Basics of Satellite Communications

(Duration: 90 Minutes)

Note: Please ask Questions Anytime!

Presenter: E. Kasule Musisi
ITSO Consultant
Email: kasule@datafundi.co.ug
Cell: +256 772 783 784
Skype: ekasule

Topics in this Module

- Birth of Satellite Communications
- Communication Links
- The Space Segment
- Satellite Design
- The Ground Segment
- Satellite Orbits
- Earth Station Registration
- Orbital Positions and Radio Interference
- Services
- Satellite Lifecycle Management
- Technology Trends
- Polarisation
- Introduction to Satellite Link Analysis

Birth of satellite communications 1/11

Communications satellites may be used for many applications:

- relaying telephone calls
- providing communications to remote areas of the Earth,
- TV direct-to-user broadcasting
- providing communications to ships, aircraft and other mobile vehicles
- etc .

Birth of satellite communications 2/11

Network Services


Cell Backhaul


Maritime Communications


Oil & Gas


Aeronautical


Disaster Recovery


Enterprise

Media Services


DTH


Cable Distribution


MCPC Platforms


Special Events


Satellite News Gathering


Mobile Video

Government Services


ISR


Military Mobility


Hosted Payloads

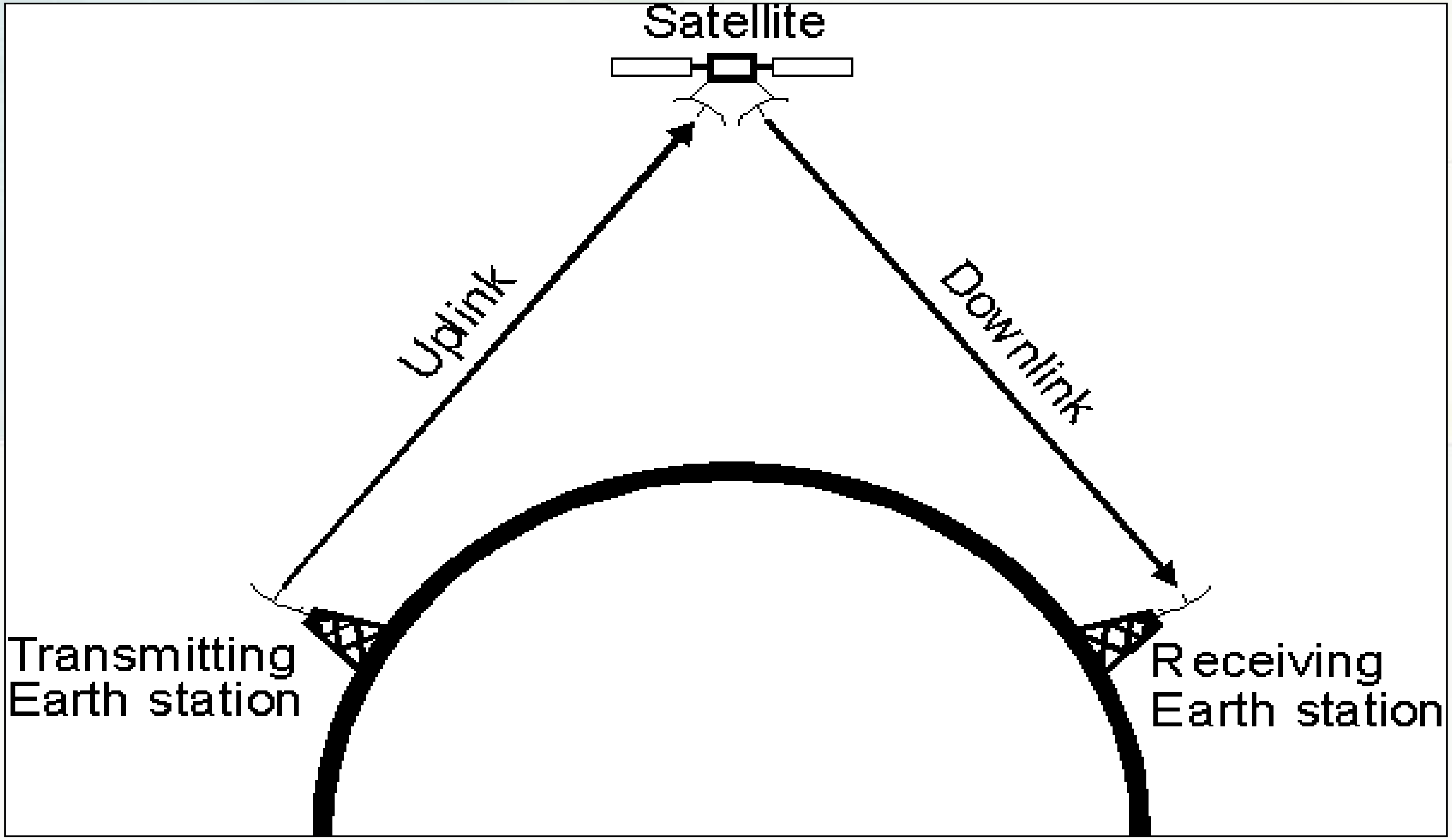

End-to-End Communications


Embassy Networks


Space Situational Awareness

Birth of satellite communications 3/11

A communications satellite acts as a repeater



Birth of satellite communications 4/11

Frequently Asked Questions (FAQs)

- **Who invented satellites?**
  - Arthur C. Clarke, who went on to be a well-read author of science fiction novels.
- **When were satellites invented?**
  - The first satellites were experimented with in the late 1950's and early 1960's. Intelsat's first satellite, which was called 'Early Bird', was launched on 6 April 1965.
- **How big is a satellite?**
  - (Based on the Intelsat 9 series) Before liftoff it's, about 4,500 kilograms! Without fuel, it's about 2,000 kilograms! The body is 5.6 meters …and the solar panels are 31 meters wide – more than a 10-story building!
- **How many years can a satellite last?**
  - It varies by satellite type. The type of satellites owned by Intelsat can last over 20 years, but typically their work life is approximately 15 years.

Birth of satellite communications 5/11

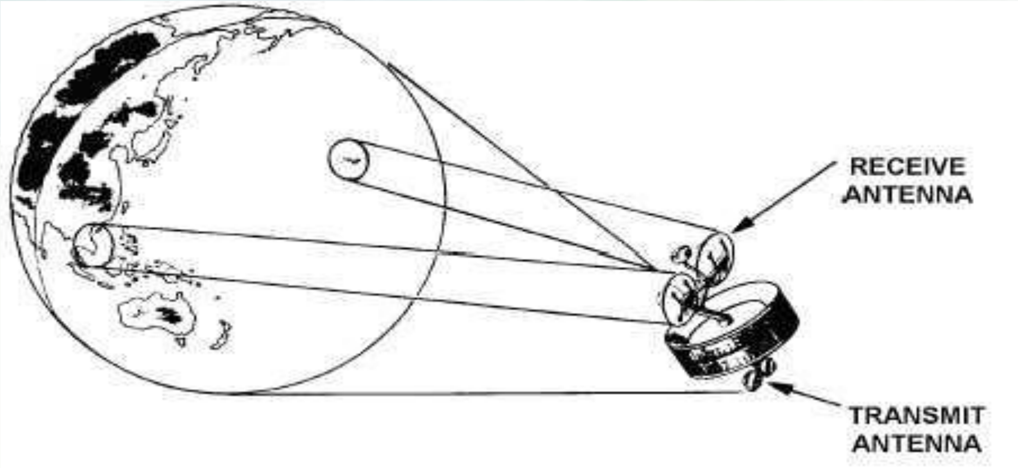
Frequently Asked Questions :

- **How do you fix satellites if they get broken?**
  - The satellites send back 'health check' information to ground engineers all the time. Pre-developed commands are sent to the satellite to perform certain functions, such as firing a booster or changing the angle of a solar panel, so that it can repair itself.
- **How does a satellite get its power?**
  - Mostly solar power collected by the solar arrays/panels. There are also batteries on the satellites for the times when the satellite passes through the earths shadow. This is called eclipse.
- **How much power does it take to transmit a signal?**
  - The power used to send a communications signal to the Earth from a satellite is about the same as a typical 60W light bulb, just like you have at home.
- **What kinds of people work in the satellite industry?**
  - All kinds! Engineers, rocket scientists, sales people, writers, accountants and lawyers.

Birth of satellite communications 6/11

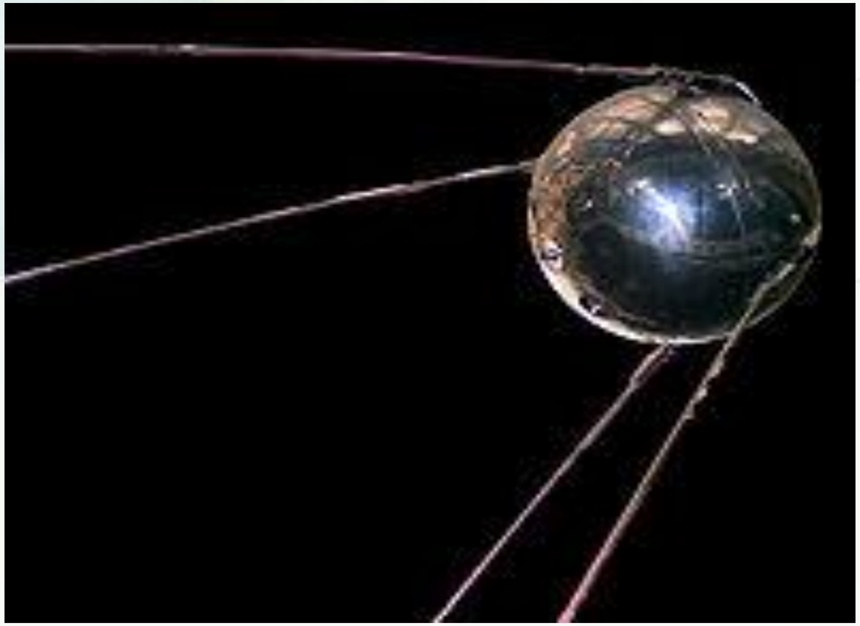
In the context of spaceflight, a **satellite** is an object which has been placed into orbit by human endeavor.

Such objects are sometimes called **artificial satellites** to distinguish them from natural satellites such as the Moon.



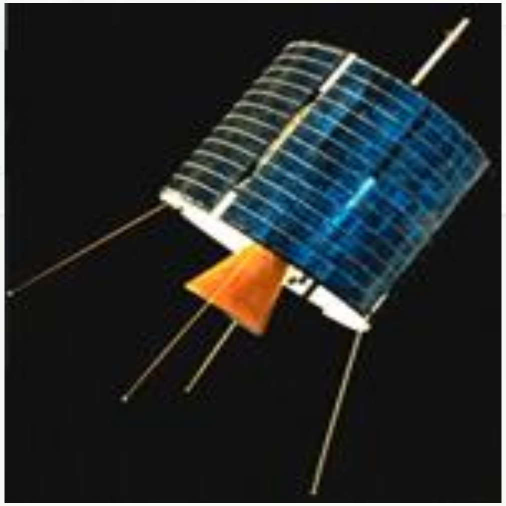
Birth of satellite communications 7/11

First satellite was launched in 1957 by Russia. It was named "Sputnik 1"



Birth of satellite communications 8/11

INTELSAT I (nicknamed **Early Bird** for the proverb "The early bird catches the worm") was the first (commercial) communications satellite to be placed in geosynchronous orbit, on April 6, 1965.



Birth of satellite communications 9/11

Benefits of Satellites

- Adaptable to customer requirements
- Mobility
- Cost advantage
- Not affected by geographical obstructions
- Quick implementation
- Alternate routing or redundancy
- Cost is independent of distance
- Cost effective for short term requirements

Birth of satellite communications 10/11

Satellites are complementary to cable for the following reasons:

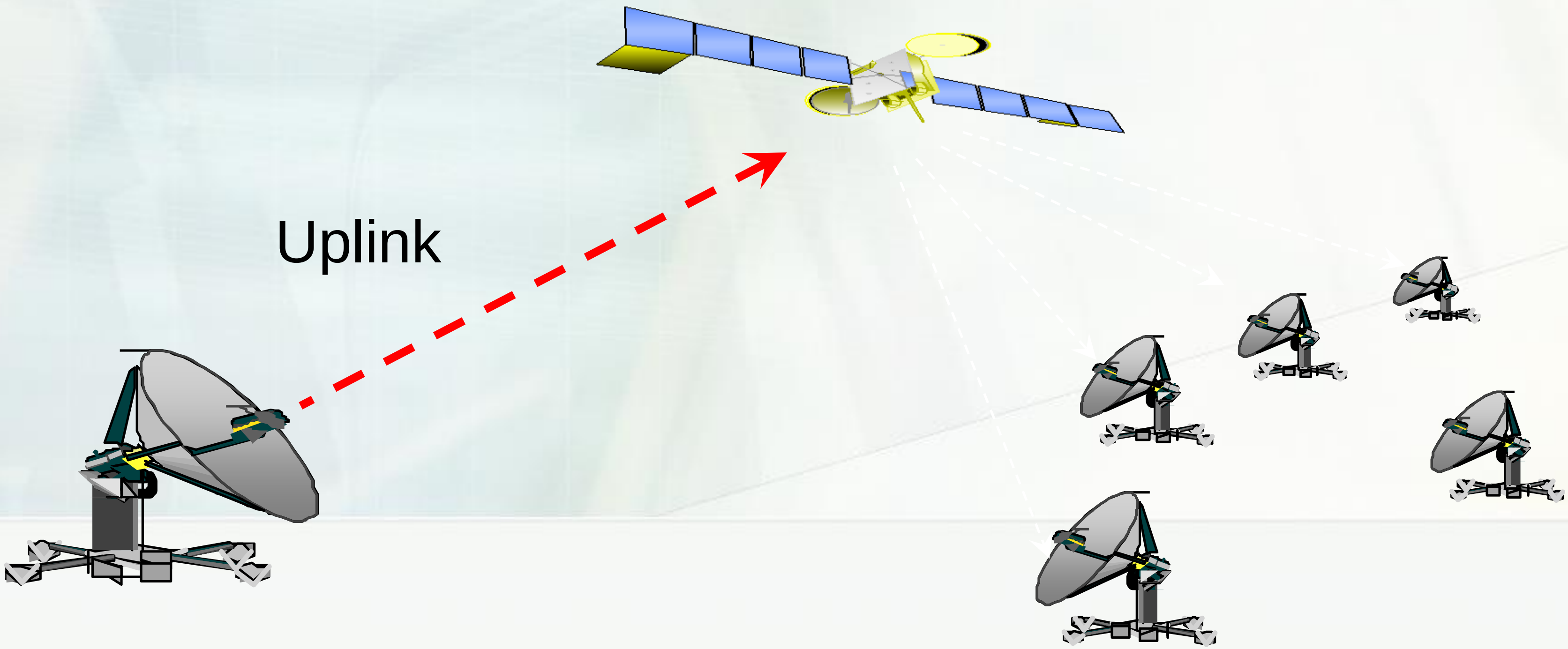
- Submarine cables (and landline fibre) are subject to cuts
- Interim solutions for cellular backhaul and internet trunking
- Satellite systems utilizing MEO (medium Earth orbit) have both high capacity and high quality (low latency) and cost.

Birth of satellite communications 11/11

Types of satellites

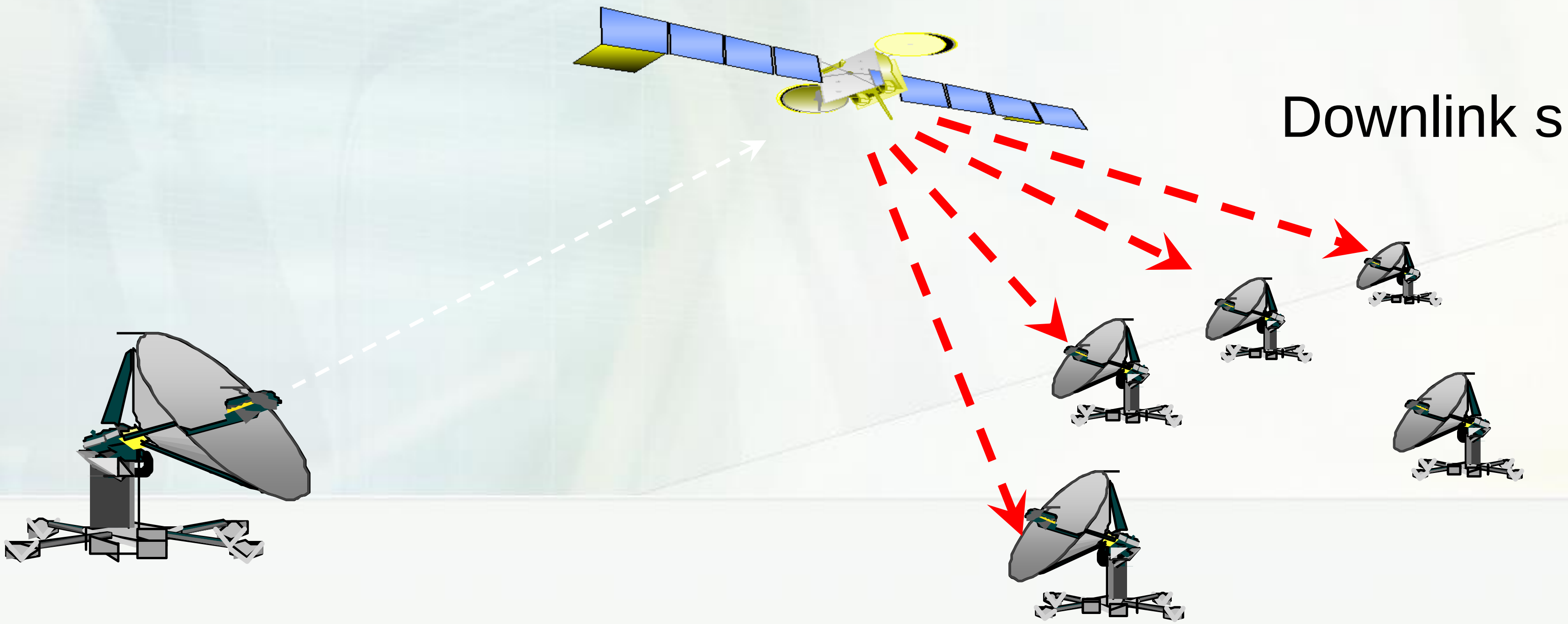
- **Communications satellites**
- **Weather satellites:** provide meteorologists with scientific data to predict weather conditions and are equipped with advanced instruments
- **Earth observation satellites**
- **Navigation satellites:** Using GPS technology these satellites are able to provide a person's exact location on Earth to within a few meters
- **Broadcast satellites:** broadcast television signals from one point to another (similar to communications satellites).
- **Scientific satellites :** perform a variety of scientific missions e.g. the **The Hubble Space Telescope**
- **Military satellites**

Communication Links 1/4



Uplink - The transmission of signals to the satellite

Communication Links 2/4



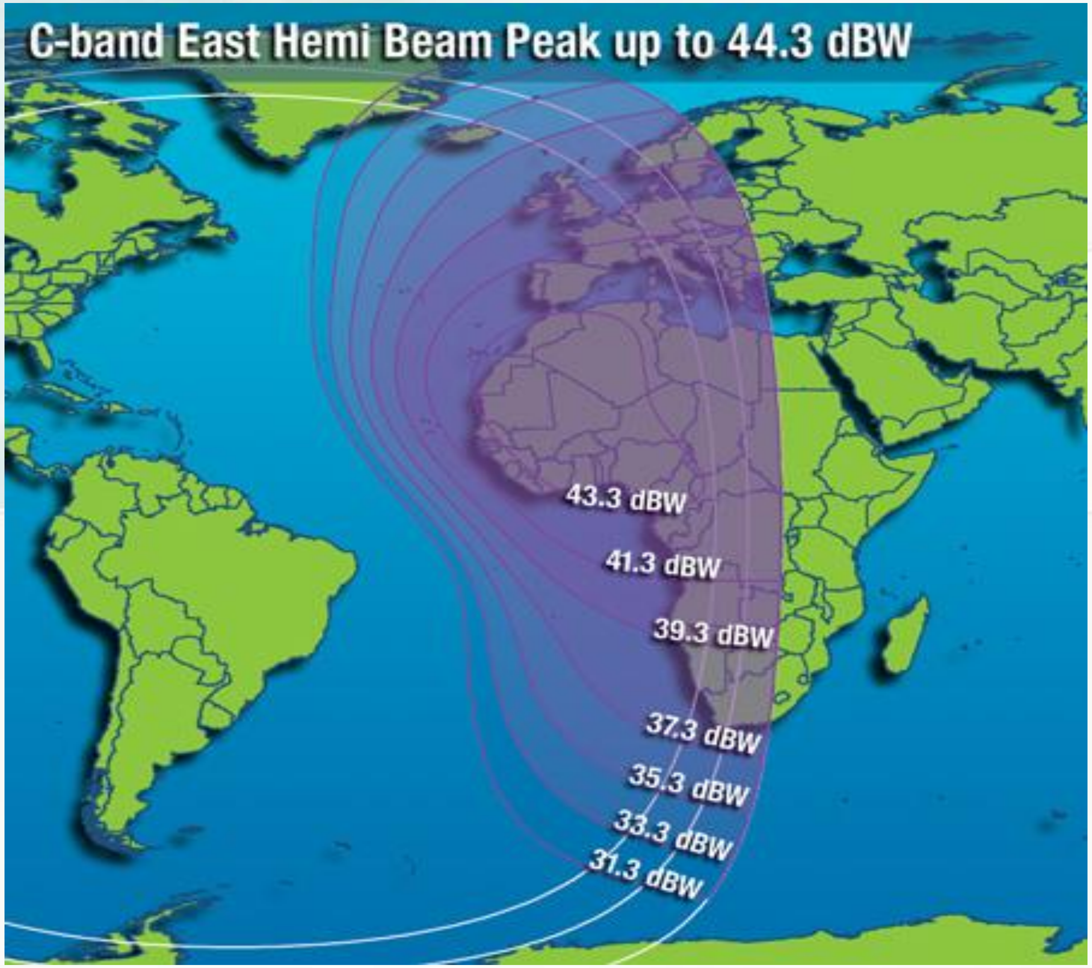
Downlink - The transmission of information from the satellite. Many Earth Stations can be covered by one satellite beam footprint

Communication Links 3/4

- NOTE:
  - Satellites receive at a different frequency than they transmit at
  - Different wavelengths give different radiation patterns on the antennae
  - This causes slightly different footprints for uplink and downlink
  - For marketing reasons the patterns may be different

Communication Links 4/4

A satellite beam "footprint"



The Space Segment 1/6

A satellite communications (satcom) system maybe looked at as comprising of three parts “space segment”, the “ground segment” and the transmission medium (the space between the Earth and the satellite)

The Space Segment 2/6

- A telecommunications satellite comprises:
  - A platform (or bus): propulsion system, fuel tanks, batteries, solar panels, attitude and orbit control functions, etc. It is usually standardized by the manufacturer.
  - A payload: the equipment used to provide the service for which the satellite has been launched. It is customized for a given mission .

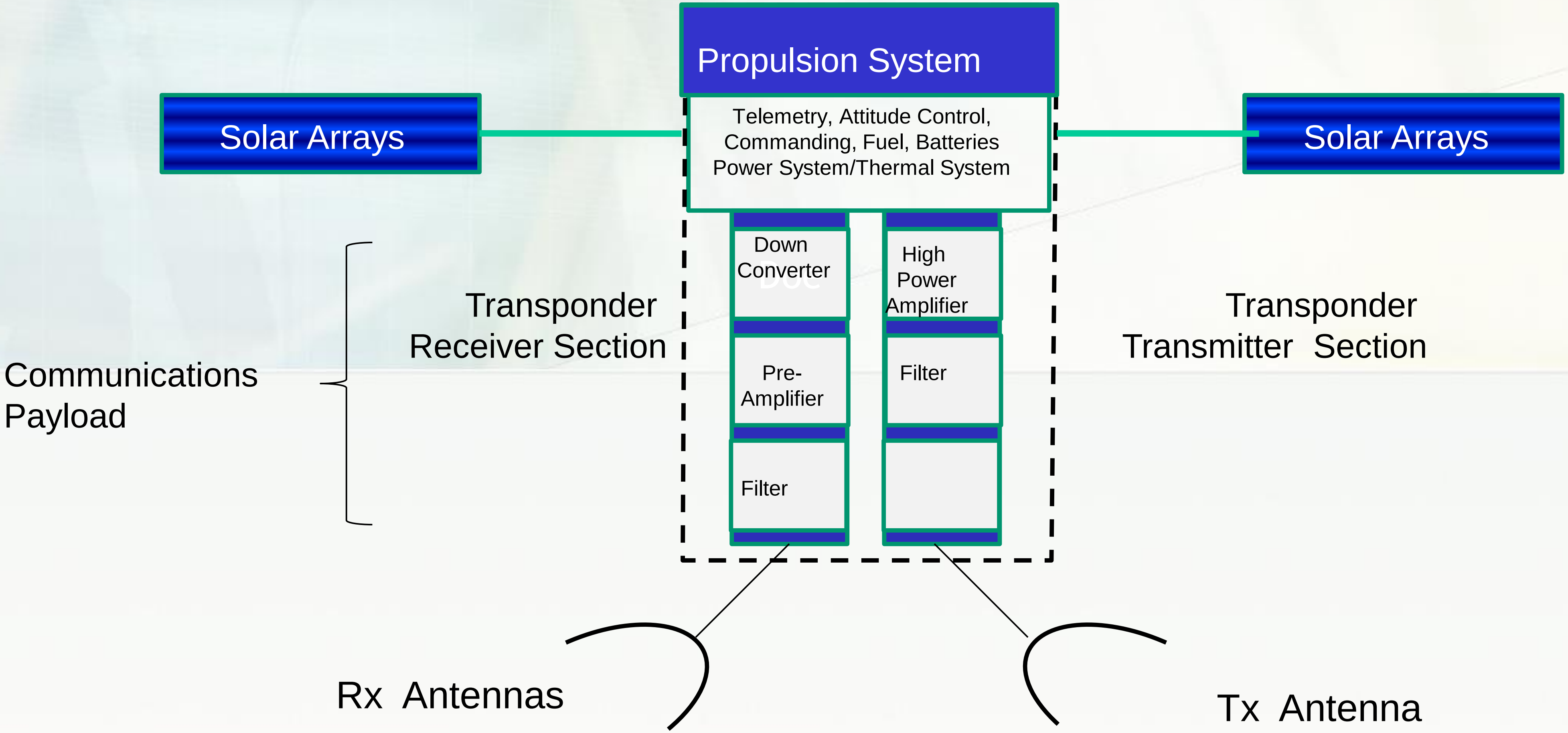
The Space Segment 3/6

The Transponder:

This is the equipment which provides the connecting link between the satellite's transmit and receive antennas. It forms one of the main sections of the payload, the other being the antenna subsystems.

The Space Segment 4/6

Block Diagram of a Communications Satellite



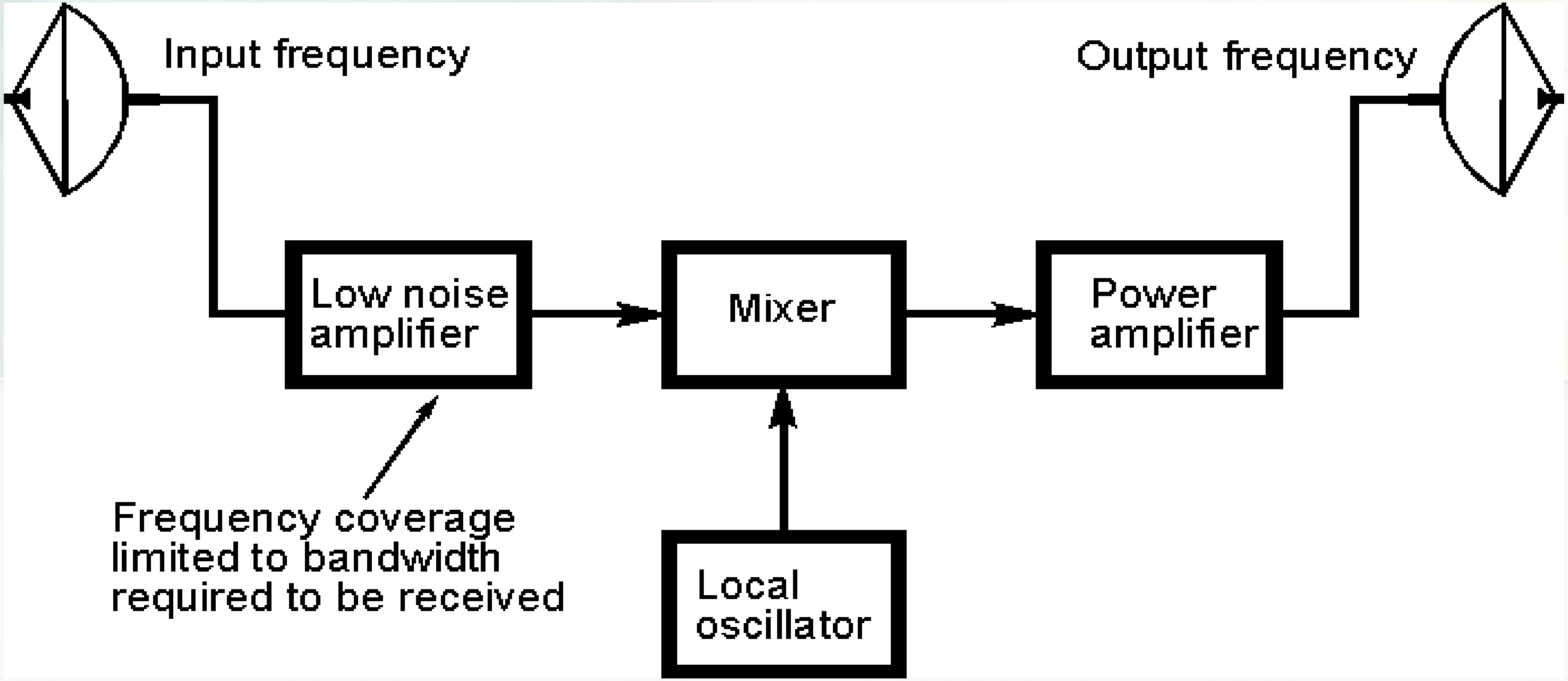
The Space Segment 5/6

Satellite Capacity

- Typically satellites have between 24 and 72 transponders.
- A single transponder is capable of handling up to 155 million bits of information per second (155 Mbps)

The Space Segment 6/6

A closer look at the Transponder



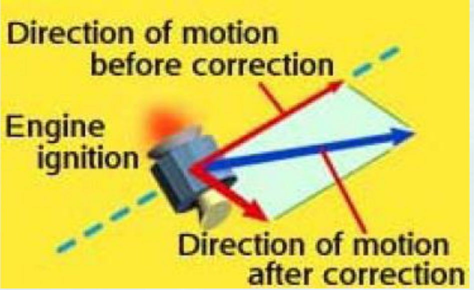
Satellite Design$_{1/1}$

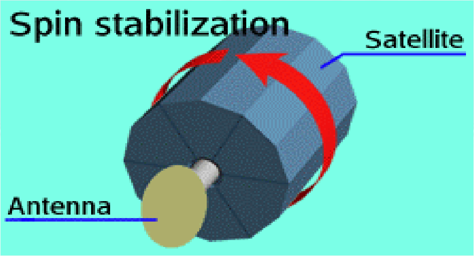
Key aspects of Satellite Design:

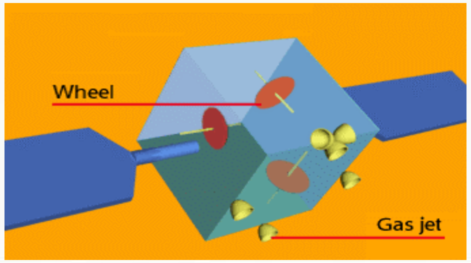
- Electrical Power
- Station Keeping
- Attitude Control
- Orbital Control
- Thermal Control

Satellite Design$_{1/2}$

Orbital Control







- Necessary keep the satellite stationary with respect to all the earth station antennas that are pointed at it.

- Each satellite carries a thrust subsystem to give it an occasional nudge to keep it "On Station."

Questions so far?

The Ground Segment 1/15

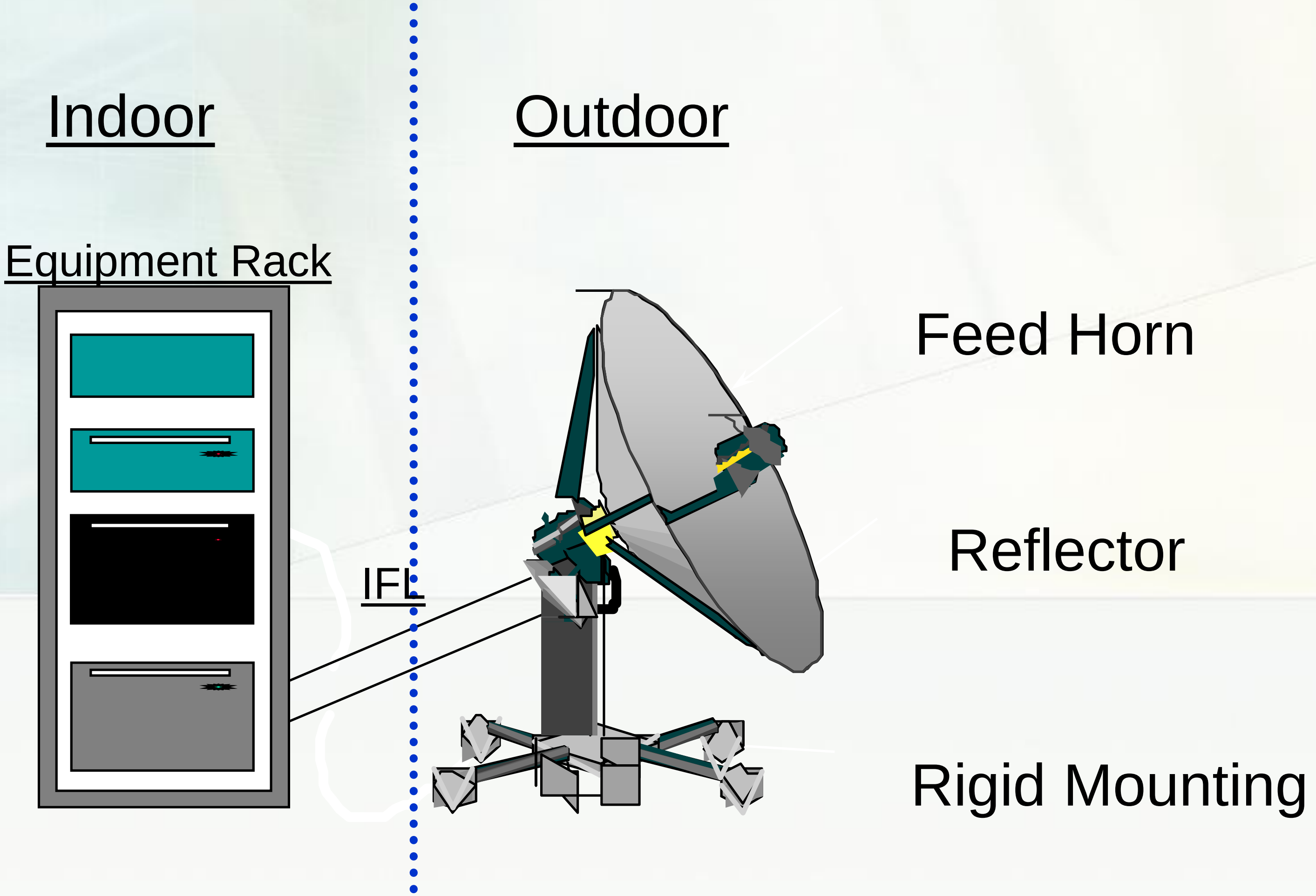
Topic Outline:

- Earth station components
- Factors governing antenna sizes
- The differences between a major earth station and a VSAT
- Permissions required to install and operate a VSAT / Earth station

The Ground Segment 2/15

Contains:

- Modems,
- RF Power Amplifiers
- Data Communications Equipment
- Data Networking Eqpt
- UPS
- etc



Earth Station Components - generic simplified diagram

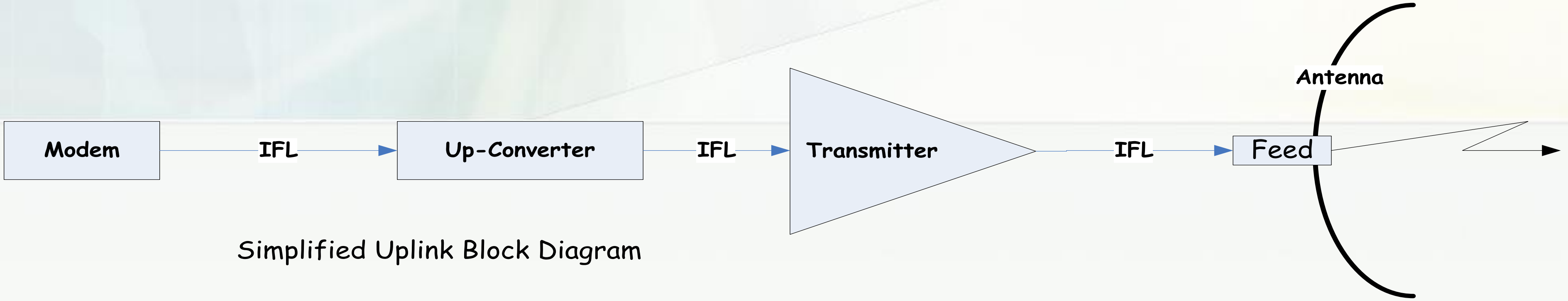
The Ground Segment 3/15

Earth Station Components- simplified list

- Reflector – Physical reflecting piece – focuses signal into the LNB assembly and / or focuses the transmission signal towards the satellite
- Feed horn – Device to accept the focussed RF signals into the LNB or conversely to output the RF signal to the satellite
- Power amplifier – Device that accepts a signal from the modem and boosts it to a suitable level for onward transmission to the satellite
- LNA,B or C – Low Noise Amplifier – Receives the signal from the satellite,
- Modem – Converts a data signal to one suitable for transmission to the satellite
- Up Converter– Converts the modulated signals from RF to RF frequency
- Down Converter– Converts the modulated signals from RF to RF frequency
- Mounting – Some form of mounting to hold the antenna assembly vertical and pointed correctly under most normal condition

The Ground Segment 4/15

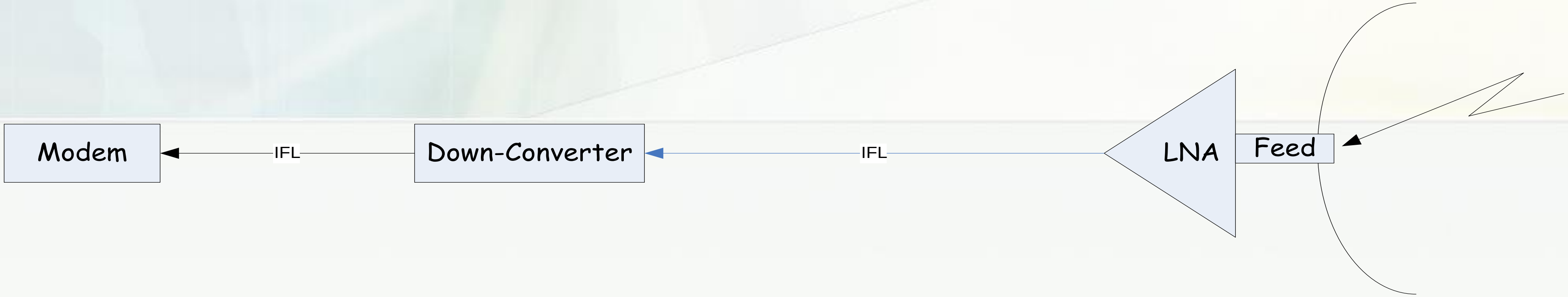
Uplink Block Diagram



Simplified Uplink Block Diagram

The Ground Segment 5/15

Downlink Block Diagram



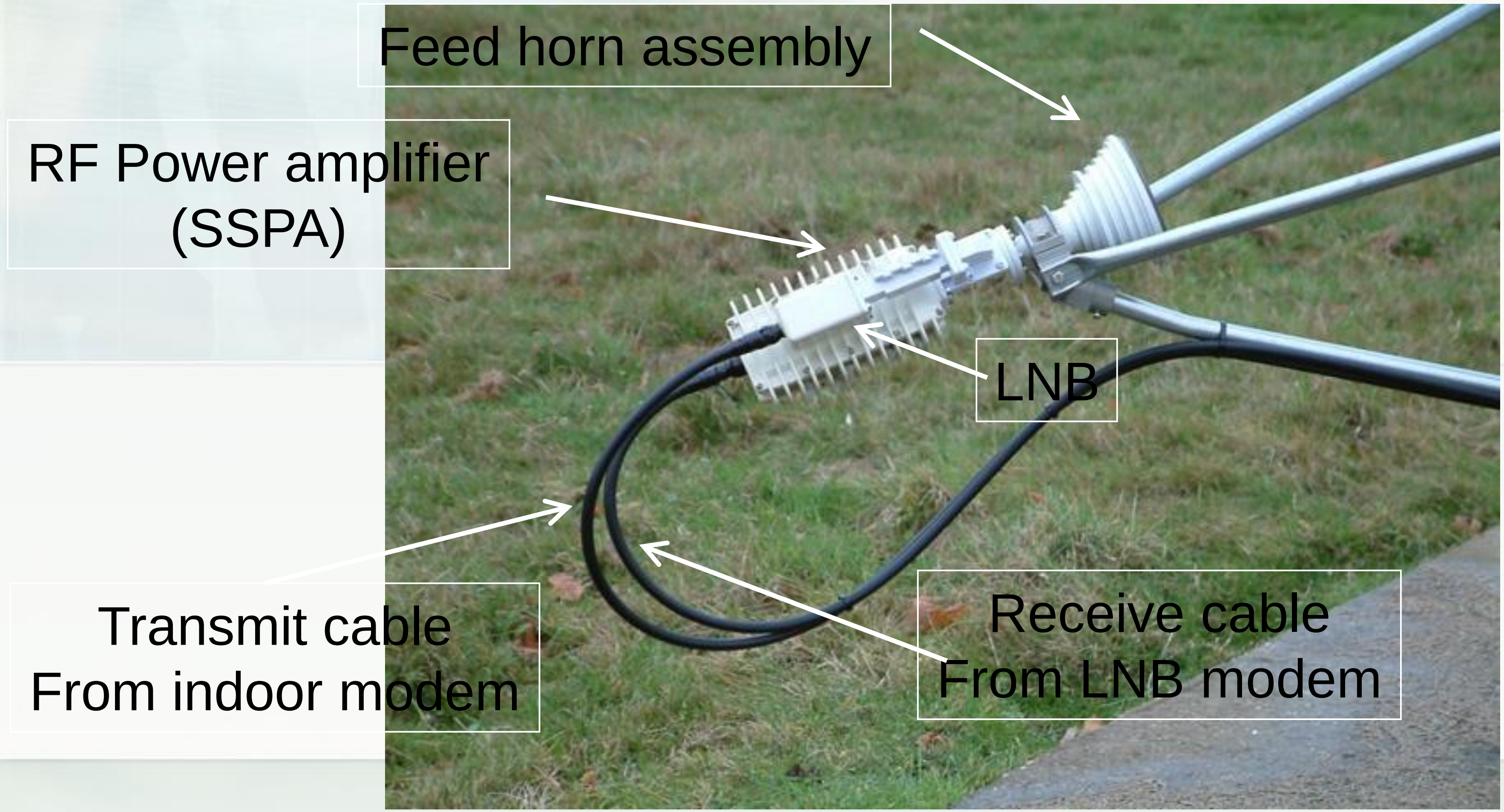
Simplified Downlink Block Diagram

The Ground Segment 6/15

Picture of a VSAT

The Ground Segment 7/15

Picture of a VSAT components



The Ground Segment 8/15

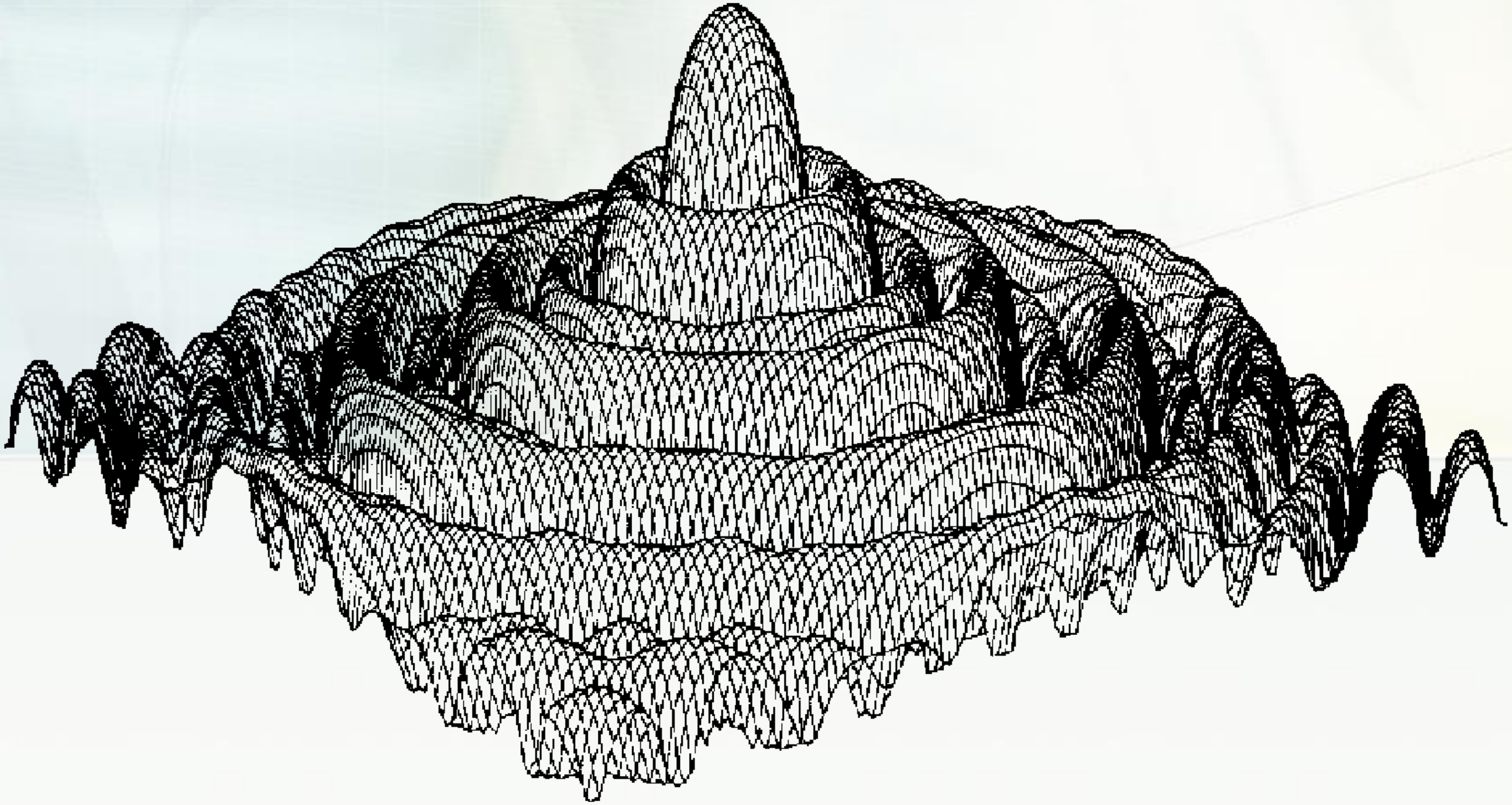
Factors governing Reflector sizes

Why install a large antenna when a small one would do the job?

- Transmission:
  - ✓Large earth stations have smaller BEAM Width's therefore point more accurately
  - ✓ Less RF signal wastage
  - ✓ Less co-satellite interference
  - ✓ Link budget requirement
  - ✓ Cost factors
    - – Larger antenna may be less than the cost of a lease with a smaller antenna

The Ground Segment 9/15

3D Antenna Radiation Pattern



The Ground Segment 10/15

- Receiving:
  - ✓Antenna Gain dictated by the Link Budget
  - ✓Large earth station can receive a weaker signal than the equivalent small antenna
  - ✓Cost implications with the Link Budget
  - ✓Planning permission

    e.g. Europe 0.9M is the minimum size

The Ground Segment 11/15

The differences between a Major Earth Station and a VSAT

- VSAT – Very Small Aperture Terminal
- A VSAT is typically a small earth station 0.7M to 3.7M
- Usually operates a single service or application

- Major Earth Station
- Typically A Major Earth station is sized from 3.7M to 16M+ weighing 20 T or mo re costing $1M+
- Basically same components in each station
- Supports multiple services
- All components redundant
- Can transmit and receive in multiple polarisations
- Usually configured with large RF power amplifiers
- Always connected to suitable Power supplies
- Usually connected to multiple terrestrial paths

The Ground Segment 12/15

Photos of Large earth station antennas

The Ground Segment 13/15

Permissions required to install & operate a VSAT / Earth station

- Just because it can work does not necessarily mean you may go out install and operate!

- Planning permission
  - ✓ Local Authority building departments
  - ✓ Zoning issues
- Landlord's permission
  Will the landlord permit your activity?
- Regulatory authority
  Does the law allow you to build and operate?

The Ground Segment 14/15

Teleports:

- Multiple large earth stations
- Well specified antennas
- Good power systems
- Ample Rack space for ancillary equipment
- 24X7 staff on-site to maintain systems
- Quality support and technical staff to assist with design, install and operation
- Good terrestrial connectivity
- Preferably to more than a single fibre supplier

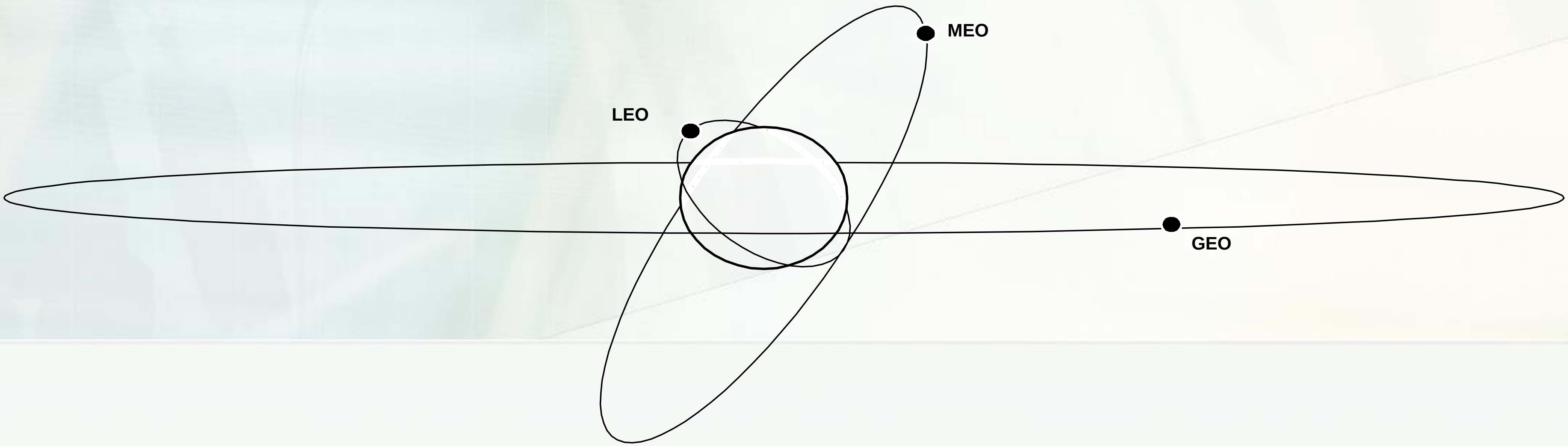
The Ground Segment 15/15

A Typical Teleport

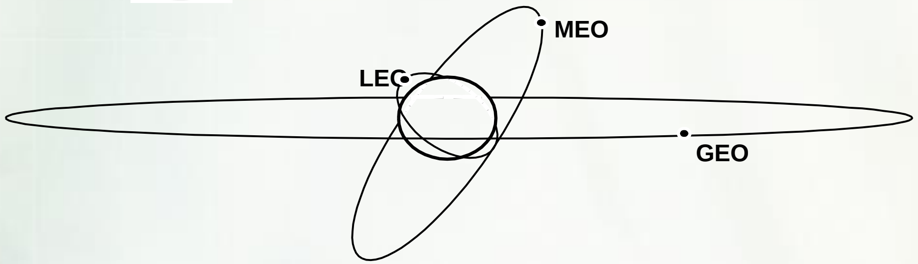
connected by Kingston

Questions so far?

Satellite Orbits 1/7



Satellite Orbits 2/7



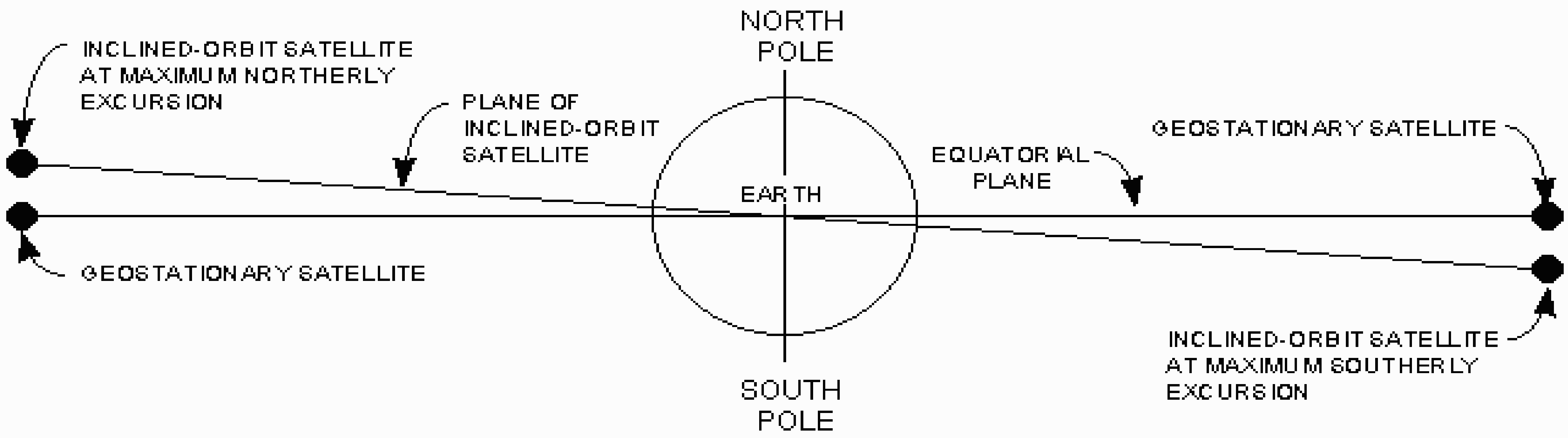
Type	LEO	MEO	GEO
Description	Low Earth Orbit Equatorial or polar orbit	Medium Earth Orbit Equatorial or Polar orbit	Geostationary Earth Orbit Equatorial orbit
Height	100-500 miles	6000-12000 miles	22,282 miles
Signal Visibility / orbit	15 min	2-4 hrs	24 hrs
Advantages	Lower launch costs Short round trip signal delay Small path loss	Moderate launch cost Small round trip delays	Covers as much as 42.2% of the earth's surface Ease of tracking No problems due to doppler
Disadvantages	Tracking antenna required Short life, 5-8 years Encounters radiation belts	Tracking antenna required Larger delays Greater path loss than LEO's	Large round trip delays Weaker signals on Earth

Satellite Orbits 3/7

Applications

- Low Earth Orbit:
  - Earth Observation
  - International Space Station
  - Satellite communications (constellations)
- Medium Earth Orbit:
  - Navigation: GPS, Galileo, GLONASS, etc
  - Satellite communications (constellations)
- Geostationary Earth Orbit:
  - Satellite communications
  - Meteorology

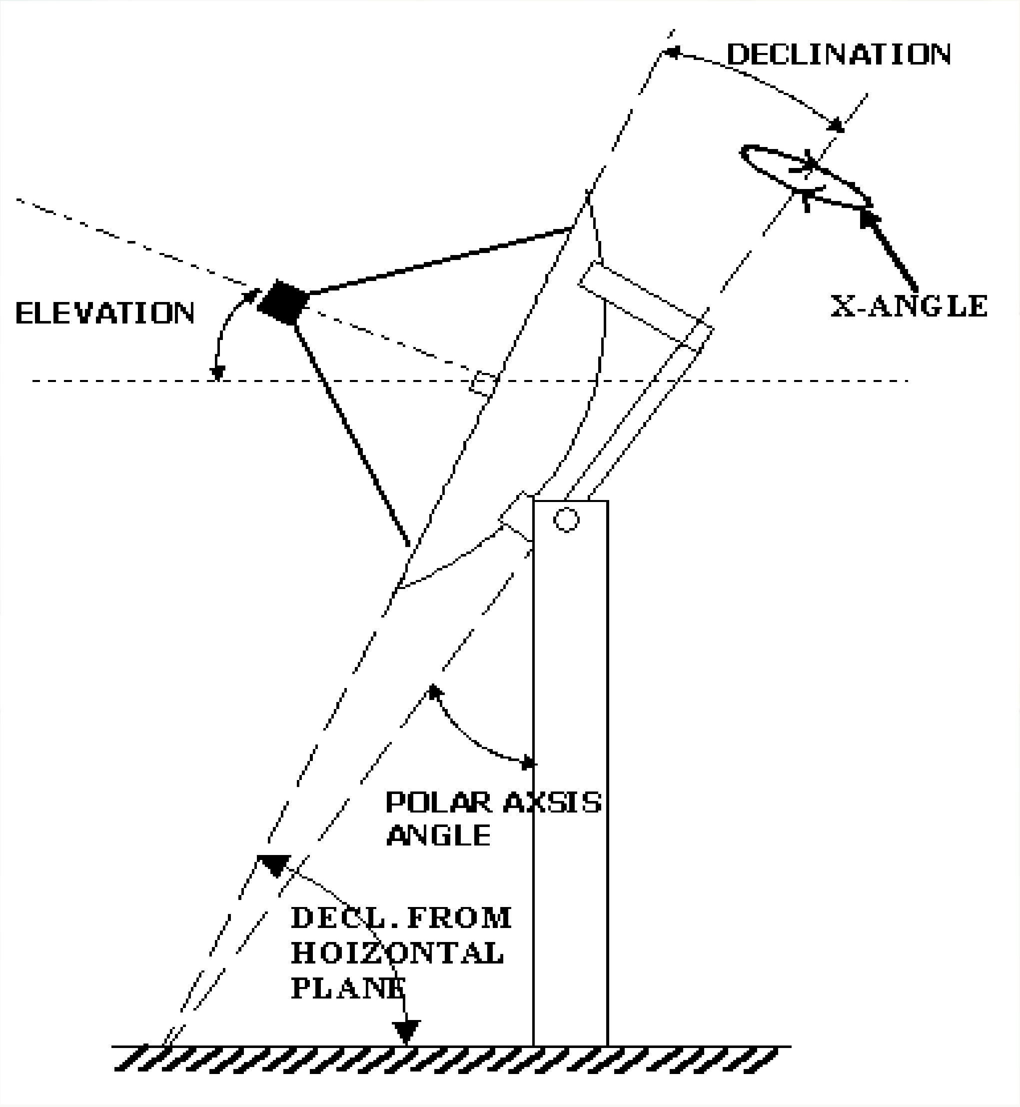
Satellite Orbits 4/7



Satellite Orbits 5/7

Inclined Orbits: Implications for earth station tracking:

Stations must have tracking systems so that their pointing is adjusted to aim at the satellite all during the day.



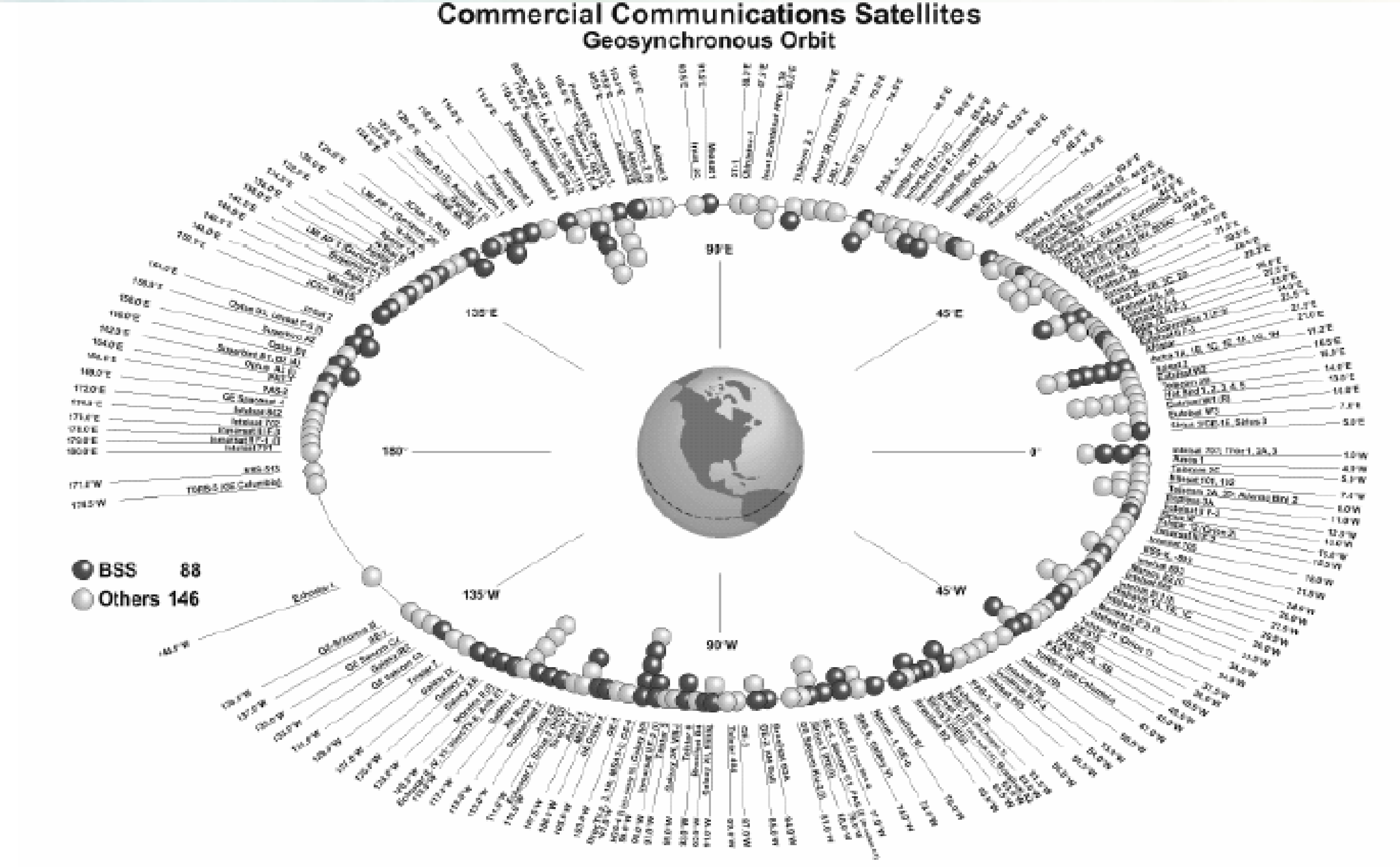
Satellite Orbits 6/7

Orbital Slot Registration

The ITU Member States have established a legal regime, which is codified through the ITU Constitution and Convention, including the Radio Regulations.

In 1988, the ITU acknowledged that all countries, including lesser developed countries, have an equal right to orbital slots. However, Article II of the Outer Space Treaty forbids any claim of sovereignty by any country in space, which would not allow countries to establish dominion over the orbital slots above their territory. At conferences in 1985 and 1988, the ITU did give all countries the rights to an orbital slot directly over their territory, which would ensure at least some access to these satellites to all countries.

Satellite Orbits 7/7



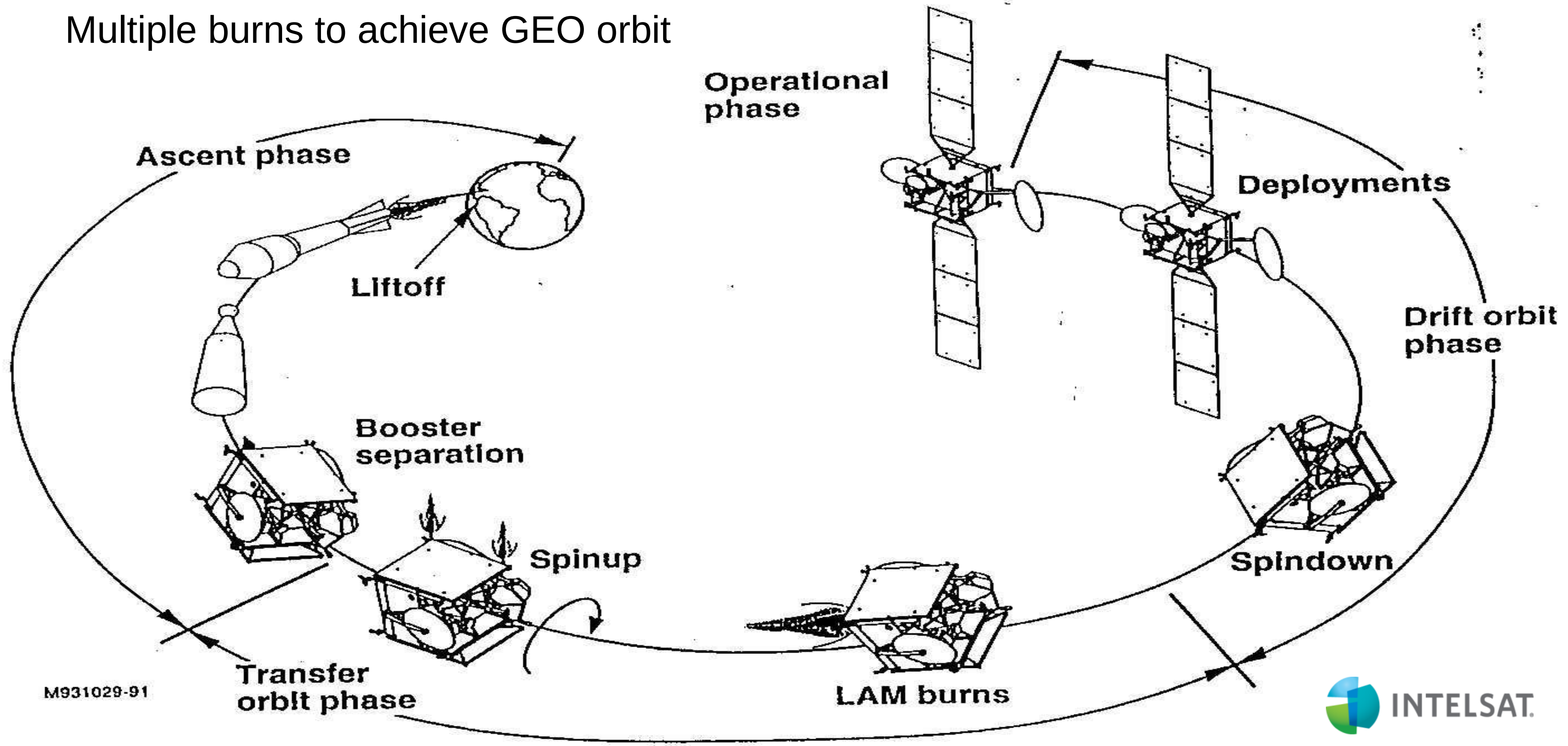
Building and launching a telecommunications satellite 1/3

- It takes about 3 years to get a GEO telecom satellite built and launched.
- Satellite payloads are customized for a given mission.
- Satellites are heavily tested on the ground in facilities that reproduce the space environment:
  - Mechanical, Thermal, Noise and RF tests
- Typical cost of a satellite is $150-$250 million
  - Some satellites can cost as much as $500 million.
  - Not including launch services ($55-$100 million) and insurance.

Building and launching a telecommunications satellite 2/3

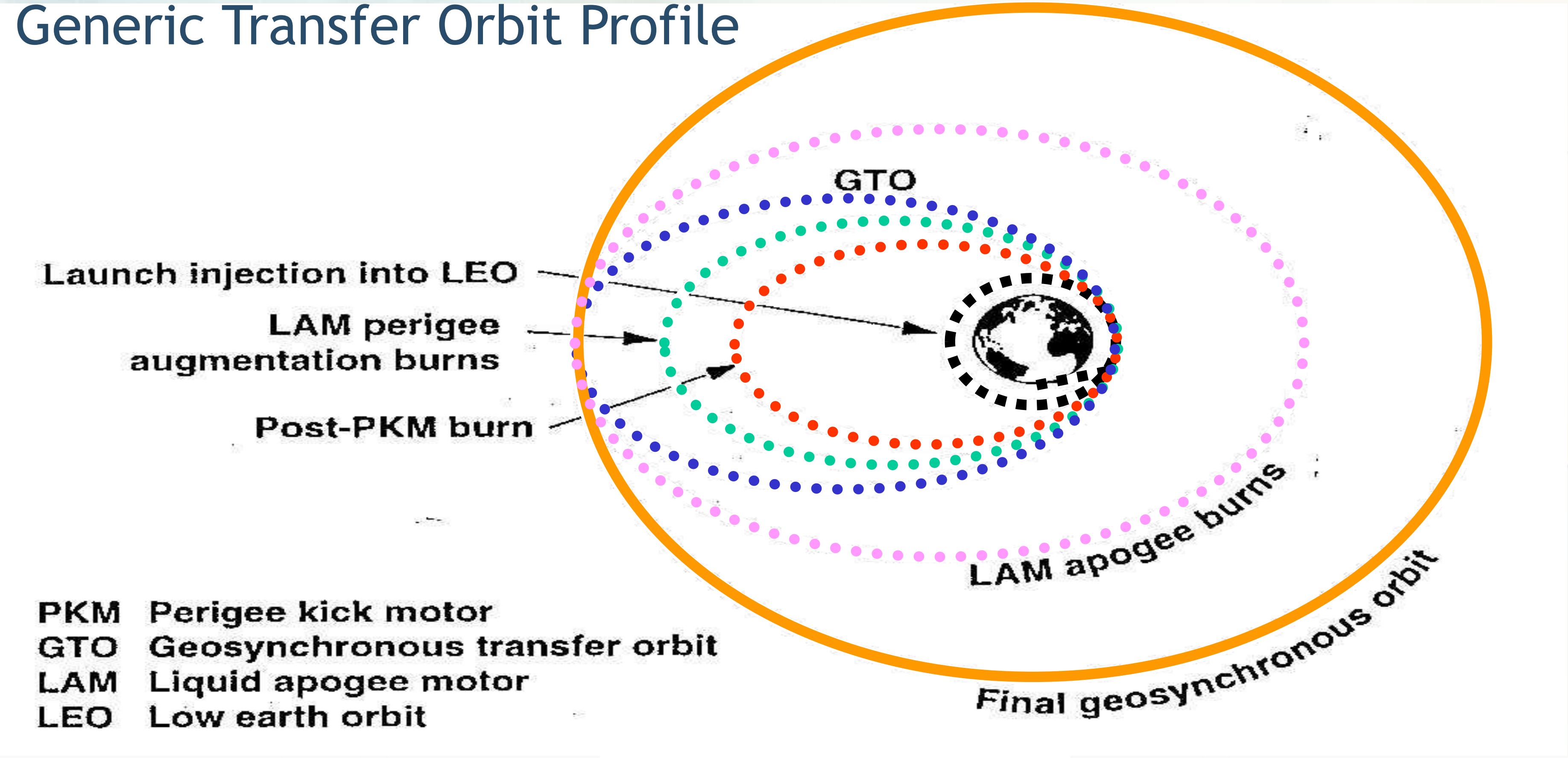
GEO Satellite Launch

Multiple burns to achieve GEO orbit



Building and launching a telecommunications satellite 3/3

Generic Transfer Orbit Profile



Earth Station and VSAT Registration 1/5

A licence is required by the national telecommunications authority of a country where any earth station as a part of a network, be it the hub, a control station or a VSAT, is planned to be installed and operated.

Earth Station and VSAT Registration 2/5

In the past, national telecommunication authorities have required licensing of individual VSAT terminals in addition to requiring a network operator's license. Then, the US Federal Communication Commission (FCC) implemented with success a *blanket licensing* approach for VSATs operated within the US.

Earth Station and VSAT Registration 3/5

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Earth Station and VSAT Registration 4/5

Blanket licensing has since gained interest among national telecommunications authorities all over the world, as a result of equipment manufacturers complying with the recommendations issued by international standardization bodies, such as the International Telecommunication Union (ITU) and the European Telecommunications Standards Institute (ETSI).

Earth Station and VSAT Registration 5/5

A licence usually entails the payment of a licence fee, which is most often in two parts: a one-time fee for the licensing work and an annual charge per station.

The licensing procedure is simpler when the network is national, as only one telecom authority is involved.

For transborder networks, licences must be obtained from the national authorities of the different countries where the relevant earth stations are planned to be installed and operated, and rules often differ from one country to another.

Orbital positions and radio interferences

Control of Interference

ALLOCATION

Frequency separation of stations of different services

REGULATORY PROTECTION

e.g. No. 22.2: Non-GSO to protect GSO (FSS and BSS)

POWER LIMITS

PFD to protect TERR services / EIRP to protect SPACE services / EPFD to protect GSO from Non-GSO

COORDINATION

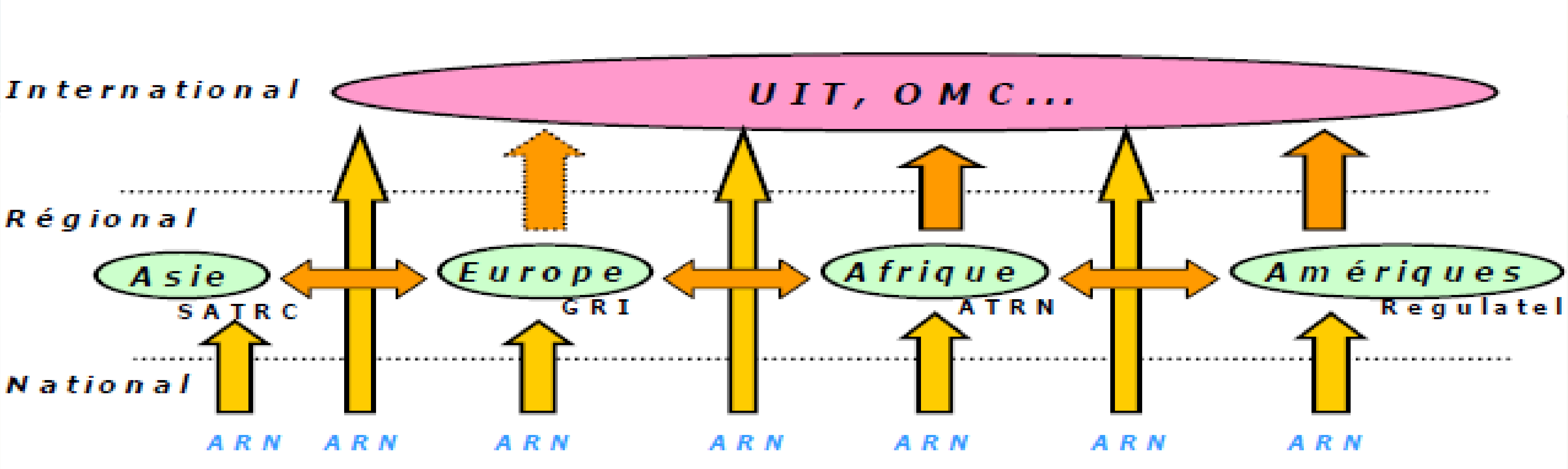
between Administrations to ensure interference-free operations conditions

Radio Regulatory Organisations 1/3

National Regulation

Ultimately the responsibility for licensing falls to a National Regulatory Authority (a Government department), e.g.

- *Ofcom in the United Kingdom*
- *FCC & NTIA in the USA*



Radio regulatory organisations 2/3

ITSO

ITSO is the continuation of INTELSAT, the intergovernmental organization established by treaty in 1973.On July 18, 2001, the satellite fleet, customer contracts and other operational assets of the Organization were transferred to Intelsat Ltd, a new private company now registered in Luxembourg and various amendments to the ITSO Agreement took effect.

Under the ITSO Agreement, as amended , ITSO's primary role was that of supervising and monitoring Intelsat's provision of public telecommunications satellite services as specified in the Public Services Agreement(PSA) entered into between ITSO and Intelsat. In addition, the Director General , on behalf of the Organization, must consider all issues related to the Common Heritage. ITSO currently has 149 Member States."

Radio regulatory organisations 3/3

ITSO

The **International Telecommunications Satellite Organization** is an intergovernmental organization charged with overseeing the public service obligations of Intelsat.

GVF

Global VSAT Forum is an association of key companies involved in the business of delivering advanced digital fixed satellite systems and services.

Satellite Operators

Satellite Operators

Intelsat, Ltd. is a communications satellite services provider. Originally formed as **International Telecommunications Satellite Organization** (**INTELSAT**), it was an intergovernmental consortium owning and managing a constellation of communications satellites providing international broadcast services. As of March 2011, Intelsat owned and operated a fleet of 52 communications satellites.

Eutelsat S.A. is a French-based satellite provider. Providing coverage over the entire European continent, as well as the Middle East, Africa, India and significant parts of Asia and the Americas, it is one of the world's three leading satellite operators in terms of revenues.

Satellite Operators

O3b is building a next-generation network that combines th[e] satellite with the speed of fiber.

Higher capacity

O3b's satellite transponders have on average three to four times the capacity of those offered by GEO satellite systems. This translates into three to four times more bandwidth – and a fiber-like experience for customers.

Greater coverage

Satellite technology can deliver Internet connectivity to any location on the planet. O3b's next-generation satellite network will reach consumers, businesses and other organisations in more than 150 countries across Asia, Africa, Latin America and the Middle East.

Satellite Operators

Lower latency

O3b's unique network of Medium Earth Orbit (MEO) satellites virtually eliminates the delay caused by standard Geosynchronous (GEO) satellites.

Round-trip data transmission time is reduced from well over 500 milliseconds to approximately 100 milliseconds.

This creates a web experience significantly closer to terrestrial systems such as DSL or Optical Fiber.

Satellite Operators

International Organization

The **International Mobile Satellite Organization (IMSO)** is the intergovernmental organization that oversees certain public satellite safety and security communication services provided via the Inmarsat satellites. These public services include:

services for maritime safety within the Global Maritime Distress and Safety System (GMDSS) established by the International Maritime Organization (IMO)

- distress alerting
- search and rescue co-ordinating communications
- maritime safety information (MSI) broadcasts
- general communications

Satelite Services

The Commercial Satellite Industry

Voice/Video/Data Communications

- Rural Telephony
- News Gathering/Distribution
- Internet Trunking
- Corporate VSAT Networks
- Tele-Medicine
- Distance-Learning
- Mobile Telephony
- Videoconferencing
- Business Television
- Broadcast and Cable Relay
- VOIP & Multi-media over IP

Direct-To-Consumer

- Broadband IP
- DTH/DBS Television
- Digital Audio Radio
- Interactive Entertainment & Games
- Video & Data to handhelds

GPS/Navigation

- Position Location
- Timing
- Search and Rescue
- Mapping
- Fleet Management
- Security & Database Access
- Emergency Services

Remote Sensing

- Pipeline Monitoring
- Infrastructure Planning
- Forest Fire Prevention
- Urban Planning
- Flood and Storm watches
- Air Pollution Management
- Geo-spatial Services

Technology trends

Market trends for capacity

- – continues to grow despite fibre deployment
- Potential shortage of capacity in some areas for certain types of capacity due to heavy cutbacks in launches
- Bandwidth is ever increasing on a per link basis

Technology trends

User demands

- Smaller terminals
- High throughput
- Enhanced capability
- Constellations
- Responsive space
- Lower costs - $1000 now and lower!
- Easier access to space segment
- Easier licensing regimes
- Open standards

Technology trends

Open Standards?

- Industry Players (Satellite Operators, Network Operators, Equipment manufacturers and=End-users) agree that Open Standards are good for everyone

- But which one is the best one or is it a multitude of answers and solutions?

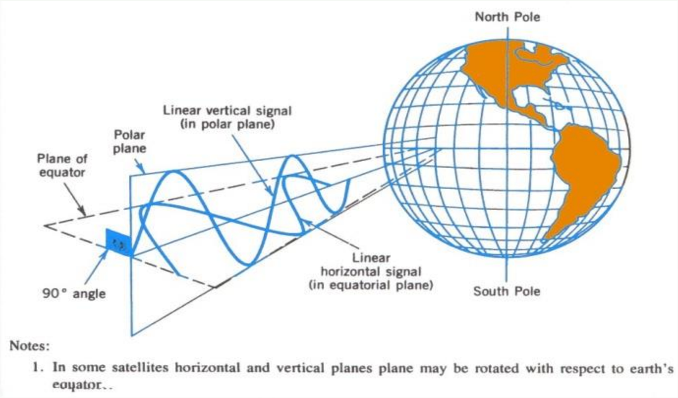
8- Technology trends

- Global usage and coordination
- Ka / Ku/ C Band
- Interference issues
- Global Regional frequency coordination

Questions so far?

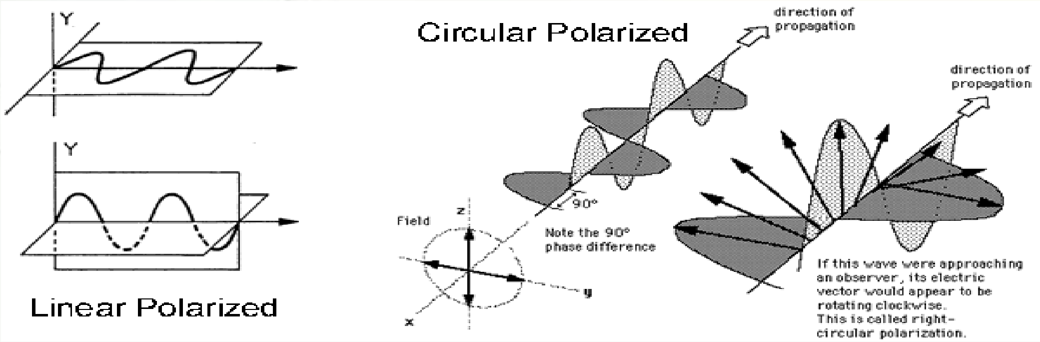
Polarization 1/5

- Linear Polarization
- Circular Polarization
- Polarization Frequency Re-use



Polarization 2/5

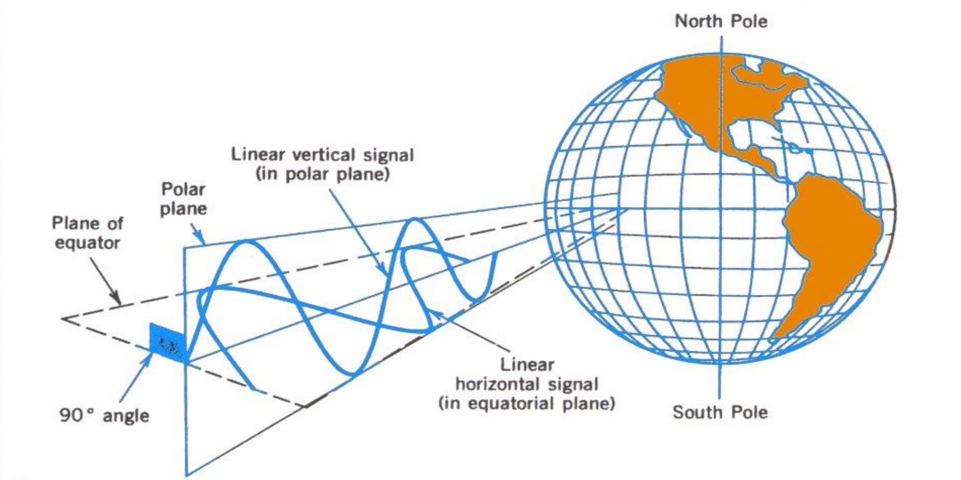
- Electromagnetic waves have an electrical field and a magnetic field which are orthogonal to each other and to the direction of propagation
- Polarization of a signal is defined by the direction of the electrical field.



- Polarization can be:
  - Linear: Horizontal (H) or Vertical (V)
  - Circular: Right Hand Circular (RHCP) or Left Hand Circular (RHLP)

Polarization 3/5

- The electrical field is wholly in one plane containing the direction of propagation
- Horizontal: the field lies in a plane parallel to the earth's surface
- Vertical: the field lies in a plane perpendicular to the earth's surface



Notes:
1. In some satellites horizontal and vertical planes plane may be rotated with respect to earth's equator..

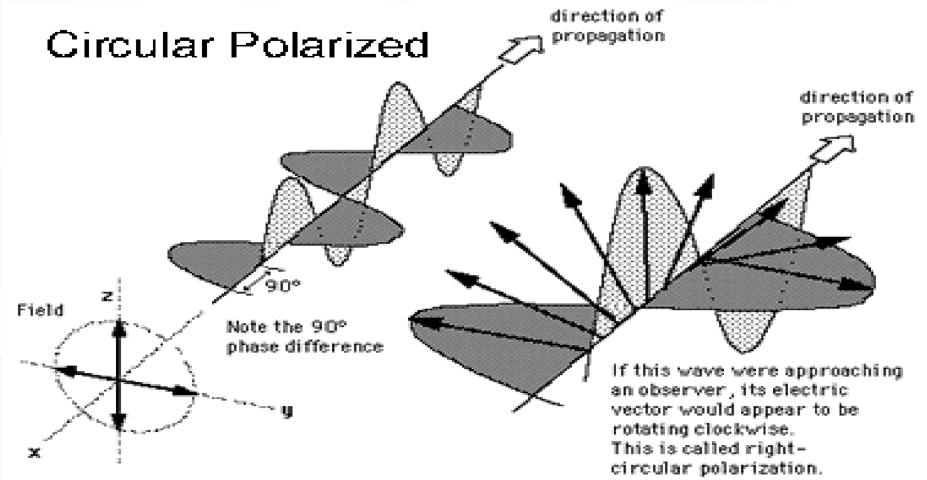
Polarization 4/5

Circular Polarization

- The electrical field radiates energy in both the horizontal and vertical planes and all planes in between

- Right-Hand Circular Polarization:
  The electrical field is rotating clockwise as seen by an observer towards whom the wave is moving

- Left-Hand Circular Polarization:
  The electrical field is rotating counterclockwise as seen by an observer towards whom the wave is moving



Polarization 5/5

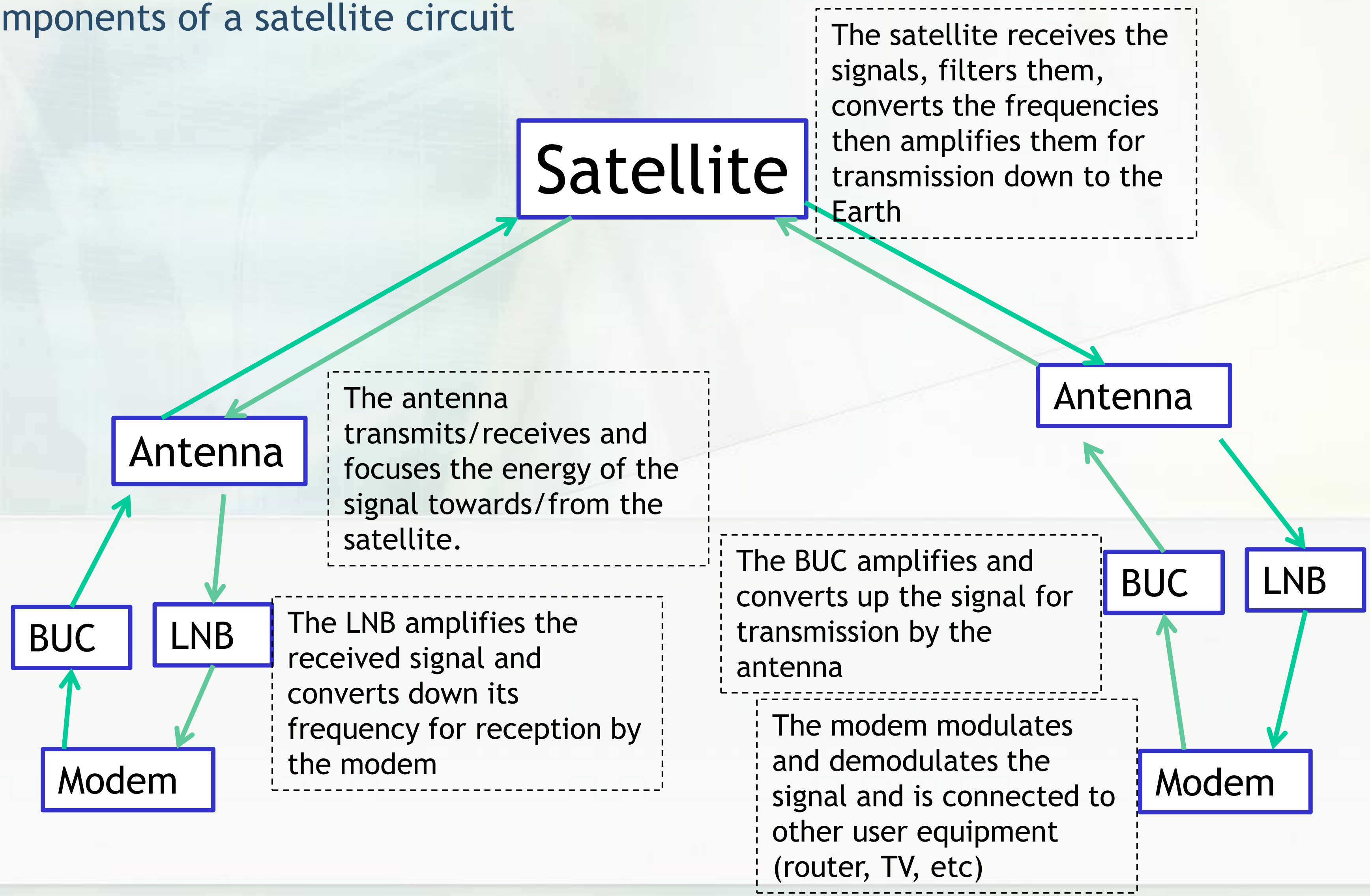
Polarization frequency re-use

- A satellite can get twice the capacity on the same frequency channels by using opposite polarizations over the same coverage area.
  - E.g. Transponder A using 6,000-6,072 MHz in vertical polarization
    Transponder B using 6,000-6,072 MHz in horizontal polarization
- In case of misalignment of polarization between transmitter and receiver, there is cross-pol interference.
- Cross-pol discrimination (XPD) is defined as the ratio of power transmitted on the correct polarization to the power transmitted on the incorrect polarization. The specified XPD is usually in the range of 20-30 dB for VSATs.

Questions so far?

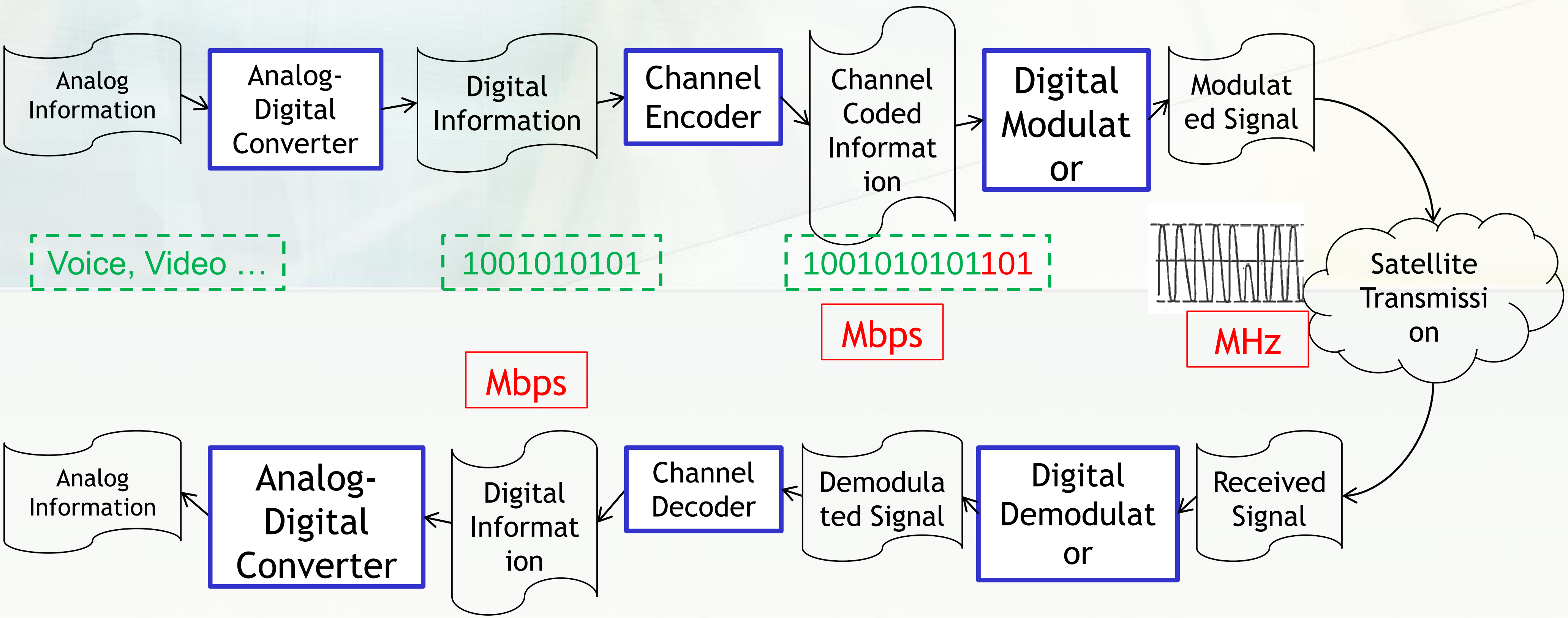
Introduction to Satellite Link Analysis $_{1/9}$

Components of a satellite circuit



Introduction to Satellite Link Analysis 2/9

- Simplified digital communications chain:



Introduction to Satellite Link Analysis 3/9

Modulation is the process of varying some characteristics of a periodic waveform, called the *carrier signal*, with a *modulating signal* that contains information.

Characteristics that can vary are the amplitude, frequency and phase.

Typical modulations used in satellite communications are PSK and QAM.

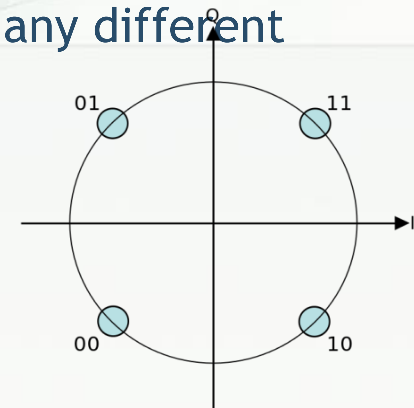
The order of the modulation how many different symbols can be transmitted with it.

E.g. Order 2: BPSK

Order 4: QPSK, 4-QAM

Order 8: 8-PSK, 8-QAM

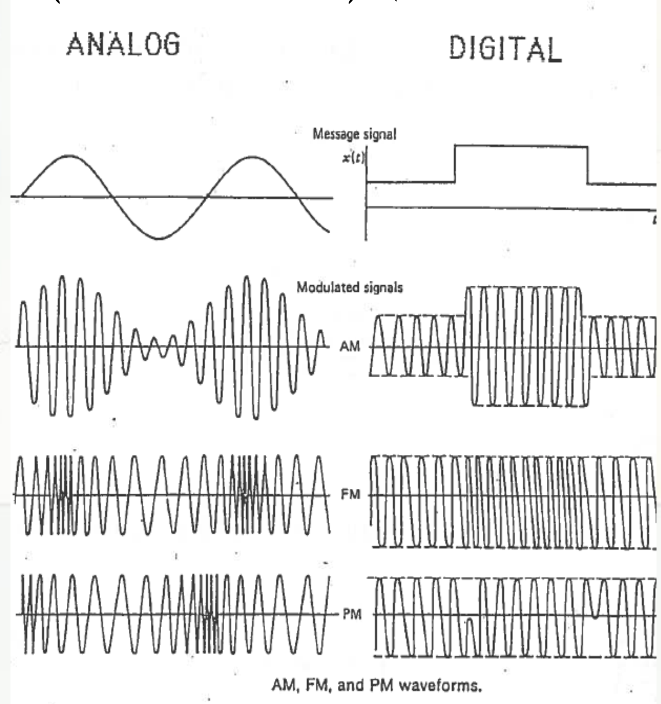
Order 16: 16-PSK, 16QAM



Constellation diagram for QPSK

Carrier signal (no information)

Modulating signal (with information)



Introduction to Satellite Link Analysis 4/9

- Channel coding (FEC: Forward Error Correction) consists of adding re bits to the useful information to allow detection and correction of er caused by the transmission channel.
- The FEC is usually given as a fraction $\frac{Number\ of\ useful\ bits}{Total\ number\ of\ bits}$
- The FEC is usually given with the modulation scheme.
- E.g.: QPSK 3/4 means that:
  - A QPSK modulation is used (order 4)
  - And for every 3 bits of useful information, 1 redundant bit is added.
    - Said otherwise, 4 bits are required to send 3 bits of information
    - Or 25% of the bits sent are useless from the user point of view (but still necessary to detect an errors)

Introduction to Satellite Link Analysis 5/9

$$BW = \frac{IR \times (1+\alpha)}{n \times FEC \times RS}$$

On the importance of **efficiency**

- From user point of view, the key parameter is Information Rate (IR) (in Mbps or kbps)
- The required bandwidth in MHz for a given information rate is directly related to the modulation and coding scheme (modcod).
  - The higher the modulation order (2^n), the less bandwidth is required
  - The higher the FEC ratio, the less bandwidth is required
  - Other parameters also matter: roll-off factor (α), Reed-Solomon coding (RS)
- The efficiency is defined as the ratio $\frac{Mbps}{MHz}$: that is the number of Mbps that can be transmitted in a given MHz. The unit is bit per second per Hz (bps/Hz)
- The higher the efficiency, the more cost-effective a service is.

Introduction to Satellite Link Analysis 6/9

$$\$/Mbps = \frac{\$/MHz}{Efficiency}$$

On the importance of **efficiency** - Examples

- 2 Mbps link using QPSK-3/4 (order $4 = 2^2$), with 25% roll-off factor and no Reed-Solomon:
  - Required bandwidth is: $2 \times (1 + 0.25) \times \frac{4}{3} \div 2 = 1.67\ MHz$
  - Efficiency is **1.20 bps/Hz**
- Same 2 Mbps link using 8PSK-3/4 (order $8 = 2^3$), with 25% roll-off factor and no Reed-Solomon:
  - Required bandwidth is: $2 \times (1 + 0.25) \times \frac{4}{3} \div 3 = 1.11\ MHz$
  - Efficiency is **1.80 bps/Hz**
- Same 2 Mbps link using 8PSK-7/8 (order $8 = 2^3$), with 25% roll-off factor and no Reed-Solomon:
  - Required bandwidth is: $2 \times (1 + 0.25) \times \frac{8}{7} \div 3 = 0.95\ MHz$
  - Efficiency is **2.10 bps/Hz**

Introduction to Satellite Link Analysis 7/9

- The selection of a modcod is constrained by the signal over noise ratio at reception:
  - The higher the modulation order, the higher the signal to noise ratio must be for the modem to be able to demodulate it.
- Signal over noise ratio is affected by:
  - Link conditions – propagation attenuation and impairments
  - Available power – on ground and on the satellite (PEB)
  - Performance of the satellite
  - Antenna size at reception
  - Capabilities of the modem
- A satellite link budget analysis will determine what modcod can be used and what are the required bandwidth and power.

What is a good efficiency?

- In general, the higher the efficiency, the better, but …
  - Efficiency is not the only parameter to consider
  - Service availability, cost of equipment, network topology, … are also key factors
- Sometimes a lower efficiency is acceptable to reduce required investment or size of equipment.
  - Example: a Direct-To-Home service with small receiving antennas and cheap demodulators will typically have a lower efficiency than a CBH service using large antennas and efficient modems.

Introduction to Satellite Link Analysis 9/9

Summary

- A signal transmitted by satellite has to be modulated and coded (*modcod*).
- The modcod scheme determines the *efficiency* which tells how many MHz are required to transmit one Mbps.
- The achievable efficiency is constrained by link conditions, satellite characteristics and available ground equipment.
- A link budget analysis is required to determine the maximum efficiency.
- Efficiency can be increased with better ground equipment (antenna, modem, amplifier) → tradeoff to be made between investment (CAPEX) and cost of bandwidth (OPEX)

End of Module 1

Thank You!

Final Questions?