National Aeronautics and Space Administration

FY24 Topic Areas Research and Technology Development (TRTD)

Large Antenna Mechanical Noise Calibration for Improved Radio Science

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Strategic Focus Area: Planetary Interiors

Objectives: The objective was to design, develop, and test a new, self-contained system projected to provide a factor of 5 reduction in the amount of “antenna mechanical noise” in Radio Science experiments. This will be referred to as the Large Antenna Noise Calibration (LANC) system.In the most sensitive Radio Science measurements carried out by the DSN (Allan deviations ~ 4 x 10-15 at 1000 s), the intrinsic mechanical instability of the large (34m) beam waveguide (BWG) antennas emerges as one of the leading noise contributors since other contributions to the noise budget can be mitigated by thermal stabilization or phase compensation. A system to improve the measurement precision by a factor of 5 by providing in-situ calibration for phase variations due to antenna mechanical noise on received spacecraft signals was built and tested at DSS-13.

Background: The current state-of-the-art concept for mitigating “antenna mechanical noise” was developed by Armstrong et al. (2008) and requires the use of a second, smaller antenna observing the spacecraft simultaneously with the 34 m DSN antenna. This second, smaller antenna is less susceptible to deformation and has a lower level of “antenna mechanical noise.” Appropriate combinations of the small antenna signal with the signal received at the 34m antenna allow the signal-to-noise ratio of the 34m antenna to be retained, but also obtain the lower level of “antenna mechanical noise” from the smaller antenna. While technically feasible, the significant challenge associated with this approach is that the DSN does not have any such smaller antennas currently. This new, self-contained system will enable the use of a sole 34 m DSN antenna.

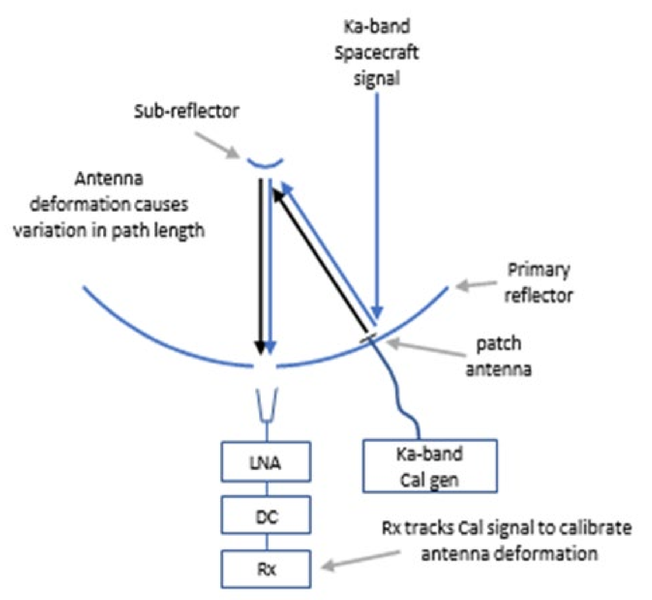

Figure 1. Calibration Tone Injection Scheme

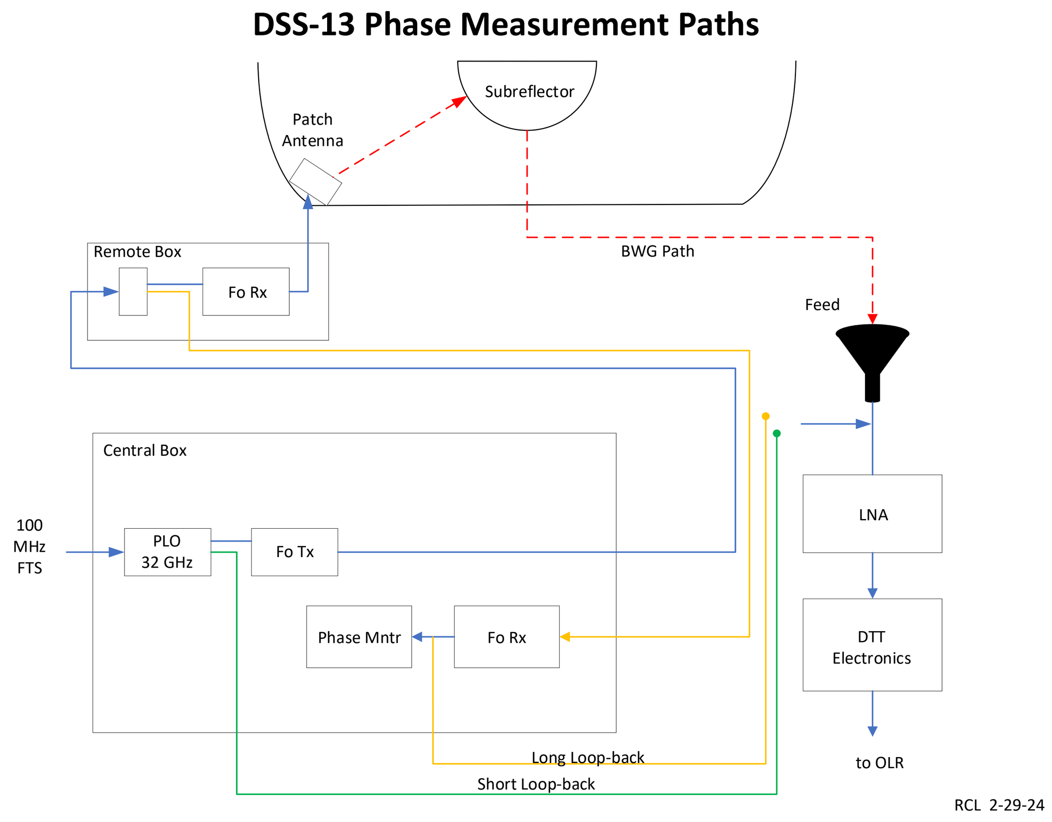

Figure 2. Calibration Tone Distribution Block Diagram

Figure 3. DSS-13 Antenna – Remote Box installation

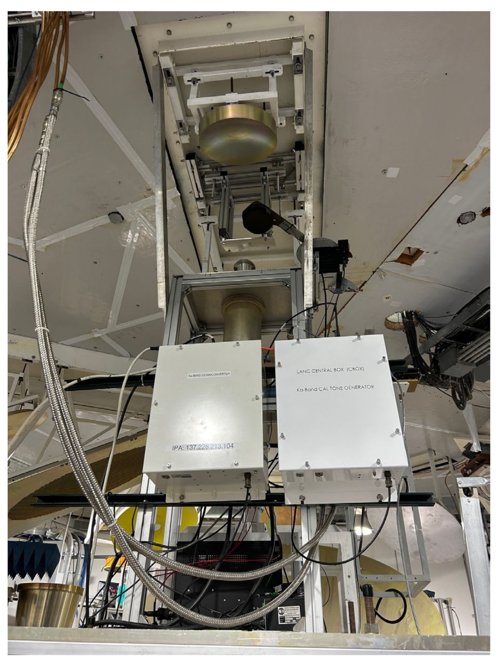

Figure 4. Central Box and Ka downconverter in pedestal

Approach : In the real-time approach for this task, phase stable calibration signals, at Ka-band, are transmitted from 2 small, patch, injection antennas, at 2 different frequencies, placed on the DSN antenna’s main reflector. The calibration signals from the injection antennas follow the same RF path as the spacecraft signal through the antenna to the feed and subsequently through the downlink electronics to the receiver (Figure 1). The receiver will record both the calibration signals and spacecraft downlink signal in parallel (Fig. 2). Tracking software will be used to extract signal phase information from both the spacecraft signal and the calibration signals. The phase data from the calibration signals will be combined and used to correct variations in the spacecraft signal thereby reducing antenna mechanical errors in the overall observation

Installation and System Testing: The 2-channel system was installed at DSS-13, including the Central Box in the pedestal of the beam waveguide antenna (shown in Fig. 4), the 2 Remote Boxes behind the main reflector and the 2 patch antennas on the main reflector (Fig. 3). Multiconductor cables and fiber cables, for the forward and return links, were routed through the azimuth and elevation cable wraps. Phase stability (Allan variance) tests were run using fiber links from the DSS-13 pedestal to the Open Loop Receiver at the Signal processing Center (SPC-10). Both the return (reference) links and the BWG injection signals were measured under different conditions. The Allan variance (AV) results for the BWG path signals are shown in Fig. 5 for the antenna at stow and also while tracking. The AV for the BWG signals during antenna tracking is much higher than while at stow, as expected. Future work will focus on using the corrected BWG cal tones to correct the actual spacecraft signals.

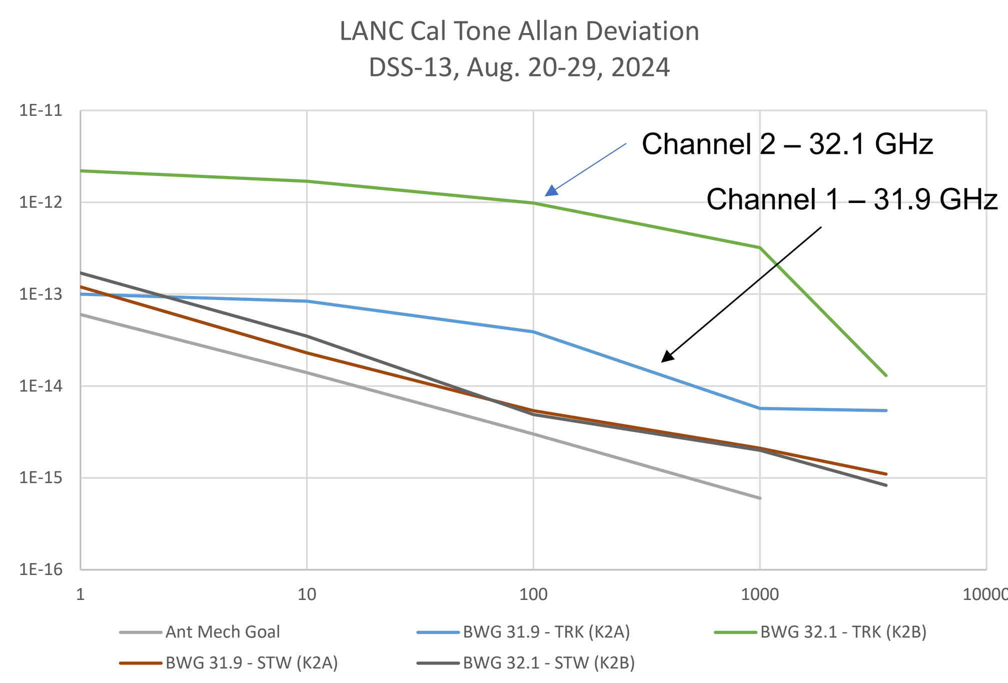

Figure 5. Allan Variance Comparison: Antenna at Stow and While Tracking

Significance/Benefits to JPL and NASA: The pre-decadal Ice Giant Mission concept study defined two prime science objectives, one of which is studying its interior and for which Radio Science techniques were identified as one of the measurements that would address the science objective. We expect that the mechanical noise reduction obtained from this calibration system will directly benefit both current Radio Science missions, such as **JUNO and Beppi Colombo**, and future missions, such as the **Uranus orbiter and probe and the Veritas Venus mission.** The improved noise performance will also make the DSN 34m antennas viable for future **gravity wave research**.

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Publications:

1. R. LaBelle, M. Ciminera, “Large Antenna Mechanical Noise Calibration (LANC) System for the NASA Deep Space Network (DSN)”, Proceedings of the IAC 2024 Conference, October, 2024.

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