LBA Calibrator Survey

1 Summary

We request two 24 hour observing sessions at ATCA, Ceduna, Mopra, Hobart, Parkes, Hartrao (and Tidbinbilla if available) for running X-band observations to determine coordinates at a milliarcsec accuracy level for $\sim$400 flat-spectrum sources in the declination zone [$-45°$, $-90°$]. We will also produce estimates of correlated flux density and source structure. The output catalogue of source positions will be of use for phase-referencing observations at the LBA, as a calibrator pool for the ATCA, ALMA, and SKA, for space navigation, and as a source list for geodetic observations. Considering success rate of 75%, the pool of known southern calibrators is expected to increase by a factor of 4.

This project extends the existing approved project v254a (Phillips et al.). The scope and source selection are essentially unchanged, but analysis approach is much improved. As such, this current project should be considered to replace v254a.

2 Why calibrators are needed

A catalogue of compact radio sources with position known at to an accuracy of several milliarcsec is needed for many applications. Among them are phase referencing for imaging weak objects with VLBI, accurate differential astrometry (for example, for pulsar and maser proper motions and parallax), spacecraft navigation, calibrators for ALMA, targets for space navigation, monitoring the Earth's rotation, and space geodesy.

3 Why new observations are needed

To date, positions of 3913 sources[1] were produced from analysis of more than 4400 24 hour VLBI experiments from 1979 through present, and from 27 VLBA Calibrator Survey experiments that the team of proposers scheduled and analyzed [1, 2, 3, 4, 5]. However, the vast majority of known calibrators lie in the northern hemisphere accessible to the VLBA. Plot 1 shows the sky calibrator density in 4° declination zones as a function of the zone declination. We see the rapid drop of source calibrator density starting with declinations $-30°$ and further south. There are only 98 calibrators in the declination zone [$-90°$, $-52°$] versus 524 objects in the declination zone [$+52°$, $+90°$]. Positions of known 98 calibrators in the [$-90°$, $-52°$] zone were derived from geodetic observations at a single baseline Hartrao/Hobart over 15 years. The probability to find a calibrator within a circle of 4°, 3°, and 2° at any given direction in various declination zones is shown in table 1. To reach such a calibrator density that within 3° at any given direction in the declination zone [$-45°$, $-90°$] at least one calibrator will be found with the probability $> 90\%$, in total, $\sim$1000 objects have to be observed. In this proposal we will concentrate on $\sim$400 brightest objects, and we will request time to observe further sources later.

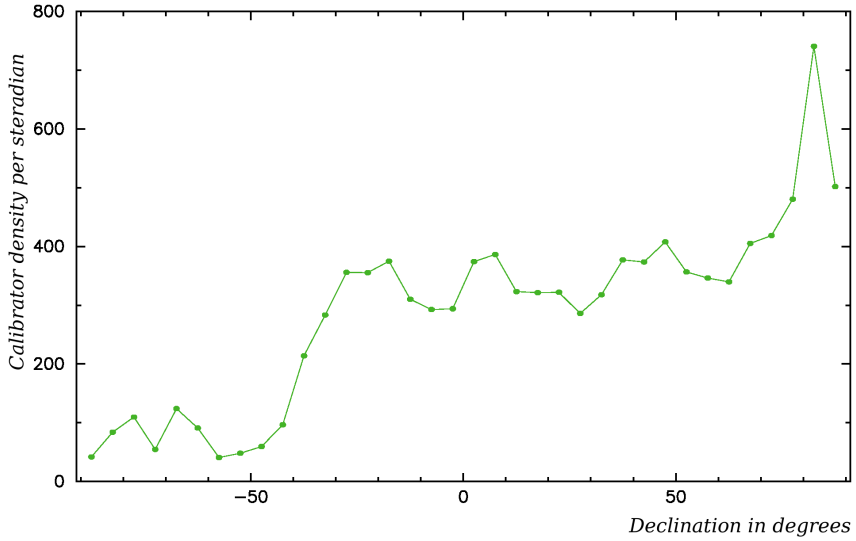
In order to address the problem of poor calibrator coverage of the southern hemisphere, we propose two 24 hour observing sessions with the LBA. We propose to observe only those sources that the VLBA cannot reach, i.e. sources in the declination zone [$-90°$, $-45°$]. We have plans to submit a separate proposal to the VLBA and to find more calibrators in the declination zone [$-52°$, $-30°$].

[1] http://vlbi.gsfc.nasa.gov/astro

Table 1: Probability to find a calibrator in the disk of the specified radius at any given direction in various declination zones

Zone	2°	3°	4°
−20°, +90°	70.2%	94.1%	99.5%
−30°, −20°	64.6%	90.7%	98.5%
−40°, −30°	45.1%	75.1%	91.6%
−52°, −40°	21.5%	42.3%	61.2%
−90°, −52°	21.3%	41.4%	61.1%

Figure 1: Calibrator source density per steradian as a function in various declination zones



4 Past observations

On 2007.06.24 a 12 hour geodetic experiment v230, using ATCA, Mopra, Ceduna, Hobart, Parkes, Seshan, and Hartrao was observed. The goal of that experiment was to determine accurate positions of ATCA, Mopra, Ceduna with centimeter level of accuracy. In addition to geodetic sources, five new sources were scheduled in this experiment. As of time of writing, 2007.12.12_21:00 UTC, the experiment is being correlated in Bonn. Fringes have been found at all 28 baselines[2]. including baselines recorded with LBADR and Mark5. Using 8 hours of the data at 6 baselines that have been correlated (17% of the experiment), we have run a preliminary solution. We found that a) all group delay ambiguities with spacings 4.8077 ns were successful resolved, no outliers found, all points were used in the solution; b) position of Ceduna and Mopra were determined with precision of 10–12 cm for the vertical component and 2–3 cm for the horizontal component; c) position accuracy of two new sources J0220-6330 and J1945-5520 detected in one scan at two baselines, Ceduna/Mopra and Mopra/Hobart, was 10–20 mas. Including in analysis all 20 scheduled observations at 10 Australian baselines, will improve the position accuracy by a factor of $\sqrt{10}$, and including 9000 km long baselines with Hartrao will improve the accuracy even further.

We consider that the previous experiment has proved the concept of the proposed observations.

[2]See http://vlbi.gsfc.nasa.gov/pet/discussion/v230/ for the current status of v230 analysis.

5 Proposed observations

We propose to observe two 24 hours sessions at X-band at ATCA, Ceduna, Mopra, Hobart, Parkes, and Hartrao. All stations will be observing at 8.4 GHz at four IF channels of 16 MHz each spread over 256 MHz with two polarizations. The stations ATCA, Ceduna, Mopra will be utilizing the LBADR disk based recording system, while Parkes, Hobart, Seshan25, Hartrao will use Mark5. The data will be correlated on the geodetic correlator at Bonn. Data from ATCA, Ceduna, Mopra and Parkes will be transfered to Bonn via the network, where they will be re-written into Mark5b. This was also successfully demonstrated for v230.

We request any Tidbinbilla antenna, if available, for the improved *uv*-coverage. While the observations do not depend on Tidbinbilla, the extra baselines will improve the accuracy of the solutions. Results of these observations will be of interest for JPL for support of future interplanetary missions and for support of Plank mission.

Candidate flat-spectrum sources in the declination range of $[-90°, -45°]$ from the AT20G catalogue will be selected on the basis of their probability of being detected using the algorithm developed and successfully tested in [4]. The catalogue AT20G will provide input for that algorithm: estimates of flux densities at 8.4 GHz and spectral indexes.

We will apply the same scheduling strategy that we have successfully applied for the VLBA Calibrator Survey [2]. The sources will be observed in a sequence that minimizes slewing in two scans of 120 seconds each. Every 1.5 hours a block of 3–4 strong sources with precisely known positions and recent maps, so called tropospheric calibrators, will be observed. Tropospheric calibrators will be scheduled in such a manner that each station will observe at least one source at the elevation range of $[5°, 20°]$ (except Parkes), one source at the elevation range of $[20°, 50°]$, and one source at the elevation range of $[50°, 90°]$. The tropospheric calibrators will also serve two other goals: 1) they will tie the resulting catalogue to the ICRF catalogue; 2) they will be used as additional amplitude calibrators.

Final data analysis will be performed at NASA using Calc/Solve software program in a similar way how positions of other 3913 sources have been determined. The expected accuracy of source positions is 1–5 mas. We will be using global GPS maps for alleviation of ionospheric errors. According to our experience of processing VLBA X-band data, unaccounted ionosphere errors will set the accuracy limit of 0.5–2.0 mas depending on the ionosphere condition.

6 Outcomes

We will publish on the web positions from each epoch within 21 days upon completion of correlation. Once the full survey is complete, we will publish the full source list with flux densities and positions and make a web searchable interface to the list.

These observations will also be used for further improving site coordinates.

The full survey will certainly also spur numerous science projects, such as investigating the AT20G population or searching for specific objects such as gravitational lenses. One such example is proposal v275, a search for super-massive black holes also being submitted this term.

References

[1] Beasley, A. J. et al., ApJS, 141, 13.

[2] Fomalont, E., Petrov, L., McMillan, D. S., Gordon, D., Ma, C. 2003, AJ, 126, 2562.

[3] Petrov, L., Kovalev, Y.Y., Fomalont, E., Gordon, D., 2005, AJ, 129, 1163.

[4] Petrov, L., Yu.Y. Kovalev, E. Fomalont, D. Gordon, 2006, AJ, 131, 1872.

[5] Kovalev, Yu.Y., L. Petrov, E. Fomalont, D. Gordon, 2007, AJ, 133, 1236.