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CALC: The Next Upgrade

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1. What is Calc?

Calc is a Fortran program that calculates theoretical VLBI delays and rates. It first computes a solid body rotation matrix which translates a set of site coordinates from the terrestrial reference frame (TRF) into the celestial reference frame (CRF). It then computes corrections to the transformed site coordinates for various effects such as the solid Earth tides, ocean loading, and pole tide, and further computes the a priori delay effects of the atmospheres and antenna axis offsets. It then computes the theoretical delays and rates using a model which includes relativistic effects. Calc also computes numerous partial derivatives of the delays and rates with respect to certain interesting effects, such as nutation, pole position, UT1, the atmosphere, site positions, and source positions, which can be used later in Solve analysis.

2. Calc History

Calc dates back to 1975, when it was derived from program VLBI-3, which was originally written by Doug Robertson and brought to GSFC. Calc originally ran on an IBM360 computer. It has been updated and expanded many times since, mostly at the GSFC analysis center. The current version (versions 9.12 and 9.13) was designed for compliance with the IERS Conventions (1966) [1]. The next upgrade, version 10, will be modified to comply with the latest IERS Conventions (2003) [2].

3. Calc Usage

There have been two primary usages of Calc over the years. First, it has been used for geodetic/astrometric analysis as part of the Calc/Solve analysis sytem. Calc/Solve is currently used at nine IVS Analysis Centers, where it runs on HP Unix workstations. Second, it has been used for generating the correlator delay models at most of the world's VLBI correlators. Correlators currently using Calc include the three Mark IV correlators, and the VLBA, DRAO, JIVE, and ATNF correlators.

4. Calc Upgrade Plan

The largest part of the current Calc upgrade involves converting the TRF-to-CRF transformation to use the non-rotating origin method, replacing the classical equinox-based method. The new transformation will be a combination of a) a precession/nutation matrix based on the IAU2000A expansion (using X and Y positions of the celestial ephemeris pole (CIP) in the geocentric refer-

ence system (GSRS), b) a polar motion matrix, which will include short period ocean tidal and nutation terms, and c) a diurnal spin matrix using the Earth Rotation Angle, which is linear with time. Calc will also compute the first and second time derivatives of this rotation matrix, and its partial derivatives with respect to X and Y nutation, UT1-TAI, and x and y pole positions.

Calc will also compute a classical, equinox-based transformation, as outlined in the IERS Conventions (2003) [2]. This will be used to compute partial derivatives of the delays and rates with respect to the classical nutation offsets, delta epsilon and delta psi.

Updates to other Calc modules will be made as necessary. Some minor changes in the solid Earth tide computation will be made, and an option to use a frequency domain computation may be included. The previous ocean loading model will be retained, but an option to use an alternate model (by L. Petrov) may be added. The pole tide model will be modified to remove the mean pole offsets, as provided by the IERS. An antenna thermal deformation model will be added. And the DE/LE405 JPL Ephemeris will be used.

Several antennas have fixed axes which are tilted slightly from their design specifications. Notably, Pie Town's fixed (vertical) axis currently tilts $\sim$4 arc-minutes to the SSW, and is increasing at a rate of $\sim$.3 arc-minutes/year (though not at a constant rate since $\sim$1991.). A few other antennas have smaller tilts that appear to be constant. Unless corrected for, the tilt at Pie Town can produce errors as high as $\pm$9 psec in the axis offset correction. Therefore, a correction for antenna axis tilts will be put into the axis offset model.

5. Timetable

Much of the upgrade work on Calc has already been completed. We expect to finish the code by the end of Spring or early Summer 2004. Modifications to Solve will then be necessary. We hope to begin using Calc 10 operationally before the end of 2004.

References

[1] McCarthy, D., IERS Technical Note 21, IERS Conventions (1996), 1996.

[2] McCarthy, D., G. Petit, IERS Technical Note 32, IERS Conventions (2003), 2003.