National Aeronautics and Space Administration

Next Breakthroughs in Radio Metric Tracking

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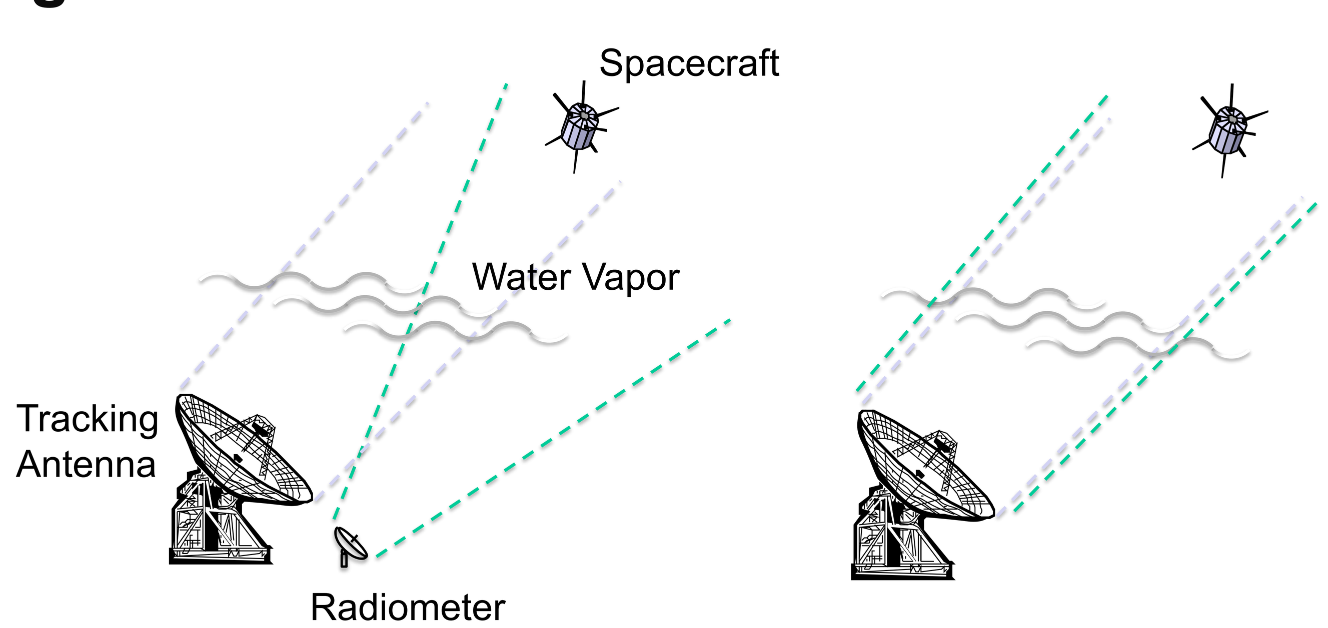
Program: FY21 R&TD Strategic Initiative   **Strategic Focus Area: Advancing Solar System Exploration with Telecommunications Links**

Objectives

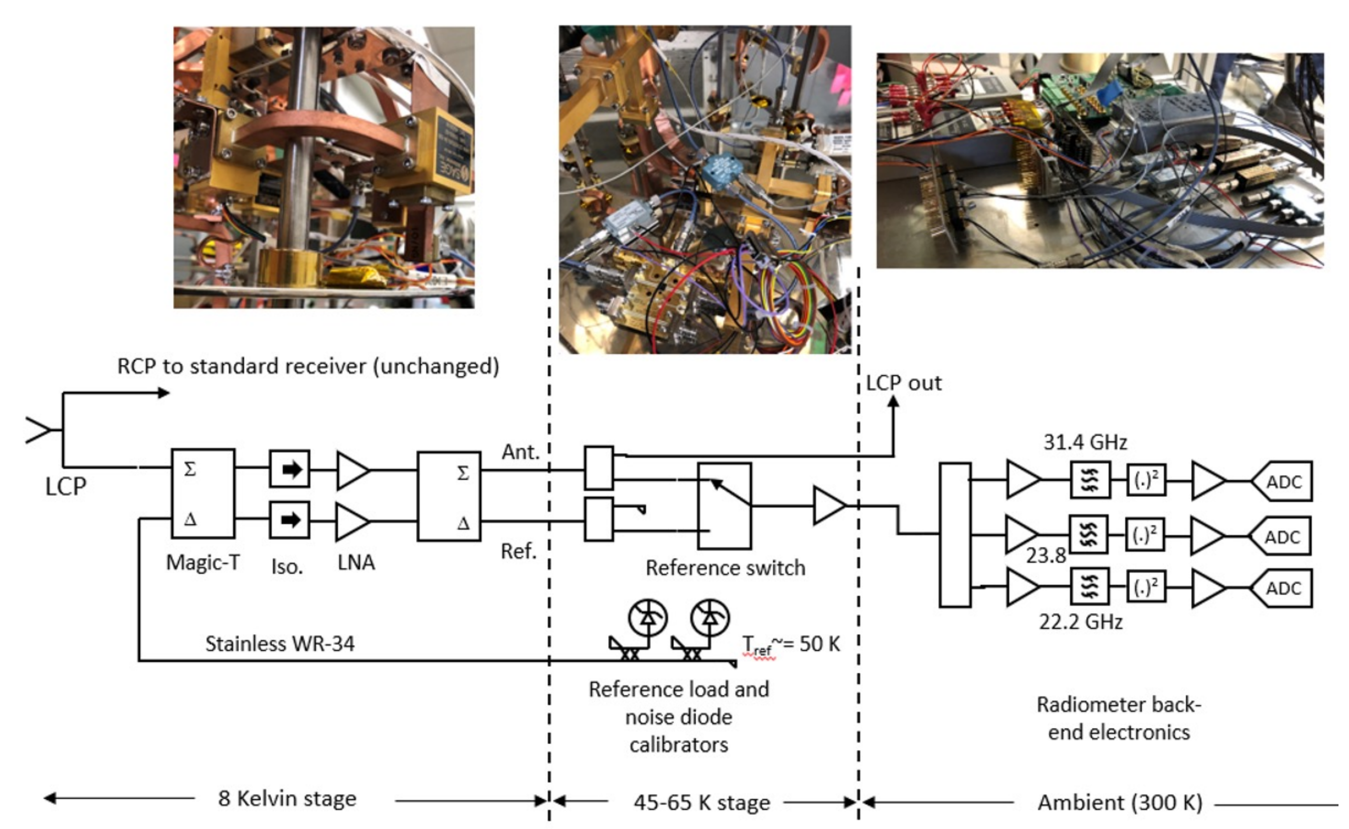
An important science data type on most solar system missions is Doppler measurements using the communication radio link to Earth — this task's objective was to improve the accuracy of these measurements. The early focus of the task was to review the state of the art in precision Doppler tracking, identifying science drivers for improving Doppler accuracy, and identifying the leading Doppler error sources at both short and long time scales. A review of literature, especially Cassini Gravity Wave experiment results, determined that current limiting Doppler errors are wet tropospheric fluctuations at short (30-100 sec) time scales and antenna mechanical noise at both short and long (1000-10000 sec) time scales. The subsequent objective of this task became the development of a prototype next generation water vapor radiometer to improve calibration of tropospheric affects at short time scales. Follow on activities are being considered to address the mechanical noise contributions.

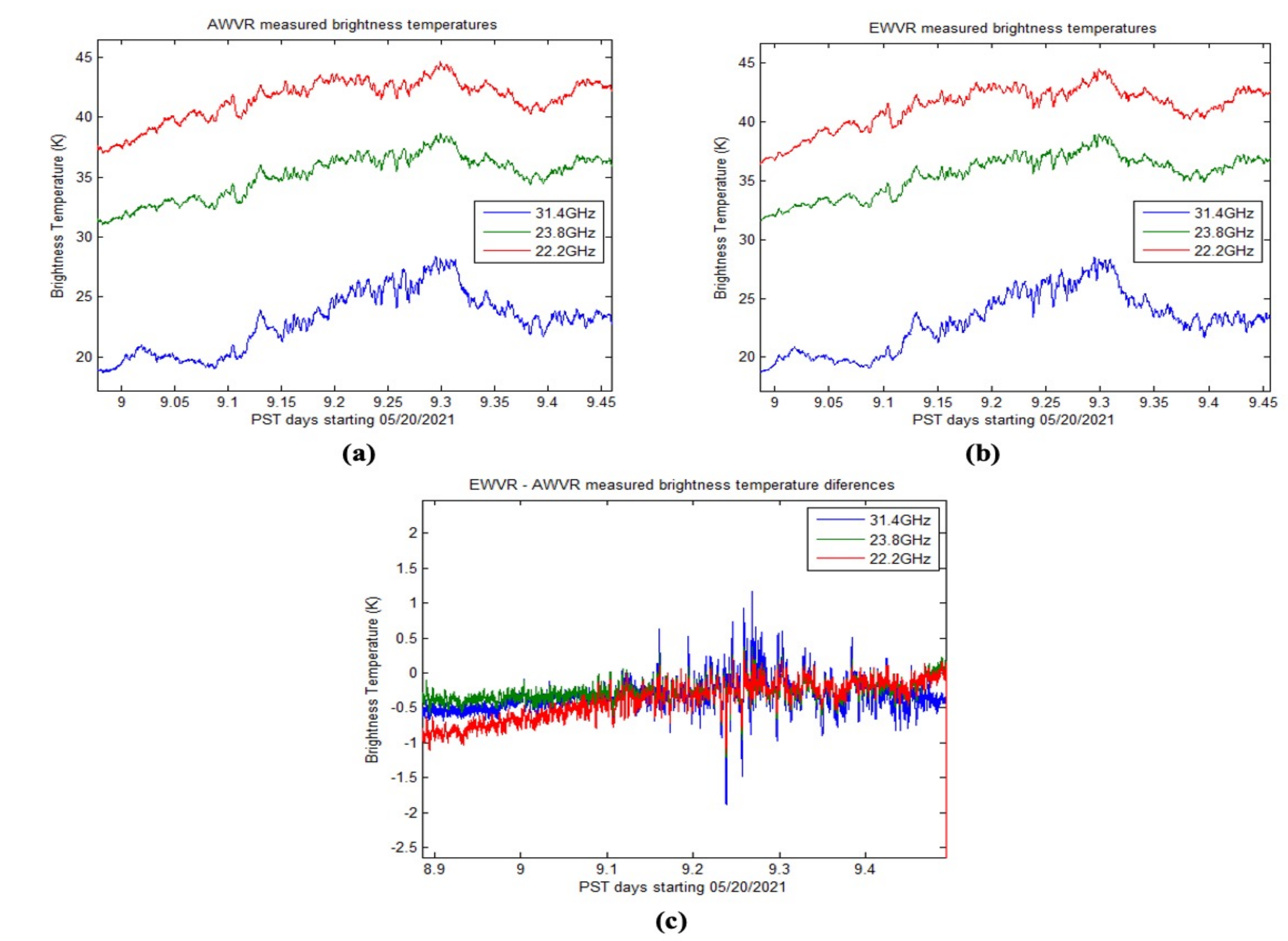
Background



In current systems a radiometer on a small antenna adjacent to a large tracking antenna makes measurements of the water vapor resulting in beam offset errors. If the radiometer is instead integrated into the tracking antenna electronics it allows water vapor calibration through the same beam removing the beam offset error. The integrated atmospheric water vapor content along the antenna to spacecraft direction is estimated by measuring sky brightness at different frequencies near and off a water emission line.

Approach and Results





1. The design of a prototype Embedded Water Vapor Radiometer (EWVR) that can be integrated with existing Deep Space Network (DSN) XXKa cryogenic front ends has been completed. The design incorporates a pseudo-correlation radiometer topology that allows the front end cryogenic receiver to simultaneously handle the antenna and radiometer reference signals without compromising the performance of either system.
2. Unique parts required to receive radiometer and antenna signals from 22 to 32 GHz were designed and procured. These include a custom broadband a polarizer, broadband LNAs, and various COTs microwave components.
3. A prototype EWVR has been integrated into a DSN XXKa cryogenic front end. The design of the EWVR was refined over a few build and test iterations to improve stability and performance.
4. Roof top tests of the EWVR were conducted at JPL taking measurements from the prototype system in parallel with measurements taken from a legacy Advanced Water Vapor Radiometer (AWVR) over a number of days.
5. Both sets of measurements were analyzed and compared. Measurements from the prototype EWVR closely matched those taken from the AWVR indicating that the EWVR is operating as desired.

Significance / Benefits to JPL and NASA

One of the few remote sensing means for studying interiors of solar system bodies is via the technique of spacecraft precision Doppler tracking, which allows measurement of the gravity field generated by an object's mass distribution. In the case of icy moons, the determination of the existence and details of sub-surface oceans is crucial to establishing whether they may be possible habitats for life. For any potential human exploration of small bodies (including Phobos and Deimos), a recognized strategic knowledge gap is their porosity or the existence of interior voids. The design work started here is expected to significantly improve Doppler accuracy and improve science return.

Publications

[A] Andre Jongeling, "Ground Station Systems to Support Radio Science in the 21st Century," poster presented at AGU Fall Meeting, 10-14 Dec. 2018, Washington,D.C.
[B] Alan B. Tanner, James S. Border, Andre P. Jongeling, Ezra M. Long, Erick Pereira, and Eli Lin. "Embedding a Water Vapor Radiometer Within a Deep Space Network Ka-band Receiver" The Interplanetary Network Progress Report, Volume 42-226, pp. 1-17, August 15, 2021

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