



GOBIERNO
DE ESPAÑA

MINISTERIO
DE FOMENTO

DIRECCIÓN GENERAL DEL
INSTITUTO GEOGRÁFICO NACIONAL

CENTRO DE DESARROLLOS TECNOLÓGICOS
CENTRO ASTRONÓMICO DE YEBES

Surface optimization of the Yebes 40-m radiotelescope using microwave holography

José A. López-Pérez

Centro Astronómico de Yebes
Instituto Geográfico Nacional (IGN), Spain

3rd RadioNet3 ERATec Workshop
September 1-2, 2014 Gothenburg, Sweden



Contents

- Introduction
- 40-m holography receiver
- Holography measurements and adjustments
- Tetrapod leg temperature measurement
- Conclusions

Most of the work presented here has been published in:

*J. A. López-Pérez et al.: “**Surface Accuracy Improvement of the Yebes 40 Meter Radiotelescope Using Microwave Holography**”.
IEEE Trans. on Ant. & Prop., vol. 62, No. 5, May 2014.*

Introduction



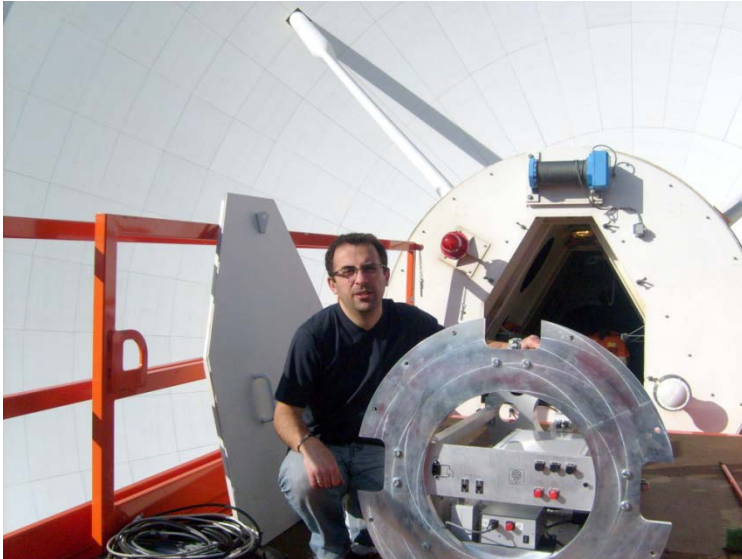
Yebes 40-m radiotelescope

$$G = \eta_a \cdot \frac{4\pi}{\lambda^2} \cdot A_f$$

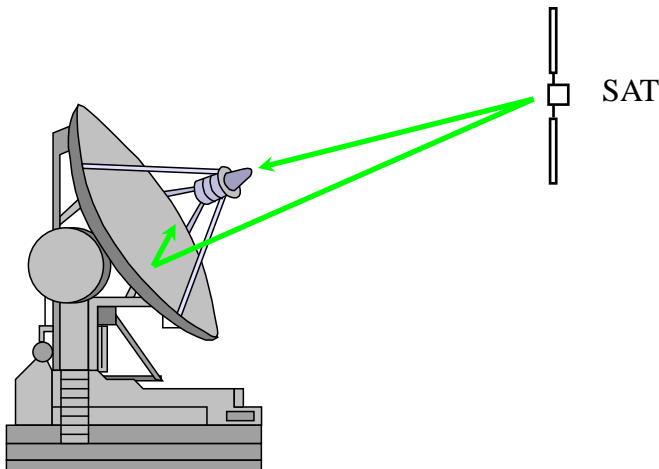
$$\eta_s = e^{-\left(\frac{4\pi\varepsilon}{\lambda}\right)^2}$$

- Large reflectors suffer from **surface deformations due to gravity, temperature and wind loads**, which cause a **reduction in aperture efficiency**, particularly at mm-wavelengths.
- Microwave **holography** is a suitable metrology technique to measure the reflector surface due to its accuracy, resolution and speed. In addition, it provides EM properties which can't be provided by other techniques.

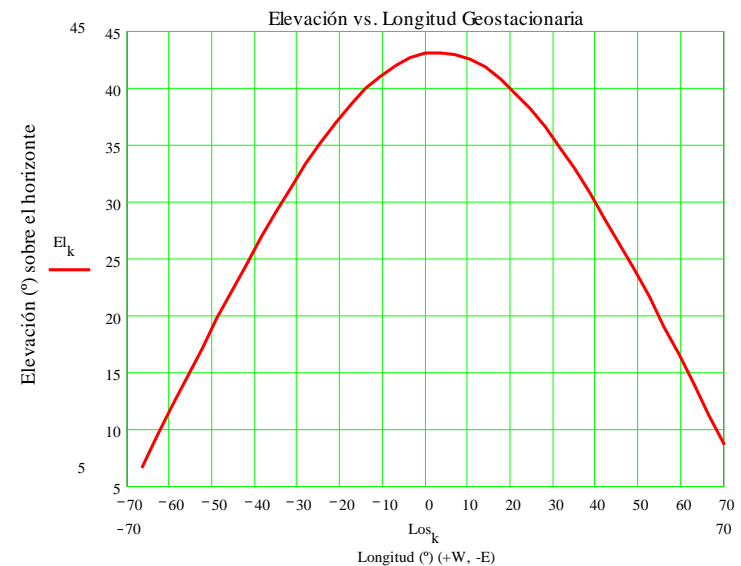
40 m holography receiver



Installing the Yebes 40-m holography receiver

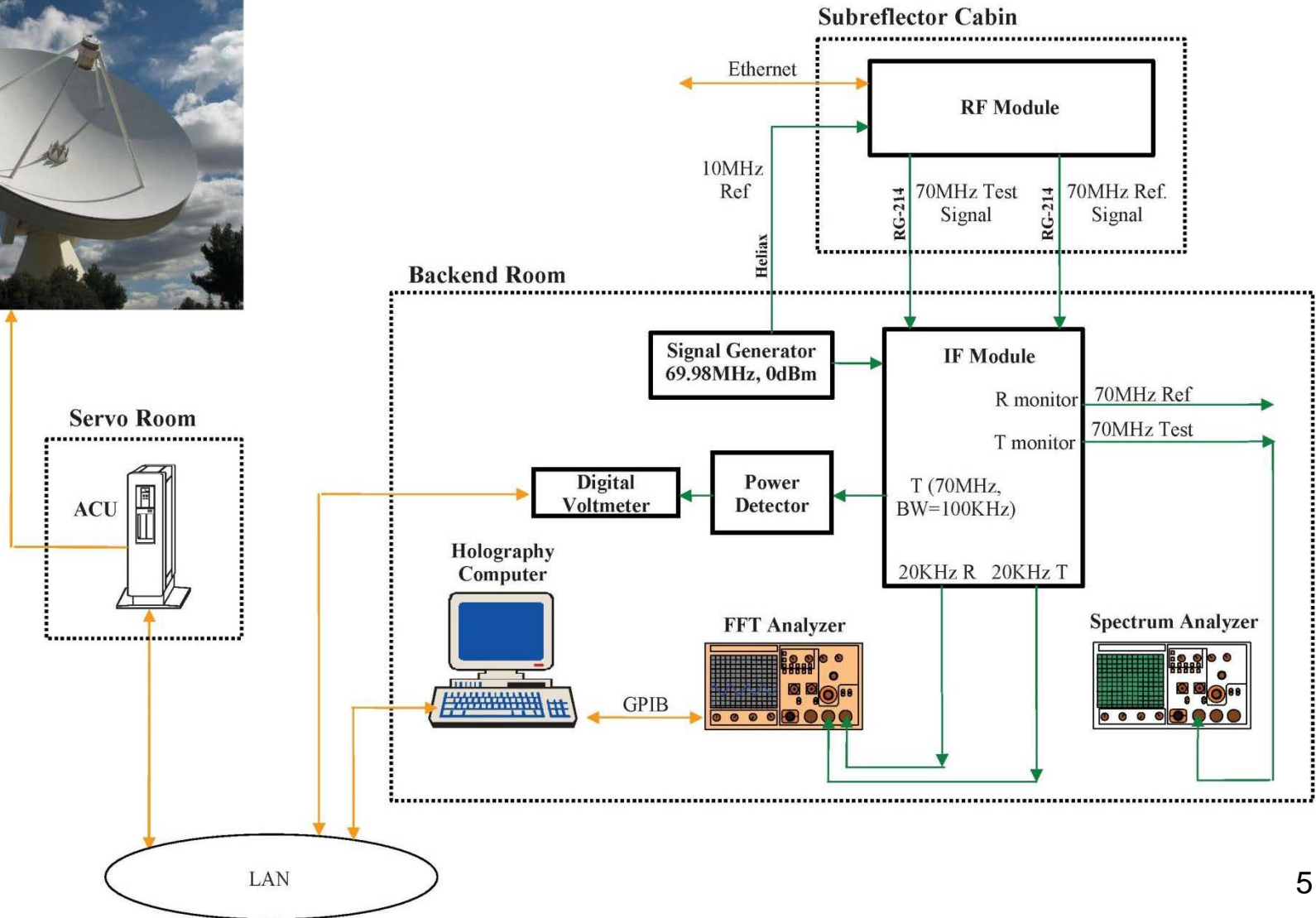


- Coherent microwave holography receiver in prime focus position.
- Using beacons from GEO satellites in Ku-band (10.9 – 12.75 GHz) available at several elevation angles (20° .. 43°).
- Permanent installation for periodic measurements.

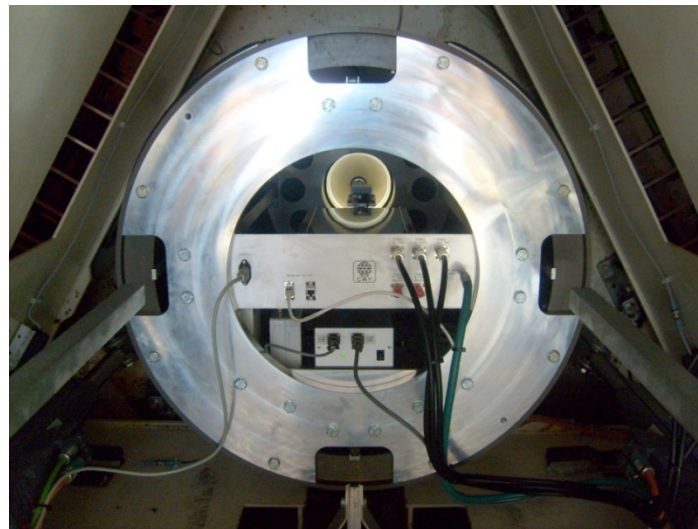
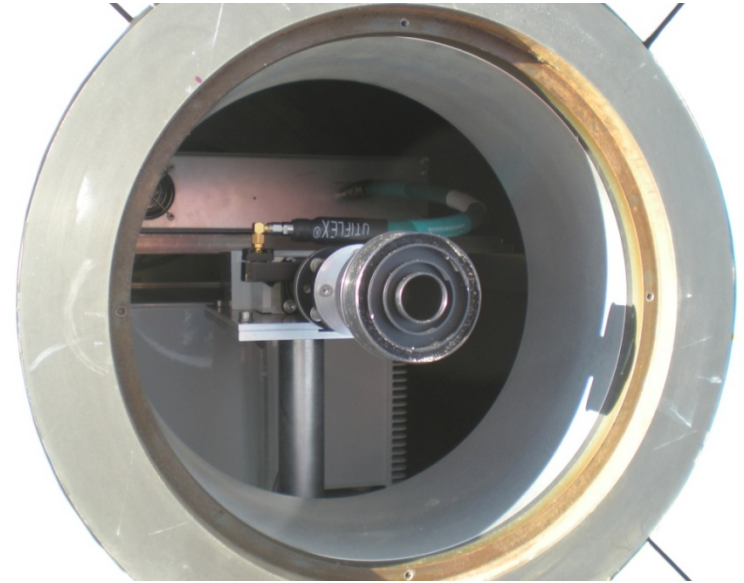
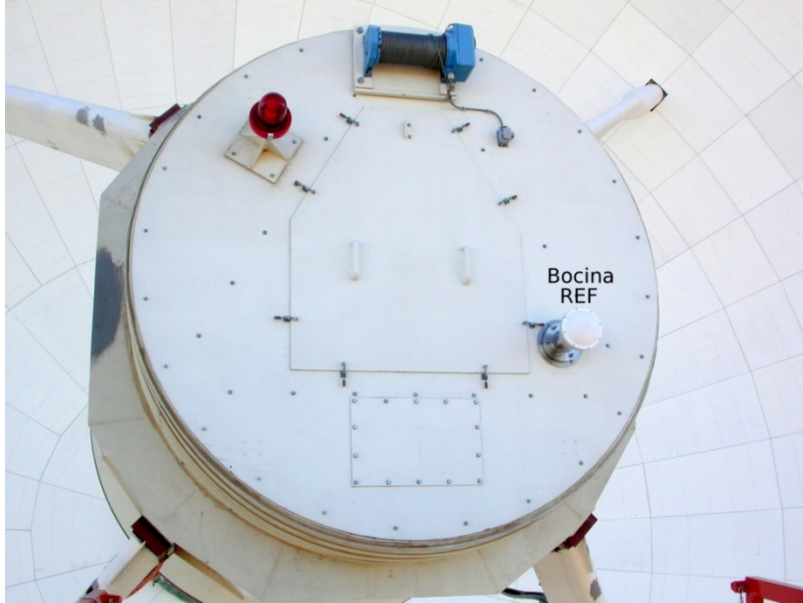


System block diagram

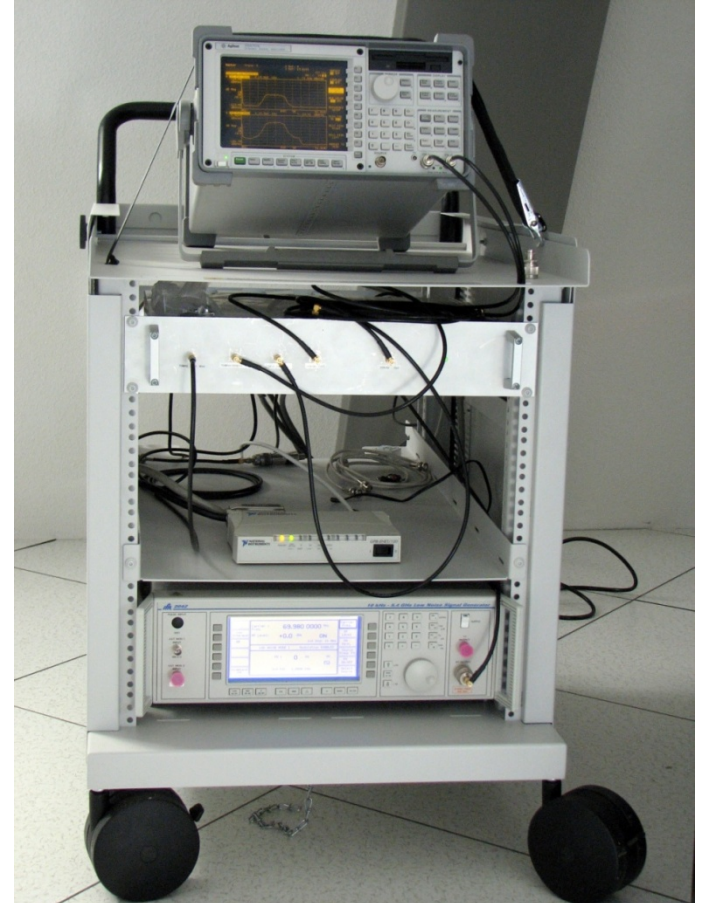
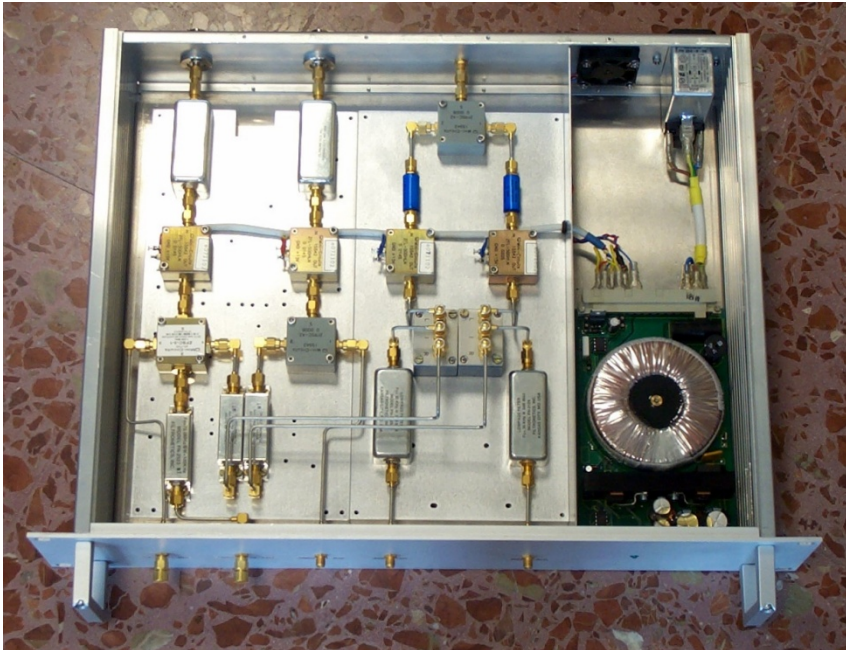
40m ARIES Radiotelescope



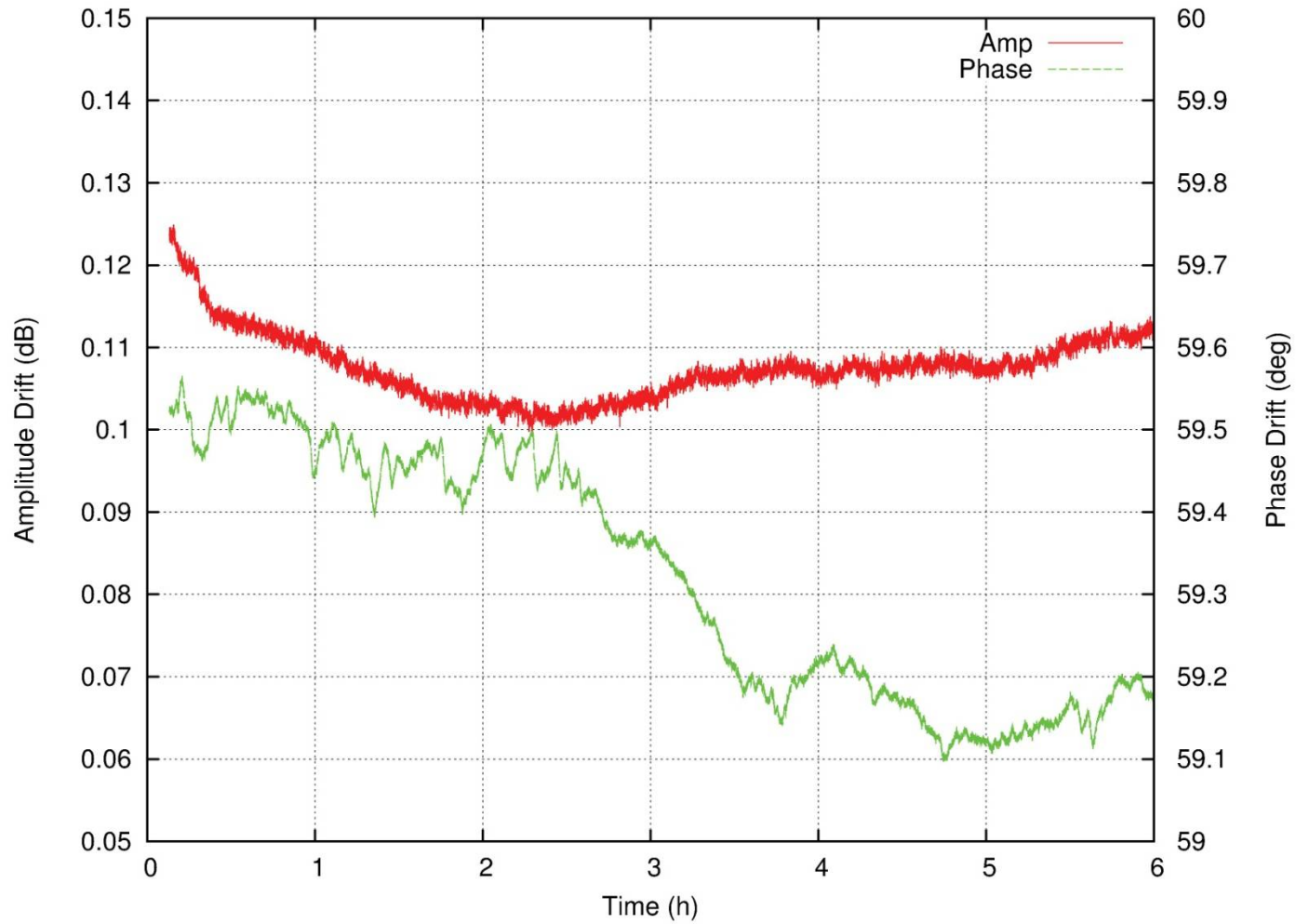
RF module installation



IF module + backend



Holography Rx stability



Summary of Holography RX parameters

- Superheterodyne dual channel receiver at room temperature
- Frequency range: 10.9 – 12.75 GHz
- Prime focus installation
- REF antenna: Conical corrugated feed with 162mm diám. HPBW=11.3°
- TEST feed: ring-choke feed -9dB @ 64°
- REF channel: $T_{rx} < 96$ Kelvin, $T_{sys} < 111$ Kelvin
- TEST channel: $T_{rx} < 83$ Kelvin, $T_{sys} < 126$ Kelvin
- IF frequency: 20 KHz
- IF BW: 10 KHz

Rx Monitor & Control SW

Miteq Downconverter Local Control Panel (JALP, Oct. 2004)

Frequency (MHz) =

IF Attenuator (dB) =

Serial Address:

Baud Rate:

Data Bits:

Parity:

Stop bits:

TCP/IP Port:

Reference Frequency Source:

Power Supply:

Synthesized Local Oscillator Lock:

Fixed Local Oscillator A Lock:

Fixed Local Oscillator B Lock:

Synthesized Local Oscillator Level:

Fixed Local Oscillator A Level:

Fixed Local Oscillator B Level:

+24V:

+20V:

+5.2V A:

+5.2V B:

RF Phase Voltage:

IF Phase Voltage:

RF Level Voltage:

Internal Temperature:

Frequency (GHz) =

Lock Indicator:

Temperature (°C):

Holocal UI:

Log Window

125 13:08:19 IF Attenuator changed to 0.2 dB
125 13:08:20 IF Attenuator changed to 0.4 dB
125 13:08:26 Frequency changed to 11452.014 MHz
125 13:08:26 IF Attenuator changed to 10.0 dB
Synthetizer switched ON
Synthetizer locked

Data Reduction & Analysis SW

The screenshot displays the ARIES CLIC X-Window interface, a calibration package for ARIES Holographies (RL, JALP). The interface includes a menu bar (CONTINUE, STOP?, SIC, Graphics, CLIC, Help) and a toolbar with buttons for GO, ABORT, CREATE, SELECT, and CALIBRATE. The main window is titled "Calibration package for ARIES Holographies (RL, JALP)" and contains various input fields and checkboxes for configuring the calibration process.

Key parameters and settings visible in the interface include:

- Scan Number? 5448
- CLIC File name? /fat32/holo/holo40mdata/holodata_2012/test5764.hpb
- Map size in pixels 256
- Fresnel Approximation? No
- Do Feed Correction? Yes
- Number of Masked Panels? 0
- Masked Panels? 1
- Mask panels under quadrupod? No
- Apodize Map? No
- Plot range (Min Max Step) in micrometers? -1000 1000 500
- Plot amplitude range (Min Max Step)? -15 0 3

The interface also features a series of buttons for solving different parameters:

- Focus offsets: (SOLVE) More input for focus
- Tracking, pointing ...: POINTING More input for pointing
- Cheat with center pixels...: (SOLVE) More input
- Scanning ...: SCANNING More input for scanning Help
- Panels ...: PANELS Input for Panels Help
- Beam map ...: BEAM Input for Beam Map Help

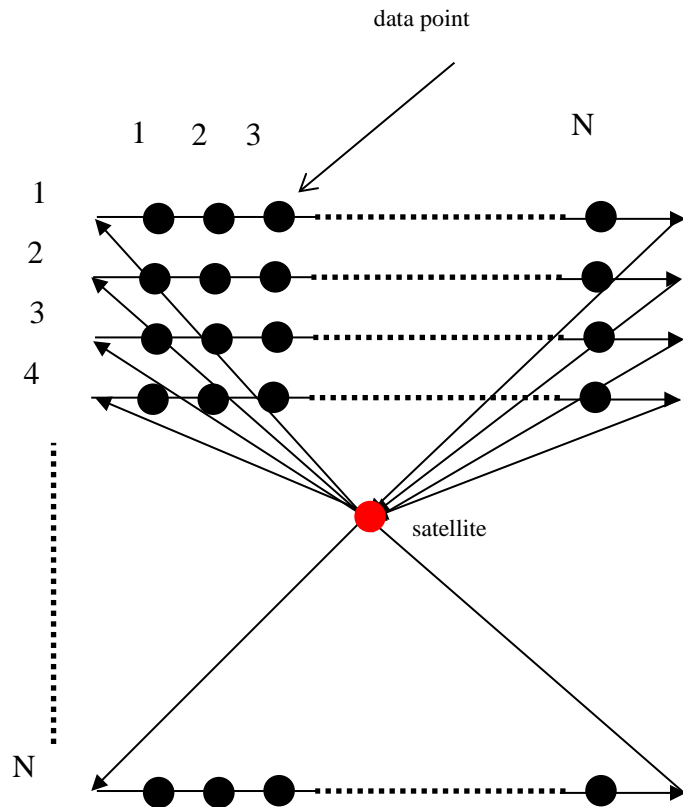
Two circular beam maps are displayed on the right side of the interface. The left map shows the amplitude (front view) with a color scale from -15.000 to 3.000. The right map shows the normal errors (front view) with a color scale from -1000.000 to 1000.000. Both maps are overlaid with a grid and show a central bright spot.

Below the beam maps, a small video window shows a live feed of the antenna structure.

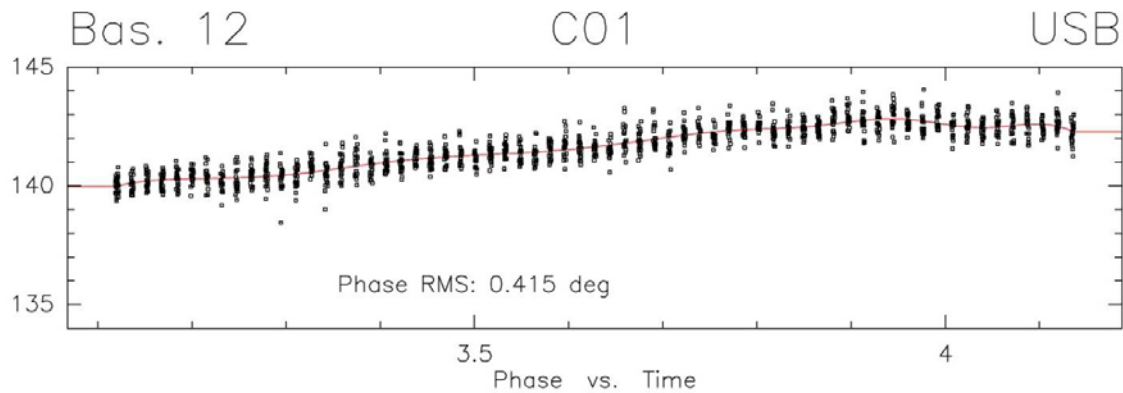
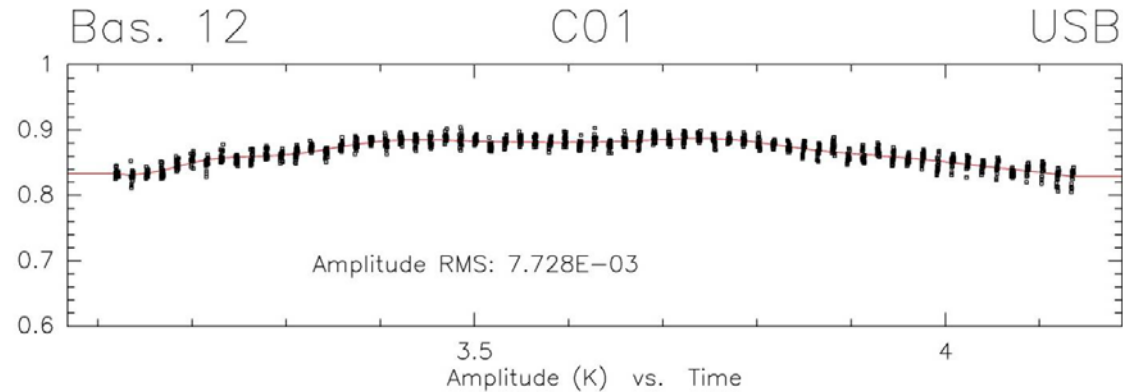
The system tray at the bottom of the window shows the time as 10:43 AM on Friday, August 01, 2014, and the system name as <GREG 0.

The ALMA Holography Software, from Robert Lucas, has been adapted to include the Yebes 40-m case.

Scanning during measurements

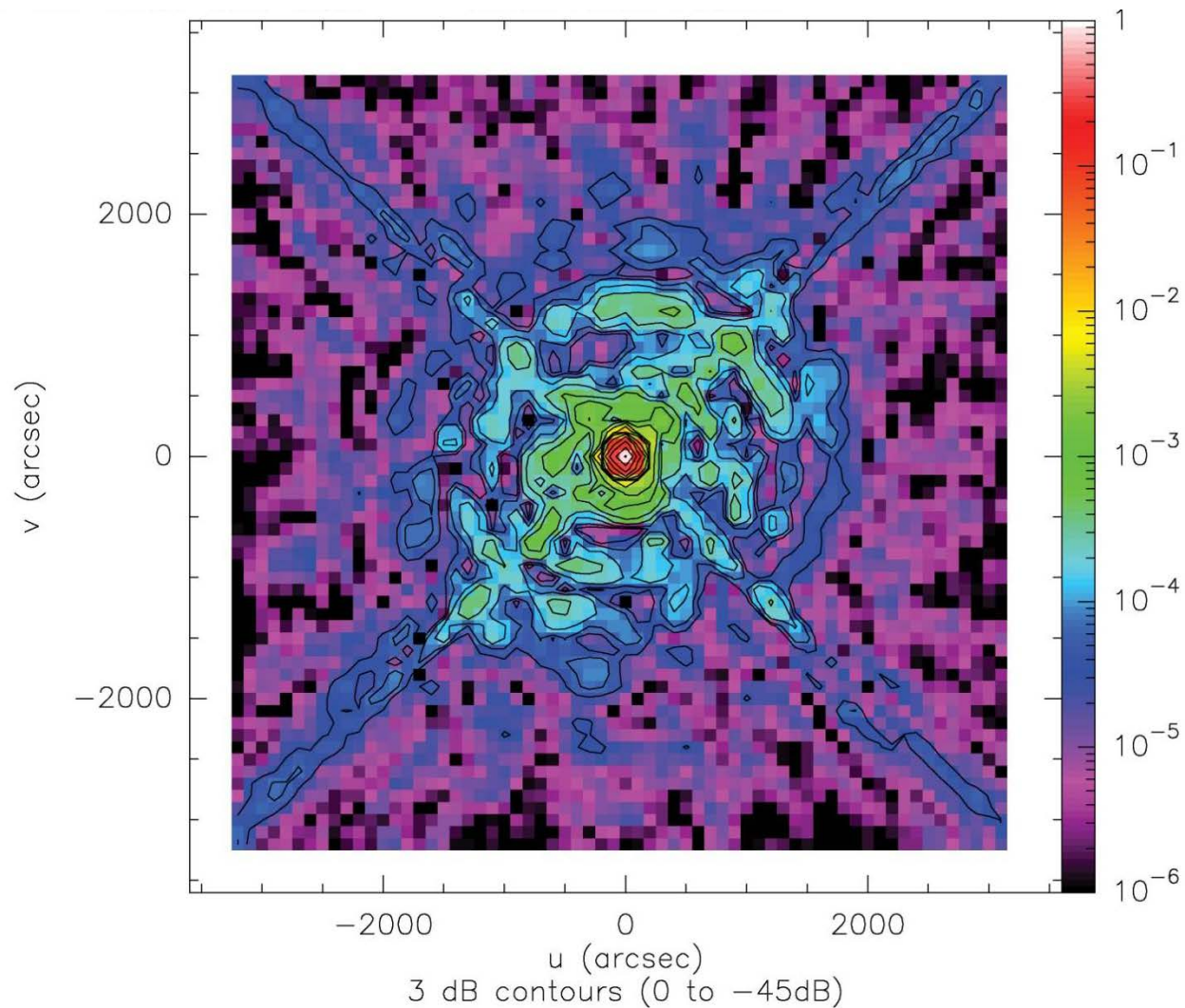


Calibration data



$$\phi_{RMS} = \frac{4\pi}{\lambda} \varepsilon_{RMS} \Rightarrow \varepsilon_{RMS} (\mu m) \cong 36.4 \cdot \phi_{RMS} (^{\circ})$$
$$\phi_{RMS} = 0.415^{\circ} \Rightarrow \varepsilon_{RMS} = 15 \mu m$$

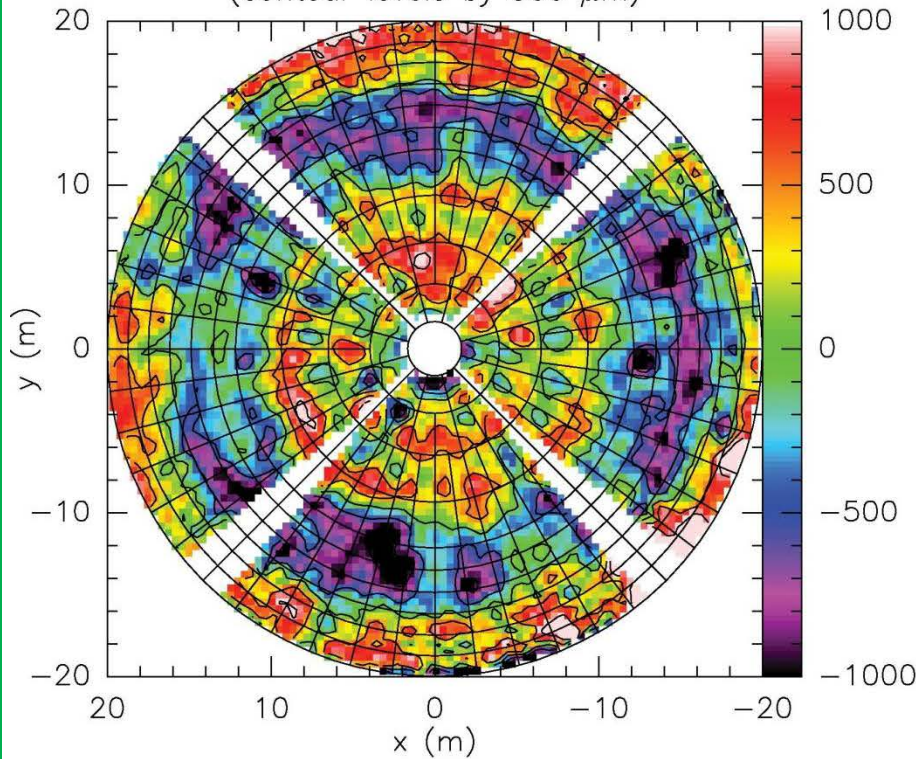
First measurements (July'2010)



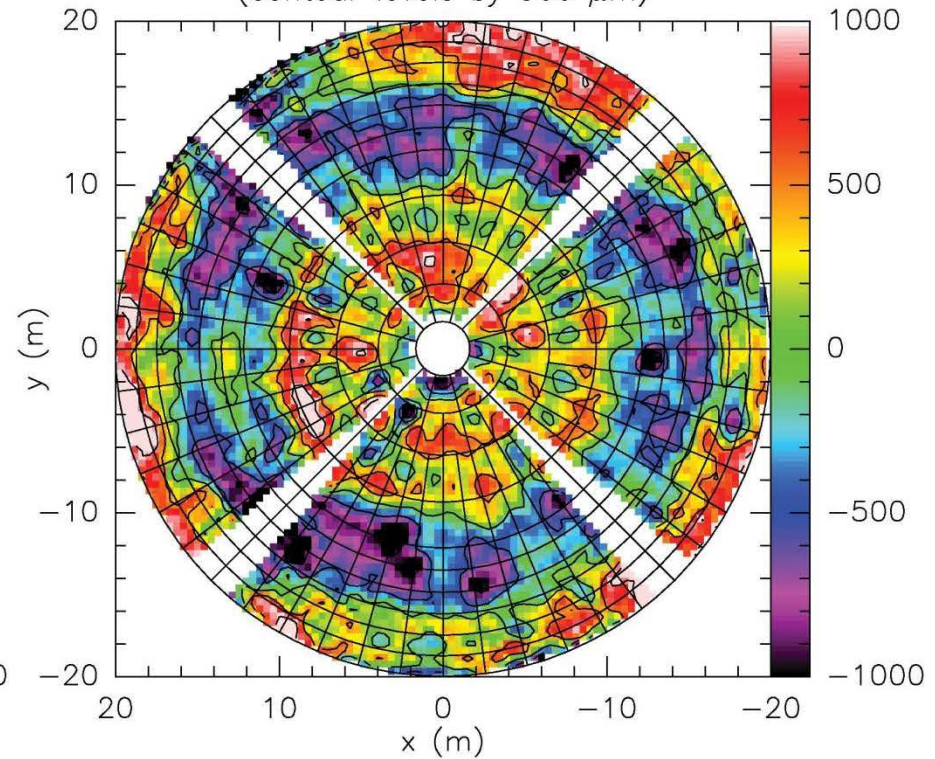
128x128 @ 100" (3.25h)

First measurements (July'2010)

Normal surface error (μm)
01-jul-2010-OAN-4546.map
(contour levels by 500 μm)



Normal surface error (μm)
02-jul-2010-OAN-4577.map
(contour levels by 500 μm)



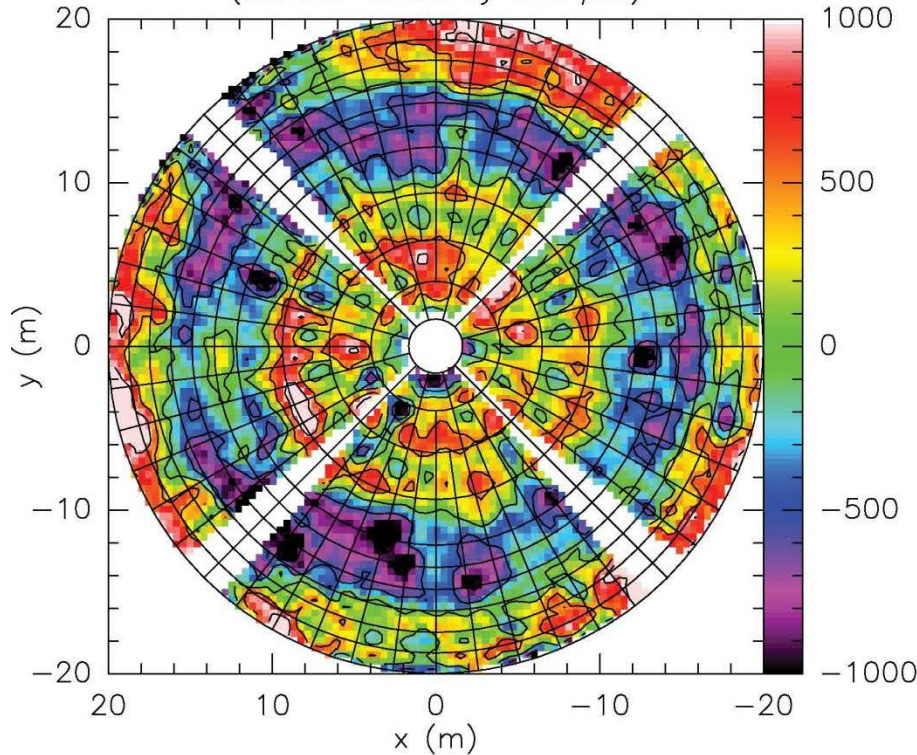
485 microns WRMS

First surface adjustments



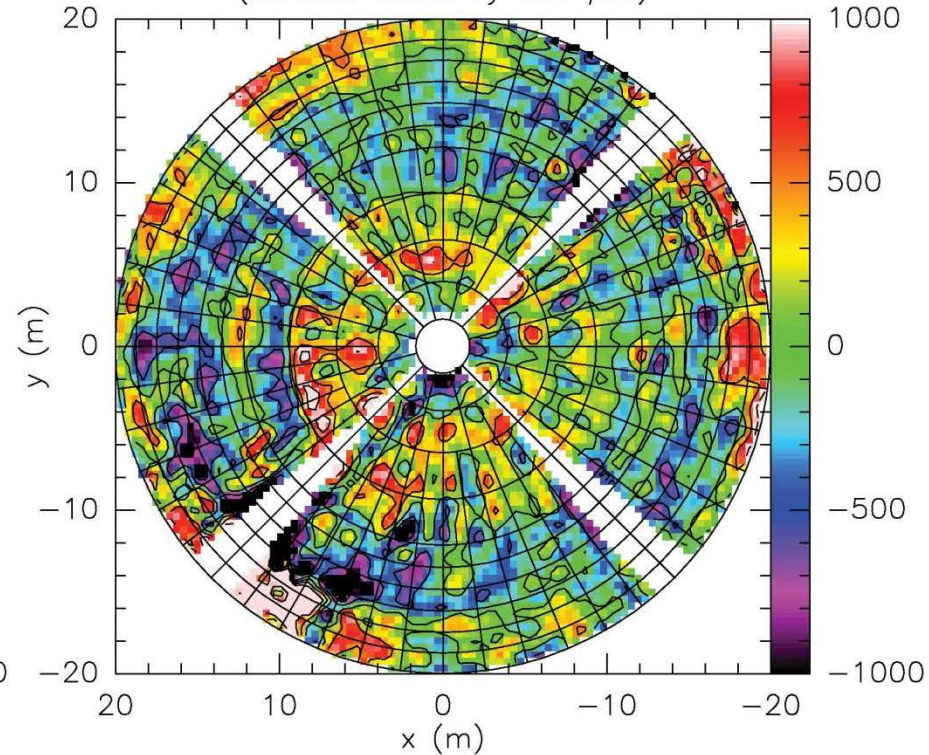
Surface check after 1st partial adjustment

Normal surface error (μm)
02-jul-2010-OAN-4577.map
(contour levels by 500 μm)



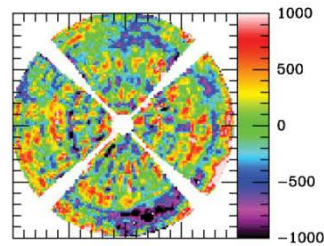
485 microns WRMS
July'2010

Normal surface error (μm)
27-sep-2010-OAN-4108.map
(contour levels by 500 μm)

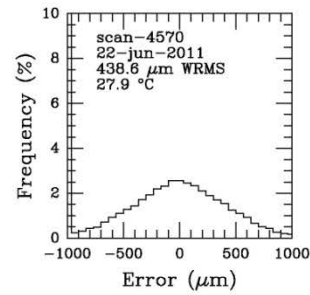


385 microns WRMS
Sept'2010

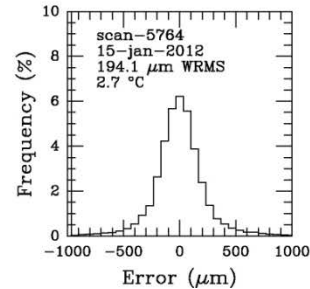
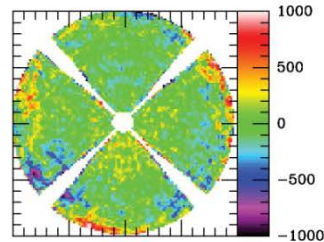
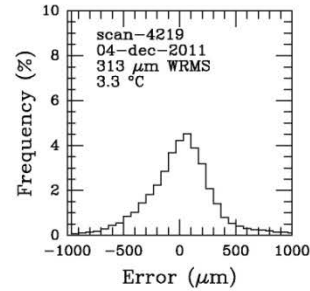
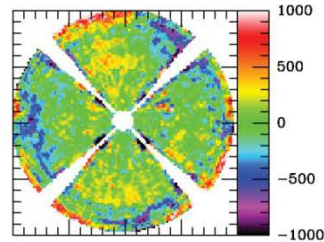
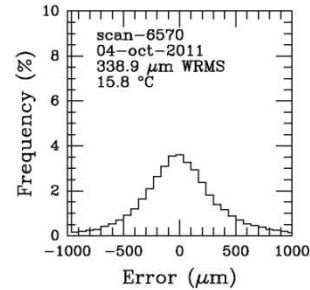
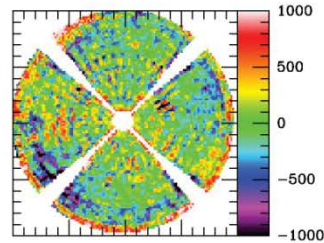
Normal Surface Error (μm)



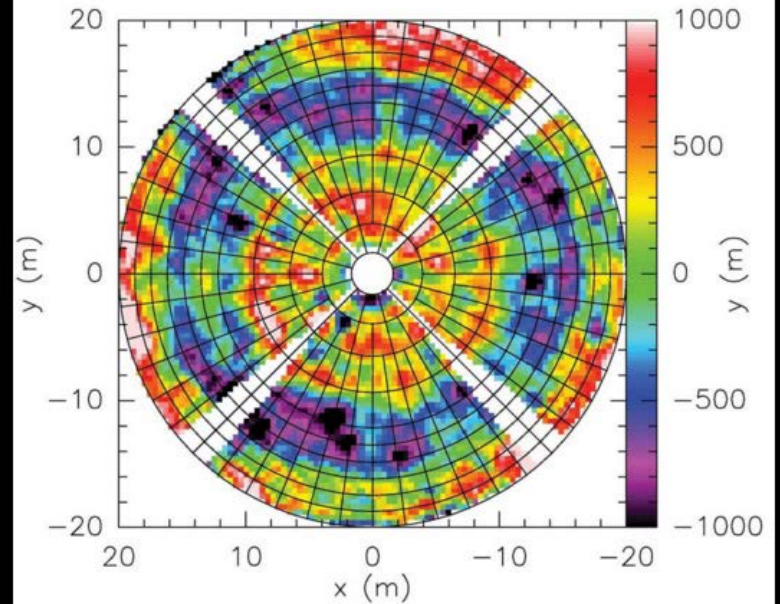
Surface Error Distribution



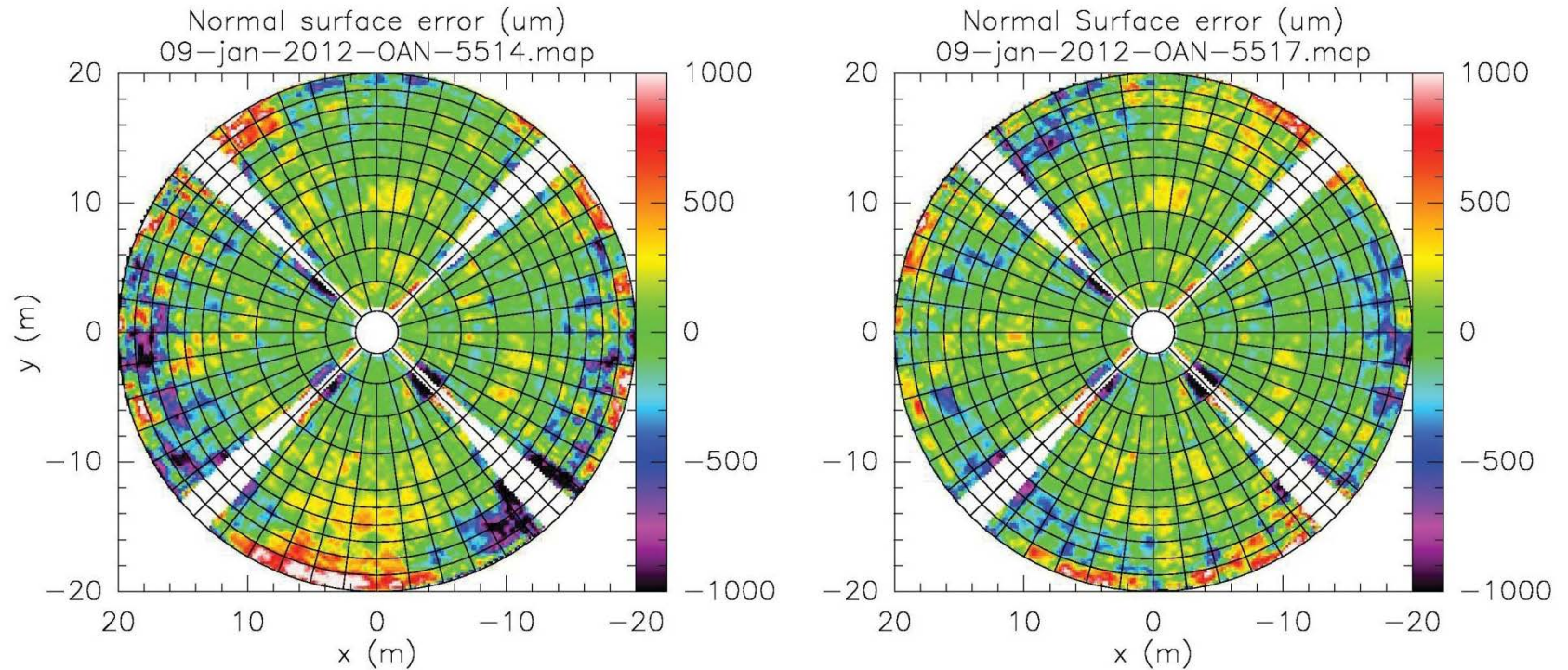
Surface improvement evolution



Surface accuracy in July'2010
485 μm WRMS

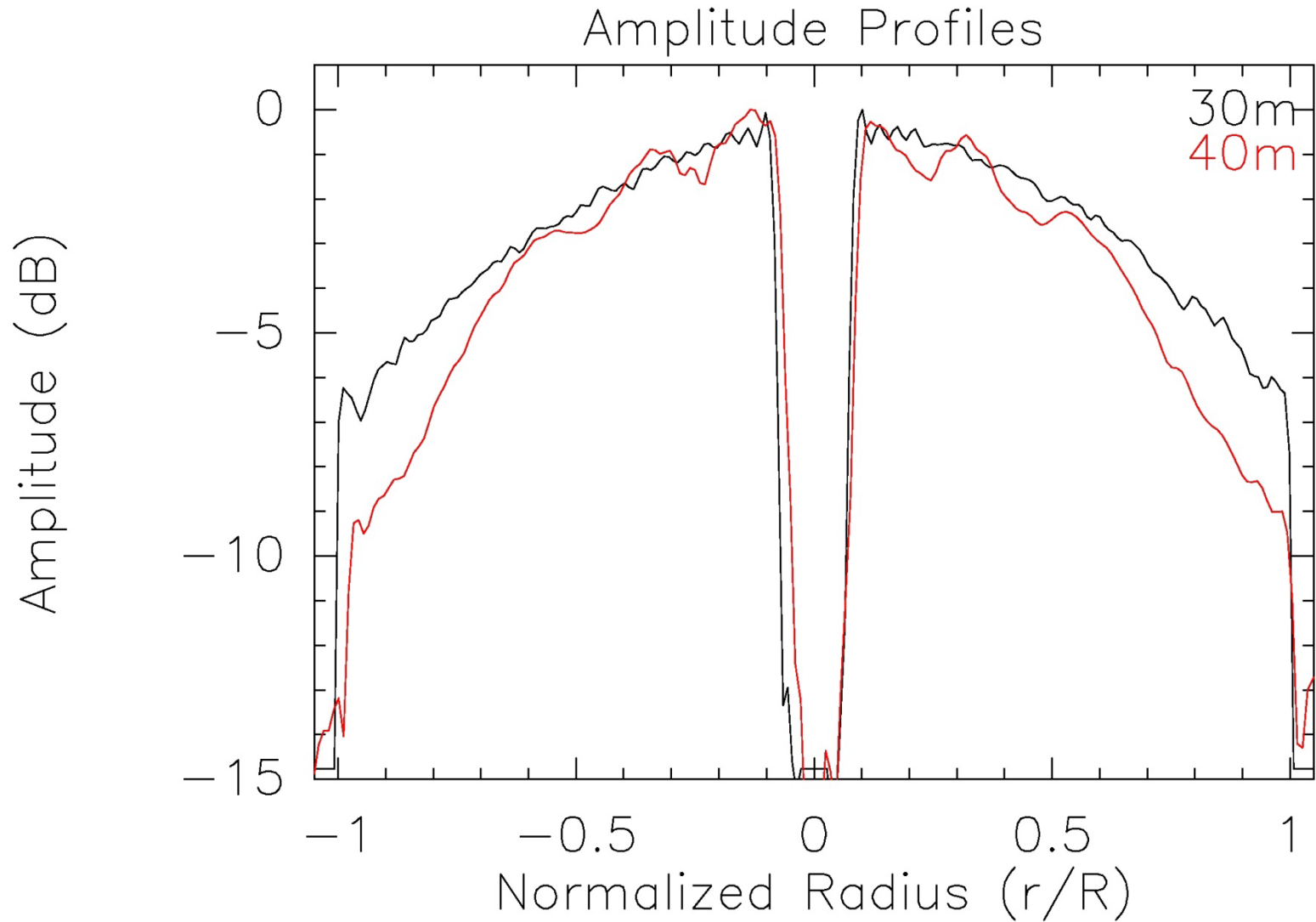


Measurement repeatability (I)

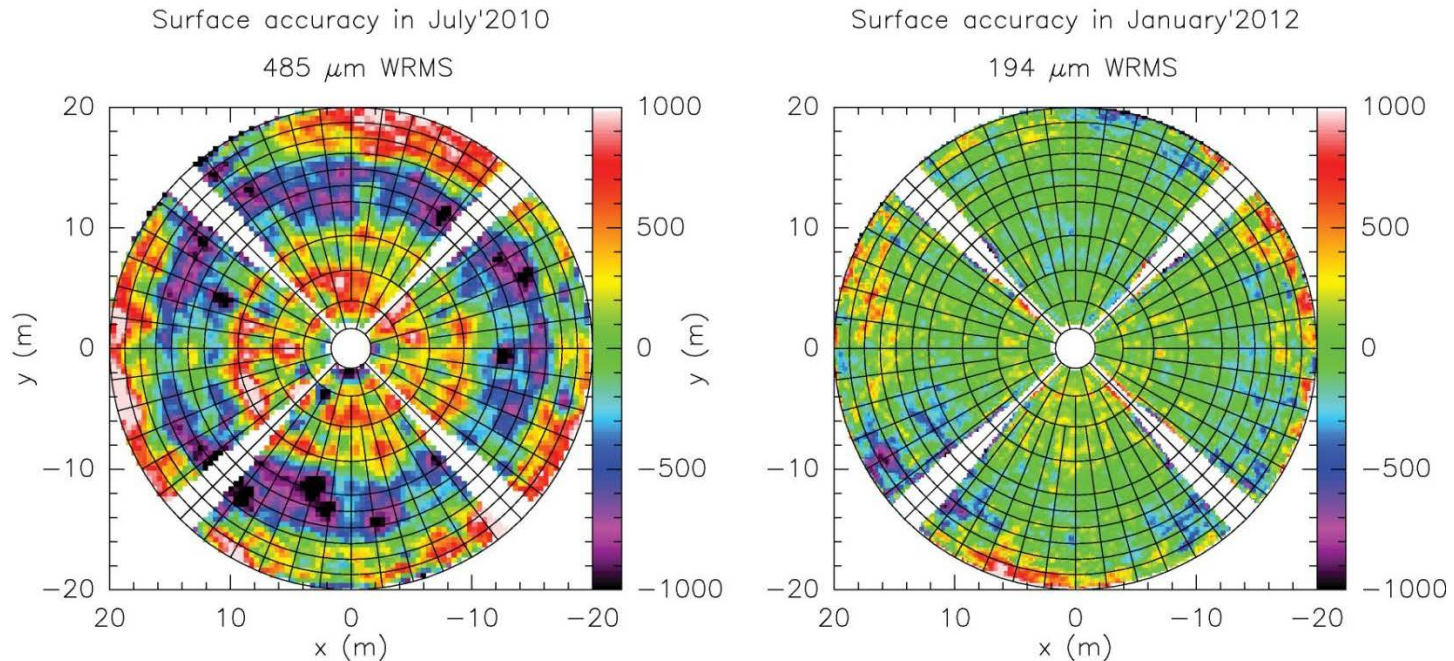


Anillo	1	2	3	4	5	6	7	8	9	10
Mapa 5514 (μm WRMS)	166	355	180	164	167	193	273	339	430	610
Mapa 5517 (μm WRMS)	161	345	176	159	137	152	243	251	270	379
Repetibilidad (μm WRMS)	44	45	58	76	115	143	203	323	467	598

Measurement repeatability (II)



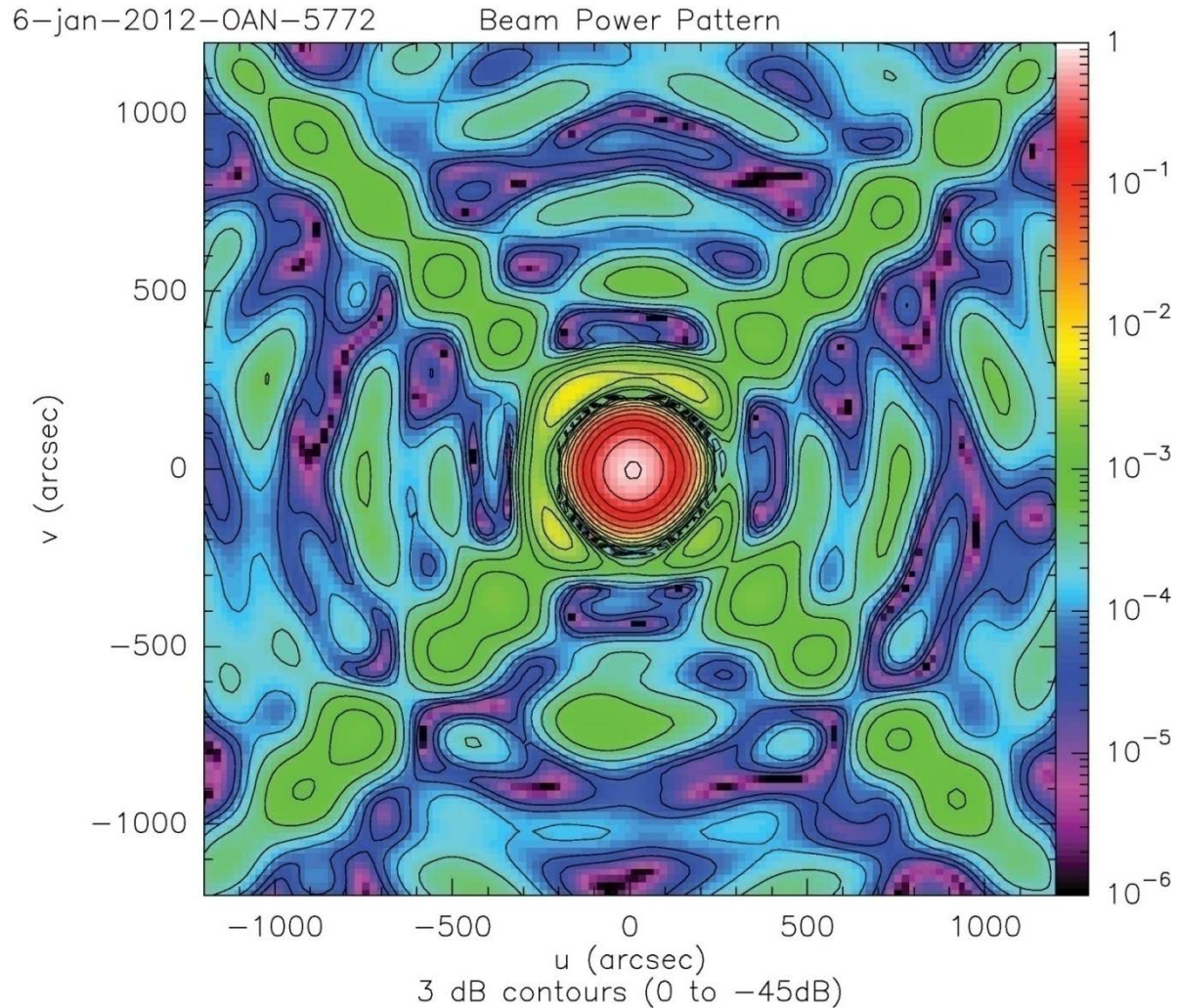
Surface improvement



	Mapa 4577				Mapa 5764			
f (GHz)	11,45	22	45	86	11,45	22	45	86
η_t (%)	65,1	65,1	65,1	65,1	65	65	65	65
η_{sp} (%)	89,6	89,6	89,6	89,6	89,7	89,7	89,7	89,7
η_b (%)	93	93	93	93	93	93	93	93
η_s (%)	95,4	84,1	47,6	4,8	99,3	97,4	89,8	70,4
η_A (%)	51,8	45,6	25,8	2,6	53,8	52,8	48,7	38,2

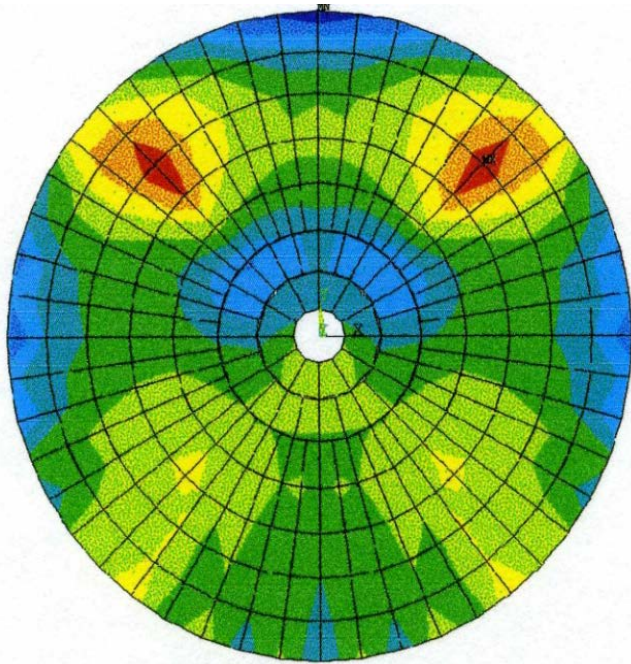
J. A. López-Pérez et al.: “Surface Accuracy Improvement of the Yebes 40 Meter Radiotelescope Using Microwave Holography”. IEEE Trans. on Ant. & Prop., vol. 62, No. 5, May 2014.

Additional results

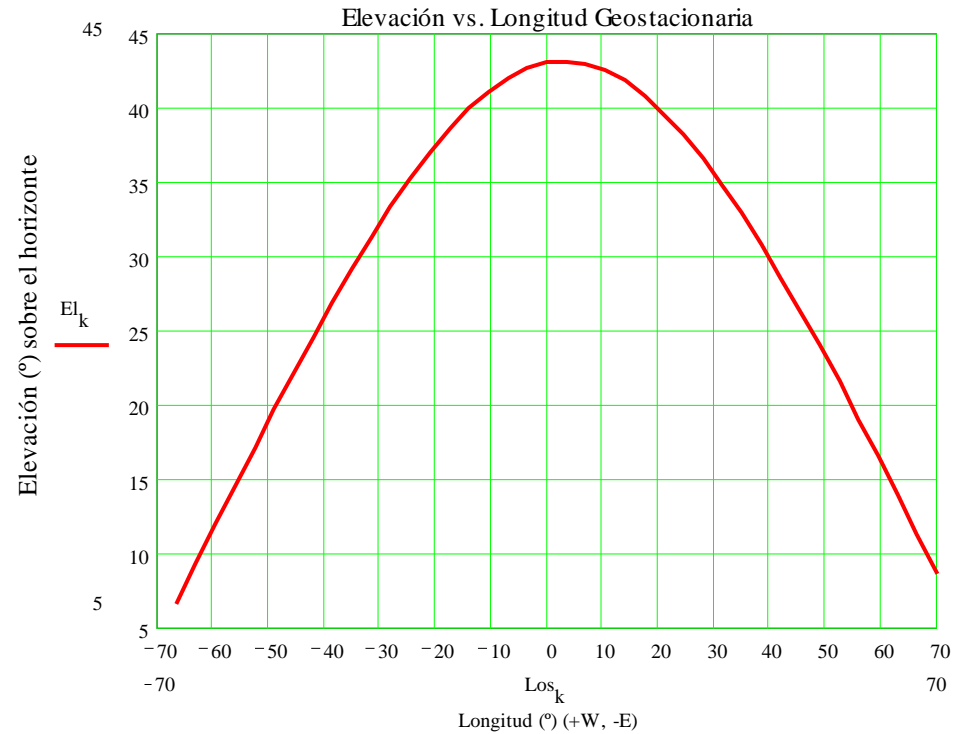


HPBW = $165''$ = 46 mdeg @ 11.45GHz

Verify FEM analysis at low elevation angles

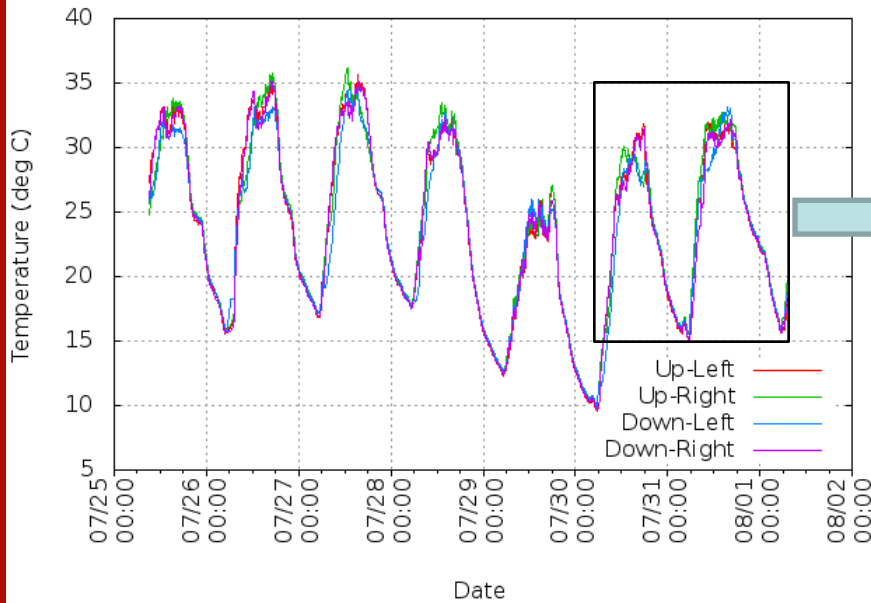


Gravity, $\varepsilon = 30^\circ$
after adjust at $\varepsilon_0 = 45^\circ$

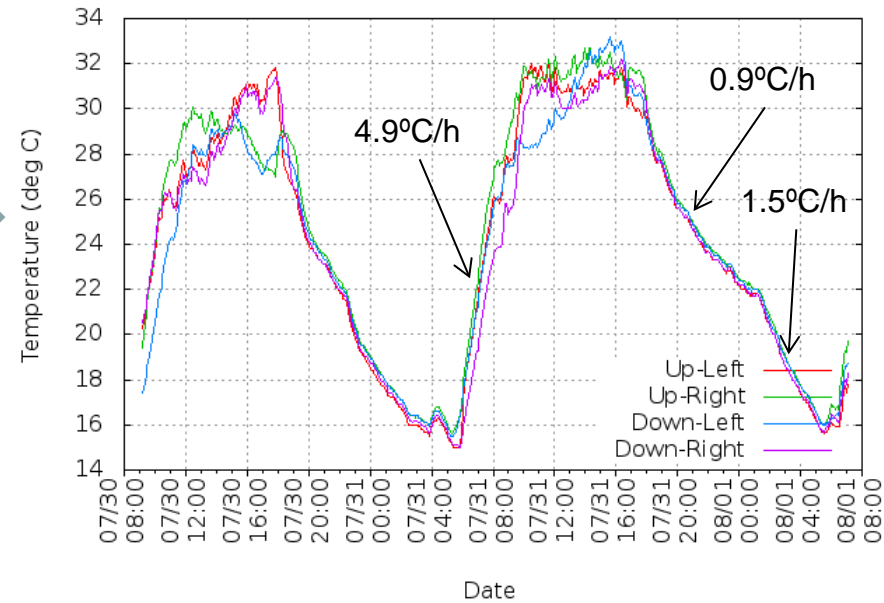


Quadrupod Temperature Measurements using PT100 1/10 class B sensors

Time evolution of 40m radiotelescope tetrapod leg temperatures



Time evolution of 40m radiotelescope tetrapod leg temperatures



$$\left. \begin{array}{l} L_{leg} = 18m \\ \alpha_{steel} \cong 0.01mm / K / m \\ \Delta T \cong 18^{\circ} C_{pk-pk} \end{array} \right\} \Rightarrow \Delta L \cong 3.2mm \cong \lambda @ 86GHz$$

Conclusions

- Design, construction, characterization and installation of a prime-focus dual channel Ku-band receiver.
- Modification of ALMA holography analysis software to include the 40-m telescope. Others could be added.
- Surface improvement from **485 to 194 microns**.
- Further measurements and adjustments to be performed at 43° with new test feed.
- Measurements at lower elevation angles to be performed.
- PT100 network to evaluate the telescope thermal behaviour.

References

- J. A. López-Pérez, P. de Vicente, F. Tercero, J. A. López-Fdez, A. Barcia, B. Galocha: **"Surface Accuracy Improvement of the Yebes 40 Meter Radiotelescope Using Microwave Holography"**. *IEEE Trans. on Ant. & Prop.*, vol. 62, No. 5, May 2014.
- G. Serra, P. Bolli, G. Busonera, T. Pisanu, S. Poppi, F. Gaudiomonte, G. Zacchiroli, J. Roda, M. Morsiani, J. A. López-Pérez, **"The microwave holography system for the Sardinia Radio Telescope"** Paper 8444-227 Proceedings of the SPIE Astronomical Telescopes and Instrumentation 2012 1-6 July, 2010. Amsterdam, Netherlands.
- D. Morris, M. Bremer, G. Butin, M Carter, A. Greve, J.W. Lamb, B. Lazareff, J.A. López-Pérez, F. Mattiocco, J. Penalver, C Thum,: **"Surface adjustment of the IRAM 30 m radio telescope"**. *Microwaves, Antennas & Propagation, IET*, February 2009, Vol. 3, Issue:1, pp. 99 - 108
- J.W.M. Baars, R. Lucas, J. Mangum, J. A. López-Pérez: **"Near-Field Radio Holography of Large Reflector Antennas"**. *IEEE Antennas and Prop. Magazine*, vol. 49, No. 5, October 2007, pp. 24-41.
- J.E. Garrido-Arenas, A. Barcia, J. A. López-Pérez, J. M. Páez: **"Improvement of a Cassegrain Antenna by Secondary Surface Corrections"**. *Microwave Journal*, March, 1999, pp. 82-98.

Thank you !!

