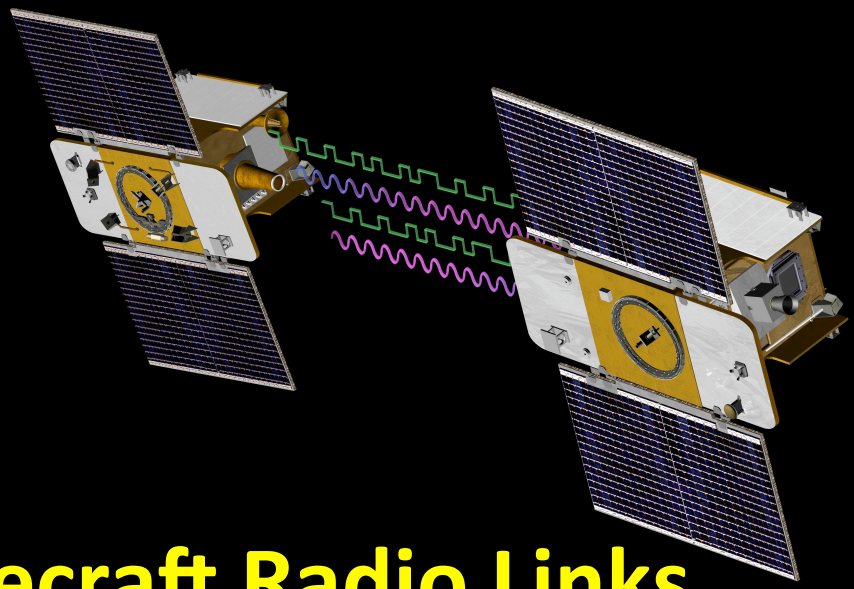
Jet Propulsion Laboratory
California Institute of Technology

8th International Planetary Probe Workshop

6-10 June 2011, Portsmouth, Virginia



Spacecraft-to-Spacecraft Radio Links

Instrumentation for Planetary Gravity, Atmospheric and Surface Sciences

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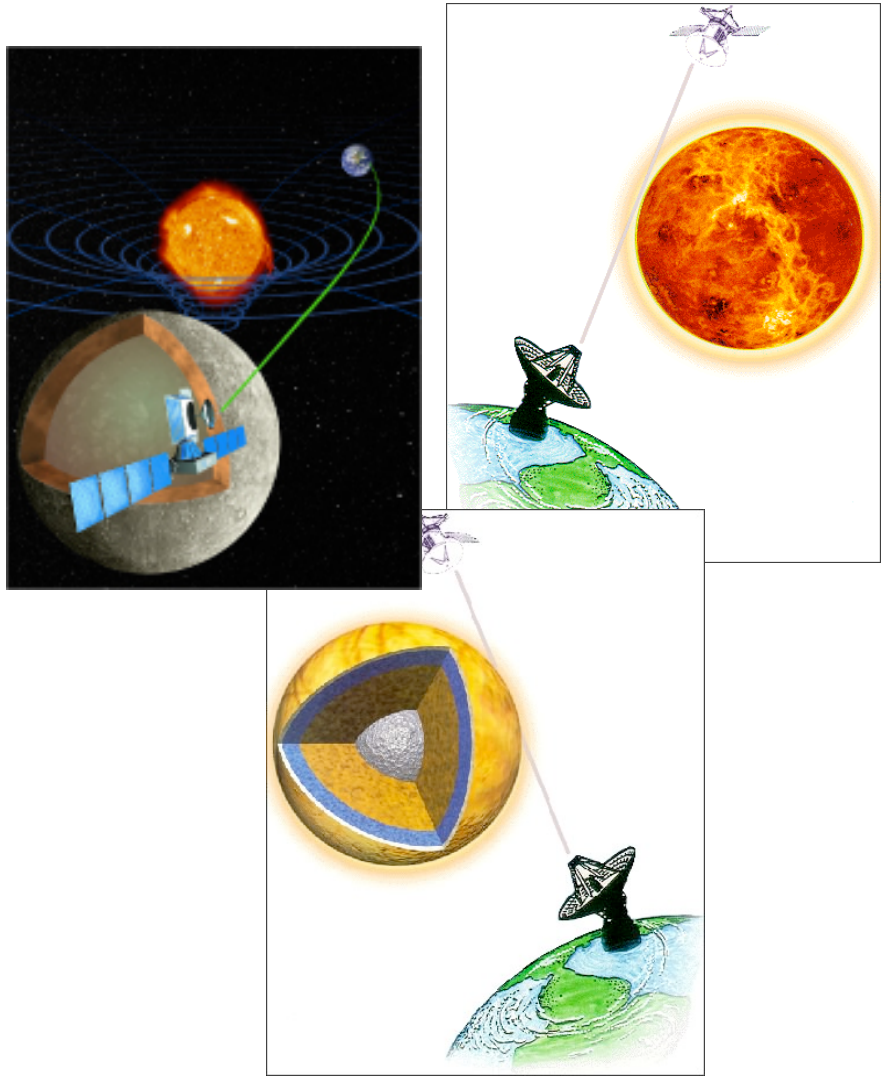
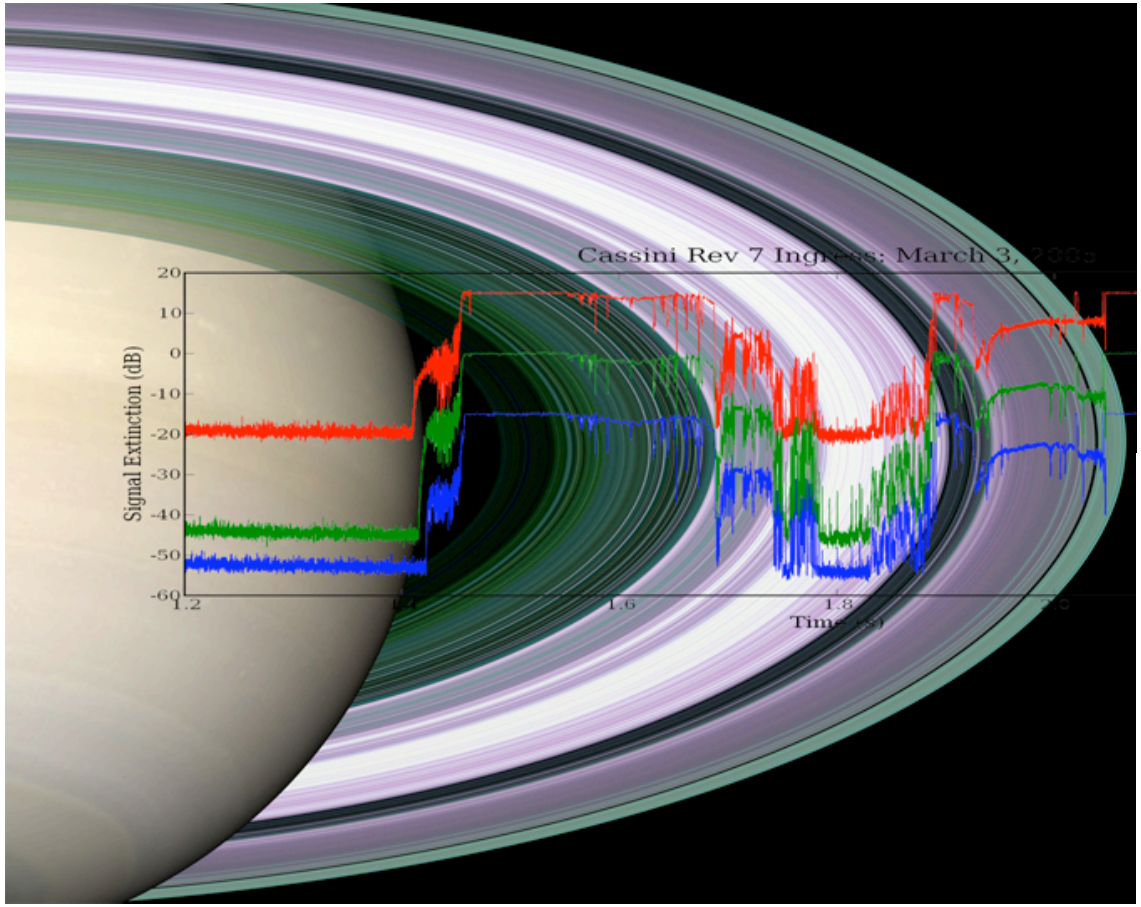
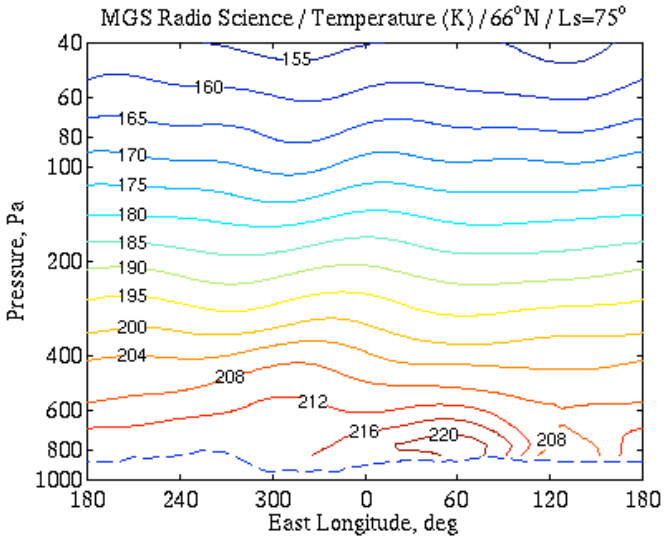
Motivation

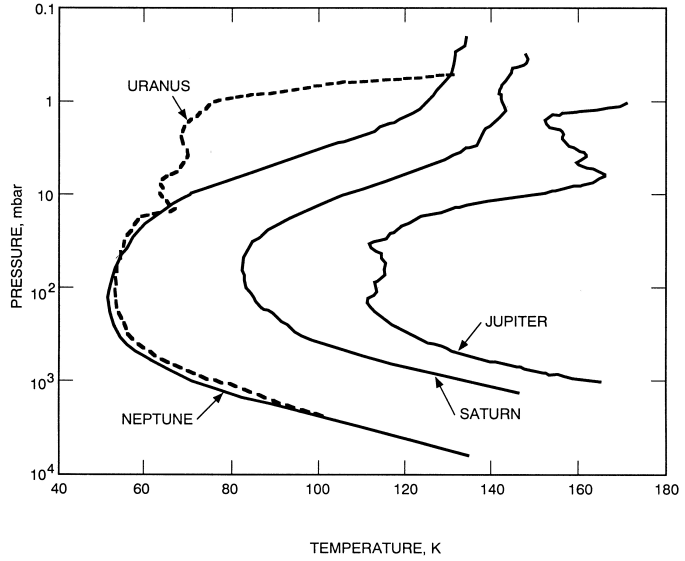
- Traditional Radio Science: links between spacecraft & ground
  - Successful in fields of ring & atmospheric occultations, gravity & interior structure, tests of theories of relativity, solar science, etc.
- Limitations on SNR & geometry
  - Especially for one-way downlink
- New configuration & instrument
- ***Spacecraft-to-spacecraft*** links
  - Significant SNR advantage
  - Improved geometrical coverage
  - Eliminate calibration of Earth atmosphere



Classic Results of Radio Occultations



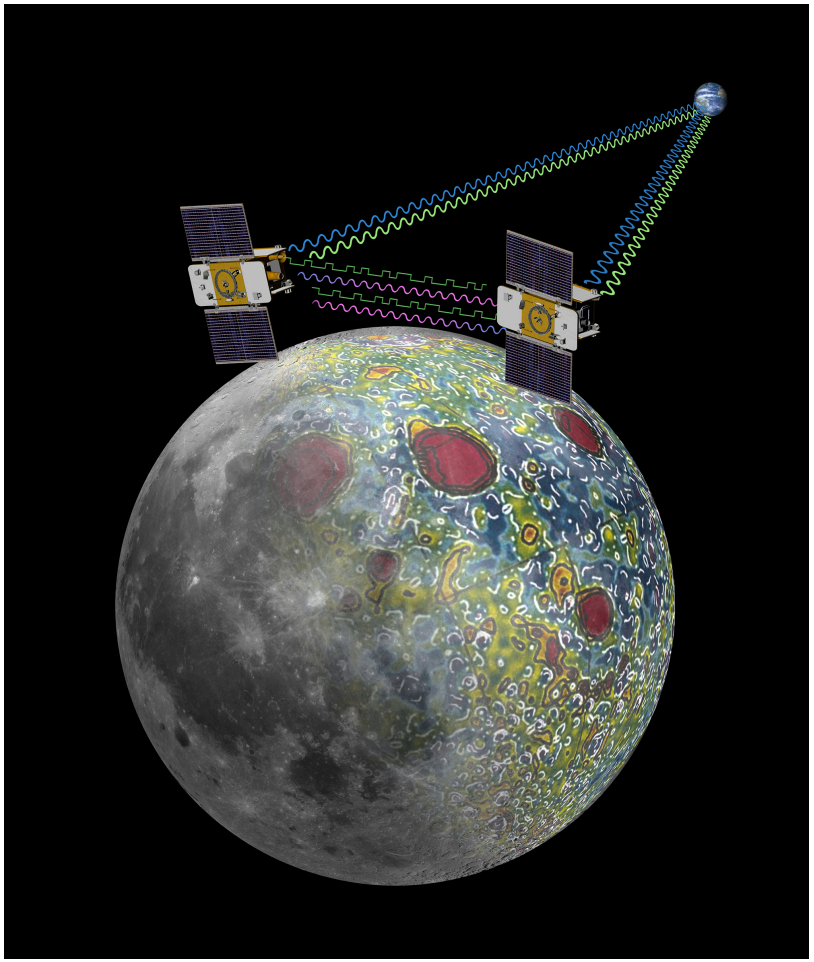




Temperature profiles for the giant planets derived from radio occultation data acquired with the Voyager spacecraft (from Lindal, 1992)

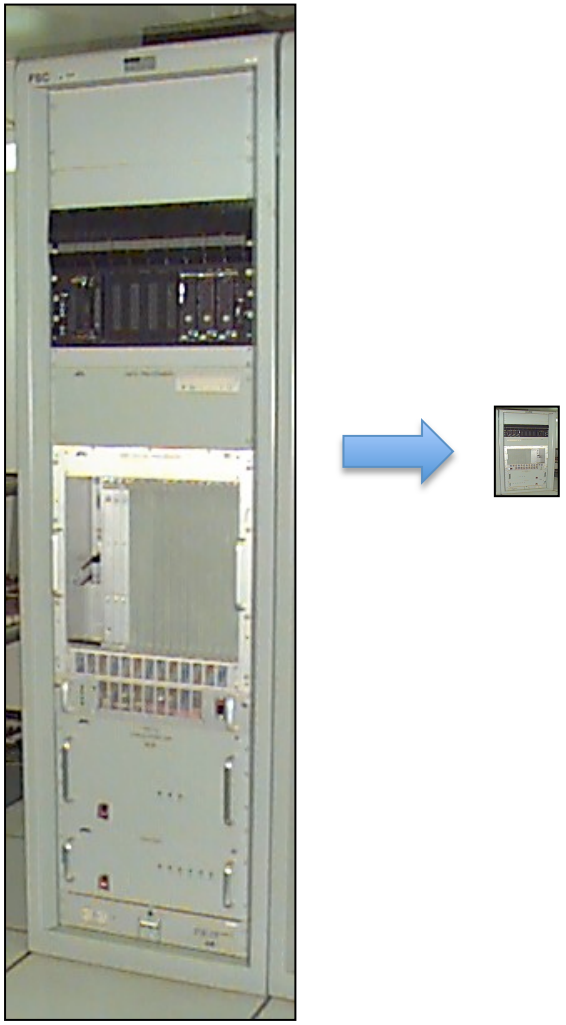
S/C-S/C Science Links to Date

- Galileo Probe to Galileo Orbiter DWE
  - Enhanced by link to Earth
- Huygens DWE
  - *Enhanced* by link to Earth
- GRACE Earth Gravity
  - Formation Flying
- GRAIL Lunar Gravity
  - Formation Flying
- SELENE Lunar Farside Gravity
  - Four-way Doppler
- Demonstration with Mars Orbiters
  - UHF between ODY & MRO
- Accidental Possible DWE
  - Phoenix EDL, lander to 3 orbiters

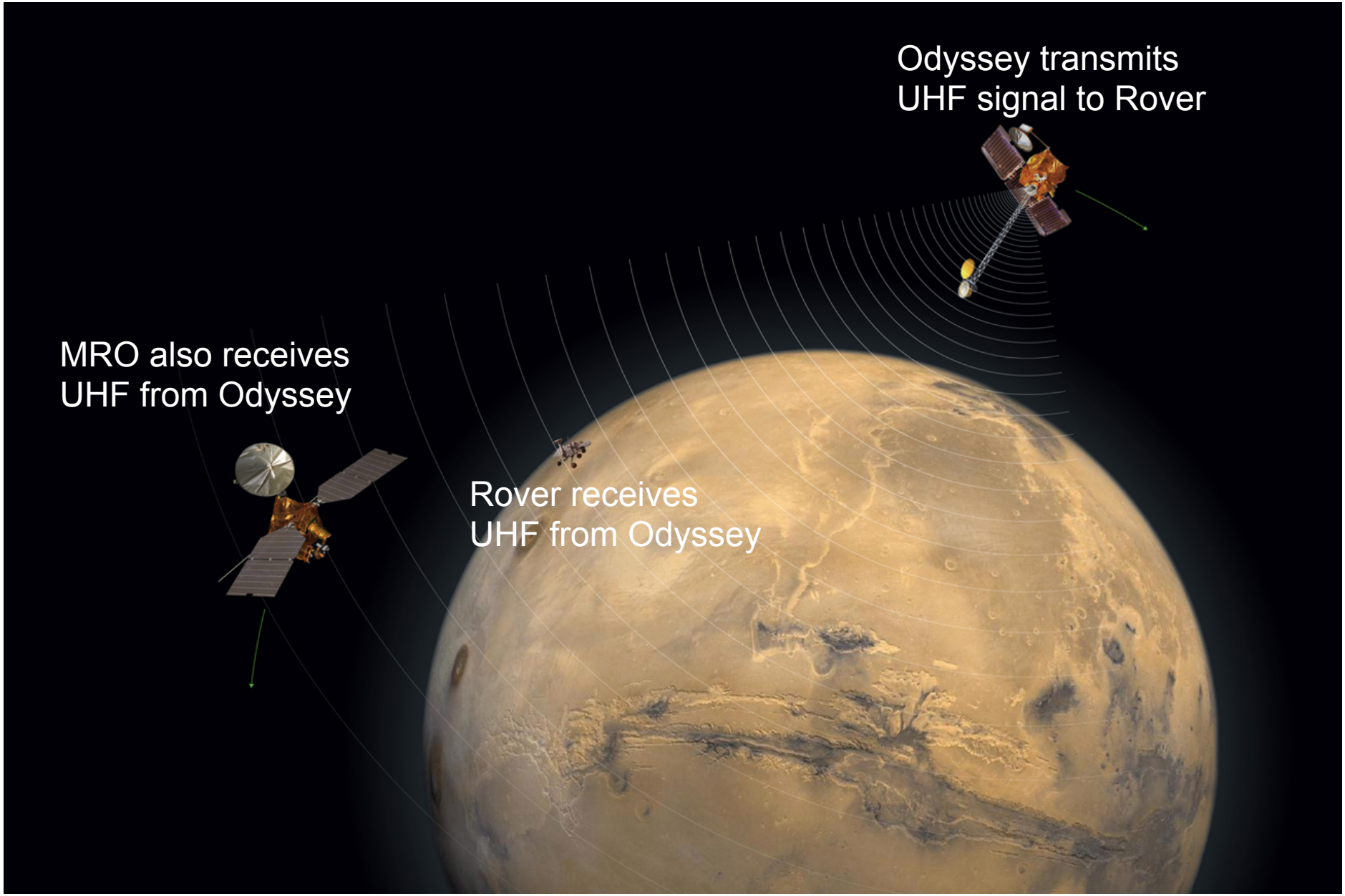


Open-Loop Receiver Miniaturization

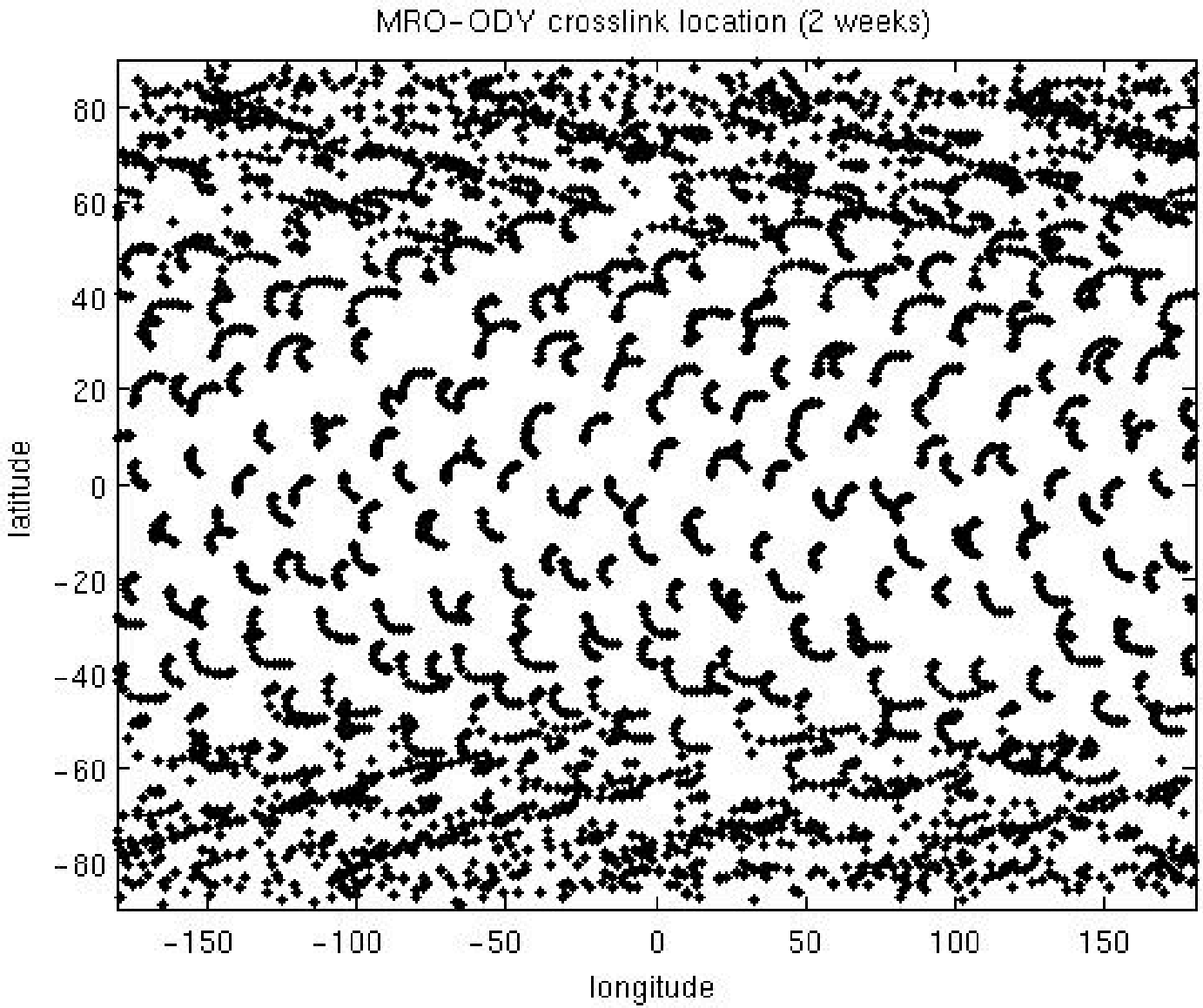
- DSN Open-Loop Radio Science Receiver (RSR) in use for decades
  - Key to proper data acquisition
- RSR Two big to fly
- ***Breakthrough***: Software radios for spacecraft transponders
- Prototype (Electra) onboard MRO used to demonstrate spacecraft-to-spacecraft radio science experiments with the Odyssey spacecraft
- New Horizons RSR for uplink occultation
- GRACE & GRAIL another receiver type for precision gravity measurements



Completed Demo of Mars Orbiters Crosslink

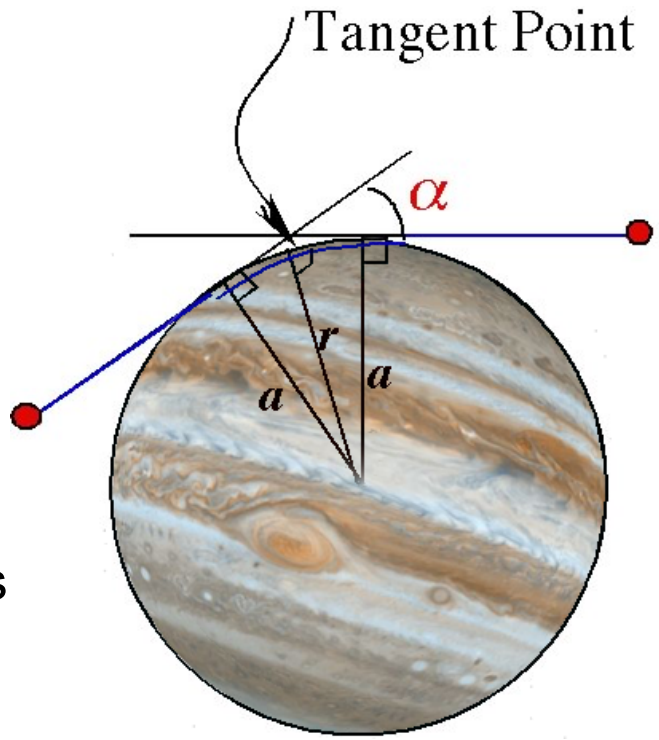


Example of global geometrical coverage



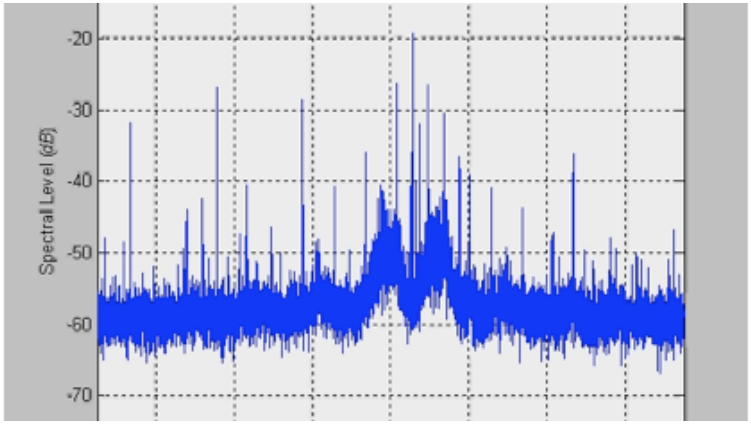
Science

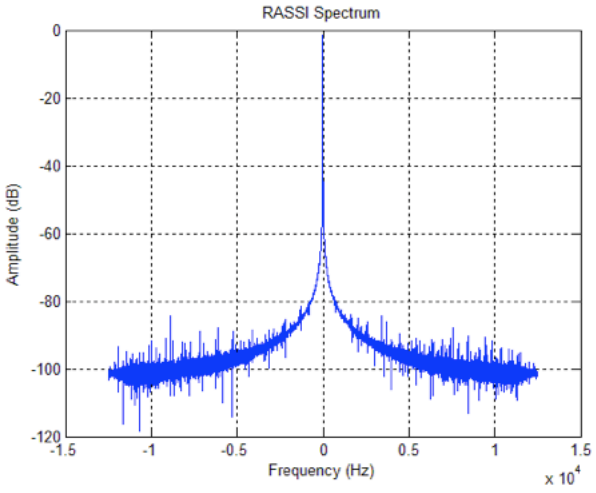
- Scenario of two Jovian system orbiters
- Potential science:
  1. Occultations of the atmosphere and ionosphere of Jupiter: Temp-Pressure
  2. Occultations of the tenuous atmospheres and ionospheres of the Jovian satellites
  3. Occultations of tenuous Jovian rings
  4. Bistatic scattering from satellite surfaces
- Appropriate wavelengths of the radio links drives the front-end down-converters and the required antennas
  - Longer wavelength to minimize attenuation from NH_3 but susceptible
  - Shorter wavelength less noisy



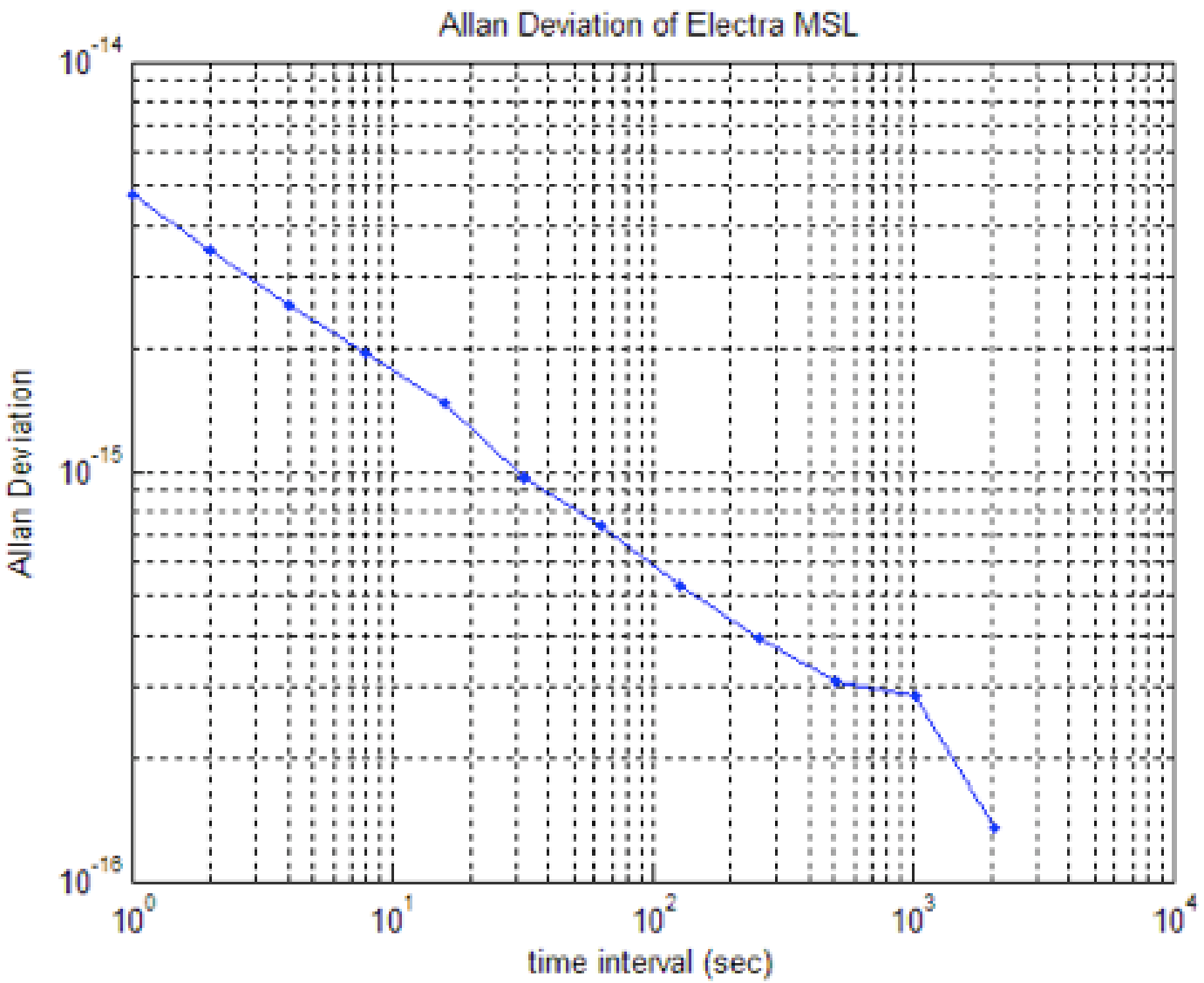
RASSI: Radio Atmospheric Sounding & Surface Scattering Instrument

- Software Radio Receiver based on Electra Payload
- Science quality oscillator, ADC, filters, etc.
- Front-end down-converters (depends on optimum wavelength)
- Advantages of Open-Loop Reception:
- Mass & power tradeoffs
- Surface scattering optimum configuration
- Digital design meets Radio Science specifications





Allan Deviation (Phase Stability)



Summary

- Investigations of planetary atmospheres and surfaces via radio occultation and scattering techniques conducted on many planets and satellites via ***one-way downlink*** from a spacecraft to a ground station
- Limitations on the received SNR or geometrical coverage can be overcome with alternate observation configurations
- ***Uplink observations*** can have SNR advantage ~3 orders of magnitude
- ***Spacecraft-to-spacecraft observations*** have significant SNR advantage and can yield improved geometrical coverage
- A special radio science receiver is required onboard the spacecraft
- New digital open-loop receiver designed to meet the Radio Science requirements
- Ready for future missions!

Acknowledgement

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