High Data Rate Communications Systems

University of Colorado at Boulder

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Himanshi Singhal
Why?

Potential of about 2500 micro/nano satellites to be launched in between 2014 and 2020. \(^{(1,2)}\)

- Current primary source are amateurs for cubesats
  - Capabilities:
    - Allows data downlink from multiple places on Earth -- a huge plus!
  - Limitations:
    - Unable to command satellite from ground
    - Limited downlink data rate
Mission Statement

High data rate (upto 1Mbps) communications system to track satellites operating in S-Band and UHF.
Mission Requirements

- **Primary Objective:** Provide data downlink and commanding capability to PolarCube for S-Band (2.4 GHz) downlink and UHF (435 MHz) uplink.

- **Secondary Objectives:**
  - Continue building reliable communications infrastructure for future COSGC missions
  - Provide data downlink and commanding capabilities for non-COSGC missions
Station Overview
Major areas of work

3 major subsystems with multiple little task teams
- Radio Frequency
- Dish Motion Control
- Ground Segment
Radio Frequency (RF)
System Specifications

- Dish (Parabolic Reflector)
  - Diameter: 4.3m
  - Efficiency: 60%
  - Gain: 38.5 dB
  - Beamwidth: 2 deg
- LMR 400 Cable Length (from Feedhorn to Receiver): 10 m
- System Noise Temperature: 482 K
- LNA Temperature: 60 K
## Architecture (Above Dish)

### RF Gain/Loss of Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Gain/Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dish</td>
<td>38.5</td>
</tr>
<tr>
<td>Splitter</td>
<td>(1.3)</td>
</tr>
<tr>
<td>LNA</td>
<td>14.2</td>
</tr>
<tr>
<td>BPF1</td>
<td>(1.15)</td>
</tr>
<tr>
<td>Isolator</td>
<td>(0.5)</td>
</tr>
<tr>
<td>UHF Splitter</td>
<td>(0.5)</td>
</tr>
</tbody>
</table>

**Diagram Notes:**
- **SMA(M) Connector**: 90 Degree SMA(M) Connector, UHF(F) to SMA(M) Adapter, N-SMA Adapter, N to SMA Adapter.
- **RF Cables**: RG405 semi-rigid, Long Run RF Cables: ##### Power Cables: #8 Gage.
- **Antennas**: UHF Box, Pedestal.
Architecture (Below Dish)

RF Gain/Loss of Components

<table>
<thead>
<tr>
<th>Gain/Loss</th>
<th>dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diplexer1 (S-Band/UHF)</td>
<td>3, 1</td>
</tr>
<tr>
<td>UHF Isolator</td>
<td>0.5</td>
</tr>
<tr>
<td>UHF Amplifier</td>
<td>14.0</td>
</tr>
<tr>
<td>Slip Rings(2)</td>
<td>1</td>
</tr>
<tr>
<td>Diplexer2 (S-Band/UHF)</td>
<td>3, 1</td>
</tr>
<tr>
<td>BPF2</td>
<td>1.15</td>
</tr>
<tr>
<td>Connectors</td>
<td>1.1</td>
</tr>
<tr>
<td>Cable (dB/m)</td>
<td>0.43</td>
</tr>
</tbody>
</table>
Link Margin

Assumptions:
Orbit: 650*650 km
Elevation Angle: 10 deg.
Slant Range: 2045 km
Frequencies used: 435.00 MHz & 2401.500 MHz
Downlink Data Rate: 1Mbps

<table>
<thead>
<tr>
<th>Link</th>
<th>S-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Losses</td>
<td>168.3 dB</td>
</tr>
<tr>
<td>S/N</td>
<td>8.2 dB</td>
</tr>
<tr>
<td>Eb/No</td>
<td>7.0 dB</td>
</tr>
</tbody>
</table>
Hardware Alignment & Procedures

- Laser and sonar to orient in three dimensions
- Bypass trailer’s mechanical imperfections to obtain an accurate measurement
Dish Motion Control
Tracking Software Design

- Create a Two Line Element (TLE) using the GPS coordinates provided by satellite’s beacon
  - Use position, velocity, time, and satellite parameters to write entries of TLE
- Use the created/provided TLE to track satellite using Azimuth/Elevation (Az/El)
  - Accounts for different Coordinate Systems, Station Location and Time Zone changes
  - Propagation Algorithm used: SGP4
    - Read TLE and calculate position at current time
  - Convert position into Az/El
- Command the Dish Rotator and Radio
  - Output Az/El data in a hexadecimal format to the Rotator and Radio through serial communication
GUI
Architecture
Architecture
Ground Segment
Architecture
Architecture
Advantages

- Custom RF components such as Band Pass Filter, Diplexers built to specifications for lower losses
- Custom Tracking Software with multiple information inputs available such as position-velocity or TLE
- Enables updating the TLE more frequently for better pointing
• Antenna alignment and dish characterization
• Implement Control Feedback Loop for Dish Motion Control
• Implement Kalman filter to predict uncertainties and updates in tracking software model
• Develop remote capabilities for future ease for operators
References


Thank You!