

Subject Name Solutions

4351103 – Summer 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

List different microwave bands with their frequency range.

Solution

Table 1: Microwave Frequency Bands

Band	Frequency Range	Wavelength
L Band	1-2 GHz	30-15 cm
S Band	2-4 GHz	15-7.5 cm
C Band	4-8 GHz	7.5-3.75 cm
X Band	8-12 GHz	3.75-2.5 cm
Ku Band	12-18 GHz	2.5-1.67 cm
K Band	18-27 GHz	1.67-1.11 cm
Ka Band	27-40 GHz	1.11-0.75 cm

Mnemonic

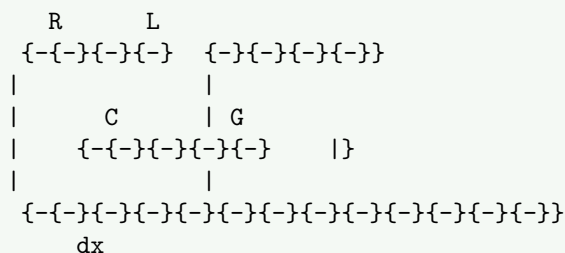
“Large Ships Can eXamine Kindly Using Knowledge Always”

Question 1(b) [4 marks]

Draw the general equivalent circuit of the transmission line. Write the equation for characteristic impedance for a lossless line.

Solution

Transmission Line Equivalent Circuit:



Circuit Elements:

- **R**: Series resistance per unit length
- **L**: Series inductance per unit length
- **C**: Shunt capacitance per unit length
- **G**: Shunt conductance per unit length

For Lossless Line ($R = 0$, $G = 0$):

Characteristic Impedance: $Z_0 = \sqrt{L/C}$

Key Points:

- **Lossless condition**: No power loss during transmission
- **Impedance matching**: Z_0 determines reflection behavior

Mnemonic

“Lossless Lines Love Constant Impedance”

Question 1(c) [7 marks]

Explain the impedance matching process using a single stub.

Solution

Single Stub Matching Process:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Source] --{} B[Main Line]
    B --{} C[Stub Connection Point]
    C --{} D[Load]
    C --{} E[Short Stub]
{Highlighting}
{Shaded}
```

Matching Steps:

Step	Process	Purpose
1	Calculate load admittance	Find $Y_L = 1/Z_L$
2	Move toward generator	Find point where $G = G_0$
3	Add stub susceptance	Cancel reactive part
4	Achieve matching	$Y_{\text{total}} = Y_0$

Design Equations:

- **Distance to stub:** $d = (\lambda/2) \times \tan^{-1}(\sqrt{R_L/R_0})$
- **Stub length:** $l = (\lambda/2) \times \tan^{-1}(B_{\text{stub}}/Y_0)$

Applications:

- Antenna matching
- Amplifier input/output
- Filter design

Mnemonic

“Single Stubs Stop Standing Waves Successfully”

Question 1(c) OR [7 marks]

Compare rectangular and circular waveguides.

Solution

Comparison Table:

Parameter	Rectangular Waveguide	Circular Waveguide
Shape	Rectangular cross-section	Circular cross-section
Dominant Mode	TE_{10}	TE_{11}
Cutoff Frequency	$f_c = c/(2a)$ for TE_{10}	$f_c = 1.841c/(2a)$ for TE_{11}

Power Handling	Lower	Higher
Manufacturing	Easy	Difficult
Mode Separation	Good	Poor
Applications	Radar, microwave ovens	Satellite communication

Key Advantages:

- **Rectangular:** Better mode control, easier fabrication
- **Circular:** Higher power capacity, rotating polarization

Mnemonic

“Rectangular is Regular, Circular Carries Current”

Question 2(a) [3 marks]

Define group velocity and phase velocity in relation to them.

Solution

Velocity Definitions:

Velocity Type	Formula	Physical Meaning
Phase Velocity	$v_p = \omega / \beta = c / \sqrt{1 - (fc/f)^2}$	Speed of constant phase
Group Velocity	$v_m = d\omega / d\beta = c \sqrt{1 - (fc/f)^2}$	Speed of signal energy

Relationship: $v_p \times v_m = c^2$

Key Points:

- **Phase velocity:** Always $> c$ (speed of light)
- **Group velocity:** Always $< c$
- **Signal travels:** At group velocity

Mnemonic

“Phase is Fast, Group Carries Message”

Question 2(b) [4 marks]

Describe the principles and workings of the Directional coupler.

Solution

Directional Coupler Principle:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Port 1 {- Input} {-}{-}{-} B[Main Line]}
    B {-}{-}{-} C[Port 2 {-} Through]}
    B {-}{-}{-} D[Port 3 {-} Coupled]}
    E[Port 4 {- Isolated} {-}{-}{-} F[Terminated]}
{Highlighting}
{Shaded}
```

Working Principle:

- **Electromagnetic coupling** between two transmission lines
- **Power division** based on coupling factor
- **Directional sensitivity** to wave direction

Key Parameters:

- **Coupling Factor:** $C = 10 \log(P_1/P_3)dB$
- **Directivity:** $D = 10 \log(P_3/P_4)dB$
- **Insertion Loss:** $IL = 10 \log(P_1/P_2)dB$

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Mnemonic
“Directional Couplers Divide Power Precisely”

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Question 2(c) [7 marks]

Explain Magic TEE with construction, operation and application.

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Solution

Magic TEE Construction:

E{-Arm (Port 3)}

|

Port 1{-}{-}{-}{-}+{-}{-}{-}{-}Port 2}

|

H{-Arm (Port 4)}

Operating Principles:

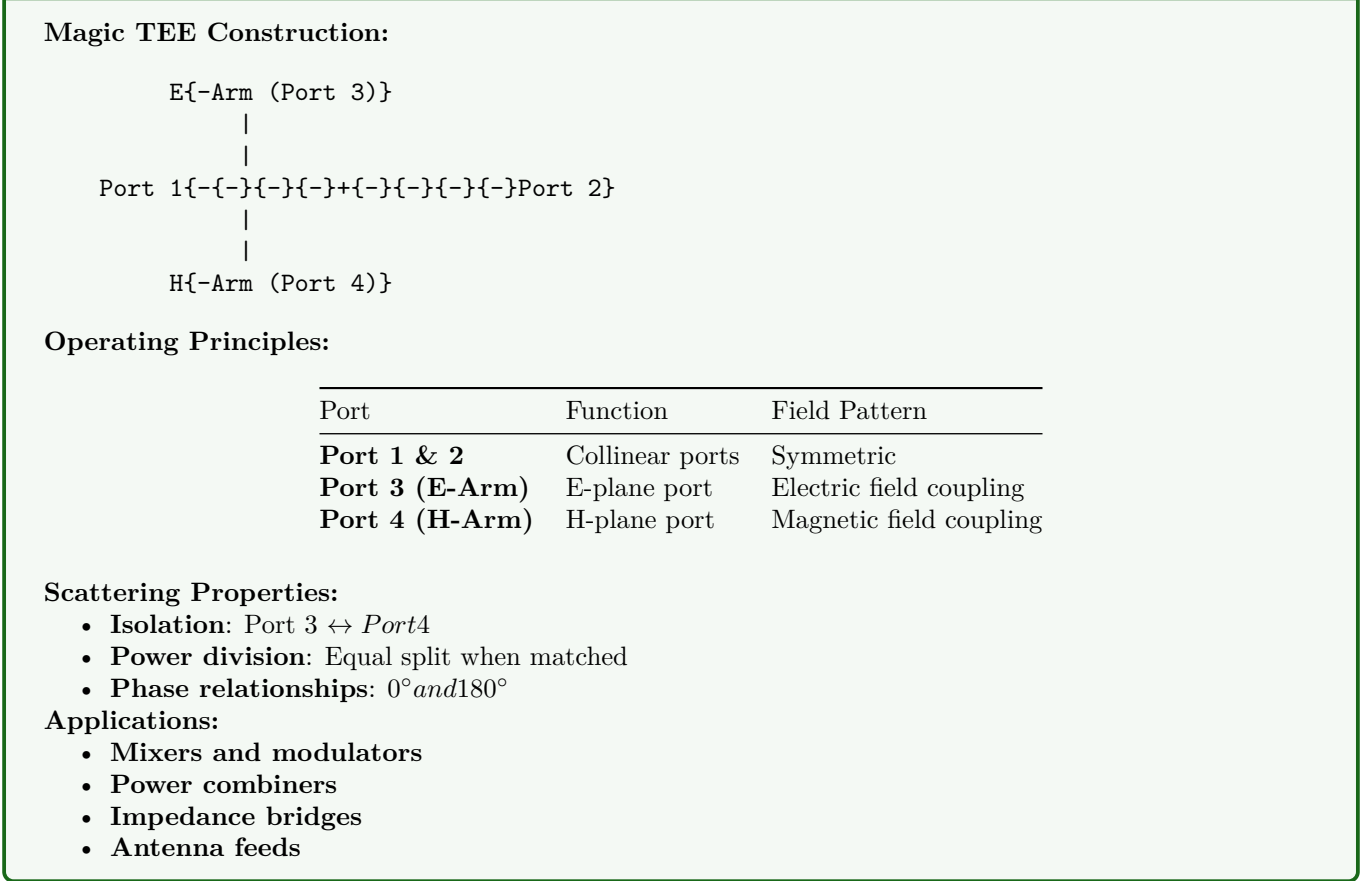
Port	Function	Field Pattern
Port 1 & 2	Collinear ports	Symmetric
Port 3 (E-Arm)	E-plane port	Electric field coupling
Port 4 (H-Arm)	H-plane port	Magnetic field coupling

Scattering Properties:

- Isolation:** Port 3 ↔ Port4
- Power division:** Equal split when matched
- Phase relationships:** 0°and180°

Applications:

- Mixers and modulators
- Power combiners
- Impedance bridges
- Antenna feeds



Magic TEE Construction:

The diagram illustrates the physical construction of a Magic Tee junction. It features two vertical arms: the top arm is labeled "E{-Arm (Port 3)}" and the bottom arm is labeled "H{-Arm (Port 4)}". Between these arms are four horizontal ports, labeled from left to right as "Port 1", "{-}{-}{-}{-}+{-}{-}{-}{-}", "Port 2", and "{-}{-}{-}{-}". Vertical lines connect each port to its corresponding arm: Port 1 and Port 2 connect to the E-Arm, while the central combined port connects to the H-Arm.

Operating Principles:

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Magic TEE Construction:

Diagram illustrating the Magic TEE Construction:

The structure consists of three horizontal lines connected by vertical lines:

- Top line: E{-Arm (Port 3)}
- Middle line: Port 1{-}{-}{-}{-}{+}{-}{-}{-}{-}Port 2}
- Bottom line: H{-Arm (Port 4)}

Vertical lines connect the top and bottom lines to the middle line at the positions of the first, third, fifth, and seventh symbols on the middle line.

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Mnemonic
“Magic TEE Creates Perfect Isolation”

Mnemonic
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Question 2(a) OR [3 marks]

Draw TE_{10}, TE_{20} modes for rectangular waveguide.

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Solution

TE₁₀ Mode (Dominant Mode) :

a

↑ b
E ↑ E
↑

Field Lines

TE₂₀ Mode :

a

↑ ↓ b
↑ E ↓ E
↑ ↓

Two Half{-Waves}

Mode Characteristics:

- **TE₁₀ :** *One half – wave variation in x – direction*
- **TE₂₀ :** *Two half – wave variations in x – direction*
- **Field patterns:** Electric field perpendicular to propagation

Mnemonic

“TE modes have Electric Transverse”

Question 2(b) OR [4 marks]

Describe the Hybrid Ring with a necessary sketch.

Solution

Hybrid Ring Structure:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Port 1] --- B[Ring Structure]
    C[Port 2] --- B
    D[Port 3] --- B
    E[Port 4] --- B
    B --- F[3 / 2 circumference]
{Highlighting}
{Shaded}
```

Operating Principle:

- Ring circumference: $3 \lambda / 2$
- Port spacing: $\lambda / 4$ apart
- Power division: Equal split between adjacent ports

Key Features:

- Isolation: Between opposite ports
- Phase relationships: 0° and 180°
- Impedance: Matched at all ports

Mnemonic

“Hybrid Rings Handle Half-wavelengths”

Question 2(c) OR [7 marks]

Explain the Isolator with principles, construction and operation.

Solution

Isolator Principle:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] --> B[Ferrite Material]
    B --> C[Output]
    C --> B
    B --> D[Magnetic Field]
    D --> B
{Highlighting}
{Shaded}
```

Construction Elements:

Component	Function	Material
Ferrite	Non-reciprocal medium	Yttrium Iron Garnet
Magnet	Bias field	Permanent magnet
Resistive Load	Absorb reverse power	Carbon/ceramic

Operating Principle:

- Faraday rotation in magnetized ferrite
- Non-reciprocal phase shift
- Forward transmission: Low loss
- Reverse transmission: High attenuation

Applications:

- Amplifier protection
- Oscillator isolation
- Antenna systems

Specifications:

- Isolation: 20-30 dB typical
- Insertion Loss: < 0.5 dB

Mnemonic

“Isolators Ignore Reverse Reflections”

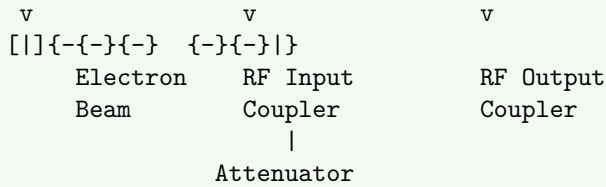
Question 3(a) [3 marks]

Draw a Traveling wave tube amplifier.

Solution

TWT Amplifier Structure:

Electron Gun	Helix Structure	Collector



Key Components:

- **Electron gun:** Produces electron beam
- **Helix:** Slow-wave structure
- **Couplers:** Input/output RF connections
- **Collector:** Collects spent electrons

Mnemonic

“TWT Transfers Wave Through Helix”

Question 3(b) [4 marks]

Describes various types of hazards due to microwave radiation.

Solution

Microwave Radiation Hazards:

Hazard Type	Effects	Safety Limit
HERP (Personnel)	Tissue heating, burns	10 mW/cm ²
HERO (Ordnance)	Explosive detonation	Variable
HERF (Fuel)	Fuel ignition	5 mW/cm ²

Biological Effects:

- **Thermal effects:** Tissue heating above 41
- **Non-thermal effects:** Cellular damage
- **Sensitive organs:** Eyes, reproductive organs

Protection Measures:

- **Shielding:** Conductive enclosures
- **Distance:** Power density $1/r^2$
- **Time limits:** Exposure duration control
- **Warning systems:** Radiation detectors

Mnemonic

“Heat Energy Requires Proper Protection”

Question 3(c) [7 marks]

Explain two cavity klystrons construction and operation with an Applegate diagram.

Solution

Two-Cavity Klystron Structure:

Mermaid Diagram (Code)

```

{Shaded}
{Highlighting}[]
graph LR

```

```

A[Cathode] -- B[Input Cavity]
B -- C[Drift Space]
C -- D[Output Cavity]
D -- E[Collector]
F[RF Input] -- B
D -- G[RF Output]
{Highlighting}
{Shaded}

```

Applegate Diagram:

```

Velocity
  \^{}
  |      Bunched      Bunched
  |      /      {      /      }
v_{{0 +{{-}}{{-}}+      {{-}}/      {{-}}{{-}}}
  |      {      /      /}
  |      Bunched      Bunched
  |
+{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}}{{-}} Distance}
Input      Drift      Output
Cavity     Space     Cavity

```

Operation Principle:

Stage	Process	Result
Velocity Modulation	RF input varies electron speed	Speed variation
Bunching	Fast electrons catch slow ones	Current bunches
Energy Extraction	Bunches interact with output cavity	RF amplification

Key Parameters:

- Transit time: Critical for bunching
- Drift space length: Optimized for maximum bunching
- Cavity tuning: Resonant frequency matching

Applications:

- Radar transmitters
- Satellite communications
- Linear accelerators

Mnemonic

“Klystrons Create Bunches Through Velocity Variation”

Question 3(a) OR [3 marks]

Draw the block diagram of the attenuation measurement method for microwave frequency.

Solution

Attenuation Measurement Setup:

Mermaid Diagram (Code)

```

{Shaded}
{Highlighting}[]
graph LR
    A[Signal Generator] -- B[Directional Coupler]
    B -- C[Device Under Test]
    C -- D[Power Meter]

```



```

B {-}{-}{ } E[Reference Power Meter]}
F[Display Unit] {-}{-}{ } G[Attenuation Reading]}
D {-}{-}{ } F}
E {-}{-}{ } F}
{Highlighting}
{Shaded}

```

Measurement Process:

- Reference measurement: Without DUT
- Insertion measurement: With DUT
- Attenuation calculation: $A = P_1 - P_2(dB)$

Mnemonic

“Attenuation Appears After Accurate Assessment”

Question 3(b) OR [4 marks]

Describe the limitation of vacuum tubes at microwave range.

Solution

Vacuum Tube Limitations:

Limitation	Cause	Effect
Transit Time	Finite electron travel time	Reduced gain at high frequency
Lead Inductance	Connecting wire inductance	Poor impedance matching
Inter-electrode Capacitance	Plate-cathode capacitance	Feedback and instability
Skin Effect	High-frequency current distribution	Increased resistance

Frequency-Related Problems:

- Input impedance: Becomes reactive
- Gain-bandwidth: Product limitation
- Noise figure: Increases with frequency
- Power handling: Decreases

Solutions:

- Special tube designs: Lighthouse tubes
- Cavity resonators: Replace tuned circuits
- Short leads: Minimize inductance

Mnemonic

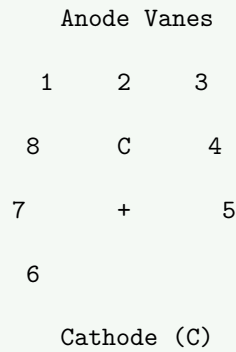
“Vacuum Tubes Fail Fast at High Frequencies”

Question 3(c) OR [7 marks]

Explain the Principle, construction, effect of the electric and magnetic field and operation of the magnetron in detail.

Solution

Magnetron Construction:



Operating Principle:

Field	Direction	Effect
Electric Field	Radial (cathode to anode)	Accelerates electrons
Magnetic Field	Axial (perpendicular to page)	Deflects electrons
Combined Effect	Cycloid motion	Phase synchronization

Operation Stages:

1. **Electron Emission:** Heated cathode emits electrons
2. **Cycloid Motion:** Efields create spiral paths
3. **Synchronization:** Electrons synchronize with RF field
4. **Energy Transfer:** Kinetic energy \rightarrow RF energy
4. **Output Coupling:** RF extracted through waveguide

Key Parameters:

- Magnetic flux density: $B = 2 \text{ mf/e}$
- Hull cutoff voltage: $V_H = (eB^2 R^2)/(8m)$
- Frequency: $f = eB/(2m) \times (\text{anodemodes})$

Applications:

- Microwave ovens (2.45 GHz)
- Radar transmitters
- Industrial heating

Mnemonic

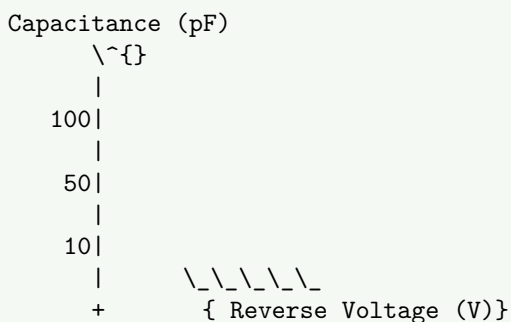
“Magnetrons Make Microwaves Through Magnetic Motion”

Question 4(a) [3 marks]

Explain the working principle of a varactor diode using a graph.

Solution

Varactor Diode Characteristics:



0 5 10 15

Working Principle:

- Reverse bias operation: Diode operated in reverse
- Depletion layer: Acts as dielectric
- Variable capacitance: $C \propto 1/V$
- Voltage tuning: Capacitance controlled by voltage

Applications:

- Voltage-controlled oscillators
- Frequency multipliers
- Parametric amplifiers

Mnemonic

“Varactors Vary Capacitance Via Voltage”

Question 4(b) [4 marks]

Explain the Gunn Effect and negative resistance for Gunn diode.

Solution

Gunn Effect Mechanism:

Parameter	Lower Valley	Upper Valley
Energy Level	Lower	Higher
Electron Mobility	High (μ_1)	Low (μ_2)
Effective Mass	Light	Heavy

Transfer Characteristic:

Current (mA)

\sim

|

| Negative

| Resistance

| Region

+ { Voltage (V) }

Threshold

Negative Resistance:

- Threshold voltage: Electrons transfer to upper valley
- Current decrease: Due to reduced mobility
- Oscillation: Negative resistance enables
- Domain formation: High-field domains propagate

Key Points:

- Materials: GaAs, InP
- Frequency range: 1-100 GHz
- Efficiency: 5-20%

Mnemonic

“Gunn diodes Generate oscillations through Negative resistance”

Question 4(c) [7 marks]

Explain frequency measurement method for microwave frequency.

Solution

Direct Frequency Measurement:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Unknown Signal] --{} B[Frequency Counter]
    B --{} C[Display]
    D[Reference Oscillator] --{} B
{Highlighting}
{Shaded}
```

Indirect Methods:

Method	Principle	Accuracy
Wavemeter	Cavity resonance	$\pm 0.1\%$
Beat Frequency	Heterodyne mixing	$\pm 0.01\%$
Standing Wave	/2 measurement	$\pm 0.5\%$

Cavity Wavemeter Setup:

Waveguide

C Output

Tuning Screw

Measurement Procedure:

1. Coupling: Weakly couple to signal line
2. Tuning: Adjust cavity for resonance
3. Indication: Monitor output for minimum/maximum
4. Calibration: Read frequency from calibrated scale

Beat Frequency Method:

- Local oscillator: Known reference frequency
- Mixer: Generates beat frequency
- Measurement: $f_{\text{beat}} = |f_{\text{signal}} - f_{\text{LO}}|$

Mnemonic

“Frequency Found through Careful Cavity Calibration”

Question 4(a) OR [3 marks]

Explain the working of a PIN diode as a switch.

Solution

PIN Diode Structure:

P+ Region | Intrinsic | N+ Region

Holes No Carriers Electrons

Switching Operation:

Bias Condition	Intrinsic Region	RF Impedance	Switch State
Forward Bias	Flooded with carriers	Low ($\sim 1\Omega$)	ON (Closed)
Reverse Bias	Depleted	High ($\sim 10k\Omega$)	OFF (Open)
Zero Bias	Few carriers	Medium	Variable

Key Advantages:

- **Fast switching:** Nanosecond response
- **Low insertion loss:** When ON
- **High isolation:** When OFF
- **Wide frequency range:** DC to microwave

Applications:

- RF switches
- Modulators
- Attenuators
- Phase shifters

Mnemonic

“PIN diodes Perform Perfect switching”

Question 4(b) OR [4 marks]

Explain stripline and Microstrip circuits.

Solution

Stripline Configuration:

Ground Plane

Dielectric

Signal Conductor

Dielectric

Ground Plane

Microstrip Configuration:

Signal Conductor

Dielectric

Ground Plane

Comparison Table:

Parameter	Stripline	Microstrip
Ground Planes	Two (sandwich)	One (bottom)
Shielding	Complete	Partial
Dispersion	Lower	Higher
Manufacturing	Complex	Simple
Cost	Higher	Lower

Applications:

- Stripline: High-performance systems
- Microstrip: PCB circuits, antennas

Design Equations:

- Characteristic impedance: Function of w/h ratio
- Effective permittivity: $\epsilon_{eff} = (\epsilon_r + 1)/2$

Mnemonic

“Striplines are Sandwiched, Microstrips are Mounted”

Question 4(c) OR [7 marks]

Explain the principles and process of amplification for a Parametric amplifier.

Solution

Parametric Amplifier Principle:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Signal  $f_s$ ] --> B[Nonlinear Reactance]
    C[Pump  $f_p$ ] --> B
    B --> D[Idler  $f_i$ ]
    B --> E[Amplified Signal]
    F[Energy Flow: Pump → Signal]
{Highlighting}
{Shaded}
```

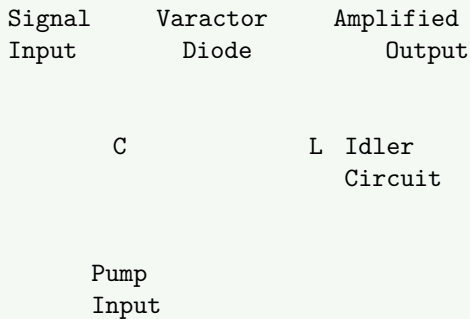
Frequency Relationships:

Parameter	Relationship	Typical Values
Pump Frequency	$f_p = f_s + f_i$	10 GHz
Signal Frequency	f_s (input)	1 GHz
Idler Frequency	$f_i = f_p - f_s$	9 GHz

Amplification Process:

1. Nonlinear Element: Varactor diode provides time-varying capacitance
2. Pump Power: High-frequency pump supplies energy
3. Frequency Mixing: Three-frequency interaction
4. Energy Transfer: Pump energy \rightarrow Signal energy
4. Impedance Matching: Optimize power transfer

Circuit Configuration:



Key Advantages:

- Low noise figure: Near quantum limit
- High gain: 10-20 dB typical
- Wide bandwidth: Limited by pump circuit

Applications:

- Satellite receivers
- Radio astronomy
- Low-noise amplifiers

Design Considerations:

- Pump power: Sufficient for nonlinear operation
- Impedance matching: All three frequencies
- Stability: Prevent oscillation

Mnemonic

“Parametric amplifiers Pump Power into signal Perfectly”

Question 5(a) [3 marks]

Compare RADAR and SONAR.

Solution

RADAR vs SONAR Comparison:

Parameter	RADAR	SONAR
Wave Type	Electromagnetic	Acoustic
Medium	Air/Vacuum	Water
Frequency	300 MHz - 30 GHz	1 kHz - 1 MHz
Speed	$3 \times 10^8 \text{ m/s}$	1500 m/s (water)
Range	Up to 1000 km	Up to 100 km
Applications	Aircraft, weather	Submarines, fishing

Common Principles:

- Echo ranging: Measure time-of-flight
- Doppler effect: Detect moving targets
- Beam forming: Directional transmission

Key Differences:

- Propagation: EM waves vs sound waves
- Attenuation: Different loss mechanisms
- Resolution: Frequency dependent

Mnemonic

“RADAR sees Radio waves, SONAR hears Sound waves”

Question 5(b) [4 marks]

Write the name of RADAR display method and explain anyone.

Solution

RADAR Display Methods:

Display Type	Description	Application
A-Scope	Range vs amplitude	Target detection
B-Scope	Range vs azimuth	2D position
C-Scope	Azimuth vs elevation	3D tracking
PPI	Plan Position Indicator	Air traffic control
RHI	Range Height Indicator	Weather radar

PPI Display Explanation:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Center {- Radar Position} {-}{-}{ B[Sweep Line {-} Antenna Direction]]
    B {-}{-}{ C[Target Blips {-} Range \& Bearing]]
    D[Circular Pattern] {-}{-}{ E[360~ Coverage]]
{Highlighting}
{Shaded}
```

PPI Features:

- Polar coordinates: Range and bearing
- Rotating sweep: Follows antenna rotation
- Persistence: Targets remain visible
- Scale selection: Adjustable range

Display Process:

1. Sweep generation: Synchronized with antenna
2. Target plotting: Distance and direction
3. Intensity modulation: Target strength
4. Map overlay: Geographic reference

Mnemonic

“PPI Provides Perfect Position Information”

Question 5(c) [7 marks]

Explain the basic pulse radar system with a block diagram.

Solution

Pulse Radar Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Master Oscillator] --> B[Modulator]
    B --> C[Power Amplifier]
    C --> D[Duplexer]
    D --> E[Antenna]
    E --> F[Target]
    F --> E
    E --> D
    D --> G[Receiver]
    G --> H[Signal Processor]
    H --> I[Display]
    J[Timer] --> A
    J --> I
{Highlighting}
{Shaded}
```

System Components:

Component	Function	Key Parameters
Master Oscillator	Generate RF signal	Frequency stability
Modulator	Create pulse train	Pulse width, PRF
Power Amplifier	Boost transmit power	Peak power, efficiency
Duplexer	Switch Tx/Rx	Isolation, switching time
Antenna	Radiate/receive	Gain, beamwidth
Receiver	Amplify echo signals	Sensitivity, bandwidth

Operating Sequence:

1. Transmission Phase:
 - Master oscillator generates RF
 - Modulator creates pulses
 - Power amplifier boosts signal
 - Duplexer routes to antenna
2. Reception Phase:
 - Antenna receives echoes
 - Duplexer routes to receiver
 - Signal processing extracts information
 - Display shows target data

Key Equations:

- Range: $R = ct/2$ (where t = round-trip time)
- Maximum range: $R_{max} = cPRT/2$
- Range resolution: $\Delta R = c/2$

Performance Parameters:

- PRF: Pulse Repetition Frequency
- Duty cycle: $\times PRF$
- Average power: $\text{Peak power} \times \text{duty cycle}$

Mnemonic

“Pulse Radar Properly Processes Reflected signals”

Question 5(a) OR [3 marks]

List the application of microwave frequency.

Solution

Microwave Applications:

Application Category	Specific Uses	Frequency Band
Communication	Satellite, cellular, WiFi	1-40 GHz
Radar Systems	Weather, air traffic, military	1-35 GHz
Industrial	Heating, drying, medical	0.9-5.8 GHz
Navigation	GPS, aircraft landing	1-15 GHz
Scientific	Radio astronomy, research	1-300 GHz
Medical	Diathermy, cancer treatment	0.9-2.45 GHz
Domestic	Microwave ovens	2.45 GHz

Key Points:

- ISM bands (Industrial, Scientific, Medical): License-free
- Penetration ability: Depends on frequency and material
- Atmospheric absorption: Increases with frequency

Mnemonic

“Microwaves Serve Many Applications Perfectly”

Question 5(b) OR [4 marks]

Compare PULSED RADAR and CW RADAR.

Solution

PULSED vs CW RADAR Comparison:

Parameter	Pulsed RADAR	CW RADAR
Transmission	Pulse train	Continuous wave
Range Measurement	Time-of-flight	Frequency shift
Velocity Measurement	Doppler in pulses	Direct Doppler
Antenna	Single (duplexer)	Separate Tx/Rx
Power	High peak, low average	Low continuous
Range Resolution	Pulse width limited	Poor
Velocity Resolution	Limited	Excellent
Complexity	High	Low
Cost	Higher	Lower

Operational Differences:

Pulsed RADAR:

- Range equation: $R = ct/2$
- Maximum range: Limited by PRF
- Blind ranges: Multiple of $cPRT/2$
- Applications: Long-range detection

CW RADAR:

- Doppler equation: $fd = 2vr/$
- Range measurement: Requires FM modulation
- No blind ranges: Continuous operation
- Applications: Speed measurement, proximity

Key Advantages:

- Pulsed: Better range capability, target separation
- CW: Better velocity accuracy, simpler design

Mnemonic

“Pulsed measures Range, CW measures Velocity”

Question 5(c) OR [7 marks]

Explain MTI Radar with the block diagram.

Solution

MTI RADAR Block Diagram:

Mermaid Diagram (Code)

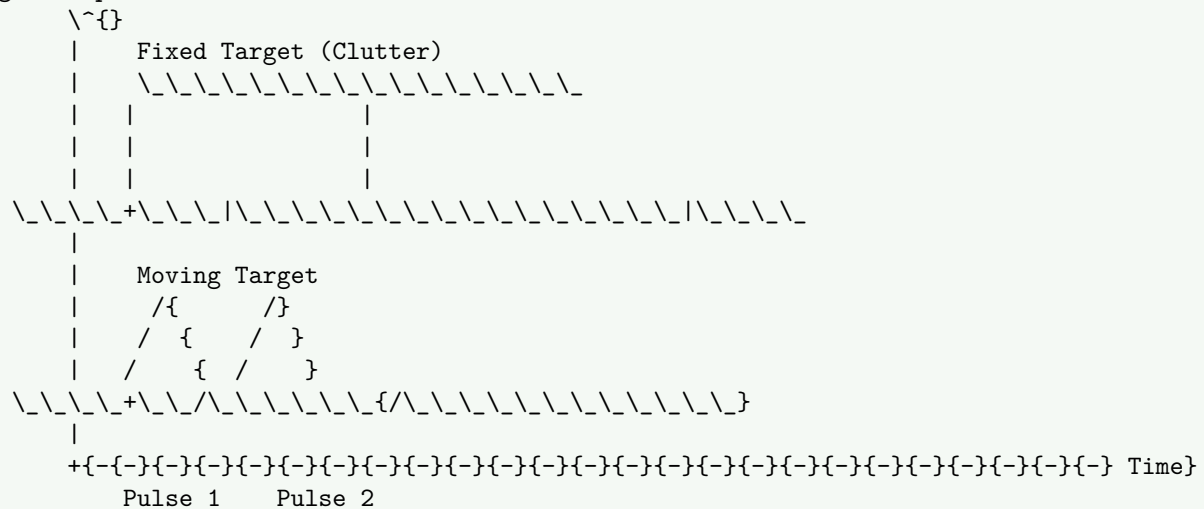
```
{Shaded}
{Highlighting}[]
graph LR
    A[Transmitter] --> B[Duplexer]
    B --> C[Antenna]
    C --> D[Target]
    D --> C
    C --> B
    B --> E[Receiver]
    E --> F[Phase Detector]
    G[STALO] --> H[Mixer]
    H --> F
    I[COHO] --> F
    F --> J[MTI Filter]
    J --> K[Display]
    G --> L[Frequency Multiplier]
    L --> A
{Highlighting}
{Shaded}
```

MTI System Components:

Component	Full Form	Function
STALO	Stable Local Oscillator	Reference frequency
COHO	Coherent Oscillator	Phase reference
MTI Filter	Moving Target Indicator	Clutter suppression
Phase Detector	-	Compare signal phases

MTI Operating Principle: Pulse-to-Pulse Comparison:

Signal Amplitude



MTI Process:

1. Coherent transmission: Maintain phase relationships
2. Echo reception: Preserve phase information
3. Phase comparison: Compare successive pulses
4. Clutter cancellation: Subtract stationary returns
5. Moving target detection: Enhance moving targets

Key Equations:

- Doppler frequency: $f_d = 2v_r \cos(\theta) / \lambda$
- Phase change: $\Delta \phi = 4\pi v_r / \lambda \times PRT$
- Blind speeds: $v_b = n\lambda / (2PRT)$

MTI Improvement Factor:

- **Definition:** Ratio of clutter power before/after MTI
- **Typical values:** 20-40 dB
- **Factors affecting:** System stability, clutter characteristics

Limitations:

- **Blind speeds:** Targets invisible at certain velocities
- **Tangential targets:** Radial velocity component needed
- **Weather effects:** Atmospheric fluctuations

Applications:

- Air traffic control: Separate aircraft from ground clutter
- Weather radar: Distinguish precipitation from terrain
- Military radar: Detect moving vehicles/aircraft

Mnemonic

“MTI Makes Targets Identifiable by Movement”