Multi-Channel Correlator Array-Fed Microwave Radiometer

Earth Science Technology Forum

NASA Ames Conference Center

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Short Title: Correlator-Array Fed Radiometer (CAFR)

CAFR Team

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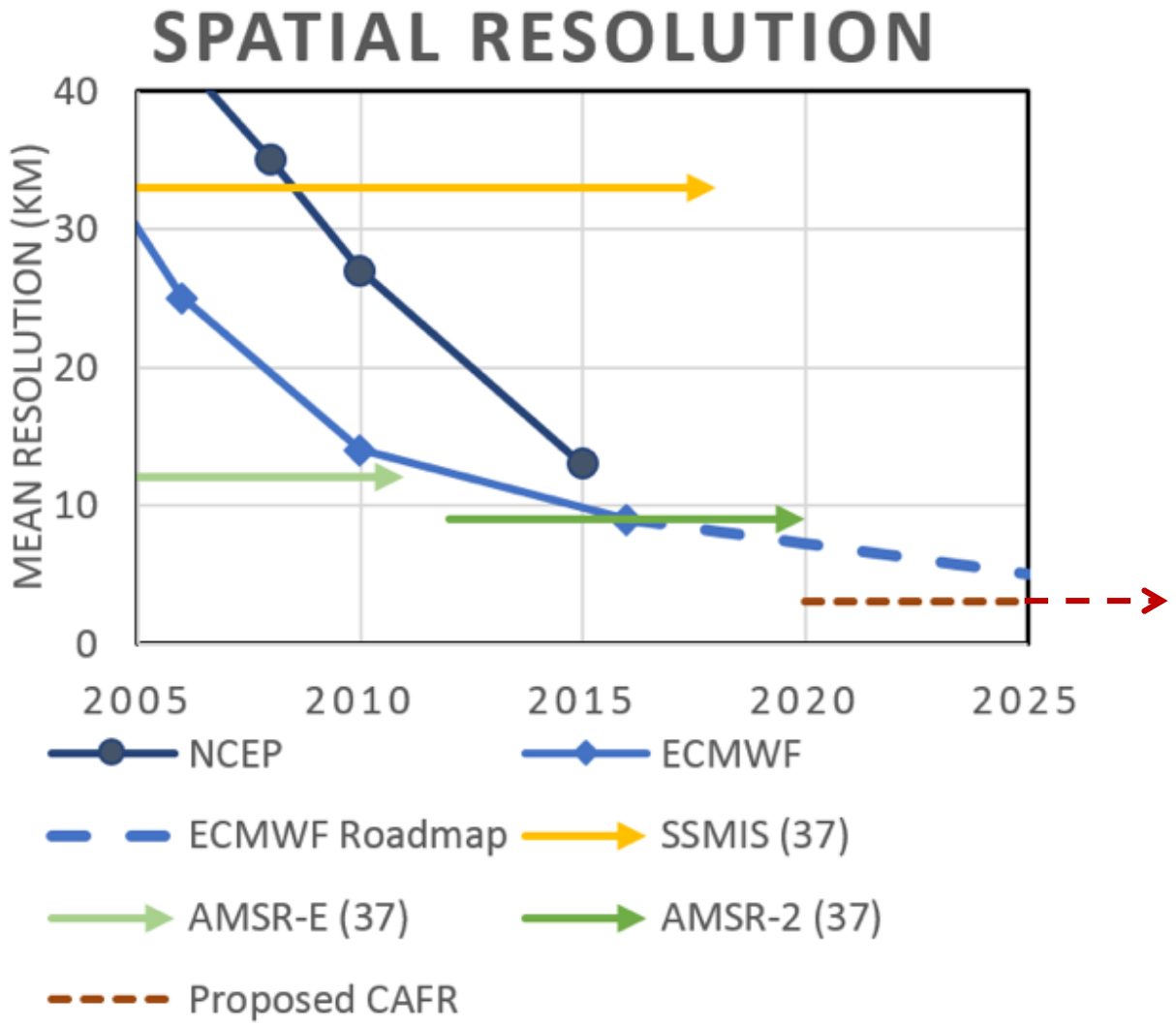
- Jared Jordan/Nuvotronics, Co-I and wideband array
- Victor Marrero/GSFC 567, Co-I and antennas
- Ali Mahnad/GSFC 567/AS&D, Antennas
- Rafael Rincon/GSFC 555, Co-I and digital receiver
- Giovanni De Amici/GSFC 555, Co-I and lab demonstration
- Jinzheng Peng/GSFC 555/USRA, forward modeling

Outline

- Motivation
- Proposed Technical Solution
- Laboratory Demonstration

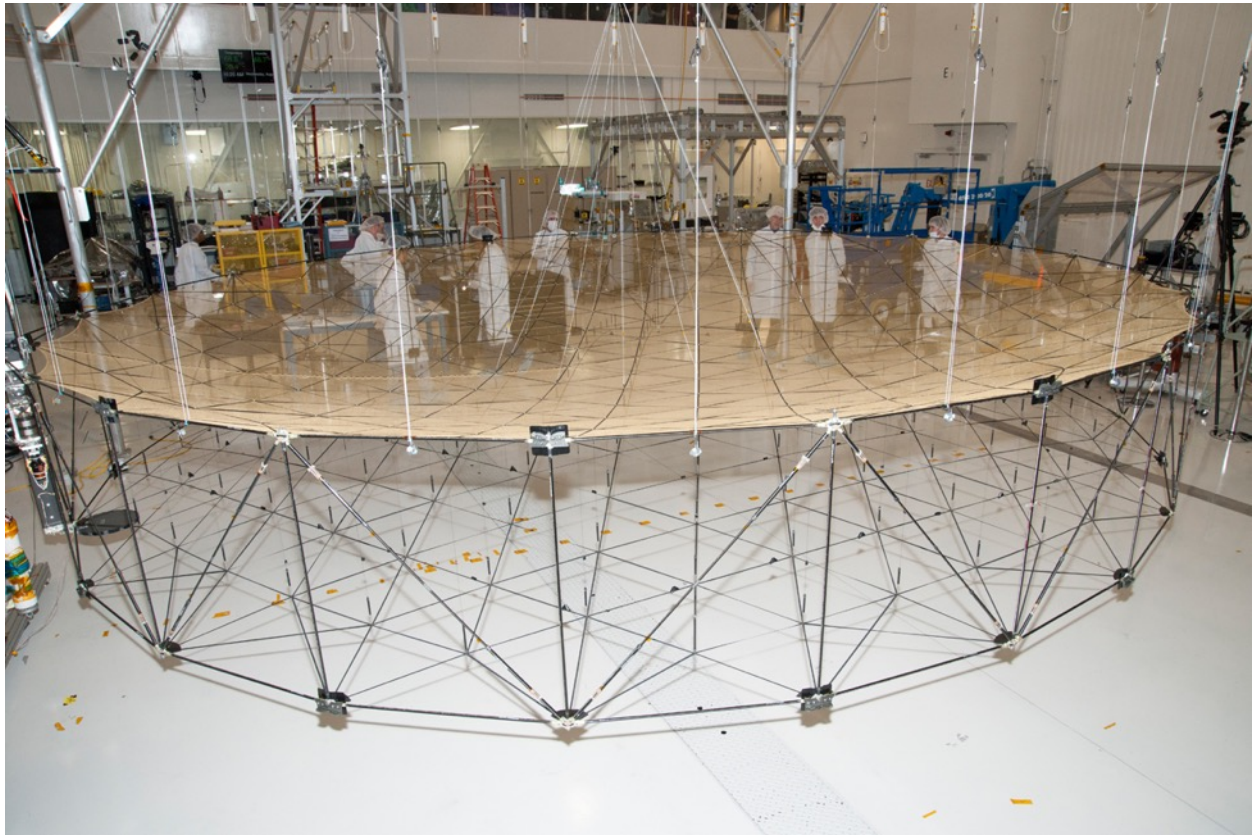
Motivation

- One of the greatest performance challenges for PMW is spatial resolution:
  - Evapotranspiration ~ 3km @ 37 GHz
  - Clouds, convection and precip ~ 5km
  - Soil moisture < 10 km, ~5 km
  - Salinity <50 km
- Data assimilation models are improving in resolution
- Technical implication of keeping NEDT
  - $N \sim (D/D_0)^2$
  - N: number of feeds
  - D_0: current reflector diameter
  - D: new reflector diameter

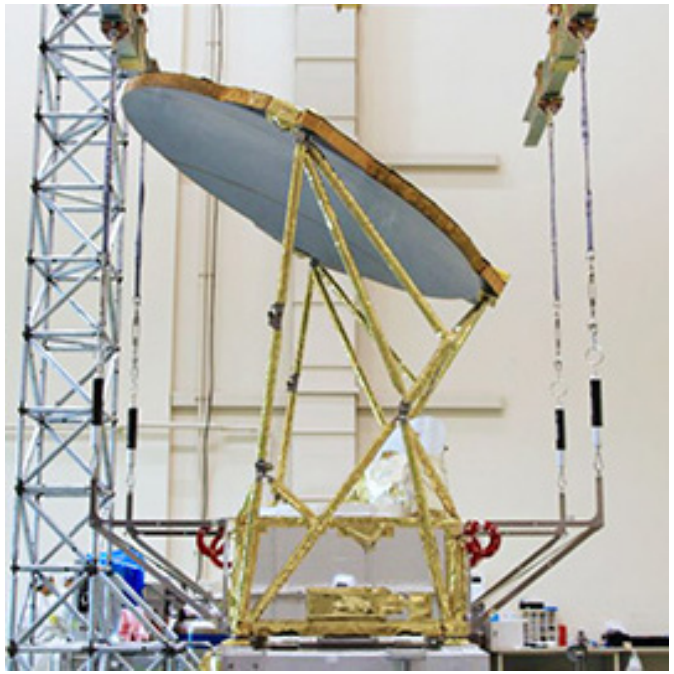


Aperture Size Must Grow

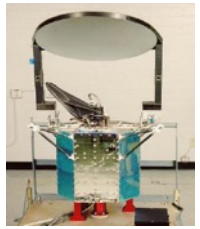
SMAP
6 m



AMSR2
2 m



SSMIS
60 cm



https://nsidc.org/data/pm/ssmis_instrument

https://www.star.nesdis.noaa.gov/mirs/amsr2.php

https://smap.jpl.nasa.gov/resources/84/antenna-fully-unfurled-during-test/

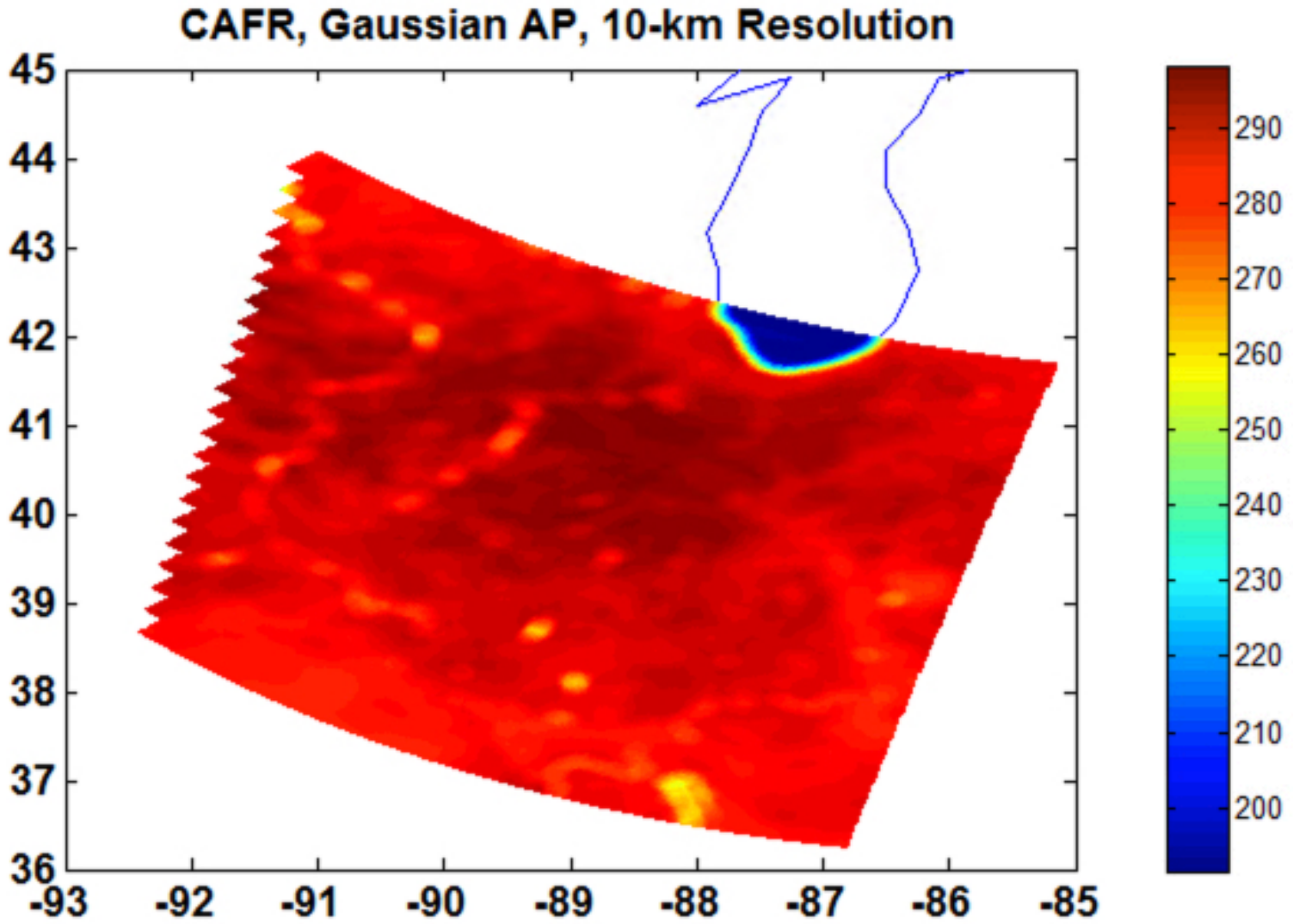
Radiometer Performance Goals

Table I. *Performance goals for an objective 6-meter multiband radiometer.*

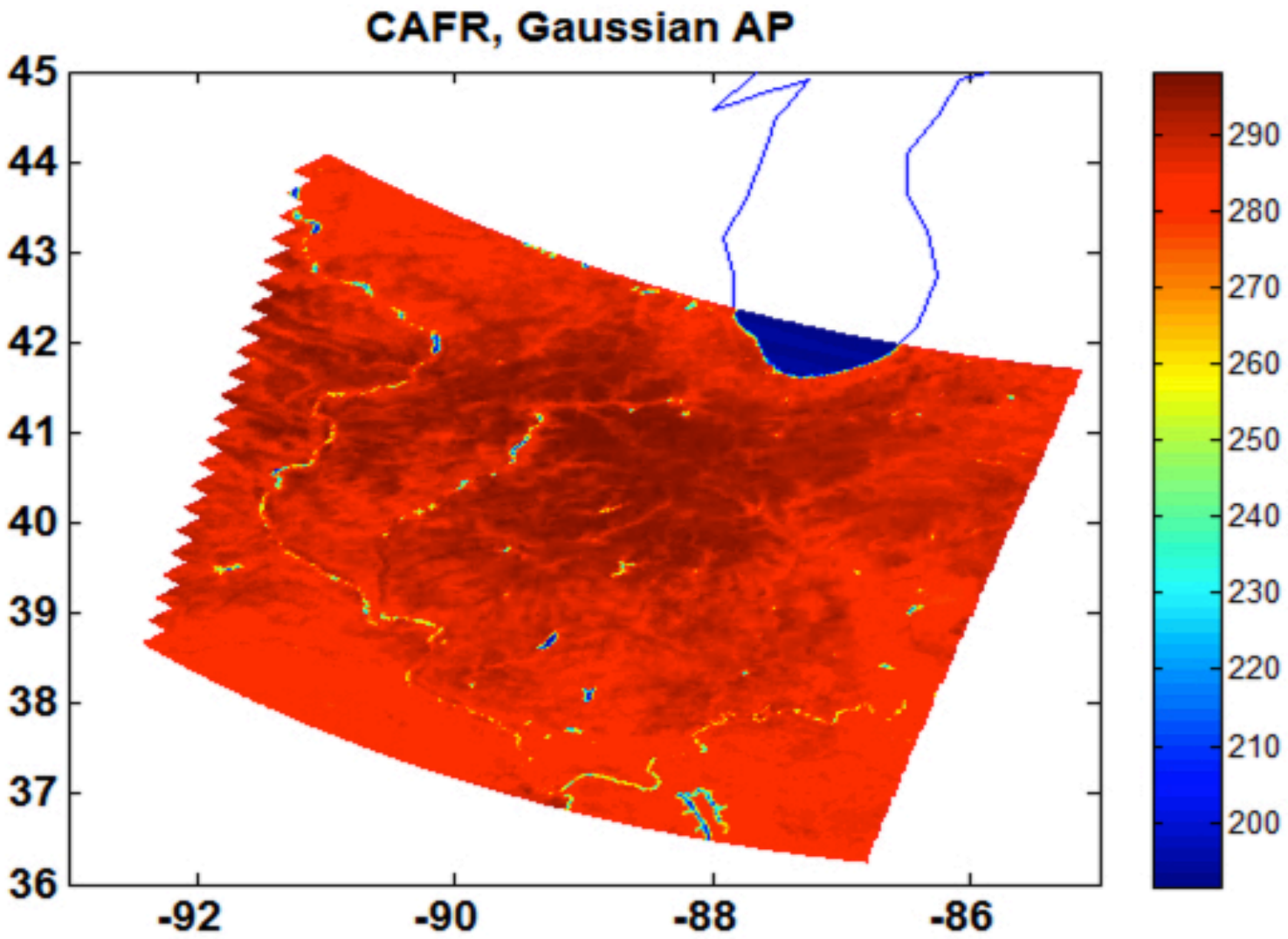
Frequency	GHz	10.65	18.7	23.8	36.5	89.0
Diameter	m	6	6	6	6	3
3dB beamwidth	deg	0.36	0.20	0.16	0.10	0.09
IFOV minor-axis	km	7.1	4.0	3.2	2.1	1.7
IFOV major axis	km	12.5	7.1	5.6	3.7	3.0
# IFOV's cross-scan		2.2	3.8	4.9	7.4	9.1
IF Bandwidth	MHz	100	200	400	1000	6000
Integration time	ms	2.69	1.53	1.20	0.79	0.65
NEDT goal	K	0.9	0.9	0.7	0.7	0.5

Beam efficiency > 95%

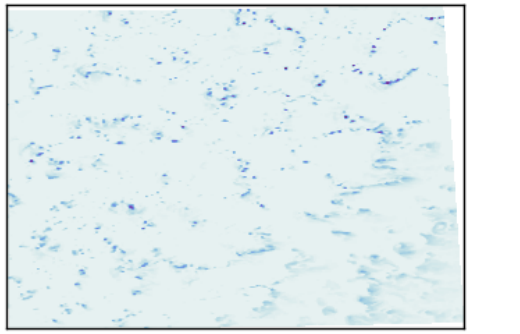
Representative 10-km Current Capability

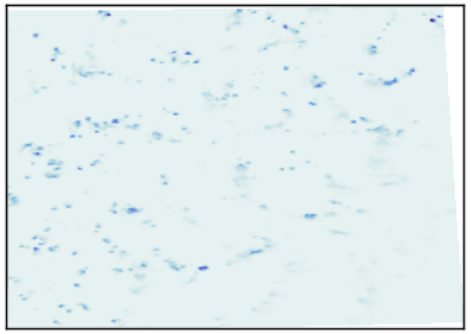


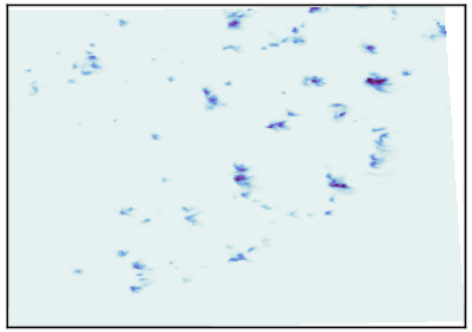
Targeted Capability – 2 km FWHM

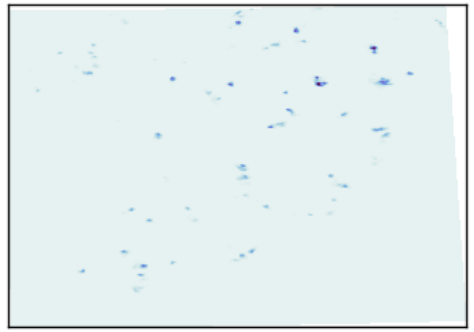


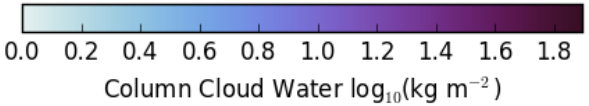
Evaluating resolution/sampling trade space: Shallow oceanic convection case

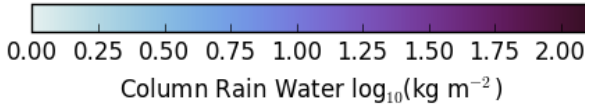


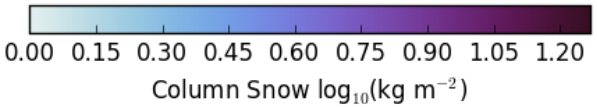


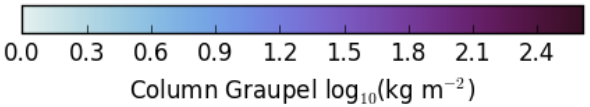


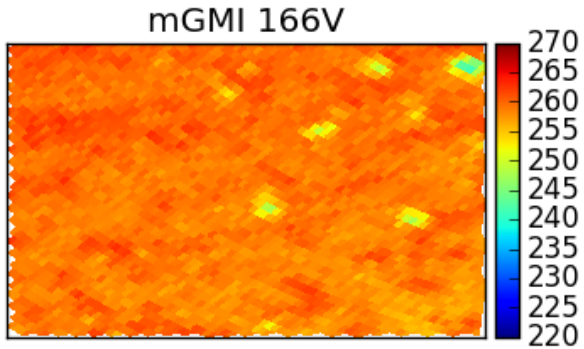




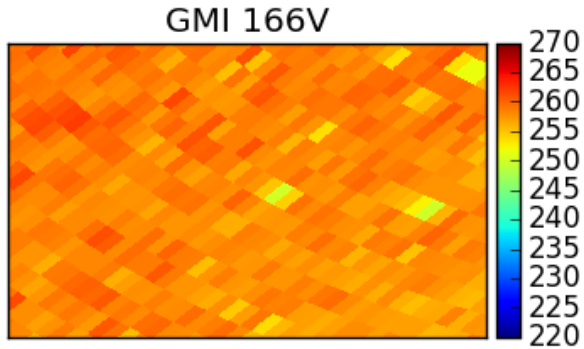




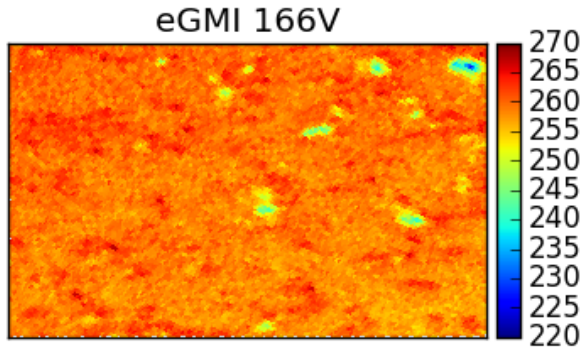




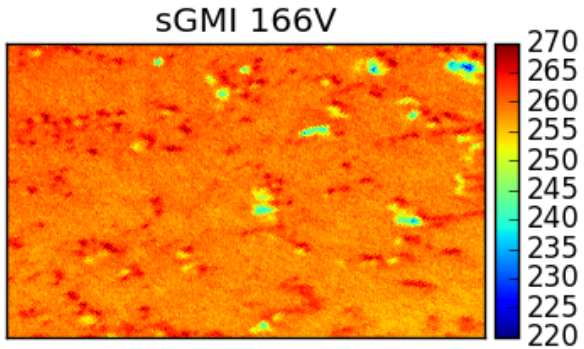
GMI w/ 3 feeds



GMI actual



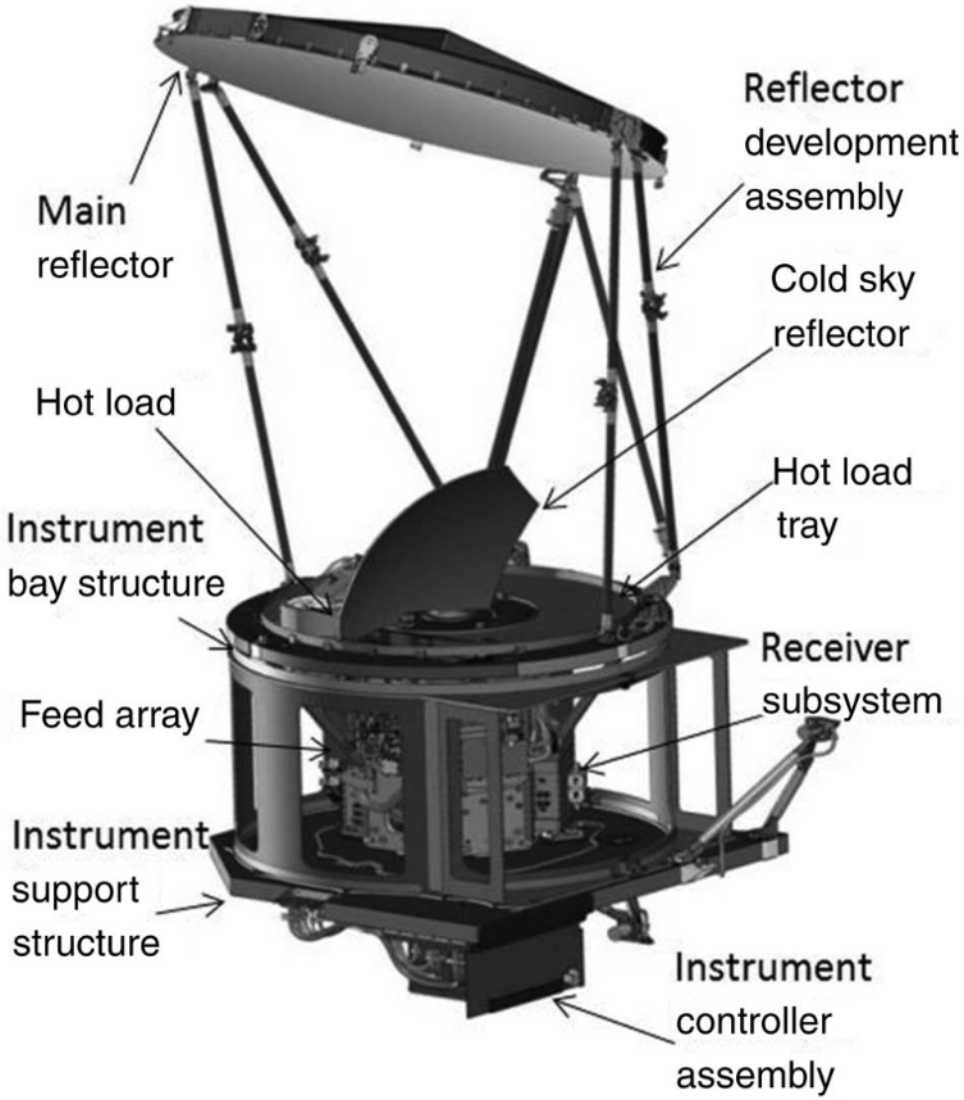
GMI w/ 2xD + 3 feeds

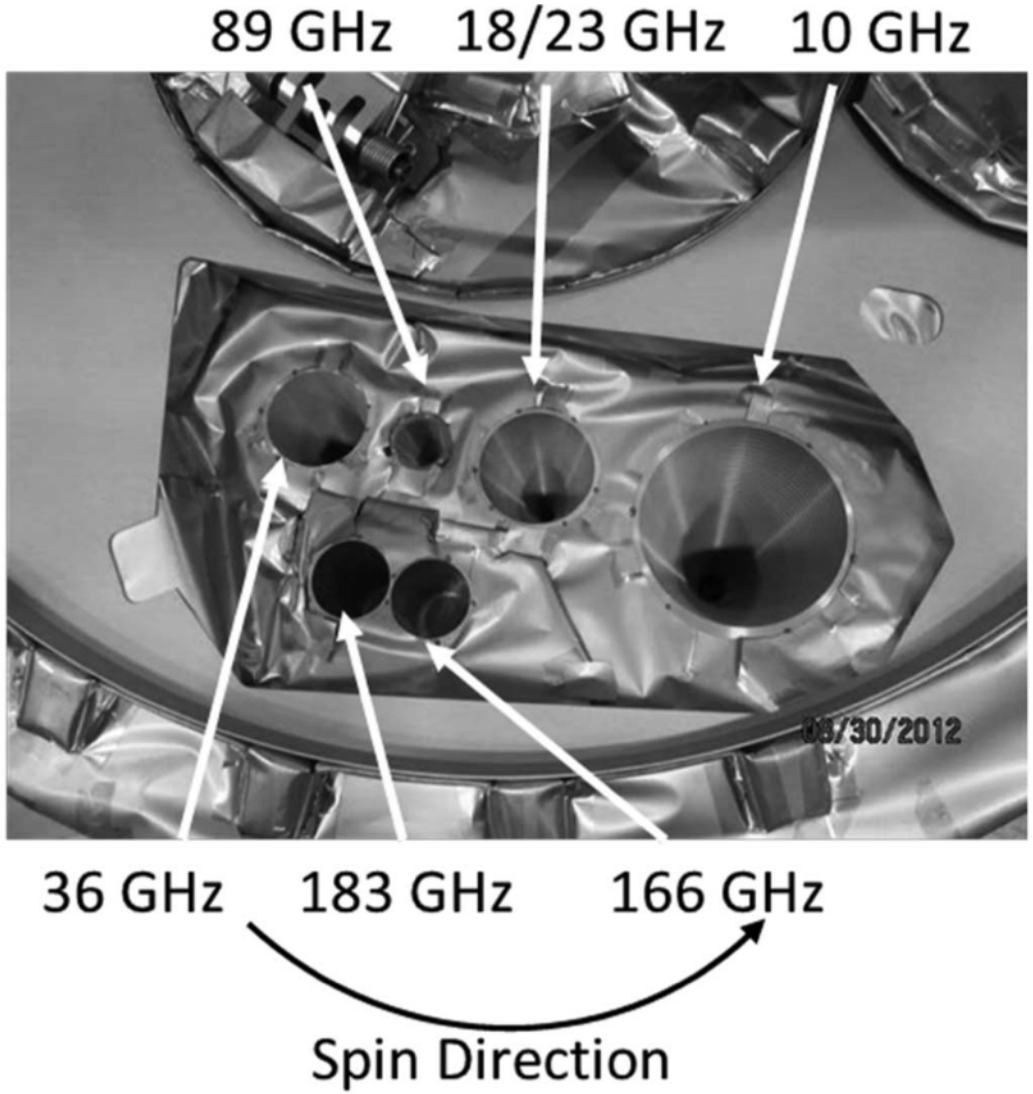


GMI w/ 4xD and 10 feeds

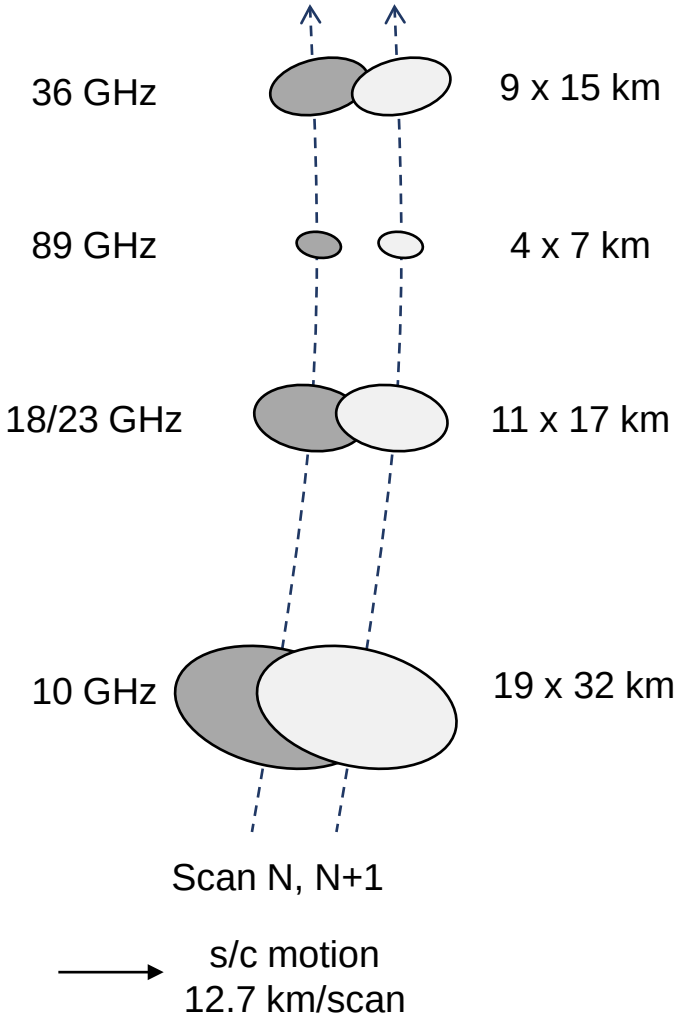
Courtesy of Joe Munchak

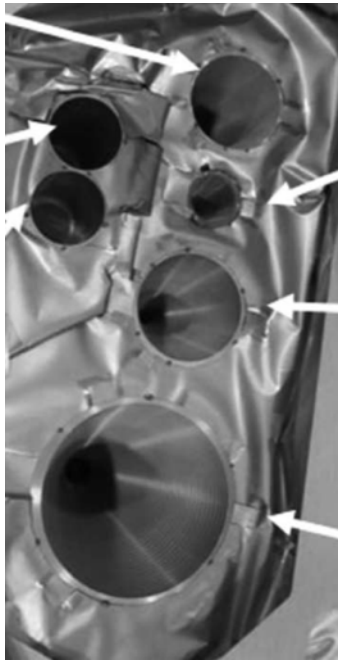
Conventional Feed Cluster





Improving Conventional Sampling Approach





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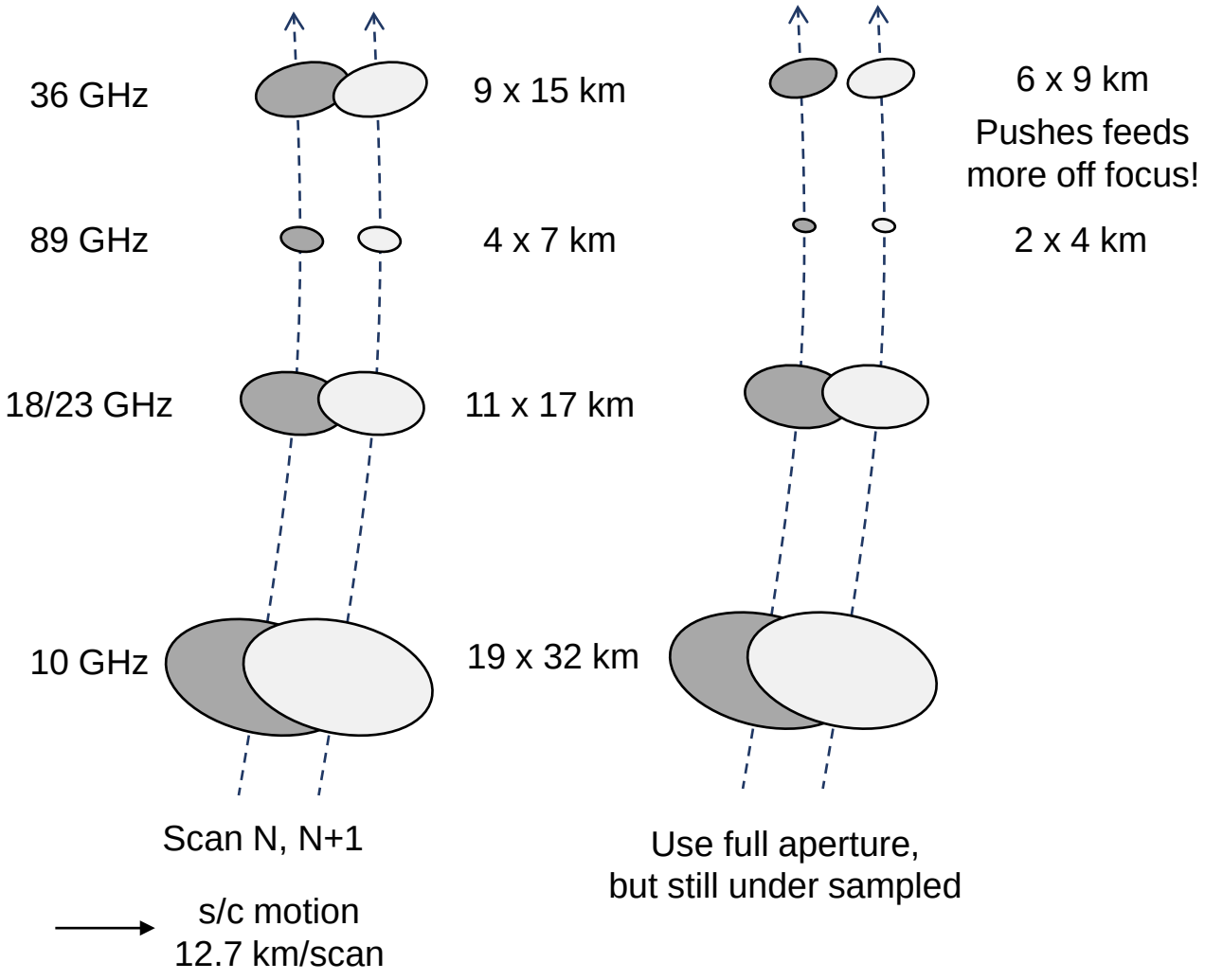

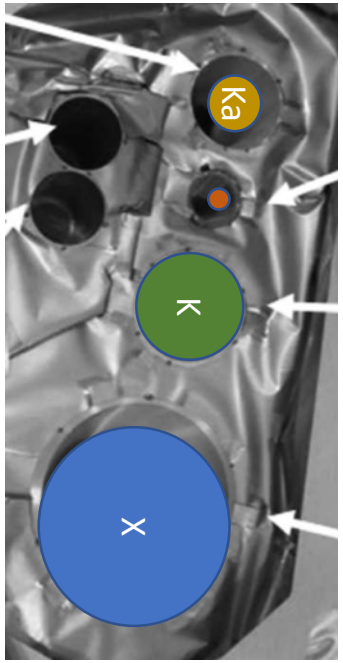

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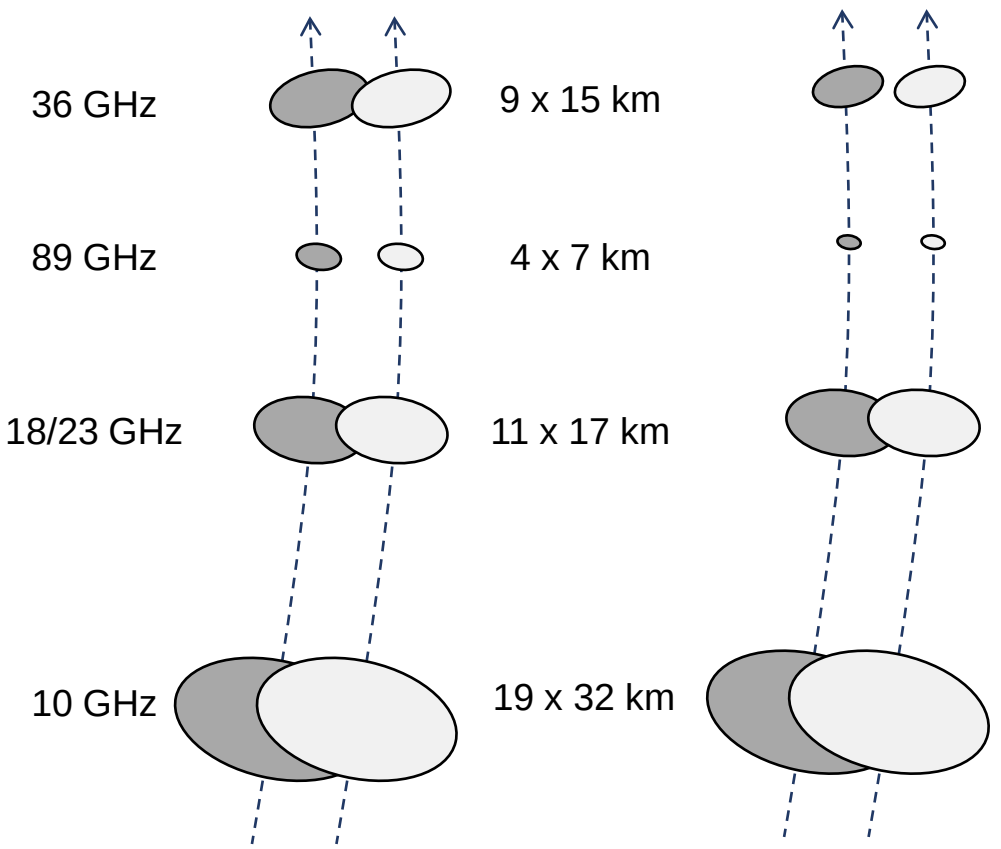


Scan N, N+1

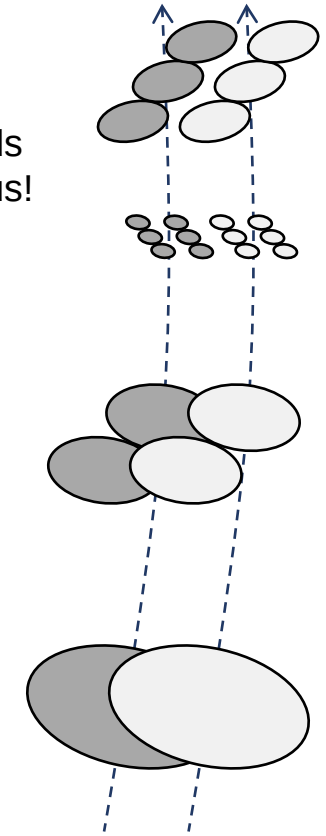
s/c motion
12.7 km/scan

Use full aperture,
but still under sampled

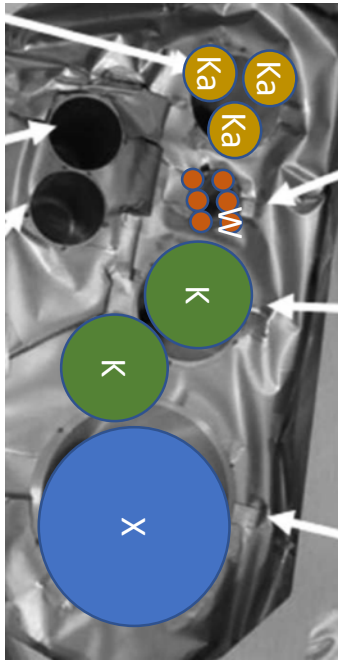
6 x 9 km

Pushes feeds
more off focus!

2 x 4 km

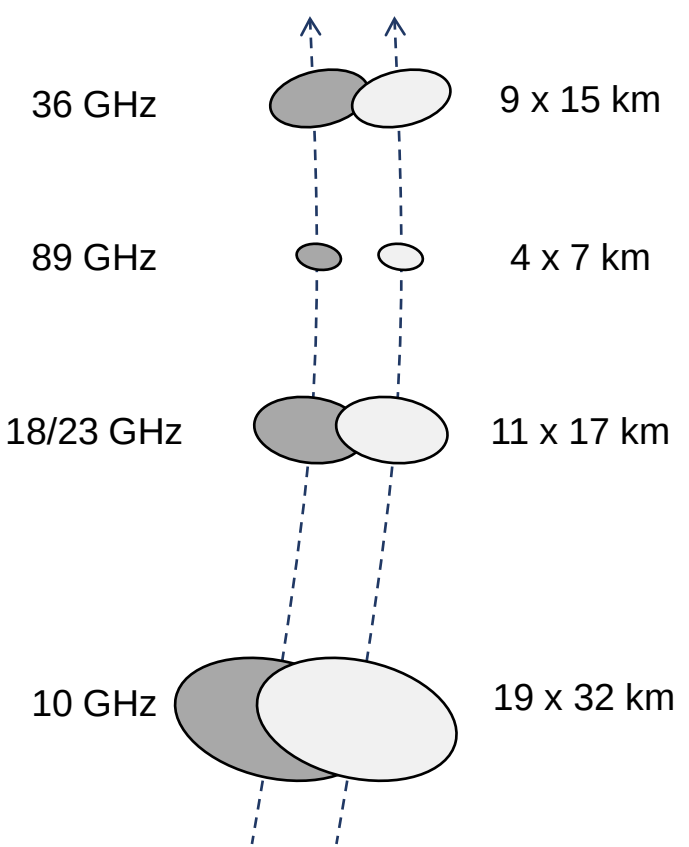


Add more beams for
Nyquist Sampling



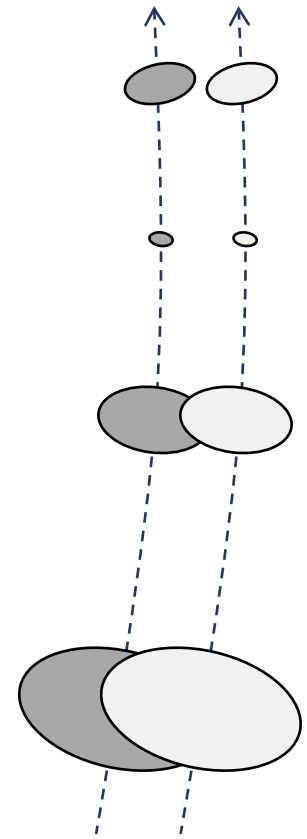
Imaginary Feed
Cluster for Nyquist
(not validated)

Improving Conventional Sampling Approach



Scan N, N+1

s/c motion
12.7 km/scan

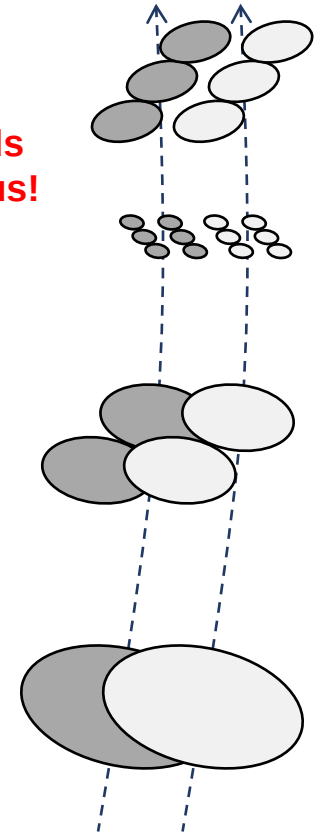


Use full aperture,
but still under sampled

6 x 9 km

Pushes feeds more off focus!

2 x 4 km



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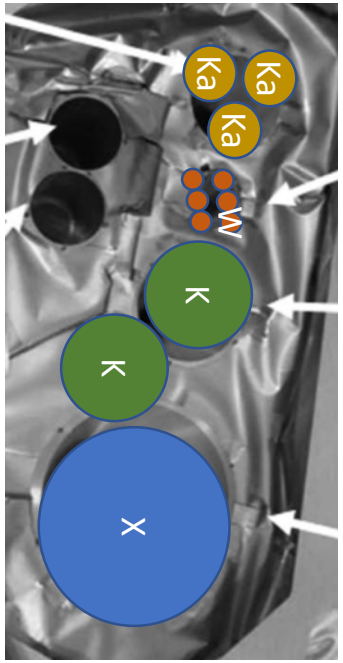
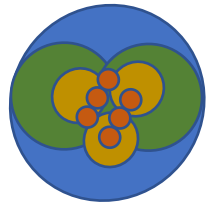


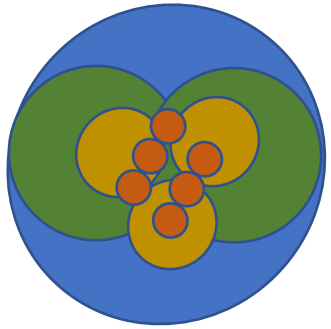
Imaginary Feed
Cluster for Nyquist
(not validated)



What if?

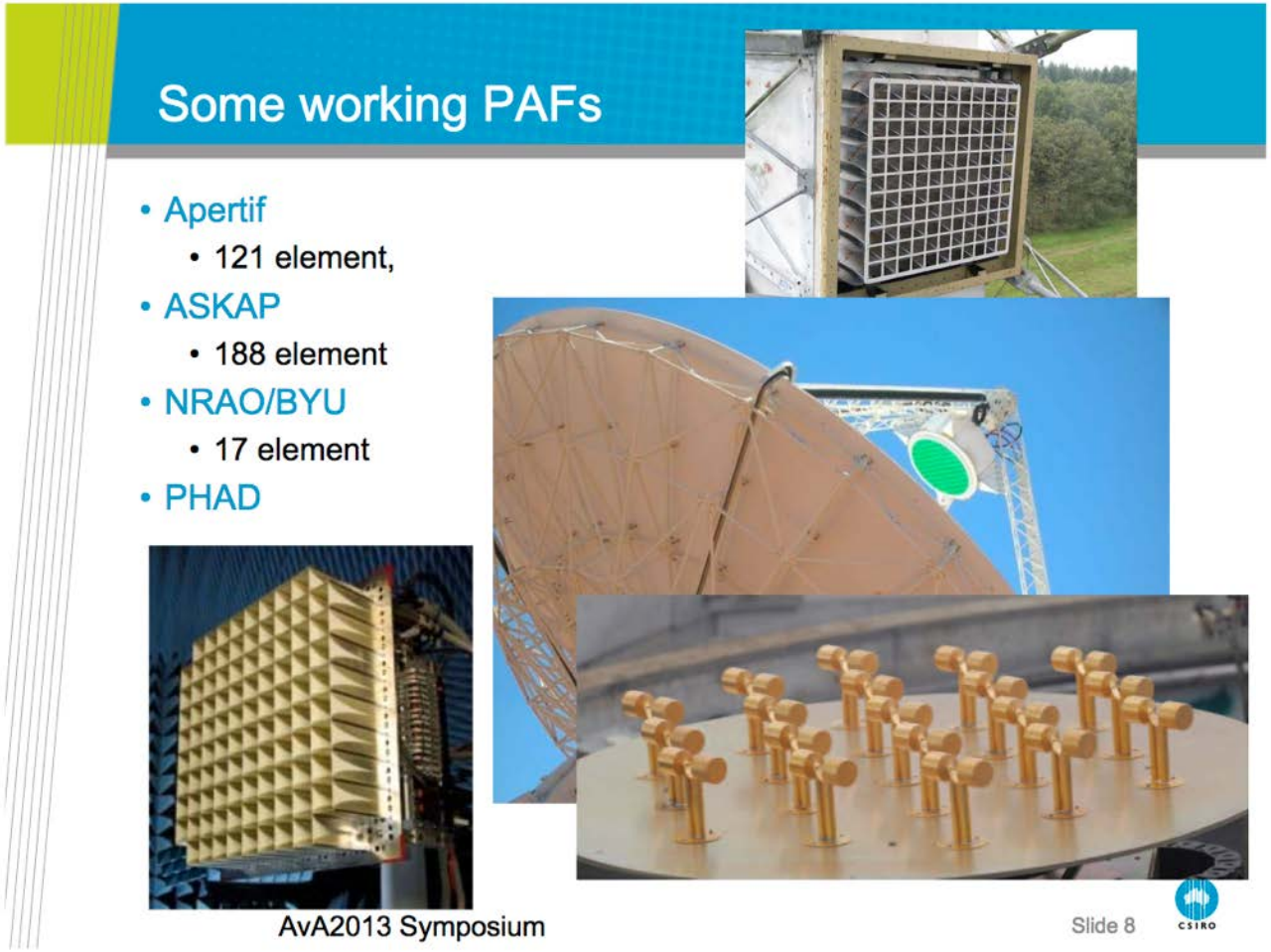
ESTO Earth Science Technology Office

Borrow (steal) from Radio Astronomy



Overlapping feed apertures at multiple frequencies -> broadband phased array feed

- Possibilities
  - Multiple beams
  - Beam steering
  - Beam shaping
  - RFI nulling

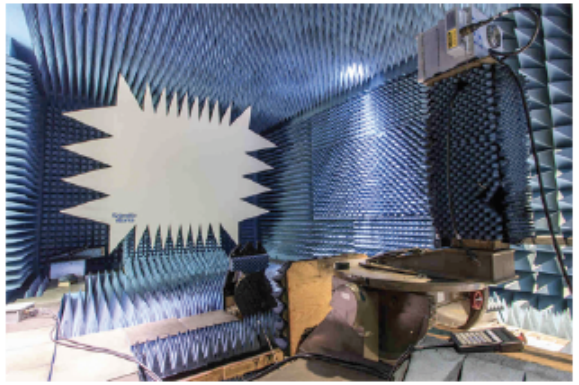


Reinventing Radio Astronomy – PAF Technology
John O'Sullivan
Centre for Astronomy and Space Science
CSIRO
2 April 2013

http://www.astron.nl/ava2013/documents/John_O_Sullivan.pdf

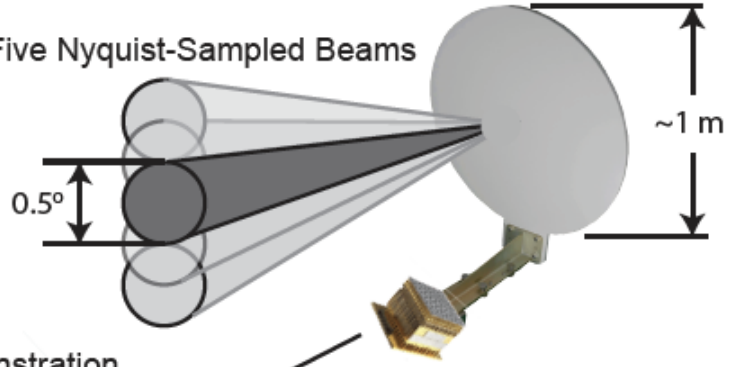
Demonstration Design

GSFC Electromagnetic Anechoic Chamber
Used for Demonstration Measurements

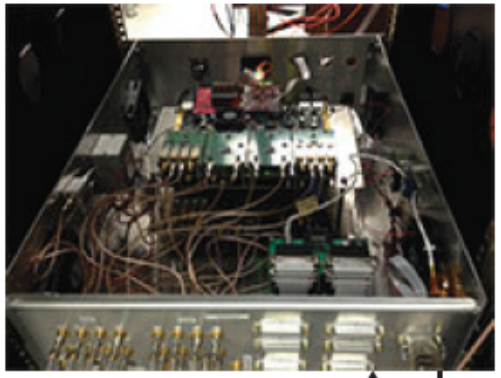


Correlation Array Fed Reflector

Five Nyquist-Sampled Beams

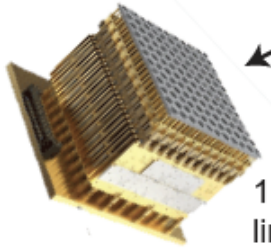


EcoSAR Processor
Digitizes and Stores Data

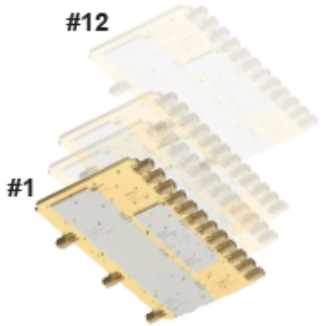


SBIR Phase 2 Feed Used for CAFR Demonstration

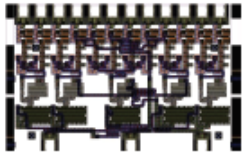
Specifications
- Six dual-polarized bands
- 9.6, 10.8, 13.6, 17.2,18.7, & 36.5 GHz
- Integrated filters and diplexers
- 11 x 12 elements
- 121 Current Sheet Array Elements
- Size: ~ 7 x 7 x 5 cm^3



12-element
line-array cards

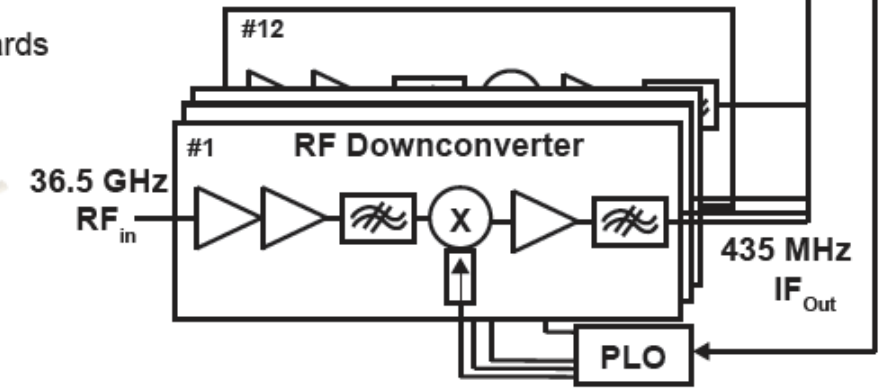


Combiner Card Detail

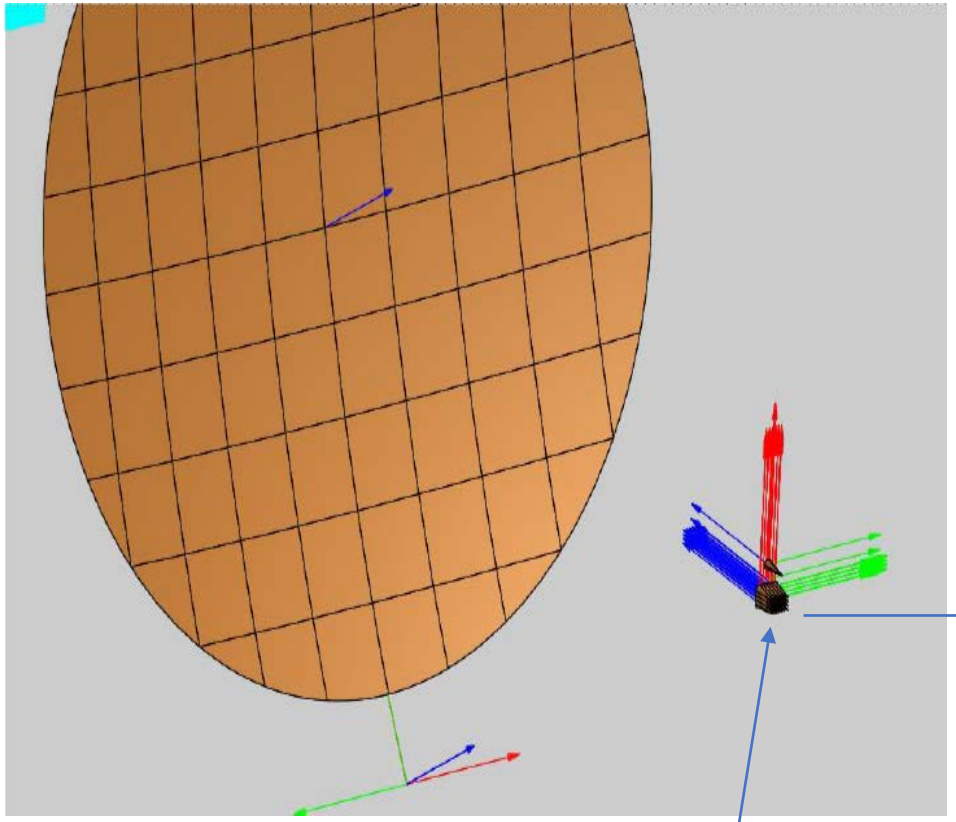


Element Combiner

12-Channel COTS Coherent Receiver

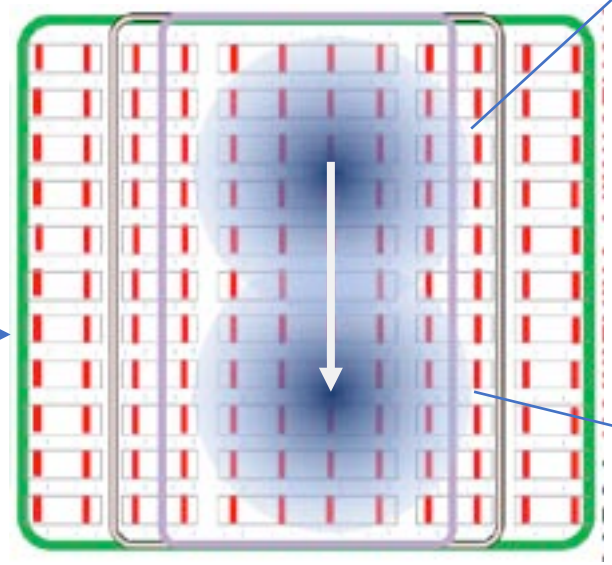


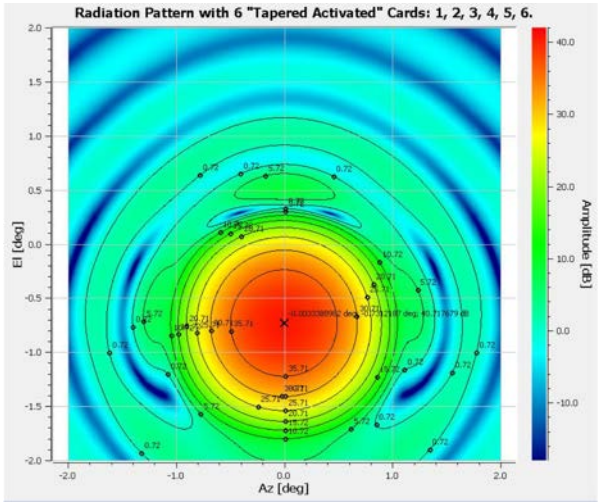
Demonstration Reflector Antenna

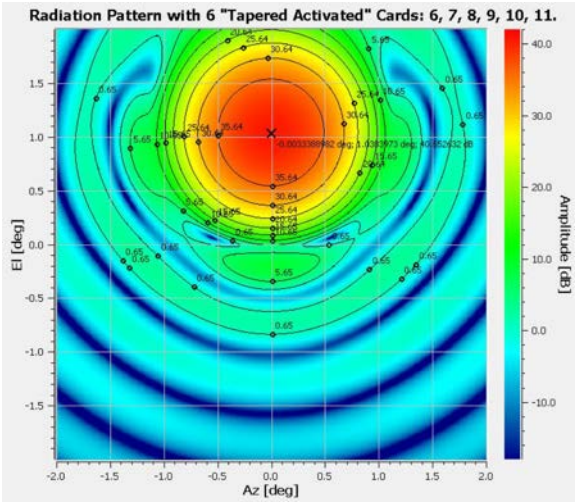


80-cm reflector

Feed array

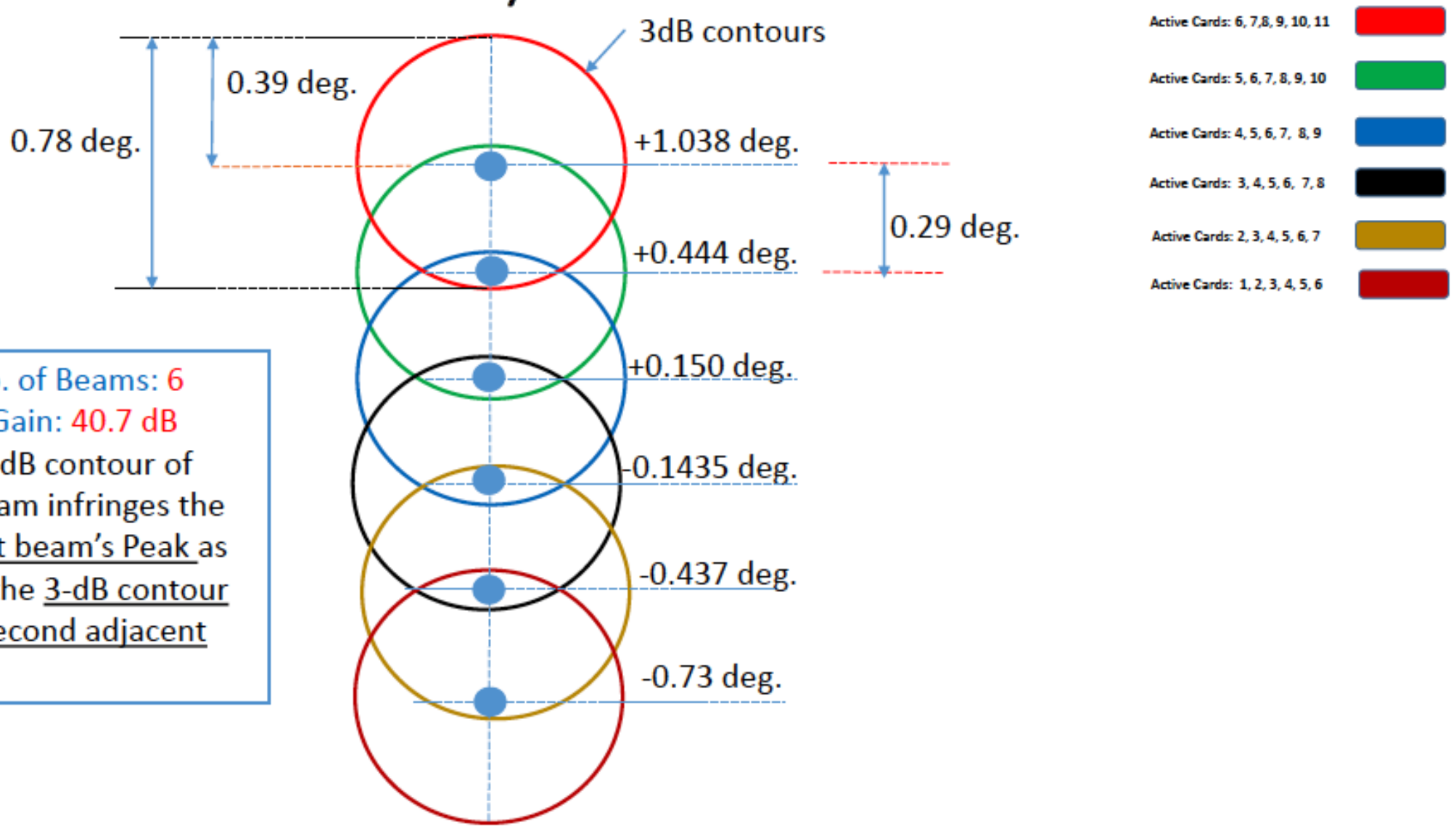






ESTO Earth Science Technology Office

Overlaid 3-dB Contours of (6) Card Groups Tapered-Activated and Advanced by "*1 Card Position*" at a Time



Total No. of Beams: 6
Typical Gain: 40.7 dB
Note: 3-dB contour of each beam infringes the adjacent beam's Peak as well as the 3-dB contour of the second adjacent beam.

Just Imagine …

http://www.astron.nl/aavp2011/documents/Torchinsky_2AASystemArchitecture14Dec2011.pdf