The Onsala Twin Telescope Project

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Abstract This paper described the Onsala Twin Telescope project. The project aims at the construction of two new radio telescopes at the Onsala Space Observatory, following the VLBI2010 concept. The project starts in 2013 and is expected to be finalized in 2017.

Keywords Onsala Space Observatory, VLBI2010, Twin Telescope

1 Introduction

In September 2011 a project team consisting of Hans Olofsson, the director of the Onsala Space Observatory, Gunnar Elgered, the head of the Department for Earth and Space Sciences at Chalmers University of Technology, Rüdiger Haas, the research group leader of the Space Geodesy and Geodynamics research group at Chalmers, Mikael Lilje, the head of the Geodesy Division of Lantmäteriet, the Swedish Mapping, Cadastral and Land Registration Authorty, and Jan Johansson, the deputy head of the Department for Measurement Technology at SP Technical Research Institute of Sweden, submitted a proposal to the National Infrastructure programme of the Knut and Alice Wallenberg (KAW) Foundation. This proposal concerned a twin-telescope system for geodetic Very Long Baseline Interferometry (VLBI) at the Onsala Space Observatory, following the VLBI2010 recommendations (Petrachenko et al., 2009). The proposal was accepted in April 2012 by KAW, and a total amount of 29.7 MSEK was granted for the project.

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2 The Onsala Space Observatory

The Onsala Space Observatory (OSO) is the National Facility for Radio Astronomy in Sweden and has the official mission to support research within radio astronomy and geosciences. The observatory was established in 1949 and is located at Råö on the Onsala-pensinsula at the Swedish West coast, about 40 km south of Gothenburg. Onsala belongs to the municipality of Kungsbacka. An aerial photo of the observatory is presented in Figure 1.

Since 1949 the observatory has been equipped with several radio telescopes of various sizes. The three existing ones today are the 25 m diameter radio telescope built in 1963, the 20 m radio telescope built in 1976, and the LOFAR station built in 2011. However, remaining parts of older telescopes, e.g. concrete foundations, are still there.

The observatory has a long and very successful record in Very Long Baseline Interferometry (VLBI) going back to 1968 (Scherneck et al., 1998). Onsala was the first European observatory to contribute to

Fig. 1 An aerial photo of Råö with the Onsala Space Observatory (Credit: Onsala Space Observtory/Västkustflyg, 2011). The white spot approximately in the center of the photo is the 30 m diameter radome that is enclosing the 20 m radio telescope.

VLBI observations (Whitney, 1974). Today OSO is contributing to observations in the European VLBI Network for Astronomy (EVN) and the International VLBI Service for Geodesy and Astrometry (IVS).

The geoscientific observations are performed using the 20 m radio telescope for geodetic VLBI, several receiving stations for Global Navigation Satellite Systems (GNSS), a superconducting gravimeter, a seismometer, a GNSS-based tide gauge, and several ground-based microwave radiometers for observations of the atmosphere (Haas et al., 2012).

3 The planned location of the Onsala Twin Telescope

The geological situation at Råö is very suitable for the construction radio telescopes since the area is dominated by bed rock of type Gneiss. A first geotechnical inspection indicated that new radio telescopes could be constructed anyywhere on the observatory premises. However, there are additional constraints. The new telescopes should be located not too far away from each other, so that they share the same atmospheric conditions, but not too close to each other either in order to avoid sky blockage. Their elevation axes should be approximately at the same height in order to guarantee equally good visibility. Furthermore, the majority of the horizon shall be free down to an elevation angle of 5°, and the existing equipment at the observatory should not be disturbed by the new telescopes. Other considerations concern the closeness to the sea, wind influence and closeness to a natural reserve in the northern part of the observatory.

Based on these considerations we located two suitable sites for the telescopes. They are in about 140 m and 210 m distance to the existing 25 m telescope and form a short east-west oriented baseline of approximately 76 m distance. Actually, the chosen places were occupied in the 1950'ies and 1960'ies by two so-called Würzburg antennas with 9 m diameter and the concrete foundations for these antennas are still there. The Würzburg antenna at the Eastern location was rebuild into a 12 m telescope in the 1960'ies. A photograph of these two antennas, taken in the 1960'ies, is presented in Figure 2. In late 1969 the 12 m telescope was unfortunately destroyed in a storm (Rydbeck, 1991).

Simulations were performed to investigate the horizon masks for the Onsala Twin Telescope. Also the impact on the horizon mask of the existing 25 m and 20 m radio telescopes was inspected. Figure 3 depicts a digital elevation model of the area, showing the location of the 25 m telescope and the planned twins, OTT1 and OTT2. The local topography is indicated by contour lines with 2 m resolution. The three telescopes are on a small peninsula that is surrounded on three sides by the sea and wetland, respectively. In about 200 to the north, there is a rocky hill with a height of more than

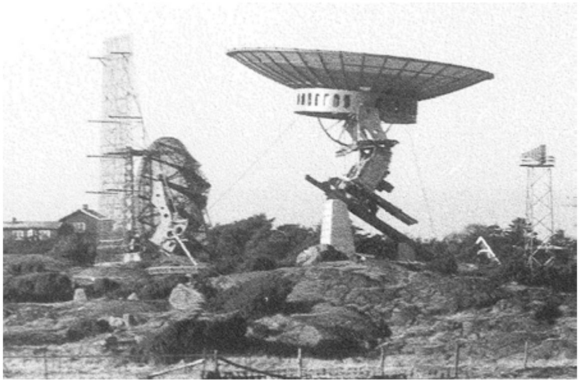

Fig. 2 Two of the parabolic antennas at Onsala in the 1960'ies. Right: The 12 m diameter telescope ("nr. 1") that was destroyed in a storm in 1969. Left: A 9 m diameter Würzburg antenna ("nr. 2"). The antennas formed a west-east baseline ("nr. 2" to "nr. 1"). The photo is taken from Rydbeck (1991).

Table 1 Distances (m) between the existing and the planned telescopes at OSO.

	25 m	OTT1	OTT2
20 m	601.1	397.3	465.3
25 m	–	209.0	136.1
OTT1	–	–	75.7

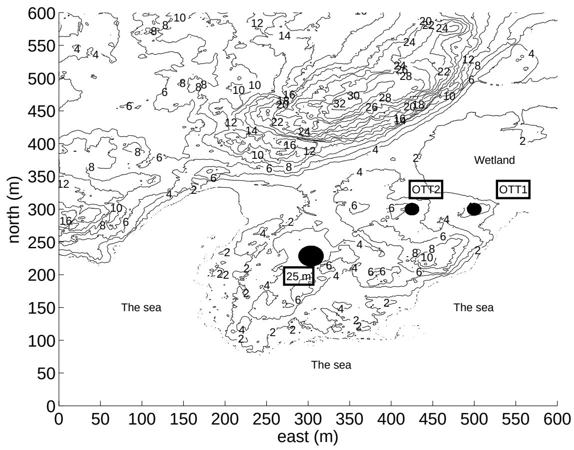

Fig. 3 Digital elevation model of a selected area of OSO, showing the location of the 25 m telescope, and the planned Onsala Twin Telescope antennas, OTT1 and OTT2. These three telescopes are on a small peninsula that is surrounded by the sea from south-west to south-east and wetland in the east. In the north, there is a rocky hill of more than 32 m height.

32 m. The foundations of the OTT twins are planned to be at a height of 5.5 m. Table 1 lists the distances between the existing and planned telescopes.

The planned OTT telescopes do not significantly impact the horizon masks of the existing 20 m and 25 m telescopes. Since the twin telescopes are not located in the same direction towards the 25 m telescope, they will not see the 25 m telescope in the same azimuth direction. This reduces the area of the horizon that is blocked for both telescopes together. Figure 4 depicts the horizon masks of the twin telescopes individually (dashed and dashed-dotted lines), and the combined horizon mask of both telescopes (solid line). The calculations were performed as seen from the lower edge of the prime reflectors, i.e. this is a kind of worst case scenario. The combined horizon of OTT is completely free above 7° elevation and blocked by less than 11 % above 5° elevation. The largest obstacle is the rocky hill towards the north of the twin telescope.

4 The environmental conditions at Onsala

The OSO site is located directly at the Swedish west coast, see Figure 1, and surrounded by the salty sea waters of the Kattegatt. It is thus experiencing a rather harsh marine climate with a high percentage of salt in the air, often westerly winds with a salty sea breeze, and salty spray in the direct vicinity of the shore. Metal constructions that are located in this environment need a very good corrosion protection to survive this harsh marine climate.

Figure 5 depicts the meteorological records of air pressure, air temperature, and relative humidity recorded at OSO during 2010–2012. The pressure variation show the frequently passing weather fronts. The annual temperature variation extends over about 40 °C, and the median relative humidity is 75 %. The extreme values that were recorded during this period are listed in Table 2.

Table 2 Information on pressure (P), temperature (T), relative humidity (RH), mean wind (MW) and gust wind (GW) recorded at the OSO during 2012–2012.

	P (hPa)	T (°C)	RH (%)	MW (m/s)	GW (m/s)
maximum	1047.1	+27.1	98.6	31.5	38.0
median	1010.8	+8.2	79.3	6.4	7.6
mean	1010.6	+7.7	77.8	5.7	8.4
minimum	962.5	−15.6	22.0	0.0	0.0

Table 3 Statistics on mean wind (MW) and gust wind (GW) for OSO during 2010–2012.

percentage of time %	MW (m/s)	GW (m/s)
99.00	≤ 16.3	≤ 20.5
99.50	≤ 17.5	≤ 22.3
99.75	≤ 19.0	≤ 24.2
100.00	≤ 31.5	≤ 38.0

Cumulative distribution functions of mean wind and gust wind recorded during 2010–2012 are pre-

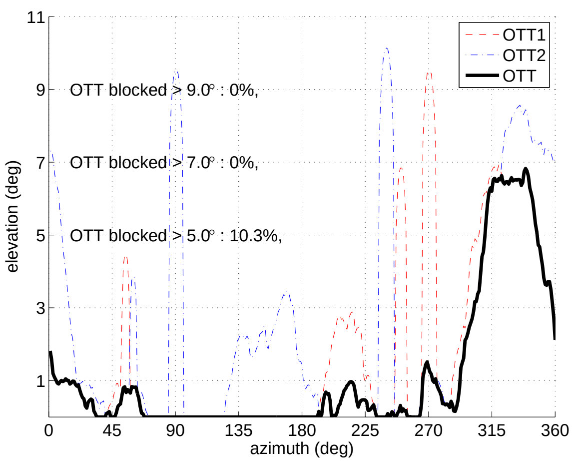

Fig. 4 Horizon masks for the individual twin telescopes, OTT1 (dashed line, red) and OTT2 (dashed-dotted line, blue), and for both OTT antennas together (solid line, black), as seen from the lower edge of the prime reflectors. The rocky hill in the north is the largest obstacle. However, the OTT horizon is completely free above 7° elevation, and less than 11 % of the horizon is blocked above 5° elevation.

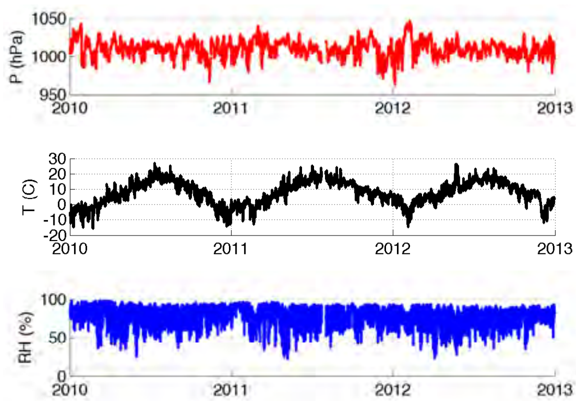

Fig. 5 Observations of air pressure (top, red), air temperature (middle, black) and relative humidity (bottom, blue) at OSO for 2010–2012.

sented in Figure 6. The standard definitions of mean wind and gust wind following the World Meteorological Organisation (WMO) are used, i.e. mean wind is the average wind speed in a 10 minute time interval, and gust wind is the maximum 3 s average wind speed during in a 10 minute time interval (Harper et al., 2010).

The corresponding wind statistics are given in Table 3. For 1 % of the time, i.e. less than 4 days per year, the mean and the gust winds exceed 16.3 m/s and 20.5 m/s, respectively. For 0.5 % of the time, i.e. less than 2 days per year, the mean and the gust winds exceed 17.5 m/s and 22.3 m/s, respectively. For 0.25 % of the time, i.e. less than 1 day per year, the mean and the gust winds exceed 19.0 m/s and 24.2 m/s, respectively.

A rose diagram of mean wind directions and mean wind speeds that were recorded during 2010–2012 is presented in Figure 7. The predominant wind direction at OSO is west-south-west where also the stronger wind speeds are observed. Wind from north-east is very seldomly exceeding 10 m/s wind speed.

5 Status and Outlook

The request for the OTT building permit has been submitted to Kungsbacka municipality in December 2012, together with the request for an exemption from the law for shoreline protection (i.e. permit of constructions within 300 m from the shoreline). In early April 2013 both request were approved by Kungsbacka municipality. However, the authorities of the county of Halland, to which Kungsbacka and Onsala belong, decided to appeal the decision of Kungsbacka municipality to grant exemption from the law for shoreline protection.

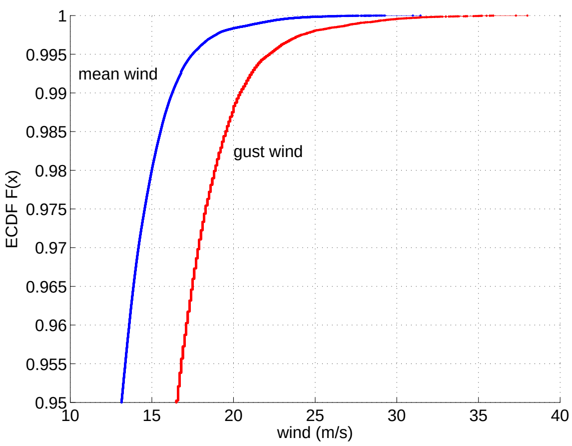

Fig. 6 Cumulative distribution functions of mean wind (blue) and gust wind (red) observed at OSO during 2010–2012.

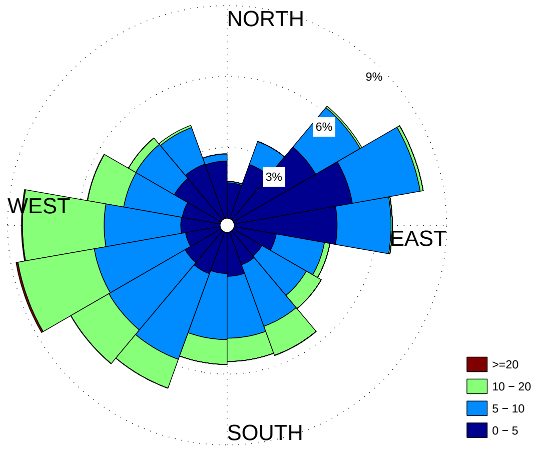

Fig. 7 Rose diagram of the mean wind direction and speed recorded at OSO during 2010–2012. Mean wind speed is represented in four colour coded groups: 0–5 m/s (dark blue), 5–10 m/s (light blue), 10–20 m/s (green), and > 20 m/s (red).

The county's environmental department inspected the planned construction sites and concluded that the eastern location (OTT1) is close to wetlands where waders were seen, in particular the Northern Lapwing (*vanellus vanellus*). According to the county's environmental department could OTT1 disturb the breeding of waders in the area. Furthermore, there are plans by the county to include the wetlands in a natural reserve. Thus, in June 2013 the county of Halland withdraw the exemption from the law for shoreline protection for OTT1.

The Onsala Space Observatory will appeal against the county's decision and thus filed an official complaint. A first meeting with lawyers will take place in late summer. Currently it is hard to foresee by how long the Onsala Twin Telescope project will be delayed, but we expect at least 6 months of delay.

Meanwhile, we are preparing the procurement papers for the antennas, so that the documents can be sent out as soon as the legal case with the county of Halland is solved. The procurement papers will basically follow the VLBI2010 recommendations (Petrachenko et al., 2009). The main features that will be required can be shortly summarized as:

- the sensitivity of each system must be better than 2000 Jy for broadband observations over 2–14 GHz
- the antennas must be fast moving and of at least 12 m diameter
- the antennas must be mechanically stiff with a good control on thermal and gravitational deformations
- the antennas have to be well suited for the harsh environmental conditions at Onsala and have to allow 24/7 operations.

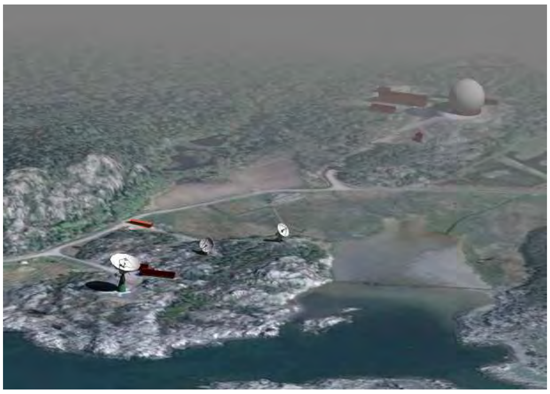

Fig. 8 An artist's view of the future Onsala Twin Telescope, together with the 25 m telescope (foreground, left) and the radome enclosed 20 m telescope (background, right).

Table 4 Expected time line of the OTT project.

2013	Approvement of building permit and exemption from the law for shoreline protection.
	Procurement process and contract for the antennas.
2014	Construction of foundation and infrastructure.
	Procurement process and contract for the signal chain.
2015	Delivery and installation of the antennas.
	Establishment of a local survey network.
2016	Delivery and installation of signal chain and electronics.
	First system tests, and local survey work.
2017	Inauguration of the Onsala Twin Telescope.
	System tests and test observations.
	Transition to regular operations.

Once the procurement for the antennas has been completed and contracts have been signed, we will continue with the procurement process of the signal chain. We also will start the preparations for the actual installation of the antennas. The expected time line of the OTT project is given in Table 4. An artist's view of the future Onsala Twin Telescope is given in Figure 8.

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