Feasibility Study of Angular Super-Resolution with the Active Surface of a Radio Telescope

Luca Olmi & Pietro Bolli
Osservatorio Astrofisico di Arcetri
Istituto Nazionale di Astrofisica (INAF)
Florence, ITALY

olmi.luca@gmail.com
pbolli@arcetri.astro.it

OUTLINE

- **Introduction**
- **Super-Resolution**
- **Super-Resolution with active surface**

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

INAF Radiotelescopes

INAF - Arcetri

Medicina-32m

Florence

Arcetri Observatory (INAF)

SRT-64m

Noto-32m

INAF
ISTITUTO NAZIONALE
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FOR ASTROPHYSICS

INAF - Arcetri

Radioastronomy Lab Arcetri

Expertise

Passive MW elements

Cryogenics and receivers

Digital signal processing (FPGA-GPU)

Antenna design

EM simulations

Projects

Large telescopes: **ALMA**, **SKA**

European Framework programs: Radionet

Italian telescopes: Medicina, Noto, **SRT**

Super-Resolution

Staff

4 research positions

1 technical position

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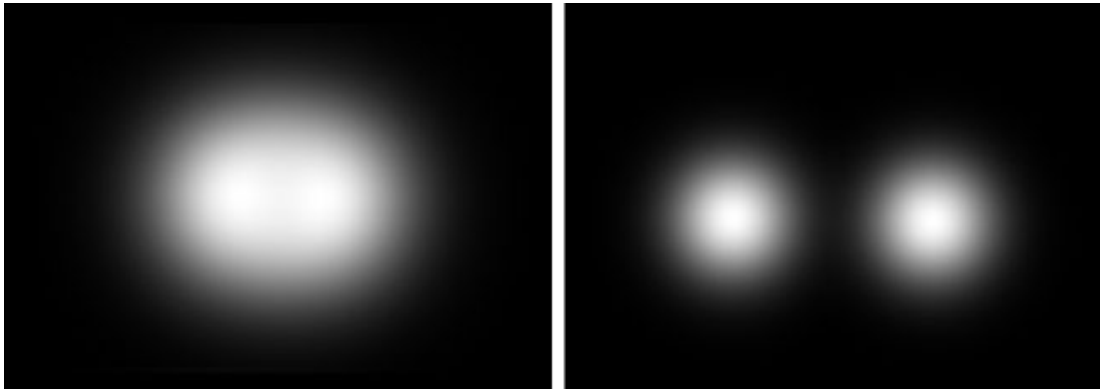
Super-Resolution

Diffraction-limited beam ~ **λ / D**

Narrow main beam

Modify optics

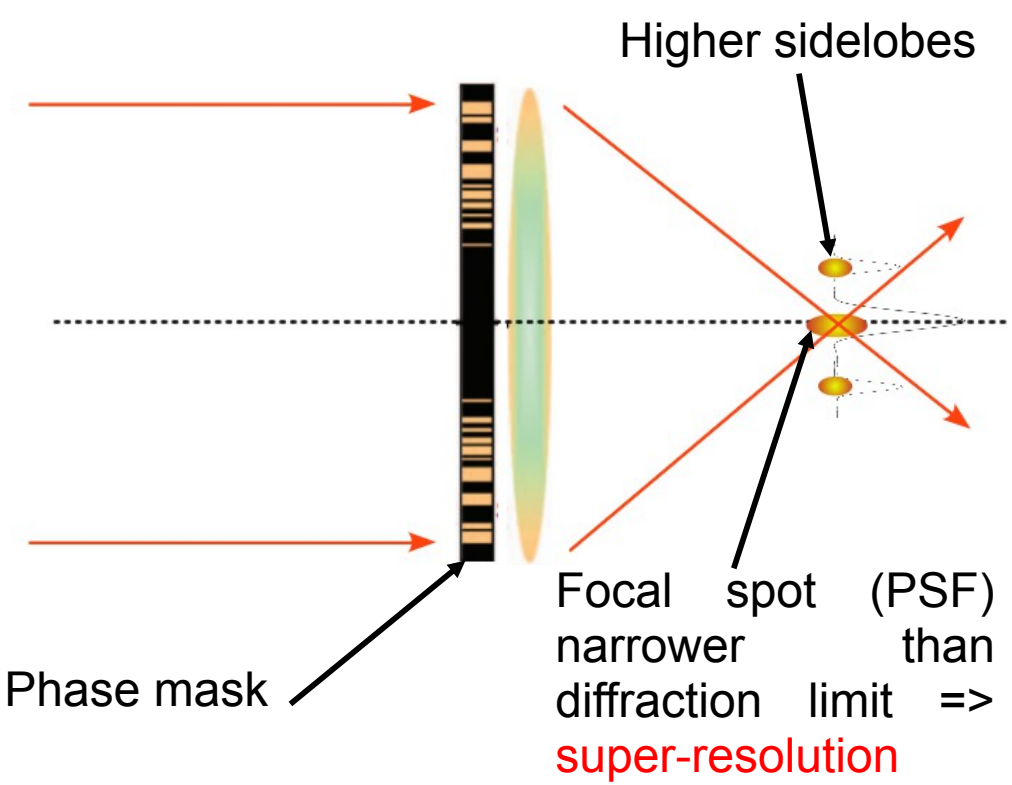
SR beam

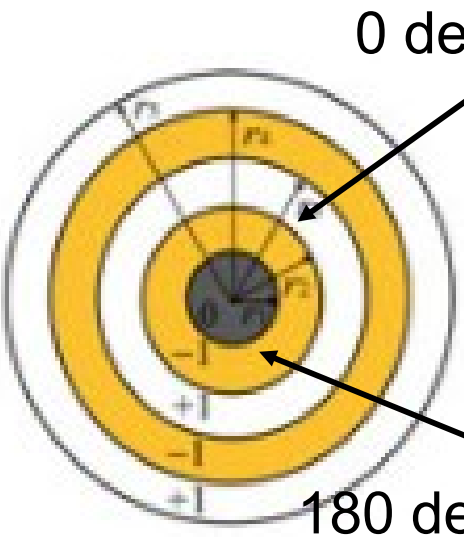


Super-resolution: improve the angular resolving power of an optical instrument beyond the **classical diffraction limit, ~ λ / D**

Super-Resolution for Telescopes

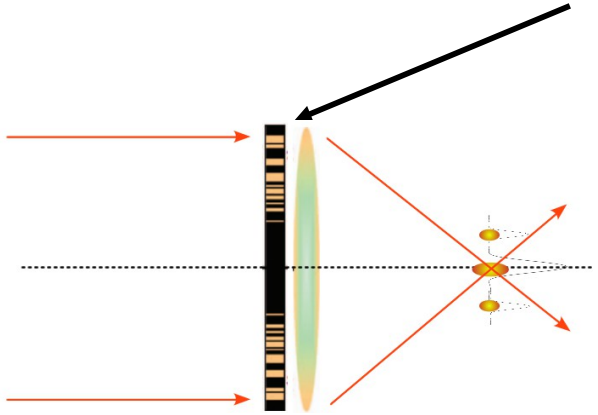
Variable transmittance pupils can achieve SR in telescopes. Simplest pupils are **binary phase** shifts masks (0 or 180 deg), also known as **Toraldo Pupils** (**TP**s)





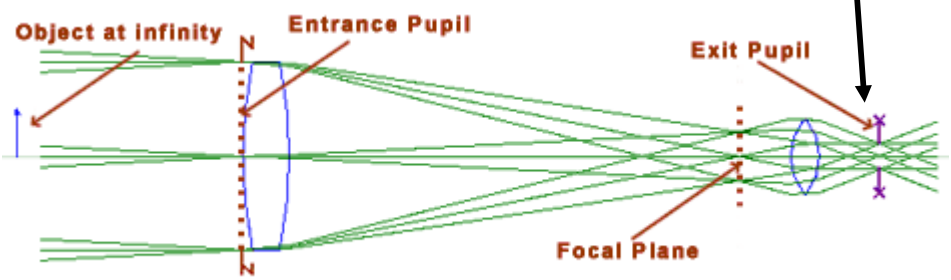
Implementation on (Radio) Telescopes

Ideally, place TP on **entrance pupil**



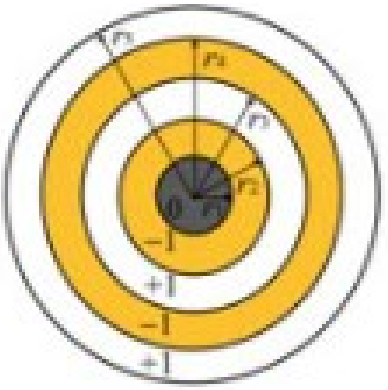
OR

Modify wavefront at **exit pupil**

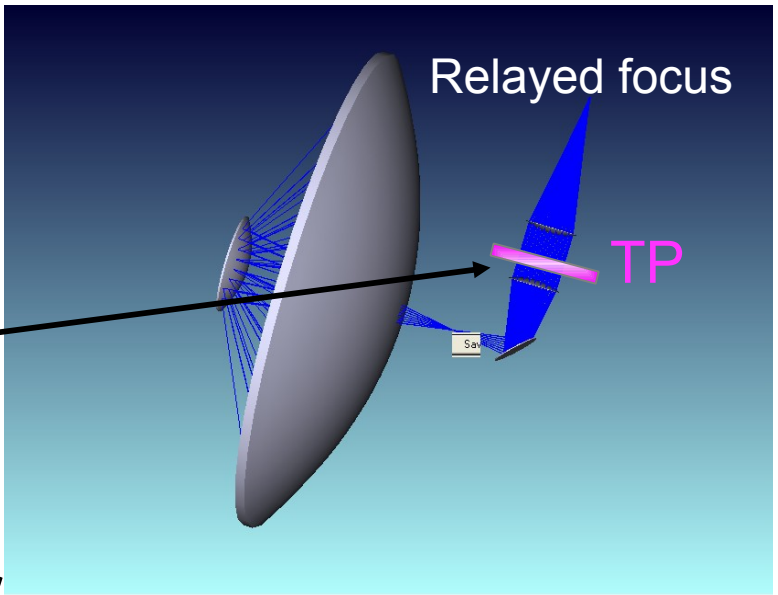


Telescope

Active surface

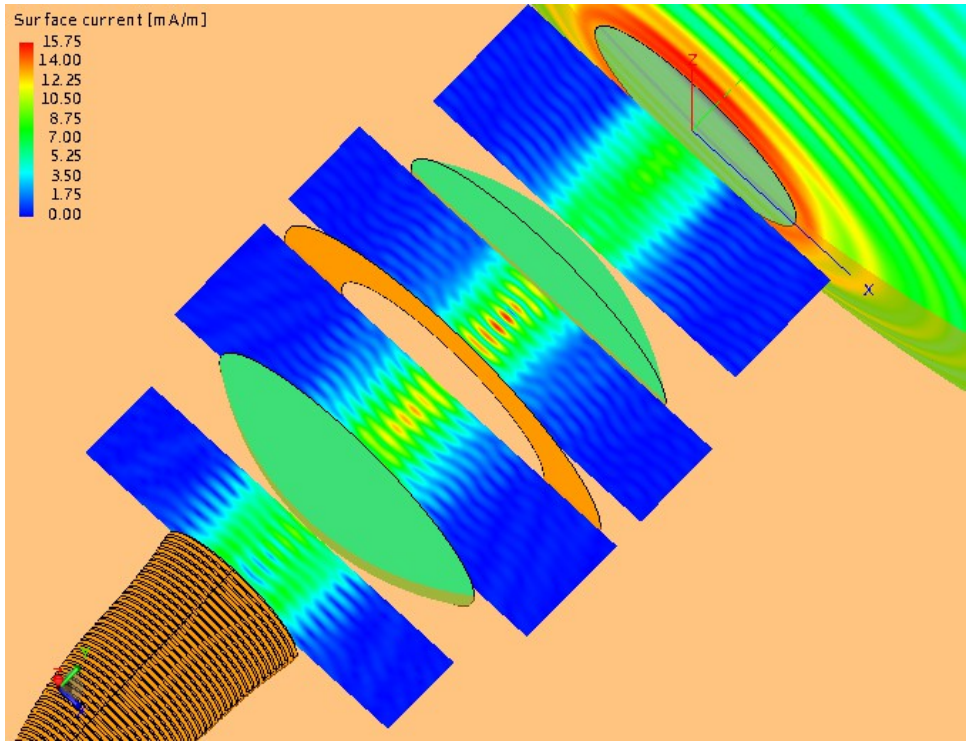


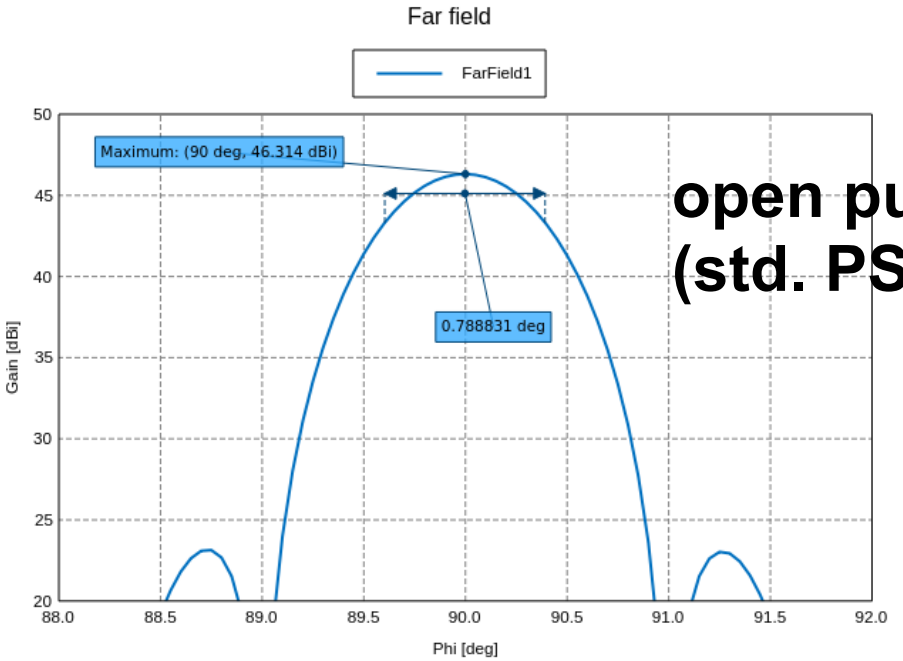
Collimator



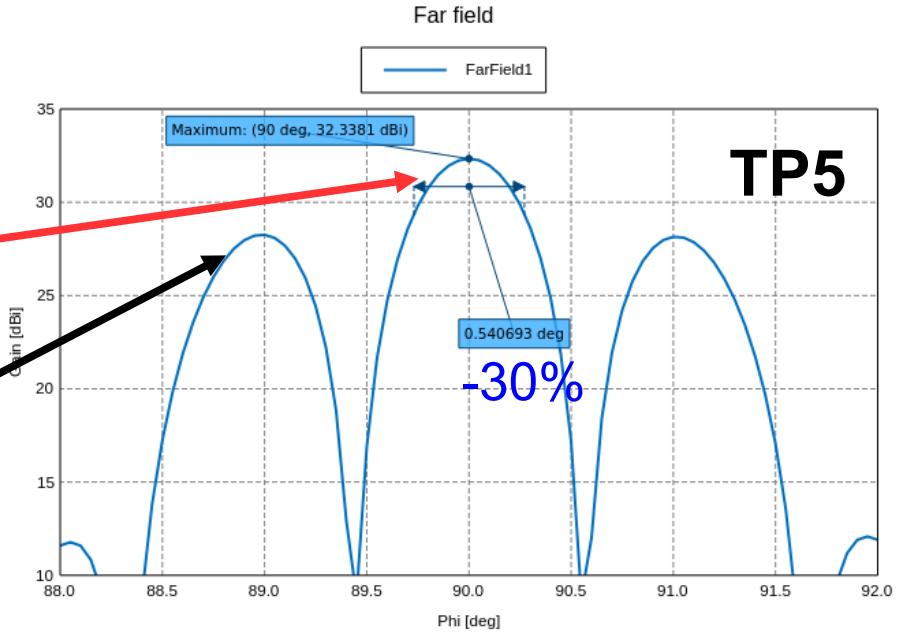
Implementation with Collimator Concept

FEKO model





open pupil (std. PSF)



Super-resolution

Higher sidelobes

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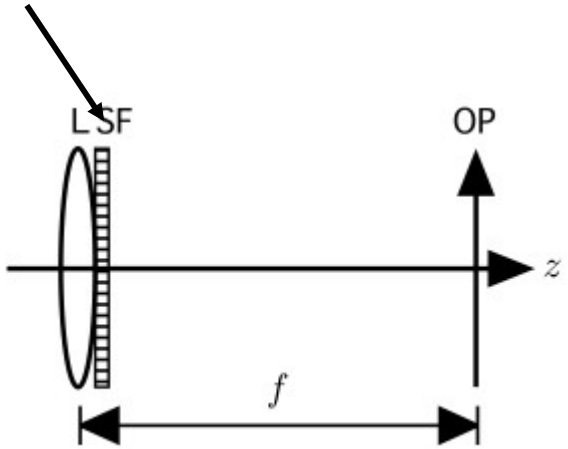
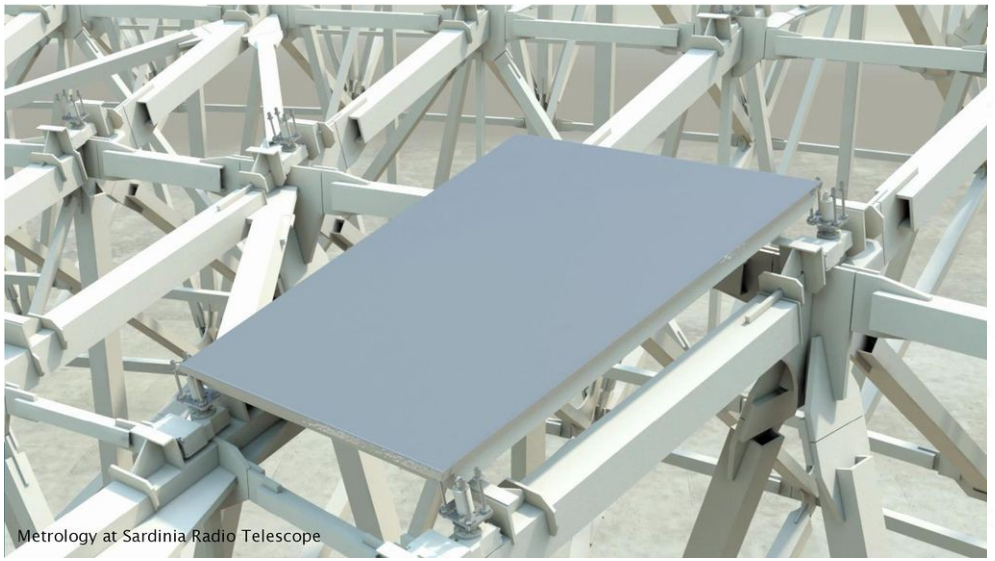
- **Super-Resolution with active surface**

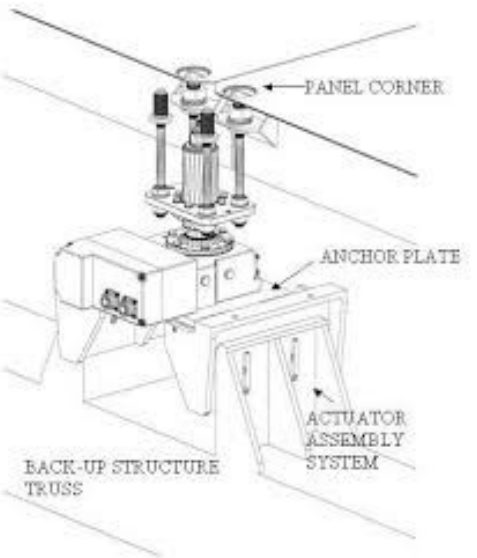
Implementation with Active Surface

Placing TP on **entrance pupil**

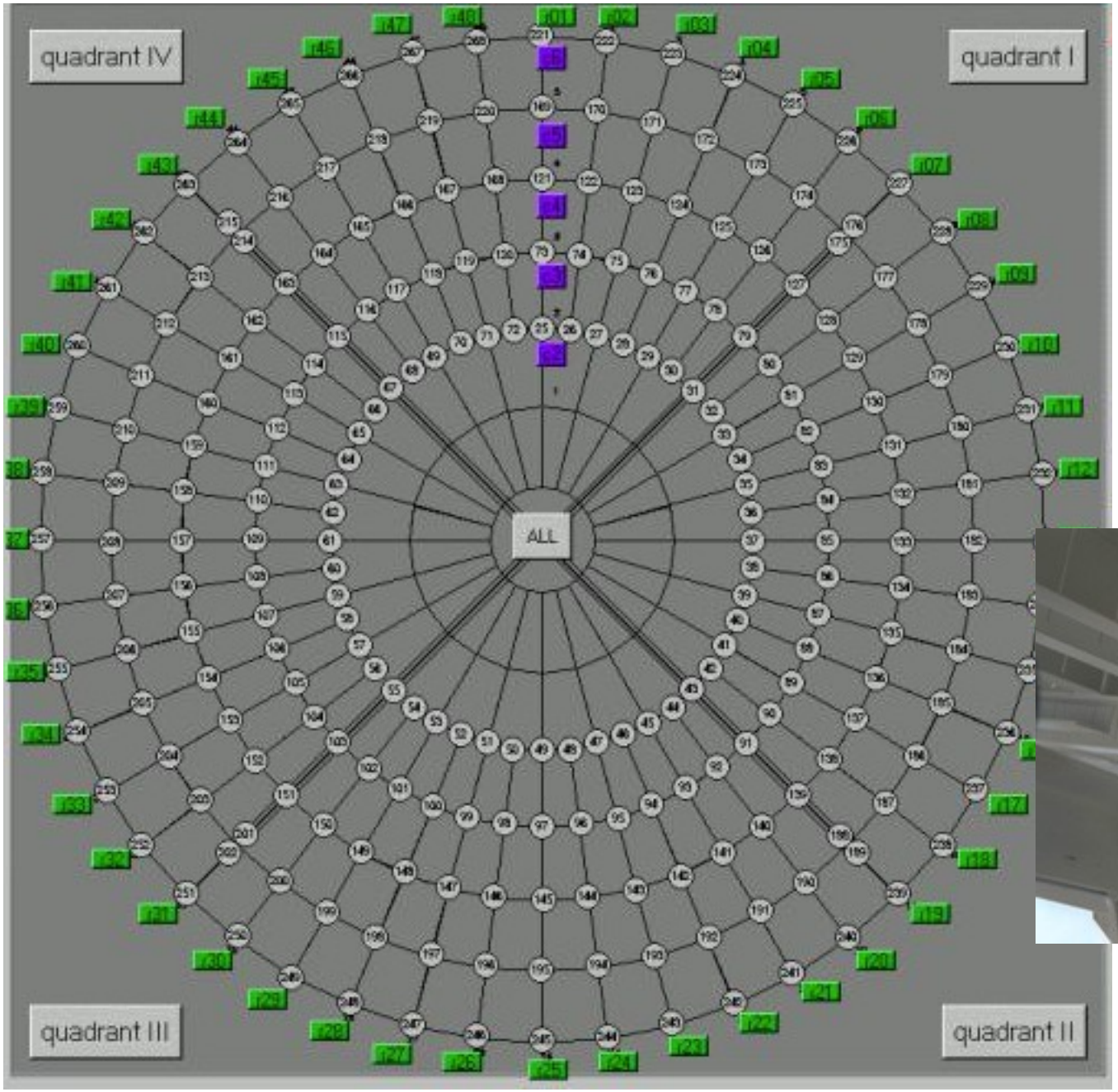


Converting entrance pupil to TP is possible with Active Surface


Metrology at Sardinia Radio Telescope



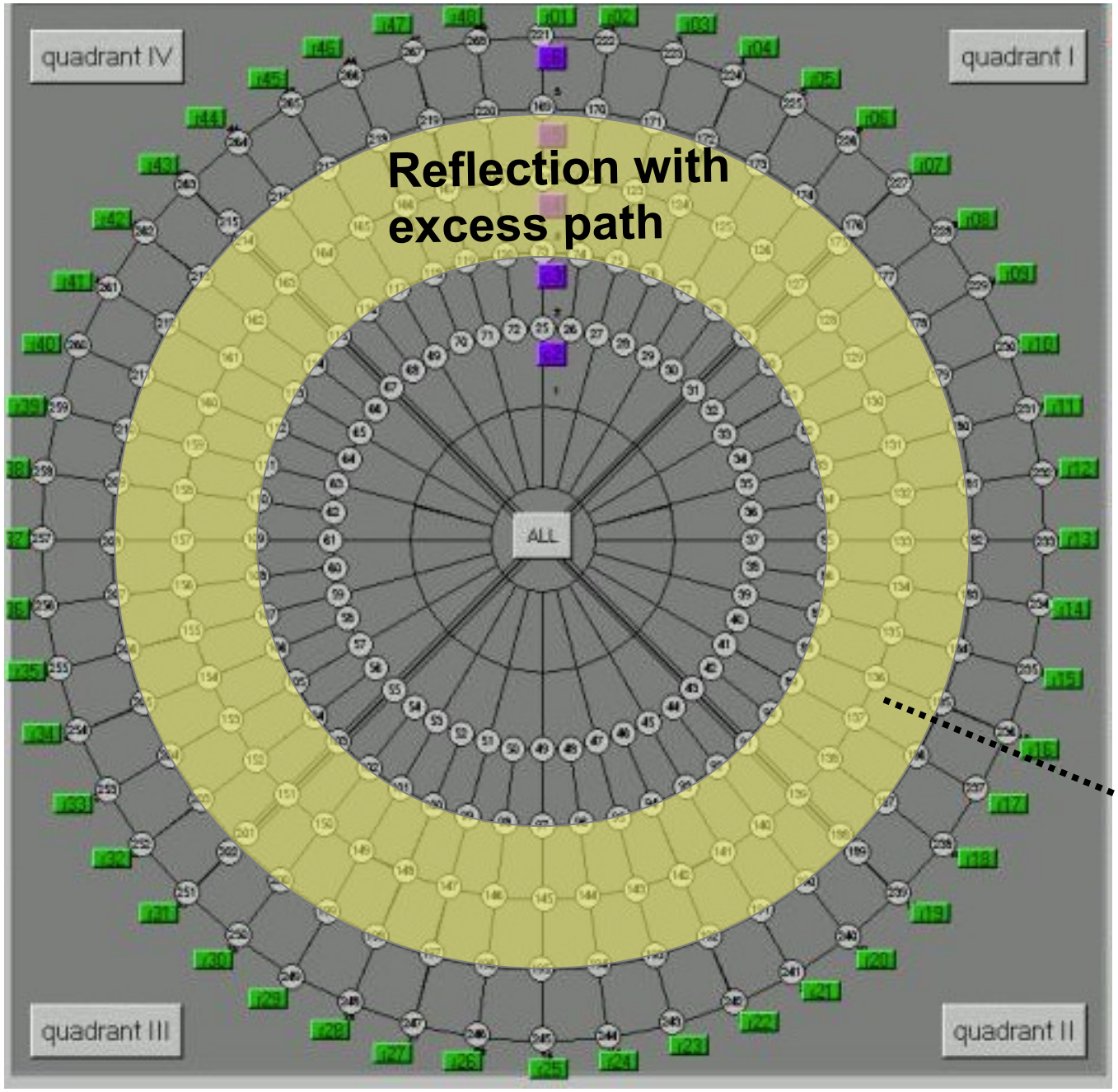
Active Surface (Noto 32-m Antenna)



248 panels in six separate rings (innermost two are fixed).

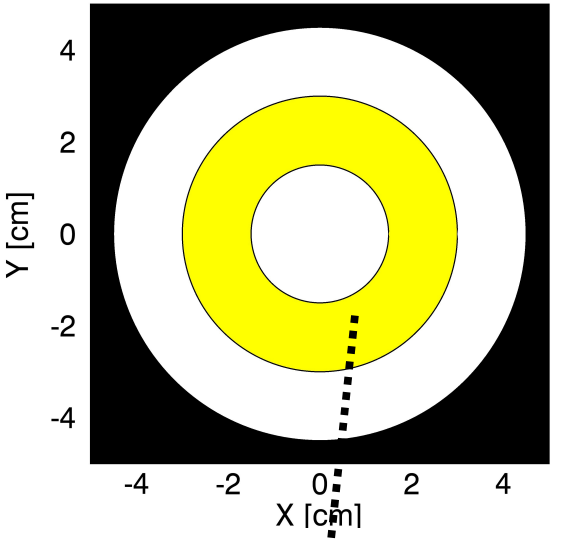
244 actuators positioned at the corners of active panels.

TP Geometry with Active Surface



Reflection with excess path

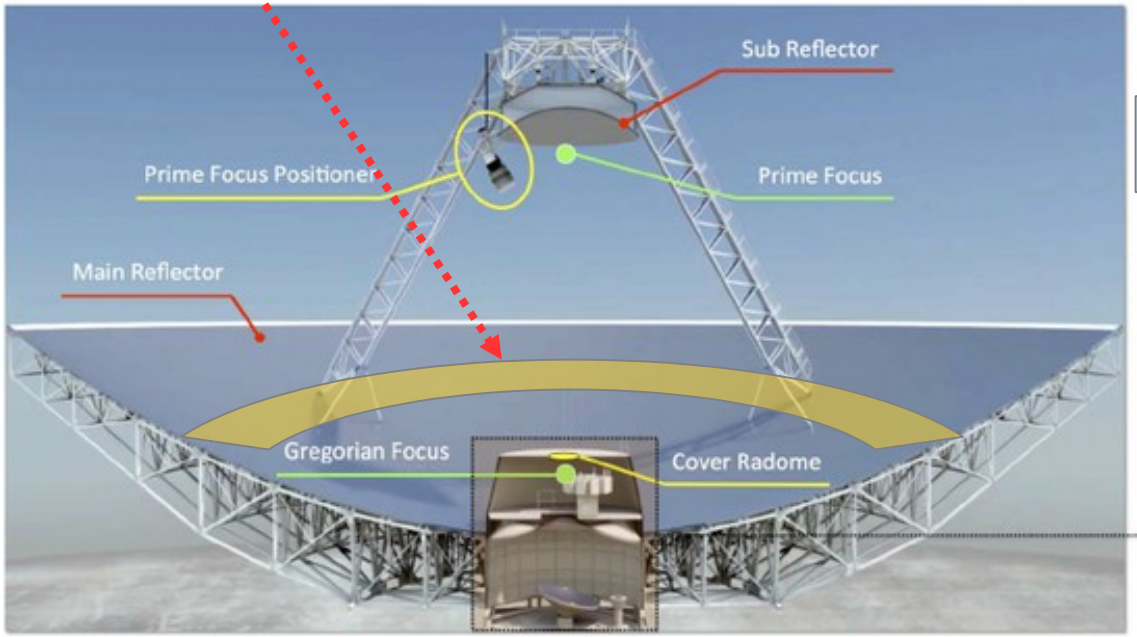
Transmission through dielectric material

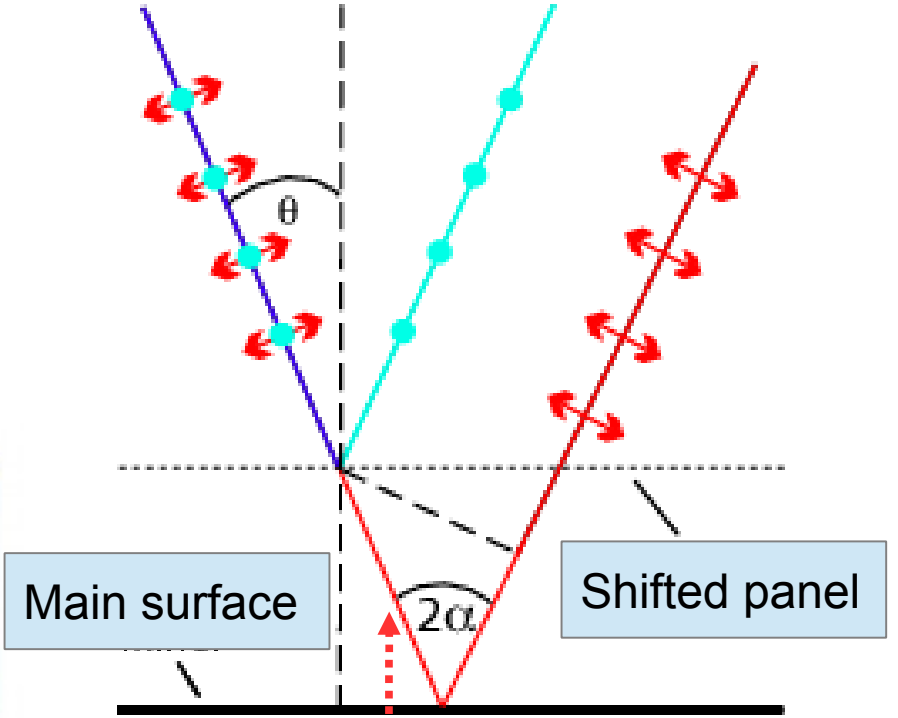


Phase-shift

TP Implementation with Active Surface

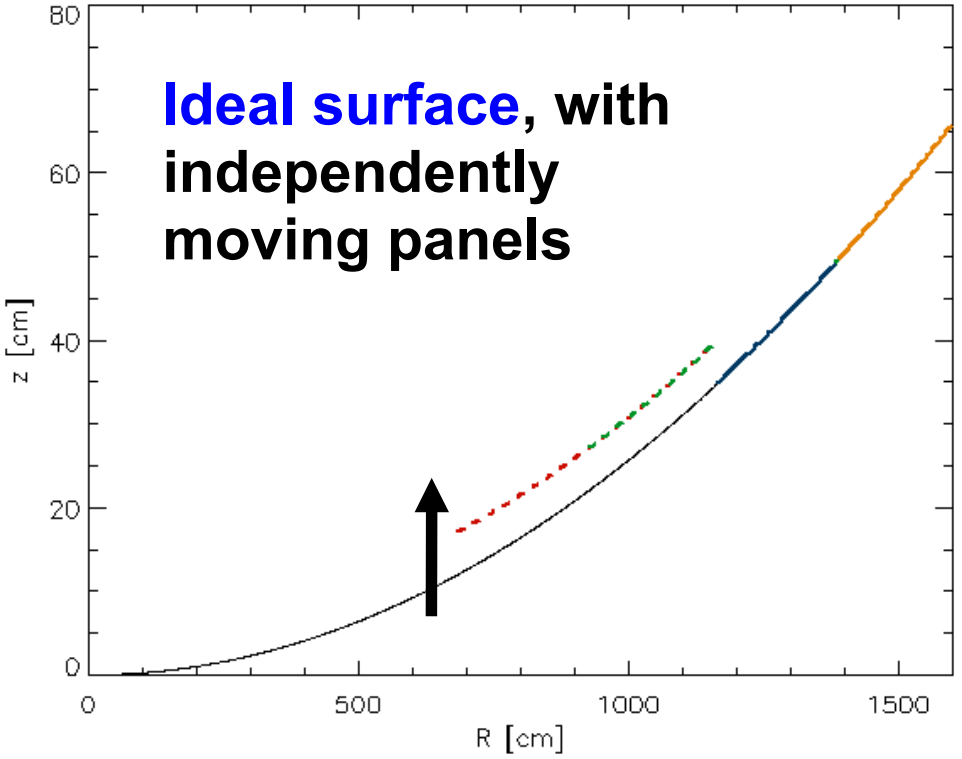
Ring(s) of active panels





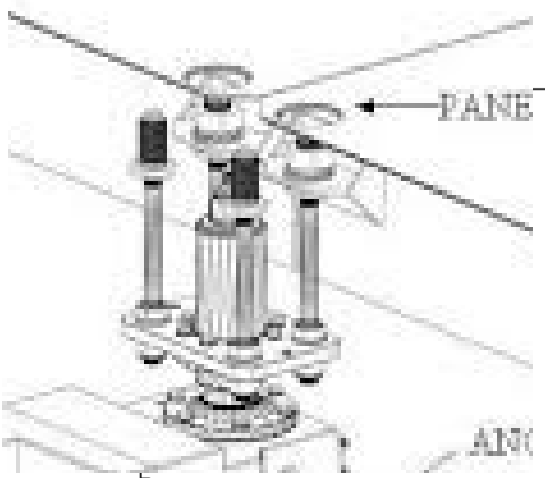
Excess optical path
=> phase shift

TP Implementation with Active Surface



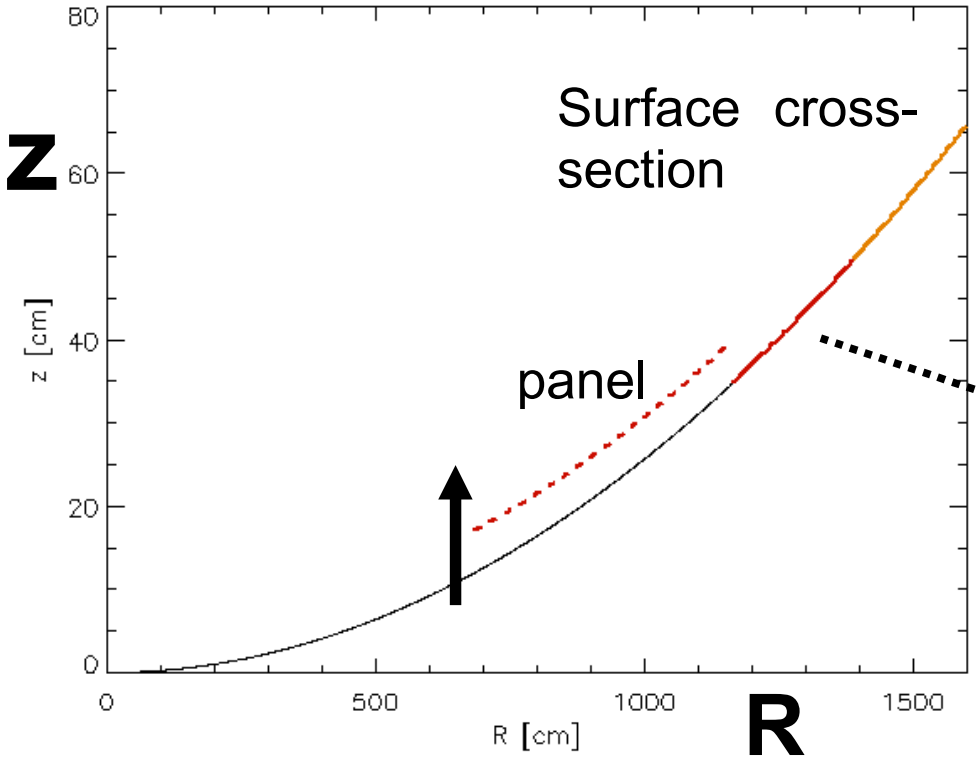
Ideal surface, with independently moving panels

Real surface, with 4-corners actuators

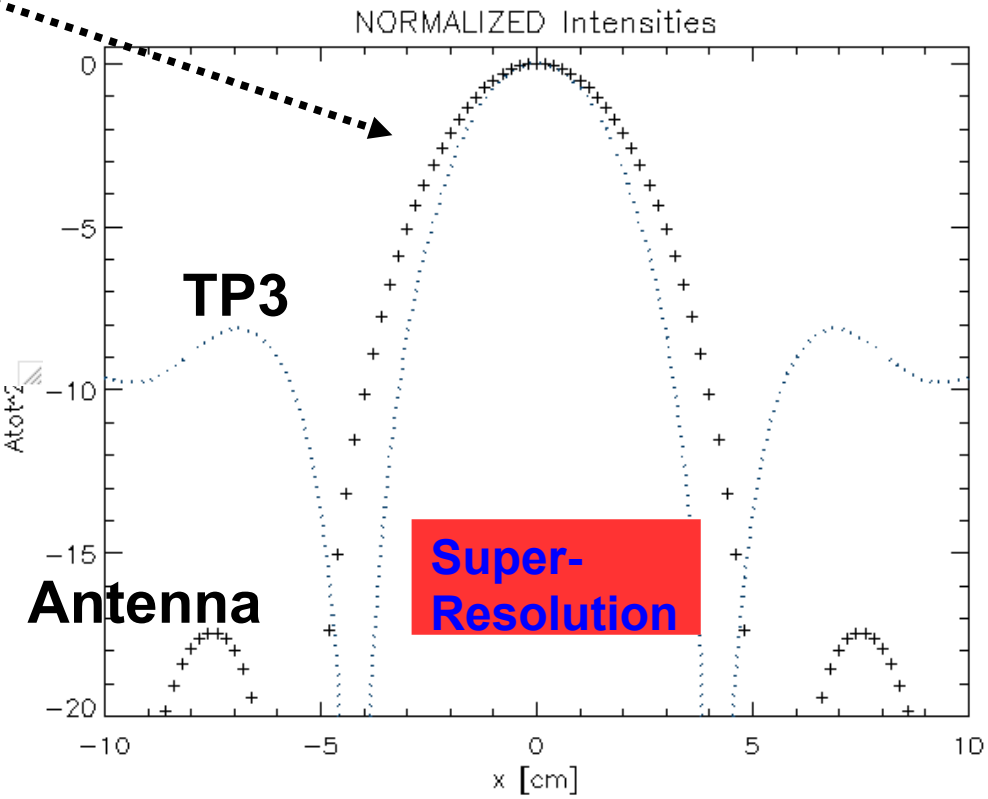


Real panels translate and rotate, introducing unwanted phase aberrations

Simulation Results with (ideal) Noto Active Surface



GRASP EM simulation of antenna PSF

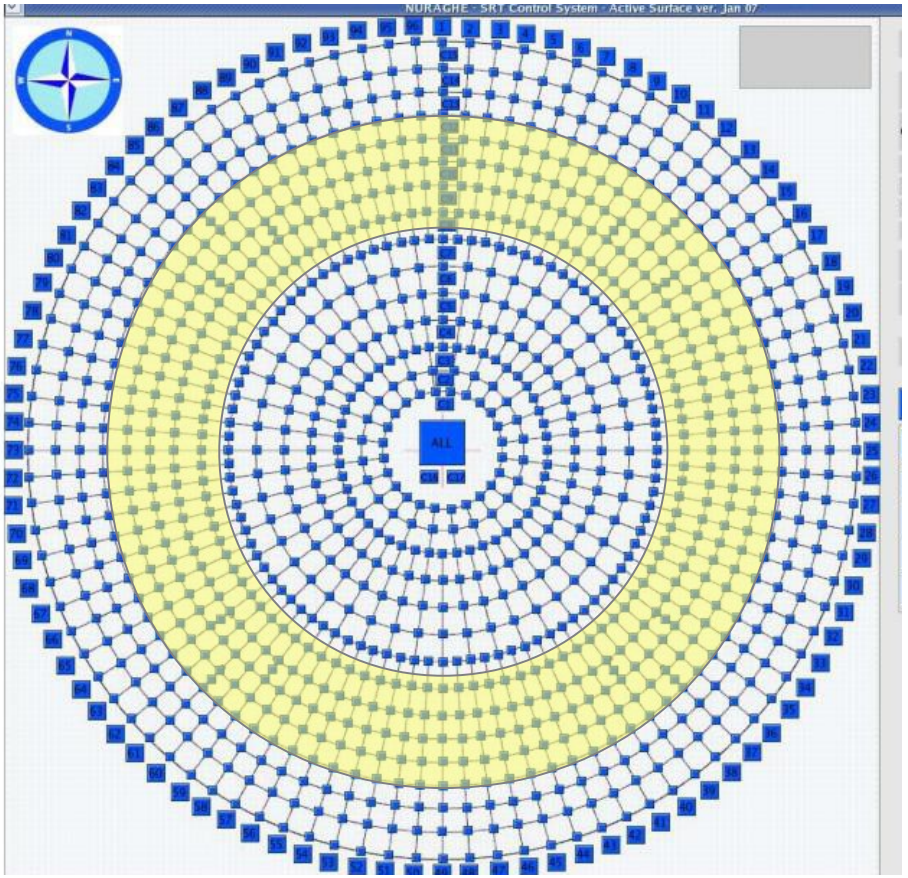


Ideal surface, with independently moving panels

Using the real active surface the SR effect is washed out.....

Next Steps

Better **spatial resolution** can be achieved with the active surface of the Sardinia radio Telescope (SRT):
1008 active panels in 14 rings
1116 actuators



Position of actuators on the primary surface of the SRT with overlayed TP3 geometry

SUMMARY

– Simulations show that Super-Resolution can be achieved by implementing a Toraldo Pupil through an **ideal** active surface on the primary reflector.

– A **real** active surface with a limited number of active panels, such as that of the Noto 32m telescope, cannot achieve SR.

– Further simulations with the active surface of the **SRT** are planned to determine whether its higher-resolution surface can indeed achieve SR.