FY23 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 is 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 x10-15 at 1000 s), the intrinsic mechanical instability of the large (34m) antennas emerges as the leading noise contributor since other contributions to the noise budget can be mitigated by thermal stabilization or phase compensation. A concept 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 proposed.

Background: Previous 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." While technically feasible, the challenge associated with this approach is that the DSN does not have any such smaller antennas currently.

Approach and Results: In the in-situ approach for this task, phase stable calibration signals, at Ka-band, will be transmitted from 3 small, patch, injection antennas, at 3 different frequencies, placed on the DSN antenna's main reflector. The calibration signals from the injection antennas will 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 Open Loop Receiver (OLR) will record both the calibration signals and spacecraft downlink signal in parallel. 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.
Preliminary Design : **Key challenge**: development of the phase stable reference distribution system. **Current concept**: use single-mode fiber optic links to 3 small patch antenna and microwave electronics assemblies mounted behind the surface of the main dish (Fig. 2). Three photonic links will carry 3 different signals (at 31.9, 32.0 and 32.1 GHz), generated by thermally stabilized, phase-locked oscillators (PLOs) in the Central Box. The fibers will be routed through the azimuth and elevation cable wraps, and will connect to the Remote Boxes mounted behind the dish surface; Patch antennas are mounted on the dish surface and will radiate the Ka-band signals toward the sub-reflector while the dish is tracking the spacecraft Ka-downlink signal. **Status**: preliminary designs of the Central and Remote Boxes have been completed, and the block diagrams are shown in Figure 3 and Figure 4 respectively. **Component testing** : Component-level testing was completed on the phase-locked oscillators, fiber optic transmitter-receiver (FO Rx/Tx) link with 200' of single-mode fiber, and the 6x6 patch antenna arrays. The phase vs temperature performance for the fiber + FO Rx is shown in Figure 5. The patch antenna pattern, with a 3 dB beamwidth of 14 degrees, was also verified in lab tests. **System testing** : Initial baseline system testing of the downlink electronics at DSS-13 was completed using a signal generator as the tone source. This tone was injected directly into the Ka-band LNA and the signal is then routed to the OLR at SPC-10.

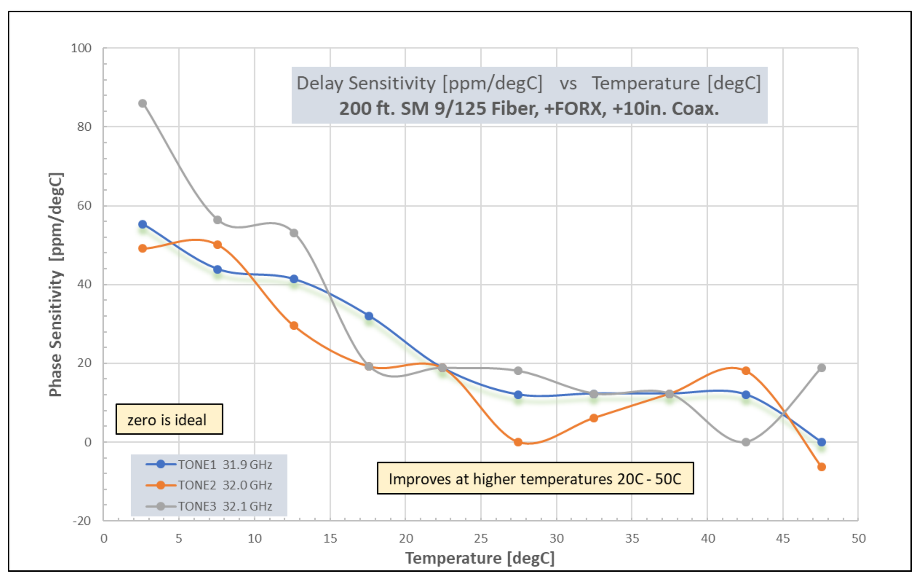

Fig. 5 Phase vs Temperature Performance for Optical Distribution

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 future Radio Science 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.**

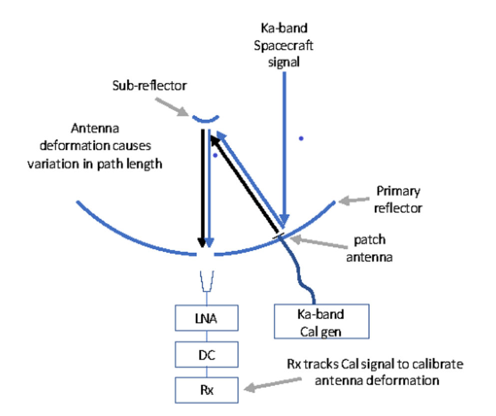
Fig. 1Calibration Tone Distribution System: Central Box

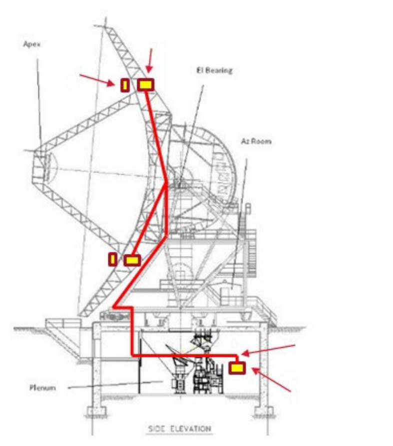
Fig. 2 Calibration Tone Fiber Optic Distribution Concept

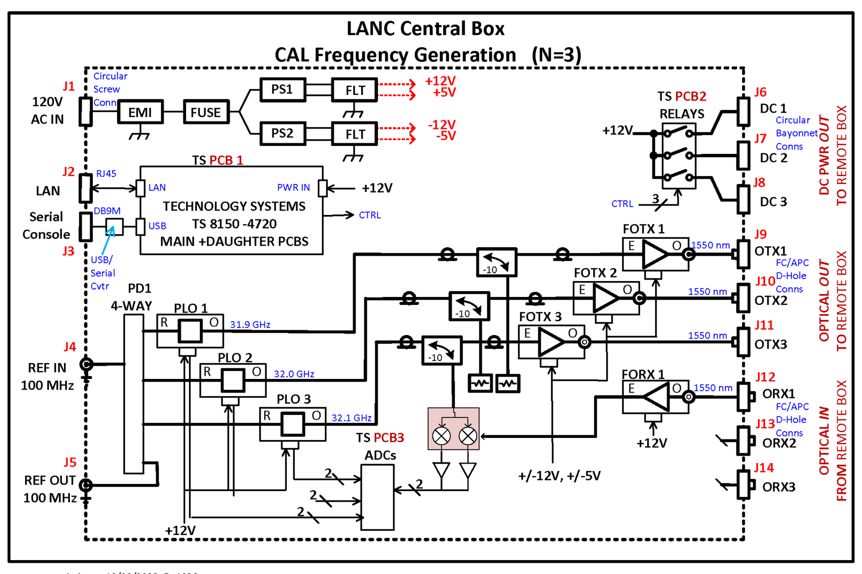

Fig. 3 Calibration Tone Distribution System: Central Box

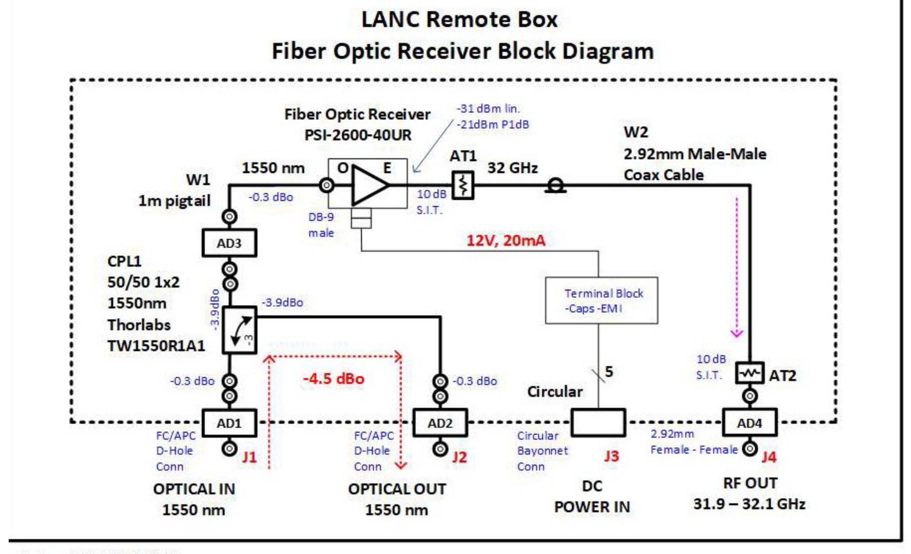

Fig. 4 Calibration Tone Distribution System: Remote Boxes

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