Satellite Communication

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Course Objectives

This course aims to provide knowledge and understanding of:

- The concepts applied in satellite communication systems
- The services and applications offered by satellite communication systems.
- Different components of satellite communication systems
- Different satellite characteristics
- Satellite multiple access techniques
- Earth station and satellite main components
- Satellite link budget calculations and link budget analysis

References:

- “HANDBOOK ON SATELLITE COMMUNICATIONS (HSC)”, Edition 3,

“The origin of the "Handbook on Satellite Communications goes back to 1980, when Study Group 4 (SG 4) of the CCIR (now ITU-R) decided on the preparation of such a Handbook, the main purpose of which was to extend to developing countries the benefit of an adequate knowledge of what was, at that moment, a relatively new and highly promising telecommunication technique".

- Bruce R. Elbert, ”The Satellite Communication Applications Handbook Second Edition”, Edition 3, Artech House, Inc., 2004

“Introduction to Satellite Communication Systems”

Contents

The satellite may take various shapes:

1. **cuboid,**
2. **cylinder,**
3. **long box,**
4. **octahedral shape,**

The main sub-systems are:

1-attitude control system : electronics, star sensor, reaction wheel, horizon sensor, ...
2- Telemetry, telecommand & communications
3- Power system : electronics, solar array, batteries, ...
4- Propulsion system : tanks, valves, thrusters, ...
5- Thermal control
6- structure
7- Payloads
8- separation system
9- Other mechanisms.

Ku-Band vs. C-Band

Ku-Band		C-Band	
Benefits	Drawbacks	Benefits	Drawbacks
It allows the use of smaller dishes	Signals susceptible to fading during rain. Attenuation range from 6 to 10 dB	Signal less susceptible to rain fading. Rain attenuation in the range of 0.4 to 1 dB	Needs slightly larger dishes when compared to Ku-Band
Higher Transponder Power	Not available every where in the world	Widely available	Lower Transponder Power
	Narrower beam coverage	Wider and even global beam coverage	

1.1: History of satellite communication

- 1945 Arthur C. Clarke publishes about „Extra Terrestrial Relays“
- 1957 first satellite SPUTNIK
- 1960 first reflecting communication satellite ECHO
- 1963 first geostationary satellite SYNCOM
- 1965 first commercial geostationary satellite “Early Bird“ (INTELSAT I): 240 duplex telephone channels or 1 TV channel, 1.5 years lifetime
- 1976 three MARISAT satellites for maritime communication
- 1982 first mobile satellite telephone system INMARSAT-A
- 1988 first satellite system for mobile phones and data communication INMARSAT-C
- 1993 first digital satellite telephone system
- 1998 global satellite systems for small mobile phones

I.2: Advantages and Disadvantages of Satellite Communication

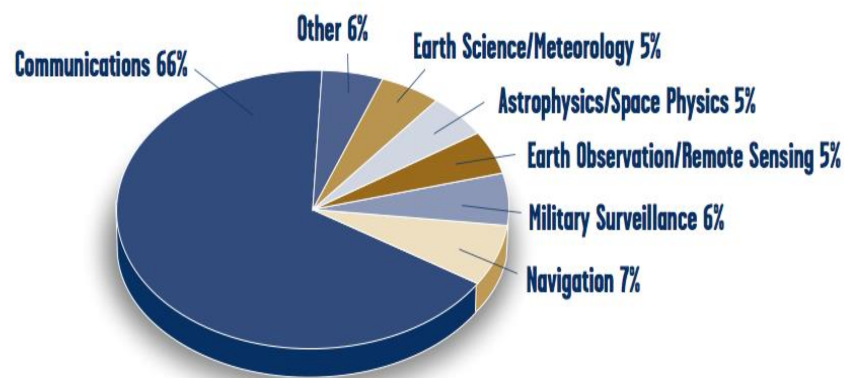
Advantages

- Covers large geographical area
- Flexible (if transparent transponders)
- Easy to install new circuits (link)
- Circuit costs independent of distance
- Temporary applications (restoration)
- Mobile applications
- Terrestrial network "by-pass"
- Provision of service to remote or underdeveloped areas
- 1-for-N multipoint standby possibilities

Disadvantages:

- Large up front capital costs (space segment and launch)
- Terrestrial break even distance expanding (now approx. size of Europe)
- Interference and propagation delay
- Congestion of frequencies and orbits

I.3: Services and Applications Offered by Satellite Communication Systems:



Satellite Services

Type of satellites

1- Satellites Size : (large, small satellites)

2- Remote sensing satellites (observing earth from space):

- Military use:
  - Spy (military information)
  - Guidance of ballistic missiles
  - Warning from ballistic missiles
  - Inspection of destructive weapons
- Civilian use:
  - Land image
  - Natural resources (oil, water, ...)
  - Weather (temperature, storms direction, clouds,

3- Navigation satellites

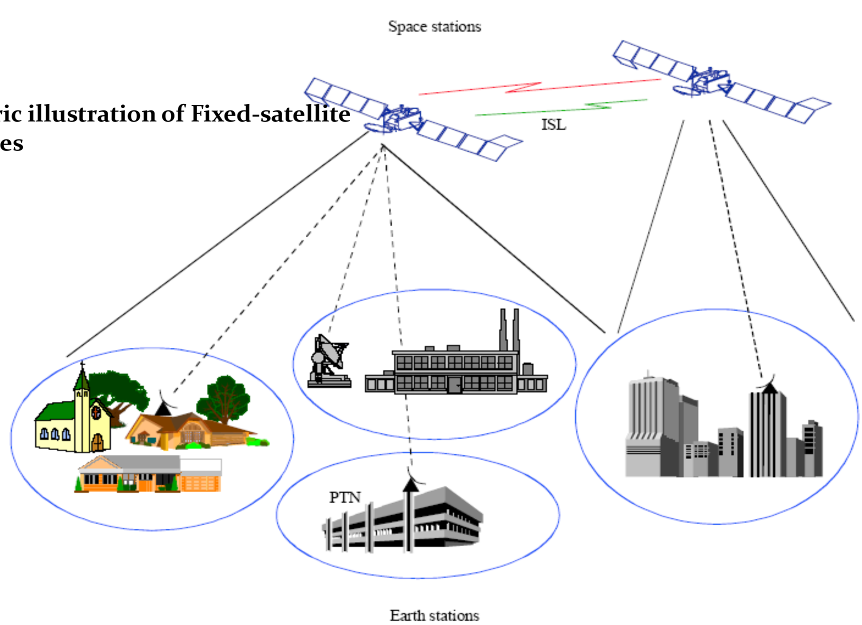
4- Science & exploration satellite:

- Manned satellite (space station, re-entry vehicles, ...)
- Unmanned satellite (probes, satellites, ...)

Satellite Applications:

- **Intercontinental communication services:**
  satellite television, long distance telephony and mobile communication, data communication, video conferencing.
- **Remote sensing and earth observation:**
  Weather, ocean conditions, volcanic eruptions, earthquakes, pollution, health of agricultural crops and forests,
- **atmospheric monitoring and space exploration:**
- **defense applications:**
  secure communications, navigation, military activity, spaying and so on.

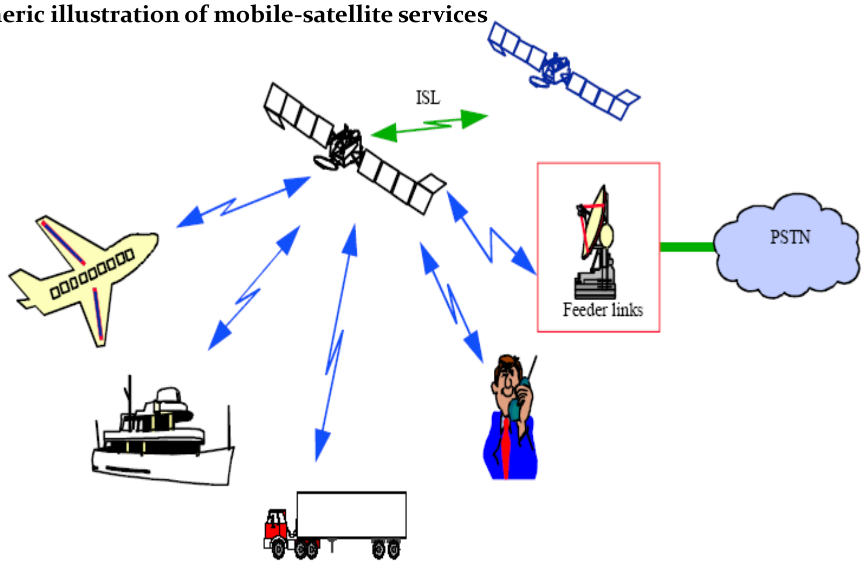
Generic illustration of Fixed-satellite services



(A possible inter-satellite link (ISL) with another satellite is represented)

PTN: public telephone network

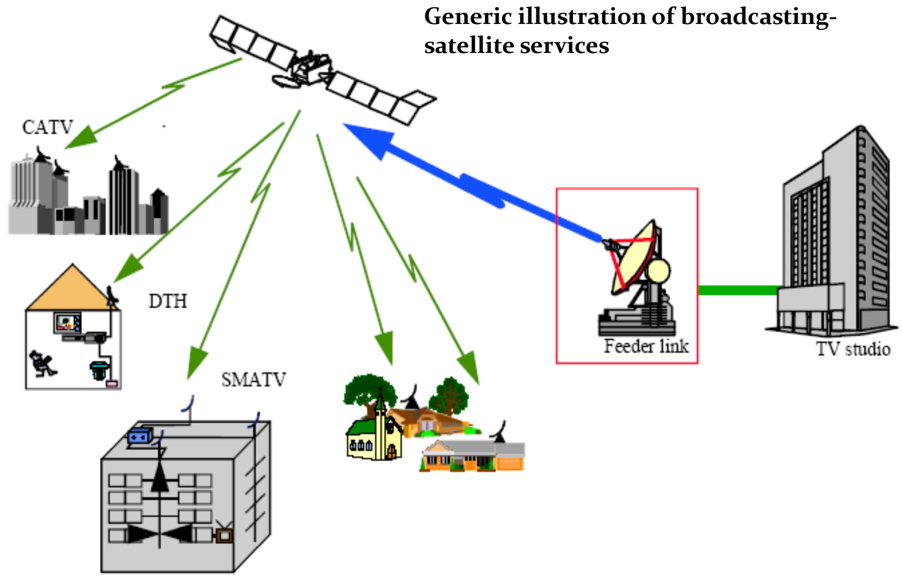
;eneric illustration of mobile-satellite services



(A possible inter-satellite link (ISL) with another satellite is represented)

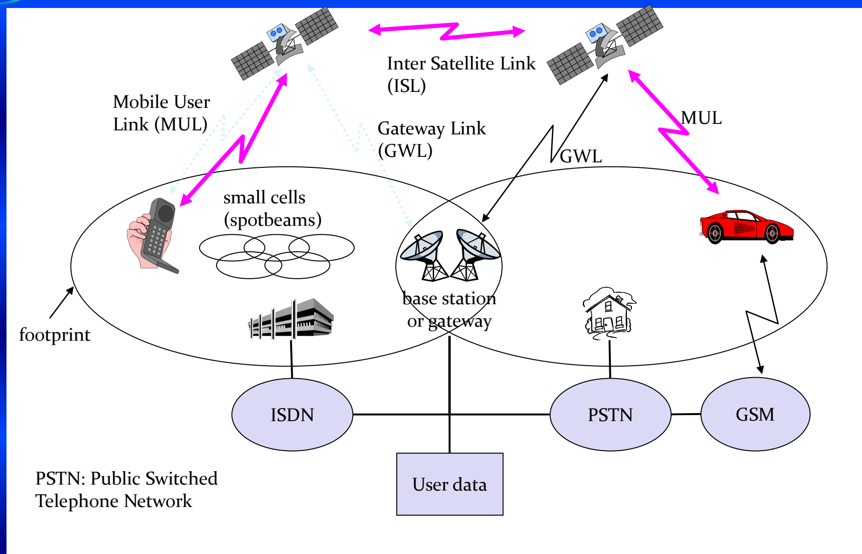
PSTN: public switched telephone network

Generic illustration of broadcasting-satellite services



CATV: Cable television network
SMATV: Satellite master antenna TV
DTH: Direct-to-home TV

Classical satellite systems



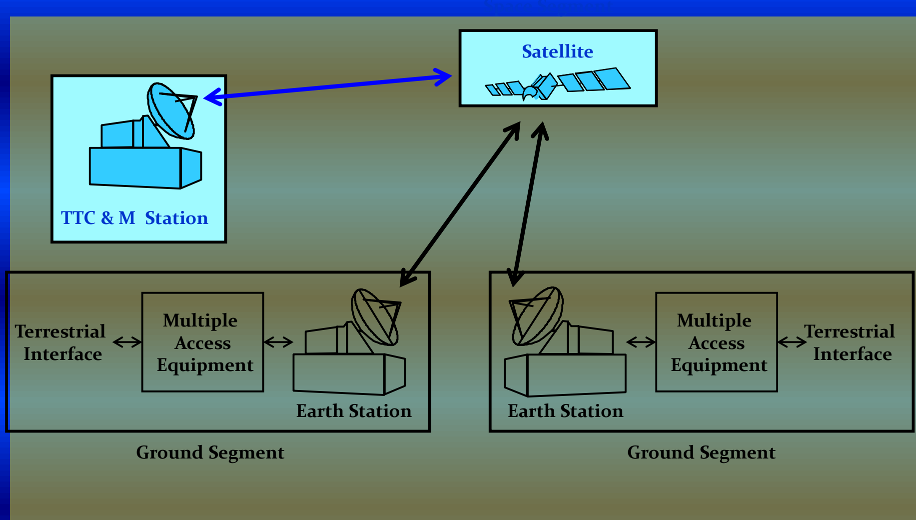
Handover in satellite systems

Several additional situations for handover in satellite systems compared to cellular terrestrial mobile phone networks caused by the movement of the satellites.

- Intra satellite handover
  - handover from one spot beam to another
  - mobile station still in the footprint of the satellite, but in another cell
- Inter satellite handover
  - handover from one satellite to another satellite
  - mobile station leaves the footprint of one satellite
- Gateway handover
  - Handover from one gateway to another
  - mobile station still in the footprint of a satellite, but gateway leaves the footprint

- Inter system handover
  - Handover from the satellite network to a terrestrial cellular network
  - mobile station can reach a terrestrial network again which might be cheaper, has a lower latency etc.

I.4: Communication Satellite:



Main Components:

1) The space segment

The space segment of a communication-satellite system consist of the satellites and the ground facilities providing the tracking, telemetry and telecommand (TTC) functions and logistics support for the satellite:

i) The satellite

It is composed of an assembly of various communication subsystems and antennas. The satellite is also fitted with service equipment to provide the following functions:

- bus structure,
- power supply,
- attitude control,
- orbit control,
- thermal control,
- telemetry, telecommand and ranging.

The telecommunication equipment is composed of transponders. There are different kinds of transponders: transparent transponders and on-board processing (OBP) transponders. The most widely used are transparent transponders.

ii) Tracking, telemetry and telecomm and:

These subsystems are used for carrying out from the ground the following operations for the logistics support of the satellites:

- tracking the position of the satellite (angular position, distance) and determining attitude while it is being placed in orbit and then throughout its life to supervise operation and transmit correction instructions,
- telemetering of various on-board functions,
- command of various on-board functions,
- supervision of telecommunication functions, especially of the carriers in the various transponders.

2) The earth segment

The earth segment is the term given to that part of a communication-satellite system, and which form the interface with the terrestrial networks. An earth station includes all the terminal equipment of a satellite link. Its generally consist of the following main items:

- The transmitting and receiving antenna, with a diameter ranging from 50 cm to more than 16 m.
- the receiver system, with a sensitive, low noise amplifier front-end having a noise temperature ranging from about 30 K, or even less, to several hundred K;
- The transmitter, with power ranging from a few watts to several kilowatts, depending on the type of signals to be transmitted and the traffic;
- The modulation, demodulation and frequency translation units;
- The signal processing units;

Basic characteristics

1) **Coverage area:** Global, regional, national

2) **Propagation delay:** An important feature of satellite links is the propagation delay. In the case of GSO systems, owing to the distance of the geostationary satellite from the Earth, the propagation time between two stations via the satellite can reach approximately 275 ms.

3) **Services:** Almost anything that can be classified as telecommunications can be carried by satellite communications. A possible classification is as follows:

- telephony/facsimile (fax), etc.;
- television, video and audio;
- data transmission and business services;
- integrated services digital network (ISDN);
- emergency communications;
- cable restoration services.

4) Multiple Access:

is the ability for several earth stations to transmit their respective carriers simultaneously to the same satellite transponder.

Three main modes of multiple access :

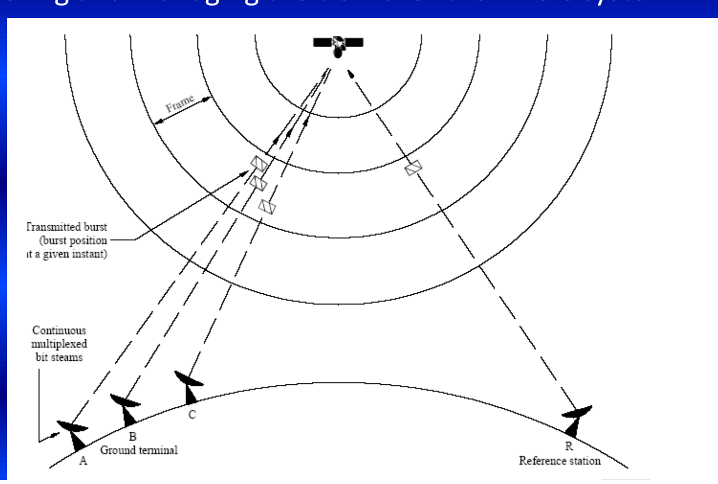
- **Frequency Division Multiple Access (FDMA)**, where each concerned earth station is assigned its own carrier frequency, inside the transponder bandwidth .
- **Time Division Multiple Access (TDMA)**, where all concerned earth stations use the same carrier frequency and bandwidth with time division (i.e. they do not simultaneously transmit their signals) .
- **Code Division Multiple Access (CDMA)**, where all concerned earth stations simultaneously share the same bandwidth and recognize the signals by various processes such as code identification .

There are also two different modes for assigning the communication channels in the transmitted carriers:

- **Pre-Assignment Multiple Access (PAMA),** in which the channels required between two earth stations are assigned permanently for their exclusive use.
- **Demand-Assignment Multiple Access (DAMA),** in which the channels' allocation is changed in accordance with the originating call . The channel is automatically selected and is connected for transmission only while the call is continued. This approach substantially increases the efficiency of the satellite transponder utilization and, more generally of the whole communication system in comparison with PAMA.

TDMA was the first major digital modulation system implemented in the INTELSAT system, where space segment capacity is allocated on the basis of sequential time shared use of the entire transponder bandwidth. Each INTELSAT TDMA network comprises **four reference stations per network including the back-up stations,** a number of traffic terminals and one satellite. The reference stations provide network timing, and control the operation of traffic terminals. The traffic terminals operate under the control of a reference station, and transmit and receive bursts containing traffic and system management information. The reference stations and the traffic terminals are interconnected by the satellite.

The first burst in the frame contains no traffic and it is used for synchronization and network control purposes. This burst is called the reference burst and is generally sent by a special reference earth station which is in charge of providing synchronization, monitoring and managing the traffic for the whole system.

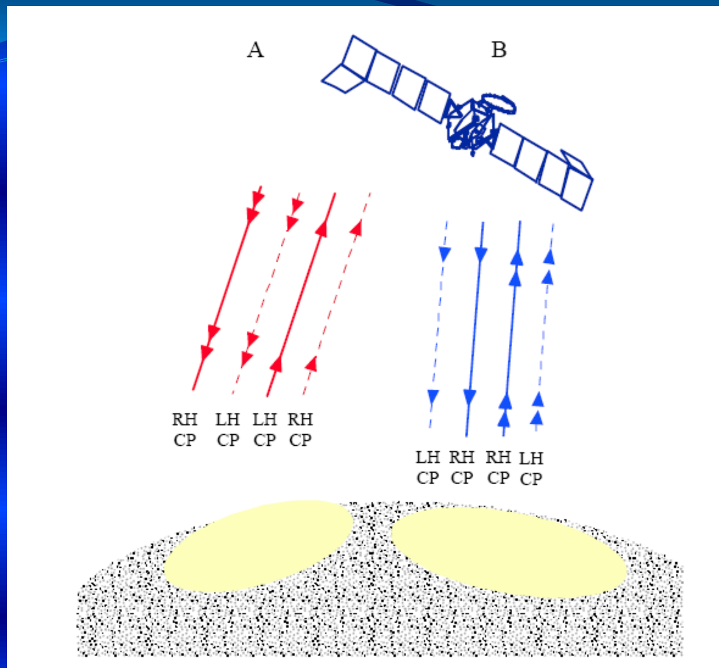


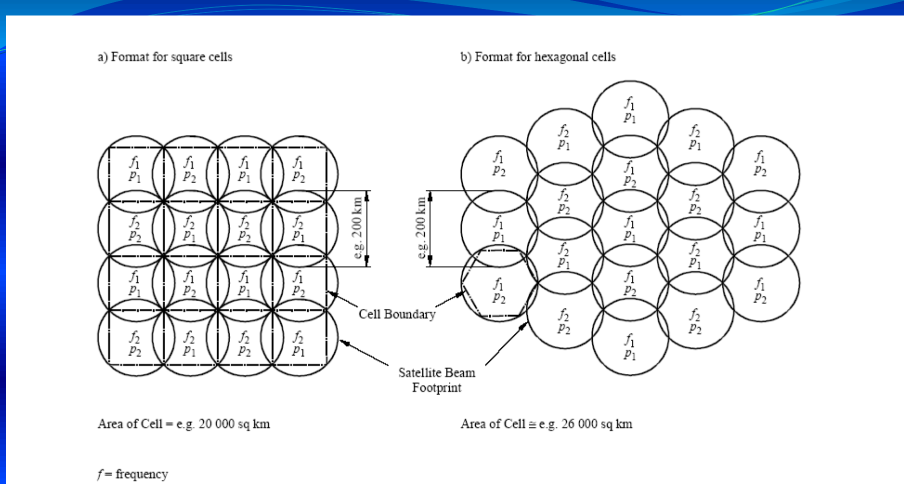
5) Frequency reuse and bandwidth utilization

A telecommunication satellite constitutes a very wide band high traffic. The primary energy sources on the satellite can supply a large number of transponders [e.g. 50 transponders with a power of 5 to 10 W on the INTELSAT-V satellite]. These transponders share the total effective bandwidth: in the frequency bands now most widely used (6/4 GHz and 14/11 GHz). The available bandwidth is 500 MHz and the bandwidth of each repeater is usually about 40 or 80 MHz. It has become current practice to reuse the available bandwidth several times, thus considerably increasing the total effective bandwidth.

This frequency reuse can be effected by two procedures, which are mutually compatible:

- frequency reuse by beam separation: the same frequency bands are transmitted by the satellite antennas using different transponders by means of directional and space-separated radiated beams;
- frequency reuse by polarization discrimination (also known as dual polarization frequency reuse): the same frequency bands are transmitted by the satellite antennas through different transponders using two orthogonal polarizations of the radio-frequency wave;





Typical illustration of frequency and dual polarization reuse in non-GSO satellite systems

Dual polarization frequency reuse on a given satellite is performed by implementing the same frequency band in two different transponders which serve the same coverage area, but with two orthogonal polarizations. The two polarizations may be linear (e.g. horizontal and vertical) or circular (right hand circular polarization: RHCP and left hand circular polarization: LHCP).

On the satellite, there can be two different antennas, one for each polarization or a common antenna can be used. In the latter case, the (transmit or receive) antenna is connected to the transponder through a microwave coupler with two orthogonally polarized ports, called an ortho-mode transducer (OMT).

Dual polarization frequency reuse techniques may be impaired by the propagation path through the Earth's atmosphere, resulting in interference between the two orthogonal polarized transmissions.

This phenomenon, referred to as depolarization or cross-polarization, is induced by two sources: Faraday effect, which is caused by the Earth's magnetic field in the ionosphere, and primarily rain or ice crystals.

Faraday effect causes a time-varying and frequency-dependent polarization rotation (not depolarization) in the orientation of the polarization plane. Peak values of Faraday rotation can be as high as 9° at 4 GHz and 4° at 6 GHz. Faraday rotation has a negligible effect on circular polarization and, in many cases for frequencies above 10 GHz, for linear polarization as well.

Rain or ice crystal-induced depolarization is caused by non-spherical rain drops, which produce a different attenuation and phase shift between orthogonal linear components of the signal which degrades the discrimination between either linearly or circularly polarized signals.