Search for more phase calibrators in the Galactic Plane at 22 GHz

1 Introduction

Nowadays, the majority of VLBI projects use phase calibrators with coordinates known at a sub-mas level. Positions of these objects were determined from analysis of dedicated VLBA observations (e.g., Petrov et al. 2006, Kovalev et al. 2007). To date, the calibrator list[1] has 3048 objects and is considered complete at a 200 mJy level of the correlator flux density for declinations $> -30^\circ$. The existence of the list of high quality calibrators with very accurate positions makes planning of observations much more efficient and easier. However, the density of calibrators is still not sufficient for finding a suitable calibrator within 1–2° of any target source, especially near the Galactic plane. To overcome this problem, a dedicated search for calibrators was conducted with VERA in 2007 (Petrov et al. 2007). During that campaign 180 new compact sources were detected, including 153 objects within 6° of the Galactic plane. However, that survey had two shortcomings. First, VERA had SEFD of 2000–3000 Jy. The probability of detecting a 100 mJy source with 120 s of integration time was about 10%; the probability of detecting a 200 mJy source was 60%. Second, that campaign was not designed for deriving source positions.

2 Our Approach

In the past, the list of bright compact sources detected at VLA and/or MERLIN served as a pool for candidates for VLBI calibrator surveys. Almost all these objects have been already surveyed with the VLBA. Since the VLBA Calibrator list is complete at the 150–200 mJy level, new calibrators are relatively faint objects. Most all-sky surveys at frequencies higher than 2 GHz are either incomplete and/or not deep enough. As a result, information about spectral indexes is sparse and unreliable. For this reason, it is more difficult to find remaining flat spectrum good candidate sources.

Our approach for a massive calibrator search is to use dedicated VLBI experiments. On 2007.11.03 a 12 hour pilot VLBI experiment, project EP062, was carried out. The goal of that EVN project was to find more calibrators at C-band observing flat spectrum sources at Ef–Jb–Tr–Mc–Nt–On. We used advantage of the high sensitivity of the EVN network that includes Effelsberg. Among 375 target sources, 330 objects have been detected, i.e. the detection rate was 88%. During 70s integration time the detection limit at the baseline Ef–Mc was 5–10 mJy depending on the elevation angle. A report which presents preliminary results from this project (Petrov & Kovalev, 2009, paper in preparation) is available at `http://astrogeo.org/calib/ep062`.

Encouraged by success pilot project EP062, we are going to exploit the technique of calibrator search surveys that was successful tested in 2007, and propose a dedicated 48 hour EVN experiment for observing a list of 613 sources at 22 GHz at Ef–Yb–Jb–Mc–Nt–On–Ro.

New calibrator candidates were found by analyzing 197 radio astronomical catalogues using the CATS database. The database includes NVSS, CLASS, CRATES (Healey et al. 2007), others. We have also used results of the recent ATCA survey at 20 GHz. Initially, we selected 1100 sources which satisfy the following criteria:

- were not observed previously with VLBI;
- galactic latitude $|b| < 6^\circ$.

[1] available at `http://astrogeo.org/rfk`

- have at least two measurements of flux density that allow estimation of their spectral index at frequencies higher than 2 GHz.
- have single-dish flux density extrapolated to 22 GHz GHz $>$ 80mJy;
- have spectral index α flatter than -0.5 ($S \sim \nu^{\alpha}$).

The majority of these sources were selected from cross-identification of NVSS and GB6 catalogues. Then we scrutinized the source spectra and rejected approximately 50% of the sources with unreliable spectra or the objects known as galactic sources. The remaining list contains 613 objects.

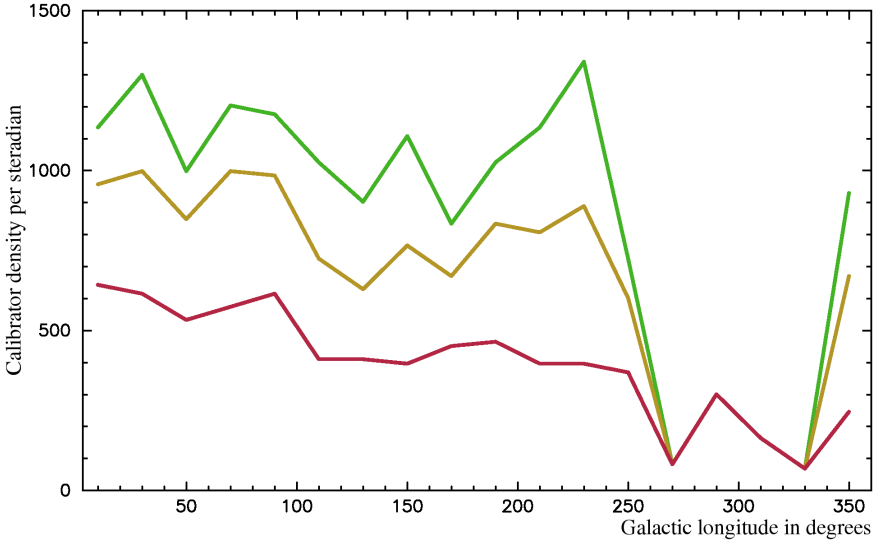
3 Goals

Our goal is to double the number of available phase calibrators in the Galactic plane. To date, 522 compact extragalactic sources within $|b| < 6^{\circ}$ were observed with VLBI. For majority of them positions were determined with the milliarcsecond level of accuracy and for some of them images are available. The proposed survey will add up to 600 more sources. This will significantly improve the probability to find a calibrator within several degrees from any target near the Galactic plane and $\delta < -40^{\circ}$. New found strong sources can be used as phase calibrators for detecting weak targets, while weak ones will provide a reference position for sufficiently strong targets, such as masers, in a relative astrometry type of observations.

The purpose of this experiment is the community service: to provide more calibrators for phase reference observations of Galactic targets, mainly water masers at the K-band. Results will also be of a particular importance for the VSOP-2 project (Tsuboi 2008) which is expected to have (*i*) fast switching capability within two degrees, (*ii*) highly sensitive K-band receiver.

Results of these observations will allows us a) to drop extended sources not suitable as calibrators; b) to make estimates of correlated flux densities and compactness of detected candidates at baselines 1–2 thousand kilometers; c) to improve coordinates of VLBI component to the 1–10 mas level.

Figure 1: The calibrator source density per steradian in various galactic longitude zones. **The lower red line** shows the current density in 2008, **the middle orange line** shows the predicted density under a conservative assumption of the detection rate of 60%, and **the upper green line** shows the predicted density assuming 100% detection rate.



4 Requested Observations and Technical Requirements

We request one 48 hour observing session. We are going to observe at 7 antennas, including Effelsberg, Yebes and Robledo. We request Robledo in order to have an extra highly sensitive antenna and ensure successful outcome of this endeavor. We include Onsala for improving the baseline coverage. Each source will be observed in two scans of 120 second long separated by approximately 6 hr in a sequence that minimizes slewing. Every 1.5 hr a burst of 4 strong compact sources with known maps (Fey et al. 2005, Jacobs et al. 2005) will be observed: two objects at elevation angles 7–30°, and two objects at elevations 50–90°. The purpose of scheduling these calibrators is a) to allow estimation of the troposphere path delay in zenith direction; b) to evaluate the atmosphere opacity; c) to improve the amplitude calibration using results of the VLA calibrator monitoring program[2] and our RATAN-600 monitoring which includes K-band (e.g., Kovalev et al. 1999).

A special consideration regarding Jodrell Bank: according to our knowledge (ref. Bob Campbell report), Jb 22 GHz receiver performance has recently significantly decreased to typical $T_{\rm sys}$ values of 200–300 K. In the case if this problem is not solved, we will consider dropping Jb from the requested network and save Mark5 disk space.

Data are requested to be recorded at 16 channels of 16 MHz each at the total bandwidth 256 MHz centered around 22 GHz, single LCP polarization, 1024 Mbit/s with 2 bit sampling. We request the data to be correlated at the Bonn correlator to allow for astrometry solutions. We request correlation with the shortest accumulation periods and the maximum number of spectral lags that the Bonn correlator is able to handle. This will provides us the largest possible fringe search window.

The expected detection limit at baselines Ef–Ro will be 15 mJy, at Ef–Yb 20 mJy, and at Ef–Mc, Ef–Nt will be 40 mJy, i.e. 5–10 times deeper than the VERA 22 GHz fringe search survey (Petrov et al. 2007). The accuracy of position determination in this experiment is estimated to be in the range of 1 to 10 mas.

Post-correlating analysis will be done with HOPS, Calc/Solve and in parallel with AIPS.

5 Deliverables

- Estimates of correlated VLBI flux density and compactness of detected sources.
- Sources positions with accuracy 1 to 10 mas.
- Positions of Jb and Ro with errors 4–10 mm.

Preliminary results will become available on-line within 30 days upon completion of correlation.

References

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[2] http://www.aoc.nrao.edu/∼smyers/calibration/