A CELESTIAL REFERENCE FRAME AT X/KA-BAND (8.4/32 GHZ) FOR DEEP SPACE NAVIGATION

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ABSTRACT

Deep space tracking and navigation are done in a quasi-inertial reference frame based upon the angular positions of distant active galactic nuclei (AGN). These objects, which are found at extreme distances characterized by median redshifts of z = 1, are ideal for reference frame definition because they exhibit no measurable parallax or proper motion. They are thought to be powered by super massive black holes whose gravitational energy drives galactic sized relativistic jets. These jets produce synchrotron emissions which are detectable by modern radio techniques such as Very Long baseline Interferometry (VLBI).

We discuss the construction of a frame based on VLBI observations of AGN at X/Ka-band (8.4/32 GHz) using intercontinental baselines. Compared to S/X-band frames such as the international standard ICRF2 (Ma et al, 2009), X/Ka-band allows access to more compact source morphology and reduced core shift. Both these improvements allow for a more well-defined and stable reference frame at X/Ka.

During sixty-seven $\sim$24-hour sessions starting in 2005 and continuing until the present using NASA's Deep Space Network baselines from Goldstone, California to Madrid, Spain and Canberra, Australia, we detected over 475 sources covering the full 24 hours of right ascension and declinations down to $-45°$. Comparison of 460 X/Ka sources in common with the international standard ICRF2 at S/X-band (2.3/8.4 GHz) shows wRMS agreement of 180 μas in RA cos(dec) and 270 μas in Dec. There is evidence for systematic errors at the 100 μas level. Known errors include limited SNR, lack of phase calibration, troposphere mismodelling, and limited southern geometry. SNR is being improved by increasing the recorded bit rate from 0.5 to 2.0 Gbps. Instrumental errors will be reduced by using a pulsed diode phase calibration system. Troposphere errors will be reduced using JPL's Advanced Water Vapor Radiometer (A-WVR). Plans are underway to improve our observing geometry in the southern hemisphere by collaborating with a tracking station in S. America.

In the next decade, we expect that ESA's optically based Gaia mission (Lindegren, 2008) will produce a frame with competitive precision. If this new frame is accurately registered with existing radio frames then it will be possible to study wavelength dependent systematic errors effecting reference frames at a very fine level of precision. In anticipation of this opportunity, we simulated a frame tie between our X/Ka radio frame and the Gaia optical frame. The simulation predicts a frame tie precision of 10–15 μas (1-σ, per 3-D rotation component) with anticipated improvements

in the radio reducing that to 5–10 μas per component by the time of Gaia's end of mission ca. 2021. Thus highly accurate cross-registration of these frames should be possible thereby enabling detailed studies of wavelength-dependent systematic errors.