

# Results of BIRALES observation campaigns for the IADC



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**Inter-Agency Space Debris Coordination Committee**



# Outline

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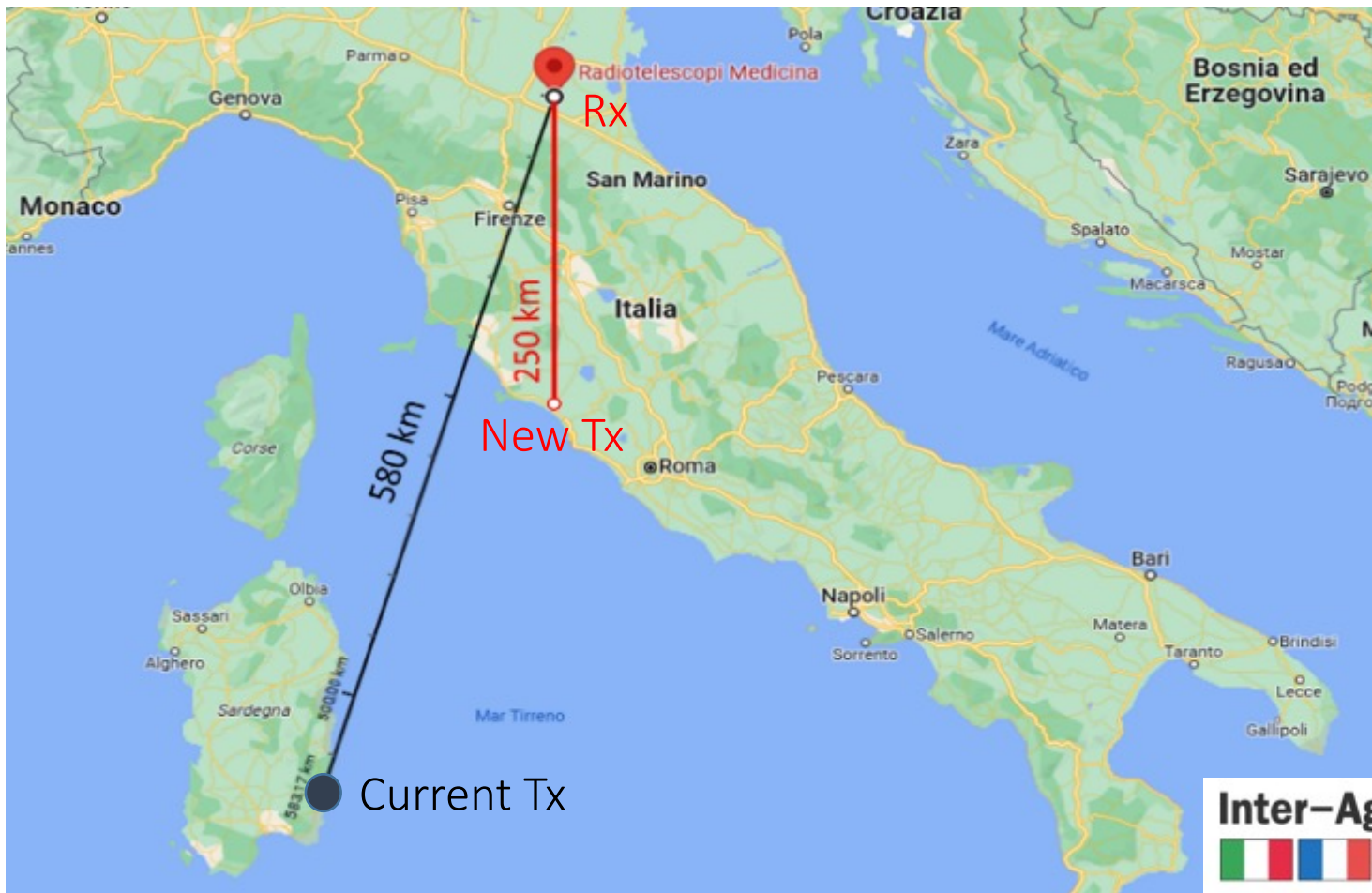
- Some remarks about the technological BIRALES upgrade;
- Pipeline for detection of multiple targets crossing simultaneously the FoV;
- Re-entry campaigns;
- Signal direction of arrivals ambiguity solution.

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# BIRALES future development

To improve the system performance and adapt it to the upgrade, that is taking place at the same time on the Northern Cross, the new transmitter will be placed on the same Northern Cross meridian, with the following benefits:



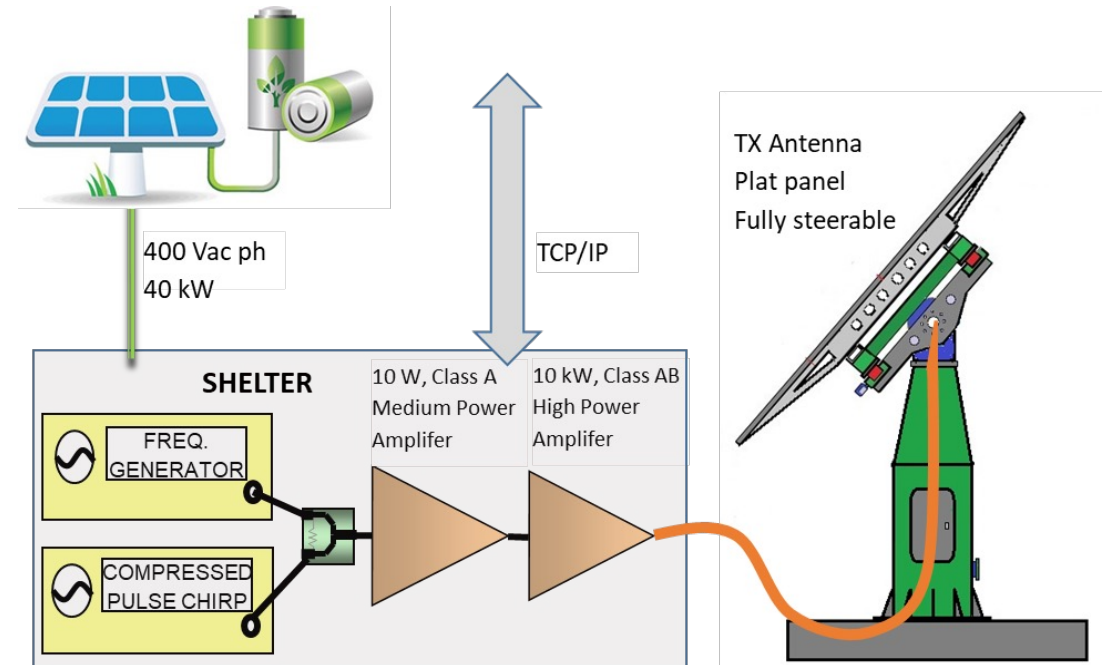
- Increase of sensitivity, due to the reduction of the baseline between the two antennas;
- Increase in the number of objects, detectable at the same time, due to the increase of the intersection volume of the beams;
- Reduction of the operating costs.

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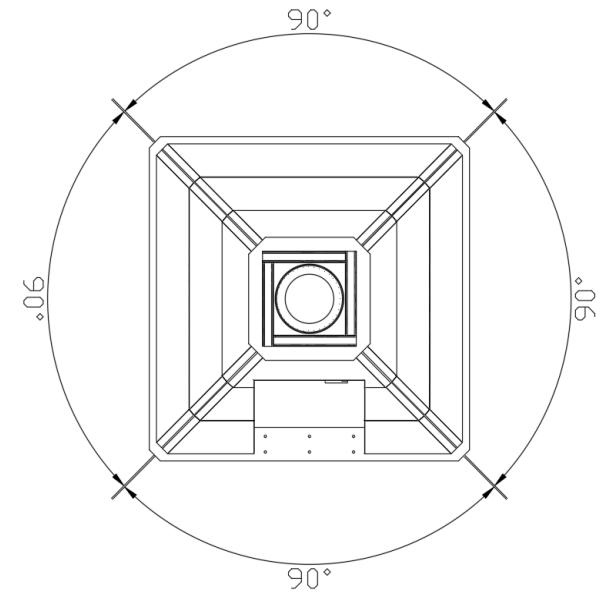
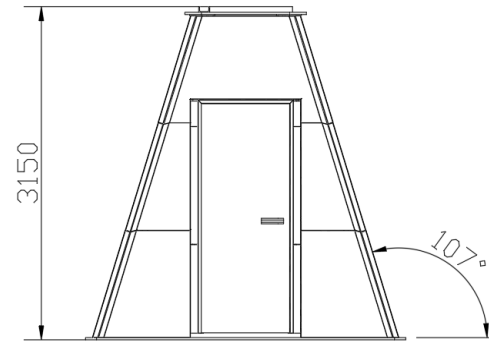
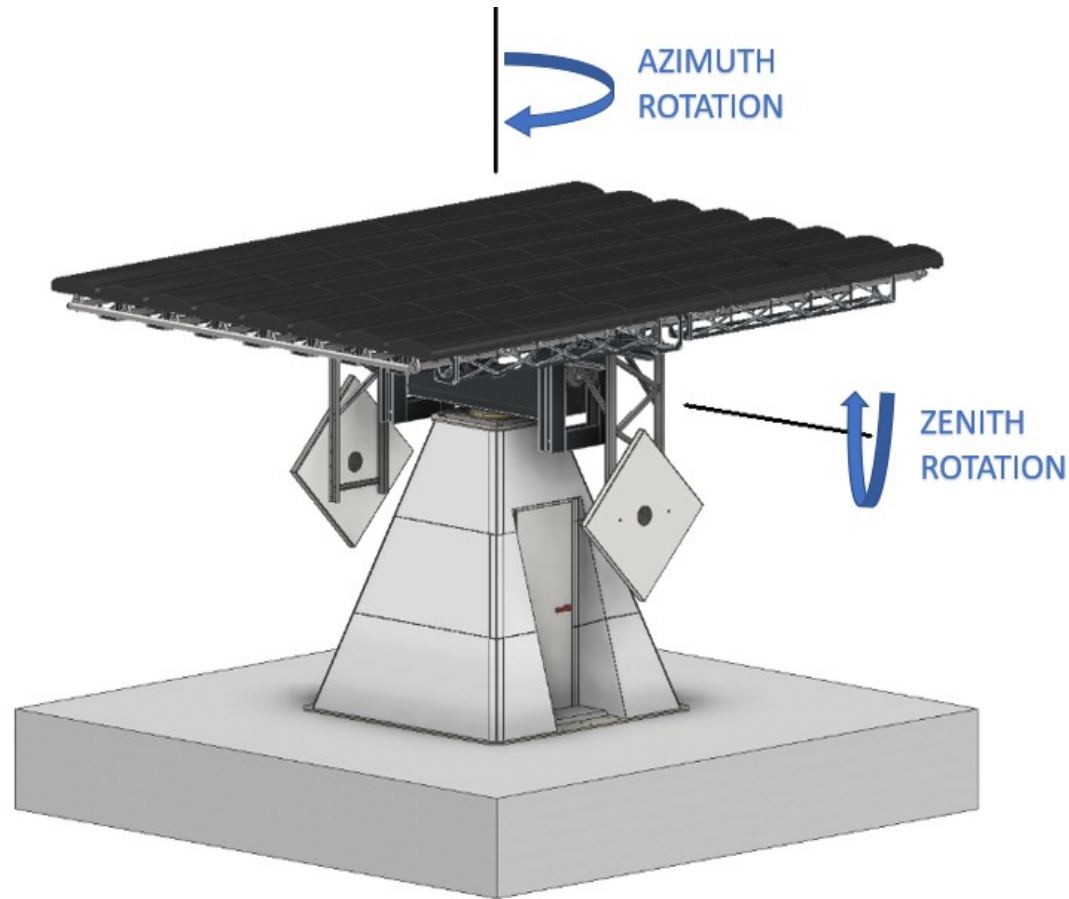


# Transmitter features

Parameter	Value
Minimum bandwidth	410÷415 MHz
s11  (Return Loss)	≤ - 25dB
Operating Power	10 kW
Polarization	Linear, horizontal
HPBW (Half Power Beam Width)	7° x 45° (HxV) survey mode 7° x 7° (HxV) high sensitivity mode
Side lobes	nearest sidelobes: ≤ -13 dB other sidelobes: << -16dB
Elevation span	30° to 150° respect to horizon
Steering	ACU controlled. Elevation axis: 1.5°/sec
Wind resistance	≤ 250 km/h for survival conditions ≤ 100 km/h for operating conditions



# Transmitting antenna



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# Transmitting antenna

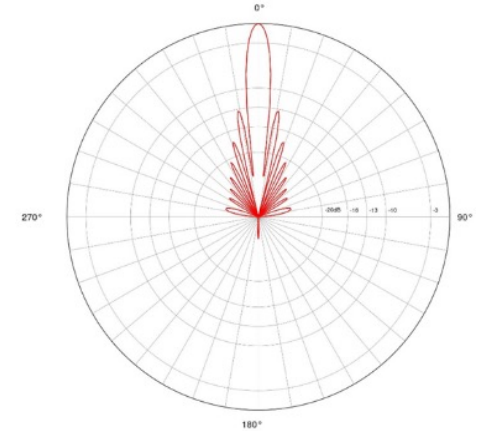
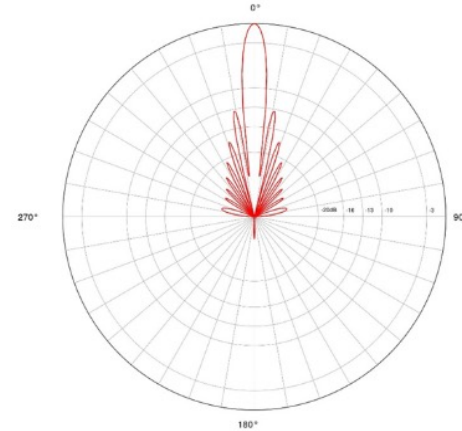
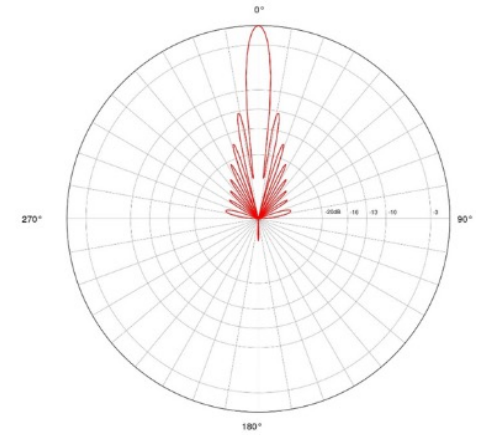
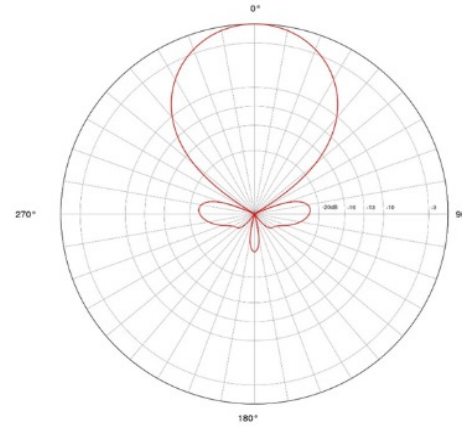
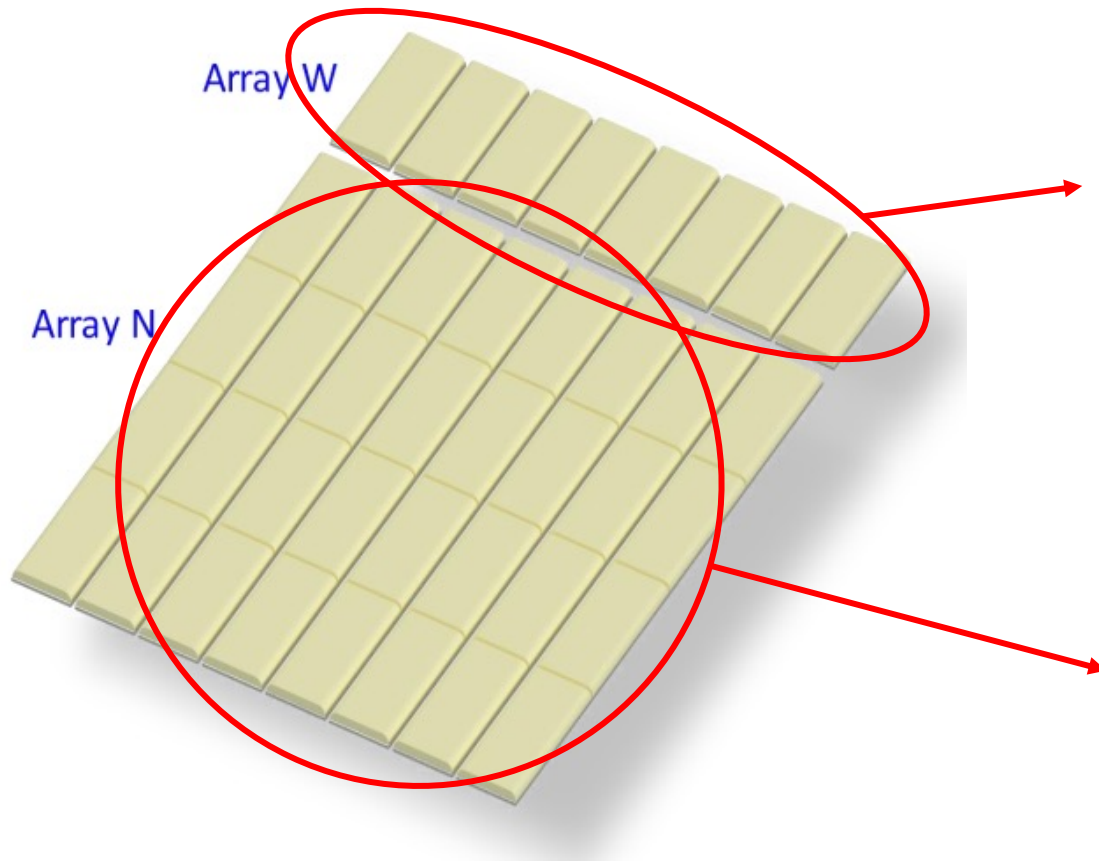
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# Tx radiating panel



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# BIRALES: Northern Cross refurbishment

Refurbishment of the total N-S arm of the Northern Cross → 64 cylindrical parabolic reflectors (array of 256 receivers and 11.000 m<sup>2</sup> of collective area).



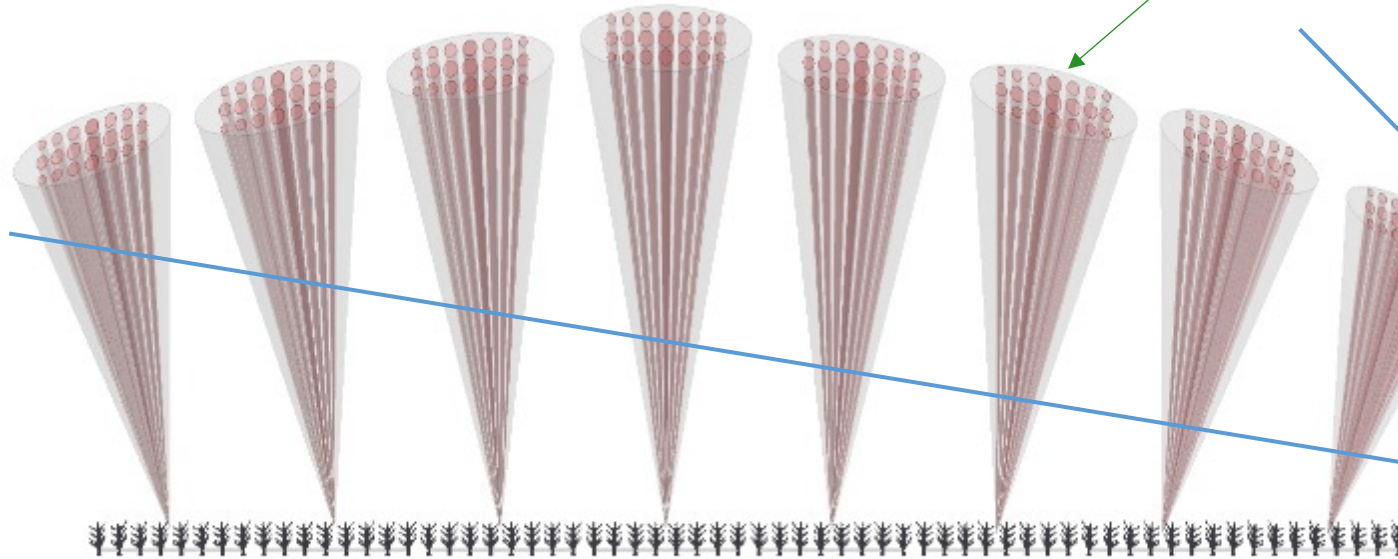
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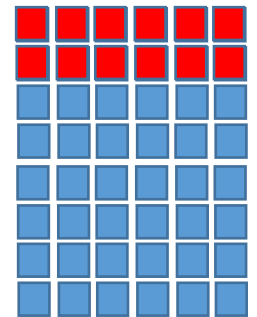
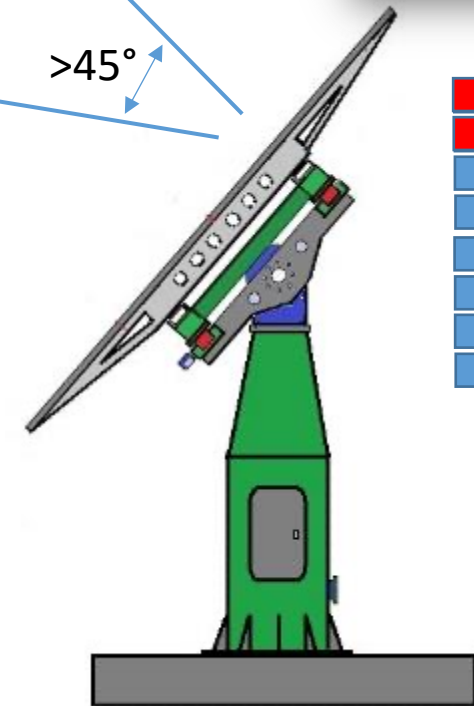


# BIRALES: survey operation mode

32 beam each FoV



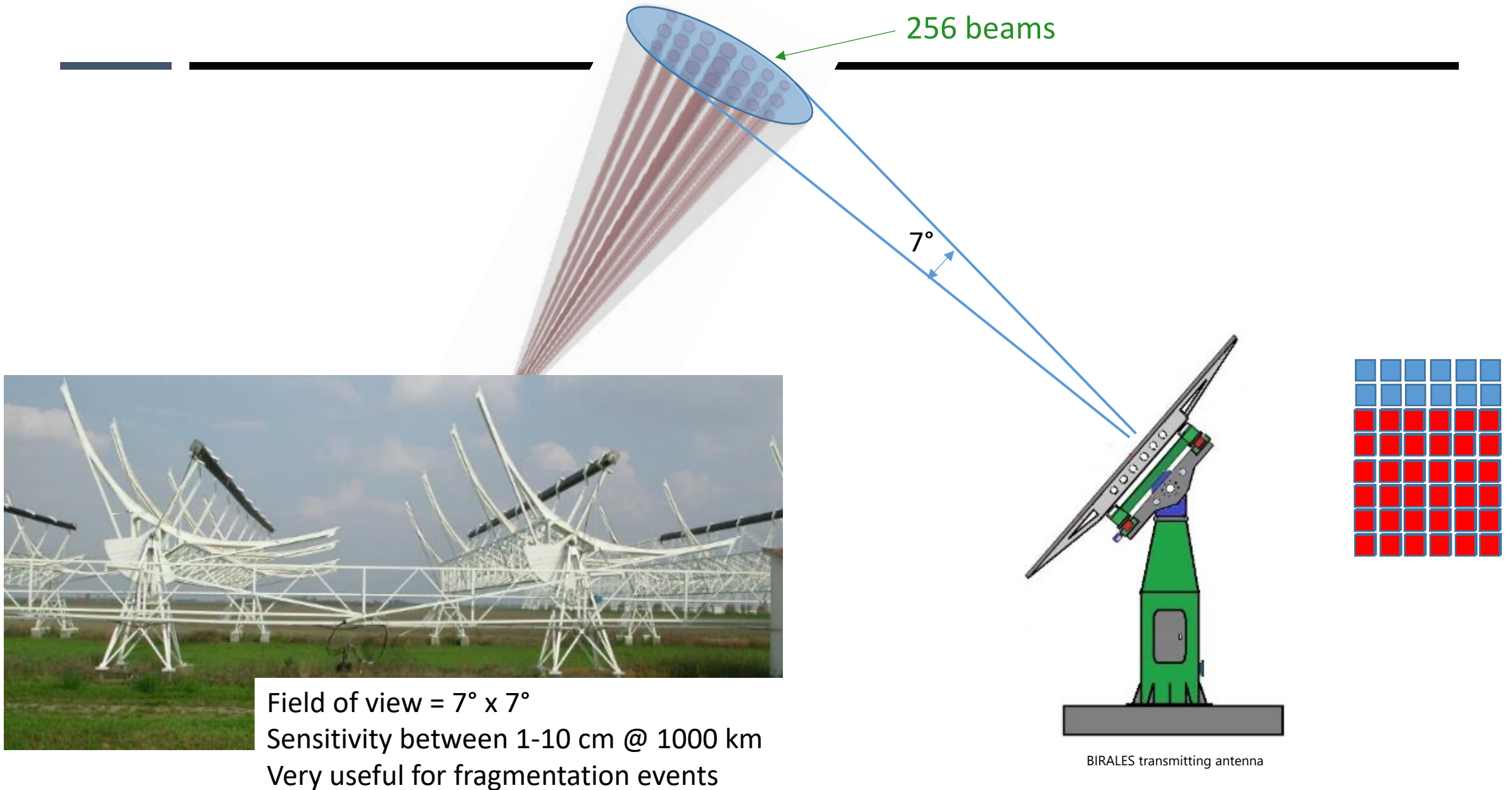
>45°



Field of view =  $45^\circ \times 7^\circ$   
Sensitivity >10 cm @ 1000km  
Useful for collision avoidance, re-entry, cataloguing

BIRALES transmitting antenna

# BIRALES: high sensitivity operation mode





# East-West arm refurbishment

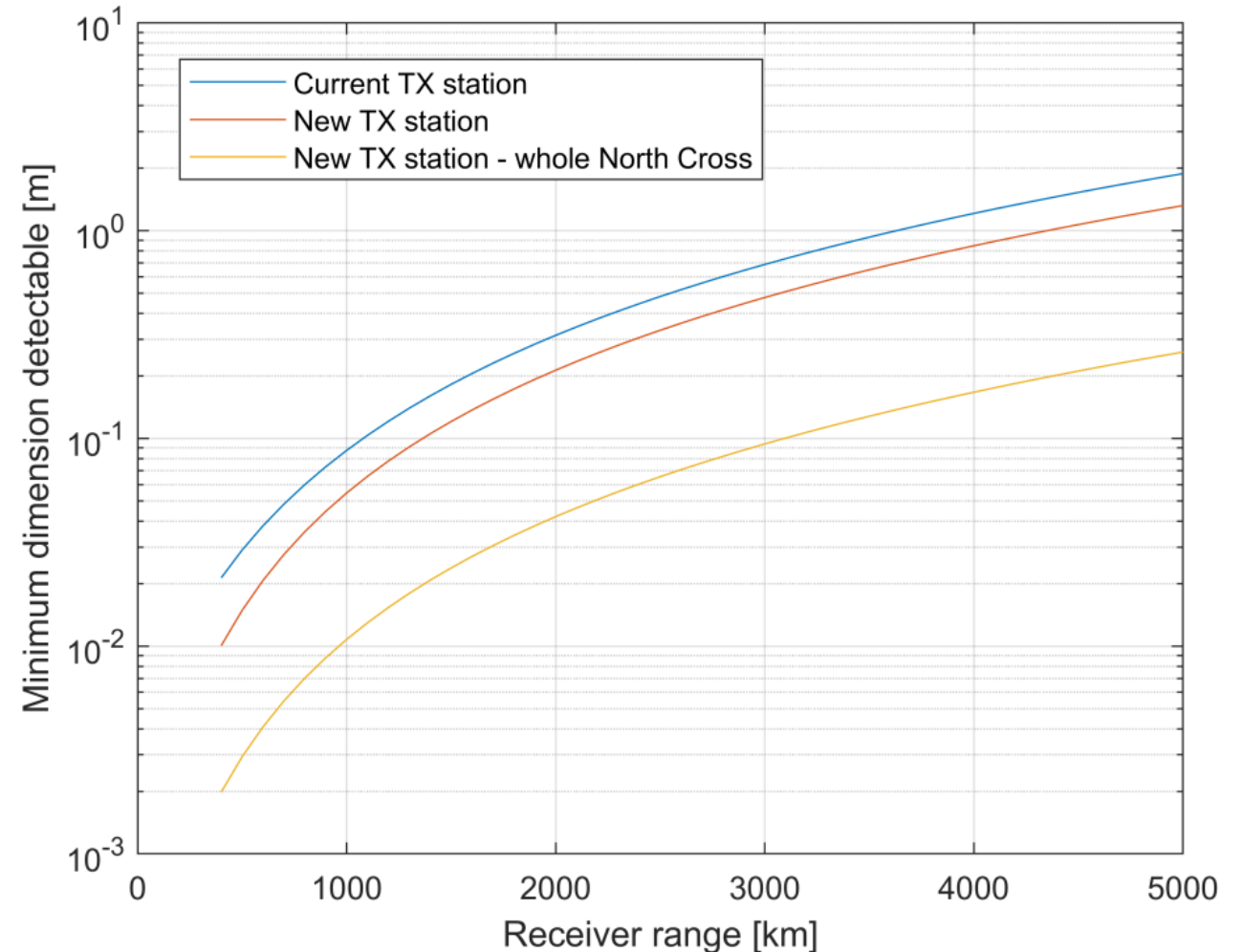
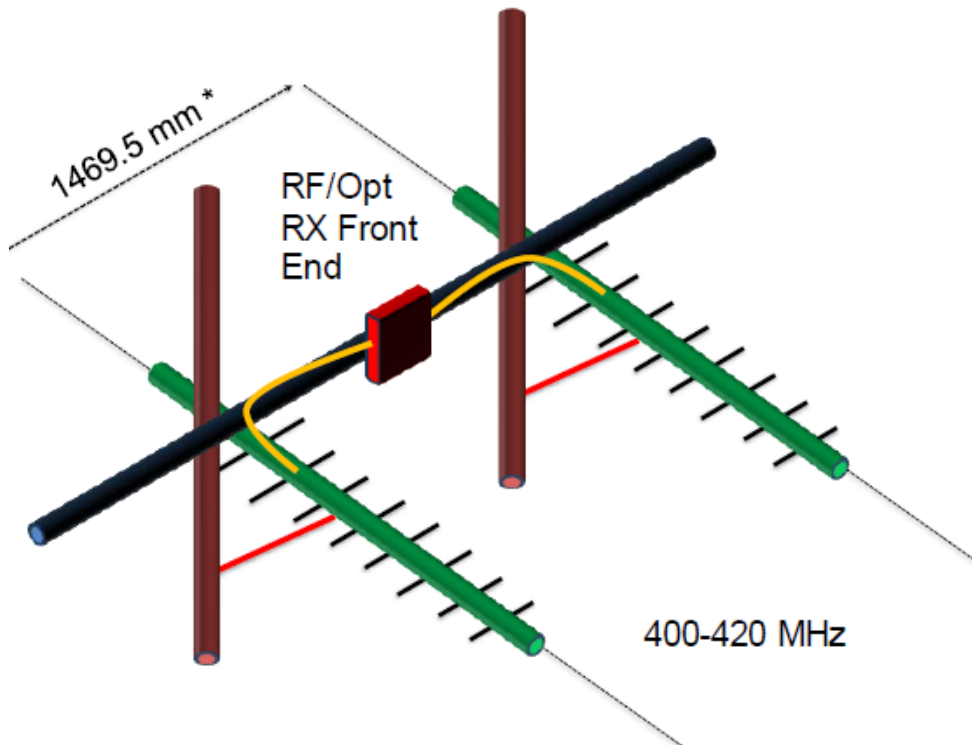
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# East-West arm refurbishment and sensitivity

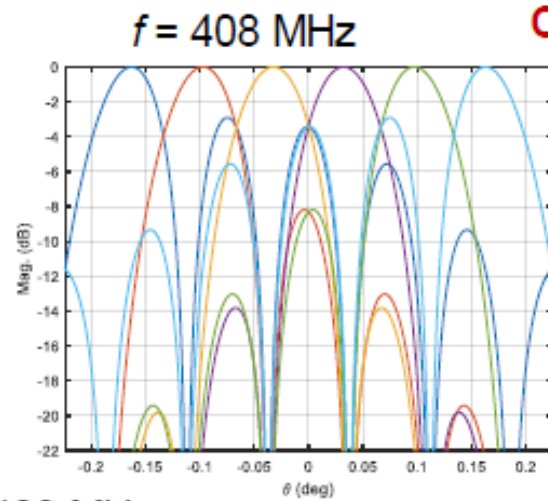
Refurbishment of the E-W arm of the Northern Cross → array of 384 receivers and about 19.000 m<sup>2</sup> of collective area.



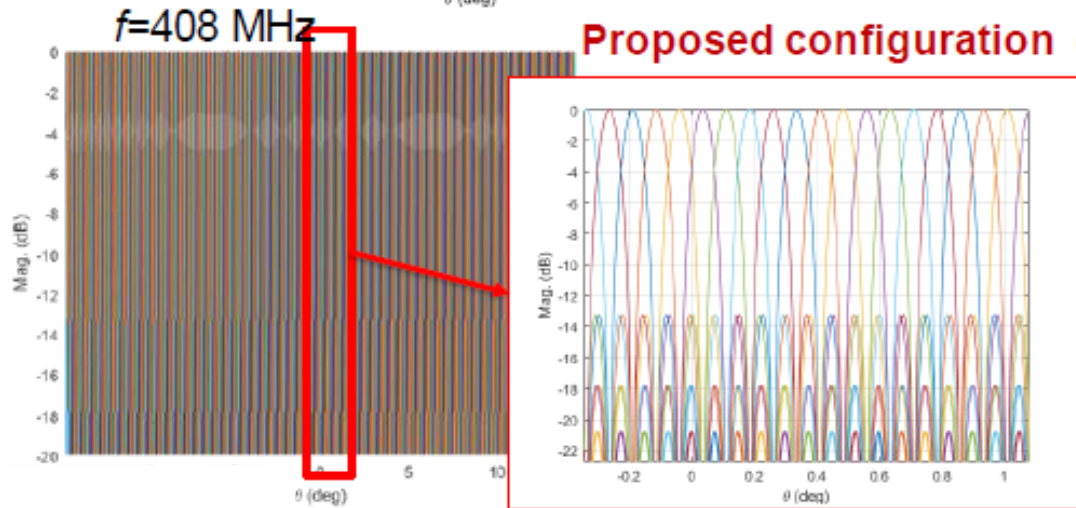
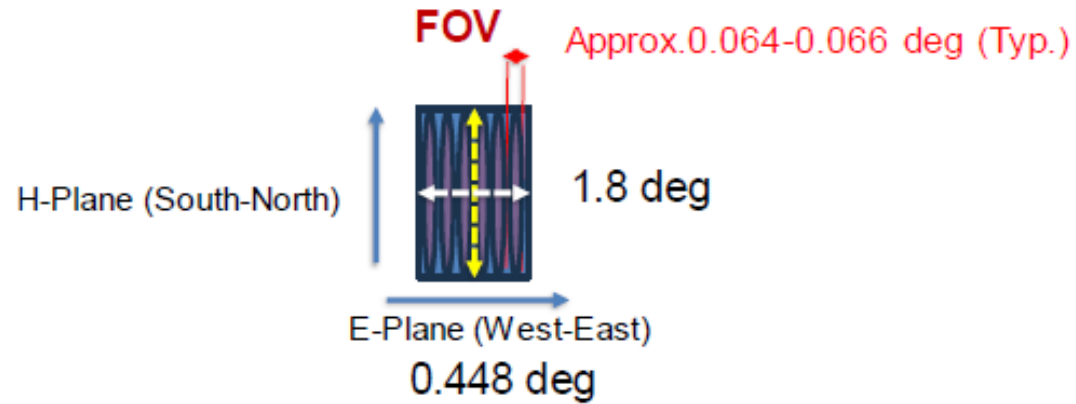
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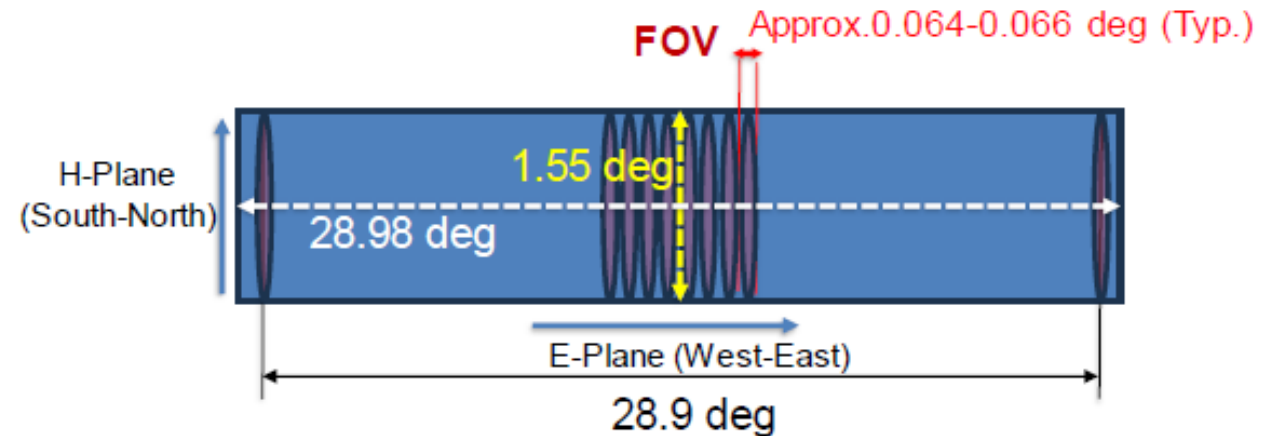
# East-West arm refurbishment and FoV



**Current situation (6-channel array-fed reflector)**

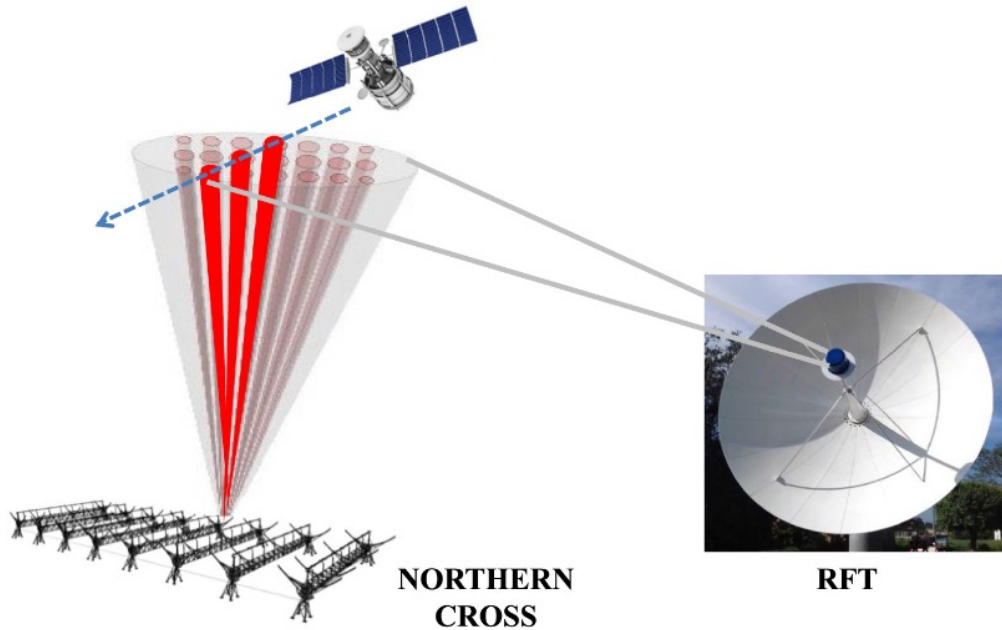


**Proposed configuration (384-channel Yagi antenna array-fed reflector)**



# Upgrade of BIRALES processing pipeline

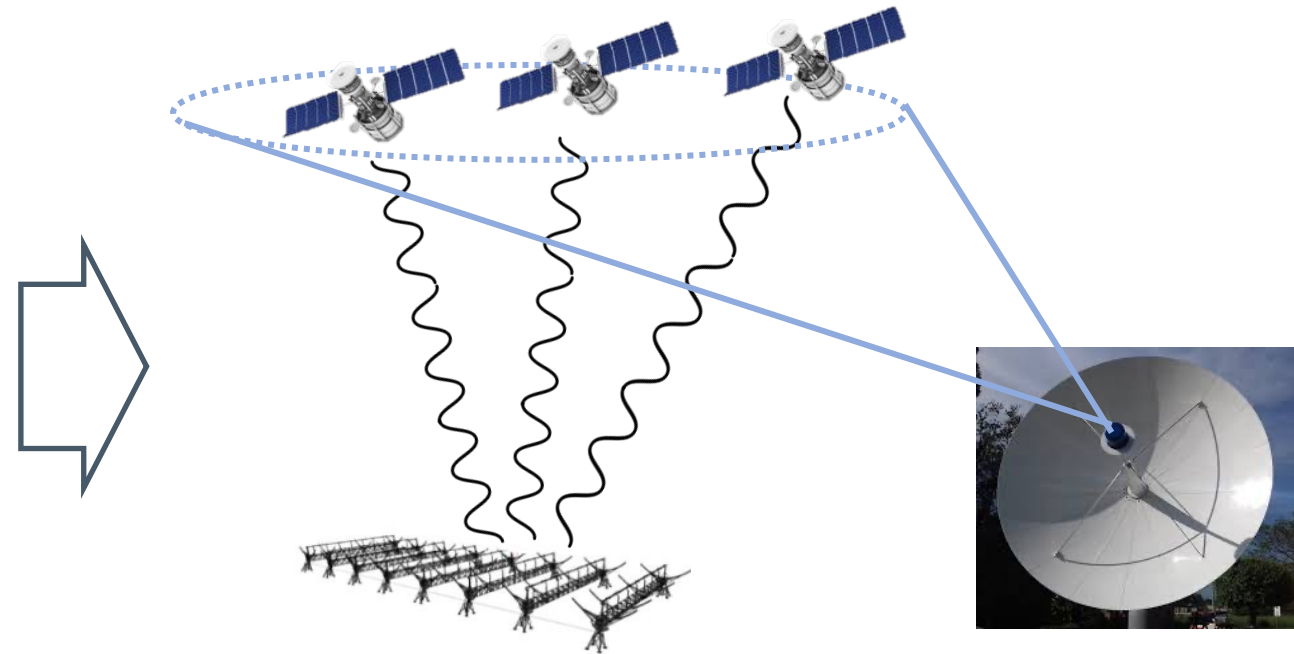
*Static beamforming* <sup>[1]</sup>



Medicina  
(Bologna)

Salto di Quirra  
(Sardinia)

*Adaptive beamforming*



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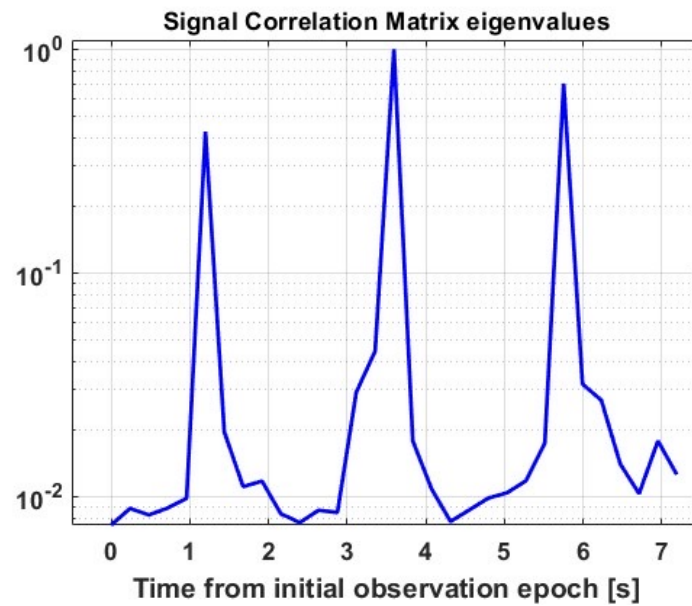


# Upgrade of BIRALES processing pipeline

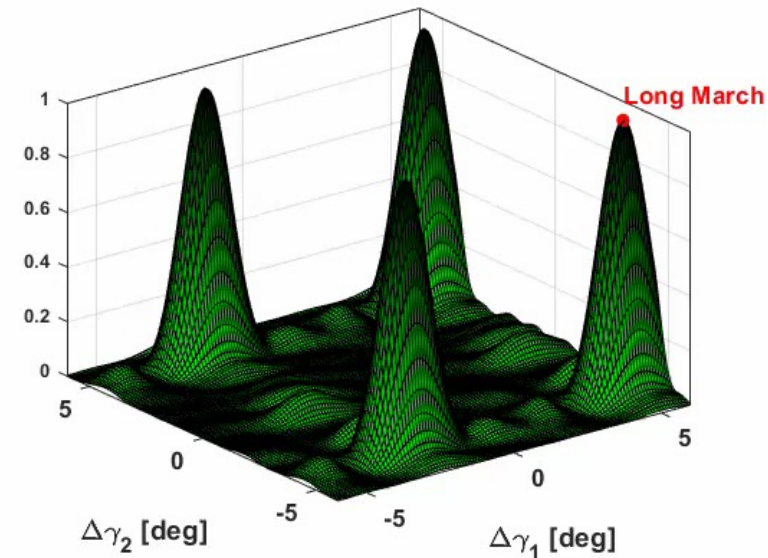
## Long March re-entry

- ▶ From Oct 31 to Nov 4, 2022
- ▶ First operational involvement in SST service

*November 1<sup>st</sup>, 2022  
h. 08:40 UTC*



*November 4<sup>th</sup>, 2022  
h. 07:29 UTC*

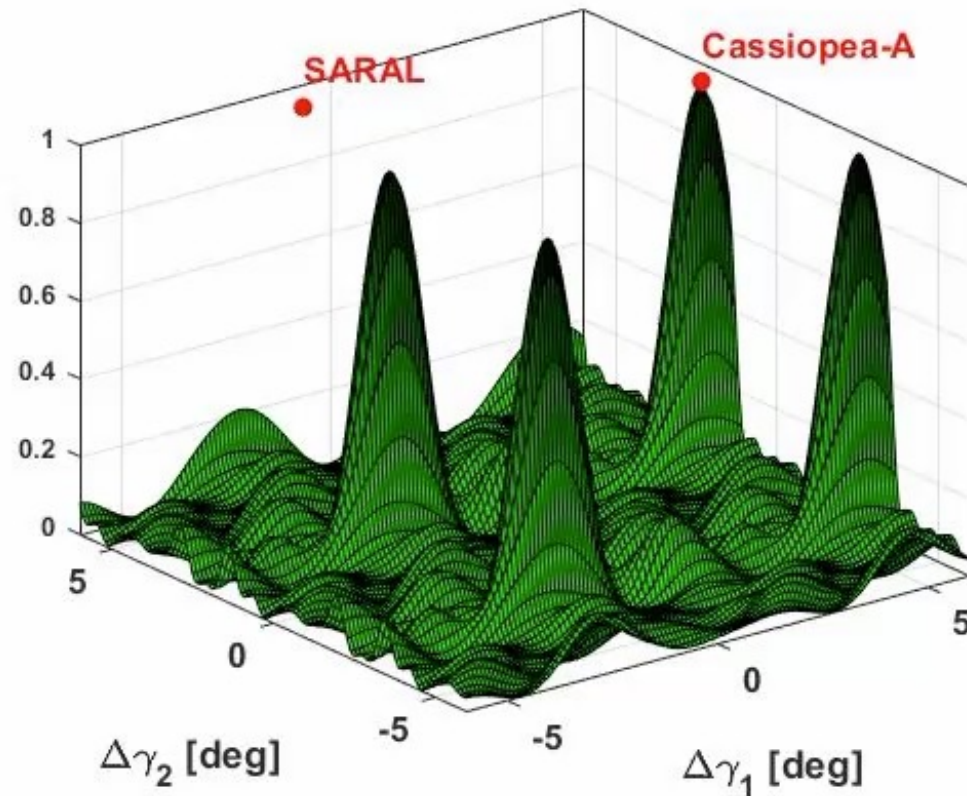


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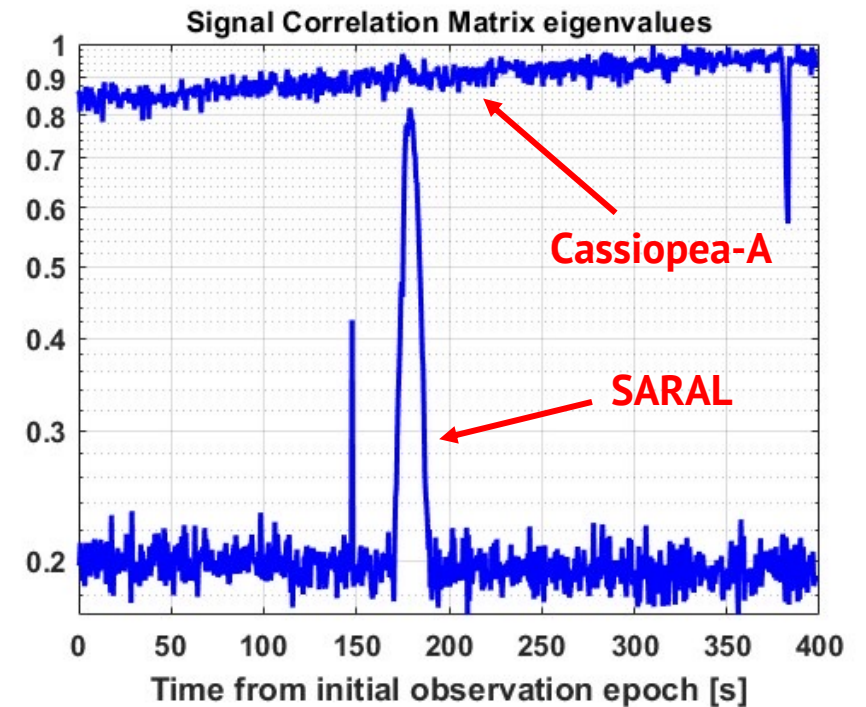


# Multiple targets detection

## SARAL transit



- ▶ December 2<sup>o</sup>, 2022
- ▶ Target: SARAL (norad ID 39086)
- ▶ Radiosource: Cassiopea-A

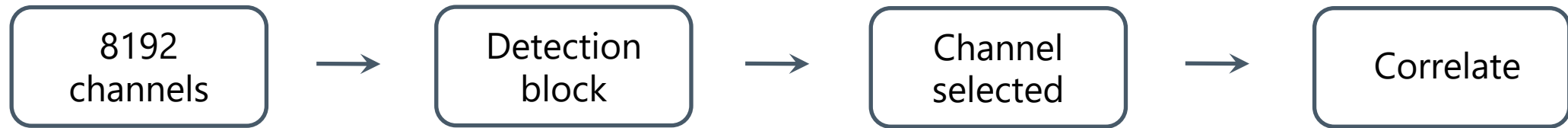


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# Multiple targets detection

- ▶ Split the receiver bandwidth in multiple channels
- ▶ Signal power increase enhances the detection rate and the angular track accuracy
- ▶ Multiple sources simultaneously detected are processed separately



$BW_{RX} \sim 85000 \text{ Hz}$



$BW_{RX} \sim 10 \text{ Hz}$



$$SNR \propto \frac{1}{BW_{RX}}$$



Angular track accuracy



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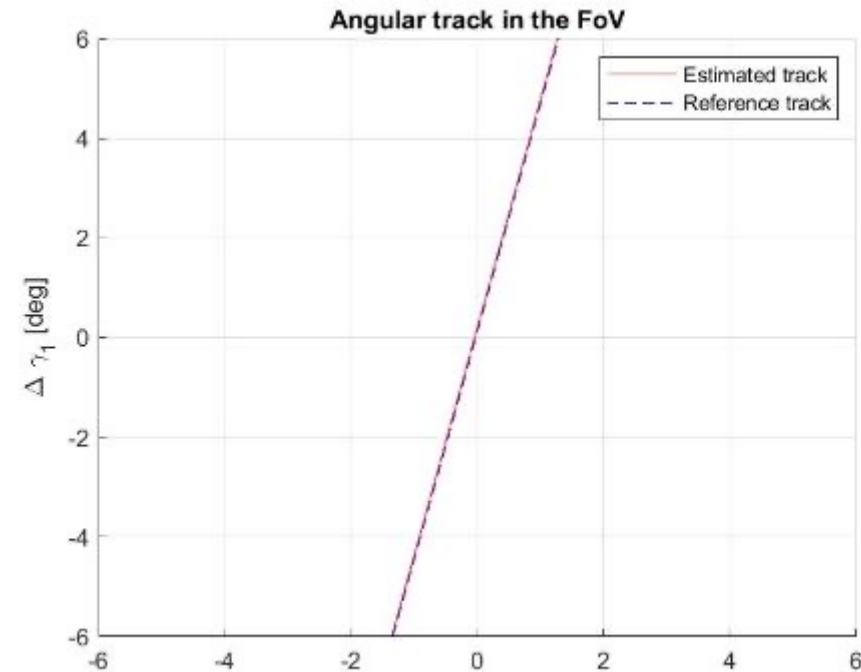
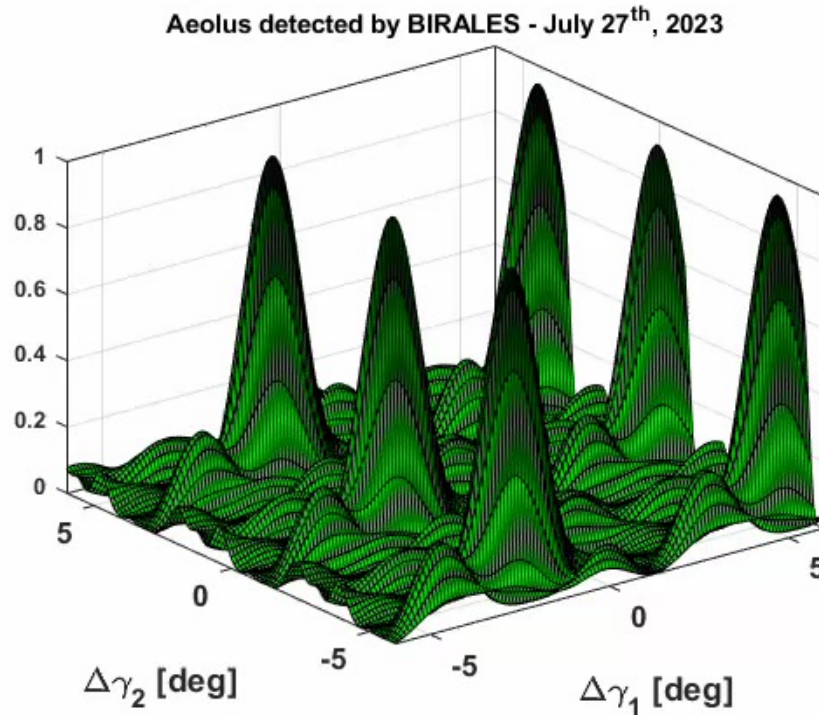




# Support to reentry campaigns

## Aeolus re-entry campaign

- ▶ July 24-28, 2023
- ▶ Target was maneuvering during July 27<sup>th</sup> observation

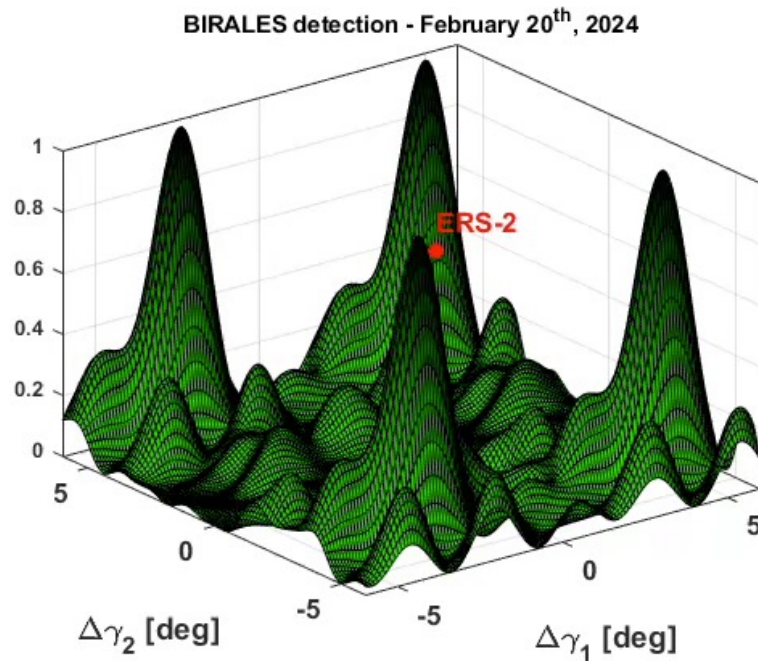


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# Support to reentry campaigns

## ERS-2 re-entry campaign

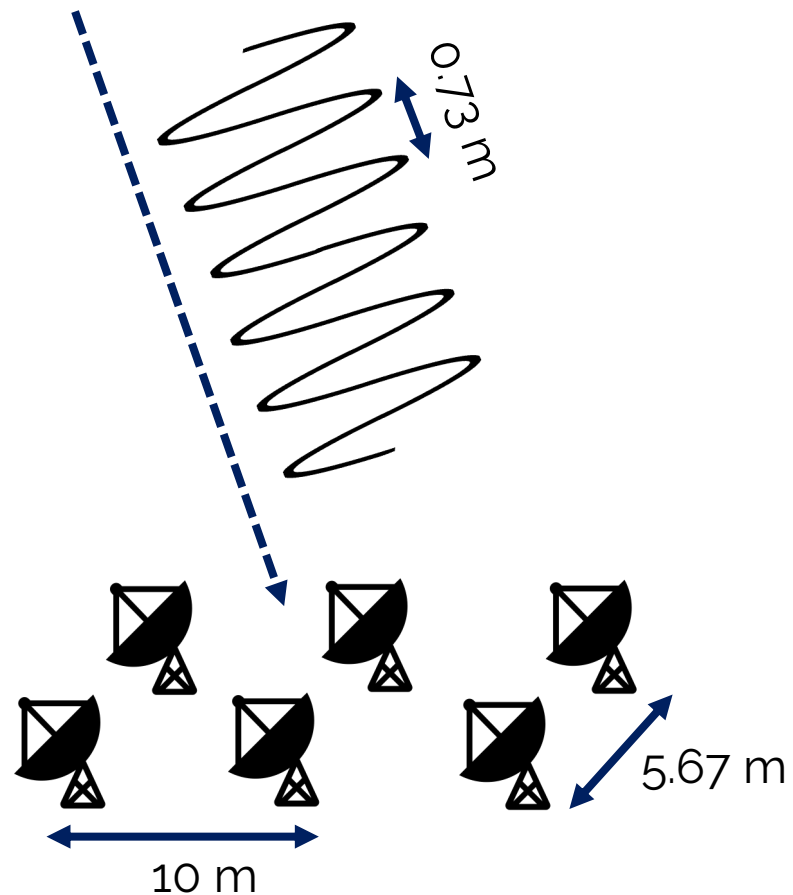


- ▶ February 7-21, 2024
- ▶ Two passages observed
- ▶ Challenging pointing angles: one TDM produced
- ▶ Treated both as catalogued and uncatalogued case
- ▶ TDM and array response video uploaded on database

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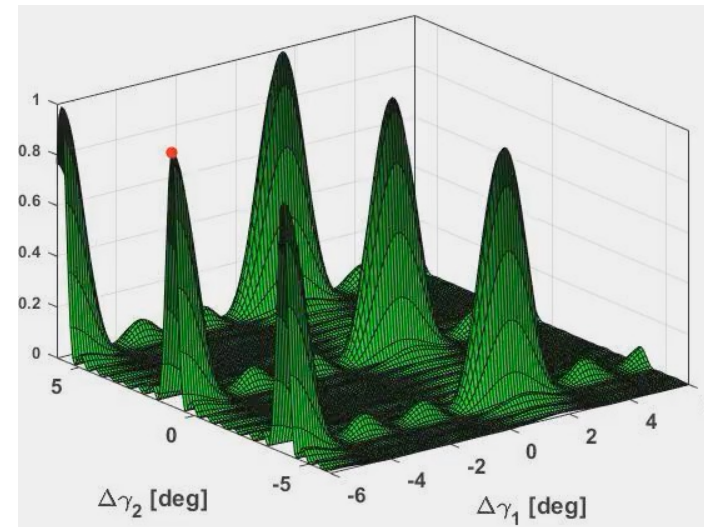


# Signal DOA ambiguity solution



DOA solution is unique if distance between antennas is less than  $\lambda/2$

- ⇒ Presence of multiple DOA estimates
- ⇒ Ambiguity solving criteria needed



● Signal DOA

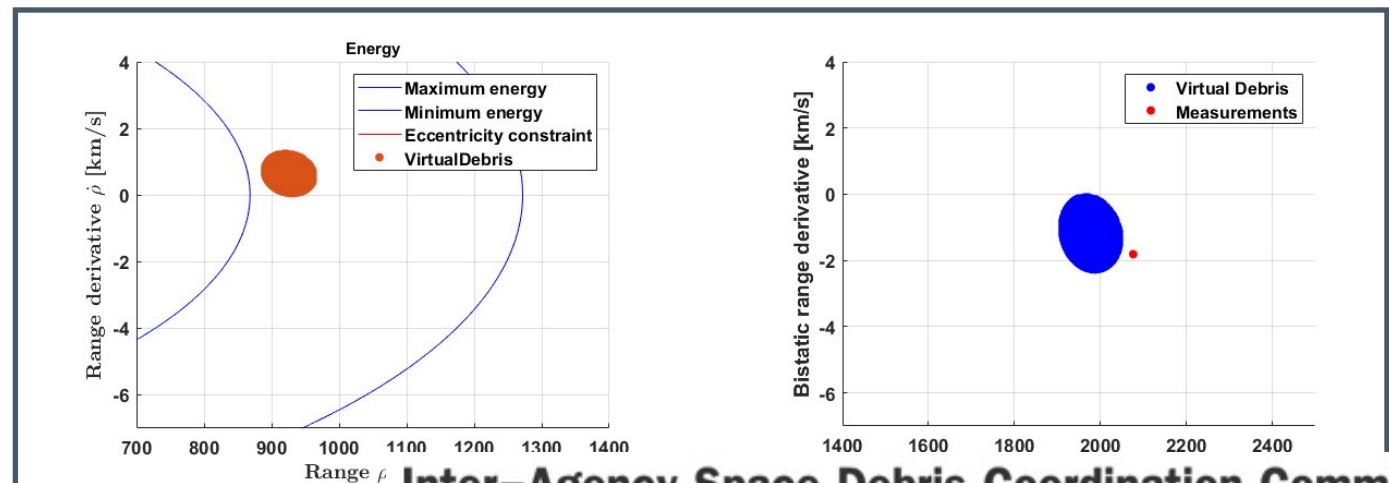
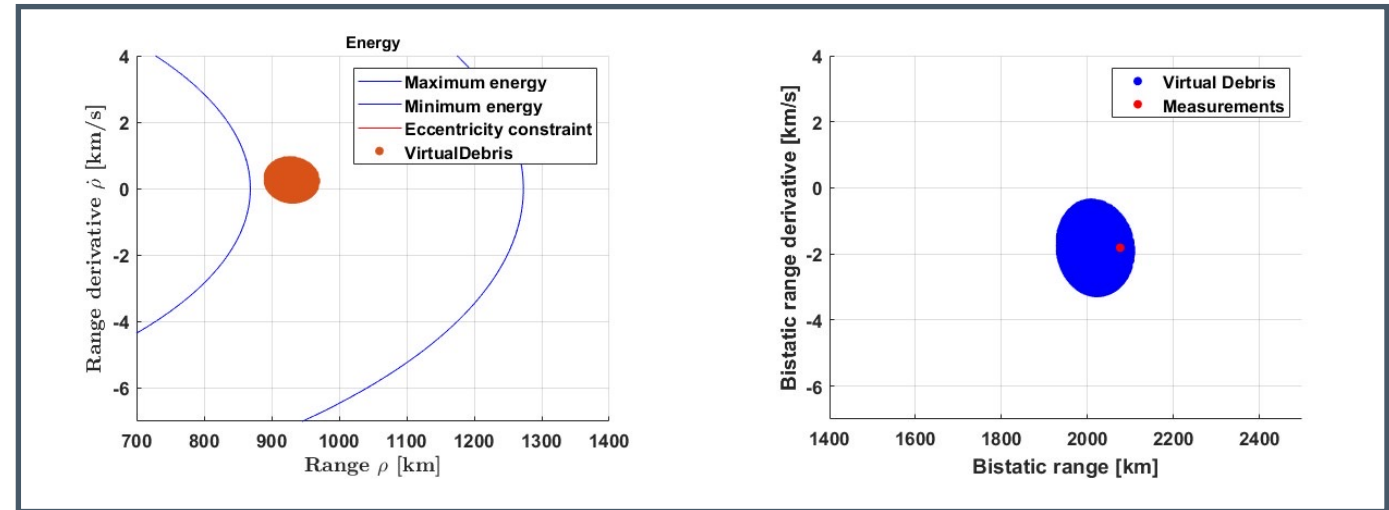
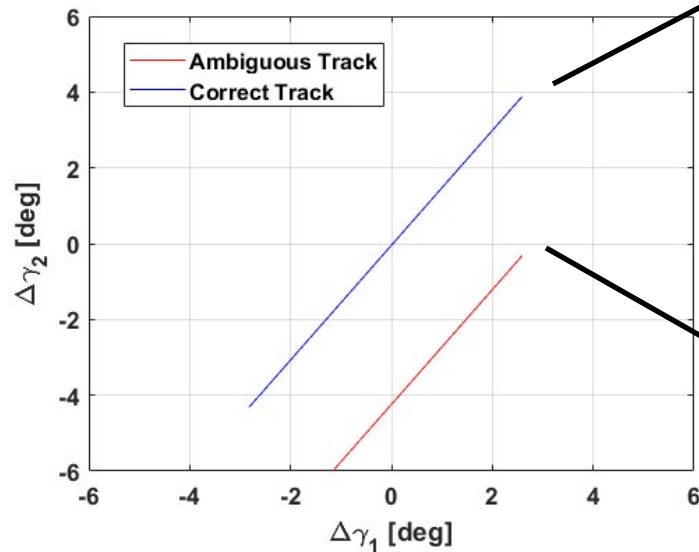
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# Signal DOA ambiguity solution: Admissible region approach

- ▶ Optical AR<sup>[1]</sup> for each track candidate
- ▶ Mapping of AR into to bistatic plane
- ▶ Check with measured DS and SR

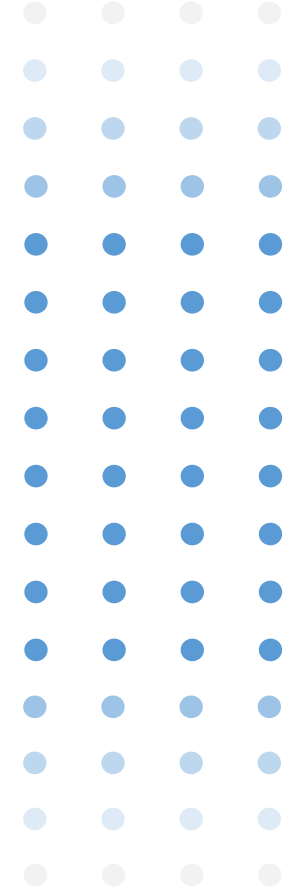
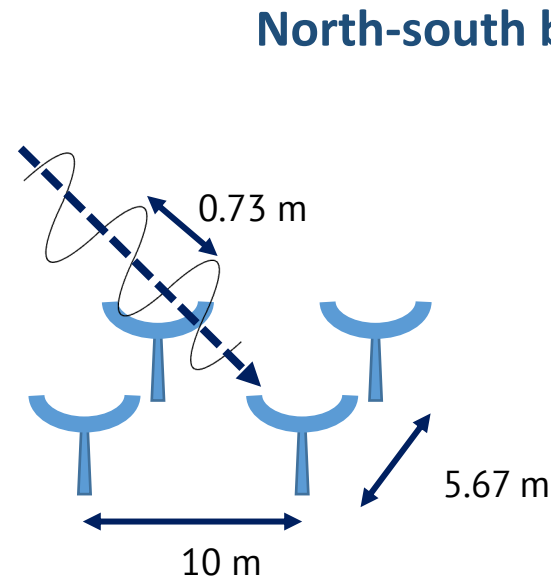
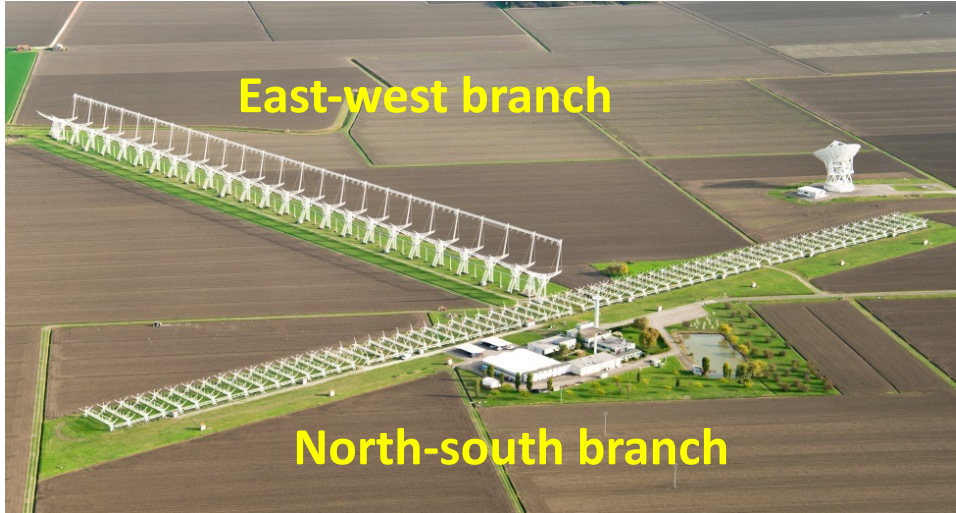


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[1] G. Tommei et al., 2007

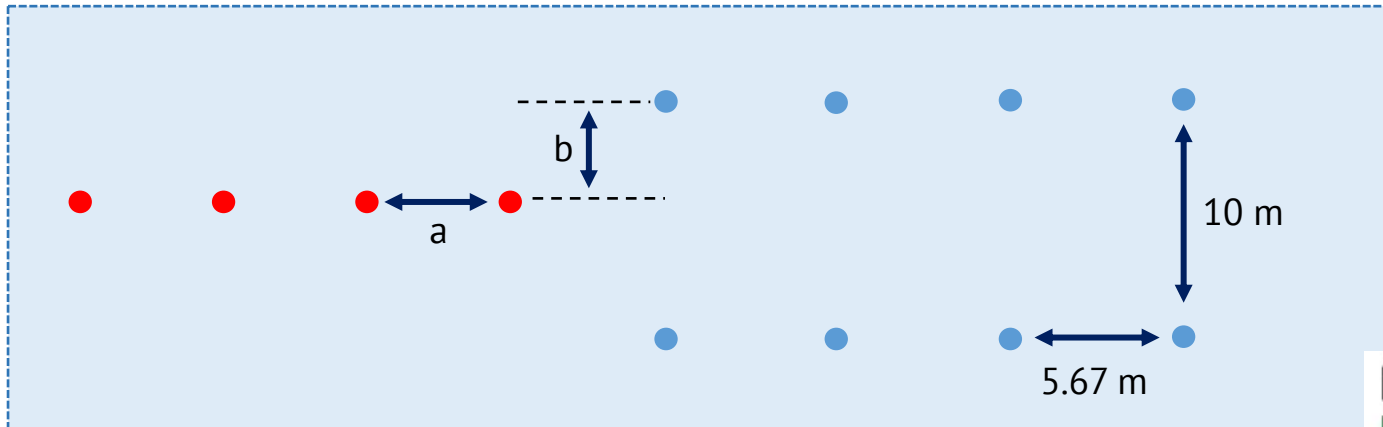
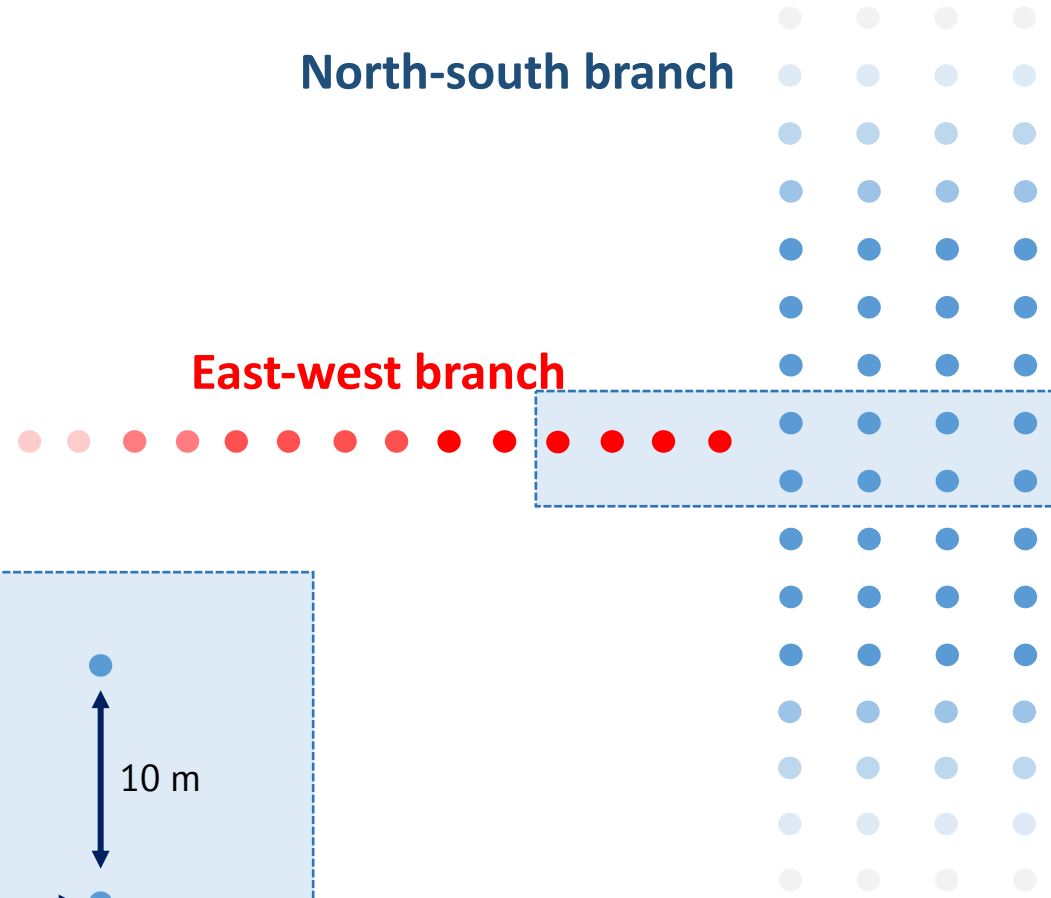
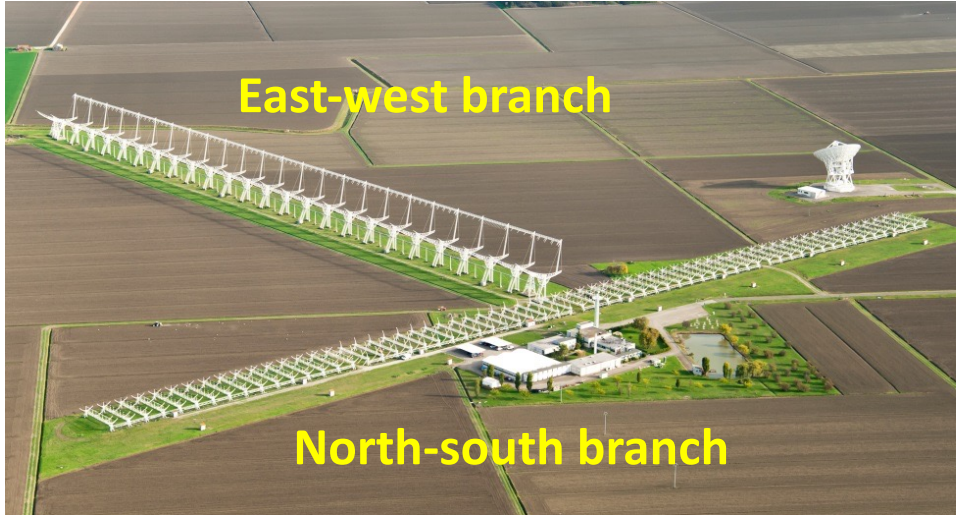
# Signal DOA ambiguity solution: Use of E-W arm



- ▶  $d > \frac{\lambda}{2}$  causes ambiguous solutions
- ▶ The constant spacing among array receivers induces the same ambiguous solutions regardless the receivers used

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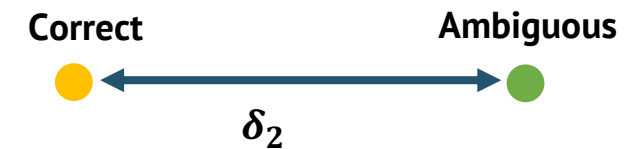
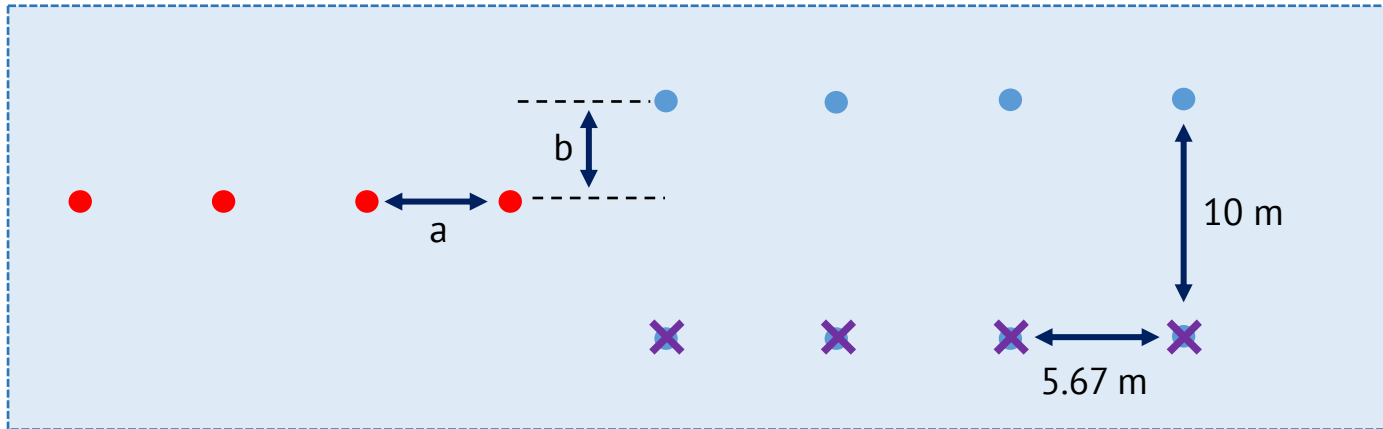
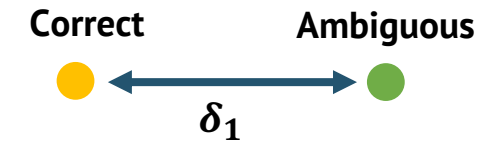
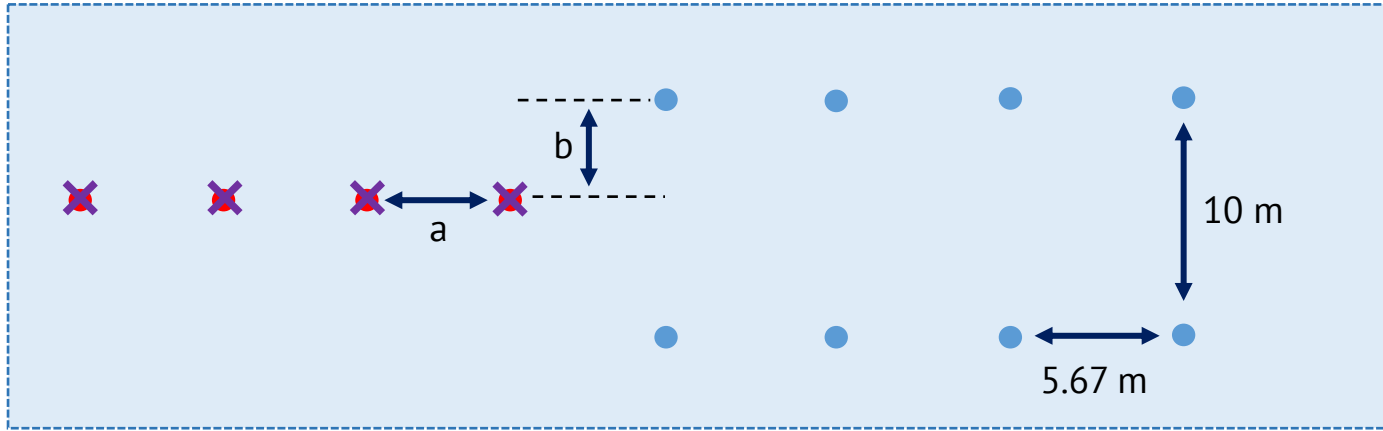
# Signal DOA ambiguity solution: Use of E-W arm



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# Signal DOA ambiguity solution: Use of E-W arm



Conditions

$$\begin{cases} a \neq k * 5.67 \\ b \neq k * 10.0 \end{cases} \quad \begin{cases} a \neq 5.67/k \\ b \neq 10.0/k \end{cases}$$

$$k \in \mathbb{N}$$

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