ITSO - Basics of Satellite Communications

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17 July 2017
Introduction

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Guidelines

• Mobile Phones: Kindly switch to Silent Mode
• Please ask questions
Contents

• Introduction to Satellite Communications

  • Satellite Economics

• Satellite Network Design

• Satellite Earth Station Equipment

• Digital Communications Techniques

• Modulation

• Technology Trends
Introduction to Satellite Communications
What is a Telecommunications Satellite?

• A telecommunications satellite is a complex machine located in outer space that:
  • Receives signals from the Earth
  • Converts, amplifies and sends signals back down to the Earth
  • Reaches millions of locations at the same time

• A telecommunications satellite comprises of:
  • A platform (or bus) which includes the propulsion system, fuel tanks, batteries, solar panels, attitude and orbit control functions, etc.
  • A payload of antennas, amplifiers, frequency converters, etc
Basis Telecommunications Satellite template

- Solar Arrays for Electrical Power
- Earth Deck with Global Beam, Telemetry And Command Antennas
- Communications Payload
- Communications Antennas
- Spacecraft Control/Propulsion
First types of Telecommunications Satellites

Telecommunications Satellite Today

IS-35e (2017)

IS-33e (2016)
Satellite Economics: Building and Launching a Telecommunications Satellite

- 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
Launching the satellite
Orbital Slots

• Consultation with the ITU for an orbital slot

• Orbital slots are “owned” by the regional country

• In orbital arc of 360°, theoretically there are 360 parking bays for satellites.

• Satellites are co-located in the orbital slots
  • Coordination is done so that the frequency, polarisation and other technical parameters do not clash.

• Within the allocated orbital slot the operator is allocated a frequency of use at the slot: C; Ku or Ka etc
Approximately 50 satellites plus IntelsatOne, a fully-integrated ground infrastructure incorporating teleports, points of presence and IP/MPLS fiber network.
Satellite for the orbital Slot

- Design of the satellite for the Orbital is based on the areas of coverage and the type of service to be deployed at the orbital location.
  - Applications: Network Services or Media
  - Network services: Trunking, VSAT networks, corporate networks
  - Media: DTT or DTH

- Red Lines are Hemi Beams
- Yellow Outlines are the zone beams
- Blue line are the Global beams
Frequency re-use on the satellite

- Frequency of use on the satellite is important
- Maximise of the use of the frequency that is allocated to satellite operator
- Frequency re-use is achieved by geographically separated beams, polarisation
- $7 \times 6 + 6 = 48$ (36Mhz units)
Typical Satellite Coverage

Coverage areas depend on the satellite type and targeted services

IS-905 C-band Zone beams

IS-23 C-band Hemi beam

IS-14 Ku-band Zone beams
Typical Satellite Coverage

Intelsat’s next generation Epic\textsuperscript{NG} satellite coverage

IS-35e C-band Spot Beams (2017)

IS-33e Ku-band Spot beams (2016)
Key Applications of Satellite Communications

**Network Services**
- Cell Backhaul

**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
Vehicles used to Launch Satellites

• Two types of launches: Sea and Land

• Launch Sites:
  • French Guinea, China, Russia, India and Cape Canaveral

Types of Launch Vehicles
Satellite Launch: IS-33e and IS-36

• IS-33e and IS-36 was launched on the 24th August 2017

Liftoff of Arianespace’s Ariane 5 with Intelsat 33e and Intelsat 36 .mp4
Satellite Earth Station Equipment
Satellite Earth Station Equipment

- Antenna
  - Types
  - Parameters

- Uplink
  - Modulation
  - Up-Converters
  - Transmitters
  - Inter Facilities Link

- RF Downlink
  - LNA / LNB
  - Down-converters
  - Demodulation
  - Inter Facilities Link
Antenna

• What is an antenna

• An antenna is a metallic structure that captures and/or transmits radio electromagnetic waves. Antennas come in all shapes and sizes from little ones that can be found on your roof to watch TV to really big ones that capture signals from satellites millions of miles away.

• The antennas that Satellite Communications use are special bowl shaped that focuses signals at a single point called a parabolic antenna. The bowl shape is what allows the antennas to both capture and transmit electromagnetic waves. These antennas move horizontally (measured in hour angle/declination) and vertically (measured in azimuth/elevation) in order to capture and transmit the signal.
Antenna

• A Satellite Earth Station Antenna
  • An effective interface between the uplink equipment and free space
  • Must be directional to beam and RF signal to the satellite
  • Requires a clear line of sight between the antenna and the satellite
Antenna

• Antenna Parameters
  
  • Gain
    
    • $G(\text{dBi}) = 20.4 + 20 \log f + 20 \log D + 10 \log h$
      
        • $f$ = frequency in GHz,
        
        • $D$ = Diameter in meters,
        
        • $h$ = Antenna Efficiency in Decimal format

• What should the be the gain of a 9.3m C-band antenna at 6.4 GHz that is at 62% efficiency?
  
  • $G = 20.4 + 20 \log 6.4 + 20 \log 9.3 + 10 \log 0.62$
  
  • $G = 20.4 + 20(0.806179) + 20(0.968482) + 10(-0.2076)$
  
  • $G = 20.4 + 16.12 + 19.37 + -2.08$
  
  • $G = 53.81 \text{ dBi}$
Antenna

• Antenna Beamwidth:
  
  • For a given antenna, the higher the frequency the narrower the 3dB beamwidth. Therefore the receive band will be broader than the transmit.
  
  • For a given frequency band, the larger the antenna aperture the smaller or narrow the beamwidth.

\[
\theta \ (deg.) = \frac{21}{fD}
\]

  • \(f\) = frequency in GHz,
  
  • \(D\) = Diameter in meters,
The rectangular box shows the positional limits for a satellite in geostationary orbit, in relation to beams from a 32m antenna and 4.5 antenna.
Antenna

- Antenna Types
  - Full Motion
    - Motorized
    - Azimuth $\pm 180^\circ$ from antenna center line ($C_L$)
    - Elevation: 5° to 90°
    - Ability to track satellites in transfer orbit
  - Fixed
    - Manual Movement
    - Provides coverage of the entire satellite arc
    - Peaked on satellite with no further adjustments
  - Limited Motion
    - Typically Motorized
    - Azimuth $\pm 60^\circ$ from antenna center line ($C_L$)
    - Elevation: 5° to 90°
    - Ability to track satellites Incline orbit satellites
    - Ability to change to different satellite orbital location
Antenna

• Antenna Position Controllers (APC)
  • Installed at base of the antenna (“Jog Controller”)
  • Toggle switches for AZ (CW/CCW), EL (Up/Down) and Polarizer
  • Serial data link for remote control with a computer
  • Transducers provide AZ & EL and Polarizer angle readouts
Antenna

• Antenna Control Unit (ACU)
  • Manually position and polarize the antenna
  • Preset satellite locations stored in memory
  • Step Track
    • Requires a suitable receiver to provide signal ACU
    • Back and forth movement in AZ and EL to ensure peak signal level
  • Memory Track
    • Creates a model of satellite motion for twenty-four hour period
    • Uses this model to track the satellite
  • Computer Track
    • Predict data from computer controls antenna movement
  • Mono Pulse
    • Relative signal phase and the sharp slope of a tracking null is used to determine peak position
    • It is not necessary to step the antenna to determine satellite orientation
    • Responds more accurately and faster to satellite dynamics
    • Primary use is for tracking transfer orbits
Antenna

• Antenna Efficiency
  • Well-designed antennas have efficiency ratings of 50% - 70%
    • Typically it is 60% - 65%
  • Efficiency is affected by:
    • Spar and feedhorn blockage
    • Subreflector alignment and placement
    • Subreflector surface tolerance and design
    • Main reflector surface tolerance or deviation
    • Feed horn loss
    • On axis alignment
    • Polarization purity
  • Efficiency can never be 100%
Antenna

• Antenna Types
  • Prime Focus parabolic reflector
    • Center Feed
    • Feed & strut blockage can be large
    • High feed line loss
      • Both Tx and Rx
    • Poor G/T Performance
Antenna

• Antenna Types
  • Parabolic reflector cassegrain
    • Typically use 5m or larger
    • Parabolic main reflector
    • Hyperboloidal subreflector
    • Subreflector and strut blockage small
    • Small feed line loss
    • Good G/T
Antenna

• Antenna Types
  • Parabolic reflector Gregorian
    • Typically use 5m or larger
    • Parabolic main reflector
    • Ellipse subreflector
    • Subreflector and strut blockage small
    • Small feed line loss
    • Good G/T
Antenna

• Antenna Types
  • Parabolic reflector offset feed
    • Typically 3.7m and smaller
  • Parabolic main reflector
  • Ellipse subreflector
  • Subreflector and strut blockage small
  • Small feed line loss
  • Good G/T
Antenna

• Antenna Types
  • Parabolic offset dual reflector gregorian
    • Offset dual reflector system
    • Main reflector parabolic
    • Subreflector elliptical
    • No Feed / Reflector blocking
    • Small feed line losses
    • Excellent C/I and cross pol purity
  • Used on satellites
Antenna

• Antenna Types
  • Simulsat
    • Receive Only
    • Captures signals across a 70° view arc
    • Upto 35 satellites are received with uniform performance
    • Each satellite illuminates a specific area
    • Signals reflect to their corresponding C-Band or Ku-Band feed
    • Feeds are adjusted, no antenna movement
Antenna

• Antenna Subreflector
  
  • In a direct feed reflector, the feed horn is located at the focus or may be offset to one side of the focus
  
  • Large earth station antennas have a subreflector at the focus
    
    • The subreflector permits the antenna optics to be located near the base of the antenna
    
    • Reduces losses because the length of the waveguide between the transmitter or receiver and the antenna feed is reduced.
    
    • The system noise temperature is also reduced because the receiver looks at the cold sky instead of the warm earth
  
  • Cassegrain
    
    • The subreflector is convex with an hyperboloidal surface
    
    • Hyperboloidal? A mathematical surface whose sections parallel to one coordinate plane form ellipses and those parallel to the other two coordinate planes form hyperbolas
  
  • Gregorian
    
    • The subreflector is concave with an ellipsoidal surface
    
    • Ellipsoidal? A geometric surface or a solid figure shaped like an oval. Any section through an ellipsoid is either an ellipse or a circle.
Antenna

• Antenna Focal Distance (f/d)
  • focal distance formula: $f/d = D^2 / 16d$
    • $D = $ Antenna Diameter
    • $D = $ depth of Parabola

<table>
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<tr>
<th>$D = 3.8 \text{ m}$</th>
<th>$d = 0.6 \text{ m}$</th>
<th>$f/d = 1.504 \text{ m}$</th>
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Antenna

- **Antenna Focal Distance (f/d)**
  - **Shallow dish antenna**
    - Long focal length increases the feedhorn’s ability to illuminate the entire reflector area providing good gain
    - More susceptible to:
      - Earth noise at low elevation angles
      - Terrestrial Interference
    - Affects antenna noise temperature
  - **Deep dish antenna**
    - Short focal length decreases the feedhorn’s ability to illuminate the entire reflector area providing less gain
    - Can provide advantages
      - Low elevation angles
      - Terrestrial interference
    - Better antenna noise temperature
Antenna

• Antenna De-Ice
  • Freezing precipitation will impact antenna performance
    • Snow or ice on the reflector surface
      • Attenuates the signal
      • De-focuses the antenna
  • Areas with freezing precipitation requires antenna de-icing infrastructure
  • Types of de-icing:
    • Electric
      • Blankets Glued to the back of the reflector
      • Forced hot air with the back structure enclosed
    • Natural Gas
      • Forced hot air with the back structure enclosed
    • Fabric Cover
      • Prevent snow / ice accumulation in the dish
    • Rain Blower
      • Blows air across feed input to prevent water buildup
Antenna

• Antenna Feed System
  • 1 Port
    • Receive Only
  • 2 Port
    • Can Receive Two signals or
    • Transmit One and Receive One
  • 3 Port
    • One Transmit and Two Receive
  • 4 Port
    • Two Transmit and Two Receive
• Polarization adjustment
  • Single plane: transmit and receive are fixed and both rotate
  • Dual plane: transmit and receive rotate separately
Antenna

- OMT and TRF
  - Ortho Mode Transducer (OMT)
    - Changes feeds circular Wave Guide to two rectangular Wave Guides
    - Separates and directs signals of two different polarities
    - Determines isolation for Circular Polarization
  - Transmit Reject Filter (TRF)
    - Blocks transmit power from Low Noise Amplifier
  - 4 Port feed will have an OMT and TRF for each polarity
3D Antenna Radiation Pattern
Polarization

- Provides increased satellite capacity (Allows frequency reuse)
- The directional aspects of the electrical field of a radio signal

**Linear (90° Out of Phase)**
- Horizontal (H)
- Vertical (V)
- All Ku-Band satellites are Linear

**Circular (180° Out of Phase)**
- Right Hand Circular (RHCP)
- Left Hand Circular (LHCP)
Linear Polarization

- **Linear Polarization**
  - The electrical field is wholly in one plane containing the direction of propagation

- **Horizontal**
  - Field lies in a plane parallel to the earth’s surface.

- **Vertical**
  - Field lies in a plane perpendicular to the earth’s surface.
Circular Polarization

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

- **Right Hand Circular Polarization (RHCP)**
  - the electric field is rotating clockwise as seen by an observer towards whom the wave is moving

- **Left Hand Circular Polarization (LHCP)**
  - the electric field is rotating counterclockwise as seen by an observer towards whom the wave is moving
Linear Polarization

• Advantage
  • Lower Cost Antenna System
    • Feed Assembly (OMT)
  • Better Cross-Pol Isolation

• Disadvantage
  – Polarization Adjustment Required
  – Polarization changes depending on Latitude and Longitude
  – Greater chance of problems due to cross-pol interference
  – Faraday rotation in the ionosphere
Circular Polarization

• Advantage
  • No polarization adjustment required
    • Fixed by Ortho-Mode-Transducer (OMT)
  • Less chance of cross-Pol interference

• Disadvantage
  – Higher cost antenna systems
    • Feed Assembly (OMT)
  – Slightly lower cross-Pol isolation
Uplink

- Uplink Block Diagram
  - Modulator / Modem
  - Up-Converter
  - Power Amplifier
  - Antenna
  - Inter Facility Link (IFL)
  - Fiber Optics
  - Co-axial cable Combiners / Splitters
  - Waveguide

Simplified Uplink Block Diagram
Uplink Block Diagram

- Modulator / Modem
- Up-Converter
- Power Amplifier
- Antenna
- Inter Facility Link (IFL)
  - Fiber Optics
  - Co-axial cable Combiners / Splitters
  - Waveguide
Modems - Selection

- **SCPC**
  - Low Throughput 64Kbps
  - High Throughput >300Mbps
  - Carrier Cancellation

- **TDM/TDMA**
  - Simple Hubless solution
  - Star Network
  - Mesh network

- **Advanced features**
  - Roll Off
Modem Interfaces

• RS232/RS422
• HSSI/G703/Ethernet
  • D-Type connector, BNC, Ethernet
• IDR G703 E1/T1
• IBS: RS422/RS232/ITU.V35
• ASI
• Ethernet
• SDI
Common Modulation Techniques

• Analogue Modulation
  • AM, FM, QAM, SM, SSB

• Digital Modulation
  • ASK, APSK, CPM, FSK, MFSK, MSK, OOK, PPM, PSK, QAM, TCM
QPSK

• One of 4 phases
• 2 bits per symbol
• 00, 10, 01, 11
Modem – Modulation QPSK

- When I and Q both change at the same time then signal transitions through Zero
  - Power changes abruptly
  - Signal distortions
Modem – Modulation QPSK

- When I and Q both change at the same time then signal transitions through Zero
  - Power changes abruptly
  - Signal distortions
Modems - Modulation

- Q – offset
  - Signal never goes through Zero
  - Better performance
Phase shift Key

- QPSK – 2 bits per symbol
- 8PSK – 3 bits per symbol
- 16APSK – 4 bits per symbol
- 32APSK – 5 bits per symbol
- etc
QAM

- Varies the vector amplitude and phase
- Bits per symbol; same as nPSK
- Requires linear power
- Good $Eb/No$ performance
Digital Modulation - Spectrum

2 bits/symbol

5 bits/symbol
Effect of Higher order Modulation

- Thermal Noise
- Phase Noise
- Linearity
- Group delay
Uplink Block Diagram

- Modulator / Modem
- Up-Converter
- Power Amplifier
- Antenna
- Inter Facility Link (IFL)
  - Fiber Optics
  - Co-axial cable Combiners / Splitters
  - Waveguide
Up-Converter (U/C)

• A device that converts an input signal known as the intermediate frequency (IF) to a desired higher frequency without disturbing the intelligence (modulation) on the incoming signal

• The method used to achieve the conversion is heterodyning. That is the mixing of two different frequencies into a non-linear device (mixer) to produce two other frequencies equal to the sum or difference of the first two, while maintaining its characteristics
Up-Converter (U/C)

• 70 / 140 MHz IF to L-Band

  • 70 MHz to L-Band
    • 70 ±18 MHz input
    • 950 – 1450 MHz output
    • Non inverting
    • 36 MHz bandwidth

  • 140 MHz to L-Band
    • 140 ±72 MHz input
    • 950 – 1450 MHz output
    • Non inverting
    • 72 MHz bandwidth
Up-Converter (U/C)

- L-Band to C-Band
  - 950 - 1450 MHz input
  - 5.925 – 6.425 GHz output
  - Non inverting (4.900 GHz LO)
  - Inverting (7.375 GHz LO)
  - 500 MHz bandwidth

- L-Band to Ku-Band
  - 950 - 1450 MHz input
  - 14.00 – 14.50 GHz output
  - Non inverting (LO = 13.050 GHz)
  - Inverting (LO = 15.450 GHz)
  - 500 MHz bandwidth
Up-Converter (U/C)

- 70 MHz to C-Band
  - 70 ±18 MHz input
  - 5.850 – 6.425 GHz output
  - Non inverting
  - 36 MHz bandwidth

- 140 MHz to C-Band
  - 140 ± 36 MHz input
  - 5.850 – 6.425 GHz output
  - Non inverting
  - 72 MHz bandwidth
Up-Converter (U/C)

• 70 MHz to Ku-Band
  • 70 ±18 MHz input
  • 14.00 – 14.50 GHz output
  • Non inverting
  • 36 MHz bandwidth

• 140 MHz to Ku-Band
  • 140 ± 36 MHz input
  • 14.00 – 14.50 GHz output
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  • 72 MHz bandwidth
Uplink Block Diagram

- Modulator / Modem
- Up-Converter
- Power Amplifier
- Antenna
- Inter Facility Link (IFL)
  - Fiber Optics
  - Co-axial cable Combiners / Splitters
  - Waveguide

Simplified Uplink Block Diagram
Power Amplifiers

• High Power Amplifiers - HPA
  • Solid State Power Amplifiers - SSPA
  • Travelling Wave Tube – TWT
  • Klystron Power Amplifier KPA

• Including/excluding Up-conversion

• Transceivers
Transceiver

- Combination Power Supply, Up / down converter, HPA and LNA - PSU
- Mounted on / at the antenna
- 70 or 140 MHz or L-Band input
- RF Output C/Ku/Ka-Band output
- Single or dual synthesized converters
  - Uplink
  - Downlink
Solid State Power Amplifiers

- Typical output power 5 to 200 Watts
- 500 MHz bandwidth
- Non Linear
- L-Band Up-Converter optional
  - Requires external 10 MHz reference
  - Requires Diplexer
- Typically \(\approx 3\) dB OBO for multi carrier operation
Solid State Power Amplifiers

- Lower Power 1- 200W
- Lower OBO for multicarrier operation
- Cost effective
- Low maintenance
- Power efficient
- Susceptible to power and lightning damage
Travelling Tube Amplifier

- Typical output power 100 – 750 Watts
- 500MHz - 750 MHz bandwidth
- Non Linear
- Built in BUC optional
  - Requires 10 MHz external reference and Diplexer
- ≈ 7 dB OBO for multi carrier operation
- ≈ 4 dB OBO with linearizer for multi carrier operation
Transmitters (HPA)

- HPA HIGH POWER AMPLIFIER
  - TRAVELING WAVE TUBE AMPLIFIER
  - WIDEBAND (FULL SPECTRUM) GREATER 500MHz
  - NON LINEAR
    - SMALL SIGNAL SUPRESSION
    - AMPLITUDE TRANSFER CURVE
Transmitters (HPA)

- SMALL SIGNAL SUPRESSION
- AMPLITUDE TRANSFER CURVE
- INTERMODULATION
Klystron Power Amplifier

- Typical output power 1000 to 3000 Watts
- Non linear
- 40 or 80 MHz bandwidth
- \( OBO \approx 2 \text{ dB} \) for dual carrier operation
  - \( \approx 7 \text{ dB} \) for multi carrier operation
Uplink Block Diagram

- **Modulator / Modem**
- **Up-Converter**
- **Power Amplifier**
- **Antenna**
- **Inter Facility Link (IFL)**
  - Fiber Optics
  - *Co-axial cable Combiners / Splitters*
  - Waveguide
Inter Facility Linking

• Co-axial cabling
  • Data and base band
  • IF
  • L-Band
  • C-Band
  • Ku-band
RF Co-axial Cabling

• Important factors
  • Higher Frequency higher losses
  • Losses indirectly proportional to cable diameter
    • Skin effect
    • To a point
  • Losses directly proportional to frequency
  • Reflections – impedance mismatch
    • Cable damage
    • Water
    • System impedance
    • Connector
Waveguide

- Used at C-Band and higher frequencies
- Lower loss than co-axial cable
- Types:
  - Rigid
  - Flexible, Flexible and twistable
  - Elliptical
- Not wideband – Frequency determines dimension
Combiners Small Signal

• Types
  • IF
  • L-band
  • C-Band/Ku-band

• Considerations
  • Losses
  • Impedance matching
  • Terminating unused ports
Combiner - Wideband

- 3dB Coupler
  - Co-axial
  - Waveguide
  - High power
  - Wideband
  - 3dB loss Dummy load required
Combiner - Filter

• Co-axial
• Waveguide
• Variances
  • One port wideband
  • Other port narrowband
  • Low insertion losses
Technology Trends
Technologies

Addressing your Bottom Line through the use of the latest technologies

- DVB-S2 Extensions
- Adaptive Coding and Modulation
- Carrier in Carrier Technology
- Lower Roll off factors
- New Technology in Satellites
- Antennas Advancements to reach new markets
DVB-S2 & Extensions

A new standard enables true convergence

• Excellent spectral efficiency:
  • Up to 40% bandwidth saving compared to DVB-S
  • Up to 2dB better than Turbo Codes
  • HDTV enabler

• Unlike DVB-S, DVB-S2 is optimised for MPEG and IP
• Allows for DTH and DTT distribution in single carrier
DVB HISTORY

DVB-S2X
- 113 ModCods
- Up to 256 APSK 11/15
- 3 Framesizes (Normal, Short, Medium)
- Linear and Non-Linear
- RO: 5%, 10%, 15%, 20%, 25%, 35%

Backward Compatible DVB-S2 Mode

DVB-S2 & Extensions

- DVB-S: 1994
- DVB-DSNG: 1999
- DVB-S2: 2005
- Newtec CCT: 2011
- Newtec S2 Extensions: 2012
- DVB-S2X: 2014
<table>
<thead>
<tr>
<th>Modulation</th>
<th>Constellation</th>
<th>Rate</th>
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<td>QPSK 13/45</td>
<td>16APSK 3/5-L</td>
<td>64APSK 11/15</td>
<td>QPSK 9/20</td>
<td>16APSK 28/45</td>
<td>64APSK 7/9</td>
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<td><strong>64APSK 5/6</strong></td>
<td><strong>8APSK 26/45-L</strong></td>
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<tr>
<td><strong>16APSK 3/5</strong></td>
<td><strong>64APSK 32/45-L</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Adaptive Coding & Modulation

- Higher throughput for the same amount of resources
- When rain fade issues arise, the modulation can adjust so as to ensure the remote stays in the network
- Allows lower per Mbps price points to be achieved, leading to more competitive prices in the market

Maximum achievable data throughput by utilizing the most efficient coding and modulation scheme at any moment in time, depending on location within the satellite contour, antenna size and atmospheric conditions.
Carrier Cancellation Technology

Typical 8PSK Link

A => B

B => A

Original Link shown for Reference

8PSK → QPSK (Spreading)

Bandwidth increases,
Power decreases

Composite Link

QPSK - With DoubleTalk Carrier-in-Carrier

Apply DoubleTalk Carrier-in-Carrier - Composite Carrier uses Less Bandwidth & Less Power Compared to Original
Roll Off

- Allocated BW directly proportional to Symbol rate X Roll off
- Typical roll off – 35%
- Most recent roll off available 5%
- Drives efficiency
Combination of Features

Equipment Vendors are integrating options to their products

- DVB-S2 with ACM
  - Satellite equipment vendors (eg. HNS, iDirect)
- Carrier in Carrier
  - ComtechEFDATA CDM-625
  - Viasat PCMA
  - DVB-S2, Carrier in Carrier with ACM
    - ComtechEFDATA CDM-750
New Technology in Satellites

Intelsat Satellite network evolution
Satellite Network Evolution

• What is a High Throughput Satellite?
  • Traditional satellites currently deliver a system data throughput of 2Gbps to 5Gbps
  • A High Throughput Satellite is a satellite that can deliver system data throughputs of 15Gbps or more.
  • This is done by the ability of frequency reuse and a combination of Spot Beams and Wide Beams
  • Spot Beam provide the ability to concentrate power (EIRP and G/T)

• Intelsat is the first in this next advancement of satellite technology and it is called:
Intelsat brings well known principles of “Frequency Reuse” & “Spot Beams” in a new configuration

Frequency reuse
(Any frequency band: C, Ku, Ka) + Spot Beams & Wide Beams

= Intelsat Epic\textsuperscript{NG}
Frequency Reuse Methodology

1. Reduce beam size.
   • This increases G/T and EIRP
2. Split frequency into 4 or 7 or 8 etc. segments or “colors”.
3. Assign each color the segmented bandwidth taking care not to assign any similar colors next to each other.
IS-33e Ku-Beams

- User Beams
  - Standard Ku-band frequencies (non-planned FSS)
  - Bandwidth from 56.25 to 225 MHz

- Core Beams
  - Use BSS and Ku-band Planned bands
    - Different bands for User Beams
  - Bandwidth sized to support all user beams in corresponding country or region, for example:

- Connectivity
  - Connectivity between any user and core beam
High Performance Satellite Platform

- High Capacity
- High Efficiency
- High Throughput
- High Performance
- Multi-band
- Resilient and Secure

- Open Platform
- Backward Compatible
- Flexible
- Complementary Overlay
- All-region Coverage
- Lower Cost of Ownership
Bandwidth
EIRP
G/T
36MHz
9MHz
This is our Existing Satellite Network…

- Global coverage
- 25 satellites over Africa
- Resilient C-band and Ku-band transponders
Now Launching 7 Epic\textsuperscript{NG} satellites
And adding OneWeb

First and only fully global, pole-to-pole high throughput satellite system

The OneWeb satellite constellation:

› Counts 700 LEO satellites
  *(moving in 18 planes of 36 satellites)*

› Very Low latency
  *(less than 30ms round trip delay)*

› Perfect for Internet across Africa with look angles better than 57° *(“overhead IP coverage”)*

Total Throughput of the system:

5 terabits per second

Credit: Airbus Defence and Space
Providing a Truly Global Network in the Sky
Designed as an overlay to the existing Ku-band Network, **Intelsat Epic NG Capacity** will scale over time, offering **CONTINUITY, GROWTH, & RESILIENCE**
Example: Ku-band Spot Beam Network

1.8M/4W KU-BAND REMOTE
Example: Ku-band Spot Beam Network

Focused EpicNG Ku-band Spot Beam

◆ SAME 1.8m/4W remotes

◆ SAME platform technology

◆ PROJECTED GROWTH now supported

200 Mbps Network throughput*

30% THROUGHPUT INCREASE

Up to 14 Mbps Return

x7 REMOTE THROUGHPUT

*Limited by platform technology
Example: Ku-band Spot Beam Network
Focused Epic<sup>NG</sup> Ku-band Spot Beam

- **SAME** 1.8m/4W remotes
- **ADVANCED** platform technology
- **SCALE** to full spot capability

![Diagram of Epic<sup>NG</sup> network throughputs and remotes]

- **Up to 2.1 Gbps**
  Network throughput on 3 spots
- **Up to 14 Mbps**
  Return throughput
- **70% THROUGHPUT INCREASE**
- **×7 REMOTE THROUGHPUT**

**ACHIEVED GOAL**
- **INCREASE NETWORK VOLUME**
- **BOOST RETURN TRAFFIC**
Example: Ku-band Spot Beam Network

Epic<sup>NG</sup> Ku-band Spot Beam

- **NEW 1.2M/2W** remotes
- **ADVANCED** platform technology
- **SCALE** to full spot capability

**ACQUIRED GOAL**

- INCREASE NETWORK VOLUME
- BOOST RETURN TRAFFIC
- ROLL OUT CHEAPER SITES

**30% THROUGHPUT INCREASE**

- Up to 1.6 Gbps
- Network throughput on 3 spots.

**REMOTE THROUGHPUT**

- Up to 6 MBPS Return
- x3

**THROUGHPUT INCREASE**

- Up to 300 THROUGHPUT INCREASE
- 30 REMOTE THROUGHPUT

**CAPEX SAVING**

- Up to 50% CAPEX SAVING
- 500 CAPEX SAVING
Antenna Advancements
Redefinition of the satellite antenna

- Electronically Steered Antennas (ESA)
- No moving parts
- Ultrathin and light
MTENNA TECHNOLOGY

Flat
Lightweight
No Moving Parts

Auto-Acquiring
Self-Provisioning
Affordable
Customer Benefits: IoT

- **Affordable** terminal
- **Hand-carry, self installation**
- Connects to existing sensor / WiFi networks
- **Efficient**, intelligent data backhaul
- Auto-acquisition and self-provisioning
- **Reliability** – no moving parts
- Global network with **scalable** throughput
- Remote and/or mobile connectivity

*Form factor, affordability, and production scalability make mTenna technology ideal for Mobility & IoT*
**Enables mobile-broadband communications: at-sea, over land and in-flight**

Revolutionary, flat, electronically steerable antenna (ESA)

**Thin**
- **Very low profile**, (aerodynamic, inconspicuous)
- **Superior form-factor**, (smaller footprint, light-weight)

**Reliable**
- **Accurate**, (faster scan, better tracking, fewer network drops)
- **Robust**, (no-moving parts, gradual degradation vs. total system failure)

**Broadband**
- **Delivers true broadband service**, (supports networks > 100Mbs)
- **Very high gain** (efficient, powerful)

**Modular**
- **Adaptable**, (expandable to support wide requirements, lowering OpEx)
- **Better logistics-tail** (easier, less costly & less timely to repair)

**Versatile**
- **Broad functionality**, (multi-beam, flat or conformal, distributed or contiguous)
- **Dynamic control**, (beam forming, tapering, ASI mitigation)
Designed to be flat or conformal – enables Aeronautical Mobile Broadband
› Navigation maps
› Weather information
› Over-the-air updates
› Streaming

› Sensors Analytics
› Video conference
› Video surveillance
Thank you

Questions?