The Effects of Hot Body Noise on Lunar Communications

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Lunar Noise Temperature Measurements

(David Morabito IPN-PR 42-166, 2006)

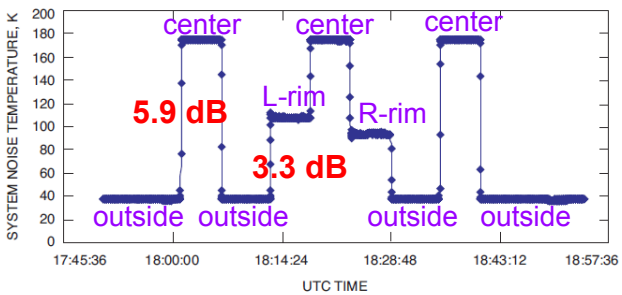


Fig. 2. S-band system noise-temperature measurements acquired on 2004/226 (S-/X-band feed position).

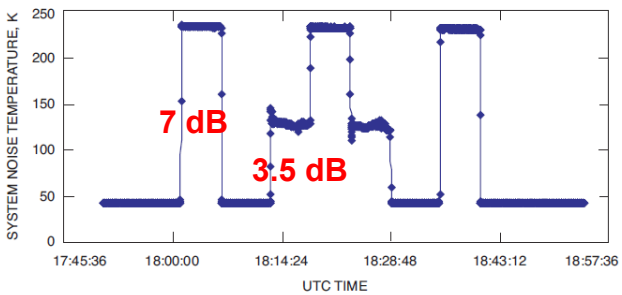


Fig. 3. X-band system noise-temperature measurements acquired on 2004/226 (S-/X-band feed position).

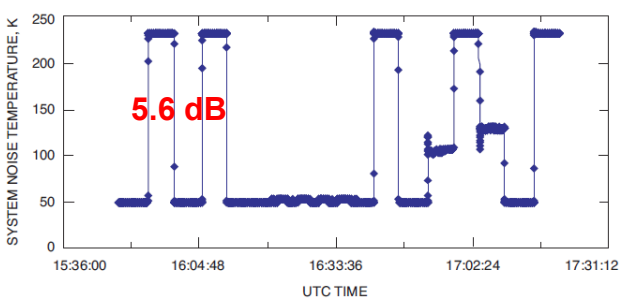


Fig. 4. X-band system noise-temperature measurements acquired on 2004/226 (X-/Ka-band feed position).

@ lunar phase ~ 153°, almost new moon (Full moon ~ 0°)

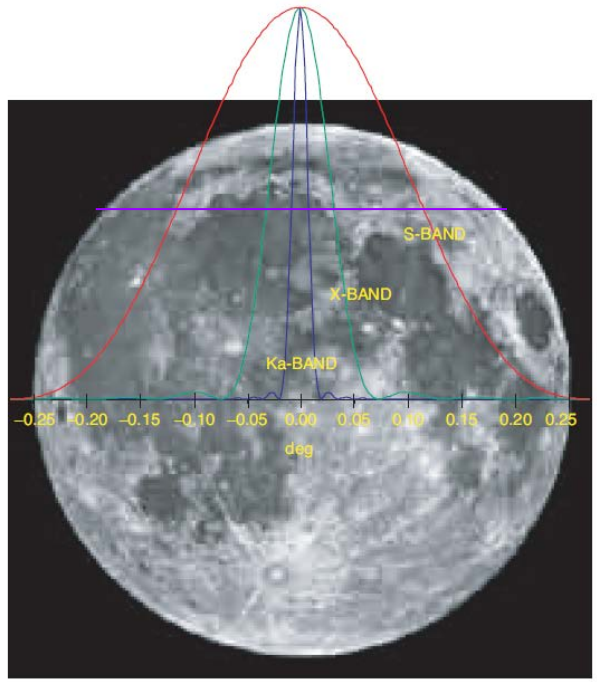


Fig. 1. Lunar disk with idealized one-dimensional beam patterns for a 34-m-diameter antenna at S-band (2295 MHz), X-band (8425 MHz), and Ka-band (32,000 MHz).

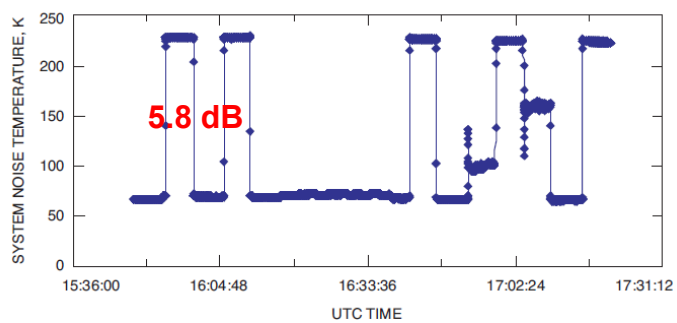
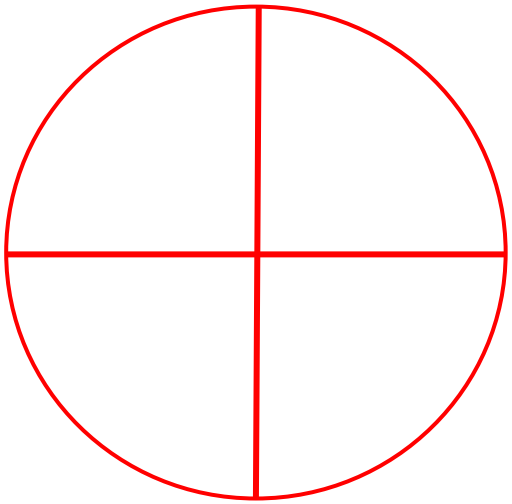
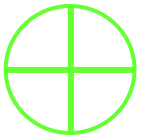


Fig. 5. Ka-band system noise-temperature measurements acquired on 2004/226 (X-/Ka-band feed position).

34-m Antenna BW



S-band (2295 MHz)



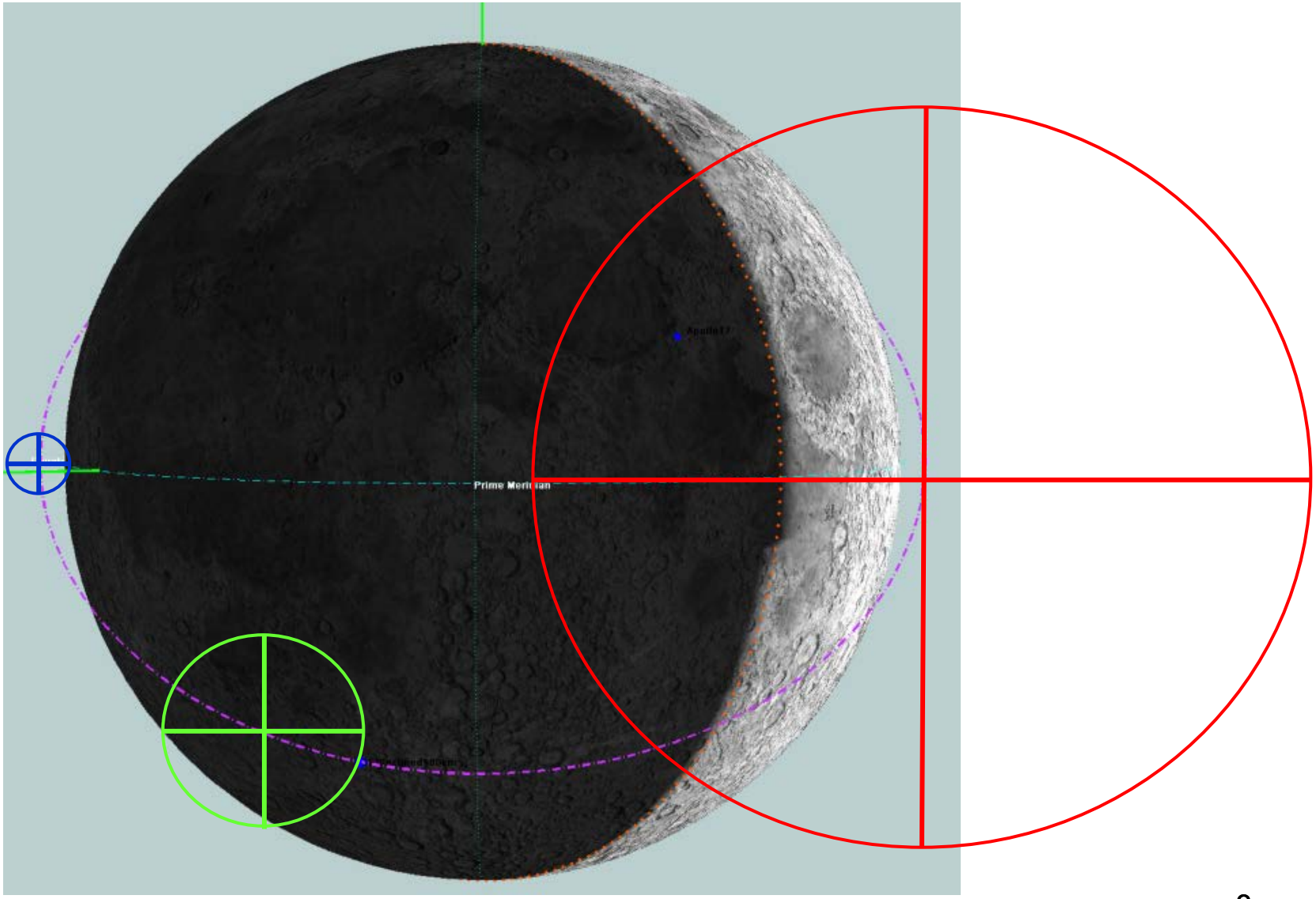
X-band (8425 MHz)

⊕

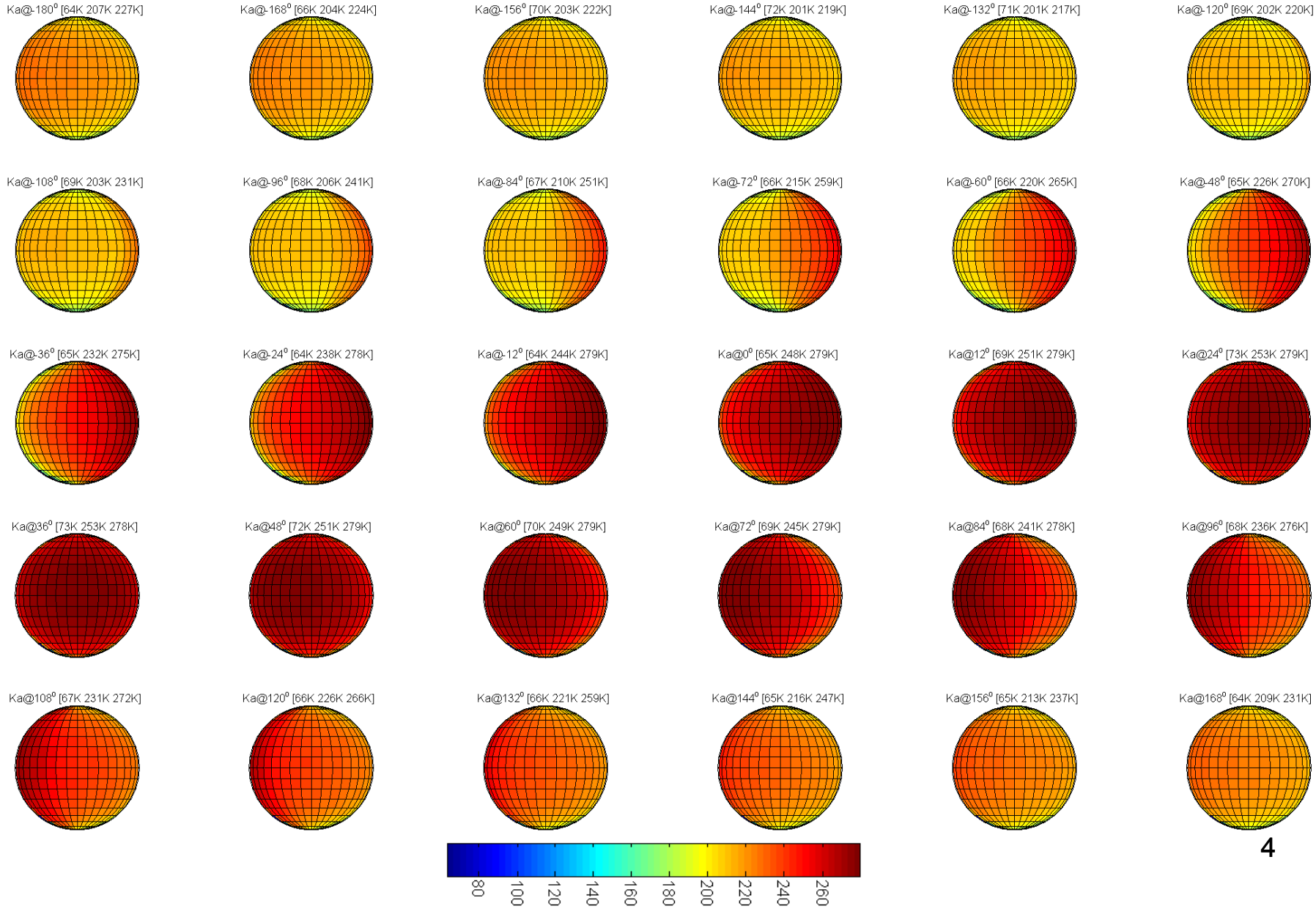
Ka-band (32,000 MHz)

Remark: Lunar body noise plays a significant role in the link budget calculation.

Impacts on Comm. Link Capabilities



Interpolated Moon Brightness Temperature Ka-Band Example (by S. Keihm 2004)



Brightness Temperature Calculation

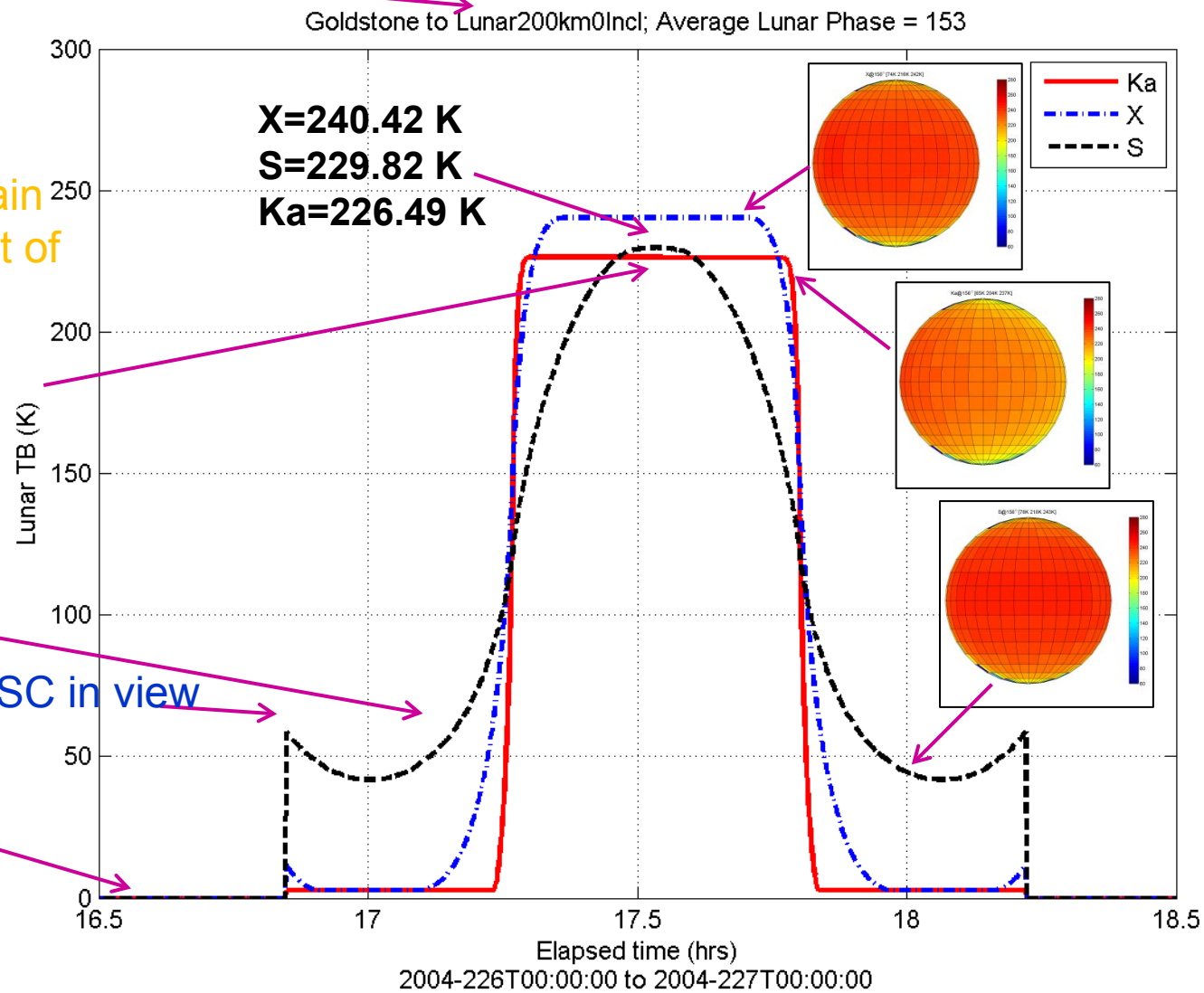
SC moves horizontally across the Moon

SC & whole main lobe are in front of Moon

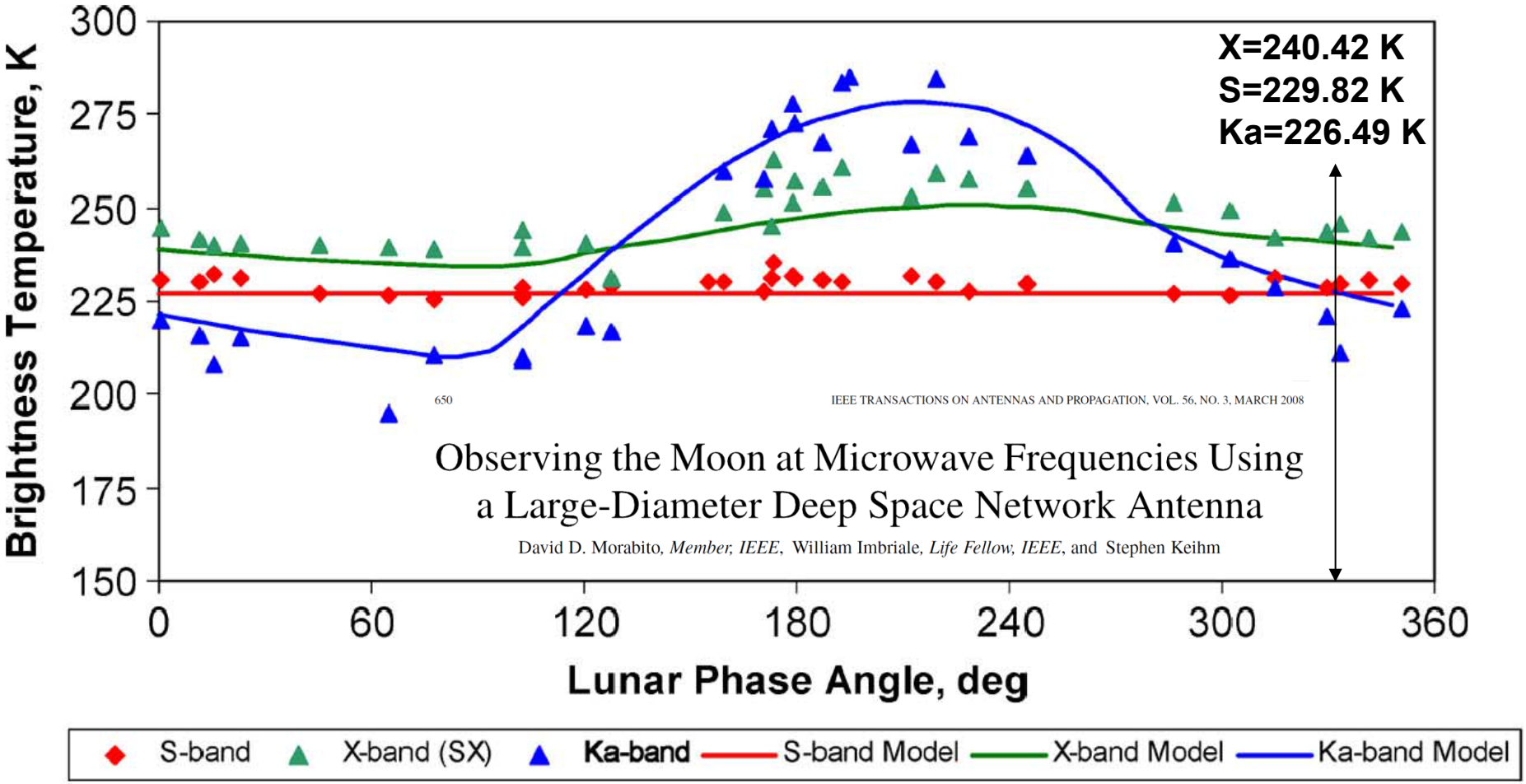
SC is on a side of Moon

SC in view

SC outside Moon vicinity



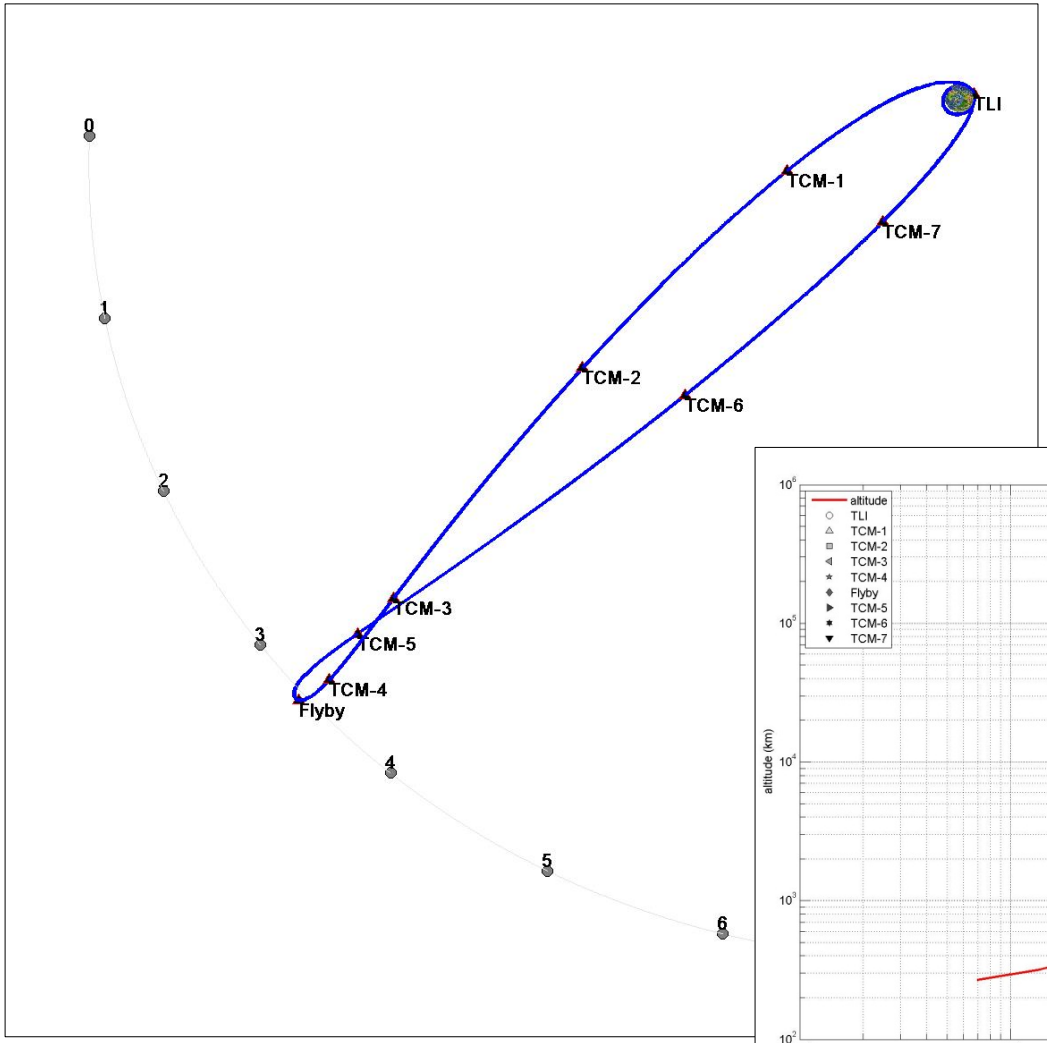
Brightness Temperature Validations



Lunar Backside Temperature Brightness

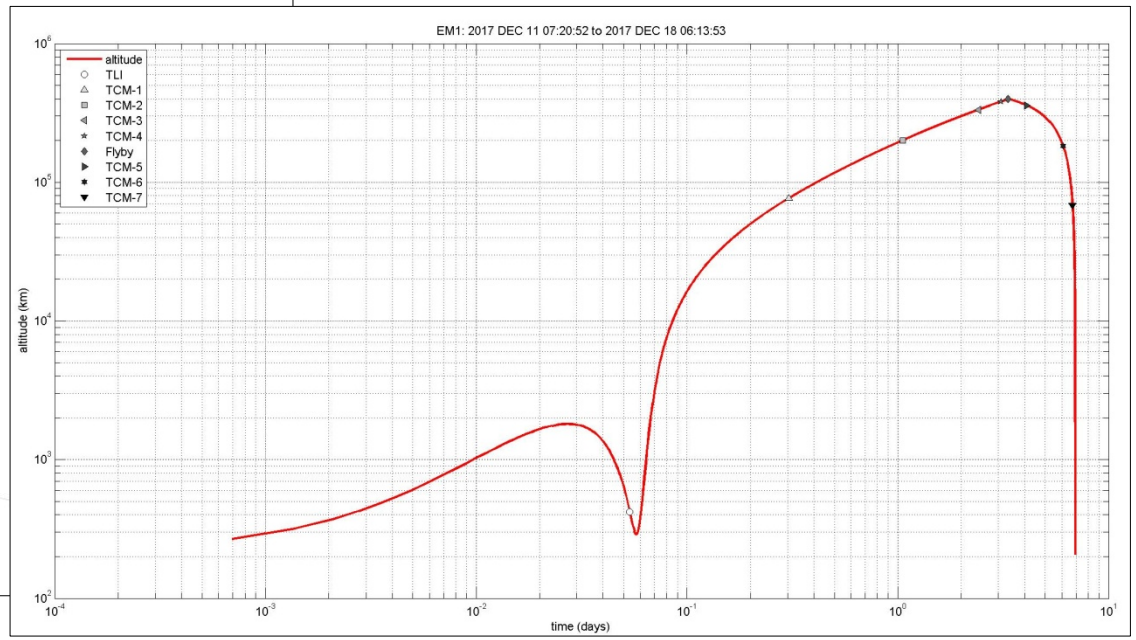
Band	Frequency (GHz)	DSN 34m BW (deg)	Moon's radius from Earth (deg)	DSH 0.75m BW (deg)	Moon's radius from EM-2 (deg)
S	2.295	0.269	0.259	12.200	3.318
X	8.415	0.073	0.259	3.327	3.318
Ka	32.000	0.019	0.259	0.875	3.318

EM-1 Trajectory

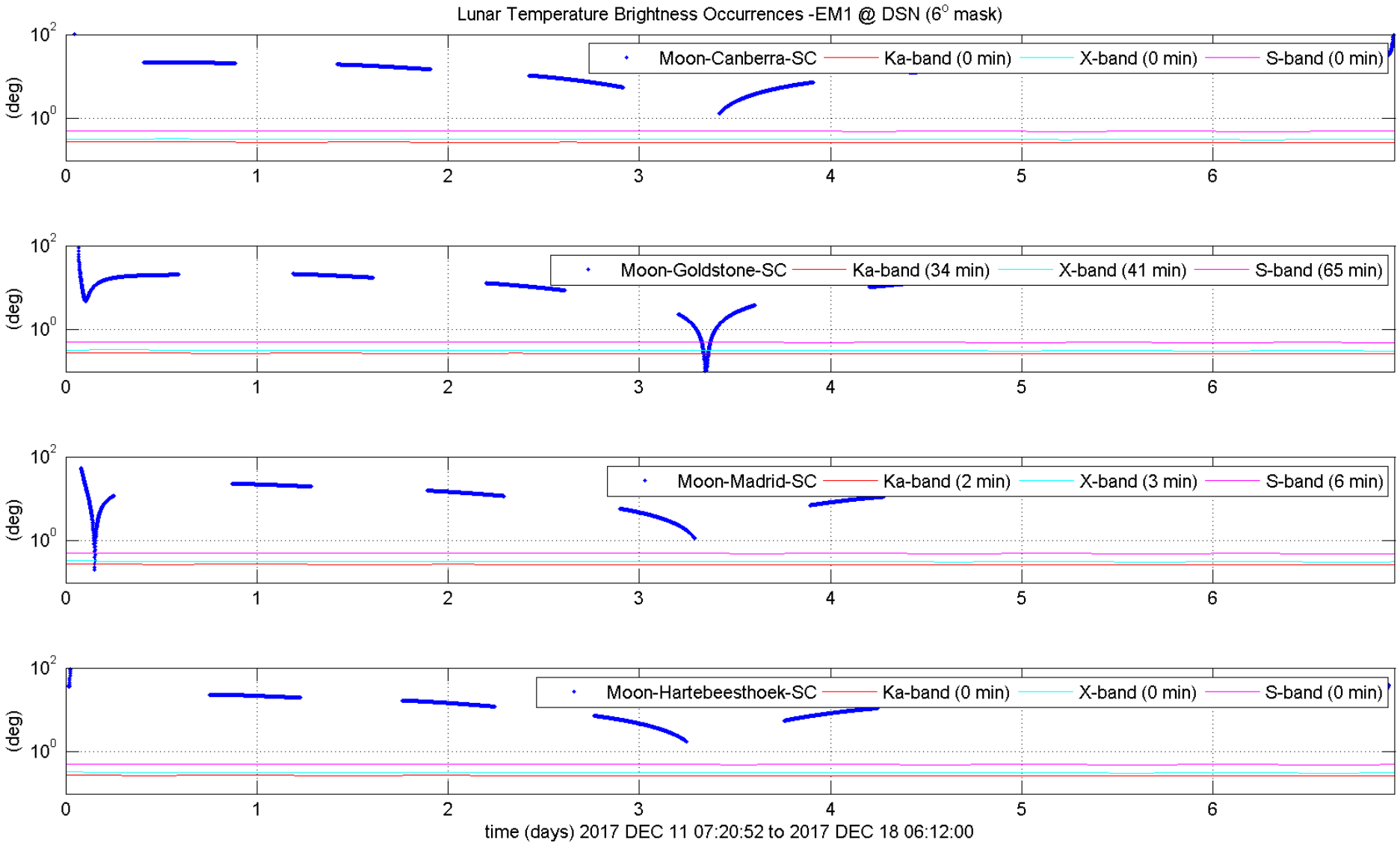


Maneuver	Time from initial epoch (days)	Notes
TLI	0.053875491	
TCM-1	0.303875491	6 hrs after TLI
TCM-2	1.053875491	1 day after TLI
TCM-3	2.415813303	22 hrs before flyby
TCM-4	3.082479970	6 hrs before flyby
Flyby	3.332479970	
TCM-5	4.082479970	18 hrs after flyby
TCM-6	6.078627137	21 hrs before EI
TCM-7	6.745293804	5 hrs before EI

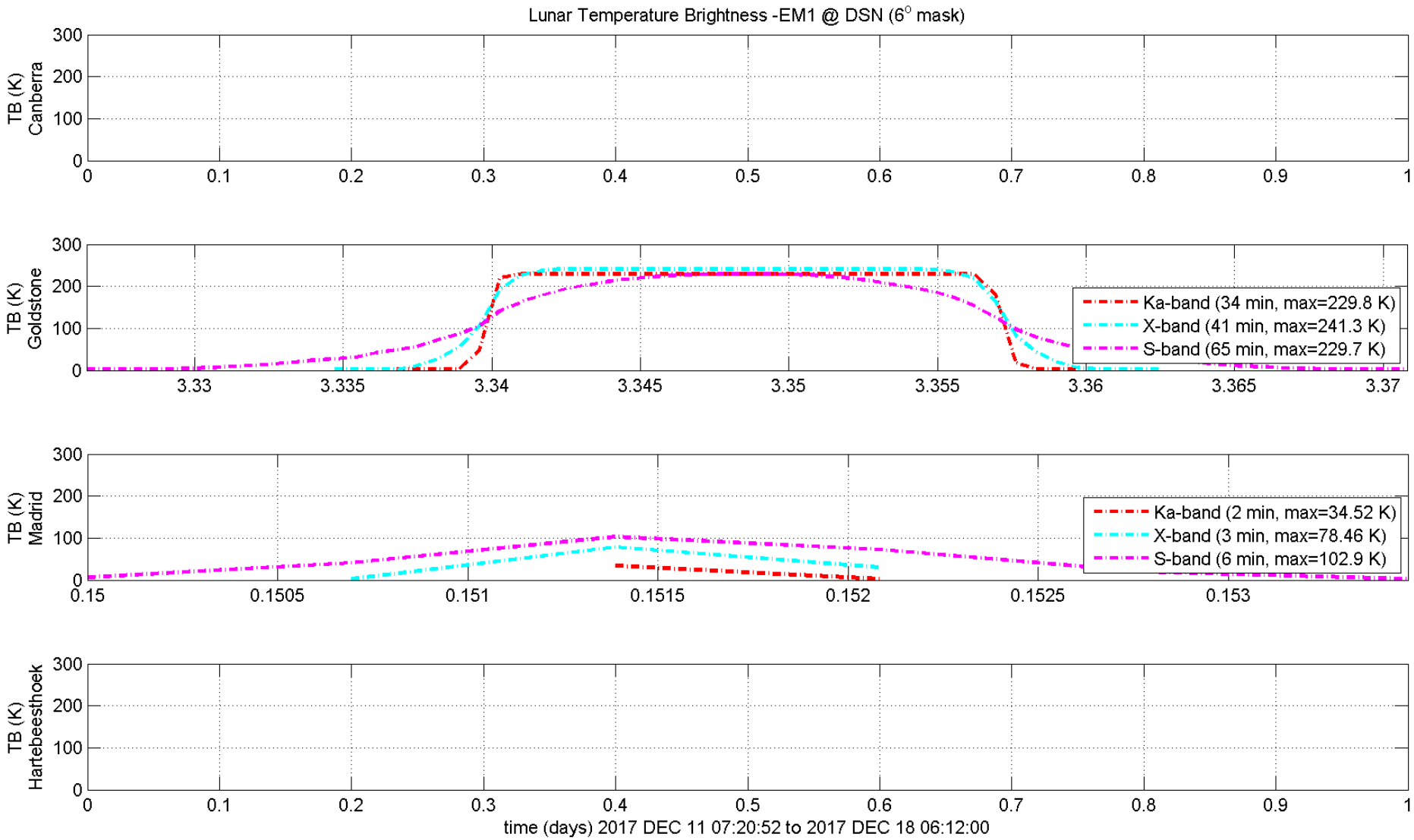
Not modeled in the trajectory



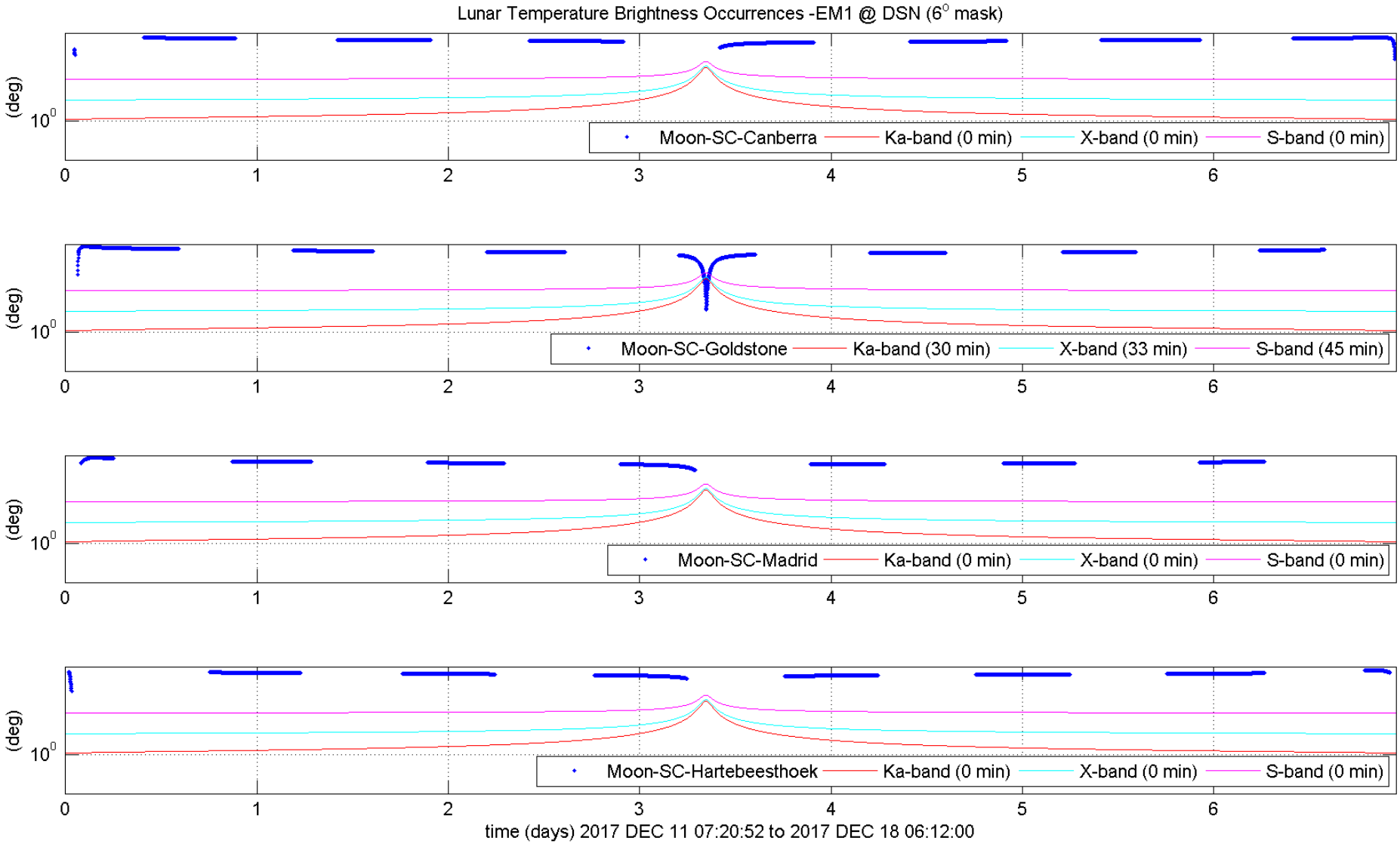
GS Beamwidths Tracking EM-1



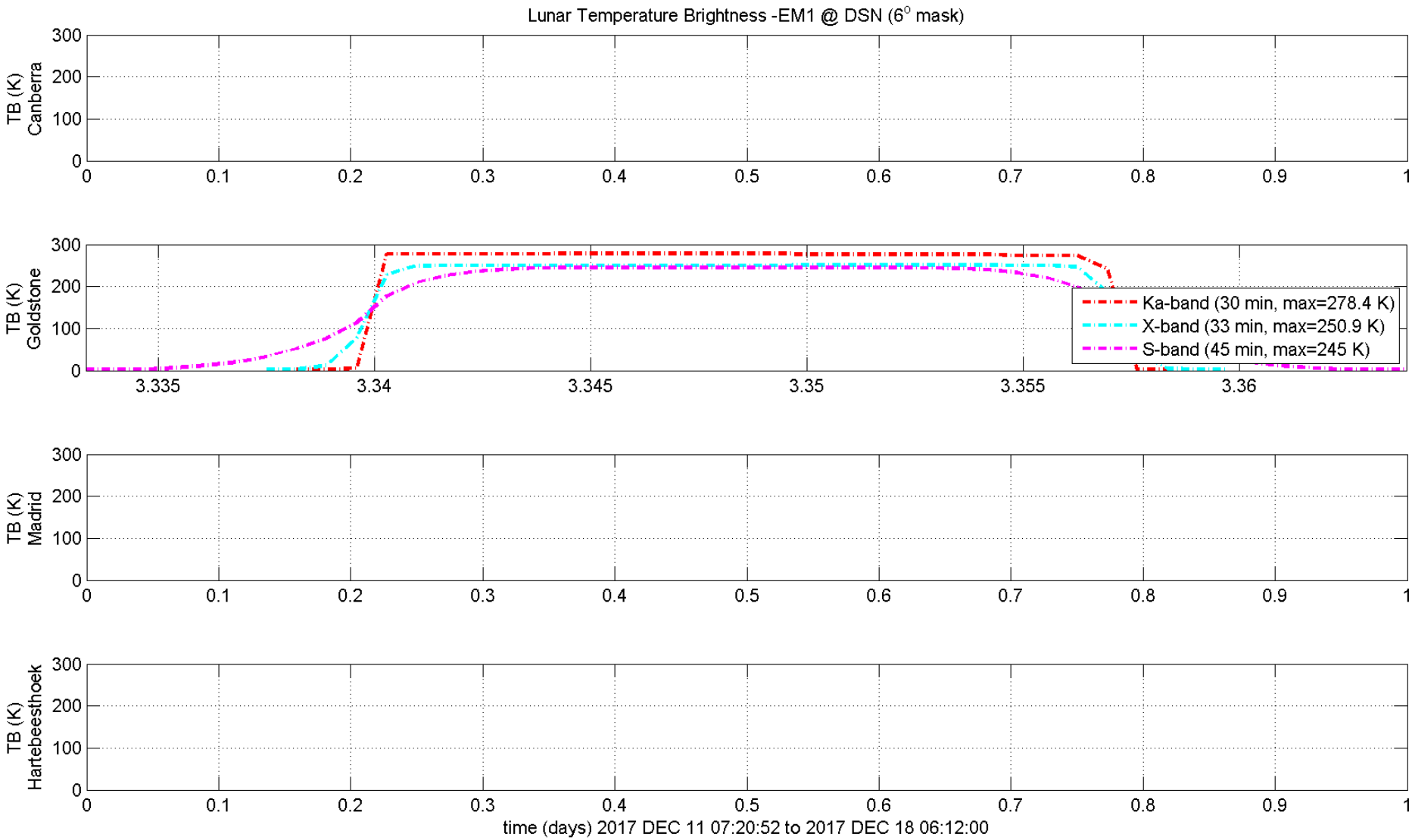
Lunar TB at GS Tracking EM-1



EM-1 Beamwidths Tracking GS



Lunar TB at EM-1 Tracking GS



Ongoing and Planned Activities

- Conducting lunar brightness temperature measurement campaigns using DSN-13 (near-side of the moon)
  - To fill the gaps of the statistics obtained in 2004
  - To validate the analytical model

- Refine high-fidelity lunar brightness temperature model that takes into account
  - Frequency
  - Lunar phase
  - Spacecraft and ground station ephemeris

- Plan to obtain LRO station monitor data to support the analysis

- Use antenna and heat transfer theories to construct brightness temperature model for the back-side of the moon with respect to the spacecraft antenna
  - To support link analysis for DSN uplink with DSH and MPCV
  - To support link analysis for cross-links between DSH and MPCV

Possible Mitigation Techniques

- Prior theoretical studies indicate that correlated noise can be cancelled using signal combining techniques, depending on degree of correlation
  - K. Cheung, V. Vilnorotter, " Channel Capacity of an Array System for Gaussian Channels with Applications to Combining and Noise Cancellation," IND Progress Report, 42-124, February 1996.
  - K. Cheung, "Eigen Theory for Optimal Signal Combining: A Unified Approach," IND Progress Report, 42-126, August 1996.

- Possible signal-combining architecture
  - Antenna array of different configurations
  - Phase array
  - Signal formats

- Plan to measure the noise characteristics and to characterize the degree of correlation using DSN antenna and array of antennas

- The noise cancellation techniques can be useful to mitigate correlated noise, e.g. hot body noise (e.g. moon) and multipath (asteroid missions)

Backup