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

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OUTLINE

- Introduction
- Super-Resolution
- Super-Resolution with active surface
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
OUTLINE

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Super-Resolution

Diffraction-limited beam $\sim \frac{\lambda}{D}$

Super-resolution: improve the angular resolving power of an optical instrument beyond the classical diffraction limit, $\sim \frac{\lambda}{D}$
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* (TPs).

- **0 deg phase shift**
- **180 deg phase shift**

Five-coronae TP (TP5)

- Focal spot (PSF) narrower than diffraction limit => super-resolution
- Higher sidelobes

180 deg phase shift (dielectric material)
Implementation on (Radio) Telescopes

Ideally, place TP on entrance pupil

**OR**

Modify wavefront at exit pupil

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**Active surface**

**Collimator**

**Telescope**

**Relayed focus**

TP
Implementation with Collimator Concept

FEKO model

Open pupil (std. PSF)

Super-resolution

Higher sidelobes

TP5

~30%
OUTLINE

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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
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

Main surface

Shifted panel

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

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
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.