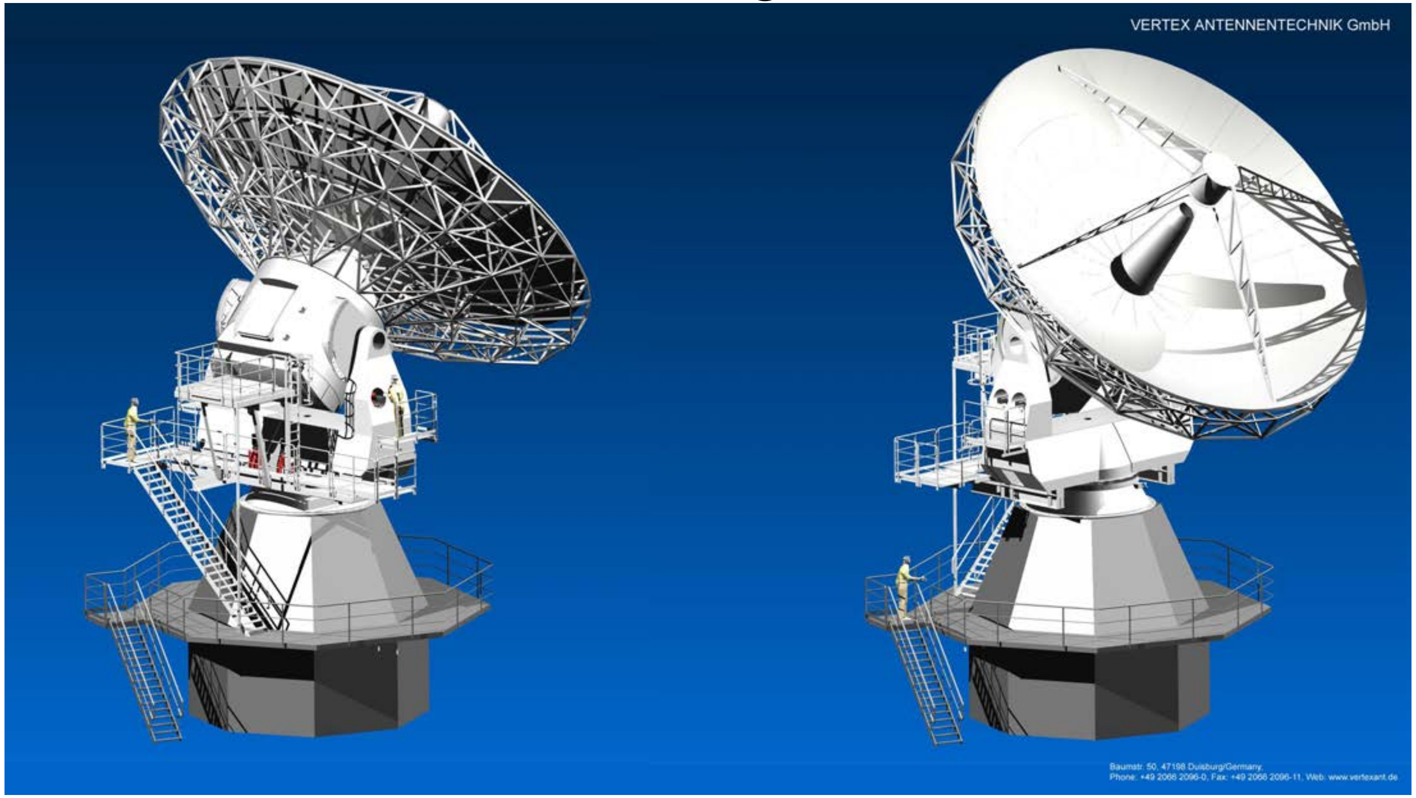
Federal Agency for
Cartography and Geodesy

The TWIN-Radiotelescopes Wettzell

Critical Design Points



G. Kronschnabl, BKG; Dr. A. Neidhardt, TUM; Dr. K. Pausch, Vertex GmbH; W. Göldi, Mirad; R. Rayet, Callisto; A. Emrich, Omnisys;

IVS WG 3 – VLBI2010: Current and future requirements
for geodetic VLBI Systems

Goals for a next generation VLBI-System:

- Determination of the relative position better than 1 mm / year
- Continuous observation of the Earth Orientation Parameters
- Very fast generation and distribution of the IVS-Products

➔ continuous, improved UT1 monitoring
➔ Improving of the Celestial Reference Frame (CRF)

Source: IVS WG3 Final Report - ftp://ivscc.gsfc.nasa.gov/pub/annual-reports/2005/pdf/spcl-vlbi2010.pdf

How to do that?

- Increasing the numbers of radio sources (up to 1000 scans/day!)
- Improvement of the Delay Observable
- Reduction von systematic errors, i.e. at the electronic devices, the antenna deformation and of the source structures
- Continuous observation rows the whole year (2 antennas)
- Improving of the network geometry
- New improved strategies at the data analysis
- Improved observation schedules
- Additional measurement system, such as a WVR
- Online data transfer via Internet
- Software correlation
- Remote observations

VLBI 2010

What are the requirements for a new observation system to fulfill the VLBI 2010 specifications?

- A fast moving antenna system with an antenna diameter of 12m or more
- A broadband receiving system at least from 2 to 14 GHz, optional a receiver at S-, X-, and Ka-Band
  - ➔ S- und X-Band compatibility (RCP)
  - ➔ stable phase centre and stable reference point
  - ➔ high antenna efficiency and low system temperature
- Improved reference and calibration systems
- New digital data acquisition systems

What does it mean, to

- **increase the number of observations means:**

- Reducing the observation time (i. e. the Integration time) needs a
- ➔ better SNR ➔ (< Tsys; > higher effective Antenna area)
- ➔ higher bandwidth (New feeds, new receivers; data boosters)
- Reducing the slewing time needs
- ➔ faster antenna drives
- ➔ more energy consumption
  ➔ a better mechanical construction
- ➔ more attrition and therefore more maintenance

- **reduce systematic errors, such as at the electronic devices, the antenna deformation and additional calibration systems:**

- ➔ better time and frequency reference
- ➔ improving of the phase delay errors, for instance at the cables
- ➔ new improved calibration systems
- ➔ additional measurement systems ➔ Water Vapor Radiometer ?

What are the key points for such an Antenna?

- Antenna diameter size 12m or more
- Fast moving antennas
- Broadband or multiband capability
- Extreme stiff reflector
- High efficiency reflector
- Low path length error
- Very good and stable reference point
- Very stabile towers
- Phase stable cables and cable wraps
- Stabile phase centre of the feed (almost frequency independent)
- Remote control
- Energy saving techniques
- Improved time and frequency reference system

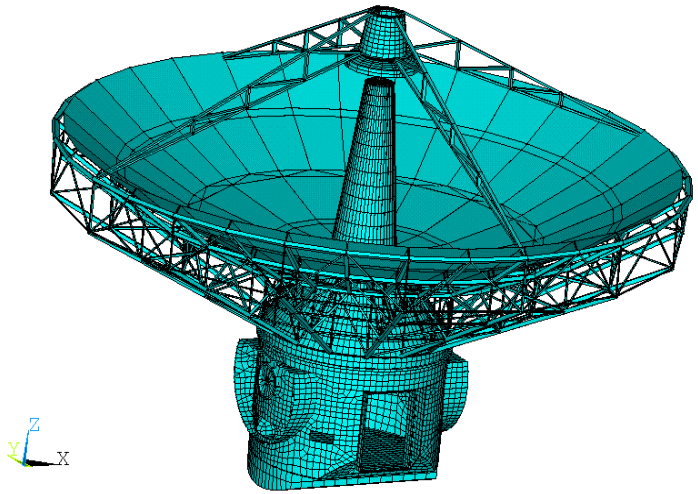
How did we realized that at Wettzell?

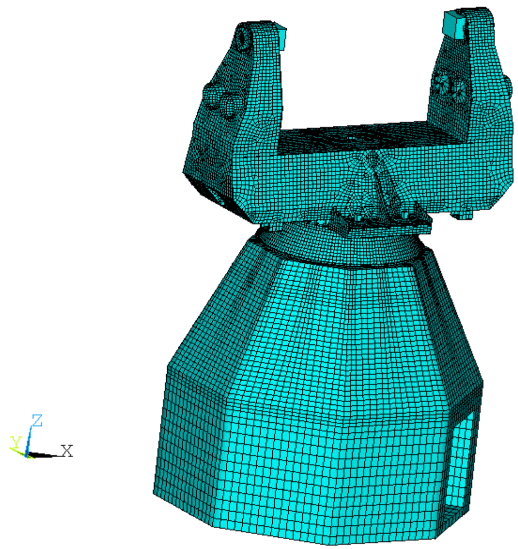
Microwave Antenna design:

- Excellent antenna efficiency by the Ringfocal Design a flare angle of about 65°
- No blockage by the Subreflector
- Broadband capability > 40 GHz
- Low ground pickup noise
- Mechanical correction of the Subreflector

Mechanical Antenne design:

- Very low Path Length Error
- Extreme stiff Main- and Subreflector,
- Extreme stiff Elevation cabin and Azimuth yoke
- Excellent Azimuth- and Elevation bearings
- High resolution hollow shaft encoder
- Very stable towers with a big basement
- Vertical and horizontal axis offset less than 5 arcsec
- Balanced antenna design with counterweights





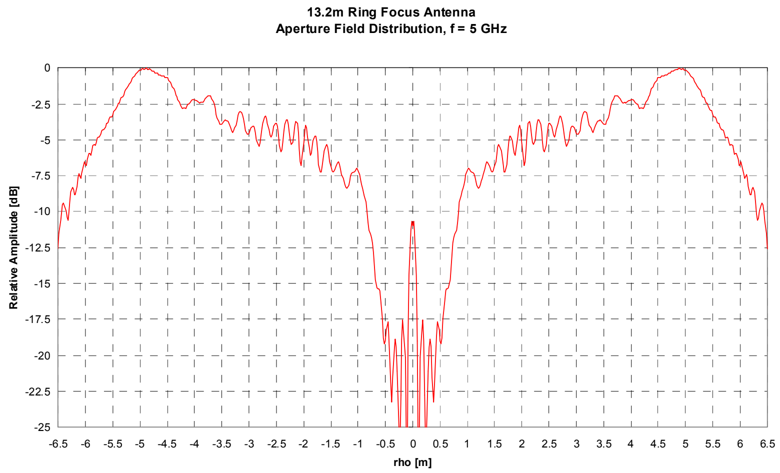
TWIN - Radioteleskop

Technical Data:

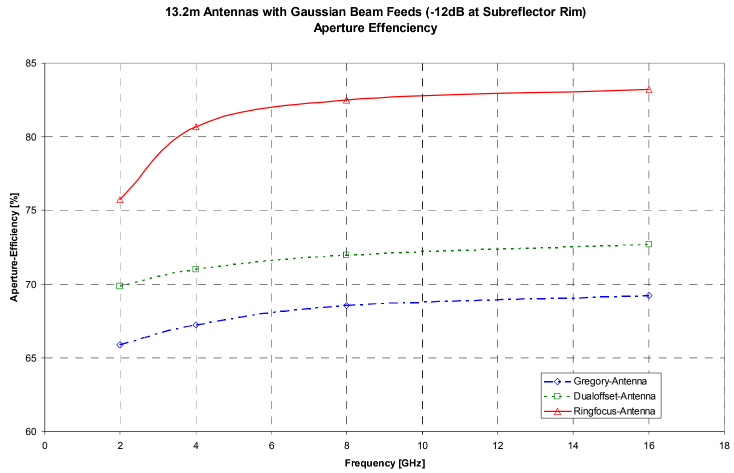
- Main reflector: 13.2m
- Ringfocal-Design
- f/D = 0.29
- Path Length Error <0.3mm
- ALMA Mounting with drive velocities of 12°/s in Azimuth and 6°/s in Elevation
- Drive range +/- 270° & 115°
- Balanced antenna design
- Excellent bearings
- 27Bit Encoder : 0.0003° resolution
- Subreflector adjustable by a Hexapod

TWIN Radioteleskop: Main reflector

Distribution of the radiated energy

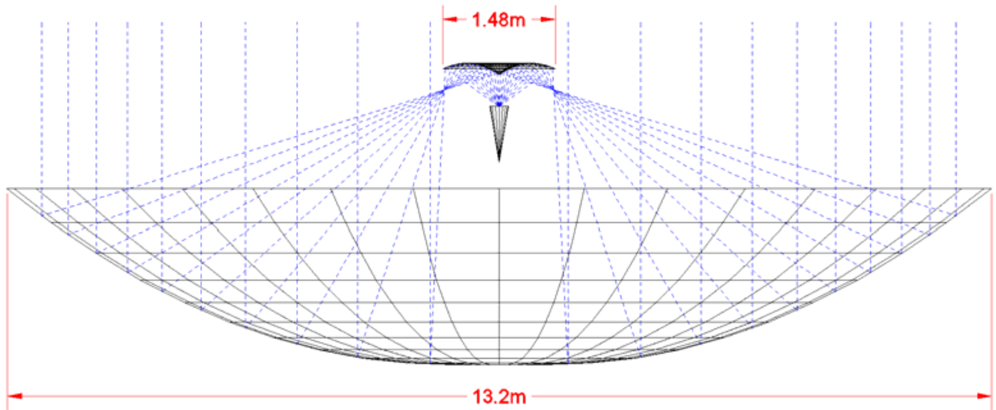


Effective beam efficiency



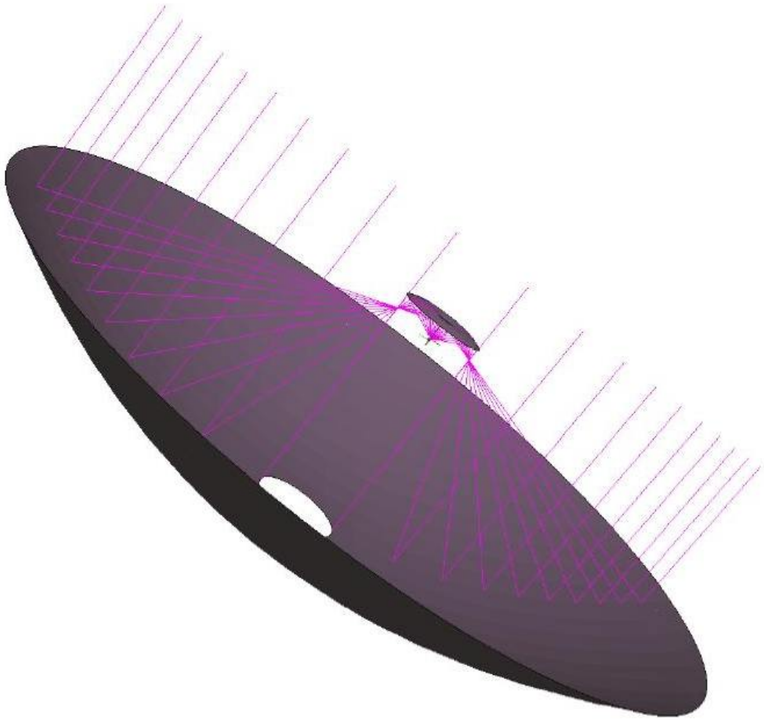
Ringfocal-Design

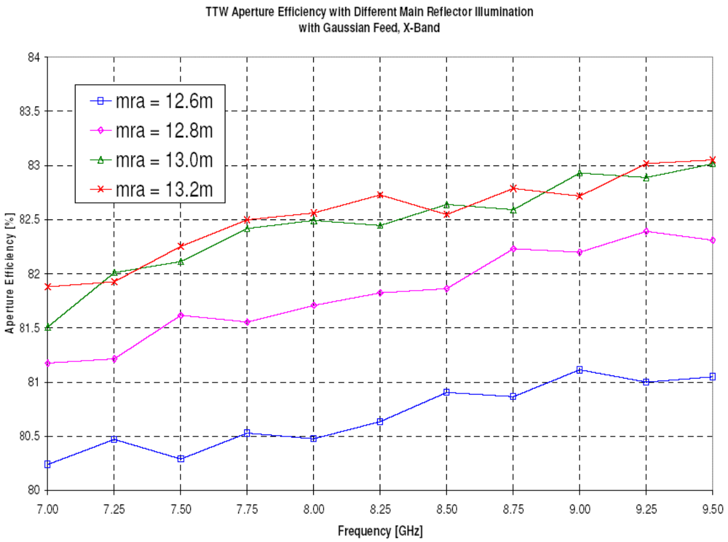
- Dual-Reflector receiving system
- optimal for large flare angles
- no blockage by the subreflector
- high illumination efficiency
- the feed horn is prevented by radiation from the sun

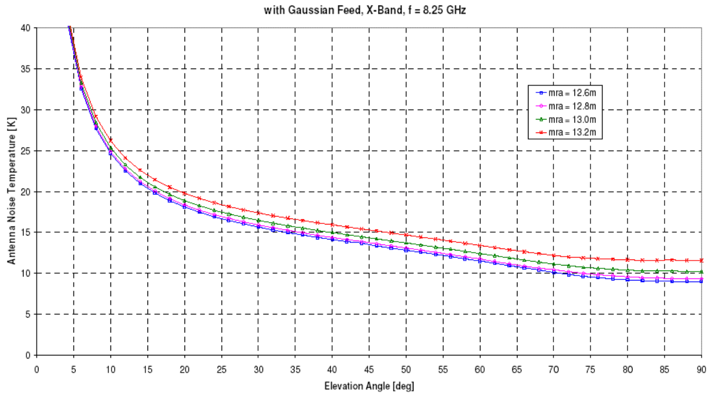


Source: Willi Göldi, Mirad; FRFF-Workshop 2009, Wettzell

Antenna efficiency and ground noise pickup







TWIN – Radioteleskop: Path Length Error

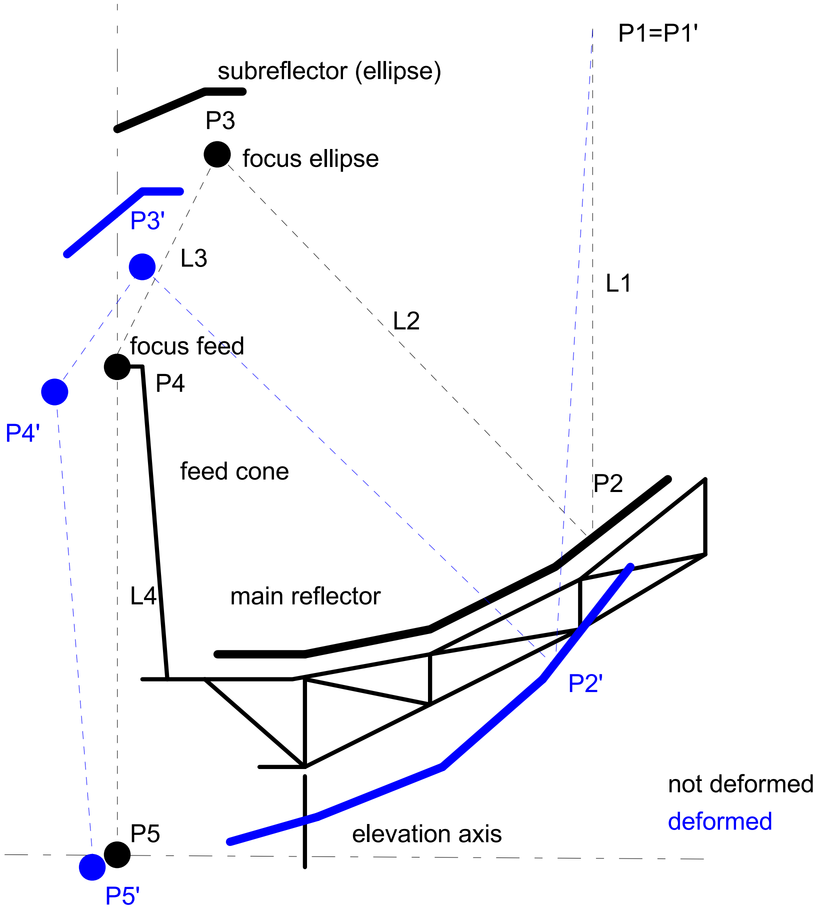
The TTW-Antenna is designed for a Path Length Error of less than 0.3mm !!

L1 = distance main axis – reflector surface
L2 = distance reflector surface – subreflector
L3 = distance subreflektor – feed focus
L4 = distance feed focus – axis intersection point

Definition: Path Length Error

- Lnot_deformed = L1+L2+L3+L4
- Ldeformed = (L1+dL1)+(L2+dL2)+ (L3+dL3)+(L4+dL4)
- L_Error = Ldeformed - Lnot_deformed

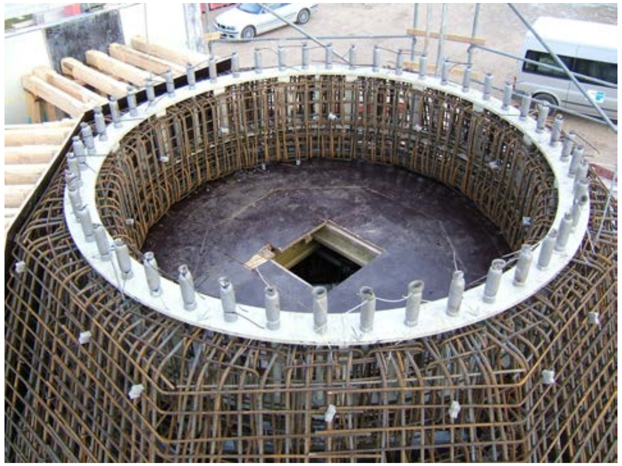
$$PathLengthError = \frac{\sum_{i=1}^{192} \left(A_i \times PathLengthError_i \right)}{\sum_{i=1}^{192} A_i}$$



Source: Vertex Design Review; Dez. 2008

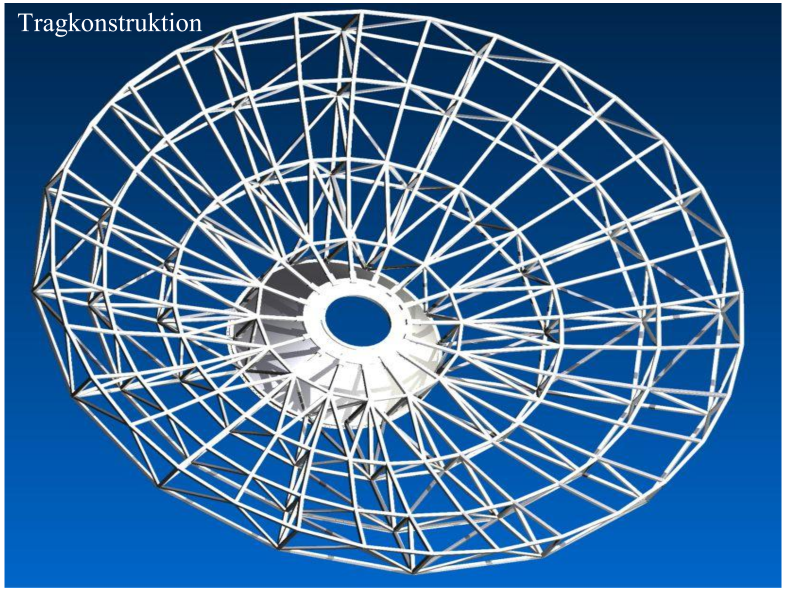
Towers for TTW

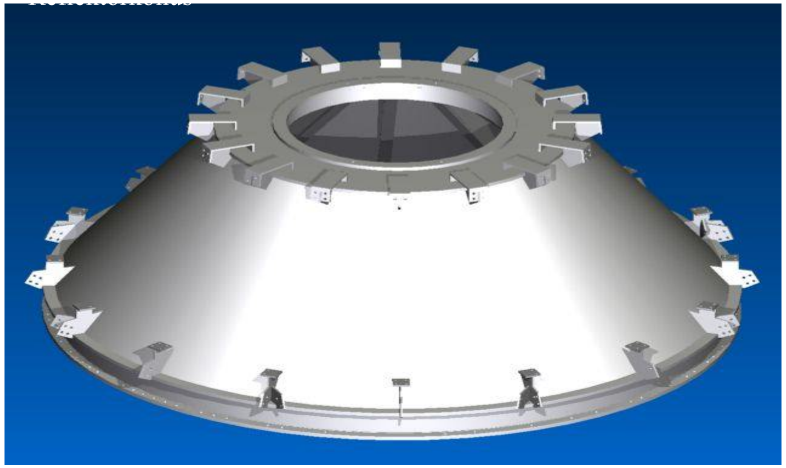
- Basement up to 6m in the ground
- Thick concret walls containing tons of steel



Zul. $\varphi_{OKT} \leq 0{,}0005\,°$	Unter Wind ≤ 40 km/h, Böen bis 50 km/h
Zul. $\varphi_{OKT} \leq 0{,}0015\,°$	Unter Temperatureinwirkung

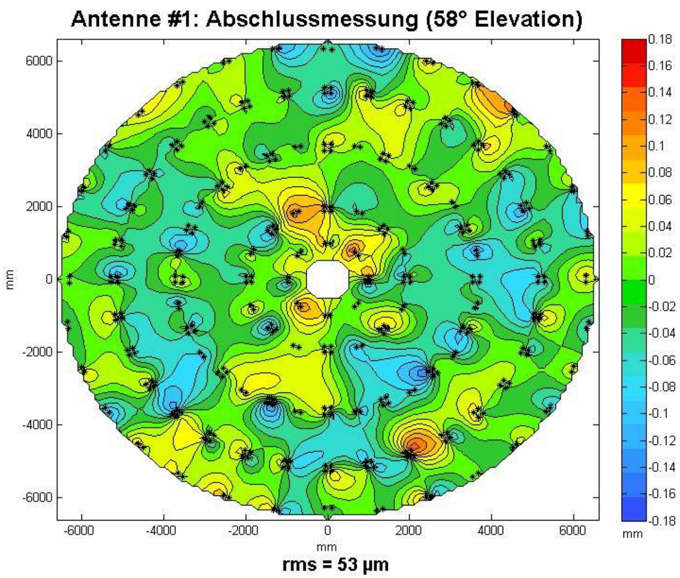
TWIN – Radiotelescope: Main reflector construction



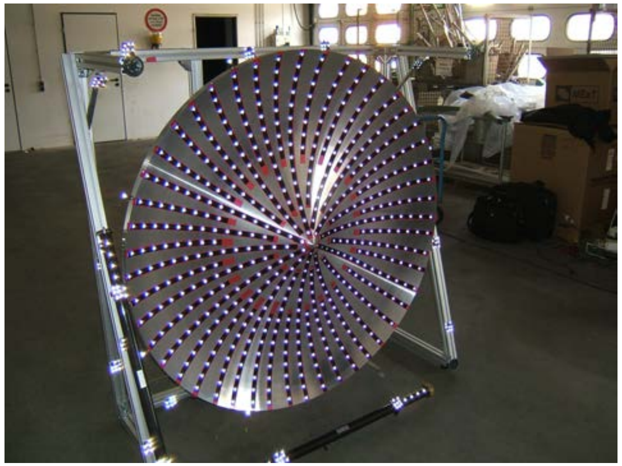


Photogrammetry

Main reflector



FAT Subreflector



Reference planes of TTW

Bezeichnung	FE-Analyse		Fotogrammetrie	
	0° El	90° El	0° El	90° El
Oberflächenfehler RMS [µm]	149	131	128	123

Tab. 2-13: Oberflächenfehler des Hauptreflektors

Bezeichnung	Transformierte FE-Daten	Fotogrammetrie
Verschiebung y_{Hr} [mm]	0.71	0.51
Verkippung $\varphi_{x,Hr}$ [Grad]	-0.021	-0.019

Tab. 2-14: Vergleich von Hauptreflektordaten bei der Elevationsänderung 90°->0°

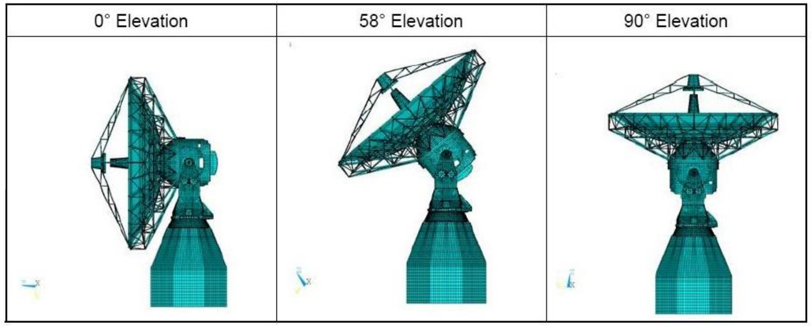
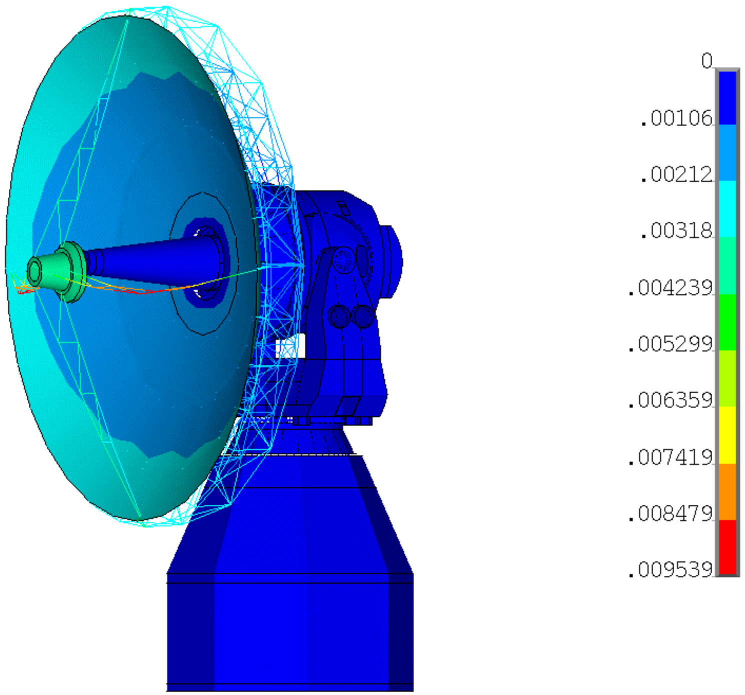
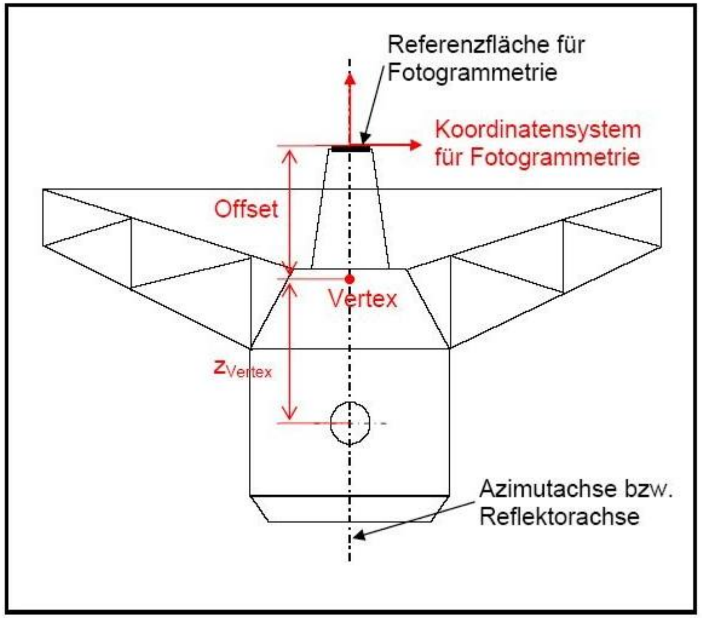


Abb. 2-1: FE-Modelle der TTW-Antenne bei 0 Grad, 58 Grad und 90 Grad Elevation





Prinzipskizze zur Referenzfläche für die Fotogrammetrie

Deformation of the Subreflector

Elevationsänderung: 90° -> 58°	Wert	Einheit
Verschiebung in x-Richtung	-0.02	[mm]
Verschiebung in y-Richtung	1.24	[mm]
Verschiebung in z-Richtung	0.26	[mm]
Verkippung um die x-Achse	0.003	[deg]
Verkippung um die y-Achse	0.002	[deg]

Tab. 10-1: Messprotokoll der gemessenen Subreflektorverschiebungen und -verkippungen bei Elevationsänderung von 90° nach 58°

Elevationsänderung: 90° -> 0°	Wert	Einheit
Verschiebung in x-Richtung	-0.07	[mm]
Verschiebung in y-Richtung	2.30	[mm]
Verschiebung in z-Richtung	2.20	[mm]
Verkippung um die x-Achse	0.006	[deg]
Verkippung um die y-Achse	0.005	[deg]

Tab. 10-2: Messprotokoll der gemessenen Subreflektorverschiebungen und -verkippungen bei Elevationsänderung von 90° nach 0°

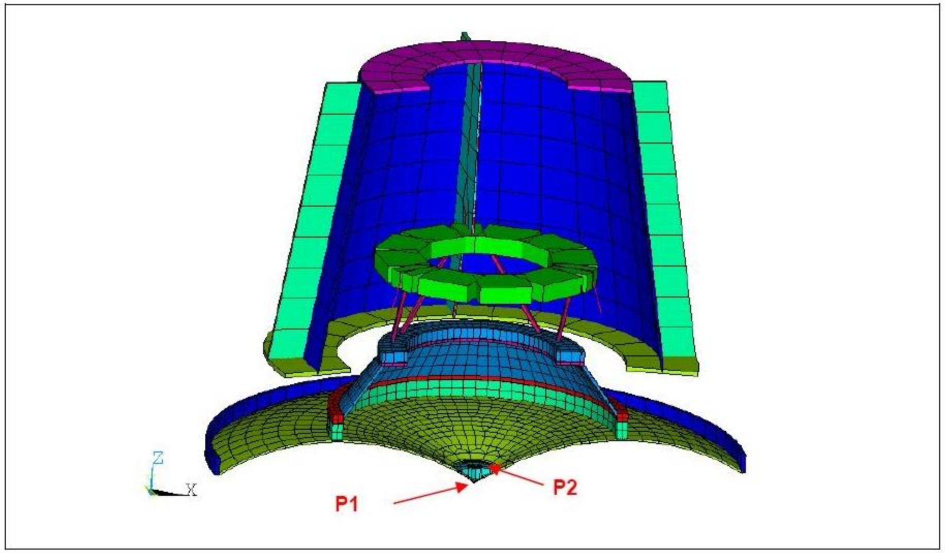


Abb. 2-3: Kopfteil mit Subreflektor und Auswertepunkte P1 und P2

Bezeichnung	Transformierte FE-Daten	Messung Mittelwert
Verschiebung y_{Sr} [mm]	2.64	2.30
Verschiebung z_{Sr} [mm]	1.73	2.07
Verkippung $\varphi_{x,Sr}$ [Grad]	0.005	0.007

Tab. 2-15: Vergleich von Subreflektordaten bei der Elevationsänderung 90°->0°

LF1 = Loading at 58°without Subreflectorcontroller

LF2 = Loading at 58° with Subreflectorcontoller

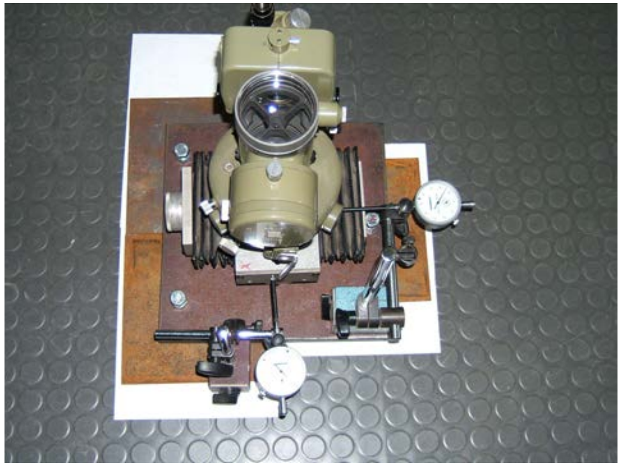
LF3 = Load with wind speed 40km/h ahead

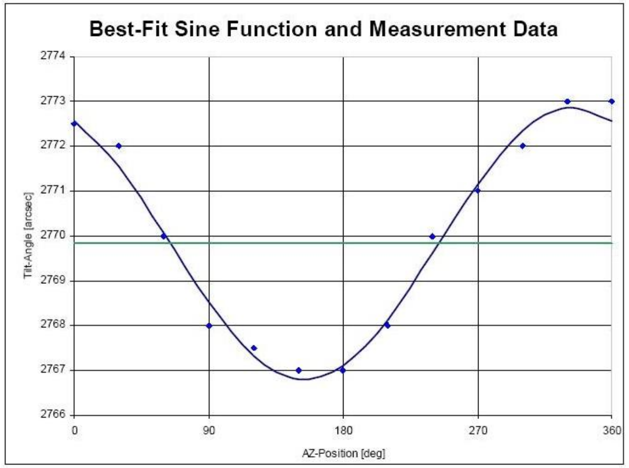
LF4 = Load with wind from one side

LF	Gain 33 GHz [dBi]	Δ-Gain [dB]	η	RMS σ [mm]
nominell	72.412			
1	72.193	-0.219	0.951	0.16
2	72.318	-0.094	0.979	0.11
3	72.408	-0.004	0.999	0.02
4	72.409	-0.003	0.999	0.02

Tab. 3-1: Betrachtung des Antennengewinns

Measurements of the vertical and horizontal axis and the intersection point

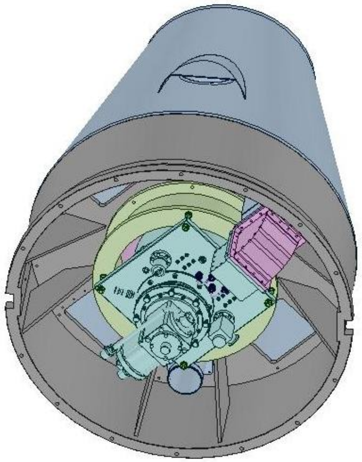


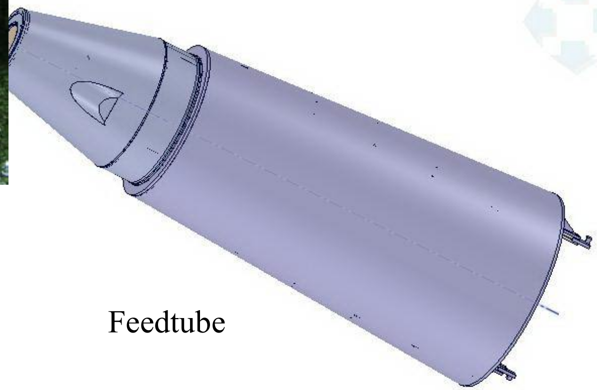


Darstellung von Messwerten der Azimutachsmessung sowie deren Bestfit-Sinusfunktion

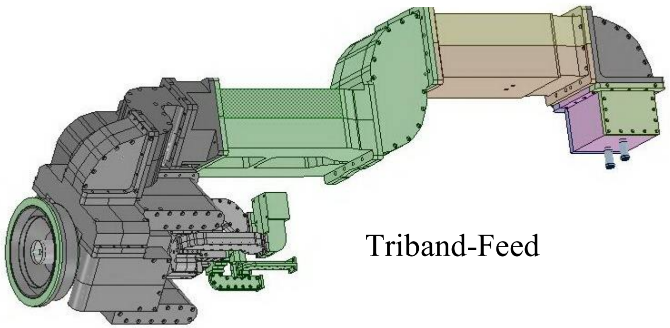
The Triband-Feed for TTW 1

Feedcone and Triband-Dewar

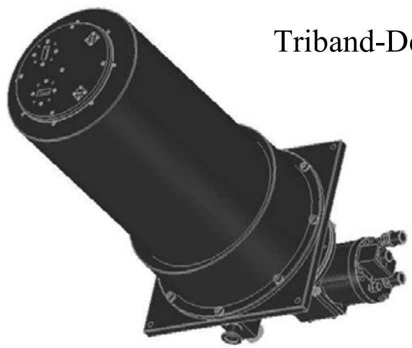




Feedtube

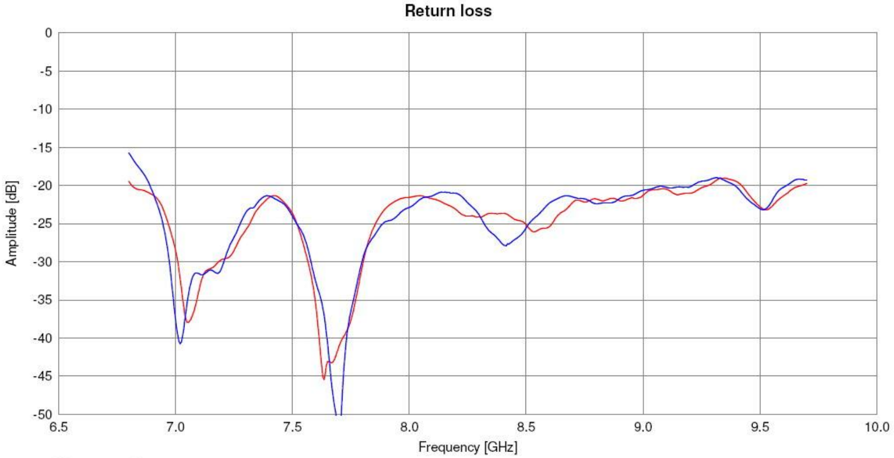


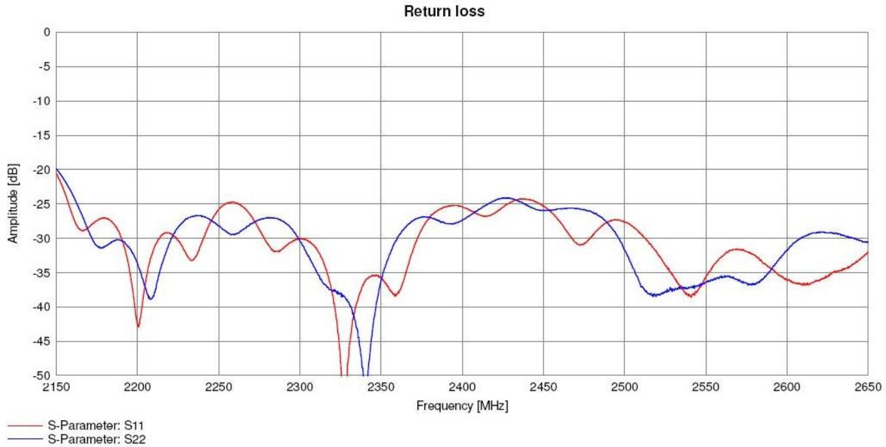
Triband-Feed



Triband-Dewar

First measurement results of the new Triband-Feed

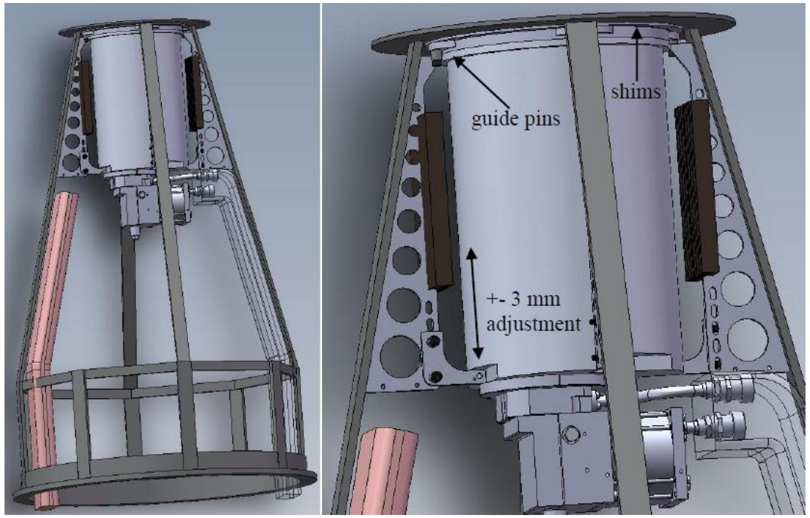




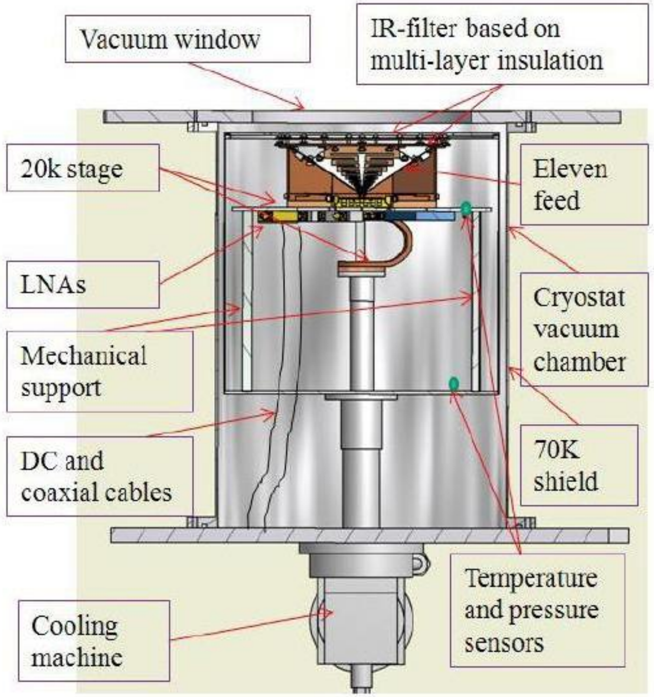
S-Parameter: S11
S-Parameter: S22

Broadband-Receiving-System: Eleven-Feed

Design proposal for the Eleven-Feed



Design Proposal Dewar



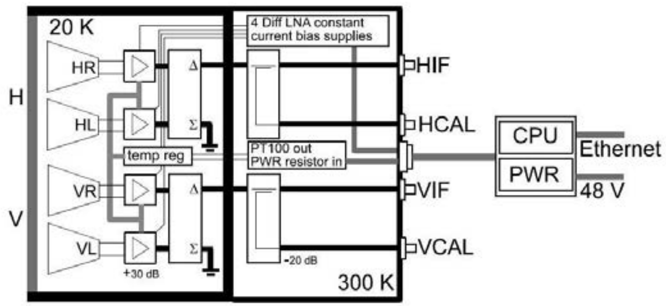


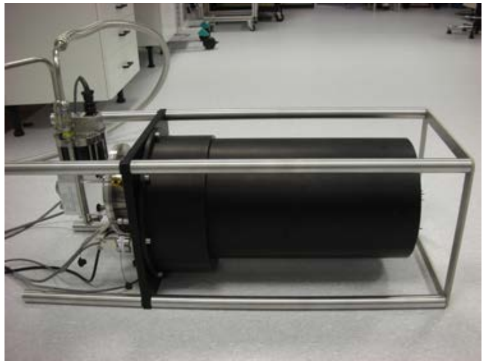
Figure 2. Eleven feed based VLBI2010 front-end

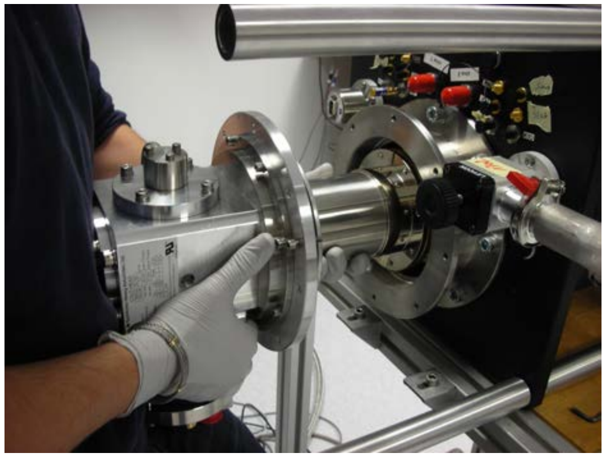
Principle Schematic

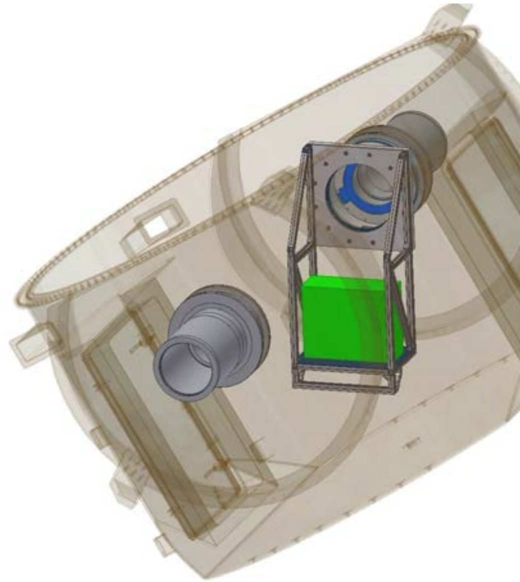
Source: A. Emrich; Omnisys.; Sweden

Other topics: Cyrogenic design

- Cooled LNA and Feeds are necessary, but how to get the heat out of the cabin?
- How to mount the Helium Compressor in the Elevation cabin?
- How to do a coldhead cylinder maintenance without removing the whole feed?







Other topics:
Cable warp and feed blower

- Choosing a cable wrap for 1000 observations a day and a high drive velocity
- Choosing RF-cables for the signal and for the frequency reference
- Choosing fiber cables for a cable wrap and 1000 bend cycles
- How to prevent the feed foils from rain, snow and ice ?

- and so on ….

Energy Saving

- Green Mode Observation
- Loading the deceleration energy back into the power network
- Heat transfer from the electronic devices and servers to warm up the main building
- Good thermal isolation of the main building and the towers

February 2012