MRO Ka-band Demonstration

by

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Introduction

- Due to lack of spectrum at X-band (8.41 GHz) NASA is switching to Ka-band (32 GHz) for its Deep Space Missions.
  - 50 MHz bandwidth at X-band vs. 500 MHz at Ka-band.
- Weather events cause greater degradation for the Ka-band link. Therefore, Ka-band needs to be operated in a different manner than the X-band.
  - Ka-band achieves maximum average capacity at a lower weather reliability than X-band (80 to 90% for Ka-band vs. 95% for X-band).
  - Studies have been done to suggest methods of operation for Ka-band.
- MRO will allow us to evaluate the proposed methods of operations for Ka-band
  - MRO is the first spacecraft to have a fully functioning independent Ka-band downlink stream.

Overview of MRO Ka-band Demo

- Launch: August 2005.
- Start of Primary Science: November 2006
  - 2-year prime science phase.
- Telecom System:
  - Maximum Downlink Symbol Rate: 6 Msps
  - 100-W X-band, 35-W Ka-band transmitted power.
  - X-band will use both BPSK and QPSK modulations while Ka-band will only use BPSK.
  - 3-m Parabolic Antenna
    - Ka-band EIRP: 101.3 dBm.
    - X-band EIRP: 95.6 dBm.
  - X-band uplink command only.
  - Coding: 8920 block length turbo codes (rates 1/2, 1/3 and 1/6), Concatenated Code (RS (255,223), interleaver depth 5, (7,1/2) convolutional code) or RS (255,223) code only.
    - Due to design limitations if one band uses turbo codes (regardless of the rate) the other band has to use RS code or concatenated code unless the same data is being transmitted over both bands.

Overview of MRO Ka-band Demo (cont.)

- Operations: Background sequencing and Mini-sequencing.
  - Background sequencing programs the spacecraft operations for four weeks at a time and will be used for statistical operation of the link.
  - Mini-sequencing fine tunes the operations on a weekly basis and was considered for evaluating weather forecasting. Mini-sequencing will not be used during the PSP due to its limited applicability and cost.
- MRO Ka-band demo will have two telemetry passes per week and 1 DDOR pass a month assigned to it during the prime science phase of the mission (November 8, 2006 through November 18, 2008).
  - MRO will be tracked by DSN's 34-m BWG subnet (only Ka-band capable antennas in the DSN).
  - DSN will also track Ka-band on a non-interference basis during MRO science passes whenever possible.
  - These passes will be used to evaluate different Ka-band operational strategies.
- MRO Ka-band demo also includes passes during the cruise phase and superior solar conjunction.
  - 10 dedicated cruise passes and a number of shadow passes.
  - 1 pass per day during solar conjunction (October 8 through November 7, 2006).

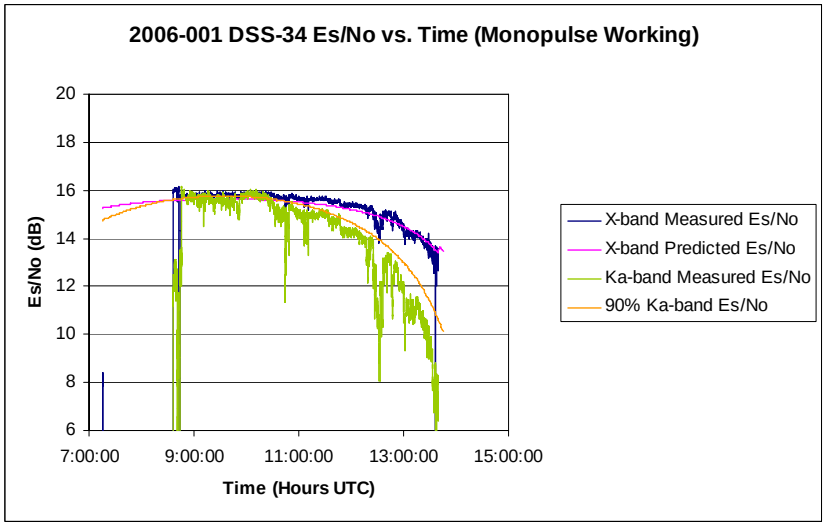
Cruise Passes

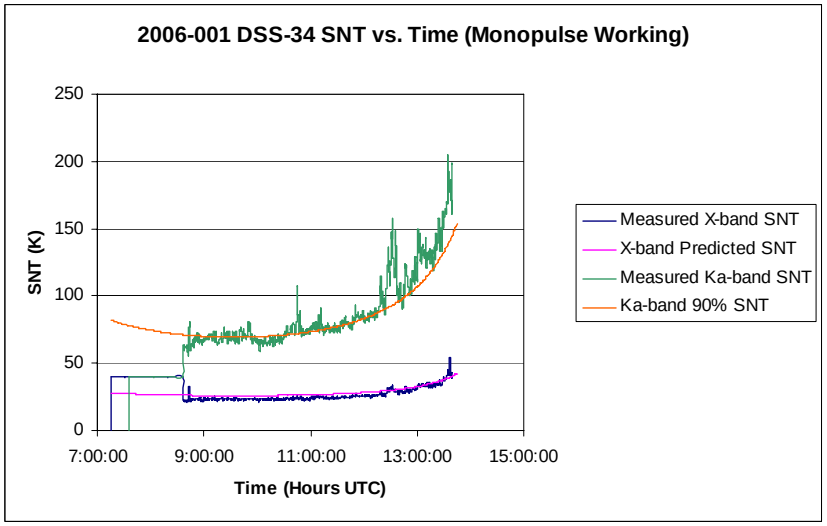
- Purpose of the Cruise Activities: To validate spacecraft and ground systems functions necessary for successful completion of the demonstration during the primary science phase (PSP).
  - 10 dedicated Ka-band telemetry passes plus a number of DDOR and Ka-band "Shadow" passes were scheduled during the cruise.
  - All spacecraft functions have been validated.
  - Almost all ground systems functions have been validated and solutions for most problem areas have been found. Most problems arise from the spacecraft being ***too powerful.***
- Highlights of Ka-band Cruise Activities:
  - First use of Turbo channel codes by a JPL mission (October 7, 2005).
  - Highest data rate ever from a planetary mission (6 Mbps, Nov. 1, 2005).
  - Largest data volume from a planetary mission during a single day and a single pass (133 Gbits, Nov. 1, 2005 over a 10 hour pass).
  - First Ka-band Wideband Delta DOR (Nov. 11, 2005).

MRO Ka-band Cruise Passes and the Weather

- The best way of evaluating the effects of the weather on the link performance is to correlate data losses with increases in the system noise temperature (SNT) and the wind speed and direction.
  - Because of very high spacecraft power, SNT measurements were not accurate at the beginning of the cruise phase and no data losses due to weather were observed.
  - Advanced Water Vapor Radiometer data were used as a substitute for SNT measurements.
  - Towards the end of Ka-band cruise activities, SNT values were being reported accurately and drops in the signal to noise ratio could be associated with increases in SNT. However, because the signal was still very strong, no data losses were observed during these passes.

Effects of Bad Weather on the Ka-band link



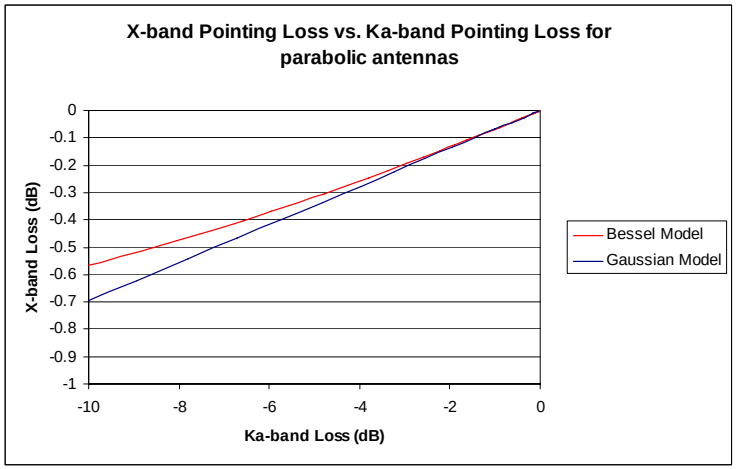


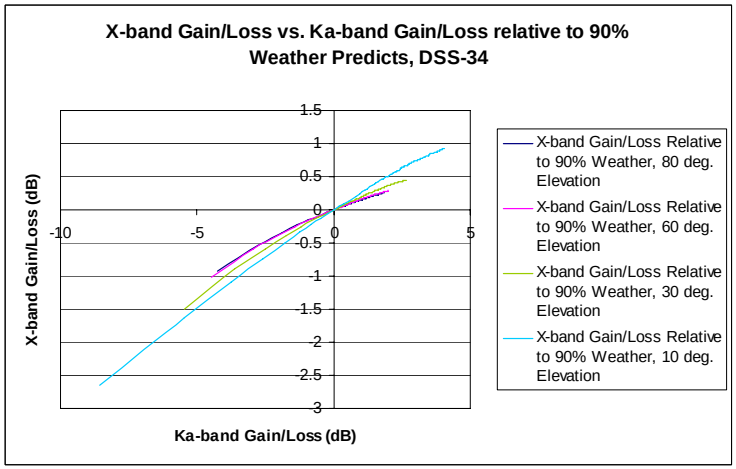
Wind losses

- Wind losses manifest themselves in two ways:
  - Deformation of the ground antenna.
    - Not very much.
  - Off-pointing of the antenna.
    - Significant.
- When active ground antenna pointing (monopulse) is used the wind losses tend to be less as the antenna is more or less on point.
  - Wind, however, could cause problems with monopulse. Analysis is on the way.

Distinguishing Between Pointing Losses and Weather Losses.

- Because MRO carries X-band, looking at the amount of degradation on X-band could determine whether the losses are due to increase in the SNT or because of pointing losses.
  - X-band SNR degrades about 1 dB per every 4 dB of Ka-band SNR degradation because of the increase in the SNT.
  - X-band SNR degrades about 0.5 dB per every 10 dB of Ka-band SNR because of mispointing.



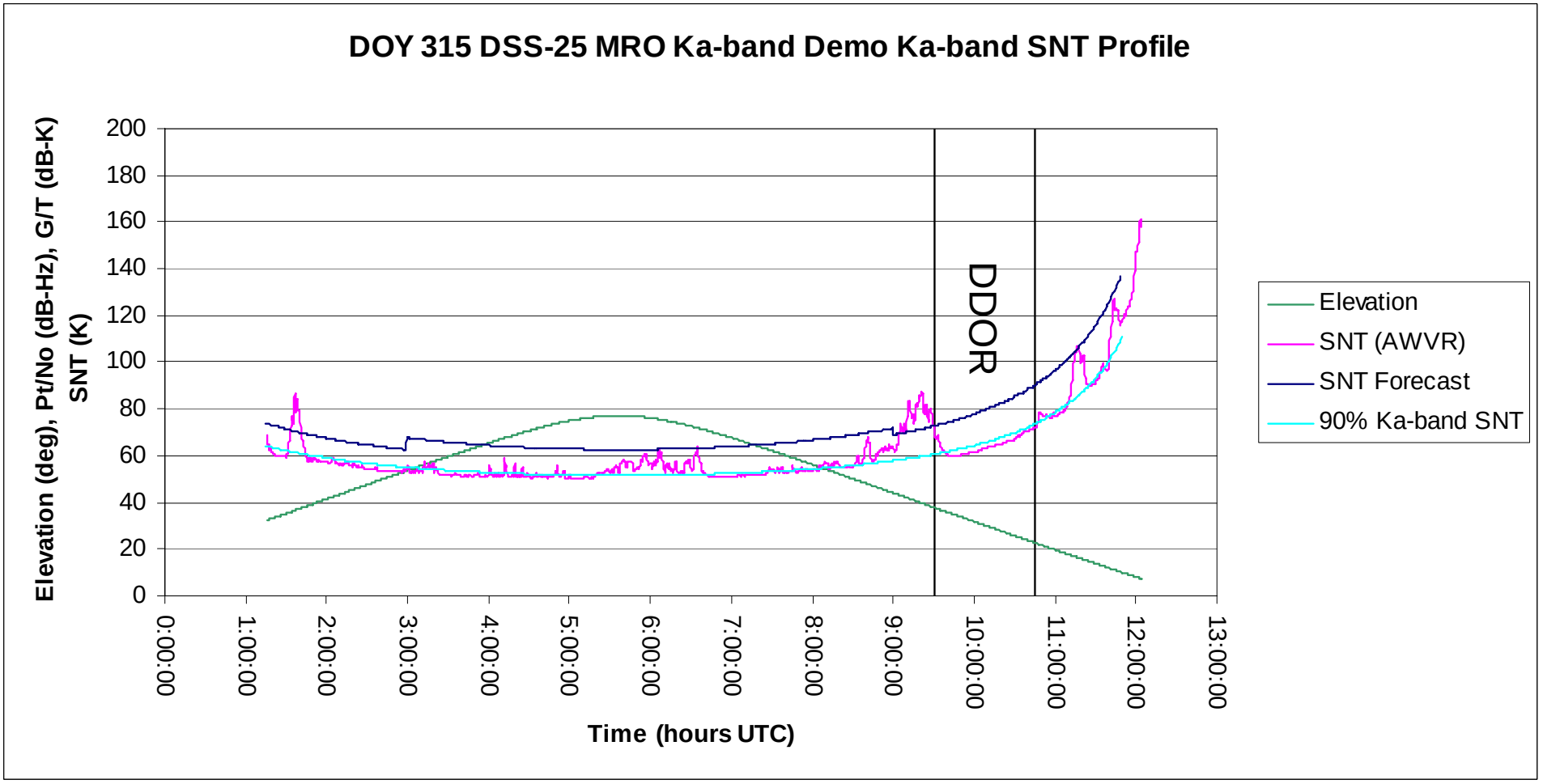


Weather Forecasting and MRO Ka-band

- Performance of existing forecasting algorithms could be analyzed using the performance of the Ka-band link.
  - Because of the sequencing procedure for MRO, weather forecasts cannot be actively used for demonstration operation.
- Forecasts have been “calibrated” only for Goldstone Deep Space Communications Complex (DSCC).
  - Calibration is a method of correlating results obtained from weather forecasting algorithms with atmospheric noise temperature observations at the site.
  - Calibration for forecasts for Madrid DSCC and Canberra DSCC will be performed later this year.
- Forecasting results for cruise passes is being analyzed.
  - Not enough passes to reach a conclusion.
  - Results for DOY 05-315 are very encouraging.

Weather forecasting for DOY 05-315

Ka-band Demonstration *Mars Reconnaissance Orbiter*



Work To Go

- Analyze wind data to see if there are any effects on the link performance.
- Troubleshoot any problems associated with the monopulse.
- Calibrate forecasts for Madrid and Canberra.
- Prepare for the primary science phase.