Feed system design of the 16m Radiotelescope of Ventspils (Latvia)

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Recapitulation of all the technical reports written during the contract with MT (Mechatronics) relative to the design, construction and measurement of the Feed System of the Ventspils 16m antenna. The bandwidth of the first-light receiver is 4.5 to 8.8GHz. First, the antenna design feasibility is discussed and chosen. Then, the work was focused in the feed design, construction and testing, with measurements in the Yebes Observatory facilities.

Fecha de creación	viernes, 29 de abril de 2016
Fecha de guardado	martes, 03 de mayo de 2016
Fecha de impresión	martes, 03 de mayo de 2016

1 Introduction.

Lativian government decided to change radically the radiotelescope located in Ventspils (Latvia). This conversion implied the replacement of optical system (as cassegrain) by dual optical with a shaped reflector. The main purpose of this restructuring is to get signals between 4.5 and 8.8 GHz to cover the radioastronomy bands of 3.6cm, 5cm and 6cm, using only one receptor in the antenna feed.

The main contractor was the company MT Mechatronic for all refurbishing works. The Yebes observatory was sub-contracted to do all works for design, construct and measure the final feed system for an amount of 70.000€ through the Centro Nacional de Información Geográfica (CNIG).

2 Scope of the reports.

TITLE	SCOPE
BASIC DESIGN GUIDELINES AND SPECIFICATIONS FOR THE 16M VENTSPILS ANTENNA	Basic specifications and boundary conditions are shown as well as the basic guidelines to the design of the antenna profile and feed for the 16m Ventspils antenna sited in Latvia.
FEASIBLE SOLUTION GEOMETRIES FOR VENTSPILS RT16	Shows the optical solution and its parameters. Different set of parameters can be done with similar antenna and feed performance. This document shows different examples of geometries that can be chosen. This documents lets the antenna builder (MTM) and the final user (VUC) to comment its preferred optical solution.
REFLECTOR FEASIBILITY AND PERFORMANCE METRICS FOR ALTERNATIVE OPTICAL DESIGNS	The first set of optical layouts was discussed between IGN and the reflector supplier. In the process of technical and project optimization an alternative design was developed. This document shows the feasibility of the design with a wideband feed design with the shape optimized Cassegrain design proposed by the reflector supplier. The alternative design is optimized with regard to the efficiency. It is compared with a classical cassegrain solution of similar dimensions to show the differences.
PRELIMINARY FEED DESIGN FOR THE 16M VENTSPILS ANTENNA	Show the design that is being developed of the feeder for the 16m Ventspils antenna. It is an electrical preliminary design. It is analysed with the shaped cassegrain antenna at three frequencies, bottom, central and upper.
FINAL FEED DESIGN FOR THE 16M VENTSPILS ANTENNA	Show the final electrical and mechanical design of the feed for the 16m Ventspils antenna. It includes all the final simulations and measurements in an scaled feed model to validate the design for construction.
FINAL FEED MEASUREMENTS FOR THE 16M VENTSPILS ANTENNA	Show the final electrical and mechanical measurements of the feed for the 16m Ventspils antenna. It includes all the final measurements in the final built feed to validate

	the prototype. It also includes the simulations of the 16m metre antenna using the measured feed as a feeder

Reference

20140829_VENTSPILS_RT16_FEED AND REFLECTOR GUIDELINES

Title

BASIC DESIGN GUIDELINES AND SPECIFICATIONS FOR THE 16M VENTSPILS ANTENNA

Costumer

MT MECHATRONICS

Written and released by:

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Edición: 01.0	Fecha: 27/08/2013	Paginas:

1 SCOPE

Basic specifications and boundary conditions are shown as well as the basic guidelines to the design of the antenna profile and feed for the 16m Ventspils antenna sited in Latvia.

2 SPECIFICATIONS

2.1 General description and specification

The antenna under design is a 16m dual reflector antenna.

Diameter primary	Dp	m	16.0
Single receiver antenna			yes
Single pixel antenna			yes
Freq. Bandwidth		GHz	4.5-8.8
Full bandwidth observation			no
Simultaneous bandwidth		GHz	1.0-1.2
Single feed coverage			yes
Receiver physical envelope			TBD
Feed positioner available			yes
Feed positioner range		mm	TBD
Receiver+positioner physical envelope			TBD
Waveguide type (circular or square)			TBD
Waveguide dimension		mm	TBD
Waveguide mechanical flange interface			TBD
M2 servo motor			no
M2 accuracy position axial (under operational conditions, elevation range and climate observational conditions)		mm	TBD
M2 accuracy position lateral (under operational conditions, elevation range and climate observational conditions)		mm	<0.7
FEED accuracy position axial (under operational conditions, elevation range and climate observational conditions)			TBD
FEED accuracy position lateral (under operational conditions, elevation range and climate observational conditions)			TBD
FEED mechanical interface to the antenna structure			TBD

2.2 Basic design guidelines

2.2.1 Dual Reflector Radiotelescope

- Based in classical Cassegrain Antenna, widely used in astronomical radiotelescopes offers a good compromise between equivalent noise temperature and efficiency with acceptable sidelobes level.
- Primary focal between 5 and 6 metres (primary focal ratio between 0.3 and 0.4)
- Equivalent focal ratio between 1.5 and 2. Limited by the size of the feeder to be reasonably below 1 metre long.
- Semiangle of subreflector illumination about 15deg at 11-12dB.

2.2.2 Feed system

- 64% bandwidth is an extremely large bandwidth and several options should be investigate to achieve good performance.
- Based in conical corrugated feed, linear profiled. Other profiles will be investigate in order to improve performance or reduce size.
- Feed size lower of 1metre long.

2.2.3 Antenna+Feed system

- Feed aperture to subreflector vertex distance between 0.5m to 1m. It implies to build a feed cone/tube between 3-4m.
- 32m reflectors characteristics can be useful to use similar equivalent focal ratio in 16m antenna.

Reference

20140915_VENTSPILS _RT16_FEED AND REFLECTOR FEASIBLE GEOMETRIES

Title

FEASIBLE SOLUTION GEOMETRIES FOR VENTSPILS RT16

Costumer

MT MECHATRONICS

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1 SCOPE

Show the optical solution and its parameters. Different set of parameters can be done with similar antenna and feed performance. This document shows different examples of geometries that can be chosen. This documents lets the antenna builder (MTM) and the final user (VUC) to comment its preferred optical solution.

2 DOCUMENTATION AND REFERENCES

Title	Reference	Edited
Basic Design Guidelines and Specifications for the 16m Ventspils Antenna	20140829_ventspils_rt16_feed and reflector guidelines.pdf	IGN

3 OPTICAL PARAMETER TABLE

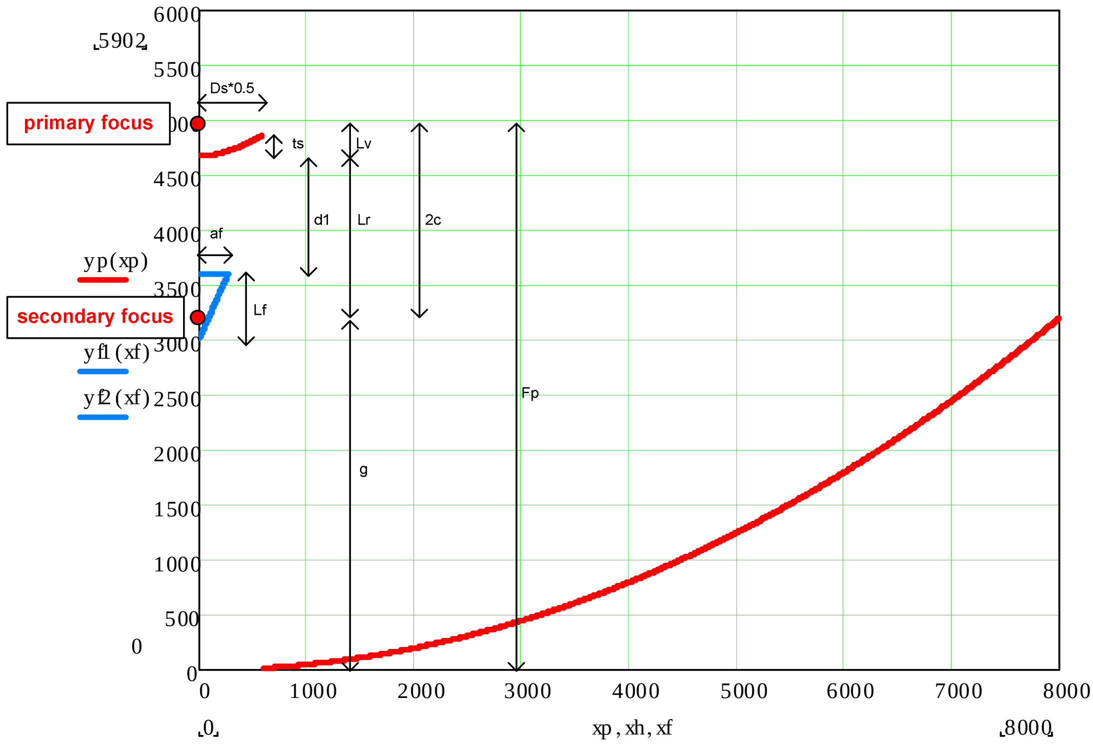
3.1 General description

The Table 1 shows the optical parameters to define the geometry of the cassegrain reflector and its feed.

Diameter primary	Dp	m	16.0
Focal primary	Fp	m	
Diameter secondary	Ds	m	
Secondary thickness	ts	m	
Foci distance	2c	m	
Secondary vertex to secondary focus	Lr	m	
Secondary vertex to primary focus	Lv	m	
Primary vertex to secondary focus	g	m	
Feed illumination half-flare angle at -11dB	θ	deg	
Equivalent Focal ratio	F/D		
Magnification	m		
Central frequency	f0	GHz	6.65
Feed phase error at central frecuency	β	rad	
Feed aperture radius (aprox.)	af	m	
Feed length (aprox.)	Lf	m	<1
Feed semiflare angle	θf	deg	
Feed aperture position to secondary vertex	d1	m	

Table 1. Optical Parameter List

3.2 Parameters layout



4 Design constraints

To determine the antenna geometry, only 4 parameter can be independently chosen. In this paragraph the constraint to the design are commented.

4.1 Focal Primary Fp

It is chosen between 5 and 6 metres to have Fp/Dp between 0.3125 and 0.3750. It changes the size of the tetrapod and the feed cone length. From the performance point of view, slightly improvement can be found in longer focals in misalignments and crosspolar behavior.

4.2 Feed maximum length Lf

It is chosen to be lower than 1 meter long. It fixes the feed illumination feed angle to be bigger than 14deg. It also fixes the maximum equivalent F/D to 2. From the performance point of view, longer F/D gives a robust alignment solution.

4.3 Foci distance 2c

Changing the foci distance, the feed goes away from the secondary, but the size of secondary increases. Secondary diameter should be below 10% of primary diameter to keep the blocking low.

5 FEASIBLE OPTICAL SOLUTIONS

Following the design guidelines and the design constraints explained before, there is still some margin to choose the final parameters. In this section several feasible solutions are shown changing Fp, θ and 2c to illustrate the possible solutions. Results of geometric parameters are shown in Table 2. Results from 1 to 9 are part of the parametric study, while results from 10 to 11 are part of more tuned solutions. Layouts of the geometry can be found in ANEXX. Antenna layouts.

				D p	p	s	s	c	r	v			/D		0		f	f	f	1
	Fp=5.0 m	θ=16deg	2c=2.5m	1 6.00	.00	.34	.21	.50	.13	.37	.50	6.0	.31	.7	.65	.0	.27	.66	2.1	.47
	Fp=5.5 m	θ=16deg	2c=2.5m	1 6.00	.50	.31	.19	.50	.10	.40	.00	6.0	.34	.2	.65	.0	.27	.66	2.1	.44
	Fp=6.0 m	θ=16deg	2c=2.5m	1 6.00	.00	.28	.17	.50	.06	.44	.50	6.0	.37	.7	.65	.0	.27	.66	2.1	.41
	Fp=5.5 m	**θ=14deg**	2c=2.5m	1 6.00	.50	.15	.17	.50	.14	.36	.00	4.0	.04	.9	.65	.0	.31	.88	9.2	.27
	Fp=5.5 m	**θ=16deg**	2c=2.5m	1 6.00	.50	.31	.19	.50	.10	.40	.00	6.0	.78	.2	.65	.0	.27	.66	2.1	.44
	Fp=5.5 m	**θ=18deg**	2c=2.5m	1 6.00	.50	.47	.21	.50	.05	.45	.00	8.0	.58	.6	.65	.0	.24	.50	5.2	.54
	Fp=5.5 m	θ=16deg	**2c=2.0m**	1 6.00	.50	.05	.15	.00	.68	.32	.50	6.0	.78	.2	.65	.0	.27	.65	2.2	.02
	Fp=5.5 m	θ=16deg	**2c=2.5m**	1 6.00	.50	.31	.19	.50	.10	.40	.00	6.0	.78	.2	.65	.0	.27	.66	2.1	.44
	Fp=5.5 m	θ=16deg	**2c=3.0m**	1 6.00	.50	.57	.23	.00	.51	.49	.50	6.0	.78	.2	.65	.0	.27	.66	2.0	.86
0	*Fp=5.5 m*	*θ=15deg*	*2c=2.8m*	*1* *6.00*	*.50*	*.38*	*.21*	*.80*	*.37*	*.43*	*.70*	*5.0*	*.90*	*.5*	*.65*	*.0*	*.29*	*.76*	*0.6*	*.62*
1	*Fp=5.0 m*	*θ=14deg*	*2c=2.5m*	*1* *6.00*	*.00*	*.18*	*.20*	*.50*	*.17*	*.33*	*.50*	*4.0*	*.04*	*.5*	*.65*	*.0*	*.31*	*.88*	*9.2*	*.30*

Table 2. Parametrical study of feasible solutions. Last line is outside of the parametric study and it is the example analyzed below

6 ANALYZED EXAMPLE

The parameter data corresponds to the line number 11 of Table 2. In principle, similar results will be found with all other solutions. It is analyzed using fundamental gaussian beam to model the feed propagation and the efficiencies are calculated using the overlap integral in the subreflector. It usually overestimates' the overall efficiency, but it is useful to know the frequency behavior of the ideal feed and antenna

The taper behavior in frequency is shown in Fig. 1. The taper is not fixed in all the bandwidth, the variation over the bandwidth should not affect to the overall aperture efficiency.

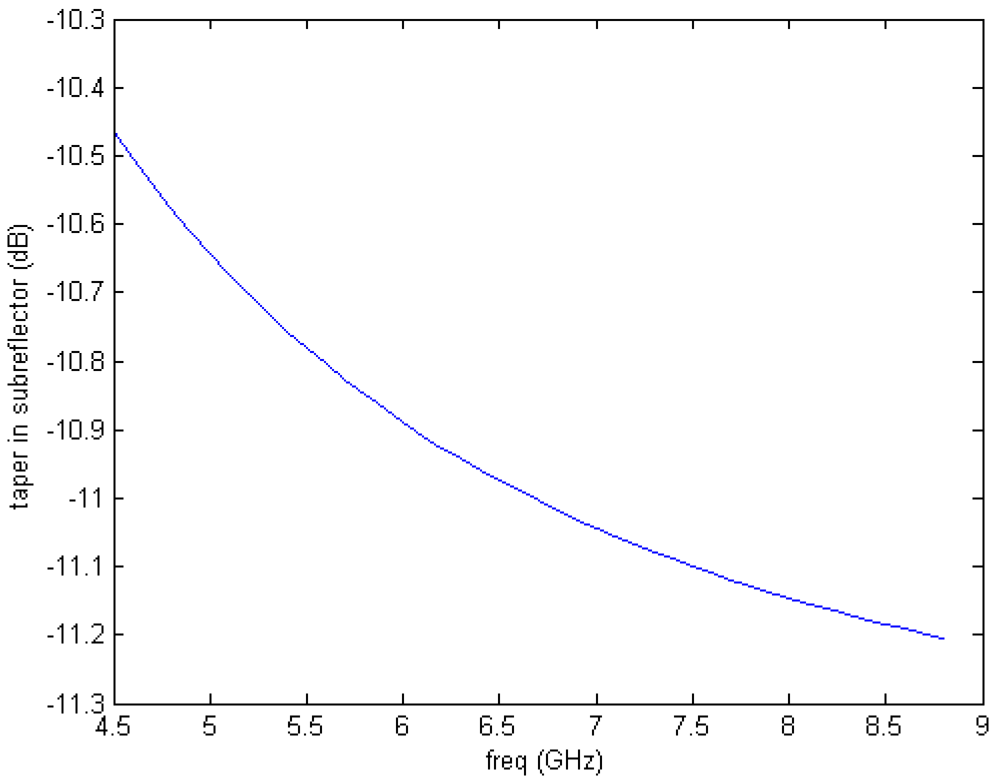


Fig. 1. Taper of feed in subreflector.

The next figure of merit analyzed is the overall aperture efficiency. The more relevant subeficiencies are calculated. The taper and spillover efficiencies related with the taper edge level, the defocus efficiency related with the phase centre variation and the blockage efficiency related with the subreflector blocking. Again, they are calculated over the single mode gaussian beam approximation.

Calculation is shown in Fig. 2. The taper and spillover efficiency are both related with the taper edge illumination level showed in Fig. 1, and both together keep in the maximum illumination efficiency point. The defocus efficiency drops less that 1% in the edges of the frequency band, so it is acceptable for this large bandwidth. The total aperture efficiency is stable enough over all the frequency band.

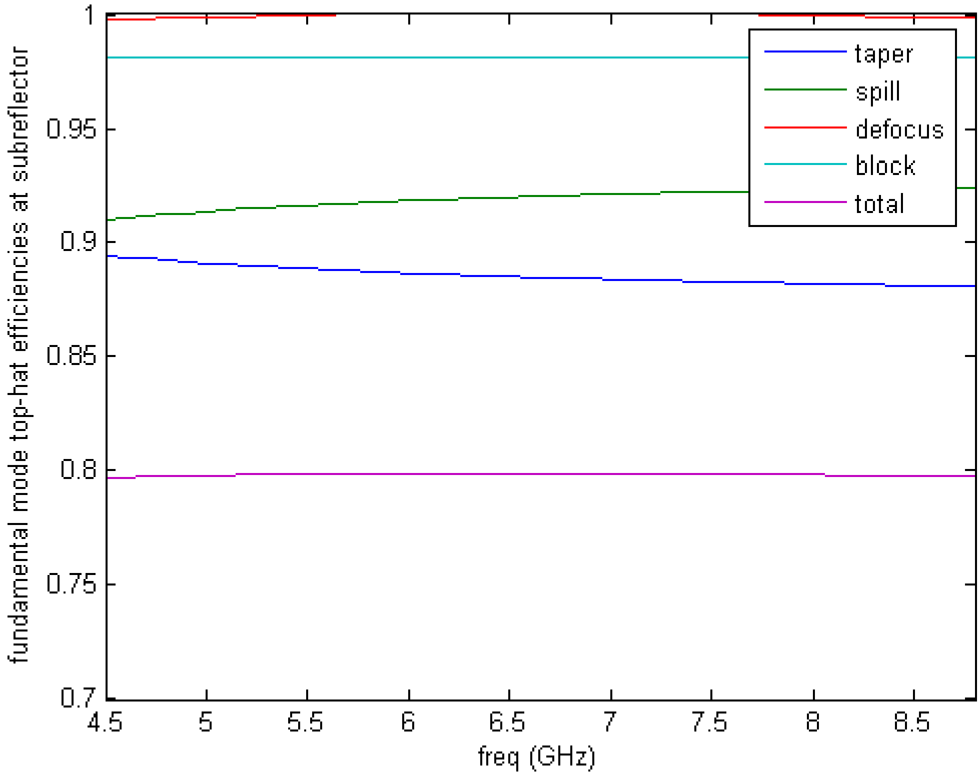


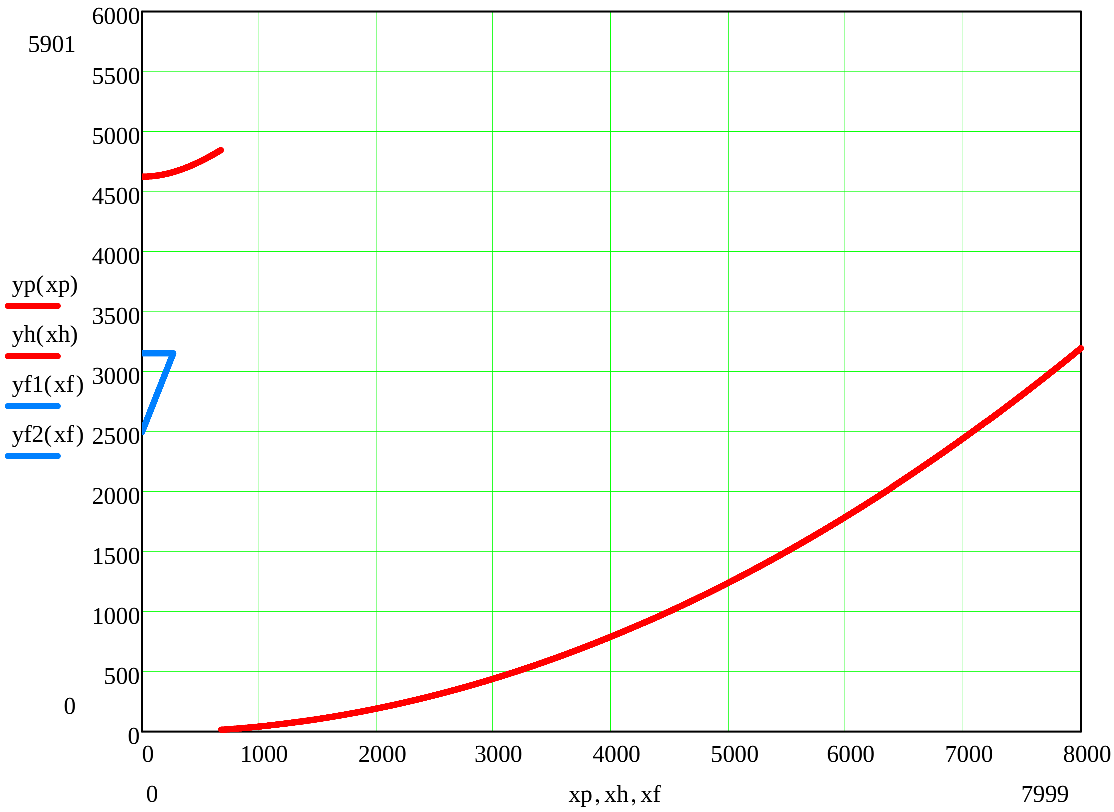
Fig. 2. Aperture efficiency over the bandwidth

7 CONCLUSIONS

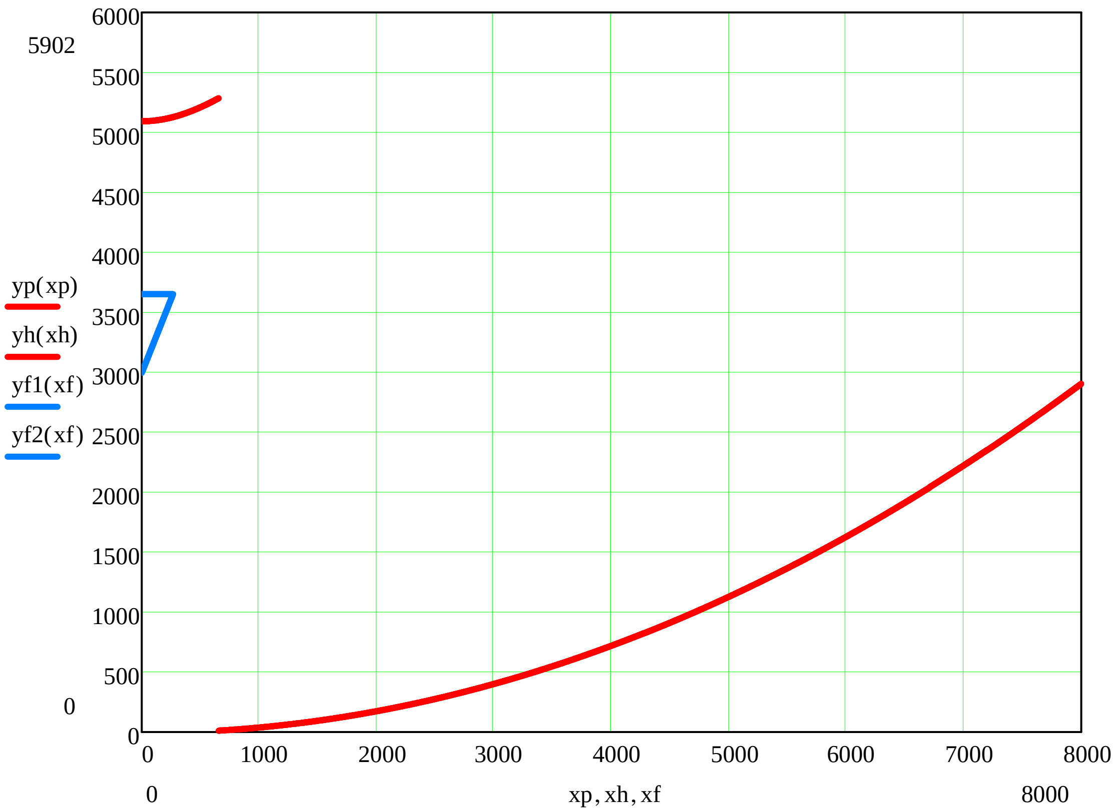
A set of parameters has been set to define feasible antenna and feed geometries based in the design guidelines. Even with the parameter constraints to keep the feed over a reasonable size, there are still some degree of freedom to choose all the parameters. Some examples are some in a parametric study of the free variables to show the possibilities of the final geometry. It can be useful to express preferences about the final geometry that they could be included in the design. As example, a particular solution has been calculated using ideal models to show the frequency behavior. All solutions showed here would show a similar performance. The performance reached is near the maximum expected in the kind of combination of reflector and feed. It is also valuable than the design would keep the phase center of feed in an stable position. A more precise analysis has to be done with the final design of the antenna and feed chosen.

8 ANEXX. Antenna layouts

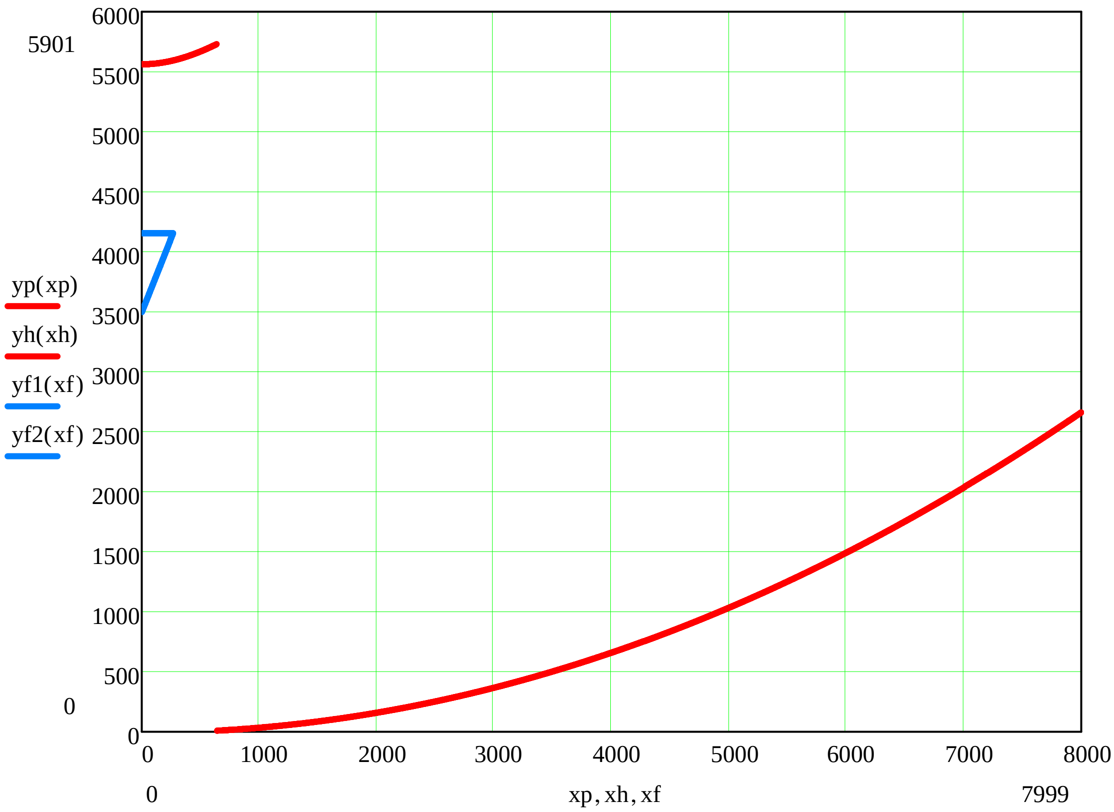
8.1 *Fp=5.0m θ=16deg 2c=2.5m*



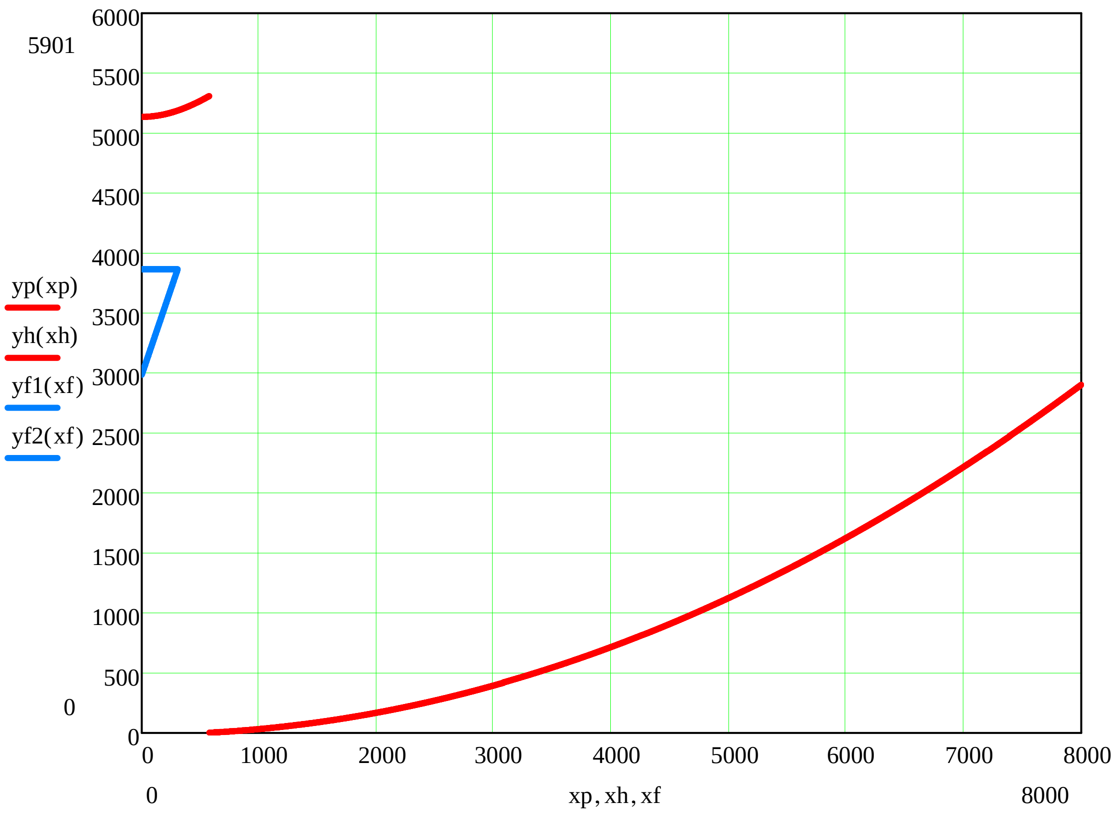
8.2 *Fp=5.5m θ=16deg 2c=2.5m*



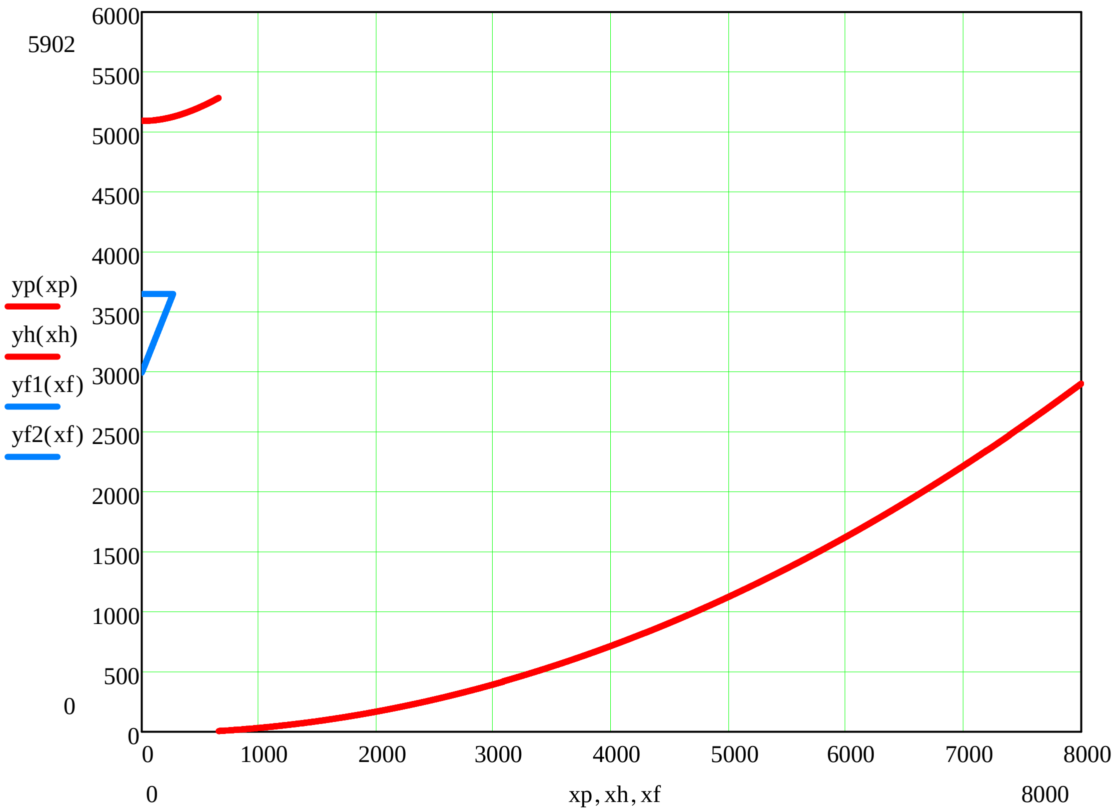
8.3 Fp=6.0m θ=16deg 2c=2.5m



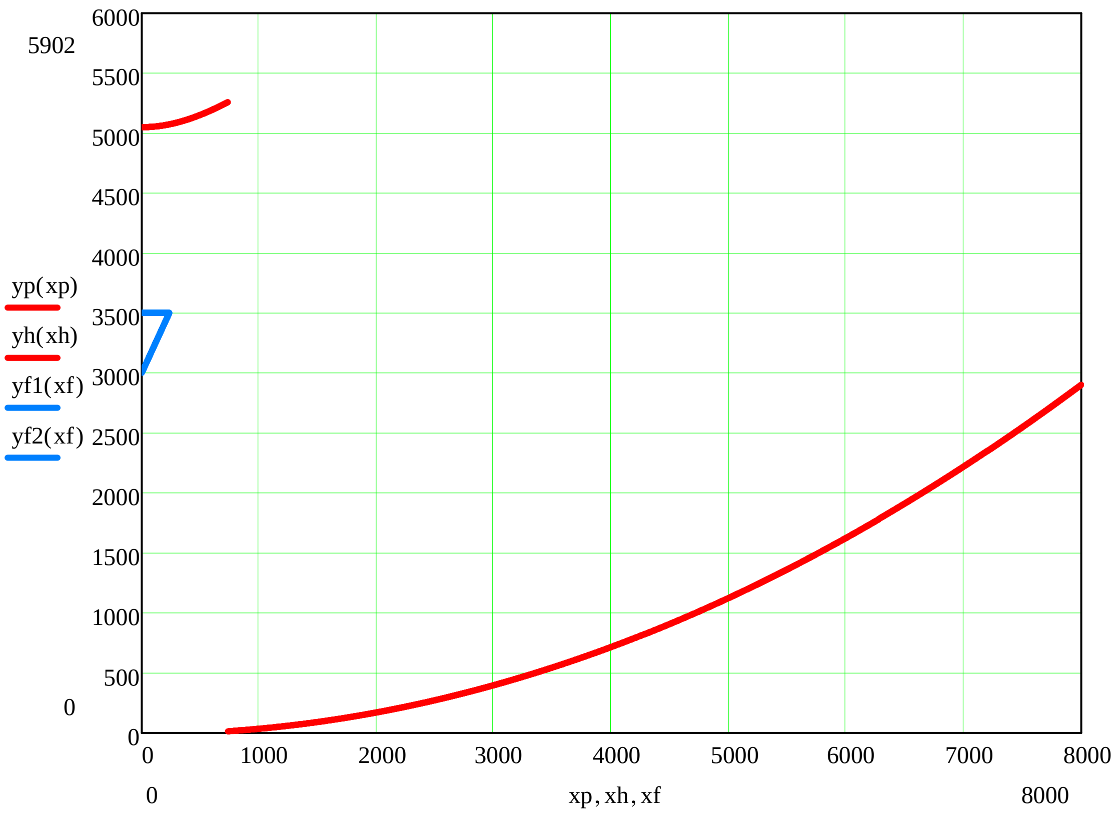
8.4 Fp=5.5m θ=14deg 2c=2.5m



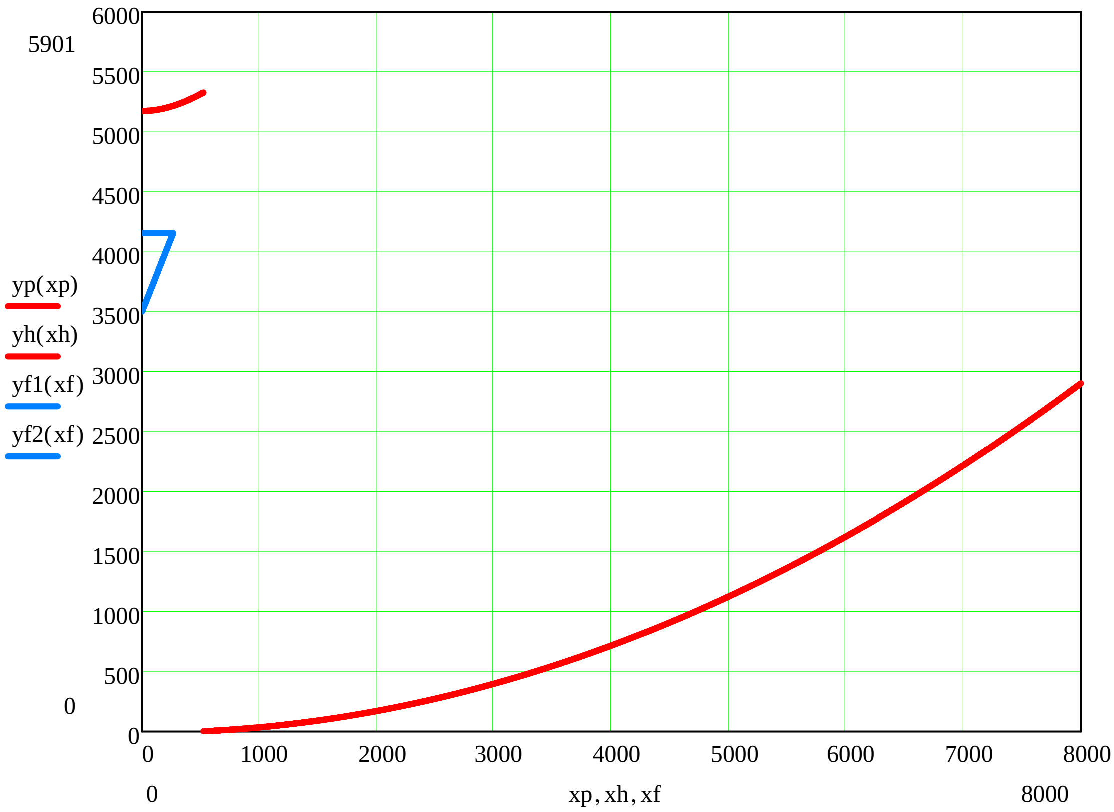
8.5 Fp=5.5m θ=16deg 2c=2.5m



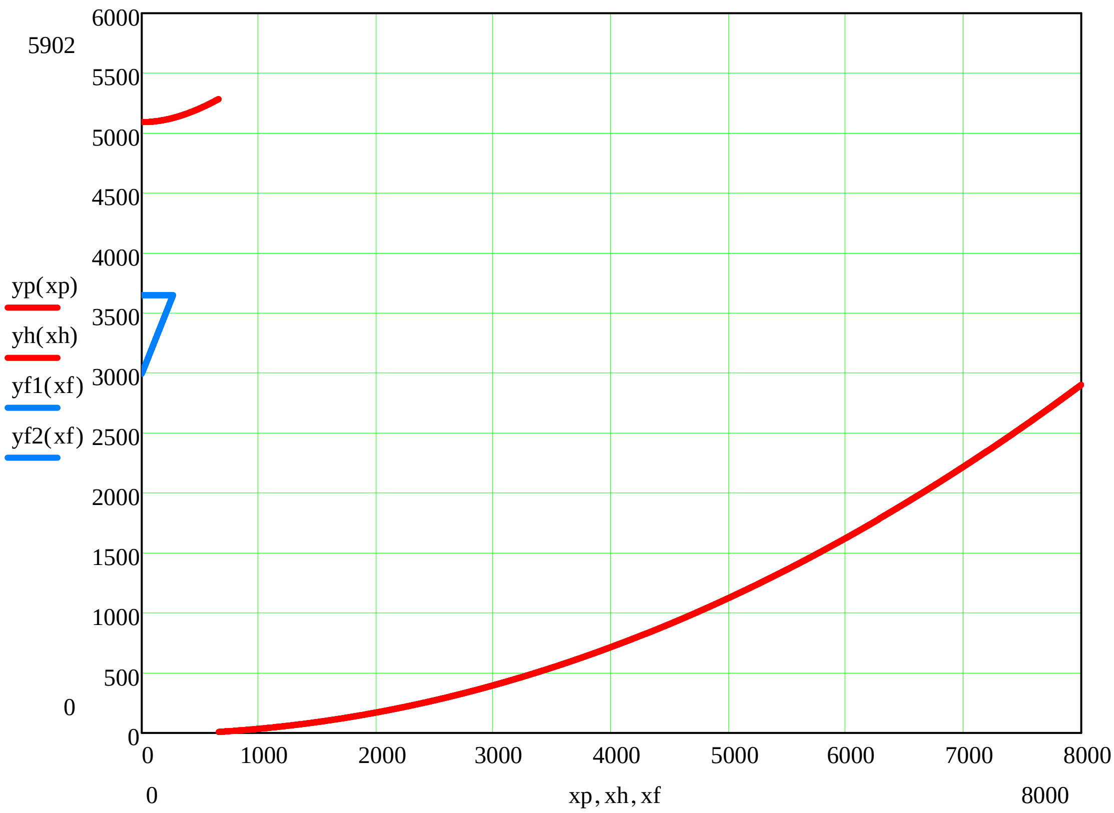
8.6 Fp=5.5m θ=18deg 2c=2.5m



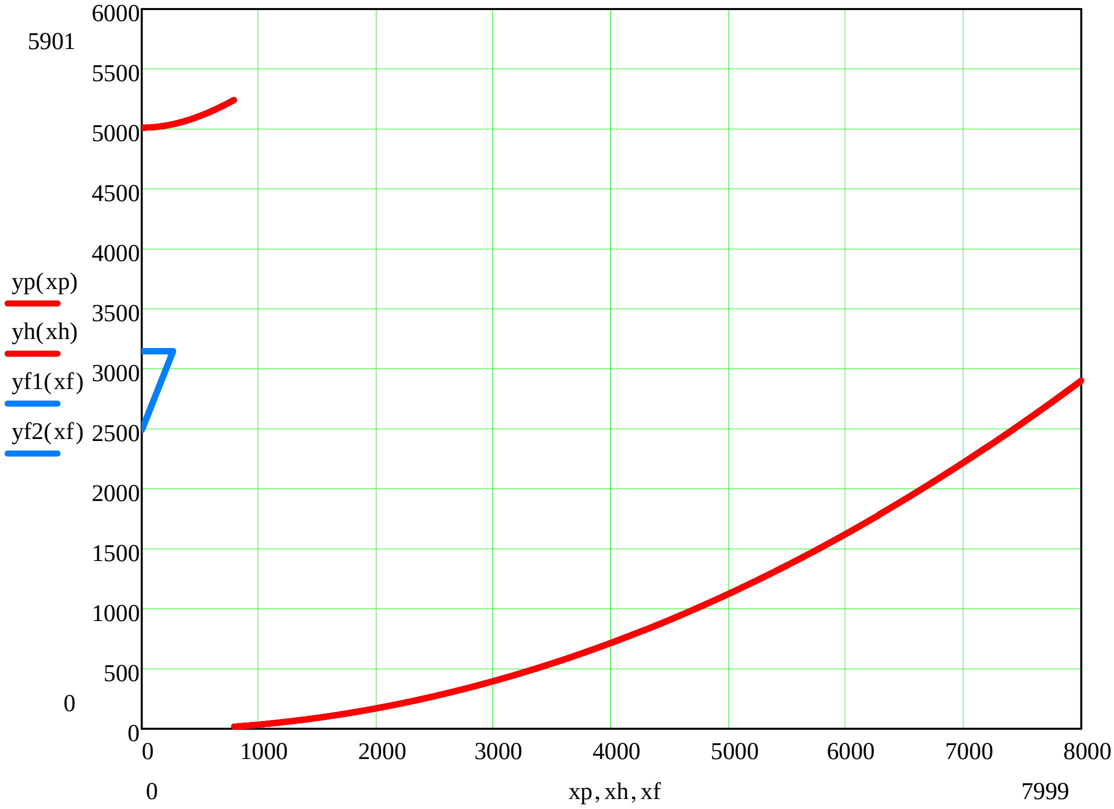
8.7 Fp=5.5m θ=16deg 2c=2.0m



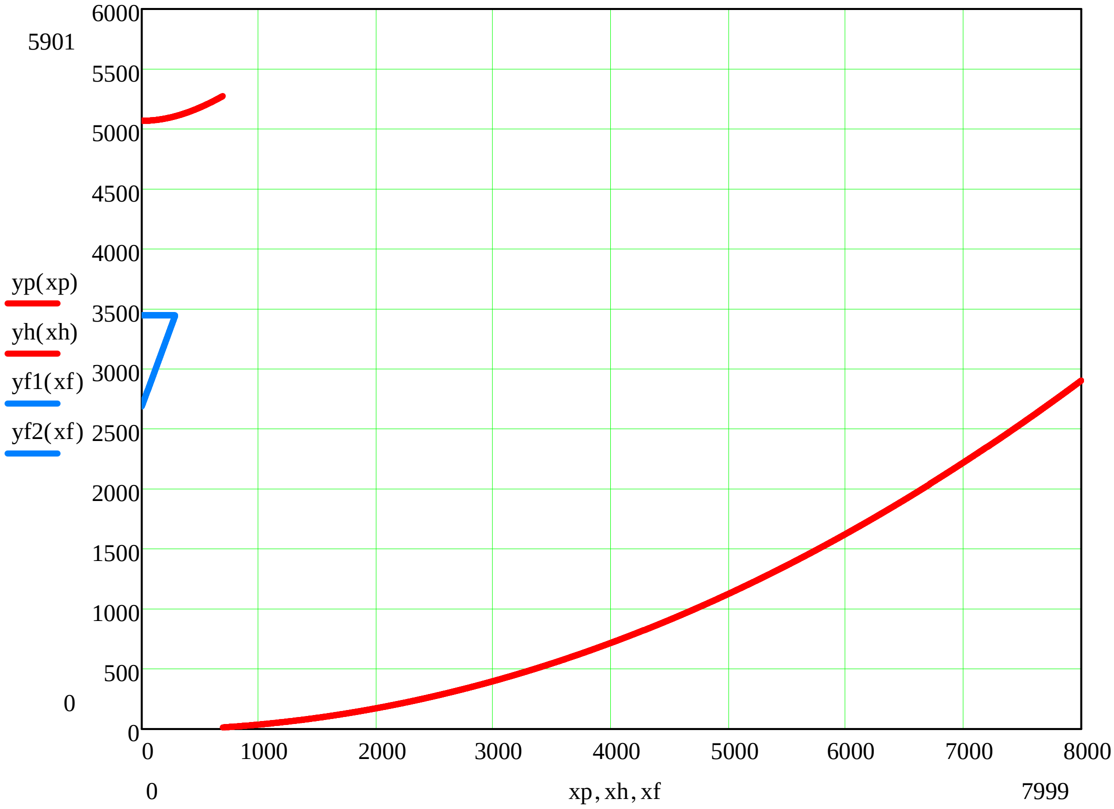
8.8 Fp=5.5m θ=16deg 2c=2.5m



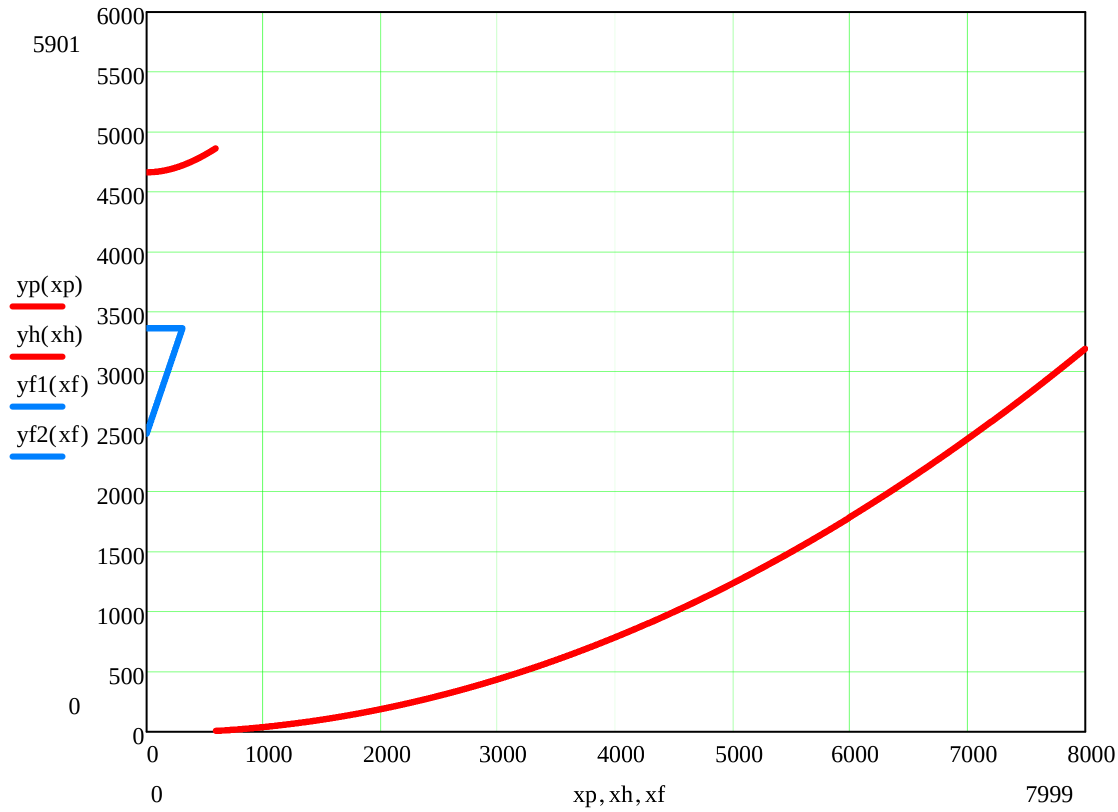
8.9 Fp=5.5m θ=16deg 2c=3.0m



8.10 Fp=5.5m θ=15deg 2c=2.8m



8.11 Analyzed Example Fp=5.0m θ=14deg 2c=2.5m



Reference

20141013_VENTSPILS_RT16_FEASIBILITY

Title

REFLECTOR FEASIBILITY AND PERFORMANCE METRICS FOR ALTERNATIVE OPTICAL DESIGNS

Costumer

MT MECHATRONICS

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1 SCOPE

The first set of optical layouts was discussed between IGN and the reflector supplier. In the process of technical and project optimization an alternative design was developed. This document shows the feasibility of the design with a wideband feed design with the shape optimized Cassegrain design proposed by the reflector supplier.

The alternative design is optimized with regard to the efficiency. It is compared with a classical cassegrain solution of similar dimensions to show the differences.

2 DOCUMENTATION AND REFERENCES

Title	Reference	Edited
Feasible solution geometries for Ventspils RT16	20140915_ventspils_rt16_feed and reflector feasible geometries.pdf	IGN
Shape optimized reflectors data files for alternative design	MainRefl.dat MainRefl_1.rsf SubRefl.dat SubRefl_1.rsf	

3 INTRODUCTION

The first step of the design of the optical solution must be the selection of the antenna layout (i.e. type of reflector) according to the specifications.

A first set of feasible optical layouts was communicated in the document 'Feasible solution geometries for Ventspils RT16'. These design were then discussed between feed supplier and reflector supplier to identify advantages and issues with regard to the particularities of the Ventspils RT 16 telescope project. The up to now discussed classical cassegrain antenna is usually chosen because it is widely used in astronomical radiotelescopes, it offers a good compromise between equivalent noise temperature and efficiency and it has acceptable sidelobes level. The operation frequency (4.5-8.8) and the wideband horn (64% relative bandwidth) to feed the antenna are arguments to have a big feed solution in a high magnification antenna. If the feed construction height is limited to about 1m (a reasonable size to be built), the antenna magnification cannot be bigger than 2, reducing the advantages of big magnification antennas.

With these limitations in mind, the first set of feasible solutions has been developed and analyzed where some parameters have constraints (the focal primary, maximum feed length and foci distance). The main performance characteristic for the feasible solutions communicated up to now is an approximate aperture efficiency of 0.8 over the frequency bandwidth.

A preliminary analysis to evaluate the characteristics of the shape optimized Cassegrain design is done in order to compare with the classical Cassegrain solution.

4 PRELIMINARY ANALYSIS

A preliminary analysis is done with one of the feasible cassegrain solution developed in the first run and the alternative solution.

4.1 Cassegrain data

The cassegrain solution is one of the up to now discussed feasible solutions. The parameters of the solution shown now are not optimal or fixed, at this moment the cassegrain solution is still open. The exact parameters finally used for the RT-16 reflector would have to be chosen between all the feasible solutions shown in ‘Feasible solution geometries for Ventspils RT16’. Performance of all the shown classical cassegrain designs is rather similar.

Diameter primary	Dp	m	16.00
Focal primary	Fp	m	5.00
Diameter secondary	Ds	m	1.18
Secondary thickness	ts	m	0.20
Foci distance	2c	m	2.50
Secondary vertex to secondary focus	Lr	m	2.17
Secondary vertex to primary focus	Lv	m	0.33
Primary vertex to secondary focus	g	m	2.50
Feed illumination half-flare angle at -11dB	θ	deg	14.0
Equivalent Focal ratio	F/D		2.04
Magnification	m		6.5
Central frequency	f0	GHz	6.65
Feed phase error at central frecuency	β	rad	7.0
Feed aperture radius (aprox.)	af	m	0.31
Feed length (aprox.)	Lf	m	0.88
Feed semiflare angle	θf	deg	19.2
Feed aperture position to secondary vertex	d1	m	1.3

Table 3. Optical parameter list of the cassegrain solution to compare

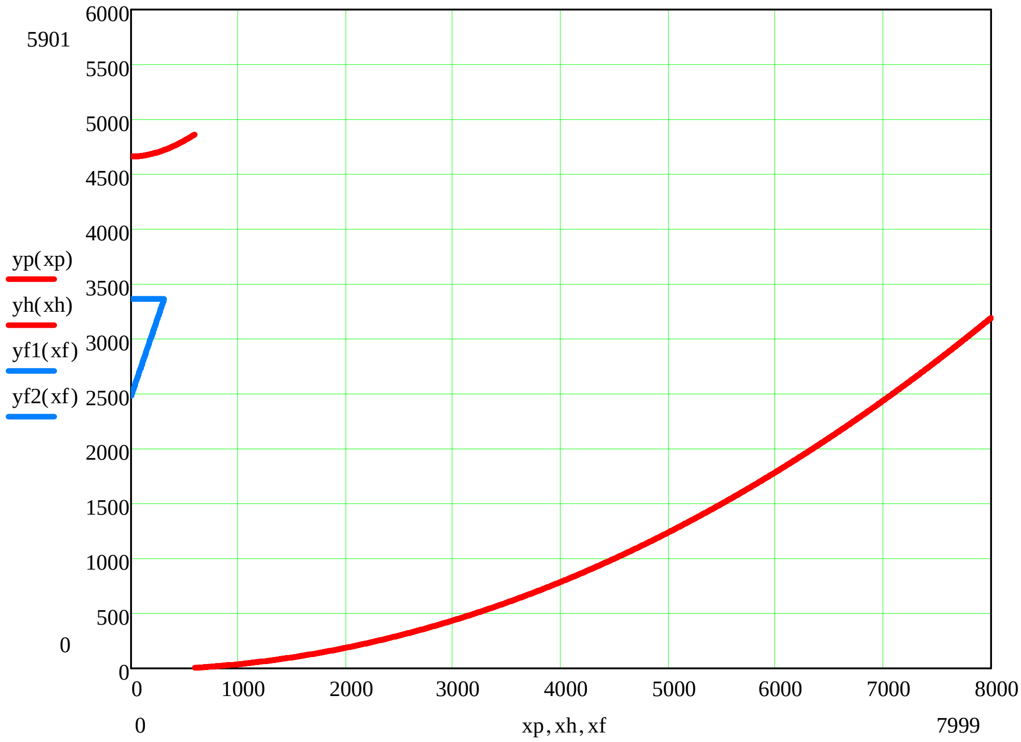


Fig. 3. One cassegrain solution geometry with feed. This geometry is used to show differences towards the alternative shape optimized cassegrain design.

4.2 Shape *optimized Cassegrain data*

Information for the alternative solution has been received on form of a file with the profiles of the primary and secondary reflector. The feed position of the phase centre is in the coordinate system origin. From the data files the following values were identified, the diameter of the primary, diameter of secondary, secondary position and feed position.

Diameter primary	Dp	m	16.00
Diameter secondary	Ds	m	1.60
Secondary thickness	ts	m	0.37
Secondary vertex to secondary focus	Lr	m	2.25
Primary vertex to secondary focus	g	m	2.09
Feed illumination half-flare angle between -11dB-14dB	θ	deg	17.0
Upper frequency (feed phase error definition)	fu	GHz	8.80
Feed phase error at central frecuency	β	rad	6.28
Feed aperture radius (aprox.)	af	m	0.20
Feed length (aprox.)	Lf	m	0.55
Feed semiflare angle	θf	deg	20.0
Feed aperture position to secondary vertex	d1	m	1.7

Table 4. Optical parameter list of the shape optimized solution to compare

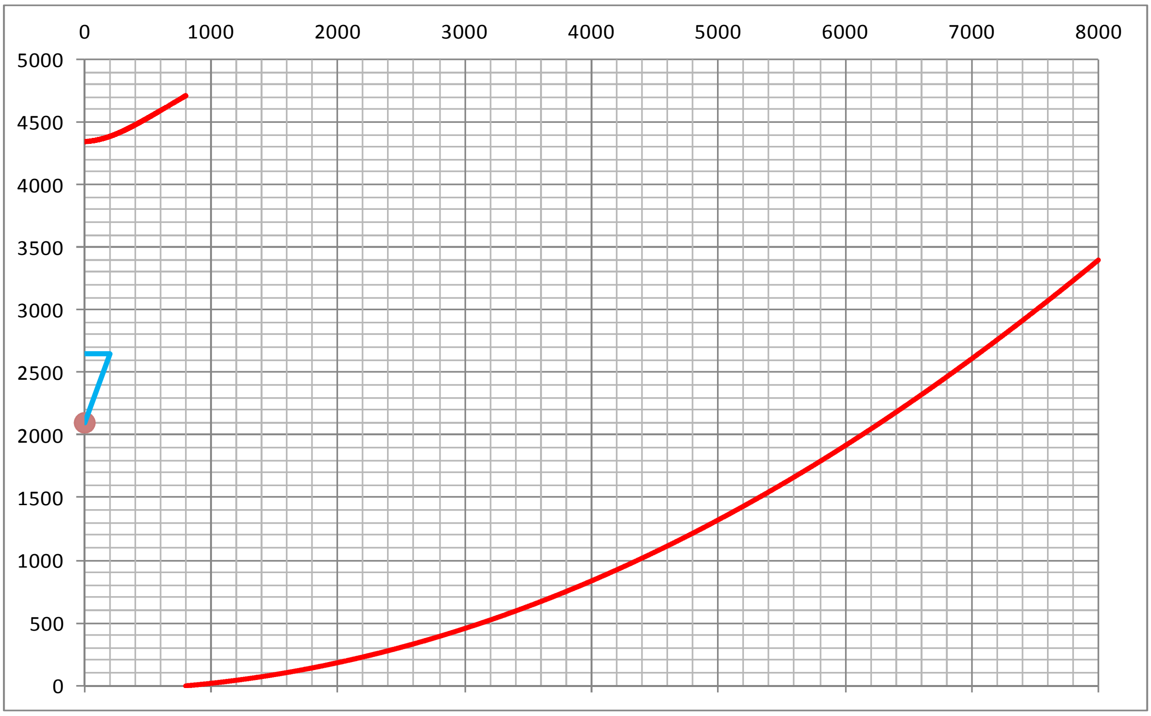


Fig. 4. Alternative solution geometry and feed which is analyzed below.

4.3 Items to compare

To compare both solutions, a Physical Optics analysis has been done. A hybrid mode feed (HE11) model, that it is placed with its phase centre in the antenna focal point, is used to analyze the antenna behavior. This model feed is a good approximation of a conical corrugated feed.

Three performance characteristics are compared:

1. **Aperture efficiency**. Evaluated over both solutions in similar conditions in the simulation. It is done in the lower, mid and upper frequency (4.50, 6.65 and 8.80GHz)
2. **Side lobe level**. Highest first sidelobe
3. **Feed and subreflector misalignments**. A big displacement in the feed and the subreflector is applied from its nominal position. The magnitude of this displacement is bigger than the real displacement that could happen. This analysis reveals the robustness of the solution to this kind of errors – but the true errors will be a lot smaller and also the effects will be smaller. The error is evaluated to the highest frequency (8.8GHz).

4.4 Cassegrain and shape optimized cassegrain design analysis

The radiation patterns of the simulations are in the Annex 0 for the cassegrain antenna, Annex 6 for the alternative shape optimized cassegrain reflector, Annex 7-11 for feed and subreflector misalignments.

Table 3 shows the results of the Physical optics calculations. There are results for the nominal positions, where all reflectors and feed is on axis. There are also misalignment results. The misalignment result figures are 1-2 orders of magnitude bigger than the final mechanical design, the misalignments are on purpose larger than to be expected in reality. The analysis was done to show the tendency of the errors in the radiation patterns and efficiency numbers.

		Cassegrain		Shape optimized Cassegrain	
		Ap. Efficiency (:1)	SLL (dB)	Ap. Efficiency (:1)	SLL (dB)
Nominal position	4.50 GHz	**0.79**	**-21**	**0.84**	**-16**
	6.65 GHz	**0.77**	**-21**	**0.86**	**-16**
	8.80 GHz	**0.79**	**-21**	**0.82**	**-16**
100mm Feed Axial	8.80 GHz	0.79	-20	0.76	-16
100mm Feed Lateral	8.80 GHz	0.77	-20	0.78	-14
1deg Feed Tilt	8.80 GHz	0.80	-20	0.80	-16
10mm Sub. Axial	8.80 GHz	0.71	-16	0.74	-17
10mm Sub. Lateral	8.80 GHz	0.78	-17	0.80	-13

Table 5. Aperture Efficiency comparison for the classical cassegrain design and the shape optimized cassegrain design.

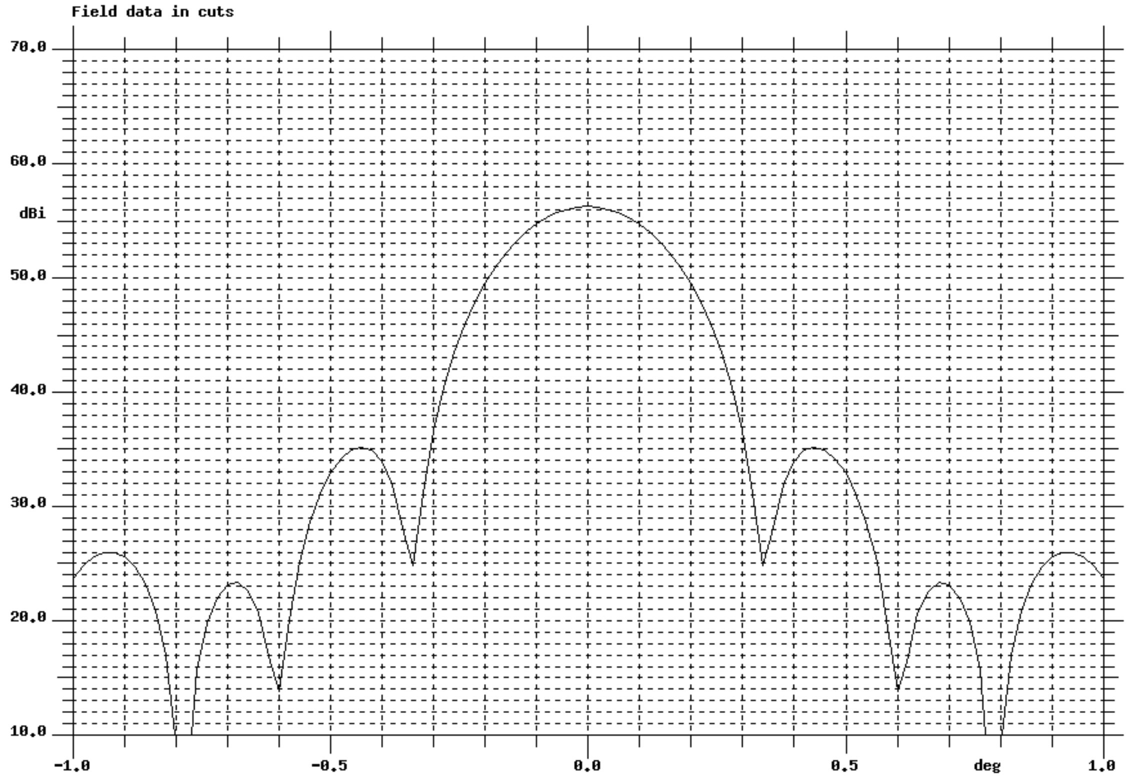
5 Conclusions

Two antennas have been evaluated, a feasible cassegrain reflector and an alternative design reflector. The shape optimized cassegrain design has a better aperture efficiency than the cassegrain antenna. On the other hand the side lobes levels of the classical design are better. Both solutions met the specification. The trade-off between the classical and the alternative design in terms of efficiency vs. side lobes needs to take the astronomical application in account.

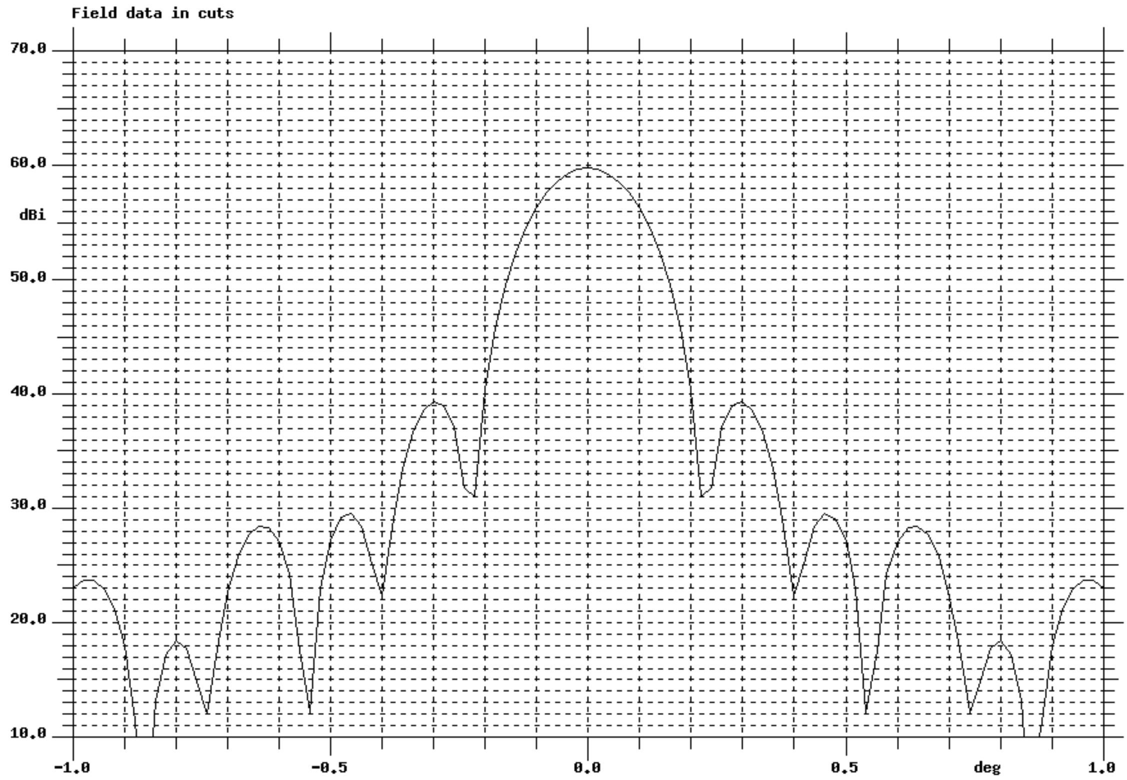
An additional misalignment analysis has been done at the highest frequency of 8.8GHz. It has been made to show that the aperture efficiency and sidelobes can degrade differently for both optical layouts. Misalignments that are 1-2 orders of magnitude larger that they would be expected to occur in reality have been applied to show the tendency of the behavior between the two antennas clearly. This analysis allows to extrapolate the antenna degradation that could happen in higher frequencies (specification: 1 to 12 GHz), since the aperture efficiency degradation due to the antenna misalignments increases when the frequency is increasing. If the antenna is going to be used up to a frequencies of 12 GHz, the mechanical design will be good enough to make the misalignments errors negligible. However, additional analysis with final mechanical design and with the expected misalignments are advisable to derive design alignment tolerances and to check the performance.

ANNEX. cassegrain radiation patterns

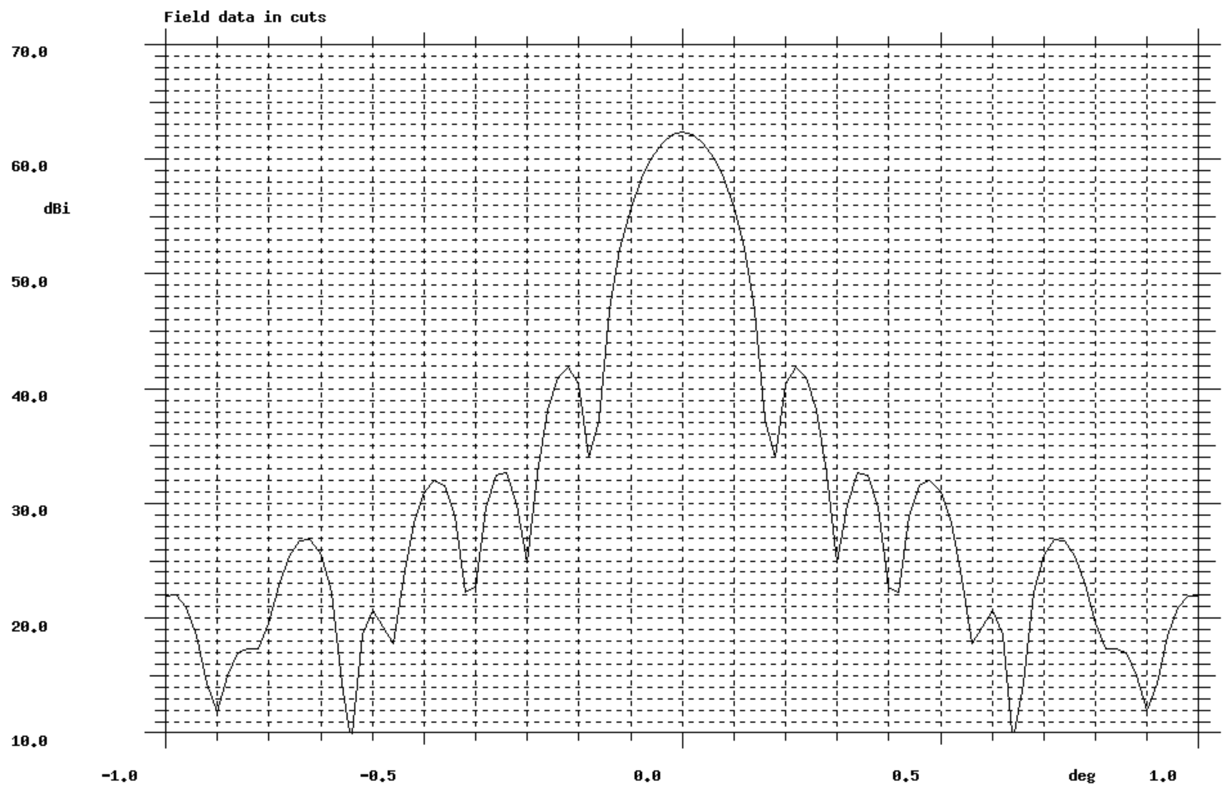
5.1 4.50GHz



5.2 6.65GHz

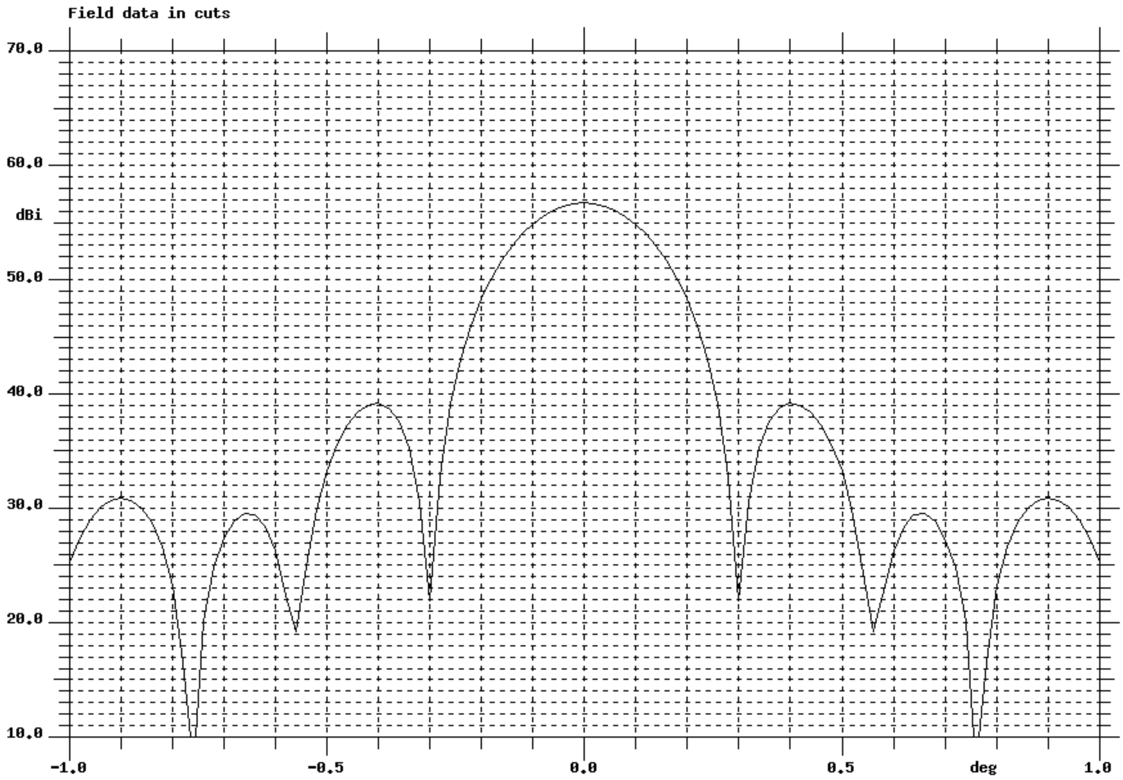


5.3 8.80GHz

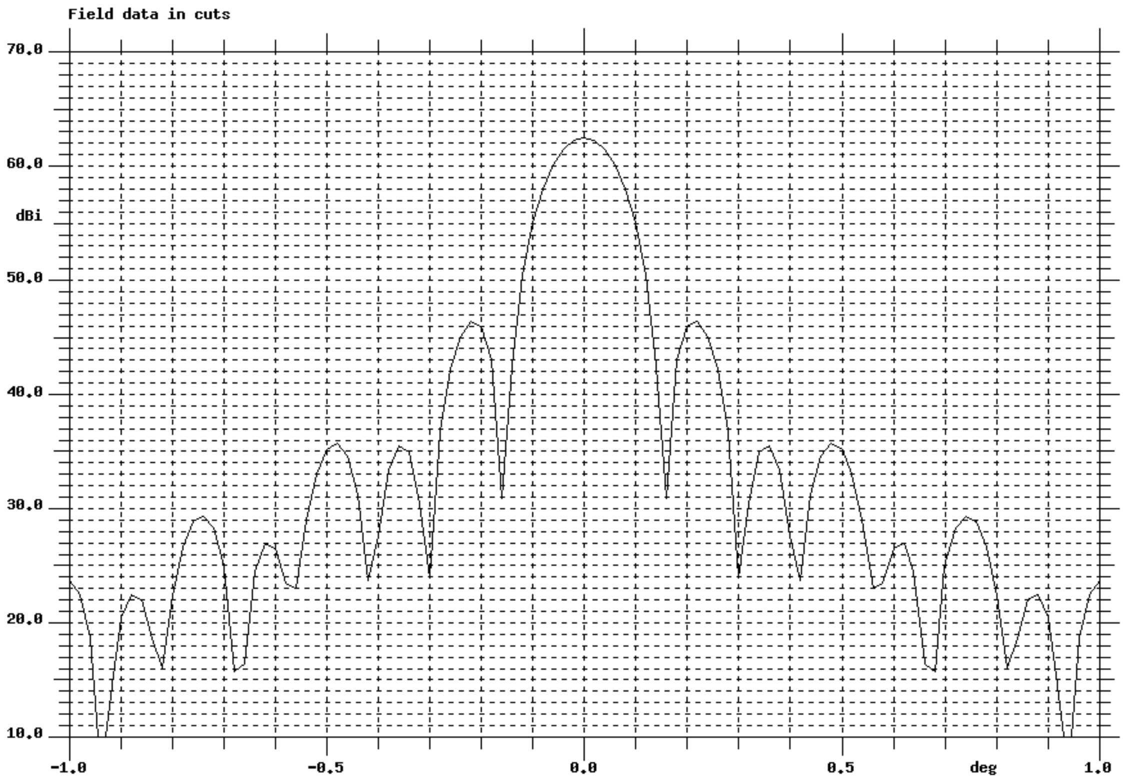

Field data in cuts
70.0
60.0
dBi
50.0
40.0
30.0
20.0
10.0
-1.0
-0.5
0.0
0.5
deg
1.0

6 ANNEX. SHAPE Optimized radiation patterns

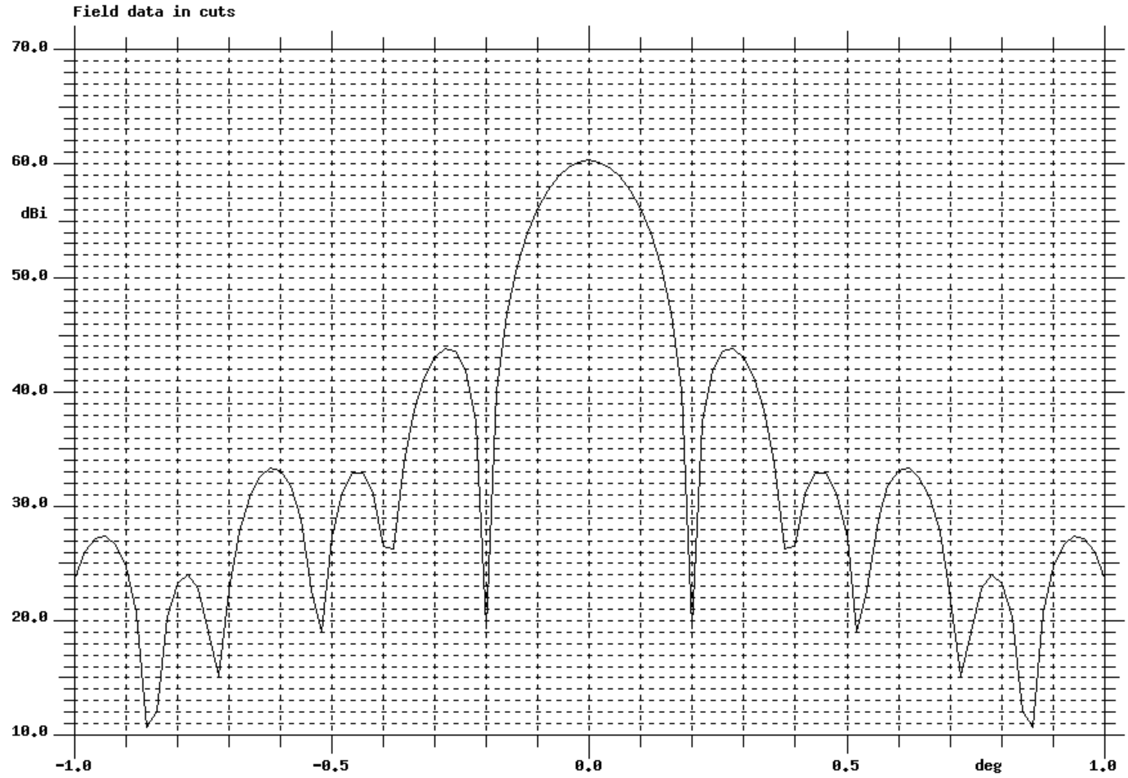
6.1 4.50GHz



6.65GHz

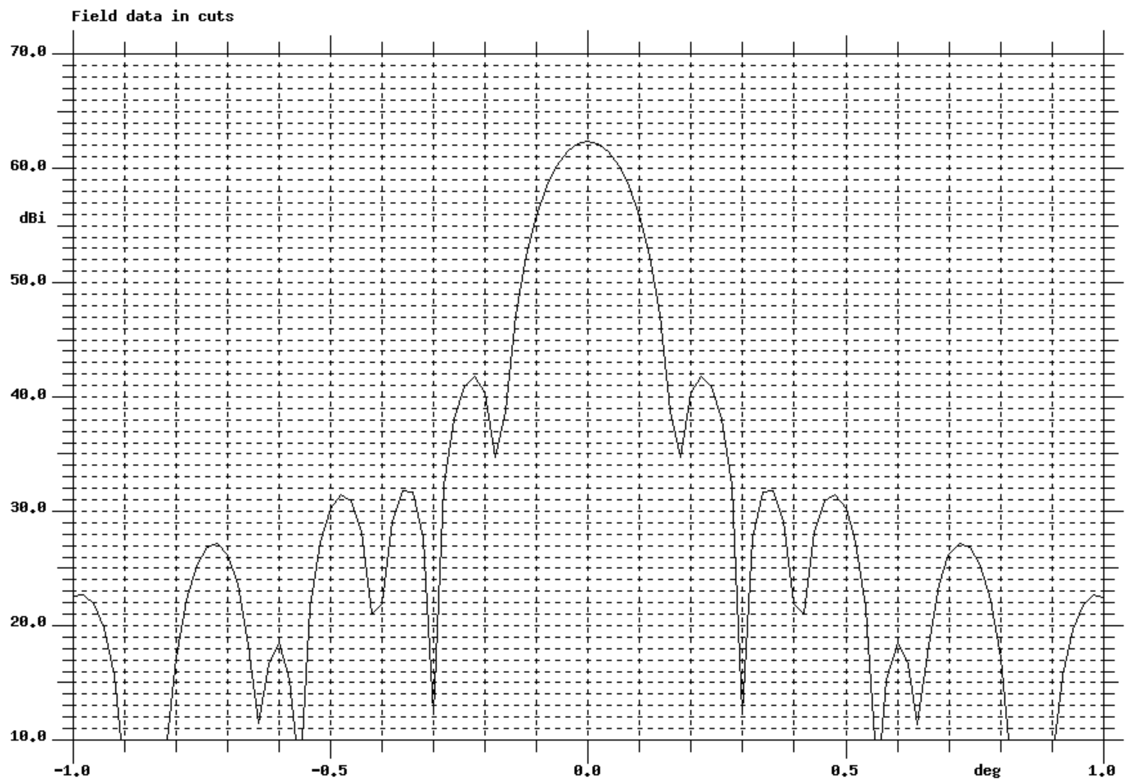


6.2 8.80GHz

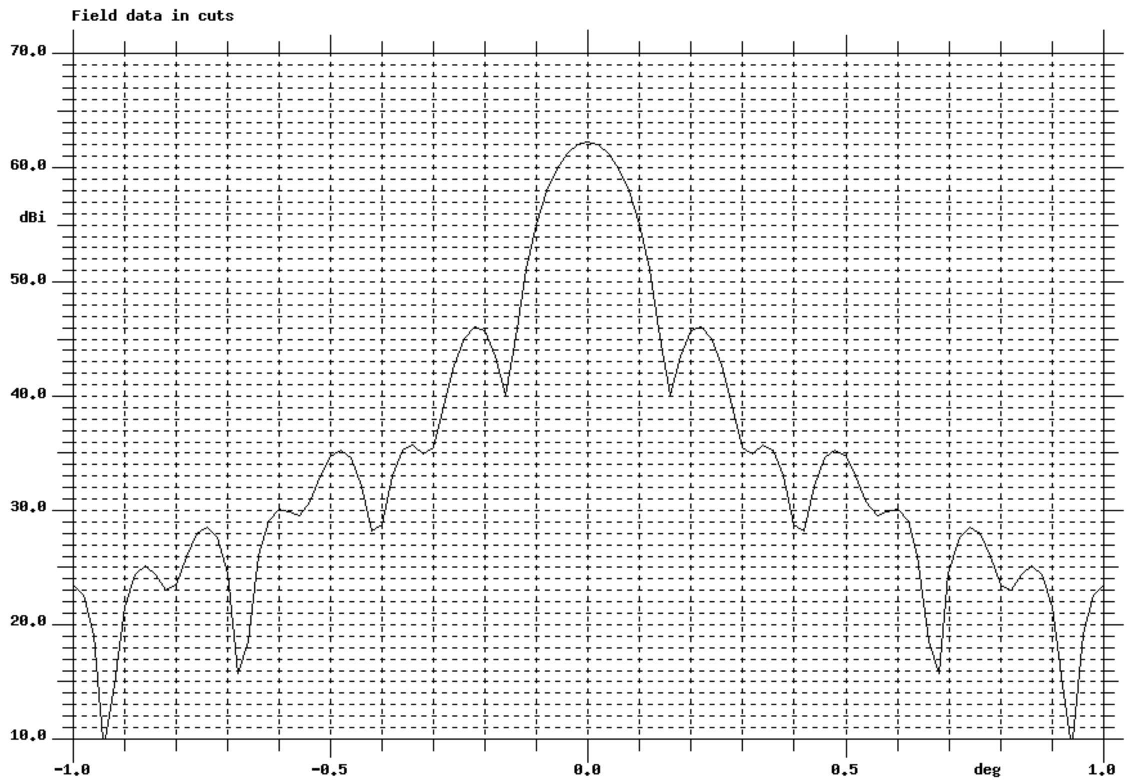

Field data in cuts
70.0
60.0
dBi
50.0
40.0
30.0
20.0
10.0
-1.0
-0.5
0.0
0.5
deg
1.0

7 ANNEX. 100mm Feed axial displacement radiation patterns

7.1 Cassegrain at 8.80GHz

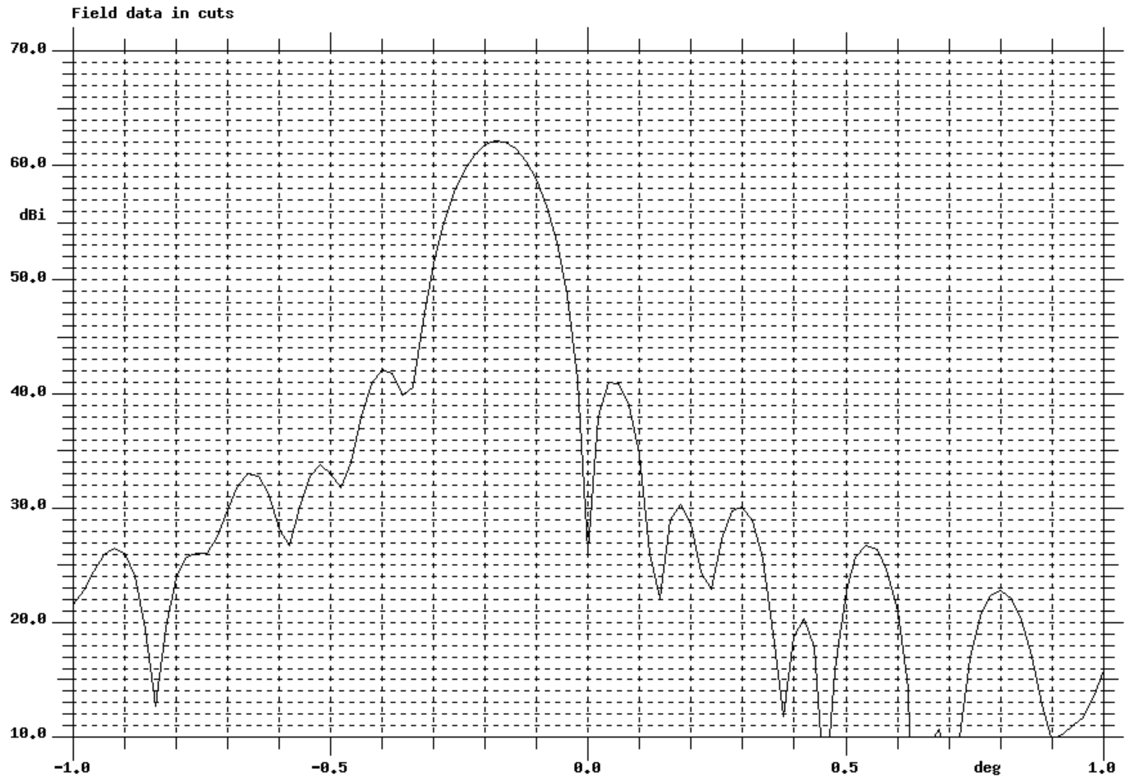


7.2 Shape optimized at 8.80GHz

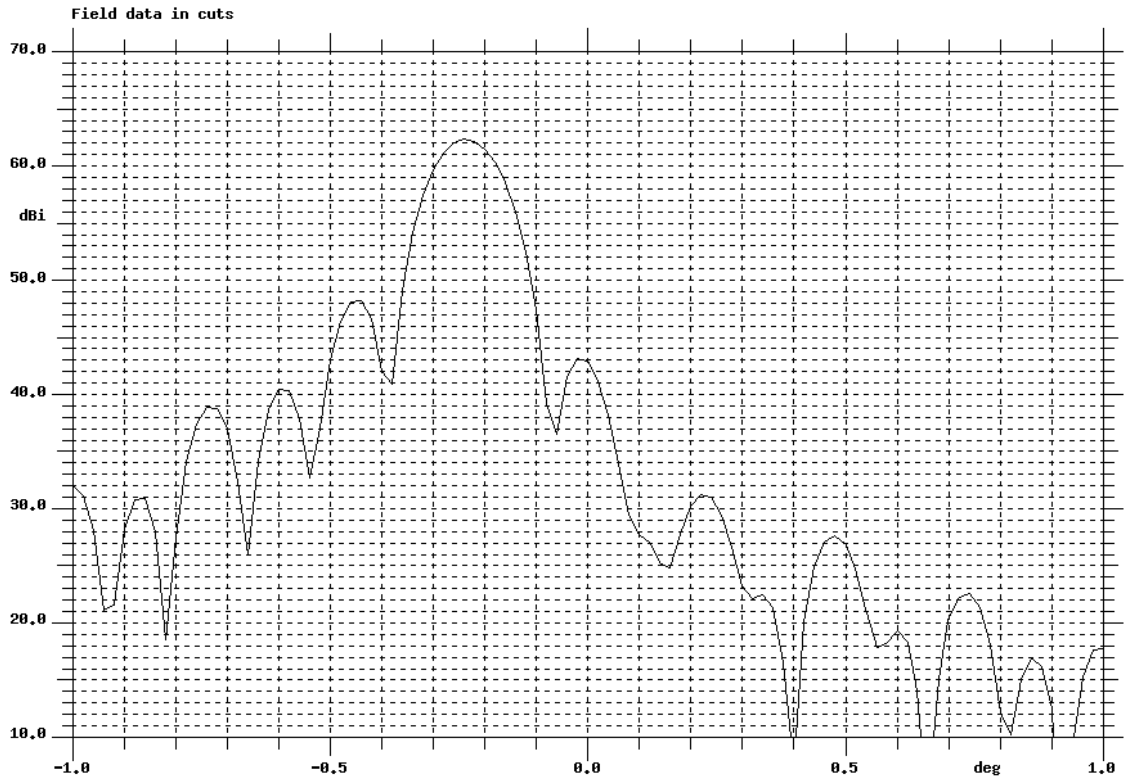


8 ANNEX. 100mm Feed lateral displacement radiation patterns

8.1 Cassegrain at 8.80GHz

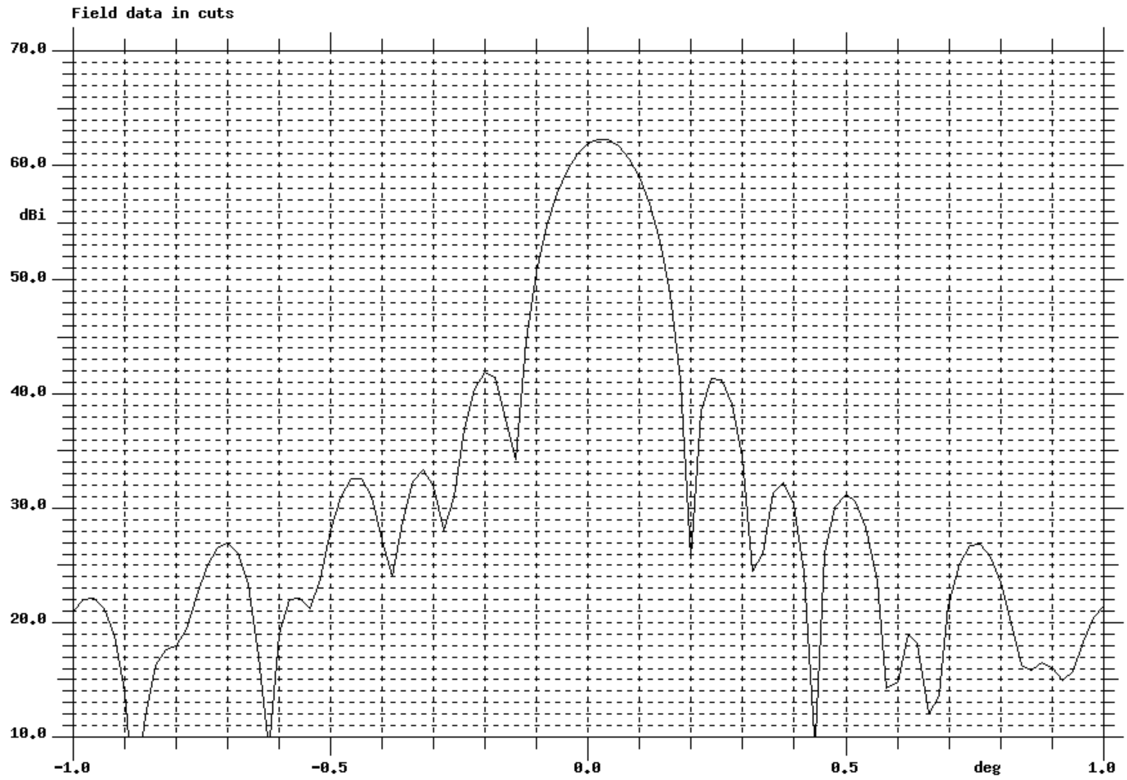


8.2 Shape optimized at 8.80GHz

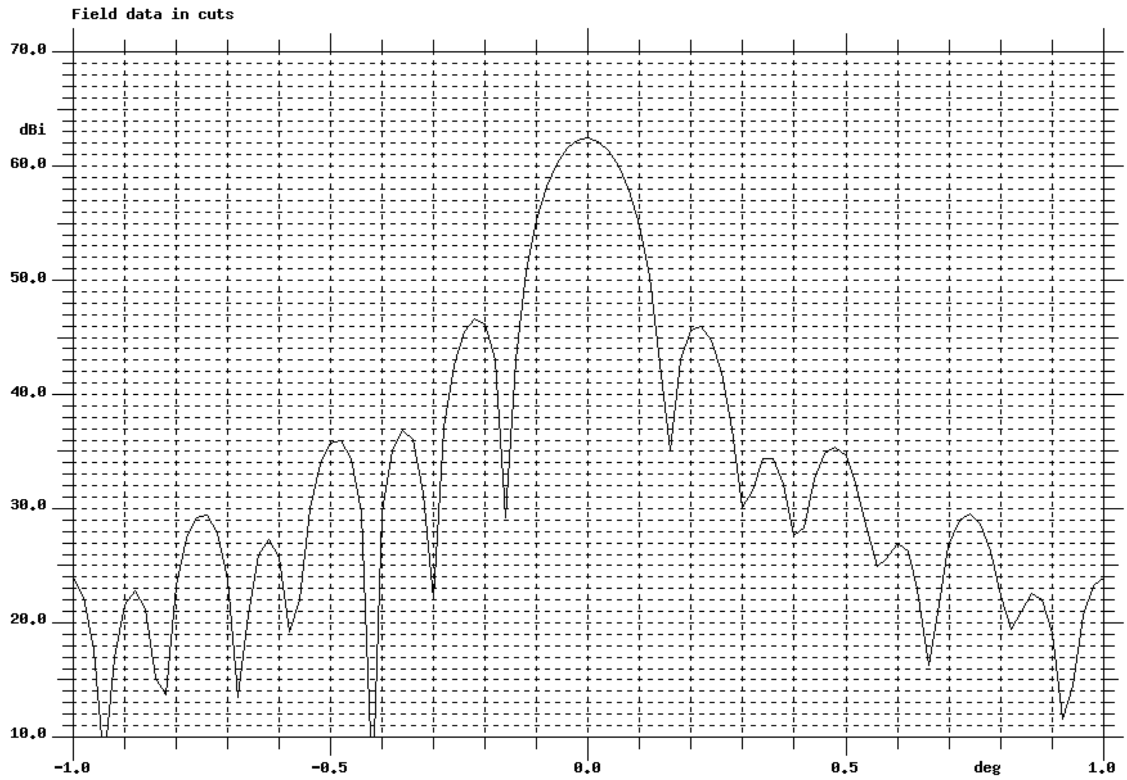


9 ANNEX. 1deg Feed tilt radiation patterns

9.1 Cassegrain at 8.80GHz

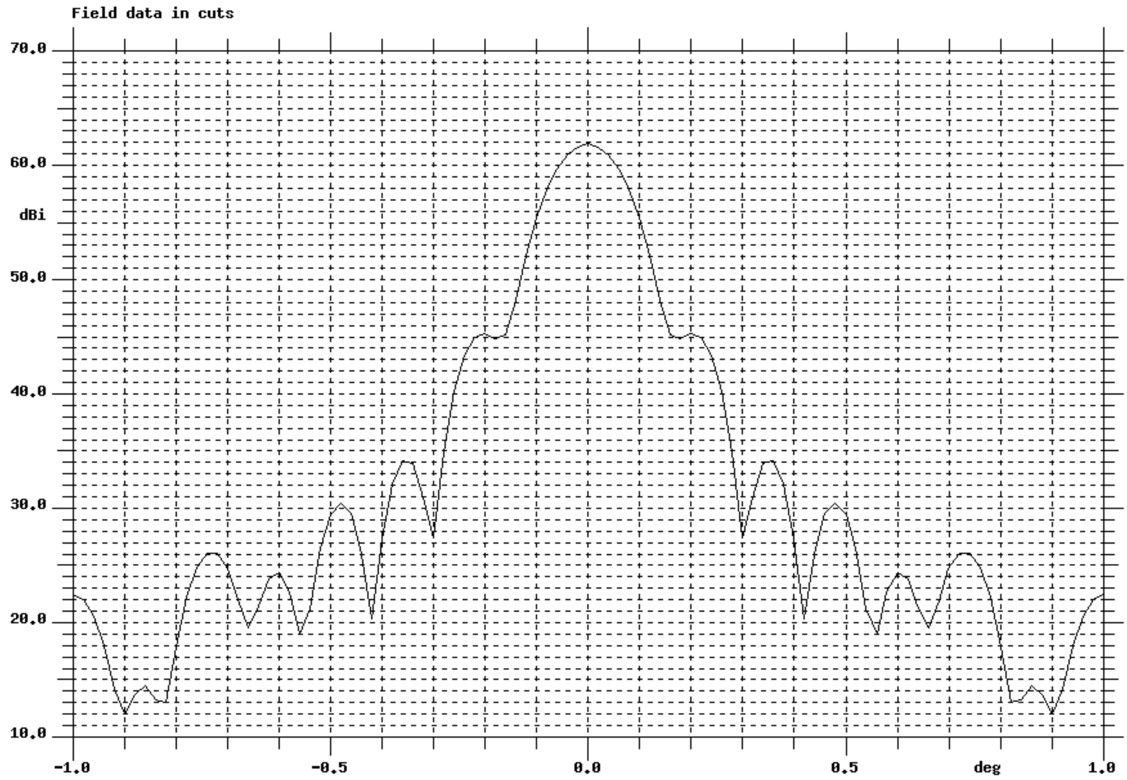


9.2 Shape optimized at 8.80GHz

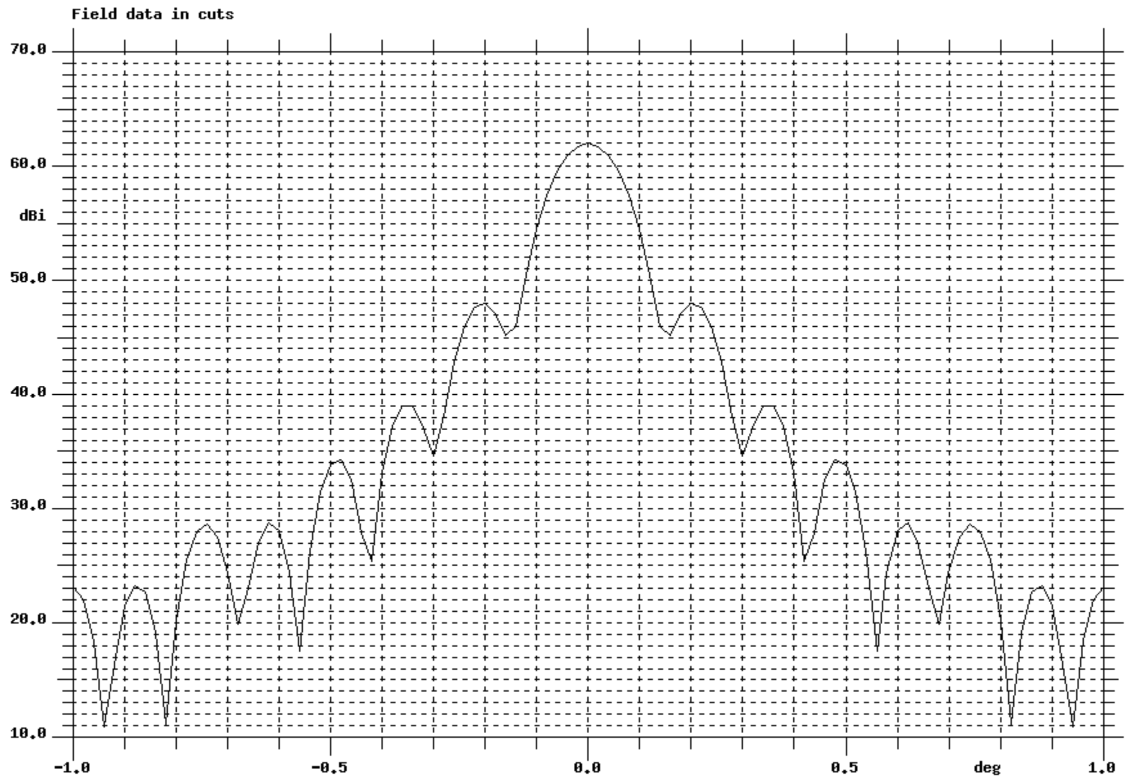


10 ANNEX. 10mm subreflector axial displacement radiation patterns

10.1 Cassegrain at 8.80GHz

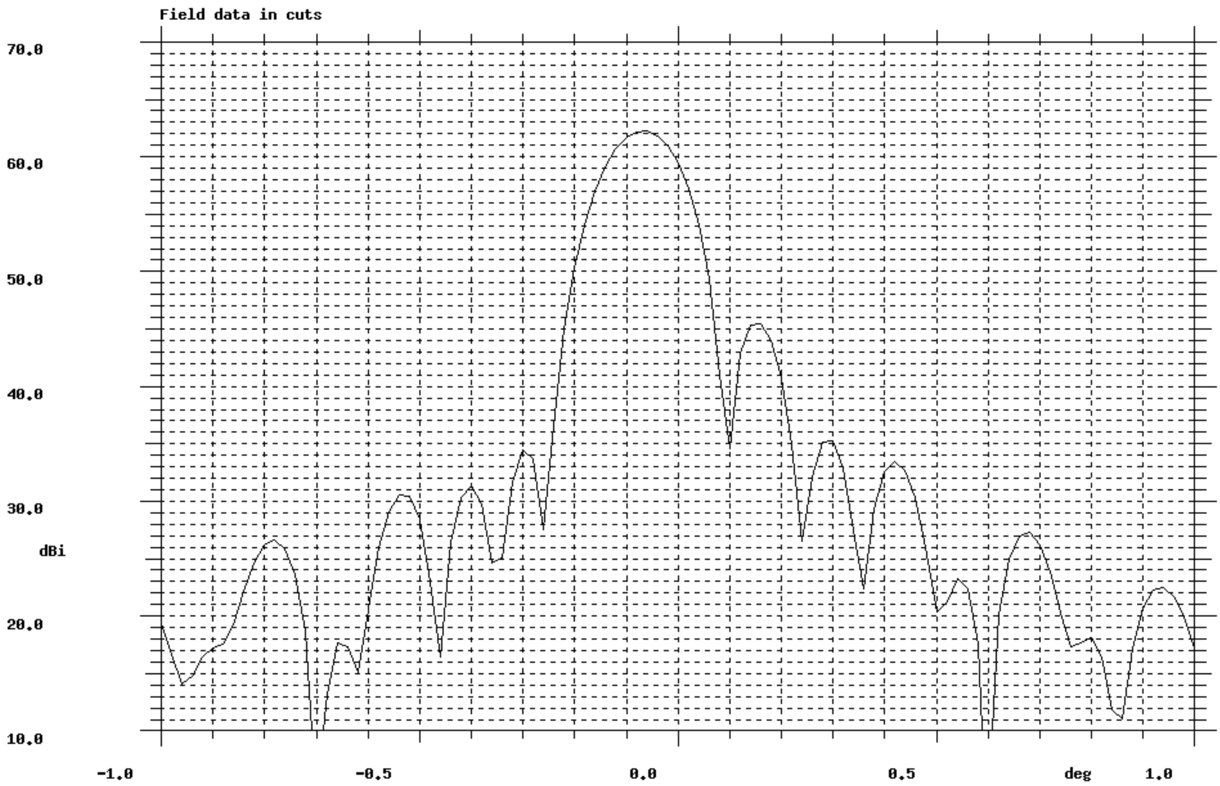


10.2 Shape optimized at 8.80GHz

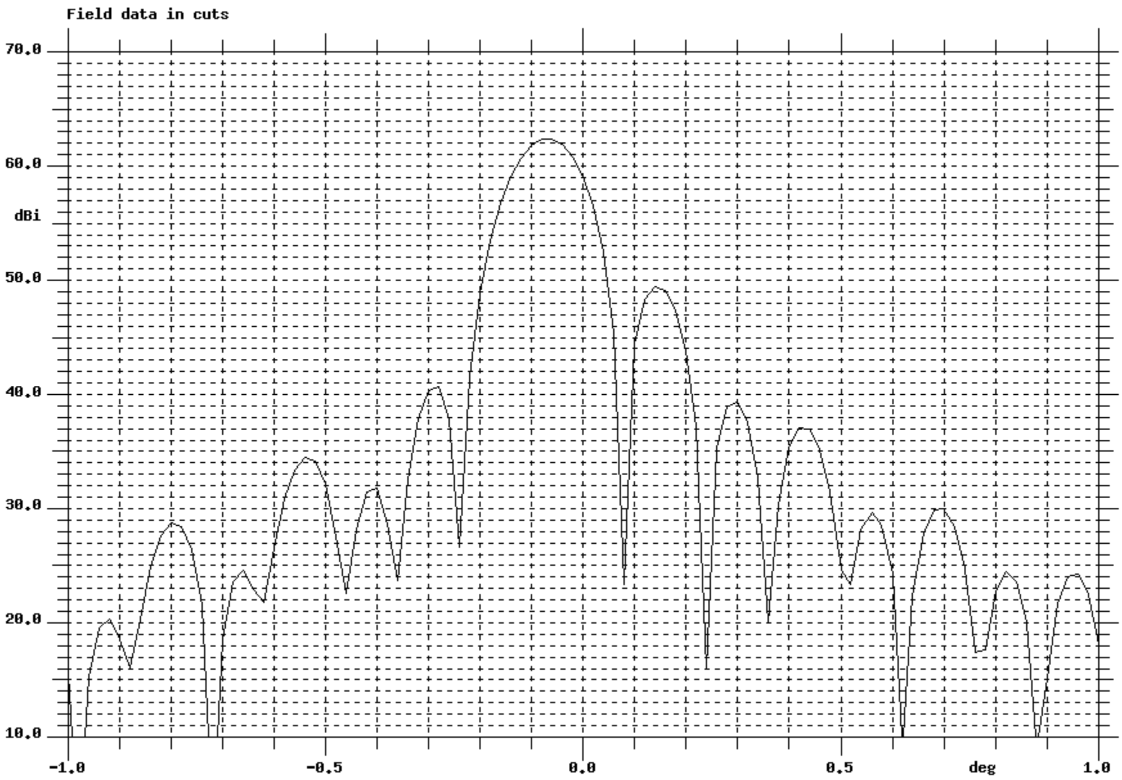


11 ANNEX. 10mm subreflector lateral displacement radiation patterns

11.1 Cassegrain at 8.80GHz



11.2 Shape optimized at 8.80GHz



Reference

20141217_VENTSPILS_RT16_PRELIMINARY_FEED

Title

PRELIMINARY FEED DESIGN FOR THE 16M VENTSPILS ANTENNA

Costumer

MT MECHATRONICS

Written and released by:

F.Tercero **S.López** **JA. López-Fdez**

Edición: 01.0	**Fecha: 17/12/2014**	**Paginas:**

1 SCOPE

Show the design that is being developed of the feeder for the 16m Ventspils antenna. It is an electrical preliminary design. It is analysed with the shaped cassegrain antenna at three frequencies, bottom, central and upper.

2 DOCUMENTATION AND REFERENCES

Title	Reference	Edited
Reflector feasibility and performance metrics for alternative optical designs	20141013_ventspils_rt16_feasibility.pdf	IGN
Receiver waveguide interface	Receiver vacuum gap and_feed_dimentions.pdf	VIRAC
Shaped reflectors data files	MainRefl.dat MainRefl_1.rsf SubRefl.dat SubRefl_1.rsf	MT

3 INTRODUCTION

An analysis to evaluate the characteristics of the shape optimised Cassegrain design has been done to show the feasibility of this antenna for the astronomical application of VIRAC. Physical Optics analysis were done with an hybrid mode feed (HE11) model, that it was placed with its phase centre in the antenna focal point. The hybrid mode feed is a good approximation of a conical corrugated feed and it is useful to check the antenna behavior by itself. Those simulations were performed to check the shape optimized cassegrain antenna.

This shape optimized antenna was proven to have higher aperture efficiency than typical cassegrain. It has also higher sidleobes but small enough for the astronomical application of VIRAC. This optimized optics were finally chosen to be implemented in the design.

On the other hand, the feed has to be developed to achieve the optimal illumination taper and phase center stability along all the frequency bandwidth from 4.50GHz to 8.80GHz. The feed has also to fit to the receiver current squared waveguide.

This report shows a preliminary feed profile to achieve the desired illumination taper and phase centre stability. It is also presented a transition from the squared waveguide to the circular waveguide port of the feed

4 General description and specification

The shaped cassegrain data information is in Table 1

Diameter primary	Dp	m	16.00
Diameter secondary	Ds	m	1.60
Secondary thickness	ts	m	0.37
Secondary vertex to secondary focus	Lr	m	2.25
Primary vertex to secondary focus	g	m	2.09
Feed illumination half-flare angle between -11dB-14dB	θ	deg	17.0

Table 1. Optical parameter list of the shaped solution to compare

The feed has to fit with the polarizer waveguide which has a squared waveguide of 45x45mm. It is not straight in the corners, it is rounded with a 5mm radius. A layout of the waveguide can be seen in the annex (8)

Waveguide type			squared
Waveguide dimension	a	mm	45
Waveguide rounded corners radius of curvature	rc	mm	5

Table 2. Waveguide parameter list

5 Feed electromagnetical design.

A wide-angle feed horn is chosen to satisfy the requirement of fixed taper illumination at 17 deg in the full bandwidth. The horn profile is optimized to have low reflection in the port, specified illumination taper, low crosspolar level and good beam symmetry. The corrugations have variable thickness and depth to match to the circular waveguide. The horn profile can be seen in Figure 1.

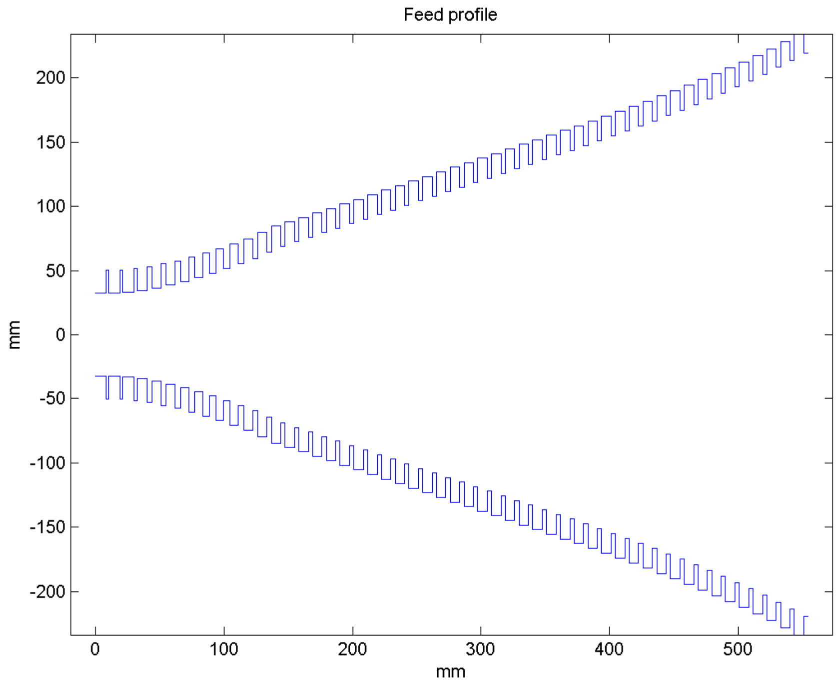


Figure 1. Feed inner profile

The port reflection in the circular waveguide is showed in Figure 2. The radiation patterns of the feed are calculated with modal matching, they can be seen in the annex (9).

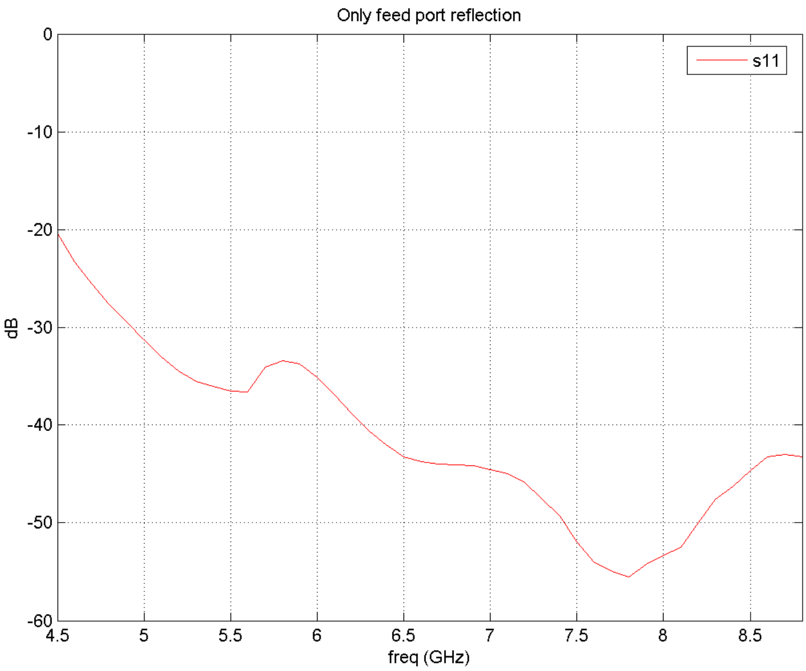


Figure 2. Feed port reflection in circular waveguide

The transition to the polarizer is planned to be an smooth square to circular waveguide transition from 45x45mm (square) to 32.4mm (radius circular). In the Figure 3, the smooth profile is shown. It was limited to be 100 mm length.

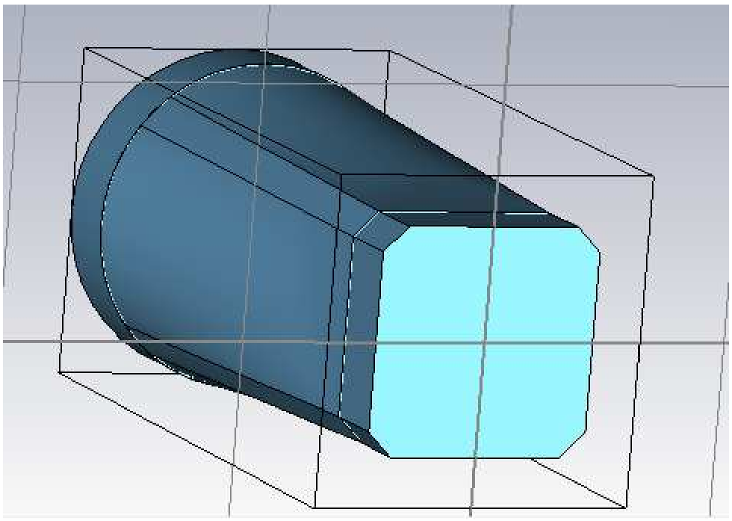


Figure 3. Square to circular transition

The port reflection of the transition is calculated with a full wave electromagnetic simulator. The port reflection can be seen in the Figure 4.

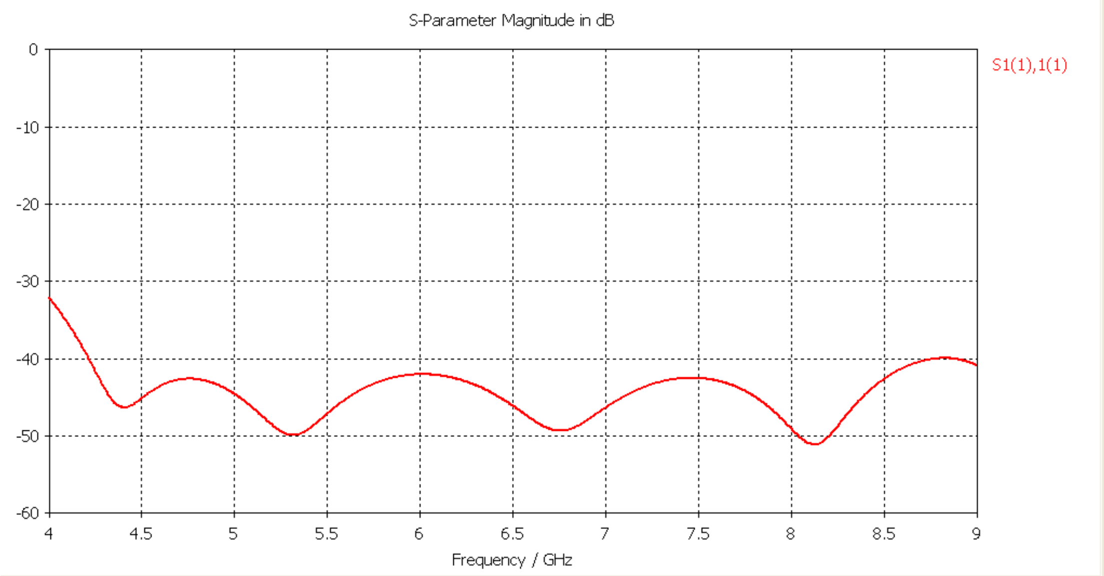


Figure 4. Square to circular transition reflection

The parameter data of the design is in the Table 3

Squared waveguide dimension	as	mm	45
Squared waveguide rounded corners radius of curvature	rc	mm	5
Circular waveguide dimension	ac	mm	32.40
Transition length	lt	mm	100.00
Feed aperture radius	af	mm	219.30
Feed length	Lf	mm	554.19
Total length (feed+transition)	ts	m	654.19

Table 3. Parametre data of the design

Final mechanical radius of the feed will be higher than the aperture radius. The total length can be also higher when the mechanical design were finished.

With this data only an approximation of weight can be done. It will manufacture in aluminum with an expected weight of 6 kg.

6 ANTENNA ANALYSIS WITH DESIGNED FEED

The feed designed is analyzed with the reflector. Standard Physical Optics calculations were done in order to check the feasibility of the designed feed.

The simulated patterns are used as feeder in the shaped cassegrain antenna. As the feed is a wide angle feed, the phase center position is approximately in the throat of the feed. To determine its position in the antenna, the focal point of the antenna must be taken as a reference point, the feed aperture position is offset 554mm to the subreflector direction (Figure 5 and Figure 6).

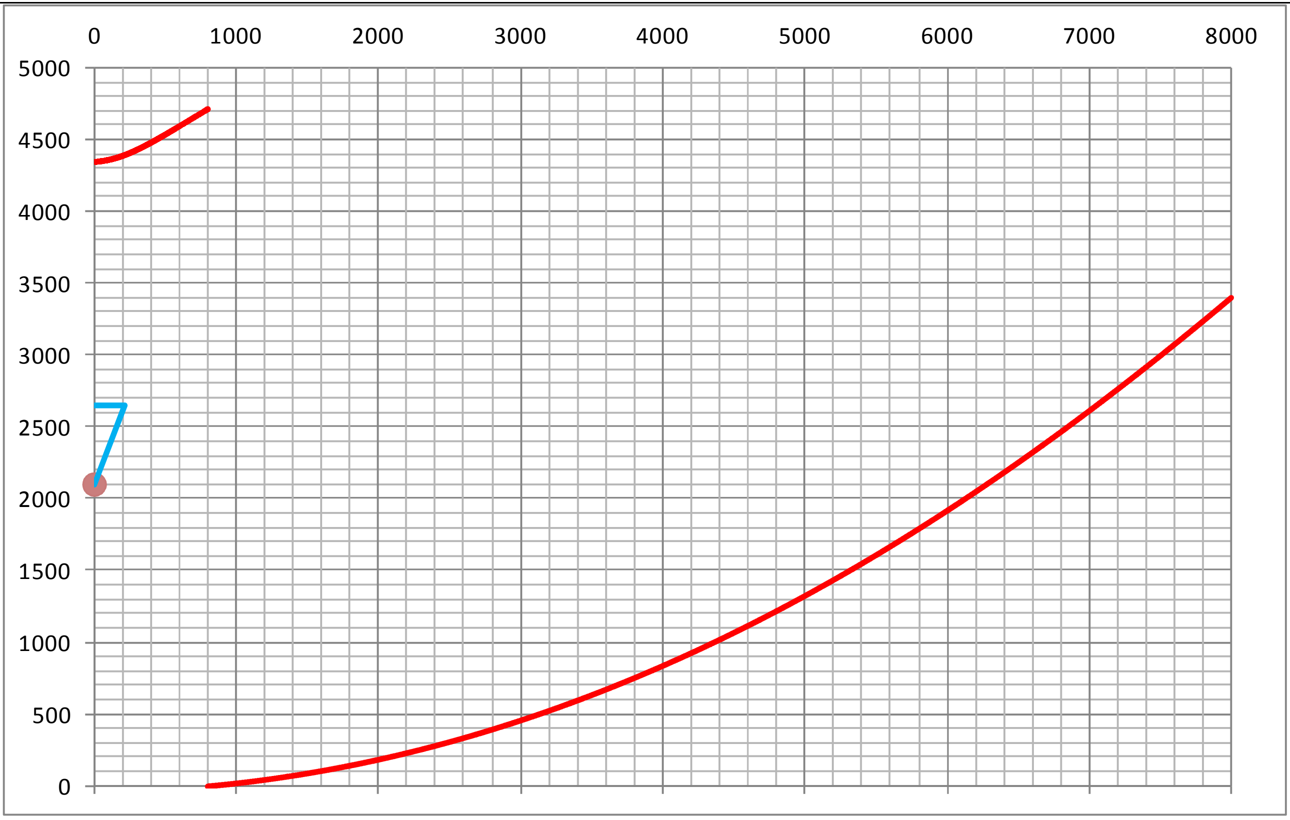


Figure 5. Shaped cassegrain and feed position

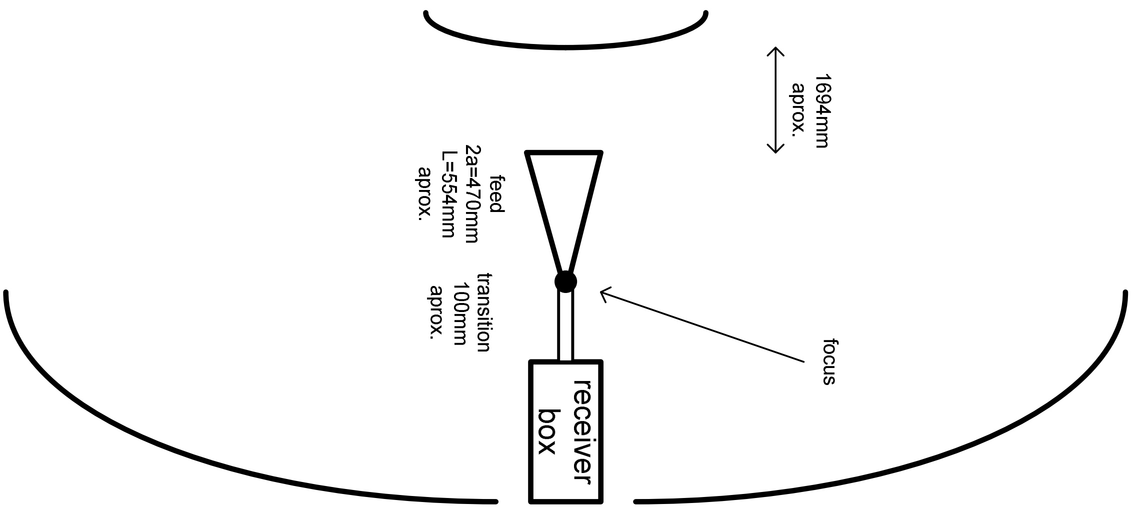


Figure 6. Layout with approximate dimensions

The performance of the feed with the antenna is as good as expected in the simulations. A high aperture efficiency is reached. The sidelobes level are also expected because the shaping. About the radiation patterns, they are symmetrical in the main beam and some asymmetries can be found in some frequencies in the sidelobes, where the feed symmetry is worse. However, these effects are very low and they do not affect the efficiency.

The results of the simulations are summarized in Table 4. The radiation pattern of the antenna with the designed feed can be found in annex 10

		Ap. Efficiency (:1)	SLL (dB)
Nominal position	4.50 GHz	**0.86**	**-17**
	6.60 GHz	**0.86**	**-17**
	8.80 GHz	**0.87**	**-16**

Table 4. Aperture efficiency of the designed feed

7 CONCLUSIONS

An electrical design of the feed has been analyzed. It is a conical profiled corrugated feed horn that satisfies the design criteria of illumination of the shaped reflector in all the frequency range (4.5GHz-8.80GHz). It also has a better than -20dB input port reflection losses and the beam symmetry is enough to have a low crosspolar component. A waveguide transition has been also designed to match to the polarizer output waveguide.

The phase centre of the feed is planned to fixed near of the feed throat to maximize the antenna gain without any additional feed movement for different frequencies.

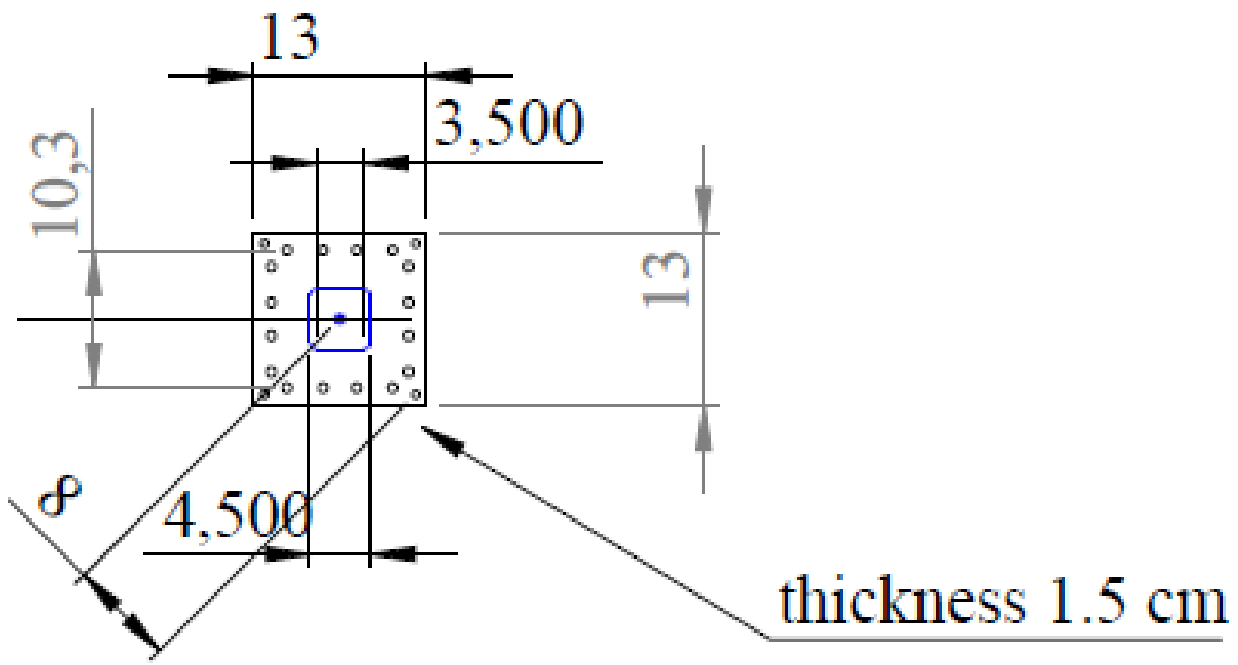
It is an electrical design, so minor changes are expected in the final feed, when the mechanical design finished. However, as the mechanical feed cone will be designed at the same time, it is recommended to have ±100mm of margin to place the final receiver and feed. The final position of feed can be given with the final mechanical design or it can adjusted by means of the receiver adjustment structure of the VIRAC.

An antenna analysis has been performed to check the feed feasibility and high aperture efficiencies have been calculated.

Further simulations of the feed must be done to assure the feed behavior before of the mechanical feed design

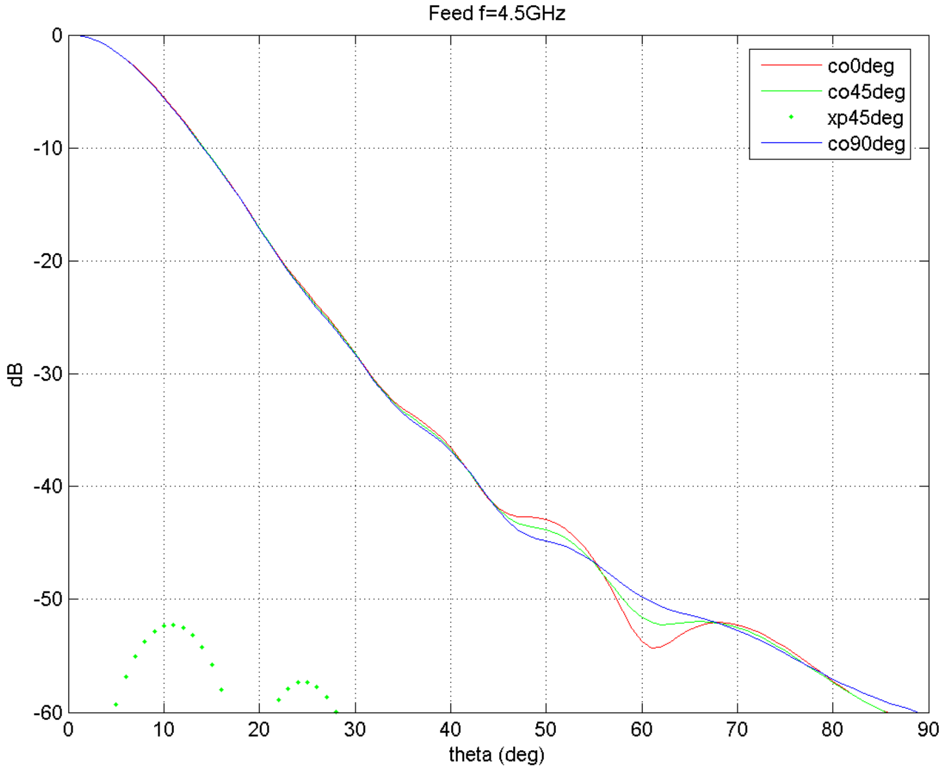
8 ANEXX. input waveguide

All the dimensions are in cm

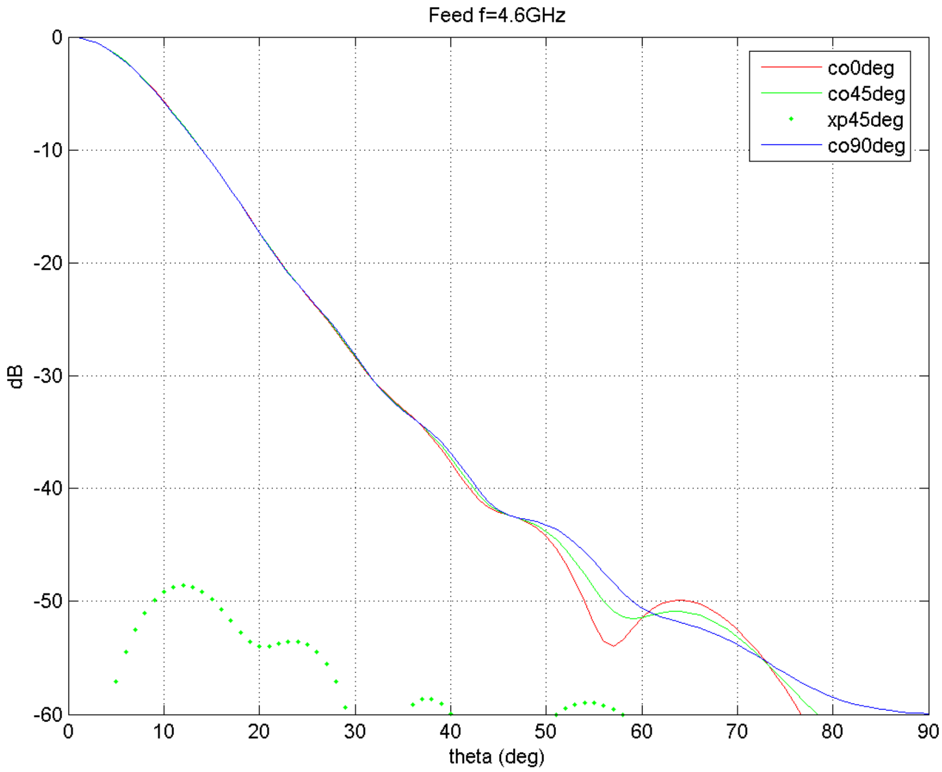


9 ANEXX. Feed radiation patterns

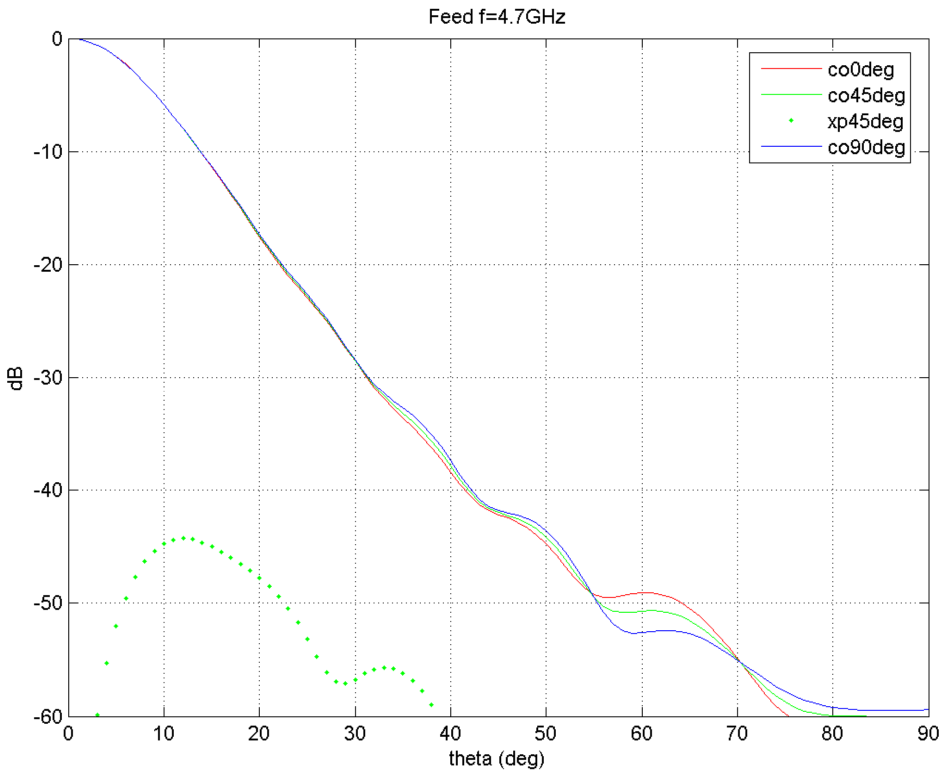
9.1 4.50 GHz



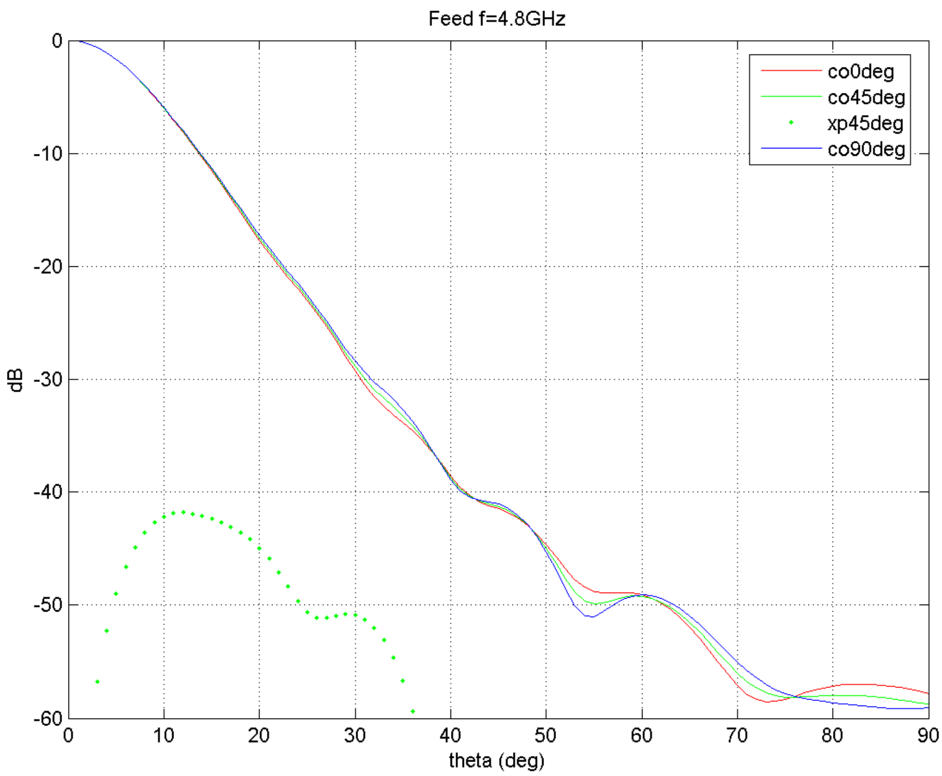
9.2 4.60 GHz



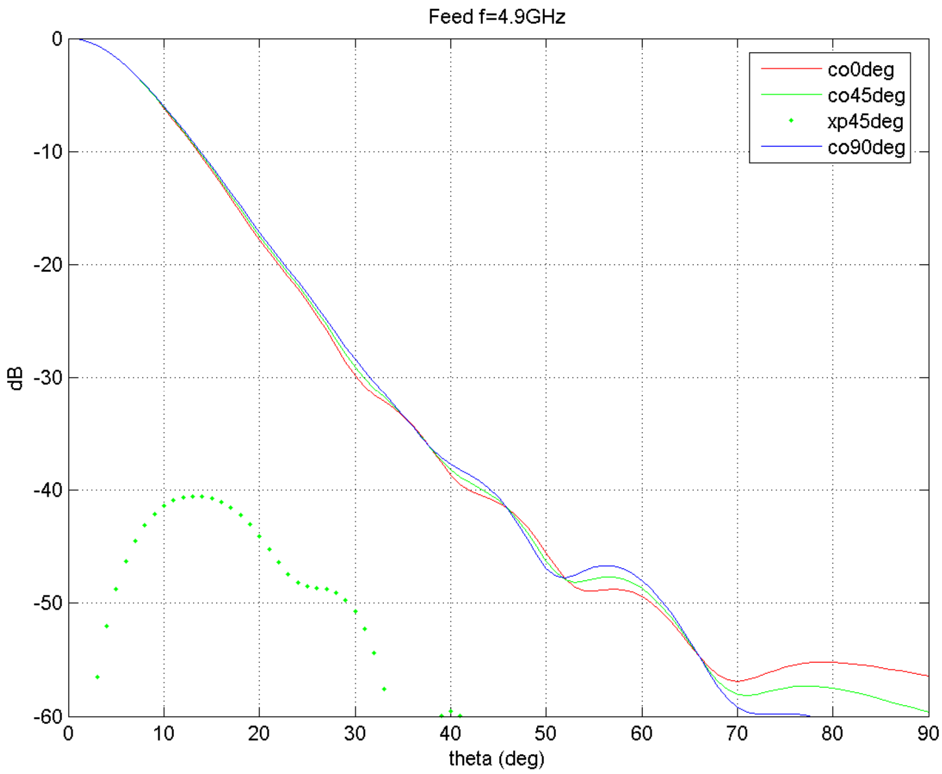
9.3 4.70 GHz



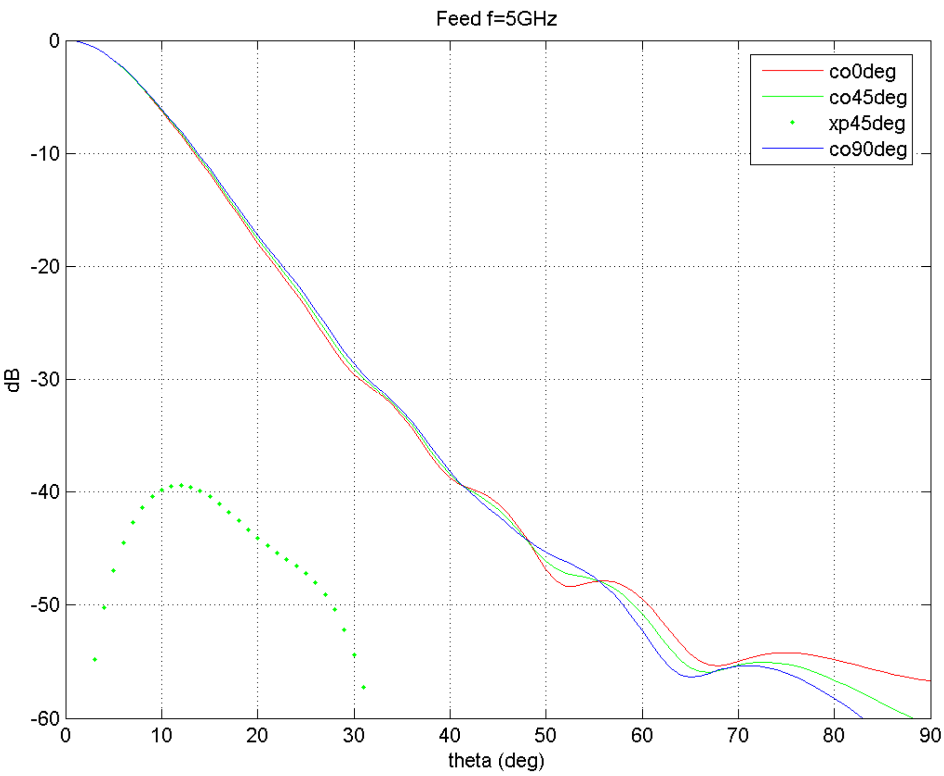
9.4 4.80 GHz



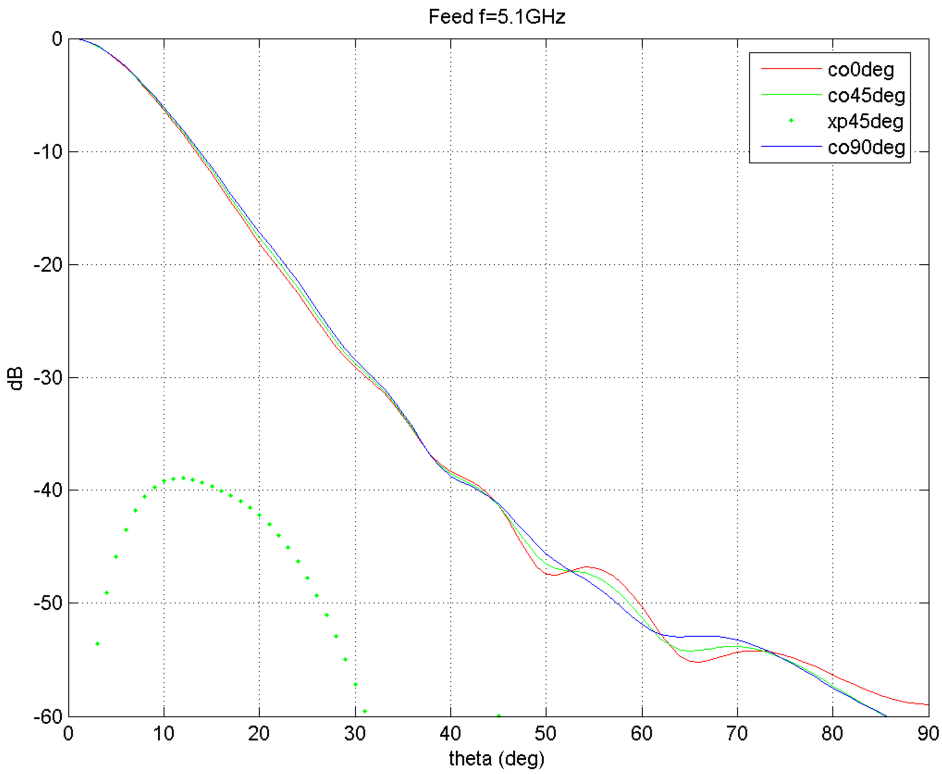
9.5 4.90 GHz



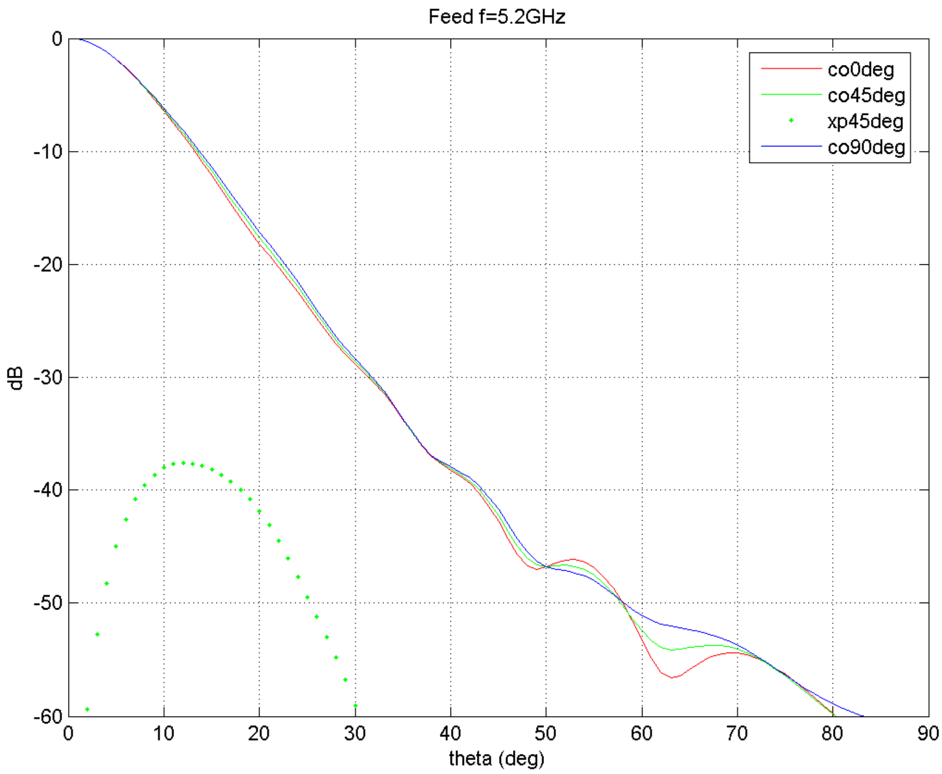
9.6 5.00 GHz



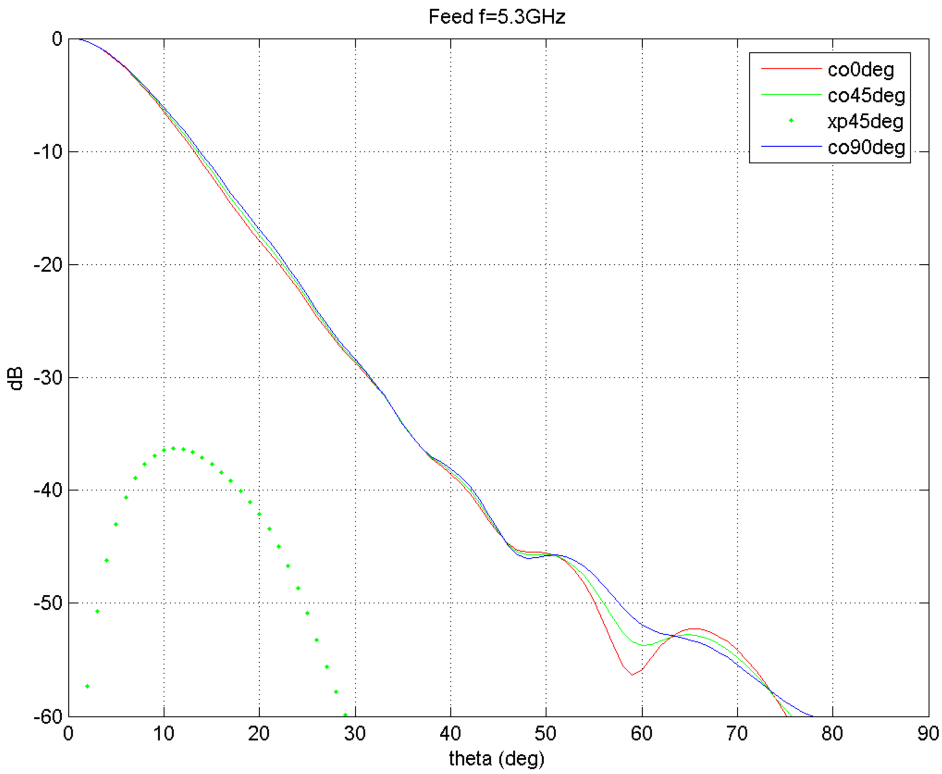
9.7 5.10 GHz



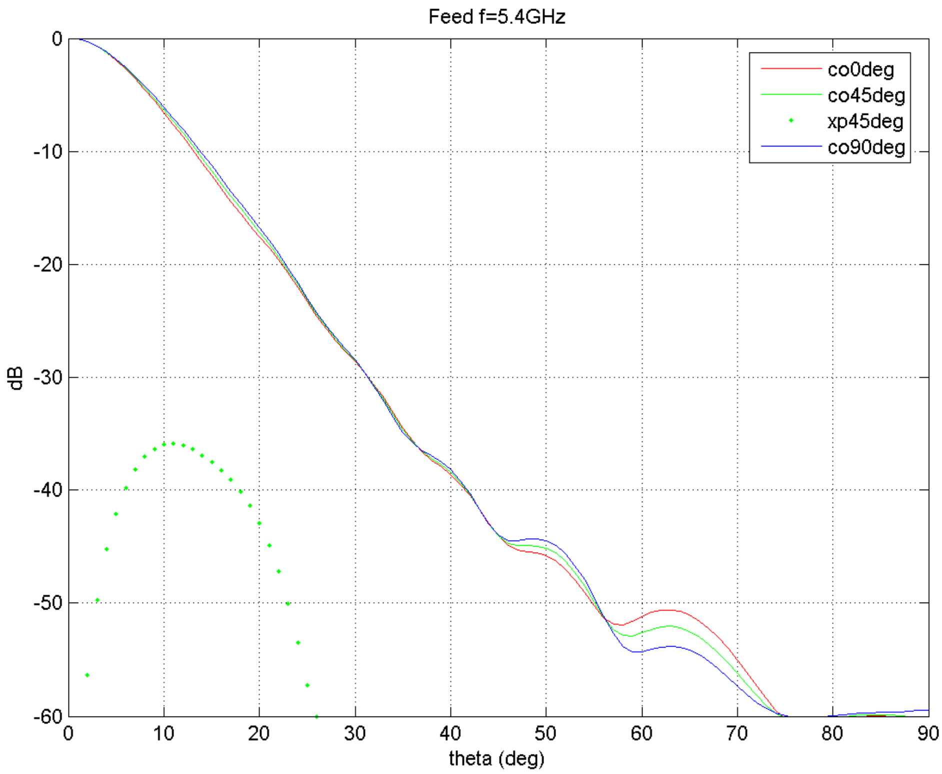
9.8 5.20 GHz



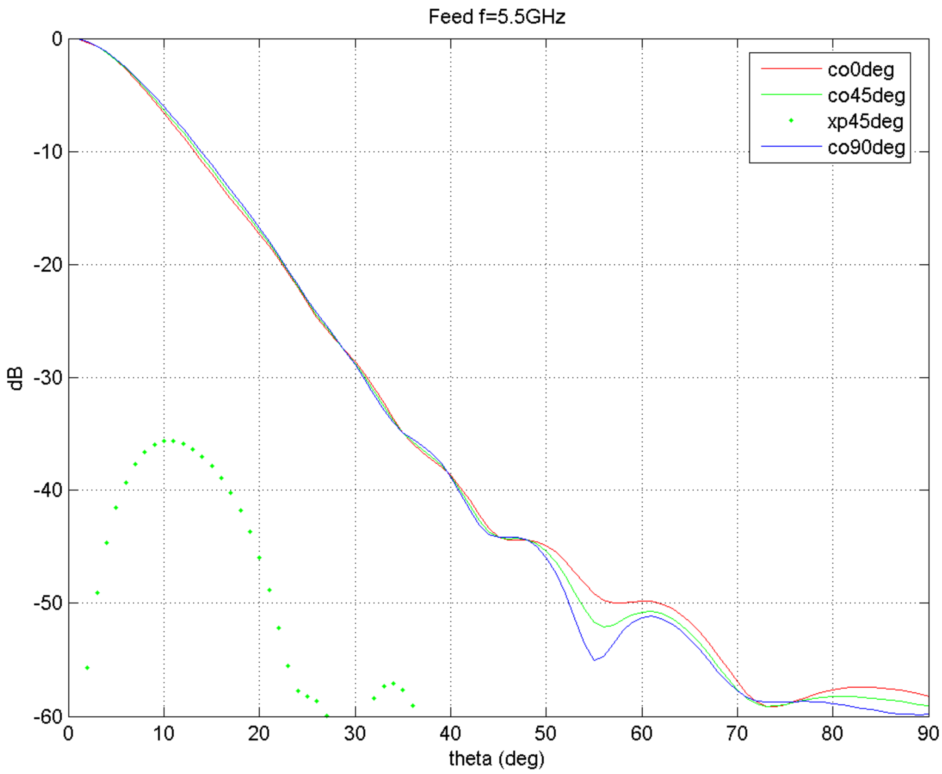
9.9 5.30 GHz



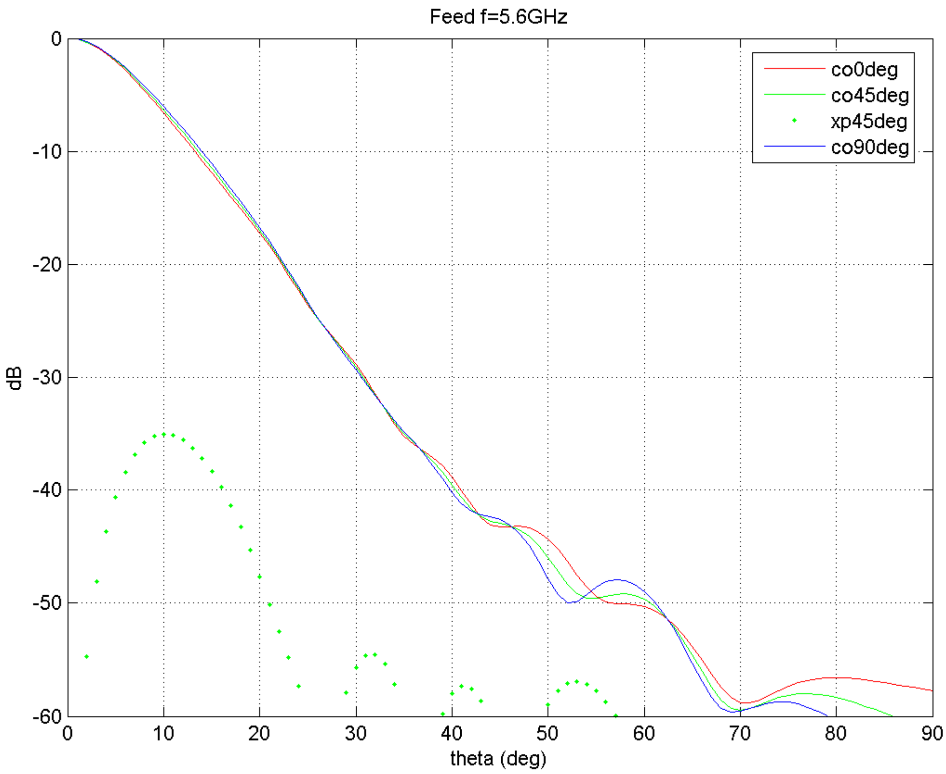
9.10 5.40 GHz



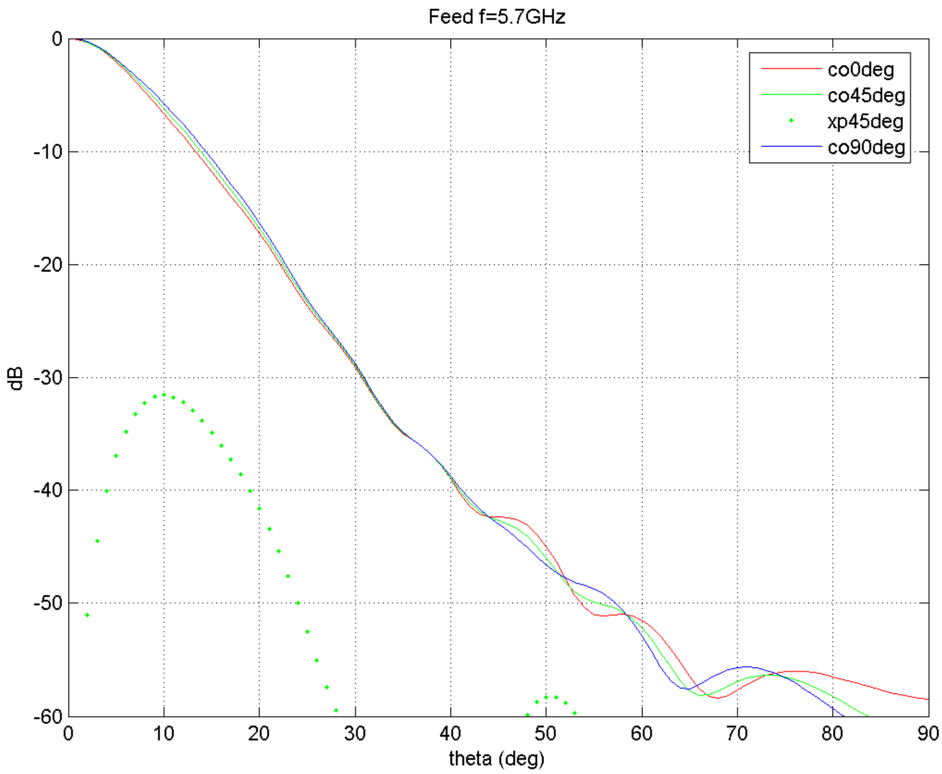
9.11 5.50 GHz



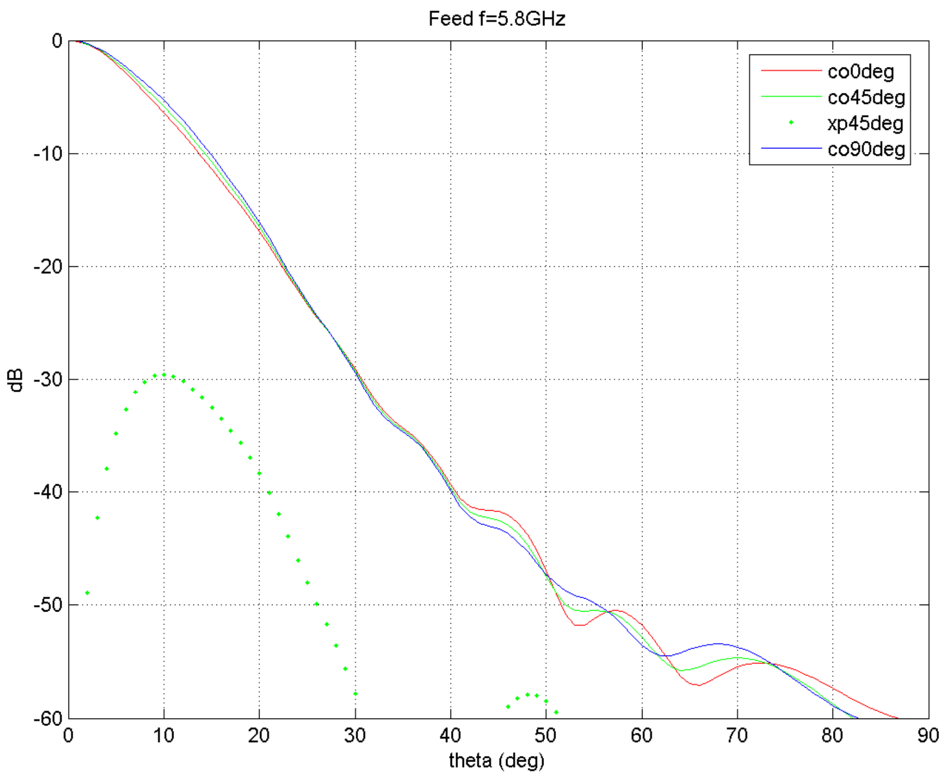
9.12 5.60 GHz



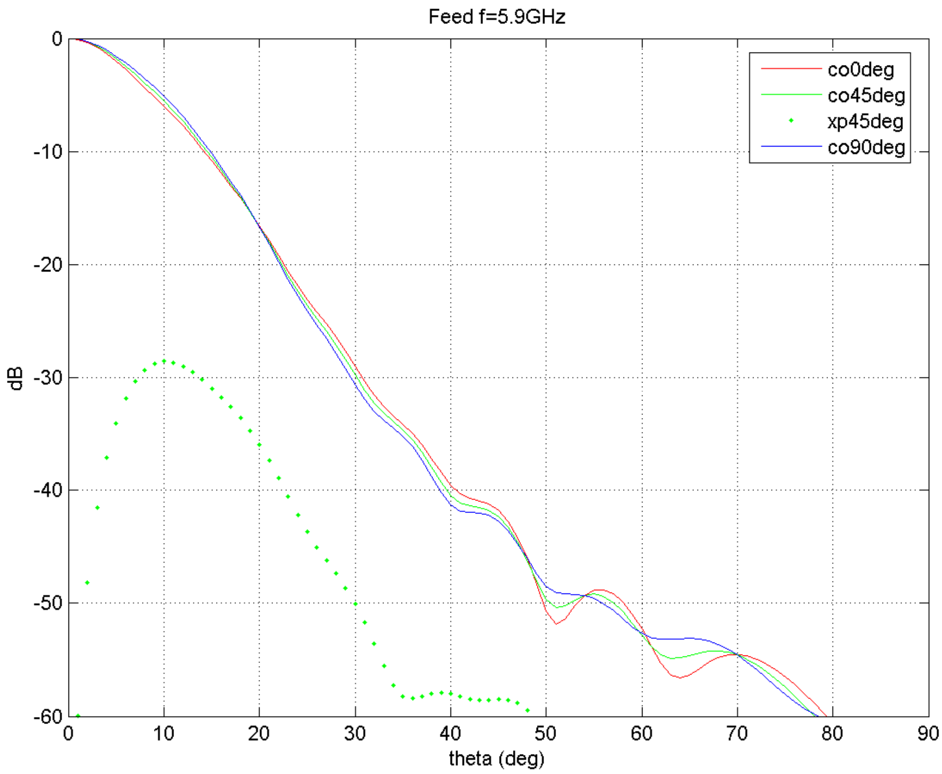
9.13 5.70 GHz



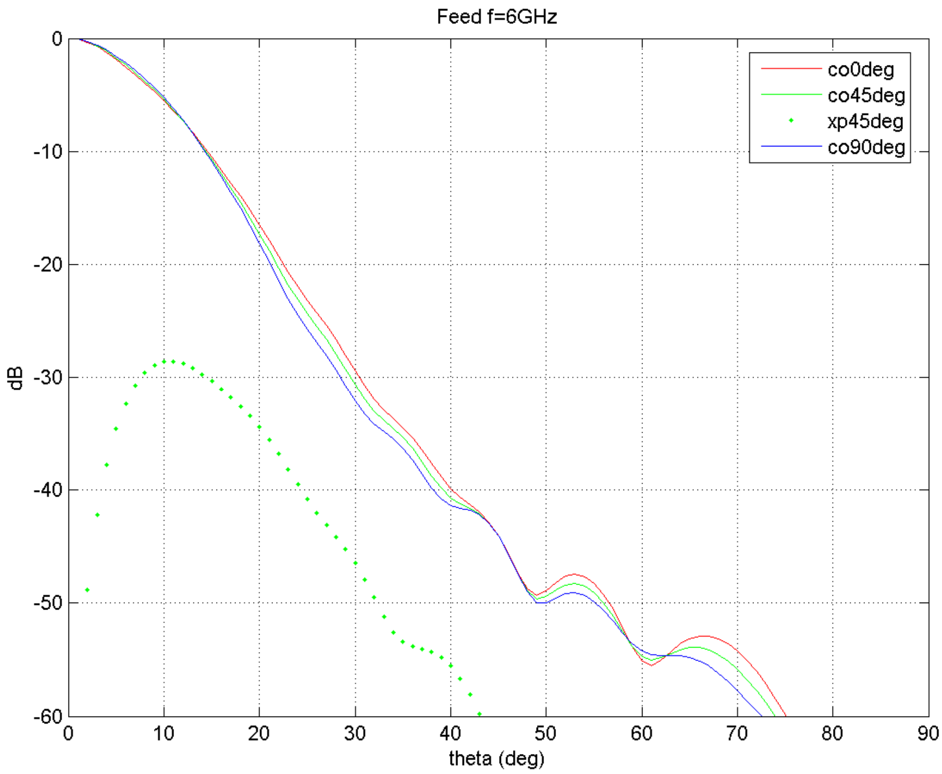
9.14 5.80 GHz



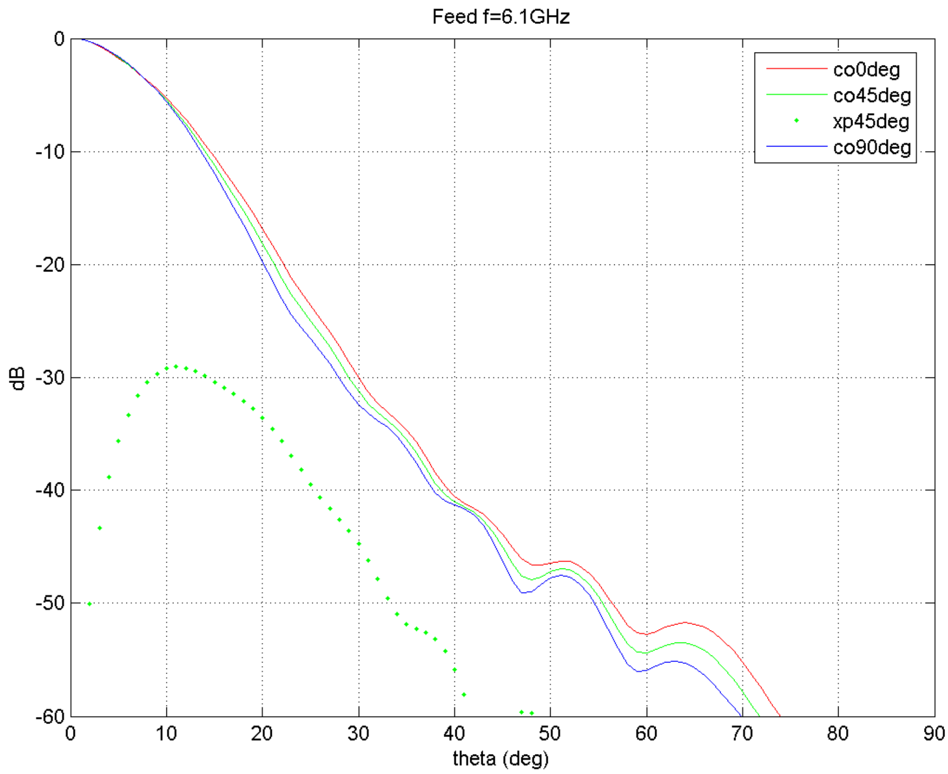
9.15 5.90 GHz



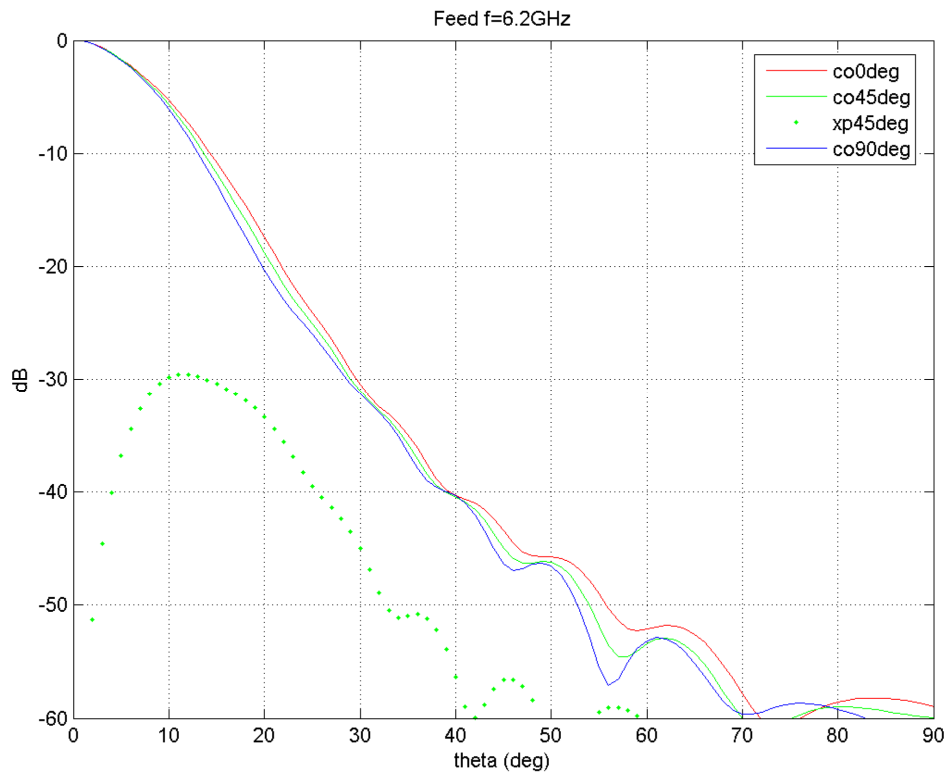
9.16 6.00 GHz



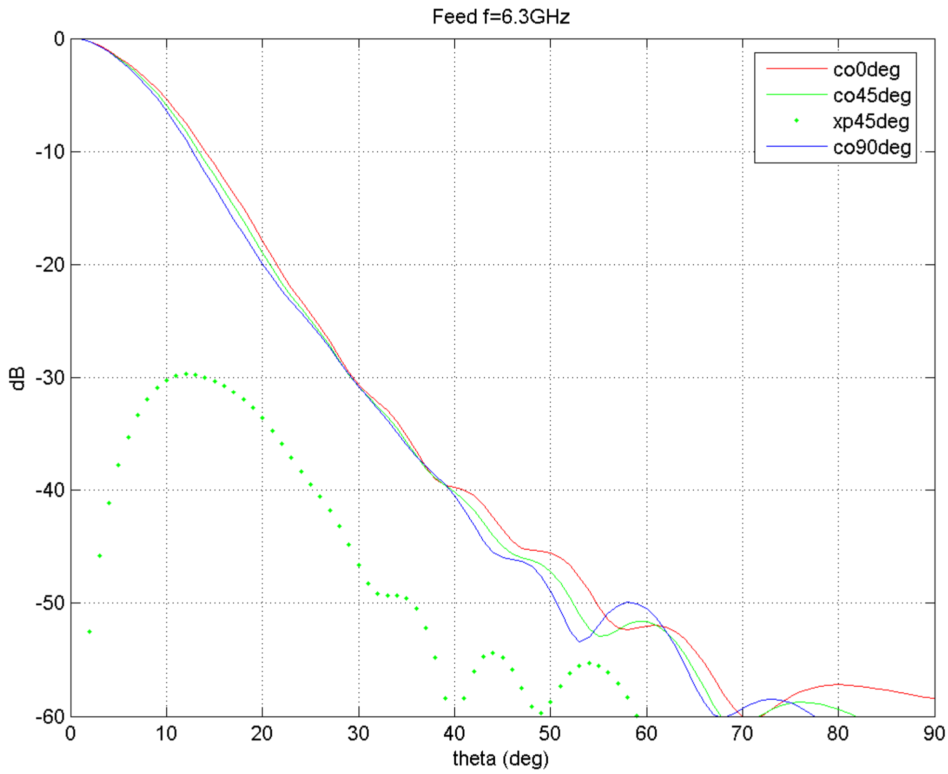
9.17 6.10 GHz



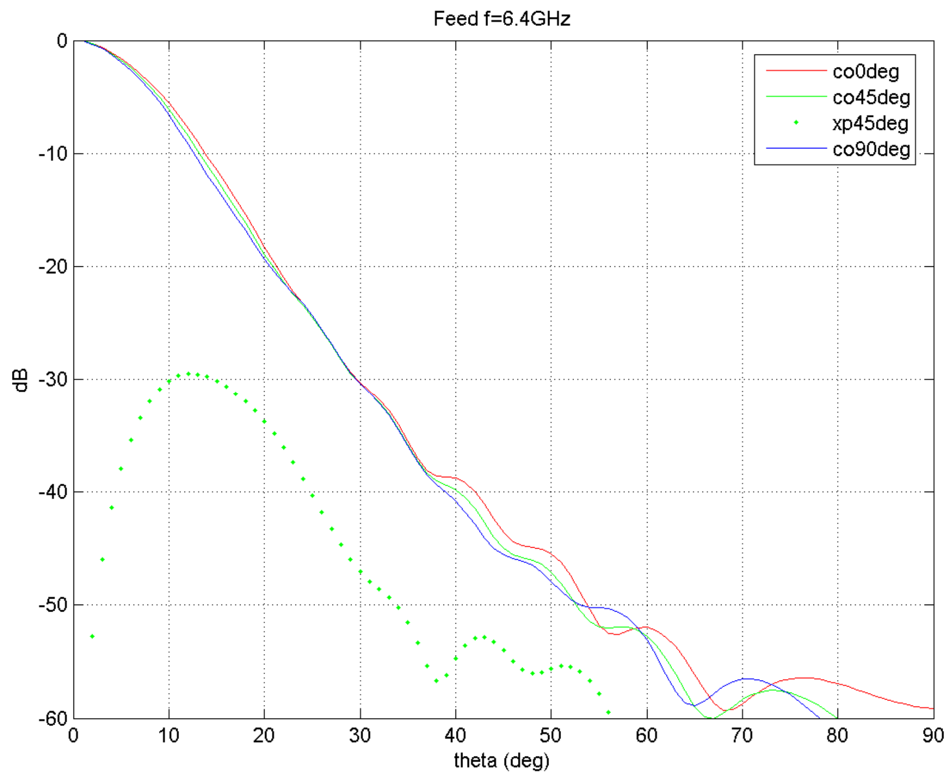
9.18 6.20 GHz



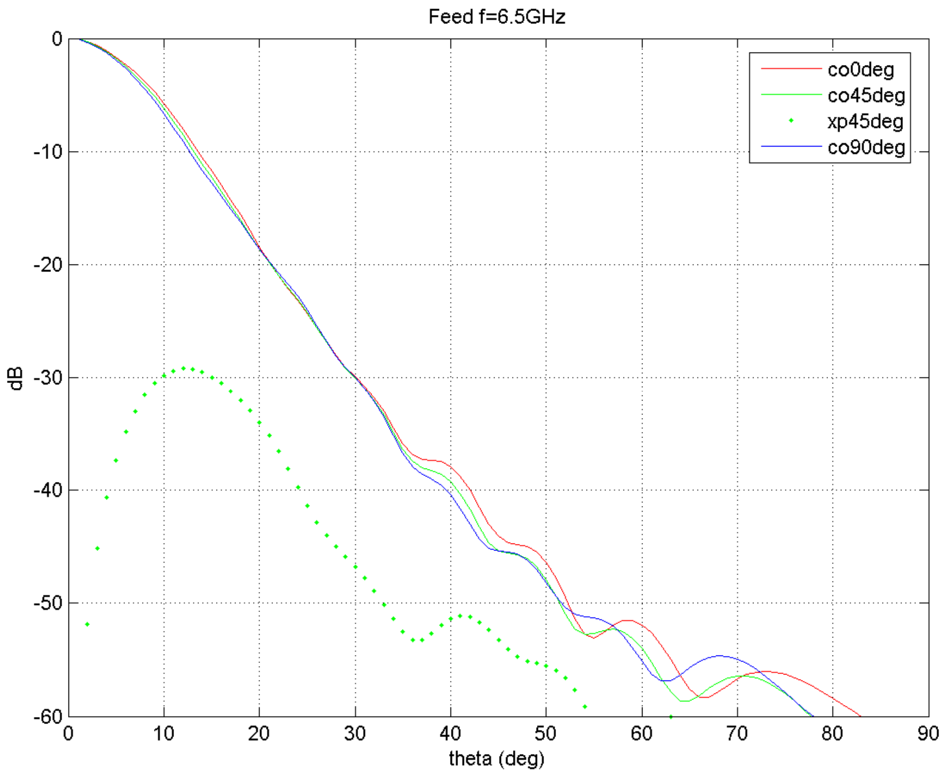
9.19 6.30 GHz



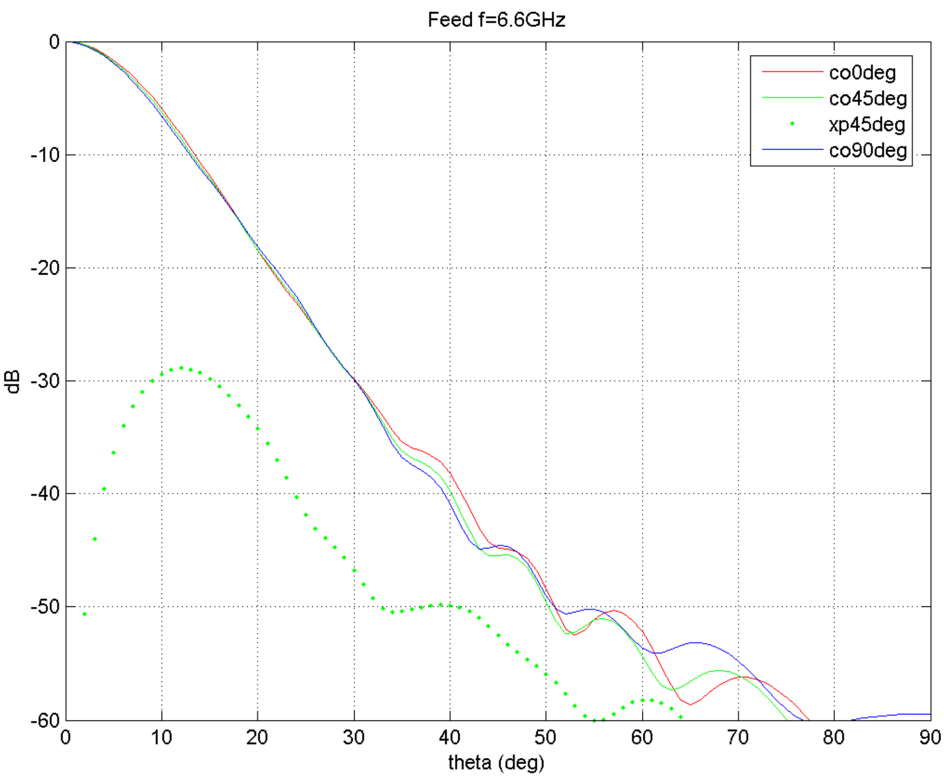
9.20 6.40 GHz



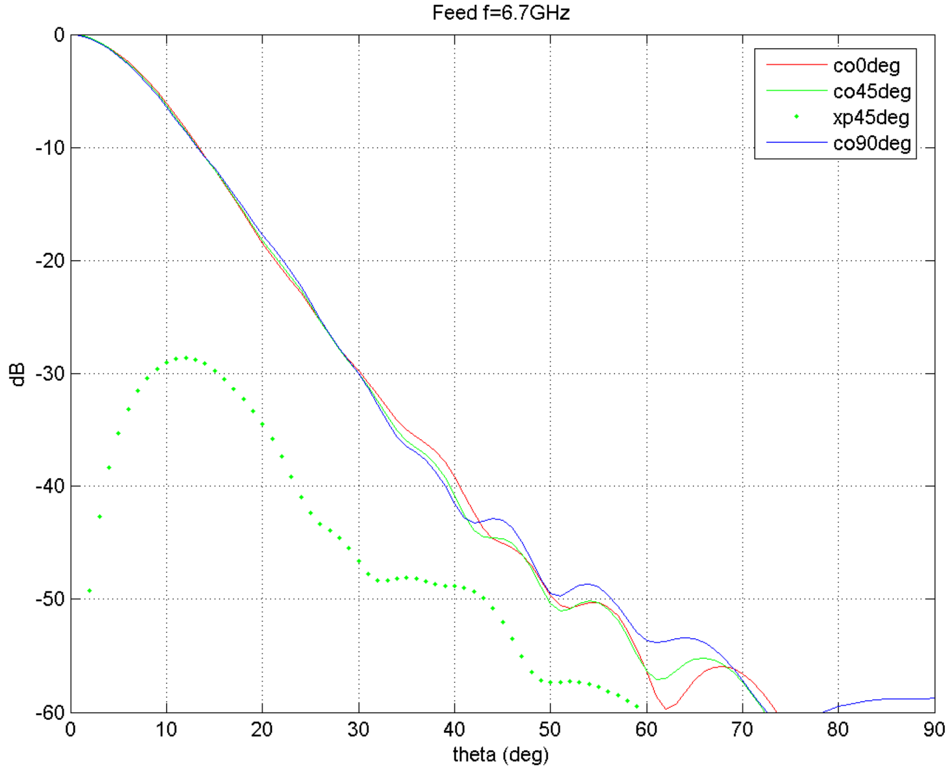
9.21 6.50 GHz



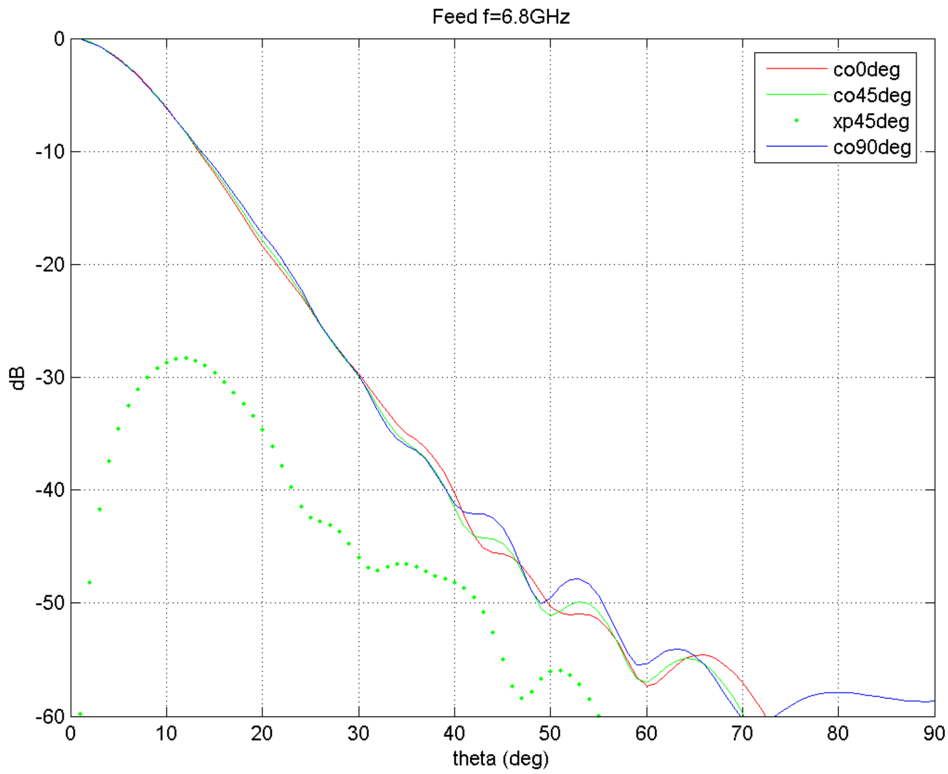
9.22 6.60 GHz



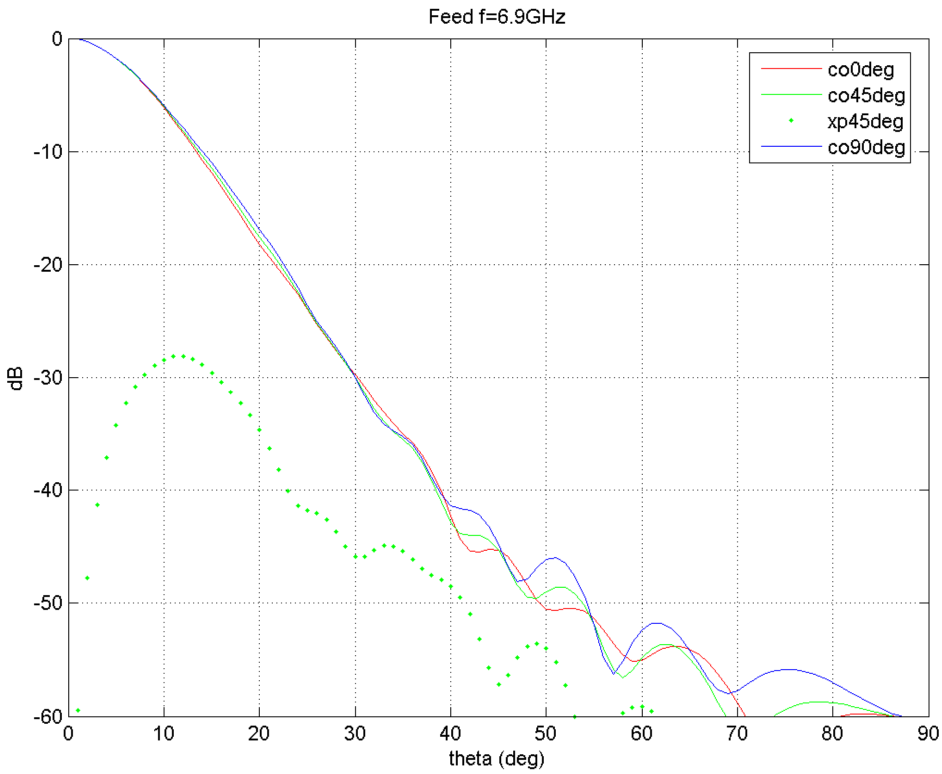
9.23 6.70 GHz



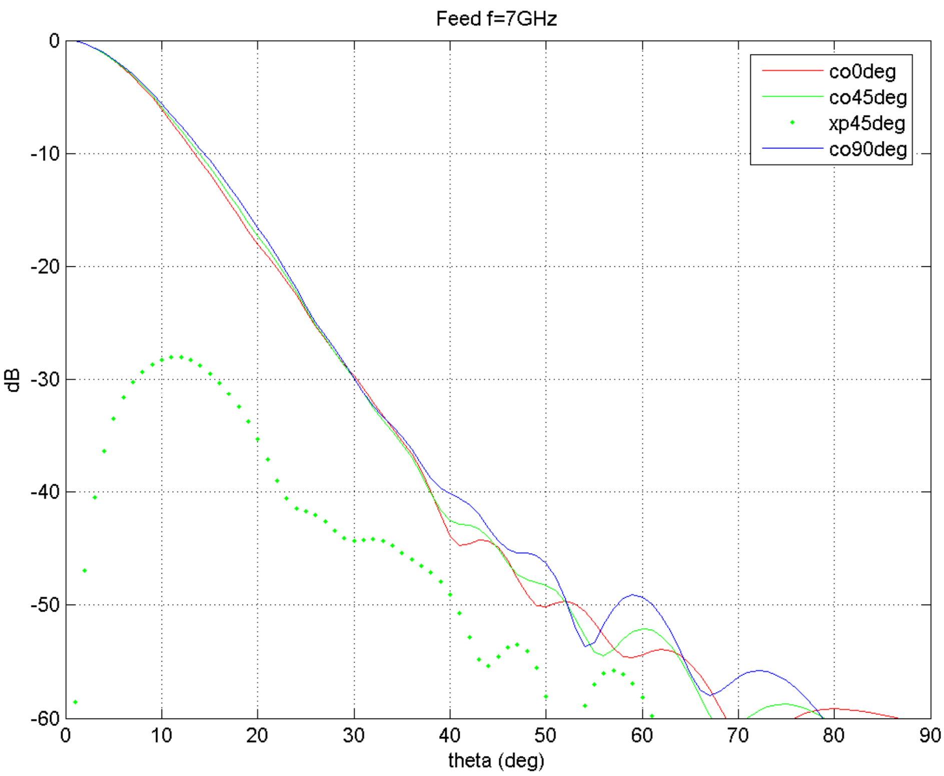
9.24 6.80 GHz



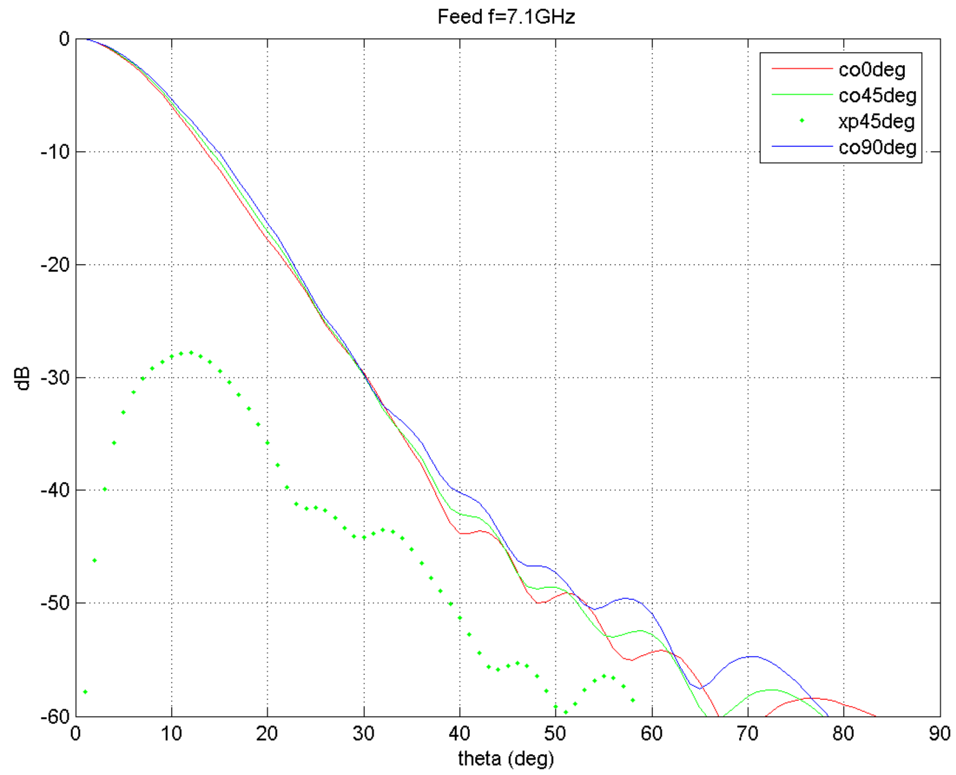
9.25 6.90 GHz



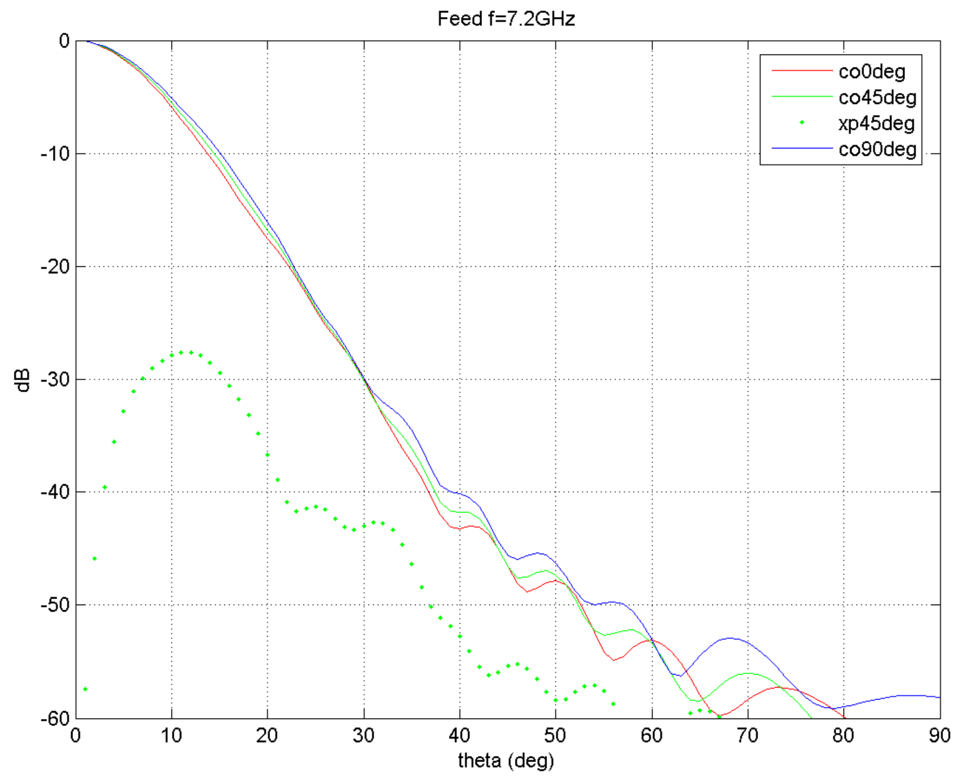
9.26 7.00 GHz



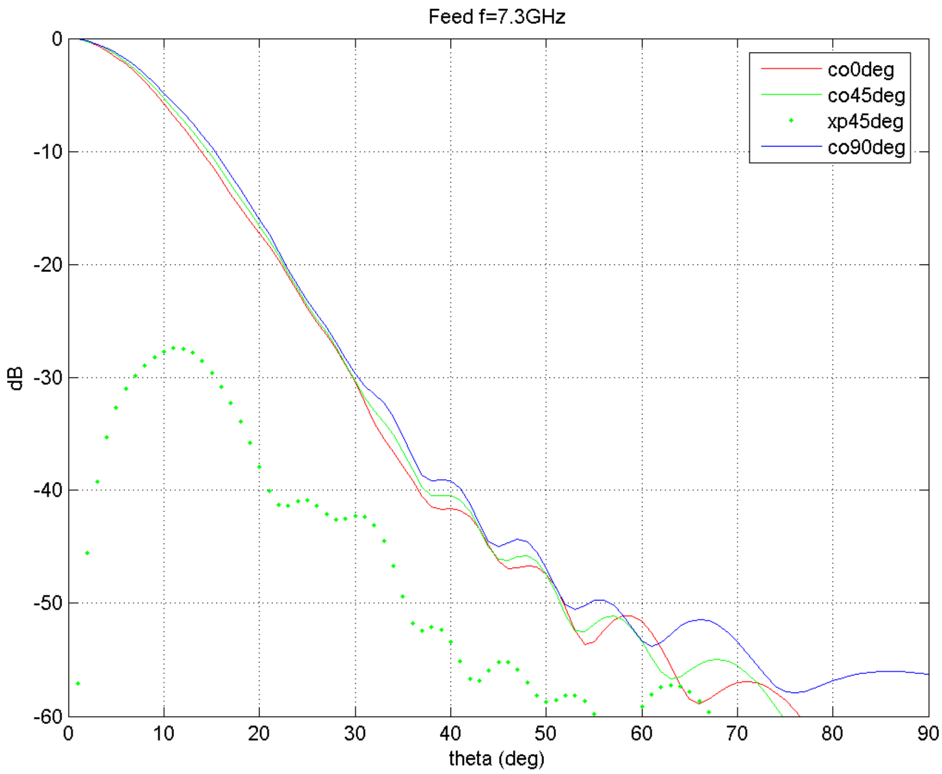
9.27 7.10 GHz



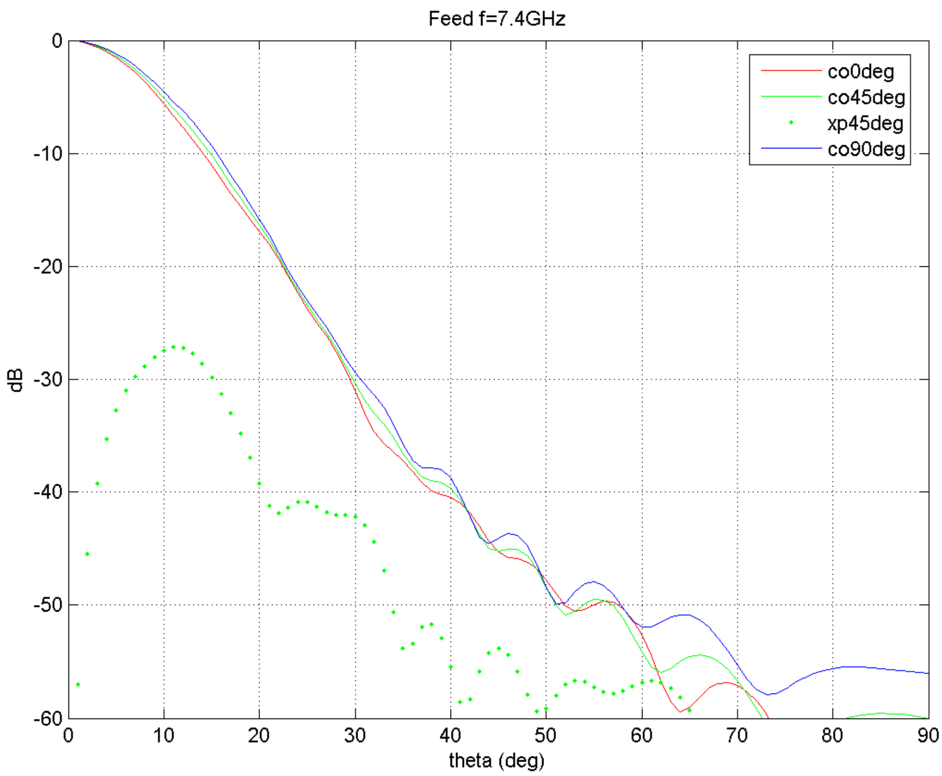
9.28 7.20 GHz



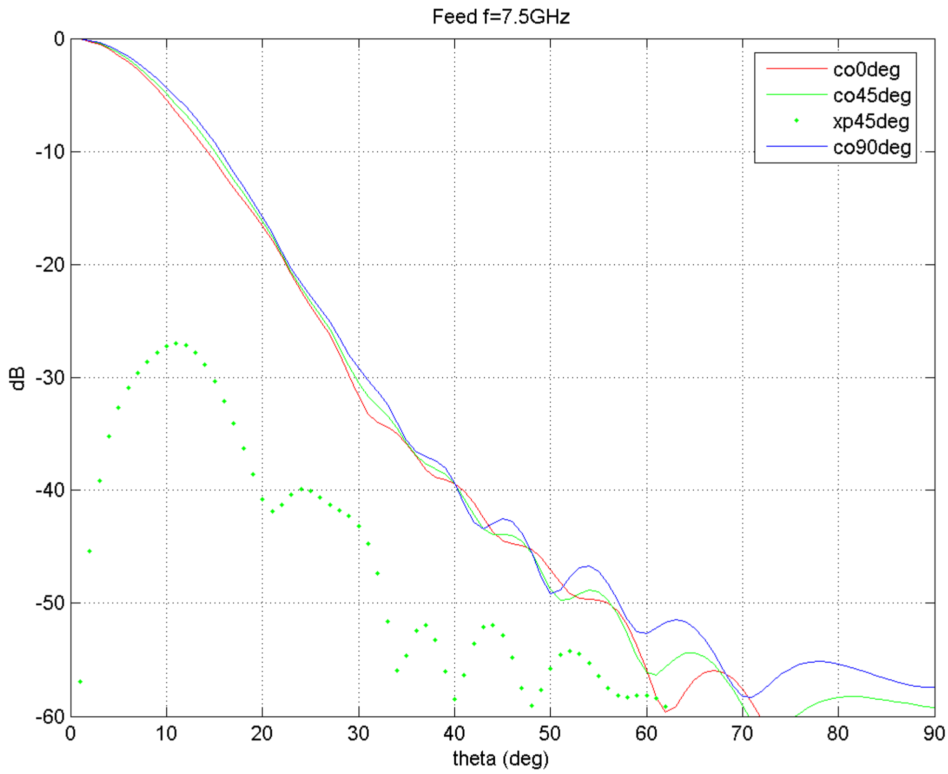
9.29 7.30 GHz



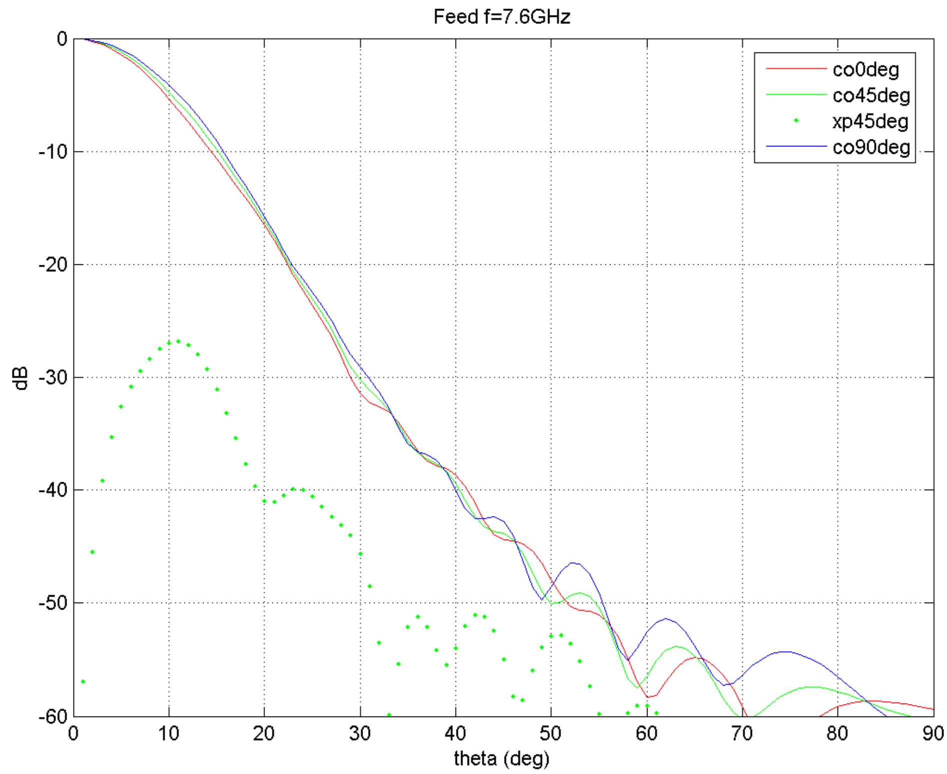
9.30 7.40 GHz



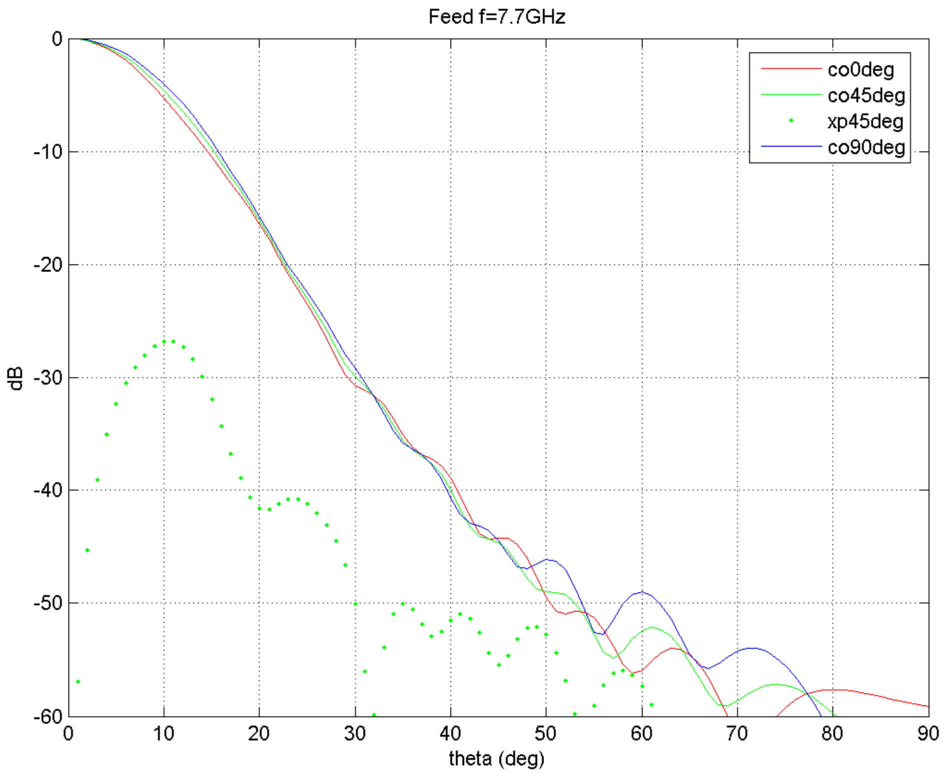
9.31 7.50 GHz



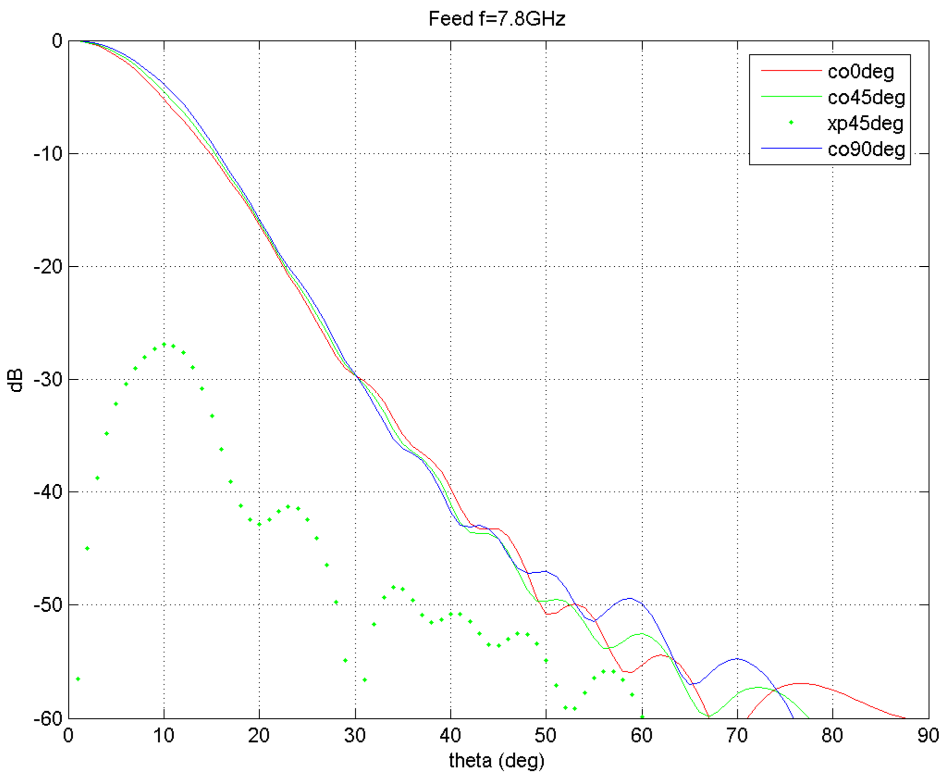
9.32 7.60 GHz



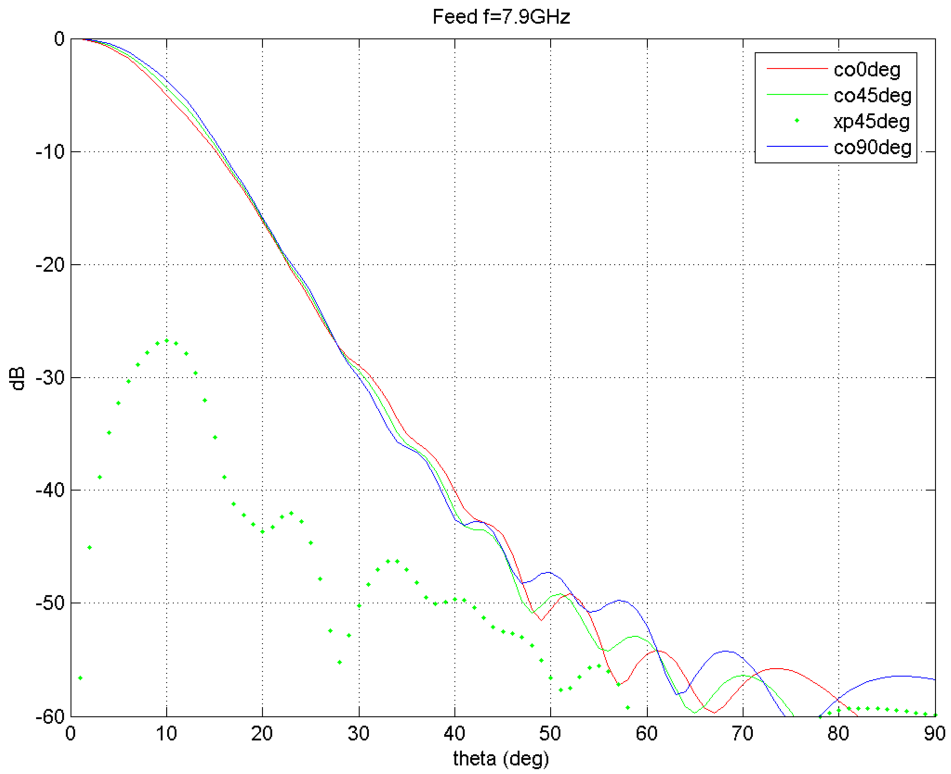
9.33 7.70 GHz



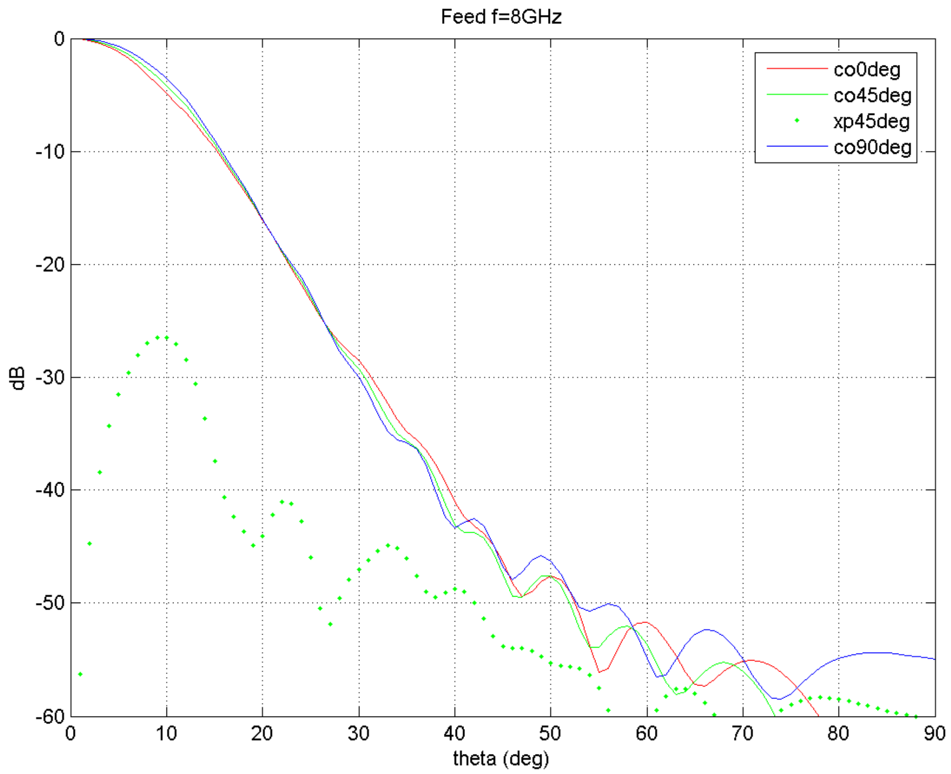
9.34 7.80 GHz



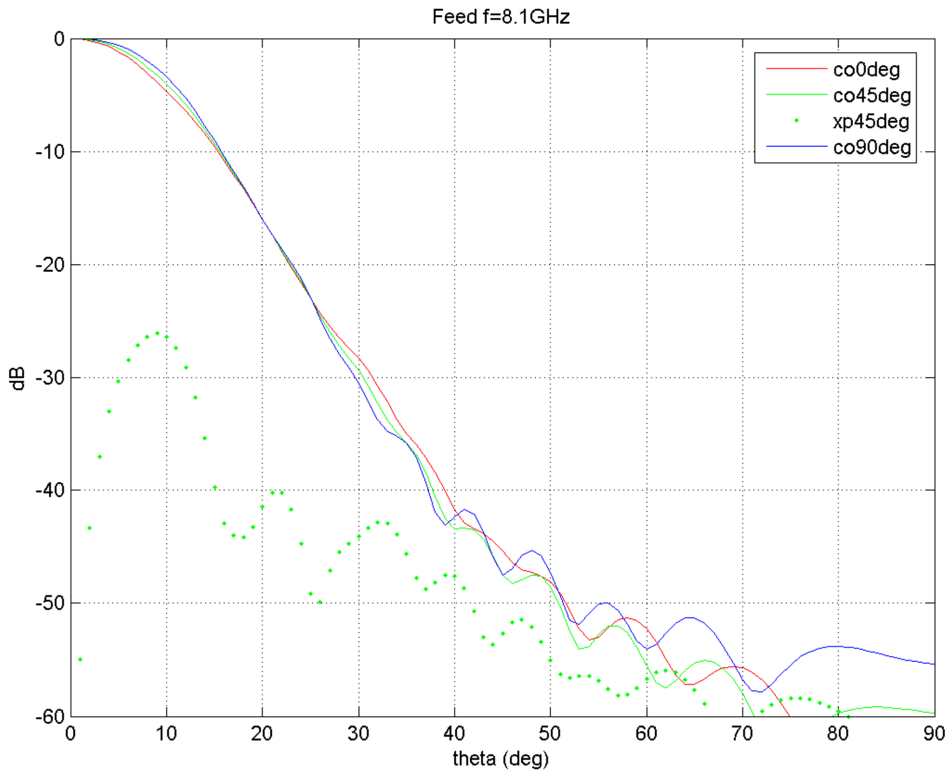
9.35 7.90 GHz



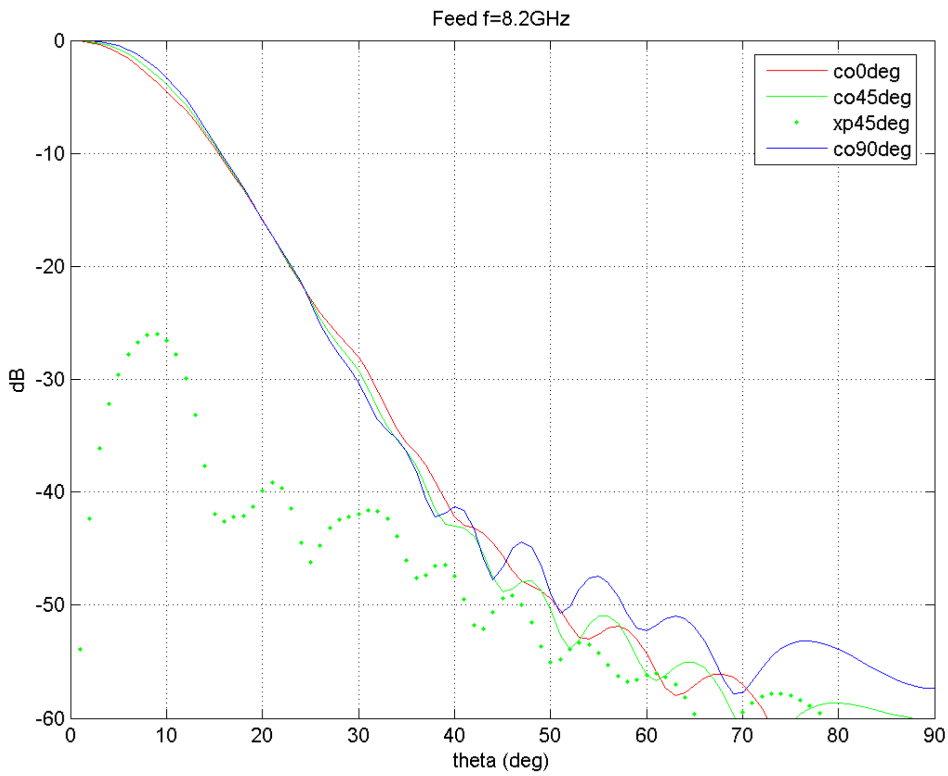
9.36 8.00 GHz



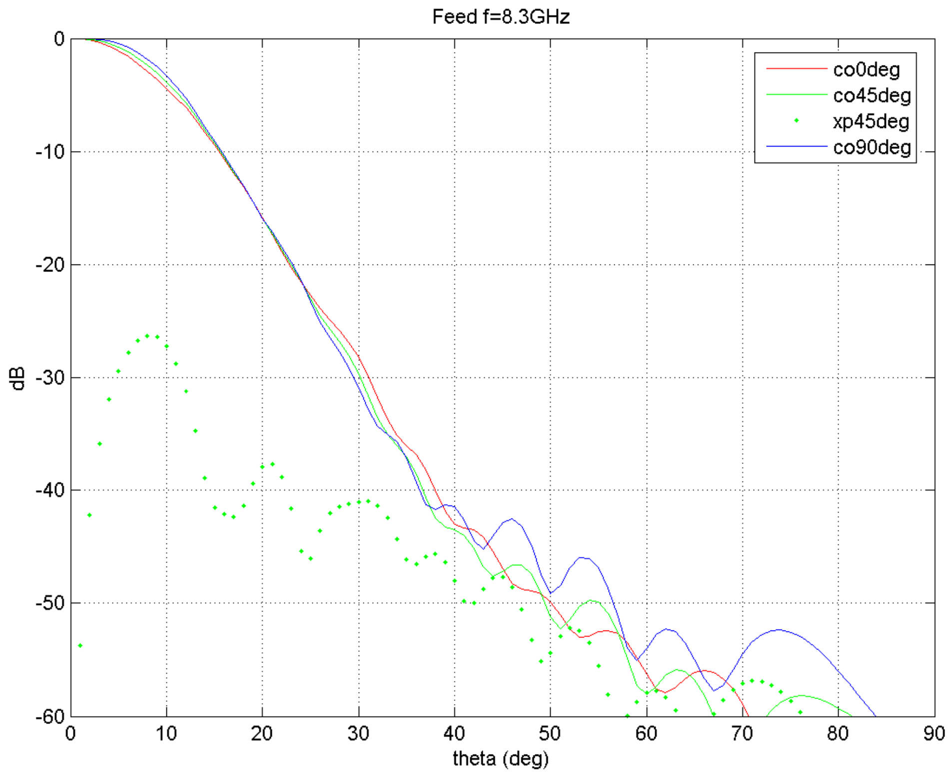
9.37 8.10 GHz



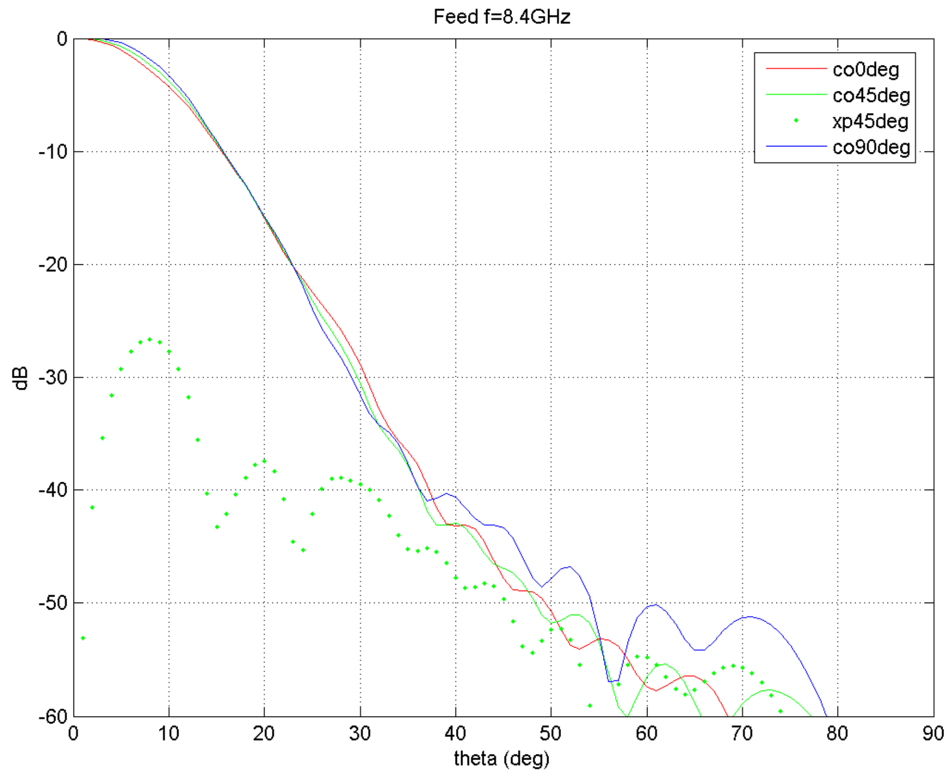
9.38 8.20 GHz



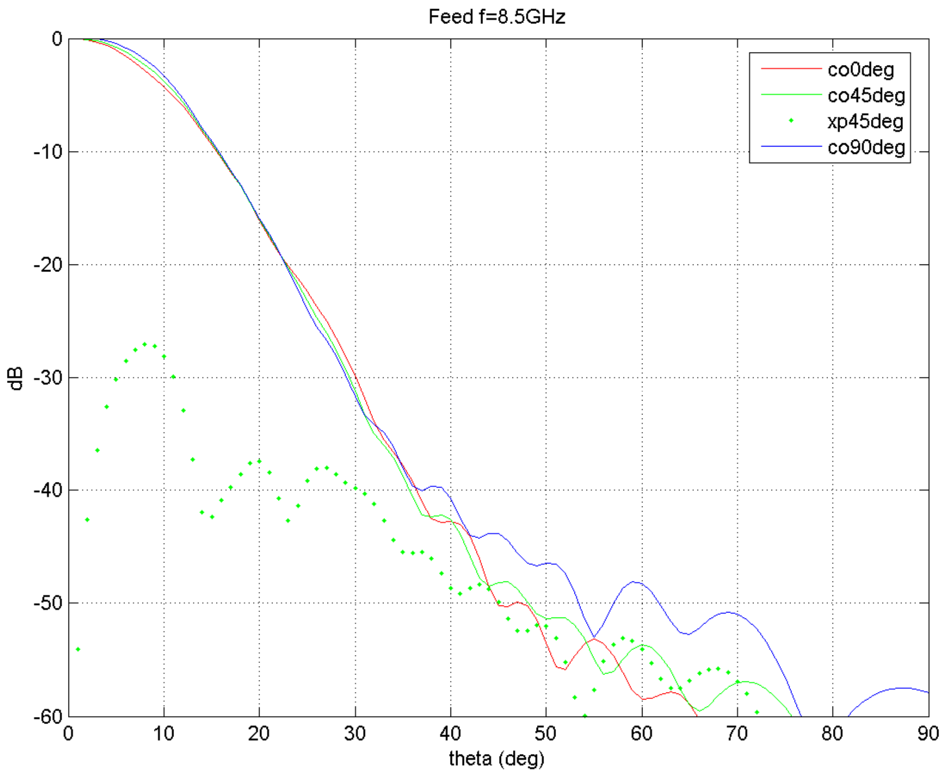
9.39 8.30 GHz



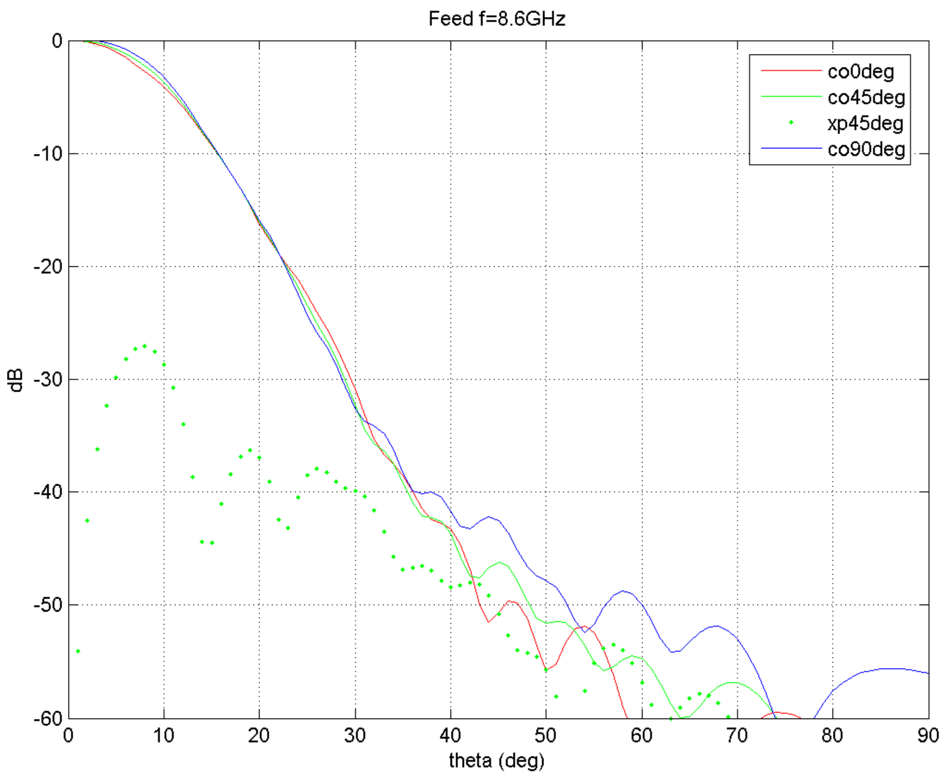
9.40 8.40 GHz



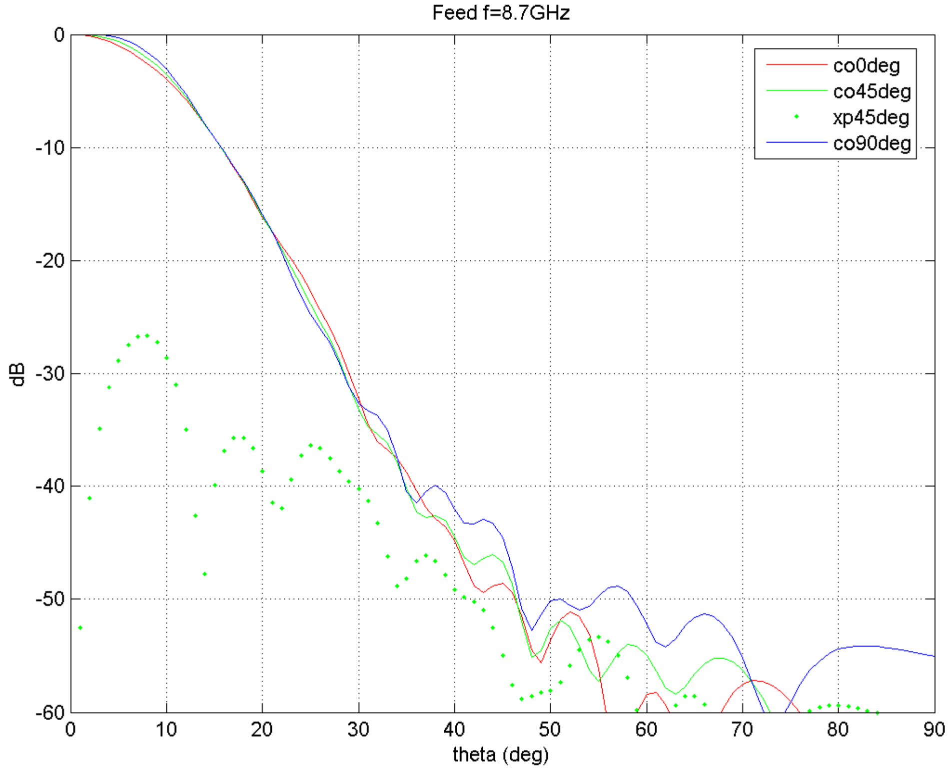
9.41 8.50 GHz



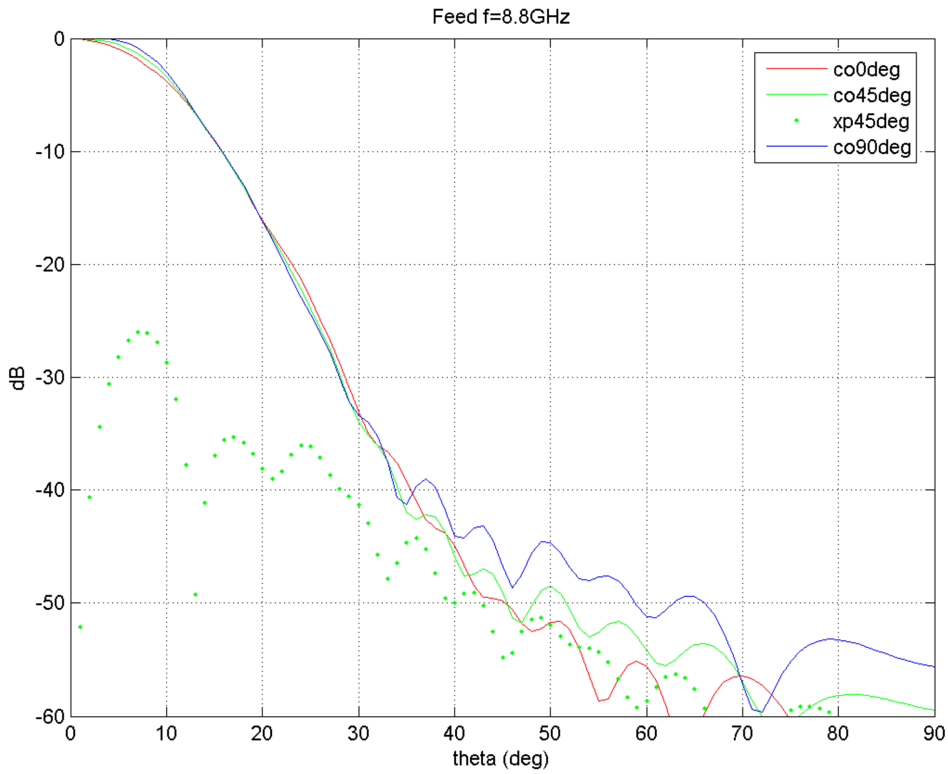
9.42 8.60 GHz



9.43 8.70 GHz

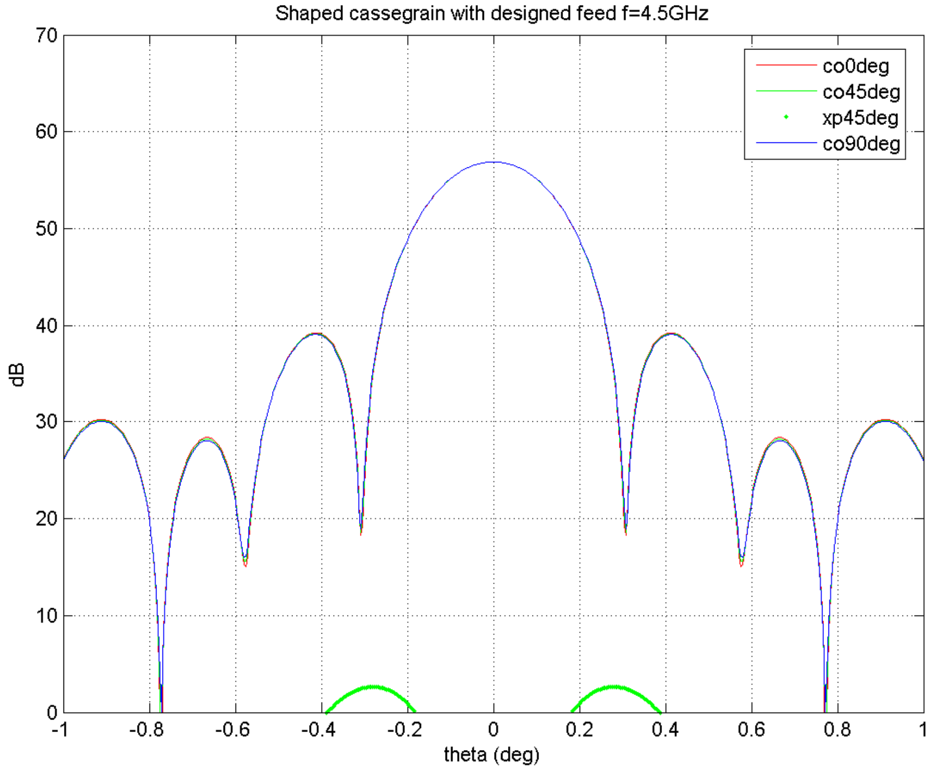


9.44 8.80 GHz

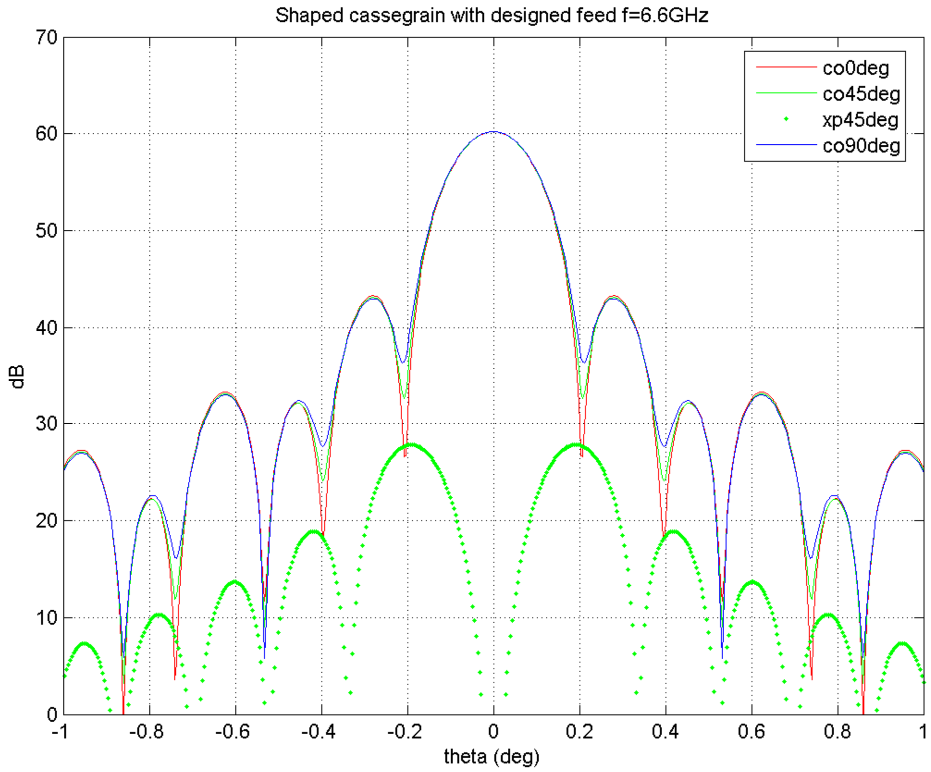


10 ANEXX. Shaped cassegrain radiation pattern

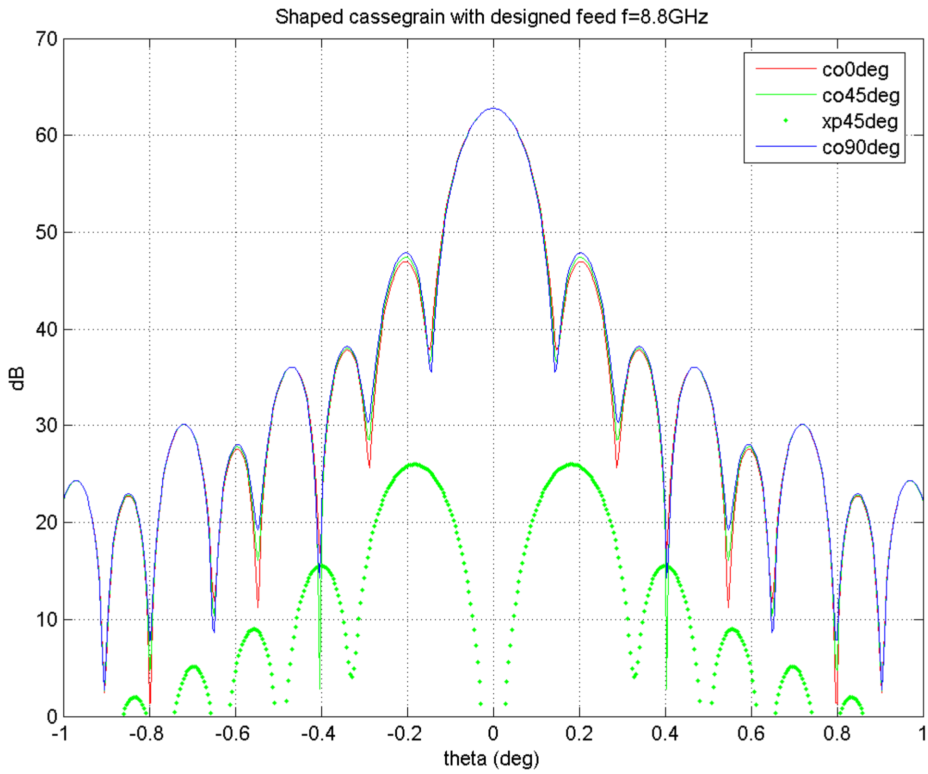
10.1 4.50 GHz



10.2 6.60 GHz



10.3 8.80 GHz


Shaped cassegrain with designed feed f=8.8GHz
co0deg
co45deg
xp45deg
co90deg
dB
theta (deg)
70
60
50
40
30
20
10
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

C.A.Y.

Reference

20140513_VENTSPILS_RT16_FINAL_FEED

Title

FINAL FEED DESIGN FOR THE 16M VENTSPILS ANTENNA

Customer

MT MECHATRONICS

Written and released by:

F.Tercero
S.López
JA. López-Fdez

Release: 01.2	Date: 13/05/2015	Pages:

1 SCOPE

Show the final electrical and mechanical design of the feed for the 16m Ventspils antenna. It includes all the final simulations and measurements in an scaled feed model to validate the design for construction.

2 DOCUMENTATION AND REFERENCES

Release 01. Initial document
Release 01.1 Modification of the interface drawing according to the new VUC information. Port dimension changed to 45.8mm
Release 01.2 Modification of the interface drawing according to the new VUC information. New G 1/8 drilled hole for air dehumidifier.

Title	Reference	Edited
Reflector feasibility and performance metrics for alternative optical designs	20141013_ventspils_rt16_feasibility.pdf	IGN
Preliminary feed design for the 16m Ventspils antenna	20141217_ventspils_rt16_preliminary_feed	IGN
Receiver waveguide interface	merijumi_foto.zip	VIRAC
Shaped reflectors data files	MainRefl.dat MainRefl_1.rsf SubRefl.dat SubRefl_1.rsf	MT

3 INTRODUCTION

An analysis to evaluate the characteristics of the shape optimised Cassegrain design was done to show the feasibility of this antenna. It concludes that the antenna proposed has a high aperture efficiency and it is suitable for the astronomical application at VIRAC.

To feed the proposed antenna, a preliminary feed design was done based only in its electrical behavior. It was showed that the proposed corrugated feed is suitable for this system keeping a very high aperture efficiency (higher that 80%) in the 4.5 GHz to 8.8 GHz bandwidth. All this information can be found in previous referenced reports.

As a finalization of the design, a detailed mechanical design is presented in this report. This design has been validated with additional simulations in a 3D full wave simulator. In addition to the simulations, an scaled feed model has been built as a proof of concept.

4 GENERAL DECRIPTION AND SPECIFICATION

The shaped cassegrain parameters are shown in Table 1

Diameter primary	Dp	m	16.00
Diameter secondary	Ds	m	1.60
Secondary thickness	ts	m	0.37
Secondary vertex to secondary focus	Lr	m	2.25
Primary vertex to secondary focus	g	m	2.09
Feed illumination half-flare angle between -11dB-14dB	θ	deg	17.0

Table 5. Optical parameter list of the shaped solution to compare

The feed has to fit with the polarizer waveguide which has a squared waveguide of 45.8x45.8mm. It is not straight in the corners, it is rounded with a 6.4mm radius. A layout of the waveguide can be seen in the annex (8)

Waveguide type			squared
Waveguide dimension	a	mm	45.8
Waveguide rounded corners radius of curvature	rc	mm	6.4

Table 6. Waveguide parameter list

5 FEED ELECTROMECHANICAL DESIGN

A wide-angle feed horn is chosen to satisfy the requirement of 11dB-14dB taper illumination at 17 deg in the full bandwidth. The horn profile is optimized to have low reflection at the port, specified illumination taper, low crosspolar level and good beam symmetry. The corrugations have variable thickness and depth to match to the circular waveguide. The horn profile can be seen in Figure 1.

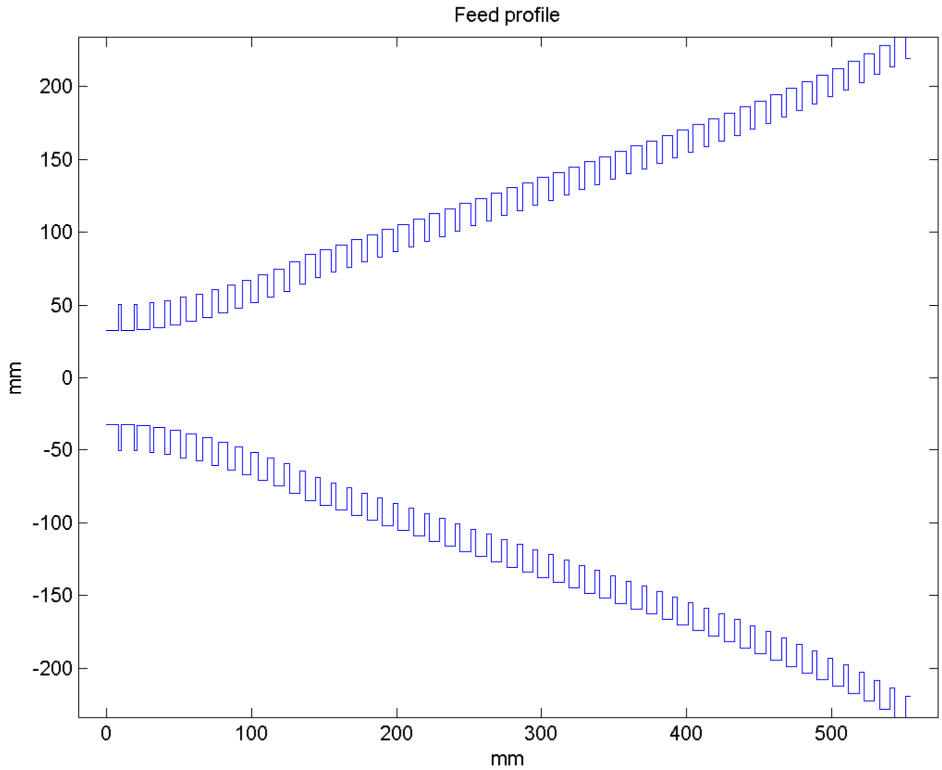


Figure 7. Feed inner profile

Circular waveguide radius	ac	mm	32.40
Feed aperture radius	af	mm	219.30
Feed length	Lf	mm	545.70

Table 7. Parameter data of the design

The port reflection figure in the circular waveguide is showed in Figure 2. The radiation patterns of the feed are calculated with modal matching, they can be seen in the annex (9).

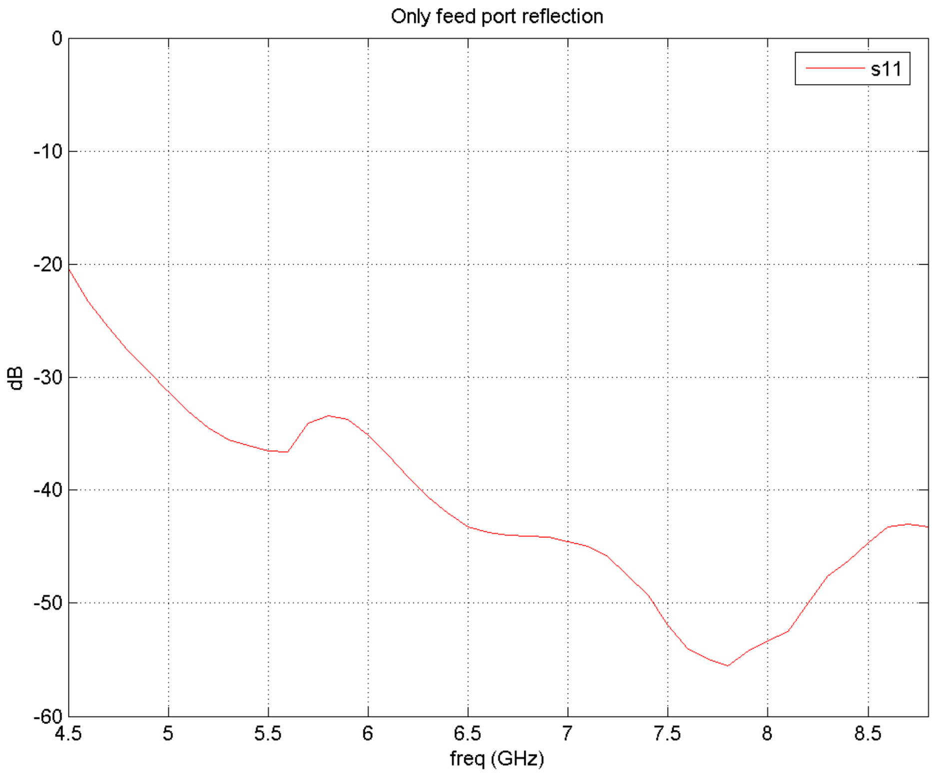


Figure 8. Feed port reflection in circular waveguide

The transition to the polarizer is an smooth square to circular waveguide transition from 45x45mm (square) to 32.4mm (radius circular). In the Figure 3, the smooth profile is shown. It was limited to be 100 mm length.

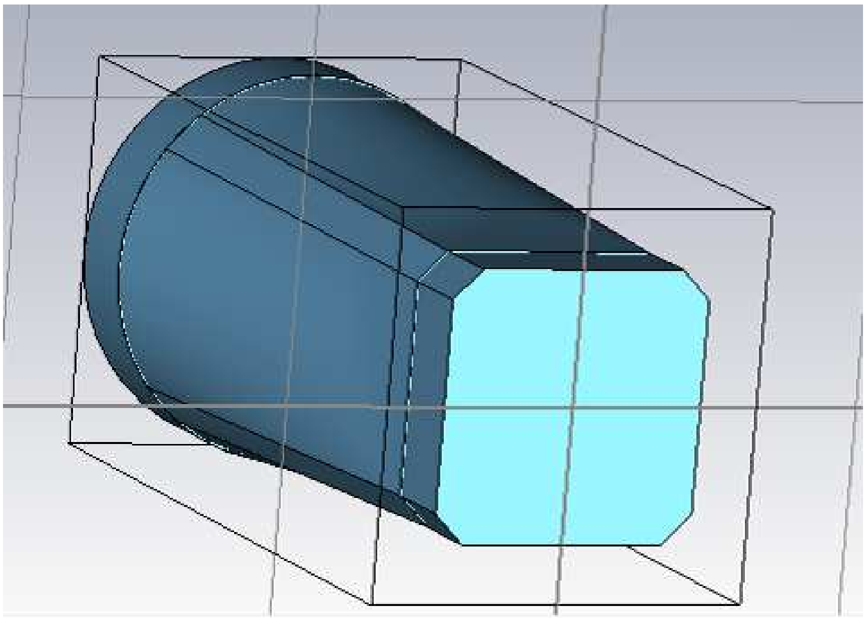


Figure 9. Square to circular transition

The port reflection of the transition (only) is calculated with a 3D full wave electromagnetic simulator. It can be seen in the Figure 4. It is not expected a great change in the reflection performance with the final 45.8mm waveguide.

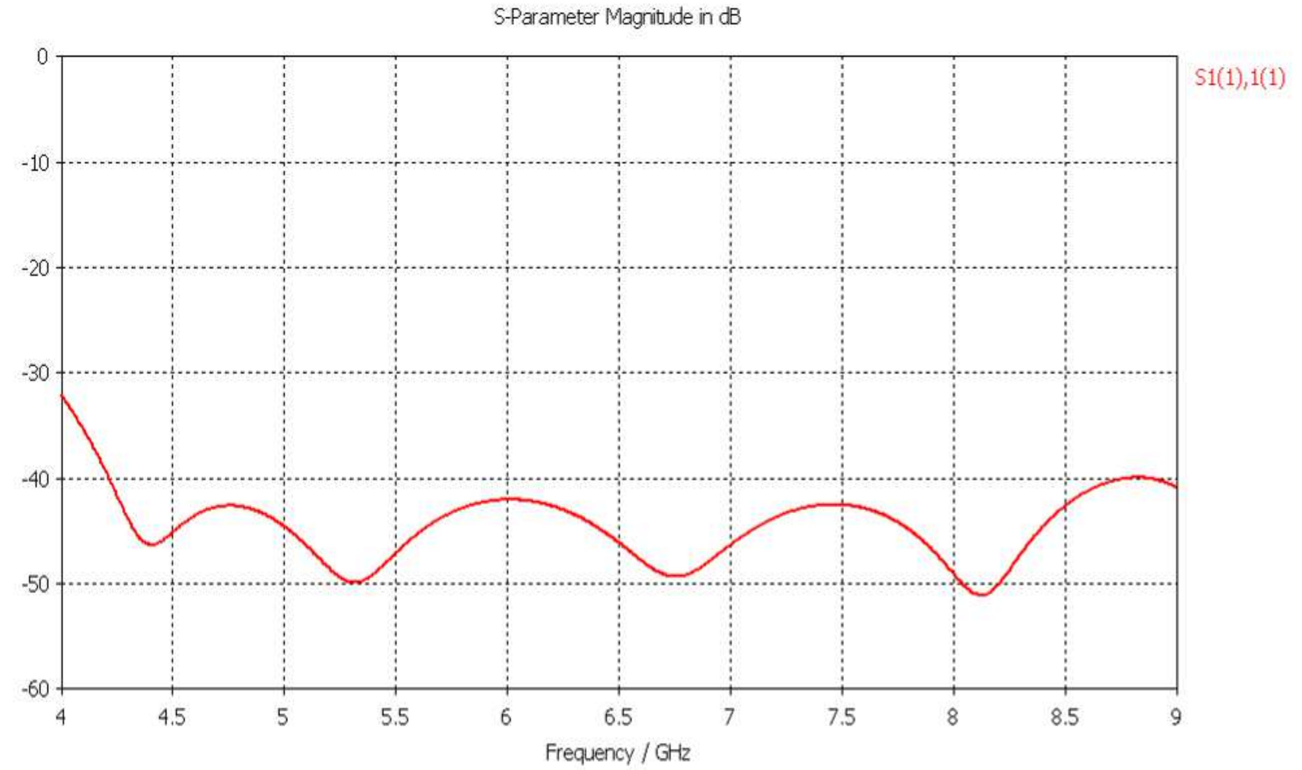


Figure 10. Square to circular transition reflection

6 FEED MECHANICAL DESIGN

The feed is designed in four pieces that are joined with threaded bolts at the flanges. The assembling accuracy is given by two precision pins at the flanges. Each piece must be machined at once in a numerical lathe.

The feed design also has the smooth transition from the VIRAC receiver to the feed port (circular waveguide of 32.4mm of radius)

The feed and transition are directly connected to the receiver with eight M8 bolts. There also are 2 flanges to attach the feed to the antenna. Both flanges have thru holes for M8 bolts. Details about all the interface details are in annex (11)

Construction is directly done machined in 6082T6 aluminum without additional plating. The estimated weight is 28 kg.

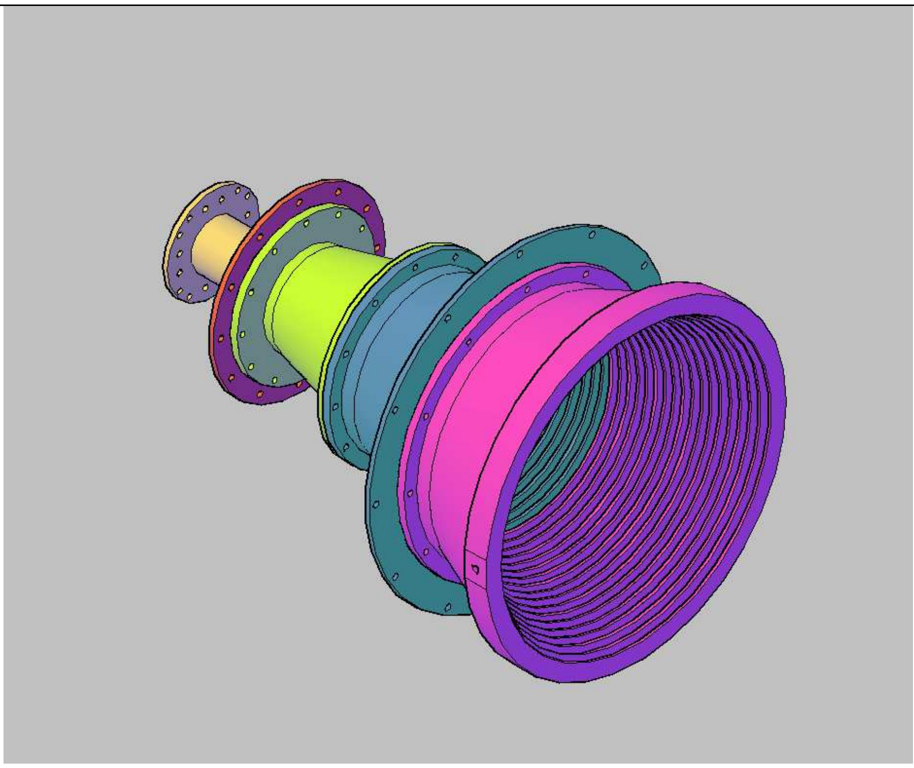


Figure 11. Feed mechanical model

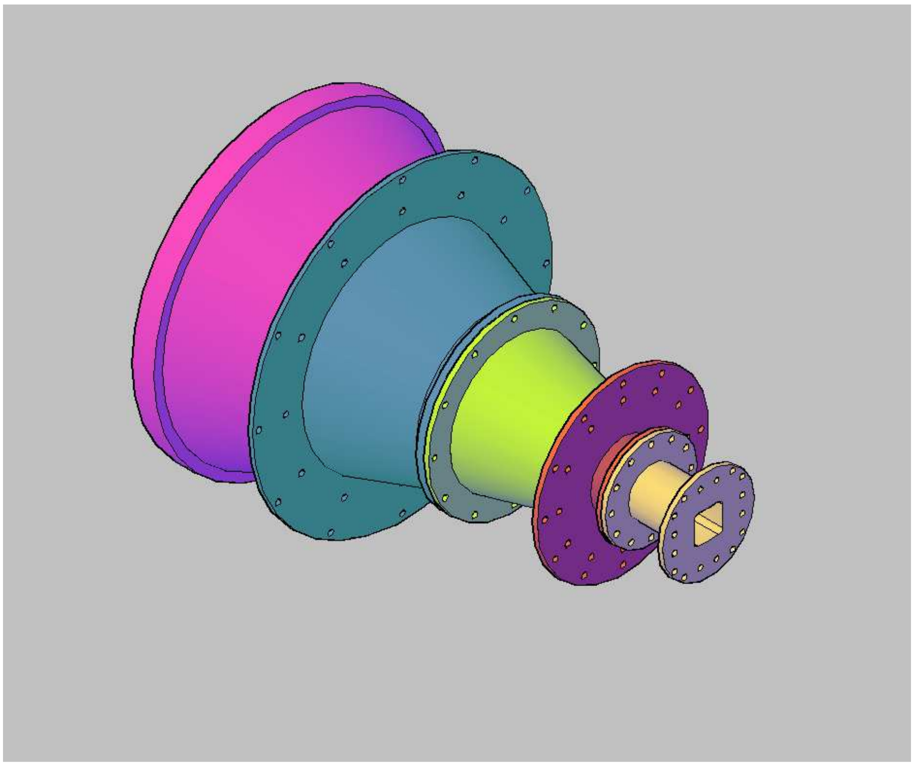


Figure 12. Feed mechanical model

7 FEED FINAL DATA SUMMARY

Frequency range	f	GHz	4.50-8.80
Feed illumination half-flare angle between -11dB-14dB	θ	deg	17.0
Waveguide type			squared
Waveguide dimension	a	mm	45.8
Waveguide rounded corners radius of curvature	rc	mm	6.4
Circular waveguide radius	ac	mm	32.40
Feed aperture radius (internal)	afi	mm	219.30
Feed aperture radius (external)	afe	mm	244.00
Transition length	Lt	mm	100.00
Feed length (only corrugations)	Lc	mm	545.70
Feed length (without transition)	Lf	mm	594.00
Feed length (feed+transition)	Lf+Lt	mm	694.00

Table 8. Parameter data of the design.

8 DESIGN VALIDATION

Before the manufacture of the feed, three types of validation tests were performed. The first is a 3D full wave simulation using the cad mechanical model in the simulator, the second one was the construction and measurement of an scaled model at a higher frequency, the last test was the simulation of the whole cassegrain antenna using physical optics, using the measurements of the scaled model as a feeder.

8.1 3D Full wave simulation of the mechanical model

The mechanical drawing, that it is going to be built, is directly imported to the 3D full wave simulator. The transition is also included in the simulation. In the Figure 13, an additional piece of guide is added to install the port in the simulator. It has not effect in the results.

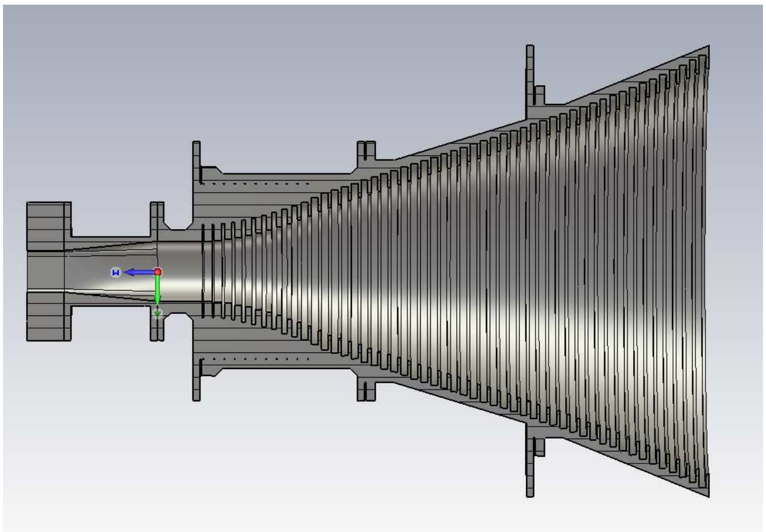


Figure 13. Section view in the full wave simulator

The port reflection figure is quite low in all the bandwidth except in the lowest frequencies. It is in any case better than -17dB.

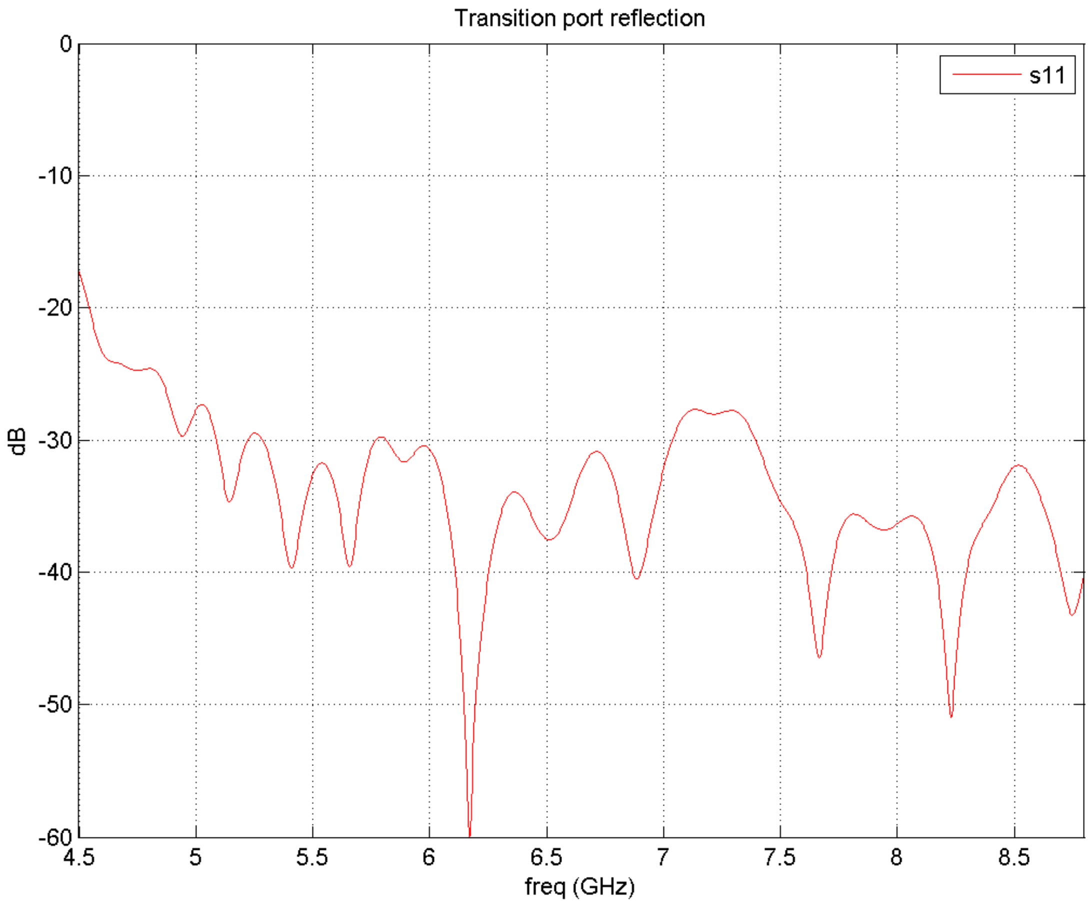


Figure 14. Feed and transition reflection

The radiation patterns were also simulated. They are showed in the annex (13). The 3D full wave simulator results are comparable to the results of the design. However, the diagrams at higher frequency (8.8 GHz) show a crosspolar level near to -15dB and an unexpected ripple in the phi=90deg cut, that it was not found in the patterns of the design. This discrepancy can be due to the simulator mesh, that it could be inadequate in the high frequency limit.

8.2 Scaled feed model

A higher frequency scaled feed model was built to prove the concept and validate the design. It has the advantage of testing the feed construction in a smaller prototype. This feed has been tested during the design phase to verify from measurements that the design is correct. It works between 13.5 GHz and 26.5 GHz. The feed model has been built with frequency relation of 3:1.

Figure 15. Scaled feed prototype

Figure 16. Scaled feed prototype

In the Table 9 the correspondence for measured and simulated frequencies of this report is shown.

Ventspils feed frequency	GHz	4.50	5.00	6.00	7.00	8.00	8.80
Scaled feed frequency	GHz	13.50	15.00	18.00	21.00	24.00	26.40

Table 9. Correspondence for frequencies in simulations and measurements between the scaled feed and the final feed

8.2.1 Radiation patterns

The radiation patters of the scaled feed were measure in the anechoic chamber. As it is an scaled feed model, the same radiation pattern is expected between the scaled feed model and the final feed.

The measurements were done with two setups. Because of the large bandwidth, two families of waveguides and adaptors were used. There was one setup to measure 13.5 to 15.0 GHz, and a second one to measure 18.0 to 26.5 GHz.

The patterns can be checked in the annex (14). The measurements from 13.5 to 15.0 GHz have crosspolar level at theta=0 higher than in previous simulation. It is because the adaptors used in the setup were not optimal. The measurements from 18.0 to 26.5 GHz show a not perfectly aligned setup inside of the anechoic chamber. Both minor defects do not affect to the validation.

At the top frequency, the crosspolar peak level is found to be below -20dB. It proves that, the cross polar peak level found in the simulations of the last section was due to an inaccuracy of the simulator. Measurements agree with the previous simulations and they confirm the validity of the designed feed.

8.2.2 Phase centre

The determination of the phase centre is essential for the feed positioning in the cassegrain antenna. The maximum antenna efficiency is reached when the phase centre of the feed coincides with focal point of the antenna. Unfortunately, the feed phase centre determination is not accurate in the microwaves simulators. In addition, it changes its position with the frequency.

In consequence, the measurement of the phase centre is the more accurate way to have the knowledge of the phase centre position.

It was measured in the scaled feed. The result is not an unique point to focus the feed with the antenna because it moves with the frequency.

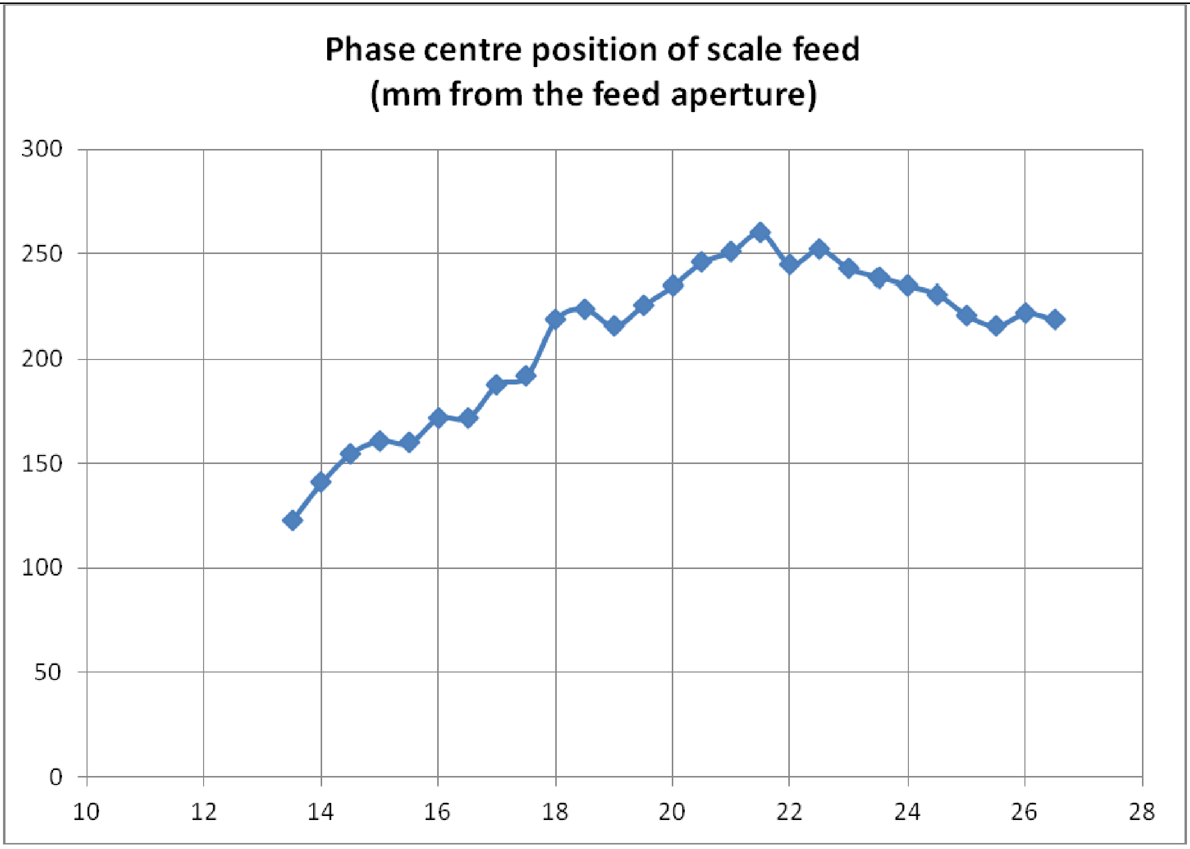


Figure 17. Feed and transition reflection

8.3 Physical optics calculation

The physical optics calculations are done with the real measured data of the scaled feed in the frequencies of the scaled feed. The correspondence with the final feed is in the Table 9.

The position of the feed in the antenna reference frame is calculated with the information of the phase centre position measured in the scaled feed. The feed should stand at one position where all the efficiency of the antenna remains high for all the bandwidth. The optimal position of the phase centre from the aperture is 220mm (this figure is chosen for the scaled feed). It is the phase centre position for the highest frequency, and it is the more sensitive to the axial misalignment.

The physical optics calculation is shown in Figure 18. The aperture efficiency is higher than 85% from 16 GHz (5.33GHz in the final feed). It drops in lower frequencies but it is still over 82%

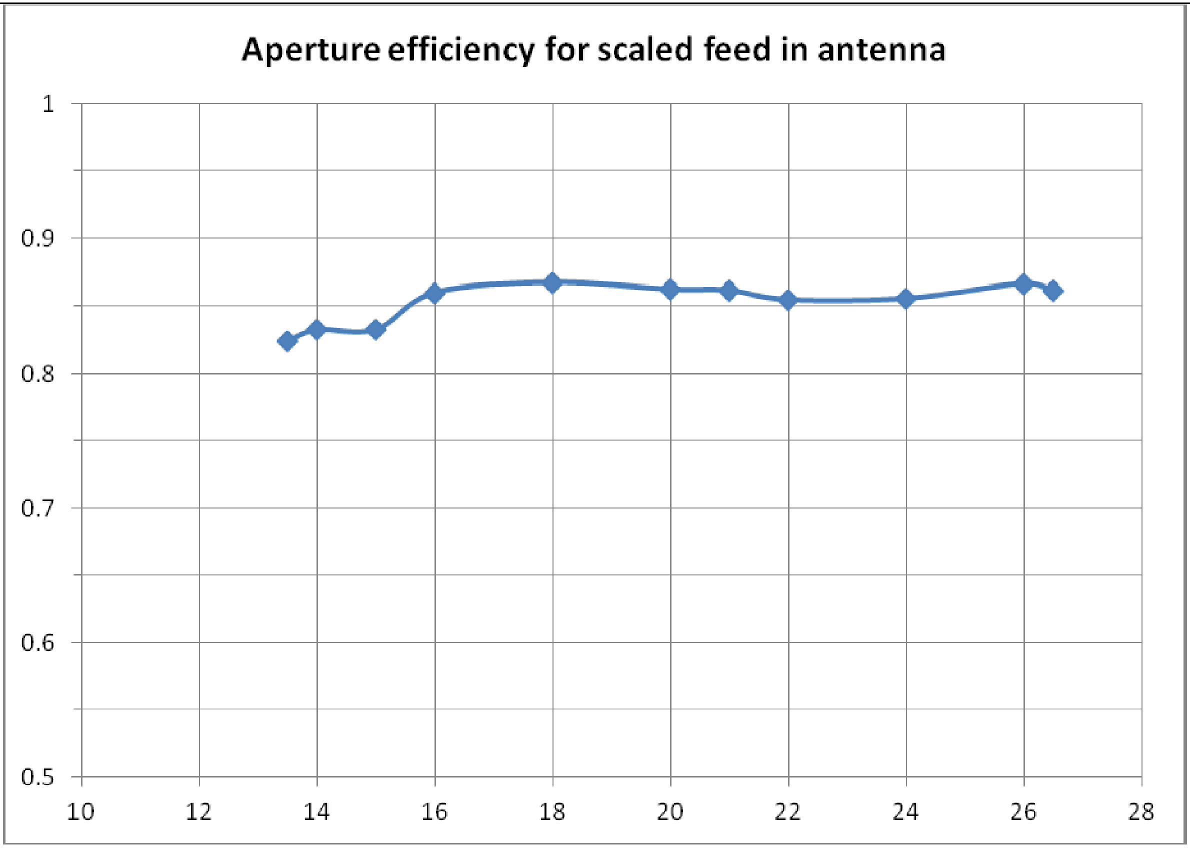


Figure 18. Aperture efficiency using the measured data of scaled feed standing in a fixed position in the antenna.

The patterns of the measured feed and antenna can be checked in annex 15. As it was mentioned in section 8.2.1, the defects in the feed measurement can be seen in the radiation patterns of the whole antenna and feed. From 13.5 to 15.0 GHz, it is found an unexpected crosspolar level at theta=0 higher than expected. It was because the adaptors in the measurement were not the optimal. From 18.0 to 26.5 GHz, a beam misalignment in the antenna is detected because the feed was not perfectly aligned in the measurement.

9 CONCLUSIONS.

This report shows the design and validation of the design of the Ventspils 16m feed. The first preliminary design was done with modal matching techniques in a previous phase. Now, it has been mechanically designed following the inner profile developed. This is the final design to be built in the workshop. Three tests were done to validate the final design:

1. 3D full wave simulations. Port reflection of the feed and transition with acceptable levels. The radiation patterns according to previous design patterns except at the top frequency where an unexpected ripple and high crosspolar level was found.
2. Scaled feed model construction. With frequency correspondence 3:1. Radiation patterns measurements matches with previous simulations and reject the high cross polar peak level previously simulated. The phase center calculation for all frequencies helped to choose the feed position inside the antenna feed cone.
3. Physical optics simulations. It is the final test to check that the design fulfils. It uses previous real measurements as a feeder.

These three tests prove that the design is ready to be built and tested. This report will freeze the design. The design should not be change after its acceptance. The only issue that it could be changed in the final test feed phase, is the position of the feed inside of the feed cone. This small change in axial position could improve the final aperture efficiency.

In this moment, we have only a predicted phase centre based on scaled feed measurements (Figure 19). It must be confirmed in the final feed measurements. The verification with the scaled feed showed that a fixed feed position was a good strategy because the aperture efficiency remained high. This fixed point in the final feed is 660mm from the aperture (interface drawing in annex 11), however it is recommended to have ±100mm of margin to place the final receiver and feed. The final position of feed can be given with the final feed test or it can be adjusted by means of the receiver adjustment structure of the VIRAC. This positional range will let adjust the phase centre position with the focal point of the antenna in the frequency range from 5.5-8.8 GHz. With a stronger criteria, the positional range should be kept in the adjustment range between 360-760mm from the aperture, in this case the phase centre of the feed could be adjusted to any predicted position. We think that it is unnecessary and a range of 660±100mm is enough to optimize the feed position in the test phase and observational phase.

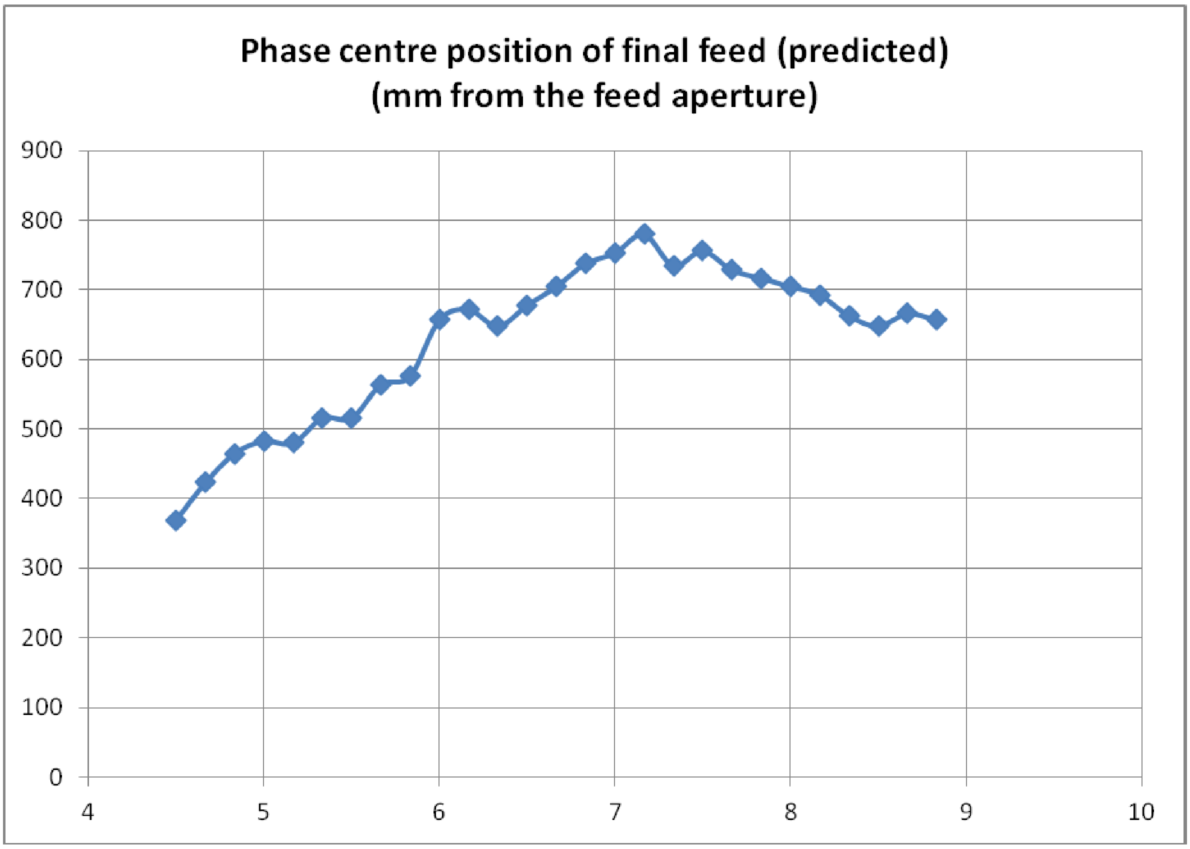


Figure 19. Prediction of the phase centre of the final feed

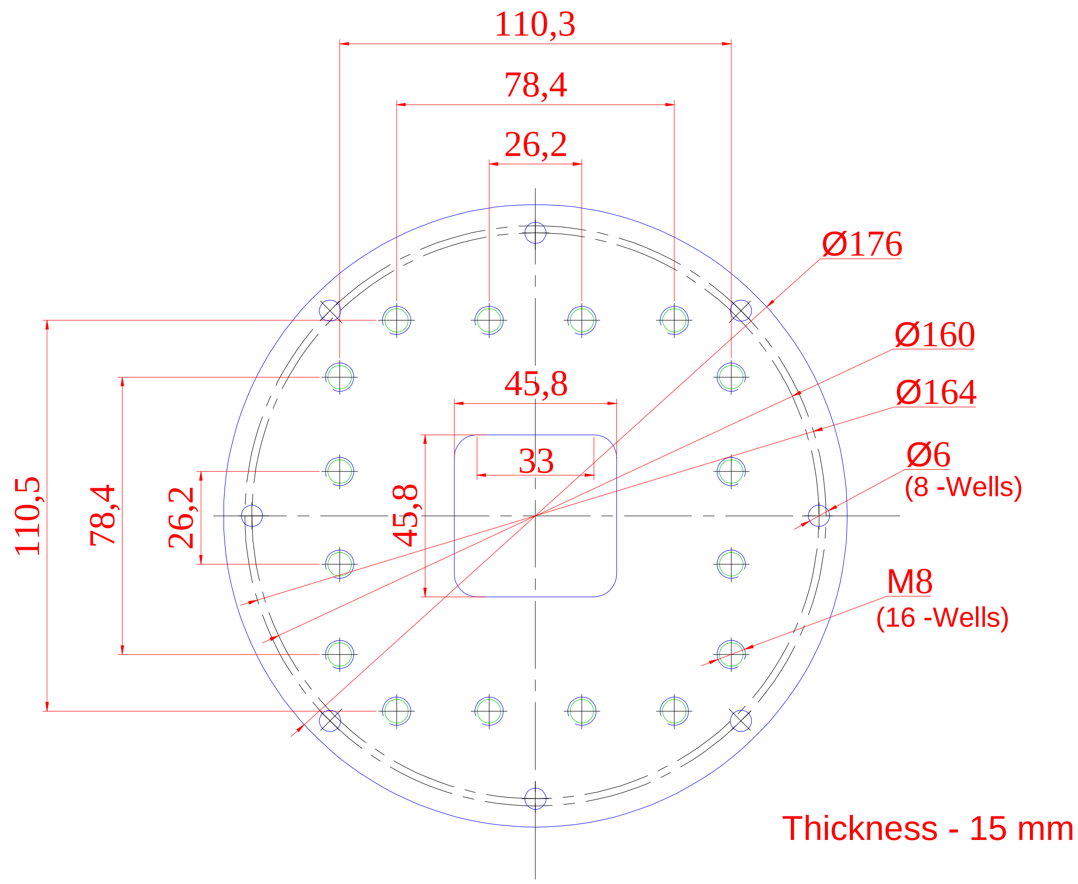
This range of adjustment could be even used in the observations to improve the efficiency in a single frequency. However, we think that the expected efficiency with the feed in a fixed position is good enough in all the bandwidth, and it was one of the success of the feed design.

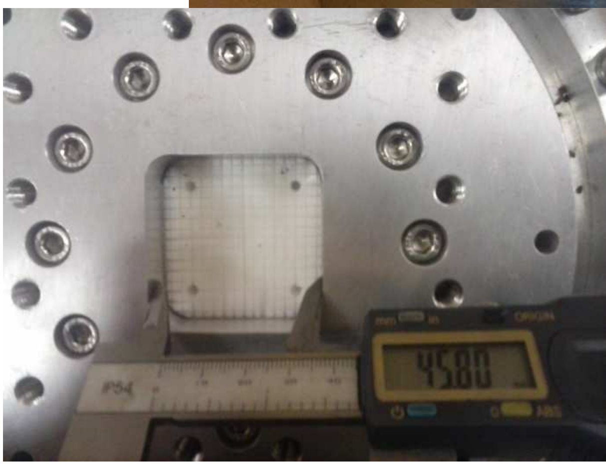
As this report freezes the design, the interface drawing must be carefully checked to prevent any interference or mismatch in the integration phase.

In addition, the construction and simulations of the scaled feed show the antenna behavior at 22GHz. It could be interesting for future applications at higher frequencies.

10 ANNEX. Input waveguide

All the dimensions are in mm

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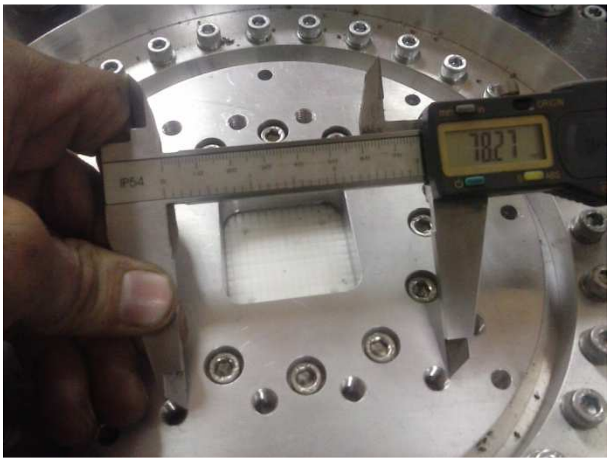
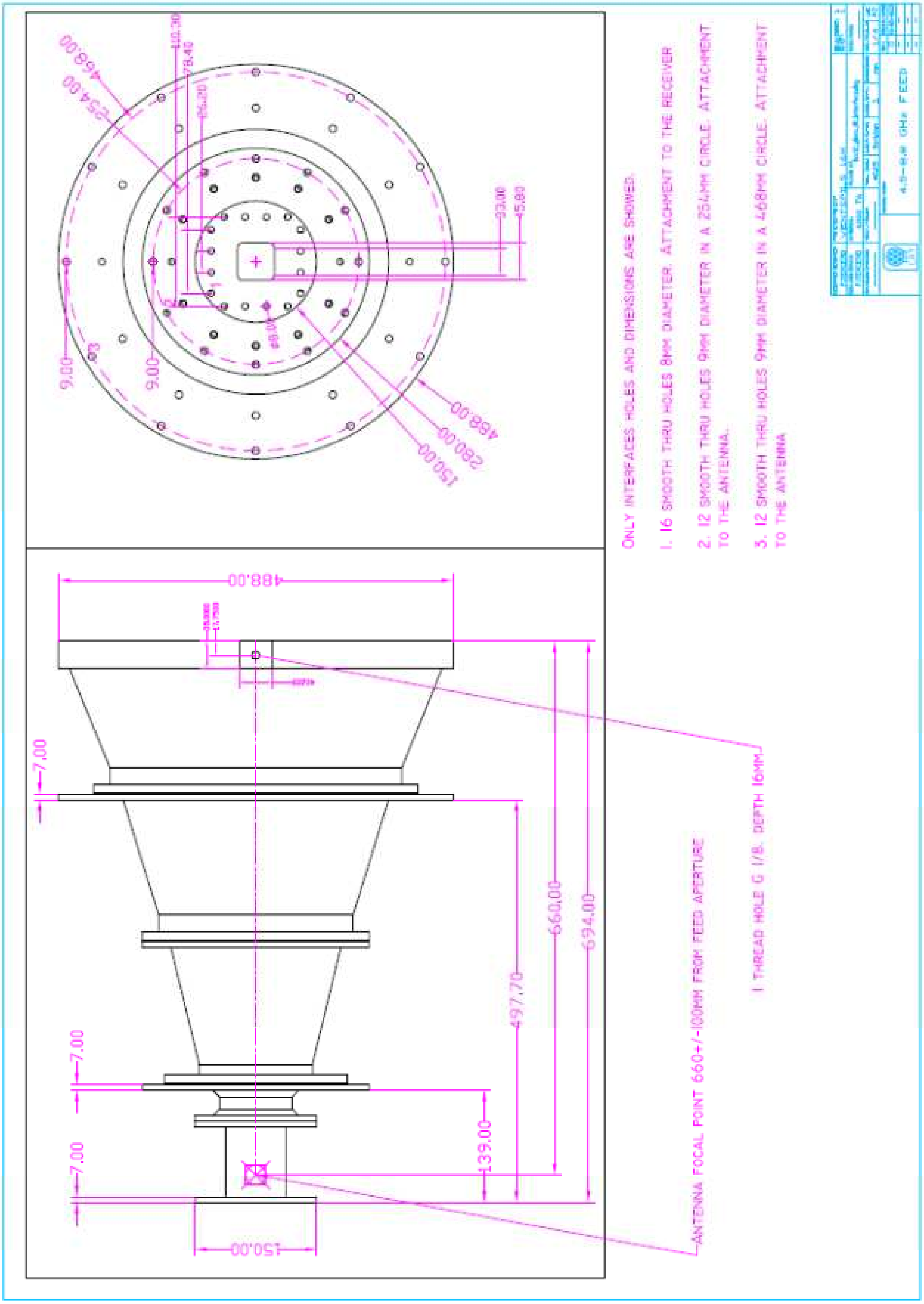

IP54

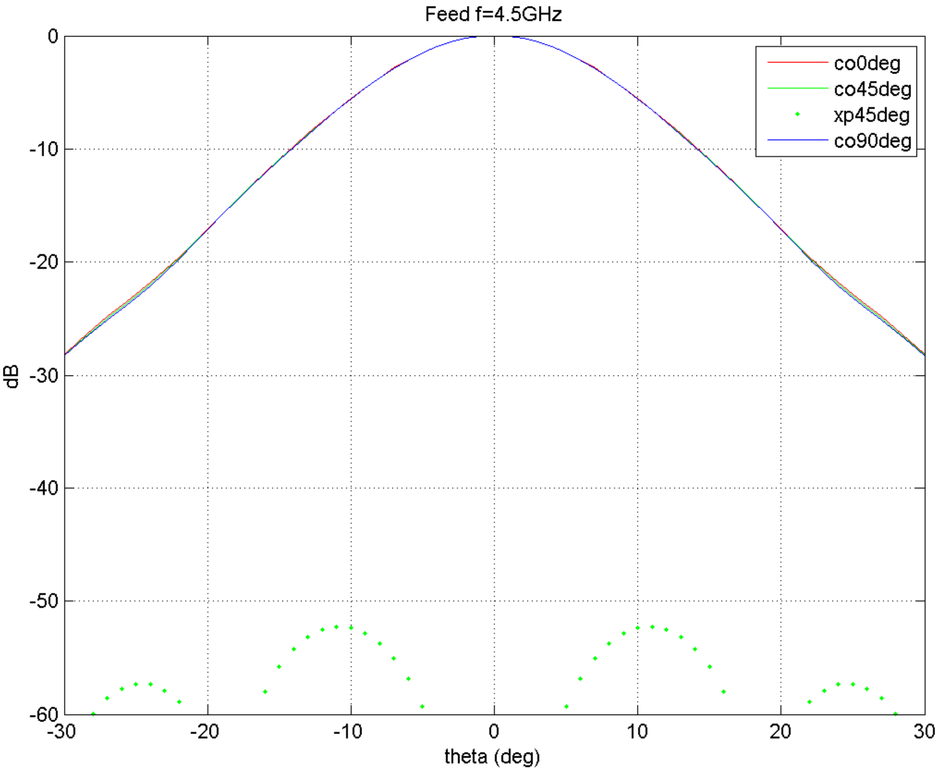

mm
in
ORIGIN
26.29
IP54
ABS

11 ANNEX. Feed interface

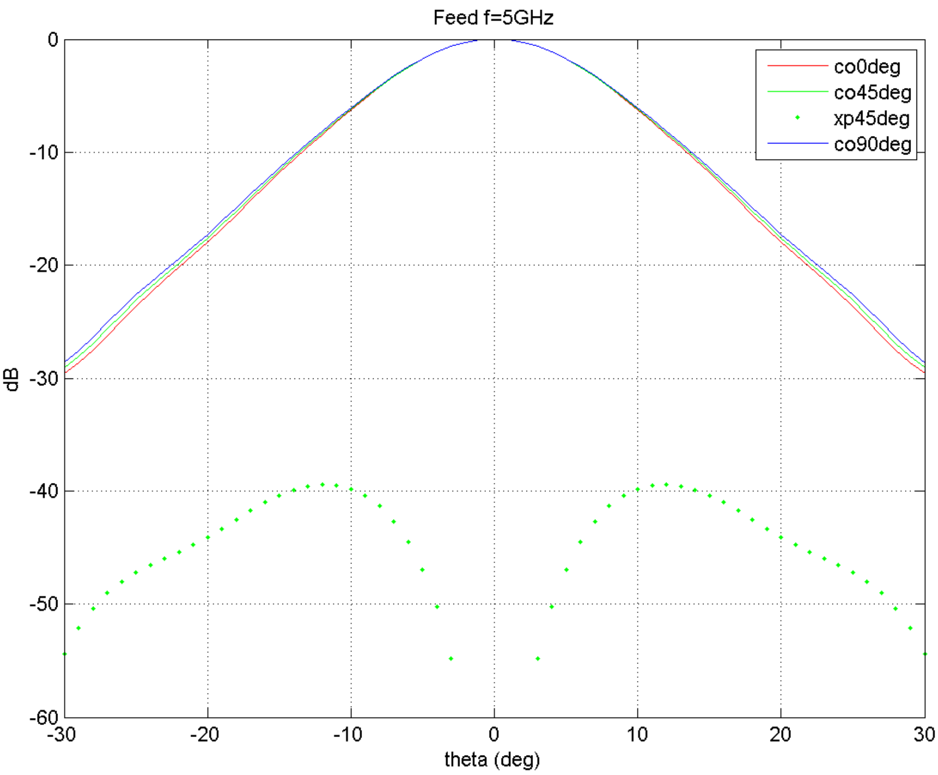


12 ANNEX. Feed radiation patterns (design with axial)

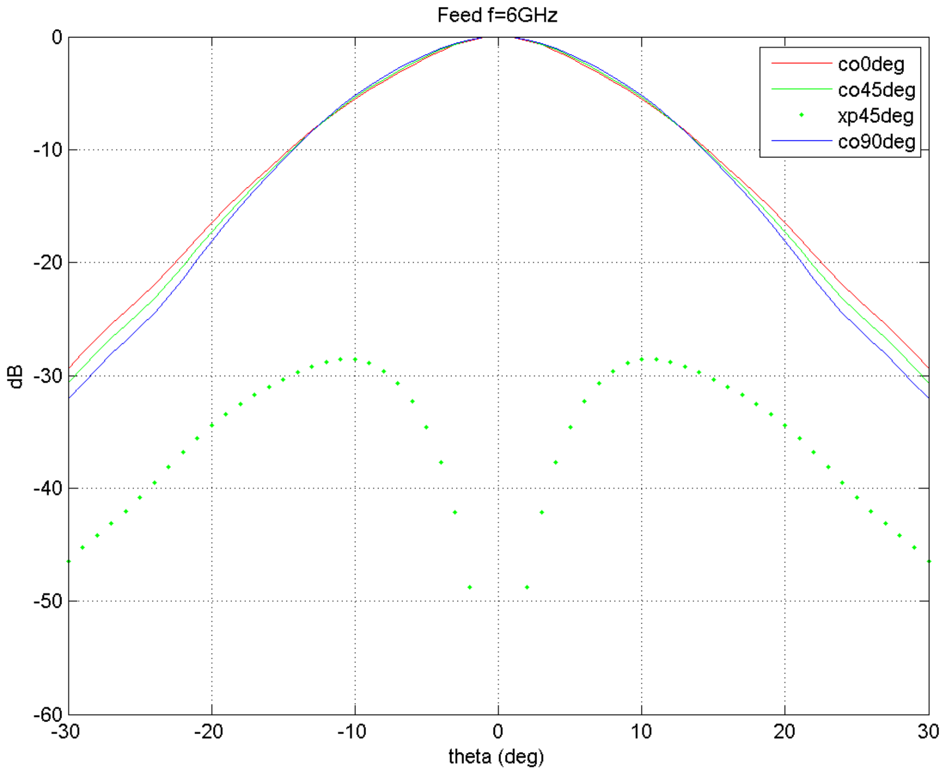
4.50 GHz



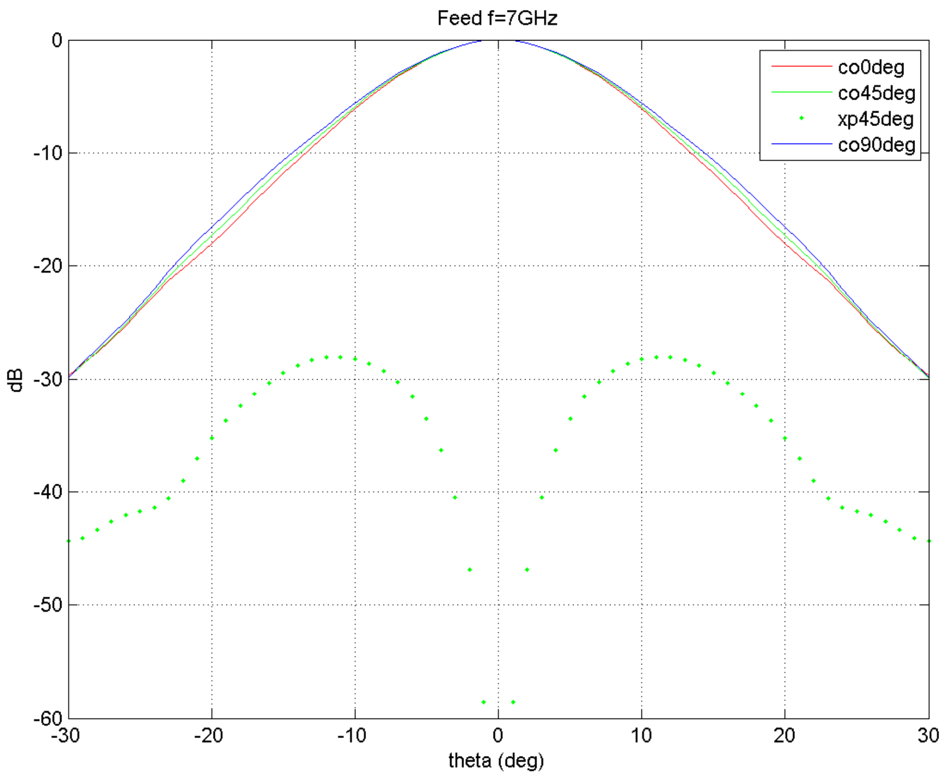
5.00 GHz



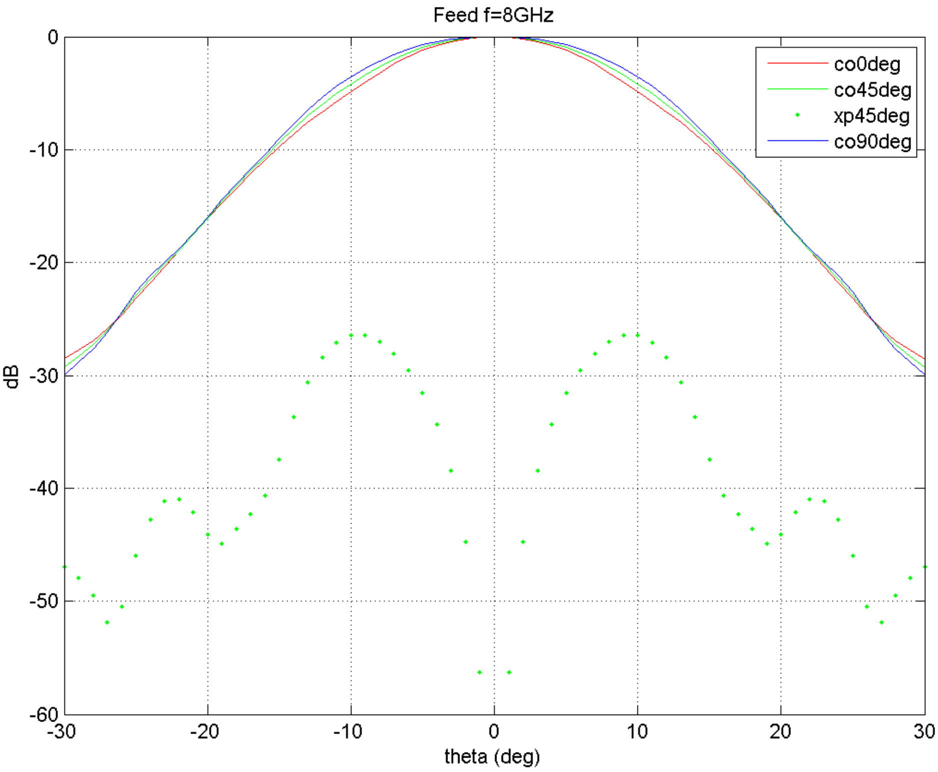
6.00 GHz



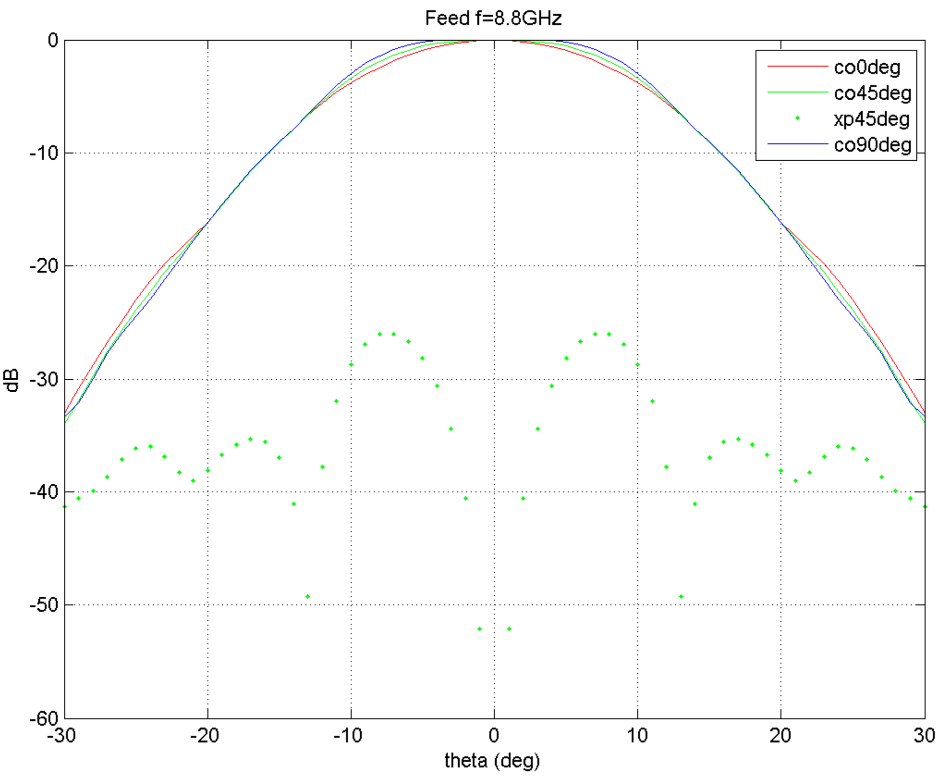
7.00 GHz



8.00 GHz

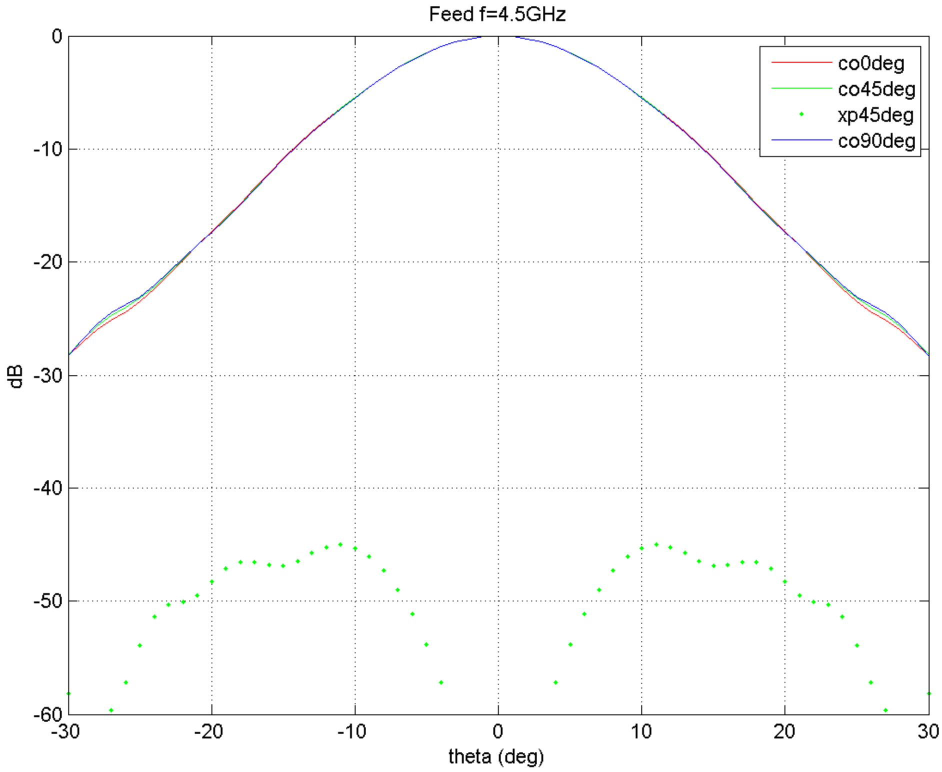


8.80 GHz

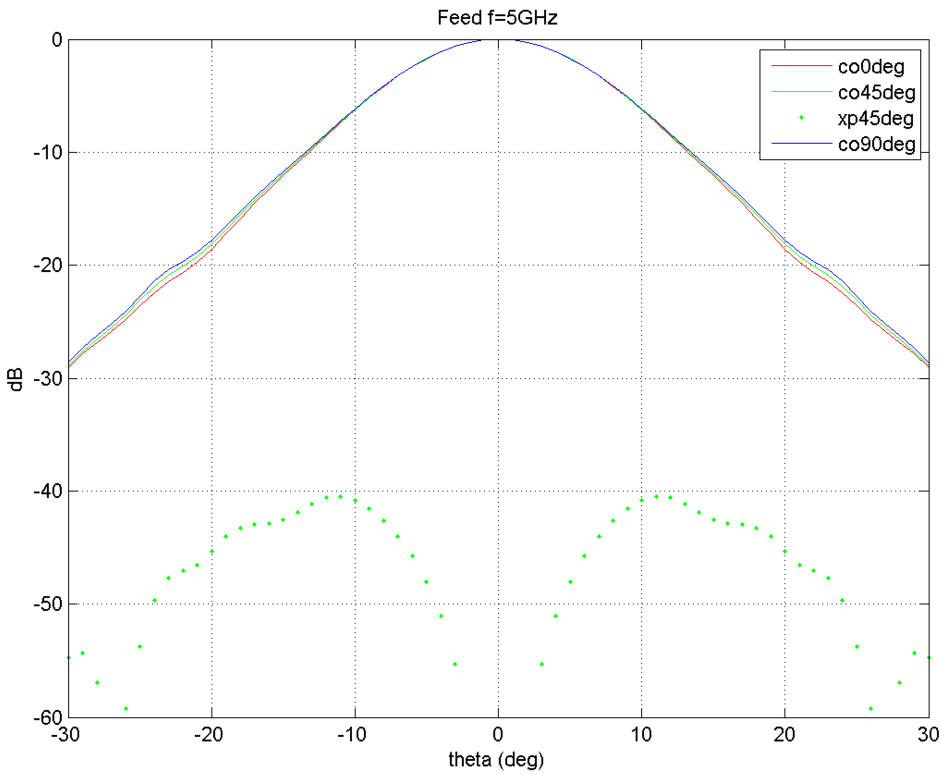


13 ANNEX. Feed radiation patterns (validation with 3d simulator)

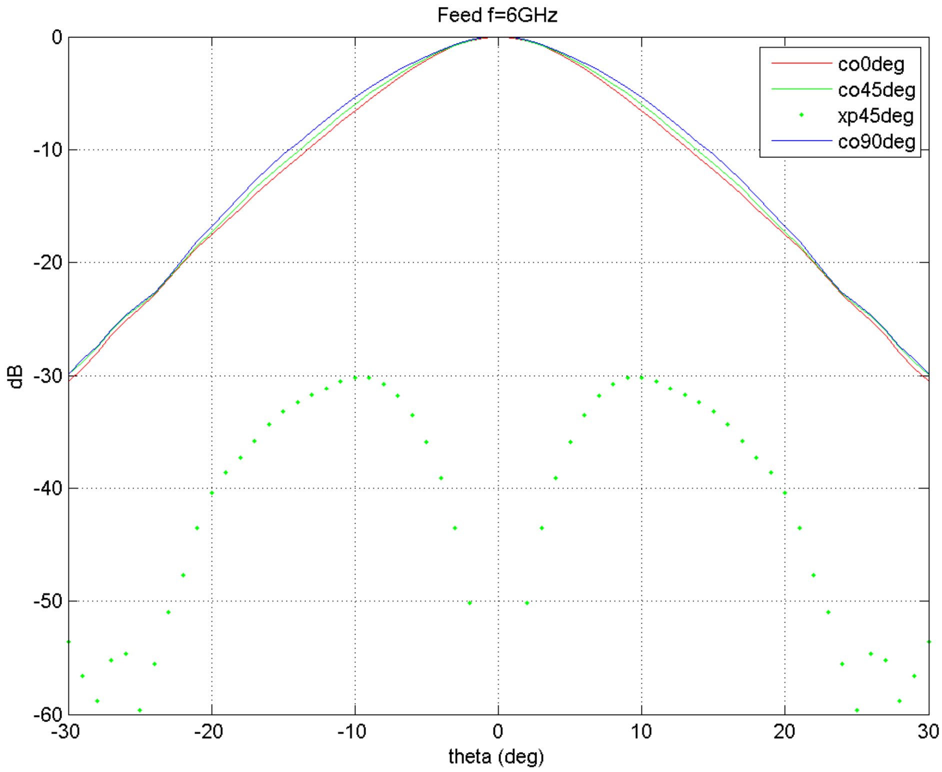
4.50 GHz



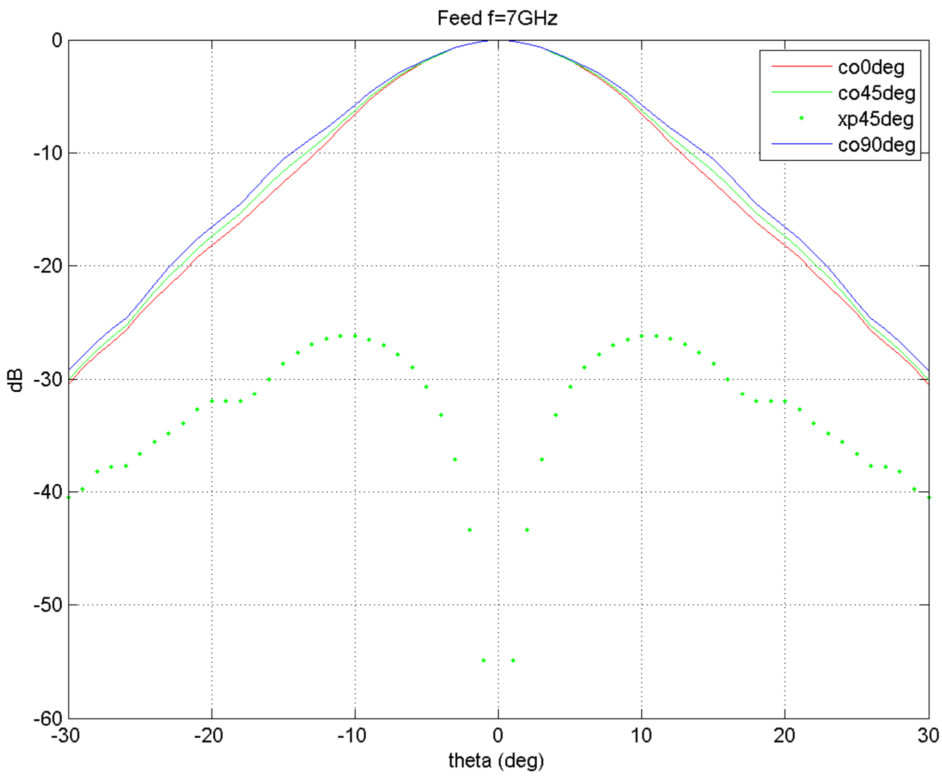
5.00 GHz



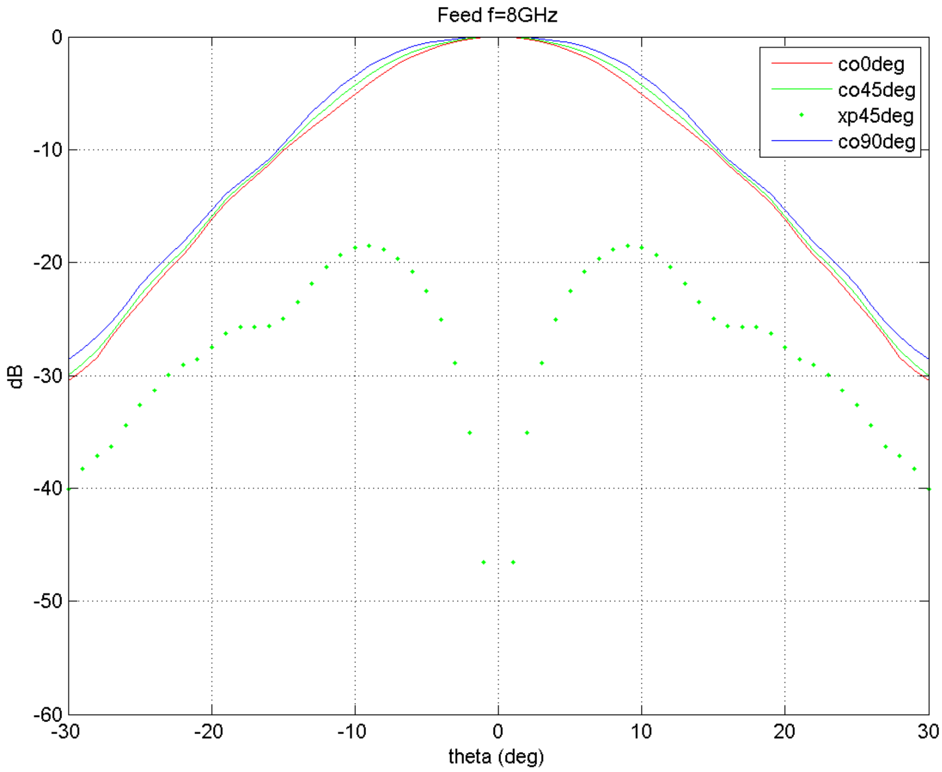
6.00 GHz



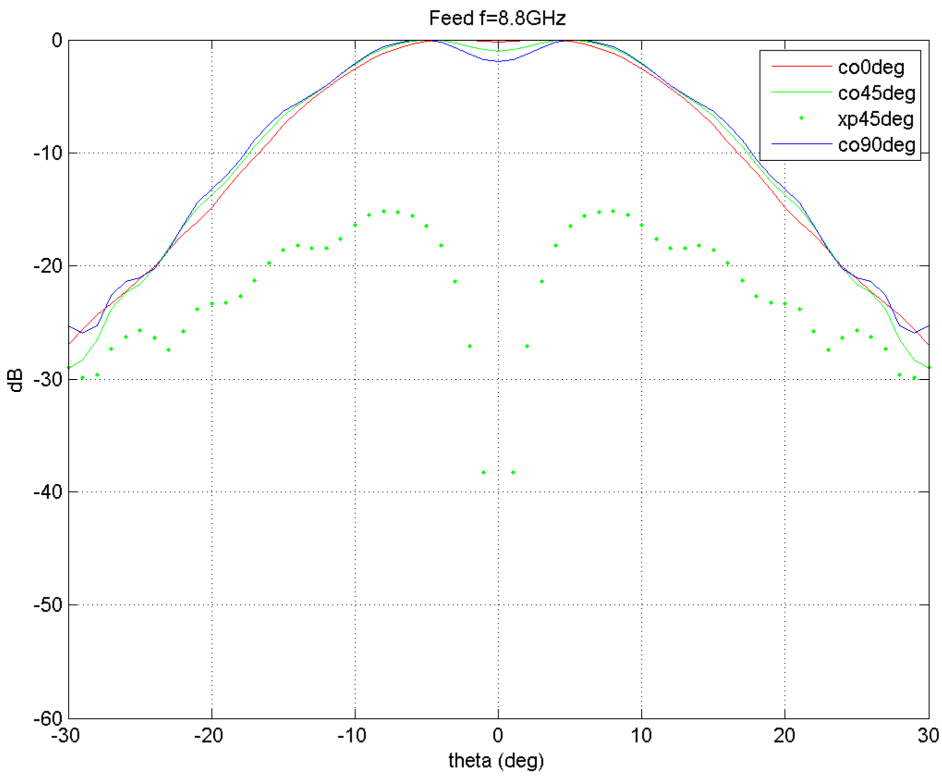
7.00 GHz



8.00 GHz

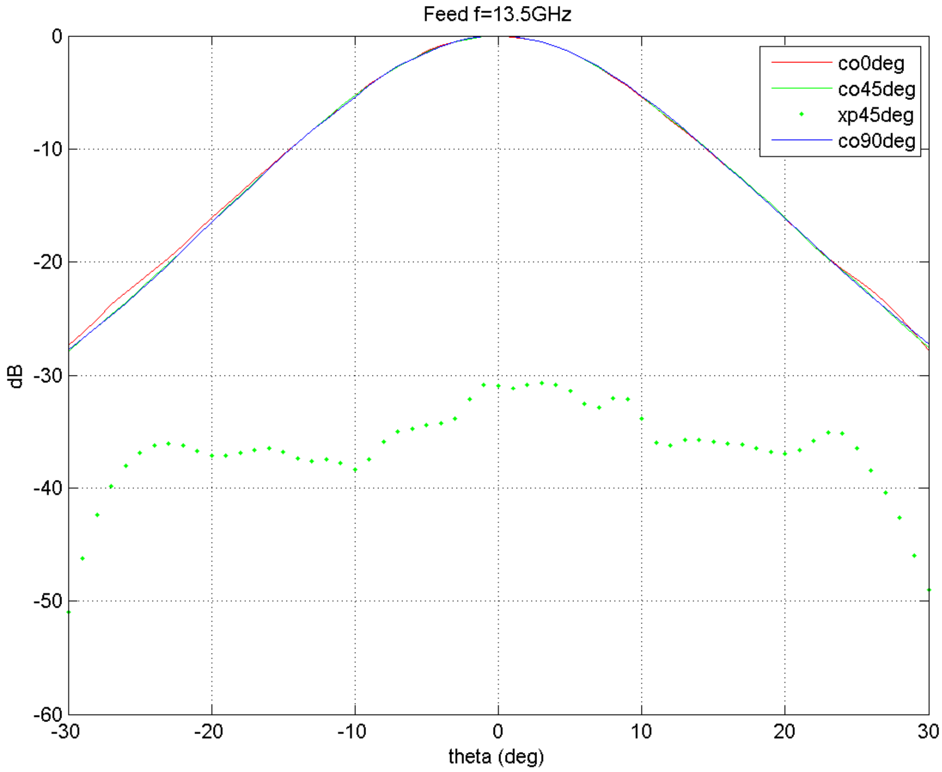


8.80 GHz

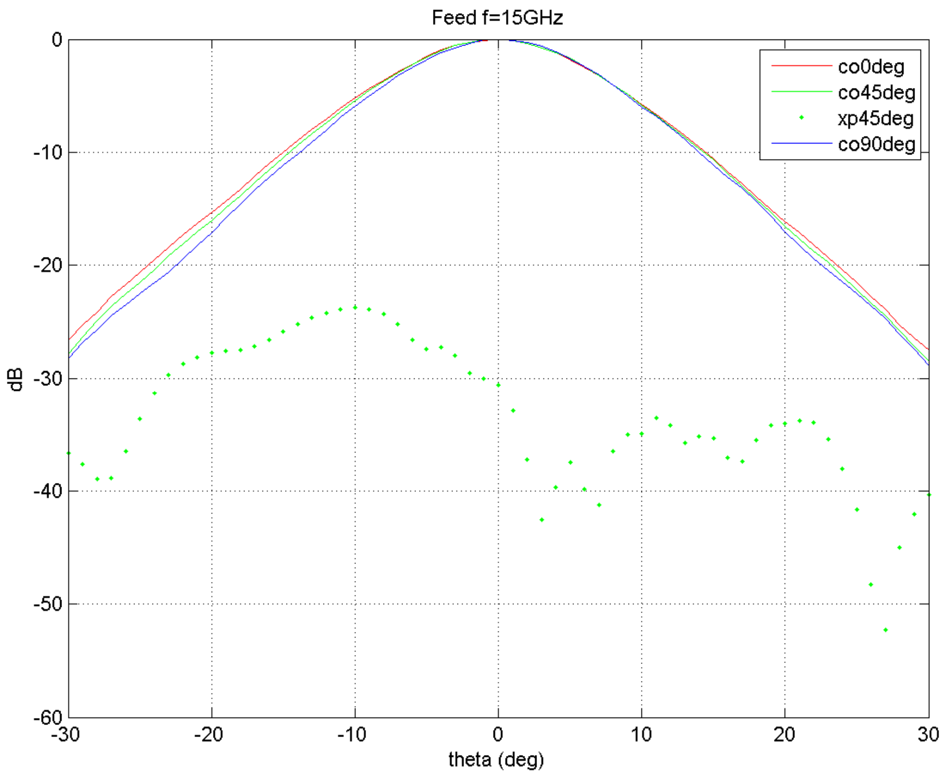


14 ANNEX. Feed radiation patterns (validation with scaled feed measurement)

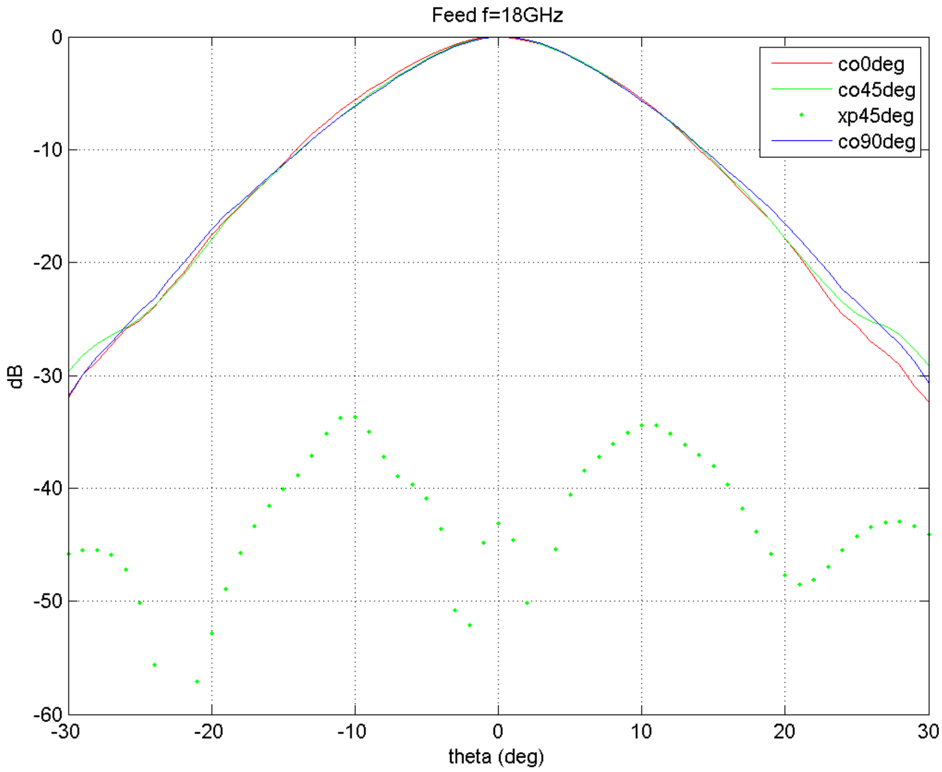
13.50 GHz



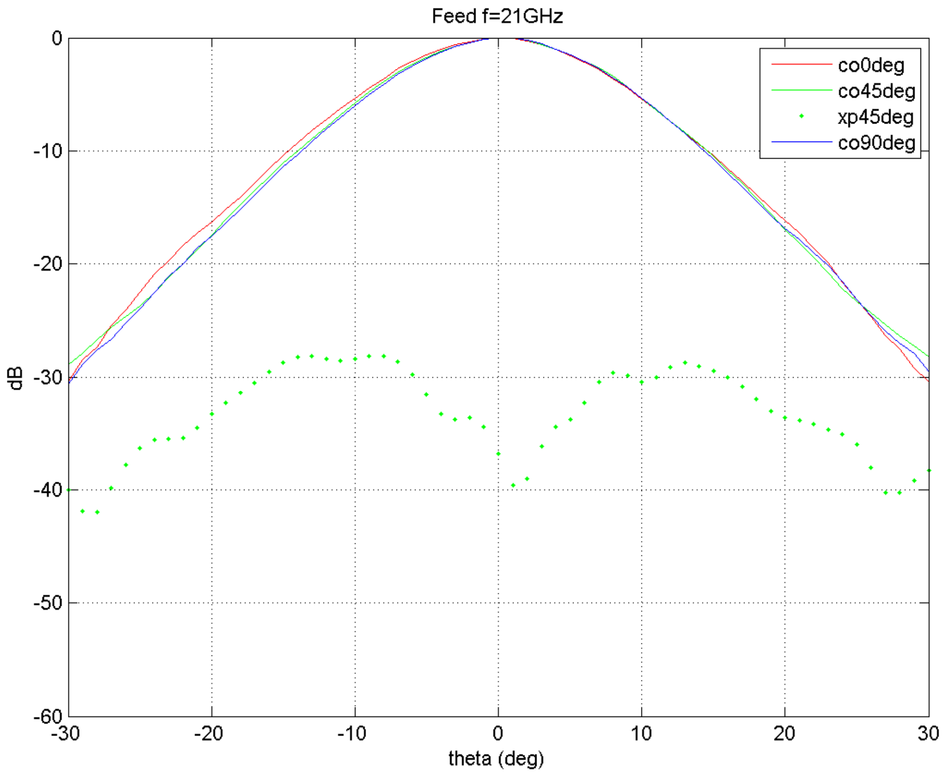
15.00 GHz



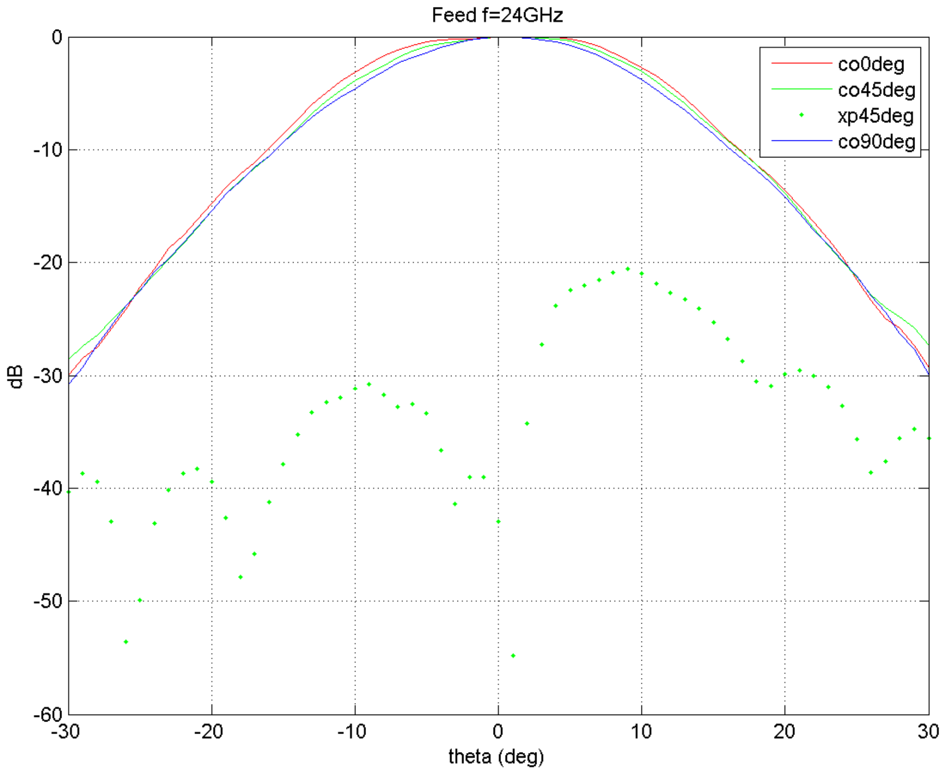
18.00 GHz



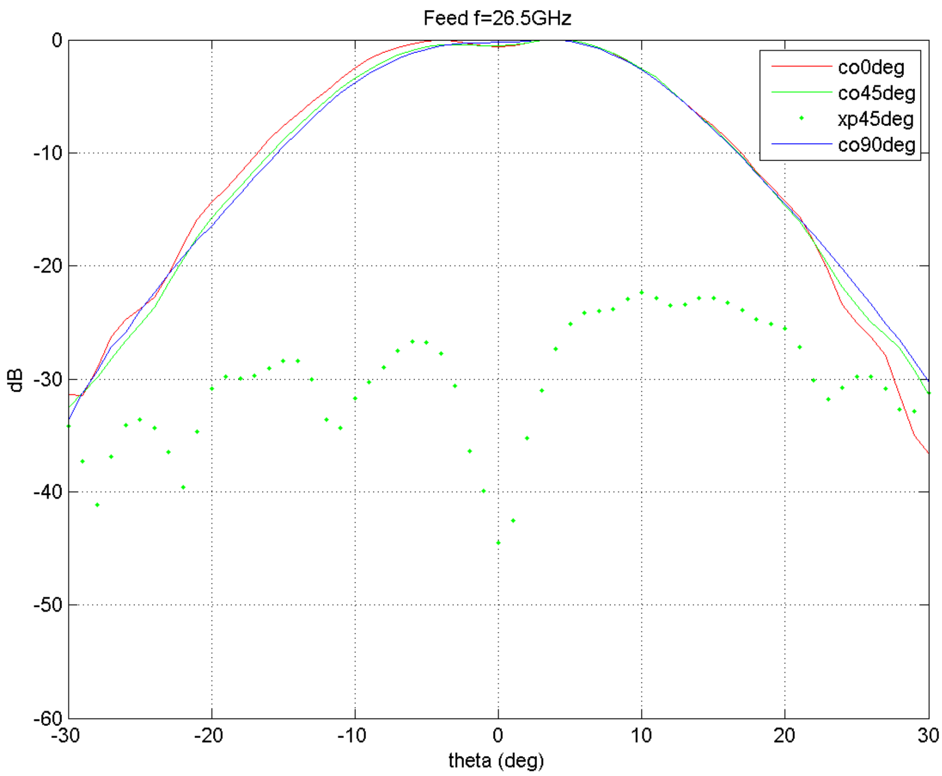
21.00 GHz



24.00 GHz

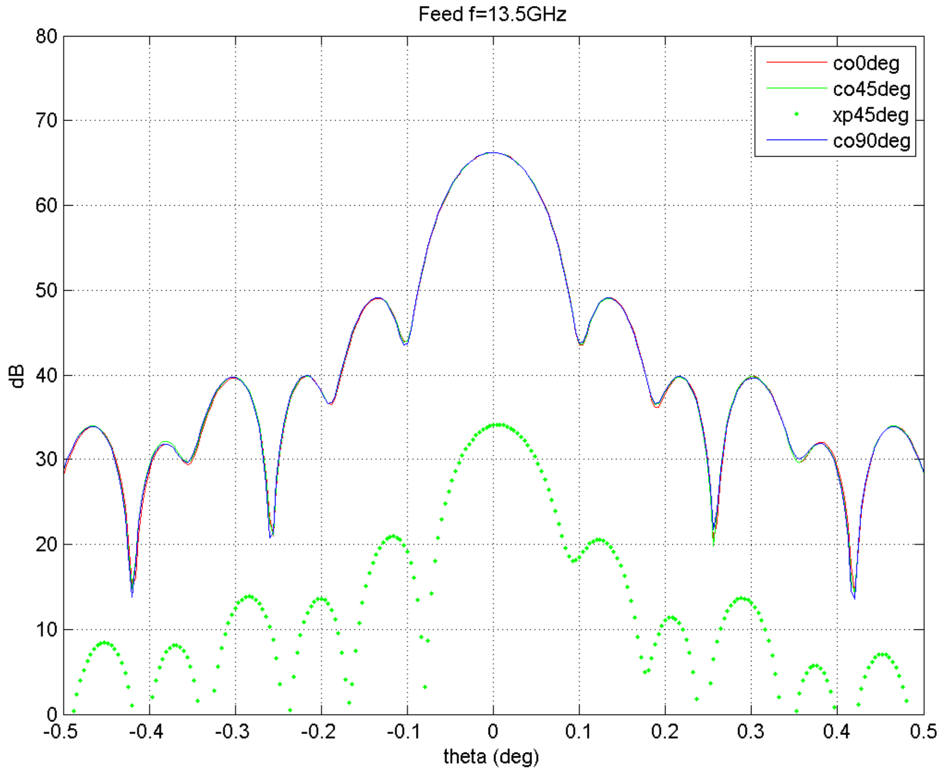


26.50 GHz

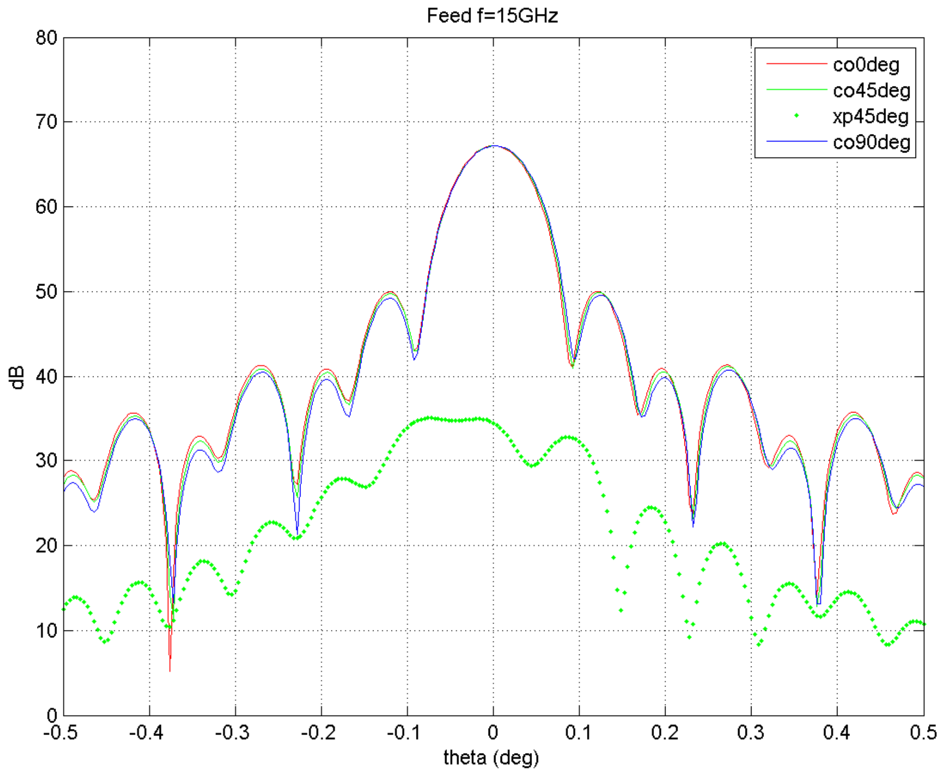


15 ANNEX. Shaped cassegrain radiation pattern (validation with scaled feed measurements)

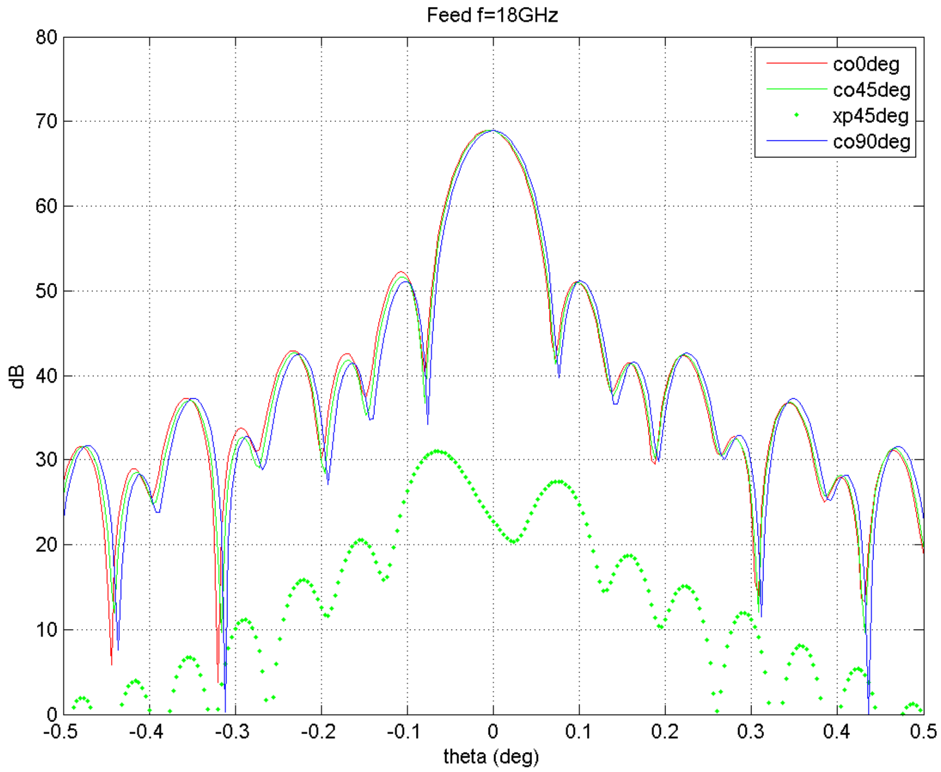
13.50 GHz



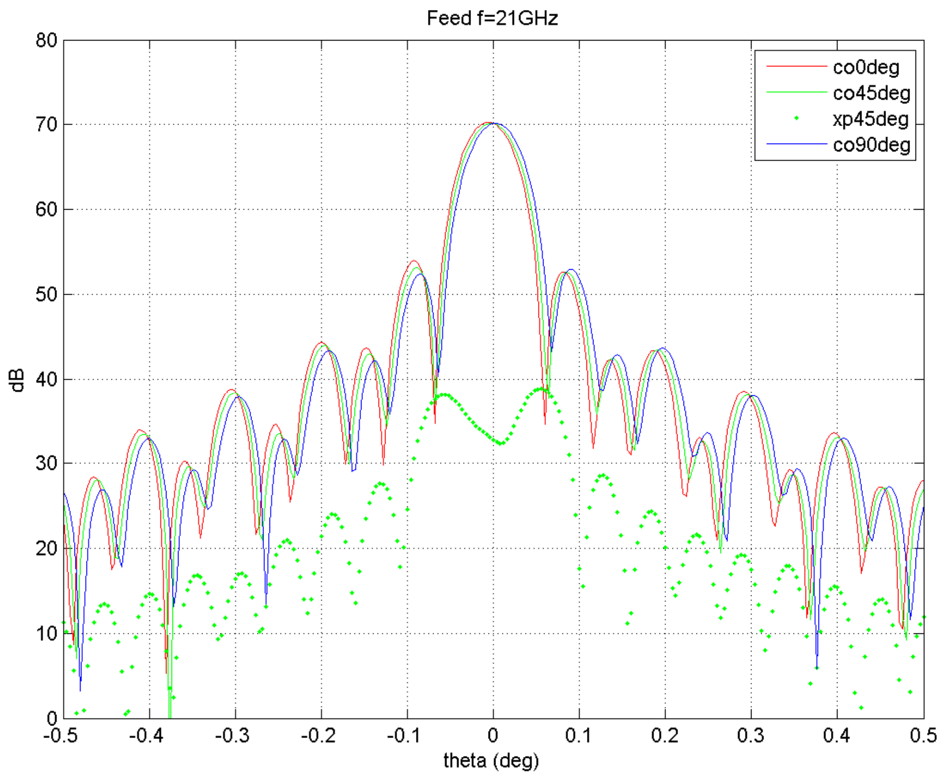
15.00 GHz



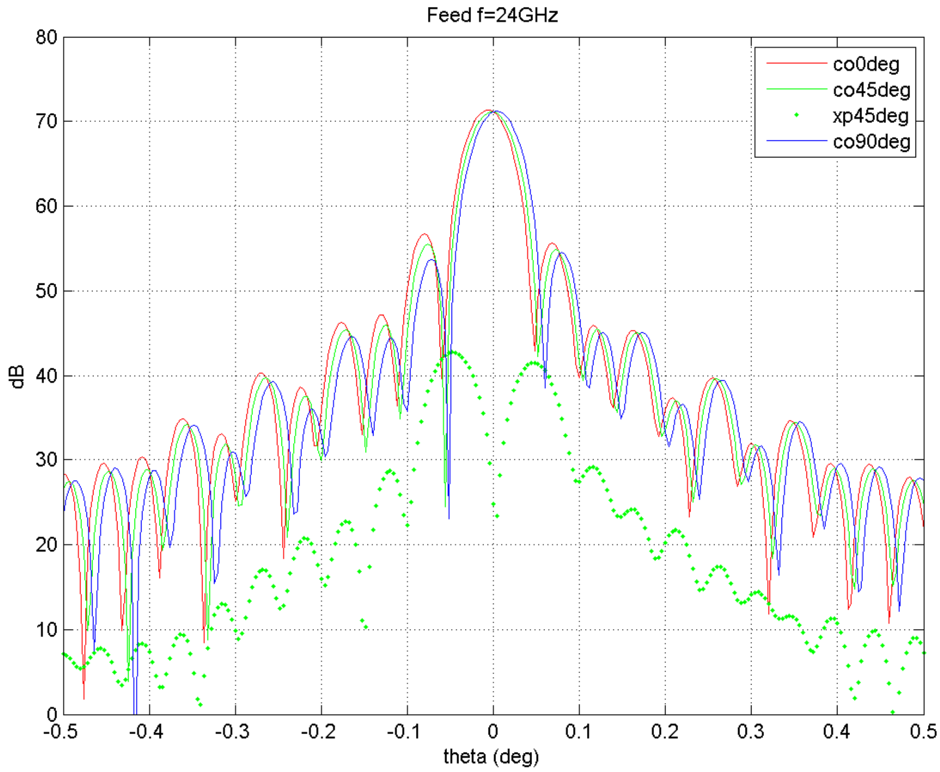
18.00 GHz



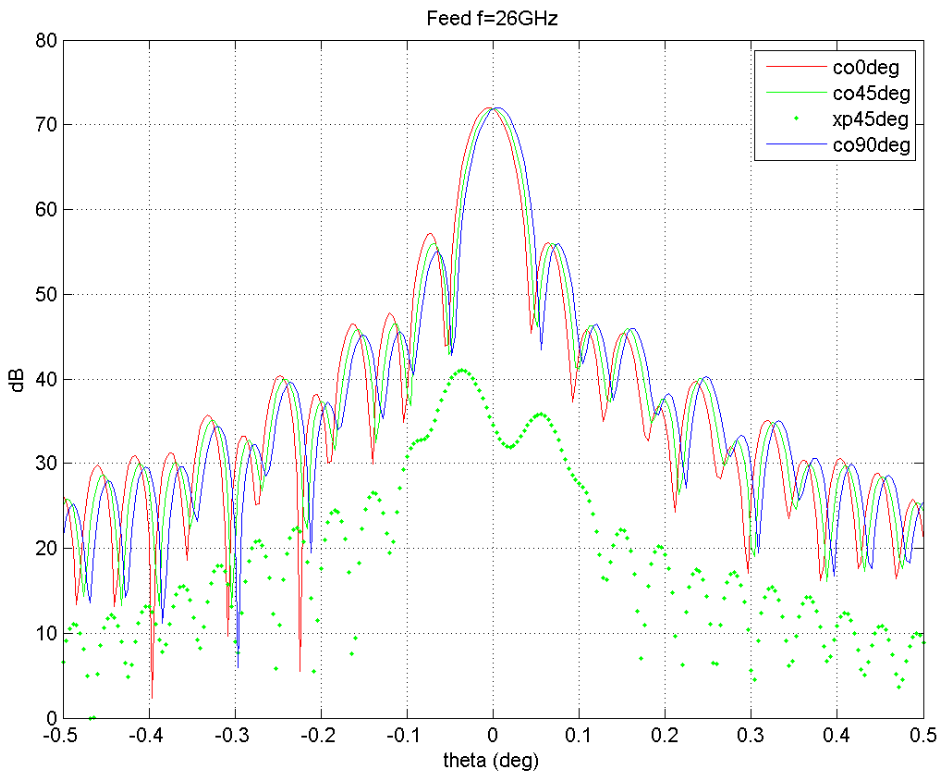
21.00 GHz



24.00 GHz



26.50 GHz



Reference

20150807_VENTSPILS_RT16_FINAL_FEED_MEAS

Title

FINAL FEED MEASUREMENTS FOR THE 16M VENTSPILS ANTENNA

Customer

MT MECHATRONICS

Written and released by:

F.Tercero
S.López
JA. López-Fdez
JM.Serna

Release: 01.0	Date: 07/08/2015	Pages:

1 Scope

Show the final electrical and mechanical measurements of the feed for the 16m Ventspils antenna. It includes all the final measurements in the final built feed to validate the prototype. It also includes the simulations of the 16m metre antenna using the measured feed as a feeder

2 Documentation and References

Title	Reference	Edited
Final feed design for the 16m Ventspils Antenna	20150513_ventspils_rt16_final_feed.pdf	IGN
Shaped reflectors data files	MainRefl.dat MainRefl_1.rsf SubRefl.dat SubRefl_1.rsf	MT

3 Introduction

A detailed design of the feed measured has been shown in the reference documentation, as well as the expected performance simulated. This report complements to the previous design document and it shows the measurements done over the prototype.

4 Design measurements.

After the manufacture of the feed, it has been measured to validate the design itself. Two measurements were done, the scattering parameter measurement and the radiation patterns over the frequency range from 4.5 GHz to 8.8 GHz.

The measurement data is used to feed the antenna in a physical optics simulation with GRASP to check the final radiation patterns of the whole feed plus reflector and take the efficiency figures.

4.1 Port reflection.

4.1.1 Port reflection calibration

We will attempt to measure in the squared port of the feed, that it is the interface point with already built VUC receiver. It complicates the measurement setup because it is not an standard waveguide and we had to fabricate additional instrumentation for the measurement. We finally built waveguide transitions from WR159 and WR112 to the squared waveguide.


Figure 20. Two couples of WR159 and WR112 to squared waveguide transitions

These transitions were used with WR159 and WR112 to coaxial transitions and a quarter wavelength squared transition to perform a TRL calibration of the vector network analyzer.

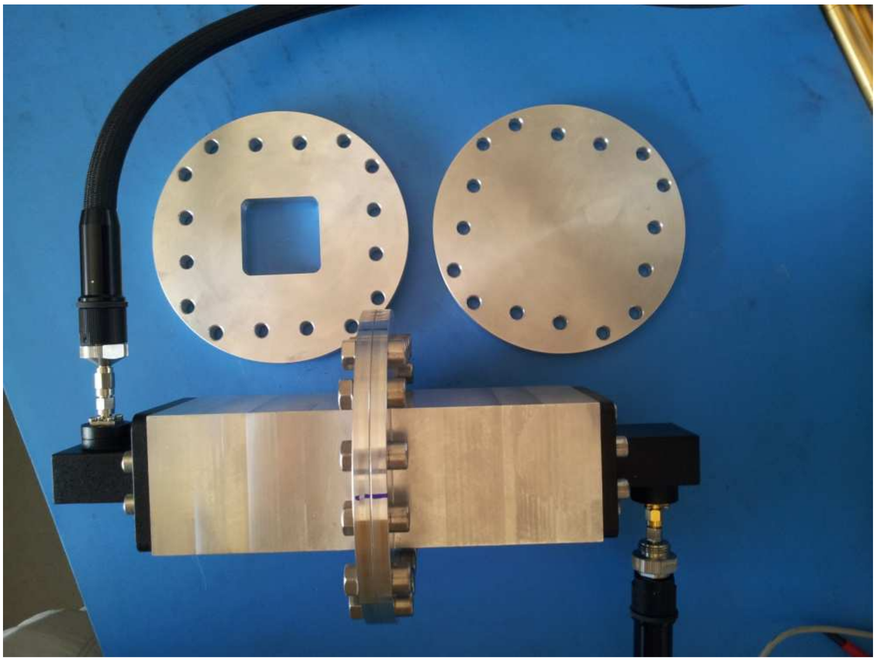


Figure 21. Thru connection for the WR159 waveguide transition. It is also shown the quarter squared waveguide and short to perform the TRL calibration

Two different waveguide standard bands were used to cover adequately: WR159 standard covers 4.90 GHz to 7.05 GHz but it was used from 4.50 GHz and WR112 standard cover 7.05 GHz to 10.0 GHz.

Even with this configuration, we could only calibrate well in the WR159 band using TRL method (see annex for thru after calibration). The reason is that the frequencies used for the WR112 are high and there are higher modes excitation in the squared waveguide. These higher modes create spikes in the WR112 bandwidth where it cannot be calibrated with the TRL method, and in consequence it cannot be measured there.

To solve this problem, we calibrate in WR112 rectangular waveguide (see annex for thru after rectangular WR112 TRL calibration). Then, in the measurement the effect of the WR112 to square waveguide transition is removed deembeding the transition. The S parameter matrix of the transition cannot be measured, however the simulation of the 3D model of the transition is used to deembeded it from the measurement.

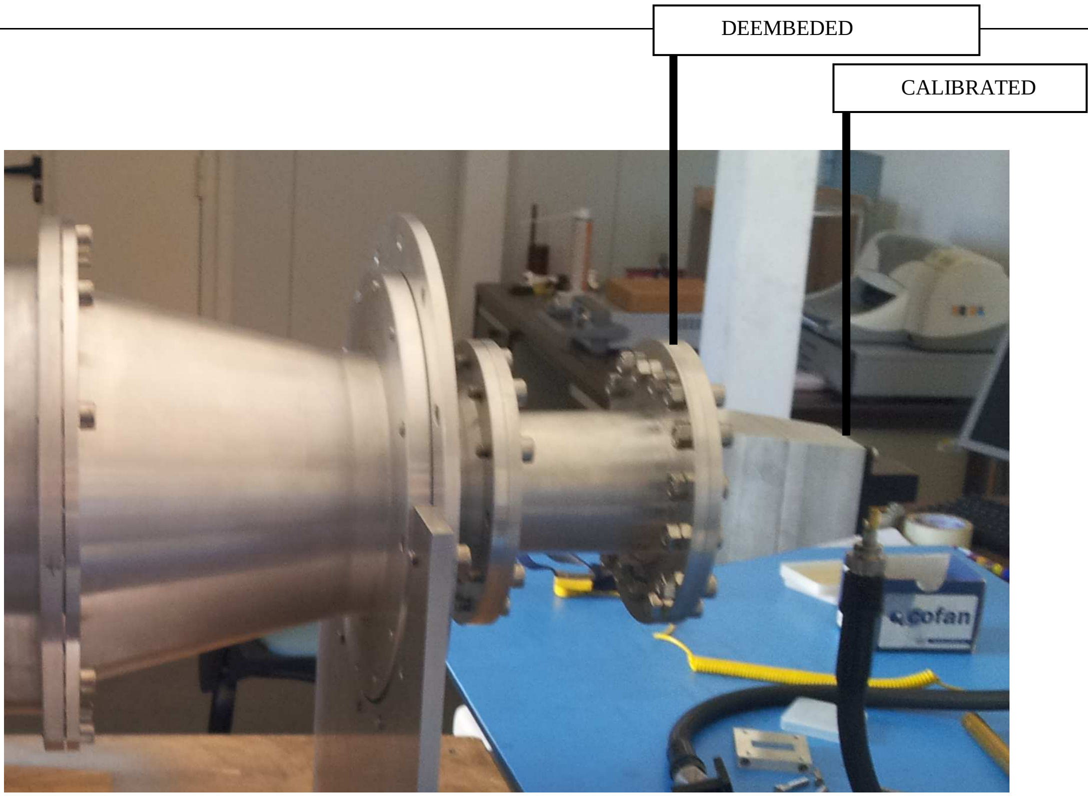


Figure 22. Measurement of port reflection setup from 4.5 GHz to 7.0 GHz. It shows the calibration plane and the deembeding transition

4.1.2 Port reflection measurement.

Taking into account the calibration setups described in the previous section, two measurements were done to cover the whole bandwidth. In the feed aperture, a microwave absorber is placed to match the aperture. In the Figure 4, the final port reflection is shown along all the feed bandwidth. It is the final measurement in the 45mm squared port, that is the interface with VUC receiver.

To compare the results with previous simulations, the measurements are compared with the previous simulations in the annex.

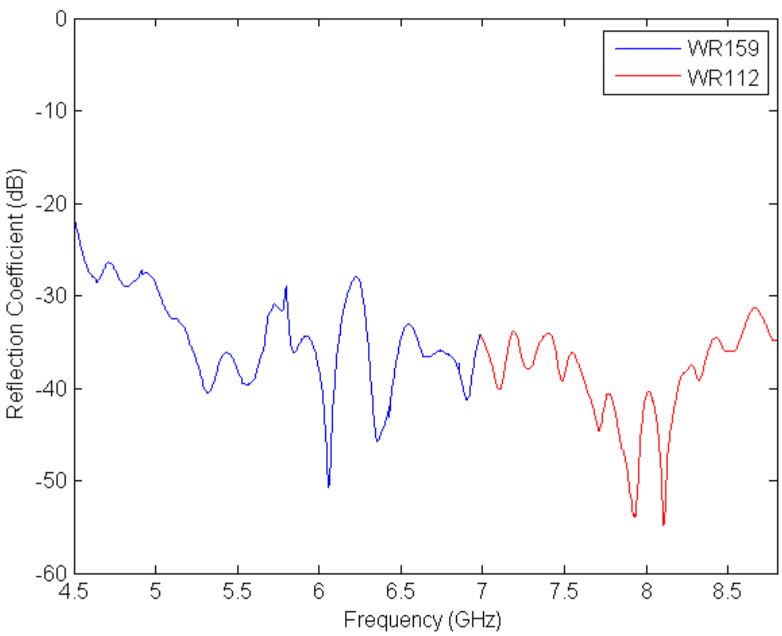


Figure 23. Measurement port reflection from 4.5 GHz to 8.8 GHz. Combination of both measurements after calibration and deembeding.

4.2 Radiation patterns

The radiation patters of the feed were measured in the Yebes anechoic chamber. The measurements were done with two setups. Because of the large bandwidth, two families of waveguides and adaptors were used. There was one setup to measure 4.5 to 7.0 GHz, and a second one to measure 7.0 to 8.8 GHz.

The patterns can be checked in the annex (10). The crosspolar worst level is better than -20 dB and asymmetries seem to be a little bit stronger than in previous scaled feed in higher frequency.

Figure 24. Measurement of radiation pattern in anechoic chamber

4.3 Phase centre

The phase centre is calculated in several frequencies along the feed bandwidth. The predictions about the phase centre in the lasts reports are confirmed with this measurement. The optimal position of the feed for all frequencies is 660mm from the aperture as it was shown in the last reports.

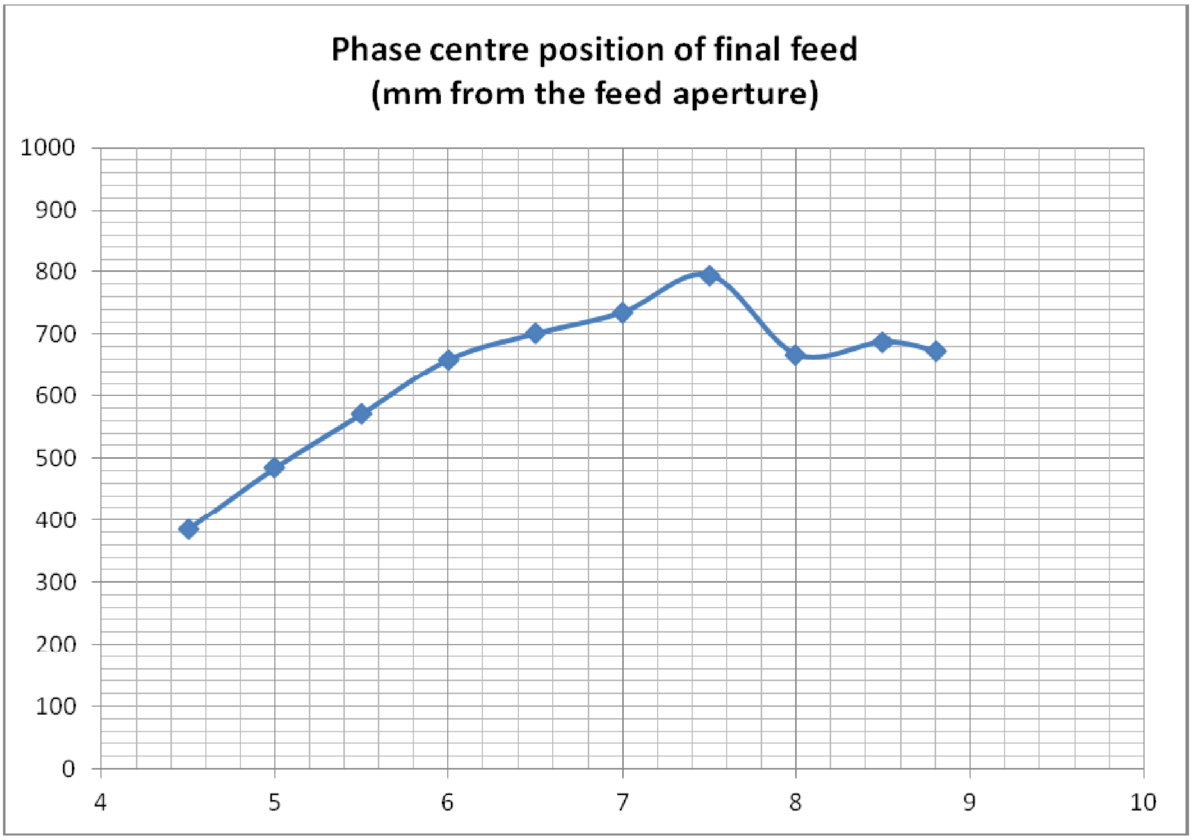


Figure 25. Feed phase centre measured from the feed aperture

4.4 Physical optics calculation

The physical optics calculations are done with the real measured data of the scaled feed in the frequencies of the final built feed.

The position of the feed in the antenna reference frame is calculated with the information of the phase centre position measured previously. The feed should stand at one position where all the efficiency of the antenna remains high for all the bandwidth. The optimal position of the phase centre from the aperture is 660mm. It is the phase centre position for the highest frequency, and it is the more sensitive to the axial misalignment.

The physical optics calculation is shown in Figure 18. The aperture efficiency is higher than 84% in the whole bandwidth.

The patterns of the measured feed and antenna can be checked in annex 15. Radiation patterns show a symmetrical beam in whole bandwidth and the feed asymmetries can be found in the different sidelobe levels, as it was expected in previous simulations.

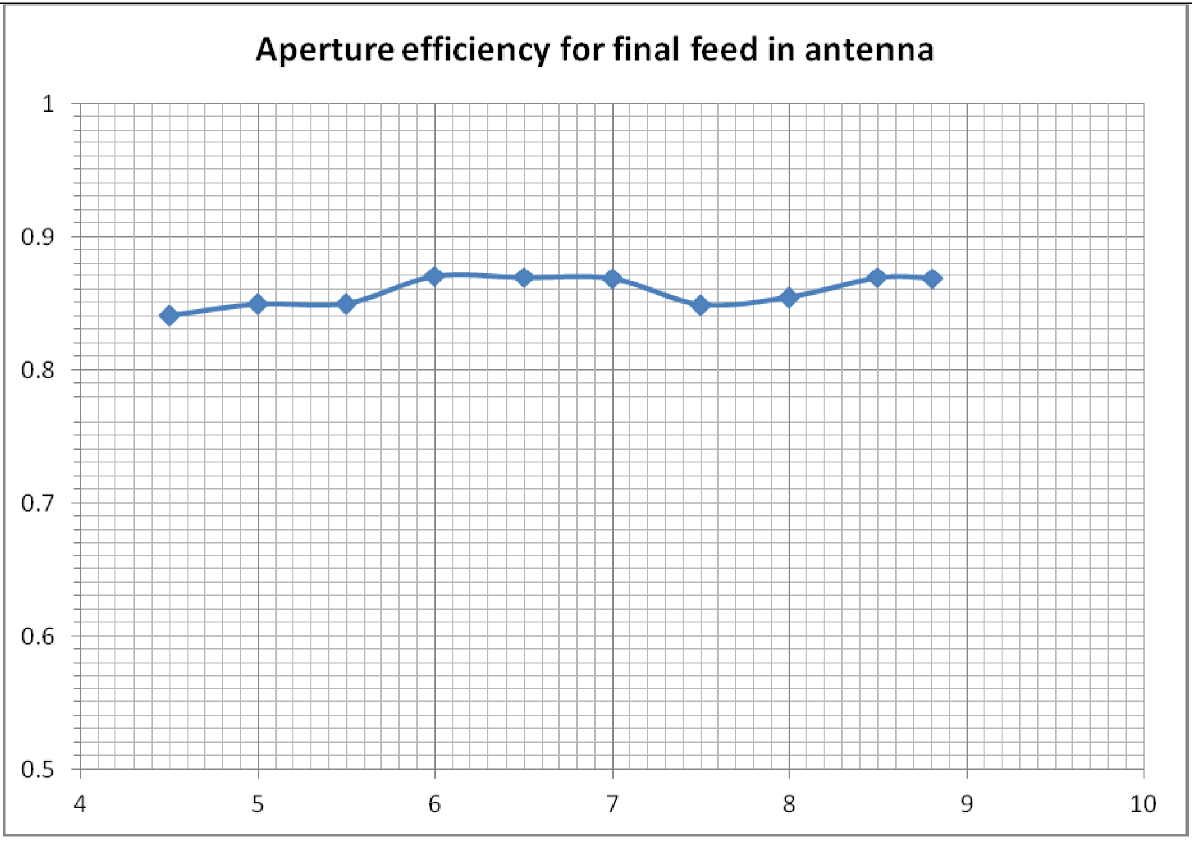


Figure 26. Aperture efficiency using the measured data of final feed standing in a fixed position in the antenna. The focal point of the antenna is at 660mm from the feed aperture.

5 Conclusions.

This report shows the final measurement and simulations of feed fabricated and installed in the 16m Ventspils antenna.

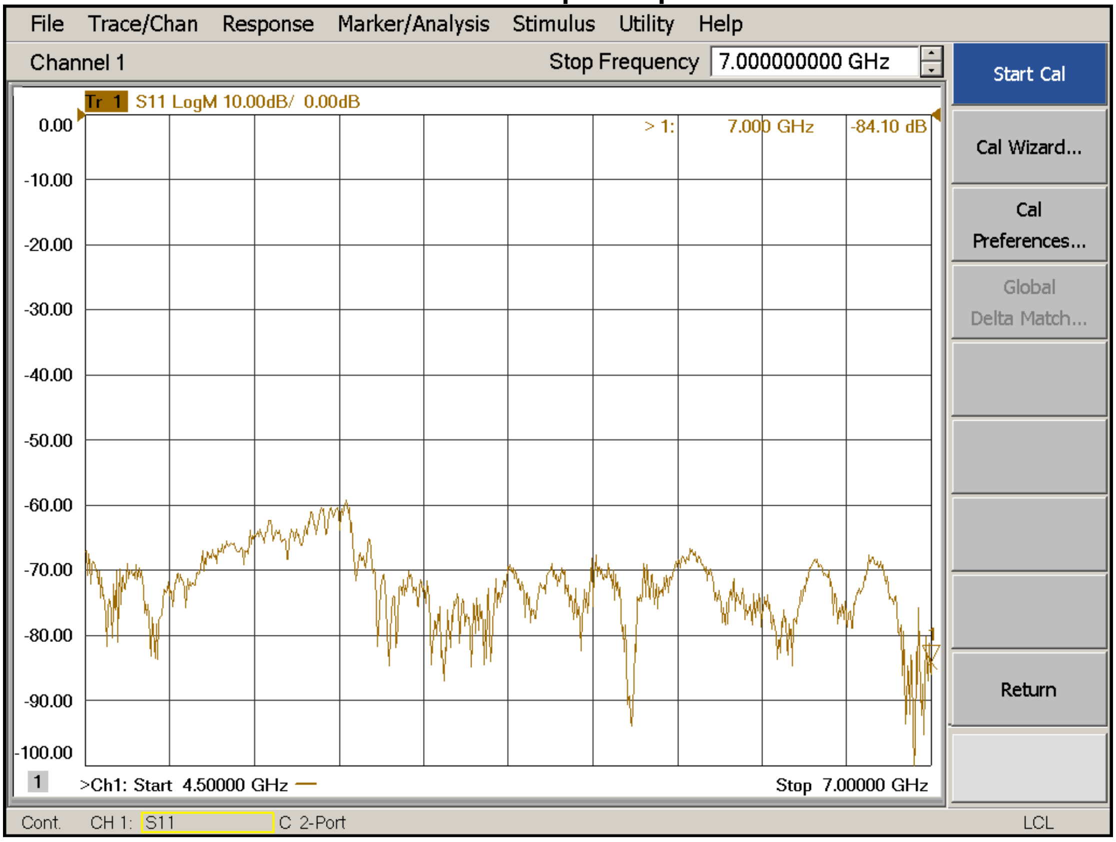
The port reflection has been carefully measured directly in the interface port without any additional transition to perform the measurement, using TRL calibration and deembeding techniques. Worst reflection figures are found near to the low frequency edge, but they are below -20dB. In the rest of the bandwidth -30dB and -40dB levels are found.

The radiation patterns were measured in anechoic chamber and they were as expected, with some asymmetries in the top frequency, as design simulations predicted. The feed's phase centre changes along the bandwidth, it reproduces the previous phase centre graph reported. The 660mm position from the aperture has been chosen as the best phase centre for the whole bandwidth, because it is the phase centre position for the highest frequencies.

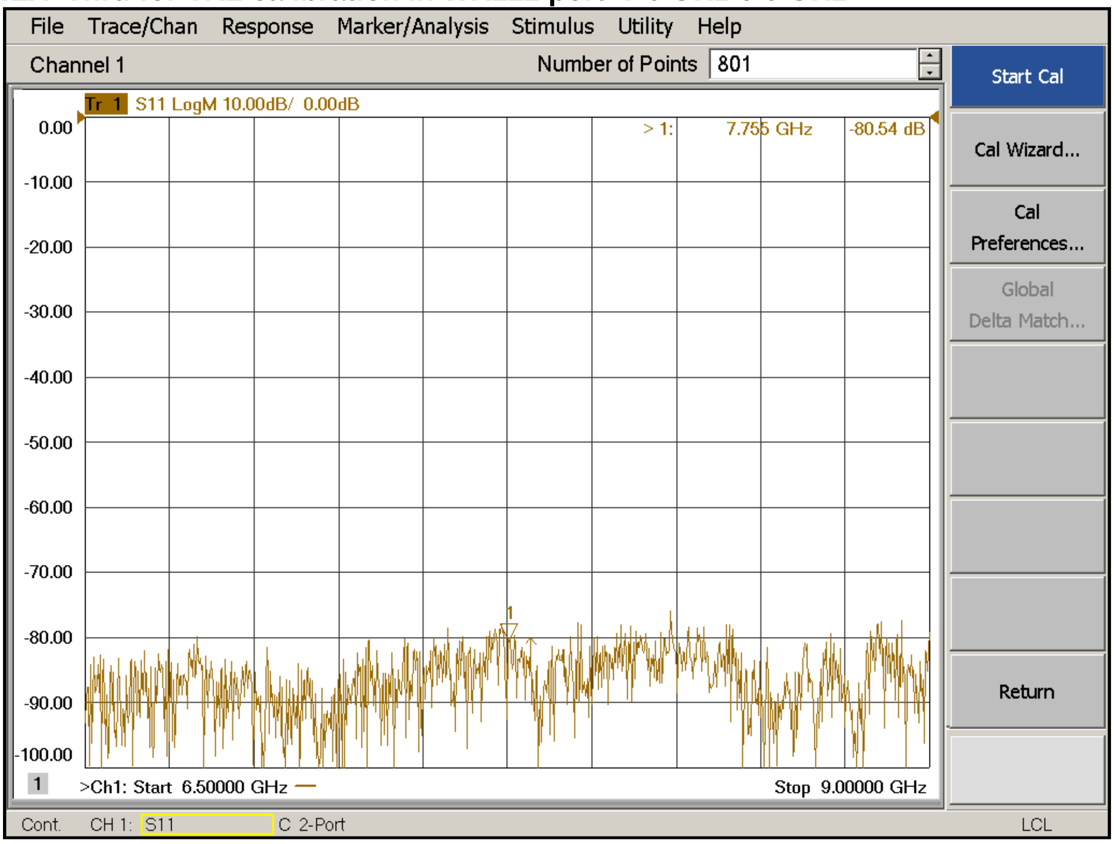
The efficiency estimation has been done by physical optics calculation with the real measured data of the feed. Final antenna efficiencies are better that 84% in the whole bandwidth.

This report ends the design, costruction, measurement and simulation of the feed system for the 16m Venstpils antenna.

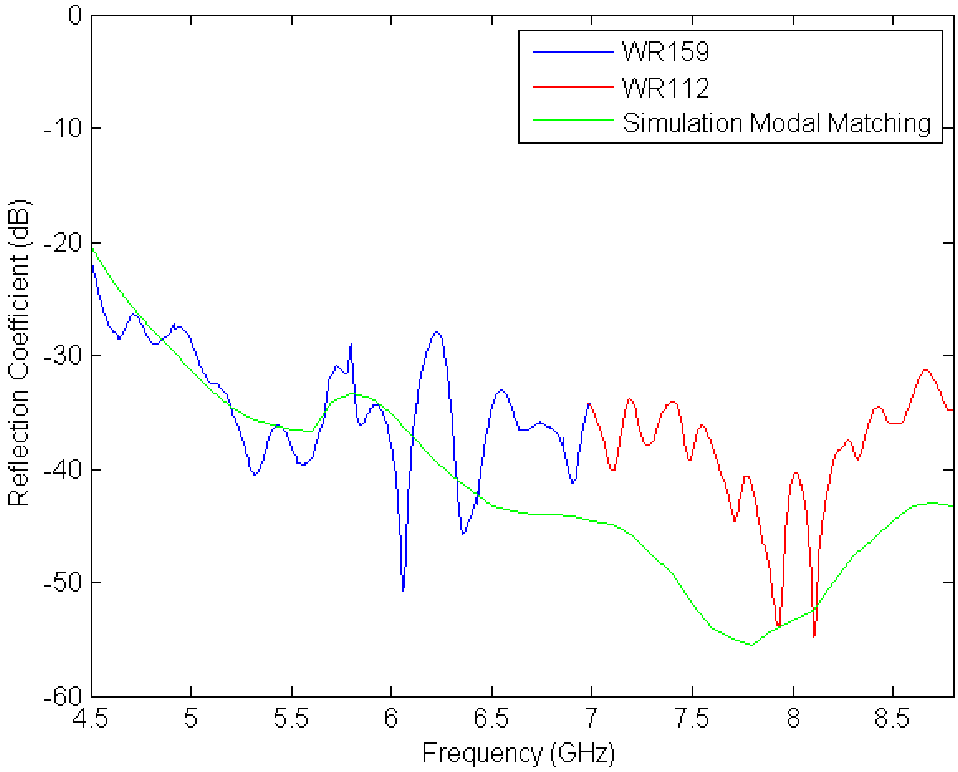
6 ANNEX. Thru for TRL calibration in 45mm squared port. 4.5 GHz-7.0 GHz



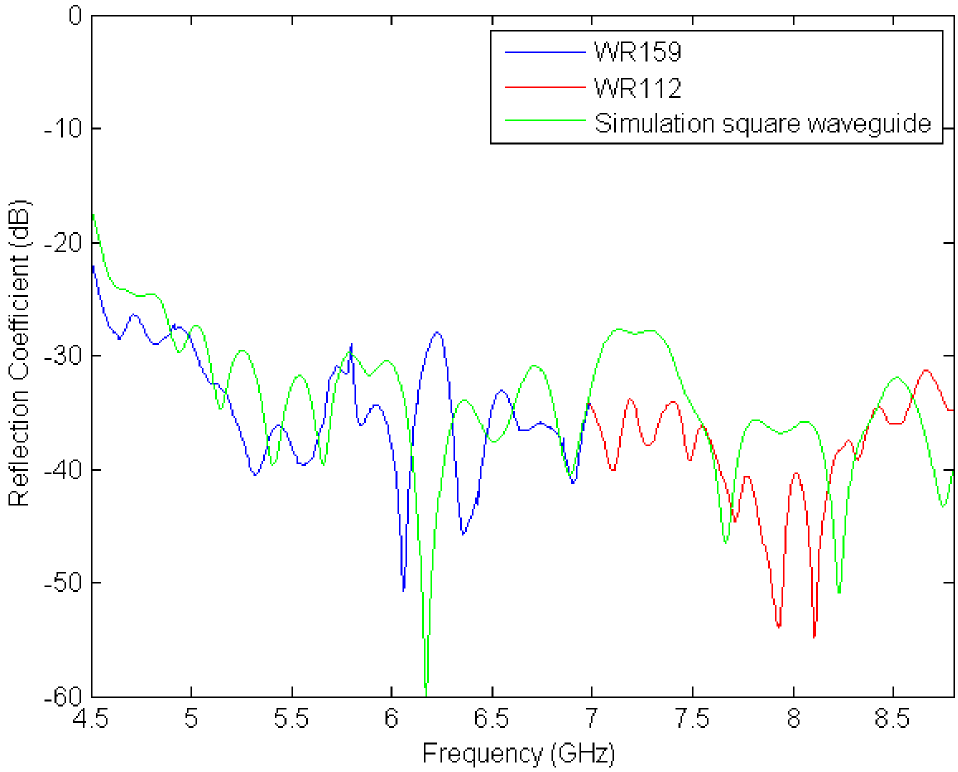
7 ANNEX. Thru for TRL calibration in WR112 port. 7.0 GHz-9.0 GHz



8 ANNEX. PORT REFLECTION COMPARATION WITH AXIAL

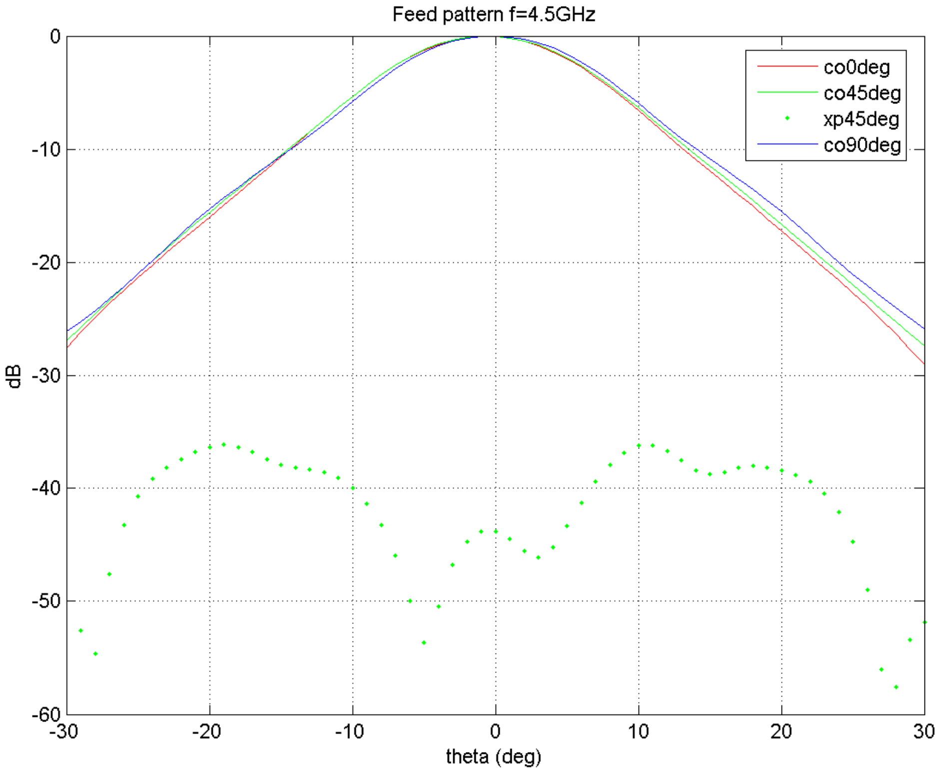


9 ANNEX. PORT REFLECTION COMPARATION WITH 3D SIMULATION

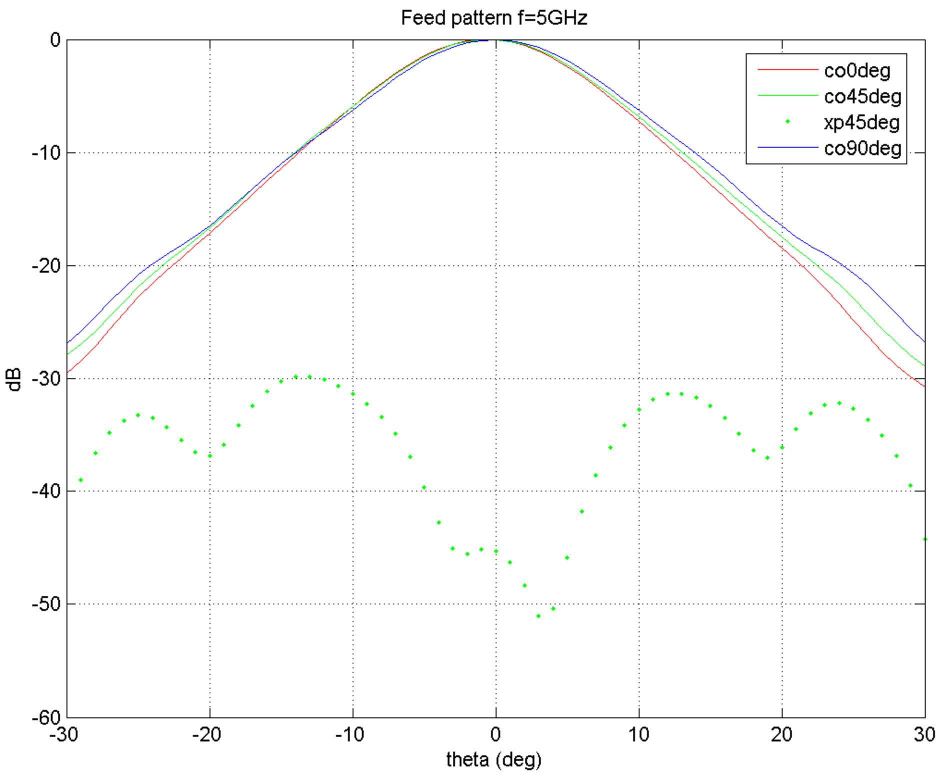


10 ANNEX. Feed measured radiation patterns

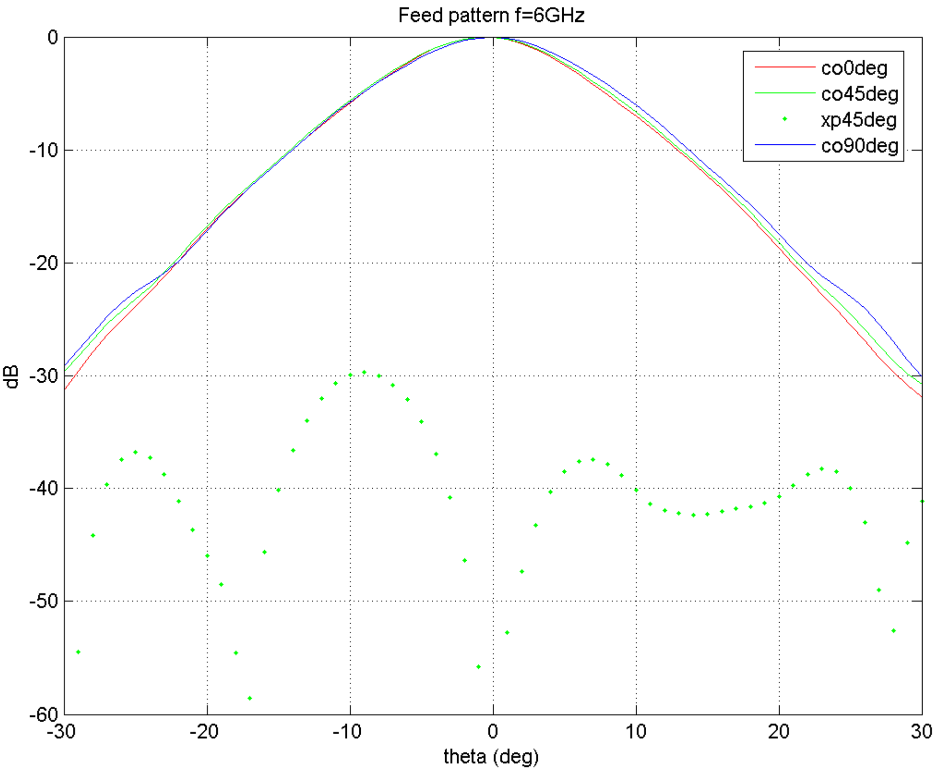
10.1 4.50 GHz



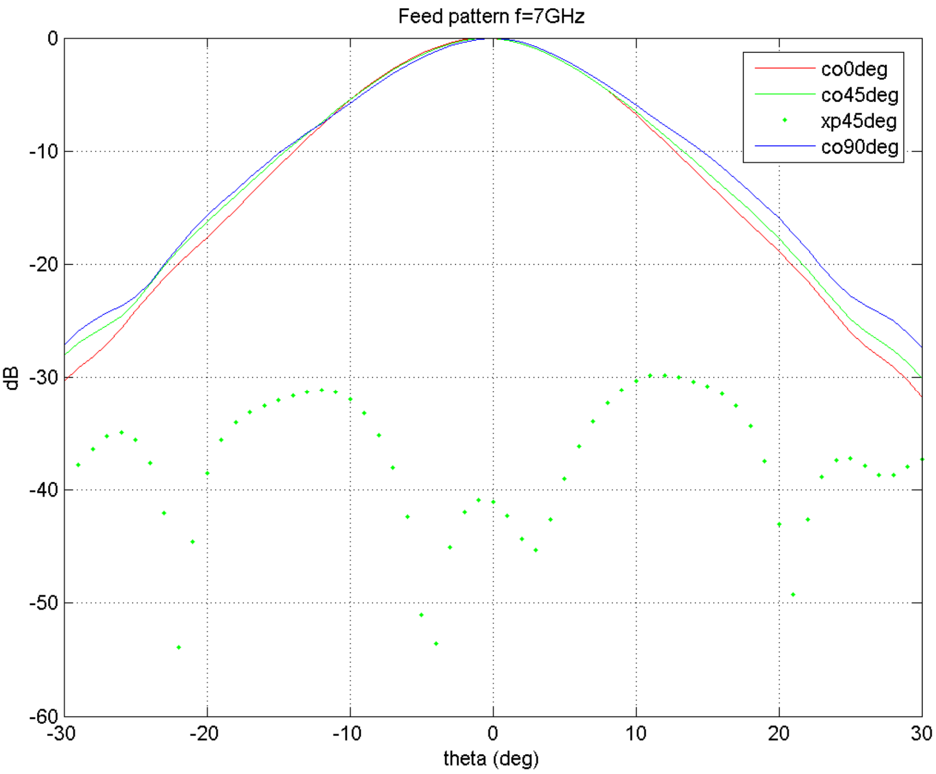
10.2 5.00 GHz



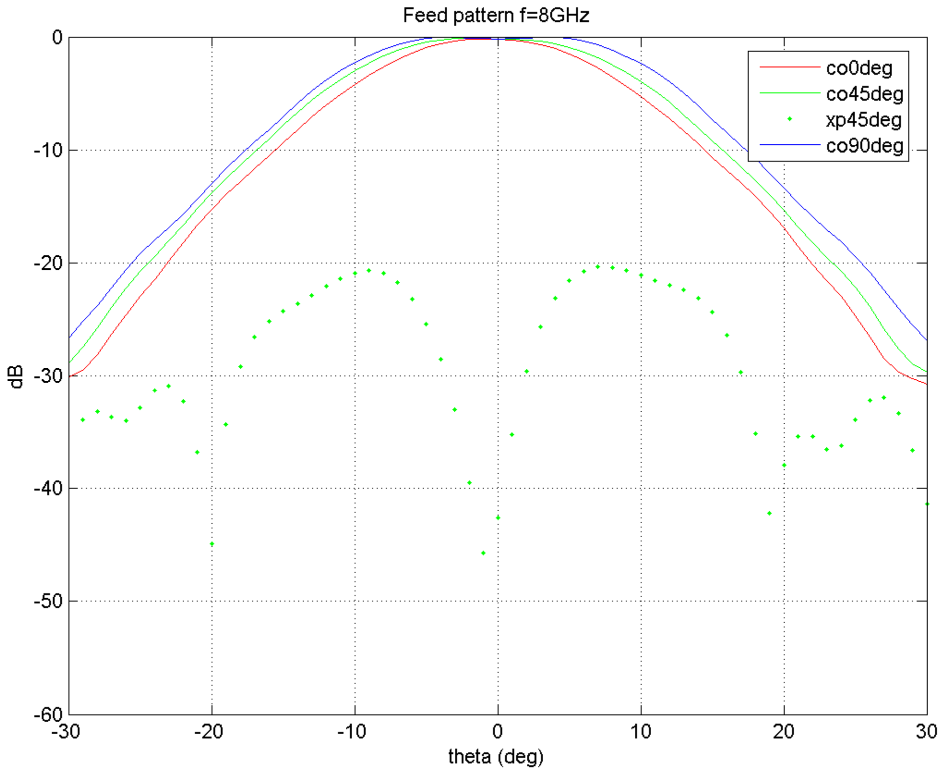
10.3 6.00 GHz



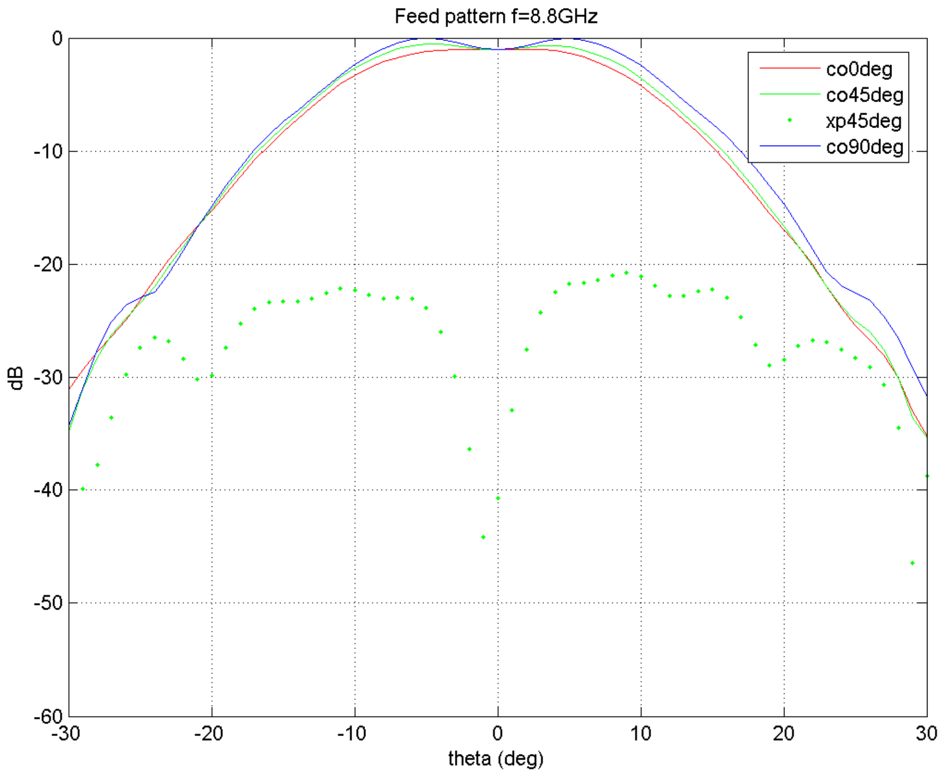
10.4 7.00 GHz



10.5 8.00 GHz

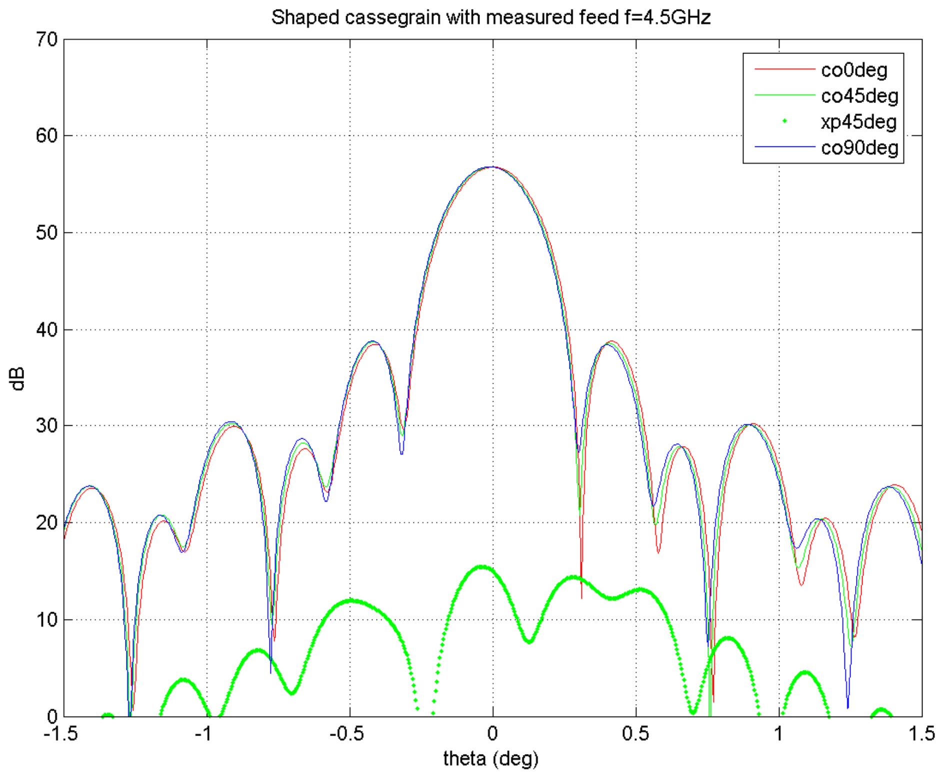


10.6 8.80 GHz

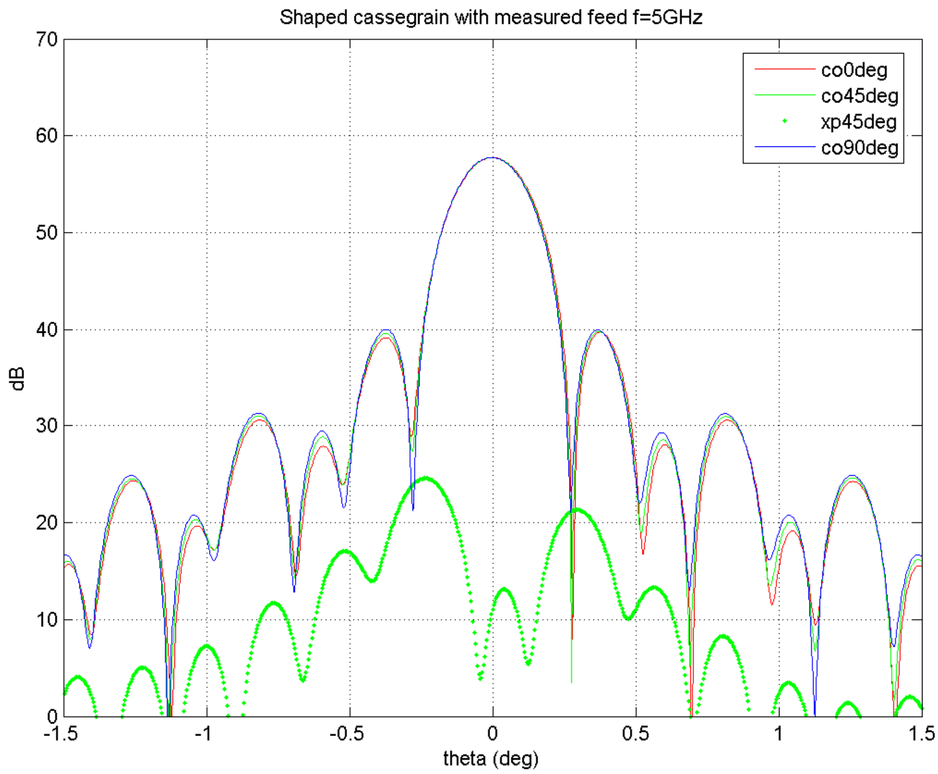


11 ANNEX. Shaped cassegrain radiation pattern (final simulations with feed measurements)

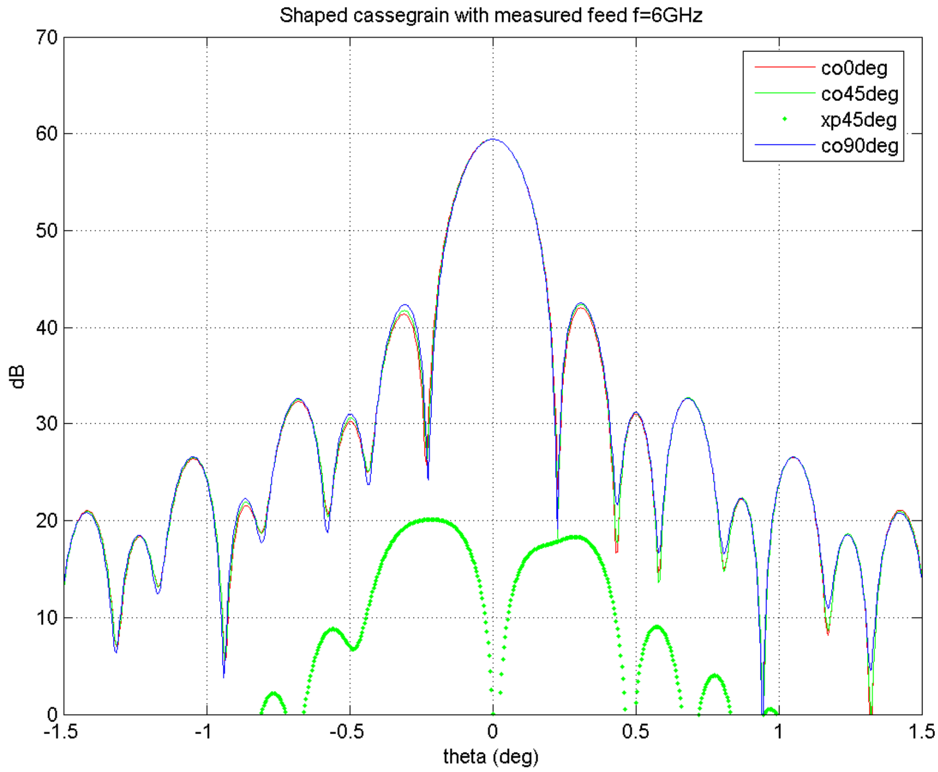
11.1 4.50 GHz



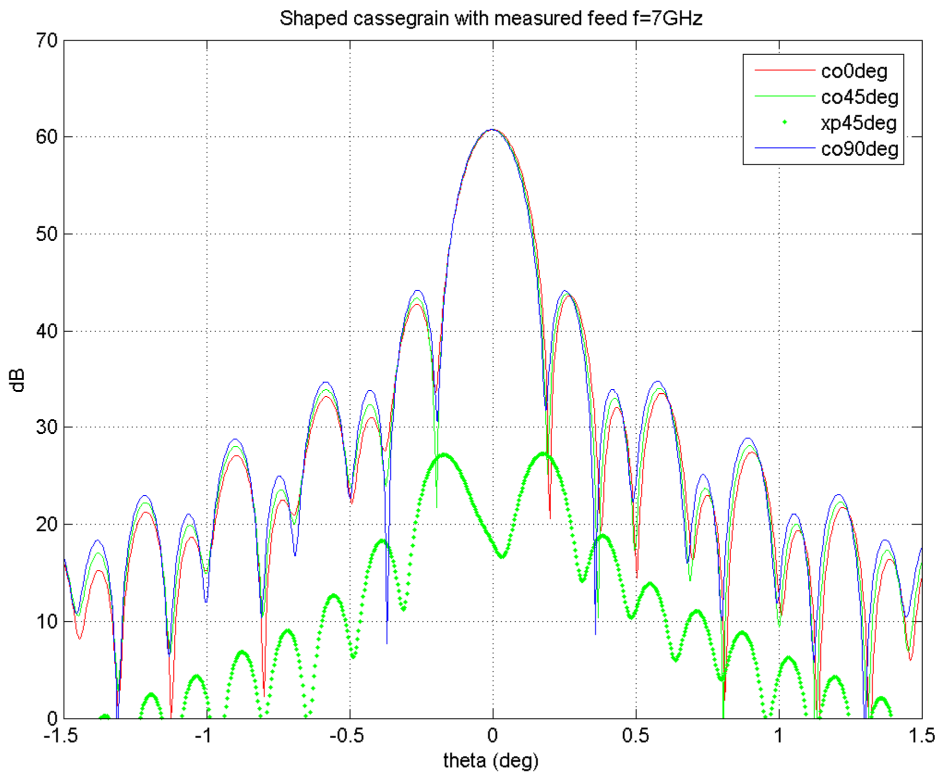
11.2 5.00 GHz



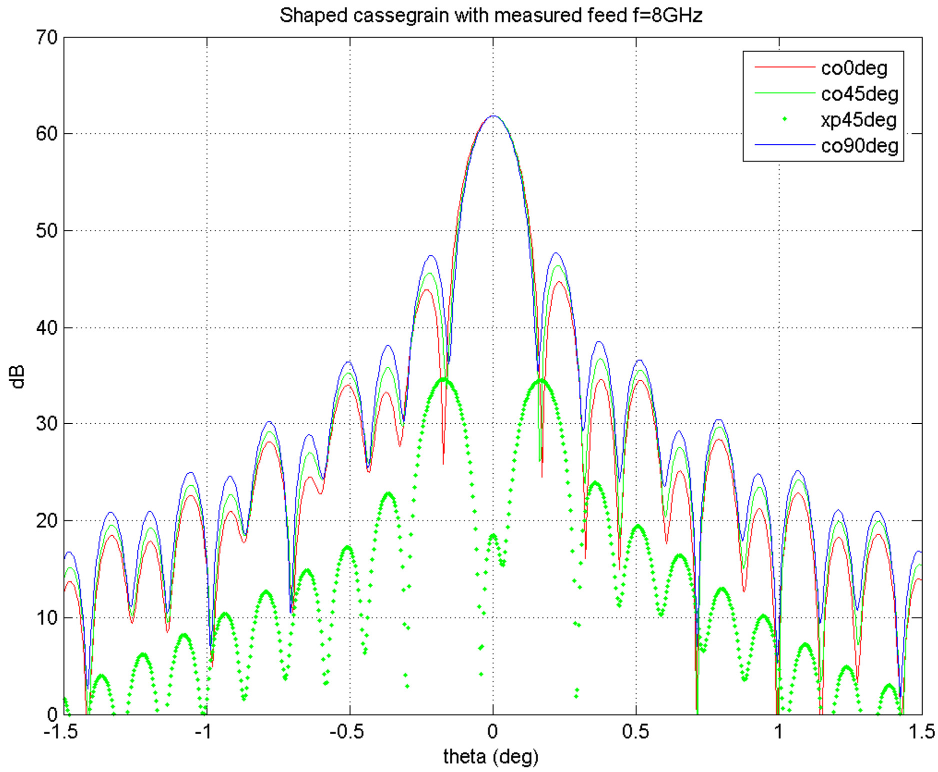
11.3 6.00 GHz



11.4 7.00 GHz



11.5 8.00 GHz



11.6 8.80 GHz