UNIT V
SATELLITE APPLICATIONS

INTELSAT Series, INSAT, VSAT, Mobile satellite services: GSM, GPS, LEO, MEO, Satellite Navigational System. GPS Position Location Principles, Differential GPS***, Direct Broadcast satellites (DBS) - Direct to home Broadcast (DTH).***

INTELSAT Series
INSAT
VSAT
Mobile satellite services
GSM
GPS
INMARSAT
LEO
MEO
Satellite Navigational System
GPS Position Location Principles
Differential GPS
Direct Broadcast satellites (DBS)
Direct to home Broadcast (DTH)

5.1 INTELSAT Series, INSAT

1. **Explain the types of INTELSAT satellites with respect to basic spacecraft characteristics and vehicle type. (April 2014)**
2. **Write about INTELSAT, INSAT and INMARSAT. (Nov/Dec 2012)**

<u>INTELSAT Series</u>

INTELSAT - International **Tel**ecommunications **Sa**tellite

- The formation of the international cooperative organization INTELSAT in 1964 paved the way for the sophistication of satellite systems available today.
- There are other international organizations but none has stood the test of time as well as the very successful INTELSAT systems, which provide voice, data, and video services.
- INTELSAT covers three main regions- AOR (Atlantic Ocean Region), IOR(Indian Ocean Region) and POR (Pacific Ocean Region).

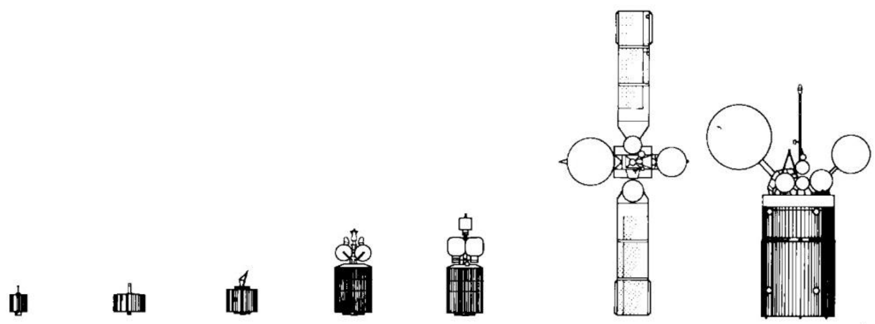
INTELSAT I:

- Known as Early Bird, this was launched in 1965 and was the first commercial communications satellite operating over the Atlantic Ocean.

- It was a cylindrical, spin-stabilized satellite and had two transponders, each with about 30 MHz of bandwidth. The RF transmit power was about 4 W, and the EIRP was 12 to 14 dBW, indicating the antenna was an omni directional type.
- The *equivalent isotropic radiated power* (EIRP) is the product of power and gain.
- About 600 solar cells provided 45 W of power for all the circuitry.
- It had a capacity of either 240 voice telephone circuits, or one good-quality television transmission.
- Its designed lifetime is extended to more than three years.

INTELSAT II:

- In 1967, three INTELSAT II satellites were put into operation.
- The first was placed over the Pacific Ocean to extend coverage to the Pacific region.
- The second was placed over the Atlantic Ocean to increase capacity for the Atlantic region, and the third was also placed over the Pacific Ocean and acted as a spare.
- INTELSAT II was very similar to Early Bird in construction, but with improved channel capacity.



Designation: Intelsat	I	II	III	IV	IV A	V	V A/V B	VI
Year of first launch	1965	1966	1968	1971	1975	1980	1984/85	1986/87
Prime contractor	Hughes	Hughes	TRW	Hughes	Hughes	Ford Aerospace	Ford Aerospace	Hughes
Width (m)	0.7	1.4	1.4	2.4	2.4	2.0	2.0	3.6
Height (m)	0.6	0.7	1.0	5.3	6.8	6.4	6.4	6.4
Launch vehicles		Thor Delta		Atlas-Centaur		Atlas-Centaur and Ariane	Atlas-Centaur and Ariane	STS and Ariane
Spacecraft mass in transfer orbit (kg)	68	182	293	1385	1489	1946	2140	12,100/3720
Communications payload mass (kg)	13	36	56	185	190	235	280	800
End-of-life (EOL) power of equinox (W)	40	75	134	480	800	1270	1270	2200
Design lifetime (years)	1.5	3	5	7	7	7	7	10
Capacity (number of voice channels)	480	480	2400	8000	12,000	25,000	30,000	80,000
Bandwidth (MHz)	50	130	300	500	800	2137	2480	3520

Figure 1.1 Evolution of INTELSAT satellites. (*From Colino 1985; courtesy of ITU Telecommunications Journal.*)

The Evolution of INTELSAT satellites.

- With satellites over the Atlantic and Pacific, two thirds of the world's area was covered by communication satellites.
- INTELSAT II was designed to have a lifetime of three years.

INTELSAT III:

- During 1969, three INTELSAT III satellites were launched over the Atlantic, Pacific, and Indian Oceans.
- This configuration saw the first global satellite coverage as initially proposed by Arthur Clarke in 1945.

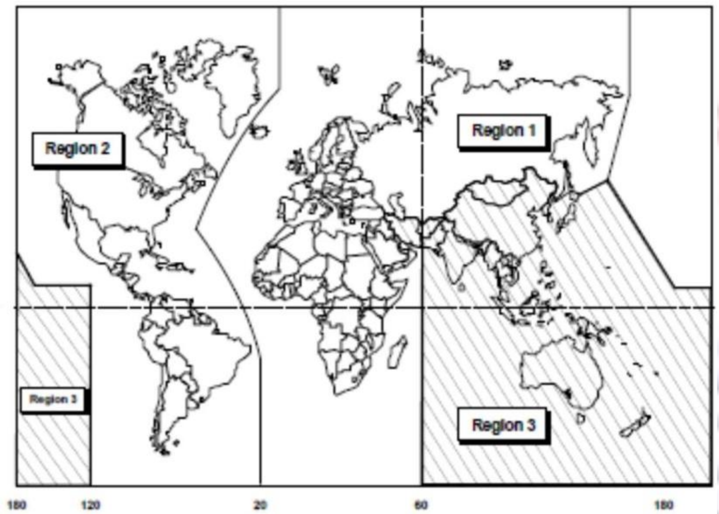


Figure: Coverage of INTELSAT

- INTELSAT III introduced some new features, such as the despun antenna.
- INTELSAT III was also the first in the series to use a highly directional antenna.
- It had a beam width of 19°, which is just 2° more than the 17° requirement for global coverage.
- The 2° margin was to allow for pointing error.
- The global antenna had a conical shape with a flare angle of 6°, and pointing accuracy was maintained by controlling the despun motors with infrared sensors that detected the earth's horizon.

INTELSAT IV:

- During the period from 1971 to 1975, eight INTELSAT IV satellites were launched, of which seven reached orbit and provided service.
- Increasing the INTELSAT IV capacity to 4000 telephony channels plus two TV channels without increasing the bandwidth required some additional frequency reuse ingenuity.
- INTELSAT IV satellites each had twelve transponders of 36-MHz bandwidth, with a 4-MHz guard band between adjacent transponders.
- The satellites had global coverage antennas and two 4.5° beamwidth spot beam antennas that were steerable from earth.
- One of the two spot beams was directed to the east and the other to the west of an ocean region.
- The objective of the spot beam transmissions was to provide more capacity for the heavier traffic-generating routes, the spot beam capacity being approximately double the global beam capacity.
- The shape of the beam could be modified by selecting the appropriate horns for transmission.

- SCPC systems were first introduced on INTELSAT IV-A to provide more flexibility, especially for low-traffic (thin) routes.

INTELSAT V:

- New technology employed on INTELSAT V included the use of the 14/11-GHz band.
- Linear polarization was used in this band because it provides better cross-polarization discrimination at this frequency than does circular polarization.
- It also used three-axis body stabilization for the first time, instead of spin stabilization.
- The solar arrays producing 1228 W (after 10 years in orbit) were on flat panels instead of around the cylindrical body, and a momentum wheel within the body of the satellite provided gyroscopic stabilization.
- TDMA was first introduced for use with INTELSAT V.
- INTELSAT V-A uses the spatial and polarization frequency reuse techniques to enhance bandwidth utilization.

INTELSAT VI:

- Satellite-switched TDMA was introduced for the first time with INTELSAT VI.
- The total available transponder bandwidth is 3330 MHz by using C- and Ku-bands, orthogonal polarization, and spatial isolation.
- The 6/4-GHz frequencies are reused six times, and the 14/11-GHz frequencies are reused twice.
- DCME started to have widespread use for more cost-effective voice traffic.

INTELSAT VII:

- The INTELSAT VII/VII-A series of satellites is a high-capacity and versatile fleet of spacecraft deployed for global service.
- The INTELSAT VII design has 26 C-band and 10 Ku-band transponders that allow 18,000 telephone calls and three color TV broadcasts simultaneously, or up to 90,000 telephone circuits using DCME.
- INTELSAT VII-A has 26 C-band and 14 Ku-band transponders, providing 22,500 telephone calls and three color TV broadcasts simultaneously, or up to 112,500 telephone circuits using DCME.
- VII-A also has independently steerable C-band spot beams for better traffic-handling capability. This satellite upgrades the IDR BER performance from 10–7 to 10–10 under clear sky conditions.
- A new feature introduced by the INTELSAT VII/VII-A satellites is the ability to reconfigure the satellite’s coverage and to meet changing traffic patterns and service requirements on a real-time basis.

INTELSAT VIII:

- The INTELSAT VIII series, with six launches between February 1997 and July 1998, has improved C-band coverage and service capacity for public switched telephony and INTELSAT Business Services, provided better quality for video services, and encouraged new international VSAT applications.

- These satellites have six fold C-band frequency reuse, twofold frequency reuse of expanded C-band capacity, and the highest C-band power level ever for an INTELSAT satellite.
- INTELSAT VIII satellites include two independently steerable Ku-band spot beams that can be pointed anywhere on the earth's surface visible from the satellite.
- There is also interconnected operation between C- and Ku-bands.
- *Satellite news gathering* (SNG) service is expanded by the capability to connect spot beams to global beams.
- Each satellite has a total of 44 transponders, of which 38 are C-band and 6 are Ku-band.
- This provides a total capacity of 22,500 two-way telephone circuits and three TV channels.
- If DCME is used, this increases the total capacity to 112,500 two-way telephone circuits.
- The satellite system lifetime is 13 to 18 years, depending on the launch vehicle.

INTELSAT IX:

- The INTELSAT IX satellites are the latest in the series.
- They will provide a much wider range of services than previously and promise such services as Internet, direct-to-home (DTH) TV, telemedicine, tele-education, and interactive video and multimedia.

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5.2 INSAT

INSAT

- **INSAT** or the ***Indian National Satellite System*** is a series of multipurpose geo-stationary satellites launched by ISRO to satisfy the telecommunications, broadcasting, meteorology, and search and rescue operations.
- INSAT satellites provide transponders in various bands (C, S, Extended C and K_u) to serve the television and communication needs of India.
- Some of the satellites also have the Very High Resolution Radiometer (VHRR), CCD cameras for metrological imaging.
- The satellites also incorporate transponder(s) for receiving distress alert signals for search and rescue missions in the South Asian and Indian Ocean Region, as ISRO is a member of the Cospas-Sarsat programme.

INSAT Satellites

- INSAT-2E
    - INSAT-3A
    - INSAT-3C
    - INSAT-3D
    - INSAT-3E
    - KALPANA-1
    - GSAT-2
    - Edusat
    - INSAT-4 Series
        - INSAT-4A
        - INSAT-4B
            - Glitch in INSAT 4B

- INSAT-4CR
- GSAT-8 / INSAT-4G
- GSAT-12
- GSAT-10

Satellites in service

Of the 24 satellites launched in the course of the INSAT program, 10 are still in operation.

INSAT-2E

- It is the last of the five satellites in INSAT-2 series {Prateek }.
- It carries seventeen C-band and lower extended C-band transponders providing zonal and global coverage with an Effective Isotropic Radiated Power (EIRP) of 36 dBW.
- It also carries a Very High Resolution Radiometer (VHRR) with imaging capacity in the visible (0.55-0.75 µm), thermal infrared (10.5-12.5 µm) and water vapour (5.7-7.1 µm) channels and provides 2x2 km, 8x8 km and 8x8 km ground resolution respectively.
- In addition to the above two payloads it has with it a Charge Coupled Device (CCD) camera providing 1x1 km ground resolution in the Visible (0.63-0.69 µm), Near Infrared (0.77-0.86 µm) and Shortwave Infrared (1.55-1.70 µm) bands.

INSAT-3A

- The multipurpose satellite, INSAT-3A, was launched by Ariane in April 2003.
- It is located at 93.5 degree East longitude. The payloads on INSAT-3A are as follows:
  - **12 Normal C-band transponders** provide Middle East to South East Asia coverage with EIRP of 38 dBW and India coverage with EIRP of 36dBW.
  - **Very High Resolution Radiometer(VHRR)**
  - A **CCD camera**.
  - A **Data Relay Transponder (DRT) A Satellite Aided Search and Rescue (SAS&R) SARP payload**

INSAT-3C

- Launched in January 2002, INSAT-3C is positioned at 74 degree East longitude.
- INSAT-3C payloads include **24 Normal C-band transponders** providing an EIRP of 37 dBW, six Extended **C-band transponders** with EIRP of 37 dBW, two **S-band transponders** to provide BSS services with 42 dBW EIRP and an **MSS payload** similar to that on INSAT-3B.
- All the transponders provide coverage over India.

INSAT-3D

- Launched in July 2013, INSAT-3D is positioned at 82 Degree East longitude.
- INSAT-3D payloads include Imager, Sounder, Data Relay Transponder and Search & Rescue Transponder.
- All the transponders provide coverage over large part of the Indian Ocean region covering India, Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania for rendering distress alert services.

INSAT-3E

- Launched in September 2003, INSAT-3E is positioned at 55 degree East longitude and carries 24 Normal C-band transponders provide an edge of coverage EIRP of 37 dBW over India and 12 Extended C-band transponders provide an edge of coverage EIRP of 38 dBW over India.
- The satellite has been decommissioned and gone out of service from April 2014.

GSAT-2

- Launched by the second flight of GSLV in May 2003, GSAT-2 is located at 48 degree East longitude and carries four Normal C-band transponders to provide 36 dBW EIRP with India coverage, two K_u band transponders with 42 dBW EIRP over India and an MSS payload similar to those on INSAT-3B and INSAT-3C.

INSAT-4 Series

INSAT-4A

- Launched in December 2005 by the European Ariane launch vehicle, INSAT-4A is positioned at 83 degree East longitude along with INSAT-2E and INSAT-3B.
- It carries 12 K_u band 36 MHz bandwidth transponders employing 140 W TWTAs to provide an EIRP of 52 dBW at the edge of coverage polygon with footprint covering Indian main land and 12 C-band 36 MHz bandwidth transponders provide an EIRP of 39 dBW at the edge of coverage with expanded radiation patterns encompassing Indian geographical boundary, area beyond India in southeast and northwest regions.

INSAT-4B

- It was launched in March 2007 by the European Ariane launch vehicle.
- Configured with payloads identical to that of INSAT-4A, INSAT-4B carries 12 K_u band and 12 C-band transponders to provide EIRP of 52 dBW and 39 dBW respectively.
- The national space agency **Indian Space Research Organisation (ISRO)** has allotted nearly seven K_u band transponders to Sun Direct; a DTH service provider from South India, and the other five to Doordarshan's **DD Direct Plus**.
- 12 transponders in the C band are for TV, radio and telecommunication purposes

INSAT-4CR

- INSAT-4CR was launched on 2 September 2007 by GSLV-F04.
- It is a replacement satellite of INSAT-4C which was lost when GSLV-F02 failed and had to be destroyed on its course.
- It carries 12 K_u band 36 MHz bandwidth transponders employing 140 W TWTAs to provide an Effective Isotropic Radiated Power of 51.5 dBW at Edge of Coverage with footprint covering Indian mainland.
- It also incorporates a K_u band Beacon as an aid to tracking the satellite.
- The satellite is designed for a mission life in of ten years.
- There were reports that the mission life of the satellite had decreased by five years as the thrusters had to burn this much fuel to restore the satellite to its correct orbit.
- However, the ISRO later refuted this claim dismissing it as false.

GSAT-8 / INSAT-4G

- GSAT-8, India’s advanced communication satellite, is a high power communication satellite being inducted in the INSAT system.
- Weighing about 3100 kg at lift-off, GSAT-8 is configured to carry 24 high power transponders in Ku-band and a two-channel GPS Aided Geo Augmented Navigation (GAGAN) payload operating in L1 and L5 bands.

GSAT-12

- GSAT-12 is configured to carry 12 Extended C-band transponders to meet the country's growing demand for transponders in a short turn-around-time.

- The 12 Extended C-band transponders of GSAT-12 will augment the capacity in the INSAT system for various communication services like Tele-education, Telemedicine and for Village Resource Centres (VRC).
- It weighs about 1410 kg at lift-off.

GSAT-10

- GSAT-10 is an Indian communication satellite which was launched by Ariane-5ECA carrier rocket in 2012.
- It will field C and Ku band transponders, and includes a navigation payload to augment GAGAN capacity.

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5.3 VSAT

3. Describe the operation of a typical VSAT system with necessary sketches. (Nov/Dec 2012, April/May 2011, Nov/Dec 2010, April/May 2010).
Explain the characteristics of a typical VSAT system and Key Components for a VSAT network. [May 2021]
Discuss on ~~INMARSAT and~~ VSAT services in detail. [May 2022]

VSAT - Very Small Aperture Terminal System

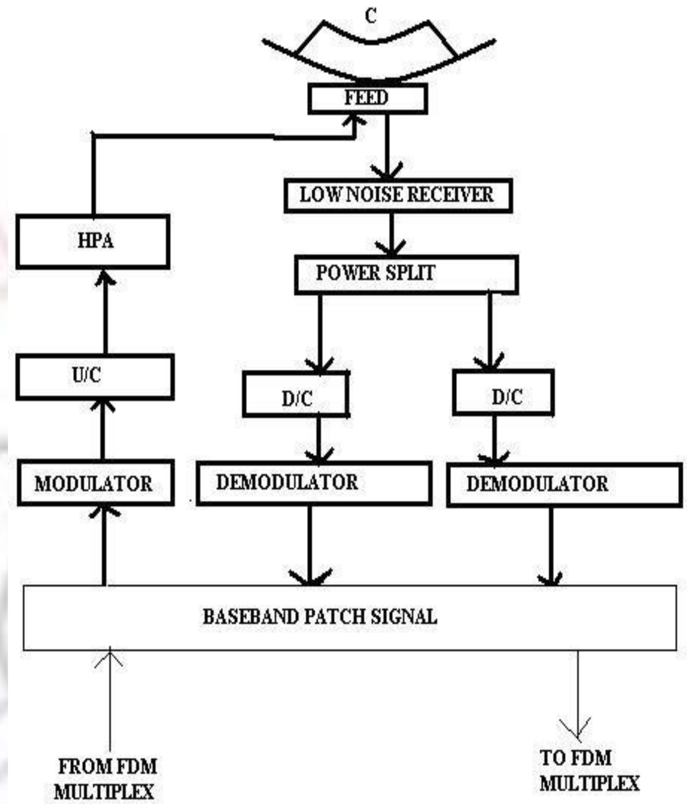
VSAT:-

- VSAT stands for very small aperture terminal system.
- A VSAT is usually defined as a terminal with an antenna with diameter 2.4 m or less, which is likely to provide digital services of 2 Mbps or less (1).
- VSAT systems operate in ku band.
- VAST systems bring telecommunications service directly to the end user without any intermediate distribution hierarchy.
- VAST systems are used to limit business and stores to a central computer system so that sale transactions can be completed more rapidly than by using a telephone line and modem, so that a central office can rapidly distributes and collect information from a large number of locations in a region on country.
- The geostationary satellite is used to line a large number of VAST's with the main switching centre in a large city.
- East VSAT acts as the link to the local snitching centre in the village (or) rural community, with the final mile of the telephony link being carried over a warless local loop.
- The basic structure of a VSAT network consist of a hub station which provides a broadcast facility to all the VSAT's in the network of the VSATS themselves which access the satellite in some from of multiple access mode is demand assigned multiple access(DAMA).

Equipment required for VSAT network:

- Antennas
- High power amplifier
- Low noise amplifier
- Up & down converter

- Echo-canceller
- Modems
- Power splitter
- Power system



- VSAT networks are characterized by a large population of small and inexpensive earth stations (VSATs) at the customer's premises.
- They communicate through relatively small antennas with a central large earth station called the hub station (figure 1).

Very Small Aperture Terminal (VSAT) systems
- Basic principles and design

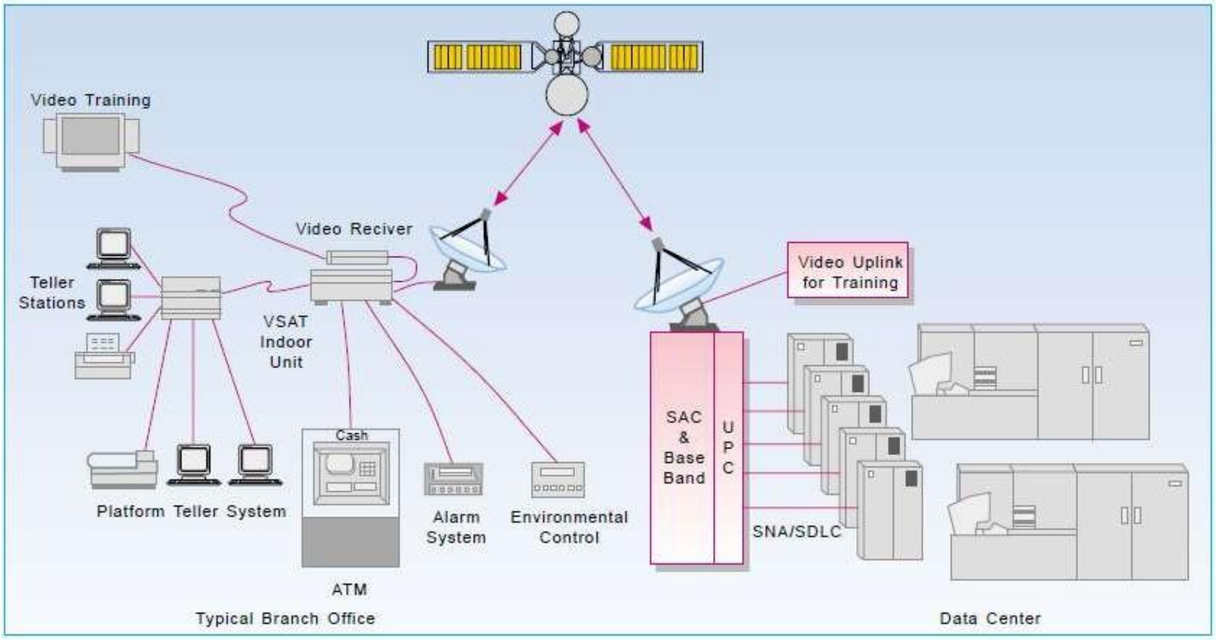


Figure: Example of a VSAT network in a Baking Environment

- The equipment characterized comprises both the "outdoor unit" and the "indoor unit". The outdoor unit is usually composed of the antenna subsystem and the associated power amplifier and **Low Noise Converter (LNC).**
- The indoor unit is composed of the remaining part of the communication chain, including the cable between the indoor and outdoor units.
- This standard does not contain the VSAT network hub station.

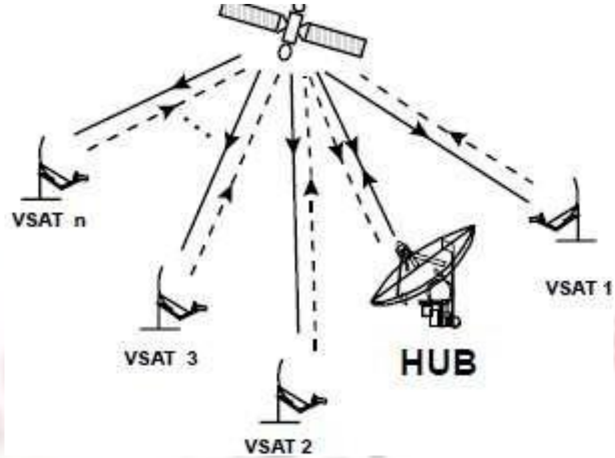
Hub station

- The entire network is organized by the hub station via the network management system (NMS).
- The operator of the network management system is responsible for the following essential functions:
  - ✓ Monitoring and controlling the network
  - ✓ Configuring the network
  - ✓ Troubleshooting the network
  - ✓ Charging.
- Communication between the NMS and network components is continually maintained.
- The NMS regularly polls the nodes of the network to obtain normal activity statistics, information about system failures and error recovery

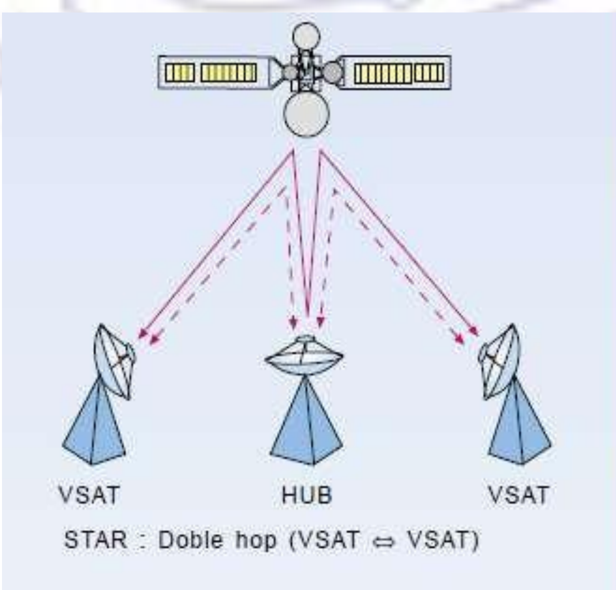
VSAT Architectures:-

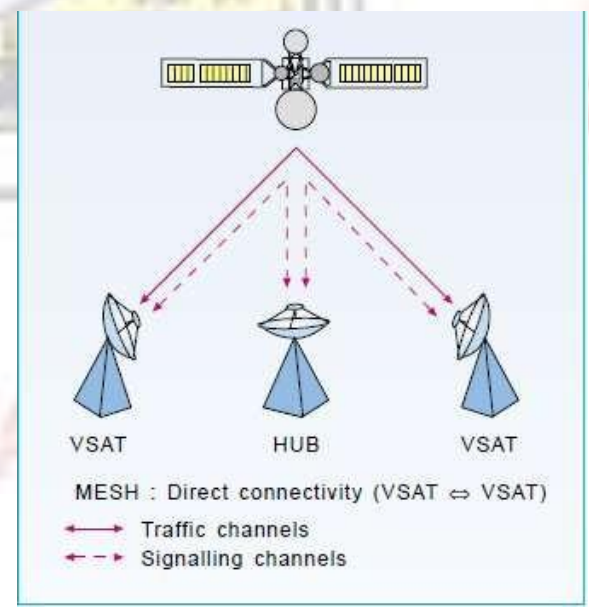
- Generally, there are two VSAT architecture which provides two-way implementation, are **Mesh and star networks.**

Star VSAT Network:-



- The *star topology* is the traditional VSAT network topology.
- The communication links are between the hub and the remote terminals.
- This topology is well suited for data broadcasting or data collection.
- In this star network architecture, all of the traffic is routed Via the master control station, (or) hub.
- If a VSAT wishes to communicate with another VSAT, they have to give the hub, thus requires "double hop" link via the satellite
- The only way to communicate between the remote terminals is via the hub station (double hop).
- This makes it impossible to offer speech services between the terminals, because the time delay in the double hop (500 ms) is too severe.
- The access techniques used in a star network can be both FDMA (frequency division multiple access), TDMA (time division multiple access), and CDMA (code division multiple access), but TDMA is the most common.
- The inbound channel (remote VSAT to hub) often use slotted Aloha which is a form of Random Access (RA).





Mesh VSAT Network:-

- In this (Mesh VSAT) network architecture, each of the VSATS has the ability to communicate directly with any of the other VSATS.
- Since, the traffic, can go to (or) from any VSAT, this architecture, is referred to as a Mesh Network.
- In *mesh topology* there is direct communication between the remote VSAT terminals.
- This minimizes the time delay which is critical concerning speech services.
- The internal signaling network will have a star topology, because the signaling processor is
- located in the central node, which is often referred to as the DAMA (demand assignment multiple access).
- The access method used in a mesh network is typically Frequency Division Multiple Access (FDMA).

Specifications

- In order to get a more precise definition of VSAT systems the European Telecommunication Standards Institute (ETSI) has proposed the following specifications of the transmit and receive terminals (2):
    - Operating in the exclusive part of the Ku-band allocated to the Fixed Satellite Services (FSS), 14.00 to 14.25 GHz (earth-to-space), 12.50 to 12.75 GHz (space-to-earth), and
- In the shared parts of the Ku-band, allocated to the FSS and FS (Fixed Services), 14.25 to 14.50 GHz (earth to- space) and 10.70 to 11.70 GHz (space-to-earth)
    - In these frequency bands linear polarization is normally used and the system operates through satellites with 3 degree spacing
    - Designed for unattended operation
    - Limited to reception and transmission of baseband digital signals
    - The information bitrate transmitted towards the satellite shall be limited to 2.048 Mbps

Disadvantages:-

Major disadvantages' are

- Mesh initial cost
- Tendency toward, optimizing systems for large networks (500 and more VSAT).
- Back of direct VSAT to VSAT links.

Applications:-

- VSAT is used by private network providing two – way communication facilities such as
    - ✓ Banking
    - ✓ Financial Intuitions
    - ✓ Airline
    - ✓ Hotel booking agencies
    - ✓ Large retail stores, etc.,

VSAT Services:

- Data distribution

- Data networking
- Voice services and
- Digitally compressed videoconferencing services.

5.4 Mobile satellite services: GSM, GPS, INMARSAT, LEO, MEO

4. Enumerate how GSM and GPS deploying satellites have improved the mobility of the customer. (May/June 2013,Nov/Dec 2012)
5. Discuss in detail about GSM mobile satellite services.*(Nov/Dec 2013)

MSAT: Mobile Satellite

- This satellite used to cover rural and remote areas.
- It uses L-band of frequency
  - uplink- 1626.5 to 1660.5MHz
  - downlink – 1550 to 1559MHz
- This band is subdivided into various sub-bands which are used for special services
- Only limited bandwidth is used in L-band (ie)5KHz channels are allocated, therefore bandwidth reduction technique such as Amplitude Companded Single Side Band (ACSSB) for analog channels and LPC-Linear predictive coding for digital signals
- Circular polarization is used with small antennas in mobile stations
- Two large L-band reflector antennas as
  (i) Omni directional
  (ii) steering antennas are used in satellites

***Services of MSAT*:**

- **MRTS: Mobile Radio Trunking Services**
  - similar to terrestrial radio services & cover wide area
  - two types of networks
- private Network: base station is owned and operated by customer's organisation
- shared Network: base station is shared by various customers service and operated by provider
- **IMRS: Interconnected Mobile Radio services**
  - used to connect user to PSTN
  - call from the mobile unit is forwarded to the gateway earth station through MSAT
- **MDS: Military Defense services**
  - used to provide two way data link between missile and fixed terminals
  - also used for electronic data exchanges

Applications of MSAT:

- Public safety: rescue & search application
- Aeronautical: air traffic control
- Marine: comm. To domestic coastal fishing vessels

- Land Application: environmental monitoring & vehicle monitoring

GSM

GSM-GLOBAL SYSTEM FOR MOBILE COMMUNICATION

- An ETSI (European Telecommunications Standards Institute) standard for 2G pan – European digital cellular with international roaming.

GSM characteristics

- Previous standard followed in cellular communication were restrictive.
- GSM – global digital standard for cellular phones that offered roaming facility.
- Earlier name for GSM was Groupe Special Mobile and used in Europe.
- GSM operate in frequency bands: 900MHz, 1800 MHz, 1900 MHz
- GSM uses FDMA and TDMA to transmit voice and data

GSM Services:

1. Teleservices: Provide communication between two end user applications according to a standard protocol.

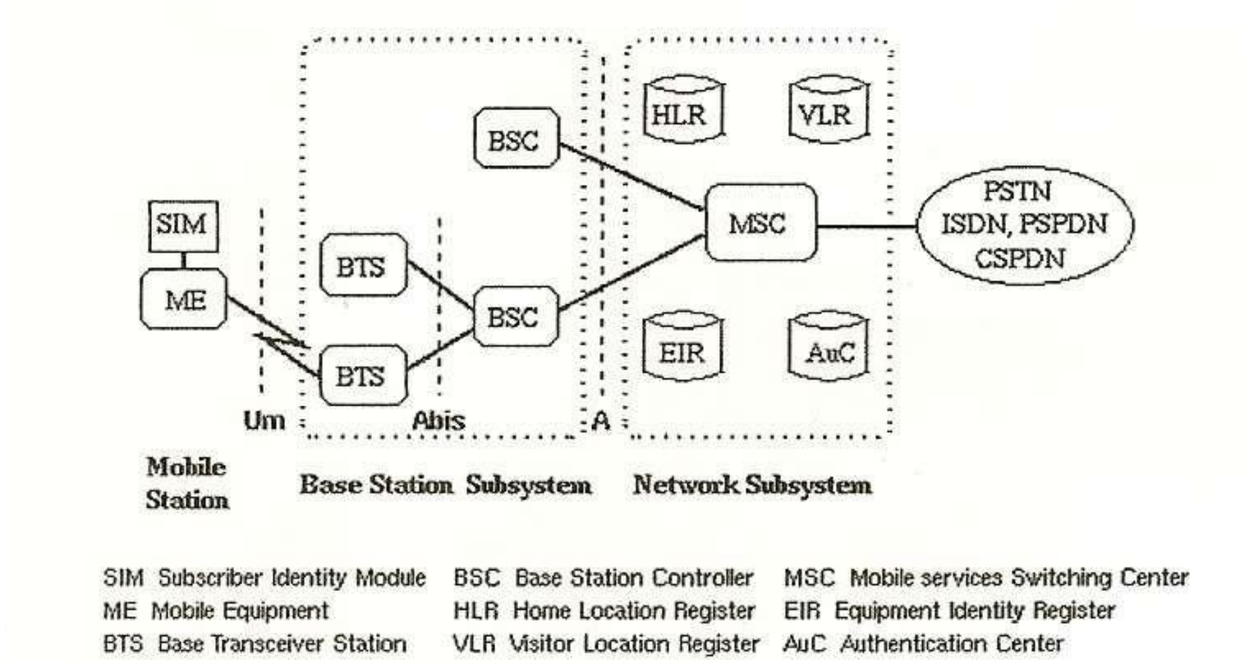
2. Bearer services: To transmit information among user network interfaces or AP(Access Point)'s.

3. Supplementary services: Not stand-alone services but they are services that supplement a bearer or teleservice.

GSM architecture

Three major segments are present in the GSM architecture. They are,

1. Mobile station (MS)
2. Base Station Subsystem (BSS)
3. Network and Switching Subsytem (NSS)



1. Mobile Station (MS)

- MS – Communicates the information with the user & modifies it to the transmission protocols of the air-interface to communicate with the BSS.
- Two elements are present in Mobile station, they are - **Mobile Equipment (ME) and Subscriber Identity Module (SIM)**
- Mobile Equipment (ME) is a Piece of Hardware includes speaker, microphone, keypad, & the radio modem. Therefore, Mobile Equipment is an expensive piece of Hardware.
- This Hardware piece contains all the components needed for the implementation of the protocols to interface with the user & the air interface to the BSS.
- SIM- is a smart card issued at the subscription time identifying the specifications of a user such as address and type of service.
- The calls in the GSM are directed to the SIM & short message are also stored in the SIM card.

2. Base Station Subsystem (BSS)

- Base Station Subsystem (BSS**)** translates between the air-interface & fixed wired infrastructure protocols.
- The needs for the wireless & wired media are different because the wireless medium is unreliable, Bandwidth limited & needs support mobility.
- Protocols used in the wireless & wired mediums are different
- Data transmission protocols over the air-interface are different from that of the wired infrastructure.
- All these translations are performed out the BSS.

Two architectural elements in the BSS

- BTS – Base Transceiver Subsystem
- BSC- Base Station Controller

3. Network and Switching Subsystem:

- Network and Switching Subsystem is responsible for Network operation

- It provides for communications with other wired and wireless Network's as well as support for registration and mainframe of the connection with the MSs.
- One Hardware element present in NSS is MSC- Mobile Switching Center
- Four Software elements present in NSS are – VLR, HLR, EIR, AUC.

HLR, VLR and EIR registers

- **Home Location Register** (**HLR**) - is a database maintained by the service provider containing **permanent data about each subscriber**
- **Visitor Location Register** (**VLR**) – database that stores **temporary data** about a subscriber; it is kept in the MSC of the of the area the subscriber is located in; when the subscriber moves to a new area the new MSC requests this VLR from the HLR of the old MSC
- **Equipment Identity Register** (**EIR**) – database located near the MSC and containing information identifying cell phones

Subscriber Identity Module (SIM) card

- SIM is a memory card (integrated circuit) holding identity information, phone book etc.
- GSM system support SIM cards
- Other systems, like **CDMA do not support SIM cards**, but have something similar called **Re-Usable Identification Module (RUIM)**

Authentication Center (AUC)

- It is a database that stores the list of authorized subscribers of a GSM network
- It is linked to the MSC and checks the identity of each user trying to connect
- It also provides encryption parameters to secure a call made in the network

GSM uplink/downlink frequency bands used

GSM Frequency band	Uplink/BTS Transmit -- FDMA technique	Downlink/BTS Receive -- CDMA technique
900 MHz	935-960 MHz	890-915 MHz
1800 MHz	1805-1880 MHz	1710-1785 MHz
1900 MHz	1930-1990 MHz	1850-1910 MHz

Basic Features Provided by GSM:

- **Call Waiting:** Notification of an incoming call while on the handset
- **Call Hold -** Put a caller on hold to take another call
- **Call Barring -** All calls, outgoing calls, or incoming calls
- **Call Forwarding -** Calls can be sent to various numbers defined by the user
- **Multi Party Call Conferencing -** Link multiple calls together

6. Explain Global Positioning System (GPS) in detail.*(Nov/Dec 2013,Nov/Dec 2011, April/May 2011, Nov/Dec 2010, April/May 2010, Nov/Dec 2009,May/June 2009)
Explain the working of Global Positioning System. [May 2021]

GPS –Global Positioning System

- GPS is NAVigational Satellite Timing And Ranging Global Positioning System (NAVSTAR GPS)
- Global Positioning Systems (GPS) is a form of Global Navigation Satellite System (GNSS)
  - ✓ Only completely functional one of its kind at this time
- Consists of two dozen GPS satellites in medium Earth orbit (The region of space between 2000km and 35,786 km)
- Made up of two dozen satellites working in unison are known as a satellite constellation
- A GPS receiver can tell its own position by using the position data of itself, and compares that data with 3 or more GPS satellites.
- To get the distance to each satellite, the GPS transmits a signal to each satellite.
  - ✓ The signal travels at a known speed.
  - ✓ The system measures the time delay between the signal transmission and signal reception of the GPS signal.
  - ✓ The signals carry information about the satellite's location.
  - ✓ Determines the position of, and distance to, at least three satellites, to reduce error.
  - ✓ The receiver computes position using trilateration.

GPS systems are made up of 3 segments

- ✓ Space Segment (SS)
- ✓ Control Segment (CS)
- ✓ User Segment (US)

Control Segment:

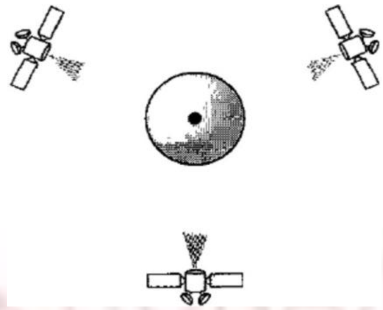
- The CS consists of 3 entities:
  - ✓ Master Control System
  - ✓ Monitor Stations
  - ✓ Ground Antennas

User Segment:

- GPS receivers are generally composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly-stable clock, commonly a crystal oscillator).
- They can also include a display for showing location and speed information to the user.
- A receiver is often described by its number of channels this signifies how many satellites it can monitor simultaneously.
- Recent receivers usually have between twelve and twenty channels.

Global Positioning System

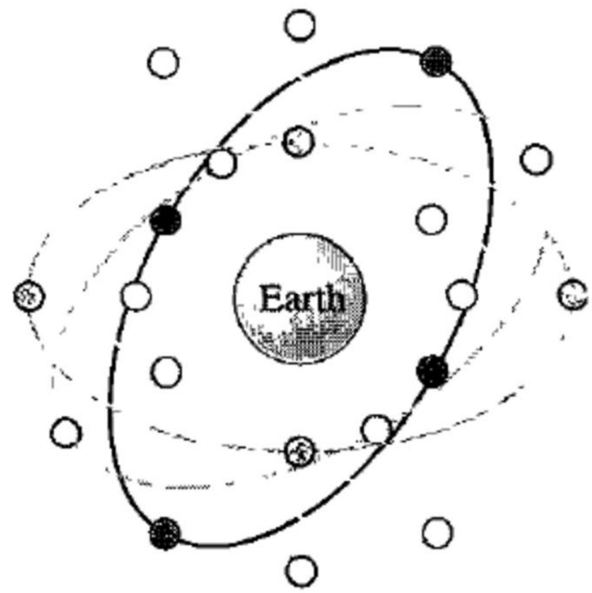
- The system consists of 24 satellites and is used for land, sea, and air navigation to provide time and locations for vehicles and ships.
- GPS uses 24 satellites in six orbits, as shown below.



Satellites in geostationary orbit

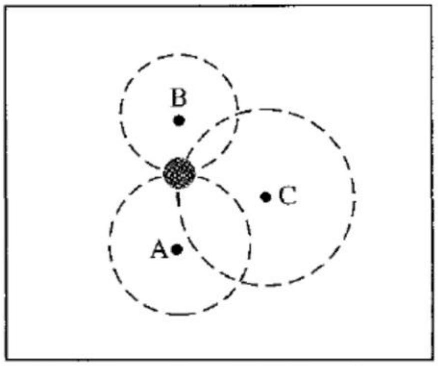
- The orbits and the locations of the satellites in each orbit are designed in such a way that, at any time, four satellites are visible from any point on Earth.
- A GPS receiver has an almanac that tells the current position of each satellite.

***Orbits for global positioning (GPS)* system.**

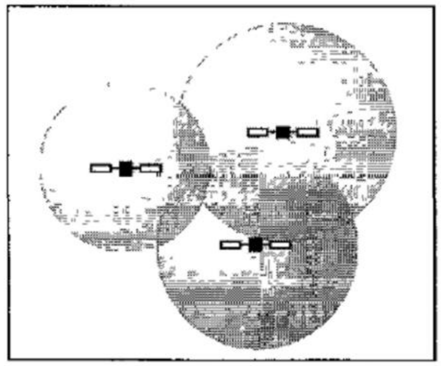


Trilateration:

- Determination of Location by GPS is based on a principle called **Trilateration**.
- The terms trilateration and triangulation are normally used interchangeably, which means using three distances, instead of triangulation, which may mean using three angles.
- On a plane, if we know our distance from three points, we know exactly where we are.
- Let us say that we are 10 miles away from point A, 12 miles away from point B, and 15 miles away from point C.
- If we draw three circles with the centers at A, B, and C, we must be somewhere on circle A, somewhere on circle B, and somewhere on circle C.
- These three circles meet at one single point (if our distances are correct), our position.
- Figure (a) shows the three-dimensional space, the situation is different.



a. Two-dimensional trilateration



b. Three-dimensional trilateration

Trilateration on a plane

- Three spheres meet in two points as shown in figure (b).
- We need at least four spheres to find our exact position m space (longitude, latitude, and altitude).

Procedures for Distance measurement:

- The trilateration principle can find our location on the earth if we know our distance from three satellites and know the position of each satellite.
- The position of each satellite can be calculated by a GPS receiver (using the predetermined path of the satellites).
- The GPS receiver, then, needs to find its distance from at least three GPS satellites (centet of the spheres).
- Measuring the distance is done using a principle called one-way ranging.
- For the moment, let us assume that all GPS satellites and the receiver on the Earth are synchronized.
- Each of 24 satellites synchronously transmits a complex signal each having a unique pattern.
- The computer on the receiver measures the delay between the signals from the satellites and its copy of signals to determine the distances to the satellites.

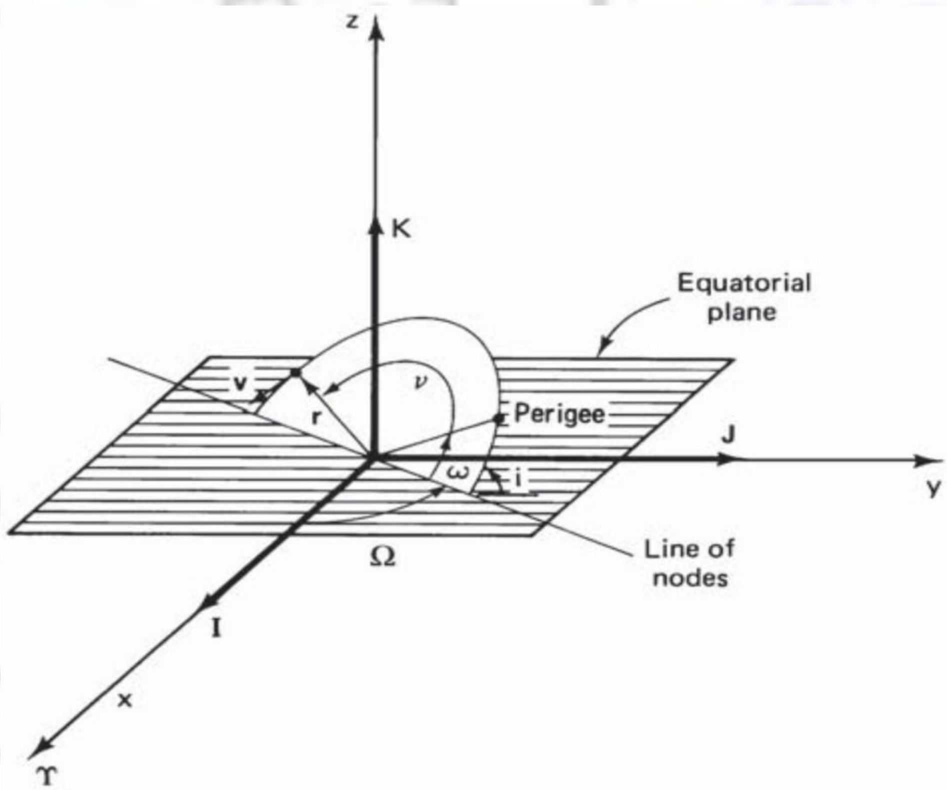
Synchronization:

- Satellites use atomic clock that are precise and can function synchronously with each other.
- There is an unknown offset between the satellite clocks and the receiver clock that introduces a corresponding offset in the distance calculation.
- Because of this offset, the measured distance is called a *pseudorange*.
- GPS uses an elegant solution to the clock offset problem, by recognizing that the offset's value is the same for all satellite being used.
- The calculation of position becomes finding four unknowns:
  - the Xr Yr zr coordinates of the receiver, and
  - common clock offset *dt*.
- There is a need to measure pesudoranges from four satellite instead of three.

- If we call the four measured pseudoranges PRl, PR2, PR3 and PR4 and the coordinates of each satellite xi, Yi, and zi (fori =1 to 4), we can find the four previously mentioned unknown values using the following four equations

$$PR_1 = [(x_l - X_r)^2 + (Y_t - Y_r)^2 + (z_l - Z_r)^2]^{1/2} + c \text{ X } dt$$
$$PR_2 = [(x_z - x_r)^2 + (yz - Y_r)^2 + (z_2 - z_r)^2]^{1/2} + c \text{ x } dt$$
$$PR_3 = [(x_3 - X_r)^2 + (y_3 - Y_r)^2 + (z_3 - zr)]^{1/2} + c \text{ X } dt$$
$$PR_4 = [(x_4 - x_r)^2 + (y_4 - y_r)^2 + (z_4 - z_r)^2]^{1/2} + c \text{ x } dt$$

- The coordinates used in the above formulas are in an Earth-Centered Earth-Fixed (ECEF) reference frame, which means that the origin of the coordinate space is at the center of the Earth and the coordinate space rotate with the Earth.
- This implies that the ECEF coordinates of a fixed point on the surface of the earth do not change.



Geocentric Equatorial Co-Ordinate (earth-centered, earth-fixed) system

***Issues That Affect Accuracy*:**

- Changing atmospheric conditions change the speed of the GPS signals as they pass through the Earth's atmosphere and ionosphere.
- Clock Errors can occur when, for example, a GPS satellite is boosted back into a proper orbit.
- GPS Jamming can be used to limit the effectiveness of the GPS signal
- GPS signals can also be affected by multipath issues

Methods of Improving Accuracy:

- **Precision monitoring**
- *Dual Frequency Monitoring*

- *Carrier-Phase Enhancement (CPGPS)*
- *Relative Kinematic Positioning (RKP)*
- **Augmentation**
  - Relies on external information being integrated into the calculation process.
  - Some augmentation systems transmit additional information about sources of error.
  - Some provide direct measurements of how much the signal was off in the past
  - Another group could provide additional navigational or vehicle information to be integrated in the calculation process.

Applications:–

- Military
- Automobiles
- For aircraft,
- Agriculture
- Disaster Relief
- Marine applications
- Railroad systems
- Recreational activities (returning to the same fishing spot)
- Heading information – replacing compasses now that the poles are shifting
- Weather Prediction
- Skydiving – taking into account winds, plane and dropzone location

INMARSAT

Discuss on INMARSAT ~~and VSAT~~ services in detail. [May 2022]

- **INMARSAT** was established as an international cooperative organization similar to INTELSAT, for providing satellite communications for ships and offshore industries.
- INMARSAT, a specialized agency of UN, was established in 1979 and became operational in 1982 as a maritime focused intergovernmental organization with headquarters located at London.
- INMARSAT establish and operate communication satellites for mobile services.
- INMARSAT has forty-four members and also provides services to nonmember countries.
- At present, INMARSAT has 10 satellites in the geostationary orbit.

They **cover four areas**:

- Atlantic Ocean - East (AOR-E)
- Atlantic Ocean - West (AOR-W)
- Indian Ocean (IOR)
- Pacific Ocean (POR).

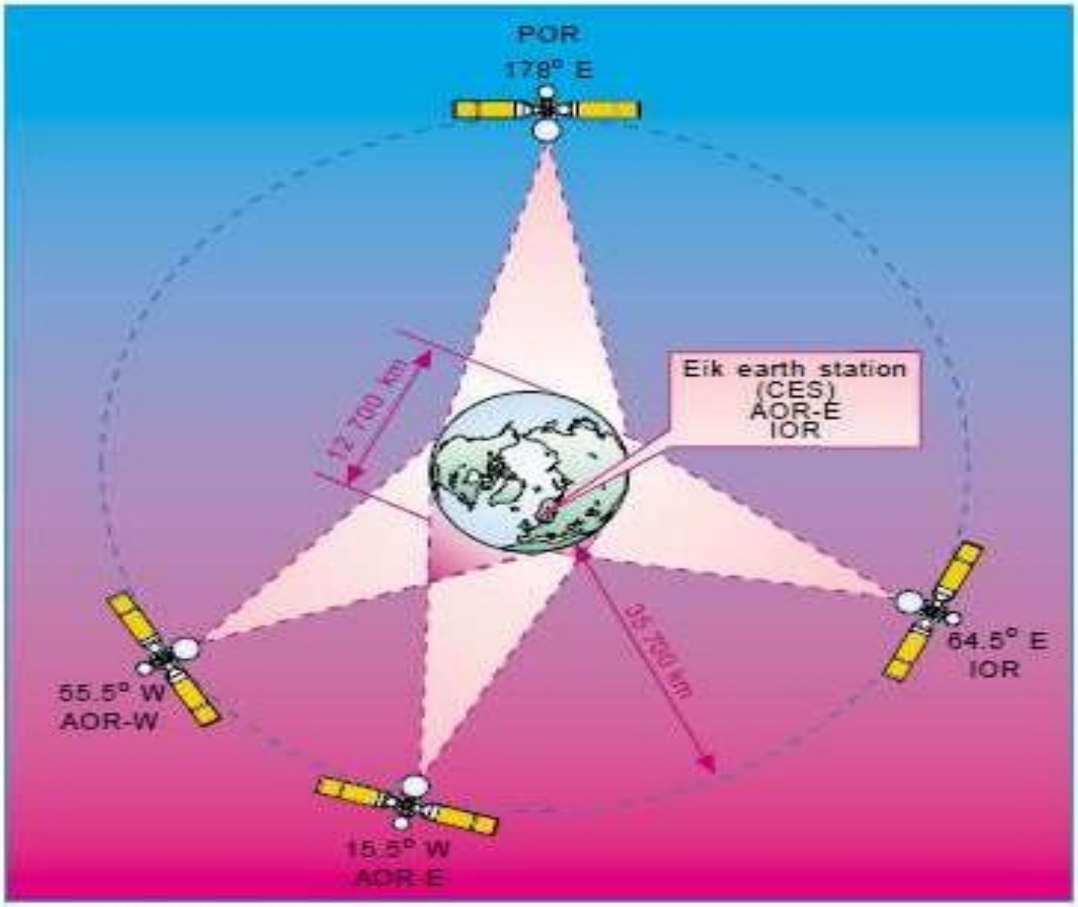


Figure 1 INMARSAT coverage area

- The INMARSAT system is made up of four main parts:
  - **The space segment**, comprising the satellites with their control stations (TT&C) and operational control
  - **The coastal earth stations (CES),** which connects the satellite transmission to the national and international telecommunication network
  - **The Network co-coordinating stations (NCS),** which handles the channel allocation in a coverage area
  - **Mobile earth station (MES),** i.e. the user terminal.

INMARSAT Features:

- INMARSAT system operates at C-band and L-band frequencies.
- The INMARSAT system uses allocations in the
  - ✓ 6 GHz band for the ground station to satellite link
  - ✓ 1.5 GHz for satellite terminal downlink
  - ✓ 1.6 GHz for terminal to satellite uplink and
  - ✓ 4 GHz for the satellite to ground station down link.

***INMARSAT series*:**

- **INMARSAT-A** has been operative since 1982.
- INMARSAT Type A mobile terminals meant for installation in large ships are quite expensive.

- It is a relatively large terminal (ca. 1 meter parabolic antenna) which is used for telephony (FM), telex and data.
- **INMARSAT-B**, which is the successor, is mainly like INMARSAT-A, but uses digital modulation.
  - This will give a better utilisation of the space segment and thereby lower prices.
- **INMARSAT-M** is a smaller and cheaper terminal which uses a lower bit rate for the telephone channel.
- Portable INMARSAT mini-M terminals are small, cost effective and easy to operate.

INMARSAT Services:

- Telephone, fax and data communications up to 64 kbps.
- Videotext, navigation, weather information and Search & Rescue.
- INMARSAT Satellites can also be used for emergency Land Mobile Communications for relief work and to re-establish communications or to provide basic service where there is no alternative.
- INMARSAT can also be used to alert people on shore for coordination of rescue activities. Apart from maritime and Land Mobile Satellite Service, INMARSAT also provide aeronautical satellite service for passenger communications

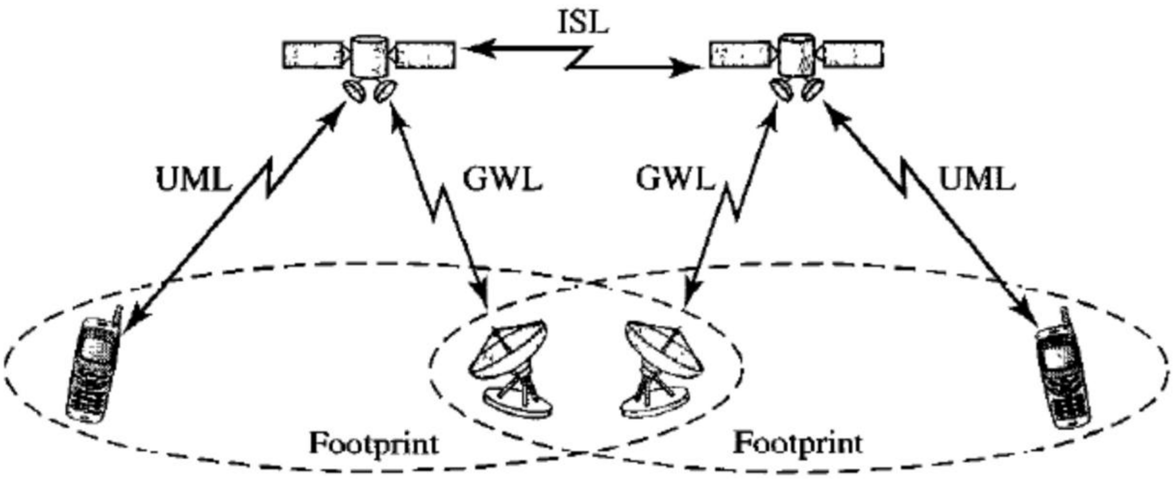
LEO Satellites:

LEO Satellites

- Low-Earth-orbit (LEO) satellites have polar orbits.
- The altitude is between 500 and 2000 km, with a rotation period of 90 to 120 min.
- The satellite has a speed of 20,000 to 25,000 km/h. An LEO system usually has a cellular type of access, similar to the cellular telephone system.
- The footprint normally has a diameter of 8000 km. Because LEO satellites are close to Earth, the round-trip time propagation delay is normally less than 20 ms, which is acceptable for audio communication.
- An LEO system is made of a constellation of satellites that work together as a network; each satellite acts as a switch.
- Satellites that are close to each other are connected through intersatellite links (ISLs).
- A mobile system communicates with the satellite through a user mobile link (UML).
- A satellite cmr also communicate with an Emth station (gateway) through a gateway link (GWL).
- Figure shows a typical LEO satellite network.

LEO satellite system

- LEO satellites can be divided into three categories:
  - ***little LEOs,***
  - ***big LEOs, and***
  - ***broadband LEOs***.
- The little LEOs operate under 1 GHz.

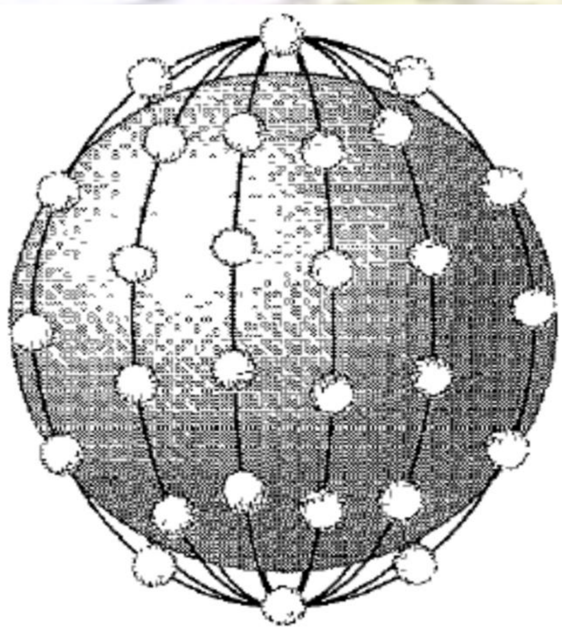


- They are mostly used for low-data-rate messaging.
- The big LEOs operate between 1 and 3 GHz.
- ***Globalstar and Iridium*** systems are examples of big LEOs.
- The broadband LEOs provide communication similar to fiberoptic networks.
- The first broadband LEO system was ***Teledesic.***

Iridium System

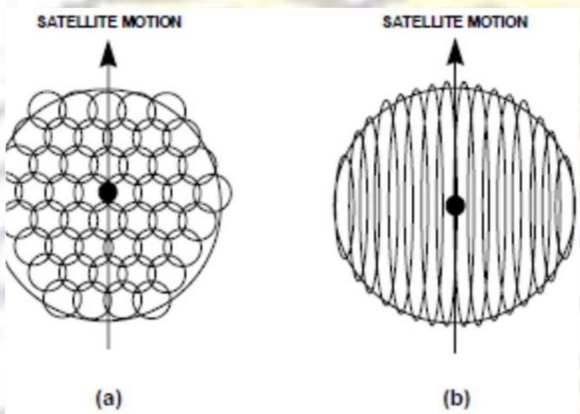
- The concept of the Iridium system, a 77 -satellite network, was started by Motorola in 1990.
- The original name, Iridium, came from the name of the 77th chemical element; a more appropriate name is Dysprosium (the name of element 66).
- The system has 66 satellites divided into six orbits, with 1 1 satellites in each orbit.
- The orbits are at an altitude of 750 km.
- The satellites in each orbit are separated from one another by approximately 32° of latitude.
- The schematic diagram of the constellation is shown below,

lridium constellation



- The Iridium system has 66 satellites in six LEO orbits, each at an altitude of 750 km.

- Since each satellite has 48 spot beams, the system can have up to 3168 beams.
- However, some of the beams are turned off as the satellite approaches the pole.
- The number of active spot beams at any moment is approximately 2000.
- Each spot beam covers a cell on Earth, which means that Earth is divided into approximately 2000 (overlapping) cells.
- In the Iridium system, communication between two users takes place through satellites.
- When a user calls another user, the call can go through several satellites before reaching the destination.
- This means that relaying is done in space and each satellite needs to be sophisticated enough to do relaying.
- This strategy eliminates the need for many terrestrial stations.
- The whole purpose of Iridium is to provide direct worldwide communication using handheld terminals (same concept as cellular telephony).
- The system can be used for voice, data, paging, fax, and even navigation.
- The system can provide connectivity between users at locations where other types of communication are not possible.



LEO spot beam patterns. (a) Iridium; (b) Globalstar.

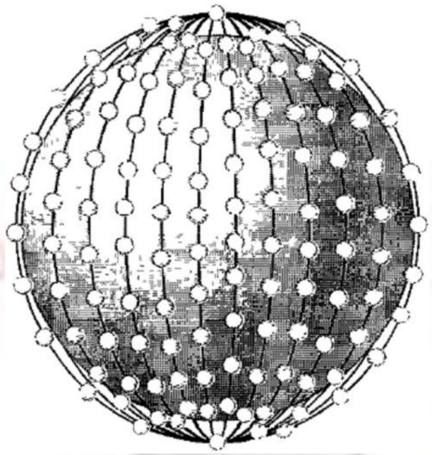
Globalstar

- Globalstar is another LEO satellite system.
- The system uses 48 satellites in six polar orbits with each orbit hosting eight satellites.
- The orbits are located at an altitude of almost 1400 km.
- The Globalstar system is similar to the Iridium system; the main difference is the relaying mechanism Communication between two distant users in the Iridium system requires relaying between several satellites.
- Globalstar communication requires both satellites and Earth stations, which means that ground stations can create more powerful signals.

Teledesic

- Teledesic is a system of satellites that provides fiber-optic-like (broadband channels,low error rate, and low delay) communication.
- Its main purpose is to provide broadband Internet access for users all over the world.
- It is sometimes called "Internet in the sky."

- Constellation Teledesic provides 288 satellites in 12 palm orbits with each orbit hosting 24 satellites. The orbits are at an altitude of 1350 km.



- Teledesic has 288 satellites in 12 LEO orbits, each at an altitude of 1350 km.
- The system provides three types of communication.
- lntersatellite communication allows eight neighboring satellites to communicate with one another.
- Communication is also possible between a· satellite and an Earth gateway station.
- Users can communicate directly with the network using terminals.
- Earth is divided into tens of thousands of cells.
- Each cell is assigned a time slot, and the satellite focuses its beam to the cell at the corresponding time slot.
- The terminal can send data during its time slot.
- A terminal receives all packets intended for the cell, but selects only those intended for its address.
- **Bands--** Transmission occurs in the Ka bands.
- **Data Rate--** The data rate is up to 155 Mbps for the uplink and up to 1.2 Gbps for the downlink.

MEO Satellites:

7. Write a brief notes on the advantages and disadvantages of using satellites in LEOs, MEOs and GEOs for mobile satellite communications. (Nov/Dec 2013,May/June 2009)

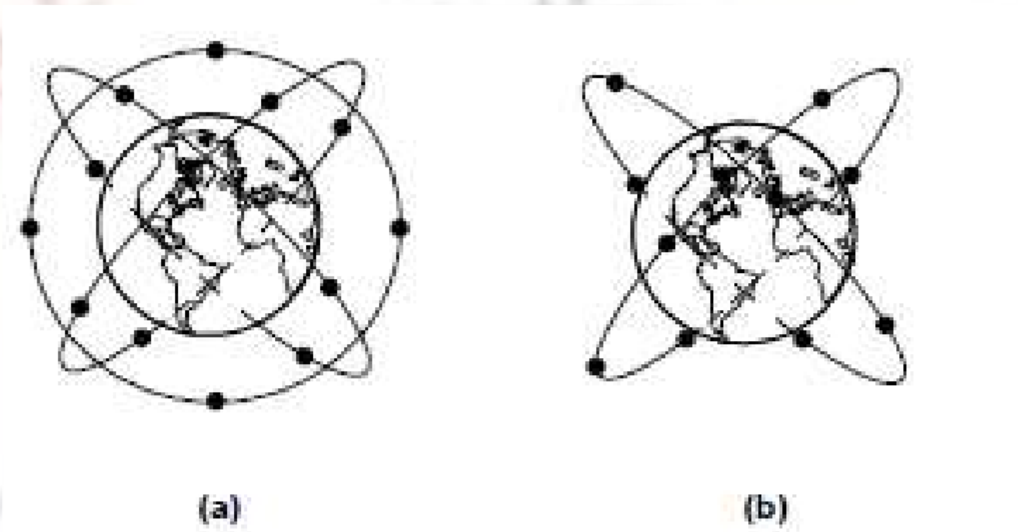
- Medium-Earth-orbit (MEO) satellites are positioned between the two Van Allen belts.

A satellite at this orbit takes approximately 6-8 hours to circle the Earth.

The MEO Odyssey satellite system

- This key feature of the Odyssey system allows multiple satellite coverage over high-population-density land areas while simultaneously maintaining single-satellite coverage of other areas including ocean regions.
- Odyssey does not use satellite diversity.
- Each spacecraft has three gimbal mounted Ka-band antennas, independently pointing toward earth for control links.

- Each satellite has 37 spot beams for mobile up- and downlinks.
- The 6-h orbital period means handovers are unnecessary for the MEO system.
- Satellite crosslinks are not needed, thereby considerably reducing system complexity.
- The MEO link margin should generally offer a high availability of service.
- The Odyssey plan has six satellites in orbit at the end of 1999 and the full 12 at the end of 2000.
- The power limitation in handsets used in MEO systems and the need for synchronization between terminals does not favor the choice of TDMA operation.
- Odyssey uses CDMA, with mobile uplinks in the L-band and downlinks in S-band.
- Three channels, each of 4.833 MHz, are used for DSSS. Each 4.833-MHz signal is BPSK modulated. Mobile terminal transmit power is in the range 0.5 to 5.0 W.



MEO orbits. (a) Odyssey; (b) INMARSAT-P (ICO).

The INMARSAT-P (I-CO) MEO system

- INMARSAT has embarked on a project that will also be a MEO satellite system.
- This project, called I-CO, was previously known as INMARSAT-P and will operate 10 satellites in MEO and two spares in two separate MEO planes.
- This 10-satellite constellation operates 5 satellites in each of two 45° inclined orbits
- At present, the system design is still evolving; currently its high capacity derives from 163 beams to and from each satellite to earth, with each beam steerable so as to remain geographically fixed during traffic activity.
- Because each beam contains 28 channels, the capacity is 4564 simultaneous calls per satellite.
- Satellite diversity is used to enhance availability by reducing the effects of shadowing. Mobile terminal up- and downlinks are in the IMT-2000 2-GHz bands.
- Although “bent pipe” transponders route calls from mobiles to their nearest earth stations as do Odyssey and Globalstar, frequencies are reused similar to Iridium (geographically fixed and in this case a four-cell reuse).
-

5.4.6 Satellite Navigational System

Discuss the position location principle involved in GPS. [Dec 2021]

GPS Position Location Principles

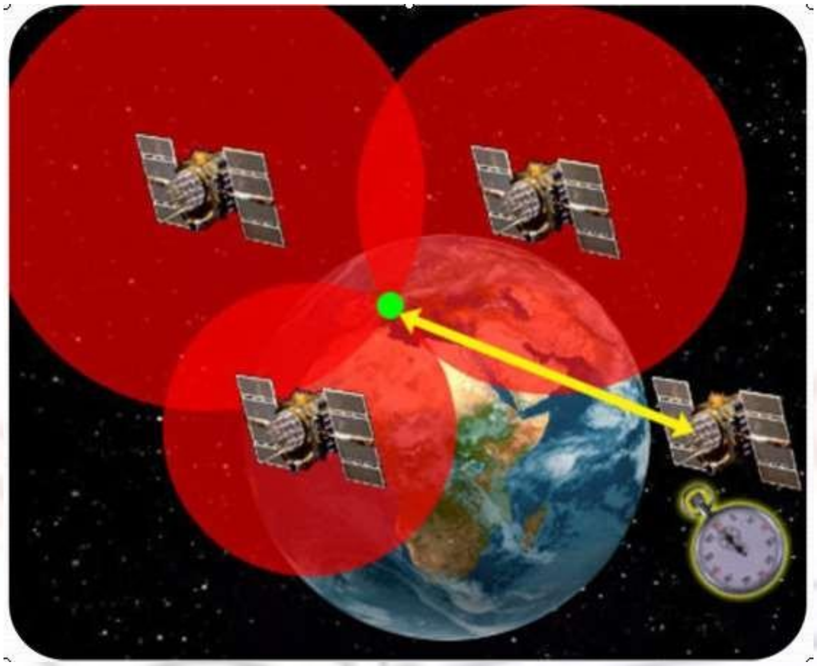
Overview

- Official name of GPS is NAVigational Satellite Timing And Ranging Global Positioning System (NAVSTAR GPS)
- Global Positioning Systems (GPS) is a form of Global Navigation Satellite System (GNSS)
  - Only completely functional one of its kind at this time
- First developed by the United States Department of Defense
- Consists of two dozen GPS satellites in medium Earth orbit (The region of space between 2000km and 35,786 km)
- Made up of two dozen satellites working in unison are known as a satellite constellation
- This constellation is currently controlled by the United States Air Force 50th Space Wing
- It costs about $750 million to manage and maintain the system per year
- Mainly used for navigation, map-making and surveying

Operation Overview

- A GPS receiver can tell its own position by using the position data of itself, and compares that data with 3 or more GPS satellites.
- To get the distance to each satellite, the GPS transmits a signal to each satellite.
  - The signal travels at a known speed.
  - The system measures the time delay between the signal transmission and signal reception of the GPS signal.
  - The signals carry information about the satellite's location.
  - Determines the position of, and distance to, at least three satellites, to reduce error.
  - The receiver computes position using trilateration.

Trilateration



Explain with diagram the function of single frequency C/A code GPS receiver. [Dec 2021] [Nov/Dec 2022]

GPS Functionality

- GPS systems are made up of 3 segments
  - Space Segment (SS)
  - Control Segment (CS)
  - User Segment (US)

Space Segment

- GPS satellites fly in circular orbits at an altitude of 20,200 km and with a period of 12 hours.
- Powered by solar cells, the satellites continuously orient themselves to point their solar panels toward the sun and their antenna toward the earth.
- Orbital planes are centered on the Earth
- Each planes has about 55° tilt relative to Earth's equator in order to cover the polar regions.
- Each satellite makes two complete orbits each sidereal day.
- Sidereal - Time it takes for the Earth to turn 360 degrees in its rotation
- It passes over the same location on Earth once each day.
- Orbits are designed so that at the very least, six satellites are always within line of sight from any location on the planet.
- There are currently 30 actively broadcasting satellites in the GPS constellation.
- Redundancy is used by the additional satellites to improve the precision of GPS receiver calculations.
- A non-uniform arrangement improves the reliability and availability of the system over that of a uniform system, when multiple satellites fail
- This is possible due to the number of satellites in the air today

Control Segment

- The CS consists of 3 entities:
  - Master Control System
  - Monitor Stations
  - Ground Antennas

Master Control Station

- The master control station, located at Falcon Air Force Base in Colorado Springs, Colorado, is responsible for overall management of the remote monitoring and transmission sites.
- GPS ephemeris is the tabulation of computed positions, velocities and derived right ascension and declination of GPS satellites at specific times for eventual upload to GPS satellites.

Monitor Stations

- Six monitor stations are located at Falcon Air Force Base in Colorado, Cape Canaveral, Florida, Hawaii, Ascension Island in the Atlantic Ocean, Diego Garcia Atoll in the Indian Ocean, and Kwajalein Island in the South Pacific Ocean.
- Each of the monitor stations checks the exact altitude, position, speed, and overall health of the orbiting satellites.
- The control segment uses measurements collected by the monitor stations to predict the behavior of each satellite's orbit and clock.
- The prediction data is up-linked, or transmitted, to the satellites for transmission back to the users.
- The control segment also ensures that the GPS satellite orbits and clocks remain within acceptable limits. A station can track up to 11 satellites at a time.
- This "check-up" is performed twice a day, by each station, as the satellites complete their journeys around the earth.
- Variations such as those caused by the gravity of the moon, sun and the pressure of solar radiation, are passed along to the master control station.

Ground Antennas

- Ground antennas monitor and track the satellites from horizon to horizon.
- They also transmit correction information to individual satellites.

User Segment

- The user's GPS receiver is the US of the GPS system.
- GPS receivers are generally composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly-stable clock, commonly a crystal oscillator).
- They can also include a display for showing location and speed information to the user.

- A receiver is often described by its number of channels this signifies how many satellites it can monitor simultaneously. As of recent, receivers usually have between twelve and twenty channels.
- Using the RTCM SC-104 format, GPS receivers may include an input for differential corrections.
- This is typically in the form of a RS-232 port at 4,800 bps speed. Data is actually sent at a much lower rate, which limits the accuracy of the signal sent using RTCM.
- Receivers with internal DGPS receivers are able to outclass those using external RTCM data.

Navigational Systems

- GPS satellites broadcast three different types of data in the primary navigation signal.
  - Almanac – sends time and status information about the satellites.
  - Ephemeris – has orbital information that allows the receiver to calculate the position of the satellite.
    - This data is included in the 37,500 bit Navigation Message, which takes 12.5 minutes to send at 50 bps.
- Satellites broadcast two forms of clock information
  - Coarse / Acquisition code (C/A) - freely available to the public. The C/A code is a 1,023 bit long pseudo-random code broadcast at 1.023 MHz, repeating every millisecond.
  - Restricted Precise code (P-code) - reserved for military usage. The P-code is a similar code broadcast at 10.23 MHz, but it repeats only once a week. In normal operation, the anti-spoofing mode, the P code is first encrypted into the Y-code, or P(Y), which can only be decrypted by users a valid key.

GPS Frequencies

- L1 (1575.42 MHz) - Mix of Navigation Message, coarse-acquisition (C/A) code and encrypted precision P(Y) code.
- L2 (1227.60 MHz) - P(Y) code, plus the new L2C code on the Block IIR-M and newer satellites.
- L3 (1381.05 MHz) - Used by the Defense Support Program to signal detection of missile launches, nuclear detonations, and other applications.

GPS Proposed Frequencies

- L4 (1379.913 MHz) - Being studied for additional correction to the part of the atmosphere that is ionized by solar radiation.
- L5 (1176.45 MHz) – To be used as a civilian safety-of-life (SoL) signal.
  - Internationally protected range for aeronautical navigation.
  - The first satellite that using this signal to be launched in 2008.

Position Calculation

- The coordinates are calculated according to the World Geodetic System WGS84 coordinate system.

- The satellites are equipped with atomic clocks
- Receiver uses an internal crystal oscillator-based clock that is continually updated using the signals from the satellites.
- Receiver identifies each satellite's signal by its distinct C/A code pattern, then measures the time delay for each satellite.
- The receiver emits an identical C/A sequence using the same seed number the satellite used.
- By aligning the two sequences, the receiver can measure the delay and calculate the distance to the satellite, called the pseudorange.
- Orbital position data from the Navigation Message is used to calculate the satellite's precise position. Knowing the position and the distance of a satellite indicates that the receiver is located somewhere on the surface of an imaginary sphere centered on that satellite and whose radius is the distance to it.
- When four satellites are measured at the same time, the point where the four imaginary spheres meet is recorded as the location of the receiver.
- Earth-based users can substitute the sphere of the planet for one satellite by using their altitude. Often, these spheres will overlap slightly instead of meeting at one point, so the receiver will yield a mathematically most-probable position.

Issues That Affect Accuracy

- Changing atmospheric conditions change the speed of the GPS signals as they pass through the Earth's atmosphere and ionosphere.
  - Effect is minimized when the satellite is directly overhead
  - Becomes greater for satellites nearer the horizon, since the signal is affected for a longer time.
  - Once the receiver's approximate location is known, a mathematical model can be used to estimate and compensate for these errors.
- Clock Errors can occur when, for example, a GPS satellite is boosted back into a proper orbit.
  - The receiver's calculation of the satellite's position will be incorrect until it receives another ephemeris update.
  - Onboard clocks are accurate, but they suffer from partial clock drift.
- GPS Jamming can be used to limit the effectiveness of the GPS signal
  - For example, it is believed GPS guided missles have been misled to attack non-target locations in the war in Afghanistan.
  - The stronger the jamming signal, the more interference can be caused to the GPS signal.
- GPS signals can also be affected by multipath issues
  - Radio signals reflect off surrounding objects at a location. These delayed signals can cause inaccuracy.
  - Less severe in moving vehicles. When the GPS antenna is moving, the false solutions using reflected signals quickly fail to converge and only the direct signals result in stable solutions.

Methods of Improving Accuracy

- Precision monitoring
  - Dual Frequency Monitoring

        - Refers to systems that can compare two or more signals
        - These two frequencies are affected in two different ways. How they are affected can be predicted however
        - After monitoring these signals, it's possible to calculate what the error is and eliminate it
        - Receivers that have the correct decryption key can decode the P(Y)-code transmitted on signals to measure the error.
    - Carrier-Phase Enhancement (CPGPS)
        - CPGPS uses the L1 carrier wave, which has a period 1000 times smaller than that of the C/A bit period, to act as an additional clock signal and resolve uncertainty.
        - The phase difference error in the normal GPS amounts to between 2 and 3 meters (6 to 10 ft) of ambiguity.
        - CPGPS works to within 1% of perfect transition to reduce the error to 3 centimeters (1 inch) of ambiguity.
        - By eliminating this source of error, CPGPS coupled with DGPS normally realizes between 20 and 30 centimeters (8 to 12 inches) of absolute accuracy.
    - Relative Kinematic Positioning (RKP)
        - Determination of range signal can be resolved to an accuracy of less than 10 centimeters (4 in).
        - Resolves the number of cycles in which the signal is transmitted and received by the receiver.
        - Accomplished by using a combination of DGPS correction data, transmitting GPS signal phase information and ambiguity resolution techniques via statistical tests — possibly with processing in real-time.
- Augmentation
    - Relies on external information being integrated into the calculation process.
    - Some augmentation systems transmit additional information about sources of error.
    - Some provide direct measurements of how much the signal was off in the past
    - Another group could provide additional navigational or vehicle information to be integrated in the calculation process.

Applications – Military

- Military GPS user equipment has been integrated into fighters, bombers, tankers, helicopters, ships, submarines, tanks, jeeps, and soldiers' equipment.
- In addition to basic navigation activities, military applications of GPS include target designation of cruise missiles and precision-guided weapons and close air support.
- To prevent GPS interception by the enemy, the government controls GPS receiver exports
- GPS satellites also can contain nuclear detonation detectors.

Applications – Civilian

- Automobiles are often equipped GPS receivers.
    - They show moving maps and information about your position on the map, speed you are traveling, buildings, highways, exits etc.

  - Some of the market leaders in this technology are Garmin and TomTom, not to mention the built in GPS navigational systems from automotive manufacturers.

- For aircraft, GPS provides
  - Continuous, reliable, and accurate positioning information for all phases of flight on a global basis, freely available to all.
  - Safe, flexible, and fuel-efficient routes for airspace service providers and airspace users.
  - Potential decommissioning and reduction of expensive ground based navigation facilities, systems, and services.
  - Increased safety for surface movement operations made possible by situational awareness.

- Agriculture
  - GPS provides precision soil sampling, data collection, and data analysis, enable localized variation of chemical applications and planting density to suit specific areas of the field.
  - Ability to work through low visibility field conditions such as rain, dust, fog and darkness increases productivity.
  - Accurately monitored yield data enables future site-specific field preparation.

- Disaster Relief
  - Deliver disaster relief to impacted areas faster, saving lives.
  - Provide position information for mapping of disaster regions where little or no mapping information is available.
  - Example, using the precise position information provided by GPS, scientists can study how strain builds up slowly over time in an attempt to characterize and possibly anticipate earthquakes in the future.

- Marine applications
  - GPS allows access to fast and accurate position, course, and speed information, saving navigators time and fuel through more efficient traffic routing.
  - Provides precise navigation information to boaters.
  - Enhances efficiency and economy for container management in port facilities.

- Other Applications not mentioned here include
  - Railroad systems
  - Recreational activities (returning to the same fishing spot)
  - Heading information – replacing compasses now that the poles are shifting
  - Weather Prediction
  - Skydiving – taking into account winds, plane and dropzone location

Differential GPS

https://www.oc.nps.edu/oc2902w/gps/dgpsnote.html

**** Explain Differential Global Positioning System (GPS) in detail.**
Show with block diagram how L1 and L2 signals are generated on board a GPS satellite. [Nov/Dec 2022]

- The Global Positioning System delivers about 6m horizontal error and 10m in three dimensions to a dual frequency user.
- This was much worse for the civilian user before the intentional degradation of the signal was removed.
- It likely will improve in the future.

- Differential GPS works by having a reference system at a known location measure the errors in the signals and send corrections to users in the "local" area.
- These corrections will not be universal, but will be useful over a significant area.
- The corrections are normally sent every few seconds.
- The user is generally some mobile platform such as a ship, car, truck or even an aircraft.

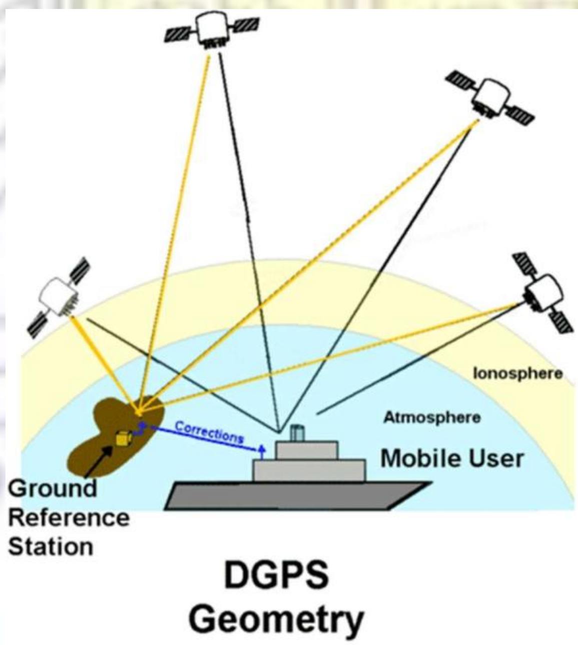


Figure 1

- For the majority of civilian users single frequency receivers are used.
- The public ranging modulation is currently only on the L1 signal.
- The only ranging signal on L2 is encrypted.
- The exceptions are survey and scientific systems that use expensive receivers with methods to work around the L2 encryption.
- The single frequency user must deal with the error produced as the signals go through the ionosphere.

- The second frequency was put on the GPS satellites to allow real time removal of the ionospheric error.
- It does this to an accuracy better than 1cm.

- The use of differential GPS produces a position solution much more accurate than that of the standalone user, either civilian or military.
- It does this even for the single frequency receivers.
- In fact all common DGPS systems work only with the L1 frequency signal, even if the receiver can track both L1 and L2 frequencies.
- It is common today to have ships navigating on DGPS with 1 to 2 meter position accuracy.

- This note will address the broad topics that lead to the GPS errors, how DGPS corrects for them, the different DGPS techniques and philosophies.

Errors in GPS Range Measurements.

- Differential GPS works by measuring the errors in GPS signals at a reference station(s) and sending the corrections to users.
- The errors in the signal at then antenna should be almost the same for another receiver close by.
- The definition of "close" depends on the specific error.

- A diagram of the errors in a GPS range measurement is shown in Figure 2.
- The true range, on the top line, is the value needed for navigation.
- It is between 20,000 and 40,000 km.
- The other large value on that line, the receiver clock error, is estimated each time a solution is performed.
- It can be thousands of kilometers in some receivers.
- The estimation of the receiver clock error is usually is done each time a new solution is done in a navigation receiver commonly every second.
- The "other" item on the top line is expanded below.
- It is only a few 10s of meters at most.

- The Selective Availability (SA), when it was turned on, had a standard deviation of about 30 meters.
- It was usually the dominant error for the civilian GPS user.
- It is zero now.
- However, when it was on, it was totally removed by DGPS systems.

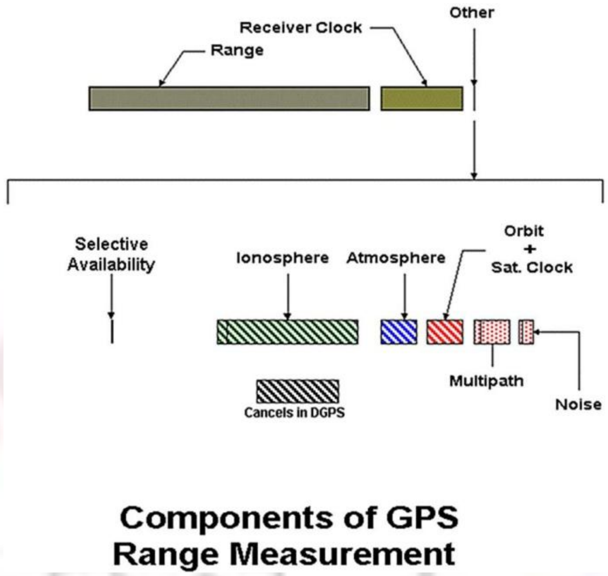


Figure 2

- The ionosphere error varies greatly with time of day, location, and the solar cycle.
- It also is a function of elevation angle.
- Low elevation angle lines of sight have a longer path length within the ionosphere than vertical paths.
- At night for high elevation angles the ionospheric error can be as low as 1 meter.
- In late afternoon, in the tropics, at solar maximum, a 20 degree elevation angle observation could have a 50 m ionospheric error.
- Ionosphere errors in the tropics at the 10 to 30 m level are common.

- The atmospheric error is about 2.5 m for a vertical line of sight.
- It varies in a very predictable way and is well modeled in most receivers.
- Only at angles below 5 degrees do complex bending effects come into play.
- Only very precise scientific work needs to go beyond the standard modeling for this error.
- The ionosphere is the dominant error for single frequency user.
- The last three errors are the dominant error sources for a dual frequency user.
- They are also important for the single frequency user.

- In order to navigate, not only are good ranges needed, but also the location of the end point of the range.
- That is, the positions of the satellites are required.
- Providing this information is the job of the US Air Force, which runs the GPS system.
- They use a series of monitor stations to acquire data in real time and estimate the position, velocity, and satellite clock error of each satellite every 15 minutes.
- They use these solutions to make a prediction of the satellite parameters for the following day.
- These predictions are then parameterized and loaded into the satellite onboard memory.
- This data is sent to the user on the GPS signal. It is called the Broadcast Ephemeris (BCE).
- On average this prediction will be 12 hours old.

- The largest error will be the satellite clock error.

- If all the satellite clocks are not synchronized, navigation is degraded. Setting all the GPS satellite clocks to a form of Universal Time Coordinated (UTC) accomplishes this. (The time differs from UTC by some integer number of seconds. For this reason it is called GPS Time.)
- Even though extremely good atomic clocks are on each satellite, there is a wander in the clocks.
- This is a random process and cannot be modeled. There may also be some residual systematic error in the predicted clock state.

- All these errors, which are marked with a diagonal bar in Figure 2, are the same for close receivers. These are the errors that are removed in DGPS systems.

- There are two remaining errors that are specific to individual receivers.
- The multipath error is caused by reflections of the GPS signals from metal objects near the antenna.
- DGPS reference stations go to great lengths to minimize this error though good antenna locations.
- The DGPS user may not have this option.
- The last error is the thermal noise inside the receiver.
- This is a function of the individual receiver design.
- It is lower in more expensive receivers.
- However each year the receiver noise level on new receivers decreases some.
- It is like the increase in speed on computers, but not quite as dramatic a change.
- Today the receiver noise varies from 2 m to 10 cm for civilian receivers.

- Today the ionosphere and Orbit-and-Clock errors are usually the dominant errors for the civilian navigator.
- DGPS essentially removes these.
- The orbit error is only slightly different for users within a 1000 km or so of the reference station.
- That cannot be said of the ionosphere error. Its change with distance from the reference station is discussed later under ionospheric divergence.

- The remaining issues in designing or choosing a DGPS system are how to get the errors to the user, and what solution technique to use.

Correction Parameterization and Distribution

- There are two approaches to parameterizing the errors measured by the reference station(s).
- In the most common approach, the range error is measured for each satellite and these satellite by satellite errors sent to the user.
- This is a point approach.
- It is valid at the reference receiver. Its validity will decrease with distance from that site.

- In the second approach multiple stations are used to estimate the errors over an extended area.
- This is called Wide Area DGPS (WADGPS).
- The Federal Aviation Administrations (FAA) Wide Area Augmentation System (WAAS) is this type of system.
- There are also commercial systems of this type.
- The corrections are parameterized in a way that allows the user to compute corrections based on his location.
- Two users separated by a 100 km or so will get different corrections from the same WADGPS parameter set.

- In both these cases the information volume is quite small.
- A few hundred bytes contain one set of corrections for all the satellites in an area.
- The corrections are sent at different rates by different systems.
- Six second updates are common.
- The more accurate systems use one second updates.
- This is still a very low data rate.
- Note that distribution of the corrections is just a communication problem.

- Standard DGPS systems normally distribute the corrections to the user over a radio link.
- The US Coast Guard has an existing system of directional radio beacons in the 275 to 325 kHz band.
- It chose to modulate the DGPS corrections from its reference stations on these signals.
- If it were not for ionospheric divergence (see below) the only limitation on the use of the US Coast Guard DGPS signals would the range at which these radio beacons can be received.
- A map showing the USCG West Coast sites, the broadcast frequencies, and their official coverage areas is shown in Figure 3.
- The original USCG system covered the West Coast, the East Coast, the Gulf Coast, the Great Lakes, and the Mississippi River.
- As seen on the map, new inland sites are now being added to the system.

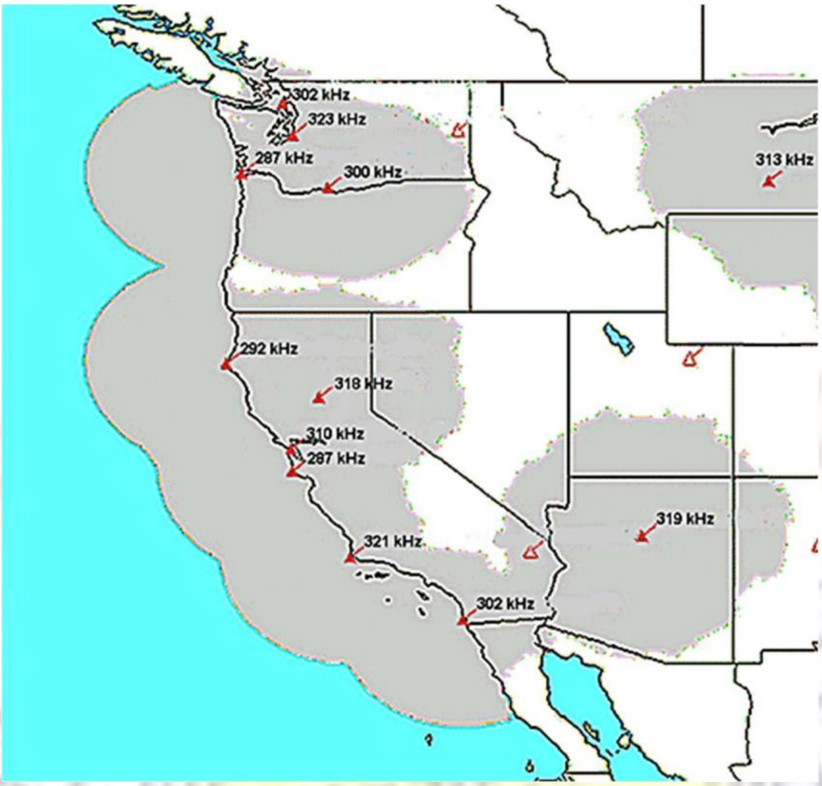


Figure 3

- The FAA uses a geostationary satellite to broadcast the WAAS corrections.
- The satellite has a transponder and just retransmits a signal originating on the ground.
- This same approach is used by at least one commercial service that provides WADGPS.

- Some other commercial services put the data on a sub-carrier on FM radio broadcasts.
- For science and surveying applications, a special radio link is often set up.
- This is usually done when a dedicated reference site is installed for a particular survey or science study or campaign.
- There are also experimental systems that deliver the corrections over the Internet.

- The format of the correction information varies.
- There are now two public formats, the RTCM-104 and the WAAS.
- The RTCM or Radio TeleCommunications, Marine, is a standards organization.
- The format was generated by its special committee number 104.
- The WAAS was designed by a similar industry/government organization, the RTCA.
- In addition many manufactures of high end equipment have a proprietary format.
- The manufacturers' formats are often aimed at the more precise DGPS method called Kinematics.

- The RTCM format was adopted by the US Coast Guard.
- This has lead to its wide acceptance.
- Essentially all receivers that do DGPS positioning accept RTCM-104 as one of their input formats.

- The FAAs WAAS format has been standardized more recently.
- However, because the signal is available thought out North America on a free basis, it is being incorporated into many receivers. (The WAAS is currently in a test and evaluation phase.)
- The WAAS format is mandated for use in aircraft, but boat, car and handheld GPS receivers are available that use it.
- This format has more error checking than the RTCM format because it is designed for a "safety of life" function.

- In most cases, a separate receiver is used to receive the DGPS corrections.
- These are then feed to the GPS receiver over a RS232 serial line.
- With this architure, the corrections could come from any of several sources.
- In some instances multiple sources are on ships and a simple switch is used to change between sources.
- In other cases standard sources (such as the US Coast Guard) are received at some convenient location and relayed by other means, such as cell telephone or VHF/UHF radio links, to the user.

Ionospheric Divergence

- The normal limitation on the utility of DGPS corrections is the difference in the ionospheric error seen by the reference station and the user.
- This ionospheric error is determined by the ionospheric conditions where the line of sight passes through 300 to 400 km altitude.
- For a vertical ray, this is overhead.
- For a low elevation ray it can be 1500 km away (about 15 degrees of earth central angle).

- The ionosphere is much more variable than the atmosphere.
- It most dramatic variation is from day to night. It essentially goes away late at night.
- It rebuilds quickly at dawn and then intensifies thought the day.
- Its decay after sunset is gradual. Maps of the peak electron density of the ionosphere are shown in Figures 4 and 5.
- These values are proportional to the ionospheric error.
- The plots are for 1800 UT, when sunrise is in the Pacific and sunset over the zero of longitude line.
- Sunrise at 300 km occurs before it does on the ground.

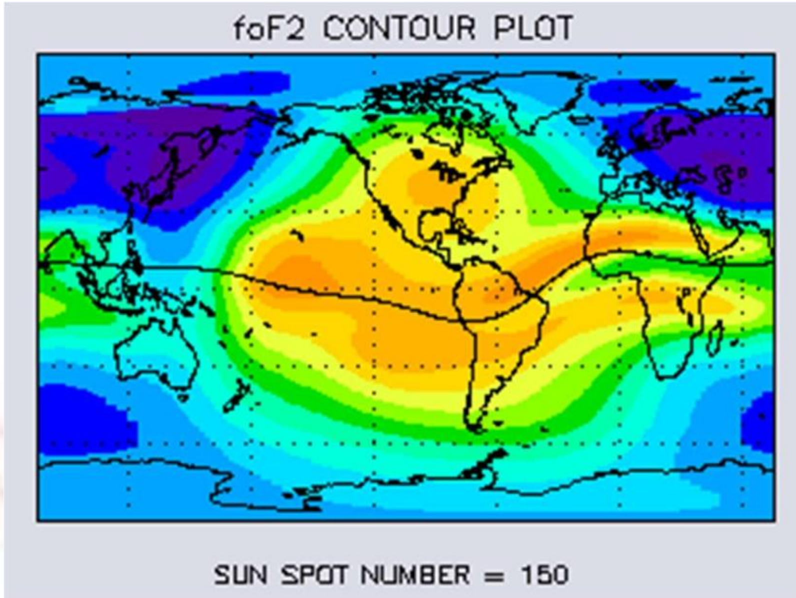


Figure 4

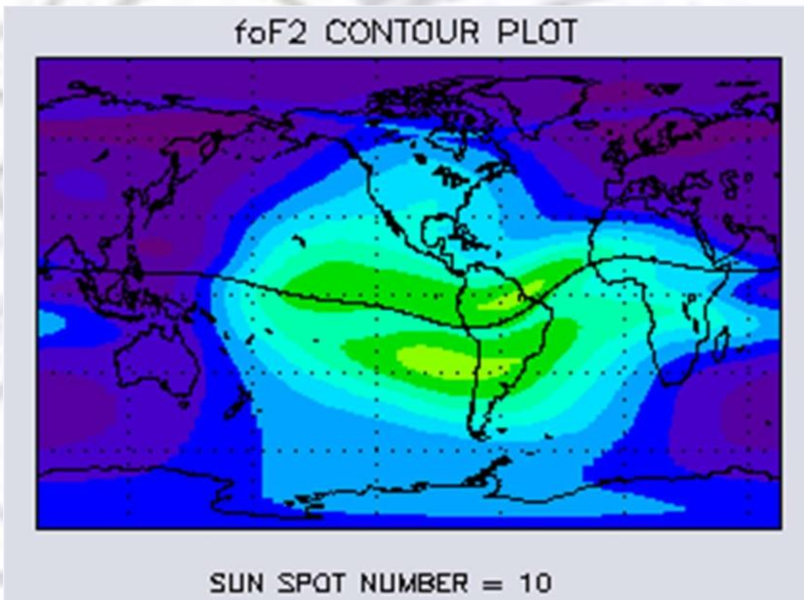


Figure 5

- The data in Figure 4 is for solar maximum.
- This occurred in 2000-2001 for the current solar cycle. The solar cycle is about 11 years long.
- Therefore the next minimum should occur in 2006.

- The two humps during the day are caused by the magnetic field of the earth.
- The peaks are about 12 degrees north and south of the geomagnetic equator, which is shown as a line on these plots.
- The precise location of these "equatorial anomalies" can vary from day to day.
- These figures are analogous to climate models, not weather data.

- The spatial gradients on the sides of these peaks will be where the largest spatial divergences in DGPS signals occur.

- There are also large gradients a dawn.
- Note that satellites to the south at 20 degrees elevation angle seen from the extreme southern US will be seen though this gradient on some days.
- Sites nearer the equator will experience this more often and at higher elevation angles.

Solution Method

- There are two common methods of finding a location with differential GPS.
- The most common method for navigation applications is to use corrected ranges.
- This is the same solution method used by the standalone user, but with some systematic errors removed.

- The survey community has used the carrier phase as its basic measurement from the beginning of GPS surveying.
- This was then applied to cases where the unknown location was in motion. This was called Kinematics.
- In practice kinematics can only be done with dual frequency data.
- Even though both frequencies are used, it is sensitive to ionospheric divergence.
- The user usually needs to be within 30 km of the reference site during the day.

- In the beginning, kinematics was only done on a post-processing basis.
- However with the increase in computation capabilities, it became possible to do the kinematic solution inside the GPS receiver. This is called Real Time Kinematics, or RTK.
- Many high end dual frequency receivers now can do RTK. It is still limited to ranges of 30 to 100 km of the reference sites.
- Also the system often needs to be initialized at 30 km or less.

- The original version of the RTCM format did not allow for the corrections necessary for RTK.
- However, revision 2 has new message formats designed for this.
- Many RTK implementations allow both the RTCM and manufacturer proprietary DGPS formats.

New Developments

- The package of changes that was accepted when the Selective Availability was turned off includes two other items important to civilian DGPS users.
- First the publicly available ranging signal will be placed on both the GPS frequencies beginning with launches in 2003.
- The earlier spacecraft only had this signal on the L1 frequency.
- This will make it possible for low end receivers now to automatically correct for the ionospheric error.
- Using the L2 signal in DGPS will require some changes to the RTCM format, but this is expected.

- Beginning in about 2007, satellites launched will have a third civilian frequency, called L5.
- This will allow kinematic solutions to be initialized and utilized at much longer ranges.

- The precise ranges will have to be determined post launch.
- It is likely that WAAS will not utilize the new signal on L2, but it is likely to use the L5 signal.
- This is due to a low, but measurable, probability of interference on L2 with some radars and mobile communications services in Europe.

- There are many science experiments done each year using GPS.
- Some, for example from NASAs Goddard Space Flight Center, have done kinematics out to a thousand kilometers.
- Experiments have been conducted on using a network of reference stations to generate standard GPS corrections.
- Receivers are becoming immune to multipath, at least for the top of the line receivers.
- The noise level in receivers is also coming down.
- Where all this will lead is unclear, but the results can only be beneficial to the GPS community.

5.5 Direct Broadcast satellites (DBS)

8. With a neat diagram, explain the home receiver for direct broadcast satellite (DBS) services. (April 2014,Nov/Dec 2011,April/May 2011, Nov/Dec 2010, April/May 2010, Nov/Dec 2009)
Explain the working of Direct Broadcast Satellites in detail. [May 2021]
Draw and explain the operation of DBS-TV set top box. [Dec 2021]

Direct Broadcast satellites (DBS)

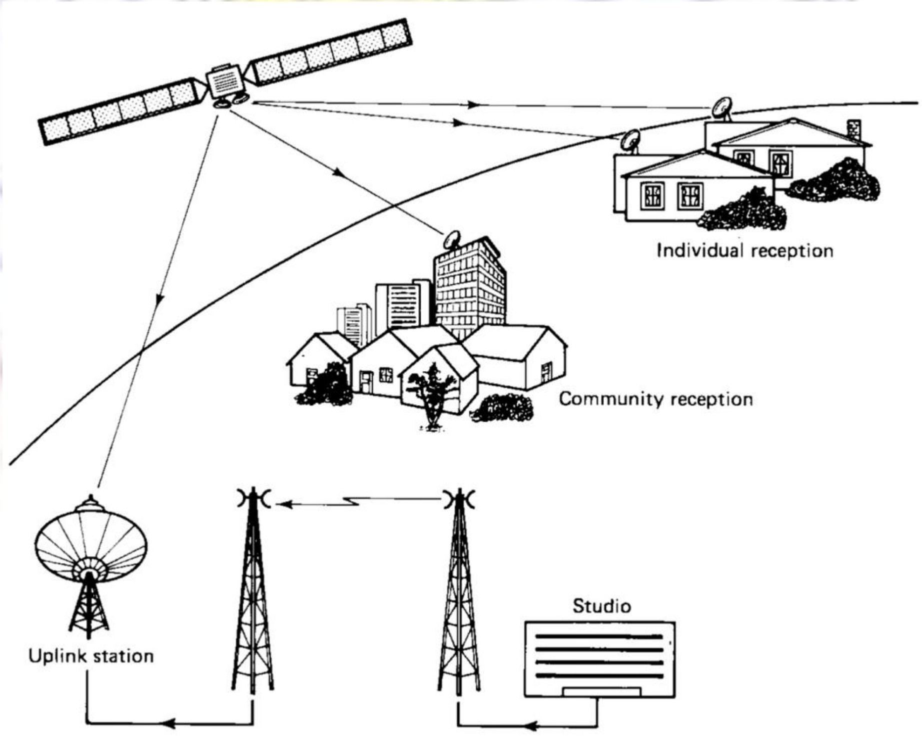


Figure. Components of a direct broadcasting satellite system.

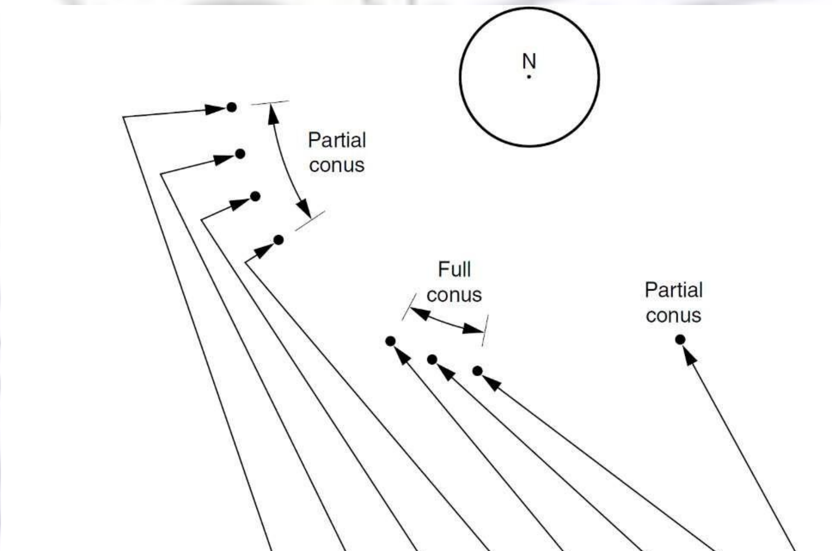
- Direct Broadcast satellite services include audio, TV, internet services
- Satellite placed in geostationary orbit Operating in Ku band with 14 GHZ for uplink and 12 GHz for downlink
- Head end receives PSTN, Video, Data services and encode into MPEG for digital transmission.

Orbital Spacing:

- Orbital spacing is 9° for high power satellites
- Although DBS satellite are spaced by 9°, cluster of satellites occupy the nominal orbital positions

Ex: at 119° W longitude

Echostar VI – 2000
Echostar IV – 1998
Echostar II - 1996



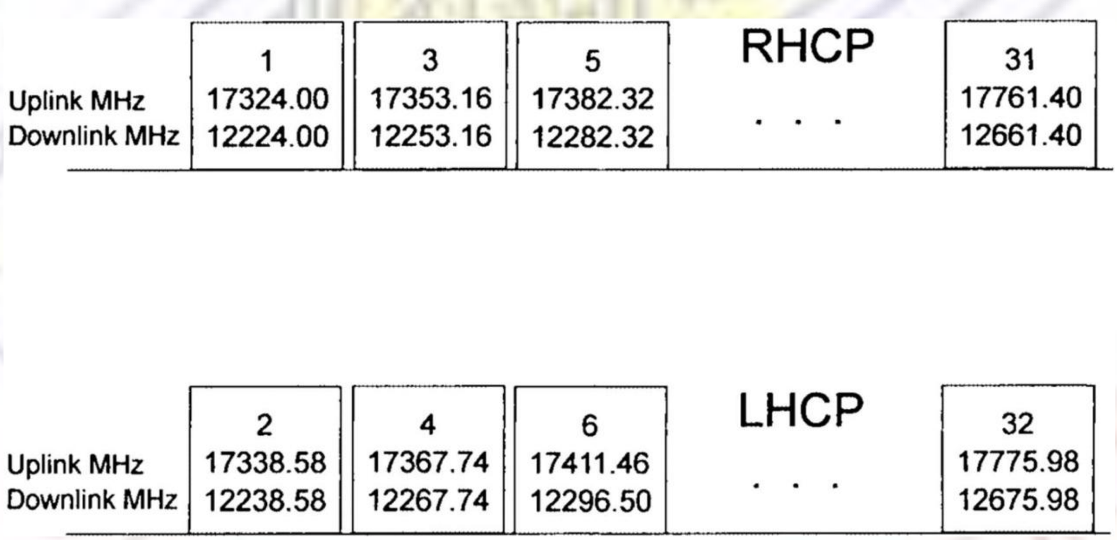
Satellite location	175°	166°	157°	148°	119°	110°	101°	61.5°
Company	Transponder totals							
Continental		11						11
DBSC	11							11
DirecTV			27				27	
Dominion		8						8
Echostar				24				
Echostar/Directsat	11	11			21	1		
MCI						28		
TCI/Tempo					11			
USSB				8		3	5	
Unassigned	10	2	5					2

Power rating:

- DBS Satellite have high EIRP ranging from 51 – 60dBw
- 57 dBw, as EIRP was decided by RARC-Regional Admin. Radio Council in 1984 for DBS
- Power rating of transponder is decided by output power of High power amplifier
- At 120W, each satellite can carry 32 no. of transponder.
- If only 16 are used, then transponder will operate with 240 W of power

Frequency and polarization:

- The frequencies for direct broadcast satellites vary from region to region throughout the world, although these are generally in the Ku band.
- For high power satellite
    - uplink = 17.3 – 17.8GHz
    - downlink = 12.2 – 12.7GHz
  - for medium power
    - uplink = 14 – 14.5GHz
    - downlink = 11.7-12.2GHz
- Only 500MHz bandwidth is available
- For 32 transponder, each can accommodate 24MHz+3MHz as guard band(tot. 27MHz)
- For calculating bit rate, 24MHz is used as bandwidth
- Transponder have RHCP & LHCP
- For ex. For region-2 which includes North America, South America, Greenland frequency use is given as below



Transponder capacity:

- Known as DTH-Direct to Home
- Audio and video components are digitalized for more no. of channels
- Compression technique is used by which bandwidth can be reduced

$$R_{sym} = \frac{B_{IF}}{1 + \rho}$$

Thus, with a bandwidth of 24 MHz and allowing for a rolloff factor of 0.2, the symbol rate is

$$R_{sym} = \frac{24 \times 10^6}{1 + .2}$$

$$= 20 \times 10^6 \text{ symbols/s}$$

Satellite digital television uses QPSK. Thus, the bit rate is

$$R_b = 2 \times R_{sym}$$

$$= 40 \text{ Mb/s}$$

This is the bit rate that can be carried in the 24-MHz channel using QPSK.

Bit rates for digital television:

- Depends on format of the picture
- Uncompressed bit rate =
- If no. of bits/pixel = 16
  - then color depth/pixel = 2^{16} = 65,536 colors
- Advanced television system committee(ATSC) has formulated some television formats as

ATSC Television Formats

Format	Name	Screen	Resolution, Pixels	Bit Rate, Mb/s at 60/30/24 Frames per Second
HDTV	1080i	16:9	1920 × 1080	N.A./995/796
HDTV	720p	16:9	1280 × 720	885/442/334
SDTV	480p	16:9	704 × 480	324/162/130
SDTV	480p	4:3	640 × 480	295/148/118

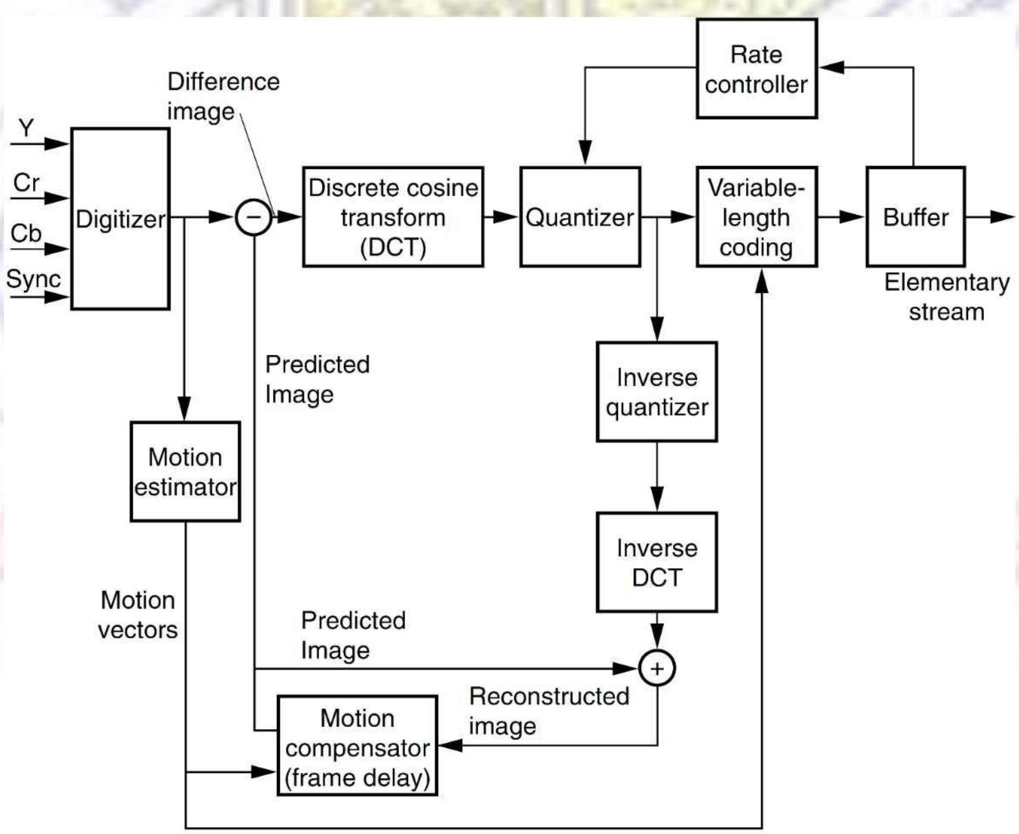
NOTE: ATSC, Advanced Television Systems Committee; HDTV, high-definition television; SDTV, standard definition television; p, progressive scanning; i, interlaced scanning; N.A., not applicable to format.
SOURCE: Booth, 1999.

- Uncompressed bit rate is ranged from 118Mbps for SDTV to 995Mbps to HDTV
- When the signal is digitized, then 216Mbps is the required bit rate
- A single transponder has to carry 8 TV program. Before transmission these programs must be converted to digital, compressed and time division multiplexed.
- QPSK for uplink generally used
- No. of channels depends on the type of program (ie) sports channel needs large bit rates, talk show need low bit rates
  - for SDTV – 4Mbps- Movie channel
  - 5Mbps – variety channel
  - 6mbps – sports channel

MPEG:

- Compression is carried out to Moving Picture Expert Group (MPEG) Standards
- MPEG is a group within ISO / IEC- International Standards Organisation / International Electro Chemical commission
- Standard concerned with bit stream syntax and decoding techniques
- Various MPEG standards
    - MPEG -1
    - MPEG – 2
    - MPEG – 4
    - MPEG – 7
- DBS uses MPEG-2 for video compression
- Analog outputs from Red(R), Green (G), Blue(B), color converted into luminance component (Y) and two chrominance components (Cr) & (Cb)

$$\begin{bmatrix} Y \\ Cr \\ Cb \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



- Y, Cr,Cb are given to digitizer block. Low sampling rate is used for colour components, known as "chroma sub sampling"
- MPEG – 2 uses 4:2:0 sampling
- Sampling is indicated by using Y:U:V ratio
    - Y - Luminance sampling rate
    - U – Cb sampling rate
    - V – Cr sampling rate
- Common ratios with digital TV are
- 4:4:4
    - sampling rates Y, Cr, Cb are equal
    - each pixel is encoded in 3 bytes
- 4:2:2
    - sampling rate of Cb & Cr are equal to half of Y
- 4:2:0
    - Cb & Cr are sampled at half of the Y sampling rate

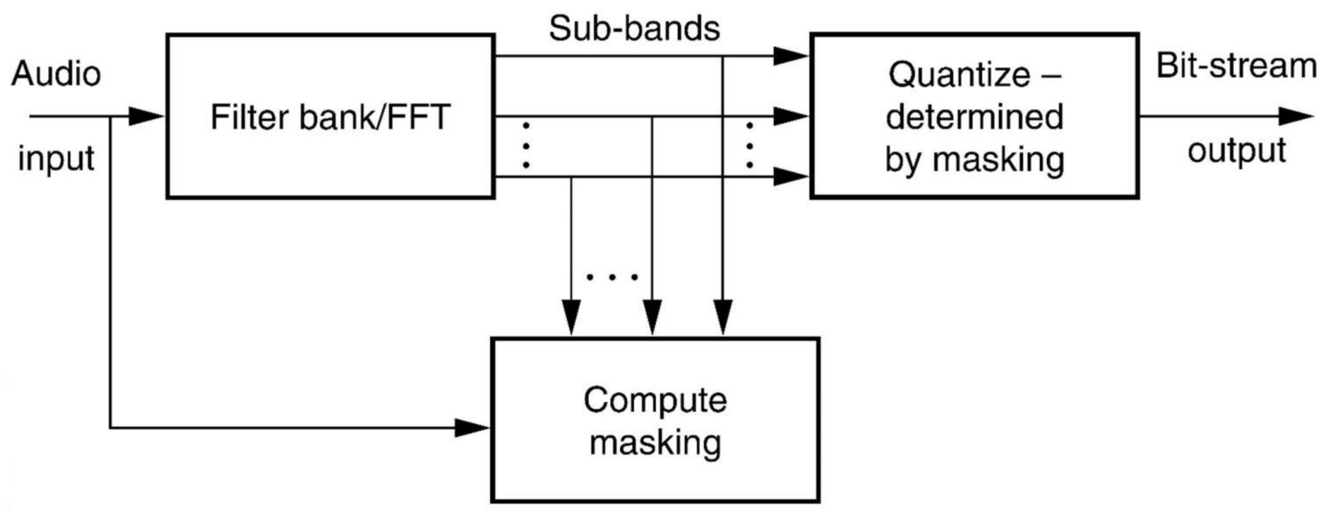
- At the output of the digitizer, difference signal is formed and it is given to DCT which convert time domain signal to frequency domain signal. If h(x,y) = H(U,V)= spatial frequencies
- Quantizer quantize H(U,V) into predetermined levels and compression is provided
- Compression is also done through motion estimation. It is done by comparing the frames with the other frames such as (i) I-frame(independent) (ii) P-frame(previous) (iii) B-frame(bidirectional)

- In DBS system
    - MPEG – 1 is used for audio compression, which support mono & 2 channel stereo
    - MPEG – 2 is used for video compression, which supports multichannel audio, mono, stereo.
    - MPEG – 2 is compatible with MPEG – 1
        - R_b bit rate = $f_s$xn
        - fs =sampling freq, n=no. of bits/sample

- For PCM, quantization noise is a major one

        - $(S/N) = 2^{2n}$
            - $= 10 \log 2^{2n}$
            - = 6ndb

MPEG-1



- Audio signal input is given to filter bank which is used to divide input signal to various subbands
- Subbands are given to masking computation block, which is used to permit identification of the masking level
- This is information is passed to quantizer which is used to quantize the subband according to noise floor. This type of masking known as " frequency masking"
- If masking effect last for a period after the masking signal is removed known as "temporal masking"
- MPEG -4 is developed by VCEG – Video Coding Expert Group of Intrnational Telecommunication Union and Telecommunication Standardization sector (ITU-T), designated as H.264 AVC, H.26L (AVC-Advanced Video Coding). Application are Video telephony, Video storage etc.

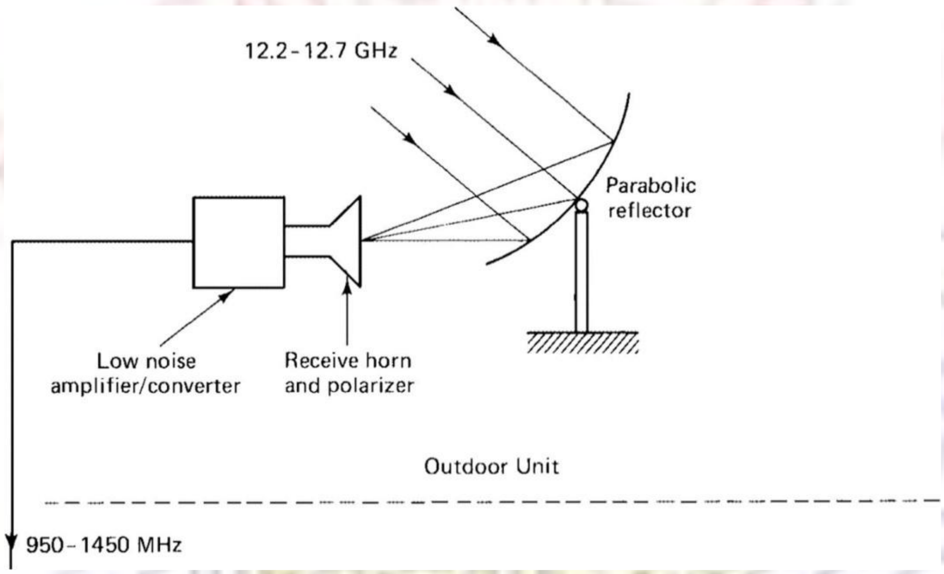
Forward Error Correction (FEC):

- FEC is necessary because compressed bit stream is severely affected by bit errors
- Random errors are corrected by convolution code
- Block errors are corrected by Reed-Solomon Code
- In FEC, overhead is added to bit stream
- In 240W transponder, bit capacity of 40Mbps is having 30Mbps as pay load and 10Mbps as overhead
- In 120W transponder, the payload is 23 Mbps and 17 Mbps as overload
- In HDTV, turbo codes and LPPC codes are used.

1. Explain home receiver indoor unit (IDU) and outdoor unit (ODU) in detail with necessary diagrams. (April 2014,Nov/Dec 2011,April/May 2011, Nov/Dec 2010, April/May 2010, Nov/Dec 2009)

Home receiver

Outdoor Unit:



Block schematic for the outdoor unit (ODU)

- ✓ The home receiver consists of two units, an outdoor unit and an indoorunit. Commercial brochures refer to the complete receiver as an integrated receiver decoder (IRD).
- ✓ Figure is the block schematic for the outdoor unit (ODU).
- ✓ This will be seen to be similar to the outdoor unit of TVRO.
- ✓ The downlink signal, covering the frequency range 12.2 to 12.7 GHz, is focused by the antenna into the receive horn.
- ✓ The horn feeds into a polarizer that can be switched to pass either lefthand circular to right-hand circular polarized signals.
- ✓ The low-noise block that follows the polarizer contains a low-noise amplifier (LNA) and a downconverter.
- ✓ The function of the LNA :
- ✓ The downconverter converts the 12.2 to 12.7 GHz band to 950 to 1450 MHz, a frequency range better suited to transmission through the connecting cable to the indoor unit.
- ✓ The antenna usually works with an offset feed, and a typical antenna structure is shown in Fig.
- ✓ It is important that the antenna have an unobstructed view of the satellite cluster to which it is aligned.
- ✓ The size of the antenna is a compromise among many factors but typically is around 18 in (46 cm) in diameter.
- ✓ A small antenna is desirable for a number of reasons. Small antennas are less intrusive visually and also are less subject to wind loading.

- In manufacture, it is easier to control surface irregularities, which can cause a reduction in gain by scattering the signal energy.
- The reduction can be expressed as a function of the root-mean-square (rms) deviation of the surface, referred to an ideal parabolic surface.
- The reduction in gain is given by

$$\eta_{rms} = e^{8.8\sigma/\lambda}$$

where σ is the rms tolerance in the same units as λ, the wavelength.

- For example, at 12 GHz (wavelength 2.5 cm) and for an rms tolerance of 1 mm, the gain is reduced by a factor

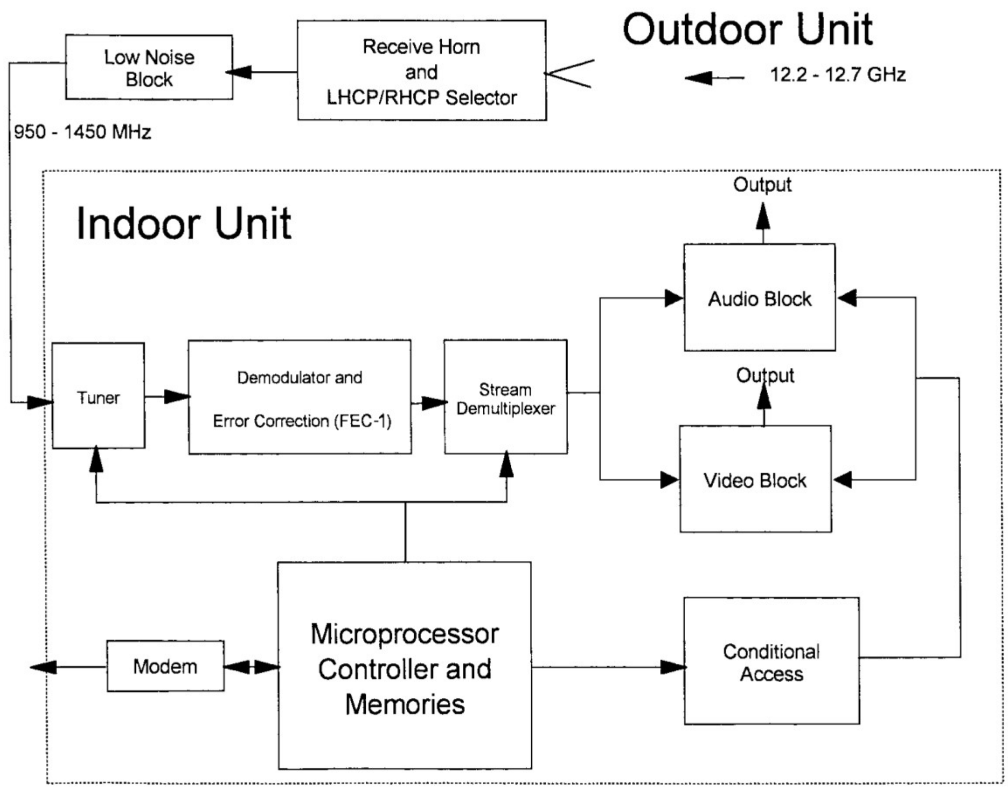
$$\eta_{rms} = e^{(8.8\times 0.1)/2.5}$$

$$= 0.7$$

- This is a reduction of about 1.5 dB.
- The isotropic power gain of the antenna is proportional to $(D/\lambda)^2$, where D is the diameter of the antenna.
- Hence, increasing the diameter will increase the gain (less any reduction resulting from rms tolerance), and in fact, many equipment manufacturers provide signal-strength contours showing the size of antenna that is best for a given region.
- Apart from the limitations to size stated above, it should be noted that at any given DBS location there are clusters of satellites.
- The beamwidth of the antenna must be wide enough to receive from all satellites in the cluster.
- For example, the Hughes DBS-1 satellite, launched December 18, 1993, is located at 101.2°W longitude; DBS-2, launched August 3, 1994, is at 100.8°W longitude; and DBS-3, launched June 3, 1994, is at 100.8°W longitude.
- There is a spread of plus or minus 0.2° about the nominal 101°W position. The -3dB beamwidth is given as approximately $70\lambda/D$.
- A 60-cm dish at 12 GHz would have a -3dB beamwidth of approximately $70\times 2.5 / 60 =$ 2.9°, which is adequate for the cluster.

The Home Receiver Indoor Unit (IDU)

- The block schematic for the indoor unit (IDU) is shown in Fig.
- The transponder frequency bands are downconverted to be in the range 950 to 1450 MHz, but of course, each transponder retains its 24-MHz bandwidth.
- The IDU must be able to receive any of the 32 transponders, although only 16 of these will be available for a single polarization.
- The tuner selects the desired transponder.
- It should be recalled that the carrier at the center frequency of the transponder is QPSK modulated by the bit stream, which itself may consist of four to eight TV programs time-division multiplexed.



Block schematic for the indoor unit (IDU)

- ✓ Following the tuner, the carrier is demodulated, the QPSK modulation being converted to a bit stream.
- ✓ Error correction is carried out in the decoder block labeled FEC^{-1}.
- ✓ The demultiplexer following the FEC^{-1} block separates out the individual programs, which are then stored in buffer memories for further processing (not shown in the diagram).
- ✓ This further processing would include such things as conditional access, viewing history of payper- view (PPV) usage, and connection through a modem to the service provider (for PPV billing purposes).

5.6 Direct to home Broadcast (DTH)

2. **With a block schematic explain about DTH system.*(April 2014, May/June 2012, April/May 2008)**
3. **Describe the signal processing blocks involved in DTH-TV transmitter and receiver with block diagram. [Dec 2021] [Nov/Dec 2022]**

Direct to home Broadcast (DTH)

Direct-to-Home Satellite Television Broadcasting:

- DTH systems are designed to transmit entertainment TV programming to home receiving Earth terminals (or, simply, home receivers).

- This is a natural extension of TV distribution by satellite, utilizing the area-coverage and single service provider features of the technology. DTH systems, also called Direct Broadcast Satellite,

Important aspects of DTH:

• The programming mix, for example, the quantity, variety, language options, and degree of interactivity, which must compete with other DTH systems and delivery mechanisms

• Receiving equipment—that is, its affordability, convenience of installation and use, integration with other video and audio devices, and aesthetics;

• Acceptability of the service price and an effective means to collect payment;

• Incompatibilities with the other DTH, radio, and cable TV systems, which are dependent on the nature of the business plan;

• Conditional access and scrambling in order to deal with copyrights, privacy, collection, regulations, and content rules (which may exist in the country markets of interest);

• Uplinking system, including the redundancy, strength, and program development and contribution facilities.

- The major elements of a DTH system are shown in Figure.1.

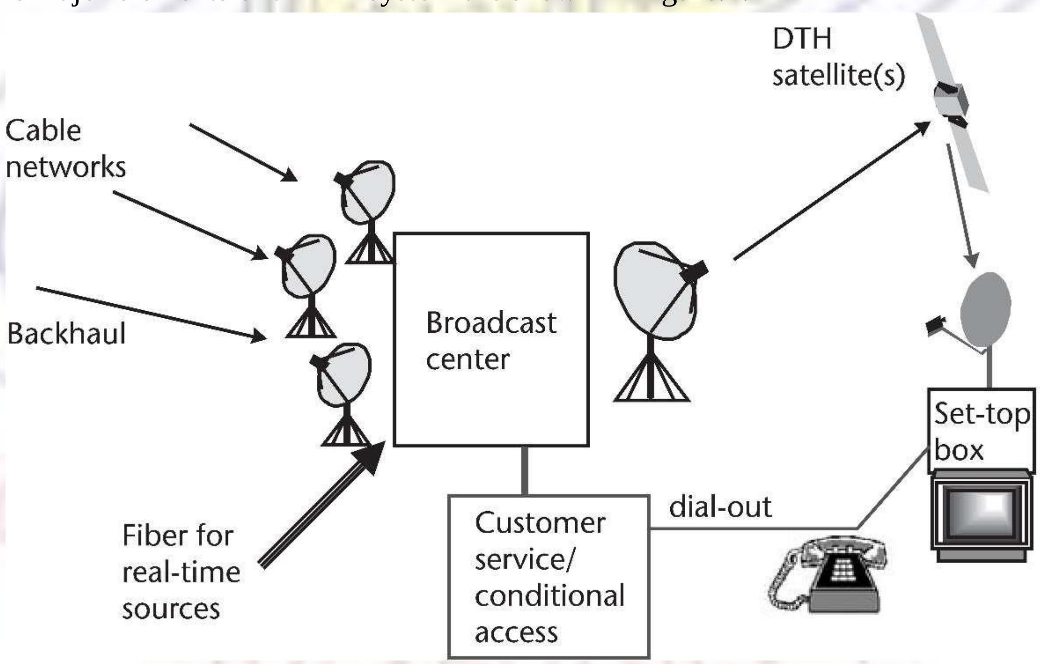


Figure 1 Major elements of a DTH system.

DTH System Architecture

- The discussion of DTH architecture focuses on the type of video processing and compression, along with the supply and cost of the set-top box.
- It encompasses the uplink systems for digitizing, compressing, and transmitting multiple television programs using the DVB-S standard, for example.

Basic Elements and Signal Flow

- The major elements of DTH system are listed as follows and are indicated in Figure 1:

1. DTH satellites in GEO (one or more):

- ✓ Spacecraft construction
- ✓ Launch services;
- ✓ Launch and on-orbit insurance.

2. TT&C:

- ✓ Controls the space segment and monitors spacecraft health;
- ✓ Verifies that transmissions to satellite do not cause interference;
- ✓ Provided by satellite operator (usually a separate company);
- ✓ Limited communication required between DTH network operator and satellite operator.

3. Broadcast center:

- ✓ Originates, acquires, and transmits program material;
- ✓ Generally centralized, with no or limited backup;
- ✓ Part of conditional access system.

4. Customer service:

- ✓ Billing and customer turn-on-off;
- ✓ Customer assistance.

Detailed configuration of the operating components of DTH

- A more detailed configuration of the operating components is presented in Figure .3.

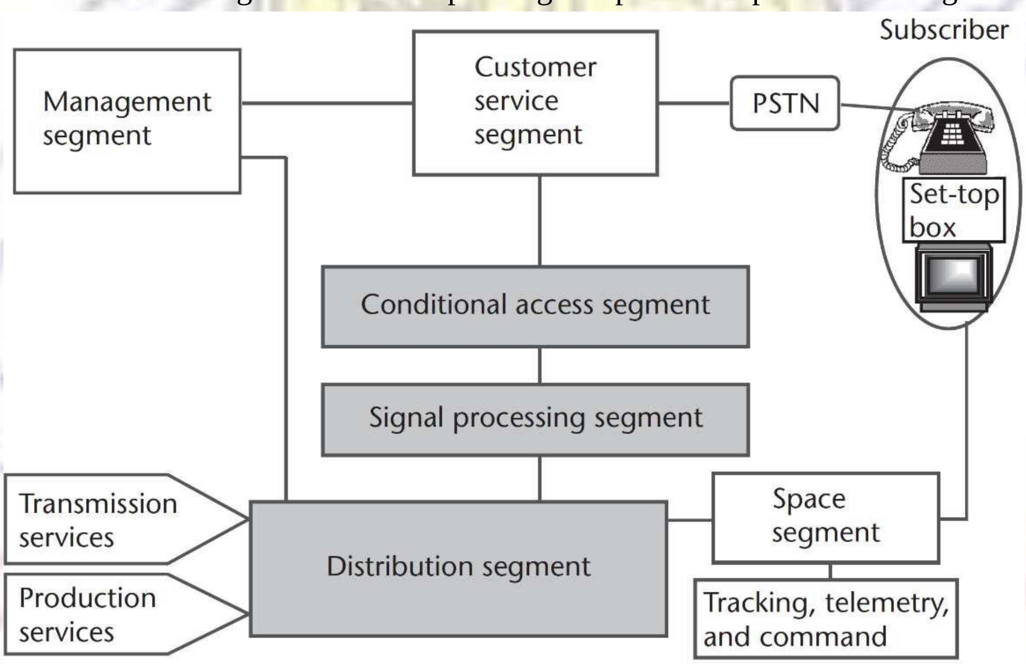


Figure: DTH system operating elements; components of the broadcast center are indicated with shaded boxes (transmission and production services may be included, depending on the configuration).

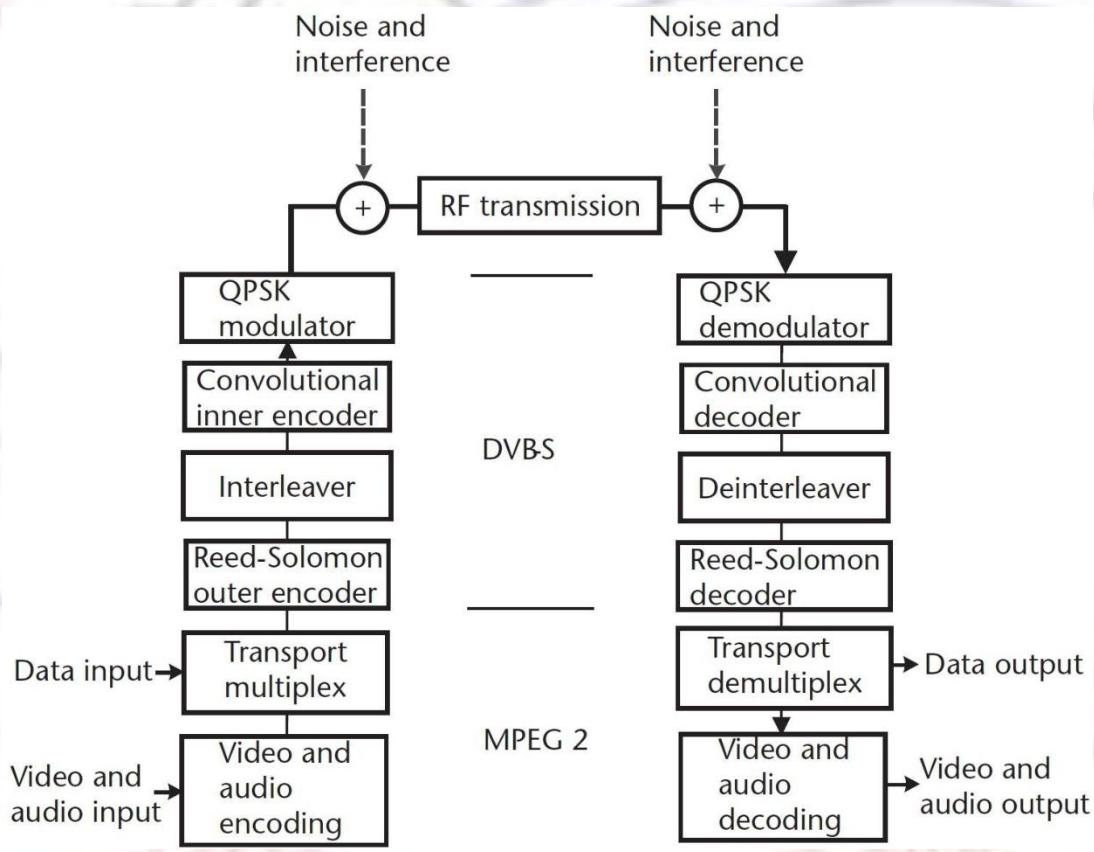
Detailed configuration of the operating components of DTH

- At the top of the diagram we find the service management functions of the network.
- These manage the interaction with the customer over the telephone and Internet, and provide the means to download PPV movie selections on a monthly basis.

- It also ties into the CA segment, which authorizes individual IRDs over the space segment.
- The technical functions at the bottom of the diagram show the physical production and transmission facilities, from content input through baseband processing and on up to the satellite.

Compression System Arrangement

- The basic arrangement of the uplink compression-encoding-modulation chain and downlink demodulation-decoding-decompression chain is presented in Figure 4.
- We are concentrating here on the uplink compression elements contained within the broadcast center Earth station.
- An equipment is included that digitizes and time division multiplexes the video, audio, and data information.
- Systems that employ FDMA use separate carriers for each video channel.
- The form of TDM could be either a fixed bit-by-bit multiplex or alternatively a statistical multiplex where data rates are adjusted based on content.



- In either case, the carrier must be transmitted by a single Earth station as the multiplexing is done on the input side of the modulator.
- The compression systems themselves fall into two categories:
  (1) Those that comply with a standard, particularly MPEG 2 or DVB (which includes MPEG 2 as a component); or
  (2) Those that use a proprietary algorithm and multiplexing scheme.

- Systems that started out in category (2) are quickly moving to MPEG 2 because of the rapidly decreasing cost of the receiving equipment.

Compare LEOand MEOsatellite. What are the advantage, disadvantage and application of LEOand MEO satellite? [May 2021]
(Additional: GEO)

	GEO (36,000km)	MEO (5,000-20,000km)	LEO (500-1,200km)
Altitude latency[1]	High	Low	Very low
Earth coverage	Very large	Large	Small
Satellites required	Three	Six	Hundreds
Data gateways	Few fixed	Regional flexible	Local numerous
Antenna speed	Stationary	1-hour slow tracking	10-minute fast tracking
Advantages	High throughput (HTS) technologies enable basic broadband internet applications	Proven low latency comparable to terrestrial networks, offers fibre-equivalent performance	Claims support for high-frequency trading, virtual gaming, and high-performance computing applications
	Fewer satellites over very large fixed geographical areas	Simple equatorial orbit covers 96% of global population	Smaller, lower power satellites batch-launched more cheaply than GEO
Disadvantages	High altitude and distant ground networking impacts latency-sensitive applications	Dual tracking antennas required to maintain continuous connectivity	Very complex tracking and ground network, plus complete constellation must be in place before service starts
	Signal power losses require larger satellites and antennas	Inclined plane orbits needed to cover high latitudes	Unproven business model, risky technology, and space debris risk

[1]Total end-to-end network latency is dependent on ground infrastructure

Table 1: Comparison of GEO, MEO, and LEO satellites

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