

Microwave Engineering & Radar System (315342)

Model Question Paper — Set A · Model Answers

Q.1

a) Advantages of waveguide over two-wire line.

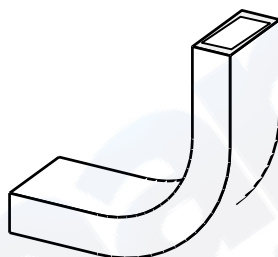
2 M

1. **Low loss:** no dielectric/radiation loss and less copper loss (large surface) → attenuation much lower than coaxial line at microwave frequencies.
2. **High power handling:** no inner conductor and air dielectric, so breakdown occurs at much higher power.
3. **No radiation loss:** fields are completely enclosed inside the metal walls.
4. **Simple, rugged construction:** a single hollow conductor; no inner conductor or supports needed.

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

b) E-plane bend and H-plane bend.

2 M



E-plane bend (bent in the plane of E, i.e. along narrow side b)



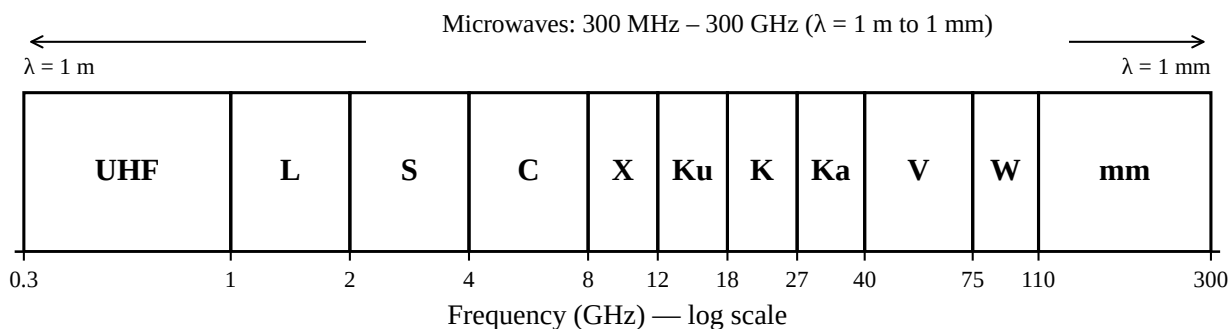
H-plane bend (bent in the plane of H, i.e. along broad side a)

Bends change the direction of the guide. To avoid reflections the mean radius of the bend should be greater than about $2\lambda_g$.

(Each sketch 1 M)

c) Microwave frequency spectrum with IEEE bands.

2 M



Microwave frequency spectrum with IEEE band designations

Microwaves: 300 MHz to 300 GHz ($\lambda = 1 \text{ m to } 1 \text{ mm}$). IEEE bands: L 1–2 GHz, S 2–4 GHz, C 4–8 GHz, X 8–12 GHz, Ku 12–18 GHz.

(Spectrum 1 M, bands 1 M)

d) Limitations of vacuum tubes at microwave frequencies.

2 M

1. **Inter-electrode capacitance** becomes a low-reactance short at microwave frequencies ($X_C = 1/\omega C$).
2. **Lead inductance** of electrode leads becomes a high series reactance ($X_L = \omega L$) and causes feedback/resonance.
3. **Transit-time effect:** electron transit time becomes comparable to the RF period, so input conductance rises and gain falls.
4. **Gain–bandwidth limitation:** resonant circuits give a fixed gain–bandwidth product; gain drops at high frequency.

(Any four, ½ M each)

e) Duty cycle and maximum unambiguous range.

2 M

Given: $\tau = 2 \mu\text{s}$, $\text{PRF} = 1000 \text{ Hz} \rightarrow \text{PRT} = 1/\text{PRF} = 1 \text{ ms}$.

Duty cycle $= \tau \times \text{PRF} = 2 \times 10^{-6} \times 1000 = \mathbf{0.002}$ (= 0.2 %)

Maximum unambiguous range $R_{\text{un}} = c / (2 \text{ PRF}) = 3 \times 10^8 / (2 \times 1000) = 150000 \text{ m} = \mathbf{150 \text{ km}}$

(Each 1 M)

f) RADAR range equation.

2 M

$$R_{\text{max}} = [P_t G A_e \sigma / ((4\pi)^2 S_{\text{min}})]^{1/4}$$

- R_{max} = maximum range of RADAR (m)
- P_t = peak transmitted power (W)
- G = gain of transmitting antenna
- A_e = effective aperture (capture area) of receiving antenna (m^2)
- σ = RADAR cross-section of the target (m^2)
- S_{min} = minimum detectable (receivable) signal power (W)

(Equation 1 M, terms 1 M)

g) Applications of SONAR.

2 M

1. Detection and location of submarines, mines and ships (navy).
2. Measuring depth of sea (echo sounding) and mapping the sea bed.
3. Fish finding (fishing industry).
4. Underwater navigation, search and rescue, locating wrecks.
5. Underwater communication and oceanographic research.

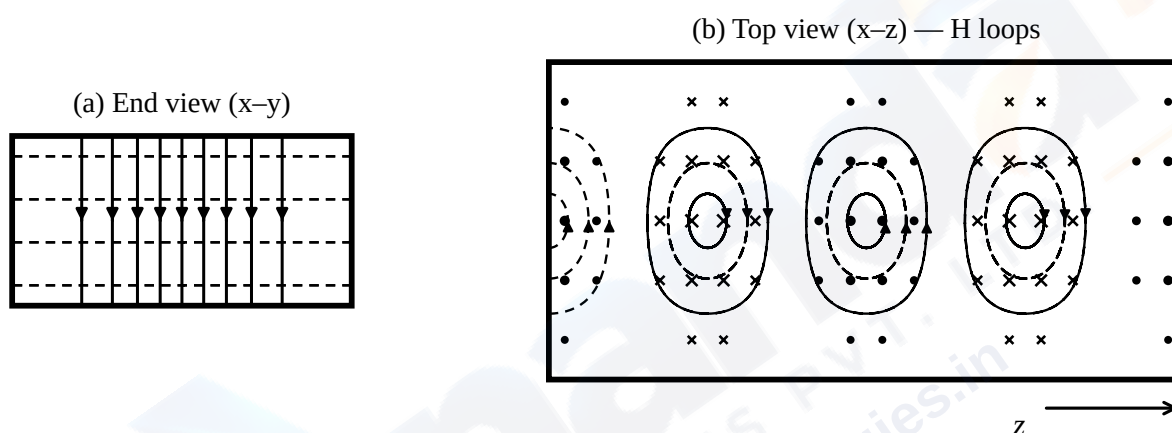
(Any four, $\frac{1}{2}$ M each)

Q.2

a) Field patterns of TE_{10} mode.

4 M

In TE_{10} mode (dominant mode) E has only the E_y component, which varies as $\sin(\pi x/a)$: maximum at the centre and zero at the side walls; there is no variation along y. H has H_x and H_z components which form closed loops in the x-z plane.



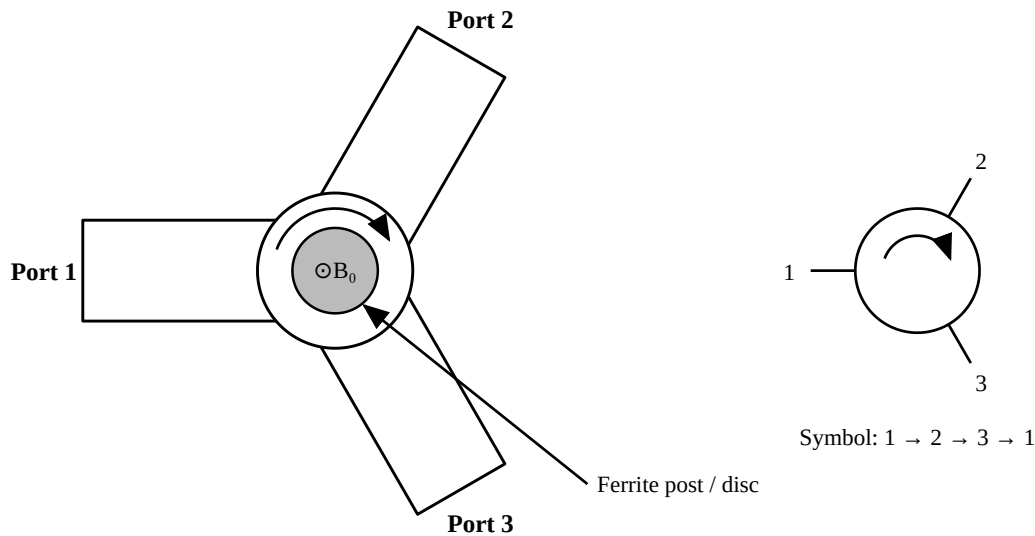
TE_{10} mode: (a) cross-section, (b) top view — solid = E, dashed = H, $\bullet / \times$ = E out of / into page

(End view 2 M, top view 2 M)

b) Three-port Y-junction circulator.

4 M

Construction: Three identical rectangular waveguide arms meet symmetrically at 120° to form a Y-junction. A ferrite post (or disc) is placed at the centre of the junction and a permanent magnet applies a dc magnetic field B_0 along the axis of the post.



Three-port Y-junction ferrite circulator (top view) and its symbol

Working: Without the magnet the junction is symmetrical and power entering one port divides equally between the other two. With the magnetised ferrite, the two counter-rotating field patterns at the junction see different permeabilities, so the standing-wave pattern is rotated by 30° . As a result a null is placed at one port: power entering port 1 comes out only at port 2, port 2 → port 3 and port 3 → port 1 (1 → 2 → 3 → 1). Reversing B_0 reverses the direction of circulation. It is a **non-reciprocal** device.

Applications: (1) Duplexer — connects transmitter and receiver to a common antenna. (2) Used as an isolator by terminating the third port in a matched load; in parametric / reflection amplifiers.

(Construction with diagram 2 M, working 1 M, applications 1 M)

c) Radiation hazards and preventive measures.

4 M

Types of radiation hazards:

- **HERP** (Hazards of Electromagnetic Radiation to Personnel): heating of body tissues; eyes (cataract) and testes are most sensitive because they have poor blood flow to remove heat. OSHA exposure limit: 10 mW/cm^2 (averaged over 6 minutes).
- **HERO** (Hazards of EM Radiation to Ordnance): strong RF fields can induce currents in the wires of electro-explosive devices (detonators, missiles) and fire them accidentally.
- **HERF** (Hazards of EM Radiation to Fuel): RF-induced sparks can ignite fuel vapour while refuelling aircraft or vehicles near high-power transmitters.

Preventive measures:

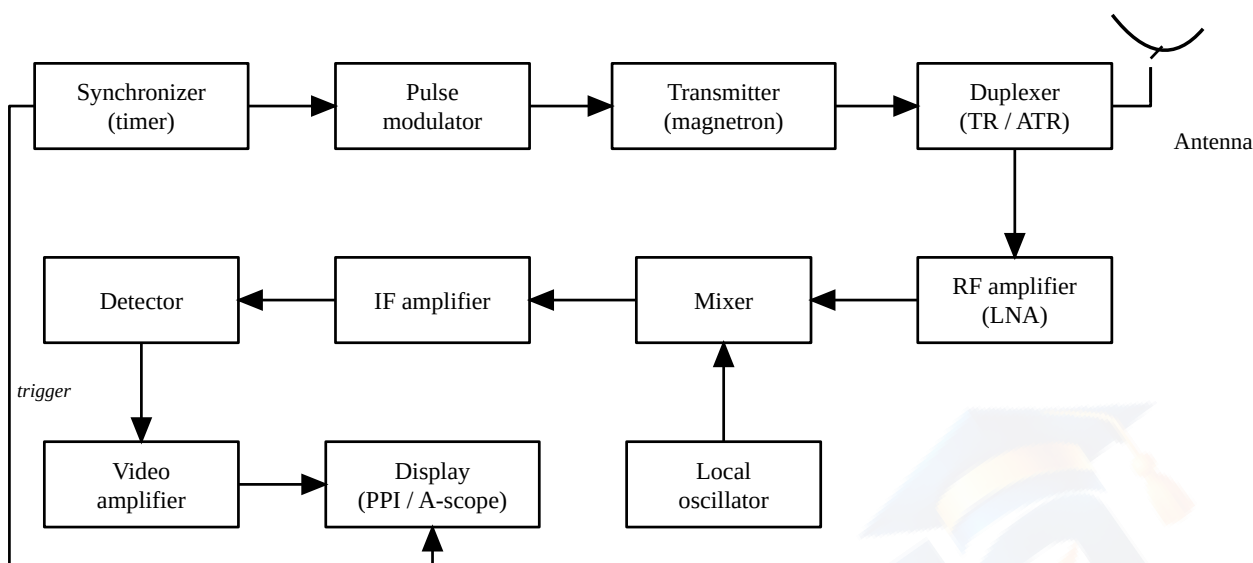
- Keep radiation density below the IEEE/OSHA safe limit; mark and fence high-power areas with warning signs.
- Never look into an open waveguide, horn or dish when the transmitter is ON; switch off before maintenance.
- Use proper shielding — metal enclosures, wire-mesh screens, door interlocks and chokes (e.g. microwave oven door).
- Terminate unused ports with matched loads; use RF leakage detectors / survey meters regularly.
- Keep ordnance and fuel away from high-power antennas; shield and short-circuit detonator leads; no refuelling during transmission.

- Personnel to wear protective clothing / RF-shielded goggles where needed; limit exposure time.

(Hazards 2 M, measures 2 M)

d) Basic pulse RADAR; function of duplexer.

4 M



Block diagram of basic pulse RADAR

The synchronizer triggers the modulator, which switches the magnetron ON for a short pulse. The pulse goes through the duplexer to the antenna. Echoes received by the same antenna pass through the duplexer to the LNA, mixer (with local oscillator) and IF amplifier, are detected, amplified as video and displayed. The display sweep starts with the transmitted pulse, so the echo position gives range ($R = c t / 2$).

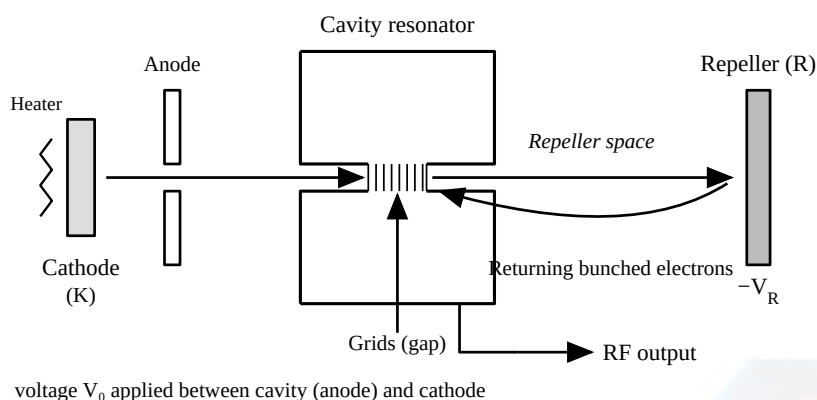
Function of duplexer: It allows a **single antenna** to be used for both transmission and reception. During the transmitted pulse it connects the transmitter to the antenna and **protects (blocks) the sensitive receiver** from the high power (TR switch fires). Between pulses it connects the antenna to the receiver and isolates the transmitter (ATR switch), so the weak echo is not lost in the transmitter.

(Block diagram 2 M, duplexer function 2 M)

Q.3

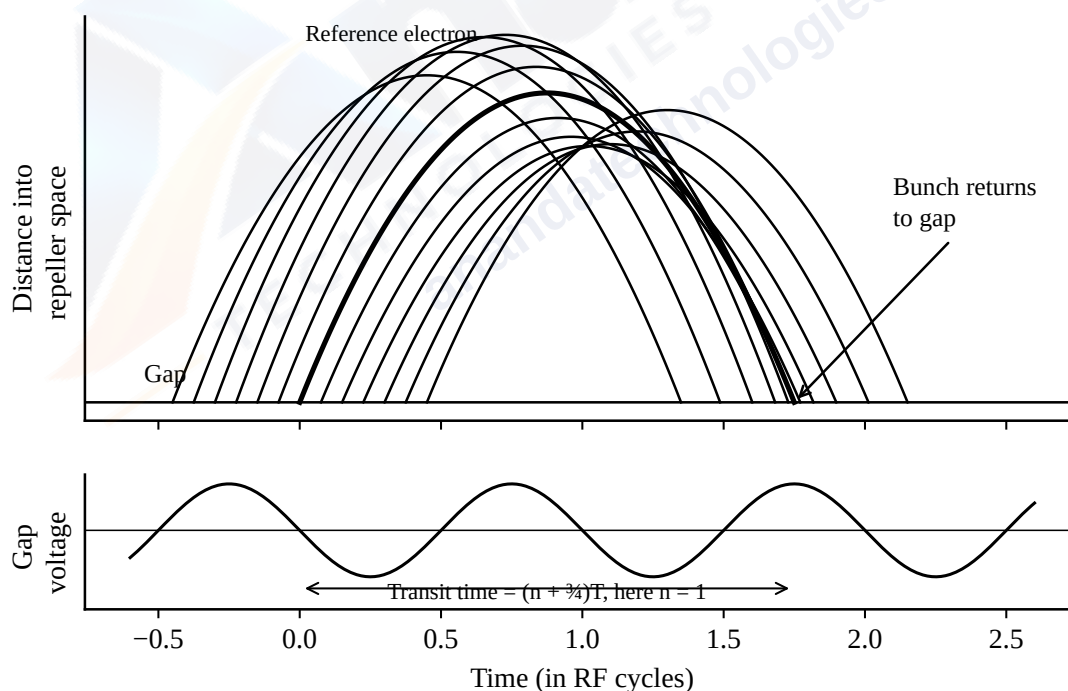
a) Reflex klystron with Applegate diagram.

4 M



Principle — velocity modulation: The electron beam from the cathode is accelerated by V_0 and passes through the gap of a single cavity. The RF voltage across the gap speeds up some electrons and slows others (velocity modulation). The beam then enters the repeller space where the repeller (at negative voltage $-V_R$) turns the electrons back towards the gap.

Faster electrons travel deeper into the repeller space and take longer to return; slower electrons return sooner. So electrons that crossed the gap at different instants return **together as a bunch**. If the bunch arrives when the gap field opposes it (transit time = $(n + \frac{3}{4})T$), the bunch gives energy to the cavity and oscillations are sustained.

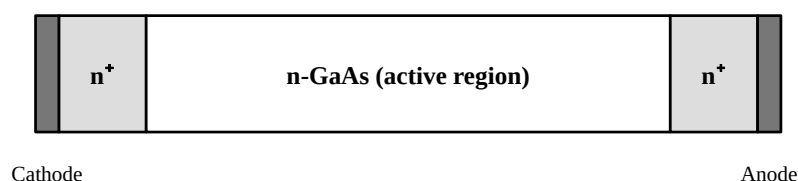


Applegate diagram of reflex klystron (computed): electrons bunch on return to the gap

(Diagram 1 M, principle 1 M, Applegate diagram with explanation 2 M)

b) Gunn diode.

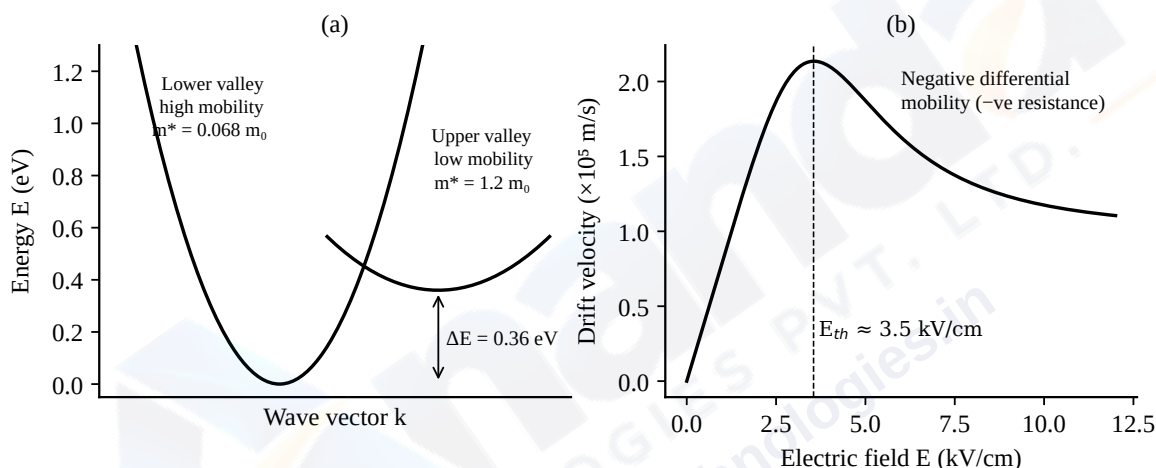
4 M



Gunn diode (n-type GaAs) structure — no p-n junction

Construction: A thin slice of n-type GaAs (or InP) with heavily doped n^+ layers at both ends for ohmic contacts. It has **no p-n junction**; it is a bulk (transferred-electron) device.

Working (Ridley–Watkins–Hilsum / transferred-electron effect): GaAs has a lower conduction-band valley (high mobility, light electrons) and an upper valley about 0.36 eV higher (low mobility, heavy electrons). At low field all electrons are in the lower valley and current rises with voltage. When the field exceeds the threshold (≈ 3.4 kV/cm) electrons gain enough energy to transfer to the upper valley, their mobility falls and the drift velocity decreases — **negative differential resistance**.



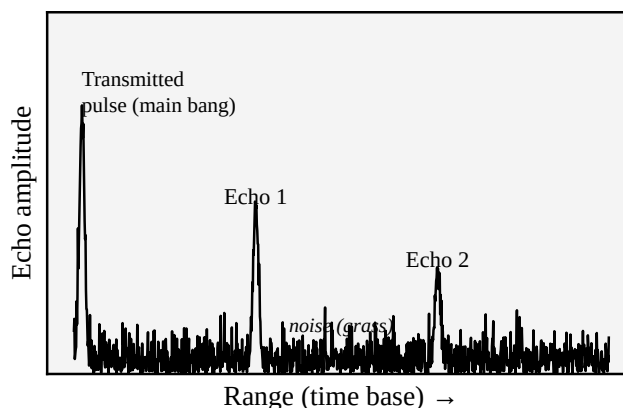
Gunn effect: (a) two-valley band structure of GaAs, (b) drift velocity vs electric field (computed)

A high-field **domain** forms near the cathode, drifts to the anode and disappears, then a new domain forms. This gives current pulses at a frequency $f = v_d/L$ (L = active length) — microwave oscillations (Gunn oscillator, 1–100 GHz).

(Construction 1 M, working 2 M, characteristic 1 M)

c) A-scope display.

4 M



A-scope display (range vs echo amplitude)

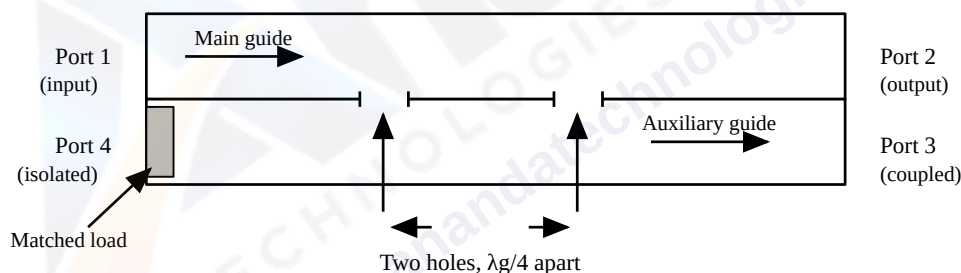
Principle: The A-scope is a deflection-modulated CRT display. A linear time base (horizontal sweep) starts at the instant the pulse is transmitted, so horizontal distance is proportional to time and hence to **range**. The detected video signal deflects the beam vertically, so each echo appears as a vertical **pip** whose height is the echo amplitude.

- The large pip at the left is the transmitted pulse (main bang).
- Range of a target = distance of its pip from the start of the sweep $\times$ range scale; $R = c t / 2$.
- Only range is shown, not direction (antenna points in one direction at a time).
- Used for tracking RADAR and for checking/ranging a selected target.

(Sketch 2 M, explanation 2 M)

d) Two-hole directional coupler.

4 M



Two-hole directional coupler

Construction: Two waveguides (main and auxiliary) share a common wall in which two small holes are cut $\lambda_g/4$ apart. One end of the auxiliary guide is terminated in a matched load.

Working: Power entering port 1 flows to port 2. A small part couples through each hole into the auxiliary guide. In the **forward** direction (towards port 3) the two coupled waves travel equal paths and add in phase. In the **backward** direction (towards port 4) the wave through the second hole travels an extra $2 \times \lambda_g/4 = \lambda_g/2$, so the two waves are 180° out of phase and cancel. Thus power couples only in one direction.

$$\text{Coupling factor } C = 10 \log_{10}(P_1/P_3) \text{ dB} \quad \text{Directivity } D = 10 \log_{10}(P_3/P_4) \text{ dB}$$

P_1 = input power, P_3 = power at coupled port, P_4 = power at isolated port. Coupling tells what fraction is sampled; directivity tells how well forward and backward waves are separated.

(Sketch 1 M, working 1 M, definitions 2 M)

Q.4

a) IMPATT, TRAPATT and BARITT comparison.

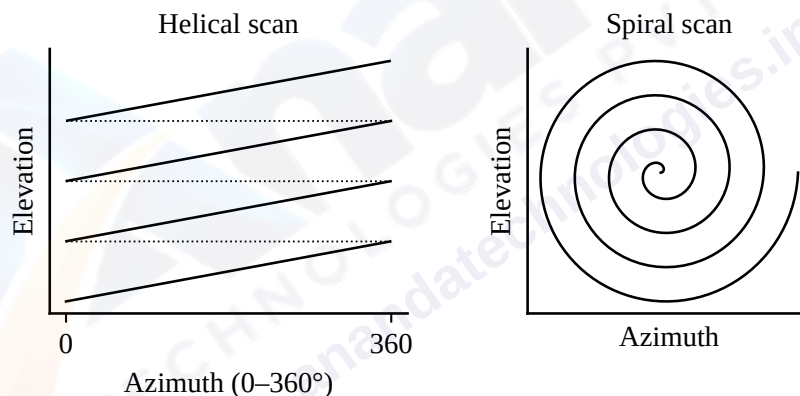
4 M

Parameter	IMPATT	TRAPATT	BARITT
Structure	$n^+ p i p^+$ (Read diode) or $p^+ n n^+$	$p^+ n n^+$	$p^+ n p^+$ (or metal–n–metal)
Operating principle	Impact ionisation (avalanche) + transit-time delay give 180° phase shift (negative resistance)	Trapped plasma avalanche triggered transit; a plasma of electrons and holes is formed and extracted	Barrier injection (punch-through) + transit-time; carriers injected over a forward-biased barrier
Efficiency	Low, about 5 – 15 %	High, about 20 – 60 %	Very low, about 2 – 5 %
Noise	High (avalanche noise ≈ 30 dB)	High	Low (no avalanche, ≈ 15 dB)
Frequency	0.5 – 100 GHz (high)	1 – 10 GHz (lower)	4 – 8 GHz typical

(Each point 1 M)

b) Helical and spiral scanning.

4 M



Radar antenna scanning patterns

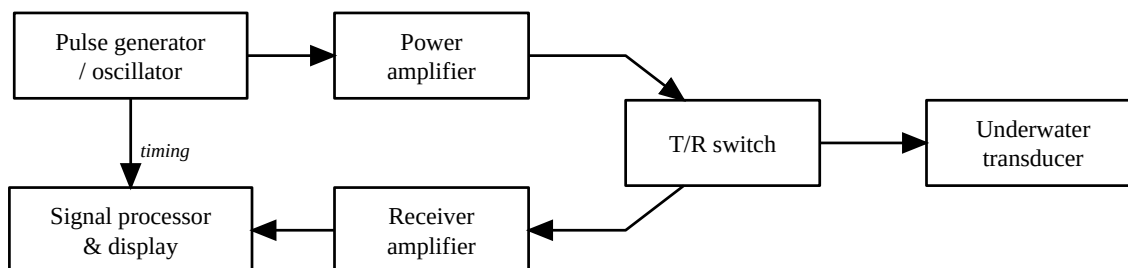
Helical scanning: The antenna rotates continuously in azimuth (360°) while it is slowly raised in elevation. After each full rotation the elevation increases by about one beamwidth; when the maximum elevation (e.g. 90°) is reached the antenna returns to the starting elevation. The beam traces a helix and covers the complete hemisphere. Used in search RADAR, e.g. SCR-584.

Spiral scanning: The beam rotates rapidly about the antenna axis while the angle between the beam and the axis is gradually increased (and then decreased). The beam path traces a spiral and covers a **cone-shaped (circular) region** in front of the antenna. No rotation of the whole antenna through 360° is needed. Used for searching a limited angular region and for target acquisition by tracking radars.

(Each method with sketch 2 M)

c) Working principle of SONAR.

4 M



Block diagram of active SONAR

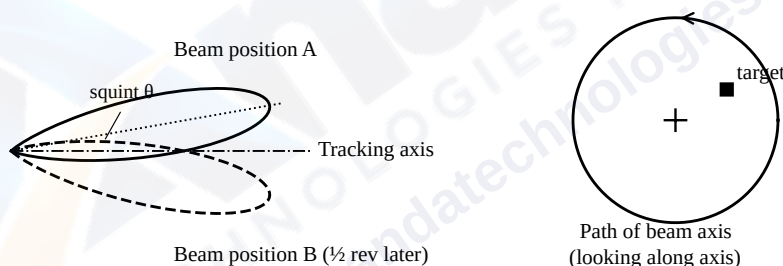
SONAR (SOund NAvigation And Ranging) uses **sound / ultrasonic waves** (about 1 kHz – 100 kHz) under water because radio waves are heavily attenuated in sea water.

- The pulse generator and power amplifier drive the transducer (piezoelectric / magnetostrictive), which converts electrical pulses into a sound pulse (ping).
- The sound travels through water ($v \approx 1500$ m/s), is reflected by a target (submarine, fish shoal, sea bed) and returns as an echo.
- The same transducer converts the echo into an electrical signal; the T/R switch connects it to the receiver amplifier; the processor measures the time t .
- Range $R = v \times t / 2$. Direction is found from the transducer orientation; target speed from Doppler shift of the echo.

(Block diagram 2 M, explanation 2 M)

d) Conical scan tracking.

4 M



Conical scan tracking: squinted beam rotates about the tracking (RF) axis

The antenna feed is placed slightly **off the focus** of the paraboloid, so the beam is squinted by a small angle from the reflector axis. The feed is rotated (nutated) so the beam axis traces a cone around the tracking (RF) axis. If the target is exactly on the axis, the echo amplitude is constant. If the target is off-axis, the echo is **amplitude modulated** at the scan frequency; the depth of modulation gives the amount of error and the phase gives the direction. These error signals drive the azimuth and elevation servo motors until the target is on the axis.

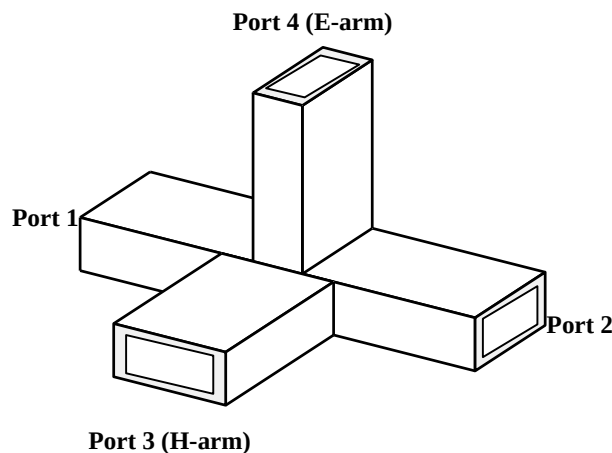
Advantage: Simple — needs only one feed and one receiver channel; gives continuous tracking in both angles.

Disadvantage: Several pulses are needed for one angle measurement, so it is affected by target-echo fluctuations (amplitude scintillation) and can be jammed; accuracy lower than monopulse.

(Sketch 1 M, explanation 2 M, advantage & disadvantage 1 M)

e) Magic tee and its properties.

4 M



Magic tee (hybrid tee)

A magic tee (hybrid tee) is a combination of an E-plane tee and an H-plane tee. Ports 1 and 2 are the collinear arms, port 3 is the H-arm and port 4 is the E-arm.

Properties:

1. Power fed at the H-arm (port 3) divides equally between ports 1 and 2, **in phase**; nothing comes out of the E-arm.
2. Power fed at the E-arm (port 4) divides equally between ports 1 and 2, **180° out of phase**; nothing comes out of the H-arm.
3. Ports 3 and 4 are isolated from each other (decoupled).
4. Equal in-phase signals fed at ports 1 and 2 add at port 3 (sum) and cancel at port 4 (difference).
5. When all ports are matched, power entering port 1 or 2 goes only to ports 3 and 4 (ports 1 and 2 are also isolated).

(Sketch 2 M, properties 2 M)

Q.5

a) Waveguide numerical (a = 2.29 cm, b = 1.02 cm, 10 GHz).

6 M

Given: a = 2.29 cm = 0.0229 m, b = 1.02 cm = 0.0102 m, f = 10 GHz, $\epsilon_r = 1$, $\mu_r = 1$.

Velocity in the filling medium $v = c/\sqrt{\epsilon_r} = 3 \times 10^8/1 = 3 \times 10^8$ m/s.

$$f_c = (v/2) \sqrt{[(m/a)^2 + (n/b)^2]}$$

i) Cut-off for TE₁₀ (m = 1, n = 0): $f_{c10} = v/(2a) = 3 \times 10^8/(2 \times 0.0229) = \mathbf{6.550 \text{ GHz}}$; $\lambda_c = 2a = 4.58$ cm.

Cut-off for TE₁₁: $f_{c11} = (3 \times 10^8/2) \sqrt{[(1/0.0229)^2 + (1/0.0102)^2]} = \mathbf{16.099 \text{ GHz}}$ → does not propagate (f < f_c) at 10 GHz.

ii) Free-space (medium) wavelength: $\lambda = v/f = 3 \times 10^8/(10 \times 10^9) = 3.000$ cm.

$$\sqrt{1 - (f_c/f)^2} = \sqrt{1 - (6.550/10)^2} = 0.7556$$

iii) **Guide wavelength:** $\lambda_g = \lambda / \sqrt{1 - (f_c/f)^2} = 3.000/0.7556 = \mathbf{3.970 \text{ cm}}$

iv) **Phase velocity:** $v_p = v / \sqrt{1 - (f_c/f)^2} = \mathbf{3.970 \times 10^8 \text{ m/s}}$

v) **Group velocity:** $v_g = v \times \sqrt{1 - (f_c/f)^2} = \mathbf{2.267 \times 10^8 \text{ m/s}}$ (check: $v_p \cdot v_g = v^2$)

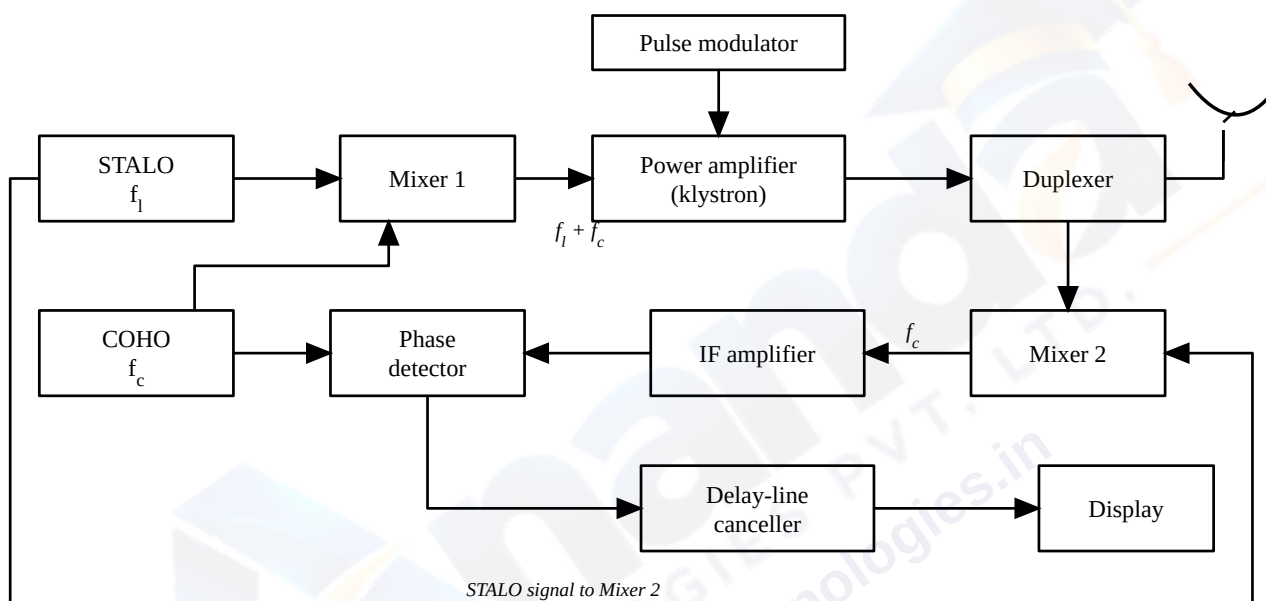
vi) **Wave impedance (TE₁₀):** $Z_{TE} = \eta / \sqrt{1 - (f_c/f)^2}$, $\eta = 120\pi/\sqrt{\epsilon_r} = 376.99 \Omega \rightarrow Z_{TE} = \mathbf{498.9 \Omega}$

Answer: $f_{c10} = 6.550 \text{ GHz}$ (propagates), $f_{c11} = 16.10 \text{ GHz}$ (does not propagate), $\lambda_g = 3.97 \text{ cm}$, $v_p = 3.970 \times 10^8 \text{ m/s}$, $v_g = 2.267 \times 10^8 \text{ m/s}$, $Z_{TE10} = 498.9 \Omega$.

(Cut-offs 2 M, λ_g 1 M, v_p & v_g 2 M, impedance 1 M)

b) MTI RADAR.

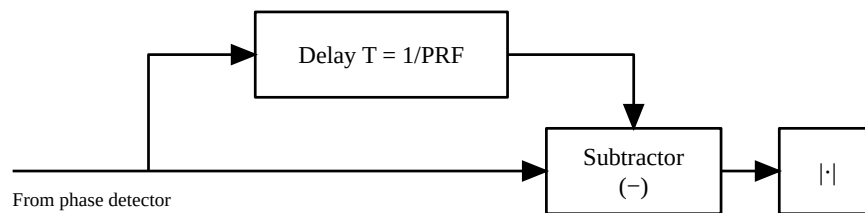
6 M



Block diagram of MTI RADAR (coherent, power-amplifier type)

Principle: The echo from a moving target has a Doppler shift, so its **phase changes** from one pulse to the next; the echo from a fixed target has the same phase every pulse. MTI RADAR compares successive echoes and removes those that do not change.

- **STALO** (stable local oscillator, f_l) and **COHO** (coherent oscillator, $f_c = \text{IF}$) are mixed in Mixer 1 to give $f_l + f_c$, which is amplified by the power amplifier (klystron) and transmitted through the duplexer.
- The echo $f_l + f_c \pm f_d$ is mixed with STALO in Mixer 2 to give IF $f_c \pm f_d$.
- The **phase detector** compares the IF with the COHO reference: output is constant amplitude for fixed targets and fluctuating (bipolar video at f_d) for moving targets.
- The **delay-line canceller** subtracts the video of the present pulse from that of the previous pulse (delay $T = 1/\text{PRF}$). Fixed-target echoes cancel; moving-target echoes remain and are displayed.



Single delay-line canceller: echo of a fixed target is cancelled

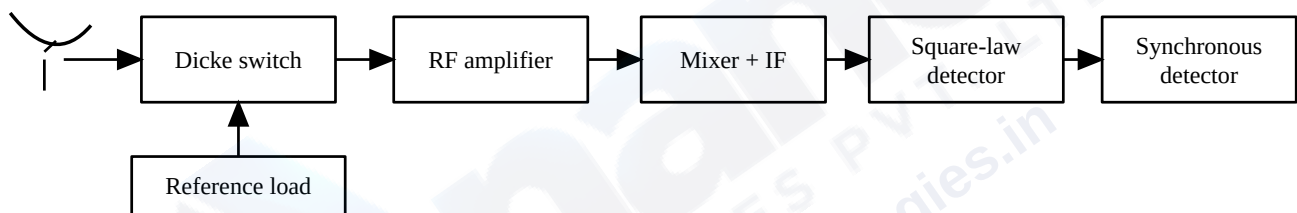
Advantages: (1) Clutter from ground, buildings, hills is removed, so moving aircraft can be seen even in heavy clutter. (2) Gives a clean PPI display with only moving targets; useful for air-traffic control and air defence.

(Block diagram 2 M, explanation 3 M, advantages 1 M)

c) Radiometer, remote sensing RADAR and biomedical applications.

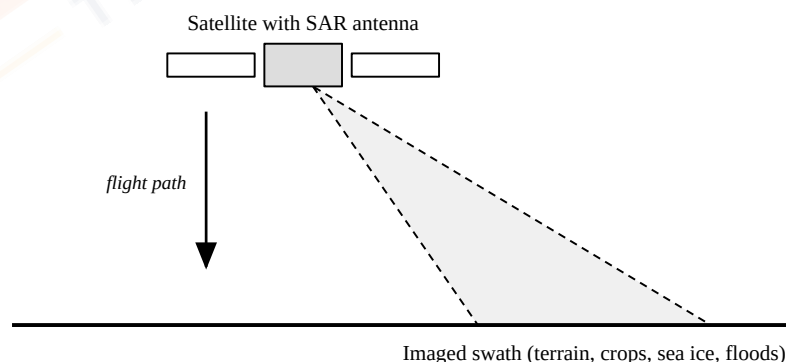
6 M

i) RADAR (microwave) radiometer: A very sensitive passive receiver that measures the natural microwave thermal noise power radiated by objects ($P = kTB$). The measured brightness temperature gives information about soil moisture, sea-surface temperature, rain, atmospheric water vapour. The Dicke radiometer switches the receiver between the antenna and a reference load and uses synchronous detection to cancel receiver gain fluctuations.



Dicke (switched) microwave radiometer — block diagram

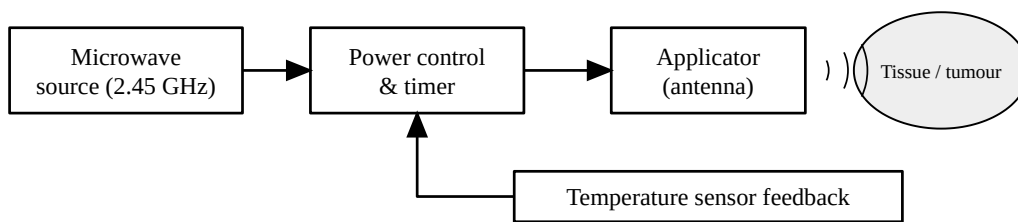
ii) Remote sensing RADAR: Imaging RADARs such as side-looking airborne RADAR and Synthetic Aperture RADAR (SAR) on aircraft/satellites send microwave pulses to the earth and form high-resolution images from the echoes. Microwaves pass through clouds and work day and night. Uses: mapping, agriculture/crop monitoring, oil-spill and flood detection, sea-ice and forest mapping.



Remote sensing RADAR (side-looking / SAR) on a satellite images the earth surface day and night

iii) Biomedical application: Controlled microwave heating (diathermy at 2.45 GHz) is used for physiotherapy and **hyperthermia** treatment of tumours; microwaves are also used in microwave

imaging, ablation of tissue and sterilisation of medical equipment.



Biomedical use: microwave hyperthermia / diathermy — controlled heating of tissue

(Each application with diagram 2 M)

Q.6

a) RADAR range and Doppler shift numerical.

6 M

i) Maximum range

Given: $P_t = 2.5 \times 10^5 \text{ W}$, $A_e = 4 \text{ m}^2$, $f = 5 \text{ GHz}$ ($\lambda = c/f = 6 \text{ cm}$), $\sigma = 12 \text{ m}^2$, $S_{\min} = 1.00 \times 10^{-13} \text{ W}$.

$$R_{\max} = [P_t A_e^2 \sigma / (4\pi \lambda^2 S_{\min})]^{1/4} \text{ (using } G = 4\pi A_e / \lambda^2 \text{)}$$

$$\text{Numerator} = 2.5 \times 10^5 \times 4^2 \times 12 = 4.800 \times 10^7$$

$$\text{Denominator} = 4\pi \times (0.06)^2 \times 1.00 \times 10^{-13} = 4.524 \times 10^{-15}$$

$$R_{\max} = (1.061 \times 10^{22})^{1/4} = 3.2095 \times 10^5 \text{ m} \approx \mathbf{320.95 \text{ km}}$$

ii) Doppler shift: $v_r = 720 \text{ km/h} = 720 \times 1000/3600 = 200 \text{ m/s}$; $\lambda = c/f = 0.06 \text{ m}$.

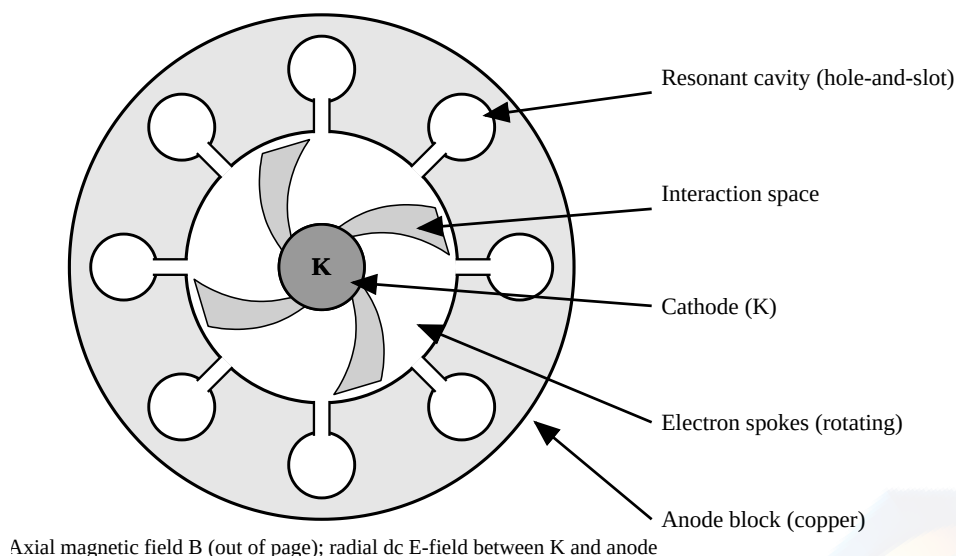
$$f_d = 2 v_r / \lambda = 2 v_r f / c$$

$$f_d = 2 \times 200 / 0.06 = \mathbf{6666.7 \text{ Hz} \approx 6.67 \text{ kHz}}$$
 (received frequency is higher, since the target approaches).

(Range 4 M, Doppler shift 2 M)

b) Cylindrical cavity magnetron.

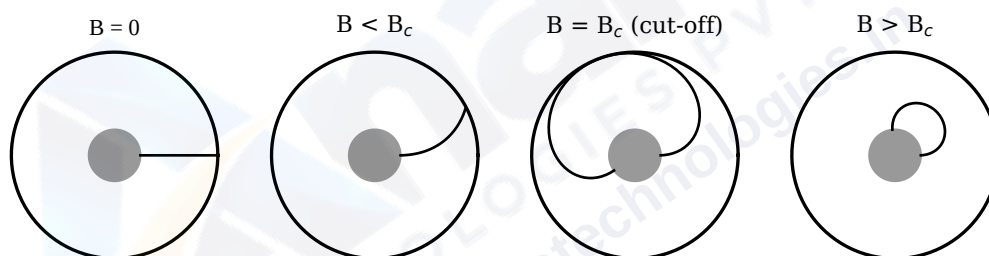
6 M



Cylindrical (cavity) magnetron — cross-section, π -mode spokes

Construction: A cylindrical cathode (K) is placed at the centre of a thick copper anode block containing a number of resonant cavities (hole-and-slot type), all opening into the interaction space between cathode and anode. A dc voltage is applied between anode (+) and cathode, giving a **radial E field**; a permanent magnet gives an **axial magnetic field B**. It is a crossed-field (M-type) tube.

Effect of E and B fields: The radial E field accelerates electrons towards the anode; the force due to B ($F = e v \times B$) bends their path. As B is increased:



Electron paths in magnetron for increasing magnetic field B (computed)

- $B = 0$: electrons move radially straight to the anode.
- B small: path is curved but still reaches the anode.
- $B = B_c$ (**Hull cut-off** field): electrons just graze the anode and return to the cathode; anode current falls to zero.
- $B > B_c$: electrons return to the cathode without reaching the anode — the normal operating condition.

Oscillations: In the operating condition the electrons rotate in the interaction space and interact with the RF fields of the cavities. Electrons in the favourable phase give energy to the RF field and are bunched into rotating **spokes** (π mode: adjacent cavities 180° out of phase). This sustains high-power oscillations, which are coupled out by a loop in one cavity.

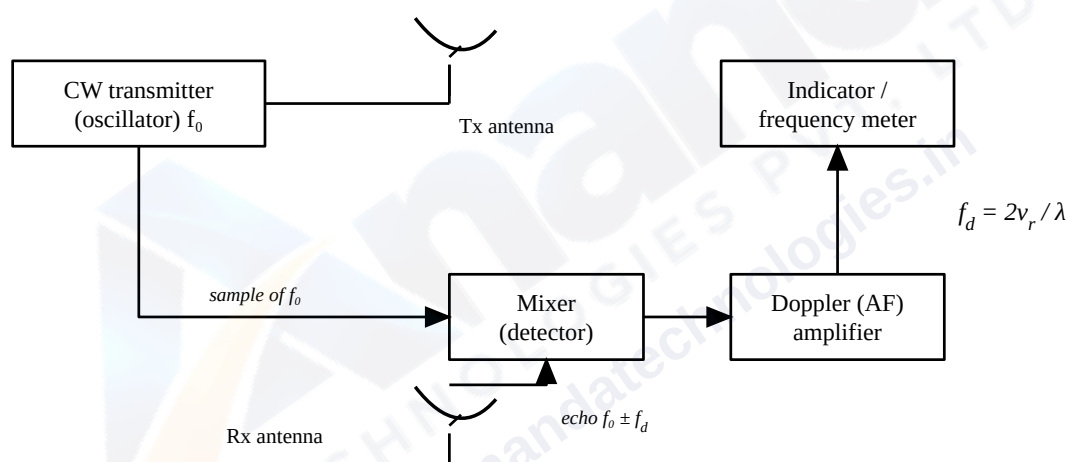
Applications: Pulsed RADAR transmitters (high peak power), microwave ovens (2.45 GHz), industrial heating.

(Diagram 2 M, effect of fields 2 M, working 1 M, applications 1 M)

c) Pulsed RADAR vs CW Doppler RADAR; CW Doppler block diagram.

6 M

Parameter	Pulsed RADAR	CW Doppler RADAR
Transmitted signal	Short high-power pulses with long rest time.	Continuous wave (unmodulated) of constant frequency.
Range measurement	Yes — from echo delay, $R = c t / 2$.	No (unmodulated CW cannot measure range).
Velocity measurement	Not directly (needs Doppler/MTI processing).	Yes — directly from Doppler shift $f_d = 2v_r/\lambda$.
Antenna	Single antenna with duplexer.	Usually separate transmitting and receiving antennas.
Power	High peak power (kW – MW).	Low power (mW – W).
Stationary targets	Detected (clutter appears on display).	Not detected (zero Doppler is rejected).
Complexity / cost	More complex (modulator, duplexer, display timing).	Simple, small and cheap.
Applications	Search & surveillance, ATC, weather RADAR.	Police speed gun, proximity fuze, vehicle speed and velocity meters.



Block diagram of CW Doppler RADAR

The CW oscillator sends a continuous wave f_0 . The echo from a moving target, $f_0 \pm f_d$, is mixed with a sample of f_0 ; the mixer output is the Doppler frequency f_d , which is amplified (AF amplifier) and measured to give the target speed.

(Comparison 4 M, block diagram 2 M)

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