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:

```
   R      L
 {-{-}{-}{-}  {-}{-}{-}{-}}
|            |
|     C      | G
|   {-{-}{-}{-}{-}    |}
|            |
 {-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
     dx
```

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**: $Z_0 determinesreflectionbehavior$

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_total = Y_0

Design Equations:

- **Distance to stub:** d = (/2) $\times tan^{-1}(\sqrt{(R\_L/R_0)})$
- **Stub length:** l = (/2) $\times tan^{-1}(B\_stub/Y_0)$

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	fc = c/(2a) for TE_{10}	fc = 1.841c/(2 a) 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	$\mathrm{v}_p = / = c/\sqrt{(}1-(fc/f)^2)$	Speed of constant phase
Group Velocity	$\mathrm{v}_m = d/d = c\sqrt{(}1-(fc/f)^2)$	Speed of signal energy

Relationship: $\mathrm{v}_p \times v_m = c^2$

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**: $\text{C} = 10 \log(\text{P}_1/P_3) dB$
- **Directivity**: $\text{D} = 10 \log(\text{P}_3/P_4) dB$
- **Insertion Loss**: $\text{IL} = 10 \log(\text{P}_1/P_2) dB$

Mnemonic

"Directional Couplers Divide Power Precisely"

Question 2(c) [7 marks]

Explain Magic TEE with construction, operation and application.

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 $\leftrightarrow Port4$
- **Power division**: Equal split when matched
- **Phase relationships**: $0° and 180°$

Applications:

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

Mnemonic

"Magic TEE Creates Perfect Isolation"

Question 2(a) OR [3 marks]

Draw TE$_{10}, TE_{20} modesforrectangularwaveguide.$

Solution

$\mathbf{TE}_{10} Mode(DominantMode):$

```
a


     ↑        b
  E  ↑  E
     ↑


Field Lines
```

$\mathbf{TE}_{20} Mode:$

```
a


↑     ↓      b
↑  E  ↓  E
↑     ↓


Two Half{-Waves}
```

Mode Characteristics:

- $\mathbf{TE}_{10} : Onehalf - wavevariationinx - direction$
- $\mathbf{TE}_{20} : Twohalf - wavevariationsinx - direction$
- **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 /2**
- **Port spacing: /4 apart**
- **Power division: Equal split between adjacent ports**

Key Features:

- **Isolation: Between opposite ports**
- **Phase relationships: 0**$°and180°$
- **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 {-.{-}{}|Blocked| B}
    D[Magnetic Field] {-{-}{} 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
     |                |                 |
```

```
  v                v                 v
[|]{-{-}{-}  {-}{-}|}
     Electron    RF Input          RF Output
     Beam        Coupler           Coupler
                    |
                 Attenuator
```

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:** $\mathbf{A} = \mathbf{P}_1 - P_2(dB)$

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:

```
        Anode Vanes

      1     2     3

     8      C      4

    7       +       5

     6

        Cathode (C)
```

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 $\rightarrow RFenergy$
4. **Output Coupling:** RF extracted through waveguide

Key Parameters:

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

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:

```
Capacitance (pF)
      \^{}
      |
   100|
      |
    50|
      |
    10|
      |     \_\_\_\_\_
      +      { Reverse Voltage (V)}
```

```
      0    5    10    15
```

Working Principle:

- **Reverse bias operation:** Diode operated in reverse
- **Depletion layer:** Acts as dielectric
- **Variable capacitance:** C 1/
- **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 ($_1$)	Low ($_2$)
Effective Mass	Light	Heavy

Transfer Characteristic:

```
Current (mA)
      \^{}
      |
      |      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	±0.1%
Beat Frequency	Heterodyne mixing	±0.01%
Standing Wave	/2 measurement	±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: fbeat = |fsignal - fLO|**

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 (~1Ω)	ON (Closed)
Reverse Bias	Depleted	High (~10kΩ)	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 stripeline 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: eff = (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 fs] {-{-}{} B[Nonlinear Reactance]}
    C[Pump fp] {-{-}{} B}
    B {-{-}{} D[Idler fi]}
    B {-{-}{} E[Amplified Signal]}
    F[Energy Flow: Pump  Signal]
{Highlighting}
{Shaded}
```

Frequency Relationships:

Parameter	Relationship	Typical Values
Pump Frequency	fp = fs + fi	10 GHz
Signal Frequency	fs (input)	1 GHz
Idler Frequency	fi = fp - fs	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** $\rightarrow Signalenergy$
4. **Impedance Matching: Optimize power transfer**

Circuit Configuration:

```
Signal     Varactor     Amplified
Input        Diode          Output



       C             L  Idler
                          Circuit



      Pump
      Input
```

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	$3\times10^8 m/s$	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: Rmax = cPRT/2
- Range resolution: ΔR = c /2

Performance Parameters:

- PRF: Pulse Repetition Frequency
- Duty cycle: $\times PRF$
- Average power: Peak power $\times dutycycle$

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
       \^{}
       |    Fixed Target (Clutter)
       |    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
       |   |                |
       |   |                |
       |   |                |
   \_\_\_\_+\_\_\_|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|\_\_\_\_
       |
       |    Moving Target
       |     /{      /}
       |    /  {    /  }
       |   /    {  /    }
   \_\_\_\_+\_\_/\_\_\_\_\_\_\_{/\_\_\_\_\_\_\_\_\_\_\_\_\_}
       |
       +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} Time}
           Pulse 1    Pulse 2
```

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: fd = 2vr cos( )/**
- **Phase change: $\mathbf{\Delta}$ = 4 vr/ $\times PRT$**
- **Blind speeds: vb = n /(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"