



# EXCHANGE OF ANTENNAS ON SWEPOS FUNDAMENTAL STATIONS

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## Introduction

Between 1992 and 1996, 21 fundamental stations were established in the SWEPOS network. These pillars have been used as the carrier of the Swedish national reference frame (SVREF 99) since then. The pillars were originally equipped with Dorne Margolin choke ring antennas, either Allen Osborne (AOAD) or Ashtech antennas.

To modernise the network, truss masts were established at the same sites between 2011 and 2012. The masts were equipped with modern and individually calibrated Leica 3D choke ring antennas with belonging radomes (LEIAR25.R3, LEIT). These were capable of tracking all new GNSS signals. The goal was to switch the carrier of SVREF 99 from pillar-based to mast-based network after some years, but that has still not been implemented.

## Why did we start to exchange antennas at the pillars 2021?

It is desirable to minimise the changes of the antenna mounting at GNSS stations used for reference frames and geodynamic studies in order to get long time series without jumps. Nevertheless, in 2021 we started to exchange antennas at some pillar stations, even though they were still working. Why did we do that?

In 2021 the use of individual calibrated antennas was highly recommended by EPN. Many of the antennas at the SWEPOS pillars were pretty old and most of them were not individually calibrated. Eight of the 21 antennas (the Ashtech antennas) could not receive all signals (e.g. L5 and Galileo). Another eight antennas (the AOAD antennas) were more sensitive to noise compared to modern antennas. In addition two old antennas had stopped working recently, in 2020.

Therefore, in order to calibrate the old antennas at the other stations, before they stopped working, we decided to exchange the antennas in a more planned way.

## Strategies and plans for the pillars

The strategy was to begin with exchanging all Ashtech antennas, since they could not receive all signals. The next step was to continue with the AOAD antennas.

We wanted to change to individually multi GNSS calibrated antennas and the question was if we could buy new antennas for this purpose? As an authority we are forced to use a public procurement before buying equipment and at that moment we did not have any agreement on antennas which we thought was suitable for the fundamental stations. Therefore we decided to use antennas we already had, which were some Javad antennas (mainly JAVRINGANT\_DM), and started a relocation of some antennas already installed at class B stations. These antennas were then calibrated.

In addition, we did not want to exchange all antennas at the same time. The reason for this was to be able to determine new "high precision" coordinates for the stations. We determine "high precision" coordinates twice a year, in the spring time and in the autumn, to minimise impact from seasonal variations. For the determination in SVREF 99 we do a local fit to at least 6 close-by fundamental stations.

Therefore we decided not to change more than 4 antennas at the same time, and these 4 antennas should be well distributed all over Sweden. The plan was to do the final exchanges in spring 2023 but these exchanges have been postponed until autumn this year.

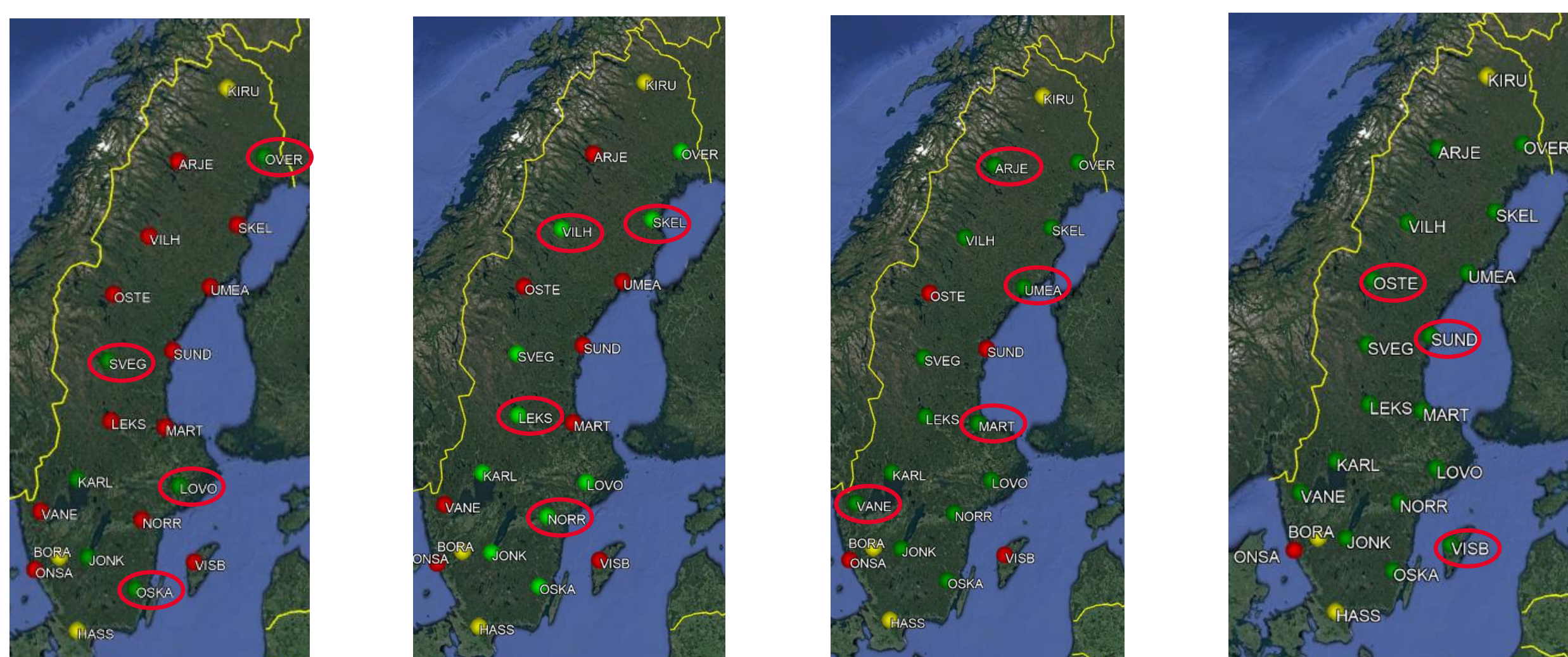


Figure 1. Autumn 2021 Figure 2. Spring 2022 Figure 3. Autumn 2022 Figure 4. Spring 2023  
Generally for all figures: ● = antenna > 20 years, ● = 10-20 years, ● = < 10 years, ○ = ant. changed

Table 1. Antennas at the pillars.

Site	Marker	Antenna type Summer 2021	Set up (2021)	Antenna type May 2023	Set up (2023)	Manufactured (year)	Calibrated (year)
ARJE	ARJ0	AOAD/M_T	OSOD 1993	JAVRINGANT_DM OSOD	2022	2010 (new element 2021) cal. 2022	
BORA	SPT0	TRM59800.00	OSOD 2020	TRM59800.00 OSOD	2020	2011, cal. 2019 (Ecco) (GPS+GLO)	
HASS	HAS0	JNSCR_C146-22-I	OSOD 2015	JNSCR_C146-22-I OSOD	2015	2005, cal. 2015 (GPS+GLO)	
JONK	JON0	JAVRINGANT_DM	OSOD 2021	JAVRINGANT_DM OSOD	2021	2014, cal. 2021	
KARL	KAD0	JAVRINGANT_DM	OSOD 2020	JAVRINGANT_DM OSOD	2020	2016, cal. 2017 (Ecco) (GPS+GLO)	
KIRU	KIR0	JNSCR_C146-22-I	OSOD 2016	JNSCR_C146-22-I OSOD	2016	2007, cal. 2008 (GPS+GLO)	
LEKS	LEK0	ASH700936D_M	OSOD 1998	JAVRINGANT_DM OSOD	2022	2014, cal. 2021	
LOVO	LOV0	ASH700936A_M	OSOD 1995	JAVRINGANT_DM OSOD	2021	2013, cal. 2021	
MART	MAR6	AOAD/M_T	OSOD 1994	JAVRINGANT_DM OSOD	2022	2009 (new element 2021) cal. 2022	
NORR	NOR0	ASH700936A_M	OSOD 1995	JAVRINGANT_DM OSOD	2022	2014, cal. 2021	
ONSA	ONS0	AOAD/M_B	OSOD 1994	AOAD/M_B OSOD	1994	1994	
OSKA	OSK0	ASH700936A_M	OSOD 1995	JAVRINGANT_DM OSOD	2021	2013, cal. 2021	
SKEL	SKE0	ASH701945C_M	OSOD 2007	JAVRINGANT_DM OSOD	2022	2016, cal. 2021	
SUND	SUN0	AOAD/M_T	OSOD 1993	AOAD/M_T OSOD	1993	1993	
SVEG	SVE0	ASH701945C_M	OSOD 2008	JAVRINGANT_DM OSOD	2021	2013, cal. 2021	
UMEA	UME0	AOAD/M_T	OSOD 1993	JAVRINGANT_DM OSOD	2022	2010 (new element 2021) cal. 2022	
VILH	VIL0	ASH701945C_M	OSOD 2010	JNSCR_C146-22-I OSOD	2022	2009 (new element 2021) cal. 2021	
VISB	VIS0	AOAD/M_T	OSOD 1993	AOAD/M_T OSOD	1993	1993	
VANE	VAE0	AOAD/M_T	OSOD 1995	JAVRINGANT_DM OSOD	2022	2016, cal. 2021	
OSTE	OST0	AOAD/M_T	OSOD 1993	AOAD/M_T OSOD	1993	1993	
OVER	OVE0	ASH700936A_M	OSOD 1995	JAVRINGANT_DM OSOD	2021	2013, cal. 2021	

## Why did we start to exchange antennas at the masts 2022?

When the masts at the SWEPOS fundamental stations were installed in 2011-2012, the idea was to switch from pillar-based network to mast-based network (to more modern and calibrated antennas), but we experienced some problems with the masts:

- Some analysis (2013-2018) showed lower rate of resolved integer ambiguities for the mast-based network compared to the pillar-based network
- The consistency between the coordinates achieved using the Bernese and GAMIT software is better for the pillar than the mast-based network (3-4 mm systematic difference in height for the masts)
- The antenna calibrations showed large variations ( $\pm 1$  cm, L3T) between individual antennas but we are not sure if the uncertainties are due to real physical differences
- Lichen growing on the Leica radomes – the surface is a bit knobbly
- The snow accumulates easier on the Leica radomes than on our OSOD radomes

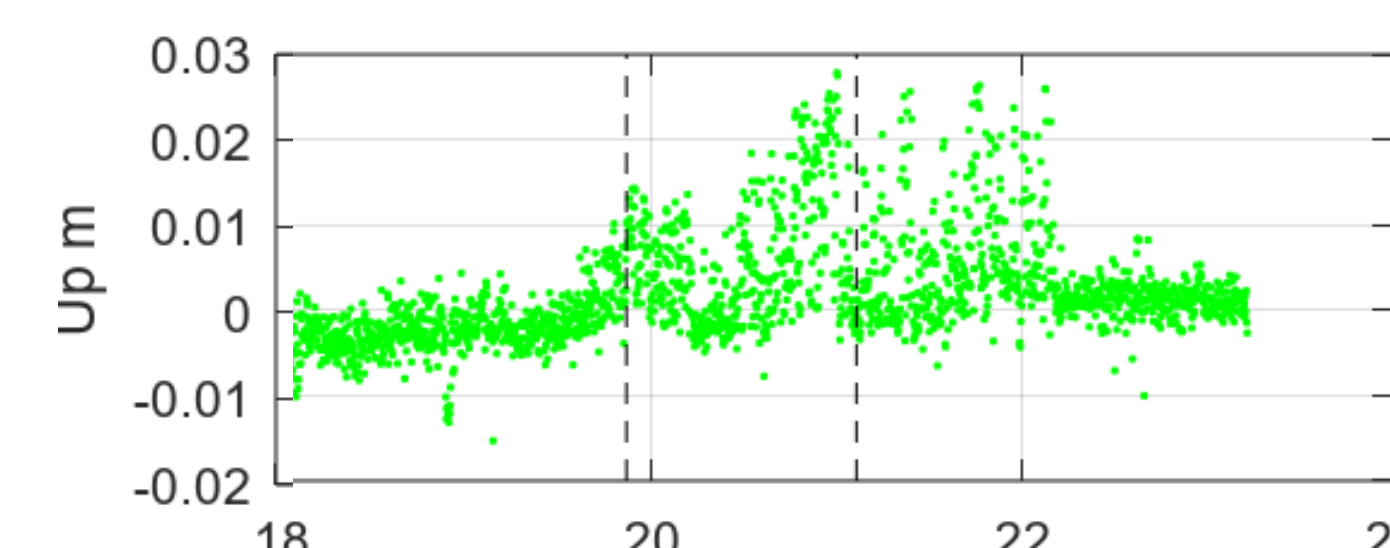


Figure 5. Time series for VANE.6 with the radome to the right. Figure 6: Radome with lichen. Figure 7: LEIAR25.R3.

## Strategies and plans for the masts

In the autumn 2022 we started to think about what we could do to resolve some of the problems with the masts, keeping in mind that all masts are EPN stations. In autumn 2022 the use of individual calibrated antennas were not required any longer for EPN stations, but type mean calibrations are needed.

To reduce snow accumulation and growing lichen we decided to change to OSOS radomes, but no type calibrations existed for the combination of LEIAR25 and OSOS. The OSOS radome is a shorter version of OSOD and is attached directly to the antenna. The radomes are hemispheric and very thin.

To obtain a type mean calibration we decided to send five LEIAR25.R3/OSOS antennas and radomes for calibration. We had two antennas available but we had to get another three as well. Therefore we had to exchange antennas at three stations. After receiving the type mean calibration the idea was to exchange just the radomes at the other stations. BUT, meanwhile we have developed and tested an antenna heater, with very promising results. Therefore we consider changing to other antennas (TPSCR.G5) with attached antenna heaters at some of the northern stations (north of LEKS and MART).

Table 2. Antennas at the masts (to the right).



Figure 6. The masts spring 2023.

- = original antenna
- = changed antenna
- = exchange 2022 (planned)

Site	Marker	Antenna type	Set up	Calibrated (year)
ARJE	ARJE6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
BORA	SPT7	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
HASS	HAS6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
JONK	JON6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
KARL	KAD6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
KIRU	KIR8	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
LEKS	LEK6	LEIAR20 LEIM	2022	Not calibrated
LOVO	LOV6	TPSCR.G5 OSOS	2022	Calibrated 2021 w/wo OSOS
MART	MAR7	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
NORR	NOR7	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
ONSA	ONS1	LEIAR25.R3 LEIT	2012	Calibrated 2011 (GPS+GLO)
OSKA	OSK6	TPSCR.G5 OSOS	2023	Calibrated 2021 without radome
SKEL	SKE8	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
SUND	SUN6	LEIAR20 LEIM	2022	Not Calibrated
SVEG	SVE6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
UMEA	UME6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
VILH	VILH.6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
VISB	VISB.6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
VANE	VAE6	TPSCR.G5 OSOS	2022	Calibrated 2021/2022 w/wo OSOS
OSTE	OST6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)
OVER	OVE6	LEIAR25.R3 LEIT	2011	Calibrated 2011 (GPS+GLO)

To have the impact of the OSOS radome well documented we have had some antennas at calibration, both with and without the OSOS radome attached. The comparison between using NONE and OSOS can be seen in table 3, 4 and 5.

The influence from the OSOS radome is very small for the Javad and Topcon antennas. For the LEIAR25 antennas the differences are larger. You can expect larger differences because the antenna is pyramidal and the antenna element will not be centric inside the hemispheric radome. Although we expected the differences to be a bit smaller. This means that we can not consider the combination LEIAR25 + OSOS as NONE as we can with the other antennas. We will have to use the type mean calibration.

Table 3. OSOS vs NONE, JAVRINGANT\_DM.

JAVRINGANT_DM Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°	0.2	-0.4	0.6
L3, 25°	0.4	-0.5	0.9
JAVRINGANT_DM Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°	0.2	-0.3	0.5
L3, 25°	0.2	-0.2	1.1
JAVRINGANT_DM Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°	0.2	-0.2	1.3
L3, 25°	0.2	-0.2	2.6
JAVRINGANT_DM Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	-0.45	-0.30	2.57
L3, 25°(GPS)	-0.11	-0.64	7.56
L3, 3°(GNSS)	-0.92	-0.28	1.30
L3, 25°(GNSS)	-0.98	-0.63	4.41
JAVRINGANT_DM Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	-0.26	0.94	0.79
L3, 25°(GPS)	-0.47	1.80	-0.74
L3, 3°(GNSS)	-0.29	-0.57	2.57
L3, 25°(GNSS)	-0.57	1.43	6.19

Table 4. OSOS vs NONE, TPSCR.G5.

TPSCR.G5 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	0.24	-0.75	0.25
L3, 25°(GPS)	0.13	-1.24	4.53
L3, 3°(GNSS)	0.44	-0.57	2.11
L3, 25°(GNSS)	0.67	-0.93	9.38
TPSCR.G5 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	-0.08	-0.32	1.79
L3, 25°(GPS)	-0.02	0.10	4.55
L3, 3°(GNSS)	0.03	-0.13	3.62
L3, 25°(GNSS)	0.23	0.16	9.12

Table 5. OSOS vs NONE, LEIAR25.R3.

LEIAR25.R3 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	-0.25	0.20	-10.92
L3, 25°(GPS)	-0.10	0.37	-25.03
L3, 3°(GNSS)	0.14	0.23	-7.20
L3, 25°(GNSS)	0.88	0.32	-12.29
LEIAR25.R3 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	-0.79	0.13	-12.94
L3, 25°(GPS)	-1.22	0.30	-27.42
L3, 3°(GNSS)	-0.45	0.07	-11.98
L3, 25°(GNSS)	-0.44	0.16	-23.79
LEIAR25.R3 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	-0.18	-0.14	-10.84
L3, 25°(GPS)	0.15	0.46	-26.67
L3, 3°(GNSS)	-0.10	-0.03	-11.29
L3, 25°(GNSS)	0.32	0.47	-25.25
LEIAR25.R3 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	0.19	0.25	-12.67
L3, 25°(GPS)	0.71	0.80	-20.23
L3, 3°(GNSS)	0.31	0.27	-9.81
L3, 25°(GNSS)	0.92	0.67	-10.37
LEIAR25.R3 Antenna	$\Delta N$ [mm]	$\Delta E$ [mm]	$\Delta H$ [mm]
L3, 3°(GPS)	0.10	0.21	-8.73
L3, 25°(GPS)	0.41	0.23	-16.43
L3, 3°(GNSS)	0.02	-0.16	-10.24
L3, 25°(GNSS)	0.17	-0.31	-20.20