"mm-VAST"

DTU-ESA
Millimiter-Wave Validation Standard Anntenna - Performance Verification

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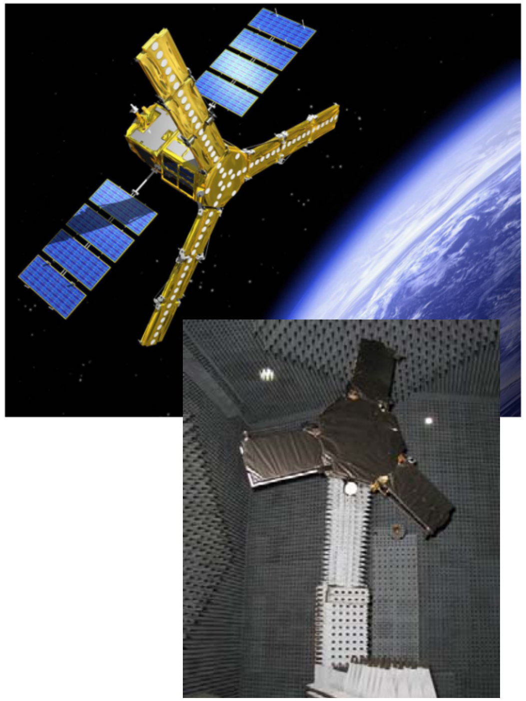
Noordwijk, The Netherlands
6-9 October 2015

DTU Electrical Engineering
Department of Electrical Engineering

DTU-ESA
Spherical Near-Field Antenna Test Facility

DTU

SMOS 1.4GHz

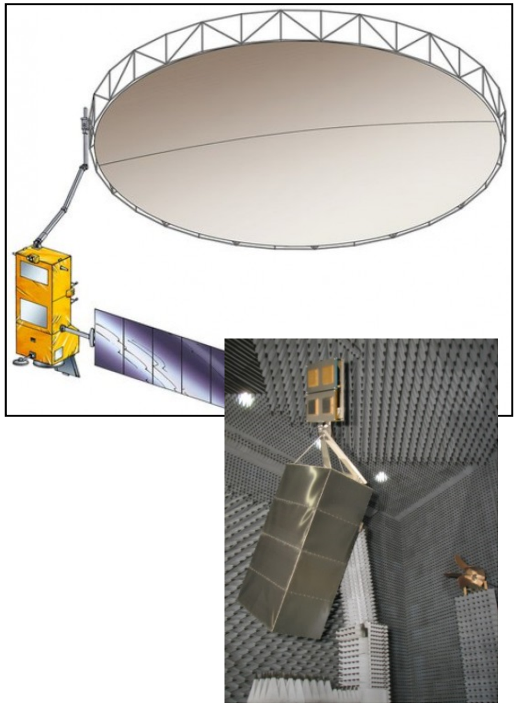


Uncertainty (3dB,1σ)

Magnitude: 0.05dB

Phase: 0.33deg.

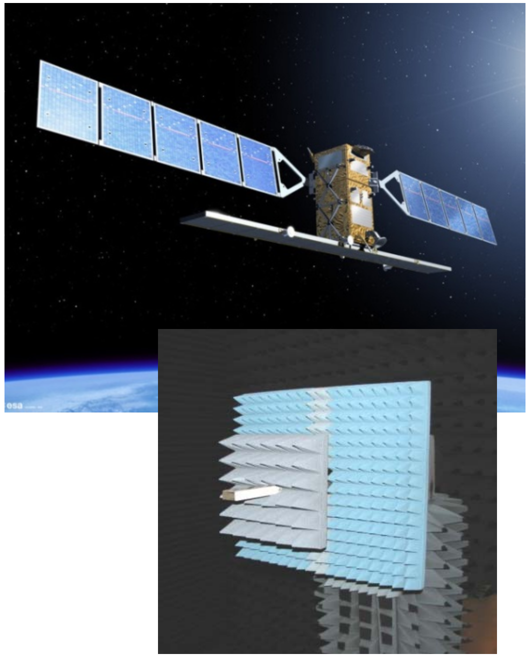
BIOMASS 435MHz



Uncertainty (1σ)

Gain: 0.15dB

SENTINEL-1 5.4GHz



Uncertainty (3dB,3σ)

Directivity: 0.03dB

Gain: 0.1dB

DTU-ESA
12 GHz Validation Standard Antenna

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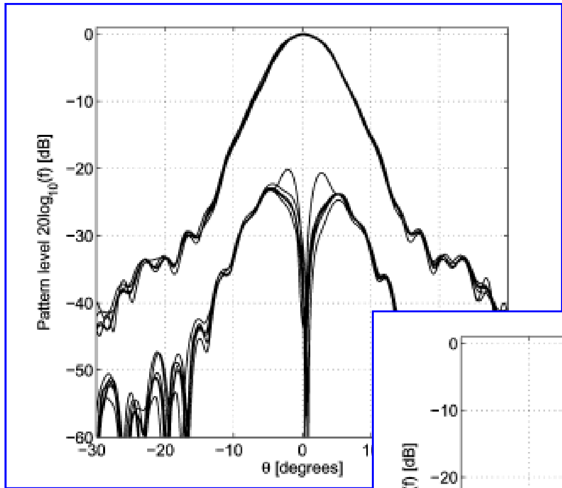
DTU-ESA 12GHz VAST Antenna

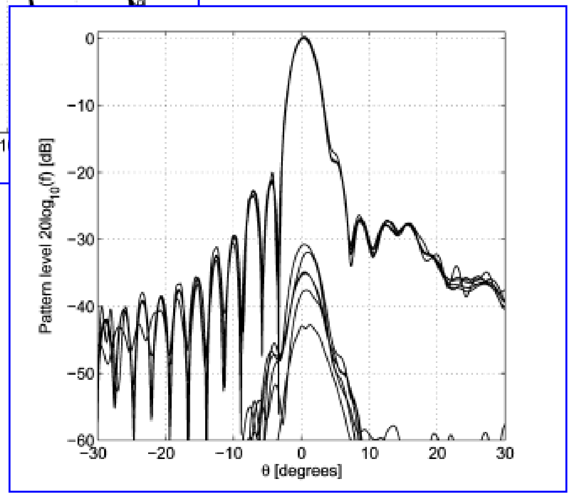
IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 57, NO. 7, JULY 2009 1863

Comparison of Antenna Measurement Facilities With the DTU-ESA 12 GHz Validation Standard Antenna Within the EU Antenna Centre of Excellence

Sergey Pivnenko, *Member, IEEE*, Janus E. Pallesen, Olav Breinbjerg, *Member, IEEE*, Manuel Sierra Castañer, *Member, IEEE*, Pablo Caballero Almena, Cristian Martínez Portas, José Luis Besada Sanmartín, Jordi Romeu, Sebastian Blanch, *Member, IEEE*, José M. González-Arbesú, Christian Sabatier, *Member, IEEE*, Alain Calderone, Gérard Portier, Håkan Eriksson, *Member, IEEE*, and Jan Zackrisson, *Member, IEEE*



Facility	On-axis Tilt Angle [degrees]	On-axis Axial Ratio [dB]	Peak Location (θ, φ) [°]
DTU1	-88.99	54.63	(0.44, 49.0)
DTU2	-89.02	52.0	(0.54, 37.0)
RSE	-88.36	53.3	(0.50, 42.3)
FTRD	–	–	–
UPM1	-89.28	66.51	(0.40, 82.8)
UPM2	–	–	(0.57, 90.0)
UPM3	–	–	–
UPC	89.7	42	(0.45, 78.0)
SMW	–	–	–

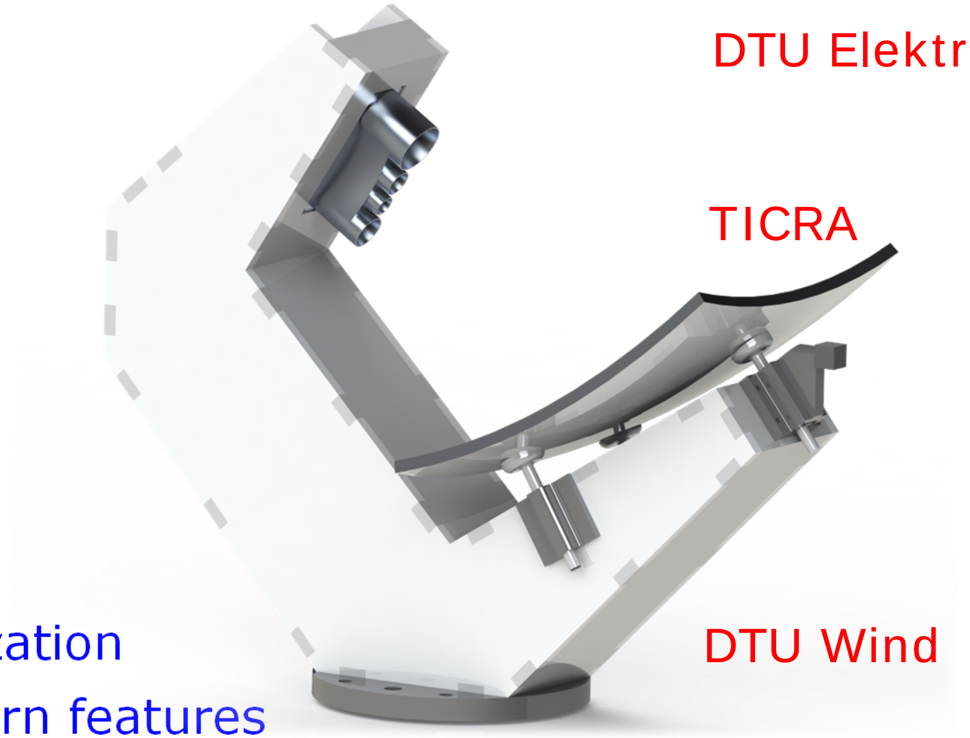


Facility	Peak Directivity [dBi]	Peak Gain [dBi]	Loss [dB]	On-Axis Gain [dBi]
DTU1	30.71	30.35	0.36	30.33
DTU2	30.72	30.59	0.13	30.56
RSE	30.67	30.41	0.26	30.40
FTRD	31.1	30.4	0.7	–
UPM1	30.65	30.39	0.26	30.36
UPM2	–	30.38	–	30.33
UPM3	–	–	–	30.39
UPC	30.87	–	–	–
SMW	30.72	30.43	0.29	–

DTU-ESA
mm- Wave Validation Standard Antenna

DTU

ESA Contract No. 4000109866/13/NL/MH
"Millimeter Wave Validation Standard (mm-VAST) antenna"
January 2014 – October 2015



DTU Elektro

TICRA

DTU Wind

Requirements:

- 17.5-20.2 GHz
  27.5-31.0 GHz
  37.5-40.5 GHz
  47.2-50.2 GHz
- gain of 30-38 dB
- return loss > 10 dB
- circular and linear polarization
- co- and cross-polar pattern features
- mechanical and optical coordinate systems
- mechanical/thermal stability -> 1/10 of measurement uncertainty

Electrical Design

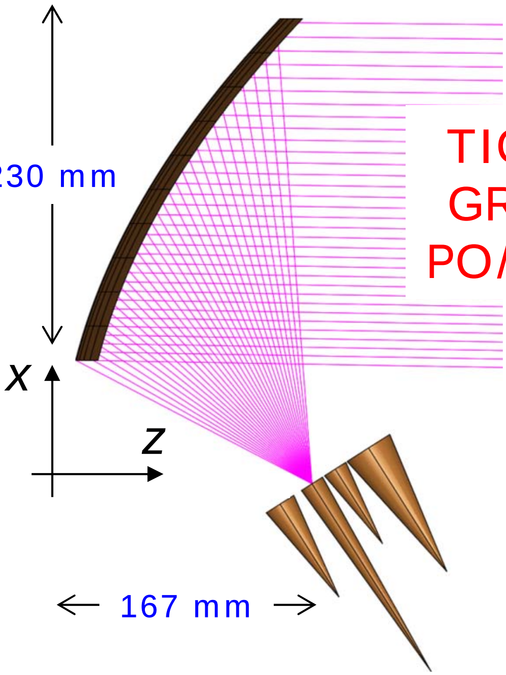
Offset square reflector

$$z = \frac{x^2}{f_x} + \frac{y^2}{f_y}$$

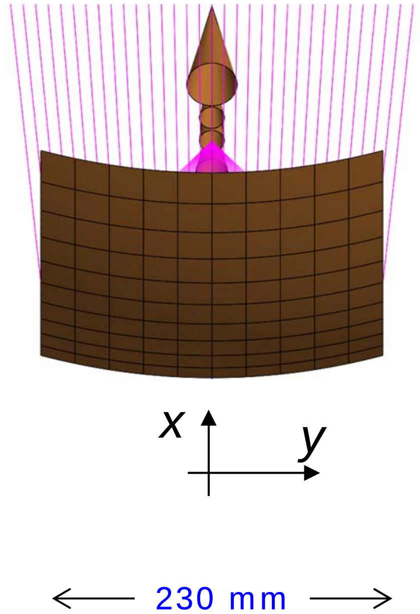
$f_x = 167$ mm

$f_y = 220$ mm

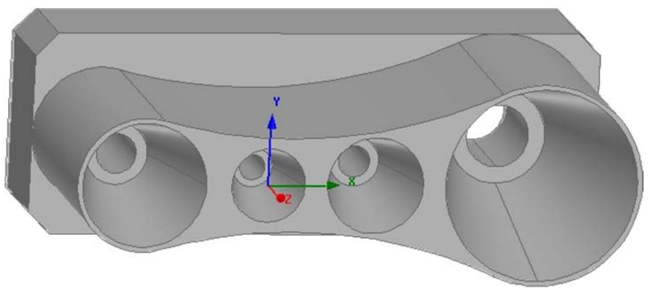
Offset angle 57.6°



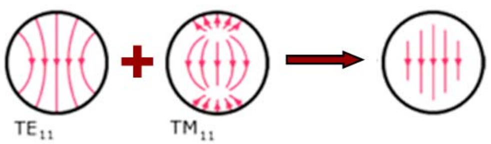
TICRA
GRASP
PO/MOM



Integrated Pickett-Potter horns

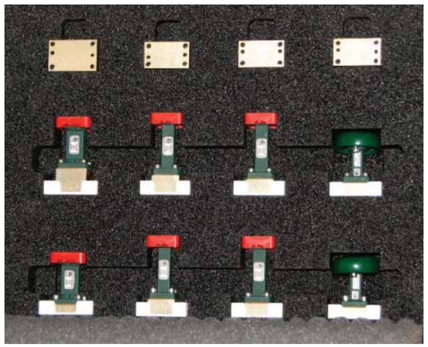


TICRA
CHAMP



Feed chain

WR- 42 28 28 22



Shorts

CP R-C transitions
Polarizer

LP R-C transitions

Mechanical Design

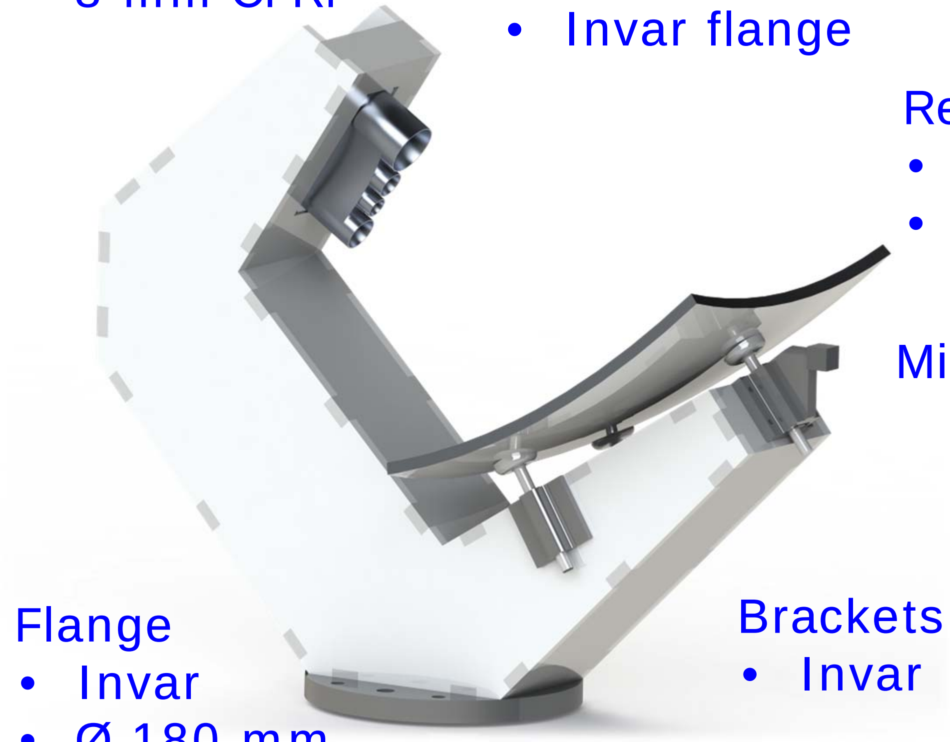
Frame
- 8 mm CFRP

Feed
- Aluminium
- Invar flange

Reflector
- 8 mm CFRP
- Silver paint

Dimensions
- 530 mm
- 440 mm
- 230 mm

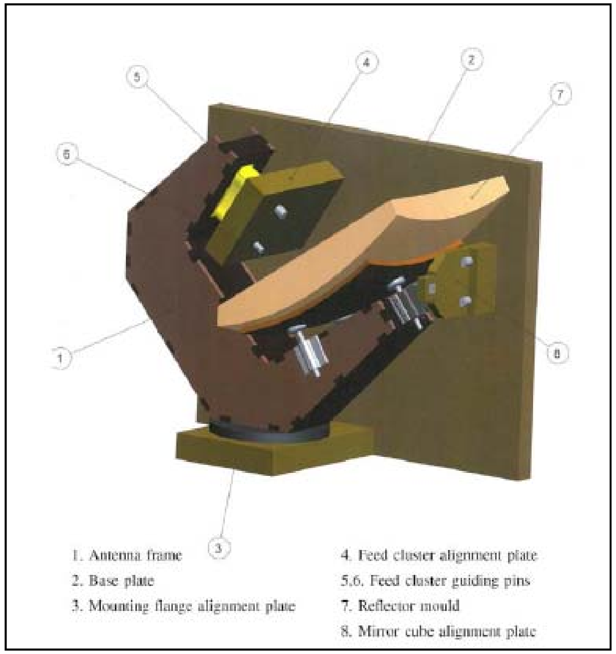
Weight
- < 10 kg.



Flange
- Invar
- Ø 180 mm

Brackets
- Invar

Mirror cube



Mechanical coordinate system
- Built-in leveller

Optical coordinate system
- Mirror cube

Mechanical and Thermal Tests

Mechanical test on separate test antenna

- Feed arm load: 80 kg (x 100).
- Reflector arm load: 160 kg (x 100).
- Feed arm displacement: 0.33 mm
- Reflector arm displacement: 0.17 mm

Measured deviations are about twice the FEM simulated deviations
– but within specs.

Thermal test I (40° temperature range) on separate test antenna

- 3D ARAMIS Digital Image Correlation system (GOM mbH)
- Random speckle pattern imaged by 2 CCD cameras

Thermal test II (survival temperature range) on mm-VAST

- 20° -> 50° -> -10° -> 50° -> -10° -> 20° (over 48 hrs).
- Climatic test chamber VKF 875-2 (DELTA)

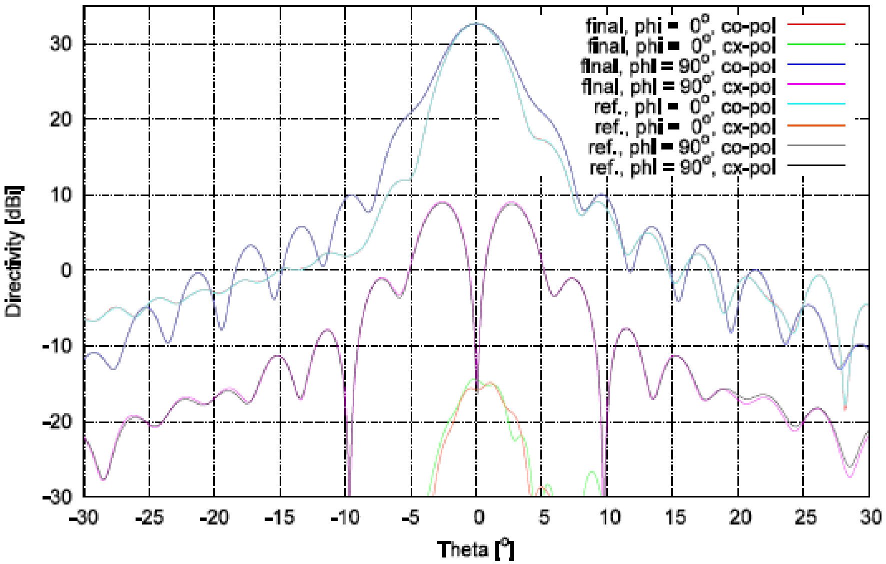
Electrical Tests I

First electrical tests → Thermal tests → Second electrical tests

Second electrical tests
- Return loss
- Radiation patterns
- Gain

Spherical near-field measurements
- full-sphere
- θ-step / ϕ-scan
- probe correction
- uncertainty estimate
- LP and CP
- 10-15 freqs per band

Band I LP: First vs. second



Peak difference: 0.039 dB

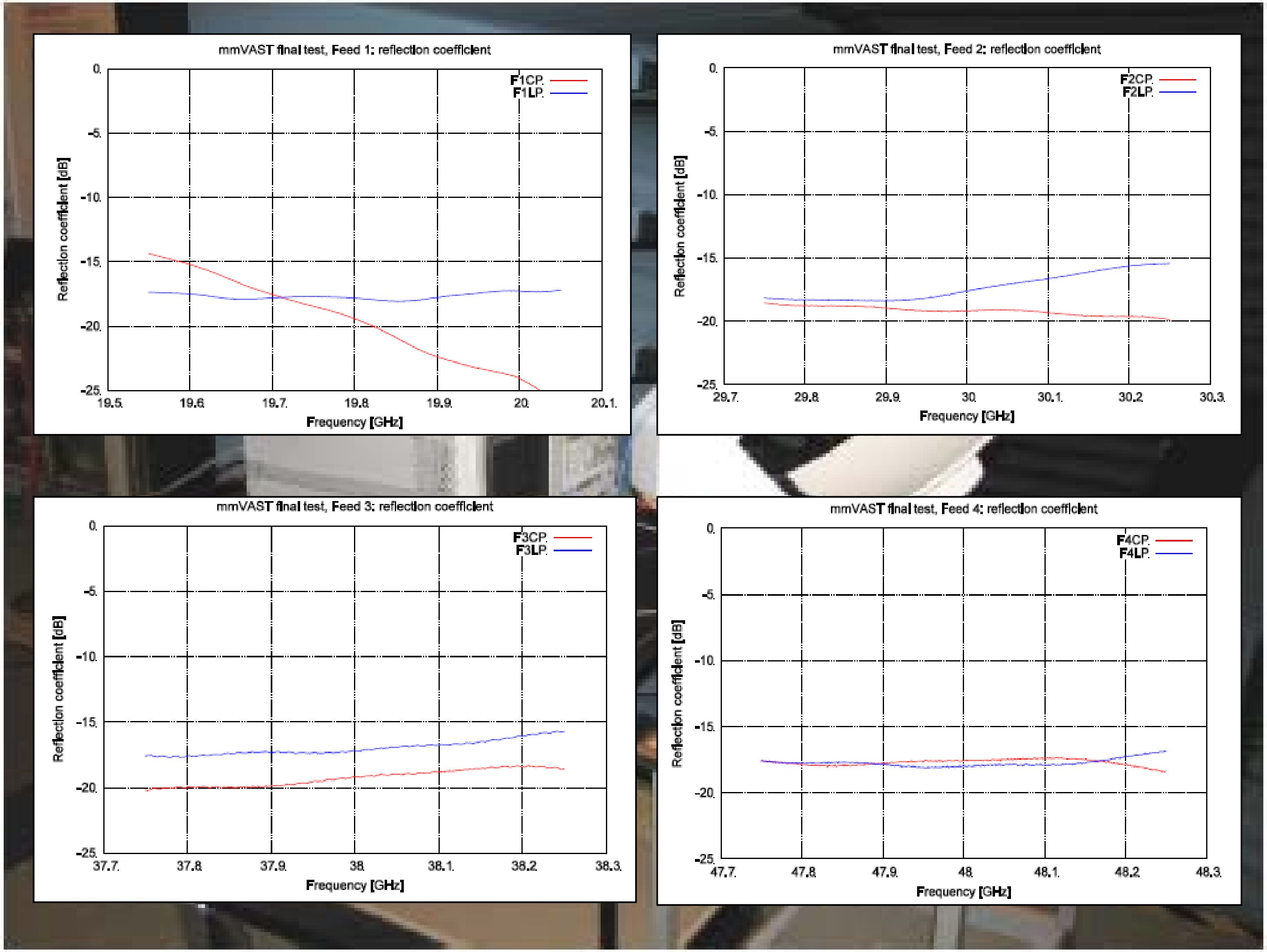
Measurement uncertainty: 0.29 dB (1σ)

-> insignificant

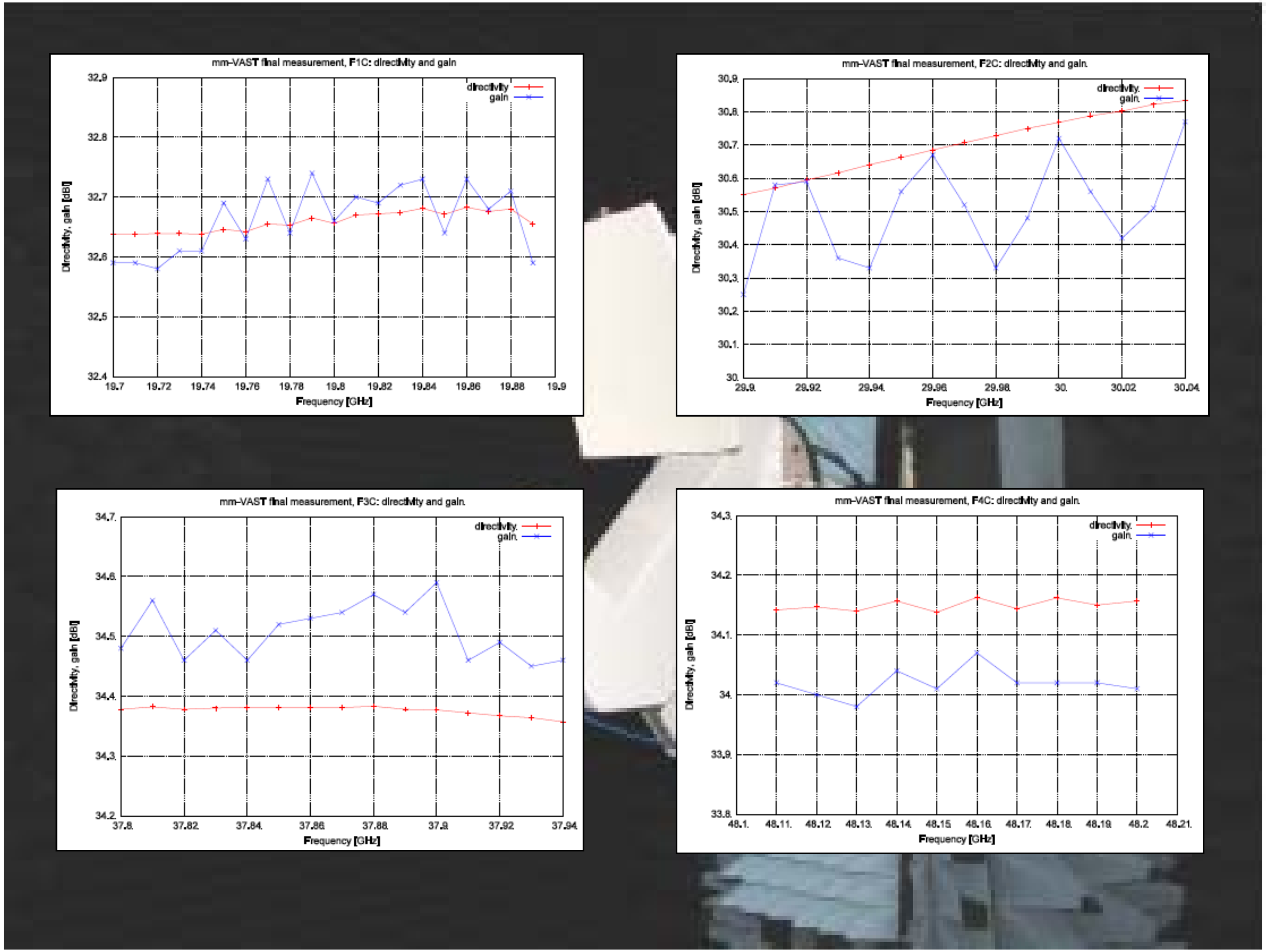
OCS/MCS Euler angles (χ_0, θ_0, ϕ_0)

- First: (219.589, 0.274, 140.498)
- Second: (218.467, 0.276, 141.623)

Electrical Tests II – Return Loss



Electrical Tests III – Gain (CP)



Electrical Tests IV – Uncertainty (Peak)

Peak directivity – band I and II

Source	Limits	STD, σ_i [dB]
Axes intersection	±0.05 mm	0.001
Horizontal axis pointing	±0.01°	0.014
Probe pointing	±0.05°	0.000
Measurement distance	±2 mm	0.000
Drift and noise		0.003
Leakage and crosstalk	< -80 dB	0.000
Amplitude non-linearity	0.05dB/10dB	0.010*
Rotary joints effect	0.1dB; 0.3°	0.010*
Channel balance amplitude	1%	0.009
Channel balance phase	1%	0.003
Probe pattern correction		0.000
Multiple reflections		0.019
Reflectivity level	< -50dB	0.000
AUT positioner effect	< -50dB	0.000
Spherical mode truncation		0.003
Combined STD		0.029
Expanded uncertainty, 2σ		0.059

Peak directivity – band III and IV

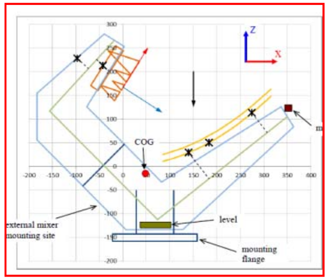
Source	Limits	STD, σ_i [dB]
Axes intersection	±0.05 mm	0.001
Horizontal axis pointing	±0.01°	0.014
Probe pointing	±0.05°	0.000
Measurement distance	±2 mm	0.000
Drift and noise		0.013
Leakage and crosstalk	< -80 dB	0.000
Amplitude non-linearity	0.05dB/10dB	0.010*
Rotary joints effect	0.2dB; 0.5°	0.015*
Channel balance amplitude	1%	0.009
Channel balance phase	1%	0.003
Probe pattern correction		0.000
Multiple reflections		0.019
Reflectivity level	< -50dB	0.000
AUT positioner effect	< -50dB	0.000
Spherical mode truncation		0.003
Combined STD		0.034
Expanded uncertainty, 2σ		0.068

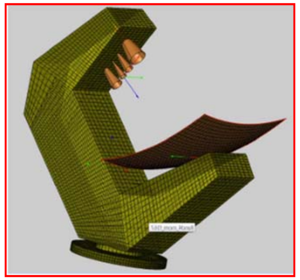
Peak gain – all bands

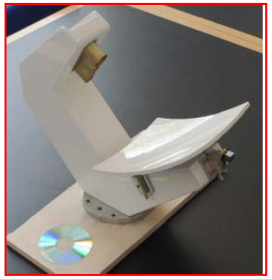
Source	Limits	STD, σ_i [dB]
SGH radiation efficiency	0.03dB (1σ)	0.03
AUT mismatch correction	0.02dB (1σ)	0.02
SGH mismatch correction	0.01dB (1σ)	0.01
Feed cable mismatch correction	0.02dB (1σ)	0.02
Amplitude non-linearity	0.05dB/10dB	0.03
Drift (between point measurements)	±0.01dB	0.01
Point comparison	±0.02dB	0.02
Cable variations	±0.1dB	0.06
Multiple reflections	±0.06dB	0.04
Combined STD		0.09
Expanded uncertainty, 2σ		0.18

Some Conclusions

- Successful design, manufacturing, and test of mm-VAST antenna
  19.76 GHz - 30.04 GHz - 37.80 GHz - 48.16 GHz (TBC)
- Single offset reflector configuration is fitting for VAST antennas
- Multi-frequency capability is challenging
  - lowest frequency drives size -> over-sized at highest frequency
- Polarization re-configurability is challenging wrt. reproducibility
  - should be carefully considered for future VAST antennas
- COTS components not generally suitable for VAST antennas
  - do not exhibit the necessary performance
  - lack mounting repeatability
  - only straight WGs, mirror cube, and leveller were COTSs
  - horn, polarizers, shorts, transitions were custom-made







INVITATION

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