Onsala Space Observatory – IVS Technology Development Center Activities during 2017–2018

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Abstract We give a brief overview of the technical development related to geodetic VLBI done during 2017 and 2018 at the Onsala Space Observatory.

1 General Information

The technical development work for geodetic VLBI at the Onsala Space Observatory (OSO) was mainly dedicated to commissioning the Onsala twin telescopes (OTT). Additional technical development concerned a new broadband feed horn and activities related to water vapor radiometry and the tide gauge station.

The main activities are summarized as follows and discussed in more detail in the subsequent sections:

- Installation and testing of the OTT DBBC3s.
- Testing the OTT CDMS systems.
- Temperature monitoring system in the OTT towers.
- Broadband feed horn.
- Water vapor radiometry.
- Tide gauge station.

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2 Installation, Testing, and Fine-tuning the DBBC3s

The two DBBC3s for OTT were delivered in March 2017 and successively installed and tested. In the following weeks and months, extensive tests were performed and improvements made in close cooperation with Gino Tuccari and Sven Dornbusch. Several upgrades of the DBBC3 hardware and software were done, and in 2018 Ed Himwich included full support of the DBBC3 in the VLBI Field System. VGOS observations were started in September 2017, and by the end of 2018 the OTT VGOS systems worked quasi-operationally. As an example, Figure 1 depicts spectra that are produced immediately after each scan in VGOS sessions and displayed on the OTT VLBI FS computers. There are spectra for all 64 channels, each one with 32-MHz bandwidth, covering the current VGOS frequency and polarization setup, as well as sampler statistics. The graphs are displayed for each scan during a VGOS session, as well as stored, and thus allow an online quality control of the ongoing session as well as a post-session identification of potential problems due to, for instance, radio frequency interference (RFI) or other problems.

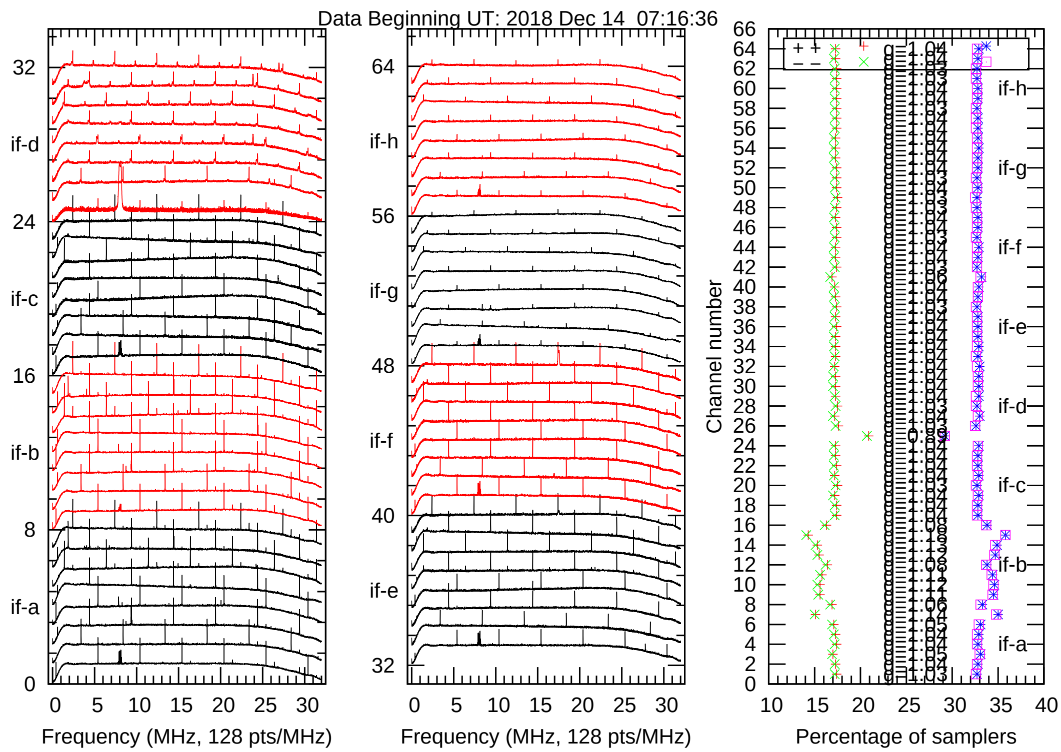

Fig. 1 Spectra of all 64 channels recorded during a VGOS scan. Black and red lines indicate H- and V-polarization, respectively. Phase-cal tones every 5 MHz are visible in all channels, but the amplitudes decrease for the higher frequencies. The sampler statistics are shown in the right graph. Disturbance due to RFI is clearly visible in the first 16 channels (if-a and if-b), which cover 3.0–3.5 GHz.

3 Testing and Fine-tuning the Cable-delay and Phase-cal Systems

Two CDMS (cable delay measuring systems) were purchased from Haystack Observatory, one for each of the OTT. Because the distance between the CDMS ground units in the maser room and the antenna units on the OTT is about 1 km, we use a fiber-based system. This solution is unique and is not used by any other observatory. As an example, Figure 2 depicts the two-way delay measurements recorded by the two systems during a VGOS test session at the end of 2018. While the data for OE show a clear relation to temperature and have an RMS of 7 ps only, the data for OW are much more noisy with an RMS of 27 ps. This indicated that the OW CDMS system was defective. It was sent for repairs to Haystack in early 2019.

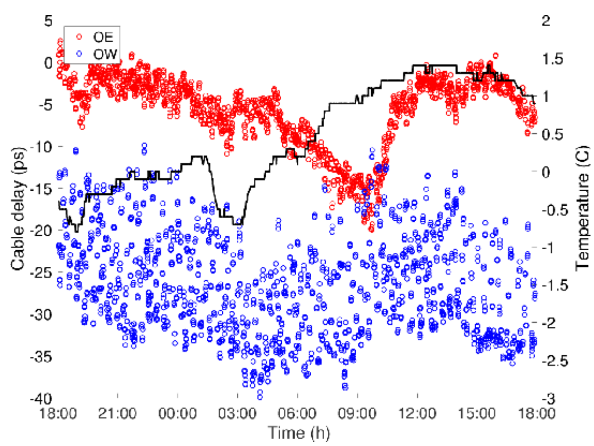

Fig. 2 Cable measurements performed with the two CDMS systems during VGOS session VT847. While the data for OE (red) show a clear relation to outside air temperature (black line, right scale) and have an RMS of 7 ps only, the data for OW (blue) are much more noisy with an RMS of 27 ps.

4 A Temperature Monitoring System for the OTT Towers

The concrete towers of the OTT were equipped with a number of temperature sensors at different levels. The two lower levels, L1 and L2, have sensors in four different azimuth directions, while the upper level, L3, has only one sensor. Temperatures are recorded with five minute temporal resolution. There are also dedicated sensors in different depths to give temperature profiles in the concrete tower. This kind of data will be used in the future to model the temperature-induced deformation of the telescope towers. As an example, Figure 3 depicts tower temperatures recorded for OTT-N during a cold and a warm day in 2018.

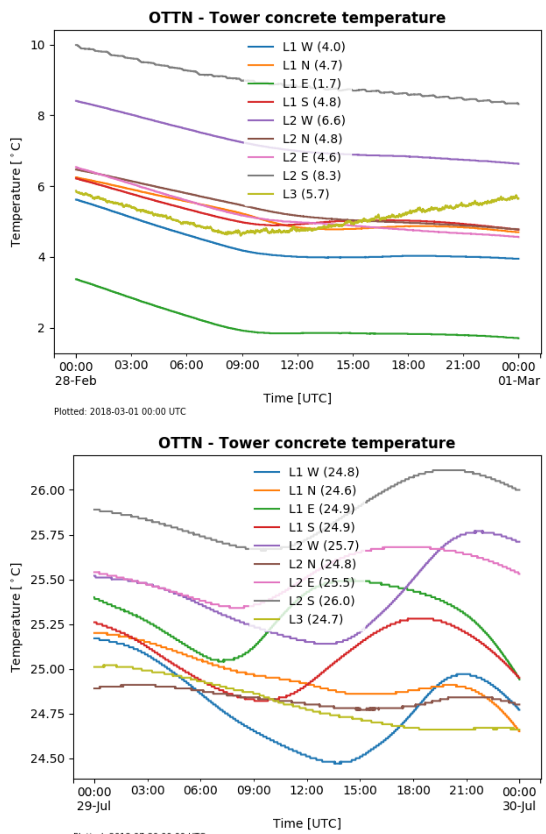

Fig. 3 Temperatures recorded in the OTT-N concrete tower on 1 March (upper plot) and 30 July (lower plot), which were the coldest and warmest days in 2018. There are temperature sensors on three levels, L1, L2, and L3, where the first two levels have sensors in four different azimuth directions. Similar plots are available for OTT-S.

5 Broadband Feed Horn

An ultra-wideband (UWB) feed horn for Band B of the Square Kilometre Array (SKA) project was designed for the frequency range 4.6–24 GHz [1]. The system performance of this UWB horn was simulated also for the OTT [2]. The results show that this horn is very well suited for the OTT. It could thus be an interesting option for VGOS in case the lower frequency band of VGOS in the future gets unusable due to RFI by, for instance, 5G mobile telephony.

6 Water Vapor Radiometry

The water vapor radiometers (WVRs) Astrid and Konrad have been operating at the observatory for approximately four and two decades, respectively. In order to secure possible future studies of the signal propagation delays caused by the wet atmosphere, the observatory has agreed to host a new prototype WVR. It is called Orwvar and has been developed by the company Omnisys Inc. in Gothenburg for the European Space Agency (ESA). Initial comparison measurements were carried out during the summer 2018 (see Figure 4). Currently we are investigating the possibility to operate Orwvar at the observatory as a long-term loan from ESA, who is the formal owner of the instrument.

7 Tide Gauge Station

The tide gauge station at the observatory has produced official data within the framework of the national observational sea level network, operated by the Swedish Meteorological and Hydrological Institute (SMHI) since mid 2015. A general description of the station was presented at the EVGA meeting in Las Palmas 2019 [3]. Motivated by the concern about the need for very accurate sea level data, at the millimeter level, the use of the very best sensors is required. During the time of operation, the root-mean-square (RMS) difference between a laser sensor and the prime sensor (the Campbell CS476, a 26-GHz radar sensor) has been about 3–4 mm. There are reasons to believe that a systematic error of the radar sensor is signal multipath in the well. In order to assess this assumption, a high

Fig. 4 The three WVRs on the 13th of July 2018. Seen from the left to the right are: Konrad, Orwvar, and Astrid. The main GNSS station ONSA is also seen, just to the right of Orwvar.

frequency radar (VEGAPULS64 operating in the 76–80 GHz frequency range) was bought. The main difference between the two radar sensors is the beam angles. The opening angle (full-width half maximum) of the VEGAPULS64 and the CS476 is 3° and 8°, respectively. The electronic laboratory staff has not been able to detect any radiation transmitted through the concrete wall, i.e., the radars do not cause any RFI affecting the radio astronomy observations.

As an example, we present the status of a comparison of the two radar sensors and a laser sensor for the time period from 19 October to 31 December 2018. The time series are presented in Figure 5. All three of these sensors are mounted in the concrete well. We note that the large variations are determined by the local weather conditions, whereas the tidal signal is approximately 20 cm peak-to-peak. Pairwise comparisons between the sensors result in biases, as well as standard deviations (SD), of a few millimeters.

8 Outlook and Future Plans

The plan for the upcoming two years is to stabilize and optimize the OTT system for VGOS operations. This includes also a calibration of the systems.

References

1. Flygare J, Pantaleev M, Conway J, Lindqvist M, Haas R (2019). Design trade-offs in feed systems for ultra-wideband VLBI observations. In: *IVS 2018 General Meeting Proceedings*. Edited by Kyla L. Armstrong, Karen D. Baver, and Dirk Behrend. NASA/CP-2019-219039, pp. 37–41, 2019.
2. Flygare J, Pantaleev M, Conway J, Lindqvist M, Helldner L, Dahlgren M, Haas R, Forkman P (2019). Ultra-wideband feed systems for the EVN and SKA - evaluated for VGOS. In: *IVS 2018 General Meeting Proceedings*. Edited by Kyla L. Armstrong, Karen D. Baver, and Dirk Behrend. NASA/CP-2019-219039, pp. 42–46, 2019.
3. Elgered G, Wahlbom J, Wennerbäck L, Pettersson L, Haas R (2019). The Onsala Tide Gauge Station: Experiences from the first three years of operation. Poster presented at the 24th European VLBI Group for Geodesy and Astrometry Working Meeting, Las Palmas, Gran Canaria, Spain, 17–19 March, 2019. available from: `https://research.chalmers.se/publication/510200`

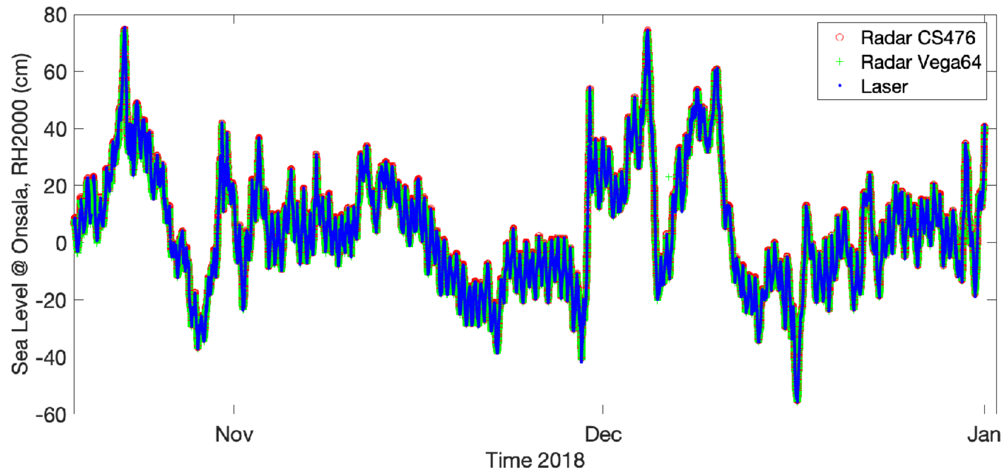

Fig. 5 Sea level recorded at Onsala.