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Relocation of Advanced Water Vapor Radiometer 1 to Deep Space Station 55

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In June of 2004, the Advanced Water Vapor Radiometer (AWVR) unit no. 1 was relocated to the Deep Space Station (DSS) 55 site in Madrid, Spain, from DSS 25 in Goldstone, California. This article summarizes the relocation activity and the subsequent operation and data acquisition. This activity also relocated the associated Microwave Temperature Profiler (MTP) and Surface Meteorology (SurfMET) package that collectively comprise the Cassini Media Calibration System (MCS).

I. Installation

The Advanced Water Vapor Radiometer (AWVR) unit no. 1 was relocated to the Deep Space Station (DSS) 55 site in Madrid, Spain, from DSS 25 in Goldstone, California, in June 2004. The associated Microwave Temperature Profiler (MTP) and Surface Meteorology (SurfMET) package that collectively comprise the Cassini Media Calibration System (MCS) also were relocated.

Prior to packing and shipping the MCS equipment to Spain, the two concrete pads with the required electrical utilities were installed west of the DSS 55 34-m dish in March and April 2004, as seen in Fig. 1. In mid-April, the MCS instruments were retrieved from the Goldstone DSS 25 site. The equipment was carefully packed in crates and shipped to Spain via cargo plane, where it arrived on May 19, 2004.

During the first 2 weeks of June, Allen Hubbard and Hans Rosenberger from JPL's Ground Based Microwave Applications Group installed the equipment on the concrete pads. First, the crates were unpacked, and the equipment was inspected for damage. A power cable for the AWVR was mistakenly not shipped, but a replacement was quickly made on-site. The electrical facilities on the concrete pads were tested and confirmed to be working properly. Next, the AWVR pedestal was located on the pad, and the approximate azimuth alignment was set by compass, followed by precision leveling with a bubble level. After this, the AWVR electronics and antenna were installed on the pedestal mount. The

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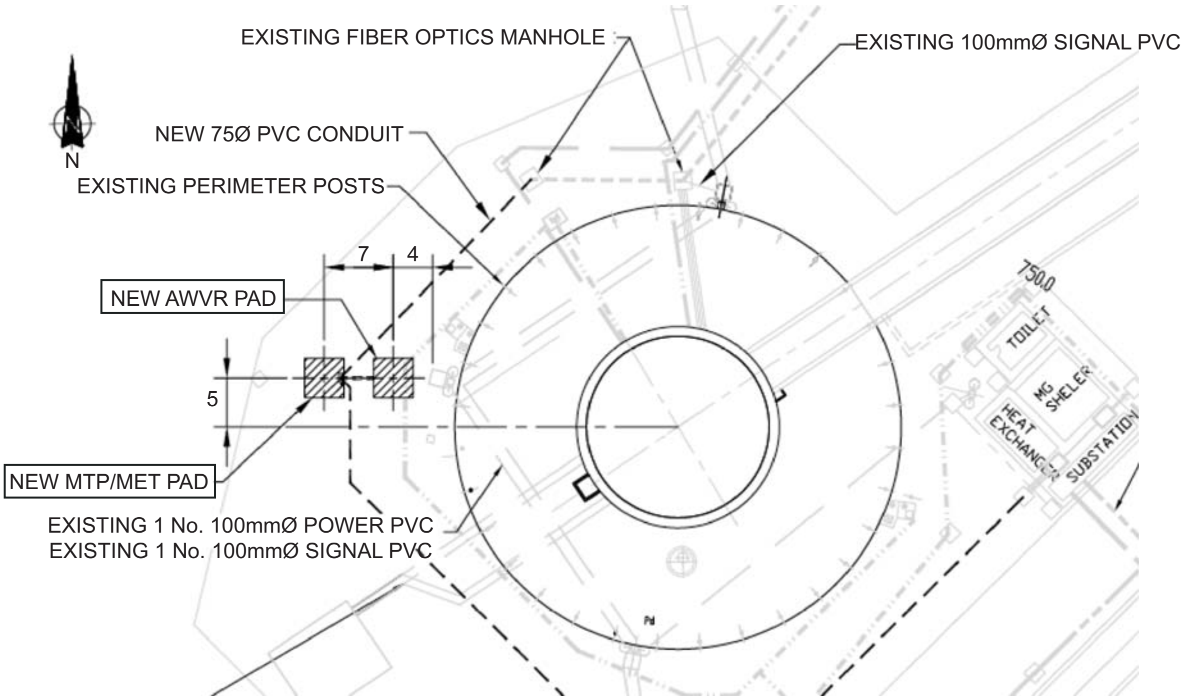

Fig. 1. DSS-55 site map with location of AWVR no. 1 as indicated to the west of the 34-m dish.

built-in computer of the AWVR then was connected to the local network. Final fine-tuning of the azimuth alignment was performed by solar ephemeris and observations. The elevation alignment also was fine-tuned by solar observations, but in this case further adjustment was not needed.

Once the AWVR was fully connected and networked, the MTP and SurfMET station were installed on the second concrete pad, as seen in Fig. 2. A Sun workstation was installed in the pedestal room to control the MTP and SurfMET station. All the instruments were tested and confirmed to be operational.

The final details of the installation process included securing a grounding strap to the AWVR. A final leveling procedure was performed on the AWVR, and a successful Sun track was executed.

Prior to departing, the JPL staff gave the Spanish personnel at the Deep Space Network (DSN) site a tutorial on operating, maintaining, and repairing the newly installed equipment (this has proven to be quite useful).

II. Operation

Operation of the AWVR now located in Madrid is generally the same, although it is now accessed with a different IP address. The nominal operating mode for the AWVR is continuous tip-curve measurements whenever there is no scheduled activity (e.g., tracking the 34-m dish movements during a Cassini pass).

In general, operation of the AWVR does not require any hands-on assistance from the technical staff in Madrid. The AWVR did experience a mechanical failure of the antenna elevation positioning motor, but this problem was resolved by personnel in Madrid from detailed instructions sent via e-mail. It is anticipated that most routine maintenance-type issues such as this that occasionally arise can be handled similarly.

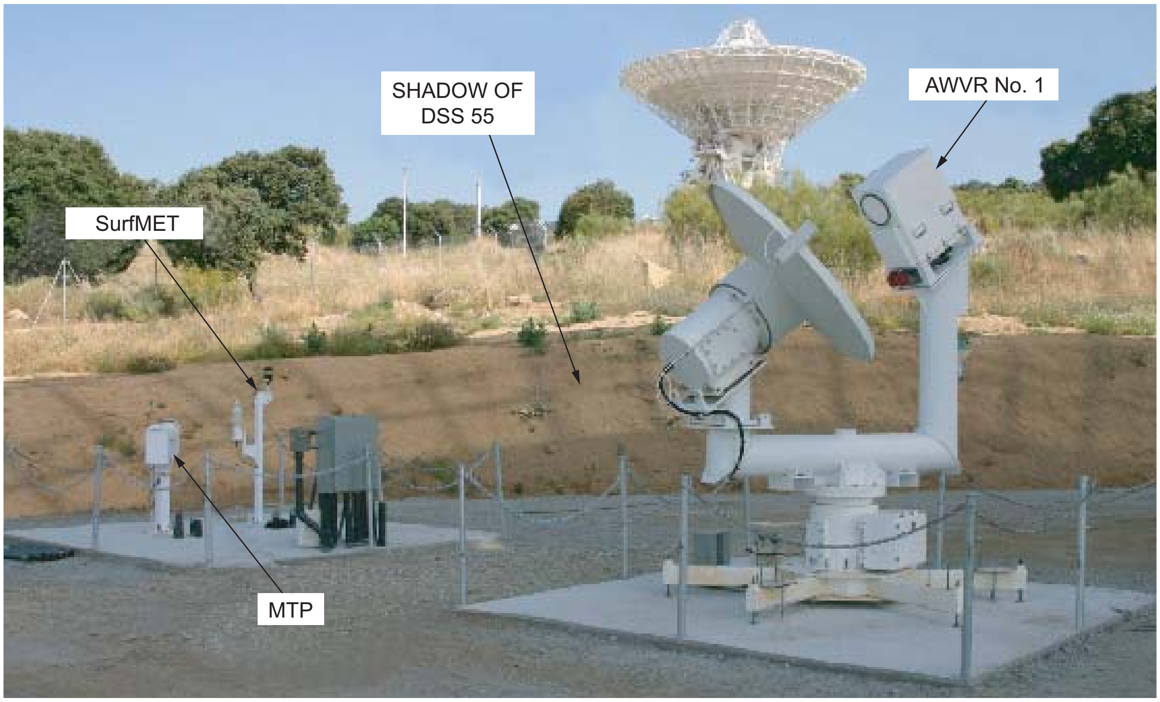

Fig. 2. Installation of AWVR no. 1, MTP, and SurfMET package in the shadow of DSS 55, Madrid, Spain; June 2004.

It should be noted that AWVR no. 1 was located to the west of the 34-m dish, primarily to support a very long baseline interferometry (VLBI) experiment. This location is not optimal for Cassini tracking, which generally follows the ecliptic plane, and, as such, the field of view is obstructed by the 34-m dish itself during a portion of any Cassini pass.

III. Applications

A. VLBI[4]

1. Introduction. Many studies have shown that astrometric applications of VLBI often have their accuracy limited by systematic errors in the models used for the refractivity of tropospheric water vapor (e.g., [2]). One approach to this problem that has been pursued over the last several decades has been to calibrate atmospheric water vapor by measuring emissions from the 22-GHz rotational line of atmospheric water vapor.

2. The VLBI Observations. The results shown in Fig. 3 are from two observing sessions done during the summer of 2004 using NASA's DSS 26 in Goldstone, California, and DSS 55 near Madrid, Spain. The first session was on day-of-year (DOY) 200 (July 18, 2004), and the second session was on DOY 217 (August 4, 2004). VLBI data were recorded simultaneously at X-band (8.4 GHz) and Ka-band (32 GHz), sampling each band at a rate of 64 megabits per second (Mbps). The data were sampled, digitally filtered, and recorded to hard disk using the JPL-designed VLBI Science Receivers (VSRs). The data then were played back over a network connection and then correlated with SOFTC (a software

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[4] This section was presented at the 205th AAS meeting: C. S. Jacobs, S. J. Keihm, G. E. Lanyi, C. J. Naudet, L. Riley, and A. B. Tanner, "Improving Astrometric VLBI by using Water Vapor Radiometer Calibrations," American Astronomical Society, 205th Meeting, San Diego, California, January 2005.

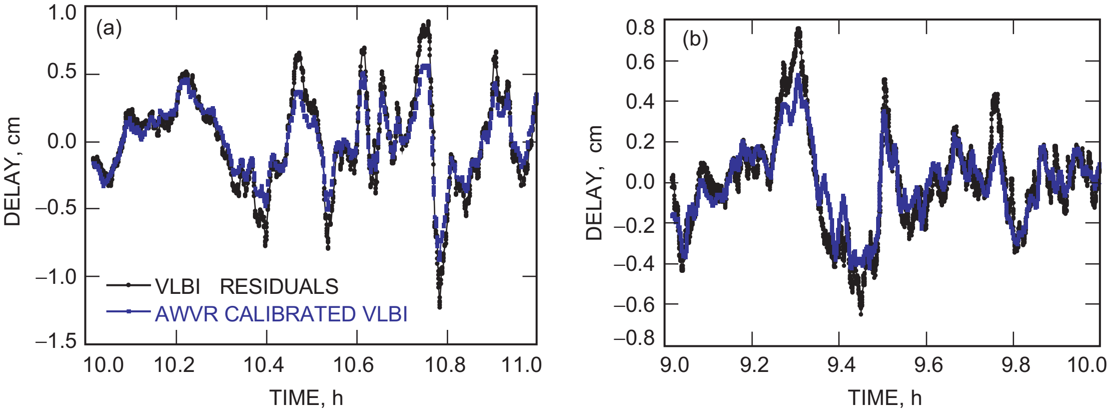

Fig. 3. VLBI phase and AWVR troposphere calibrations are well correlated: (a) VLBI delay residuals DOY 200, Ka-band, DSS 26–DSS 55 and (b) VLBI delay residuals DOY 217, Ka-band, DSS 26–DSS 55.

correlator).[5] Fringe fitting was done with fringe fitting software [3]. This procedure resulted in a phase delay measurement for each second of an hour-long scan. The observed elevations were moderate, ranging from roughly 30 to 50 deg, as seen in Table 1.

3. The Advanced WVR. The JPL-designed and -built AWVR is a microwave radiometer with observing bands at 22.2, 23.8, and 31.4 GHz. Design highlights include a 1-m offset parabolic antenna that provides a highly efficient 1-deg beam and very high radiometric stability. Drifts in the radiometric calibrations are well below 0.01 K of brightness temperature on time scales of 10,000 s. The key to this stability is the non-cryogenic instrument enclosure, which uses thermo-electric coolers to maintain an internal temperature of 35 ± 0.005 deg C in all weather. In addition to the AWVR, the atmospheric measurement suite also includes an MTP and a SurfMET package that are used to better constrain the water vapor retrievals of the AWVR. A detailed description of the AWVR system is given in [1].

The AWVR design concentrated on improving three areas relative to our previous generation of WVRs. First, the previous design's simple feed horn was improved upon by adding the 1-m clear-aperture dish antenna. This narrowed the beam to about 1 deg from the feed horn's ~7-deg beam, resulting in an instrument that more nearly samples the same spatial scales as the VLBI antenna. It also allows observation much closer to the horizon before ground pickup through side lobes becomes a problem. Second, the gain stability of the radiometer was improved so that brightness temperature drifts are kept at the 10-mK level. Third, atmospheric modeling was improved by adding the MTP to empirically determine the atmospheric temperature versus altitude above the site during the measurements.

4. Results. The plots in Fig. 3 show the VLBI phase residuals in black and the AWVR wet troposphere delay in blue. A quadratic was solved for from the VLBI–AWVR differences in order to remove slowly changing systematic effects such as station location and nutation mismodeling.

The plots in Fig. 3 clearly show a high correlation between the VLBI phase and the AWVR troposphere calibrations. The improvement in residuals is a bit less than a factor of three. For example, as seen in Fig. 4, the DOY 200 VLBI phase residuals improved from 3.4 mm down to 1.2 mm—a factor of 2.8 improvement.

The Allan standard deviation of the VLBI phases was calculated to examine the range of time scales over which the VLBI residuals are being improved. Figure 5 shows the VLBI data before (red) and after

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[5] S. T. Lowe, *SOFTC: A Software VLBI Correlator*, Jet Propulsion Laboratory (internal document), Pasadena, California, in preparation, 2005.

Table 1. Observed elevations during VLBI observation, DOYs 200 and 217.

Time,	Elevation, deg	
DOY/hh:mm	DSS 26 (California)	DSS 55 (Madrid)
200/10:00	31.7	53.3
200/11:00	43.7	41.9
217/09:00	33.0	52.0
217/10:00	45.	40.6

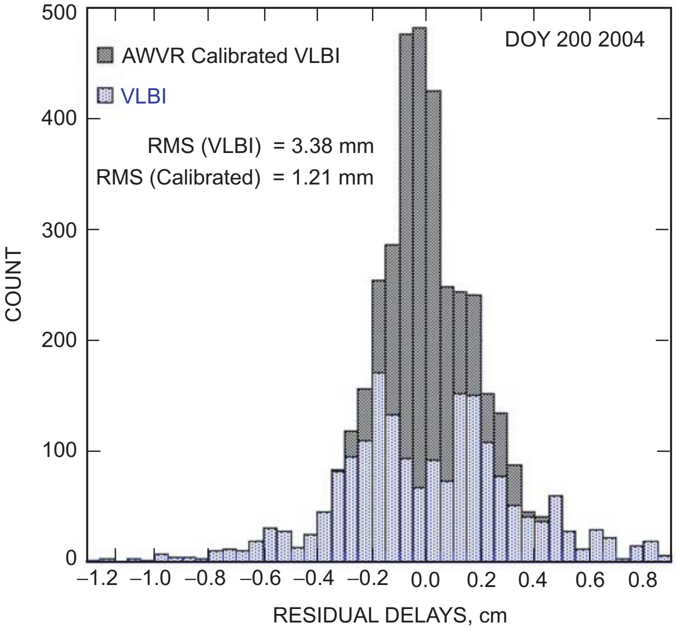

Fig. 4. Delay residuals with and without AWVR calibrations (DSS 26–DSS 55, Ka-band).

(green) the AWVR calibration. The result shows a strong improvement on time scales of 10 to 1000 seconds. For time scales shorter than 10 seconds, signal-to-noise ratio (SNR) considerations for the AWVR measurement forced its shortest measurement integrations to be ~10 seconds—thus, the lack of significant improvement on times scales less than 10 seconds. The DOY 200 and 217 experiments lasted only 3600 seconds, thus limiting our ability to examine the quality of calibrations on time scales much longer than 1000 seconds. A longer data arc will have to be taken before we can evaluate the quality of calibrations on time scales from 10,000 seconds to a day, which are also of interest to global VLBI astrometry.

B. Cassini Tracking

Having the AWVR in Madrid allows corrections to be made to the received Ka-band signals when tracking Cassini. Without the AWVR, corrections for the presence of water in the troposphere along the Cassini line of sight would be impossible. Thus, the relocation of the AWVR opens up many more opportunities for doing Ka-band science with Cassini because the Madrid DSN station can be used as well as Goldstone.

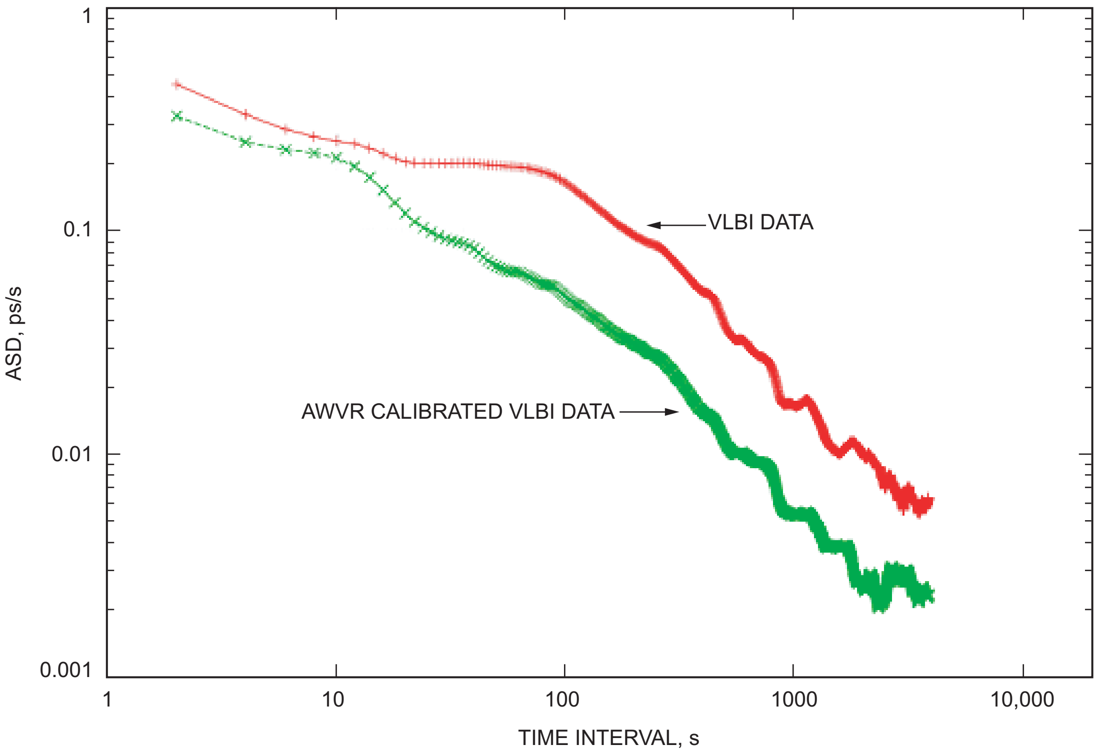

Fig. 5. Plot of Allan standard deviation showing improvement due to AWVR calibration (DOY 200 2004).

IV. Conclusion

In June 2004 the AWVR unit no. 1 was successfully relocated to the Madrid DSS 55 site and was quickly brought online and fully operational. Although the impetus for the relocation was in support of VLBI experiments, in fact Cassini has been able to make even more use of the AWVR at its new home. The AWVR originally was planned to be returned to Goldstone during fiscal year 2005; however, at present there appears to be no urgent need to do so, and until such time, it will likely remain in Madrid.

References

[1] A. B. Tanner and A. L. Riley, “Design and Performance of a High-Stability Water Vapor Radiometer,” *Radio Science*, vol. 38, no. 3, 8050, doi:10.1029/2002RS002673, 2003.

[2] R. N. Treuhaft and G. E. Lanyi, “The Effect of the Dynamic Wet Troposphere on Radio Interferometer Measurements,” *Radio Science*, vol. 22, pp. 251–265, March–April 1987.

[3] S. T. Lowe, *Theory of Post-Block II VLBI Observable Extraction*, JPL Publication 92-7, Jet Propulsion Laboratory, Pasadena, California, July 15, 1992.