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Towards the determination of the geodetic position of non-geodetic EVN antennas

M. E. Gomez, P. Charlot, R. M. Campbell, M. Kettenis, A. Keimpema

Abstract One of the goals of the EC Horizon 2020 project JUMPING JIVE was to establish a geodetic path at the European VLBI Network (EVN) correlator at JIVE (SFXC). This was successfully implemented in 2019, and since then we have conducted two EVN geodetic-type experiments at K-band, EC065 and EC076, taking advantage of this new capability. The two experiments exercised all aspects of the new geodetic path, from correlation to data export in MK4 format and post-processing, using standard geodetic analysis tools. These were carried out in 2018 and 2020, and involved both geodetic and non-geodetic EVN antennas, including Sardinia, Torun, and the Jodrell Mark2 telescope, along with the e-MERLIN outstations and KVN (Korean VLBI Network) telescopes. The main goal is to obtain precise geodetic coordinates for these antennas. The project will also consider the results from similar experiments conducted previously, going back to 2000, to allow for the estimation of the station velocity. This contribution presents the current state of the project.

Keywords JUMPING JIVE, EVN, VLBI

1 Introduction

In the last three years, as part of the JUMPING JIVE project, the EVN software correlator at JIVE

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(SFXC) was upgraded to be able to correlate geodetic experiments. This capability allows one to obtain positions of telescopes but also Earth's orientation parameters (EOP) and source positions from SFXC through a fully-validated geodetic path. Besides the usual geodetic applications, a precise knowledge of the geodetic coordinates of the telescopes is also important for phase-referencing when observing weak sources, and therefore of benefit to astrophysics.

The upgrade of the SFXC includes the handling of sessions with sub-netting and guarantees that the correlator output data can be post-processed and analyzed in a geodetic standard way. To validate the procedure, we correlated, post-processed and analyzed an IVS-R1 session whose methodology and results were published in Gomez et al. (2019).

Once the geodetic path was successfully implemented and checked, we performed two EVN experiments: EC065 in 2018 and EC076 in 2020. EC065 has been correlated, post-processed and analyzed following the mentioned geodetic path while EC076 is currently under processing.

Although these are the first geodetic experiments correlated by the SFXC, this is not the first time that geodetic experiments are conducted with the EVN. Previous experiments include TP001, carried out in 2000 and correlated in Bonn, which provided initial VLBI coordinates for the EVN non-geodetic telescopes (Charlot et al., 2001).

As EC076 is still in the post-processing stage, we focus here on the results achieved for EC065 and the comparison of the estimated coordinates for the non-geodetic telescopes from these data with those obtained from TP001.

Exp. /Station	Bd	Cm	Da	Ef	Hb	Hh	Jb	Kn	Kt	Ku	Ky	Mc	Mh	Nt	O6	Pi	Sr	Sv	T6	Tr	Ur	Yb	Zc
EC065	✓			✓		✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EC076	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 1: Data availability for EC065 and EC076 (see the full names of EVN stations on the EVN web site at <http://www.evlbi.org>).

2 EVN observations

Since the geodetic path was established, two geodetic-type EVN experiments, EC065 in 2018 and EC076 in 2020, have been carried out. These were conducted in K-band and involved geodetic telescopes as well as non-geodetic ones, including Sardinia, Torun, the Jodrell Mark2 telescope, the e-MERLIN out-stations and the KVN antennas. The main goal of these experiments was to determine the geodetic coordinates of the mentioned non-geodetic telescopes.

EC065 was carried out on June 13, 2018, with a total of 20 telescopes scheduled, including the e-MERLIN out-stations and the Korean telescopes of Yonsei, Ulsan and Tamma. Unfortunately, reconstruction of the total delays for the e-MERLIN turned out not to be possible because of fibre-delay corrections applied to the data prior to its eventual sampling and recording (this situation has been addressed prior to EC076). This led us to abandon correlation for these stations. Additionally, two of the Korean telescopes failed to participate, hence leaving a total of 14 telescopes out of the initial 20 scheduled, with only Jodrell Bank, Sardinia, Torun and KVN-Yonsei left as non-geodetic telescopes, the latter observing for only 12 hours. During the experiment, 62 ICRF3 sources (among which 28 defining) were observed, with 478 scans scheduled over the 24-hour duration of the experiment.

EC076 was carried out on October 23, 2020, and included Tianma65 and Urumqi besides the antennas that participated in EC065, while Noto could not join. Additionally, Hobart 26, which is not part of the EVN, was also arranged to improve the geometry in the southern hemisphere. Fringes have been obtained for 20 out of the 22 scheduled antennas. This was also a 24-hour experiment and all sources observed were ICRF3 defining sources. The stations that participated in these two EVN experiments are listed in Table 1.

3 Modeling and analysis strategy

EC065 was correlated with SXFC and post-processed with HOPS following the established path. The analysis was done with VieVS (Böhm et al., 2018) in a standard way based on the modeling presented in Table 2. As only a single frequency was observed, it is mandatory to model ionospheric effects. For this purpose, we tested the use of CODE and JPL maps. The resulting differences were insignificant, which is in agreement with the findings of Lanyi et al. (2010), and the final solution was obtained by using a CODE map.

Data/Models	Comments
Ephemeris	JPL421
Earth Orientation Parameters	IERS C04
Terrestrial Reference Frame	ITRF2014
Celestial Reference Frame	ICRF3(K)
Ocean Tide Loading	FES2012
Ionospheric correction	CODE
Galactic Acceleration	YES
Tropospheric hydrostatic model	Saastamoinen
Tidal atmospheric loading	Vienna
Non-tidal atmospheric loading	Vienna
Tropospheric Mapping function	VMF3

Table 2: Models (non-exhaustive list) used for the analysis of the EC065 experiment.

The datum was defined by not-net-rotation and no-net-translation constraints with respect to ITRF2014. Source coordinates were treated as fixed, while station coordinates and EOP were estimated together with clocks and tropospheric parameters. The last three were estimated as piecewise linear functions with time interval of 24 hr for EOP (rel. constr. of $0.1 \mu\text{as}$), 30 minutes for the zenith wet delay (rel. constr. 1.5 cm) and 60 minutes for the clock interval (rel. constr. 1.3 cm). In this case we considered one rate and one quadratic term per clock.

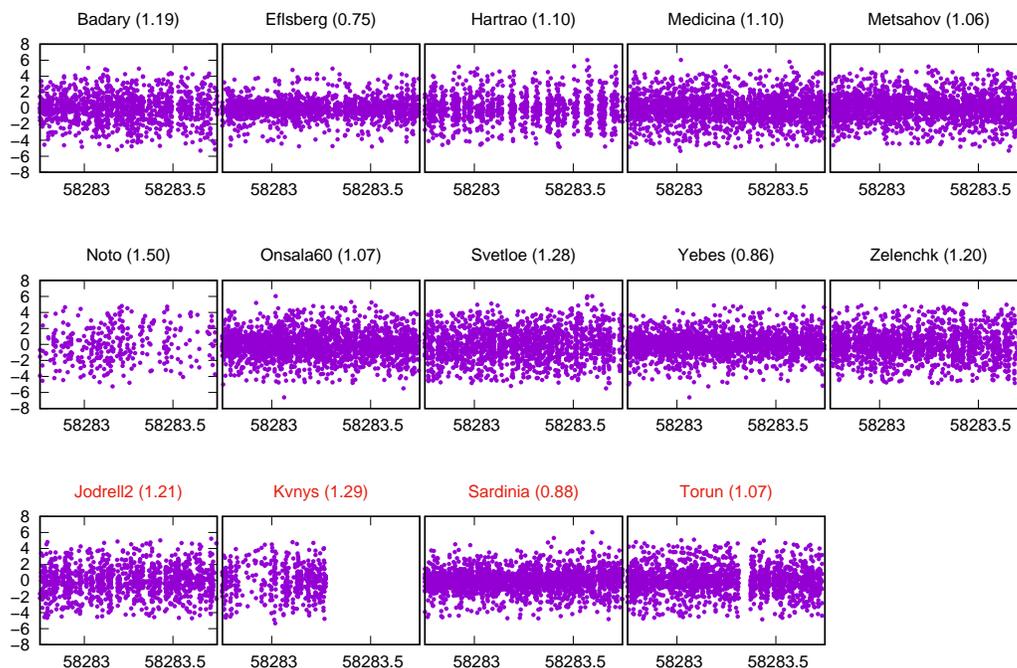


Fig. 1: Post-fit residuals per station in cm and weighted RMS in parenthesis. Each point represents an observation on a baseline that includes the mentioned station.

Station	$\sigma_{pos}[cm]$
Jodrell2	1.31
KVNYS	2.10
Sardinia	0.60
Torun	0.89

Table 3: Position uncertainties for the four non-geodetic EVN telescopes that observed in EC065.

4 Results

The post-fit residuals per station obtained after the analysis with VieVS are plotted in Figure 1. It can be appreciated that non-geodetic and geodetic antennas show residuals of the same order (about 1 cm) and as expected, the lowest values relate to the biggest antennas (Efflsberg, Sardinia and Yebes).

Regarding the coordinates of Jodrell2, KVN- YONSEI (KVNYS), Sardinia and Torun, Table 3

shows the uncertainty on the estimated positions for these stations. The values obtained are consistent with the quality of the observations and the post-fit residuals shown in Figure 1.

As mentioned in the introduction, this geodetic-type experiment was not the first one that involved EVN telescopes. Geodetic positions of Jodrell2 and Torun were first determined from a dedicated experiment run by the EVN in November 2000 (TP001, Charlot et al., 2001) with an accuracy of about 5 cm. Taking into account that almost two decades have passed since then, one can derive the velocity for Jodrell2 and Torun by comparing the results of TP001 and EC065. In order to compute these velocities, the coordinates obtained from TP001 were transformed into ITRF2014 by applying the procedure and transformation parameters given on the ITRF web page ¹. Figure 2 shows

¹ http://itrf.ensg.ign.fr/doc_ITRF/Transfo-ITRF2014_ITRFs.txt

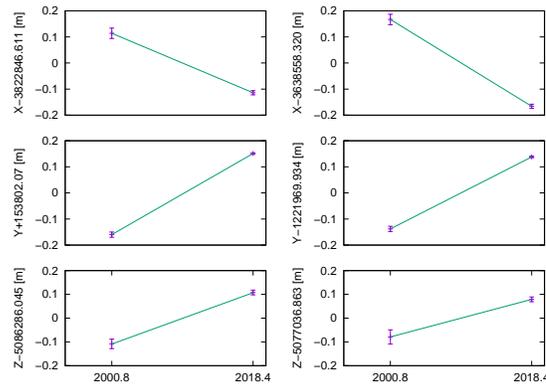


Fig. 2: Velocity components estimated for Jodrell2 (left) and Torun (right).

the (X, Y, Z) components of the velocities for Jodrell2 and Torun. The magnitude of these, 25-30 mm/yr, is in agreement with the motions derived from plate tectonic models for Europe.

5 Conclusions and Perspectives

Two non-standard geodetic-type experiments, EC065 and EC076, have been carried out with the EVN, correlated at JIVE, and post-processed by using a newly-established geodetic path developed under JUMPING JIVE. The post-fit residuals obtained after the analysis of EC065 are at the level of 1 cm for both the geodetic and non-geodetic telescopes. Position uncertainties for the non-geodetic antennas are at the same level. A comparison with the coordinates of Jodrell2 and Torun for TP001 (in 2000) and EC065 (in 2018) indicates velocities of 25-30 mm/yr. The magnitude and direction of these is in agreement with motions predicted from plate tectonic models fro Europe.

In the future, we expect to combine the results of EC065 and EC076 and to include previous experiments in the analysis.

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