Astrophysical Phenomena Revealed by Space VLBI
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Experiences with the Space VLBI Geodesy Experiment

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Abstract

The primary purpose of the Space VLBI Geodesy Demonstration Experiment (GEDEX) is to test how this new potential space geodetic technique works in practice. We present our experience and outline the limitations of using VSOP data.

1 Introduction

Space VLBI (SVLBI) is a new observing technique extending VLBI baselines into space. Although present-day SVLBI is designed for radio astronomical purposes, the potential geodetic and geophysical applications of this space technique have been investigated since the mid-eighties (Fejes 1994, and references therein). Feasibility studies showed that SVLBI is in principle capable of *(i)* tying the terrestrial and celestial reference frames, *(ii)* determining the geocentric positions of the ground VLBI stations without collocations with other satellite-based space geodetic (e.g. satellite laser ranging or Global Positioning System) stations, and *(iii)* improving the accuracy of the SVLBI satellite orbit determination using delay and delay rate observables as new types of tracking data. Ground based VLBI is a key observing technique in geodesy and geodynamics, as it provides external reference to measure the Earth rotation and orientation, and highly accurate measurements of inter-continental baselines on the Earth (Sovers et al. 1998).

2 Geodesy Demonstration Experiment with VSOP Data

Studies of geodetic SVLBI were based on the assumption that the new technique is an "add on development": it can do everything what the ground based geodetic VLBI can do, but it has also valuable additional capabilities since one of the interferometer elements is orbiting around the geocenter (Fejes et al. 1996). Although this assumption is not strictly true for HALCA, it was appropriate to propose a demonstration experiment for the first-ever dedicated SVLBI satellite to test the concept of geodetic SVLBI using real data. The primary objectives of GEDEX (Fejes et al. 1996) are to demonstrate that geodetic SVLBI can work in practice, to identify problems and to use the experience gained for formulating recommendations concerning future space VLBI missions. The GEDEX project was granted observational data from the VSOP Survey Program. Data from General Observing Time (GOT) observations can also be used. The actual status of the GEDEX data acquisition, data base and pre-processing, and the development of processing software was reported in Kulkarni et al. (1998) and Fejes (1999). An international working group was established to carry out software developments by adopting existing VLBI and/or orbit determination programs for geodetic SVLBI. We pre-processed a test VSOP experiment and made the data available for developing and testing the processing software. This work involved definition of new data formats and setting up a procedure to obtain total delay and delay rate observables.

3 Data Flow and Pre-Processing

The concept of GEDEX data handling is based on a central data base at the FÖMI Satellite Geodetic Observatory (SGO, Hungary), and distributed processing at the participating institutes. The FITS files routinely produced for VSOP astrophysical experiments do not contain all the necessary information to reconstruct the total delays and rates for the SVLBI baselines. In the case of the data coming from the S2 correlator at Penticton, Canada (Carlson et al. 1999), the only path fully tested so far, HALCA spacecraft a priori model delays are not included in the standard FITS file distribution, but must be obtained separately. The same applies for a priori station clock offsets and rates used at the time of correlation. Satellite reconstructed orbit data, as well as Ku band Doppler tracking data can be obtained from the Navigation Group at the Jet Propulsion Laboratory (USA). However, the format of the latter data files still requires the development of a proper program interface.

The NRAO AIPS package can be used to handle SVLBI visibility data exported on FITS archive tapes at the correlators. Special non-AIPS programs are required to import space antenna a priori delay polynomial coefficients and clock parameters into the appropriate extension tables of the FITS visibility data file. Baseline-based total delays and rates are calculated by the AIPS task CL2HF developed for ground based geodetic VLBI data reduction. Several minor modifications had to be done before it could be used for the test data. The HF extension table is converted to a special format using a separate non-AIPS program for further processing (e.g. geodetic parameter estimation, satellite orbit improvement). This file contains the total delays, rates, their formal errors, and station clock offsets.

4 Preliminary Results

As a test case, we used data from the VSOP GOT experiment V003b, 1.6 GHz observation of 3C446 (Paragi et al. 2000). HALCA observed the source on 4 Dec 1997, together with the Australia Telescope Compact Array, Hartebeesthoek, Seshan and Usuda. The correlation was done at Penticton. Spacecraft *a priori* model delays and station clock offsets were received from the correlator upon request. They were incorporated in the appropriate CL extension table of the FITS visibility data file. After pre-processing, the resulting sample delay and delay rate file and the reconstructed orbit file were placed into the GEDEX data base, ready to use for developing and testing GEDEX data reduction software. Most recently, preliminary results with the modified GINS software for analysis of space geodetic technique data shows that the observed delays can be reproduced using the reconstructed orbit with an rms of 13.7 ns (U. Meyer, priv. comm.).

According to our experience, the practical implementation of the idea of geodetic VLBI using VSOP data poses several problems. They are closely related to the observing setup of the VSOP experiments. Ground based geodetic VLBI experiments are scheduled in a way which provides good temporal and spatial sampling, i.e. day-long experiments using a large network of antennas with short (few minutes) scans on many different sources separated by large angles on the sky. Current space VLBI technique is unable to provide resources for such observations. Ground based geodetic VLBI employs the technique of bandwidth synthesis (Thompson et al. 1986) to reduce the errors in group delay observable. It can be shown that the 32 MHz VSOP bands would lead to a loss of accuracy of about two orders of magnitude with respect to the usual ground based geodetic VLBI experiments. Ground based geodetic experiments use two observing frequencies (at S and X bands) to overcome the difficulties in estimating the dispersive ionospheric delay, while VSOP space VLBI observations use single frequencies. Instrumental phase-cal information, unlike in the case of most astrophysical

SVLBI observations, have crucial importance for geodetic SVLBI experiments, in order to properly separate geometric and instrumental effects. The lack of reliable phase-cal data is one of the reason why so many VSOP experiments can not qualify as a potential test case for GEDEX.

5 Conclusions

We established a GEDEX data base structure, defined the data preprocessing procedure, developed pre-processing programs and evaluated a test SVLBI observation according to the standards above. We determined the baseline-based total delays and delay rates for the V003b experiment. The resulted delays are in good agreement with what is expected from the reconstructed satellite orbit data. At the present stage of our work, we may conclude that space VLBI could in principle be used for geodetic experiments. However, there are many practical difficulties with VSOP space VLBI data for potential geodetic use.

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