Subject Name Solutions

4351104 – Summer 2025

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Write key features of 4G and 5G system.

Solution

Table 1: Key Features Comparison

Feature	4G System	5G System
Data Speed	Up to 100 Mbps	Up to 10 Gbps
Latency	30-50 ms	1-10 ms
Technology	LTE, OFDM	MIMO, Beamforming
Applications	Video streaming	IoT, AR/VR

Key Points:

- **4G**: Uses LTE technology with OFDM modulation for high-speed data
- **5G**: Ultra-low latency enables real-time applications like autonomous vehicles
- **Network Slicing**: 5G allows virtual networks for specific applications

Mnemonic

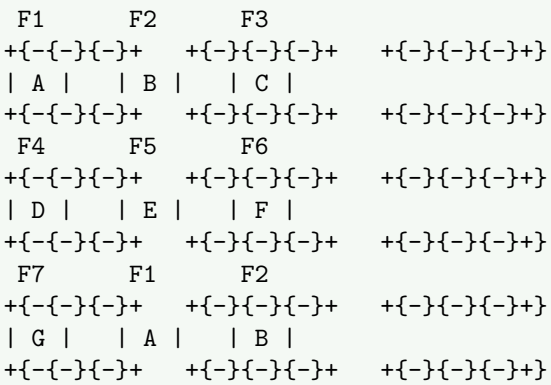
"4G Fast, 5G Super-Fast"

Question 1(b) [4 marks]

Explain concept of frequency reuse in cellular mobile system.

Solution

Diagram:



Key Points:

- **Frequency Reuse**: Same frequencies used in non-adjacent cells to increase capacity
- **Co-channel Distance**: Minimum distance between cells using same frequency
- **Cluster Size**: Group of cells using different frequencies (typically 3, 4, 7, 12)
- **Capacity Improvement**: More users served with limited spectrum

Mnemonic

"Same Frequency, Different Places"

Question 1(c) [7 marks]

If a total of 33 MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex communication. If 1 MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels for cluster size of 7.

Solution

Given Data:

- Total bandwidth = 33 MHz
- Channel bandwidth = 25 kHz (simplex)
- Control spectrum = 1 MHz
- Cluster size = 7

Calculations:

Step 1: Available spectrum for traffic Traffic spectrum = 33 - 1 = 32 MHz

Step 2: Total duplex channels Each duplex channel needs $2 \times 25kHz = 50kHz Total channels = 32MHz \div 50kHz = 640 channels$

Step 3: Control channels Control channels = 1 MHz $\div 25kHz = 40 channels$

Step 4: Distribution per cell

- Voice channels per cell = $640 \div 7 \approx 91 channels$
- Control channels per cell = $40 \div 7 \approx 6 channels$

Final Distribution Table:

Parameter	Total	Per Cell
Voice Channels	640	91
Control Channels	40	6
Total Channels	680	97

Mnemonic

"Divide Total by Cluster"

Question 1(c OR) [7 marks]

List out types of cells and explain each.

Solution

Table 2: Types of Cells

Cell Type	Coverage	Power	Applications
Macro Cell	1-30 km	High	Rural areas
Micro Cell	100m-1km	Medium	Urban areas
Pico Cell	10-100m	Low	Buildings
Femto Cell	10-50m	Very Low	Homes

Detailed Explanation:
Macro Cells:
- **Coverage**: Large geographical areas (1-30 km radius)
- **Power**: High transmission power (up to 40W)
- **Usage**: Rural and suburban areas with low user density

Micro Cells:
- **Coverage**: Medium areas (100m to 1km radius)
- **Power**: Medium transmission power (1-10W)
- **Usage**: Urban areas, highway coverage

Pico Cells:
- **Coverage**: Small indoor/outdoor areas (10-100m)
- **Power**: Low transmission power (100mW-1W)
- **Usage**: Shopping malls, airports, offices

Umbrella Cells:
- **Special Type**: Covers multiple smaller cells
- **Purpose**: Handles high-speed mobile users
- **Advantage**: Reduces handoffs for fast-moving users

Mnemonic

"Macro-Micro-Pico-Femto = Big to Small"

Question 2(a) [3 marks]

Define cell and cluster.

Solution

Definitions:
Cell:
- **Definition**: Geographical area covered by one base station
- **Shape**: Typically hexagonal for planning purposes
- **Function**: Serves mobile users within its coverage area

Cluster:
- **Definition**: Group of cells using different frequency sets
- **Purpose**: Enables frequency reuse pattern
- **Common Sizes**: 3, 4, 7, 12 cells per cluster

Table 3: Cell vs Cluster

Parameter	Cell	Cluster
Unit	Single coverage area	Group of cells
Frequency	One frequency set	Multiple frequency sets
Reuse	Cannot reuse nearby	Enables frequency reuse

Mnemonic

"Cell = One Area, Cluster = Group Areas"

Question 2(b) [4 marks]

Explain effect of cluster size on capacity and interference.

Solution

Effects Table:

Cluster Size	Capacity	Interference	Co-channel Distance
Small (3,4)	High	High	Short
Large (7,12)	Low	Low	Long

Key Effects:
On Capacity:
- **Smaller Cluster**: More channels per cell, higher capacity
- **Larger Cluster**: Fewer channels per cell, lower capacity
- **Formula**: Channels per cell = Total channels $\div Clustersize$

On Interference:
- **Smaller Cluster**: Higher co-channel interference
- **Larger Cluster**: Lower co-channel interference
- **Trade-off**: Capacity vs. Quality

Co-channel Distance:
- **Relationship**: D = R$\sqrt{(3N)} where N = clustersize$
- **Effect**: Larger N means larger distance between co-channel cells

Mnemonic

"Small Cluster = More Capacity, More Interference"

Question 2(c) [7 marks]

Write key features of IS-95, CDMA2000 and WCDMA.

Solution

Comparison Table:

Feature	IS-95	CDMA2000	WCDMA
Generation	2G	3G	3G
Data Rate	14.4 kbps	2 Mbps	2 Mbps
Chip Rate	1.2288 Mcps	3.6864 Mcps	3.84 Mcps
Bandwidth	1.25 MHz	1.25 MHz	5 MHz

IS-95 Features:
- **Technology**: First commercial CDMA system
- **Voice Quality**: Better than GSM in some conditions
- **Soft Handoff**: Maintains multiple connections during handoff
- **Power Control**: Precise power control reduces interference

CDMA2000 Features:
- **Backward Compatibility**: Works with IS-95 networks
- **High Data Rate**: Up to 2 Mbps for 1xEV-DO
- **Multimedia**: Supports voice, data, and video
- **Efficiency**: Better spectrum efficiency than IS-95

WCDMA Features:
- **Global Standard**: Used worldwide for 3G
- **High Capacity**: Supports more simultaneous users
- **QoS Support**: Different service classes for applications
- **International Roaming**: Global compatibility

Mnemonic

"IS-95 First, CDMA2000 Faster, WCDMA Global"

Question 2(a OR) [3 marks]

Explain cell splitting.

Solution

Definition: Cell splitting is a technique to increase system capacity by subdividing congested cells into smaller cells.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Original Large Cell] {-{-}{} B[Split into 4 Smaller Cells]}
    B {-{-}{} C[Cell 1]}
    B {-{-}{} D[Cell 2]}
    B {-{-}{} E[Cell 3]}
    B {-{-}{} F[Cell 4]}
{Highlighting}
{Shaded}
```

Process:

- **Step 1**: Identify congested cell with high traffic
- **Step 2**: Install new base stations with lower power
- **Step 3**: Reduce original base station power
- **Step 4**: Create multiple smaller coverage areas

Benefits:

- **Capacity Increase**: More channels available in same area
- **Better Signal Quality**: Shorter distances improve signal strength

Mnemonic

"Split Big Cell into Small Cells"

Question 2(b OR) [4 marks]

Write functions of HLR and VLR in GSM.

Solution

Functions Table:

Database	Full Form	Primary Functions
HLR	Home Location Register	Permanent subscriber data
VLR	Visitor Location Register	Temporary visitor data

HLR Functions:

- **Subscriber Profile**: Stores permanent subscriber information (IMSI, services)
- **Location Tracking**: Maintains current location area of subscriber
- **Authentication**: Provides authentication keys for security
- **Service Management**: Controls subscribed services and restrictions

VLR Functions:

- **Temporary Storage**: Stores visiting subscriber data temporarily
- **Local Services**: Enables services for roaming subscribers

- **Call Routing**: Assists in routing calls to visiting subscribers
- **Authentication Copy**: Maintains copy of authentication data from HLR

Interaction:

- HLR updates VLR when subscriber roams to new area
- VLR requests subscriber data from HLR during registration

Mnemonic

"HLR = Home Data, VLR = Visitor Data"

Question 2(c OR) [7 marks]

Describe RFID technology.

Solution

RFID Overview: Radio Frequency Identification uses electromagnetic fields to identify and track tags attached to objects.

System Components:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[RFID Reader] {-{-}{} B[Radio Waves]}
    B {-{-}{} C[RFID Tag]}
    C {-{-}{} D[Stored Data]}
    C {-{-}{} B}
    B {-{-}{} A}
{Highlighting}
{Shaded}
```

Types Table:

Type	Power Source	Range	Applications
Passive	Reader's energy	0.1-10m	Access cards
Active	Internal battery	10-100m	Vehicle tracking
Semi-passive	Battery + Reader	1-30m	Temperature sensors

Key Features:
- **No Line of Sight**: Works without direct visual contact
- **Multiple Reading**: Can read multiple tags simultaneously
- **Data Storage**: Can store and update information
- **Durability**: Resistant to environmental conditions

Applications:
- **Inventory Management**: Warehouse and retail tracking
- **Access Control**: Building and vehicle access
- **Payment Systems**: Contactless payment cards
- **Supply Chain**: Product tracking from manufacturing to sale

Advantages:
- **Fast Reading**: Instant identification without scanning
- **Automation**: Reduces manual data entry errors
- **Real-time Tracking**: Continuous monitoring of assets

Mnemonic

"Radio Frequency Identifies Everything"

Question 3(a) [3 marks]

Draw GSM architecture.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Mobile Station] {-{-}{} B[BTS {-} Base Transceiver Station]}
    B {-{-}{} C[BSC {-} Base Station Controller]}
    C {-{-}{} D[MSC {-} Mobile Switching Center]}
    D {-{-}{} E[HLR {-} Home Location Register]}
    D {-{-}{} F[VLR {-} Visitor Location Register]}
    D {-{-}{} G[PSTN/ISDN]}

    H[Authentication Center] {-{-}{} D}
    I[Equipment Identity Register] {-{-}{} D}
{Highlighting}
{Shaded}
```

Components:
- **MS**: Mobile Station (handset + SIM)
- **BTS**: Radio interface with mobile
- **BSC**: Controls multiple BTS, handles handoffs
- **MSC**: Switching and call control
- **HLR/VLR**: Database for subscriber information

Mnemonic

"Mobile Talks Through BTS-BSC-MSC"

Question 3(b) [4 marks]

Write GSM 900 specifications.

Solution

GSM 900 Specifications Table:

Parameter	Specification
Frequency Band	890-915 MHz (Uplink), 935-960 MHz (Downlink)
Channel Spacing	200 kHz
Total Channels	124 channels
Modulation	GMSK (Gaussian MSK)
Access Method	TDMA/FDMA
Frame Duration	4.615 ms
Time Slots	8 per frame
Speech Coding	13 kbps RPE-LTP

Key Features:

- **Digital Transmission**: Superior voice quality compared to analog
- **International Roaming**: Global compatibility standard
- **Security**: Encryption and authentication built-in
- **SMS Support**: Short message service capability

Coverage:

- **Cell Radius**: Up to 35 km (rural areas)
- **Power Classes**: 5 classes from 0.8W to 20W

Mnemonic

"900 MHz, 200 kHz spacing, 8 time slots"

Question 3(c) [7 marks]

Explain mobile to landline and landline to mobile call procedure in GSM.

Solution

Mobile to Landline Call Procedure:

```
sequenceDiagram
    participant MS as Mobile Station
    participant BTS as BTS/BSC
    participant MSC as MSC
    participant PSTN as PSTN/Landline

    MS{-BTS: Call Request}
    BTS{-MSC: Forward Request}
    MSC{-MSC: Authenticate User}
    MSC{-PSTN: Route Call}
    PSTN{-MSC: Ring Response}
    MSC{-BTS: Ring Indication}
    BTS{-MS: Ring Back Tone}
    PSTN{-MSC: Call Answered}
    MSC{-MS: Connect Call}
```

Steps:

1. **Call Initiation**: Mobile dials landline number
2. **Channel Assignment**: BSC assigns traffic channel
3. **Authentication**: MSC verifies subscriber
4. **Routing**: MSC routes call to PSTN gateway
5. **Connection**: End-to-end connection established

Landline to Mobile Call Procedure:

```
sequenceDiagram
```

```
    participant PSTN as PSTN/Landline
    participant MSC as Gateway MSC
    participant HLR as HLR
    participant VMSC as Visited MSC
    participant MS as Mobile Station

    PSTN{-MSC: Call to Mobile}
    MSC{-HLR: Location Request}
    HLR{-VMSC: Get Routing Number}
    VMSC{-MSC: Return Routing Number}
    MSC{-VMSC: Route Call}
    VMSC{-MS: Page Mobile}
    MS{-VMSC: Page Response}
    VMSC{-MS: Ring Mobile}
```

Steps:

1. **Call Reception**: PSTN receives call to mobile number
2. **HLR Query**: Gateway MSC queries HLR for location
3. **Location Update**: HLR provides current MSC information
4. **Paging**: Visited MSC pages mobile in location area
5. **Connection**: Mobile responds and call is connected

Key Differences:

- **Mobile Originating**: Direct routing through serving MSC
- **Mobile Terminating**: Requires location lookup through HLR

Mnemonic

"Mobile Out = Direct, Mobile In = Find First"

Question 3(a OR) [3 marks]

Explain fast and slow frequency hopping.

Solution

Frequency Hopping Types:

Table 4: Fast vs Slow Hopping

Parameter	Fast Hopping	Slow Hopping
Hop Rate	> Symbol Rate	< Symbol Rate
Symbols per Hop	< 1	> 1
Complexity	High	Low
GSM Usage	Not used	Used (217 hops/sec)

Fast Frequency Hopping:

- **Definition**: Frequency changes multiple times per symbol
- **Characteristics**: Very high hop rate, complex implementation
- **Advantage**: Excellent interference resistance

Slow Frequency Hopping:

- **Definition**: Multiple symbols transmitted per frequency
- **GSM Implementation**: 217 hops per second
- **Advantage**: Simple to implement, effective interference averaging

Mnemonic

"Fast = Many hops per symbol, Slow = Many symbols per hop"

Question 3(b OR) [4 marks]

Explain authentication process in GSM.

Solution

Authentication Process:

```
sequenceDiagram
    participant MS as Mobile Station
    participant MSC as MSC/VLR
    participant HLR as HLR/AuC

    MS{-MSC: Location Update Request}
    MSC{-HLR: Send IMSI}
    HLR{-HLR: Generate RAND, SRES, Kc}
    HLR{-MSC: Return Triplet (RAND, SRES, Kc)}
    MSC{-MS: Authentication Request (RAND)}
    MS{-MS: Calculate SRES using A3 algorithm}
    MS{-MSC: Authentication Response (SRES)}
    MSC{-MSC: Compare SRES values}
    MSC{-MS: Accept/Reject}
```

Key Components:

- **RAND**: Random number (128 bits)
- **SRES**: Signed response (32 bits)

- **Kc**: Cipher key (64 bits)
- **Ki**: Individual subscriber authentication key

Process Steps:

1. **Challenge**: Network sends random number (RAND)
2. **Response**: Mobile calculates SRES using Ki and RAND
3. **Verification**: Network compares received and expected SRES
4. **Result**: Authentication success or failure

Security Features:

- **Mutual Authentication**: Prevents fake base stations
- **Unique Keys**: Each subscriber has individual Ki
- **Challenge-Response**: Prevents replay attacks

Mnemonic

"Random Challenge, Signed Response, Compare and Accept"

Question 3(c OR) [7 marks]

Draw and explain block diagram of Signal processing in GSM.

Solution

GSM Signal Processing Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Speech Input] {-{-}{} B[Speech Coder]}
    B {-{-}{} C[Channel Coder]}
    C {-{-}{} D[Interleaver]}
    D {-{-}{} E[Burst Formatter]}
    E {-{-}{} F[Modulator]}
    F {-{-}{} G[RF Section]}
```

```
    G {-{-}{} H[Antenna]}

    I[Antenna] {-{-}{} J[RF Section]}
    J {-{-}{} K[Demodulator]}
    K {-{-}{} L[Burst Detector]}
    L {-{-}{} M[De{-}interleaver]}
    M {-{-}{} N[Channel Decoder]}
    N {-{-}{} O[Speech Decoder]}
    O {-{-}{} P[Speech Output]}
{Highlighting}
{Shaded}
```

Transmitter Processing:
Speech Coding:
- **Function**: Converts analog speech to 13 kbps digital
- **Algorithm**: RPE-LTP (Regular Pulse Excitation - Long Term Prediction)
- **Frame Size**: 20 ms speech frames

Channel Coding:
- **Purpose**: Adds redundancy for error correction
- **Types**: Convolutional coding, block coding
- **Output**: Protected 22.8 kbps data stream

Interleaving:
- **Function**: Spreads coded bits across multiple time slots
- **Benefit**: Combats burst errors from fading
- **Types**: Block interleaving over 8 time slots

Burst Formatting:
- **Process**: Organizes data into GSM burst structure
- **Components**: Training sequence, guard bits, data bits
- **Types**: Normal burst, access burst, sync burst

Modulation:
- **Technique**: GMSK (Gaussian Minimum Shift Keying)
- **Bandwidth**: 200 kHz channel spacing
- **Symbol Rate**: 270.833 kbps

Receiver Processing:
- **Demodulation**: Recovers digital bits from RF signal
- **Equalization**: Compensates for multipath distortion
- **Error Correction**: Uses channel coding redundancy
- **Speech Decoding**: Reconstructs original speech

Key Features:
- **Digital Processing**: All operations in digital domain
- **Error Protection**: Multiple levels of error correction
- **Adaptive**: Parameters adjust to channel conditions

Mnemonic

"Speech-Code-Interleave-Burst-Modulate-Transmit"

Question 4(a) [3 marks]

Draw block diagram of baseband section.

Solution

Baseband Section Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
```

```
    A[DSP Processor] {-{-}{} B[Audio Codec]}
    B {-{-}{} C[Speaker]}
    D[Microphone] {-{-}{} B}
    A {-{-}{} E[Memory Interface]}
    E {-{-}{} F[Flash Memory]}
    E {-{-}{} G[RAM]}
    A {-{-}{} H[Control Interface]}
    H {-{-}{} I[Keypad]}
    H {-{-}{} J[Display]}
    A {-{-}{} K[RF Interface]}
    A {-{-}{} L[SIM Interface]}
{Highlighting}
{Shaded}
```

Components:

- **DSP**: Digital signal processing for speech and data
- **Audio Codec**: Analog-to-digital conversion
- **Memory**: Program storage (Flash) and working memory (RAM)
- **Control**: User interface management
- **Interfaces**: RF section, SIM card connections

Functions:

- **Signal Processing**: Speech coding, echo cancellation
- **Protocol Stack**: GSM layer 1, 2, 3 protocols
- **User Interface**: Display, keypad, audio management

Mnemonic

"DSP Controls Audio, Memory, Display, RF"

Question 4(b) [4 marks]

Explain EDGE.

Solution

EDGE Overview: Enhanced Data rates for GSM Evolution - improves data transmission in GSM networks.
Key Features Table:

Parameter	GSM/GPRS	EDGE
Modulation	GMSK	8-PSK
Data Rate	9.6-171 kbps	Up to 473 kbps
Generation	2.5G	2.75G
Symbol Rate	270.833 ksps	270.833 ksps

Technical Improvements:

- **Advanced Modulation**: 8-PSK carries 3 bits per symbol vs 1 bit in GMSK
- **Link Adaptation**: Automatically switches between GMSK and 8-PSK
- **Enhanced Coding**: Better error correction schemes
- **Incremental Redundancy**: Improved retransmission strategy

Benefits:

- **Higher Data Rates**: 3x faster than GPRS
- **Backward Compatibility**: Works with existing GSM infrastructure
- **Cost Effective**: Software upgrade to existing networks
- **Multimedia Support**: Enables better mobile internet experience

Applications:

- **Mobile Internet**: Faster web browsing
- **Email**: Quick email with attachments
- **Multimedia Messaging**: MMS support
- **Video Calls**: Basic video communication

Mnemonic

"EDGE = Enhanced Data rates for GSM Evolution"

Question 4(c) [7 marks]

Draw and explain block diagram of mobile handset.

Solution

Mobile Handset Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Antenna] {-{-}{} B[Antenna Switch]}
    B {-{-}{} C[RF Transceiver]}
    C {-{-}{} D[Baseband Processor]}
    D {-{-}{} E[Audio Section]}
    E {-{-}{} F[Speaker/Microphone]}

    D {-{-}{} G[Display Controller]}
    G {-{-}{} H[LCD Display]}

    D {-{-}{} I[Keypad Interface]}
    I {-{-}{} J[Keypad]}

    D {-{-}{} K[Memory Controller]}
    K {-{-}{} L[Flash Memory]}
    K {-{-}{} M[RAM]}

    D {-{-}{} N[SIM Interface]}
    N {-{-}{} O[SIM Card]}

    P[Battery] {-{-}{} Q[Power Management]}
    Q {-{-}{} C}
    Q {-{-}{} D}
    Q {-{-}{} R[Charging Circuit]}
{Highlighting}
{Shaded}
```

Major Sections:
RF Section:

- **Antenna**: Transmits and receives radio signals
- **Duplexer**: Separates TX and RX signals
- **RF Transceiver**: Up/down conversion, amplification
- **Frequency Synthesizer**: Generates carrier frequencies

Baseband Section:

- **DSP**: Digital signal processing for speech and data
- **Protocol Stack**: Implements GSM protocols
- **Control Unit**: Manages all mobile functions
- **Memory Interface**: Controls program and data storage

Audio Section:

- **Audio Codec**: A/D and D/A conversion
- **Audio Amplifier**: Drives speaker
- **Microphone Amplifier**: Amplifies voice input
- **Hands-free Support**: External audio accessories

User Interface:

- **Display**: Shows information to user (LCD/OLED)
- **Keypad**: User input interface
- **LED Indicators**: Status indication
- **Vibrator**: Alert mechanism

Power Management:

- **Battery**: Energy storage (Li-ion typically)
- **Charging Circuit**: Battery charging control
- **Power Regulation**: Voltage regulation for all sections
- **Power Saving**: Sleep modes and power optimization

Memory System:

- **Flash Memory**: Program storage and user data
- **RAM**: Working memory for program execution
- **SIM Interface**: Secure element for subscriber identity

Interconnections:

- **Control Bus**: Command and control signals
- **Data Bus**: Information transfer
- **Power Bus**: Power distribution
- **Audio Bus**: Voice and audio signals

Operation:

1. **Receive**: Antenna → *RF* → *Baseband* → *Audio* → *Speaker*
1. **Transmit**: Microphone → *Audio* → *Baseband* → *RF* → *Antenna*
1. **Control**: User input → *Baseband* → *Displayoutput*
1. **Processing**: All operations controlled by baseband processor

Mnemonic

"Antenna-RF-Baseband-Audio-Display-Power"

Question 4(a OR) [3 marks]

Explain radiation hazards due to mobile.

Solution

Radiation Hazards:

SAR (Specific Absorption Rate):

- **Definition**: Rate of energy absorption by human body
- **Unit**: Watts per kilogram (W/kg)
- **Limit**: 2.0 W/kg (Europe), 1.6 W/kg (USA)

Health Concerns Table:

Effect	Risk Level	Symptoms
Thermal	Confirmed	Tissue heating

Non-thermal	Under study	Headaches, fatigue
Long-term	Uncertain	Cancer concerns

Prevention Measures:

- **Distance**: Keep phone away from body during calls
- **Duration**: Limit call duration
- **Hands-free**: Use headsets or speakerphone
- **Low SAR**: Choose phones with lower SAR values

Safety Guidelines:

- Avoid sleeping with phone near head
- Use airplane mode when not needed
- Keep calls short and use text when possible

Mnemonic

"SAR measures absorption rate"

Question 4(b OR) [4 marks]

Describe working of charging section in mobile handset.

Solution

Charging Section Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AC Adapter] {-{-}{} B[Rectifier]}
    B {-{-}{} C[Voltage Regulator]}
    C {-{-}{} D[Charging Controller]}
    D {-{-}{} E[Battery]}
    D {-{-}{} F[Current Monitor]}
    F {-{-}{} G[Protection Circuit]}
    G {-{-}{} H[Temperature Sensor]}
{Highlighting}
{Shaded}
```

Components & Functions:

Charging Controller:

- **Function**: Controls charging current and voltage
- **Types**: Linear and switching mode controllers
- **Protection**: Prevents overcharging and overheating

Charging Process:

1. **Constant Current**: Initial high current charging (fast charge)
2. **Constant Voltage**: Voltage maintained, current decreases
3. **Trickle Charge**: Low current maintenance charging
4. **Cut-off**: Charging stops when battery full

Protection Features:

- **Over-voltage Protection**: Prevents damage from high voltage
- **Over-current Protection**: Limits maximum charging current
- **Temperature Monitoring**: Stops charging if battery gets too hot
- **Reverse Polarity**: Prevents damage from wrong connection

Battery Management:

- **Fuel Gauge**: Monitors battery capacity
- **Cell Balancing**: Ensures equal charging of battery cells
- **Health Monitoring**: Tracks battery condition over time

Mnemonic

"Control Current, Voltage, Temperature, and Time"

Question 4(c OR) [7 marks]

Draw and explain block diagram of DSSS transmitter and receiver.

Solution

DSSS Transmitter Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Data Input] {-{-}{} B[Data Modulator]}
    B {-{-}{} C[Spreader/Mixer]}
    D[PN Code Generator] {-{-}{} C}
    C {-{-}{} E[RF Modulator]}
    E {-{-}{} F[Power Amplifier]}
    F {-{-}{} G[Antenna]}
{Highlighting}
{Shaded}
```

DSSS Receiver Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    H[Antenna] {-{-}{} I[RF Amplifier]}
    I {-{-}{} J[RF Demodulator]}
    J {-{-}{} K[Correlator/Despreader]}
    L[PN Code Generator] {-{-}{} K}
    K {-{-}{} M[Data Demodulator]}
    M {-{-}{} N[Data Output]}
    K {-{-}{} O[Synchronization]}
    O {-{-}{} L}
{Highlighting}
{Shaded}
```

Transmitter Operation:
Data Modulation:

- **Input**: Original data stream (low rate)
- **Modulation**: BPSK or QPSK modulation
- **Output**: Modulated narrowband signal

Spreading Process:

- **PN Code**: Pseudo-random binary sequence (high rate)
- **Spreading**: XOR operation between data and PN code
- **Result**: Wideband spread spectrum signal

RF Modulation:

- **Carrier**: High frequency carrier signal
- **Modulation**: Spread signal modulates RF carrier
- **Transmission**: Signal transmitted through antenna

Receiver Operation:
RF Processing:

- **Reception**: Antenna receives spread spectrum signal
- **Amplification**: Low noise amplifier boosts weak signal
- **Demodulation**: Recovers baseband spread signal

Despreading Process:
- **Correlation**: Received signal correlated with same PN code
- **Synchronization**: PN code timing synchronized with received signal
- **Output**: Original narrowband data signal recovered

Key Parameters:
- **Processing Gain**: Ratio of spread bandwidth to data bandwidth
- **Chip Rate**: Rate of PN code (higher than data rate)
- **Spreading Factor**: Processing gain value

Advantages:
- **Interference Rejection**: Resistant to narrowband interference
- **Low Probability of Intercept**: Difficult to detect and jam
- **Multiple Access**: Many users can share same frequency
- **Multipath Resistance**: Reduces fading effects

Applications:
- **CDMA Cellular**: IS-95, CDMA2000, WCDMA
- **GPS**: Global positioning system
- **WiFi**: 802.11b spread spectrum mode
- **Military**: Secure communications

Mnemonic

"Data Spreads with PN, Correlates to Recover"

Question 5(a) [3 marks]

Explain the concept of spread spectrum.

Solution

Spread Spectrum Concept: A communication technique where the transmitted signal bandwidth is much wider than the minimum required bandwidth.

Basic Principle:

Parameter	Before Spreading	After Spreading
Bandwidth	Narrow (data rate)	Wide (chip rate)
Power Density	High	Low
Interference	Vulnerable	Resistant

Key Characteristics:
- **Bandwidth Expansion**: Signal spread over wide frequency range
- **Processing Gain**: Improvement in signal-to-noise ratio
- **Pseudo-random Sequence**: Spreading code known only to intended receiver
- **Security**: Difficult for unauthorized users to intercept

Benefits:
- **Jam Resistance**: Immune to intentional interference
- **Low Power Density**: Coexists with narrowband systems
- **Multiple Access**: Many users share same spectrum
- **Privacy**: Encrypted-like transmission

Mnemonic

"Spread Wide, Gain Processing Power"

Question 5(b) [4 marks]

Write criteria of spread spectrum and its applications.

Solution

Spread Spectrum Criteria:
Technical Criteria:

1. **Bandwidth**: Transmitted bandwidth » Information bandwidth
2. **Processing Gain**: Gp = Spread BW / Data BW $\geq 10dB$
2. **Pseudo-random**: Spreading sequence appears random
3. **Synchronization**: Receiver must sync with transmitter code

Performance Criteria Table:

Criteria	Requirement	Benefit
Processing Gain	> 10 dB	Interference rejection
Code Length	Long period	Security and randomness
Cross-correlation	Low	Multiple user separation
Auto-correlation	Sharp peak	Synchronization

Applications:
Military Communications:

- **Anti-jam**: Resistant to enemy jamming
- **LPI/LPD**: Low probability of intercept/detection
- **Secure**: Encrypted transmission

Cellular Systems:

- **CDMA**: IS-95, CDMA2000, WCDMA
- **Capacity**: Multiple users per frequency
- **Quality**: Reduced interference

Satellite Communications:

- **GPS**: Global positioning system
- **Weather**: Satellite data transmission
- **Broadcasting**: Satellite radio/TV

Wireless Networks:

- **WiFi**: 802.11b DSSS mode
- **Bluetooth**: Frequency hopping
- **Cordless Phones**: 2.4 GHz band

Mnemonic

"Military, Cellular, Satellite, Wireless use Spread Spectrum"

Question 5(c) [7 marks]

Explain call processing in CDMA.

Solution

CDMA Call Processing Sequence:

```
sequenceDiagram
    participant MS as Mobile Station
    participant BTS as Base Station
    participant BSC as Base Station Controller
    participant MSC as Mobile Switching Center

    Note over MS,MSC: Call Origination
    MS{-BTS: Access Request (Random Access)}
    BTS{-MS: Access Grant (Assign Code)}
    MS{-BTS: Call Setup Request}
    BTS{-BSC: Forward Call Request}
    BSC{-MSC: Route Call Setup}
    MSC{-BSC: Assign Traffic Channel}
    BSC{-BTS: Allocate Walsh Code}
```

```
    BTS{-MS: Traffic Channel Assignment}
    MS{-BTS: Confirm Assignment}
    Note over MS,MSC: Call in Progress
```

Call Origination Process:
Step 1: System Access
- **Random Access**: Mobile sends access probe on access channel
- **Power Control**: Gradually increases power until acknowledged
- **Code Assignment**: Base station assigns unique spreading code

Step 2: Authentication
- **Challenge**: Network sends authentication challenge
- **Response**: Mobile responds with calculated authentication
- **Validation**: Network validates mobile identity

Step 3: Channel Assignment
- **Walsh Code**: Unique orthogonal code assigned for forward link
- **PN Offset**: Base station identified by PN sequence offset
- **Power Level**: Initial transmission power set

Step 4: Traffic Channel Setup
- **Service Options**: Voice, data, or multimedia service negotiated
- **Rate Set**: Transmission rate configured (Rate Set 1 or 2)
- **Handoff Parameters**: Neighboring cell information provided

Call Processing Features:
Soft Handoff:
- **Multiple Connections**: Mobile maintains links to multiple base stations
- **Diversity**: Improves call quality and reliability
- **Make-before-Break**: New connection established before old one dropped

Power Control:
- **Closed Loop**: Rapid power adjustments (800 Hz rate)
- **Open Loop**: Initial power estimation
- **Purpose**: Minimize interference, maximize capacity

Variable Rate Vocoder:
- **Rate Adaptation**: Transmission rate varies with speech activity
- **Silence Detection**: Lower rates during speech pauses
- **Capacity**: Increases system capacity

Call Termination Process:

```
sequenceDiagram
    participant PSTN as PSTN
    participant MSC as MSC
    participant HLR as HLR
    participant BSC as BSC/BTS
    participant MS as Mobile Station

    PSTN{-MSC: Incoming Call}
    MSC{-HLR: Location Request}
    HLR{-MSC: Routing Information}
    MSC{-BSC: Page Mobile}
    BSC{-MS: Paging Message}
    MS{-BSC: Page Response}
    BSC{-MSC: Page Response}
    MSC{-BSC: Setup Traffic Channel}
    BSC{-MS: Channel Assignment}
    MS{-BSC: Assignment Complete}
    Note over PSTN,MS: Call Connected
```

Key CDMA Features:
Rake Receiver:
- **Multipath Combining**: Combines multiple signal paths
- **Diversity Gain**: Improves signal quality
- **Finger Assignment**: Each finger tracks different path

Capacity Advantages:
- **Frequency Reuse**: Same frequency used in all cells

- **Interference Limited**: Capacity limited by interference, not frequency
- **Voice Activity**: Statistical multiplexing increases capacity

Quality Features:

- **Error Correction**: Forward error correction coding
- **Interleaving**: Protects against burst errors
- **Adaptive Rates**: Data rate adapts to channel conditions

Call States:

1. **Idle**: Mobile monitoring paging channel
2. **Access**: Attempting to access system
3. **Traffic**: Active call in progress
4. **Handoff**: Transitioning between base stations

Mnemonic

"Access-Authenticate-Assign-Traffic-Handoff"

Question 5(a OR) [3 marks]

Write features of Zigbee and advantages.

Solution

Zigbee Features:
Technical Specifications Table:

Parameter	Specification
Standard	IEEE 802.15.4
Frequency	2.4 GHz, 915 MHz, 868 MHz
Data Rate	250 kbps (2.4 GHz)
Range	10-100 meters
Power	Ultra-low power

Key Features:

- **Mesh Network**: Self-organizing and self-healing network
- **Low Power**: Battery life up to years
- **Low Cost**: Inexpensive hardware implementation
- **Simple Protocol**: Easy to implement and deploy

Advantages:

- **Long Battery Life**: Optimized for battery-powered devices
- **Network Reliability**: Multiple routing paths available
- **Scalability**: Supports thousands of nodes
- **Interoperability**: Standard ensures device compatibility

Applications:

- **Home automation, Industrial monitoring, Smart lighting**

Mnemonic

"Low Power, Mesh Network, Many Applications"

Question 5(b OR) [4 marks]

Explain OFDM with block diagram.

Solution

OFDM Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Serial Data] {-{-}{} B[Serial to Parallel]}
    B {-{-}{} C[QAM Modulator]}
    C {-{-}{} D[IFFT]}
    D {-{-}{} E[Add Cyclic Prefix]}
    E {-{-}{} F[Parallel to Serial]}
    F {-{-}{} G[RF Transmission]}

    H[RF Reception] {-{-}{} I[Serial to Parallel]}
    I {-{-}{} J[Remove Cyclic Prefix]}
    J {-{-}{} K[FFT]}
    K {-{-}{} L[QAM Demodulator]}
    L {-{-}{} M[Parallel to Serial]}
    M {-{-}{} N[Serial Data]}
{Highlighting}
{Shaded}
```

OFDM Principle: Orthogonal Frequency Division Multiplexing divides high-speed data into multiple parallel low-speed streams transmitted simultaneously on different frequencies.

Key Components:

IFFT/FFT:

- **IFFT**: Inverse Fast Fourier Transform creates orthogonal subcarriers
- **FFT**: Fast Fourier Transform recovers data at receiver
- **Orthogonality**: Subcarriers don't interfere with each other

Cyclic Prefix:

- **Function**: Prevents inter-symbol interference
- **Implementation**: Copy of signal end added to beginning
- **Length**: Longer than channel delay spread

Advantages:

- **Spectral Efficiency**: High data rate in limited bandwidth
- **Multipath Immunity**: Resistant to fading channels
- **Flexible**: Easy to implement with DSP

Applications:

- **4G LTE**: Mobile communication standard
- **WiFi**: 802.11a/g/n/ac standards
- **Digital TV**: DVB-T, ISDB-T standards

Mnemonic

"Orthogonal Frequencies Divide Multiplexed data"

Question 5(c OR) [7 marks]

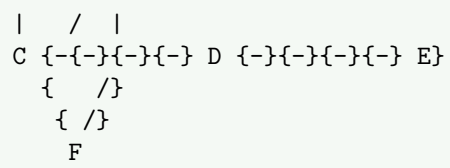
Describe MANET.

Solution

MANET Overview: Mobile Ad-hoc Network is a self-configuring network of mobile devices connected wirelessly without fixed infrastructure.

Network Topology:

```
A {-{-}{-}{-} B}
|    / |
```



Key Characteristics:
Architecture Table:

Parameter	MANET	Cellular Network
Infrastructure	No fixed base stations	Base stations required
Topology	Dynamic, changes frequently	Fixed cell structure
Routing	Multi-hop peer-to-peer	Single hop to base station
Cost	Low deployment cost	High infrastructure cost

MANET Features:
Dynamic Topology:
- **Mobile Nodes**: All nodes can move freely
- **Changing Links**: Network connections change as nodes move
- **Self-Organization**: Network automatically reconfigures

Multi-hop Communication:
- **Relay Function**: Nodes act as routers for other nodes
- **Path Discovery**: Dynamic route finding to destination
- **Distributed Control**: No central coordination needed

Routing Protocols:
Proactive Protocols:
- **DSDV**: Destination Sequenced Distance Vector
- **Characteristic**: Maintain routing tables continuously
- **Advantage**: Routes available immediately
- **Disadvantage**: High overhead in mobile environment

Reactive Protocols:
- **AODV**: Ad-hoc On-demand Distance Vector
- **DSR**: Dynamic Source Routing
- **Characteristic**: Find routes only when needed
- **Advantage**: Lower overhead
- **Disadvantage**: Route discovery delay

Hybrid Protocols:
- **ZRP**: Zone Routing Protocol
- **Combination**: Proactive within zone, reactive between zones
- **Balance**: Overhead vs. delay optimization

Advantages:
- **No Infrastructure**: Quick deployment without base stations
- **Flexibility**: Network adapts to changing topology
- **Cost Effective**: Lower setup and maintenance costs
- **Robustness**: No single point of failure

Disadvantages:
- **Limited Bandwidth**: Shared wireless medium
- **Power Consumption**: Routing functions drain battery
- **Security Issues**: Vulnerable to attacks
- **Scalability**: Performance degrades with network size

Applications:
Military Operations:
- **Battlefield Communications**: Soldier-to-soldier communication
- **Emergency Response**: Disaster relief coordination
- **Surveillance**: Sensor network deployment

Commercial Applications:
- **Vehicular Networks**: Car-to-car communication
- **Sensor Networks**: Environmental monitoring
- **Conference Networks**: Temporary meeting networks
- **Personal Area Networks**: Device interconnection

Challenges:
Technical Challenges:
- **Routing Overhead**: Control message bandwidth consumption
- **Quality of Service**: Difficulty in guaranteeing service levels
- **Power Management**: Energy-efficient operation
- **Interference**: Co-channel interference from multiple hops

Security Challenges:
- **Authentication**: Verifying node identity
- **Data Integrity**: Ensuring message authenticity
- **Privacy**: Protecting user information
- **Denial of Service**: Preventing network attacks

Performance Metrics:
- **Throughput**: Data delivery rate
- **Delay**: End-to-end packet delivery time
- **Packet Loss**: Percentage of lost packets
- **Energy Consumption**: Battery life optimization

Future Trends:

- **Integration**: Combination with cellular and WiFi networks
- **IoT Applications**: Internet of Things device networks
- **5G Integration**: Part of 5G network architecture
- **AI-based Routing**: Machine learning for optimal routing

Mnemonic

"Mobile Nodes, Ad-hoc Routing, No Infrastructure, Temporary Networks"