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CENTRO DE DESARROLLOS TECNOLÓGICOS
CENTRO ASTRONÓMICO DE YEBES

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

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

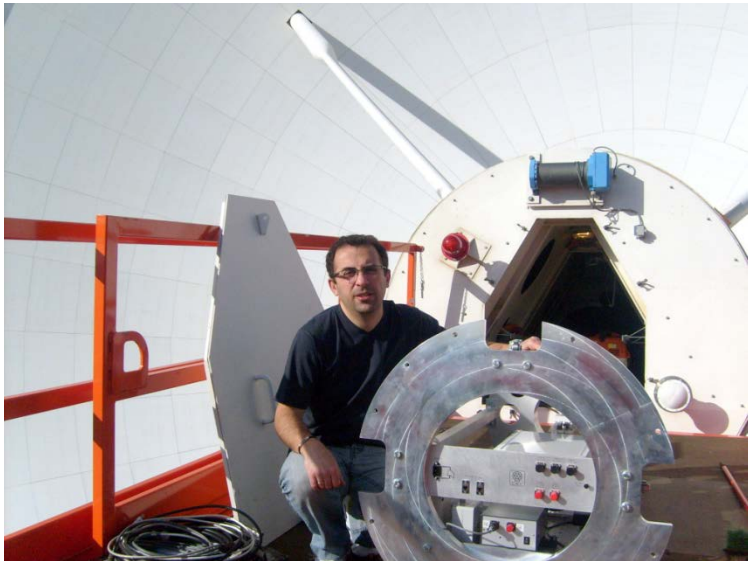
$$G = \eta_a \cdot \frac{4\pi}{\lambda^2} \cdot A_f$$

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

- Large reflectors suffer from **surface deformations due to gravity, temperature and wind loads**, which cause a **reduction in aperture efficiency**, particularly at mm-wavelengths.

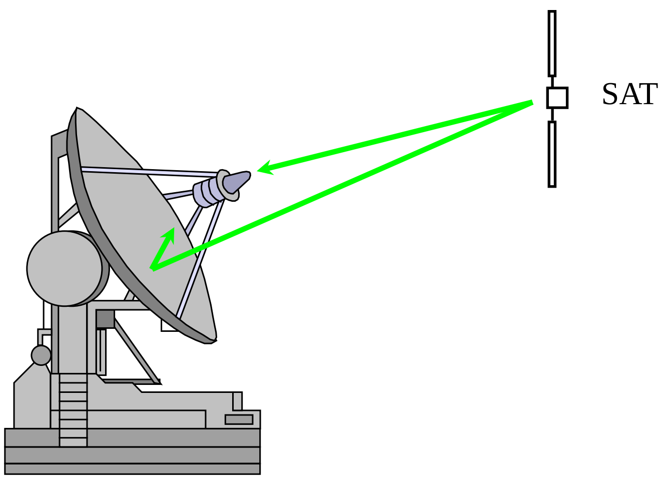
- Microwave **holography** is a suitable metrology technique to measure the reflector surface due to its accuracy, resolution and speed. In addition, it provides EM properties which can't be provided by other techniques.

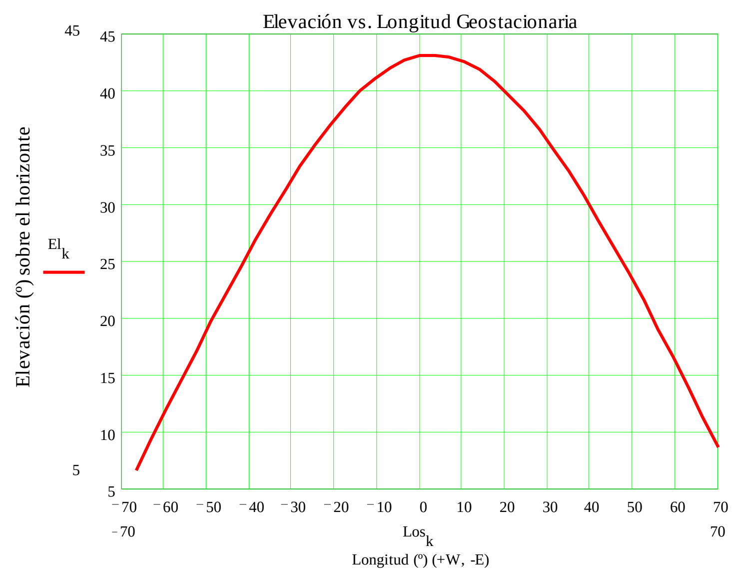
40 m holography receiver



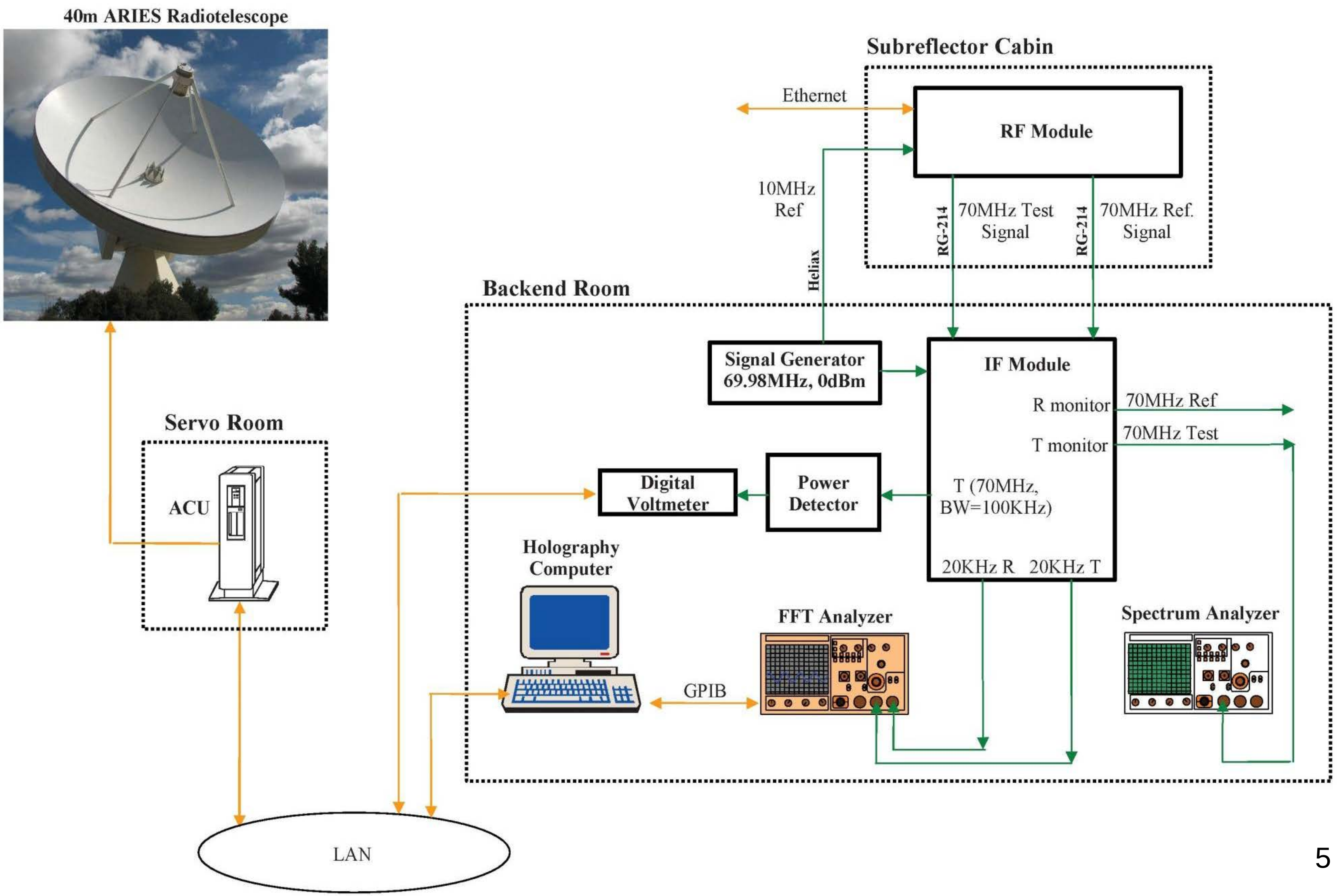
Installing the Yebes 40-m holography receiver

- 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 (20º .. 43º).
- Permanent installation for periodic measurements.

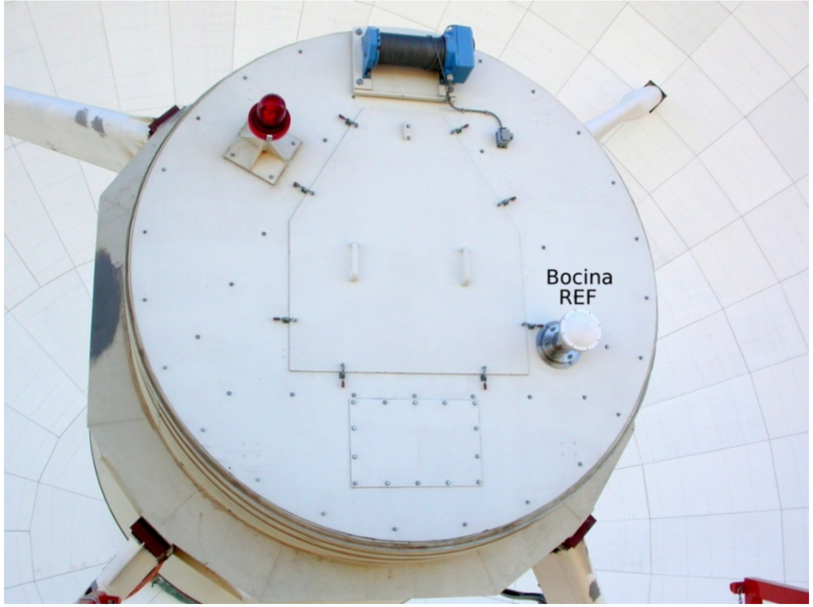


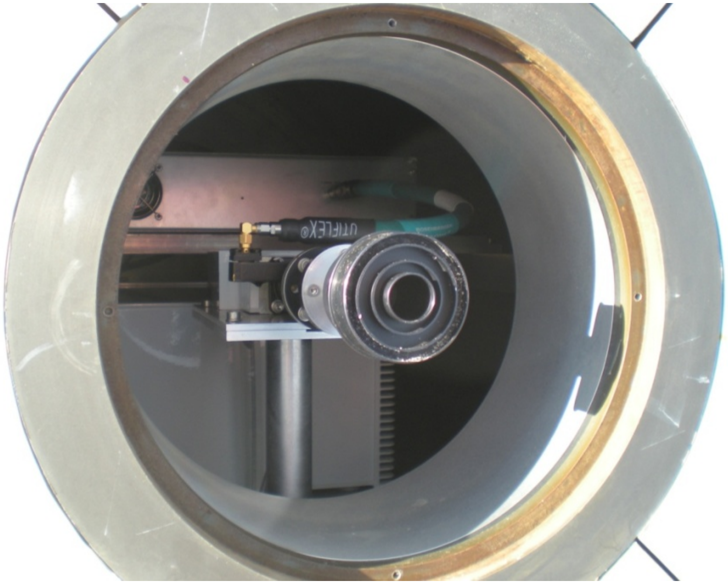


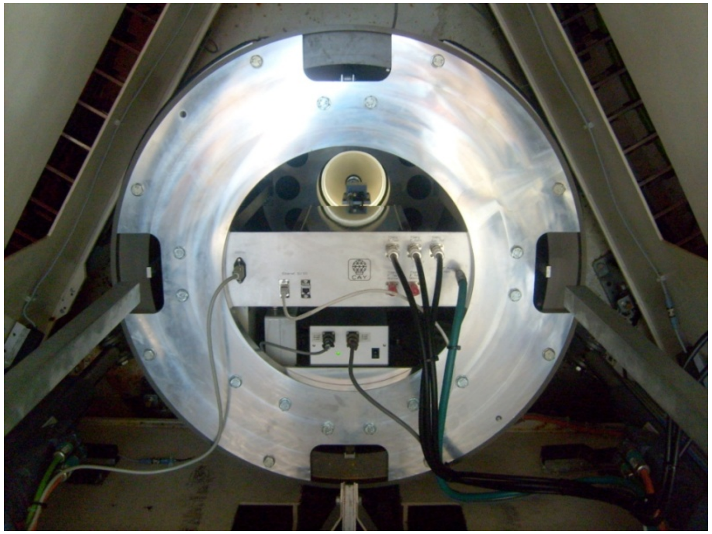
System block diagram



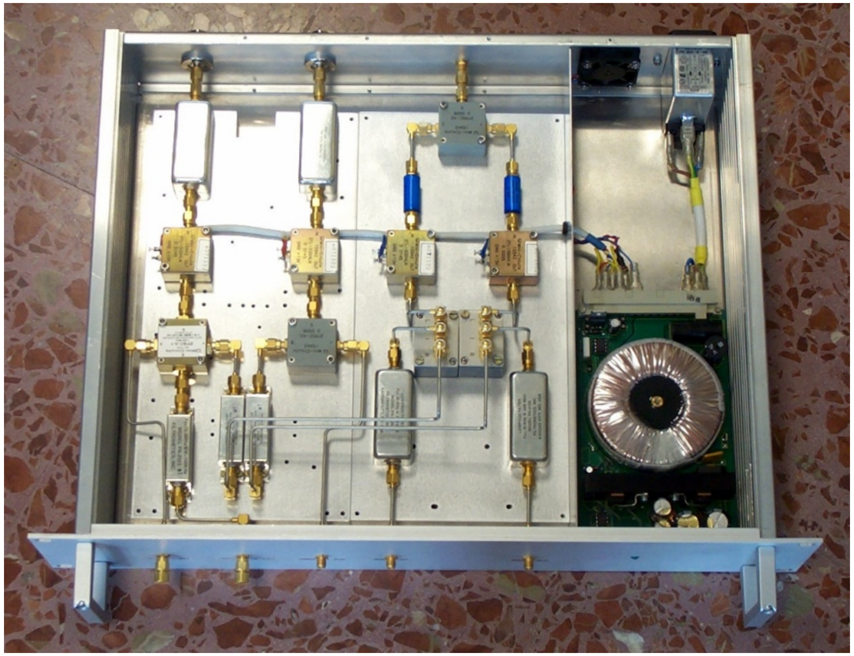
RF module installation

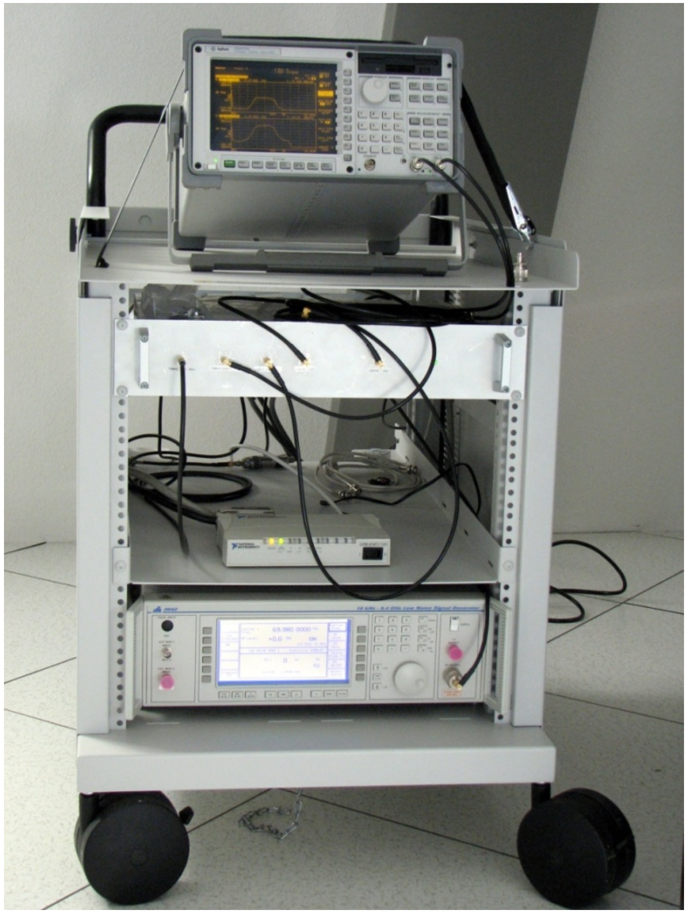




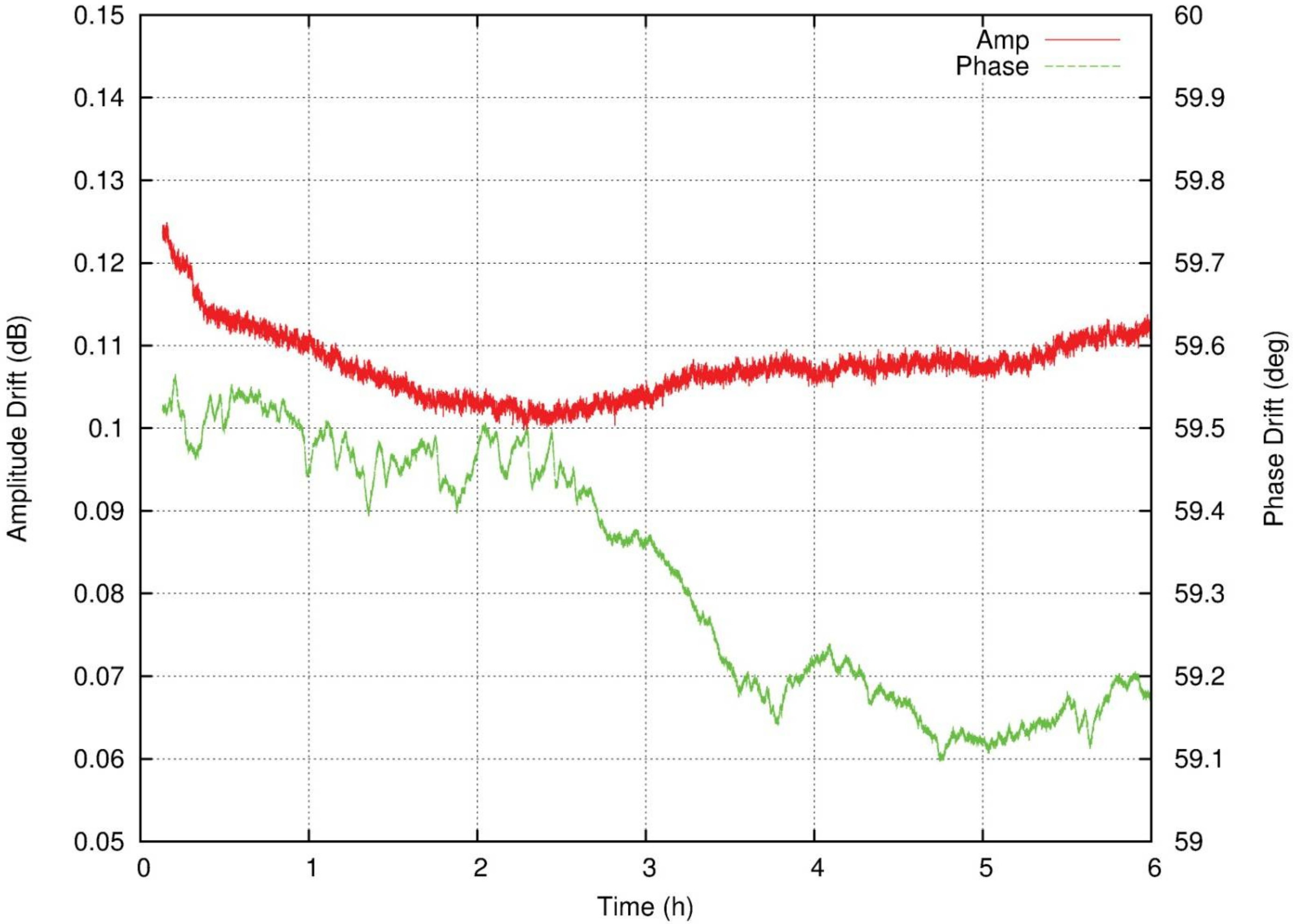


IF module + backend





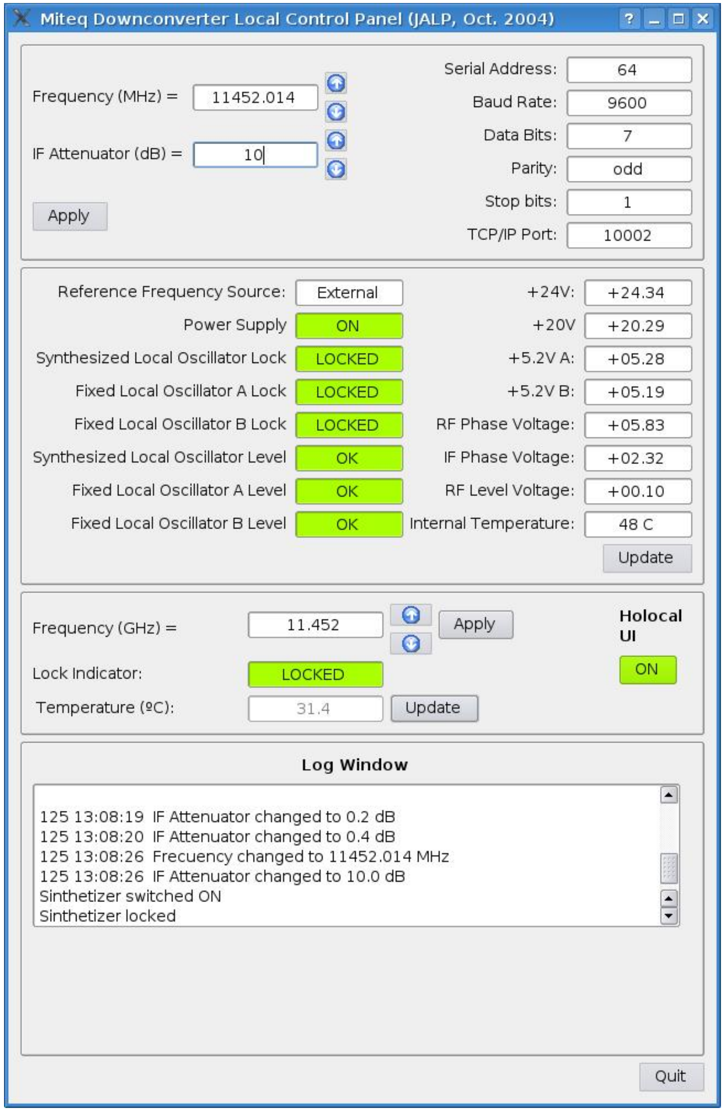
Holography Rx stability



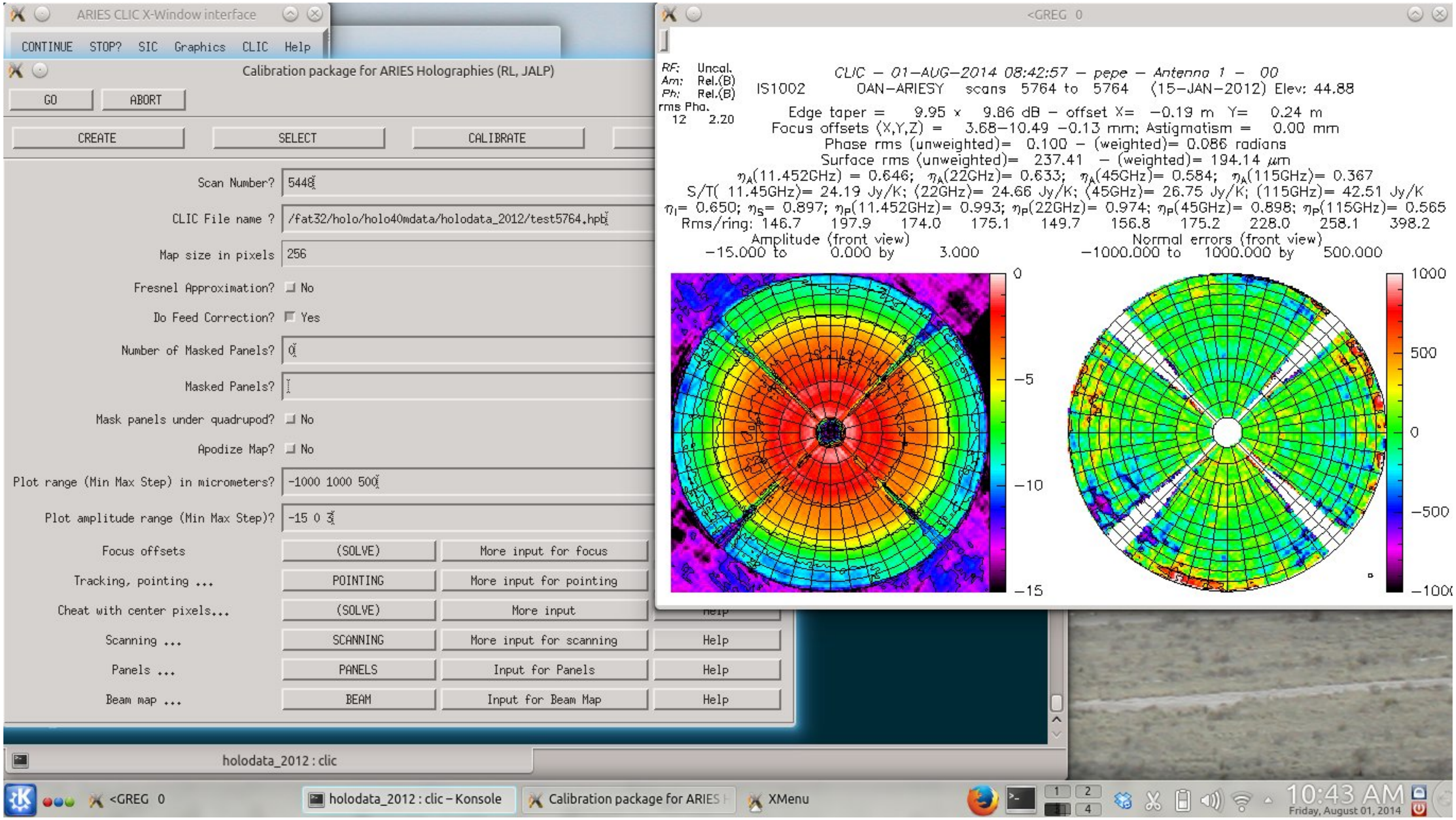
Summary of Holography RX parameters

- 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=11.3º
- TEST feed: ring-choke feed -9dB @ 64º
- REF channel: Trx < 96 Kelvin, Tsys < 111 Kelvin
- TEST channel: Trx < 83 Kelvin, Tsys < 126 Kelvin
- IF frequency: 20 KHz
- IF BW: 10 KHz

Rx Monitor & Control SW

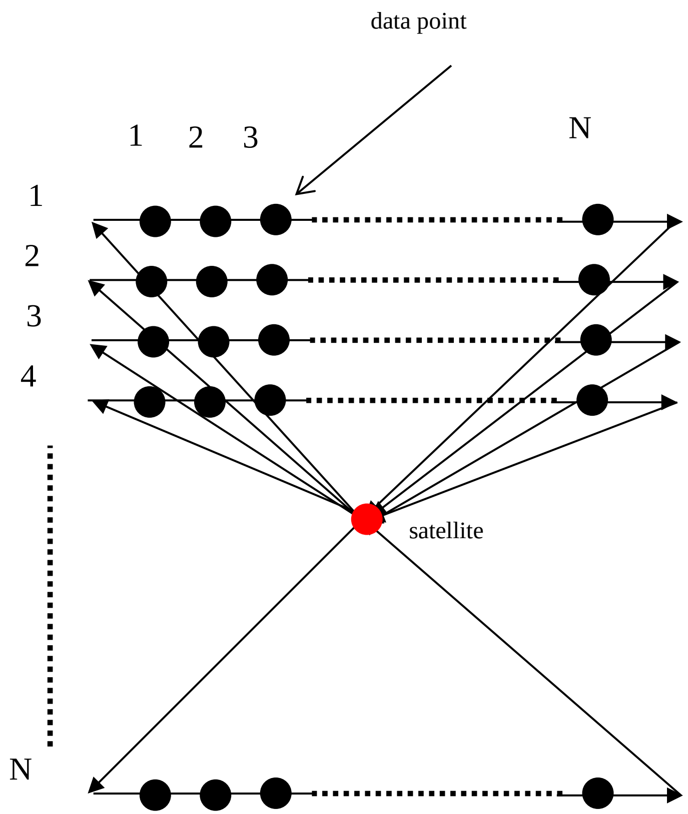


Data Reduction & Analysis SW

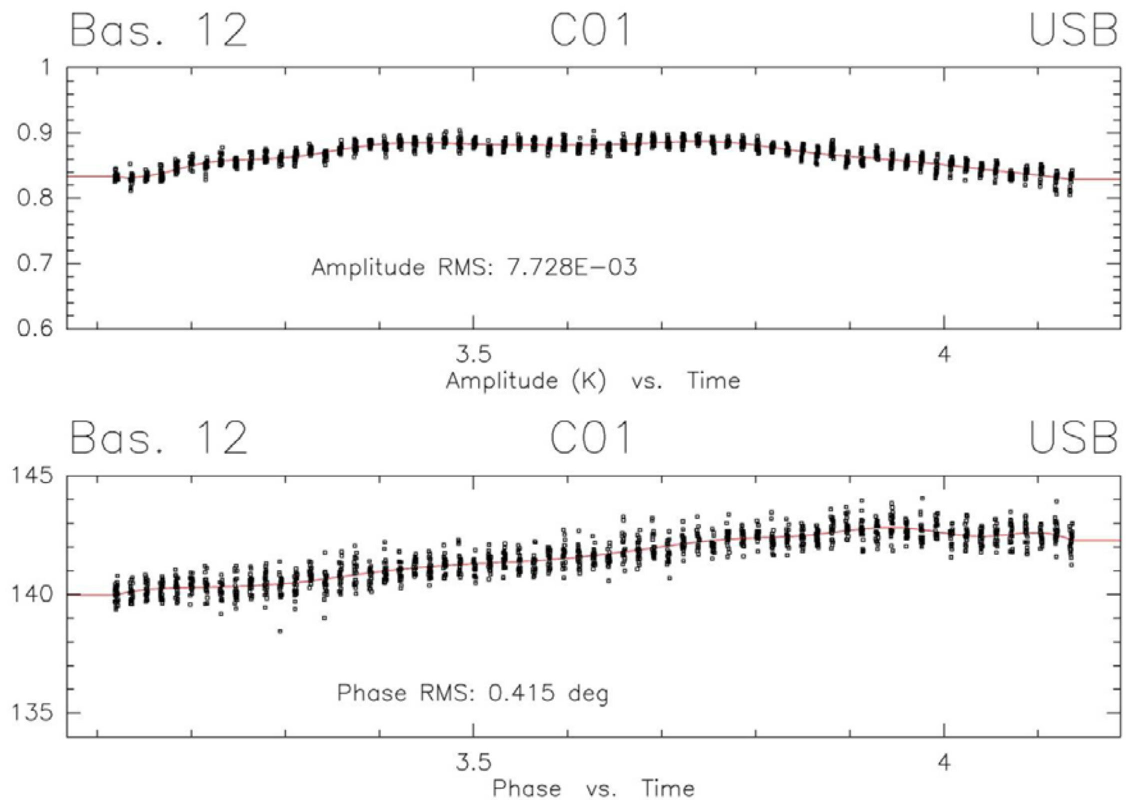


The ALMA Holography Software, from Robert Lucas, has been adapted to include the Yebes 40-m case.

Scanning during measurements



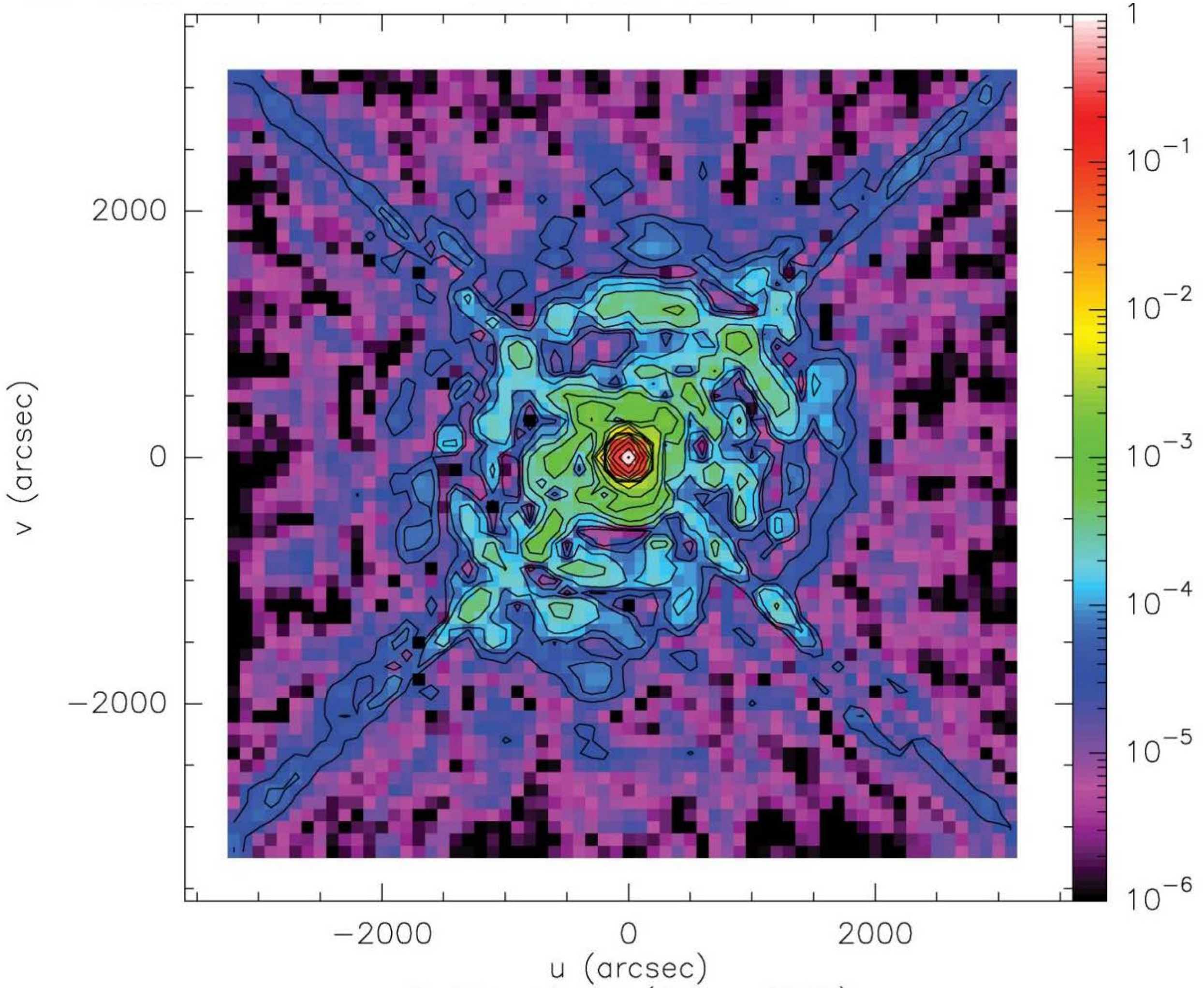
Calibration data



$$\phi_{RMS} = \frac{4\pi}{\lambda}\varepsilon_{RMS} \Rightarrow \varepsilon_{RMS}(\mu m) \cong 36.4 \cdot \phi_{RMS}\left({}^{0}\right)$$

$$\phi_{RMS} = 0.415^{0} \Rightarrow \varepsilon_{RMS} = 15\mu m$$

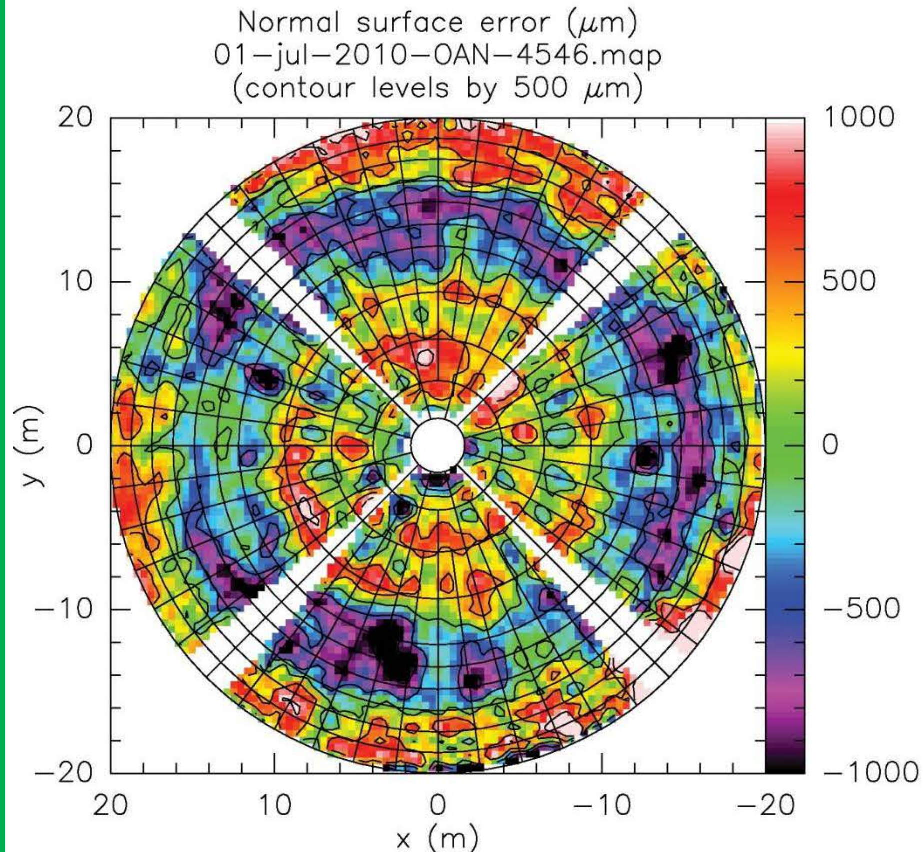
First measurements (July'2010)

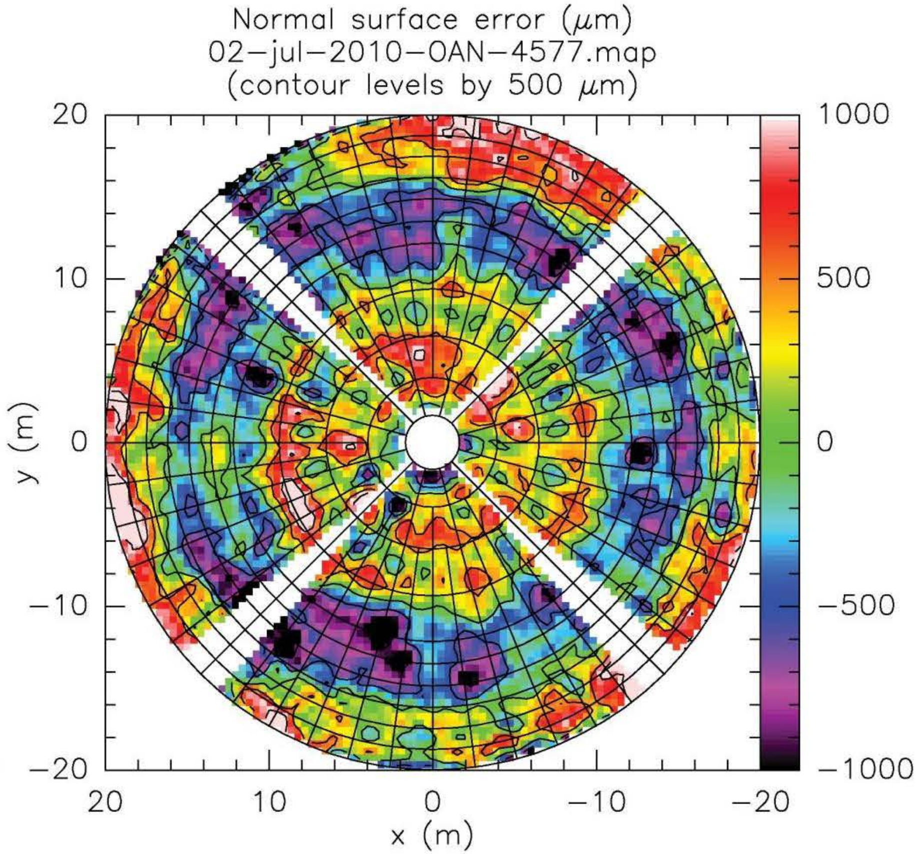


3 dB contours (0 to −45dB)

128x128 @ 100" (3.25h)

First measurements (July'2010)

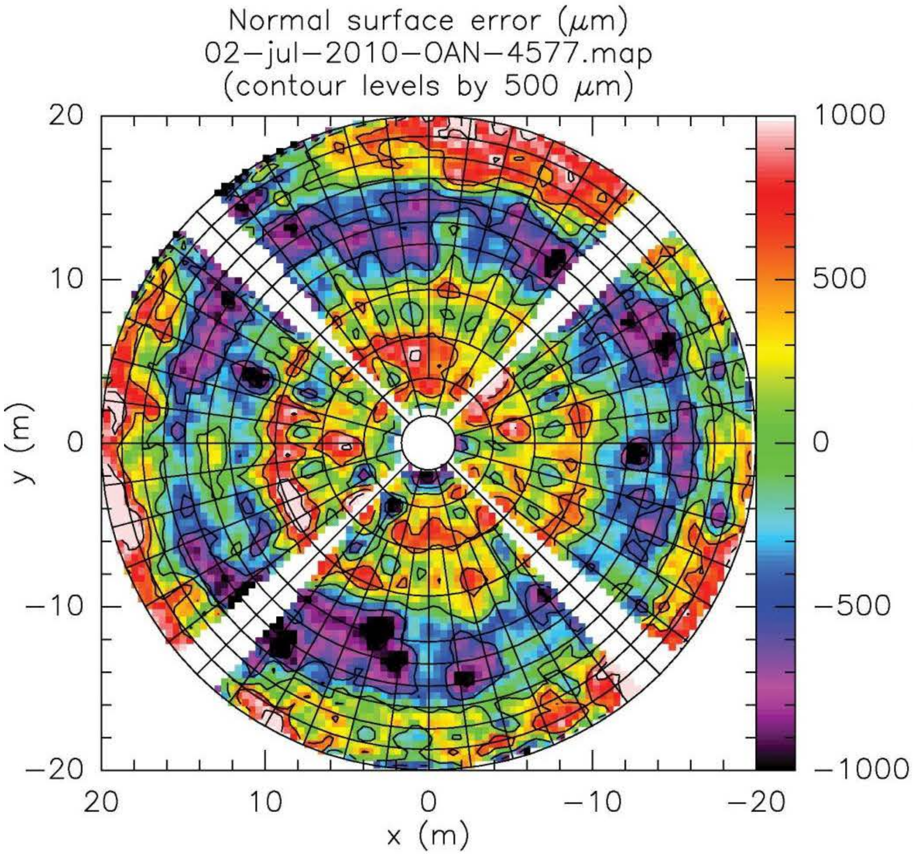




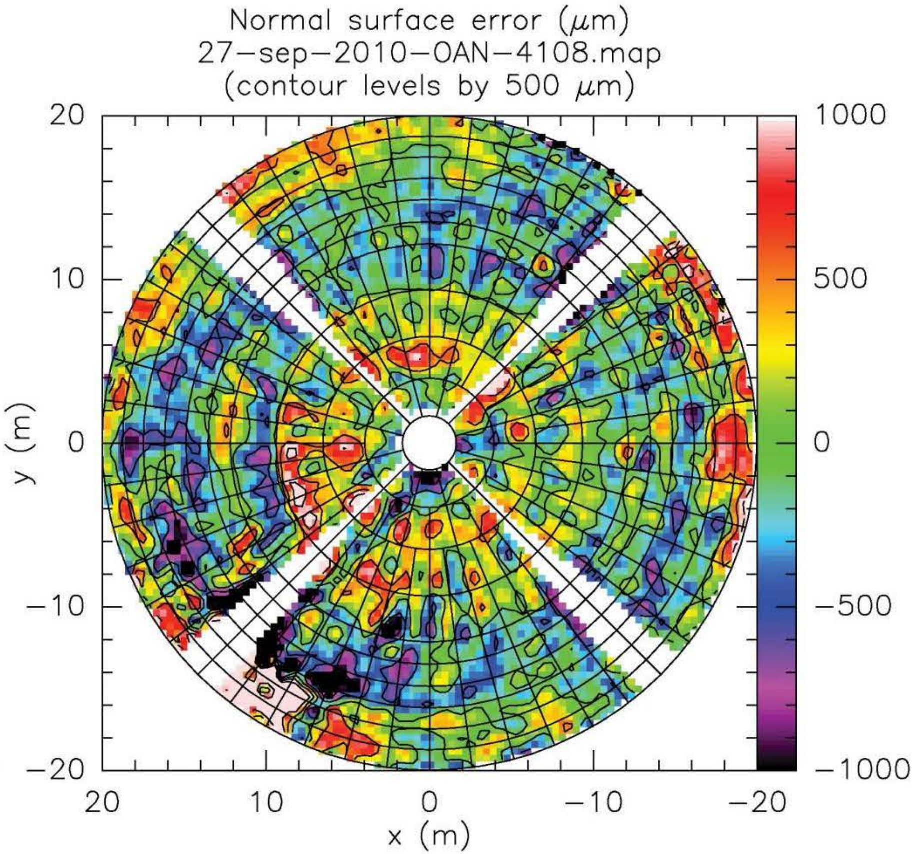
485 microns WRMS

First surface adjustments

Surface check after 1st partial adjustment

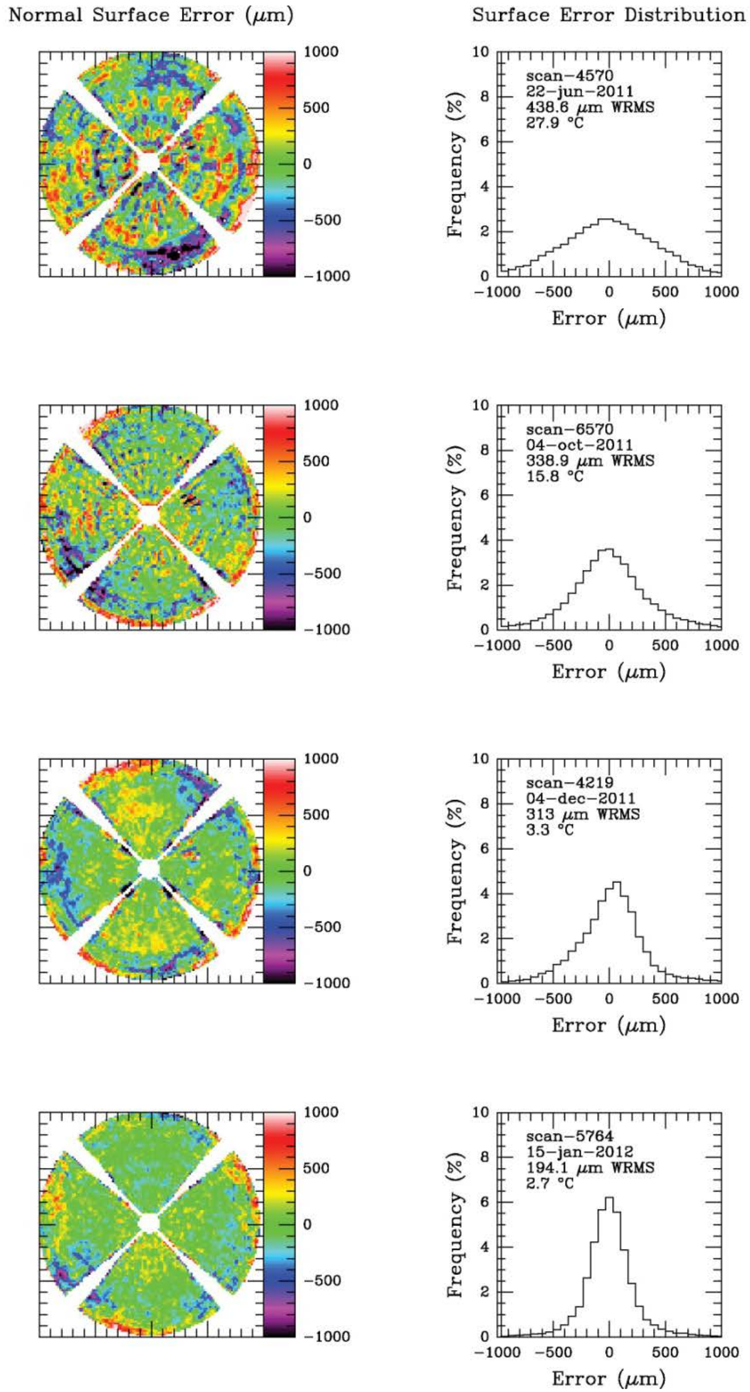


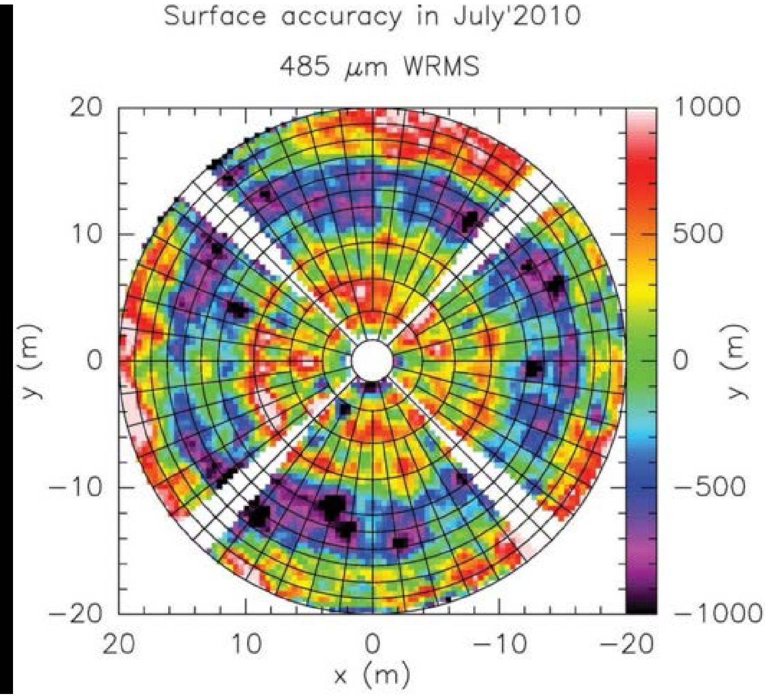
485 microns WRMS
July'2010



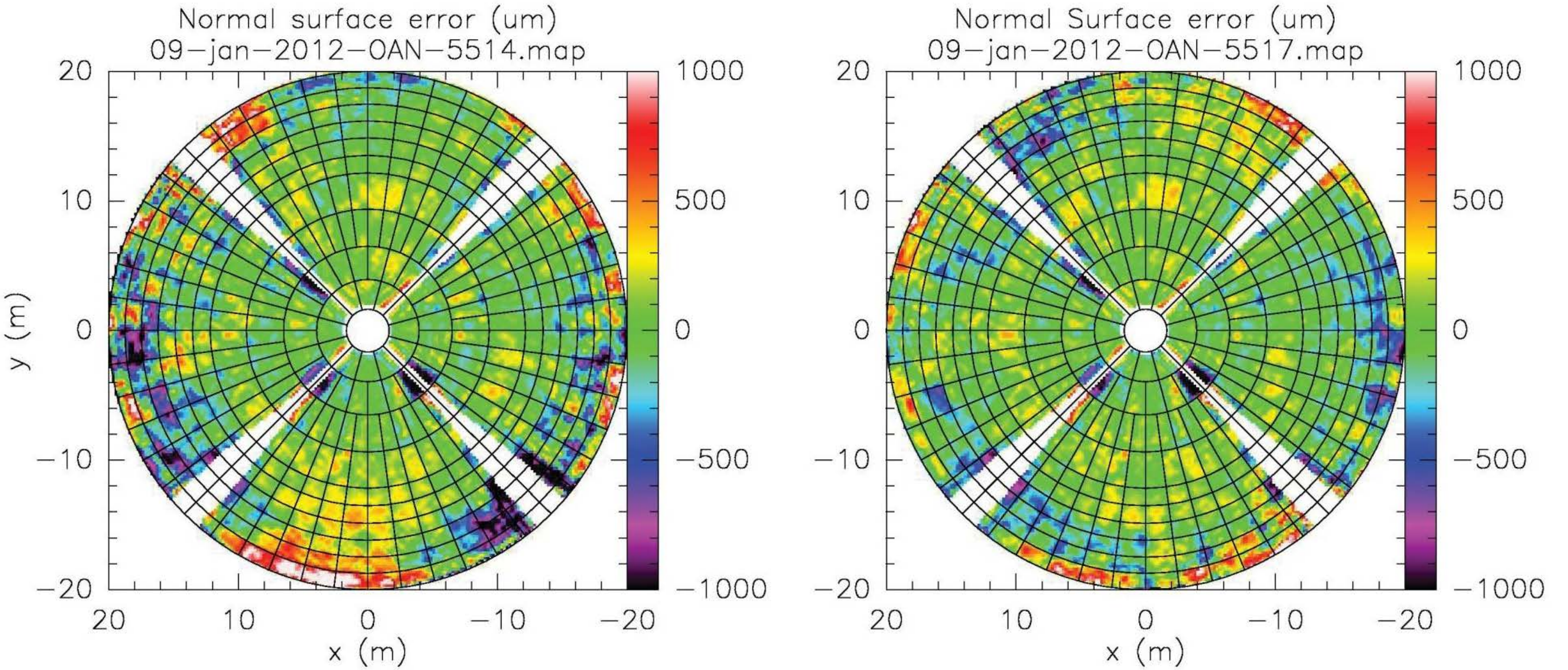
385 microns WRMS
Sept'2010

Surface improvement evolution



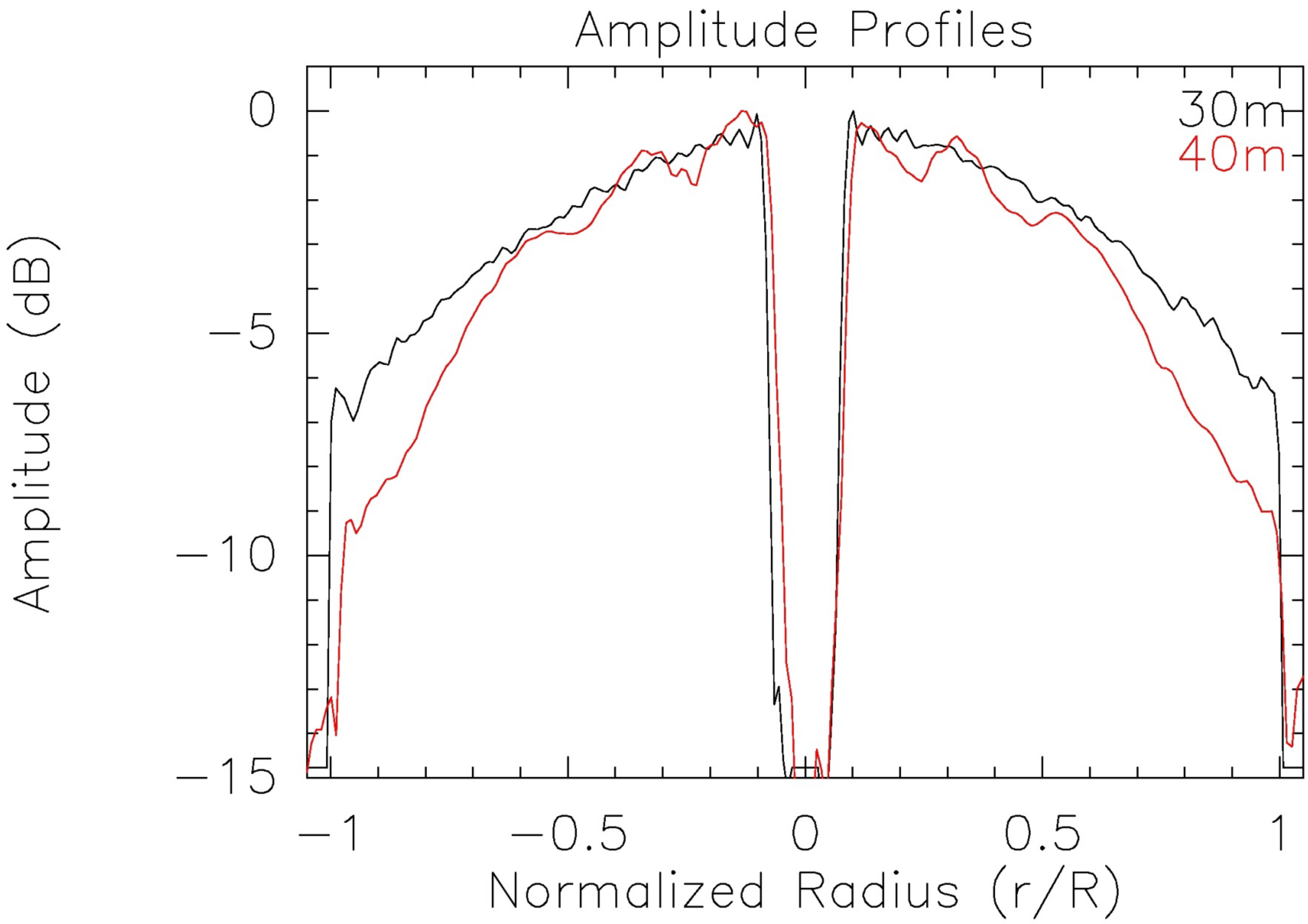


Measurement repeatability (I)

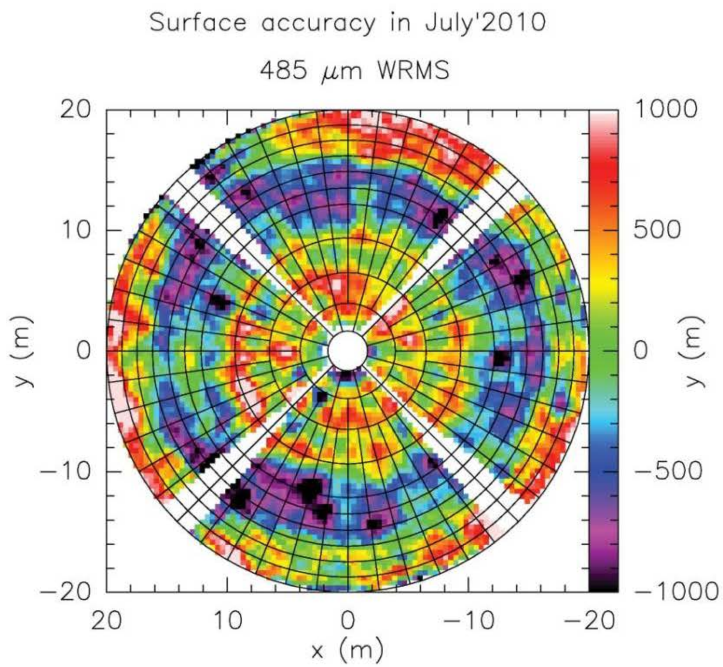


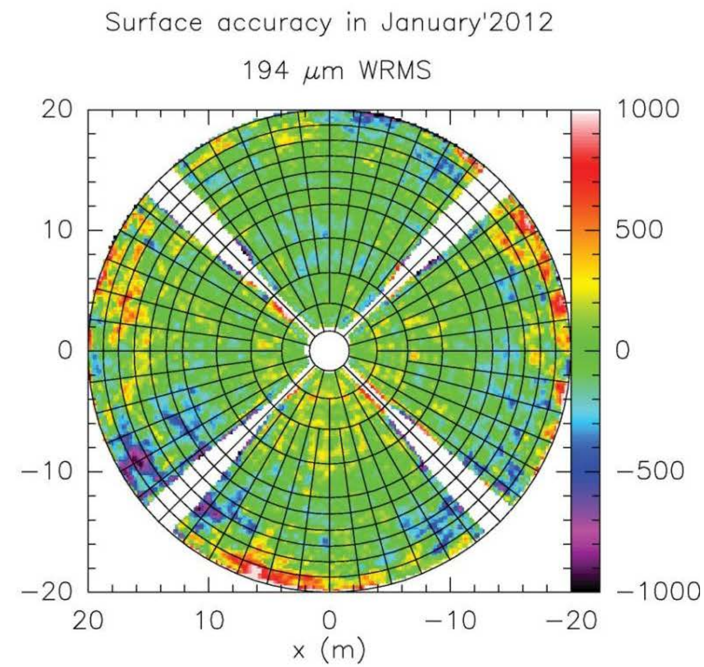
Anillo	1	2	3	4	5	6	7	8	9	10
Mapa 5514 (μm WRMS)	166	355	180	164	167	193	273	339	430	610
Mapa 5517 (μm WRMS)	161	345	176	159	137	152	243	251	270	379
Repetibilidad (μm WRMS)	44	45	58	76	115	143	203	323	467	598

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**

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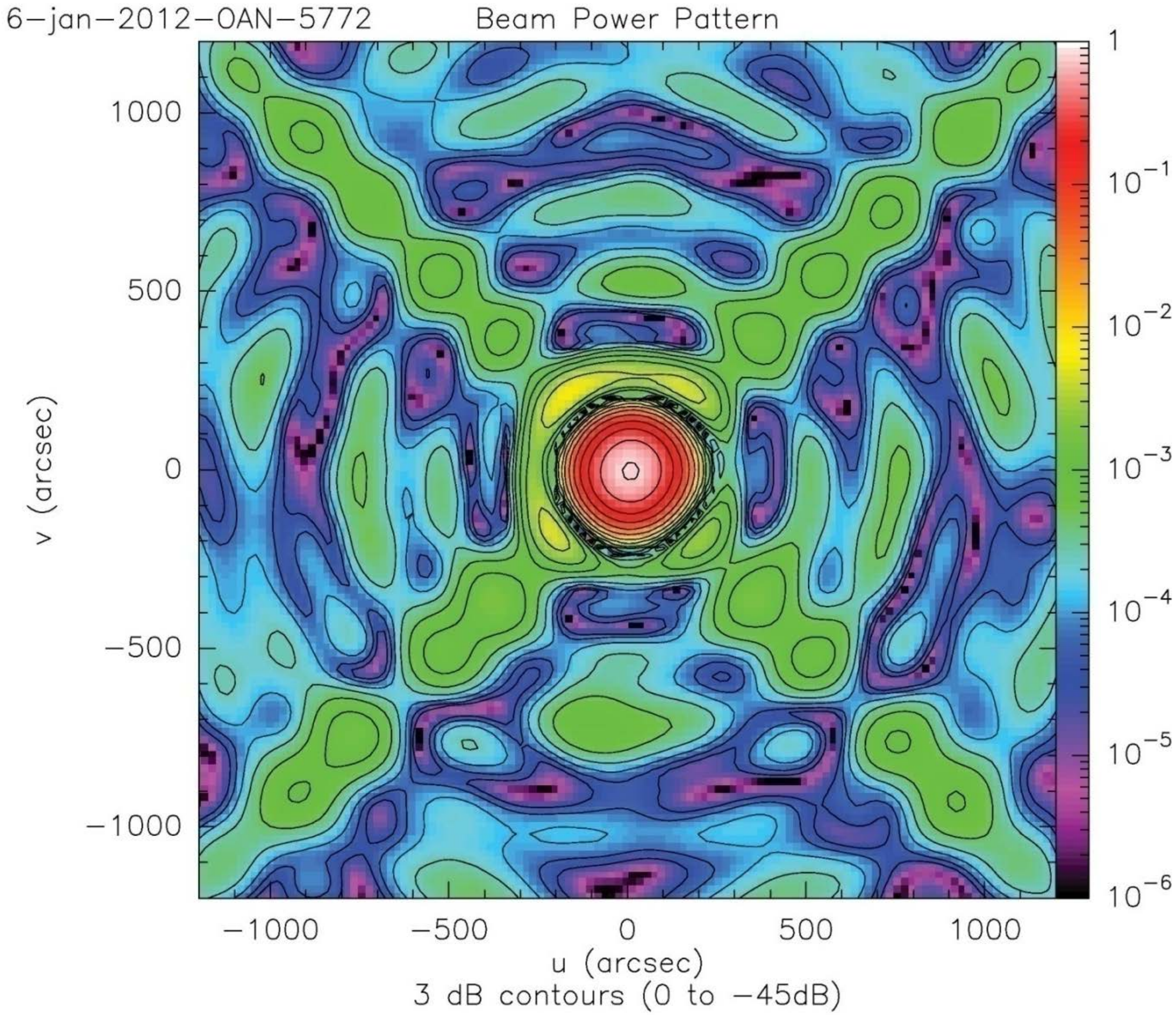
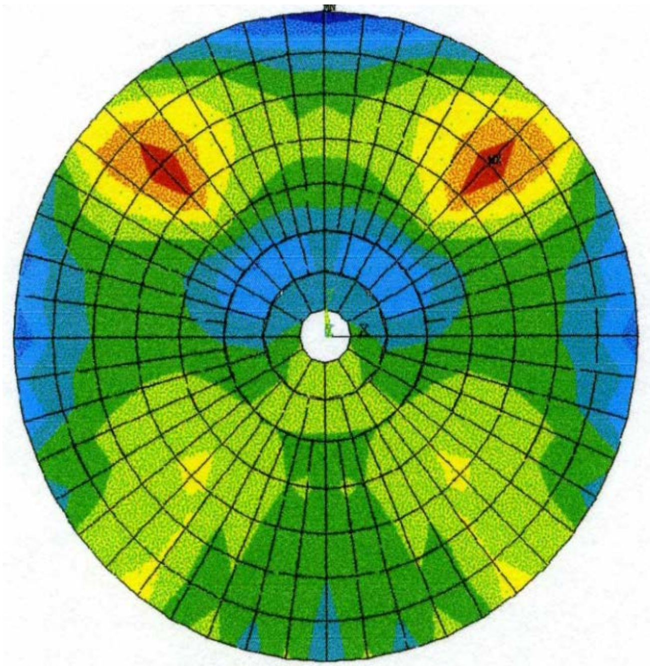
Additional results

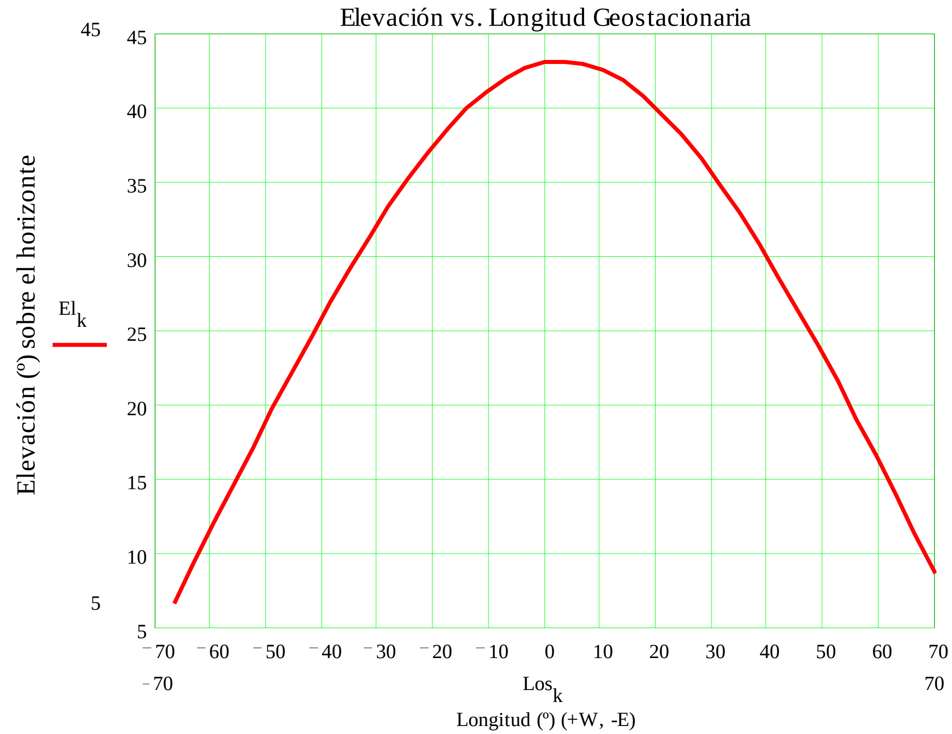


HPBW = 165” = 46 mdeg @ 11.45GHz

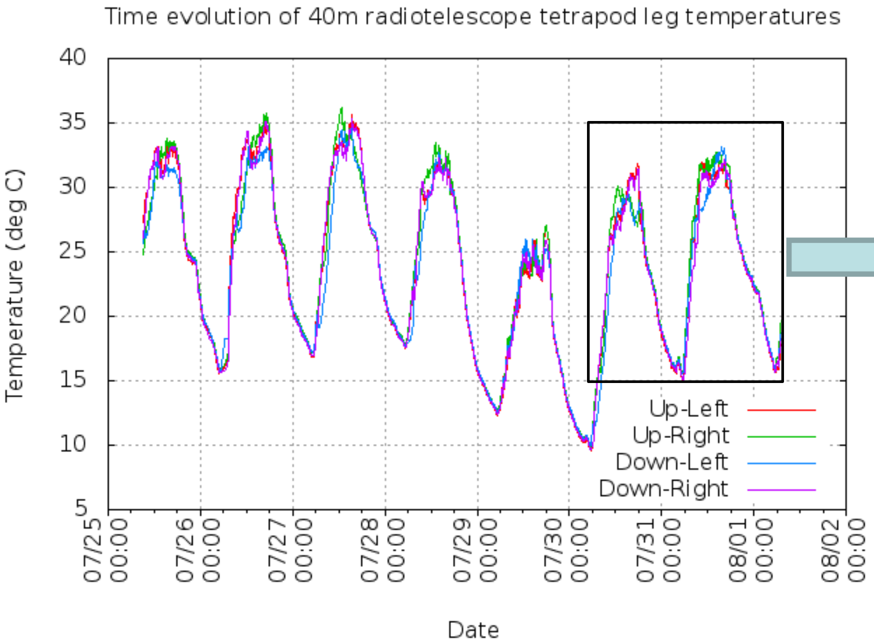
Verify FEM analysis at low elevation angles

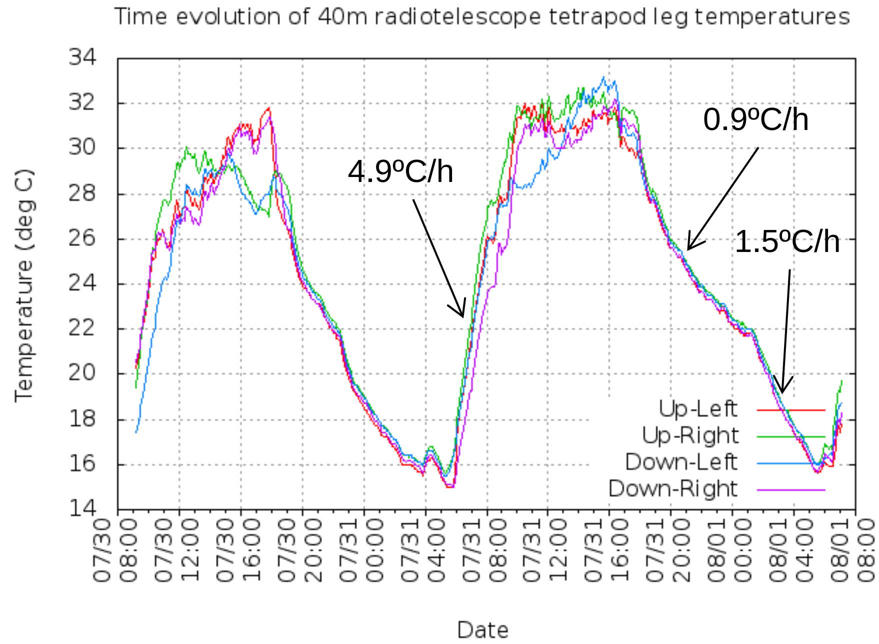


Gravity, $\varepsilon = 30°$
after adjust at $\varepsilon_0 = 45°$



Quadrupod Temperature Measurements using PT100 1/10 class B sensors





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

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 43º 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 Atenna by Secondary Surface Corrections"***. Microwave Journal, March, 1999, pp. 82-98.

Thank you !!