Unit - 5 The Space segment Access and Utilization

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- Introduction :-

- A transponder channel aboard a satellite may be fully loaded by a single transmission from an earth station.

- This is referred to as a single-access mode of operation. It is also possible, for a transponder to be loaded by a number of carriers from a number of earth stations, & each earth station may transmit one or more of the carriers. This mode of operation is termed "Multiple access".

- The need for multiple access arises because more than two earth stations, will be within the service area of a satellite.

- The two methods of multiple access are freq^n-division multiple access (FDMA) and Time-division multiple access (TDMA). These are analogous to frequency-division multiplexing (FDM) & Time-division multiplexing (TDM).

- A third category of multiple access is code-division multiple access (CDMA). In this method each signal is associated with particular code that is used to spread the signal in frequency & / or time.

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o Space segment access methods :-

- Multiple access means access to a given facility or a resource by multiple users. In the context of satellite communication, the facility is the transponder and the multiple users are the various terrestrial terminals under the foot-print of the satellite.

- The transponder provides the communication channel (s) that receives the signals beamed at it via uplink and then retransmit the same back to the earth for intended users via the downlink.

- Multiple users are geographically dispersed and certain specific techniques, to are used to allow them a simultaneous access to the satellite transponder.

- Commonly used multiple access techniques include the following :-

1] TDMA (Time Division multiple access)

2] FDMA (Frequency Division multiple access)

3] CDMA (Code Division multiple access)

4] SDMA (Space Domain multiple access)

1) TDMA (Time Division Multiple Access) :-

- TDMA is a method that divides the available bandwidth into different time slots, assigning each user a unique time slot for transmission.

- In the case of TDMA, different Earth stations in the satellite's footprint make use of the transponder by using a single carrier on a time division basis.

- The composite time multiplexed signal modulates a high freq^n carrier using any of the digital carrier modulation techniques.

- Multiple time multiplexed signals from other stations having the same carrier freq^n are then able to access the satellite by allowing each station to transmit during its allotted time slot.

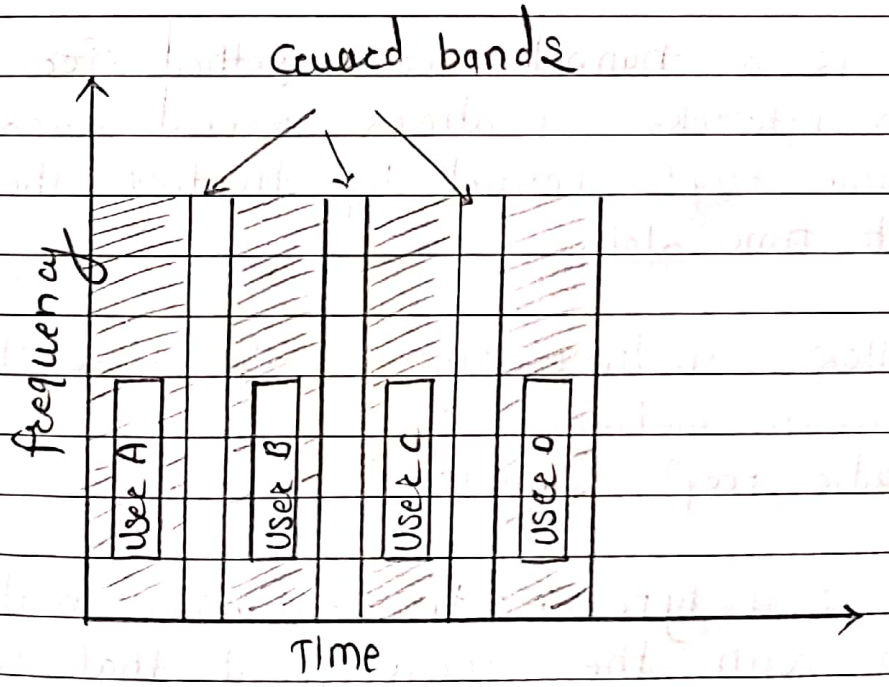
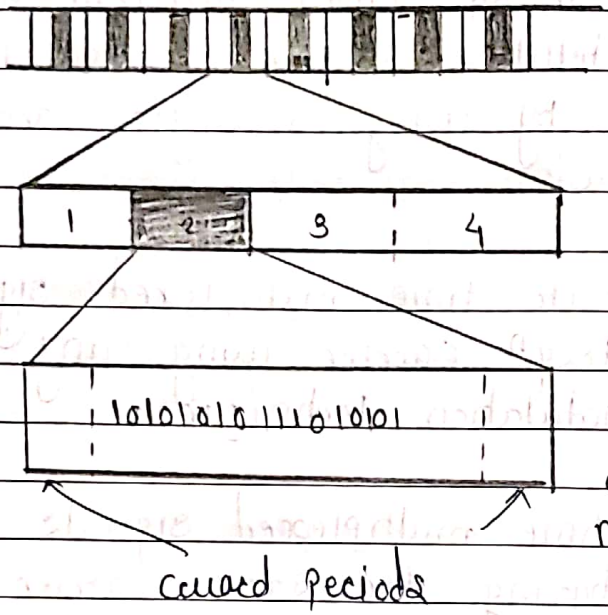


fig :- TDMA overview

- TDMA was first used in satellite satellite comm^n systems by Western Union in its Westar 3 communications satellite in 1979.

- It is now used extensively in satellite comm^n.



data stream divided into frames

frames divided into time slots. Each user is allocated one slot.

Time slot contains data with guard period if needed for synch^n.

fig:- TDMA frame structure.

- TDMA is a channel access method for shared medium networks. It allows several users to share the same freq^n channel by dividing the signal into different time slot.

- This allows multiple stations to share the same transmission medium.
e.g. Radio freq^n channel.

- TDMA is a type of time-division multiplexing (TDM), with the special point that instead of

having one transmitter connected to one receiver.

- TDMA is used in the digital 2G cellular systems such as Celobal syotem for mobile.

o Advantages of TDMA :-

- Data rate is faster
- Bandwidth efficient
- It is cheaper than FDMA
- full power efficiency is possible i.e mobile device can save their battery power by turning off transmitting and receiving data.

2] Frequency Division Multiple Access (FDMA) :-

- FDMA allocates different frequency band to multiple users, allowing simultaneous data transmission over seperate freq^n channels.
- In the case of FDMA, different each stations are able to access the total available BW in the satellite transponders (s) by virtue of their different carrier freq^n, thus avoiding interference among multiple signals.
- FDM (freq^n division multiplexing), which is the process of grouping multiple base band signals

into a single signal so that it could be transmitted over a single communication channel.

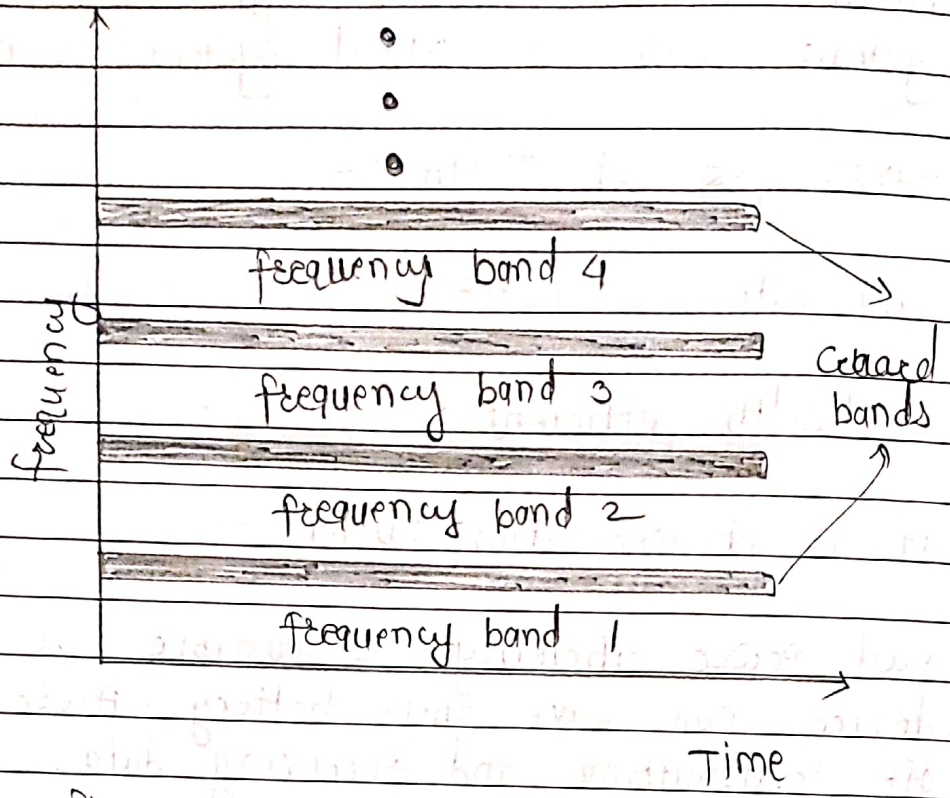


fig :- FDMA overview

- FDMA is channel access method used in some multiple-access protocols.
- FDMA allows multiple users to send data through a single communication channel such as coaxial cable or microwave beam, by dividing the BW of channel into seperate non-overlapping freq^n sub channels and allocating each sub-channel to seperate user.
- Each user operates within their dedicated freq^n range, preventing interference.

- suitable for analog & digital transmissions but less efficient for digital data due to freq^n band limitations.

- It requires filters and freq^n planning to minimize interference & optimize spectral efficiency.

- Used in satellite, radio, and television broadcasting.

- Example :- FM radio broadcasting uses FDMA to allocate different freq^n to diff. stations.

o Advantages and disadvantages of FDMA :-

Advantages :-

- A little synchronization required.

- Low ISI effect.

- Availability of resources for all time.

Disadvantages :-

- Requires expensive filters.

- Causes signal spreading.

- causes radiation leakage.

3] Code Division Multiple Access (CDMA) :-

- CDMA enables multiple users to transmit data simultaneously over the same freqⁿ spectrum by using unique codes to differentiate betⁿ transⁿ
- In the case of CDMA, the entire bandwidth of the transponder is used simultaneously by multiple Earth stations at all times.
- CDMA allows multiple Earth stations to access the same carrier freqⁿ and bandwidth at the same time.
- CDMA is a channel access method used by various radio communication technologies.
- CDMA employs spread spectrum technology & a special coding scheme.
- CDMA optimizes the use of available bandwidth as it transmits over the entire freqⁿ range & does not limit the users freqⁿ range.
- It is used as the access method ~~im~~ in many mobile phone standards. IS-95, also called "cdma one".
- It can be also used as channel or medium access technology. like ALOHA.

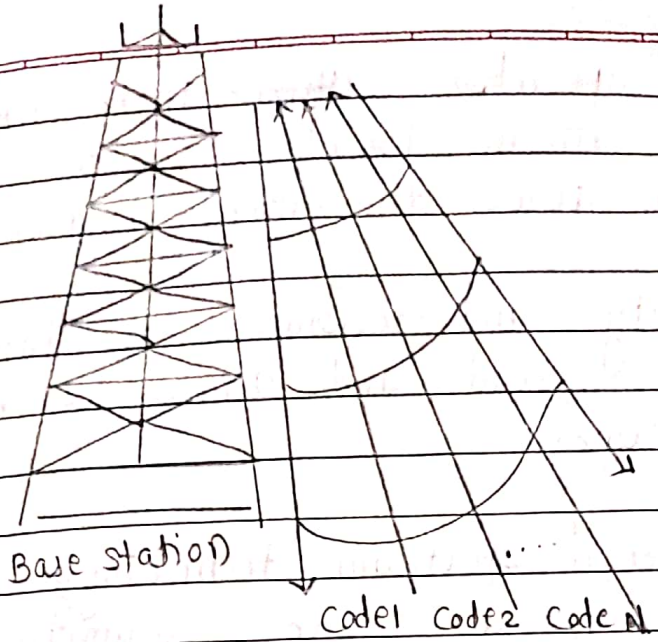
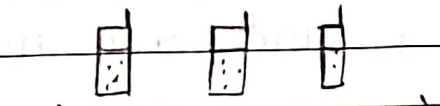


fig:- forward link:
a composite signal which is transmitted to all users and differentiated by codes.



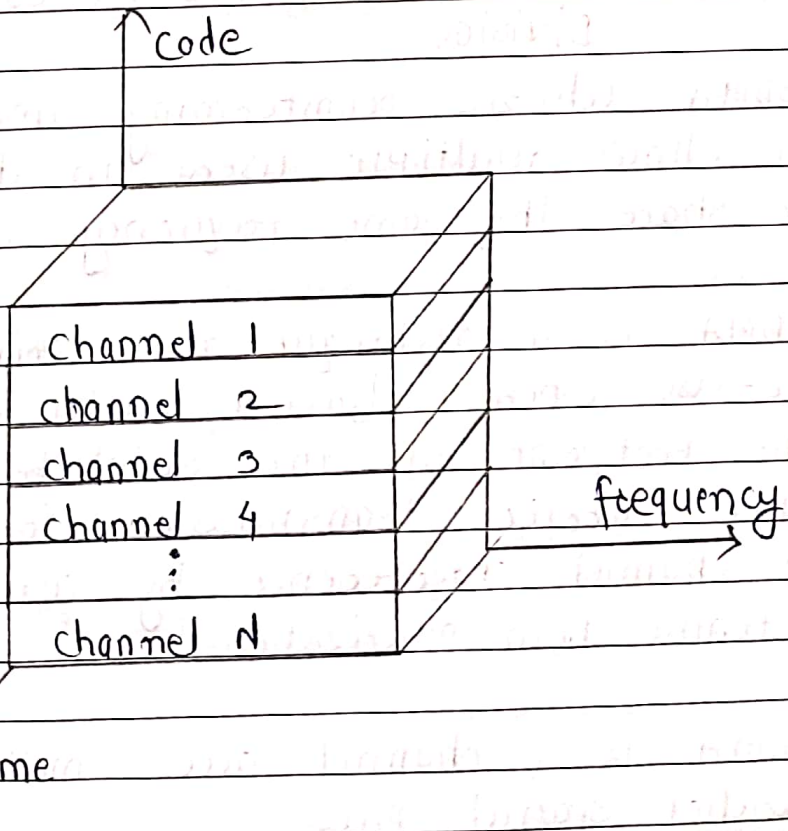


fig:- CDMA in which each channel is assigned a unique code which is orthogonal to codes used by other users.

- Each user operates ~~within~~ their ~~dedicated~~ is assigned a unique pseudo-random code that spread their signal across the entire bandwidth.

- High security and resistance to interference since signals are spread and appear as noise to unauthorized users.

- Utilizes spread spectrum technology to improve efficiency & reduce power consumption. Used in 3G and 4G mobile networks.

- Example :- Qualcomm's CDMA technology used in mobile phones and satellite communications.

4] Space Domain/ Multiple Access (SDMA) :-
Division

- SDMA utilizes beamforming and spatial seperation to allow multiple users in different locations to share the same frequency and time resources.

- SDMA is a technique that primarily allows freq^n re-use where adjacent Earth stations within the footprint of the satellite can use the same carrier transmission freq^n and still avoid co-channel interference by using orthogonal antenna beam polarization.

- SDMA is a channel access method based on creating parallel spatial pipes.

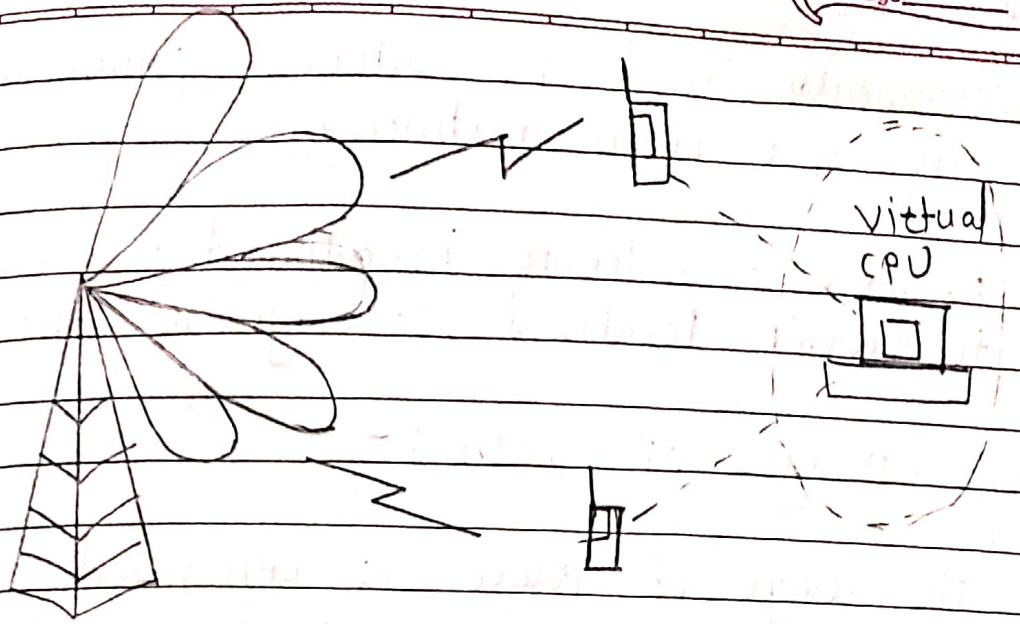


fig :- schematic of SDMA.

- SDMA is a multiple access scheme that optimizes the use of the available spectrum & minimizes power consumption by taking advantage of the directional properties of dish antennas.

- In traditional networks, the base station has no information on position of mobile units within the cell and radiates the signal in all directions within the cell in order to provide radio coverage.

- Directs signals toward specific geographic loca^n, optimizing spectral efficiency.

- Uses advanced antenna technology, such as phase array antennas, to create multiple beams.

- Reduced interference by focusing signals on targeted areas rather than broadcasting to the entire coverage region.

- Commonly used in satellite communication systems with spot beam technology.
- Example :- Satellite broadband services use SDMA to provide localized coverage in different region.

o Advantages of SDMA :-

- The usage of power is optimized & wastage of energy in transmission is minimized.
- Multiple receivers operating on the same freq^n can receive signals from the same transmitter without having to divide the freq^n range.
- Completely free from interference.
- Enhanced performance.
- The radiated energy of each receiver can be controlled & regulated.

o Dis-advantages of SDMA :-

- If two receivers operating in the same freq^n have the same spatial location, the freq^n band have to be split into channels to accomodate both the mobile stations.
- Network design can get a little tedious.

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Difference bet^n FDMA, TDMA & CDMA :-

FDMA	TDMA	CDMA
Frequency division multiple Access	Time Division Multiple Access	code Division multiple Access
FDMA shares a single BW among multiple stations by dividing it into sub-channels.	It share the time slot of transmission through satellite	CDMA share both BW and time among multiple stations with seperate unique code.
Each station is allocated with freq^n band for all the time to send data	There is a time-slot given each stations to transmit data	It allows each stations to transmit data over the entire freq^n all the time.
Code-word is not required	code-word is not required	Each ~~used~~ user is assigned with unique code sequence.
synchronization is not required	synchronization is required	synchronization not required.
It uses continuously signals for data transmission.	It uses signals in bursts for data transmission	It uses digital signal.
It requires guard band bet^n adjacent bands	It requires the guard time of the adjacent time slot	CDMA requires both guard band & guard times.

8) Low data-rate	Medium data-rate	High data-rate
9) Limited cell capacity	Restricted cell capacity	No capacity restriction.
10) High cost	Low cost	High installation cost & Low operation cost
11) Less flexible	Moderate flexible	Highly flexible.
12) Advantages :- - simple, reliable	- flexible - Entirely digital	- Highly flexible - soft signal hand off - Highly secure trans^n.
13) Disadvantages. - Inflexible - fixed frequencies.	- It requires guard space synchronization problem	complex receivers.
14) Applications :- - Telephone systems - Radio systems - cable TV - GSM used FDMA is comb^n with TDMA	Applications - Digital cellular comm^n - satellite systems - GSM, IS-136, & iDEN	Applications :- - cellular systems - GPS - Personal comm^n service - subscriber access control

Assignment Methods :-

- Assignment methods refer to how resources are allocated to users in a satellite communication system.

- The common assignment strategies includes :-

- Fixed Assignment (FA) :-
- Demand Assignment (DA) :-
- Random Access :-

* Fixed Assignment (FA) :-

- Pre-allocated resources assigned to user permently.

- The fixed assignment method is a technique used to allocate resources to specific tasks.

- It can be used to assign channels to mobile devices in wireless networks.

- Fixed Assignment mtd in organizations :-
- A method for allocating resources to specific tasks.

- Resources could be monetary, personal, or technological.

Demand Assignment (DA) :-

- Resources allocated dynamically based on user demand.
- Demand Assigned multiple Access (DAMA) is a mtd for allocating BW to users in satellite comm? systems.
- DAMA uses a central controller to dynamically assign bandwidth based on user demand.
- This method is more efficient than fixed-assigned multiple access (FAMA). which allocates channels permently.

Random Access :-

- Users transmit without pre-allocated resources, competing for available bandwidth.
  e.g ALOHA, Slotted ALOHA.
- Random Access assignment mtd refer to techniques where data or resources are allocated to users or locations within a system without any predetermined order.

Introduction to Digital Satellite and Mobile Satellite communication :-

* Digital satellite communication :-

- Digital satellite communication is the transmission of digital signals (data, voice & video) through satellites using digital modulation techniques.

- It offers advantages such as improved noise immunity, higher data rates, efficient bandwidth usage, and enhanced security.

Block Diagram of Digital Satellite Communication System :-

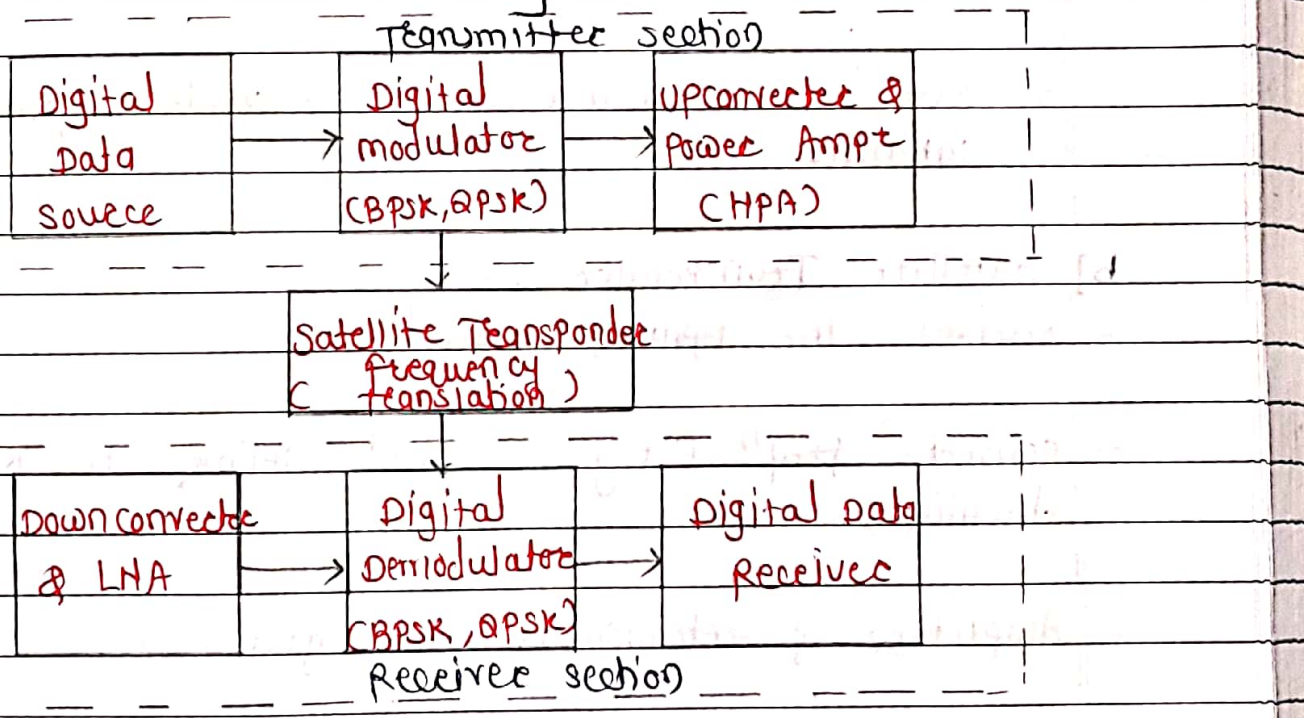

fig :- Block diagram of Digital satellite communication.

Component of Digital satellite comm^n system :-

a] Transmitter section :-

1. Digital data source :- Generate data in digital format.

2. Digital Modulator :- Converts binary data into modulated signals using BPSK, QPSK, 8-PSK, or QAM

3. Upconverter :- converts the baseband signal to a higher freq^n for satellite transmission.

4. High power Amplifier (HPA) :- Amplifies the signal before transmission.

5. Satellite Antenna (Uplink) :- sends signals to the satellites.

b] Satellite Transponder :-

- Receives the uplink signal
- converts freq^n (e.g C-band uplink to Ku-band downlink).
- Amplifies & retransmits the signal.

c] Receiver section :-

1. Down converter & Low noise Amplifier (LNA) :- converts the received signal to a lower freq^n & amplifies it.

2. Digital Demodulator :- Recovers the original digital data.

3. Digital Data Receiver :- Processes the received data for end-user applications.

Advantages :-

- Higher Data rates :- supports broad band appli? like internet & multimedia.
- Better noise immunity :- Digital signals are less affected by noise and interference.
- Efficient Bandwidth Usage :- Advanced modulation techniques optimizes spectrum uses.
- security & Encryption :- Digital transmission allows data encryption for security.
- flexible & scalable :- can handle multiple user efficiently.

Applications :-

- Broadcasting
- Internet services
- Mobile communications
- Navigations & GPS
- Military & defense.

Mobile Satellite Communication :-

- Mobile satellite communication enables communication betⁿ mobile users through satellites, providing coverage in remote areas where terrestrial networks are unavailable.

- It is widely used for maritime, aviation, military and disaster recovery applications.

Block Diagram :-

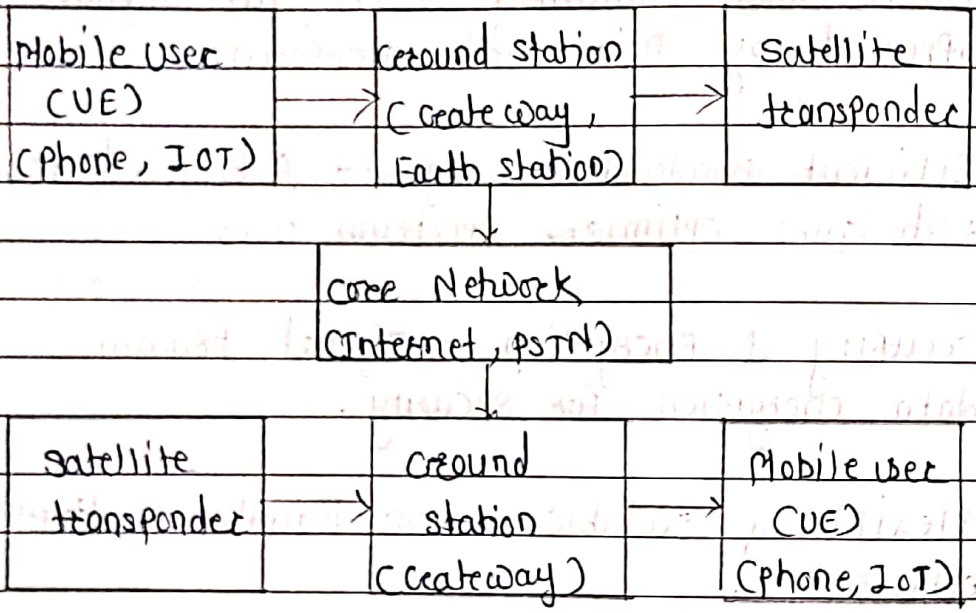

fig:- Block diagram of mobile satellite communication.

~~Components~~

Components :-

a] User Equipment (UE) :-

- Mobile devices such as satellite phones, IoT sensors emergency beacons & vehicle terminals.

b] Satellite segment :-
- Geostationary (GEO), Medium Earth orbit (MEO), or Low Earth orbit (LEO) satellites.
- Acts as a relay bet^n mobile users & ground stations.

c] Ground station (Gateway) :-
- Connects satellites to terrestrial network like the internet, telephone networks (PSTN) & cellular networks.

d] Core Network :-
- Manage data routing, authentication & services like voice, messaging & internet access.

Types :-

1) GEO (Geostationary orbit) :-
- Located at 35,786 km altitude, covering large areas.
- Used in inmarsat, Thuraya & VSAT services.

2) MEO (Medium Earth orbit) :-
- 5,000 - 20,000 km altitude, with lower latency than GEO.
- Used in O3b and navigation systems.

3) LEO (Low Earth orbit) :-

- 500 - 2000 km altitude, low latency - requires multiple satellites.
- used in starlink, oneweb, Iridium, Globalstar for global coverage.

Advantages :-

- Global coverage.
- Disaster Resilience.
- support Mobility.
- secure communication.

Application :-

- Maritime communication.
- Aviation.
- Emergency & Disaster Relief.
- Remote Area connectivity.
- Military & defence.

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Q.1 Explain FDMA & TDMA in detail.

Q.2 Write a short note on SDMA.

Q.3 Explain the features of CDMA.

Q.4 Differentiate bet? TDMA, FDMA, CDMA & SDMA.

Q.5 Explain Mobile satellite communication & Digital satellite communication in detail.