Satellite and Optical Communication

BEC515D

MODULE 3

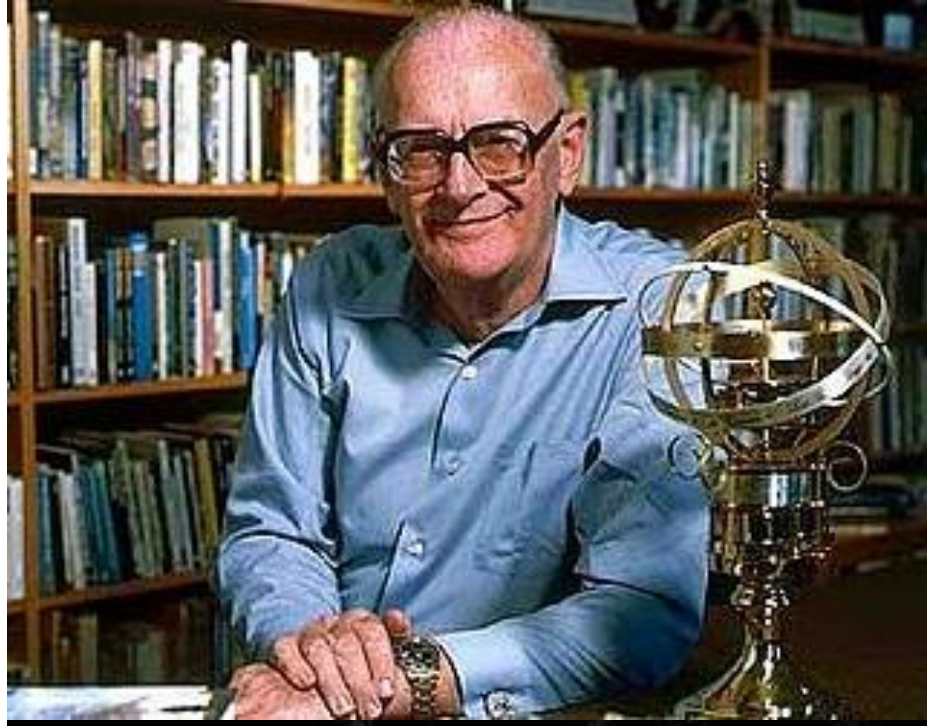
Communication Satellites

Introduction to Communication Satellites

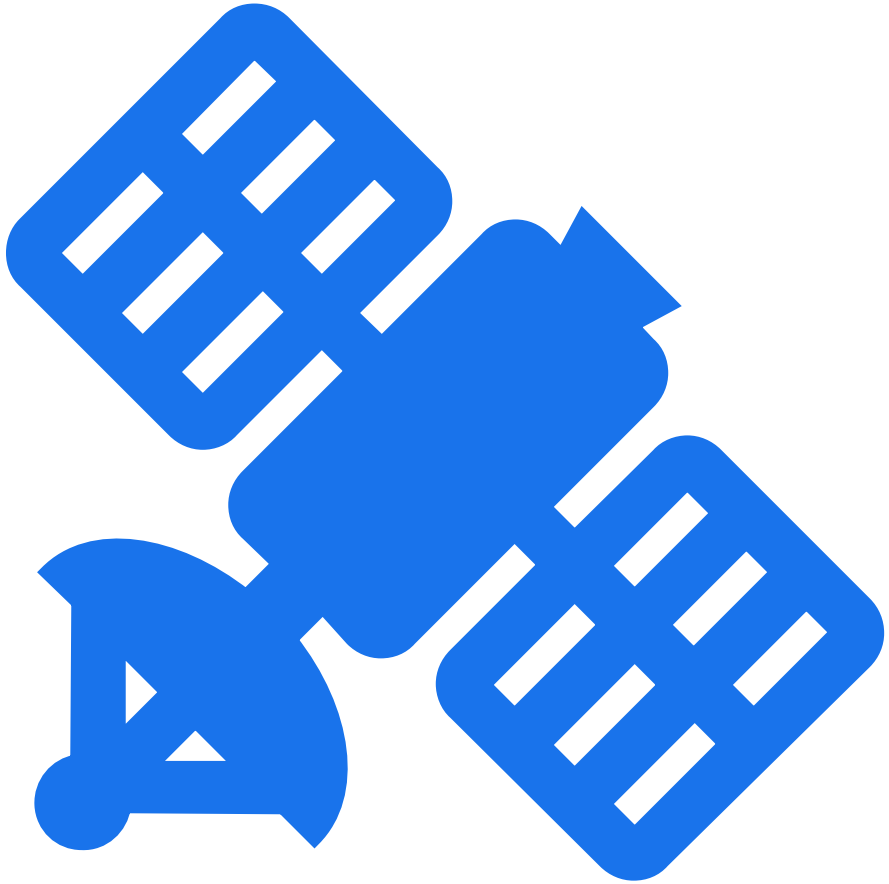
- Communication Satellites – Most common type of satellite launched.
  - Act as repeater stations in space.
  - Used for point-to-point, point-to-multipoint, and multipoint services.
- Applications:
  - Television Broadcasting
  - International Telephony
  - Data Communication

Introduction to Communication Satellites

- 1945: Science fiction writer **Arthur C. Clarke** proposes using geostationary satellites to relay radio signals.
  - His concept laid the groundwork for modern satellite communication.
- 1962: The launch of **Telstar-1** makes the concept a reality.
  - First intercontinental link between the USA and Europe.
  - Provided both telephony and television services.
- To date more than 12000 communication satellites have been launched.
- These electronic birds have tied the whole world together and made it look like a global village.



Communication-Related Applications of Satellites



Communication-Related Applications of Satellites

- Telecommunication satellites provide a varied range of services including television broadcasting, international telephony, and data communication.
- Traditionally used for TV and telephony, now includes newer services like the internet and multimedia.
- Face competition from terrestrial networks, particularly fiber optics.

Satellite Television (Satellite TV)

- **Definition:** Uses satellites to relay TV programs from a source to a large geographical area.
- **Orbit:** Employs Geostationary Earth Orbit (GEO) satellites.
- **Configuration:** Uses a point-to-multipoint configuration.
- **Systems:**
  - Television Receive-Only (TVRO)
  - Direct Broadcasting Satellite (DBS)

Satellite Telephony

- **Services:** Provides both long-distance (intercontinental) and mobile telephony.
- **Purpose:** Complements or bypasses terrestrial networks.
- **Advantages:** Particularly useful for large distances, sparsely populated regions, or difficult geographical terrain.
- **Configuration:** Uses point-to-point satellite links.

Data Communication Services

- **Services Offered:** Includes data, broadcast, and multimedia services such as:
  - Image and video transfer
  - Voice
  - Internet access
  - Two-way computer interactions
- **Configuration:** Provides multipoint interactive connectivity.
- **Technology:** Uses low-cost Very Small Aperture Terminals (VSATs).

Types of Satellite Orbits

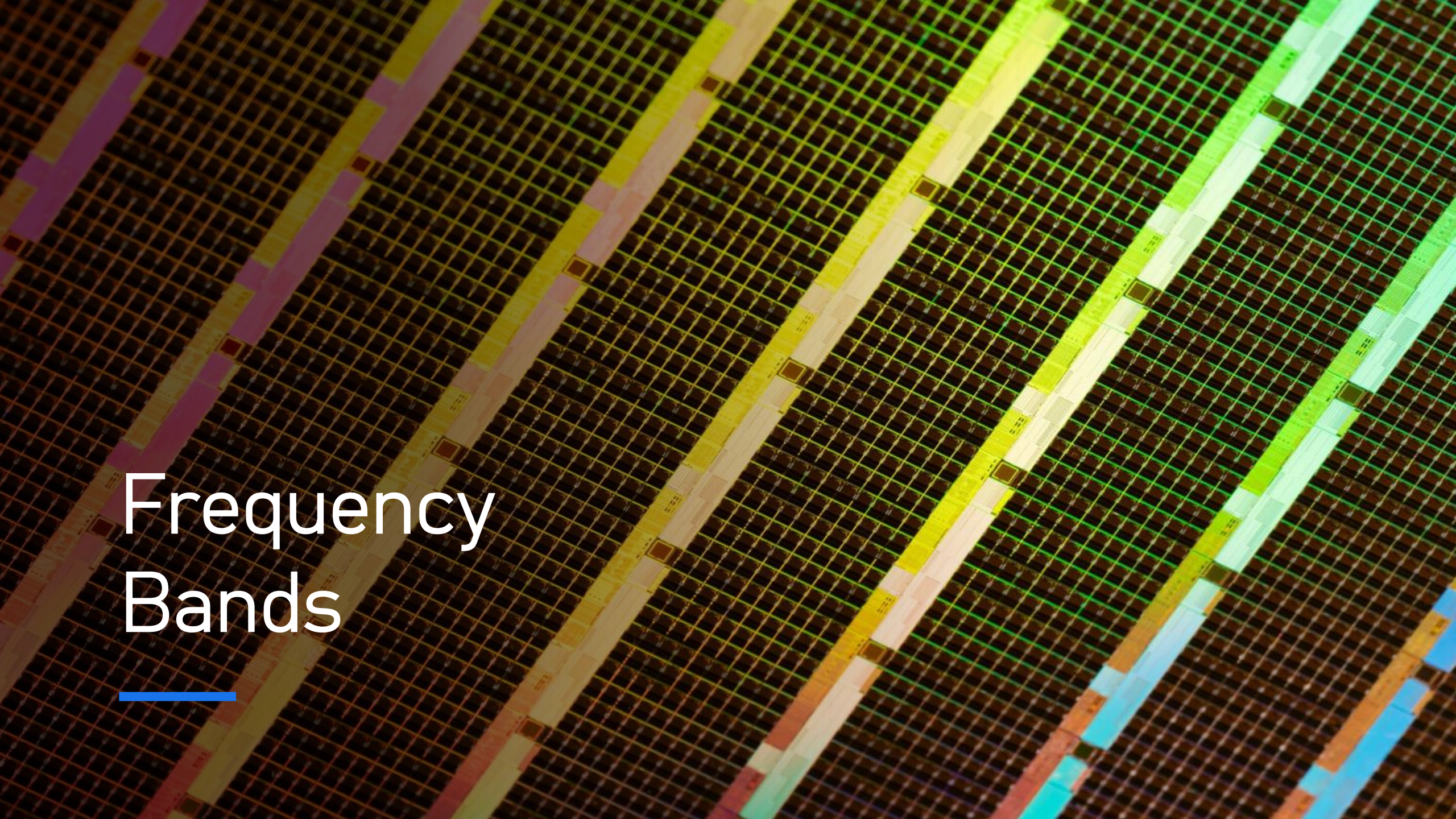
- **Geostationary (GEO):** Maintain a fixed position relative to the Earth.
  - Key for traditional and novel services like internet access.
- **Non-Geostationary (Non-GEO):** Constellations of satellites in Low Earth Orbit (LEO), Medium Earth Orbit (MEO), or Highly Elliptical Orbit (HEO).
- **Applications by Orbit:**
  - **GEO:** Best for broadcasting (TV, radio) and telephony.
  - **Non-GEO:** Well-suited for newer services like messaging, voice, data, and video conferencing.

Geostationary Satellite Systems

- **History:** The preferred orbit, providing most of the revenue for operators.
- **First Satellite:** Early Bird (Intelsat 1) in 1965.
- **Notable Missions:** Intelsat, Inmarsat, Telstar, Galaxy, etc.
- **Key Current Applications:** DTH satellite television and VSAT services.

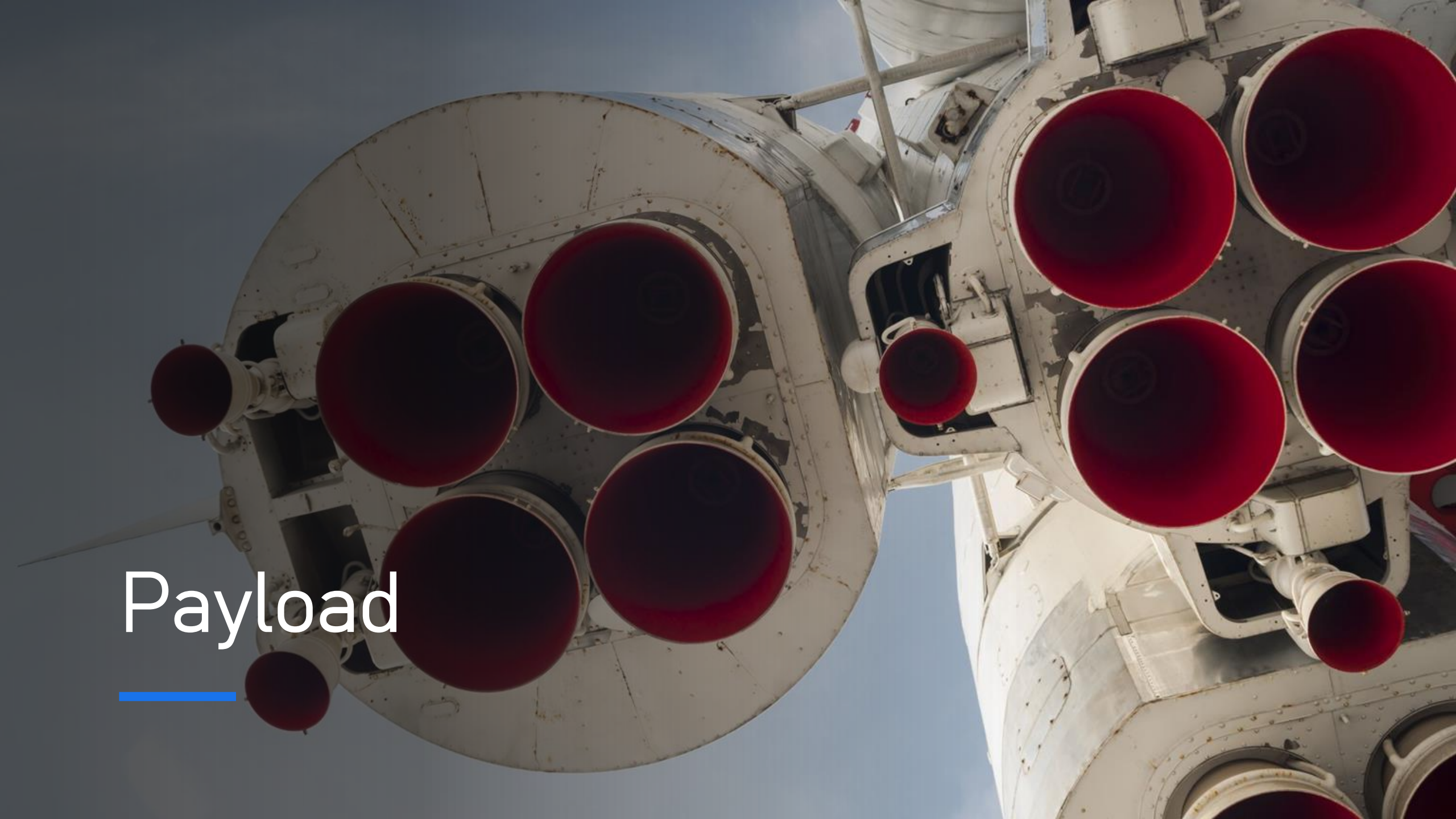
Non-Geostationary Satellite Systems

- **Emerging Role:** Developed to provide global mobile communication and other specialized services.
- **Challenges:** The cost of building a satellite constellation is huge.
- **Status:** Systems are still in the developmental stage.
- **Examples:** Starlink, IRIDIUM, Orbcomm, Globalstar, and ICO.


Frequency
Bands

Frequency Bands

- Satellite communication employs electromagnetic waves for transmission of information between Earth and space.
- The bands of interest for satellite communications lie above 100MHz including the VHF, UHF, L, S, C, X, Ku and Ka bands.



Payload

Payload

- The transponder is the essential payload of any communication satellite.
- Basic elements of a satellite communication system include the ground segment and the space segment.
- Ground Segment:
  - Comprises Earth stations for transmitting and receiving.
  - Provides access to the space segment.
  - Connects users and terrestrial networks.
- Space Segment:
  - One or more satellites.
  - Acts as a repeater station.
  - Provides point-to-point, point-to-multipoint, or multipoint services.

Payload

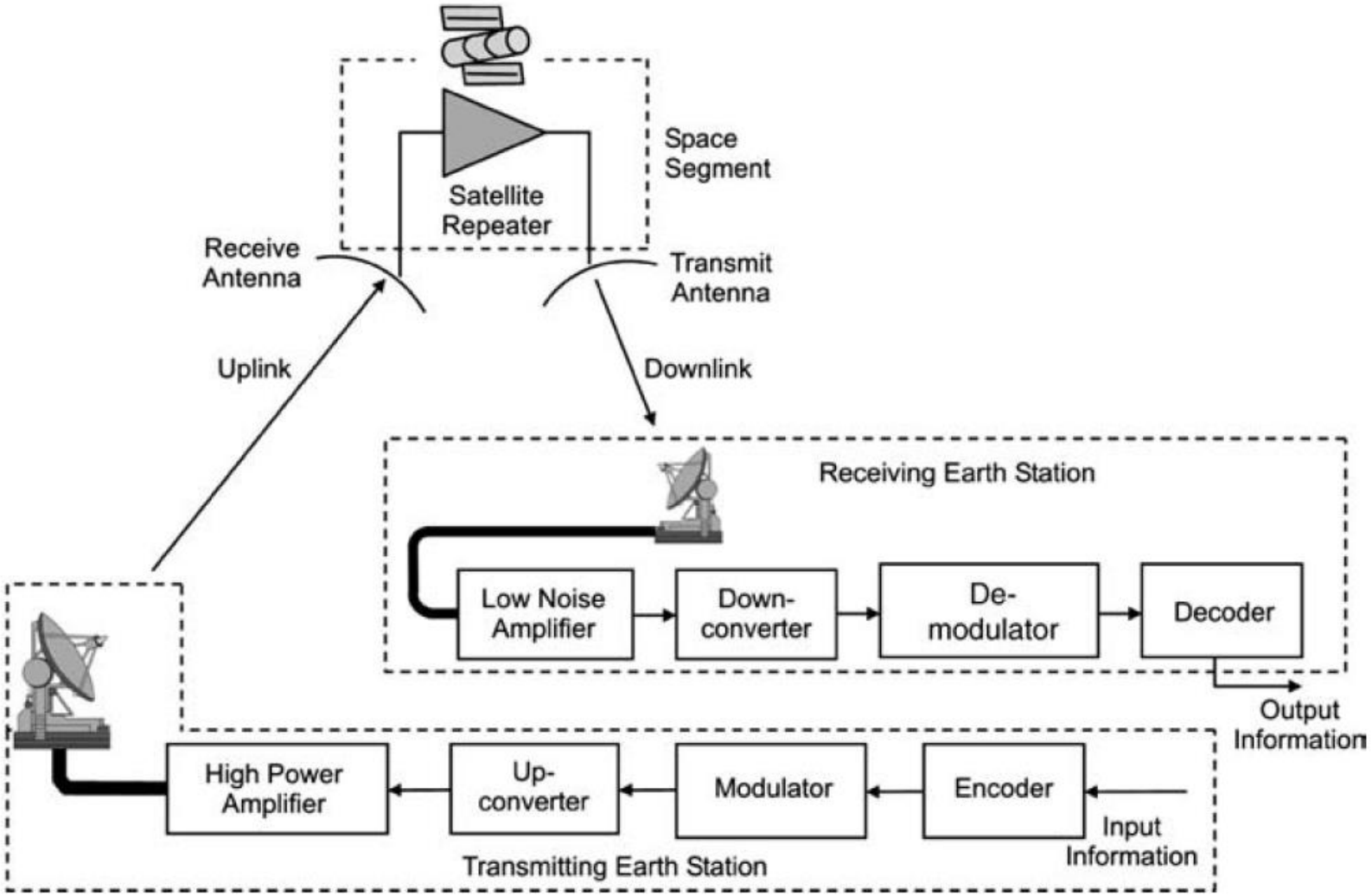


Figure 9.1 Basic elements of a satellite communication system

Transponder

The Uplink Process (Earth to Satellite)

- Objective: Transmit information from an Earth station to the satellite.
- Process:
  - Information (voice, video, data) is modulated.
  - Signal is up-converted to a microwave frequency band (e.g., C, Ku, Ka).
  - Amplified to the required power level.
  - Beamed up to the satellite.

Transponder

- The Transponder
- **Function:** An on-board repeater that performs two key tasks:
  - **Amplifies** the weak uplink signal.
  - **Down-converts** the signal to a different frequency before retransmission.
- **Frequency Conversion:**
  - Essential to avoid interference between the powerful uplink and downlink signals.
  - The downlink frequency is typically **lower** than the uplink frequency to minimize atmospheric propagation losses and save power.
- **Capacity:** Satellites can carry anywhere from 10 to 100 transponders.

Transponder

- The Downlink Process (Satellite to Earth)
- Objective: Transmit information from the satellite back to Earth.
- Process:
  - The weak downlink signal is received by an Earth station, DTH, or mobile receiver.
  - The signal is amplified.
  - Down-converted to a lower frequency.
  - Demodulated and converted back into a baseband signal.

Transponder

Transponder Bandwidth & Capacity

- **Satellite Bandwidth:** The total available bandwidth is divided into individual frequency channels.
  - **C and Ku bands:** Typically 500 MHz total bandwidth.
  - **Ka band:** Typically 2000 MHz total bandwidth.
- **Transponder Bandwidth:** Each transponder handles a separate channel, typically 30-80 MHz wide.
  - **Common sizes:** 27, 36, 54, and 72 MHz.
- **Transponder Equivalent (TPE):** A measure of satellite capacity.
  - Defined as a transponder with a **36 MHz bandwidth**.
  - Example: A 72 MHz transponder equals two TPEs.

Types of Transponders

- Transponders may be broadly classified into two types depending upon the manner in which they process the signal:
  1. Transparent or bent pipe transponders
  2. Regenerative transponders

Transparent or Bent Pipe Transponders

- Transparent transponders process the uplink satellite signal in such a way that only their amplitude and the frequency are altered
  - The modulation and the spectral shape of the signal are not affected.
- They are also referred to as ‘bent pipe’ transponders as they simply transmit the information back to Earth.
- Transparent transponders comprise an input filter, low noise amplifier (LNA), down converter, input multiplexer, channel amplifiers, high power amplifiers and output de-multiplexer.

Transparent or Bent Pipe Transponders

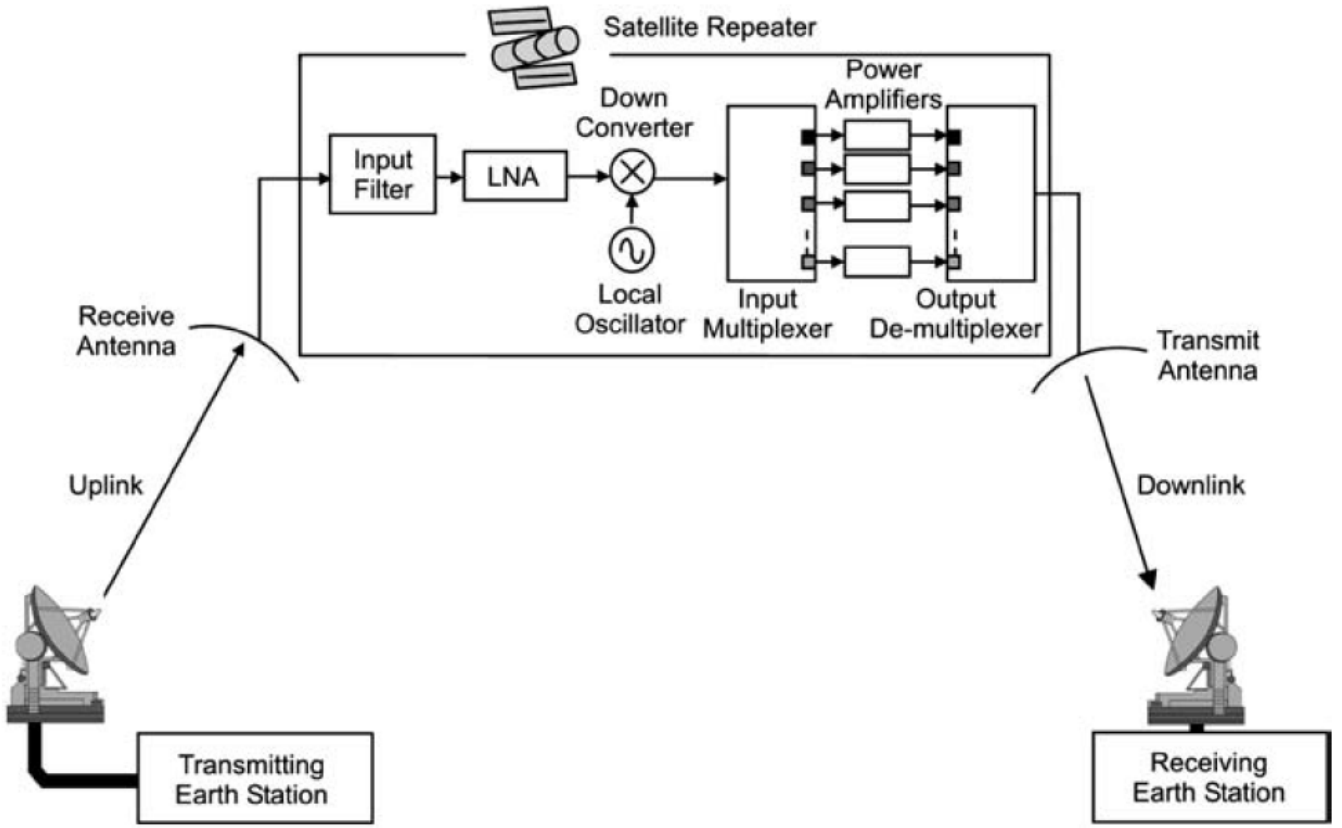


Figure 9.2 Transparent transponders

Transparent or Bent Pipe Transponders

- **Input Filter & LNA:** Receive and amplify the weak uplink signal.
- **Down Converter:** Shifts the signal frequency from the high uplink frequency band (e.g., C-band uplink 5.925–6.425 GHz) to the lower downlink band (e.g., C-band downlink 3.7–4.2 GHz).
- **Input Multiplexer (IMUX):** Separates the full bandwidth into individual channels.
- **Power Amplifiers:** Amplify each channel (using **TWTAs** for high power or **SSPAs** for lower power).
- **Output De-multiplexer:** Combines all the amplified channels for transmission back to Earth.

Regenerative Transponders

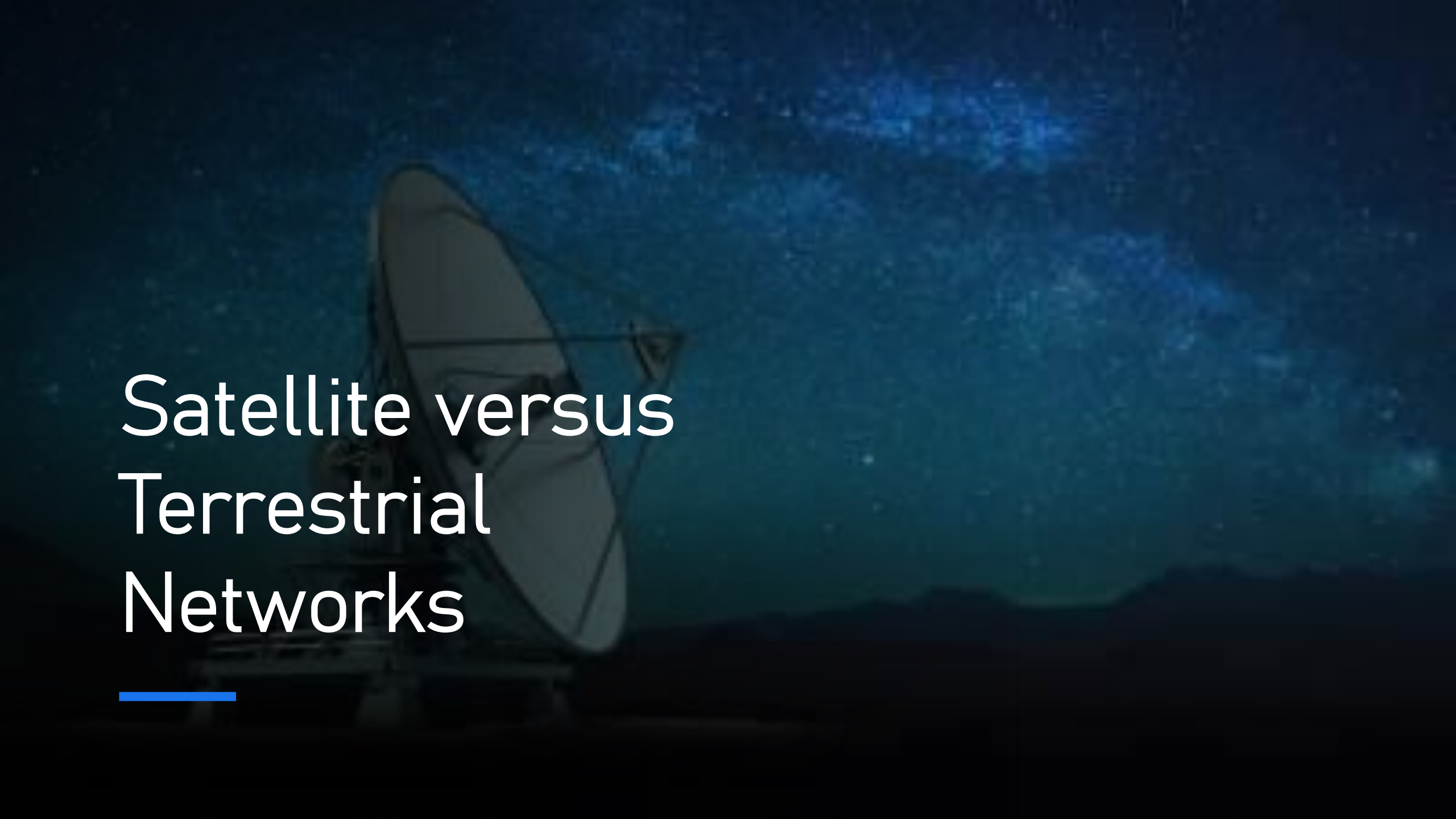
- These transponders perform onboard processing of the received signal before re-transmission.
- Also known as **digital processing repeaters**.
- They actively alter and restore the signal quality, which improves throughput and error performance.
- Offers flexibility to optimize the transmission link for specific services.
- **Key Processes:**
  - Demodulation
  - Error correction
  - Data reformatting

Regenerative Transponders

- Types of Regenerative Transponders
  - Satellite-Switched TDMA Transponders:
    - Use wideband RF and IF switching to route channels.
  - Narrowband Digital Processing Transponders:
    - Utilize channel routing and digital beam forming.
  - Demod-Remod Transponders:
    - These are the most advanced, as they completely **demodulate** the signal, correct errors, and then **re-modulate** the information before re-transmitting it.

Transponder Performance Parameters

- **Effective Isotropic Radiated Power (EIRP):** The product of the transmit antenna gain and the maximum RF power per transponder.
  - Defines **downlink performance** and the satellite's coverage area.
  - Typical values are around **40 dBW for C-band** and **55 dBW for Ku-band**.
- **Gain-to-Noise Temperature Ratio (G/T):** The ratio of the receive antenna gain to the noise temperature of the satellite receiving system.
  - Defines **uplink performance** and the satellite's ability to "hear" signals from Earth.



Satellite versus Terrestrial Networks

Satellite versus Terrestrial Networks

- Satellites, initially conceived to provide support services to terrestrial communication networks, have made a great deal of progress in the last fifty years.
- Satellites have established themselves as a pioneering element of communication networks.
- However, with the advances made in the field of terrestrial communication network technology, like the advent of fibre optic technology, satellites are facing tough competition from the terrestrial networks.

Advantages of Satellites Over Terrestrial Networks

1. Broadcast property– wide coverage area
   - A single transmission can cover vast geographical areas, making it ideal for point-to-multipoint services like television.
2. Wide bandwidth–high transmission speeds and large transmission capacity
   - Offers large transmission capacity and high speeds, though modern fiber optic networks now provide comparable capabilities.
3. Geographical flexibility– independence of location
   - Reaches remote locations, difficult terrains, and developing nations where terrestrial networks are non-existent or impractical.
4. Easy installation of ground stations
   - Ground stations are significantly simpler, faster, and cheaper to install than laying extensive terrestrial cables.

Advantages of Satellites Over Terrestrial Networks

5. Uniform service characteristics
   - Delivers consistent service characteristics across the entire coverage area (its "footprint"), avoiding fragmentation from different terrestrial operators.
6. Immunity to natural disaster
   - Unaffected by ground-based natural disasters such as earthquakes, floods, or storms that can destroy terrestrial networks.
7. Independence from terrestrial infrastructure
   - Can deliver services directly to the end-user (e.g., DTH, mobile satphones) without relying on ground links.
8. Cost aspects– low cost per added site and distance insensitive costs
   - The cost of communication is independent of the distance between the points on the ground.
   - Adding a new user within the satellite's footprint is highly cost-effective.

Disadvantages of Satellites with Respect to Terrestrial Networks

1. Transmission delay
   - Geostationary (GEO) satellites introduce a delay of a quarter second (~250 milliseconds) as the signal travels to space and back.
   - Unsuitable for real-time applications like online gaming or fast-paced financial trading.
   - Can degrade the quality of voice calls.
   - Data protocols requiring acknowledgements are slowed down significantly.
2. Echo effects
   - The long transmission delay can cause speakers to hear an echo of their own voice.
   - Modern echo suppressors have improved quality for single-hop connections, but the problem can still persist, especially in double-hop satellite links.
3. Launch cost of a satellite
   - While ground stations are relatively inexpensive, the cost to build and launch a satellite into orbit is huge.

Satellite Telephony

Satellite Telephony

- Satellites provide both long distance point-to-point trunk telephony services as well as mobile telephony services, either to complement or to bypass terrestrial networks.
- Allows users to either connect to the regular telephone network or place calls directly through a satellite link.
- Potential users of these services include international business travellers and people living in remote areas.
- Satellite telephony networks employ point-to-point duplex satellite links enabling simultaneous communication in both the directions.

Satellite Telephony

- Single GEO satellites or a constellation of LEO, MEO and GEO satellites are used for providing telephony services.
- Telephone satellite links generally employ circuit-switched systems offering a constant bit rate services, but only for the limited duration of the call.
- However, sometimes dedicated or preassigned bandwidth services are used, in which the communication is maintained continuously for an extended period of time, for heavy telephone trucking applications.
- Some of the major satellite systems offering voice services are Intelsat, Eutelsat, Inmarsat, Globalstar, Iridium, ICO, Ellipso and Odyssey systems.

Satellite Telephony

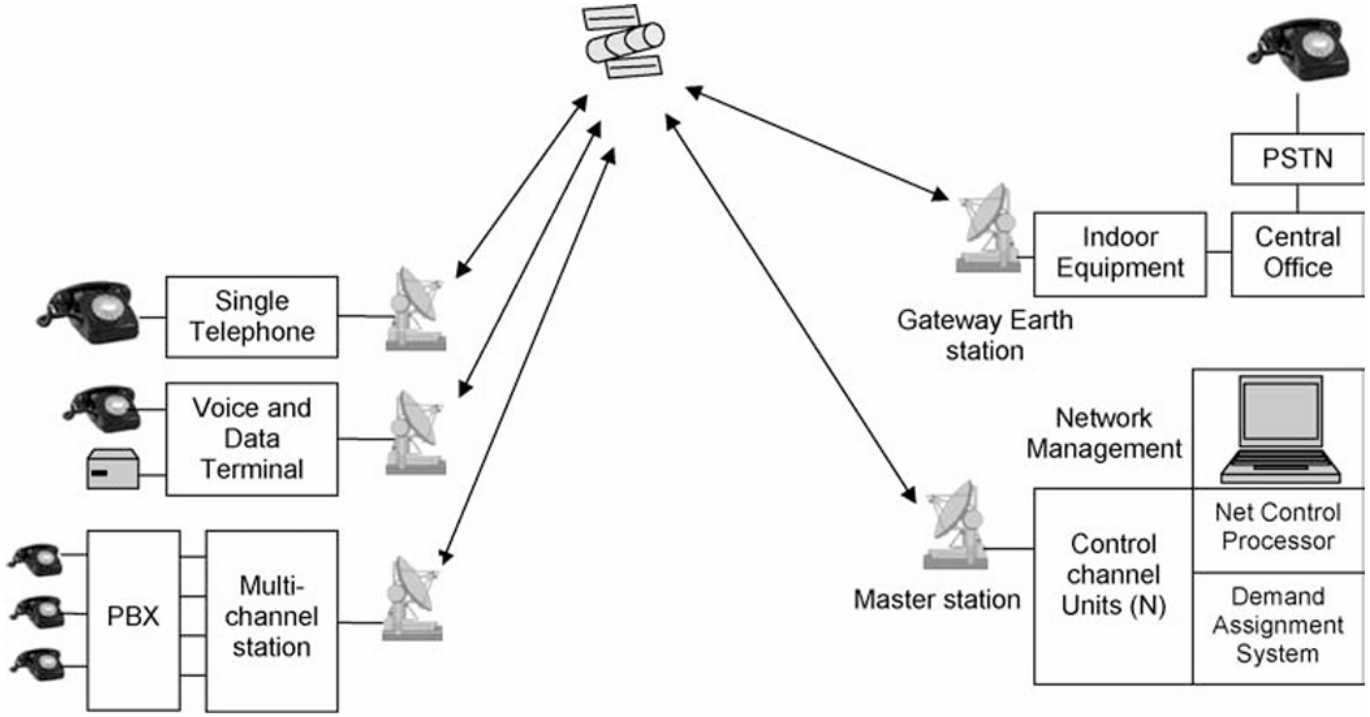


Figure 9.3 Satellite point-to-point telephone networks (PBX, private branch exchange; PSTN, public switched telephone network)

Satellite Telephony

Various steps in making a call through a satellite network are outlined below:

1. The user lifts the receiver when he or she wants to make a call. This sends a request to the local Earth station, which in turn sends a service request to the master station.
2. If the master station is able to provide the satellite capacity, it sends a confirmation signal to the local Earth station, resulting in a dial tone in the telephone instrument.
3. The user then dials the destination number, which is transferred to the control station, which determines the destination Earth station and signals it that a connection needs to be established.
4. The destination Earth station then signals the called party of the incoming call by ringing that telephone instrument.
5. The satellite capacity is allocated to the connection and the telephone link is established once the called party lifts the handset.
6. Once the conversation is over, the calling party hangs up the receiver, hence indicating to the local Earth station to terminate the call.

Point-to-Point Trunk Telephone Networks

- Traditional use of satellites for long-distance, intercontinental phone services, known as "thin-route" services.
- These services are used in areas where terrestrial networks are not feasible due to low population density or difficult terrain.
- Part of Fixed Satellite Services (FSS), they typically utilize C and Ku bands and geostationary (GEO) satellites.
- Examples of satellites used include Intelsat, Europestar, Eutelsat, and PamAmSat.
- While they provide reliable and secure communication, their popularity is declining due to the growth of new technologies like fiber optics.

Mobile Satellite Telephony

- Provides interactive voice communication to mobile users via satellite.
- Targets two key markets:
  - **Global business users** who need worldwide coverage with a single device.
  - **Unserved regions** lacking basic terrestrial telecommunication infrastructure.

Mobile Satellite Telephony

Evolution of Services

- **Early History:** The first experiments began in 1977.
  - The first civilian mobile satellite, **Inmarsat**, launched in 1982.
- **Generations:**
  - **Generation I & II (1980–1998):** Used **GEO satellites** to provide telephony to relatively large mobile terminals.
  - **Generation III:** Introduced constellations of **LEO, MEO, HEO, and GEO satellites** to provide voice and multimedia services to smaller, handheld devices.

Mobile Satellite Telephony

Global Mobile Personal Communication Services (GMPCS)

- The term for third-generation mobile satellite services.
- Provides transnational and global two-way voice, fax, messaging, and data services.
- Accessed with small, easily transportable terminals.
- **System Types:** Includes GEO, MEO, HEO, big LEO, small LEO, and broadband GMPCS systems.
- **Frequency Bands:** Most systems use **L and S bands**, while broadband GMPCS operates in the **Ku band**.

Mobile Satellite Telephony

Table 9.1 Features of the various GMPCS systems

Types of GMPCS	Services offered	Frequency range	Terrestrial counterpart	Examples
Little LEO (data only GMPCS)	Data services like messaging in the store-and-forward mode	Below 1 GHz	Messaging services like paging and mobile data services	Orbcomm
Big LEO including LEO, HEO and MEO satellites (narrowband GMPCS)	Real time voice and data services	1–3 GHz	Cellular telephone	Iridium, Globalstar (LEO orbit), ICO constellation (MEO orbit) and Ellipso constellation (HEO orbit)
GEO (narrowband/ broadband MSS)	Both store-and-forward and real time voice, data and video services	1.5–1.6 GHz and around 2 GHz	Cellular ISDN	Inmarsat, ACeS (Asia cellular satellite), APMT (Asia-Pacific mobile telecom-munications), ASC and Thuraya satellite systems
Boadband GMPCS (broadband FSS)	Real time multimedia including voice and data	Above 10 GHz	Fibre optics	Sky Bridge Teledesic constellation

Satellite Television

Satellite Television

- The most popular application of communication satellites, accounting for approximately 75% of the market.
- Uses satellites to relay TV programs from a central broadcast center to a large geographical area.
- Satellites are ideally suited for this due to their ability to provide wide-area coverage.
- Examples include **INSAT** (India), **GE** and **Galaxy** (US), **Astra** and **Hot Bird** (Europe), and **JCSAT** (Japan).
- Can transmit directly to individual users or work with existing terrestrial and cable TV networks.

A Typical Satellite TV Network

- A satellite TV network uses a **GEO satellite** as a **point-to-multipoint repeater**.
- It receives a telecast from a central hub and retransmits it to a wide geographical area.
- The network has two main parts:
  - **Uplink Section:** Sending the signal to the satellite.
  - **Downlink Section:** Receiving the signal from the satellite.

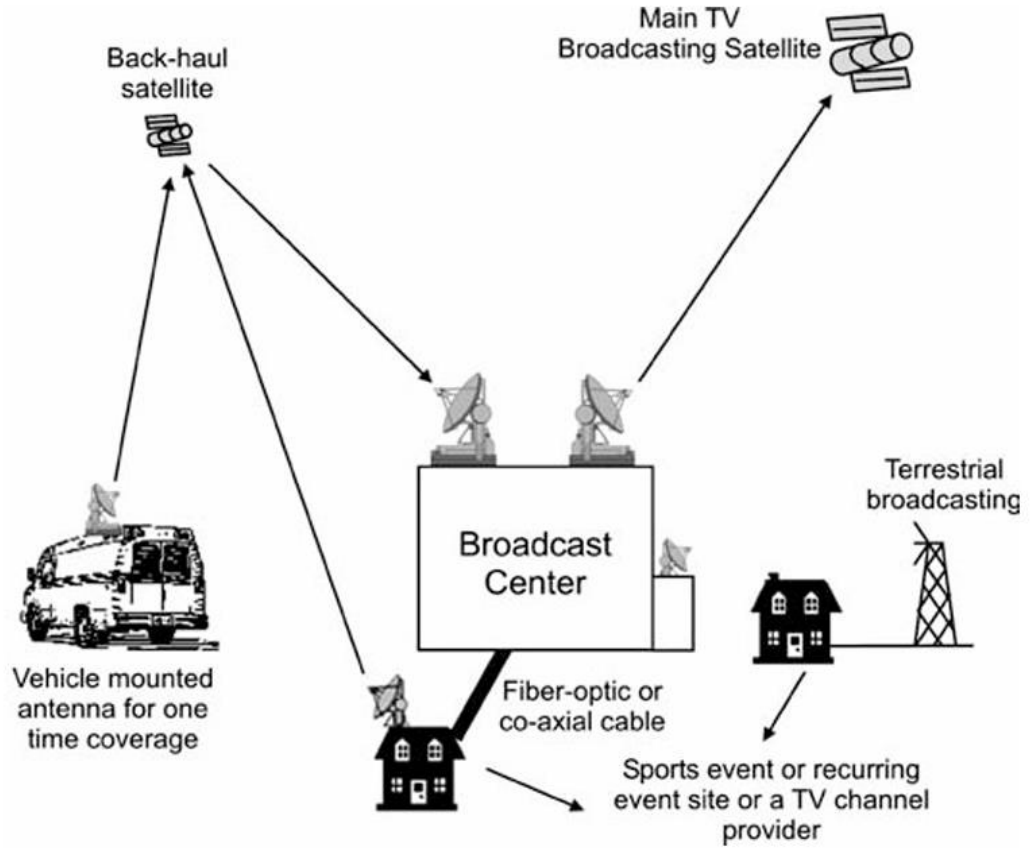


Figure 9.4 Uplink section of satellite TV networks

A Typical Satellite TV Network

- The Uplink Section comprises three main components:
  - **Programming Source:** Provides TV signals (channels, news, sports) to the broadcasting center.
    - Uses terrestrial links (fiber, microwave) or **back-haul satellites** for transmission.
  - **Broadcasting Center:** The system's central hub.
    - Processes and prepares the signals for satellite transmission.
    - Adds content like advertisements or commentary.
    - Generally encrypts the signal and transmits it in the **C-band (analog)** or **Ku-band (digital)**.
  - **Main Broadcasting Satellite:** Receives the signal from the broadcasting center.

A Typical Satellite TV Network

- The Downlink Section comprises the main broadcasting satellite and the TV receiving net work.
  - The main broadcasting satellite retransmits the signal to different types of receiving networks.
  - Three ways the signal reaches the user:
    - **Terrestrial Broadcasting:** Terrestrial centers receive the signal and retransmit it to users via VHF/UHF bands, requiring a directional yagi antenna.
    - **Cable TV:** The signal is received by a **cable TV head-end** and then distributed to users through a cable network.
    - **Direct-to-Home (DTH):** Users receive the signal directly from the satellite using a small, dedicated satellite dish mounted at their location.

Satellite–Cable Television

- **Satellite-Cable TV** uses satellites to deliver TV programs to **cable TV head ends**.
- This system evolved from early "Community Antenna Television" (CATV), which served small communities.
- It is a complex network using coaxial and fiber optic cables to distribute signals from a central head end to subscribers.

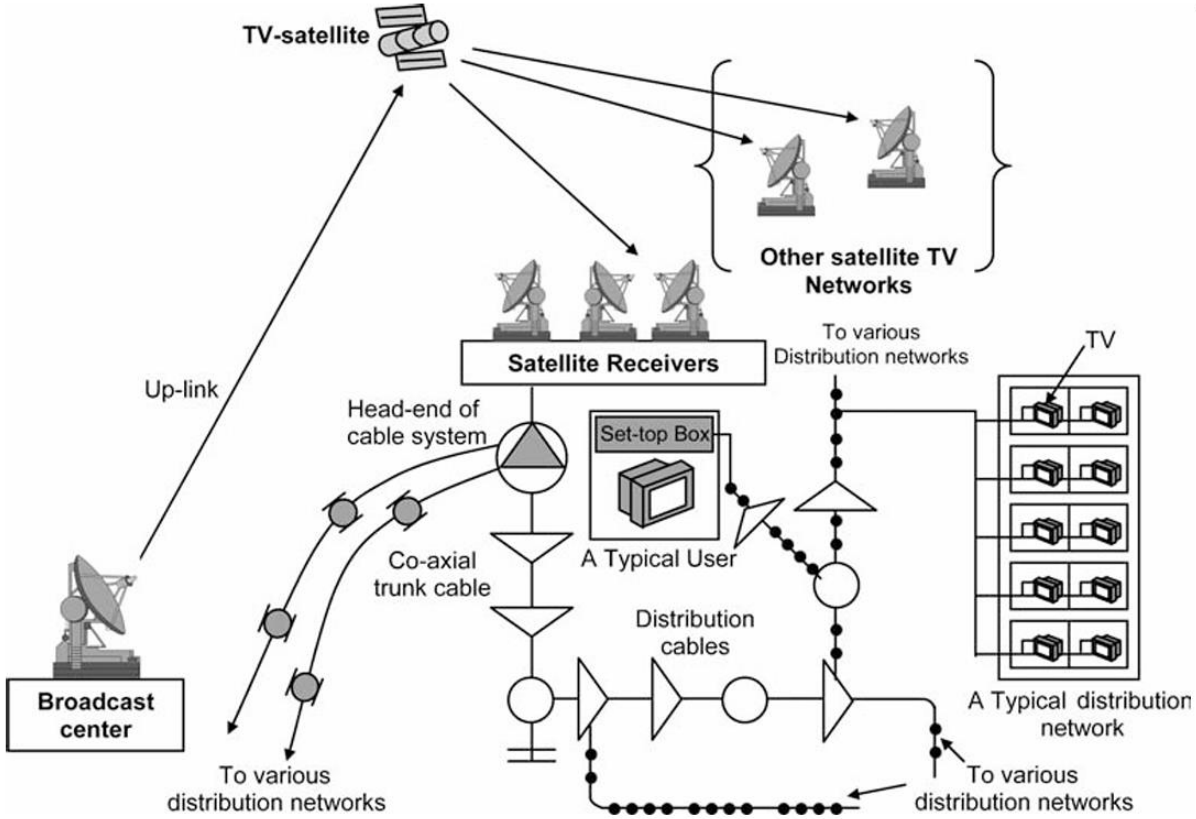


Figure 9.5 Satellite cable television

Satellite–Cable Television

- The Cable Head End is the central distribution station.
  - It receives programming from multiple satellites using either multiple antennas or a single dish with multiple feeds.
  - Signals are received in either analog format (C-band) or digital format (Ku-band).
  - The head end can process digital signals and transmit them to users in either digital or analog format.
- Distribution and Subscriber Access
  - The processed TV channels are transmitted over a cable network to subscribers who pay a monthly fee.
  - To prevent unauthorized viewing, the programs are scrambled.
  - Subscribers require a set-top box to descramble and retrieve the original signal from the cable.
  - In addition to satellite feeds, operators may also transmit their own recorded programming.

Satellite–Local Broadcast TV Network

- A system where a satellite provides programming directly to local terrestrial broadcasting stations.
- These local stations re-transmit the TV signals to users over the air using **UHF and VHF** microwave bands.
- The broadcast range is limited by line-of-sight, typically **50–150 km**.
- Users receive the signal using directional antennas, such as **yagi antennas**.
- This system is sometimes combined with a satellite–cable TV network for broader distribution.

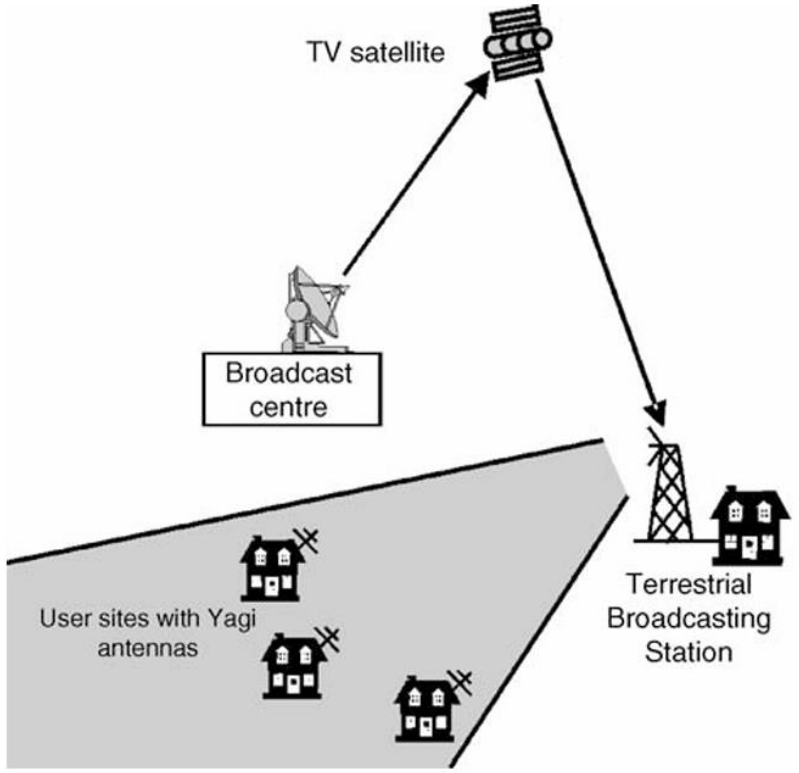


Figure 9.6 Typical satellite local-broadcast TV network

Direct-to-Home Satellite Television

- **Direct-to-Home (DTH)** refers to receiving TV programs directly from a satellite using a personal receiving antenna.
- DTH is classified into two main types based on frequency band and antenna size:
  - Television Receive-Only (TVRO)
  - Direct Broadcasting Satellite (DBS)

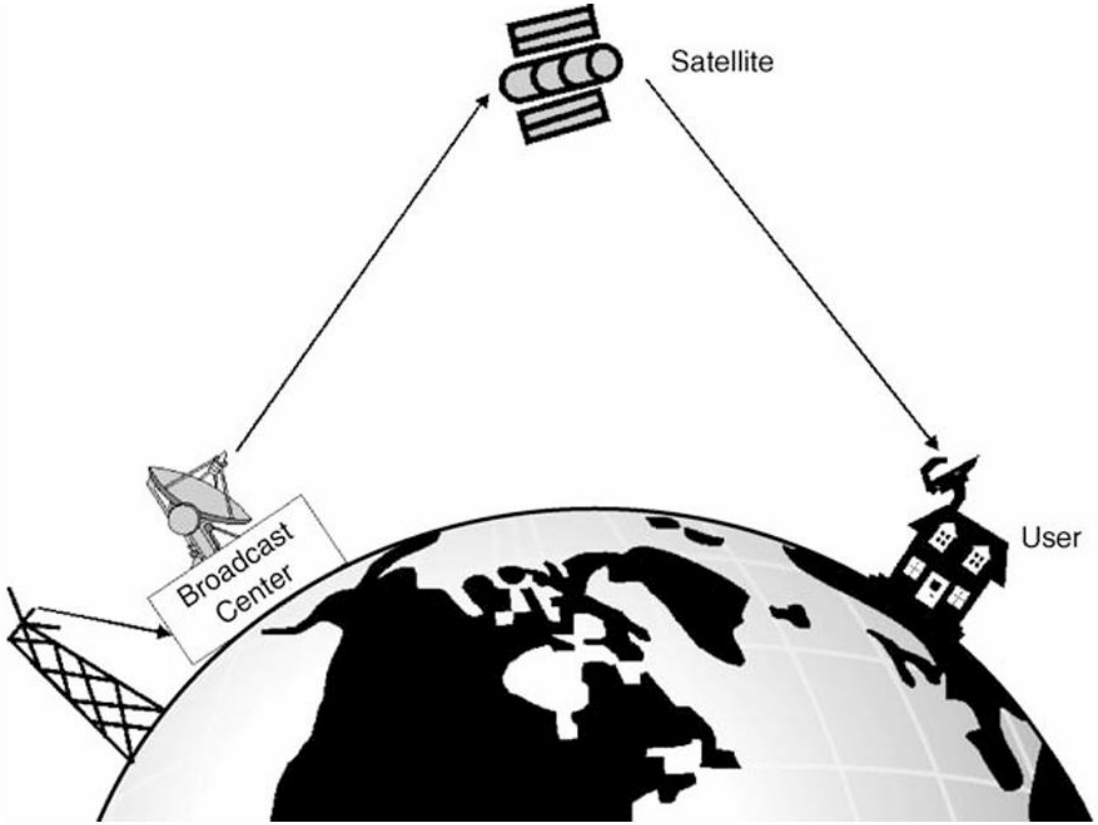


Figure 9.7 Direct-to-home satellite television

Television Receive-Only (TVRO) Services

- Uses large dishes (**6 to 18 feet**) to receive **analog signals** from satellites in the **C-band**.
- **Features:**
  - The large antenna size is needed due to the longer C-band wavelength.
  - Each satellite transponder typically provides only one channel.
  - Antennas are often **steerable** to access different satellites.
- TVRO was the original form of DTH in the 1980s but has been largely replaced by DBS.
  - However, TVRO systems still exist and are being updated to receive digitally scrambled programming channels from Ku band satellites.
  - It is based on **open standards**, offering a wide variety of free channels.

Direct Broadcasting Satellite (DBS) Services

- Uses small, fixed dishes (**45-60cm**) to receive **digitally compressed signals** from high-powered satellites in the **Ku-band**.
- **Features:**
  - Digital compression (**MPEG-2**) allows for **5-12 channels per transponder**, eliminating the need for a steerable dish.
  - It is a **closed system** that uses encryption, requiring a **set-top box** to descramble the signals.
  - There are no free-to-air channels.
- A more recent development, DBS is easier and cheaper to install than TVRO, making it the dominant DTH standard today.

Direct Broadcasting Satellite (DBS) Services

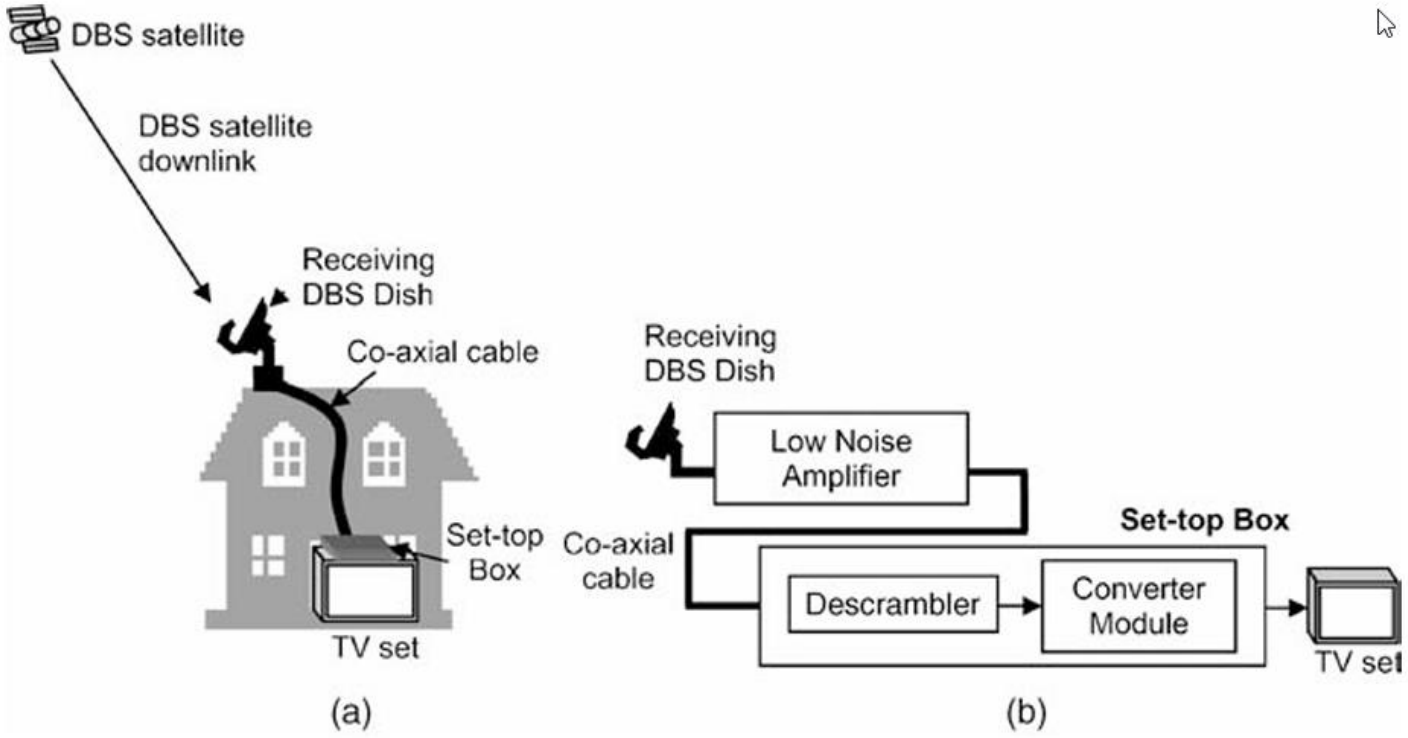


Figure 9.8 (a) DBS receiver set-up (b) Block diagram of a DBS receiver

Modern DTH Services

- Newer digital DBS systems offer a wide range of advanced services:
  - High Definition Television (HDTV)
  - Interactive TV (shopping, voting)
  - Personal Video Recording (PVR)
  - Video-on-Demand (VOD)
  - Pay TV (pay-per-view)
  - High-speed internet access

Satellite Radio

Satellite Radio

- A system that provides high-fidelity audio broadcast services to radio stations or directly to users.
- Offers excellent sound quality due to a wide audio bandwidth of 5–15kHz and low noise.
- Uses GEO satellites in a point-to-multipoint network, similar to satellite TV.
- **Distribution:** Can deliver signals in two ways:
  - **Indirectly:** To terrestrial AM/FM radio stations, which then add local content and re-broadcast to users.
  - **Directly:** To a user's radio receiver.
- Sirius and XM Radio are prominent examples.

Regional Satellite Systems

Regional Satellite Systems

- Satellite missions designed to provide communication services to a group of countries on a **regional basis**, not a global one.
- Primary Goal is to strengthen the communication resources and infrastructure of countries within the same region.
- International satellite systems are too broad and not optimized for the specific needs of individual countries.
  - Regional satellite systems focus on a specific geographical area.
- Regional satellite systems offer services like:
  - Digital Video & Broadcasting
  - Voice & Data Services
  - Mobile Communications

Regional Satellite Systems

Major Regional Satellite Operators

- EUTELSAT – Europe, the Middle East, Africa, and large parts of Asia and the Americas.
- Arabsat – The Middle East, Africa, and large parts of Europe.
- AsiaSat & Measat – The Asia Pacific region.

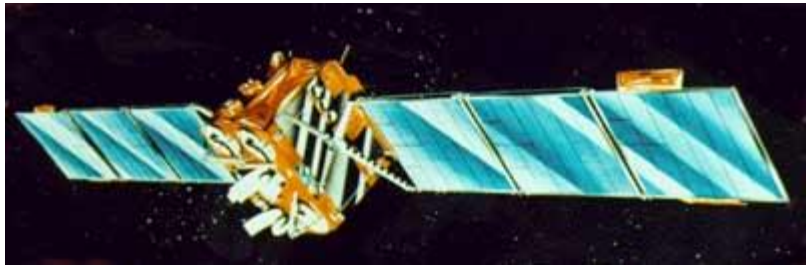
Regional Satellite Systems

Specialized Regional Systems

- ACeS (Asia Cellular Satellite):
  - Region: Asia
  - Services: Provides fully digital video, voice, and data services.
- Thuraya:
  - Region: Middle East, North & Central Africa, Europe, Central Asia, and the Indian subcontinent.
  - Services: Focuses on mobile communication services.

EUTELSAT (European Telecommunication Satellite Organization)

- Founded in 1977, to manage regional satellite services in Europe.
- First Launch (1978) – Orbital Test Satellite (OTS) – for link testing.
- First Service Satellite (1983) – ECS-1 – providing TV and telecom services.
- The initial ECS programme evolved into the global Eutelsat organization of today.



ECS-1

EUTELSAT (European Telecommunication Satellite Organization)

- EUTELSAT has 24 satellites in Geostationary Orbit (GEO).
  - 20 are fully operated by EUTELSAT, 4 are leased.
- Serves over 150 countries.
- Services are available to nearly 90% of the world's population.
- Comprehensive Services:
  - TV & Radio Broadcasting
  - Internet & Broadband Services
  - Corporate Networking & Data
  - Mobile Communications

EUTELSAT (European Telecommunication Satellite Organization)

The EUTELSAT Satellite Families

- Atlantic Bird Series:
  - **Services:** Video, IP (Internet Protocol), and data communication.
  - **Coverage:** Europe, the Middle East, and North Africa.
- Eutelsat Series:
  - **Services:** A new generation providing Internet, TV, business networks, and telephony.
  - **Coverage:** Flexible coverage over Europe, Asia, and Africa.
- Eurobird Satellites:
  - **Primary Service:** Broadcasting and telecommunications.
  - **Coverage:** Focused on Western and Central Europe.

EUTELSAT (European Telecommunication Satellite Organization)

The EUTELSAT Satellite Families

- Hot Bird Family:
  - **Primary Service:** A major provider of television services.
  - **Also Offers:** Radio and multimedia services.
  - **Coverage:** Europe, North Africa, and the Middle East.
- SESAT (Siberia-Europe Satellites)
  - **Unique Feature:** Provides services over an extremely large geographical area.
  - **Coverage:** Extends from the Atlantic Ocean to Eastern Russia, including Siberia.
  - **Steerable Spot Beams:** Allows for targeted service delivery to areas like the Indian subcontinent.
  - **Services:** Corporate data, long-distance telephony, and high-power Ku-band services.

National Satellite Systems

National Satellite Systems

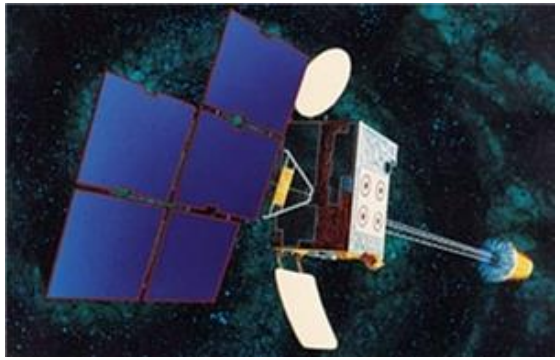
- Also called domestic satellite systems.
- Provides communication services tailored to the specific needs of a single country.
- Initially launched by developed nations like the USA, USSR and Canada, and now also used by countries like India, China, Japan, etc.
- Key examples include **INSAT** (India), **Sinosat** (China), **Brasilsat** (Brazil), **Optus** (Australia), and **Galaxy** (USA).

INSAT (Indian National Satellite)

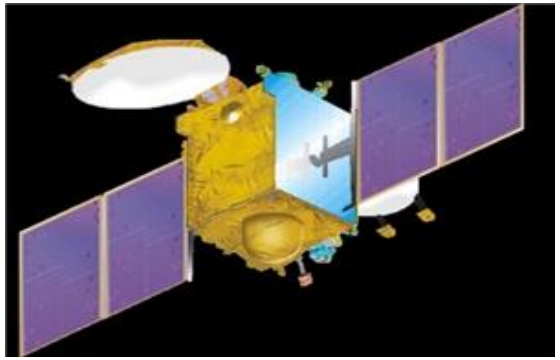
- Operated by the Indian Space Research Organization (ISRO), INSAT is one of the largest domestic communication satellite systems in the world.
- It is a joint venture of the Department of Space (DOS), Department of Telecommunications (DOT), Indian Meteorological Department (IMD), All India Radio (AIR) and Doordarshan.
- Provides crucial services across the nation:
  - Telecommunications
  - Television Broadcasting
  - Meteorology and Disaster Warning
  - Mobile Satellite Services

INSAT (Indian National Satellite)

- The program began with the launch of INSAT-1A in 1982.
- INSAT-1A belonged to the INSAT-1 series, further comprising INSAT-1B, 1C and 1D satellites.
- The INSAT-1 series was followed by INSAT-2 and INSAT-3 series of satellites.
- They were superceded by the INSAT-4 series of satellites.



INSAT-1A



INSAT-4CR

Reference

- Anil K. Maini, Varsha Agrawal, ***Satellite Communications***, Wiley India Pvt. Ltd., 2015, ISBN: 978-81-265-2071-8.