A Low-Frequency and Wide-Band Reflector Antenna Feed for Future Earth Observation Radiometers

Final Review – 23 November 2022

AGENDA

Welcome to the Final Review

Participants:

Consortium:

- EOSOL: Aitor Martínez, Rubén Caballero, Mikel Goñi and Gonzalo Crespo
- Airbus: Josep Closas, Tamara Coello

ESA:

- Hoda Nematollahi
- Jean Christophe Angevain
- Valerie Dutto

2. PROJECT OBJECTIVES

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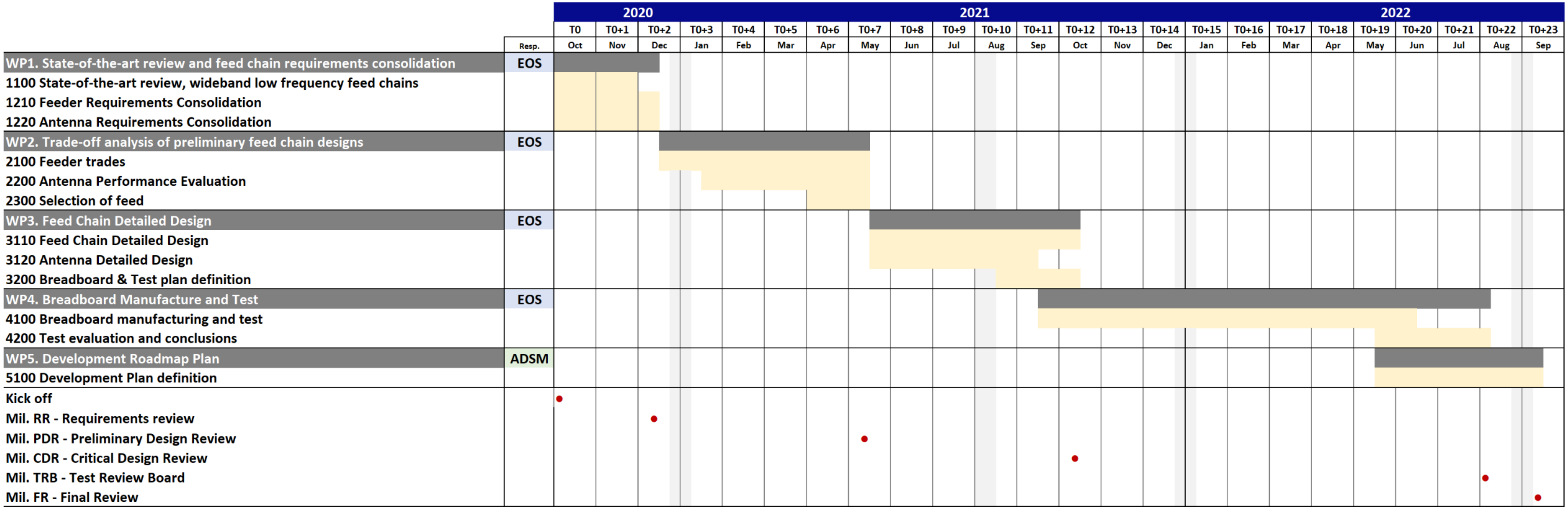
- **Design, BB and test a wideband, circularly polarised feed chain that operates from 0.4 – 2 GHz for CryoRad mission**, to address scientific challenges in Polar Regions, specifically measurement of sea ice thickness and temperature.

- The design shall be based on the assumption that a **cluster of three feeds will be illuminating an ideal reflector** to demonstrate the required swath can be achieved. This means the individual feeds shall be suitably sized to **accommodate in the launch faring**.

- The **RF performance of the feed shall be measured** and a **simulation of the full reflector and three feeds** shall be performed to determine the secondary beam patterns.

Initial project plan and schedule



3. PROJECT PLAN AND SCHEDULE

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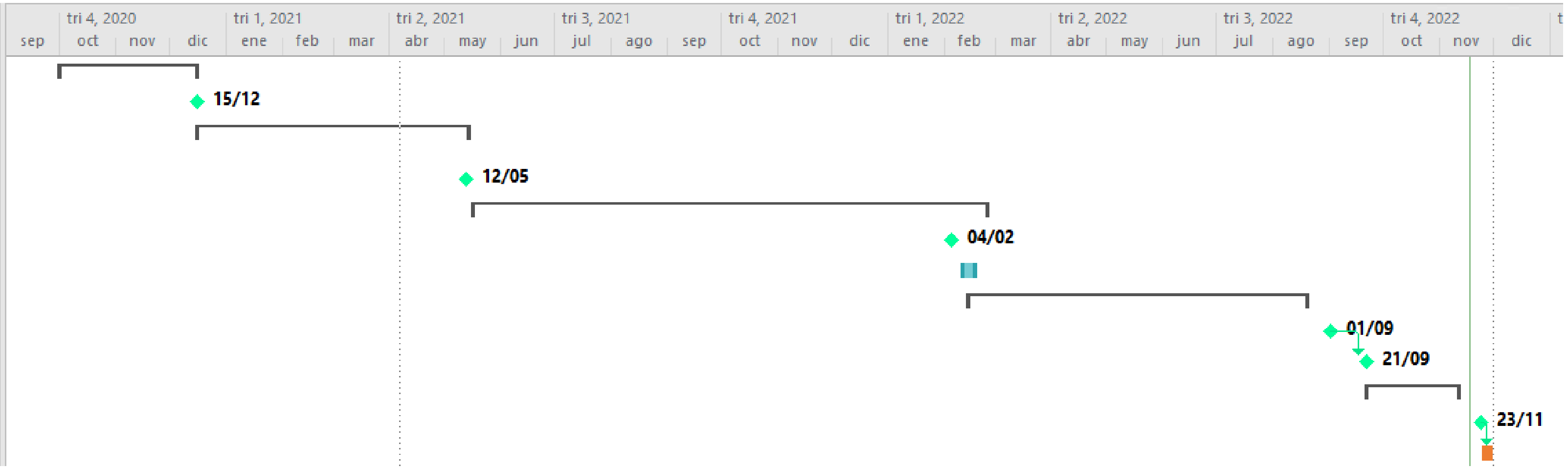
Final schedule

Nombre de tarea	Duración	Comienzo	Fin
1000 - SoA and requirements	**54 días**	**jue 01/10/20**	**mar 15/12/20**
RR	1 día	mar 15/12/20	mar 15/12/20
2000 - Trade-off analysis of preliminary feed chain designs	**108 días**	**mié 16/12/20**	**vie 14/05/21**
PDR	1 día	mié 12/05/21	mié 12/05/21
3000 - Feed chain detailed design	**204 días**	**lun 17/05/21**	**jue 24/02/22**
CDR	1 día	vie 04/02/22	vie 04/02/22
RIDs and CDR actions closing	5 días	vie 11/02/22	jue 17/02/22
4000 - Breadboard manufacture and test	**135 días**	**lun 14/02/22**	**vie 19/08/22**
TRB	1 día	jue 01/09/22	jue 01/09/22
TRB (2)	1 día	mié 21/09/22	mié 21/09/22
5000 - Development Roadmap Plan	**37 días**	**jue 22/09/22**	**vie 11/11/22**
FR (Final Review)	1 día	mié 23/11/22	mié 23/11/22
CCD (Contract closure docuementation)	5 días	jue 24/11/22	mié 30/11/22



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Deliverables

Reference	Name	Qty	Type	Method	WP/Task	Milestone
TN1/D1	State of the art review	1	Document/ File	Delivery (USB)	Task1	RR
TN2/D2	Consolidated antenna requirements, cluster	1	Document/ File	Delivery (USB)	Task1	RR
TN3/D3	Feed chain concepts trade-off	1	Document/ File	Delivery (USB)	Task2	PDR
TN4/D4	Feed chain preliminary design and analysis	1	Document/ File	Delivery (USB)	Task2	PDR
TN5/D5	Antenna detailed design	1	Document/ File	Delivery (USB)	Task3	CDR
TN6/D6	Breadboard antenna test plan and procedure	1	Document/ File	Delivery (USB)	Task3	CDR
TECHNICAL	Breadboard CAD model	1	Document/ File	Delivery (USB)	Task3	CDR
TECHNICAL	RF Model	1	Document/ File	Delivery (USB)	Task3	CDR
TN6/D6	Breadboard antenna test plan and procedure, updated	1	Document/ File	Delivery (USB)	Task4	TRB
TN7/D7	Test report	1	Document/ File	Delivery (USB)	Task4	TRB
TN8/D8	Development Roadmap	1	Document/ File	Delivery (USB)	Task5	FR
END of CONTRACT	High Resolution Photograph	1	Document/ File	Delivery (USB)	Task5	FR
END of CONTRACT	HW User Manual	1			Task5	FR
END of CONTRACT	TDP Technical Data Package	1			Task5	FR
END of CONTRACT	AB Abstract	1			Task5	FR
END of CONTRACT	FP Final Presentation	1			Task5	FR
END of CONTRACT	ESR Executive Summary Report	1			Task5	FR
END of CONTRACT	FR Final Report	1			Task5	FR
END of CONTRACT	CCD Contract Closure Documentation	1			Task5	FR
HW1	Feed chain breadboard hardware	1	Document/File	Delivery (USB)	Task4	TRB

4. PROJECT OVERVIEW

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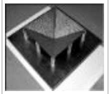
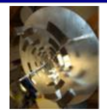
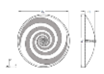
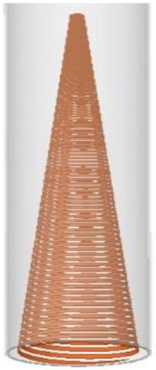
Trade-off summary for analysed feed types:

Name	CLSAA	CLSA	CLSA	QRH	OBQR	CSA	EFA	CSA	SA	VIA
Image										
Brief description	700mm length CLSA array of 4 elements	1m length CLSA array with 2 tilted elements	1m length CLSA based on [13] with 54 turns	QRH with 700 aperture based on [6]	700mm aperture OBQR with CFRP ridges based on [9]	Conical sinuous feed chain based on [22]	Eleven feed horn based on [21]	Quasi-Self-Complementary feed [23]	Spiral Antenna with Parabolic Reflector cavity	A Vivaldi Antenna Array
Polarisation	Single Circular	Single Circular	Single Circular	Dual Linear	Dual Linear	Dual Linear	Dual Linear	Dual Linear	Single Circular	Dual Linear
Bandwidth	4	4	4	4	3	4	4	4	3	1
Phase centre stability	3	2	2	4	4	4	4	3	4	-
Directivity	4	4	3	3	2	3	2	3	2	3
Directivity flatness over freq.	4	4	4	2	2	4	4	3	2	-
Return loss	3	3	3	3	3	2	1	2	2	2
Sidelobe level	3	4	4	4	4	4	4	3	2	1
Aperture efficiency	4	4	4	3	3	3	3	3	2	2
Insertion loss (*)	2	3	4	3	3	1	1	1	2	1
Accommodation in payload	Evaluated designs that fit in the volume while being able to illuminate 3 beams within the available volume									
Length	3	2	2	3	3	3	4	4	4	3
Cluster Mass	4	4	4	1	2	4	4	3	4	2
Robustness and stiffness	2	2	2	4	4	2	2	3	3	2
Manufacturing complexity	3	2	2	3	3	2	2	2	4	2
Final score	3,25	3,17	3,17	3,08	3,00	3,00	2,92	2,83	2,83	1,90

CLSA or Conical log-spiral antenna



Single circular polarization

✓ Gain, polarization and input impedance UWB performance
✓ Single circular polarization generated by the structure
✓ High aperture efficiency with reduced base dimension (at the expense of length increase)
✓ Mature technology successfully used in a similar application (not space but in an airplane)

✗ Limited achievable maximum directivity
✗ Considerable space required between feeds in the cluster arrangement
✗ Challenging balun design required in terms of bandwidth and losses.

→ The CLSA feed has been selected from the trade-off because it is able to generate low AR circular polarization and achieve high aperture efficiency.

4.2.1 Antenna and Feed cluster configuration

- The antenna performance requirements :

Reflector diameter	**< 12.5m**	
Frequency range	0.4 GHz - 2 GHz	
Beam Eficiency	>93 %	
Wide Beam efficiency	>96%	
HPBW	3.5 deg @ 0.4 GHz	0.7 deg @ 2 GHz
Resolution	8 km @ 0.4 GHz	40 km @ 2 GHz

- The antenna geometry main drivers:
  - The compromise between the geometric resolution and the beam efficiency.
  - Illumination factor in which the pattern of the feed illuminates the reflector (tapering) at the edges of the reflector.

- Due to the low directivity in general of the analysed feeds and the limitation on the reflector diameter, a low F/D is needed in order to maximize the taper and, consequently, the beam efficiency required for radiometric applications.

- A limitation on the target HPBW was detected, since a reflector diameter greater than 15m is needed in order to achieve the requirement and preserve the efficiency performances.

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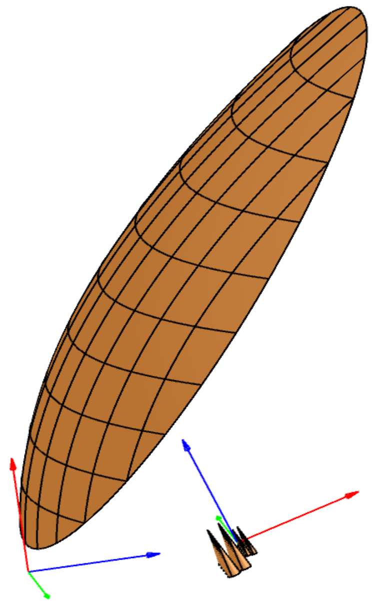
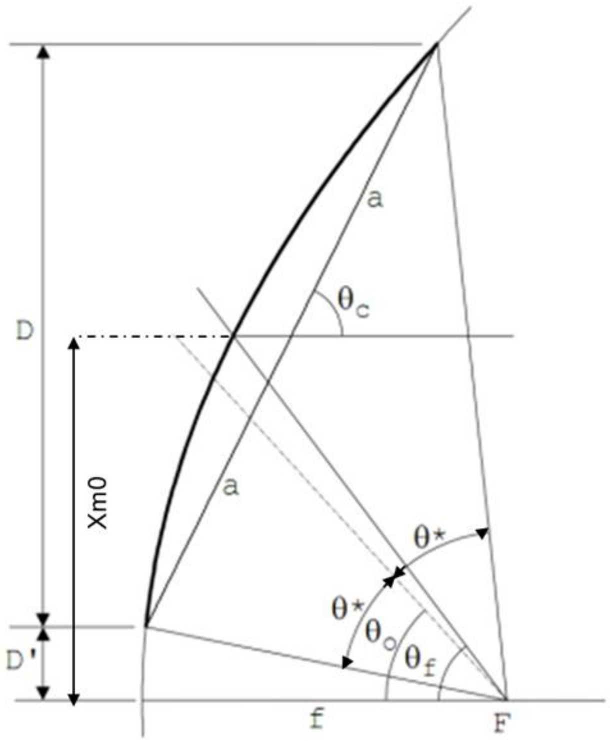
4.2.1 Antenna and Feed cluster configuration

- The antenna assembly consists of an offset parabolic reflector implemented by means of an LDR looking to nadir with the maximum allowed diameter of 12.5m and a F/D = 0.38.



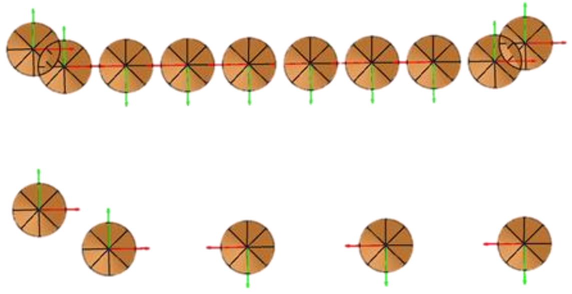


Dimension	Value
Main reflector projected aperture (D)	12.5 m
Main reflector focal length (F)	4.75 m
F/D	0.38
Xm0 = C+D/2	7 m
Clearance (C)	0.75 m
Half-angle subtended. Taper angle (θ*)	49.85º
Feed cluster orientation (θf)	72.77º
Offset angle (θo)	58.87º

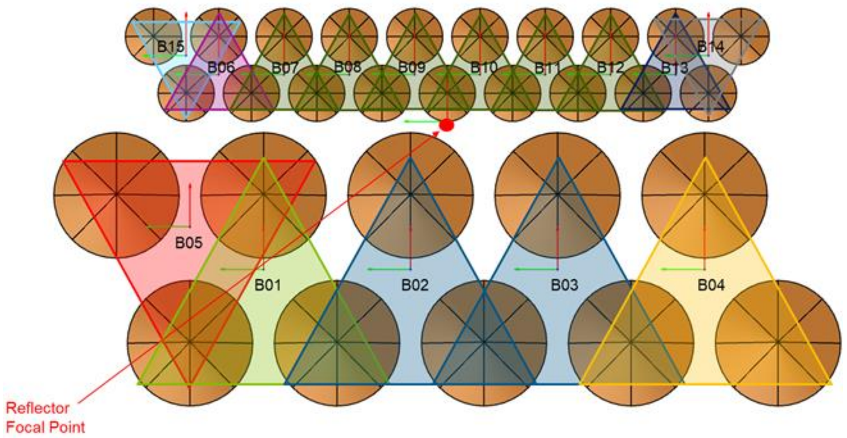
4.2.1 Antenna and Feed cluster configuration

- A feed cluster is needed in order to cover the total swath width of the instrument (120km).
- Due to the low directivity of the feeders by themselves, the multi feed per beam solution was included considering sub-arrays comprised by three different feeders.
- To introduce smaller feeds covering the high range of frequencies is needed in order to cover the total swath without gaps for the complete frequency range (400MHz-2GHz).
- The feeders position has been optimised to fulfil along track beam separation, footprint and beam efficiency requirements (orbit altitude of 650 km).
- The feed cluster selected is comprised by 10 LFWF and 19HFWF in Multi Feed Per Beam configuration (= 5 LF + 10 HF beams)

Beams Configuration:

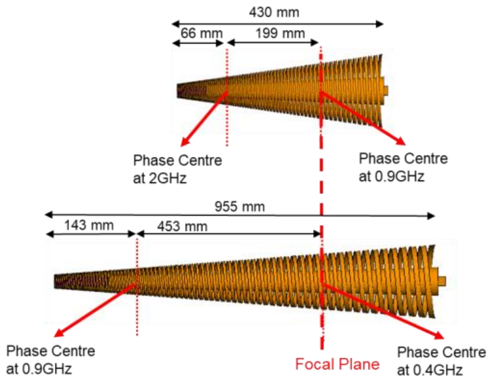


Feed Cluster Configuration:



4.2.1 Antenna and Feed cluster configuration

- An analysis considering the phase centre information was performed in order to define the LFWF and HFWF location with respect to the focal plane.
- The following configuration has been selected as baseline in order to preserve both, beam resolution and efficiency, for the complete frequency range:



- It can be observed that an equivalent feed accommodation has been selected for both types of feeds, since the phase centre of the lower frequency for each feeder is located at the focal plane.

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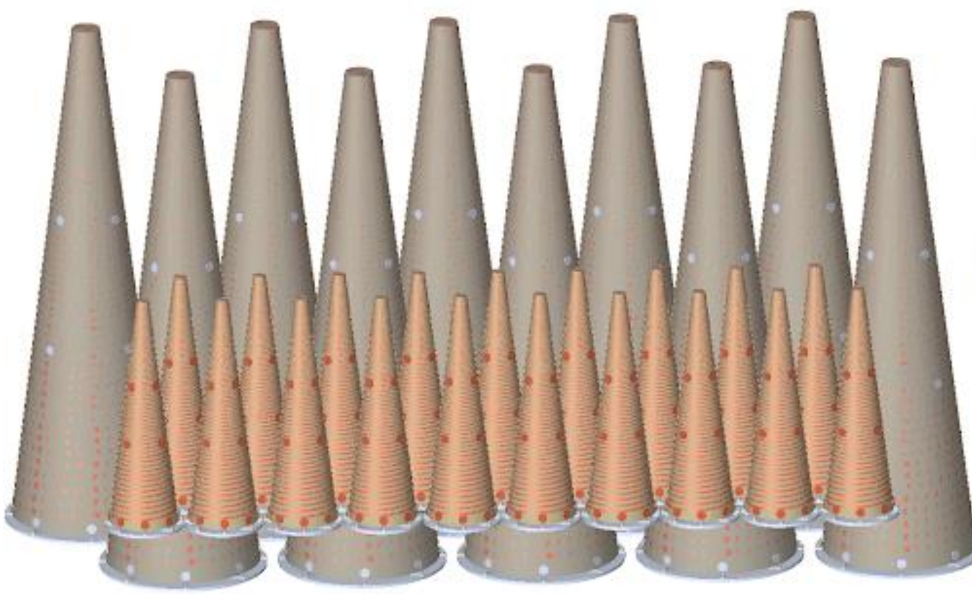
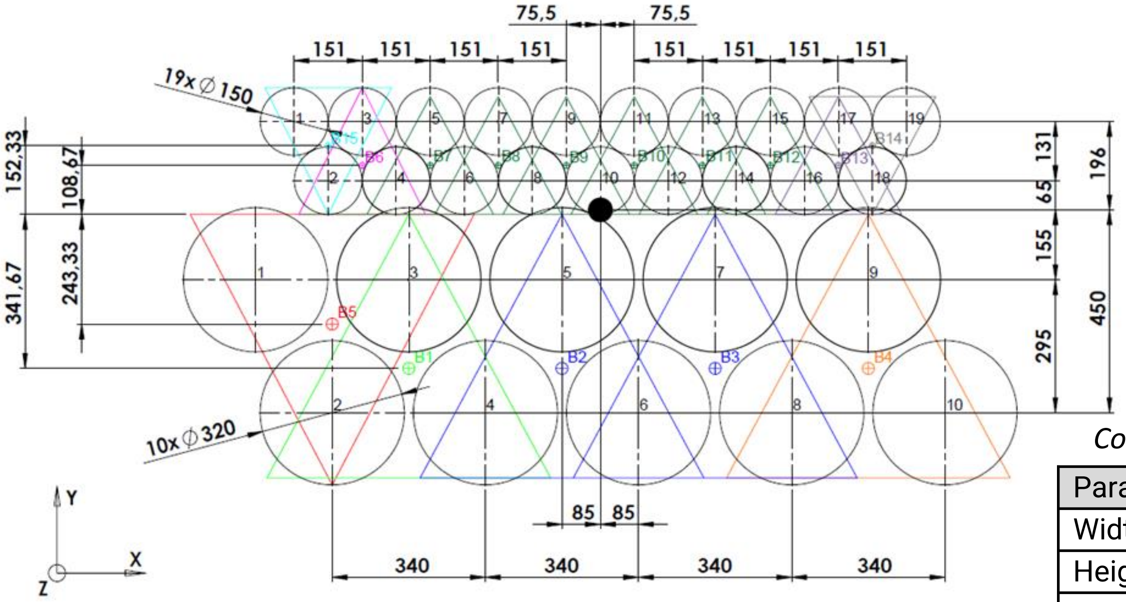
4.2.1 Feed cluster configuration

It was concluded that two different arrays are necessary to cover the required swath with the appropriate performance:

- **Low Frequency Array (LFA) comprised by 10 LFWF CLSAs**, working from 400 MHz to 900 MHz band, being D=320mm and H=1000mm.
- **High Frequency Array (HFA), comprised by 19 HFWF CLSAs**, working from 900 MHz to 2 GHz band, being D=150mm and H=460mm.





Complete cluster properties

Parameter	Unit	Value
Width	mm	1850
Height	mm	527
Length	mm	988
Mass	kg	27.3

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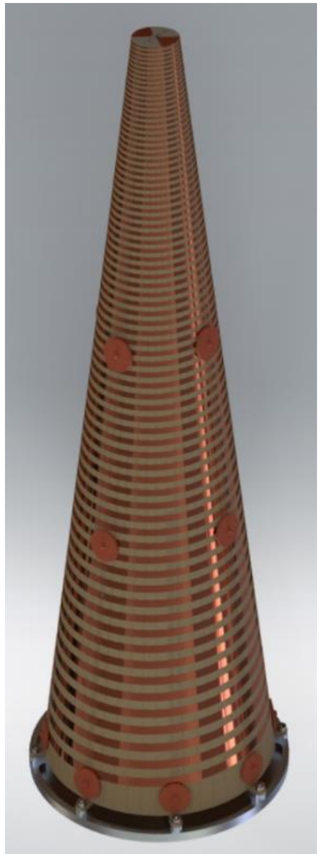
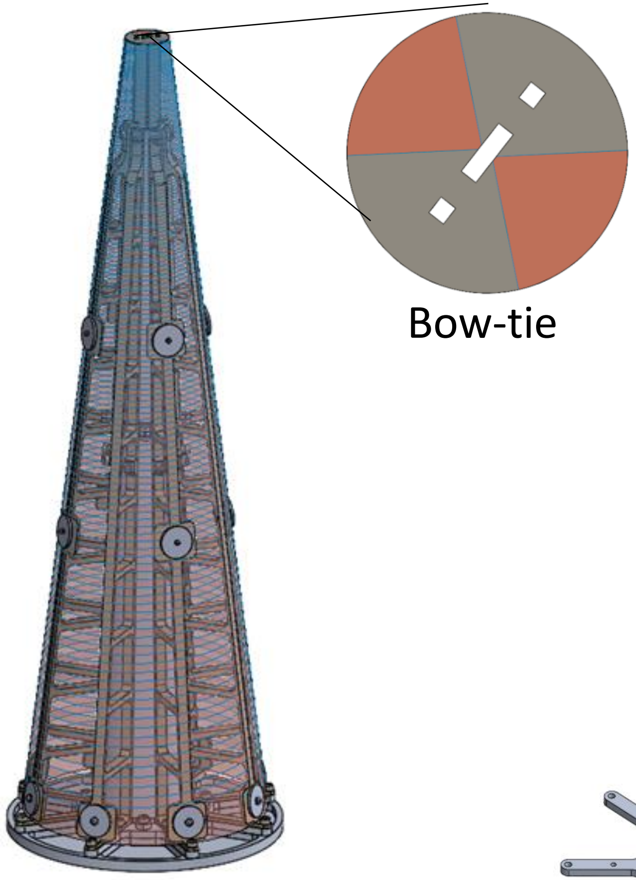
4.2.2 Feed and sub-array RF design

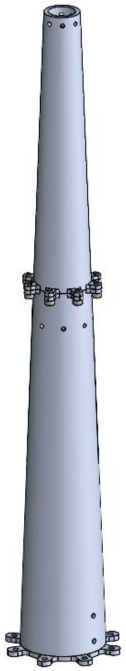


HFWF Feed render

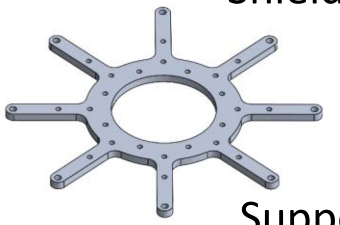


Bow-tie

HFWF Feed with transparency

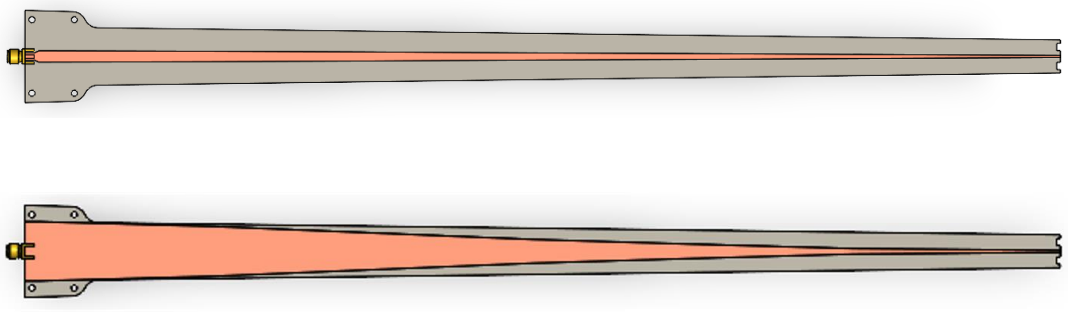


Shielding cone

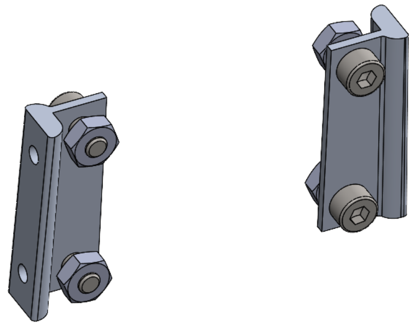


Support base

Balun top and bottom



Balun support



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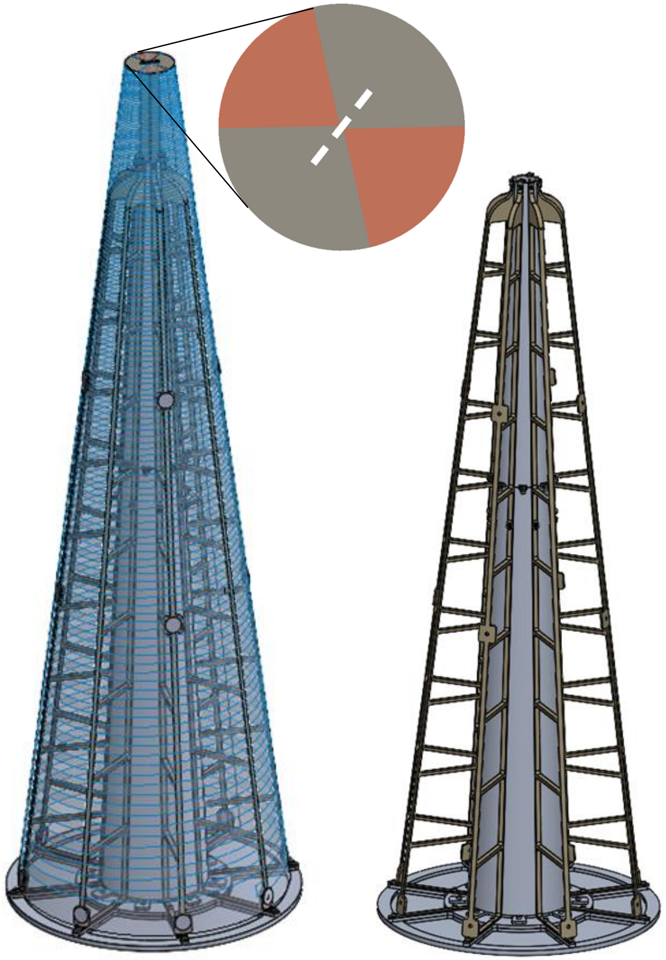
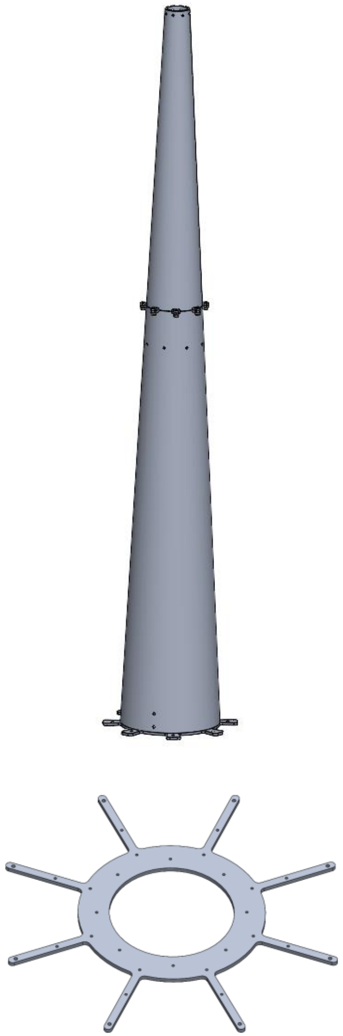
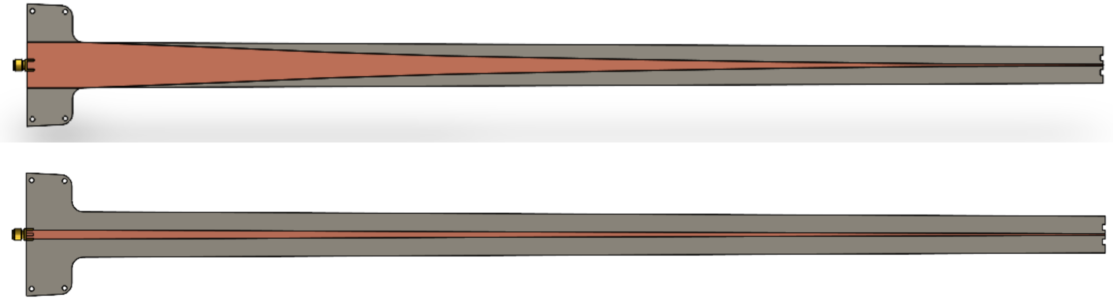
4.2.2 Feed and sub-array RF design







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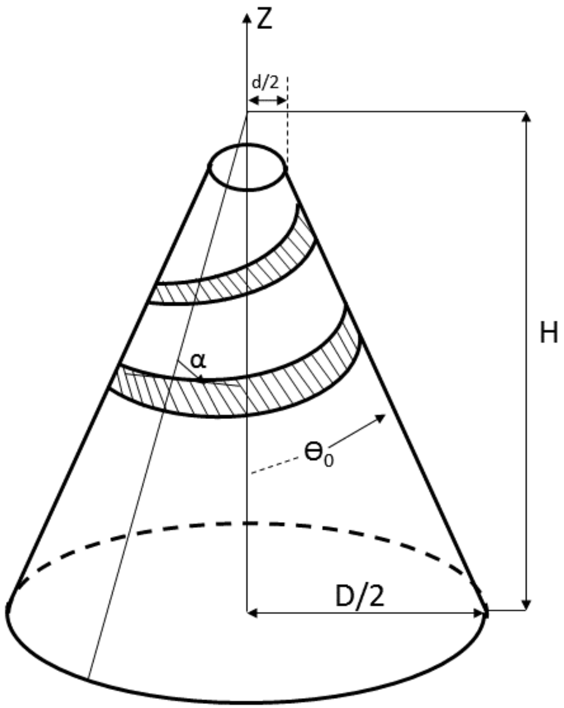
4.2.2 Feed and sub-array RF design



HFWF feed

Mechanical properties of HFWF feed

Parameter	Unit	Value
Lower diameter (D)	mm	150
Height (h)	mm	455
Mass	kg	0.75
Mass center (x , y , z)	mm	(0 , 0 , 204)

Spiral definition parameters of HFWF feed

Parameter	Unit	Value
Conical angle (θ)	º	7
Spiral wrap angle (α)	º	2.85
Angular arm width (δ)	º	90
Spirals bottom diameter (D)	mm	130
Spirals top diameter (d)	mm	24
Spirals height (h)	mm	430
Sheet bottom diameter	mm	133
Sheet top diameter	mm	24
Sheet height	mm	442
Turns nº	-	38

LFWF feed

Mechanical properties of LFWF feed

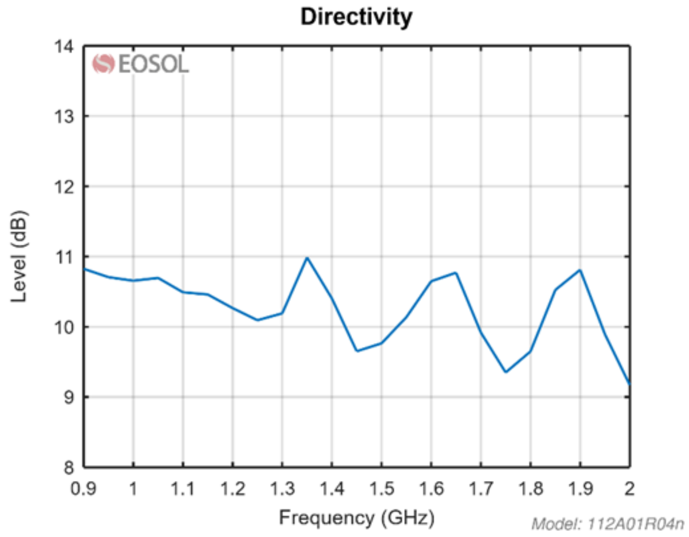
Parameter	Unit	Value
Lower diameter (D)	mm	320
Height (h)	mm	988
Mass	kg	2.75
Mass center (x , y , z)	mm	(0 , 0 , 327)

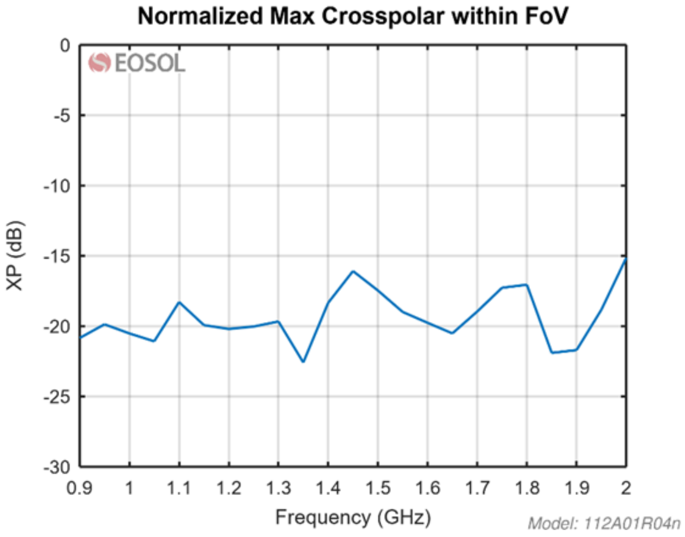
Spiral definition parameters of LFWF feed

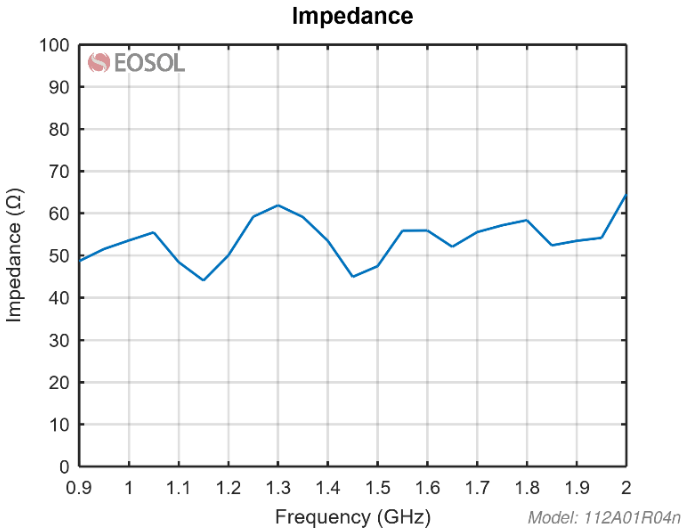
Parameter	Unit	Value
Conical angle (θ)	º	7
Spiral wrap angle (α)	º	3.44
Angular arm width (δ)	º	90
Spirals bottom diameter (D)	mm	290
Spirals top diameter (d)	mm	54
Spirals height (h)	mm	955
Sheet bottom diameter	mm	320
Sheet top diameter	mm	54
Sheet height	mm	974
Turns nº	-	38

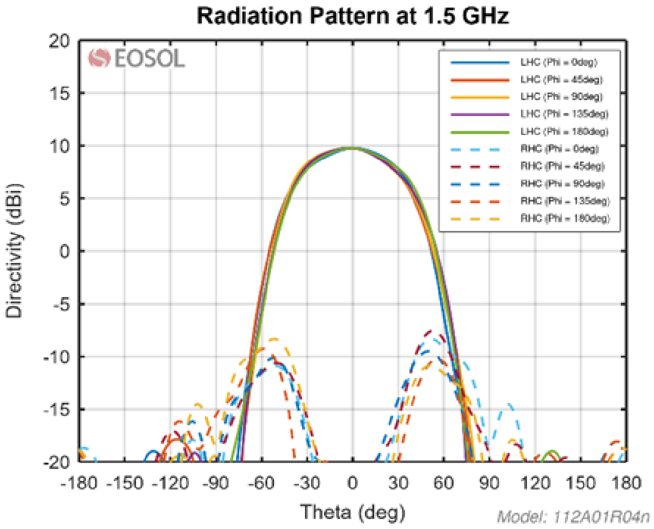
4.2.2 Feed and sub-array RF design

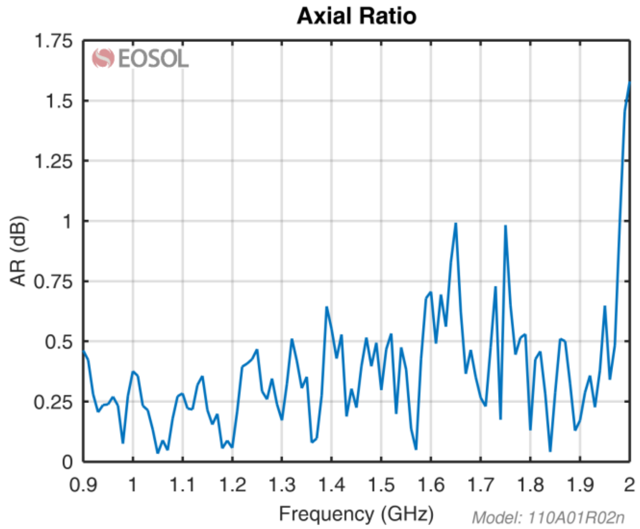
HFWF feed

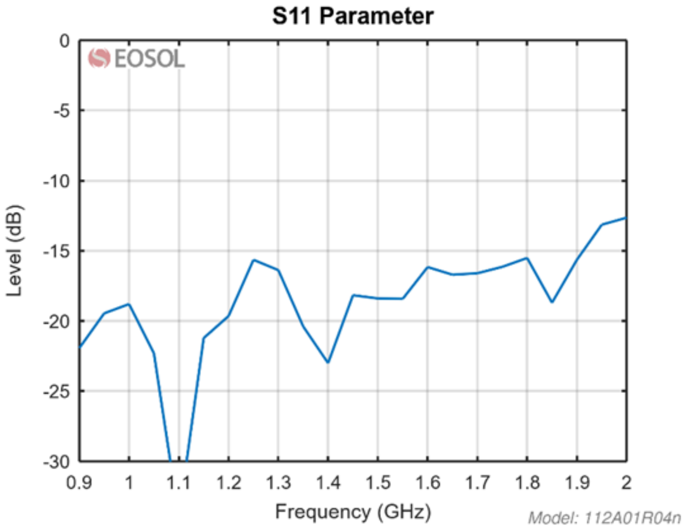












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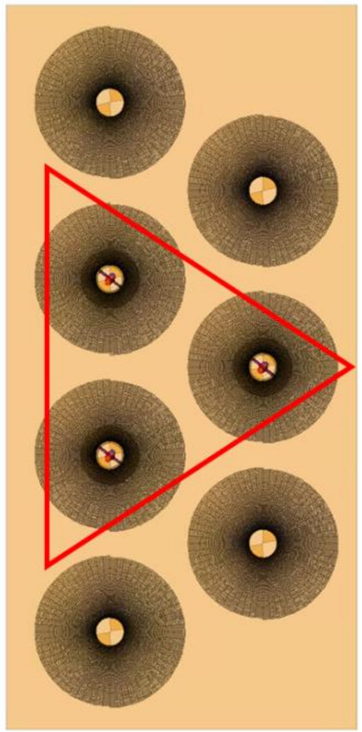
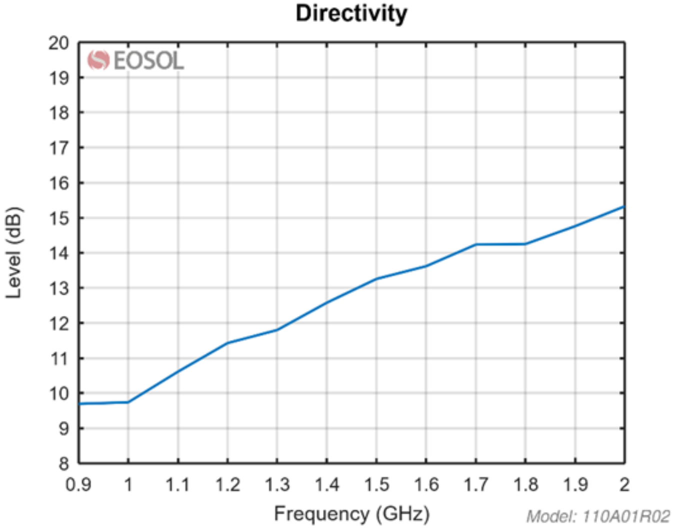
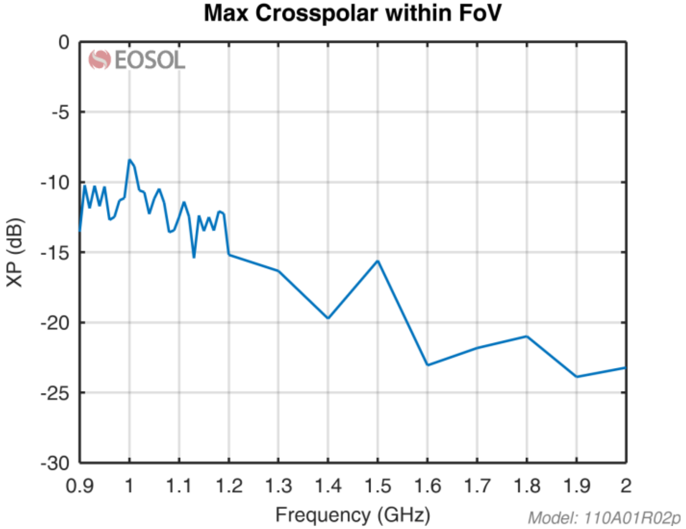
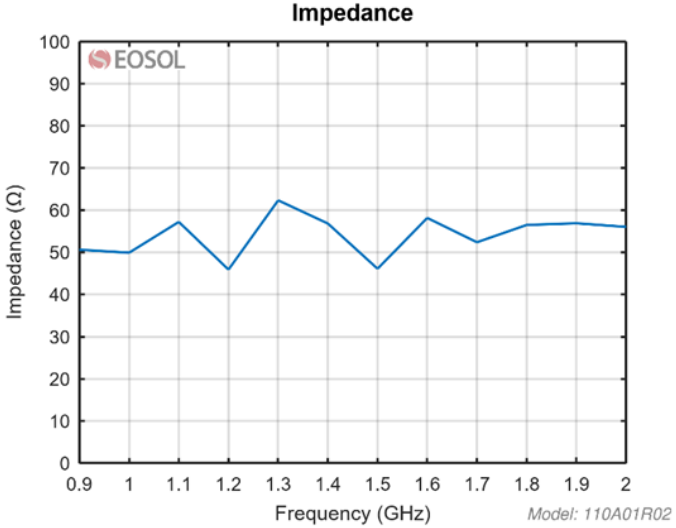
4.2.2 Feed and sub-array RF design

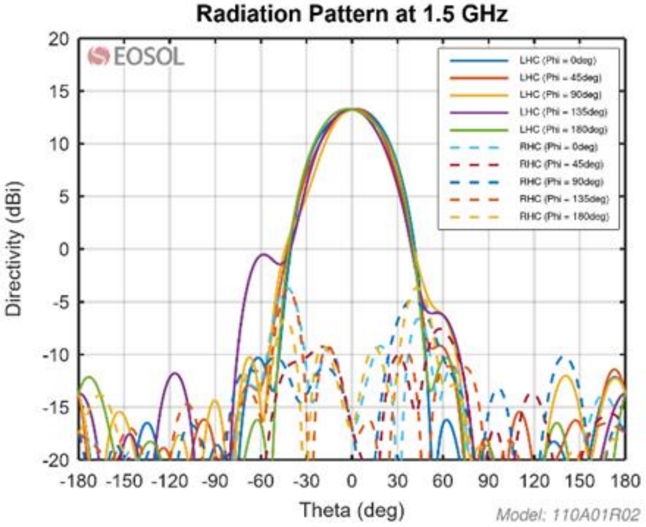


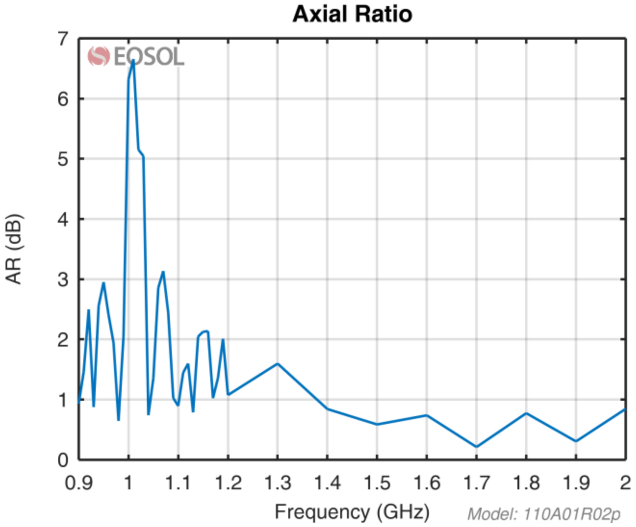
HFWF Sub-array

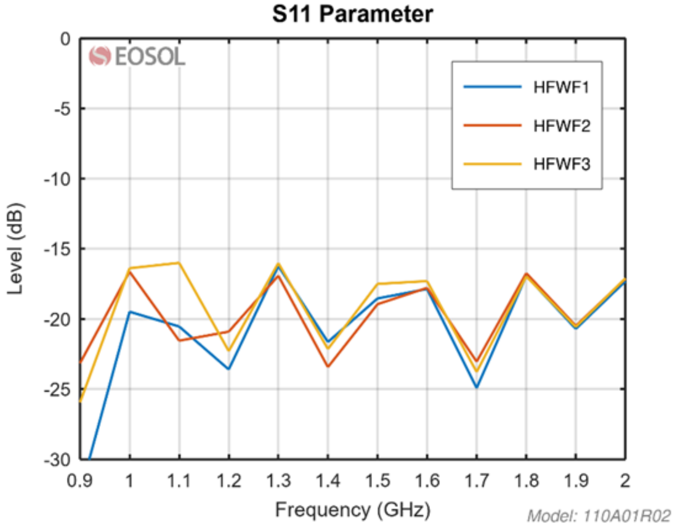












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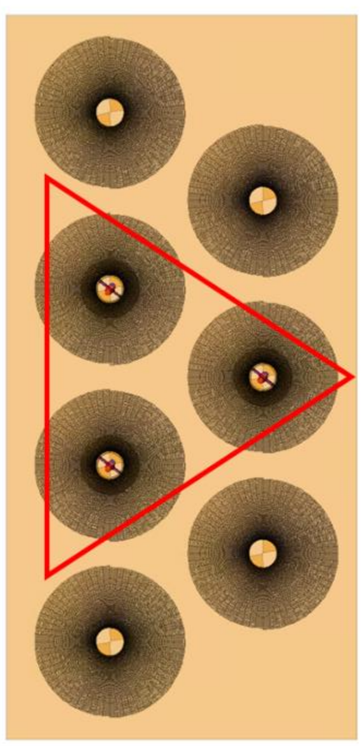
4.2.2 Feed and sub-array RF design



HFWF Sub-array

REQ.	Parameter	Unit	Case 1
HFWF-40	Frequency band	GHz	0.9 - 2.0
HFWF-130	Return loss	dB	> 15
-	Directivity	dB	9 - 15
HFWF-120	Max XP within FoV from 0.9 – 1.3 GHz	dB	< -10
HFWF-120	Max XP within FoV from 1.3 – 2.0 GHz	dB	< -15
HFWF-70	Axial ratio at boresight from 0.9 – 1.3 GHz	dB	< 3
HFWF-70	Axial ratio at boresight from 1.3 – 2.0 GHz	dB	< 1.6
HFWF-60	Max phase centre variation	mm	200
HFWF-125	Integrated power within FoV from 0.9 – 1.2 GHz	%	> 83
HFWF-125	Integrated power within FoV from 1.2 – 2.0 GHz	%	> 89
HFWF-140	Maximum insertion loss	dB	< 1.03 @ 0.9 GHz <0.78 @ 1.5 GHz <0.62 @ 2.0 GHz
HFWF-155	Maximum phase variation at -10 dB	ºpp	@ 0.9 < 170 @ 1.5 < 70 @ 2.0 < 60

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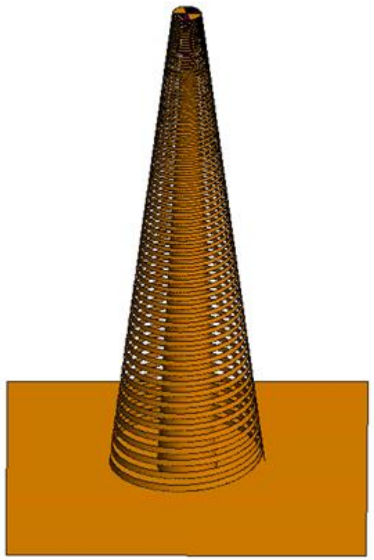
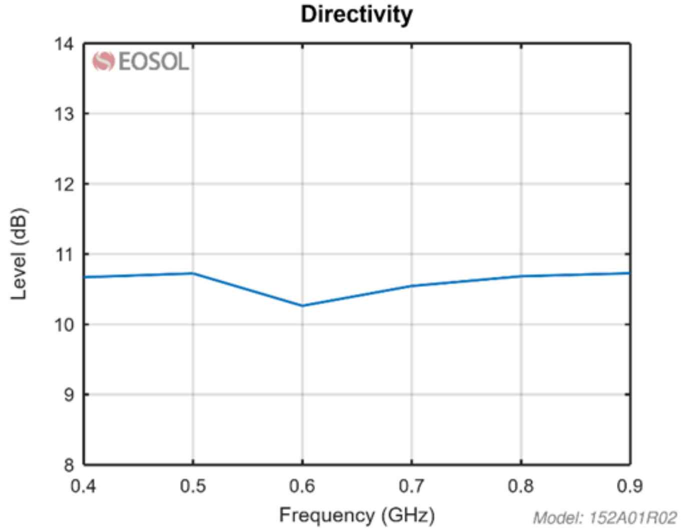
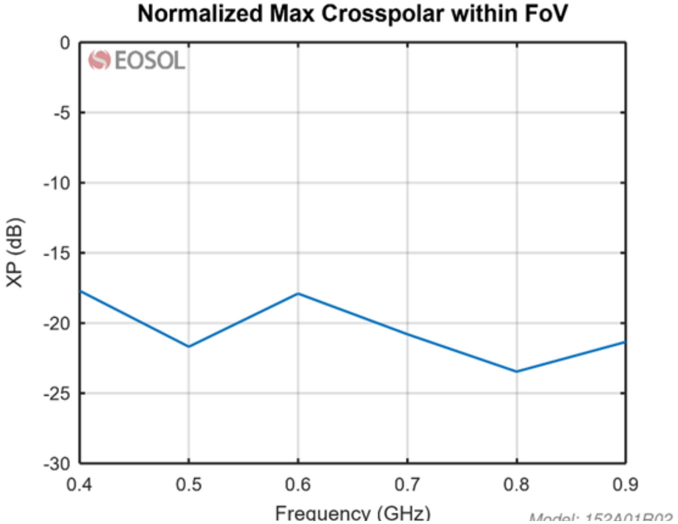
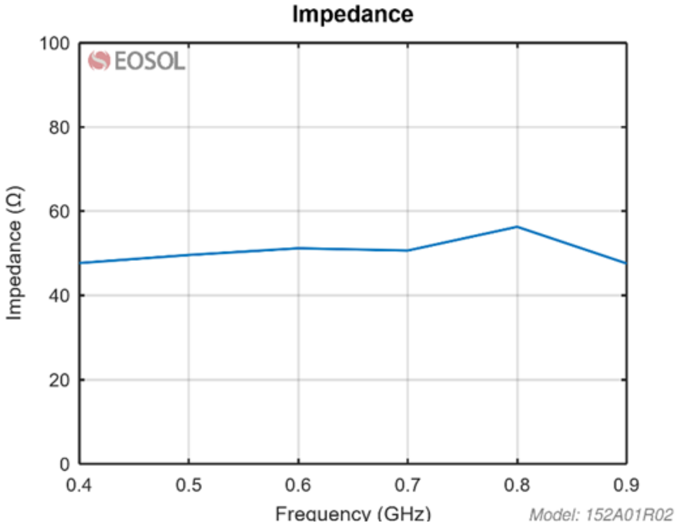
4.2.2 Feed and sub-array RF design

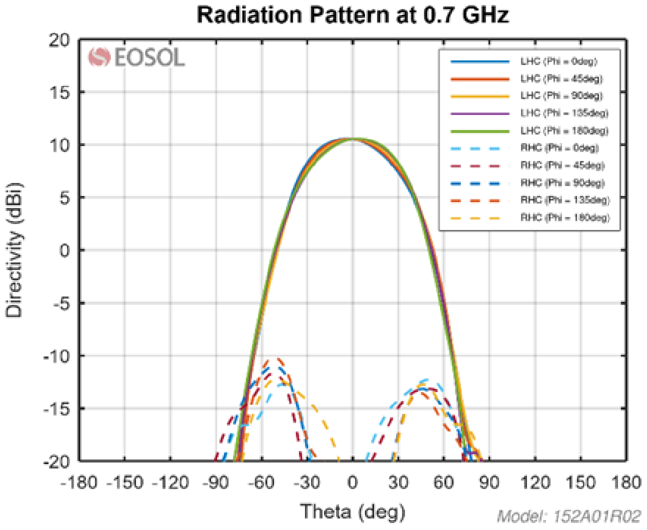


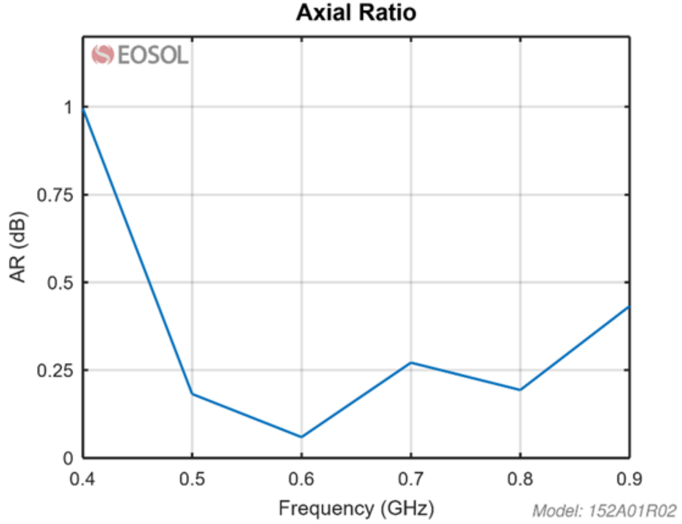
LFWF feed

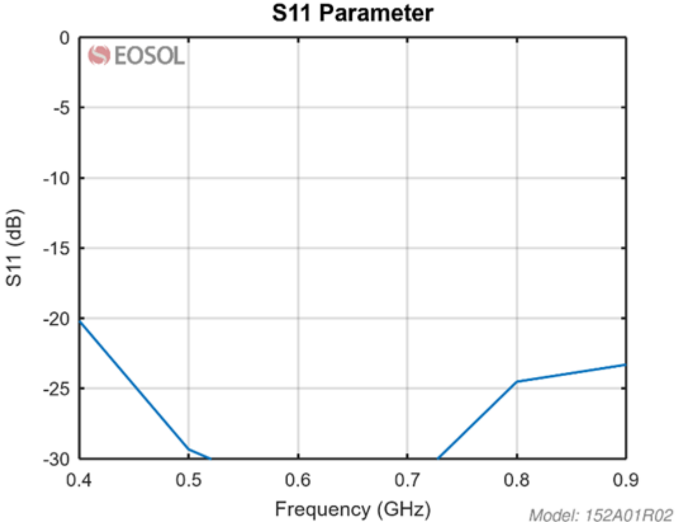




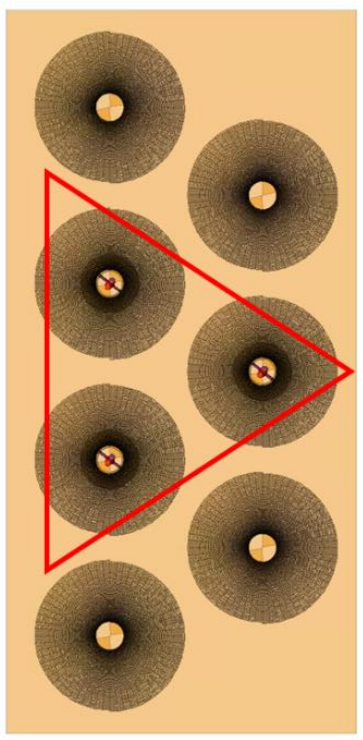




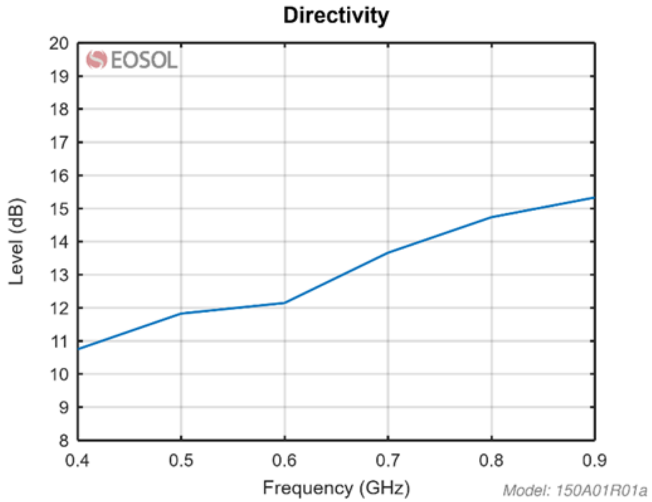


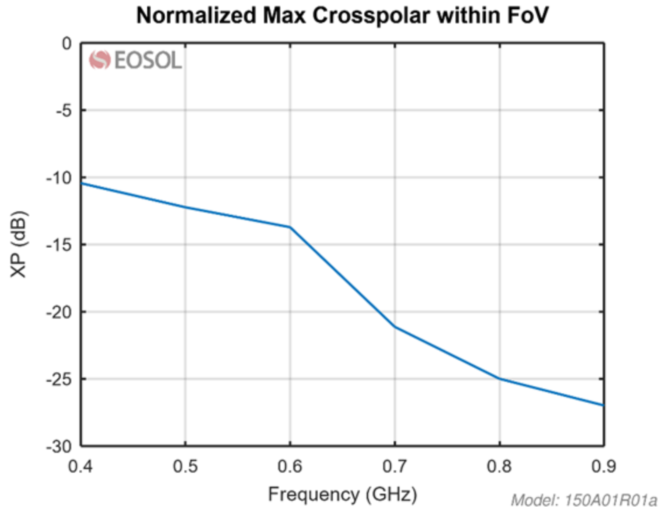


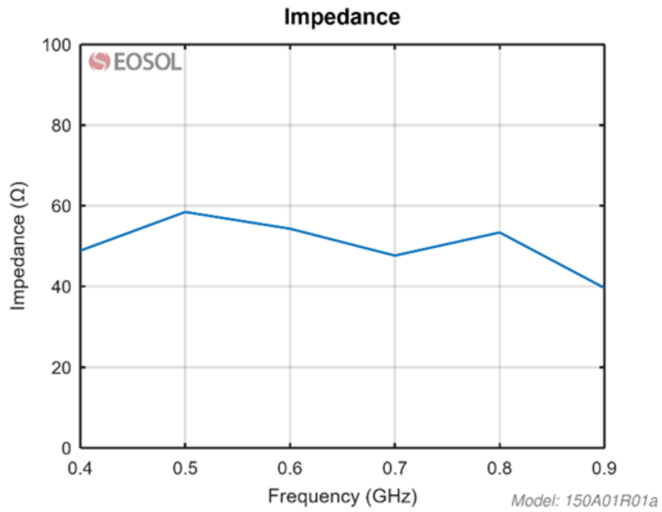
4.2.2 Feed and sub-array RF design

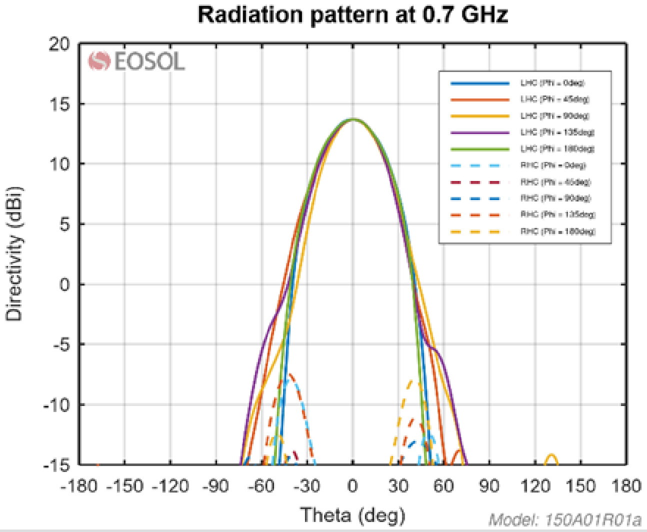


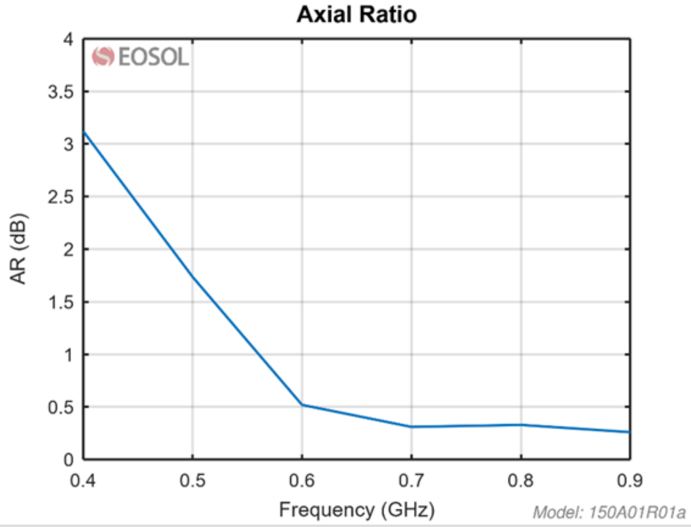
LFWF Sub-array

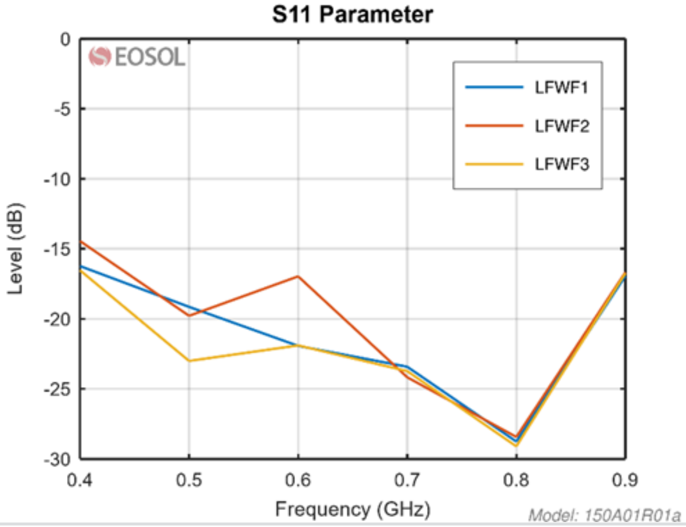












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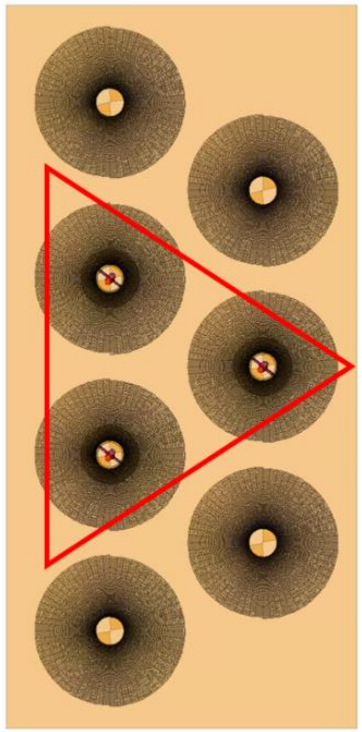
4.2.2 Feed and sub-array RF design



LFWF Sub-array

REQ.	Parameter	Unit	Case 1
LFWF-40	Frequency band	GHz	0.4 - 0.9
LFWF-130	Return loss	dB	> 15
-	Directivity	dB	10.75 -15.25
LFWF-120	Max XP within FoV from 0.4 – 0.6 GHz	dB	< -10
LFWF-120	Max XP within FoV from 0.7 – 0.9 GHz	dB	< -20
LFWF-70	Axial ratio at boresight from 0.4 – 0.6 GHz	dB	< 3.1
LFWF-70	Axial ratio at boresight from 0.7 – 0.9 GHz	dB	< 0.5
LFWF-60	Max phase centre variation	mm	453
LFWF-125	Integrated power within FoV from 0.4 – 0.5 GHz	%	> 82
LFWF-125	Integrated power within FoV from 0.5 – 0.9 GHz	%	> 91
LFWF-140	Maximum insertion loss	dB	0.4 GHz : < 0.82 0.7 GHz : < 0.54 0.9 GHz : < 0.42
LFWF-155	Maximum phase variation at -10 dB	ºpp	@ 0.4 < 50 @ 0.7 < 38 @ 0.9 < 27

4.2.3 Feed mechanical and thermal analysis

Temperature limits considered compatible with CRYO Feeder:

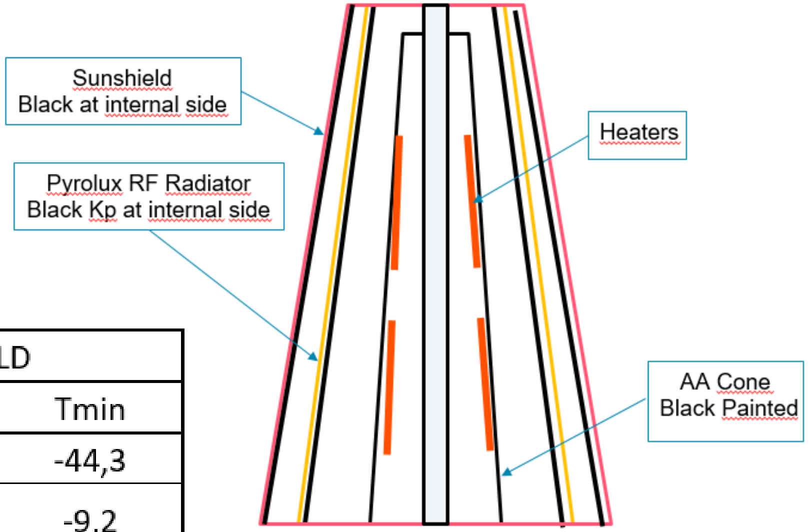
MATERIALS	Tmax	Tmin
All	+75ºC	-60ºC

Two extreme cases has been considered for thermal design and analysis:

Hottest case. Sun is coming by a lateral side. This case produces highest temperatures in one area and maximum circumferential gradients (corresponding to a solstice of a 650 Km SSO orbit): 1420W/m2 is the solar input assumed value (maximum value in winter solstice at 1AU). No other external inputs are considered.

Coldest case. No external inputs are considered (applicable to any orbit)

- Due to the feeder is radiating element, only RF transparent thermal isolation element can be considered. In this way a sunshield performed with Germanium coated 100CB Black kapton is installed externally.
- On other hand, in the internal Pyrolux face (radiating element) will be installed a black Kapton tape with acrylic adhesive. This cancels the transparency and homogenize the internal temperatures.
- Additionally to keep the Feeder into temperature some heater are installed in the internal side of central cone.
- The power installed is 7 W to ensure all the components of Feeder are compliant with temperature requirements

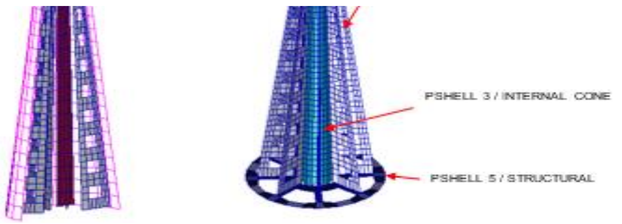


	HOT		COLD	
	Tmax	Tmin	Tmax	Tmin
Radiating surface	40,0	-37,1	-11,6	-44,3
Base	58,2	-10,3	27,1	-9,2
Aluminium cone	10,9	7,9	58,8	43,5
Stiffners	28,7	-29,0	29,4	-35,4
Balun	9,6	-10,7	50,2	-13,7
Upper closing	-13,2	-22,6	-37,6	-37,6

4.2.3 Feed mechanical and thermal analysis

- Feeder design proposed is analysed to check stress and Margin of safety under typical sine & random environments
- All the components of Feeder are simulated with PSHELL Nastran elements
- The dynamic stiffness of the proposed mechanical design is checked given its first three modes at frequencies over 80 Hz. All of these modes are bending modes.
- Due to the low stiffness of some components of the Feeder, as the radiating layer, many local modes without relevant mechanical appears. Thus, all modes with effective masses lower than 10% has been ignored

MODE	FREQUENCY	T1	T2	T3	R1	R2	R3
1	2,89E+00	1,11E-02	5,03E-03	5,79E-13	4,34E-04	1,03E-03	5,47E-11
2	6,78E+00	1,87E-03	1,37E-03	1,44E-10	6,07E-05	5,56E-04	2,04E-09
26	6,86E+01	1,24E-02	6,23E-03	5,10E-09	7,27E-04	8,91E-04	7,42E-09
27	7,33E+01	3,87E-06	7,77E-06	1,34E-09	5,85E-07	6,16E-07	1,99E-09
28	7,66E+01	1,17E-03	7,09E-03	5,99E-12	9,21E-04	5,94E-05	3,01E-09
29	**8,25E+01**	8,00E-02	**1,11E-01**	9,80E-08	1,59E-02	8,14E-03	5,82E-08
30	8,36E+01	5,14E-02	4,04E-02	1,61E-09	3,85E-03	8,34E-03	3,47E-08
31	8,56E+01	3,26E-07	1,29E-06	3,93E-08	1,12E-07	1,87E-08	7,92E-08
32	**8,71E+01**	2,62E-02	**1,22E-01**	2,74E-08	1,24E-02	3,47E-03	1,28E-07
33	**8,90E+01**	**1,70E-01**	5,13E-02	1,26E-07	6,53E-03	1,86E-02	3,12E-08
34	9,43E+01	6,34E-03	1,70E-02	1,43E-07	1,66E-03	6,55E-04	1,42E-08
35	9,49E+01	4,71E-02	1,03E-02	1,94E-09	1,17E-03	4,78E-03	7,11E-09



Sine Margins

SINE X	
Zone	Minimum MoS (YIELD)
RIBS	8.26
BASE	2.31
CONE	4.61

SINE Y	
Zone	Minimum MoS (YIELD)
RIBS	8.21
BASE	2.90
CONE	5.89

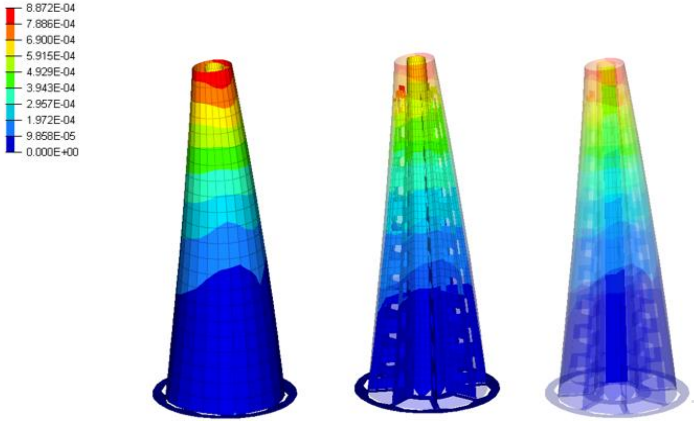
SINE Z	
Zone	Minimum MoS (YIELD)
RIBS	55
BASE	185
CONE	338

Radom margins

RANDOM X	
Zone	Minimum MoS (YIELD)
RIBS	51
BASE	34
CONE	37

RANDOM Y	
Zone	Minimum MoS (YIELD)
RIBS	49
BASE	35
CONE	35

RANDOM Z	
Zone	Minimum MoS (YIELD)
RIBS	193
BASE	75
CONE	69

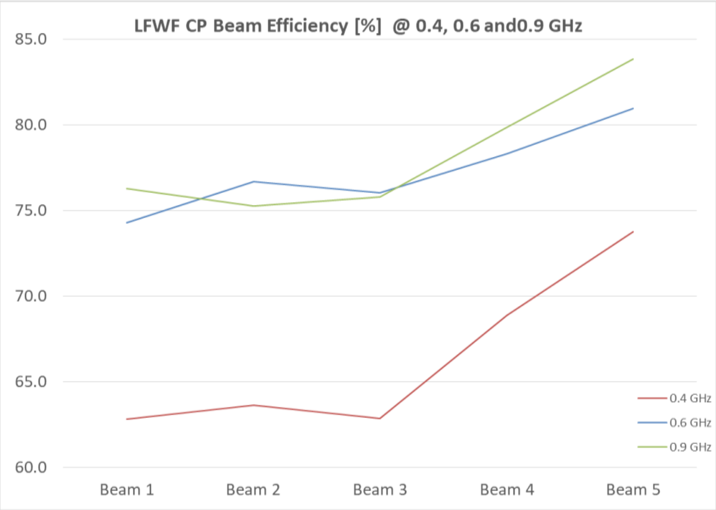


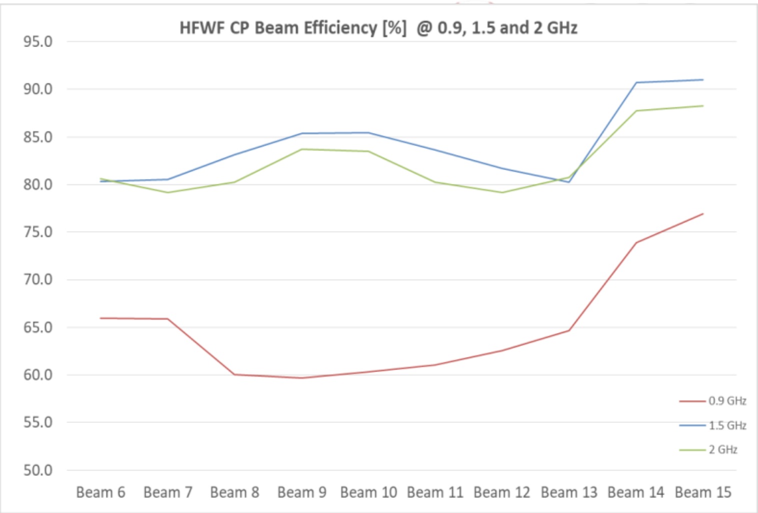
- Thermo-elastic behaviour of both balun and radiating element (pyrolux layer) are analysed considering extreme temperatures obtained at hot and cold thermal cases
- For both the maximum displacements from the initial position are in the order of 0.1 mm.

4. PROJECT OVERVIEW

4.2. Feed chain detailed design

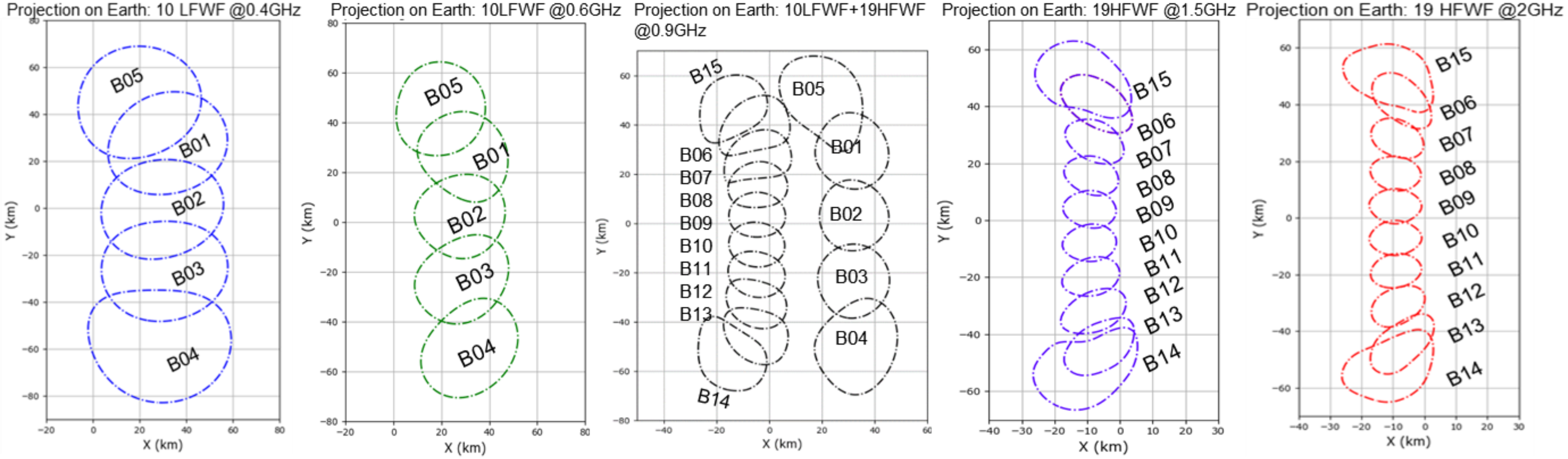
4.2.4 Antenna reflector performance





- The Antenna and geometrical performance have been analysed.

- The high frequency beams at the edges still maintain quite an elliptical shape due to the gain in directivity of the feed treated as an array.
- The main antenna system limitations are the cross-polar level and antenna efficiencies.



HPBW (º):	4.16 – 4.82	3.1 – 3.4	1.75 – 3.49	1.3 – 2.8	1.21 – 2.46
FP (km):	47.3 – 55.3	35.8 – 39.1	19.7 – 35.2	14.7 – 30.3	14.1 – 26.6
XP 2.5x3dB contour (dB)	-15.5 – -12	-16.5 – -19.5	-29.5 – -16.7	-17.8 – -20.4	-27 – -23

4.2. Feed chain detailed design

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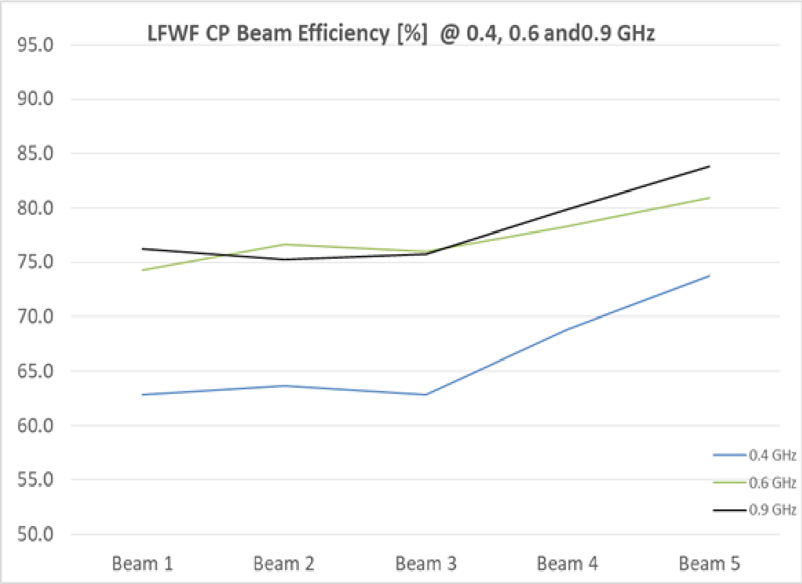
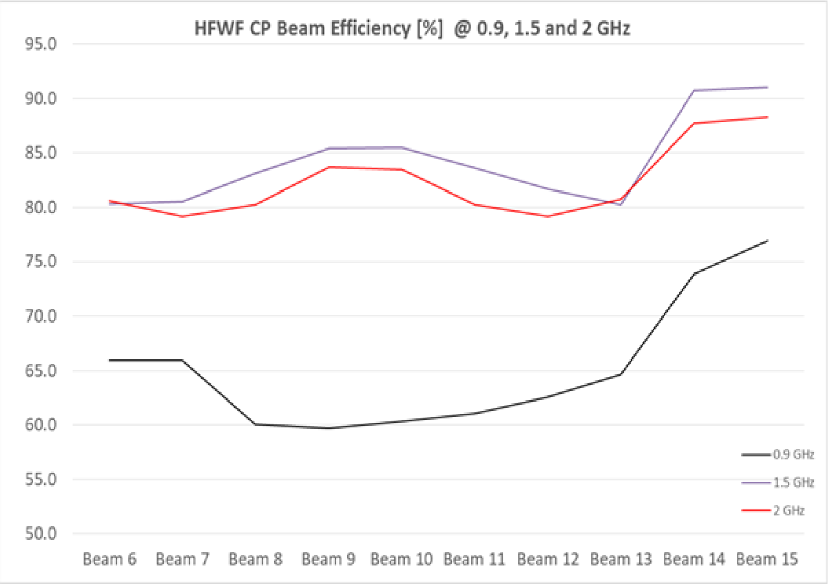
4.2.4.1 Antenna reflector performance:

- The beam efficiency is computed as the integrated power in the main beam (2.5 times the fitted ellipse) relative to the total power received by the antenna, considering only the CP component.
- A degradation of efficiency can be observed for the lower frequencies of each sub-array type.





Frequency	0.4 GHz	0.9 GHz	2 GHz
Wide Beam Eff (%) - MEAN	72	74	86.4

- It has been detected that the main plausible root for the beam efficiencies results is the reflector spill-over.
- To improve the efficiency, the following options have been considered :
  - A greater reflector (D>15m) → Maximum diameter allowed is 12.5m
  - Feed Cluster pointing enhancement: optimize the feed cluster orientation
  - To discard the sky contribution using processing techniques

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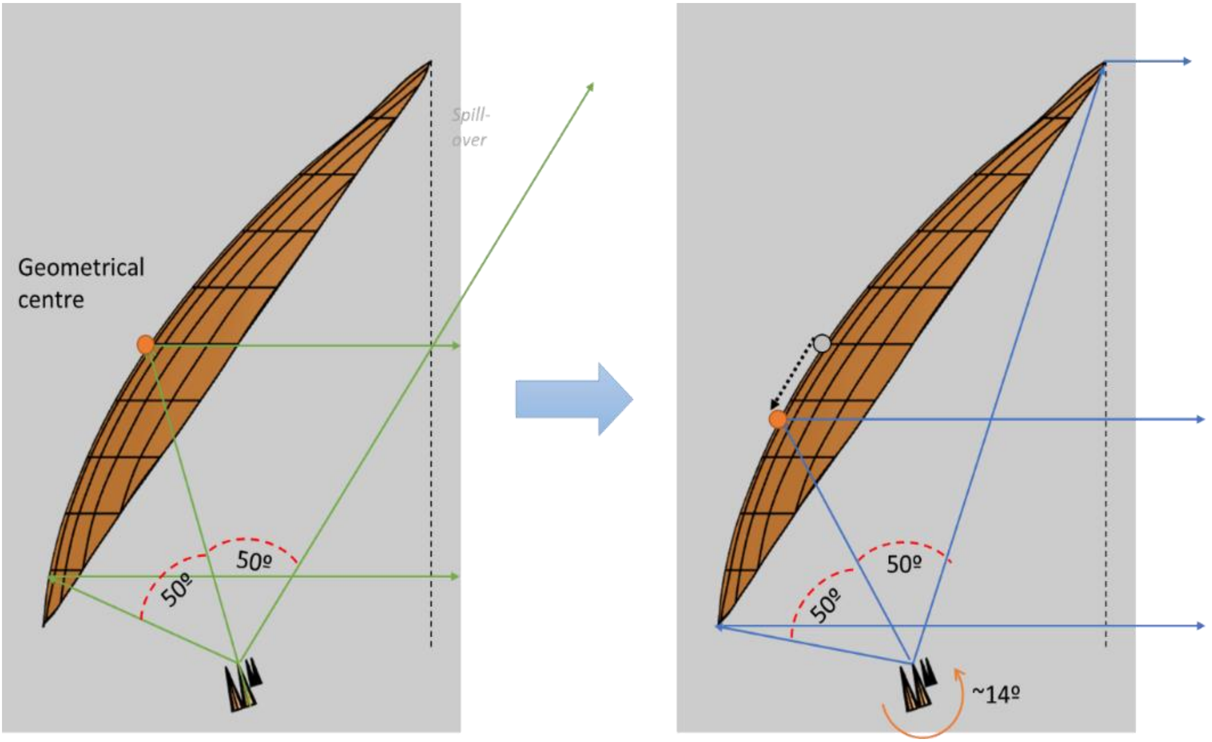
4.2.4 Antenna reflector performance: POINTING ENHACEMENT

- The antenna configuration has been optimized in terms of feed fluster orientation in order to reduce the spill-over and improve the beam efficiency performance.
- The selected baseline, in line with general reflector design, consists in pointing the feed cluster to the reflector's geometrical centre (θ_f).
- However, it has been observed that, due to the antenna atypical geometry selected (F/D is significantly low) the beam efficiency results can be improved when the feed cluster is pointing about 14º below the geometrical centre (θ_o) when the illumination of the feed over the reflector is symmetrical.

Half-angle subtended. Taper angle (θ*)	49.85º
Feed cluster pointed to the reflector's geometrical centre (θf)	72.77º
Symmetrical illumination of the reflector ($\boldsymbol{\theta_o}$)	58.87º



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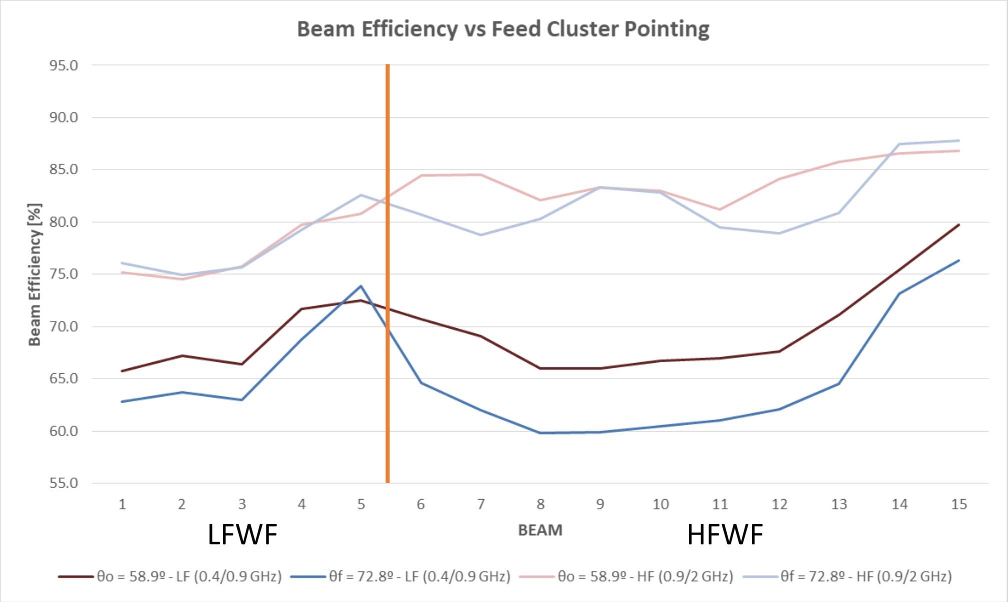
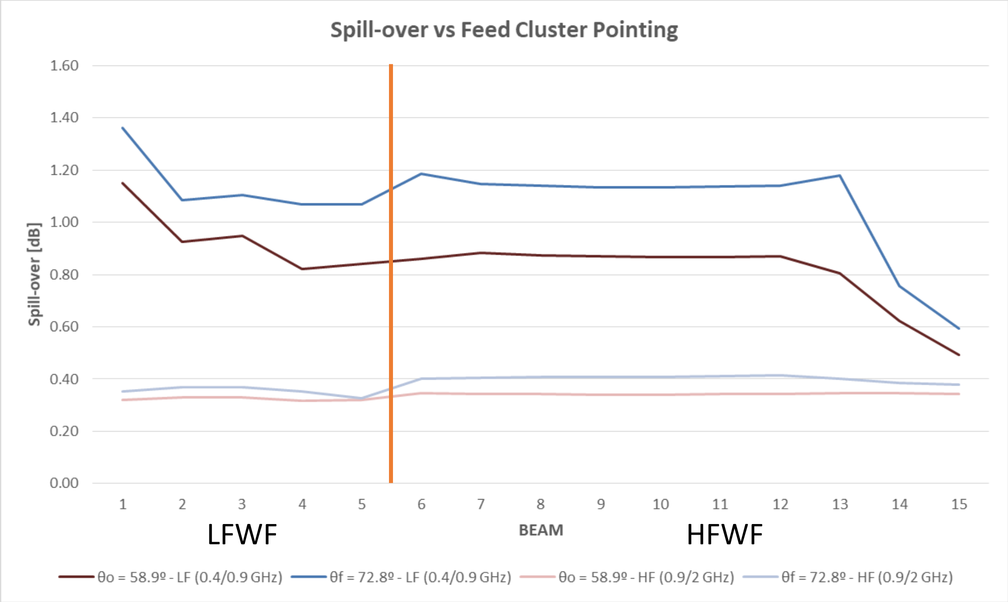
4.2.4 Antenna reflector performance: POINTING ENHACEMENT

- Following figures show the improvements in terms of beam efficiency and spill-over between both feed cluster pointing configurations.





- A significant improvement on the beam efficiency can be observed for the low frequencies of each channel (0.4 GHz for LFWF and 0.9 GHz for HFWF). For the higher frequencies, the values of the efficiencies are similar for both configurations with a slight improvement for the new pointing configuration

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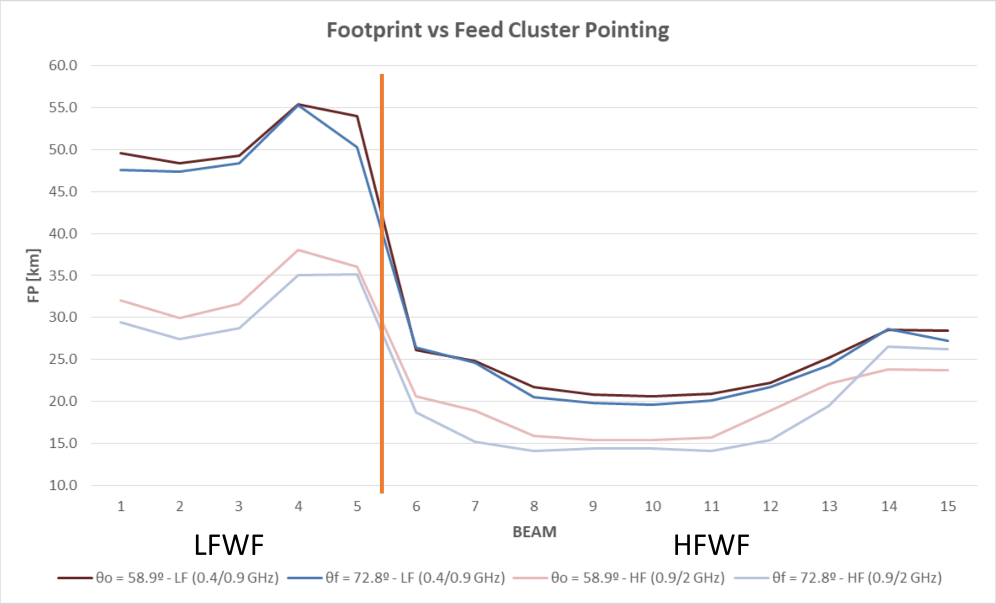
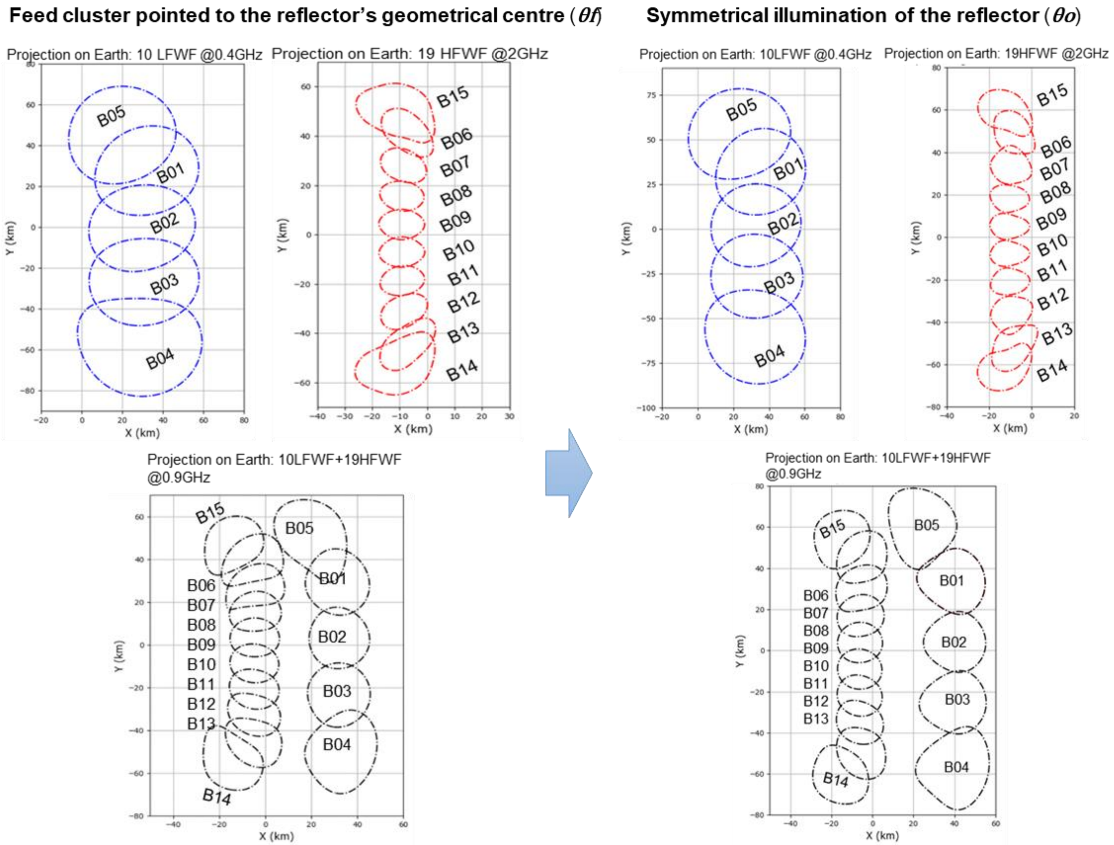
4.2.4 Antenna reflector performance: POINTING ENHACEMENT

- The geometrical performances for the symmetrical feed cluster pointing have been analysed and compared with the current baseline configuration.





- The footprint size is slightly larger than for the current baseline configuration. However, it can be observed that the beam shape of the feeders located at the extremes of the feed cluster seem to improve.

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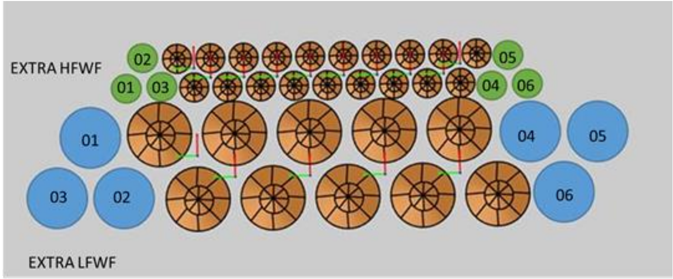
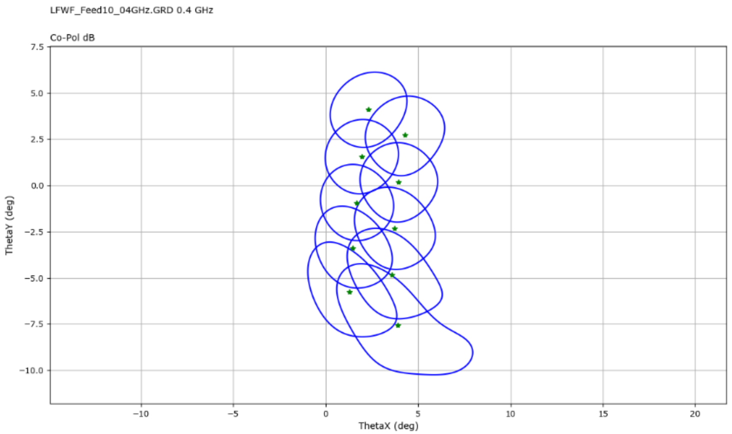
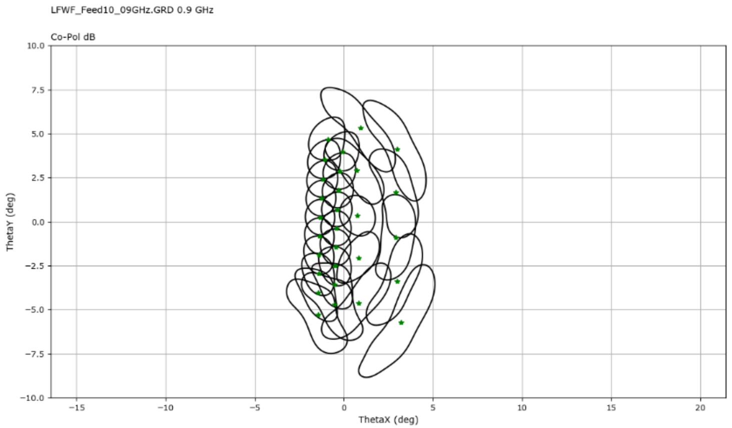
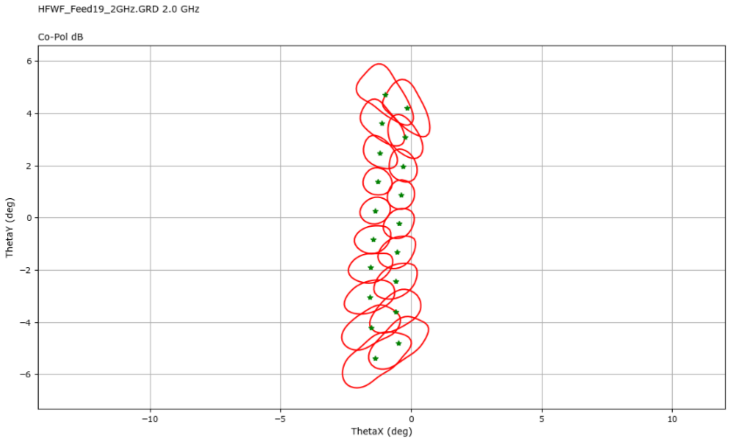
4.2.4 Antenna reflector performance: Digital Beam Forming

- The overlap between beams, allow to explore the possibility of beam forming (baselined in the digital domain to increase flexibility and not to degrade losses in front of the LNA).
- This would open the door to a beam scanning instrument (digitally) and with processing applied independently to the different frequency sub-bands
- The idea is to combine not only three feeds as baselined but as many as possible, with different amplitude and phase weights
- Standalone Feed patterns have been included to the GRASP model in order to increase the number of beams at the extreme directions
- Beams are compared with the ones obtained with the baseline array configuration of 3 elements
- Result show good improvements for the HF channels but no improvement for LF
- Loss of resolution due to the combination (would require large reflector to recover) but large impact on beam efficiency
- Further improvement could be achieved with more evolved algorithms to derive the weight coefficients









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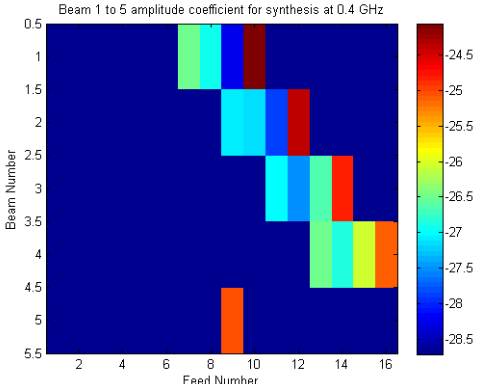
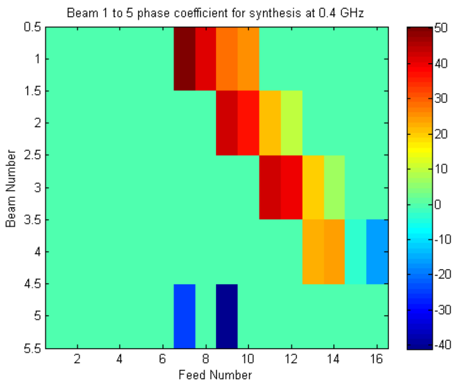
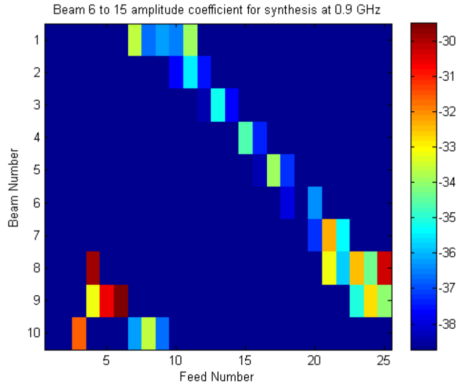
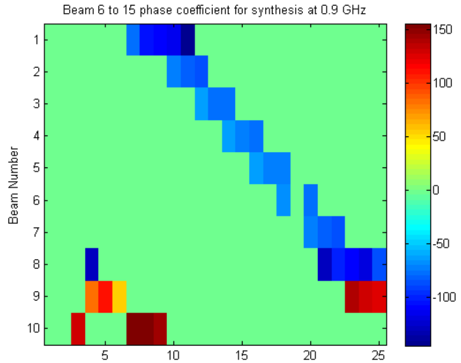
4.2.4 Antenna reflector performance: Digital Beam Forming

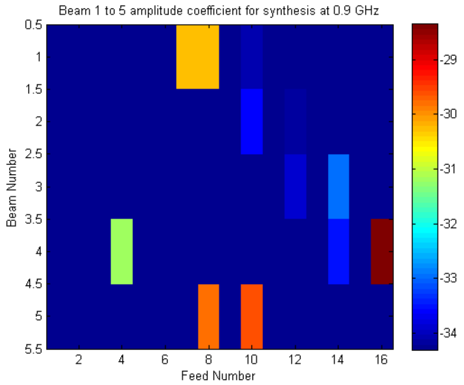
- Beam coefficients show that for LF only 3 (up to 4 but with low contribution) contribute to the formation of the synthesized beam
- Similary for HF the beam synthesis is defined by the current subarray pattern (very small contribution of the other beams

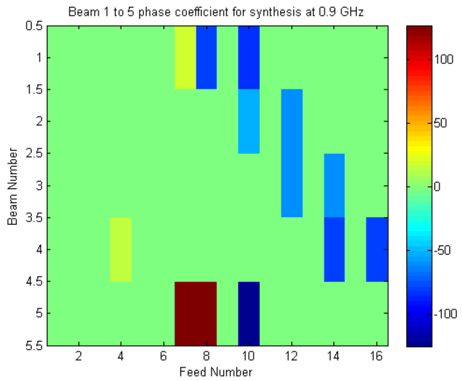


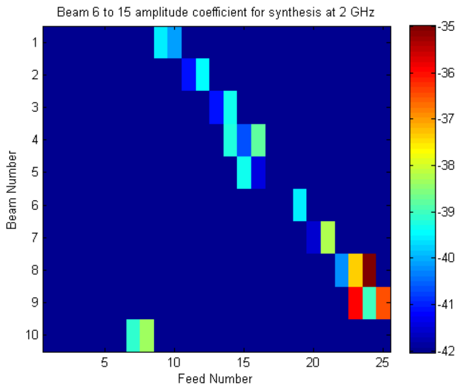


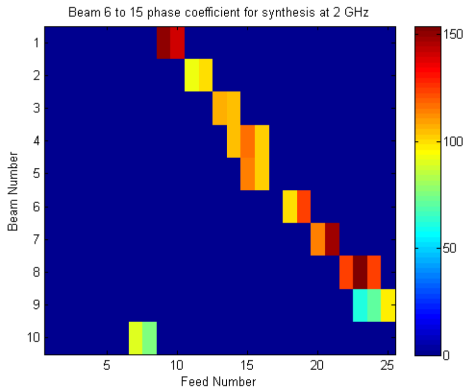




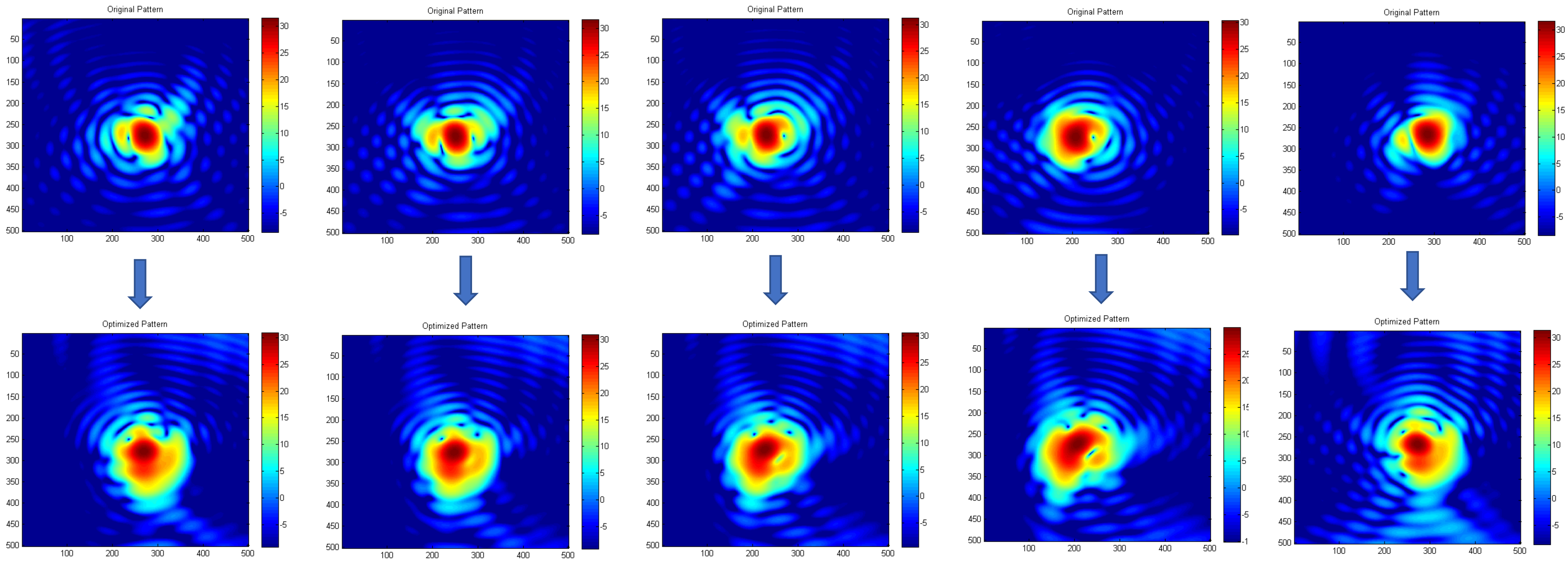




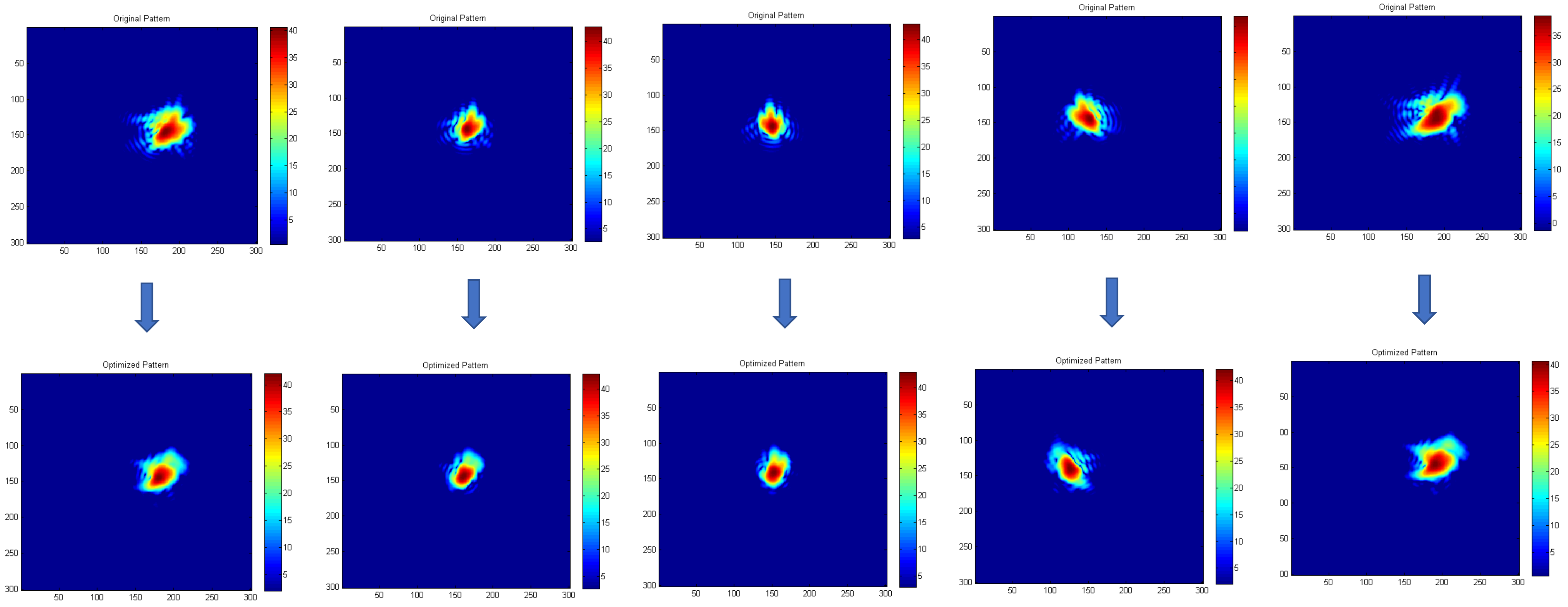




4.2.4 Antenna reflector performance: Digital Beam Forming



4.2.4 Antenna reflector performance: Digital Beam Forming



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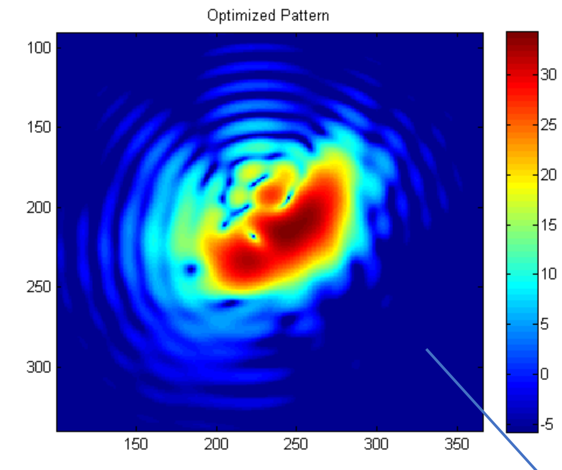
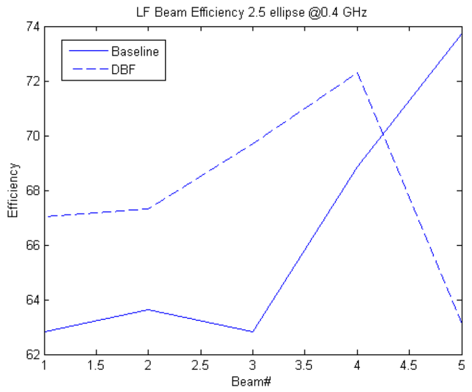
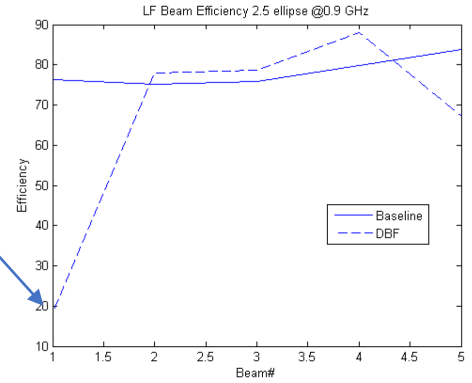
4.2.4 Antenna reflector performance: Digital Beam Forming

- Clear improvement on beam efficiency for HF and slight improvement for LF (probably due to resolution decrease)
- Slight degradation of resolution for most cases
- Outlier for beam 1 from LFWF @0.9 GHz due to double lobe in beam and difficulty to fit an ellipse

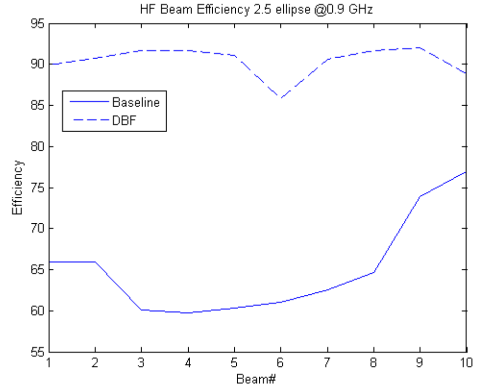


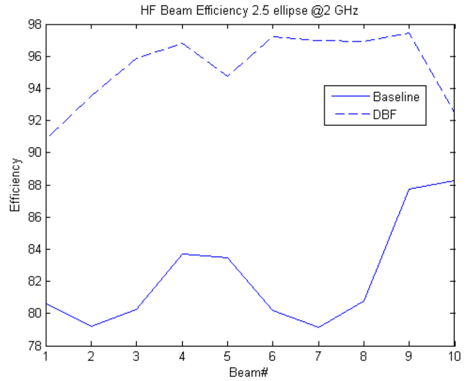
LF Feeds Beam Efficiency



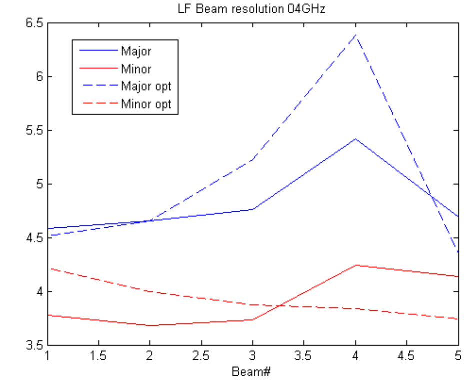


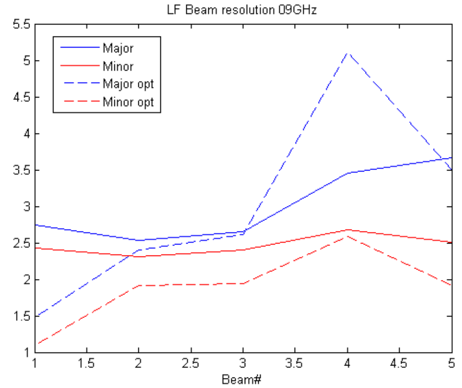
HF Feeds Beam Efficiency



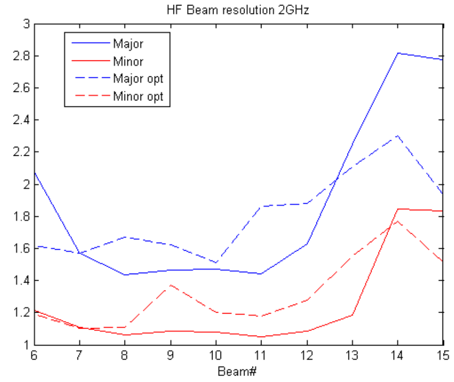


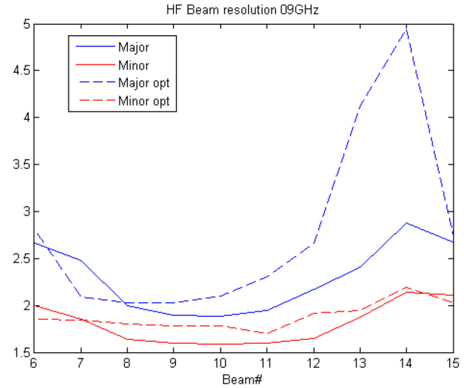
LF Feeds Beam Resolution





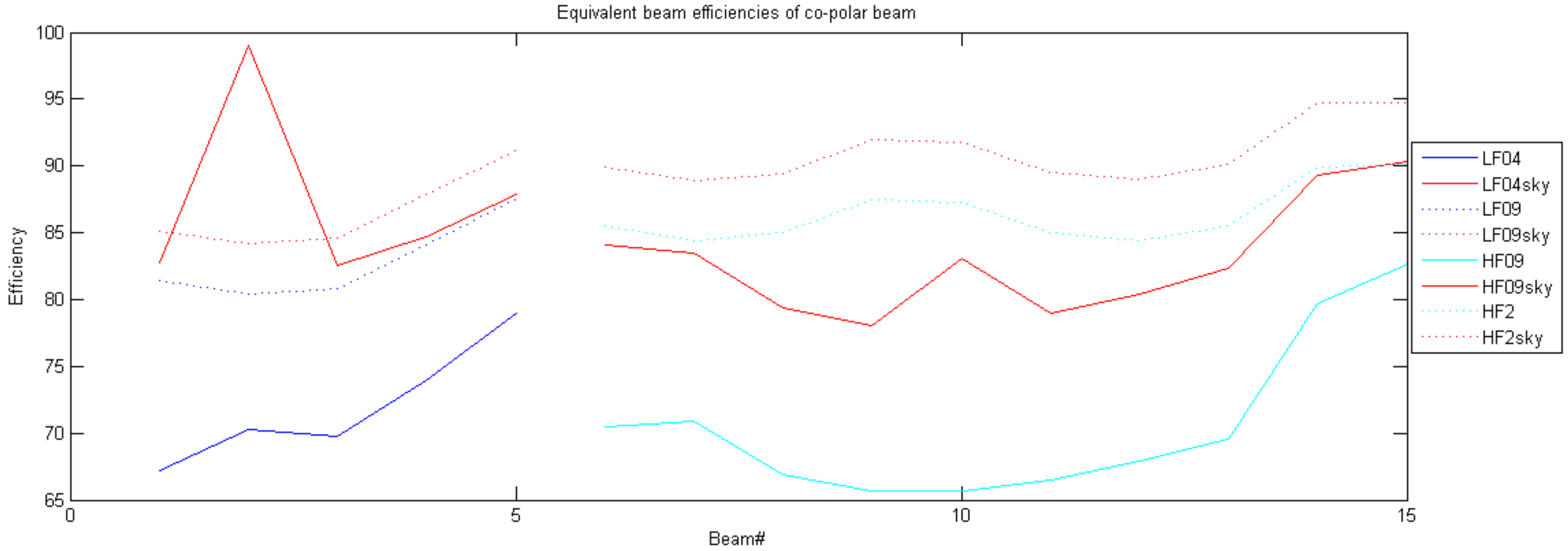
HF Feeds Beam Resolution

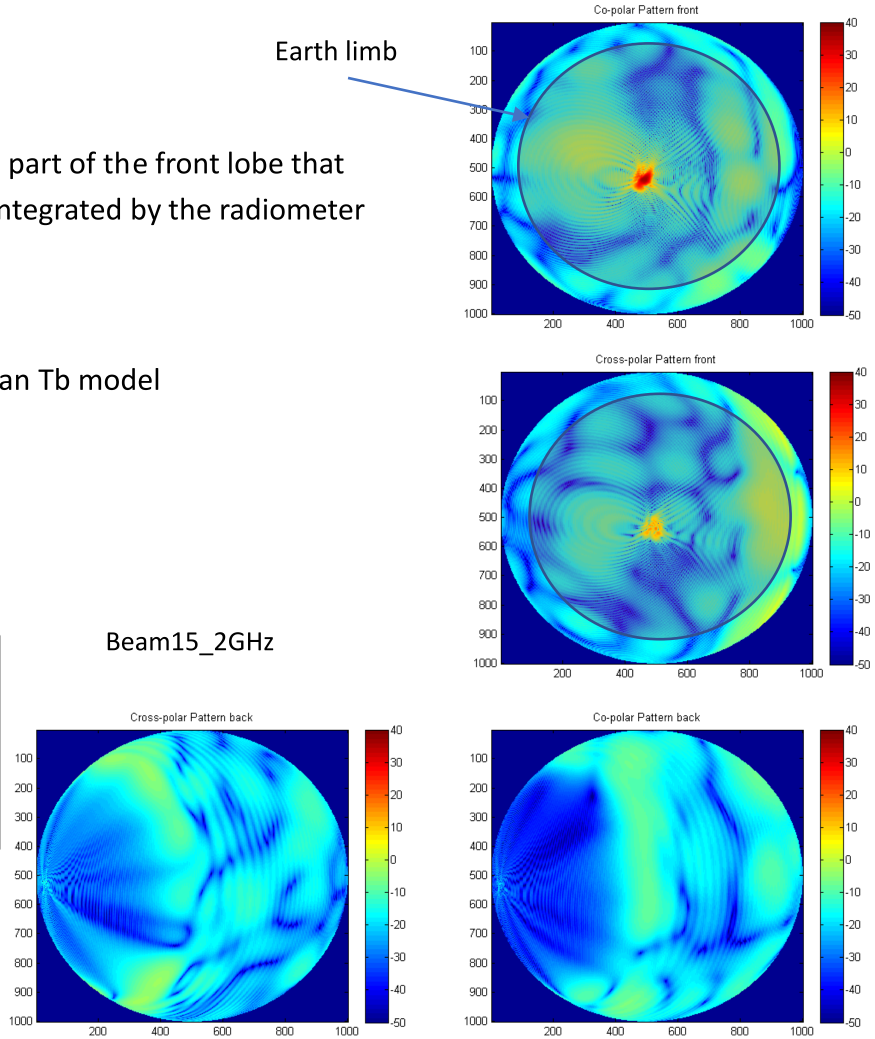




4.2.4 Antenna reflector performance: Beam Efficiency Re-Computation

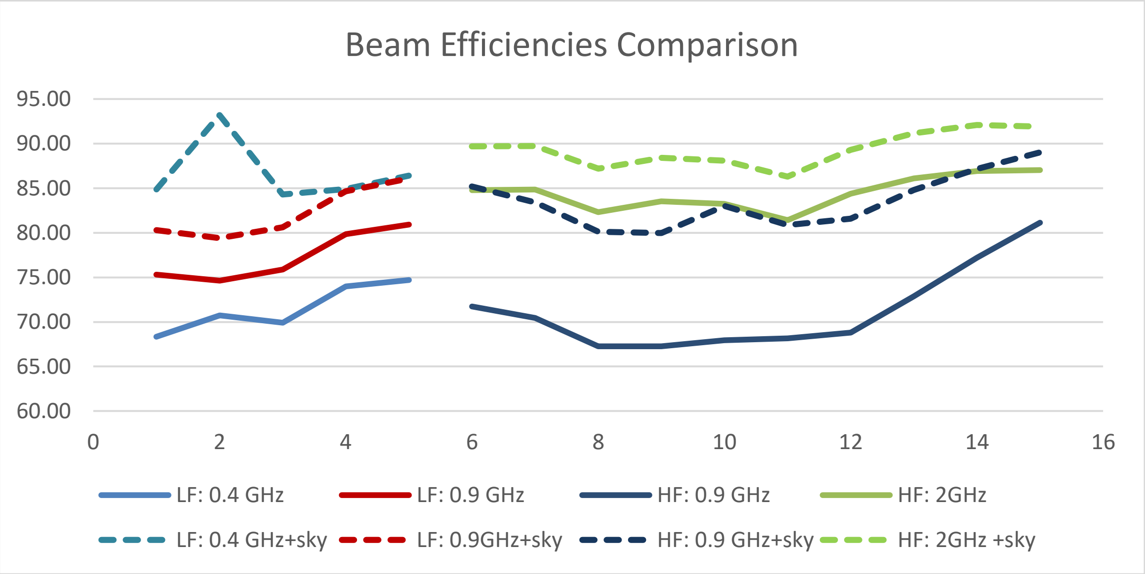
- Antenna affected by large spill-over due to the low directivity of the feeds-> Increase of backlobe levels
- Beam Efficiency can be recomputed discarding the part of radiation that is acquired through the back lobes and the part of the front lobe that points towards the sky since the Tb of the sky is known and its contribution (bias) can be removed from the signal integrated by the radiometer (as if effectively there was no radiation coming from those directions)
- There is a clear improvement of all the co-polar beam efficiency values when removing those contributions
- Additional improvement could be achieved using a receiver in the cross-polar channel or an Earth or adding an Ocean Tb model

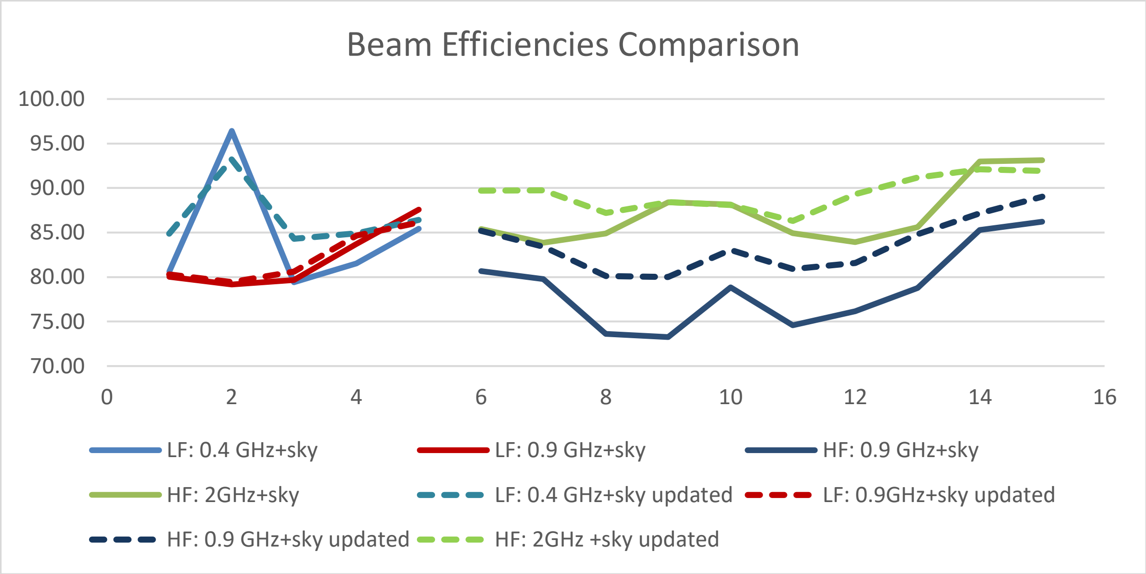




4.2.4 Antenna reflector performance: Beam Efficiency Re-Computation

- Same approach has been applied to the beams derived from the updated pointing strategy
- Improvement is clear for all beams as in the previous case
- Comparison between the previous beams corrected with the cold sky contribution also shows improvement, reaching values >80 % and around 90% for the highest frequencies



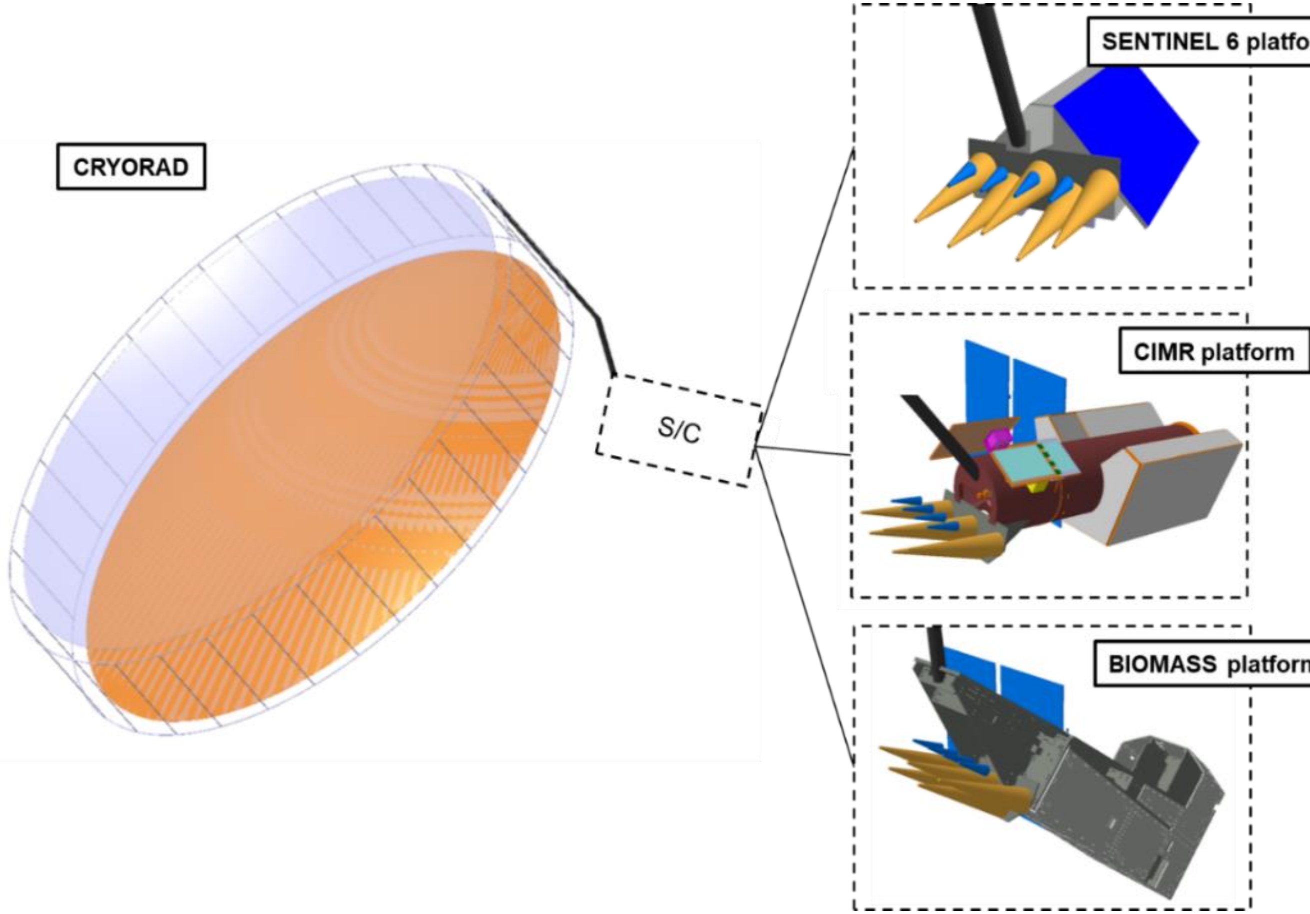


4.2.4 Antenna Accommodation

Trade-off has been performed considering three different platform mechanical concepts and the main constraints imposed by the CryoRad mission:

- Accommodation of the Large Deployable Reflector (LDR)
- Maximization of the allowable envelope for the feed array
- Compatibility with Vega-C

Use of stowed reflector dimensions from HPS consultancy



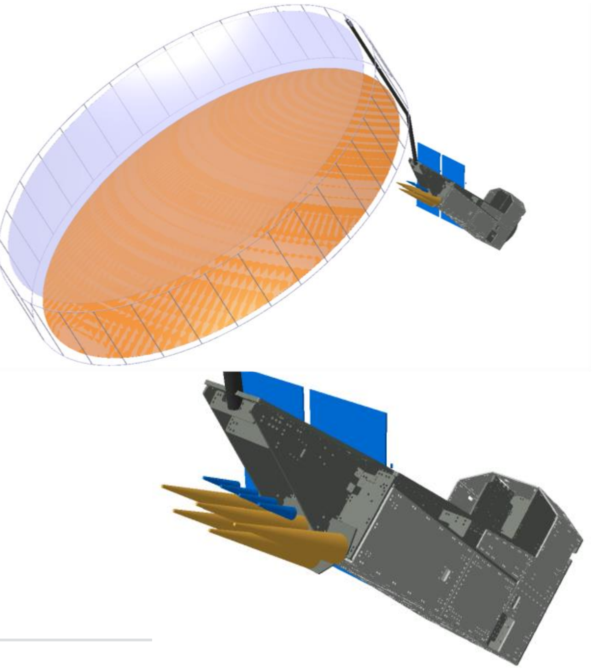
Initial accommodation using the initially feed array concept (5FF+4HF)

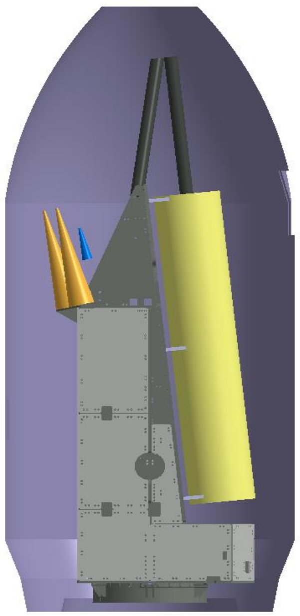
Three mechanical platforms have been analysed

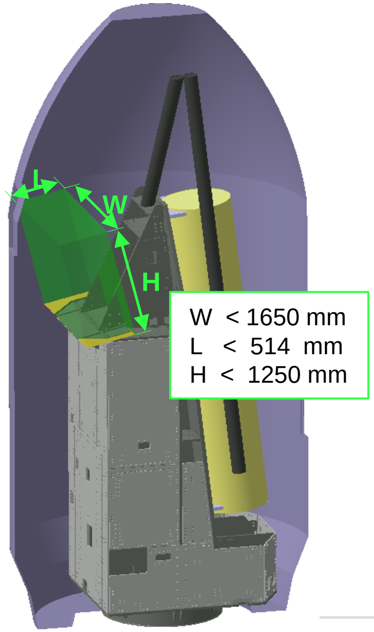
- The one based on the **SENTINEL-6 platform**
  - offers an optimum solution for the accommodation of the solar panels as the angle of the sun changes along the year, but limits the accommodation of the reflector to one of its sides
- The one of **CIMR**
  - with the reflector being mounted on a central tube
- The one for **BIOMASS**
  - which has been especially design to accommodate an LDR of 12m folded rib reflector at P band following the design

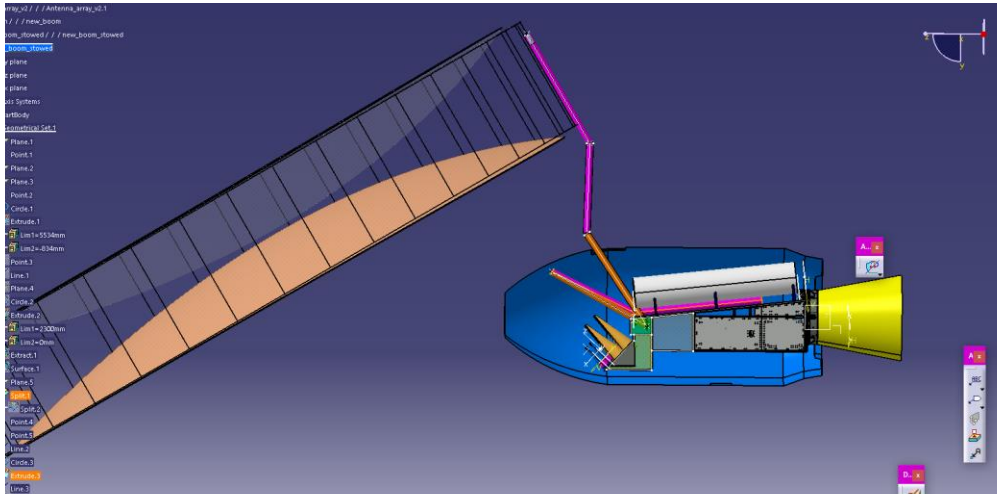
4.2.5 Antenna Accommodation: Biomass Platform

- Platform concept consists of a panelled prism that provides a cut-out for the accommodation of the stowed reflector and a support structure for the root of the boom. The use of orientable, deployable solar panels is required
- Feed accommodation on platform structure similar to the one of Biomass requires some adaption: moving the stowed reflector package more vertical and to remove supporting structure not to interfere with the feeds FoV
- Design converging towards the Cryosat concept, beneficial for the mission in case of non SSO orbit is selected
- Accommodation updated to the latest information received from HPS for a 12.5m reflector (worst case) and F/D=0.38



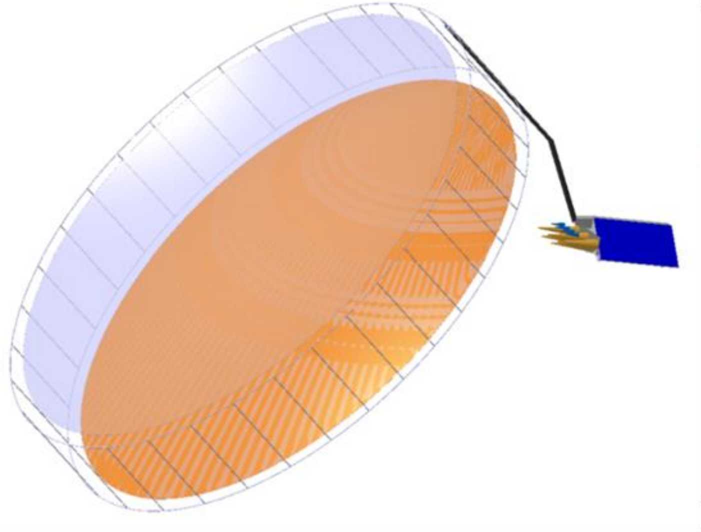


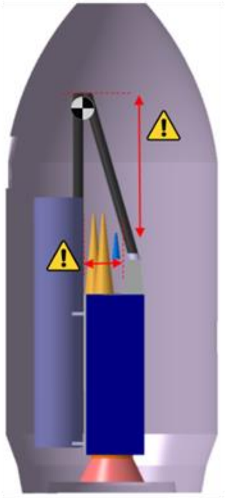


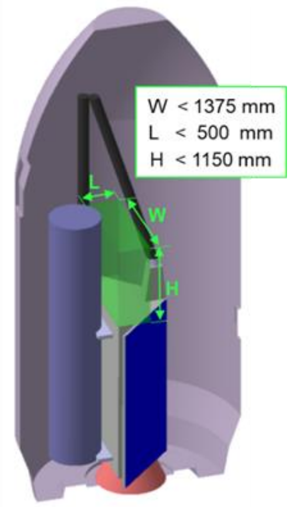


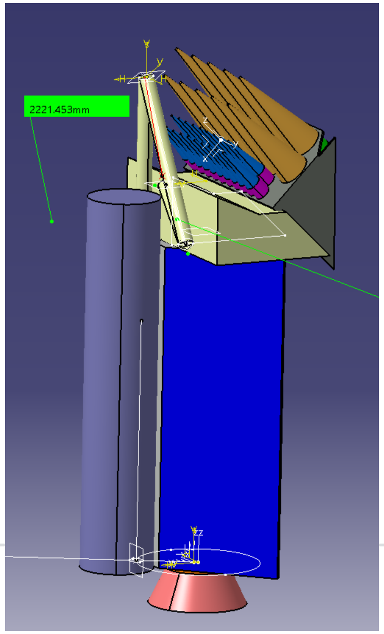
4.2.5 Antenna Accommodation: Sentinel-6 Platform

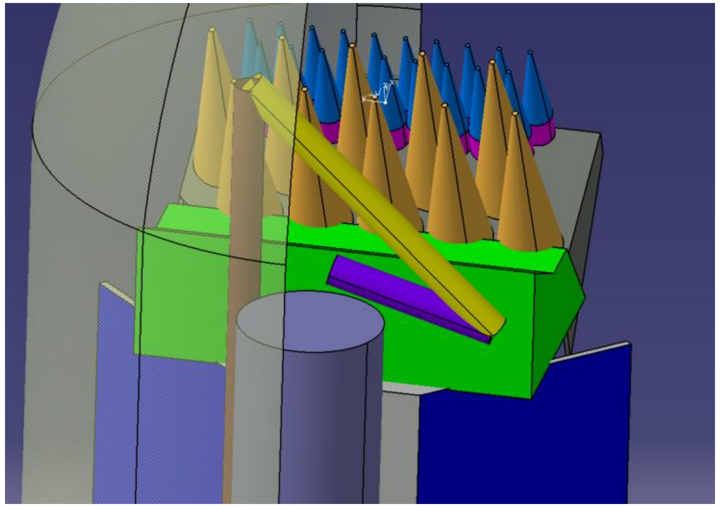
- The SENTINEL 6 platform concept consists of a panelled prismatic structure and was initially considered given its main advantages:
  - integrated solar panels (no orientable deployable panels required)
  - size and compactness.
- Main issue is found with the large dimensions of the LDR for CryoRad, with a stowed height largely exceeding the height of the platform structure
  - A significant portion of the stowed reflector's height remains unsupported and has no mechanical interface with the platform with the expected introduction of large mechanical loads
  - The accommodation of the feed array is largely restricted between the stowed reflector and the root of the boom. Minimum clearance exists between some feeds and the boom, and little flexibility exists in the orientation and position of the array.
- No show-stopper is found for a three segments configuration on this platform. A two segments boom needs more detailed study. Deployment concept needs to be adapted to fit updated boom length and in order not to have the boom in the FoV of the feeds





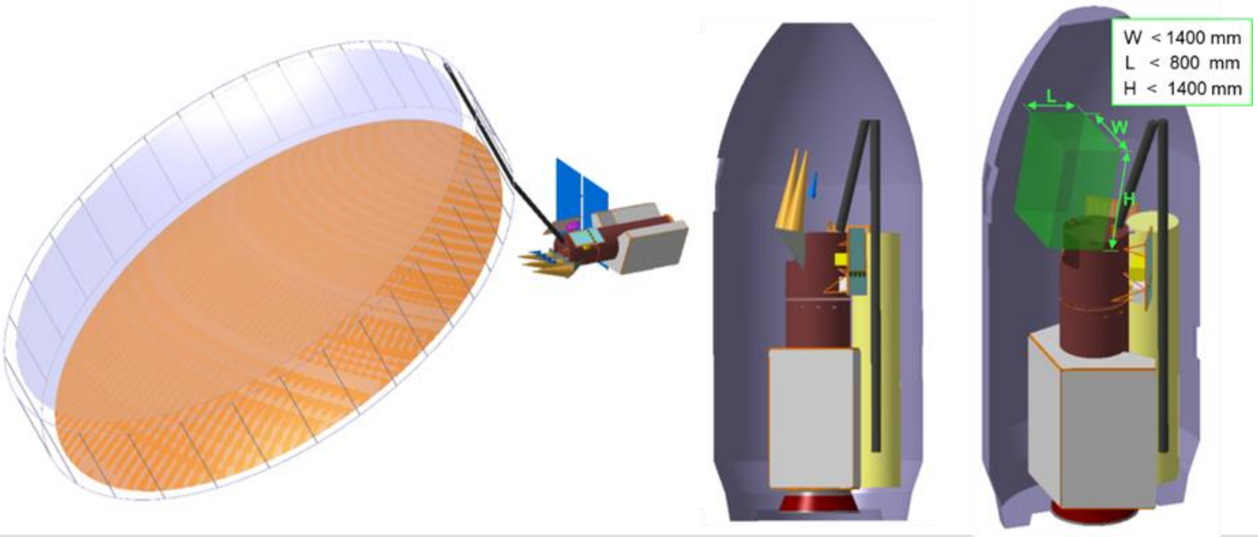






4.2.5 Antenna Accommodation: CIMR Concept

- The CIMR platform (airbus concept) consists of a Ø937mm main tube as the main load path, with the payload module installed on top and a panelled structure to accommodate the platform equipment.
- Its main advantage is the large room available upon the payload module for the accommodation of the feed array
- The large dimensions of the stowed reflector require to enlarge the platform structure introducing a significant offset of the reflector CoG with respect to the launcher's centre axis. The use of orientable deployable solar panels is required.
- The accommodation of the feed array is equivalent to previous two platforms. The ad-hoc upper structure provides the array support function as well as for any needed hinge.
- No show-stopper is found for a three segments configuration on this platform. A two segments boom needs more detailed study but it is considered out of the scope at this stage (i.e. feed array CDR).



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4.2.6 Design Matrix of Compliance

REQ. ID	Type	Parameter	Unit	Requested	Offered	SoC
ANT-10	Electrical	Polarization	-	Single-circularly polarised	RHCP	C
ANT-20	Electrical	3 dB beam width for the secondary pattern / antenna pattern	degrees	3.5 @ 400MHz 0.7 @ 2 GHz	4.5 @ 400MHz 1.7 @ 2 GHz	NC
ANT-30	Electrical	The combined swath achieved from three feeds shall be degrees across track	degrees	(+/-) 7.2	> (+/-) 7.2	C
ANT-40	Electrical	Main Beam Efficiency (MBE) for the secondary pattern (2.5 times 3dB footprint)	%	93	Nominal > 76 Sky correction < 86	NC
ANT-50	Electrical	Wide Beam Efficiency (WBE) for the secondary pattern (3 times 3dB footprint)	%	96	Nominal > 80 Sky correction < 90	NC
ANT-60	Electrical	Maximum Crosspolar level on the main beam	dB	> -21.5	**LFWF** 0.4 GHz: < -12 0.9 GHz: < -28 **HFWF** 0.9 GHz: < -17 2.0 GHz: < -25	PC
ANT-70	Electrical	Return loss at antenna level	dB	> 15	> 15	C
ANT-80		*Not applicable*				
ANT-90	Electrical	The ideal parabolic reflector a diameter and a focal length	m	D> 12.5 f/D < 0.5	D: 12.5 f/D: 0.38	C
ANT-100	Electrical	The different -3dB beams should overlap at all frequencies.	-			C
ANT-110	Mechanical	The ~~three~~ feed cluster shall be able to fit	-	Inside a Vega C faring.	Can be accommodated	
ANT-120	Mechanical	The mass of the feed cluster shall not exceed	kg	< 15 TBD	41, can be supported	NC
ANT-130	Mechanical	Vibrational Requirement	-	Compatible with a Vega C launch		C
ANT-140	Thermal	The temperature range the feed shall be operational over	ºC	-50 + 70 C TBC		C

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4.2.6 Design Matrix of Compliance

REQ. ID	Type	Parameter	Unit	Requested	Offered	SoC
HFWF-40	Electrical	The feed chain shall be fully operational within the 0.9 GHz to 2 GHz bandwidth.	GHz	0.9 to 2	0.9-2.0	C
HFWF-50	Electrical	Feed polarization	-	Single-circularly polarised (LHCP or RHCP)	LHCP	C
HFWF-60	Electrical	The phase centre location of the feed shall be provided at each frequency within the RF bandwidth. The variation in phase centre must not deviate more than +/- TBD mm over the RF bandwidth	mm	< 130	250	NC
HFWF-70	Electrical	Axial ratio at boresight of the sub-array within the full RF bandwidth in HFWF-40	dB	< 1.5	0.9-1.2 GHz: < 3 1.2-2.0 GHz: < 1.6	NC
HFWF-80	Electrical	Directivity at diagram peak of the sub-array for the frequency band specified in HFWF-40.	dB	> 12	0.9-1.3 GHz: > 9 1.3-2.0 GHz: > 11.75 2.0 GHz: > 15	PC
HFWF-90	Electrical	The sub-array shall comply with the next Field of View (FoV), where all requirements within this document shall be met.	º	• 0º < theta < 50º • 0º < phi < 360º		C
HFWF-100	Electrical	The sub-array shall comply with the following taper values for the frequency band specified in HFWF-40.	dB	<-9 at an elevation angle of 50º <-20 at an elevation angle of 75º <-30 at an elevation angle of 100º	0.9-1.1 GHz: <-8 @50º 1.1-2.0 GHz: < -9 @50º 0.9-1.2 GHz: <-18@75º 1.2-2.0 GHz: < -20 @75º 0.9-2.0 GHz: <-20 @100º	PC
HFWF-120	Electrical	Maximum crosspolarization level of the sub-array for the frequency band specified in HFWF–40.	dB	< -21.5 (TBC)	0.9 GHz: < -11 0.9-1.2 GHz: < -11 1.2-2.0 GHz: < -17	NC
HFWF-125	Electrical	The integration of each sub-array radiation pattern (co-polar and cross-polar) in the conical angular field of view corresponding to [0<θ<50°] and [0<ϕ<360°] of the overall radiation pattern power over the complete frequency range specified for HFWF-40	%	> 97	0.9-1.2 GHz: > 83 1.2-2.0 GHz: > 87	NC

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4.2.6 Design Matrix of Compliance

HFWF-130	Electrical	Return loss of the sub-array in HFWF-40.	dB	> 15 (TBC)	> 15 (Typ)	PC
HFWF-140	Electrical	Maximum insertion loss of the feed chain for the complete frequency band specified in HFWF-40	dB	< 0.3 (TBC)	0.9 GHz : < 1.03 1.5 GHz : < 0.78 2.0 GHz : < 0.62	NC
HFWF-155	Electrical	Phase variation at all frequencies at -10 dB from the peak in HFWF-40 Phase reference is the phase center location at each frequency	ºpp	15	@ 0.9 < 170 @ 1.5 < 70 @ 2.0 < 60	NC
HFWF-165	Mechanical	Feed volume	mm	< 151 (W) x 151 (L) x 1250 (H)	150 (W) x 150 (L) x 460 (H)	C
HFWF-170	Mechanical	Feed cluster arrangement volume constraints	mm	The feed cluster arrangement shall not exceed the following volume constraints when organized as the following figure W<1400mm L< 800 mm H<1250 mm	Can be accommodated	C
HFWF-180	Mechanical	The mass of the feed including Mass Maturity Margin.	kg	< 1 (TBC) Note: Margins shall be declared by the contractor.	0.8	C
HFWF-190	Mechanical	The feeder assembly in hard-mounted conditions shall have their first resonance frequency above:	Hz	TBD	82	C
HFWF-230	Thermal	Operating Design Temperatures: Non-Operating Design Temperatures: Storage temperature range:	ºC	-50 to +70 (TBC) -50 to +70 (TBC) 10 to +30 (TBC)		C
HFWF-240	Mechanical	The feeder array shall be designed to withstand without degradation the sinusoidal environment defined by:		Axis / Frequency (Hz) / level (g) / Sweep rate All axes / 5 - 20 / Max shaker amplitude / 20 - 100 / 21 g / 2 oct/mn		C
HFWF-250	Mechanical	The feeder array shall be designed to withstand without degradation the random environment defined by:		Perpendicular to mounting plane Axial (Z-axis): 20 - 80 / + 3 dB/oct 80 - 200 / 0.5 g^2/Hz 200 - 400 / 0.3 g^2/Hz 400 - 2000 / -6 dB/oct g rms / 15.4 Parallel to mounting plane Lateral (X- and Y-axis): 20 - 80 / + 4 dB/oct 80 - 1000 / 0.1 g^2/Hz 1000 - 2000 / -3 dB/oct g rms / 12.8		C
HFWF-260	Mechanical	The feeder array shall be designed to withstand without degradation the following shock environment applied independently at each axis:		Frequency / 100 Hz / 2kHz / 10kHz Shock response spectrum (Q=10) at unit interface / 20g / 2000g / 2000g		C

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4.2.6 Design Matrix of Compliance

REQ. ID	Type	Parameter	Unit	Requested	Offered	SoC
LFWF-40	Electrical	The feed chain shall be fully operational within the 0.4 GHz to 0.9 GHz bandwidth.	GHz	0.4 to 0.9	0.4-0.9	C
LFWF-50	Electrical	Feed polarization	-	Single-circularly polarised (LHCP or RHCP)	LHCP	C
LFWF-60	Electrical	The phase centre location of the feed shall be provided at each frequency within the RF bandwidth. Maximum variation over the RF bandwidth.	mm	< 280	453	NC
LFWF-70	Electrical	Axial ratio at boresight of the sub-array within the full RF bandwidth in LFWF-40	dB	< 1.5	0.4-0.6 GHz: < 3 0.6-0.9 GHz: < 0.5	PC
LFWF-80	Electrical	Directivity minimum level at diagram peak of the sub-array for the frequency band specified in LFWF-40.	dB	> 10.6	0.4-0.6 GHz: > 11 0.6-0.8 GHz: > 12 0.8-0.9 GHz: > 15	C
LFWF-90	Electrical	The sub-array shall comply with the next Field of View (FoV), where all requirements within this document shall be met.	º	• 0º < theta < 50º • 0º < phi < 360º		C
LFWF-100	Electrical	The sub-array shall comply with the following taper values for the frequency band specified in LFWF-40.	dB	<-9 dB at an elevation angle of 50º <-20dB at an elevation angle of 75º <-30dB at an elevation angle of 100º	0.4-0.5 GHz: <-9 @50º 0.5-0.9 GHz: < -15 @50º 0.4-0.5 GHz: <-15@75º 0.5-0.9 GHz: < -20 @75º 0.4-0.9 GHz: <-20 @100º	PC
LFWF-120	Electrical	Maximum level in crosspolarization with respect to the peak in main polarization of the sub-array for the frequency band specified in LFWF– 40.	dB	< -21.5 (TBC)	0.4 GHz: < -11 0.5-0.6 GHz: < -12.5 0.6-0.7 GHz: < -15 0.7-0.8 GHz: < -20 0.8-0.9 GHz: < -25	NC

4.2.6 Design Matrix of Compliance

LFWF-125	Electrical	The integration of each sub-array radiation pattern (co-polar and cross-polar) in the conical angular field of view corresponding to [0<θ<50°] and [0<ϕ<360°] shall exceed 95% of the overall radiation pattern power over the complete frequency range specified for LFWF-40	%	> 95	0.4-0.5 GHz: > 82 0.5-0.9 GHz: > 91	NC
LFWF-130	Electrical	Return loss of the sub-array at the output port.	dB	> 15	15	C
LFWF-140	Electrical	Maximum insertion loss of the feed chain for the complete frequency band specified in LFWF-40	dB	< 0.4 (TBC)	0.4 GHz : < 0.82 0.7 GHz : < 0.54 0.9 GHz : < 0.42	NC
LFWF-155	Electrical	Phase variation at all frequencies at -10 dB from the peak in LFWF-40 Phase reference is the phase center location at each frequency	ºpp	15	@ 0.4 < 50 @ 0.7 < 38 @ 0.9 < 27	NC
LFWF-165	Mechanical	Feed chain volume	mm	< 340 (W) x 340 (L) x 1250 (H)	320 (W) x 320 (L) x 1000 (H)	C
LFWF-170	Mechanical	Feed cluster arrangement volume constraints	mm	W<1650 L< 514 H<1250	Fits within the volume	C
LFWF-180	Mechanical	Mass of the feed chain, including Mass Maturity Margin. Note: Margins shall be declared by the contractor.	Kg	< 1.5	< 2.5	NC
LFWF-190	Mechanical	First resonance frequency of the feeder assembly in hard-mounted conditions	Hz	> 150	will not be analyzed	NA

4. PROJECT OVERVIEW
4.3. Feed and sub-array manufacturing

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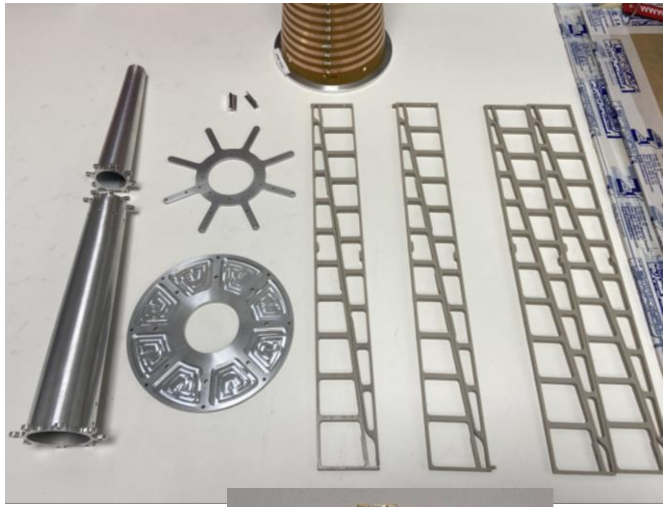
- → Manufacturing of <u>3 x HFWF feeds</u> *(SN103, SN104, SN105)*
- → Manufacturing of <u>4 x HFWF dummies</u> used for embeeded configuration *(SN106)*

Spiral and bow-tie

Balun



Structure

4. PROJECT OVERVIEW
4.3. Feed and sub-array manufacturing

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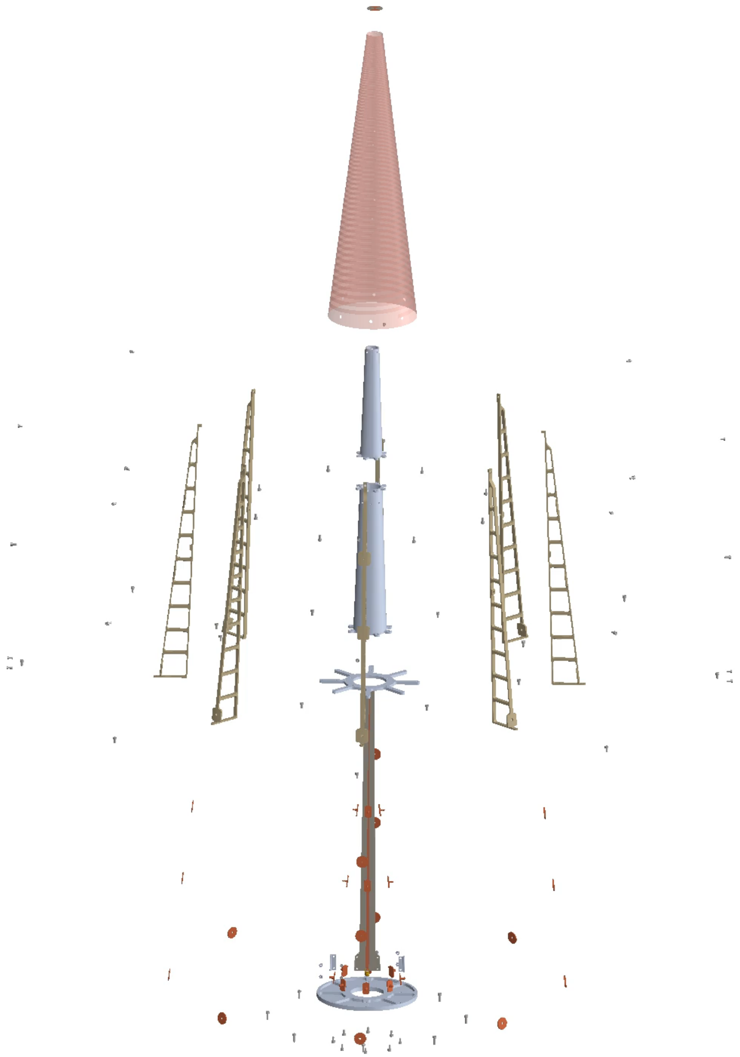

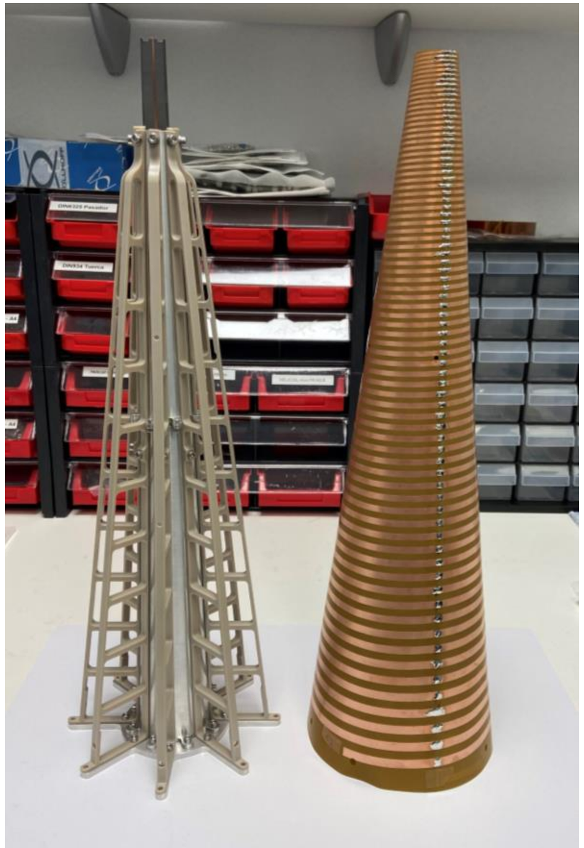

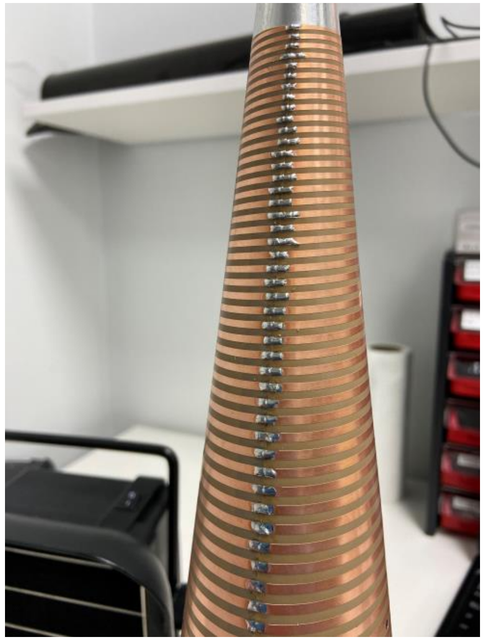

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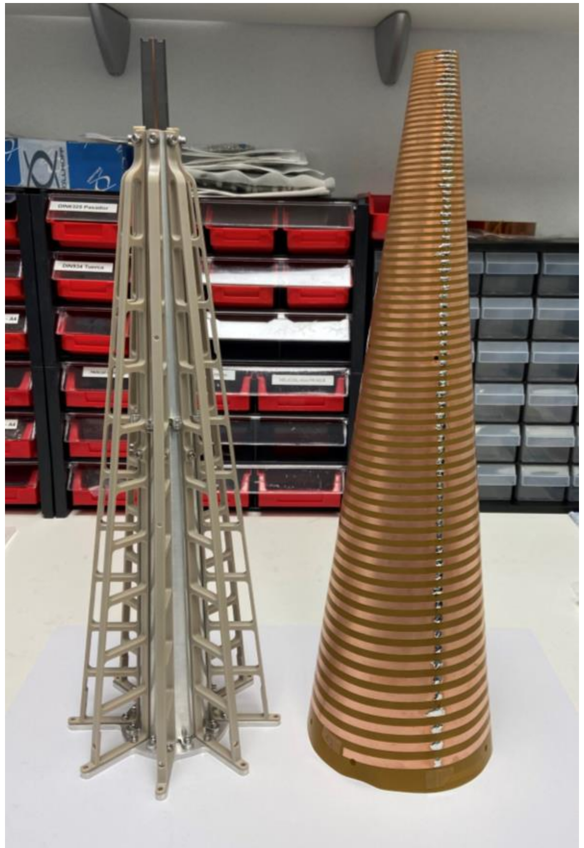
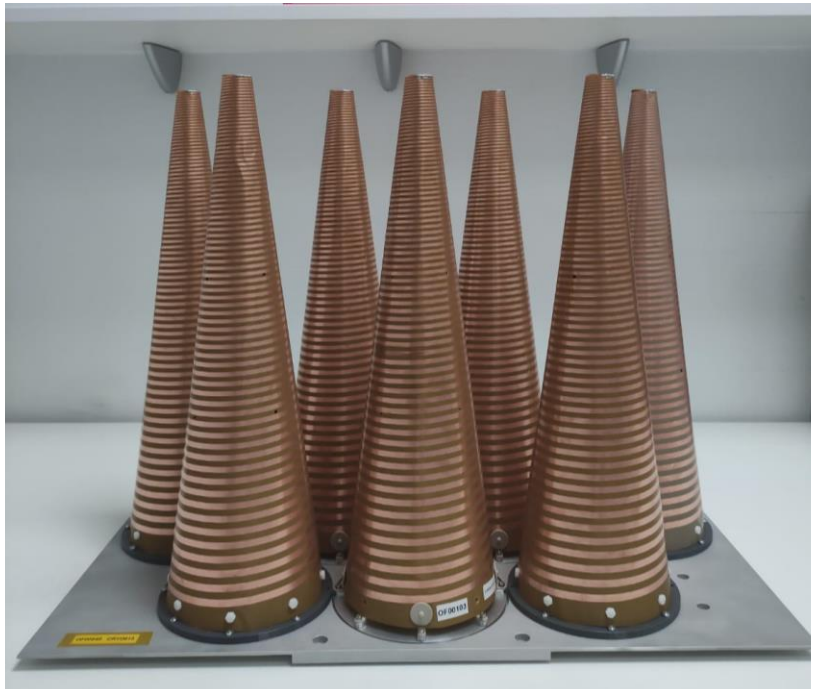
ASSEMBLY OF FEEDS



SUB-ARRAY EMBEDDED CONFIGURATION



4.4. Feed and sub-array RF tests

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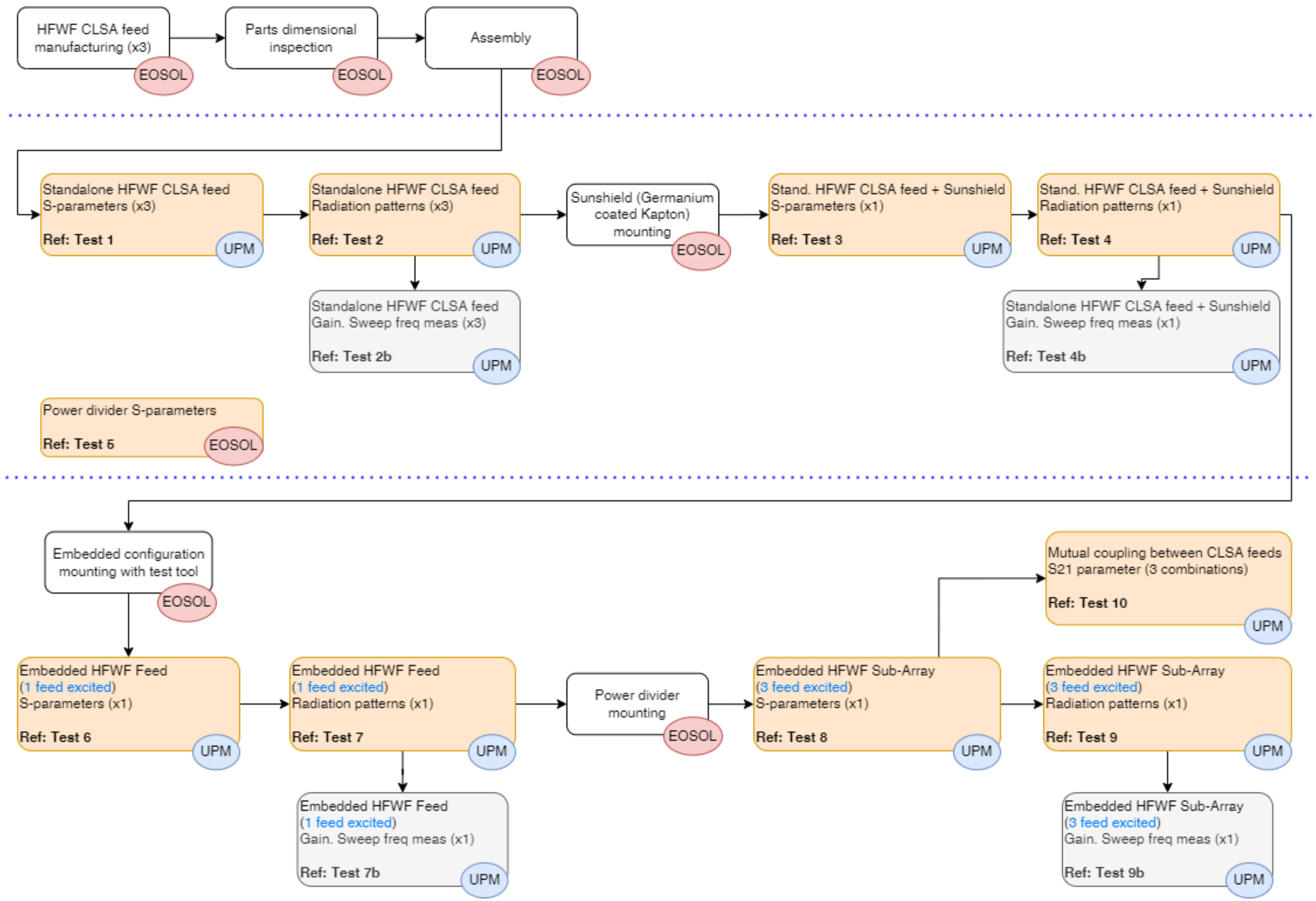

Name	Test	Qty	Executor
HFWF-CLSA	**Test 1. Standalone HFWF CLSA feed S-parameters** Return loss	3	EOSOL/ UPM
HFWF-CLSA	**Test 2. Standalone HFWF CLSA feed RP** Radiation patterns, phase centre variation, gain measurement	3	UPM
HFWF-CLSA	**Test 2b. Standalone HFWF CLSA feed Gain** Gain. Sweep frequency measurement	3	UPM
HFWF-CLSA	**Test 3. Standalone HFWF CLSA feed + sunshield S-param** Return loss	1	UPM
HFWF-CLSA	**Test 4. Standalone HFWF CLSA feed + sunshield RP** Radiation patterns, phase centre variation, gain measurement	1	UPM
HFWF-CLSA	**Test 4b. Standalone HFWF CLSA feed + sunshield Gain** Gain. Sweep frequency measurement	1	UPM
POWER DIVIDER 1:3	**Test 5. Power Divider S-parameters** Return loss, Insertion loss	1	EOSOL/ UPM
HFWF-CLSA	**Test 6. Embedded HFWF feed S-parameters.** 1 feed of 3 excited Return loss	1	UPM
HFWF-CLSA	**Test 7. Embedded HFWF feed RP.** 1 feed of 3 excited Radiation patterns, phase centre variation, gain measurement	1	UPM
HFWF-CLSA	**Test 7b. Embedded HFWF feed Gain.** 1 feed of 3 excited Gain. Sweep frequency measurement	1	UPM
HFWF-SUB-ARRAY	**Test 8. Embedded HFWF sub-array S-parameters.** 3 feeds excited with power divider Return loss	1	UPM
HFWF-SUB-ARRAY	**Test 9. Embedded HFWF sub-array RP.** 3 feeds excited with power divider Radiation patterns, phase centre variation, gain measurement	1	UPM
HFWF-SUB-ARRAY	**Test 9b. Embedded HFWF sub-array Gain.** 3 feeds excited with Gain. Sweep frequency measurement	1	UPM
HFWF-SUB-ARRAY	**Test 10. Mutual coupling between CLSA feeds. S parameters** Coupling between pair of feeds	1	UPM

TEST 1 & 2: STANDALONE HFWF CLSA

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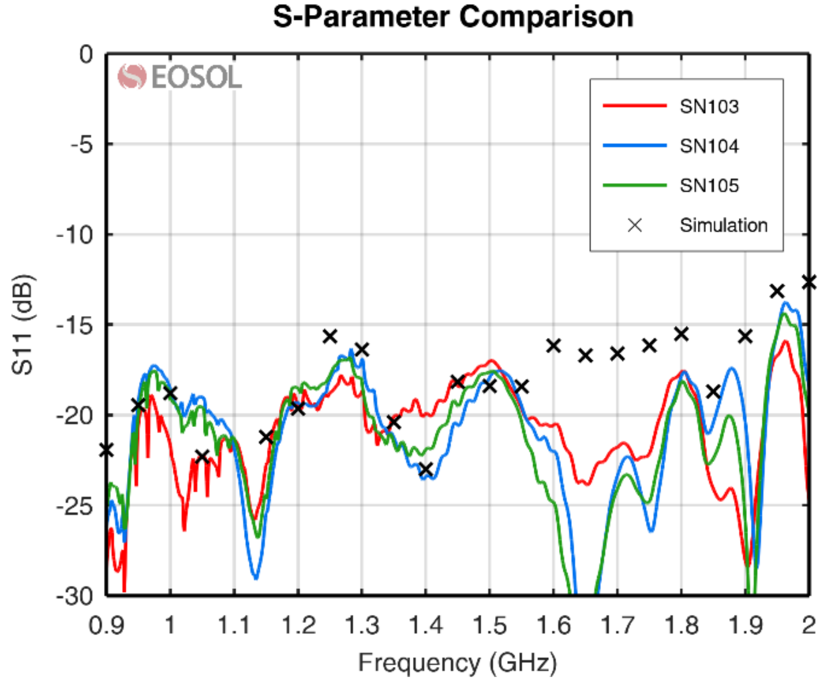
Test set-up configuration image of SN103



The measured **S11 parameter** results are typically under -15 dB in the complete frequency band.

4. PROJECT OVERVIEW

4.4. Feed and sub-array RF tests

TEST 1 & 2: STANDALONE HFWF CLSA

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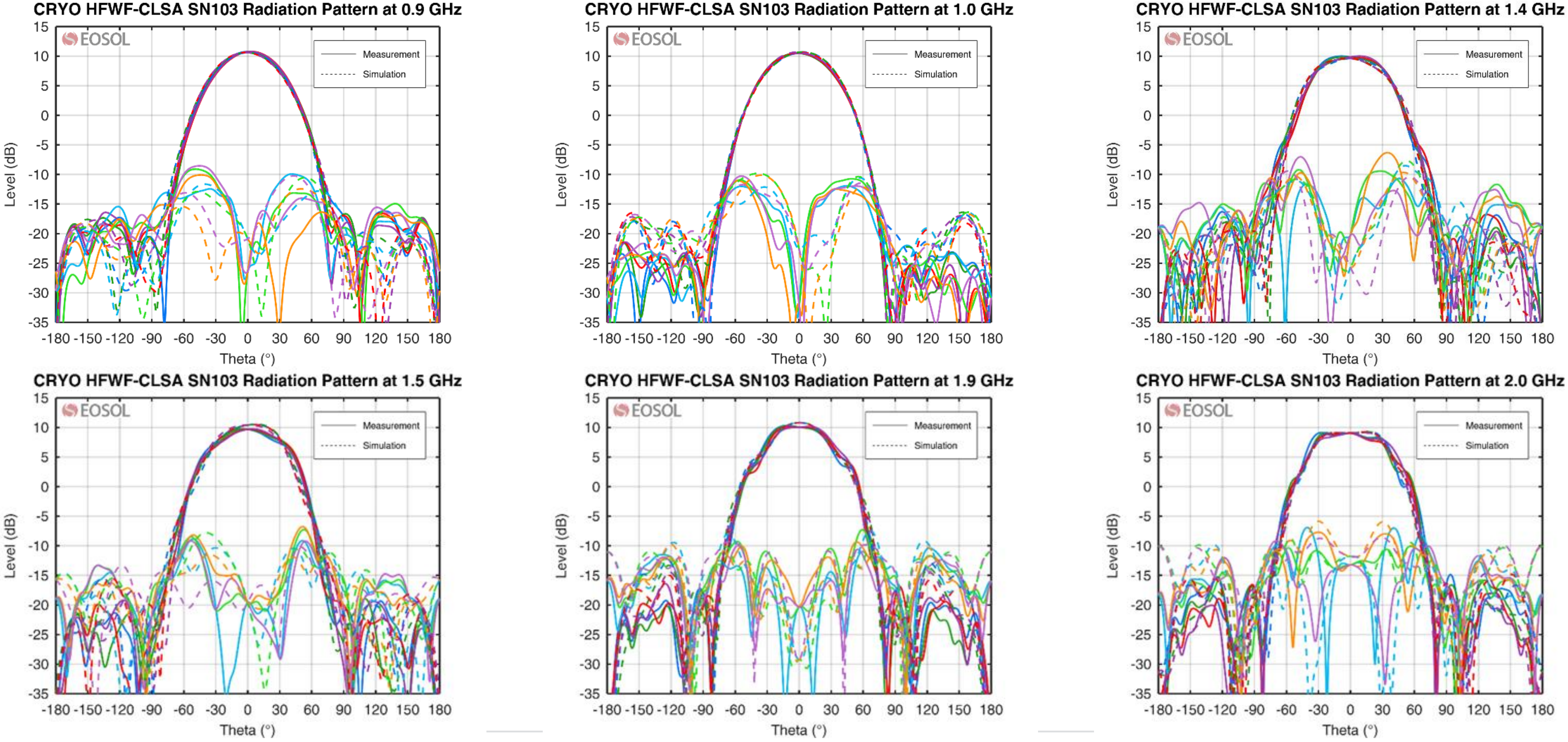

4. PROJECT OVERVIEW
4.4. Feed and sub-array RF tests

TEST 1 & 2: STANDALONE HFWF CLSA

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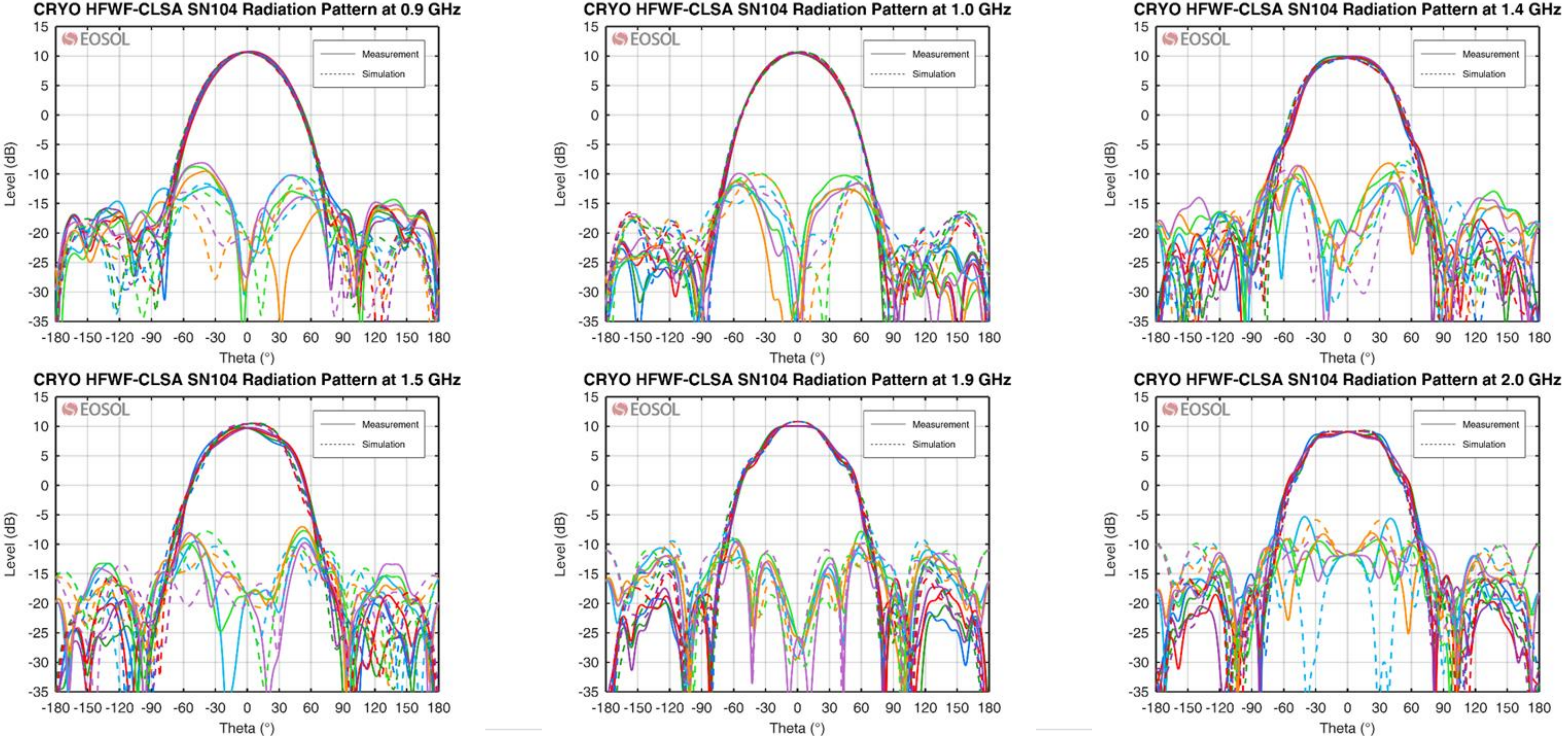

4. PROJECT OVERVIEW
4.4. Feed and sub-array RF tests

TEST 1 & 2: STANDALONE HFWF CLSA

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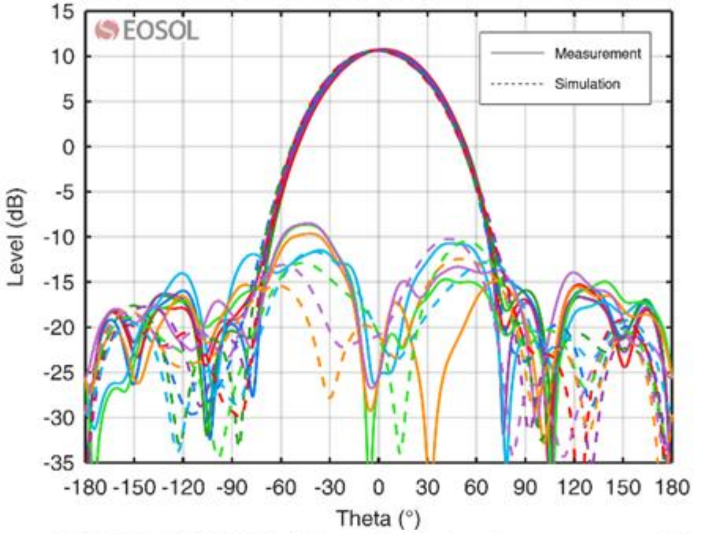
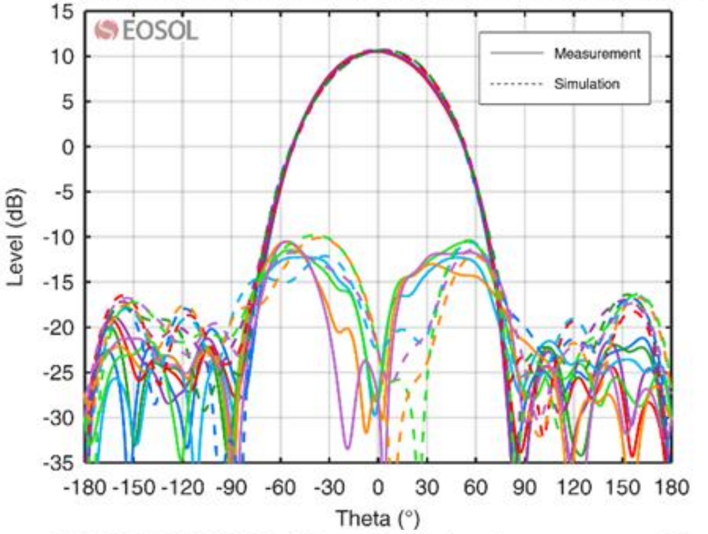
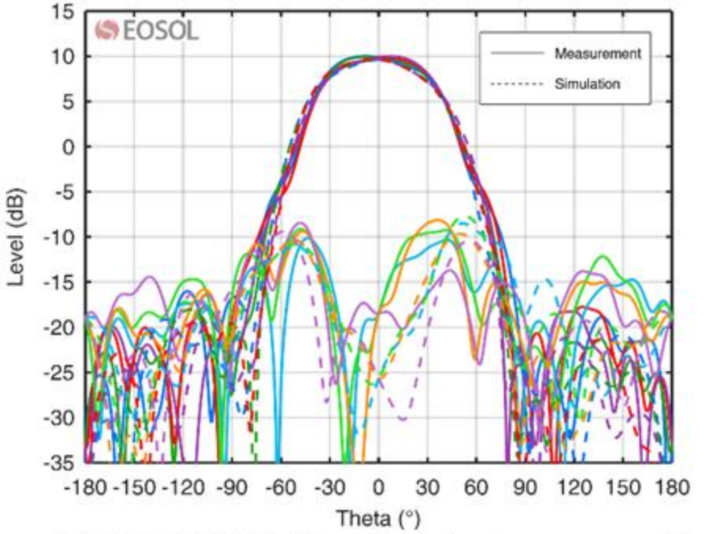
CRYO HFWF-CLSA SN105 Radiation Pattern at 0.9 GHz



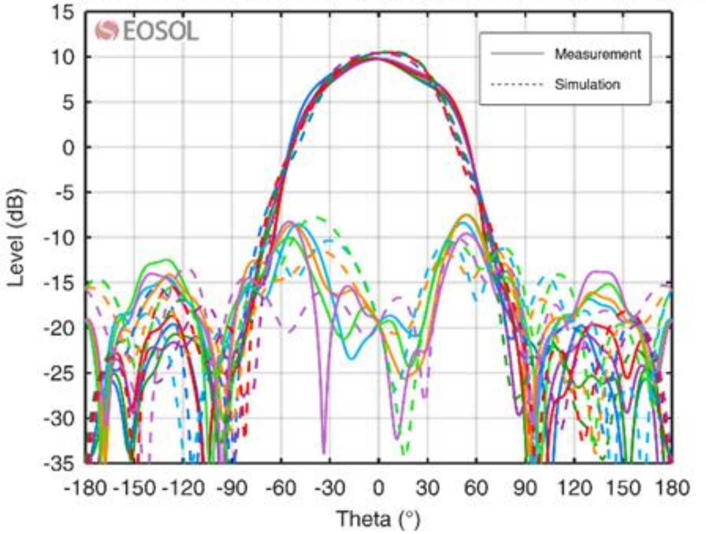
CRYO HFWF-CLSA SN105 Radiation Pattern at 1.0 GHz



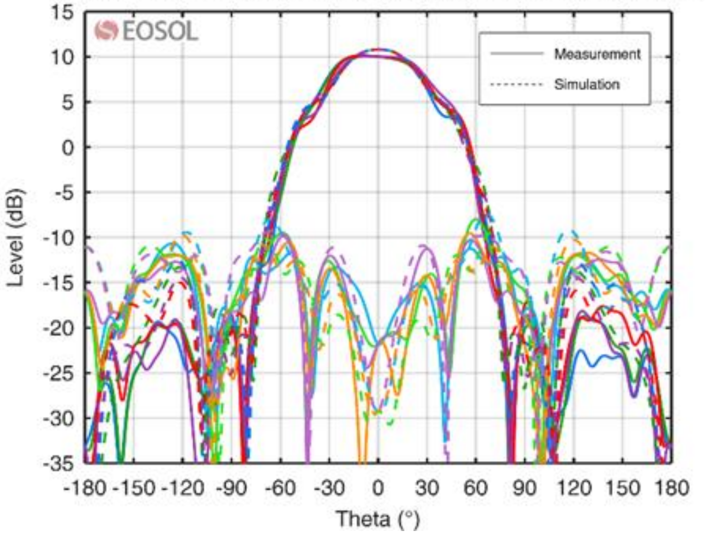
CRYO HFWF-CLSA SN105 Radiation Pattern at 1.4 GHz



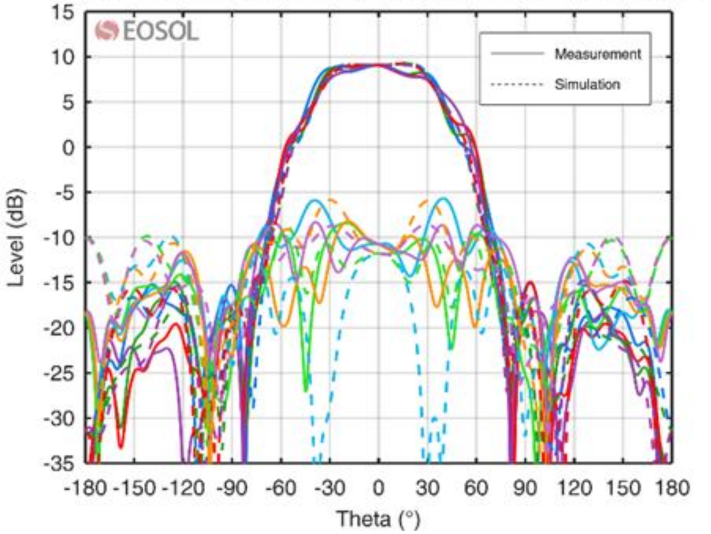
CRYO HFWF-CLSA SN105 Radiation Pattern at 1.5 GHz



CRYO HFWF-CLSA SN105 Radiation Pattern at 1.9 GHz



CRYO HFWF-CLSA SN105 Radiation Pattern at 2.0 GHz



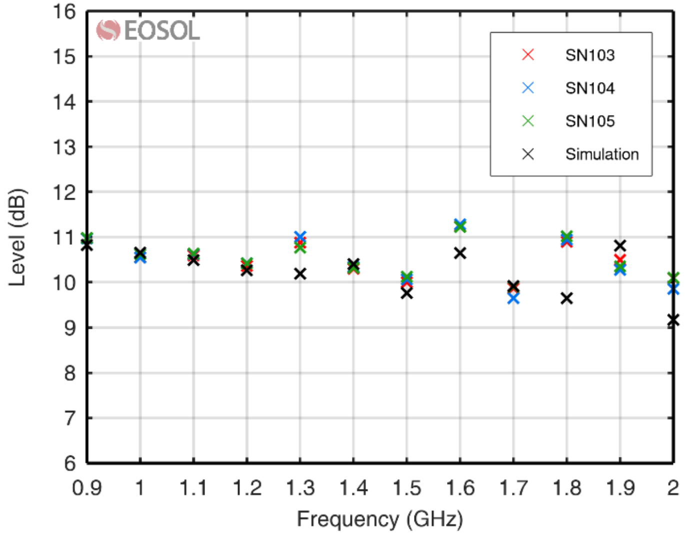
4. PROJECT OVERVIEW

4.4. Feed and sub-array RF tests

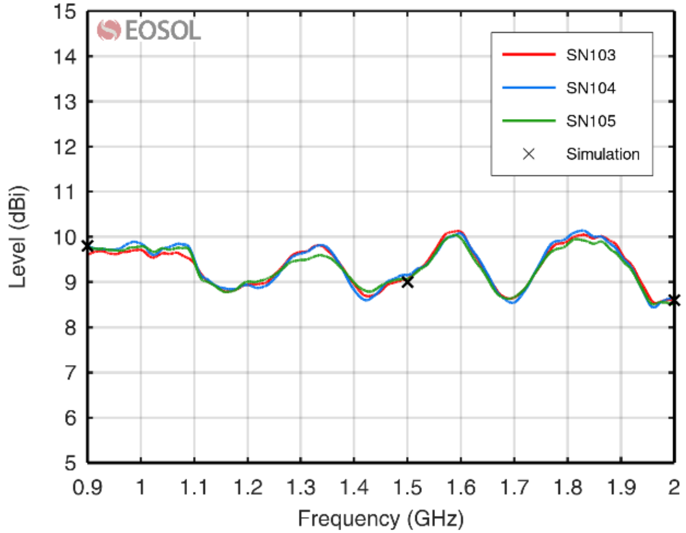
TEST 1 & 2: STANDALONE HFWF CLSA

AIRBUS EOSOL

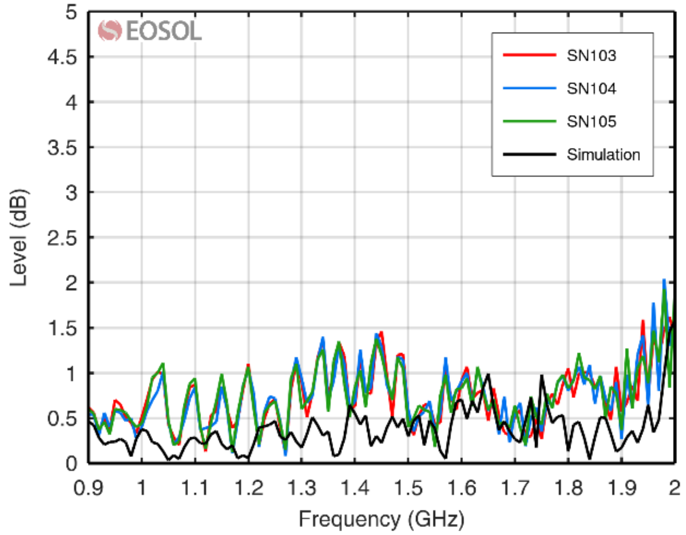
HFWF-CLSA Directivity Comparison



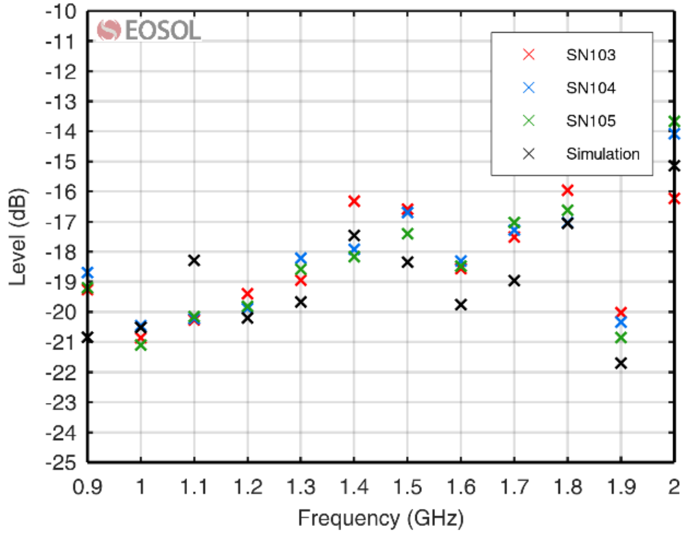
HFWF-CLSA Gain Comparison



HFWF-CLSA Axial Ratio Comparison



HFWF-CLSA Normalized XP within FoV



- Precise **directivity** values.
- The measured **gain** is very similar between the 3 feeds and simulation which proves a precise manufacturing, assembly and a precise simulation.
- The measured **axial ratio** is under 1.5 dB from 0.9 to 1.95GHz and lower than 2dB from 1.95GHz to 2.0 GHz.
- The measured normalized **maximum crosspolar level** within the FoV is lower than -16 dB over the complete frequency band except at 2 GHz where it is increased up to -13.5 dB.

TEST 1 & 2: STANDALONE HFWF CLSA

AIRBUS EOSOL

- Precise directivity, gain and insertion losses simulation results.
- Model SN103 has some extra insertion losses around 0.15 dB at 0.9 GHz.

Directivity, gain and insertion loss table of SN103

Parameter	Origin	0.9 GHz	1.5 GHz	2.0 GHz
Directivity (dB)	Simulated value	10.83	9.78	9.22
	Measured SN103	10.75	9.7	9.05
Gain (dBi)	Simulated value	9.8	9	8.6
	Measured SN103	9.59	9.07	8.6
Insertion Loss (dB)	Estimated value by simulation	1.03	0.78	0.62
	Estimated value from SN103	1.15	0.62	0.46

Directivity, gain and insertion loss table of SN104

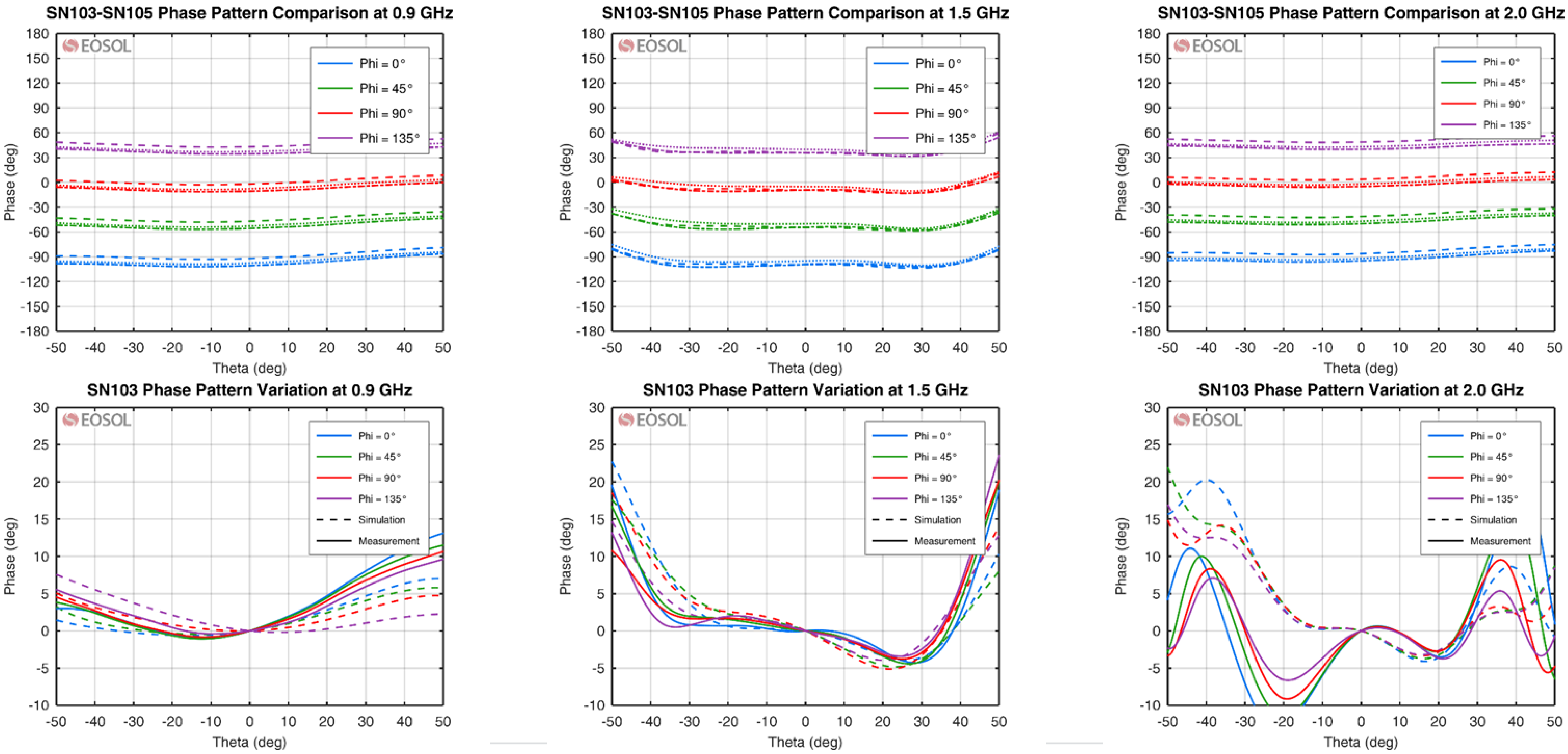
Parameter	Origin	0.9 GHz	1.5 GHz	2.0 GHz
Directivity (dB)	Simulated value	10.83	9.78	9.22
	Measured SN104	10.72	9.71	9.08
Gain (dBi)	Simulated value	9.8	9	8.6
	Measured SN104	9.81	9.16	8.66
Insertion Loss (dB)	Estimated value by simulation	1.03	0.78	0.62
	Estimated value from SN104	0.91	0.56	0.42

Directivity, gain and insertion loss table of SN105

Parameter	Origin	0.9 GHz	1.5 GHz	2.0 GHz
Directivity (dB)	Simulated value	10.83	9.78	9.22
	Measured SN105	10.72	9.76	9.08
Gain (dBi)	Simulated value	9.8	9	8.6
	Measured SN105	9.79	9.08	8.51
Insertion Loss (dB)	Estimated value by simulation	1.03	0.78	0.62
	Estimated value from SN105	0.94	0.68	0.57

TEST 1 & 2: STANDALONE HFWF CLSA

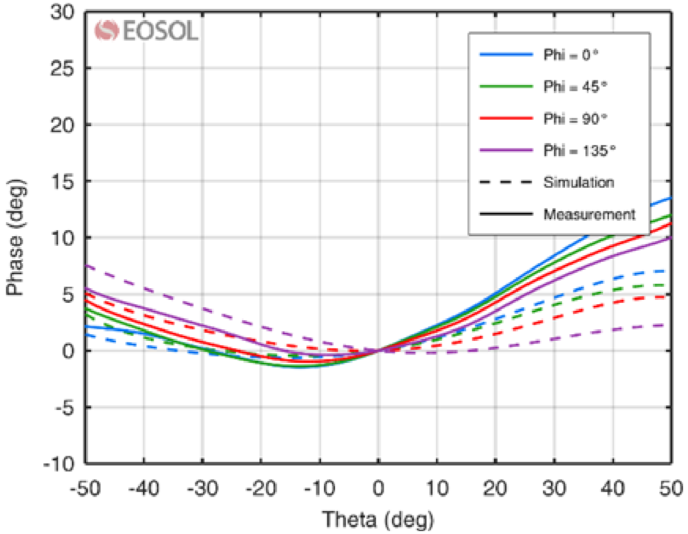
AIRBUS EOSOL



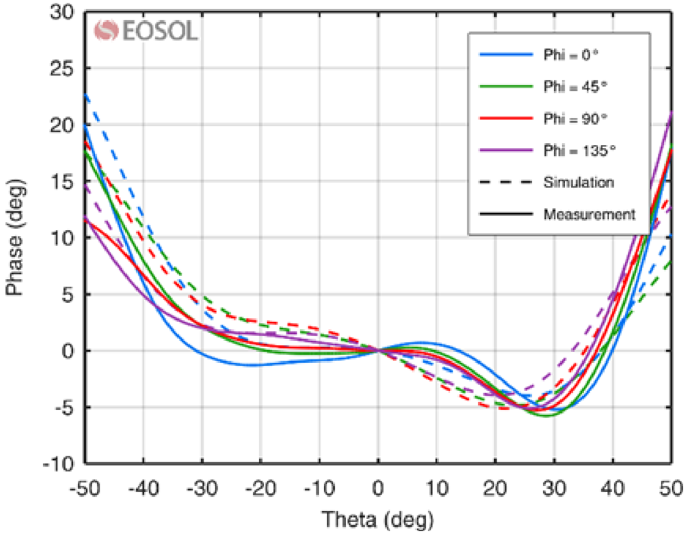
TEST 1 & 2: STANDALONE HFWF CLSA

AIRBUS EOSOL

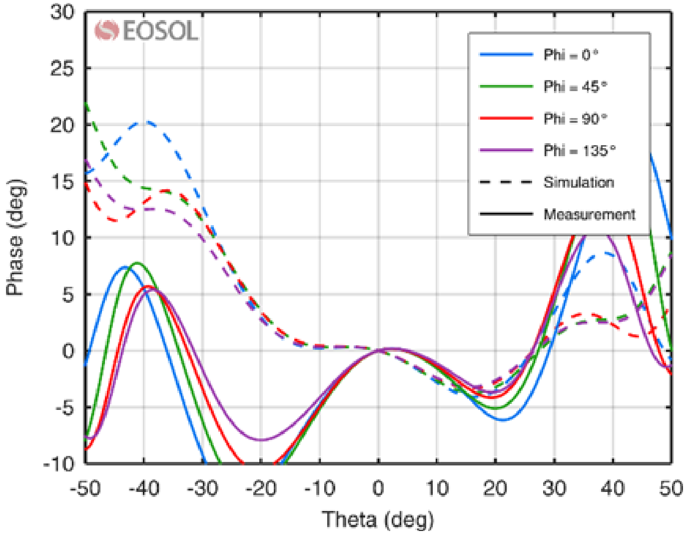
SN104 Phase Pattern Variation at 0.9 GHz



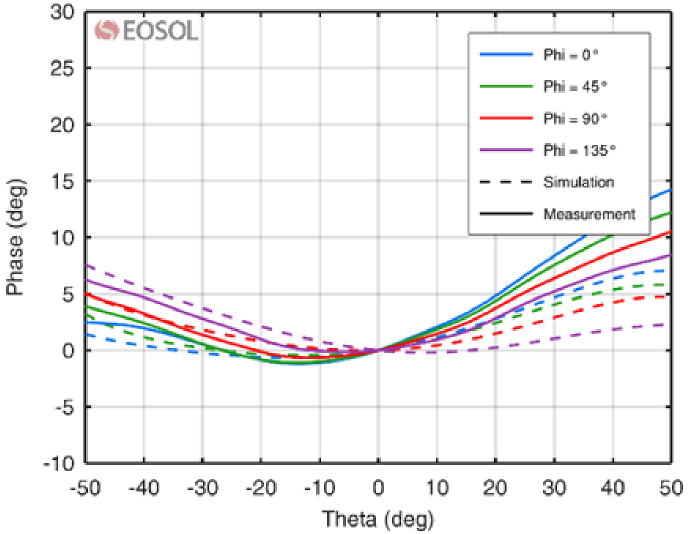
SN104 Phase Pattern Variation at 1.5 GHz



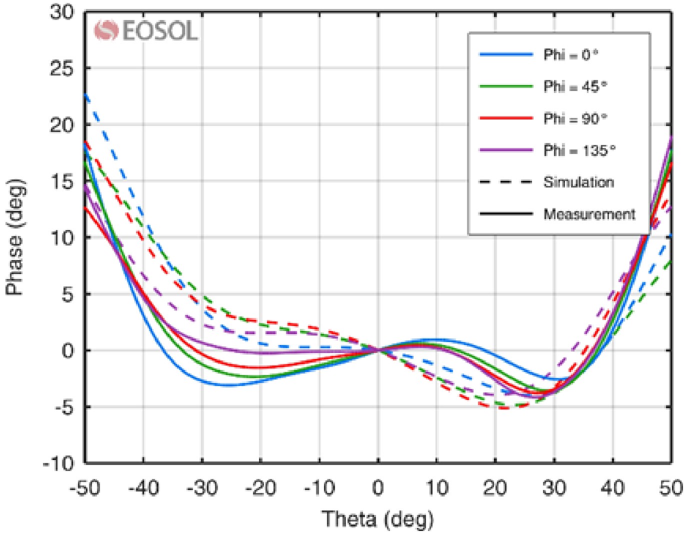
SN104 Phase Pattern Variation at 2.0 GHz



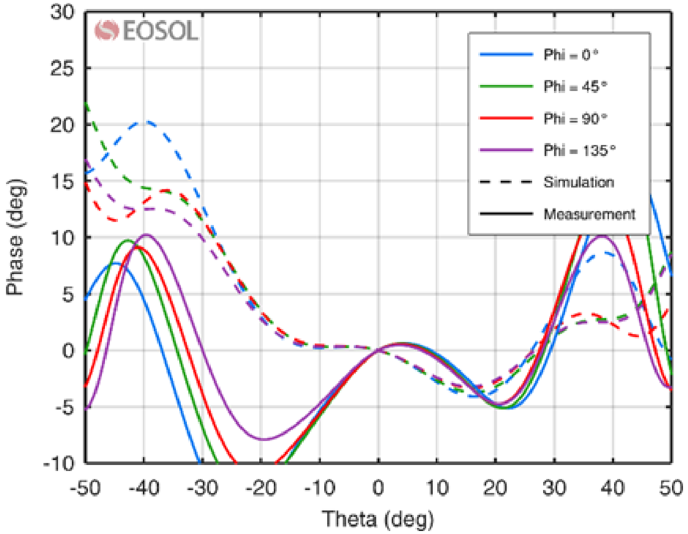
SN105 Phase Pattern Variation at 0.9 GHz



SN105 Phase Pattern Variation at 1.5 GHz



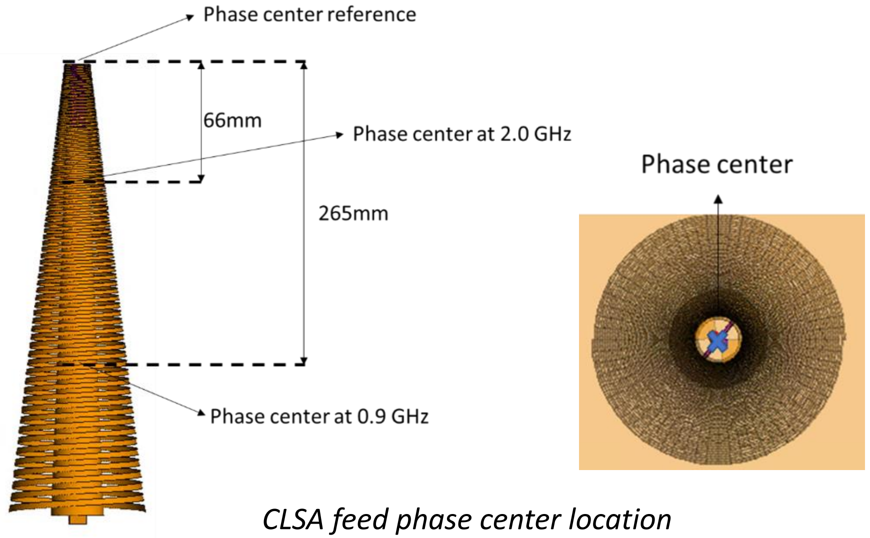
SN105 Phase Pattern Variation at 2.0 GHz



Regarding to the **phase radiation patterns:**

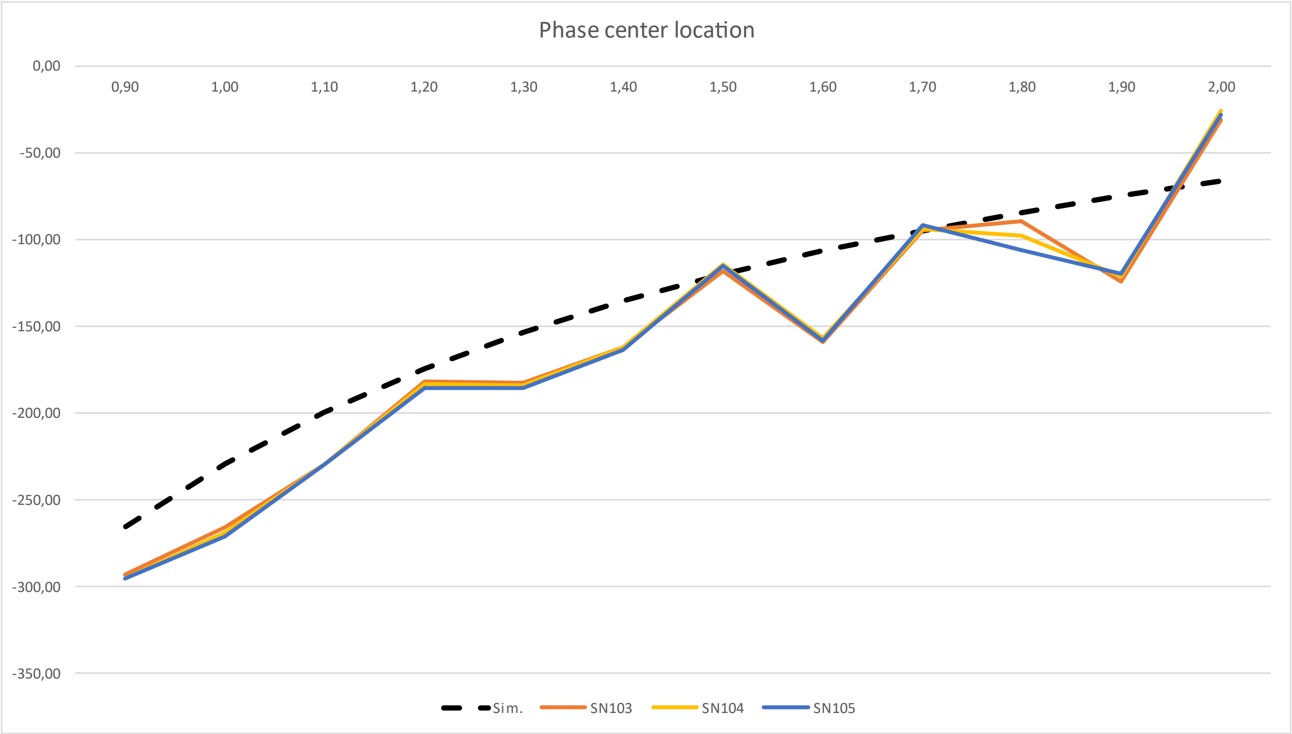
- The manufactured feeds perform as expected from simulation.
- It can be seen that the phase matches among the three different tested models with **minimum variations**.
- Maximum variations are 7º at 0.9 GHz, 5º at 1.5GHz and 10º at 2GHz, which correspond with phase center differences of 6.5 mm, 3mm and 4 mm respectively considering the frequency.

TEST 1 & 2: STANDALONE HFWF CLSA



CLSA feed phase center location reference figures

Simulated and measured phase center location of the manufactured feeds



- The support structure affects the radiation and its phase center location.
- The phase center in the manufactured model is very similar to the simulated model.

CONCLUSIONS OF TEST 1 & 2

- The three tested feeds perform very **similar** among them with **results** very similar to the simulation ones.
- The simulation model is very **accurate** and the manufacturing and assembly precision is enough.
- The only parameter that is quite different is the **maximum phase center variation** due to the inconsistent phase center results from the tests and the simulation.

Standalone HFWF feed RF performance summary

Parameter	Unit	Simulation	SN103	SN104	SN105
Frequency band	GHz	0.9-2.0	0.9-2.0	0.9-2.0	0.9-2.0
Directivity at theta=0	dB	> 9.15	> 9.8	> 9.6	> 9.8
Realised gain at theta=0	dB	> 8.6	> 8.6	> 8.6	> 8.6
Return loss	dB	> 15	> 16	> 14	> 14
Max XP within FoV	dB	< -15	< -16	< -14	< -14
Axial ratio at theta=0 from 0.9 – 1.9 GHz	dB	< 1	< 1.5	< 1.5	< 1.5
Axial ratio at theta=0 from 1.9 – 2.0 GHz	dB	< 1.5	< 1.6	< 2	< 1.9
Max phase centre variation	mm	200	262	270	268

TEST 3 & 4: STANDALONE HFWF CLSA - SUNSHIELD

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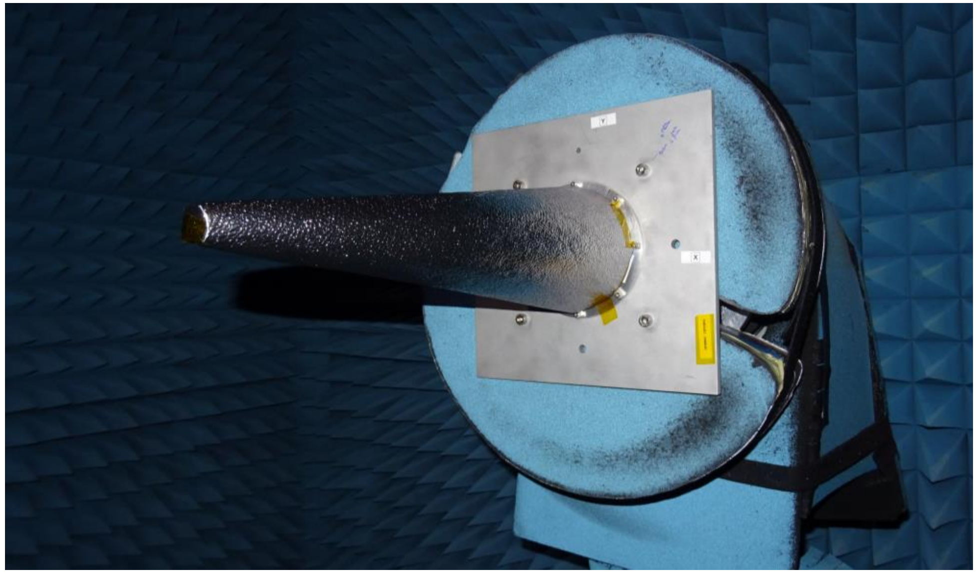
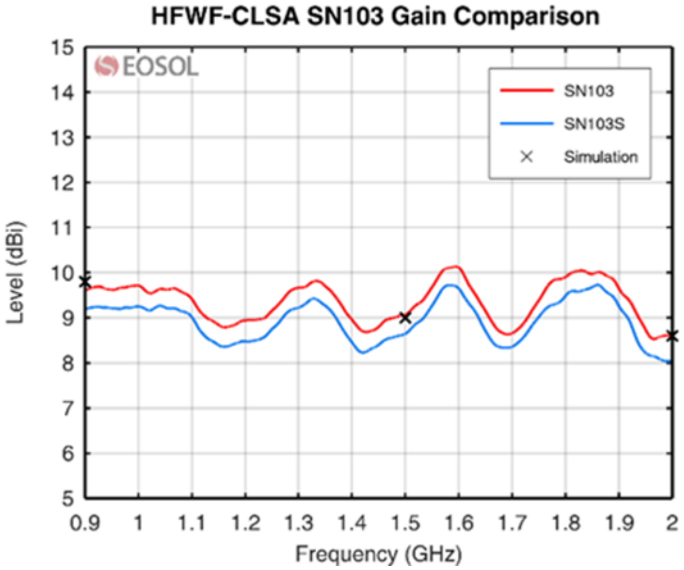
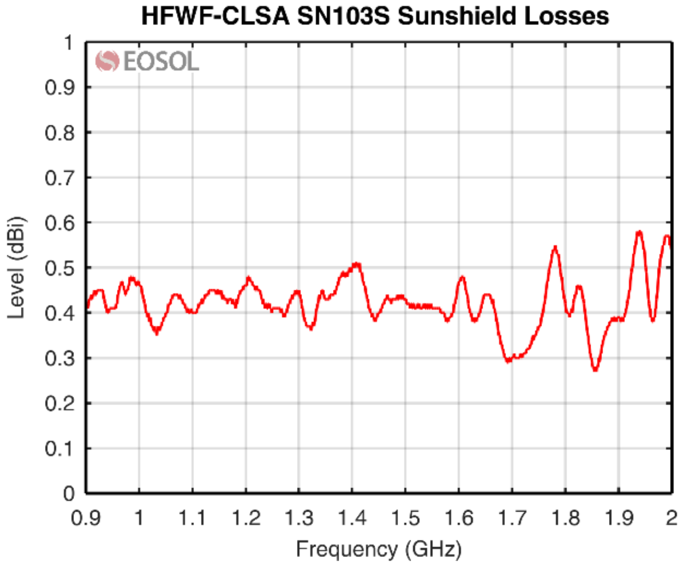


Test set-up configuration image of SN103S (SN103 with sunshield)

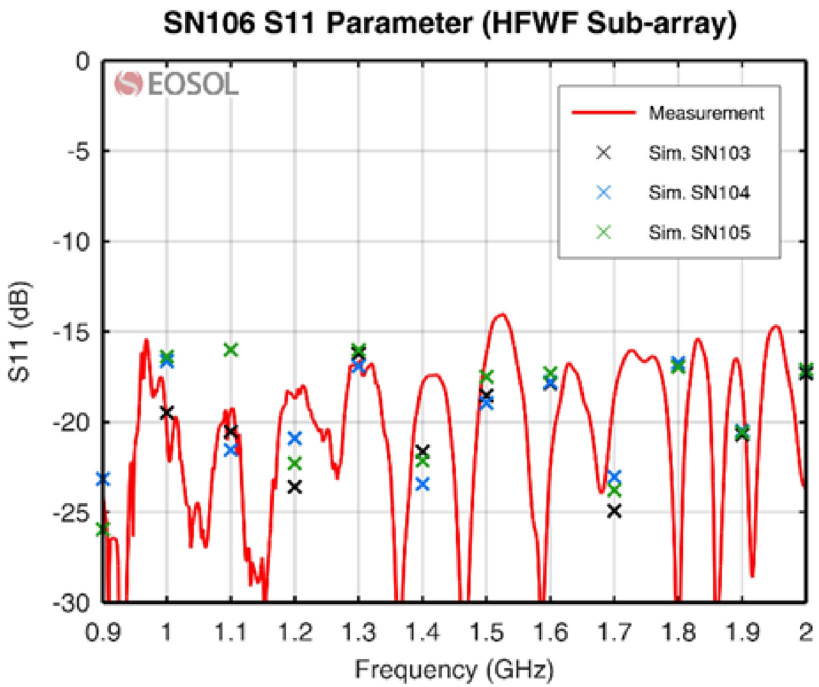




- It can be concluded that the **sunshield is almost invisible** to this feed **except** for the **extra losses** and its impact in the gain parameter. The sunshield introduces around 0.4 – 0.6 dB of losses.

TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY

Test set-up configuration image of SN106 (Embedded sub-array)



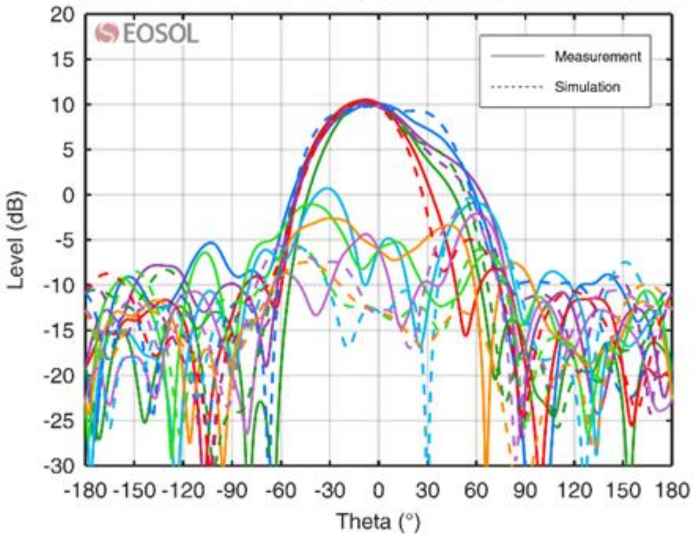
The measured **S11 parameter** results are under -15 dB in the complete frequency band except at 1.52 GHz where it increases to -14 dB.

4. PROJECT OVERVIEW

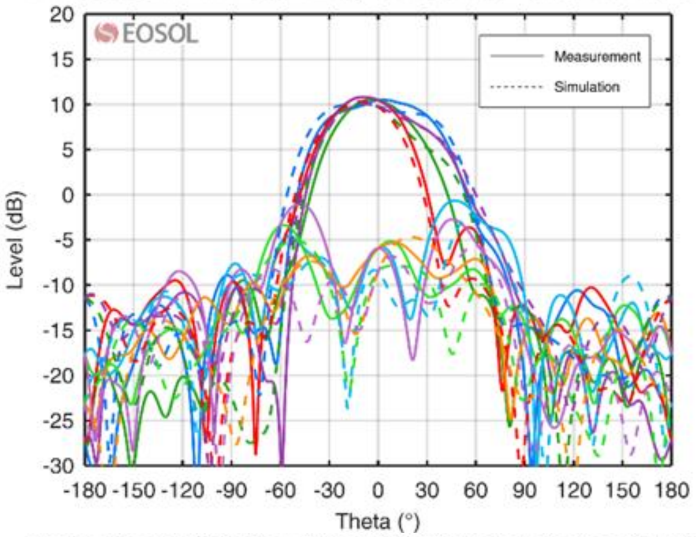
4.4. Feed and sub-array RF tests

TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY

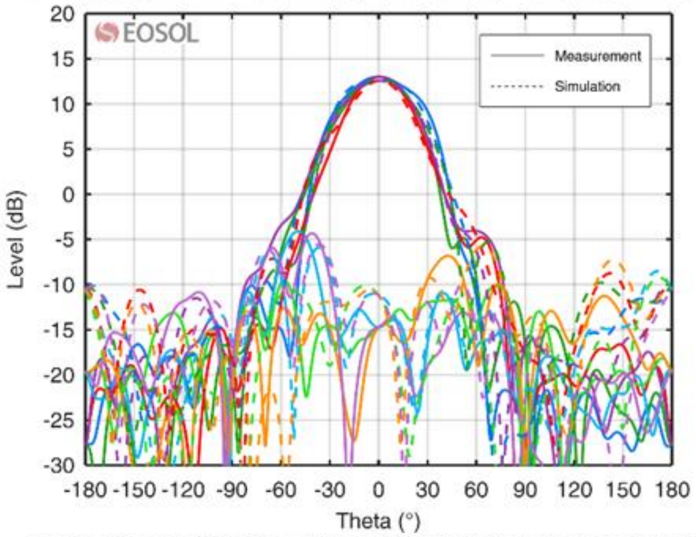
Embedded HFWF-Sub-Array SN106 Rad Pattern at 0.9 GHz



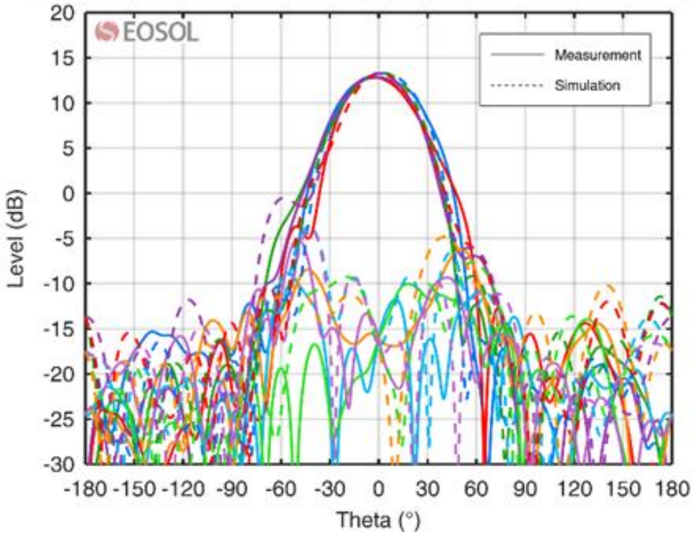
Embedded HFWF-Sub-Array SN106 Rad Pattern at 1.0 GHz



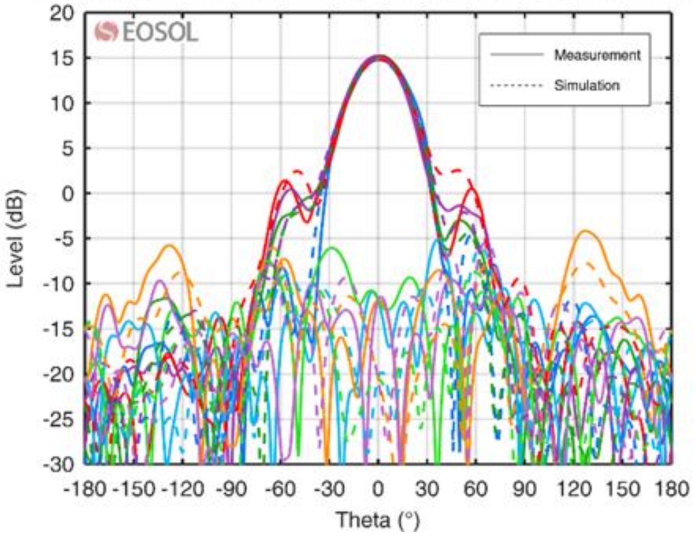
Embedded HFWF-Sub-Array SN106 Rad Pattern at 1.4 GHz



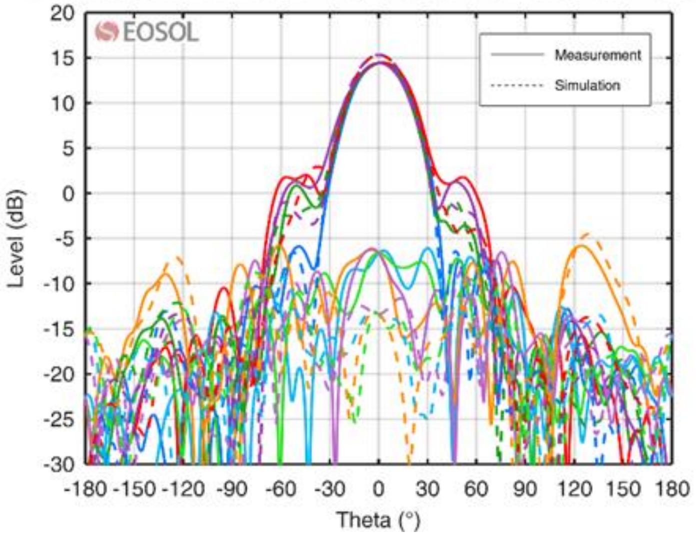
Embedded HFWF-Sub-Array SN106 Rad Pattern at 1.5 GHz



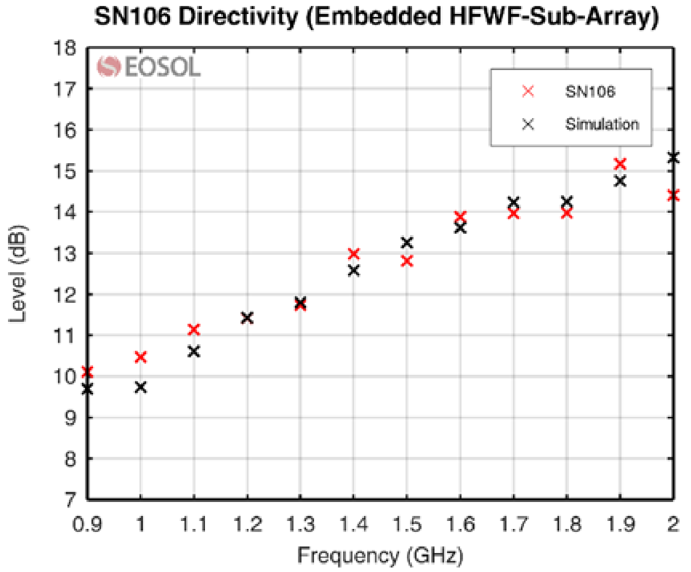
Embedded HFWF-Sub-Array SN106 Rad Pattern at 1.9 GHz

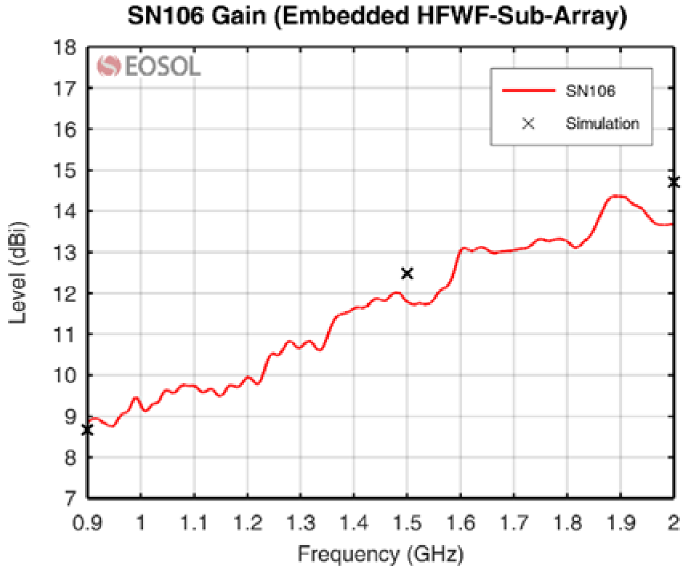


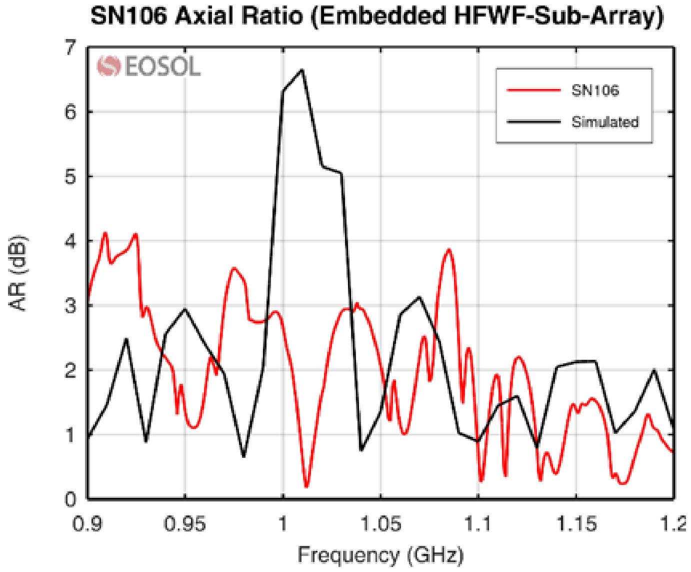
Embedded HFWF-Sub-Array SN106 Rad Pattern at 2.0 GHz

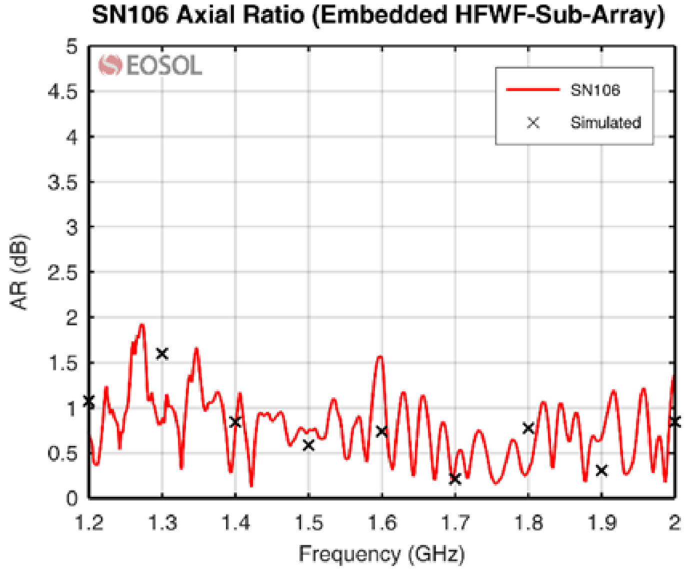


TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY









- The **directivity** in the measured model is **lower** than the simulated one, by up to 1 dB depending on the frequency.
- The **gain** is not very similar between the measurement and the simulation, difference increases as frequency does.
- The **axial ratio** ripple increases the axial ratio around 1 - 2 dB from the simulation, especially at the lowest frequencies.
- The simulated **crosspolar level** matches the measured which increases around 2 or 3 dB.

TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY

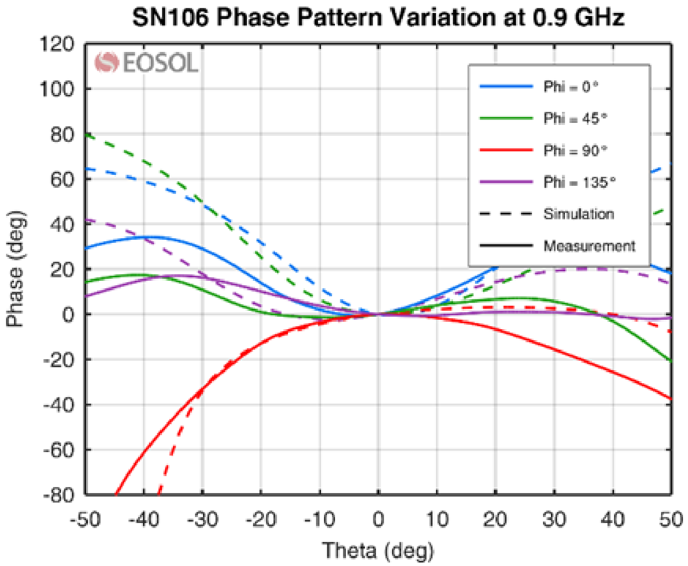
EOSOL

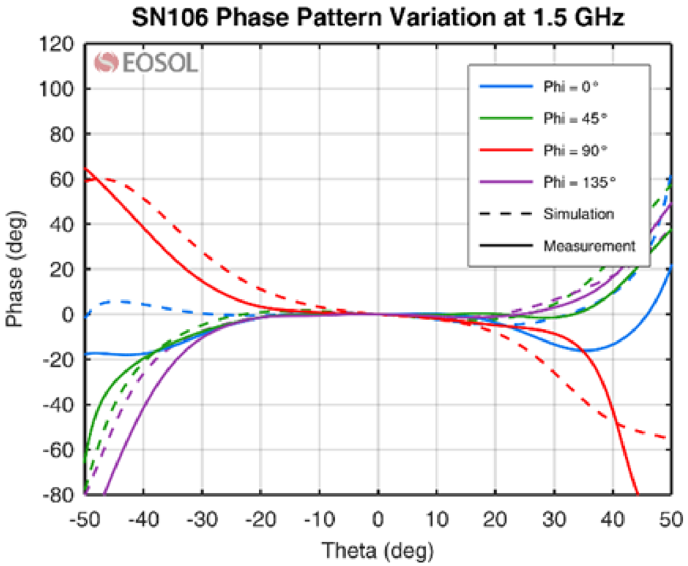
- Estimated **insertion losses** of the measured array are around 0.3 dB higher than the estimation by simulation.
- Due to the limited simulation resources to perform a complete detailed embedded sub-array simulation, the simulated model is simplified and differences may appear from it.

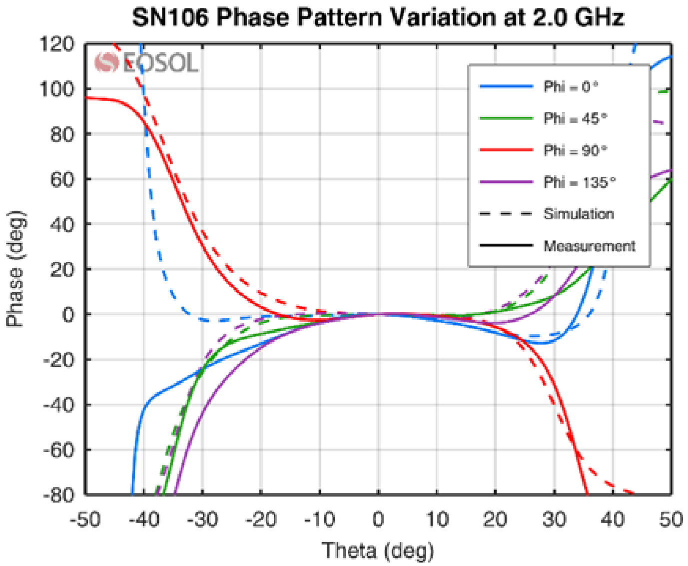
(*) The simulated gain is an approximation: the simulated directivity minus the estimated insertion loss of the standalone feed.

Parameter	Origin	0.9 GHz	1.5 GHz	2.0 GHz
Directivity (dB)	Simulated value	9.73	13.28	15.42
	Measured SN106	10.26	12.87	14.42
Gain (dBi)	Simulated value (*)	8.7	12.5	14.8
	Measured SN106	8.9	11.8	13.7
Insertion Loss (dB)	Estimated value by simulation	1.03	0.78	0.62
	Estimated value from SN106	1.36	1.07	0.72

TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY

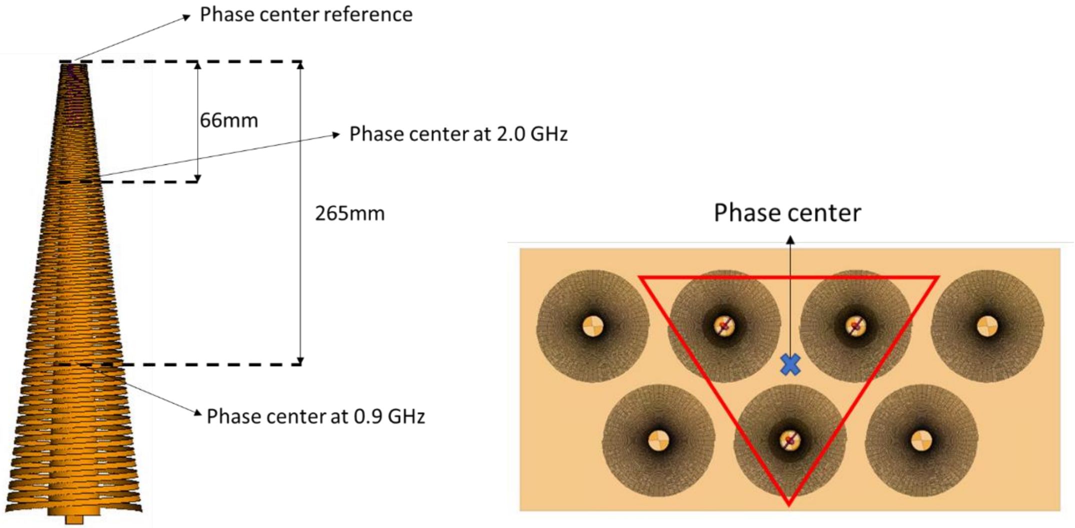






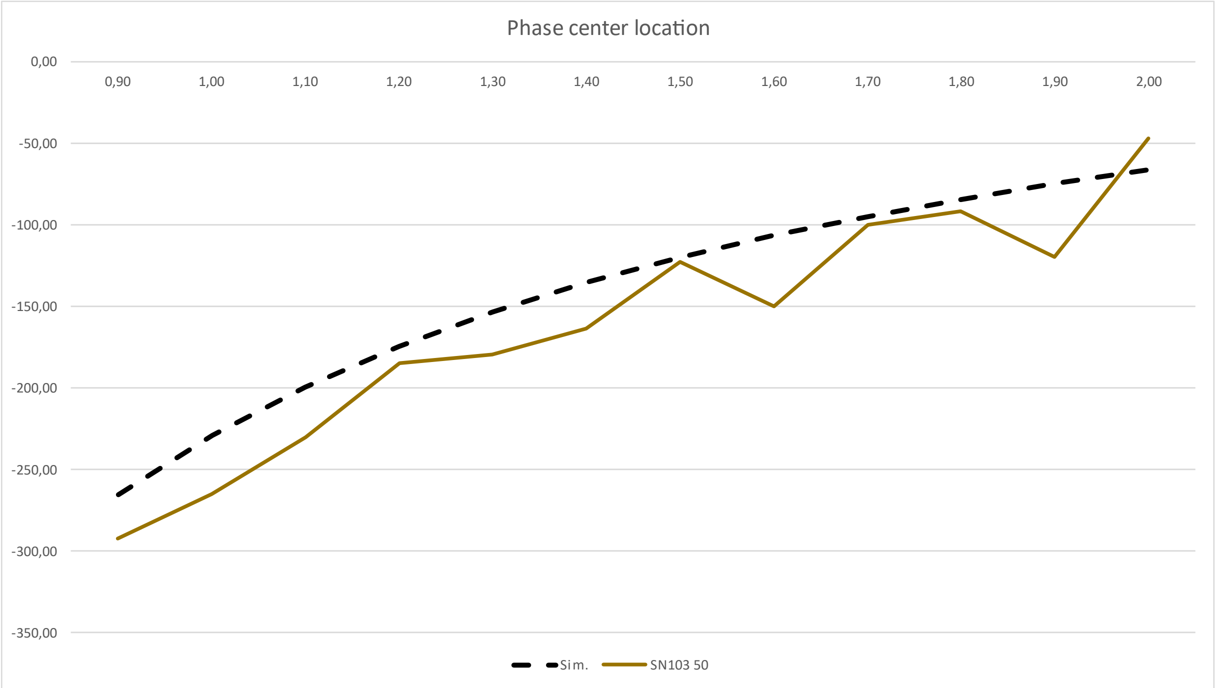
- The **maximum phase difference** between measured and the proposed simulation results at 0.9 GHz in the beamwidth at -10dB (from theta -50º to 50º) is approximately 115º (-80 to 35).
- The **maximum phase difference** between measured and the proposed simulation results at 1.5 GHz in the beamwidth at -10dB (from theta -40º to 40º) is approximately 80º (-40 to 40).
- The **maximum phase difference** between measured and the proposed simulation results at 2.0 GHz in the beamwidth at -10dB (from theta -30º to 30º) is approximately 80º (-40 to 40).

TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY



Embedded sub-array phase center location reference figures

Simulated and measured phase center location of the embedded sub-array



- The phase center in the manufactured model is very similar to the simulated model and also to the standalone feed too.

TEST 8 & 9: EMBEDDED HFWF SUB-ARRAY

EOSOL

CONCLUSIONS OF TEST 8 & 9

- It can be concluded that the **simulation model is accurate** and the manufacturing and assembly precision is enough.

  → However, a more detailed complete simulation model will increase the simulation model accuracy.

- The **crosspolar level and axial ratio** have increased, as it is expected from a manufactured model.

Embedded HFWF sub-array RF performance summary

Parameter	Unit	Simulation	SN106 embedded
Frequency band	GHz	0.9-2.0	0.9-2.0
Directivity	dB	9.75 - 15	10 – 15
Realised gain	dB	> 8.7	> 8.7
Return loss	dB	> 16	> 14 (min) > 15 (typ)
Max XP within FoV from 0.9 – 1.3 GHz	dB	< -12	< -9.6
Max XP within FoV from 1.3 – 2.0 GHz	dB	< -15	< -16
Axial ratio at boresight from 0.9 – 1.3 GHz	dB	< 3	< 4.1
Axial ratio at boresight from 1.3 – 2.0 GHz	dB	< 1.6	< 1.6
Integrated power within FoV from 0.9 – 1.2 GHz	%	> 83	> 83
Integrated power within FoV from 1.2 – 2.0 GHz	%	> 89	> 87
Max phase centre variation	mm	200	250
Maximum phase variation at -10 dB	ºpp	@ 0.9 < 170 @ 1.5 < 70 @ 2.0 < 60	@ 0.9 < 115 @ 1.5 < 80 @ 2.0 < 80

4.4. Feed and sub-array RF tests

REQ. ID	Type	Parameter	Unit	Requested	Simulation	SN106 sub-array	SoC
HFWF-40	Electrical	The feed chain shall be fully operational within the 0.9 GHz to 2 GHz bandwidth.	GHz	0.9 to 2	0.9 to 2.0	0.9 to 2.0	C
HFWF-50	Electrical	Feed polarization	-	Single-circularly polarised (LHCP or RHCP)	LHCP	LHCP	C
HFWF-60	Electrical	The phase centre location of the feed shall be provided at each frequency within the RF bandwidth. The variation in phase centre must not deviate more than +/- TBD mm over the RF bandwidth	mm	< 130	200	250	NC
HFWF-70	Electrical	Axial ratio at boresight of the sub-array within the full RF bandwidth in HFWF-40	dB	< 1.5	0.9-1.2 GHz: < 3 1.2-2.0 GHz: < 1.6	0.9-1.3 GHz: < 4.1 1.3-2.0 GHz: < 1.6	NC
HFWF-80	Electrical	Directivity at diagram peak of the sub-array for the frequency band specified in HFWF-40.	dB	> 12	0.9-1.3 GHz: > 9 1.3-2.0 GHz: > 11.75 2.0 GHz: > 15	0.9-1.3 GHz: > 10 1.3-2.0 GHz: > 11.75 2.0 GHz: > 15	PC
HFWF-90	Electrical	The sub-array shall comply with the next Field of View (FoV), where all requirements within this document shall be met.	º	• 0º < theta < 50º • 0º < phi < 360º	-	-	C
HFWF-100	Electrical	The sub-array shall comply with the following taper values for the frequency band specified in HFWF-40.	dB	<-9 at an elevation angle of 50º <-20 at an elevation angle of 75º <-30 at an elevation angle of 100º	0.9-1.1 GHz: <-8 @50º 1.1-2.0 GHz: < -9 @50º 0.9-1.2 GHz: <-18@75º 1.2-2.0 GHz: < -20 @75º 0.9-2.0 GHz: <-20 @100º	0.9-1.1 GHz: <-8 @50º 1.1-2.0 GHz: < -9 @50º 0.9-1.2 GHz: <-18@75º 1.2-2.0 GHz: < -20 @75º 0.9-2.0 GHz: <-20 @100º	PC
HFWF-120	Electrical	Maximum crosspolarization level of the sub-array for the frequency band specified in HFWF–40.	dB	< -21.5 (TBC)	0.9 GHz: < -11 0.9-1.2 GHz: < -11 1.2-2.0 GHz: < -17	0.9 GHz: < -9.6 0.9-1.4 GHz: < -11 1.4-2.0 GHz: < -16	NC

4.4. Feed and sub-array RF tests

EOSOL

REQ. ID	Type	Parameter	Unit	Requested	Simulation	SN106 sub-array	SoC
HFWF-125	Electrical	The integration of each sub-array radiation pattern (co-polar and cross-polar) in the conical angular field of view corresponding to [0<θ<50°] and [0<ϕ<360°] of the overall radiation pattern power over the complete frequency range specified for HFWF-40	%	> 97	0.9-1.2 GHz: > 83 1.2-2.0 GHz: > 89	0.9-1.2 GHz: > 83 1.2-2.0 GHz: > 87	NC
HFWF-130	Electrical	Return loss of the sub-array in HFWF-40.	dB	> 15 (TBC)	> 15	> 14	PC
HFWF-140	Electrical	Maximum insertion loss of the feed chain for the complete frequency band specified in HFWF-40	dB	< 0.3 (TBC)	0.9 GHz : < 1.03 1.5 GHz : < 0.78 2.0 GHz : < 0.62	0.9 GHz: < 1.36 1.5 GHz: < 1.07 2.0 GHz: < 0.72	NC
HFWF-155	Electrical	Phase variation at all frequencies at -10 dB from the peak in HFWF-40 Phase reference is the phase center location at each frequency	ºpp	15	0.9 GHz < 170 1.5 GHz < 70 2.0 GHz < 60	0.9 GHz < 115 1.5 GHz < 80 2.0 GHz < 80	NC
HFWF-160	Mechanical	Feed chains manufacturing and Surface finish of the feed chains	-	Space qualified materials	-	-	C
HFWF-165	Mechanical	Feed volume	mm	< 151 (W) x 151 (L) x 1250 (H)	150 (W) x 150 (L) x 460 (H)	150 (W) x 150 (L) x 460 (H)	C
HFWF-170	Mechanical	Feed cluster arrangement volume constraints	mm	W<1400mm L< 800 mm H<1250 mm	Can be accommodated	Can be accommodated	
HFWF-180	Mechanical	The mass of the feed including Mass Maturity Margin.	kg	< 1 (TBC)	0.8	0.8	C
HFWF-190	Mechanical	The feeder assembly in hard-mounted conditions shall have their first resonance frequency above:	Hz	TBD	82	82	C

5. ACTIONS ITEMS PENDING

AIRBUS EOSOL

Phase centre location results

TN7
Test 2, 4, 7, 9

Sunshield losses

TN7. Annex 6

Reference	Date	Action Num.	Description	Resp.	Status	Due Date
CRYO-EOS-MNG-MTN-020	TRB	AI20_1	EOSOL will analyse again all phase results, along with UPM Laboratory, in order to review the method used for the phase centre calculation and to obtain clear figures about phase variation, including the following points: - Review the post-processing method used by UPM to obtain clear and valid phase centre results. To specify the angular range used (theta: 1 dB, 3 dB…) for this calculation. - Evaluate the possibility of obtaining phase variation figures (planar) translating the phase centre at each frequency. - Evaluate the reason for the 90º difference between phi cuts and study if it could be derived from the X-Y phase centre alignment. - Check whether the asymmetries at phase radiation patterns are derived from a phase centre misalignment at X-Y, in simulations.	EOSOL	Open	21/09/2022
CRYO-EOS-MNG-MTN-020	TRB	AI20_2	EOSOL is going to carry out a simulation of the CLSA feed (simplified model) with and without sunshield over the copper spiral in order to compare the simulated losses of the sunshield. Besides, if possible, a simulation with space between copper spiral and sunshield will be done.	EOSOL	Open	21/09/2022
CRYO-EOS-MNG-MTN-020	TRB	AI20_3	(Subjected to action AI20_2) EOSOL will perform a waveguide insertion loss (IL) measurement of a representative sample of the sunshield material to check the IL performance.	EOSOL	Open	21/09/2022
CRYO-EOS-MNG-MTN-021	TRB2	AI21_4	EOSOL is going to contact two laboratories in order to check the feasibility of carrying out the waveguide IL measurement of a sample of the sunshield material. If possible, the test will be carried out. If not possible, EOSOL will let ESA know about it and about the decision to be able to justify this issue.	EOSOL	Open	28/09/2022

6.1. Conclusions

ANTENNA:

1. **The antenna is comprised of a large deployable reflector and a feed cluster.**
    1. The proposed CLSA feed cluster solution comprised of two types of arrays -> 10 low frequency and 19 high frequency feeds.
    2. 120 km swath with a limited number of beams -> 5 low freq. and 10 high freq.
    3. Each beam is generated by 3 feeds.

2. **The achievable resolution is lower** than required even using an ideal gaussian feed. Moreover, the measured embedded sub-array has lower performance due to the phase center variation, the phase variation and the pattern shape. Directivity will increase and resolution will be improved if a larger reflector is employed.

3. **The beam efficiency improvement applying some techniques**.
    1. Improvement considering the contribution of the sky to brightness
    2. The contribution of the crosspolar component is considered in the computation of the efficiency.
    3. Beam efficiency can also be improved, especially for the high frequency channels by using digital beamforming techniques, which will provide additional scanning flexibility to the antenna.

6.1. Conclusions

AIRBUS EOSOL

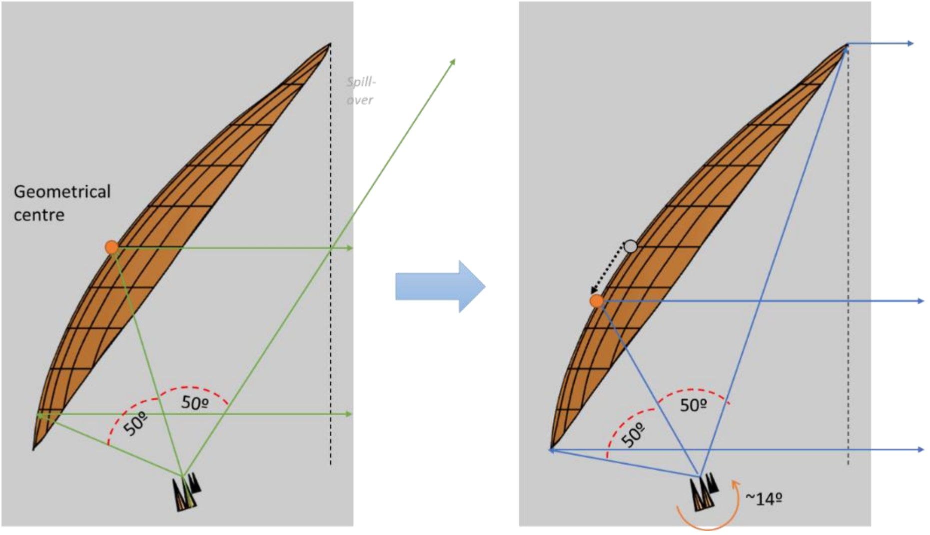
FEED:

4. **Standalone feed measured results match the simulated results**: Three single feeds in standalone configuration have been tested and the measured results match with high precision the simulated results. This verifies a precise manufacturing, assembly and simulation model of each one of the feeds.
5. **The embedded sub-array measured results match the simulated results:** They match with minor deviations that are considered normal and expected. The embedded simulation model can be accurate by adding more details to it -> more calculation resource required.
6. **The phase center location estimation is quite accurate**. The phase center location has a variation not only in the propagation Z axis but also in X and Y axes due to the support structure of each feed and the embedding. The X and Y variation can be noticed in the phase radiation patterns that are not symmetrical in both simulation and measurement.
7. **The standalone feed has wideband high performance** and the design can be easily updated to cover more bandwidth maintaining the performance and constant radiation patterns over frequency. The complete frequency range of observation could be implemented with a single type of feeds. However, to met antenna and coverage needs two sub-bands are considered.
8. **The insertion losses of the feed are higher than required.** However, they can be reduced by employing shorter feeds with less turns that will perform similarly at array level.

6.2. Design updates

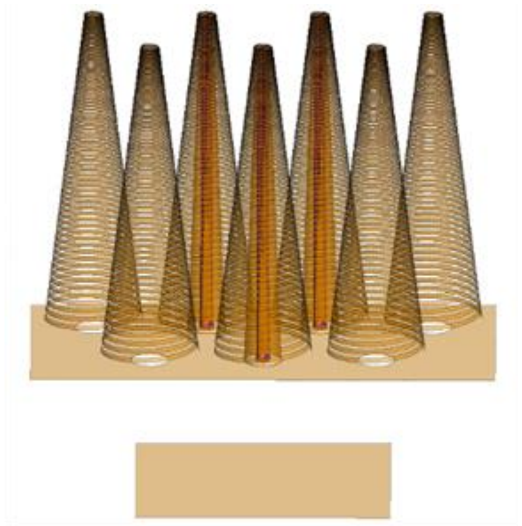
1. Feed cluster enhancement:

The antenna configuration has been optimized in terms of feed cluster orientation in order to reduce the spill-over and consequently, improve the beam efficiency performance.



2. HFWF CLSA feed model update:

In the manufactured feed, the metallic shielding cone covering the balun is placed on the ground plane having contact with it. The HFWF embedded sub-array simulation model has been updated in TN5 document and now the metallic shielding cone is also in contact with the ground plane.



6.3. Limitations and areas of improvement

AIRBUS EOSOL

Antenna beam efficiency:

- Maximum achievable **directivity** of the feed **is limited** due to the required array configuration.
- The inter-element spacing limited by high frequencies.
- This limits the feed and sub-array directivity at low frequencies.
- An ideal gaussian beam with a taper of -12 dB at the edge of the reflector offer a partial power up to 90% in the reflector and with -9dB it can be up to 83%.

Improvement:

- The first thing that can be done is **increasing the directivity** of the feed/sub-array, especially at the lowest frequencies of each sub-band where the directivity is the lower. -> Larger number of elements in the Sub-array.
- The feed directivity increment could allow the antenna configuration to have higher f/D ratio and improve the beams shape and may allow the antenna to achieve better beam efficiency values.

6.3. Limitations and areas of improvement

AIRBUS EOSOL

Directivity:

- At the lowest frequencies, the directivity is lower than required due to the **area limited by the embedding**.
- This reduces the antenna beam efficiency due to the spillover. Some beams, especially at **low frequencies are affected by a large spillover**, which results in an increase of the backlobe noise contribution.

Improvement:

The directivity can be increased if **more elements** are **added to the sub-array**, i.e. groups of 4 feeds instead of 3.

Axial ratio and crosspolar level:

- Axial ratio performance of the antenna is low **at the lowest frequencies** of each sub-array, especially at 0.4 GHz.
- The **inter-element spacing** at those frequencies **limits the feeds performance** increasing the axial ratio and the crosspolar level.

Improvement:

It has been seen that the metallic cone that improves the standalone feed axial ratio also increases the embedded sub-array axial ratio. Therefore, by **removing the metallic cone**, the embedded performance may improve. Moreover, **improved support structures** can be designed to reduce its impact on RF performance.

Also, a **single feed-per-beam** feeding cluster can be configured to improve the axial ratio and crosspolar level.

6.3. Limitations and areas of improvement

AIRBUS EOSOL

Phase center location variation:

- The phase center location variation is higher than the proposed in the requirement. **A wide phase center location variation reduces the antenna efficiency and resolution**.
- The impact on antenna RF performance of the phase center location has been taken in consideration in the antenna simulations.

Improvement:

The phase center variation **can be reduced with a shorter CLSA->** Directivity reduced, but, as the embedding is the main directivity limitation, a reasonable trade-off could be achieved.

Reduced phase center variation will improve the antenna beam efficiency. A trade-off between directivity and phase center variation should be done at antenna level.

Single circular polarization:

- The selected polarization for a possible CRYORAD mission is circular in order to avoid the effects of the Faraday rotation.
- **No need to measure simultaneously the two polarizations** since the observation geometry is looking towards the **nadir** direction and there is little variation of the incidence angle.
- However, having a high cross –polar levels, especially at low frequencies for each of the feed types **requires:**
  - To have the **cross-polar pattern** of the feed **very well characterized** on ground-> Contribution removed
  - To introduce a dual polarizationmfeed-> full polarization matrix.

Improvement:

The error introduced by typical pattern measurements accuracy, together with a deployable reflector model should be considered in the overall radiometric accuracy budget, so that it can be assessed whether the errors introduced are acceptable.

6.4. Roadmap to TRL5

AIRBUS EOSOL

Future steps and technical challenges to TRL5

1. Feed array arrangement and beamforming techniques

- In the project same sub-array for all frequencies -> For low freq. could improve performance with 4 element.
- Digital beamforming will be analysed including independent radiation pattern for each feed.
- Triangular vs square arrangement analysed for beam efficiency improvement.

2. Larger offset mesh reflector analysis

- 15 m diameter will improve the resolution and the beam efficiency of the antenna.
- A trade-off analysis between different F/D values with the new diameter.

3. Trade-off analysis of dual polarization measurements

- Developed an array cluster comprised single polarization feeds based on SoW requirements.
- The measurement of both polarizations (circular or linear) will have advantages:
    - Correction of high crosspolar levels by postprocessing.
    - Measurement of faraday rotation at these frequencies.
- Array cluster of single polarization feeds (bigger) vs dual polarization feeds (Alternative feed required)

AIRBUS EOSOL

Future steps and technical challenges to TRL5

4. Insertion loss and phase center variation reduction

Length and number of turns reduction:

-> Insertion loss and phase center variation reduction.

-> Directivity reduction and crosspolar degradation does not affect at sub-array level because the embedding has higher impact.

5. LFWF manufacturing

- HFWF manufactured in the project.
- LFWF requires a PCB with a length > 1m which is a challenge due to limitation to 600-800 mm in most of manufacturers.

6. Study of sunshield placement over the array cluster

- Low loss of the material at 0.4-2 GHz frequencies.
- 0.4-0.5 dB losses demonstrated during gain measurements.
- Sunshield placement over the feeds and/or array needs to be analysed.

AIRBUS EOSOL

Future steps and technical challenges to TRL5

7. Design under embedded environment of complete array cluster, HFWF and LFWF

- Demonstrated that design and optimization in stand-alone environment leads to some wrong conclusions about performance in embedded environment.
- Challenge in array simulation and analysis due to solvers and required resources:
  - Simulation of High Frequency array and Low Frequency array together.
  - Optimization of feed in a relevant embedded environment.

8. Life test and S parameters and losses/gain characterization during thermal cycling

- Life test of sub-arrays: Vibration and thermal cycling.
- Characterization of insertion losses over temperature ->

  -> Gain measurement during thermal cycling

6.4. Roadmap to TRL5

AIRBUS EOSOL

Effort and cost to reach TRL5

Once the future steps and the technical and technological challenges have been evaluated, a new program can be detailed for a future project development.

The work to be carried out is divided into four (4) main packages, presented below:

1. Array and feed preliminary design and trade-offs:

The first activity in the project is to carry out a revision of different array configurations and beamforming techniques, and evaluate the design trade-offs which have been identified during CRYO project. The main objective is to confirm the technology selected is correct for a future mission development.

2. Feed chain and antenna reflector detailed design:

This package includes the feed and sub-array detailed design, according to the areas of improvement presented. Furthermore, mechanical and thermal simulations for the feed and array will be carried out, including configuration and placement for sunshield thermal protection and confirmation does not affect the RF performance. Finally, antenna reflector design will be carried out according to the last feed array designs.

3. Breadboard manufacture and test (to TRL5):

This third activity includes the feed and sub-array manufacturing and RF. In this case, not only HFWF feeds will be manufactured but also the low frequency ones (LFWF) will be manufactured so as to verify the feasibility and deal with the limitations presented.
Moreover, one feed will be subjected to life tests in order to reach TRL5 with enough evidence.

4. Conclusions and future steps:

In the last step of the project, new conclusions will be drawn, an evaluation of the objectives of the project will be done and compared to the initial expectations, and finally future steps will be presented.

6. CONCLUSIONS AND ROADMAP TO TRL5 (WP5)

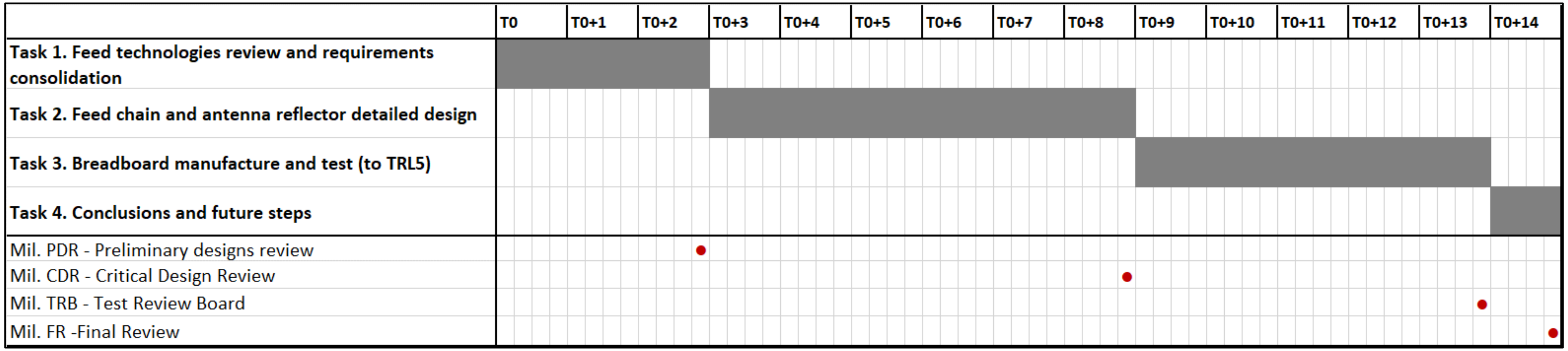
6.4. Roadmap to TRL5

Effort and cost to reach TRL5: based on the program activities aforementioned

Task	Name	Description	Manpower effort (h)	Manpower cost (€)	Other direct cost (€)	Total cost/Task (€)	Schedule
1	**Array and feed preliminary design and trade-offs**	Preliminary design and trades-off based on: - Feed array arrangement and beamforming techniques - Larger offset mesh reflector analysis - Trade-off analysis of dual polarization measurements - Insertion loss and phase centre variation reduction - Requirements consolidation for technologies selected	1040	72.400 €	- €	72.400 €	3m
2	**Feed chain and antenna reflector detailed design**	- Feed RF detailed design according to areas of improvement and technical challenges presented (Reduce length of CLSA feed, design under embedding environment) and based on Task 1. This activity includes standalone feed and array configurations. - Feed Mechanical and thermal detailed design, including validation in relevant environment. - Array mechanical and thermal detailed design, including validation in relevant environment. In this activity final configuration and placement of thermal protection (sunshield) shall be evaluated. - Antenna and system reflector detailed design.	2250	161.000 €	15.000 €	176.000 €	6m
3	**Breadboard manufacture and test (to TRL5)**	- LFWF and HFWF Feeds manufacturing (sub-array) - Feed/Array radiofrequency test campaign - Feed life tests: mechanical (vibration, shock) and thermal cycling to verify critical functions of the elements (e.g. soldered joints, robustness) - Feed S-parameters/Gain test under thermal cycling	860	55.600 €	160.000 €	215.600 €	5m
4	**Conclusions and future steps**	- Draw relevant conclusions of the project and limitations encountered - Future steps	330	23.800 €	- €	23.800 €	1m
		Total	4480	312.800 €	175.000 €	**487.800 €**	**15m**

6.4. Roadmap to TRL5

Schedule according to the activities presented:



6.4. Roadmap to TRL5

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Market Opportunities

Two main opportunities have been identified where the developed CLSA and feed could be used.

- Future **CRYORAD mission** which will be presented as candidate for Earth Explorer EE12.
  -> The array feed could be identified as critical technology for a phase 0/A to develop the array up to TRL 5.

- **Giovanni Macelloni** as the scientific of CRYORAD is working on the evolution of different technologies of the 0.4-2 GHz instrument and will develop an airborne instrument where the CLSA could be used.

7. PROBLEM AREAS AND CORRECTIVE ACTIONS

- ALL RISKS WAS CLOSED AT CDR

8. MILESTONE PAYMENT STATUS

Last payment is expected to be released after FR

PAYMENT PLAN proposed by ESA					
Start date	T0	T0+7	T0+12	T0+23	
MILESTONE PAYMENT PLAN	KO	PDR	CDR	FR	Total
EOS	97.000	9.000	82.000	89.115	277.115,00
ADSM	0	51.000	15.000	6.885	72.885,00
	97.000	60.000	97.000	96.000	**350.000,00**

9. FINAL DOCUMENTATION AND CONTRACT CLOSURE

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Final review Minutes of meeting: *Eosol will prepare and deliver the Final review MoM and actions.*

Final documentation according to SoW: *¿Delivery date for these documents?*

▪ Photo. High resolution pictures	Done
▪ HW-UM. HW user manual	Done
▪ TDP. Technical data package	Done
▪ AB. Abstract	Pending
▪ FP. Final presentation	Pending
▪ ESR. Executive summary report	Done
▪ FR. Final report	Done

Contract closure documents: *¿Can we proceed with this document?*

- CCD. Contract closure document **– In progress**

THANK YOU FOR YOUR PARTICIPATION IN THIS PROJECT

☺

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