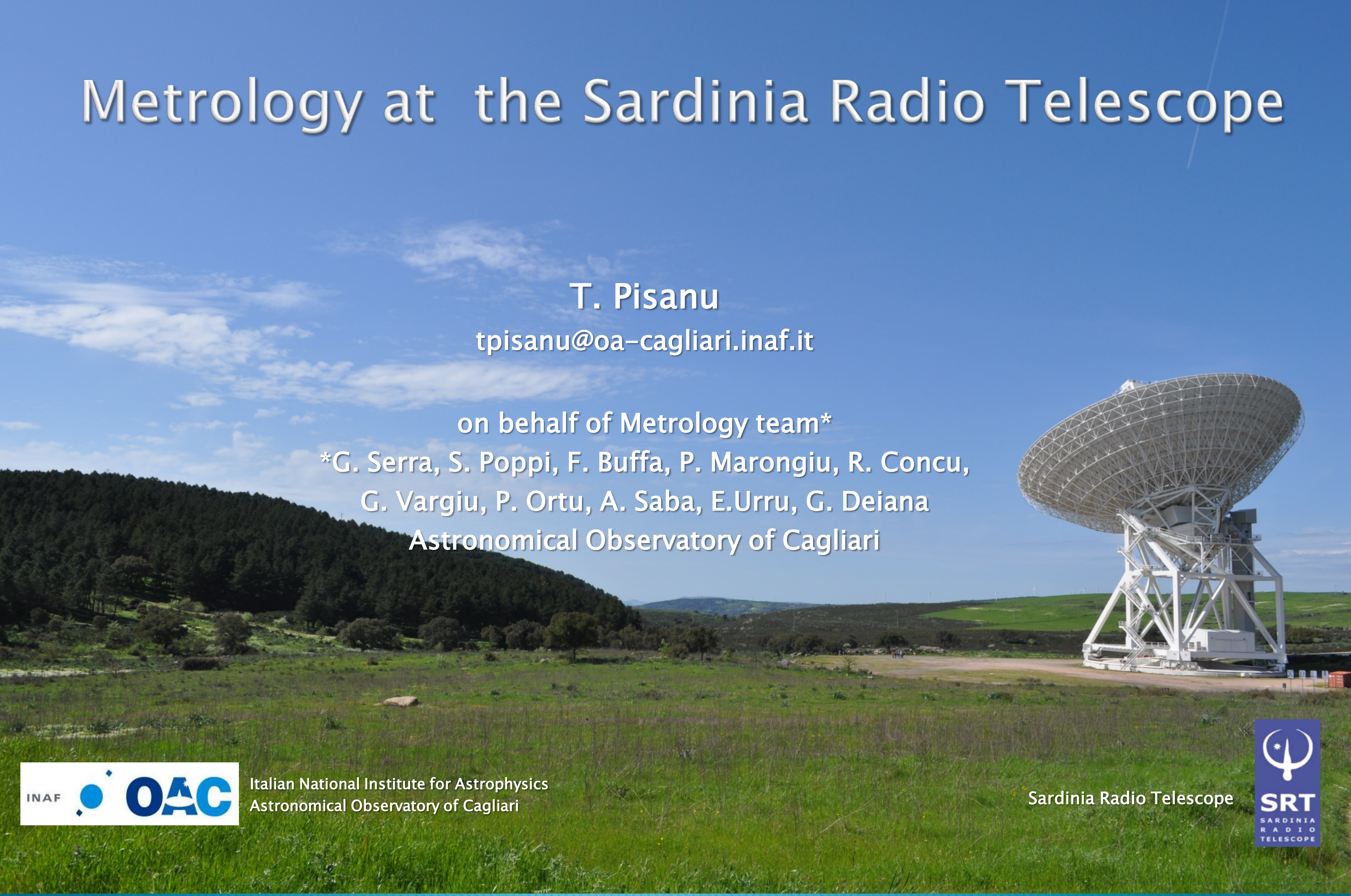

Metrology at the Sardinia Radio Telescope

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on behalf of Metrology team*

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Sardinia Radio Telescope

SRT SARDINIA RADIO TELESCOPE

Metrology and Control of Large Telescopes

Green Bank WV, USA, September 19-24, 2016

Agenda

- SRT main characteristics description
- SRT status at the end of the astronomical validation
- Work progress status of the first SRT metrology systems:
  - With-phase microwave holography
  - Inclinometers
  - Temperature probes
  - Optical laser and Position sensing devices (PSD)
- Conclusions

SRT Project

z:

September 30th 2013, SRT opening cerimony, 2014 end of the scientific commissioning and on 2016 started the early science. On 2017 we need to stop the antenna operation to start with the refurbishment of the primary reflector actuators.

Colla

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Ministero dell'Istruzione dell'Università e Ricerca

SRT technical specifications

Gregorian Configuration with shaped surfaces

Primary Mirror D=64 m – 1008 panels - 65 μm ; Secondary Mirror D=7.9 m – 49 panels - 50 μm

Active Surface: Primary mirror adjustable with 1116 actuators

12 motors (eight in azimuth and four in elevation)

29 bit absolute encoders (error 0,8 arcsec);

Six focal positions

Can host up to 20 dual polarization receivers;

ACU based on a BECKHOFF hardware

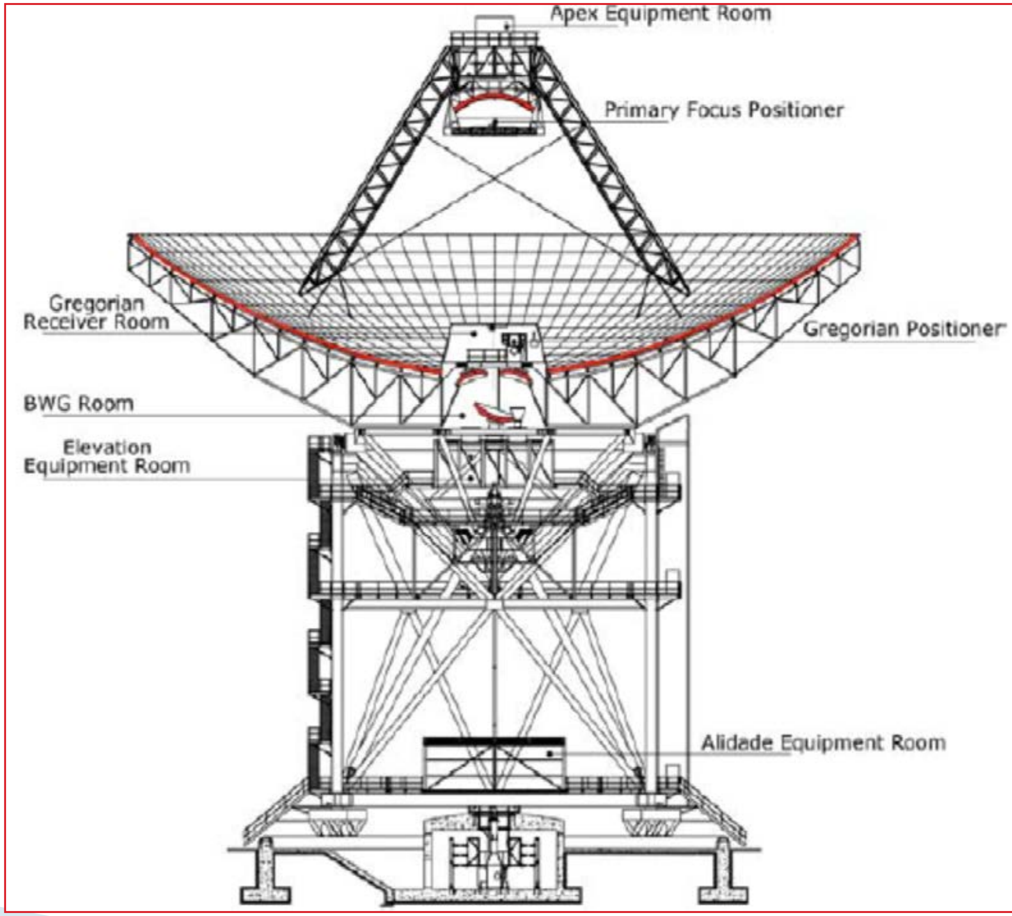
Primary surf. Accuracy goal: ≈ 150 μm RMS

Pointing accuracy goal (RMS): 2 ÷ 5 arcsec

Max antenna efficiency goal: ≈ 60 %

Gain exp. 0.50 to 0.70 K/Jy @ 0.3–50GHz and 0.34 K/Jy @ (70– 115GHz).

Frequency agility



SRT status: installed receivers

F/D =2.35
7.5GHz < *f* < 115GHz

18-26,5 GHz

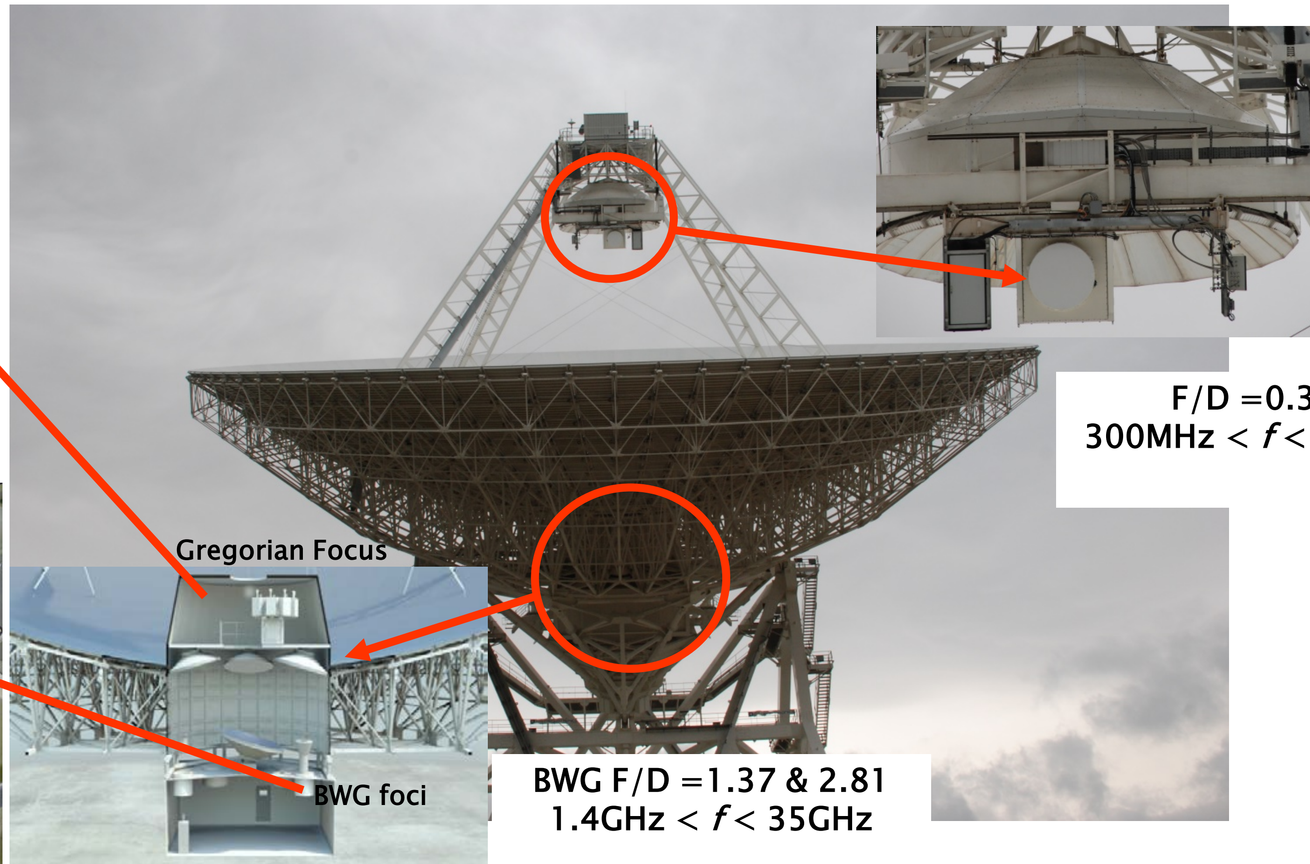
K-band receiver

5.7-7.7 GHz

C-band receiver

0.305-0.410 /1.3-1.8 GHz

P/L-band receiver



F/D =0.33
300MHz < *f* < 20GHz

BWG F/D =1.37 & 2.81
1.4GHz < *f* < 35GHz

S-band (3-4.5 GHz) and Q-band (33-50 GHz) multifeed receivers founded and in developement. A 100 GHz receiver got from IRAM and an X-Ka band

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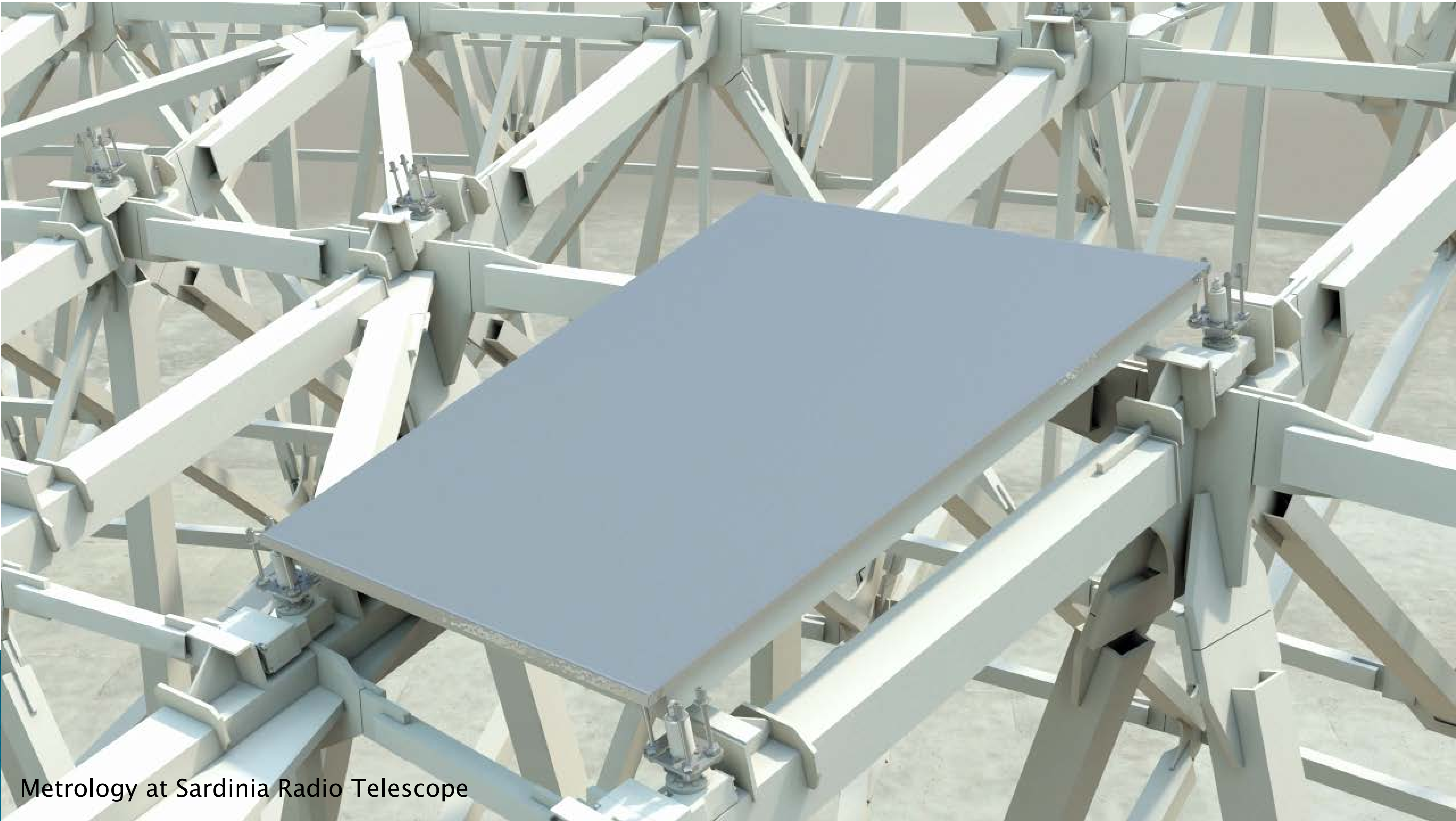
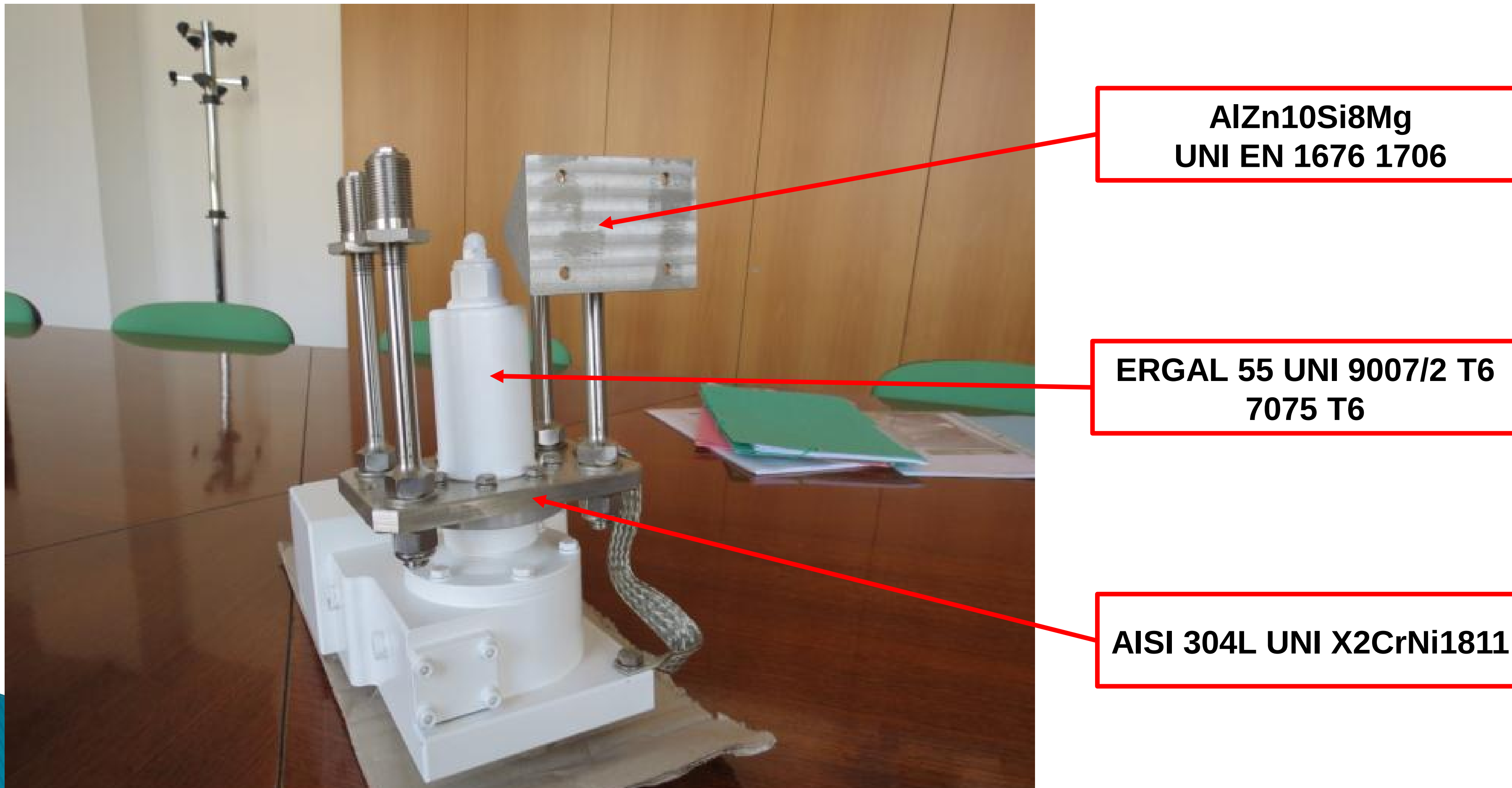
Active surface: shape of primary mirror controlled with actuators

- Compensate deformations of the primary mirror
- Convert shaped profile to a true-parabola (for primary focus)



Actuators problem: Corrosion phenomena

The problem with the actuators was due to two concurring negative phenomena, like strain-induced-corrosion and galvanic currents. The coupling of two alloys, like steel and ERGAL contributed to increase those two phenomena, creating cracks in the ERGAL part and compromising the actuators integrity.

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SRT status: surface accuracy

After the first panels alignment of the secondary and primary mirror with fotogrammetric measurement (by SIGMA 3D) AICON DPA mit Nikon D3X, 24.5 MPixel (6048 x 4032) 2 Scale bars, TrafoStar

Subreflector surface

Accuracy: ~ 60 µm RMS @ 45° elevation

Primary reflector surface

Accuracy: ~ 290 µm RMS @ 45° elevation

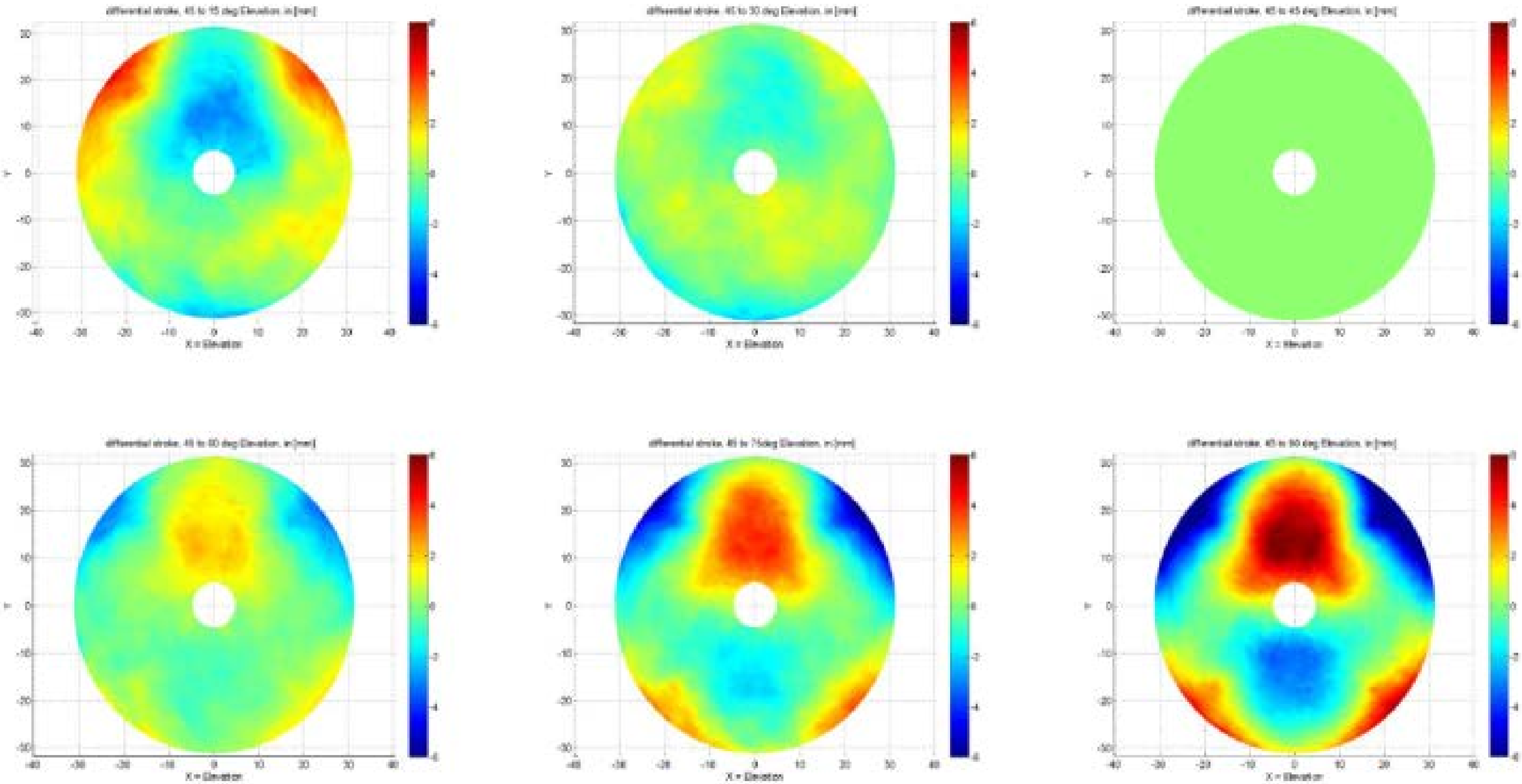
Accuracy in the adjacent panels corner alignment better than 100 µm

Overall RMS accuracy of the reflecting surfaces ε~ 310 µm (= λ/20 @ ~ 48 GHz)

Very good surface efficiency up to 48 GHz

Primary mirror Fotogrammetry results

Surface deflections in different elevation positions from 15 to 90 deg elevation, refered to 45 deg reference



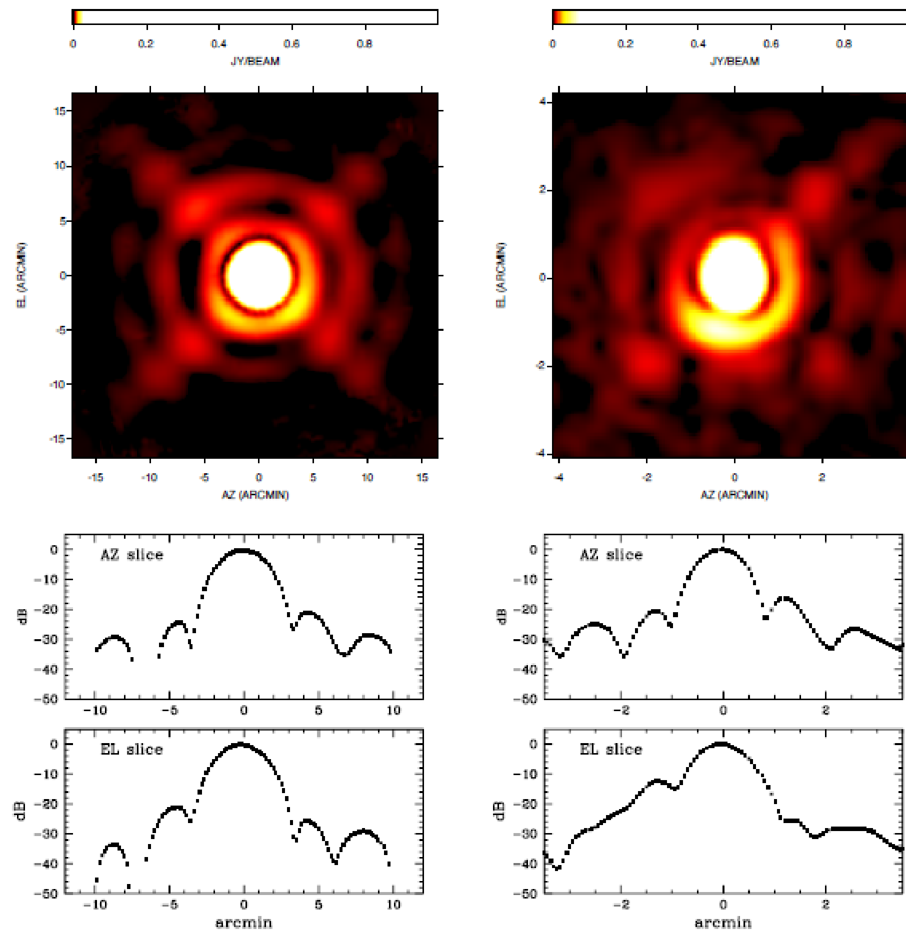
SRT status: antenna performances

Top:
Elevation-averaged beam patterns (in Jy/beam) of 20 OTF scans

Bottom:
Beam cross-sections along the Azimuth and Elevation axes (in dB).

Calibrator 3C147 @ 7,24 GHz
Calibrator 3C84 @ 25,54 GHz

Fitting a Gaussian we can find the secondary lobe intensity averaged over an annulus of
4.5' radius and 3' width is -24 dB and the third lobe is – 33 dB in which it is possible to see the effect of the trusses of the quadripod but for the K band the secondary lobe is -12 dB so not in specific



Courtesty of SRT Astronomical Validation (Prandoni et al. in preparation)

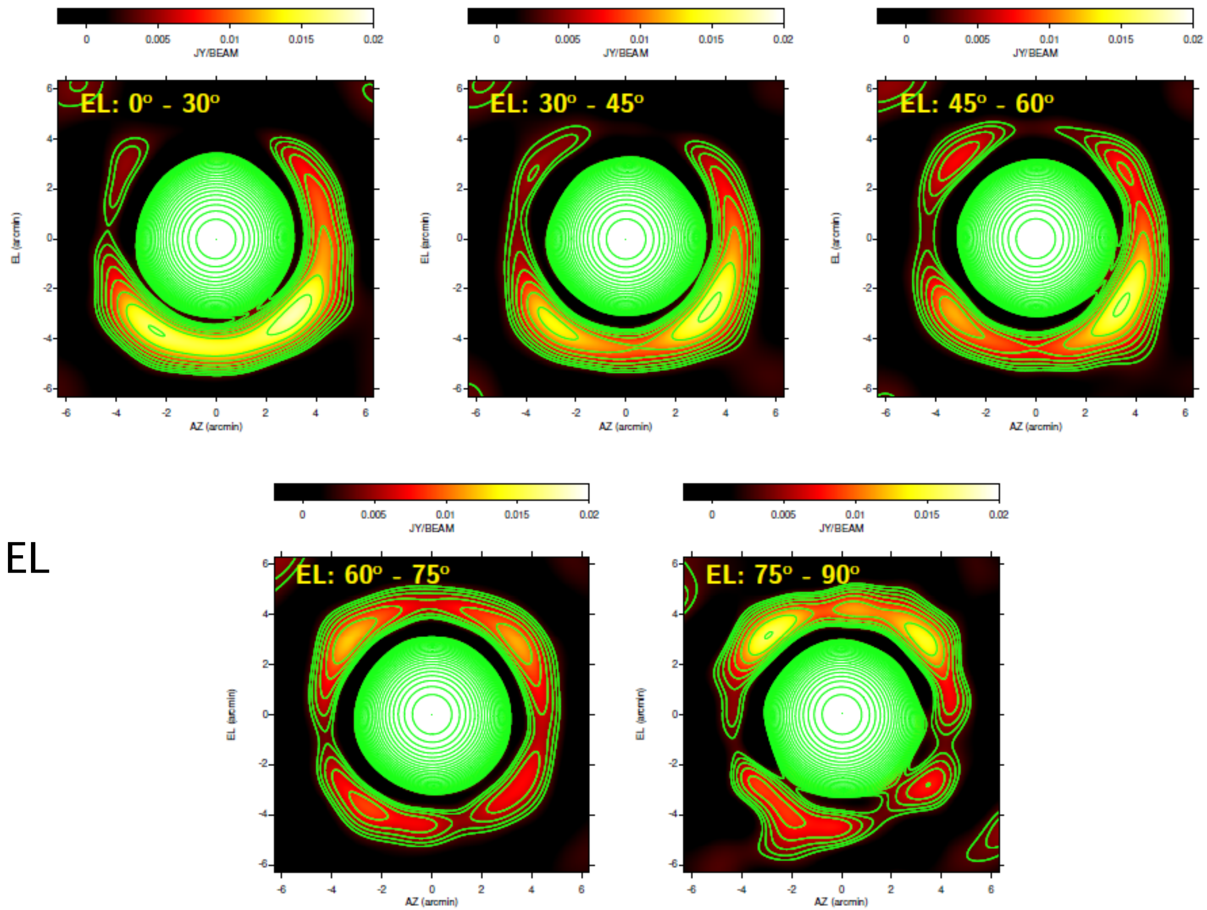
SRT status: antenna performances

Map dimension 6’ x 6’

Maps of Contour levels start at -25 dB and increase by 1 dB.

HPBW 2.6 arcmin

The secondary lobe moves from the upper part to the lower moving from the 60° EL

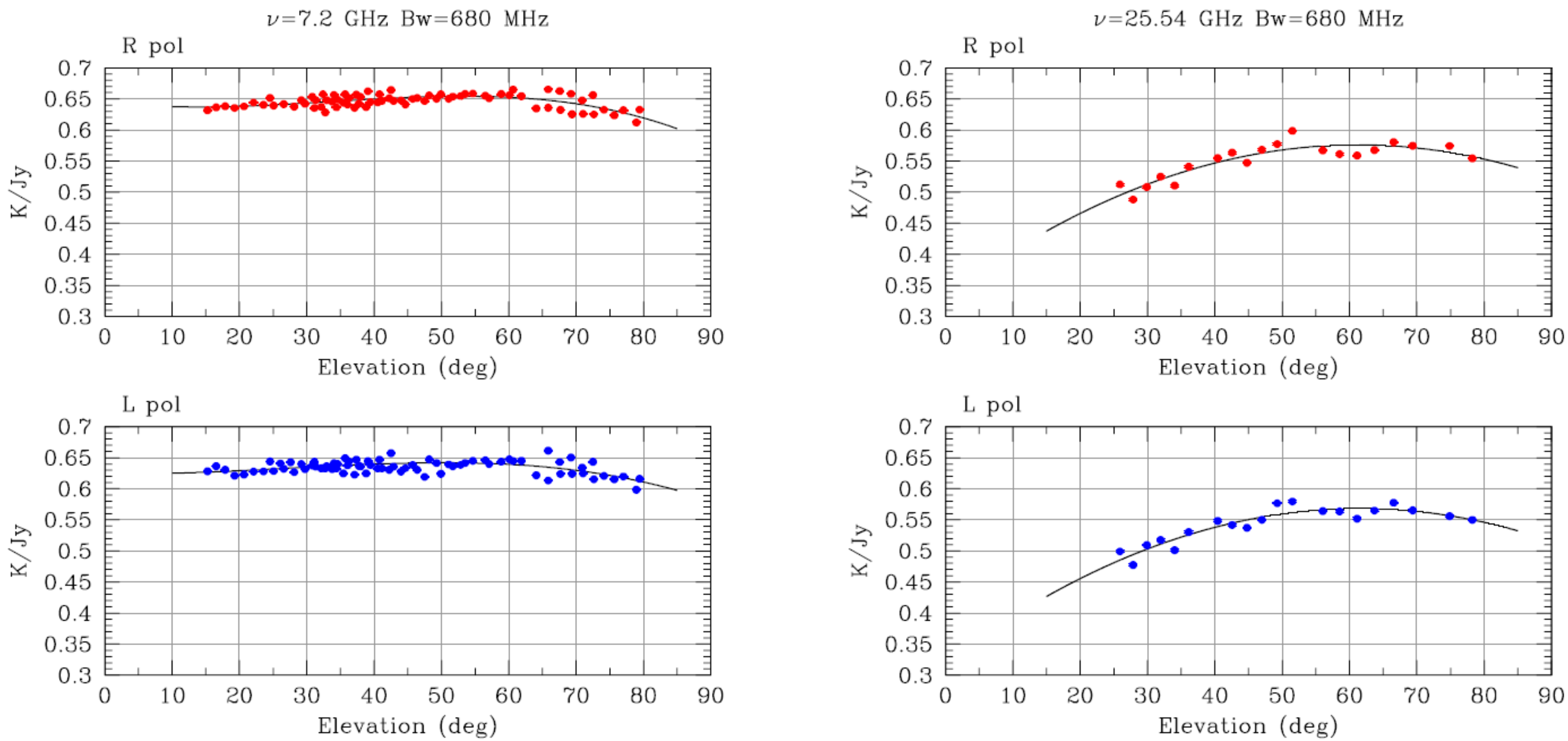


Courtesty of SRT Astronomical Validation (Prandoni et al. in preparation)

SRT status: antenna performances

After the fine tuning of the telescope with active surfaces working, the pointing model allows SRT to observe at 22 GHz with a:

- focusing accuracy < 1 mm
- an azimuth and elevation pointing errors < 4 arc sec



Courtesty of SRT Astronomical Validation (Prandoni et al. in preparation)

SRT metrology short-term goals

Waiting for the higher frequency receivers, the metrology team is working to further improve the current SRT efficiency

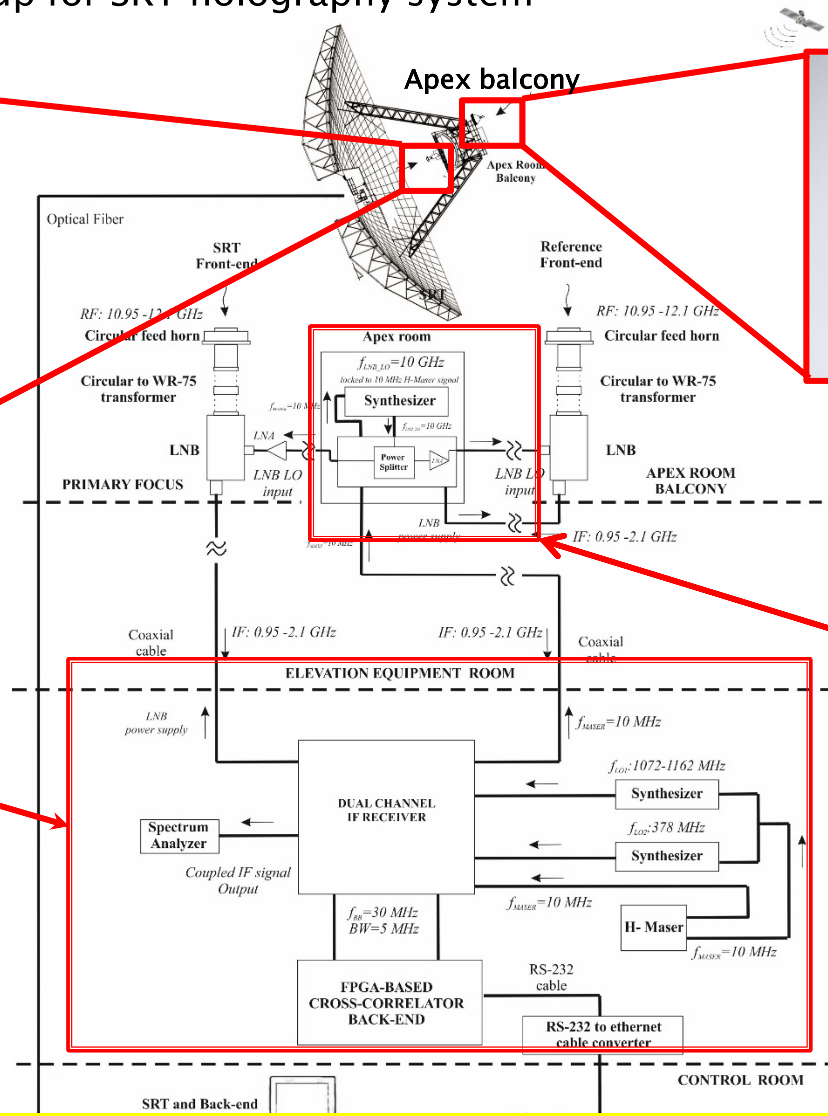
- Short-term goals:
  - To measure the primary surface accuracy better than 150 μm (i.e. an overall surface accuracy 190 μm, a very good efficiency up to ~80 GHz) with **Microwave holography system** to measure RT far-field pattern by pointing a Ku-band GEO satellite (elevation angle 44 deg);
  - To contribute to correct azimuth and elevation pointing errors < HPBW/10 (~ 1 arcsec with HPBW =12 arcsec @ 100 GHz) with **two inclinometers on top of the alidade structure;**
  - **Temperature sensors** for reducing detrimental thermal gradient effects on the pointing errors;
  - To correct pointing errors and focusing accuracy < λ/10 (~0.3 mm @ 100 GHz) with **optical laser-PSDs** behind the subreflector central panel;

Status of holography system

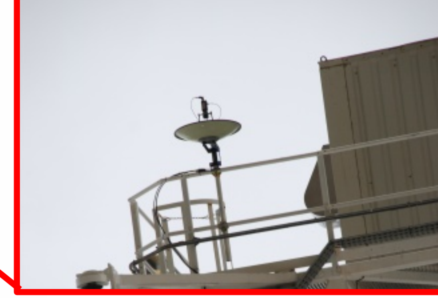
New measurement set-up for SRT holography system

RT front-end

modified LNB
on the primary focus



Reference front-end



0.6m-diameter antenna and
modified LNB

RF equipment for injecting the
10 GHz LO signal to LNBs
at the apex room

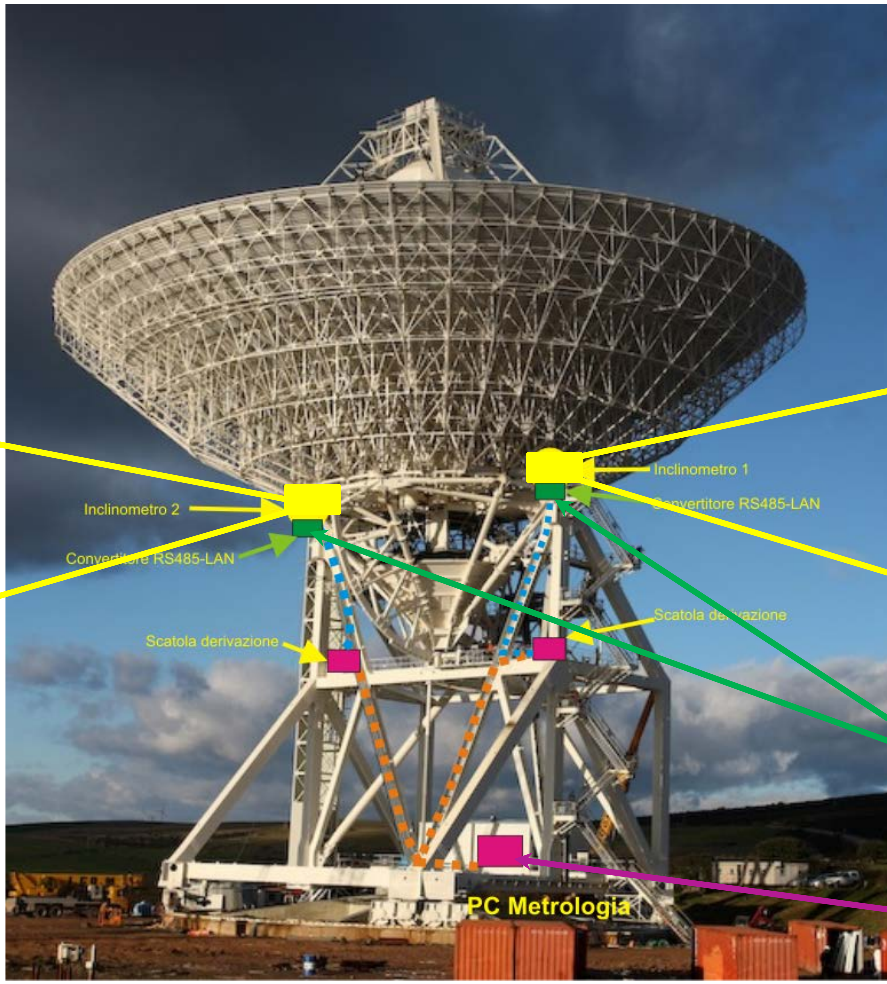
RF electronics rack at EER
(where IF-BOX and digital
backend will be soon installed)

Installation completed by 2014 and few months ago we started the first holography campaign at SRT

Status of Inclinometer

On the base of the recommendations coming from the SRT thermal design study

Inclinometer #1



Inclinometer #2
(not installed yet)

RS485-LAN converter

Inclinometer control PC

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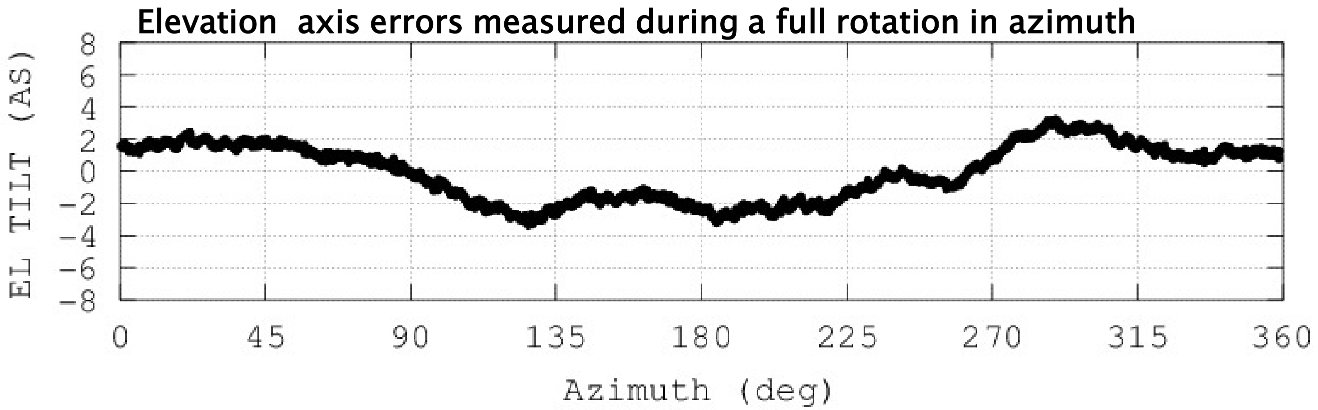
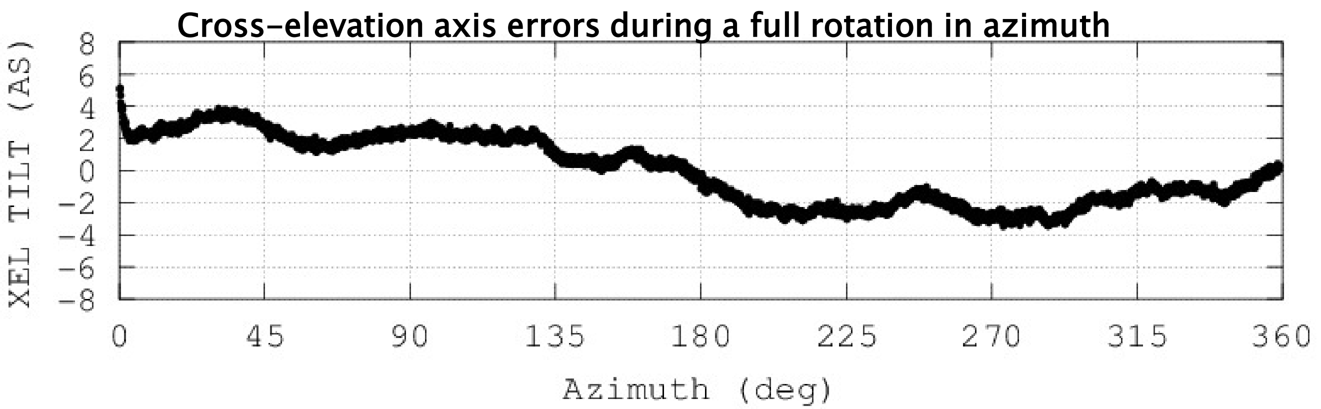
Status of inclinometer

Tests to check the planarity of the azimuth rail



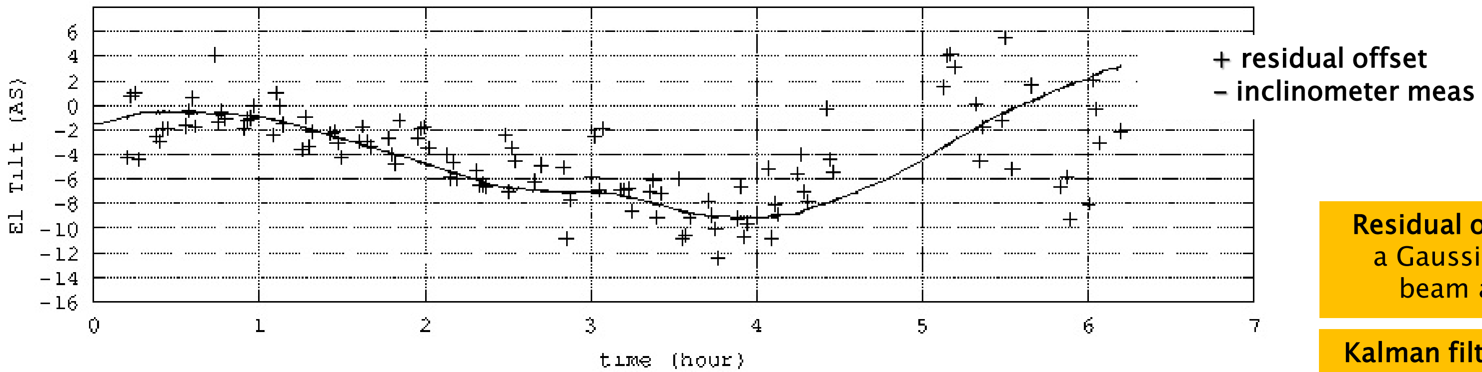


Systematic errors not far from the expected one (±3 arcsec) deriving from the rail planarity tolerance. However they can be included in the antenna pointing model

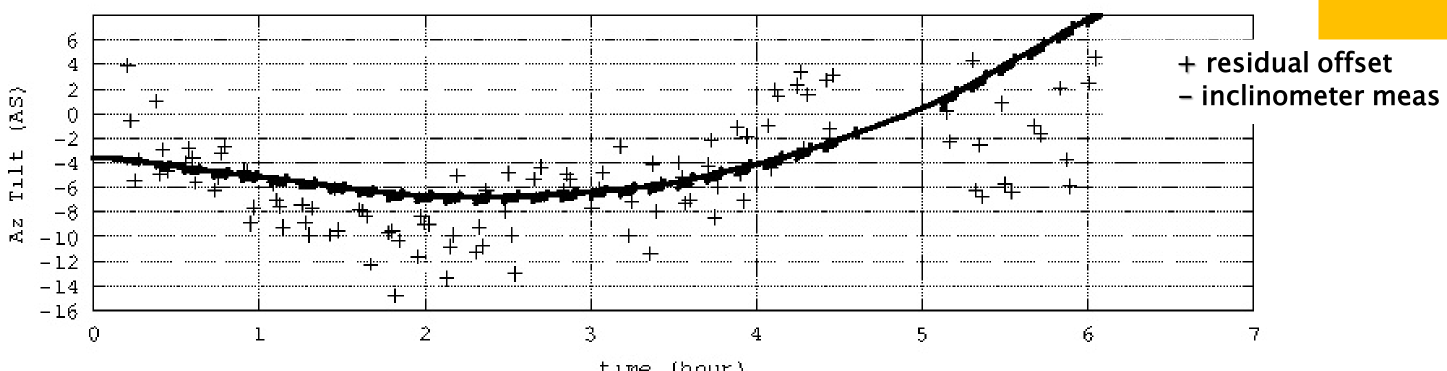
Work progress status of inclinometer

Inclinometer measurement during astronomical observation on a circumpolar radio source at 23 GHz (K-band receiver) from sunrise to noon.

Elevation axis errors caused by antenna thermal deformations



Azimuth axis errors caused by antenna thermal deformations



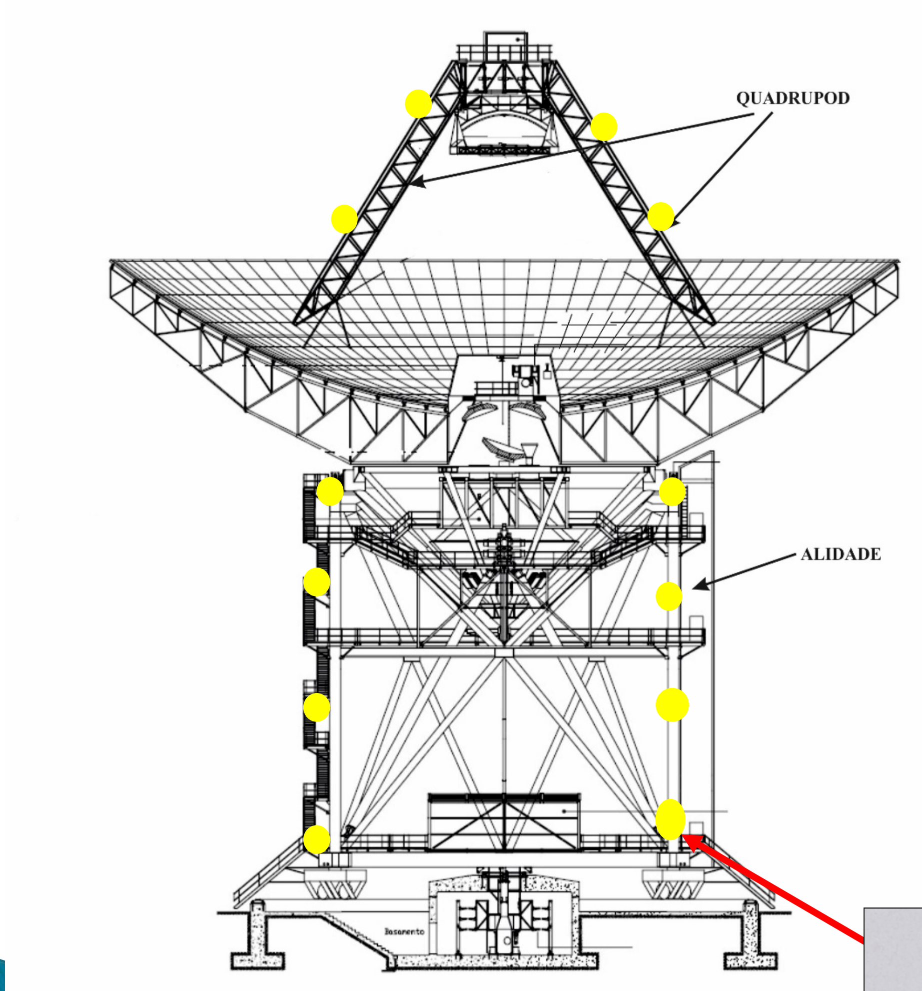
Residual offsets calculated from a Gaussian fit of the antenna beam after a cross-scan.

Kalman filter was used to remove the noisy high frequency components due to antenna acceleration.

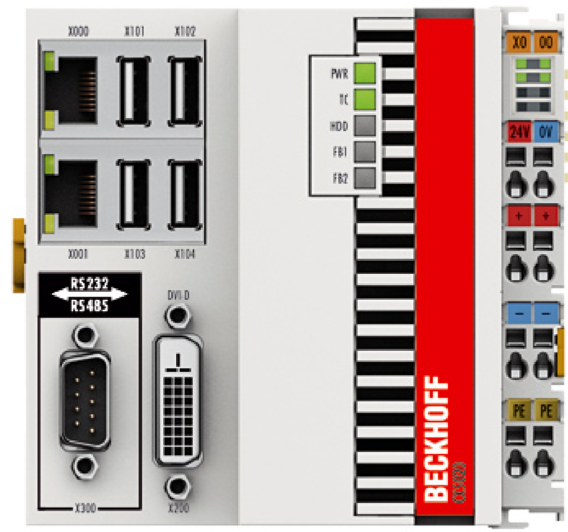
NOTE. With the antenna pointing model working, **residual offsets** take into account both alidade and quadripod temperature variation (not only alidade as in the inclinometer measurement)

Status of temperature probes

The number and position of the temperature probes on SRT structure were inferred by FEM model:



- 16 probes on the alidade
- 8 probes on the quadrupod

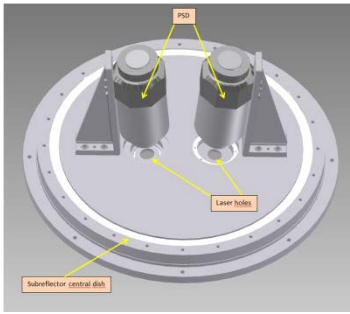


Probes installation, cabling and interfacing with Beckhoff embeddes PC will be soon accomplished

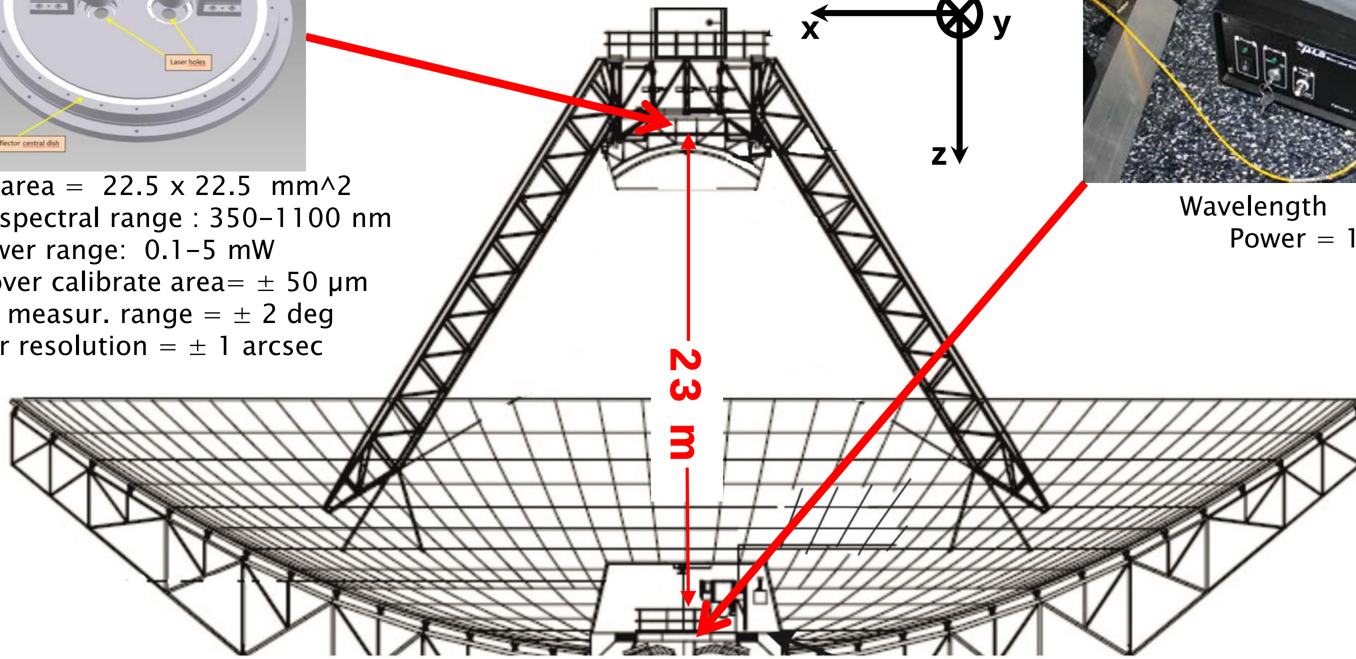
Status of optical laser PSD

Two PSD for a real-time measurement of the secondary mirror misalignments, one is already installed behind the central panel of the sub-reflector and we are testing its performances

PSDs



Sensitive area = 22.5 x 22.5 mm^2
Operational spectral range : 350-1100 nm
power range: 0.1-5 mW
Accuracy over calibrate area= ± 50 μm
Angular measur. range = ± 2 deg
Angular resolution = ± 1 arcsec



Laser diodes

Wavelength = 658 nm
Power = 10 mW

PSDs can measure X, Y, Z translation (derived by two X measur.) and X,Y axes rotation of the subreflector. Only one at the moment is installed.

SRT metrology future plans

- Include inclinometer, PSD and temperature probe data in the antenna pointing model in order to reduce the errors and to try to compensate for alidade and quadrupod thermal deformations

- Beside the traditional holography, we plan to use the Out-of-Focus method on SRT for a quasi-real time mapping of the primary surface deformations, due even to thermal gradients effects and the linear sensors

- New systems: Laser Tracker and Real Time photogrammetry

Conclusions

- Many thanks to Richard for his efforts in organizing this workshop;
- I think that if we could have this workshop few years ago we could be in a better condition in the development of an efficient and well organized Metrology plan for SRT.

Thanks for your attention!

Any questions?