JPL VLBI Analysis Center Report for 2010

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Abstract

This report describes the activities of the JPL VLBI Analysis Center for the year 2010. We continue to do celestial reference frame, terrestrial reference frame, earth orientation, and spacecraft navigation work using the VLBI technique. In 2010 we doubled our default reference frame data rate to 448 Mbps. Our international collaboration to build celestial frames at K- (24 GHz) and Q-bands (43 GHz) matured to roughly part-per-billion (ppb) accuracy. Our in-house work to build a reference at X/Ka-bands (8.4/32 GHz) is also close to ppb accuracy. We supported several missions with VLBI navigation measurements. We continue to study ways to improve spacecraft tracking using VLBI techniques.

1. General Information

The Jet Propulsion Laboratory (JPL) Analysis Center is in Pasadena, California. Like the rest of JPL, the center is operated by the California Institute of Technology under contract to NASA. JPL has done VLBI analysis since about 1970. We focus on spacecraft navigation, including:

1. Celestial Reference Frame (CRF) and Terrestrial Reference Frame (TRF) are efforts which provide infrastructure to support spacecraft navigation and Earth orientation measurements.
2. Time and Earth Motion Precision Observations (TEMPO) measures Earth orientation parameters based on single baseline semi-monthly measurements. These VLBI measurements are then combined with daily GPS measurements as well as other sources of Earth orientation information. The combined product provides Earth orientation for spacecraft navigation.
3. Delta differenced one-way range (ΔDOR) is a differential VLBI technique which measures the angle between a spacecraft and an angularly nearby extragalactic radio source. This technique thus complements the radial information from spacecraft doppler and range measurements by providing plane-of-sky information for the spacecraft trajectory.
4. ΔVLBI phase referencing uses the VLBA to measure spacecraft positions.

2. Technical Capabilities

The JPL Analysis Center acquires its own data and supplements it with data from other centers. The data we acquire is taken using NASA's Deep Space Network (DSN).

1. Antennas: Most of our work uses 34-m antennas located near Goldstone (California, USA), Madrid (Spain), and Tidbinbilla (Australia). These include the following Deep Space Stations (DSS): the "High Efficiency" subnet comprised of DSS 15, DSS 45, and DSS 65 (see Figure 1) which has been the most often used set of antennas for VLBI. More recently, we have been using the DSN's beam waveguide (BWG) antennas: DSS 13, DSS 24, DSS 25, DSS 26, DSS 34, DSS 54, and DSS 55. Less frequent use is made of the DSN's 70-m network (DSS 14,

DSS 43, and DSS 63). Typical X-band system temperatures are 35K on the HEF antennas. The 70-m and BWGs are about 20K. Antenna efficiencies are typically well above 50% at X-band.

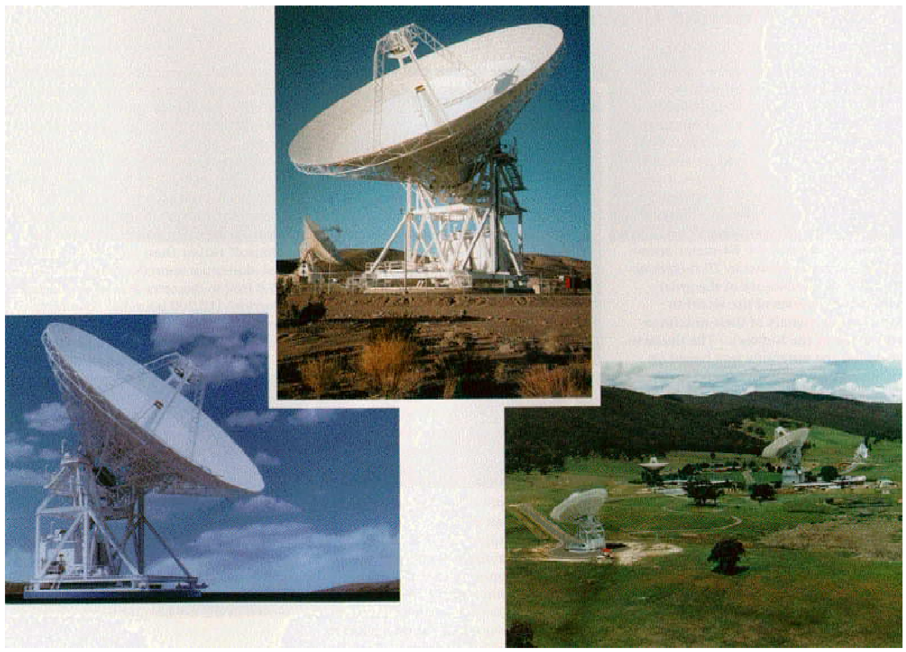

Figure 1. The three 'high-efficiency' DSN antennas: Goldstone (center); Robledo, Spain (lower left); and Tidbinbilla, Australia (lower right). These antennas have an optimum efficiency at X-band (8.4 GHz)—the standard frequency for solar-system exploration. These antennas were completed before 1986 for the Voyager Uranus encounter. In the 1990s, Ka-band (32 GHz) BWG antennas (not shown) were added.

2. Data acquisition: We use the Mark 5A VLBI data acquisition systems. In addition, we have JPL-unique systems called the VLBI Science Recorder (VSR) and the Wideband VSRs (WVSR) which have digital baseband converters and record directly to hard disk. The data is later transferred via network to JPL for processing with our software correlator.
3. Correlators: The JPL VLBI Correlator has been exclusively based on the SOFTC software which handles the ΔDOR, TEMPO, and CRF correlations. The software correlator has also been used for connected element interferometry tests of antenna arraying.
4. Solution types: We run several different types of solutions. For ΔDOR spacecraft tracking we make narrow field ($\approx 10^\circ$) differential solutions. The TEMPO solutions typically have a highly constrained terrestrial (TRF) and celestial frame (CRF) as a foundation for estimating Earth orientation parameters. These reference frames are produced from global solutions which then provide the framework needed for use by TEMPO and ΔDOR.

3. Staff

Our staff are listed below along with areas of concentration. Note that not all of the staff listed work on VLBI exclusively, as our group is involved in a number of projects in addition to VLBI.

- Durgadas Bagri: VLBI instrumental calibrations and TEMPO.
- Jim Border: ΔDOR spacecraft tracking.
- Mike Heflin: ΔDOR, CRF and TRF. Maintains MODEST analysis code.
- Chris Jacobs: S/X, K, Q, X/Ka CRFs, and TRF.
- Peter Kroger: ΔDOR spacecraft tracking.
- Gabor Lanyi: VLBA phase referencing, ΔDOR, WVR, K-Q CRF, and TRF.
- Steve Lowe: Software correlator, fringe fitting software, ΔDOR.
- Walid Majid: ΔDOR, VLBA phase referencing.
- Chuck Naudet: WVR, Mark 5A support, and K-Q CRF.
- Lyle Skjerve: Field support of VLBI experiments at Goldstone.
- Ojars Sovers: S/X, K, Q, and X/Ka CRFs and TRF. Maintains MODEST analysis code.
- Alan Steppe: TEMPO and TRF.

4. Current Status and Activities

In order to support the DSN's move to Ka-band (32 GHz), JPL is leading a collaboration (Lanyi et al., Charlot et al.) with Goddard, the U.S.N.O., NRAO, and the Bordeaux Observatory to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz).

JPL's X/Ka-band (8.4/32 GHz) CRF was presented in two papers by Jacobs et al. The X/Ka to Gaia optical frame tie potential was discussed by Bourda, Charlot, and Jacobs.

During 2010 our default Mark 5A rate was increased to 448 Mbps yielding a very high sensitivity VLBI system when combined with the DSN's large apertures and low system temperatures.

VLBI spacecraft tracking continues to provide measurements of angular position in support of mission navigation and planetary ephemeris development (Border, 2009). Jones et al. report on work done with Cassini to improve the Saturn ephemeris. Measurements of Mars Reconnaissance Orbiter and Odyssey were obtained to improve the Mars ephemeris, while ESA provided measurements of Venus Express to improve the Venus ephemeris. Measurements were taken during interplanetary cruise to support navigation for Messenger, New Horizons, Deep Impact, Dawn, and Akatsuki. Finally, measurements were obtained of Hayabusa during its return trip to Earth to ensure successful targeting for landing the sample capsule in central Australia.

5. Future Plans

In 2011, we hope to improve TEMPO and reference frame VLBI by increasing data rates to 896 Mbps. Operational Ka-band phase calibrators have been built and are planned for deployment in 2011. Work on the Digital Back End (DBE) continues. Our next generation fringe fitting program is also expected to come online. We anticipate refereed publications on our X/Ka celestial reference frame work. On the spacecraft front, we plan to continue supporting a number of operational missions while further improving techniques for using VLBI for spacecraft tracking.

Acknowledgements

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