Ultra-Compact Ka-Band Parabolic Deployable Antenna (KaPDA) for Cubesats

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05/28/14
# The KaPDA Team

<table>
<thead>
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<th>Name</th>
<th>Group</th>
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KaPDA Overview

- **Challenge** – Data rates are a limiting factor on CubeSat missions beyond LEO
- **Objective** – High-rate CubeSat communications with DSN
  - Over 100x increase over state-of-the art data rate requires a Ka-band deployable high-gain antenna (HGA)
  - Would provide over a 10,000x increase over a X-band patch antenna
- **Solution** – A low-cost deployable HGA stowing in ~1.5U

### Data Rate Comparison

<table>
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<tr>
<th>Range (AU)</th>
<th>Data Rate (bps)</th>
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<tr>
<td>0.001</td>
<td>100,000,000</td>
</tr>
<tr>
<td>0.01</td>
<td>10,000,000</td>
</tr>
<tr>
<td>0.1</td>
<td>1,000,000</td>
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<tr>
<td>1</td>
<td>100,000</td>
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- Ka-band, 1w, deployable dish
- S-band, 1w, deployable dish
- X-band, 1w, patch antenna

**Aeneas Parabolic Deployable Antenna (APDA) on-orbit**
Existing CubeSat Antennas

• Existing parabolic and parabolic like antennas
  – Goer-wrap composite reflector
  – Reflector transformed from the CubeSat body
  – Inflatable cone/cylinder shaped reflector
  – Reflectarray
  – Mesh Antennas

• All are designed for S-band operation
  – Except for reflectarray

• Ka-band provides data rate advantages
  – But requires greater surface accuracy

• Mesh design was the most practical to upgrade
Approach

- ANEAS parabolic deployable antenna (APDA) launched in Sept. 2012
- Folding rib architecture was attractive for stowing efficiency
- Redesign the 0.5 m S-band APDA
  - JPL is collaborated with USC/ISI to test APDA and develop KaPDA
  - Surface characterization of APDA revealed a complete redesign would be required for Ka-band operation
- Design requirements
  - 42 dBi goal at 34 GHz for downlink to DSN
    - Equals 50% efficiency or surface distortions of under 0.57 mm RMS
  - Stows within 1.5U, and deploys with adequate mesh tension

APDA Hardware: Deployed and Stowed
Antenna Configuration

- Configurations were explored for stowed size and gain
  - Gregorian
  - Cassegrainian
  - Hat-style feeds
- Cassegrainian configuration was selected

<table>
<thead>
<tr>
<th>Configuration type</th>
<th>Gain, dBi</th>
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<tr>
<td>Gregorian</td>
<td>44.0</td>
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<tr>
<td>Cassegrainian</td>
<td>43.6</td>
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<tr>
<td>Hat feed 1</td>
<td>43.1</td>
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<tr>
<td>Hat feed 2</td>
<td>43.3</td>
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General Architecture

- Antenna configuration drove architecture
  - Cassegrainian design was improved for gain
- Similar folding rib geometry to APDA
  - Required additional sub-reflector, horn, and waveguide

Key KaPDA Components

- Sub-reflector
- Latch
- Tip Rib
- Root Rib
- Horn
- Cable Plate
- Hub
- Waveguide Outlet

KaPDA Stowed

KaPDA Deployed
• Surface accuracy improves with more ribs
• Clearance space decreases with the number of ribs
• A balance between RF and clearance was found at 30-32 ribs
• A number of hinge designs were explored
  – Single pin hinge
  – Laminated hinge
  – SOSS hinge
  – Double hinge
  – Composite hinge
• Hybrid of single pin and laminated hinge will be used
• Stop opposite to the hinge pin controls deployment
Deployment Design

- Deploy arms via cables and springs
- 30 lbs of deployment force required to tension mesh
- Key Challenge: apply 30 lbs without whiplash
- Considered deployment drivers
  - Motors driving threaded rods
  - Scissors lift
  - Cables and pulleys driven by motors
  - Inflating bladder
- Inflating bladder system chosen
  - Controlled deployment
  - Only 4.7 psi required to deploy antenna

Spring and Cable Deployment

Original Cable Only Deployment
Deployment Design

- **Deployment Sequence**
  
  A. **Stowed Condition**
  
  B. **Hub is driven upwards by an inflating bladder**
  
  C. **Mechanical stop prevents the cable plate from traveling any further, deploying ribs. Ribs release sub-reflector, and as tips clear, they spring open.**
  
  D. **The hub continues upwards until the root ribs have fully deployed and hub is latched in place.**
KaPDA Parameters and Progress

- **Parameters:**
  - 0.5 meter dish stowing within 1.5U
  - RF analysis shows 42.9 dB of gain before manufacturing tolerances
  - Operations frequencies of 34.2 GHz to 34.7 GHz and 31.8 GHz to 32.3 GHz
  - Goal to operate at 37.5 GHz

- **Progress:**
  - Conceptual design has been completed
  - Initial RF and structural analysis completed
  - Next Steps
    - Detail RF tolerance analysis
    - Deployment breadboard
    - Engineering Model
    - RF verification of engineering model
  - Current R&TD through FY16; hope to accelerate
    - Deliverable is test-validated flight-like antenna

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<thead>
<tr>
<th>Diameter (m)</th>
<th>Design</th>
<th>Stretch Goal</th>
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<td>0.5</td>
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<td>0.75</td>
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<table>
<thead>
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<th>Frequency (GHz)</th>
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<table>
<thead>
<tr>
<th>Gain (dBi)</th>
<th>Design</th>
<th>Stretch Goal</th>
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<td>46.4</td>
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<table>
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<th>Efficiency (%)</th>
<th>Design</th>
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<table>
<thead>
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<th>Size (U)</th>
<th>Design</th>
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<tbody>
<tr>
<td>1.5</td>
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<td>2.5</td>
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Table of Design Parameters
KaPDA stands to enable opportunities for a host of new Cubesat missions by allowing high data rate communication which would allow using high fidelity instruments or venturing further into deep space, including interplanetary missions.