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Obtaining Local-Tie Vectors from Short-Baseline Interferometry

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Abstract With the VLBI Global Observing System (VGOS) being the next step in the development of geodetic VLBI, it is necessary to connect the new VGOS network to the existing legacy S/X telescopes. At the Onsala Space Observatory (OSO), this is being done by short-baseline interferometry between the VGOS Onsala twin telescopes ONSA13SW and ONSA13NE and the legacy antenna ONSALA60.

The main aim of these sessions, referred to as ONTIE, is to obtain local-tie vectors between these three OSO telescopes that all take part in regular geodetic VLBI observations. Each ONTIE session is about 24 h long, during which all three telescopes observe simultaneously the same sources at X-band. A total of 37 ONTIE sessions have been observed since April 2019. In November 2021, the ONTIE sessions were for the first time observed with alternative observation frequency setups in order to mitigate the influence of known RFI. Additionally, scheduling was done—also for the first time—with *VieSched++* instead of *sked*.

Interesting findings of the ONTIE sessions include unexpected offsets in the results of group and phase delays, jumps in the coordinates of the twin telescopes, and apparent yearly trends that might be an artifact of unmodeled thermal expansion of the telescopes that is left in the data.

Future ONTIE sessions are envisioned to happen on a regular basis and could, as a by-product, also serve as quasar flux-monitoring sessions by investigation of the recorded system temperatures during observation.

This paper summarizes the current status and results of the ONTIE sessions.

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1 Introduction

The three antennas ONSALA60 (On), ONSA13NE (Oe), and ONSA13SW (Ow) at the Onsala Space Observatory (OSO) are regularly used for short-baseline interferometry measurements. These dedicated measurements are referred to as ONTIE sessions and have been carried out since April 2019. This kind of session is important for determining local ties for the International Terrestrial Reference Frame (ITRF) between the legacy S/X telescopes and the new generation VLBI Global Observing System (VGOS) telescopes.

Since April 2019 we carried out 37 ONTIE sessions. Throughout these, we used six different frequency setups, and we used two different software packages to schedule the experiments. The databases of the first 25 sessions (until 2020-11-13) have already been published by [1].

In Section 2 we present the setup of the 12 new sessions in 2021 and 2022. Section 3 is dedicated to the data of 30 ONTIE sessions and the discussion of the results. Section 4 gives a short look at the further scope.

2 Experiment Setup and Methods

On is a legacy S/X antenna of 20-m diameter, recording right-handed circular polarized signals. Both Oe and Ow are part of the new VGOS telescope generation and are commonly referred to as the Onsala twin telescopes. They have a diameter of 13.2 m and record linearly polarized signals (horizontal and vertical). All three telescopes share the ability to observe in X-band; ONTIE sessions make use of the 8–9 GHz frequency range. The baseline between the twin telescopes Oe and Ow is about 75 m long, and their distance to On is about 470 m and 550 m, respectively (cf. Figure 1).

All sessions were scheduled with *sked* [2], except for the three latest ones in November 2021 (on1323, on1324, and on1325), which were scheduled with *VieSched++* [3]. We chose the radio sources for the ONTIE sessions from the list which currently serves as the radio source catalog for the IVS operational VGOS series (VO). In addition to the individual horizon mask of each telescope, we set a cut-off angle of 5°. The session length was always 23 h or 24 h, with a minimum duration of 30 s per scan. The last three sessions (November 2021) are an exception as the minimum scan length was reduced to 10 s. Figure 2 shows an exemplary sky plot of observed sources during a 24 h ONTIE session.

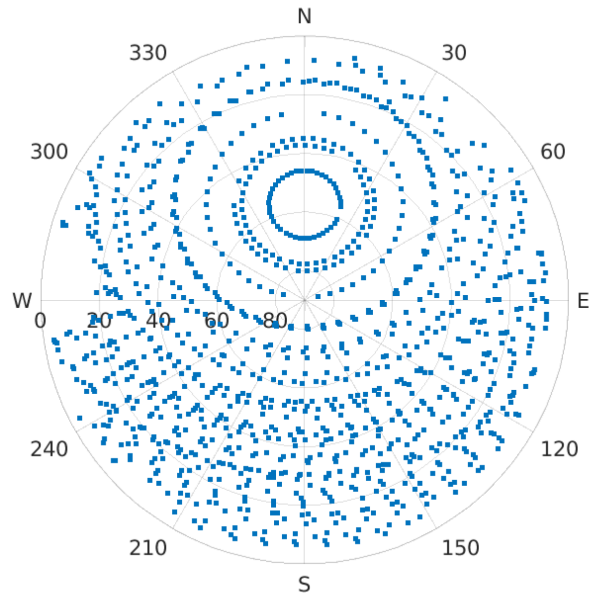

Fig. 2 Sky plot of the 23-h ONTIE session on1325 (2021-11-21) for ONSALA60, including 55 sources to which 1,133 scans were observed.

Fig. 1 The telescopes On, Oe, and Ow at the Onsala Space Observatory.

We observed on eight channels with 32 MHz bandwidth each, and the frequency setup for the new sessions presented here corresponds to configuration C. For the latest three sessions in November 2021, three different setups were used (see Table 1). These configurations D–F aim at avoiding local Radio Frequency Interference (RFI) and are based on short-term local RFI measurements. RFI is one of the biggest issues in VLBI, as strong artificial signals impede the observation of the much weaker astronomical signals and can even damage the receivers. Concerning the choice of observation frequencies, in particular for the new VGOS network or global campaigns designed for specific purposes, the schedulers clearly benefit from knowing the local RFI situation at each station.

The RFI recordings at OSO were carried out with a spectrum analyzer in max-hold mode, i.e., the maximum occurring power per frequency during the recording time will be stored. This allows very strong RFI to be seen immediately; however, it does not reveal for how long a particular RFI signal was actually present. Figure 3 shows the recorded RFI data as a blue curve: the larger the power, the stronger the RFI. We therefore

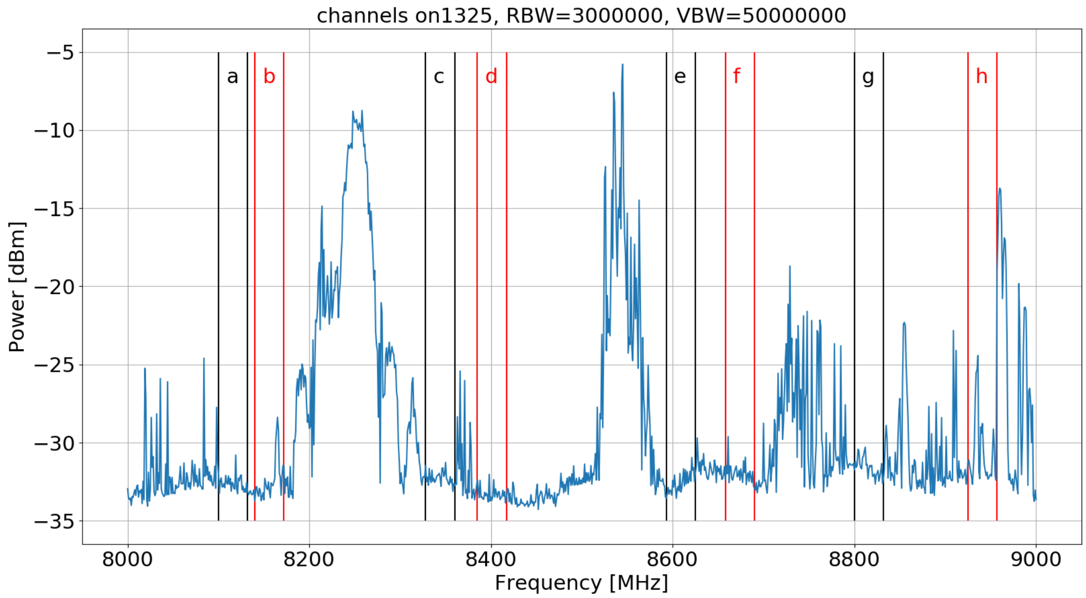

Fig. 3 Fourfit channels a–h used during session on1325 (2021-11-21) in order to mitigate RFI influence (blue). This corresponds to configuration F in Table 1. The channels are alternately represented in black and red in order to make them more perceptible.

Table 1 List of frequency configurations in addition to [1], denoting the lower edge of each correlated BBC channel with the bandwidth 32 MHz. Frequencies given in MHz.

Fourfit channel	Conf. C	Conf. D on1323	Conf. E on1324	Conf. F on1325
a	8,244.99	8,099.99	8,099.99	8,099.99
b	8,284.99	8,139.99	8,139.99	8,139.99
c	8,384.99	8,384.99	8,384.99	8,327.99
d	8,544.99	8,544.99	8,456.99	8,384.99
e	8,764.99	8,764.99	8,799.99	8,592.99
f	8,884.99	8,884.99	8,884.99	8,657.99
g	8,924.99	8,924.99	8,924.99	8,799.99
h	8,964.99	8,964.99	8,964.99	8,924.99

aim to place our channels where the least interference occurs.

Configurations D–F were chosen on the basis of these RFI data and the technical limitations of the recording system. These technical limitations are the reason why the fourfit channel d could not be moved up to a higher frequency and why there is no third channel in the range of 8300–8500 MHz. The fourfit channels a–h displayed as well in Figure 3 represent the setup for the session on1325/configuration F, for which all channels were shifted compared to the setup which had been regarded as the standard setup until then (configuration C as in [1], also listed in Table 1 here).

The correlation of the new ONTIE session data was done with DiFX, the fringe fitting with HOPS, and the analysis with ASCoT, following the same strategy applied by [1]. In particular, we used DiFX version 2.5.4 and HOPS version 3.23 to correlate and fringe fit on1323, on1324, and on1325.

3 Results

In this paper, we exclude all sessions where a phase calibration signal for On was not available, i. e. we focus on a total of 30 sessions.

Figures 4 and 5 show the phase and group delay results obtained from the ONTIE sessions, with 3σ uncertainties. The coordinates of Oe and Ow were solved relative to On; displayed are the differences in the East, North, and Up components w. r. t. the a priori coordinates. Coordinate solutions for Oe are displayed as blue circles and for Ow as yellow squares. The bars indicate the respective 3σ uncertainties. The black dashed vertical lines mark the installation (2020-05-19) and dismount (2021-03-02) of a focal finder (FF) on Oe.

The focal finder was installed in order to determine the optimal position of the receiver. Due to Covid-19 related restrictions the FF stayed on Oe much longer

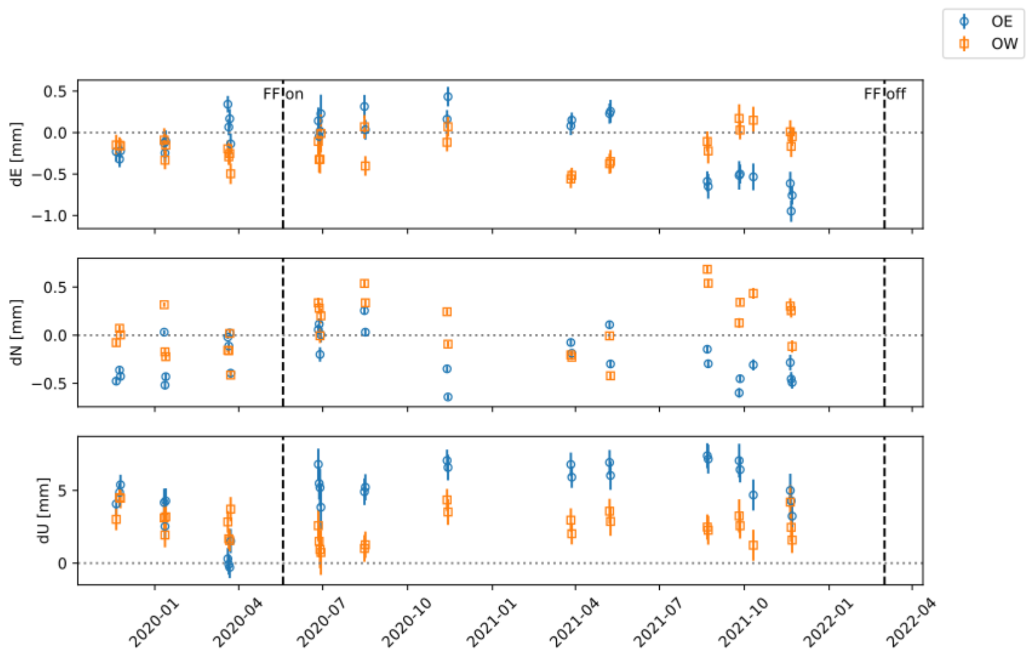

Fig. 4 Phase delay results obtained from ONTIE sessions for the coordinate solution differences w. r. t. the a priori coordinates, displayed separately for dE, dN, and dU versus the respective date of each session. Sessions without phase cal for On are excluded. Blue circles are used for Oe; yellow squares are used for Ow. Bars indicate the respective 3σ uncertainties. Dashed vertical lines mark the mount and dismount of the focal finder (FF) on Oe.

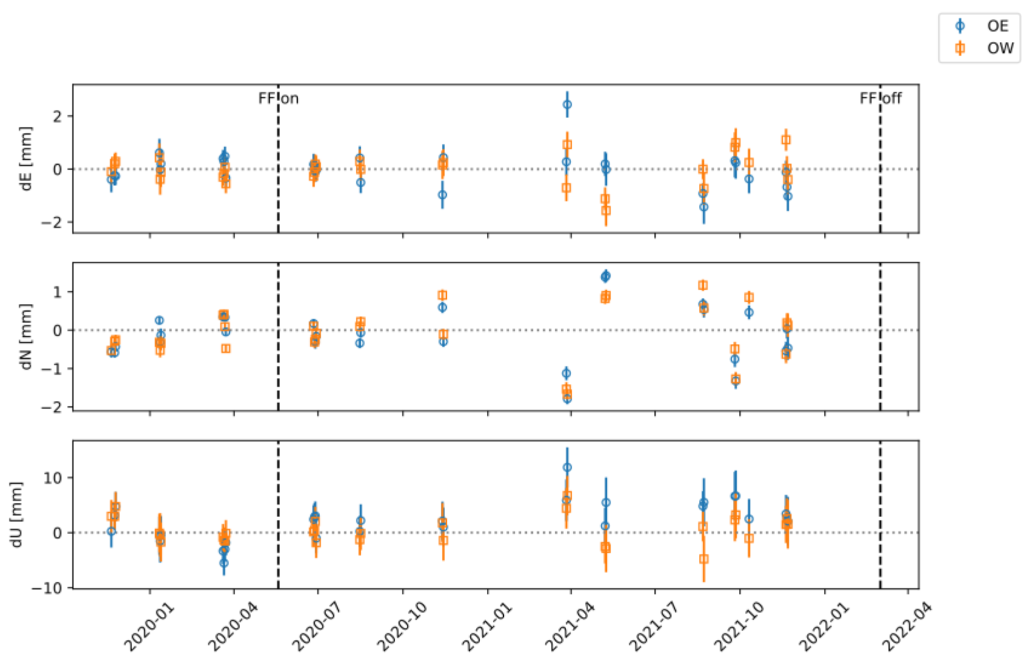

Fig. 5 Group delay results obtained from ONTIE sessions for the coordinate solution differences w. r. t. the a priori coordinates, displayed separately for dE, dN, and dU versus the respective date of each session. Sessions without phase cal for On are excluded. Blue circles are used for Oe; yellow squares are used for Ow. Bars indicate the respective 3σ uncertainties. Dashed vertical lines mark the mount and dismount of the focal finder (FF) on Oe.

than originally intended. After the installation of the FF on Oe, we observe an offset of roughly 4 mm between the phase delay coordinate solutions for Oe and Ow in the Up component (cf. Figure 4). An investigation of the FF following its dismount revealed that a movable component within the FF might have led to an unintended elevation-dependent effect on the observations.

Comparing the Up component solutions from phase delays and group delays (Figures 4 and 5), we observe another offset of about 3 mm between those two solutions, which seems to be of a systematic nature. This has already been noted by [1]. However, it is not yet clear what causes this offset, and it needs further investigation.

Looking at the Up components from both phase and group delay analysis, we further note a signature that could be a seasonal variation. This could be related to unmodeled thermal expansion of the telescope towers. Investigation of the tower height data and the models of all telescopes within ASCoT is currently ongoing, possibly aided by a higher repetition rate of the ONTIE experiments.

4 Ongoing Research and Further Scope

Ongoing research around the ONTIE sessions includes the search for the optimal frequency setup in order to mitigate the influence of local RFI. As a first approach, RFI has been recorded on different weekdays and at different times of the day, while Oe was running in a standard IVS VGOS session, as well as while positioning it at zero degrees elevation pointing to the north. This position is considered to be best in protecting the receiver from RFI, especially ship radar. As mentioned before, we recorded RFI in max-hold, which does not display how long a particular RFI signal lasted. We therefore aim for scan-wise RFI measurements during future experiments, so that we know their time stamp and also possibly direction.

More ONTIE sessions after the dismount of the FF on Oe will be performed and analyzed to test the hypothesis of its assumed elevation-dependent influence on the measurements. Also, experiments with the FF installed on Ow are planned, in order to investigate the expected impact of the FF.

Our further scope, besides having more and regular ONTIE sessions, includes a revision of the source list that is currently being used for scheduling and an investigation into if the position results from ONTIE experiments agree with independent classical local measurements.

Moreover, we also intend to continue using the recorded T_{sys} data for flux monitoring of the observed sources. Because this data is automatically recorded during each experiment, it is already available to us. A first analysis of these data has been carried out by [4], which revealed, i. a., significant long-term variability for some frequently used sources in IVS sessions.

References

1. Varenius E, Haas R, and Nilsson T (2021) Short-baseline interferometry local-tie experiments at the Onsala Space Observatory. *Journal of Geodesy* 95, doi:10.1007//s00190-021-01509-5.
2. Gipson J (2018) Sked VLBI Scheduling Software User Manual. Web document https://ivscc.gsfc.nasa.gov/IVS_AC/sked_cat/SkedManual_v2018October12.pdf
3. Schartner M (2021) VieSched++ VieVS VLBI Scheduling Software. Web document https://github.com/TUW-VieVS/VieSchedpp
4. Varenius E, Maio F, Le Bail K, and Haas R (2022). Broad band flux-density monitoring of radio quasars with the Onsala twin telescopes. Submitted to *Experimental Astronomy*.