

## Actual Results of the Local Survey at the FS-Wetzell

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### Abstract

The local survey performed on a Fundamental Station (FS) has two objectives:

- to provide precise ties between the reference points of the space technique systems,
- to monitor changes in the local positions, e.g. due to local movements or instabilities.

At the FS-Wetzell local geodetic networks have been established in order to derive the excentricity vectors and to monitor the stability. The networks have been observed periodically. This paper summarizes the results of the observations and show measurements of seasonal variations in height of the VLBI reference point.

### 1. Local Survey - General Remarks

The collocation of different space techniques (VLBI, SLR, LLR, microwave techniques (GPS, GLONASS, DORIS, PRARE)) at Fundamental Stations enables to make use of the different sensitivities e.g. on the gravity field, center of mass, Earth rotation, etc.. The key for the combination is the knowledge of the local excentricities, which have to be derived from a local survey. A major task for the survey is the determination of the invariant point for the space technique system. The definition of the invariant point or of the reference point e. g. for a VLBI-radiotelescope or for a SLR/LLR telescope is the intersection of the azimuth axis with the elevation axis. In general the intersection point is physically not available and a direct access is not possible. 3D-coordinates for the reference point have to be derived by fixed survey markers close to the invariant point. The motion along both axis, azimuth and elevation axis, moves the marker on a sphere. The center of the sphere is the invariant point and has to be determined by the observation of discrete marker locations. The observation of the survey markers fixed on the telescope has to be carried out with reference to fixed ground markers of a local survey network. Important for the determination of local ties is a local survey network which consists of geodetic markers in stable monuments. Periodical observations will indicate local movements, which can result from instable monumentation or real local movements.

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## 2. Required Information

For all network points and system reference points coordinates can be derived from the local survey. Coordinates are dependent on the reference system, in which they are evaluated in. Coordinate differences, if the network is correctly orientated to the north, are invariant to the reference system. It is preferred and recommended to provide coordinate differences with respect to a main monument. For further investigations it is important to provide standard deviations for the components or much better to provide the variance-covariance matrix, which results from the network adjustment. It has to be mentioned, that the standard deviations obtained by the adjustments are too optimistic. A realistic impression of the accuracy of the local excentricities can be derived by comparison of independent results obtained from observations at different epochs. The documentation of the results, an unambiguous description of the reference site is most important in order to avoid misinterpretations.

## 3. Geodetic Networks in Wettzell

At the FS-Wettzell various geodetic networks have been established.

- Local Network (LN) with an extension of 200m across the station area for
  - determination of the local excentricities,
  - detection of local movements,
- Small Footprint Network (SFN) with an extension of 1-4 km which is a result from the orientation network established for the 3rd. generation SLR-System,
- Footprint Network (FPN) with an extension of 30 km for
  - detection of regional movements in the area of Wettzell
- Gravity Network for
  - verification of height changes and gravity variations.

The networks have been observed periodically. Pillars have been constructed for the monumentation. Figure 1 shows the concrete pillar, which is founded 2m deep in the ground, by a concrete block of 1.5m x 1.5m. The pillar is shielded by a external concrete tube, to avoid expansion due to sun radiation and to avoid mechanical disturbances. On top of the pillar a force centering is fixed for the installation of geodetic measurement equipment.

The local network (LN) is shown in the figure 2. The footprint networks (SFN and FPN) are shown in figure 3.

## 4. Observations of the Network

The LN and the FPN have been observed periodically. Due construction work the network configuration changes at the different epochs. Comparable results were obtained at the last three epochs:

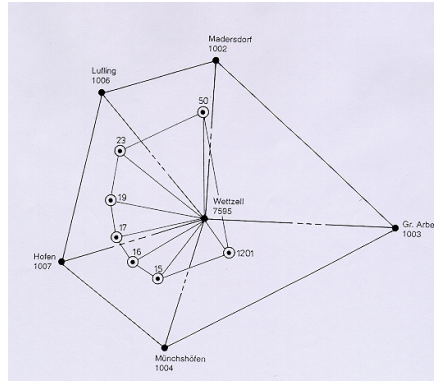
- WETTZELL 87 (Epoch 87)
  - distance measurements with GEOMENSOR (<1mm),
  - directions measured with Kern and Wild "high precision theodolites,



Figure 1. Monumentation Pillar with the force centering



Figure 2. The Local Network Wettzell



**Figure 3. Footprint Network Wettzell (SFN, FPN)**

	$sX$ [mm]	$sY$ [mm]	$sZ$ [mm]
std. dev.	0.73	0.65	0.76
max. dev.	1.01	0.74	1.10

**Table 1. Standard Deviations of the coordinates derived from GPS-observations**

- levelling with Zeiss Ni2,
- astronomical azimuth determination for the orientation,
- WETTZELL 93 (Epoch 93)
  - distance measurements with MEKOMETER ME 5000,
  - directions measured with Wild T3000,
  - levelling with Ni 002,
  - GPS observations on all points of the FPN and on 6 LN-points,
  - data and variance-covariance matrix is available,
- WETTZELL 96 (Epoch 96)
  - distance measurements with MEKOMETER ME 5000,
  - directions measured with Wild T3000,
  - levelling with Ni 002,
  - GPS observations on all points of the FPN and on 6 LN-points,
  - data and variance-covariance matrix is available.

## 5. Results of the Adjustment of WETTZELL 96

As an example the results of the epoch 96 are taken to demonstrate the accuracy which is obtained by the local survey (Lang, 1996). At first the GPS-observations have been analysed. The standard deviations of the GPS-derived coordinates (in ITRF) for the FPN-points and some LN-points are given in table 1.

	sy [mm]	sx [mm]	sh [mm]
std. dev.	0.23	0.28	0.41
max. dev.	0.53	0.88	1.75

**Table 2.** Standard Deviations of the coordinates derived as 3 D-adjustment of terrestrial observations

residuals	X [mm]	Y [mm]	Z [mm]
quadr. means	1.70	0.49	1.54
max. dev.	2.22	0.84	2.56

**Table 3.** Residuals after 7P-Transformation LN to FPN

The terrestrial observations (distances, directions, levelling, geoid) carried out in the LN have been used for a 3D-adjustment. The standard deviations obtained from the adjustment are shown in table 2.

Both networks have been combined using the identical points where GPS observations had been carried out. The transformation, employing identical points and the variance-covariance-matrices, resulted in a set of coordinates or coordinate differences in the three dimensional reference frame (ITRF). The mean residuals obtained for the identical points are summarized in table 3.

## 6. Results of the Deformation Analysis

The results and observations from the Epoch93 and Epoch96 have been used for a deformation analysis (Lang, 1997). For Epoch 87 neither raw observations nor the variance-covariance matrix are available. A comparison of the results via a Helmert transformation was carried out by H. Lang (Lang, 1995). The results of the deformation analysis is summarized for the FPN in the table 4 and for the LN in table 5.

Concerning the results of the FPN-analysis, it could be stated that two sites show up with significant changes. Due to grown up trees in the environment of those stations the results are biased. The FPN was designed in the 70ies when GPS did not play a role. The FPN is currently redesigned for the employment of permanent GPS-observations.

Concerning the results of the LN, due to the height internal precision of the terrestrial results some points indicated significant changes of the order of 1-2mm. The changes are due to construction work on the FS-Wetzell or due to seasonal height variations (real or influenced by the external conditions). The results of the deformation analysis requires the following consequences:

- residuals  $> 2\text{mm}$ : investigate the reason for the change,
- residuals  $>1.5\text{mm} < 2.0\text{mm}$ : observe the behaviour of the site,
- residuals  $< 1.5\text{mm}$ : no action required, residuals are regarded as noise.

Point No.	residuals[mm]				remarks
	dX	dY	dZ		
1002	0.03	-2.34	0.30	2.53	no change
1004	0.76	-0.01	-0.19	0.78	
1006	-1.54	2.24	0.58	2.78	
1201	-0.14	0.11	-0.69	0.71	
<b>quadr. means</b>	<b>0.98</b>	<b>1.62</b>	<b>0.48</b>	<b>1.95</b>	
50	20.52	1.15	28.44	35.09	significant change
1003	44.34	15.18	48.25	67.27	

Table 4. Deformation analysis — footprint network

Point No.	residuals[mm]				remarks
	dx	dy	dh		
6	-0.23	-0.20	0.08	0.32	no change
11	0.17	0.02	0.39	0.42	
301	-0.07	0.08	-0.57	0.58	
501	0.25	0.07	-0.41	0.49	
801	-0.12	0.03	0.51	0.53	
<b>quadr. means</b>	<b>0.18</b>	<b>0.10</b>	<b>0.43</b>	<b>0.48</b>	
401	0.69	0.49	-2.68	2.80	significant changes
201	-0.67	0.96	0.27	1.21	
7598	-0.12	0.51	0.99	1.12	
10	-0.50	-0.43	0.85	1.08	
12	-0.20	1.08	-0.20	1.12	
101	0.47	0.38	1.64	1.74	
13	0.78	-0.22	0.49	0.94	
7596	-0.70	-0.10	2.35	2.45	
9	-0.03	-0.92	2.88	3.02	
7595	0.07	1.22	0.60	1.37	
14	-0.72	0.77	1.11	1.53	
1201	-0.14	0.22	2.27	2.28	
7597	-0.61	-0.52	2.45	2.58	
<b>quadr. means</b>	<b>0.52</b>	<b>0.69</b>	<b>1.72</b>	<b>1.92</b>	

Table 5. Deformation analysis — Local network

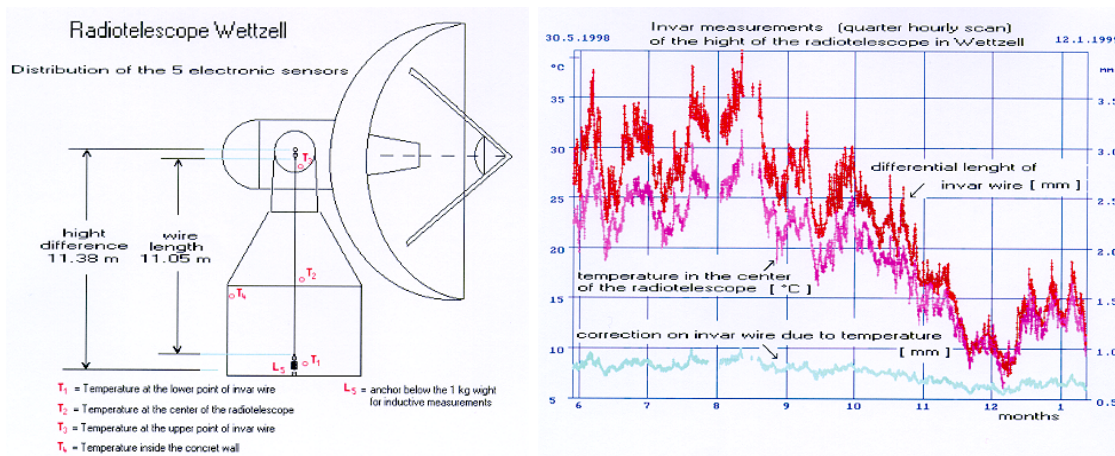


Figure 4. Scheme of the height variation measurements and results

## 7. Seasonal Variations in Height, demonstrated at the Radiotelescope Reference Point

The air temperature differences between summer and winter are in the domain of  $+30^{\circ}\text{C}$  in summer and  $-20^{\circ}\text{C}$  in winter. Due to the thermal expansion of steel and concrete the height of the telescope shows the temperature influence. At the radiotelescope the height variations are continuously monitored. Figure 4 shows the principle and results. An invar-wire is fixed close to the reference point (11,38m above the ground). A capacitive detector on the ground monitors the variations. Figure 4 shows the height variations in correlation with the temperature for the period from May 30, 1998 to January 12, 1999. The maximum variation in height was more than 3mm, which is, concerning the precision of VLBI, not negligible.

## References

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