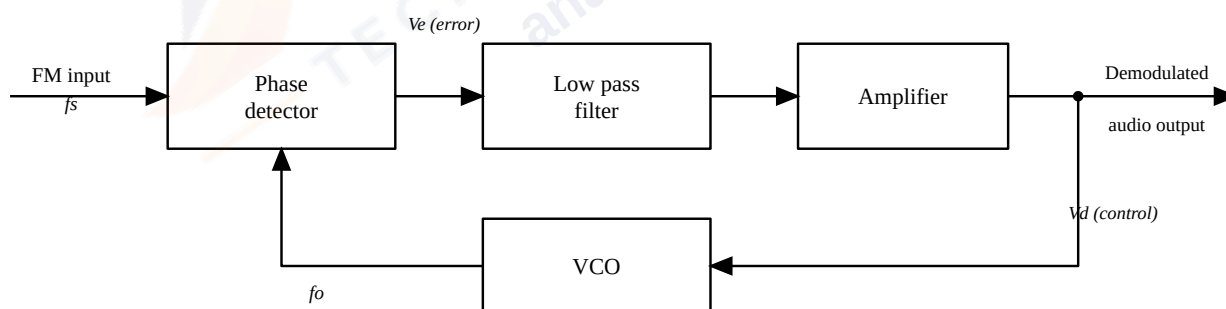


Fig.: PLL as FM demodulator

- **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) Frequency range for applications.

6 M

Application	Frequency range
Voice communication	300 Hz – 3.4 kHz (VF band)
Short wave (international) broadcasting	3 MHz – 30 MHz (HF band)
FM radio broadcasting	88 MHz – 108 MHz (VHF band)
RADAR	1 GHz – 40 GHz (UHF / SHF microwave bands)
Power transmission	50 Hz / 60 Hz (ELF band, 30 – 300 Hz)
Cellular phones	800 MHz – 2.6 GHz (UHF band; e.g. 900 / 1800 MHz)

(1 M each)

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