Spacecraft-to-Earth Communications for Juno and Mars Science Laboratory
Critical Events

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Outline

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Introduction

• Deep Space communications typically utilize closed loop receivers and Binary Phase Shift Keying (BPSK) or Quadrature Phase Shift Keying (QPSK).

• Critical spacecraft events include orbit insertion and entry, descent, and landing:
  – Low gain antennas -> low signal-to-noise-ratio
  – High dynamics such as parachute deployment or spin -> Doppler shift

• During critical events, open loop receivers and Multiple Frequency Shift Keying (MFSK) used.

• Entry, Descent, Landing (EDL) Data Analysis (EDA) system detects tones in real-time.
System Design
• Tone detection is accomplished using an FFT-based frequency and frequency rate loop on the carrier
• Each critical event is divided into time segments with different signal dynamics: cruise, entry, parachute deployment, bridle and bouncing, landing
• Real time- maximum performance with minimum latency
• 4 EDA systems:
  – 2 for MSL
  – 2 for Juno
Juno

- Launched August 5, 2011
- Cruise time to Jupiter is about 5 years
- Uses an Earth-Gravity-Assist that relies on deep space maneuvers about a year after launch
- Torroidal Low Gain Antenna used for critical maneuvers

### Table 1- Planned dates of Juno EDA Usage

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Tones Tests</td>
<td>September 7, 2011</td>
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<tr>
<td>Deep Space Maneuvers</td>
<td>September 2012</td>
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<tr>
<td>Jupiter Orbit Insertion</td>
<td>July 4-5, 2016</td>
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<tr>
<td>Period Reduction Maneuver</td>
<td>October/November 2016</td>
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Juno Tones Tests

- In-flight tones test took place on September 7, 2011
- Tones may be high or low priority
- High priority tones must be $\geq 3$ sec in duration
- Tones test sequence included 4 cases:
  - Basic Tones: complete range of 1-512, adjacent frequencies
  - Prioritization: high and low priority tones in rapid succession
  - Sustained Sequence: 10 tones, each emitted for 3 seconds
  - Flurry of Tones: mix of high and low priority tones
- Three tests took place:
  - A: DSS-14
  - B: DSS-14 and DSS-43
  - C: DSS-43
Juno Tones Tests Results

Pc/No of 50 dB-Hz, 1 RPM spin

All tones detected
Simulations of Juno JOI

Pc/No of 12-15 dB-Hz, 5 RPM spin expected

>98% of tones detected
Mars Science Laboratory

- Launched on November 26, 2011
- Entry, Descent, and Landing on Mars on August 5, 2012
- Direct-To-Earth communications during EDL will utilize X-band. Relay communications to Mars Odyssey will utilize UHF.
- UHF communications blackout due to plasma during entry.
- Low gain antennas used:
  - Parachute Low Gain Antenna (PLGA)
  - Titled Low Gain Antenna (TLGA)
  - Descent Low Gain Antenna (DLGA)
Mars Science Laboratory Entry, Descent, and Landing
• Fiber link from MSL Test bed to Portable Radio Science Receiver -> EDA
• Four MSL Test Bed tones tests took place in February
  – Nominal case
  – Thermal faults
  – Power Analog Module failure
  – Failure of Guided entry
• All tones detected
• Pc/No as low as 20 dB-Hz but no dynamics
MSL EDL Doppler and Doppler Shift
Simulations of MSL EDL

MSL EDL Residual Carrier Frequency

2/21/12

Residual Frequency (Hz)

Time from Entry (seconds)
Conclusions

• EDA software successfully ported to new hardware

• EDA configuration files developed for Juno
  • 100% of tones detected in Juno in-flight tones tests
  • >98% of tones detected in Juno JOI simulations
  • 100% of tones detected in MSL Test Bed tones tests

• EDA configuration files for MSL EDL currently in development