ESA Innovation Triangle Initiative (ITI)
Contract No.
4000114624/15/NL/MH/GM
Title: Compact K/Ka band antenna feed for multi-beam satellite communications

Final Presentation

ESA ITI proposal B00016918

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Date: 2018-12-05

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Final Presentation prepared by UPM, UAM, and AIRBUS

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Motivation.

- Next satellite systems operate in the 18.2-20.2 GHz and 28-30 GHz bands, with very stringent mechanical constraints, especially the footprint dimension.

- In these systems, the prior solution for user-type feeds was based on a dual-band orthomode transducer plus mono-phase polarizer, which requires better bandwidth and axial ratio. Another solution, typically bulky and cumbersome, is to use a feed chain based on six-port junctions with matched loads at two of the non-used ports.

- A different approach has been proposed and developed in this project, based on a feed chain composed of four elements: diplexer, single-mode waveguide, bi-phase polarizer and horn antenna.

- It presents the advantages of wide-band, low axial ratio, high isolation, compactness and modular design. The aim of this project is to design, manufacture and test a compact K/Ka-band two-port feed breadboard using the novel feed chain configuration, for optimum electrical performance with a simple and compact geometry.

- This *Final Presentation* shows the activity developed on this ITI-project for designing, manufacturing, and testing a complete antenna feed based on this new feed configuration with bi-phase polarizer.

Contents.

1) Review: Actual Antenna feeds for Circular Polarization Systems. Types.

Types

Classification by working frequency band(s) and single/dual polarization per band(s)	Antenna feed Configuration
T1: Mono-Band and Dual-Polarization (2-port feed)	A) Asymmetric-OMT + Mono-Phase-Polarizer
	B) Septum-OMT
	C) Self-diplexed Union (Six-port-Turnstile)
T2: Bi-Band and Single-Polarization (2-port feed)	A) Asymmetric-OMT + Mono-Phase-Polarizer
	B) Septum-OMT
	C) Self-diplexed Union (Six-port-Turnstile)
	D) Diplexer + Bi-phase Polarizer (AFeNSat)
T3: Bi-Band and Dual-Polarization (4-port feed)	A) Diplexers+Symmetric-OMT + Mono-Phase-Pol
	B) Self-diplexed Union (Six-port-Turnstile)

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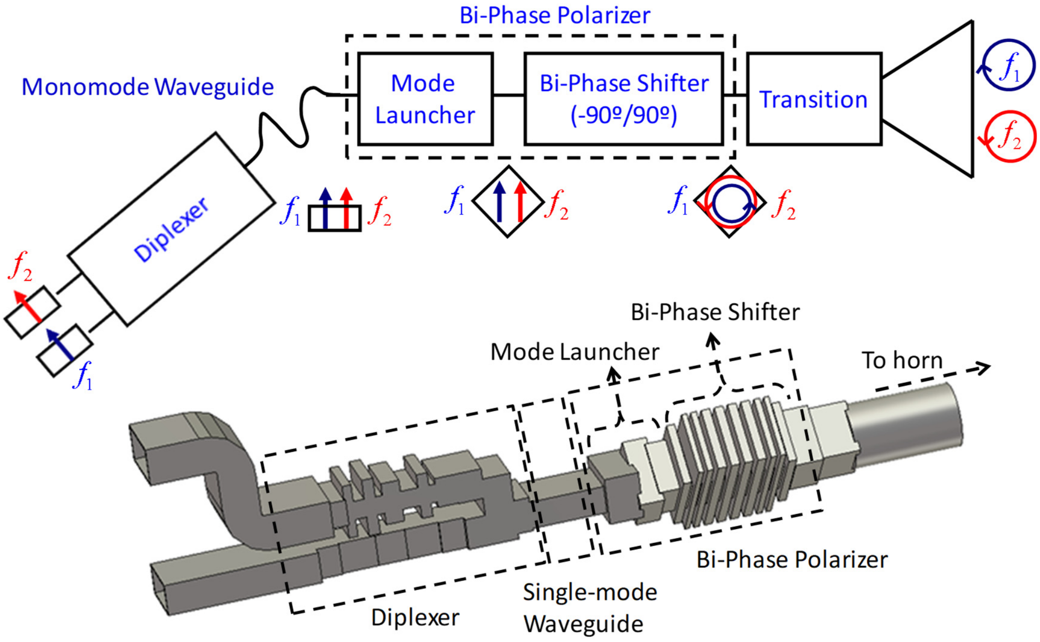
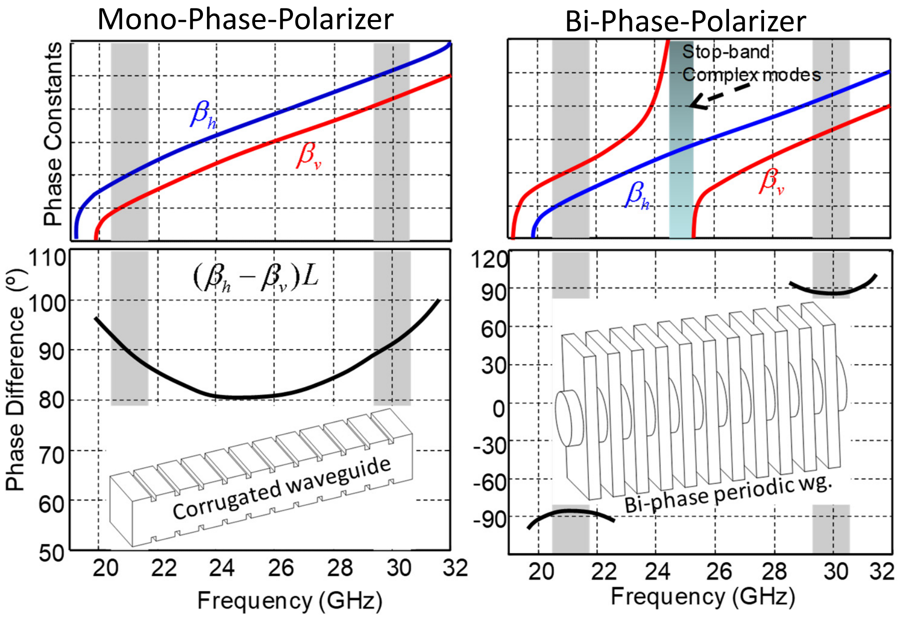
1) Initial **Concept** for the Antenna Feed to be Developed in the ITI (Type T2-D Feed). (I)

- Block diagram of the proposed antenna feed and one possible waveguide implementation:



1) Initial **Concept** for the Antenna Feed to be Developed in the ITI (Type T2-D Feed). (II)

- Phase constants and phase difference of (left) conventional corrugated waveguide and (right) bi-phase periodic waveguide:



Concept to be further researched in this ITI, with new geometries, improved performance and compactness

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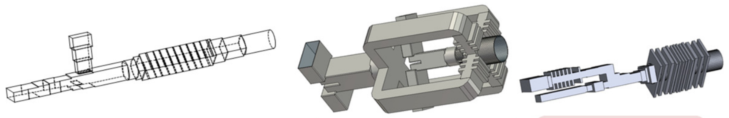
1) Initial **Concept** for the Antenna Feed to be Developed in the ITI (Type T2-D Feed). (and III)

- Comparison of the prior art solutions (OMT + polarizer and six-port junction-based) and the proposed antenna feed denoted as diplexer + bi-phase polarizer:



	OMT + Polarizer	**Six-port junction-based**	**Diplexer + Bi-phase polarizer**
Bandwidth	**Poor**	**Excellent**	**Good**
Separation between bands	**Poor**	**Good**	**Good**
Performance degradation when elements connected	**Very poor**	**Good**	**Excellent**
Versatility components interconnection	**Poor**	**Poor**	**Excellent**
Axial length	**Poor**	**Good**	**Excellent**
Compactness	**Good**	**Very poor**	**Excellent**

J. M. Rebollar, C. A. Leal-Sevillano, J. R. Montejo-Garai, J. A. Ruiz-Cruz, "Dual frequency-band antenna feed with different circular polarizations in each band", Spanish **Patent: ES-2441471**

1) Revised Final Specifications for the ITI-ESA project: **electrical-mechanical.**

Proposed solution called AFeNSat (Antenna Feeding Network for New Generation Satellite Communications) using a Diplexer and a Bi-phase Polarizer.

	TX / RX
Frequency bands	19.2 -20.2 / 29.0-30.0 (GHz)
Return Loss	> 24 dB / > 24 dB
Inter-band isolation	Tx-Rx: > 60 dB
Insertion Loss	< 0.15 dB / < 0.15 dB
Polarization	RHCP (LHCP) / LHCP (RHCP)
On-axis Axial Ratio	< 0.20 dB / < 0.20 dB (38.8 dB XP)
Level of Higher order modes (TM01-TE21)	-40 dB
Matching loads	NO
Horn Antenna Return Loss	> 40 dB

		TX / RX
Diplexer + Launcher + Bi-Phase Shifter	diameter	< 30 mm
	Length	< 90 mm (for diplex). Total < 140 mm
Horn Antenna	diameter	< 40 mm
	Length	< 230 mm
Mechanical Complexity		Low (*)

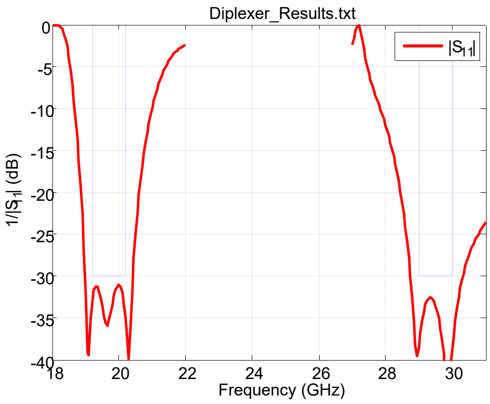
Port RX: WR28: 7.112 x 3.556 mm

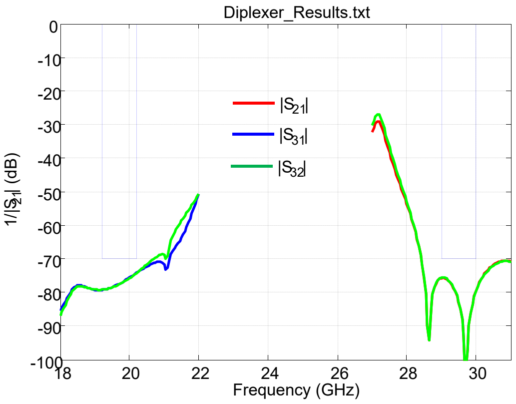
Port TX: WR51: 12.954 x 6.477 mm

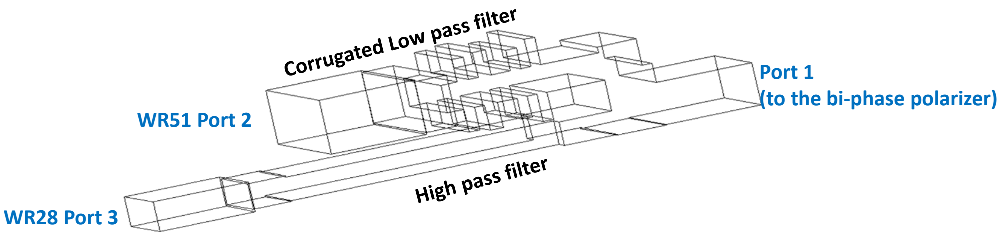
Port CIR: Radius 5.6 mm (diameter 11.2 mm)

2.1) Diplexer electrical design.

- Diplexer designed for 30 dB return loss.
  Return Loss at the common port
- Diplexer designed for 70 dB isolation.
  Transmission between ports







2.2) Bi-Phase Polarizer electrical design.

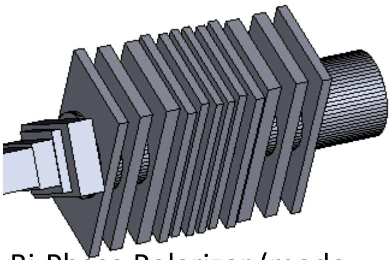
➢ The Bi-Phase Polarizer has two parts: **mode-launcher plus Bi-Phase Shifter**, which are first designed separately, and then integrated into the same component for compactness.

➢ The initial designs for the bi-phase polarizer were based on the topologies researched before the starting of the ITI activity, but also, other geometries were analyzed during the ITI project. **In fact, the final Bi-Phase Polarizer topology ("folded stubs") was obtained during the development of the ITI activity**.

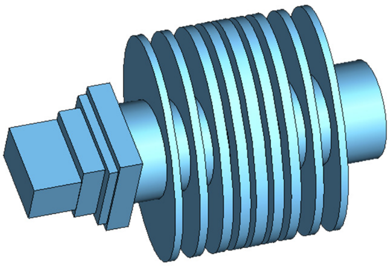
➢ To exploit the researched topologies as much as possible (from the performance and geometry point of view), structures that could be simulated by **full-wave in-house mode-matching** method were selected.

- Different mode launchers were analyzed: a) with waveguide rotation, b) with internal waveguide sections, c) **combination of both (as in the final design)**.
- Different Bi-Phase-Shifters were analyzed: a) square-rectangular, b) circular-rectangular, c) circular-elliptical, d) square-elliptical, e) ridge sections, e) stubs, f) **folded stubs (as in the final design).**

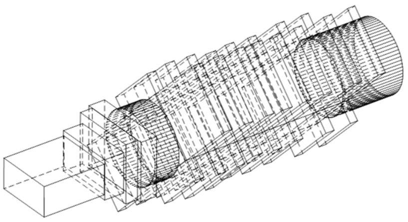
2.2) Examples of Researched Geometries for the Bi-Phase Polarizer. (I)



- Bi-Phase Polarizer (mode launcher and circular and rectangular waveguides).



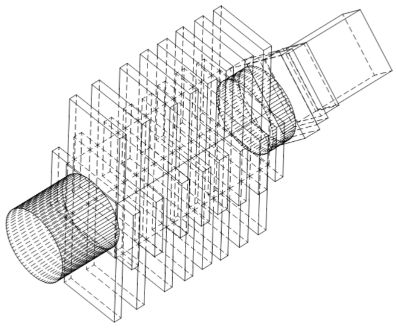
- Bi-Phase Polarizer (mode launcher and then elliptical and circular waveguides).



- Bi-Phase Polarizer (mode launcher and then square and rectangular waveguides).

➢ After those initial studies, a geometry based **on stubs with different dimensions for the vertical and horizontal polarization** was selected, based on its potential performance for achieving the broadband behavior, and easier manufacturing than the other geometries.

➢ **The cross-shape stubs had 37 mm (approx.) in one dimension: this was an issue to be considered.**



2.2) Examples of Researched Geometries for the Bi-Phase Polarizer. (II)

Comments on the cross-section specs.

➢ Transversal shape of the previous cross-shape stubs was not fitting within the 30 mm diameter envelope specified for the project.

➢ Two actions were proposed for increasing the phase difference between the two orthogonal polarizations, aiming to reduce the transversal dimensions:

a) trials with irises at the square section between the cross-shapes (see two options a.1, a.2, in next slide). In the optimizations that were performed with the limited available time , specifications were not achieved and no clear path was seen.

b) folded stubs. Its manufacturing was initially checked by Airbus: bending the stubs would not have significant differences with respect to classical stubs. This option was finally chosen because a clear path to achieve all the specs was noticed, and it will be seen later.

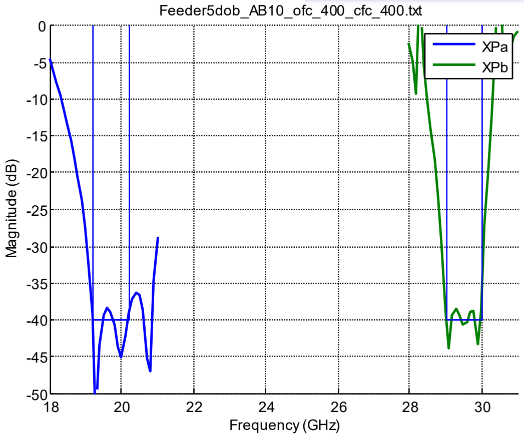
2.2) Bi-Phase Polarizer with "***folded stubs***".

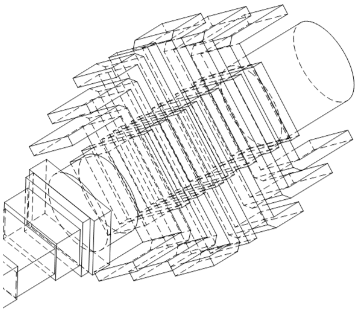
➢The Bi-Phase Polarizer with cross/square shapes and folded stubs was fulfilling the specs within the required envelope of 30 mm.

➢The design was done assuming all widths and separation between stubs > 1 mm.

➢ For the final design, other design was carried out using ***7 stubs and other mode-launcher***, with the advantage of more uniformity in the dimensions for easier manufacturing.

➢ Sensitivity analysis (± 0.01mm, ± 0.02mm, ± 0.05mm) was done for the shifter designs with 6 and 7 stubs and was similar between them, and also to other designs that were also tried. A preliminary conclusion is that **maximum possible accuracy in manufacturing will be needed.** The performance and sensitivity is shown later for the final design.





2.3) Horn electrical design.

The proposed horns are two horns used on previous telecom programs, in theory they were available, but at the end only #1 was available for the RF tests.

Both horns were optimized for narrower operating bands, a typical User Beam bandwidth:

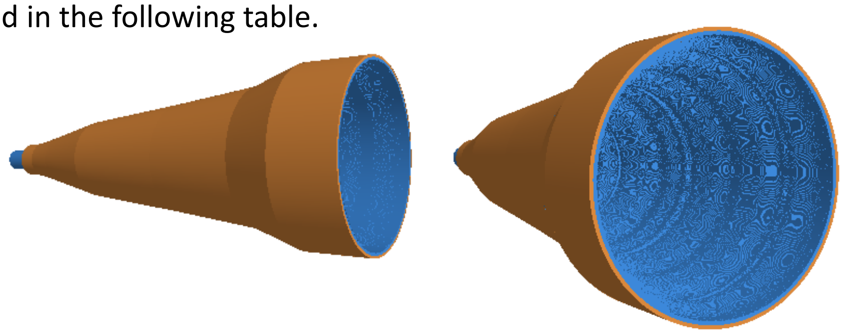
- TX: 19.7 – 20.2 GHz
- RX: 29.5 – 30.0 GHz

Due to this, the horns are not fully compliant to the 40dB return loss requirements in the full band but only on a part of it (see next slides).

Following figures show a 3D view of the internal profile of the horns.

General dimensions are included in the following table.

Parameter	Dimension (mm)
Aperture	66.0
Length	231.0
WG interface	11.2



2.3) Horn electrical design.
“Tub1 Telecom1” and “Tub1 Telecom2”.

The main electrical performances of the K/Ka antenna horn are shown on next table. Values are presented for the Design Band and for the Extended Band to complete the K/Ka requirements.

HORN TUB-1 TELECOM#1

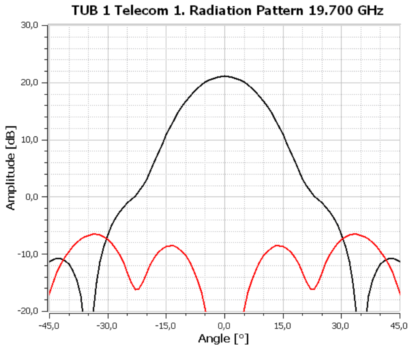
	Tx band		Rx Band	
Frequency (GHz)	Extended Band	Design Band	Extended Band	Design Band
	19.2-19.7	19.7-20.2	29.0-29.5	29.5-30.0
Max. S11 (dB)	< -26	< -30	< -40	< -34
Max XPD (dB)		< -30		< -35

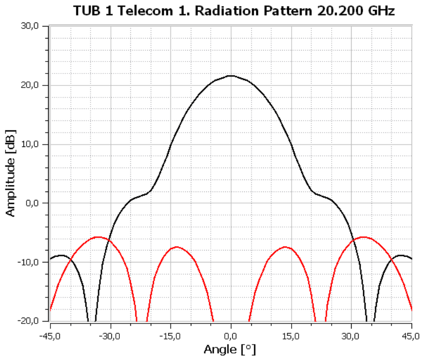
HORN TUB-1 TELECOM#2

	Tx band		Rx Band	
Frequency (GHz)	Extended Band	Design Band	Extended Band	Design Band
	19.2-19.7	19.7-20.2	29.0-29.5	29.5-30.0
Max. S11 (dB)	< -20	< -30	< -26	< -36
Max XPD (dB)		< -26		< -27

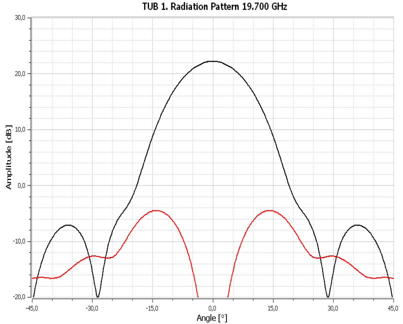
2.3) Horn electrical design.
"Tub1 Telecom1-2". Radiation Pattern TX Band.

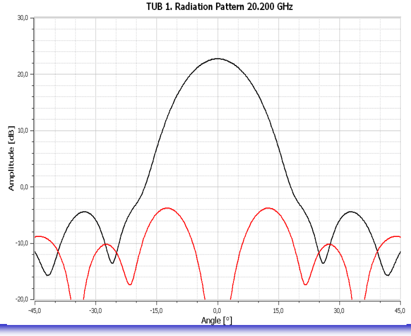
- **HORN TUB-1 TELECOM#1:** Radiation Patterns. TX Band


TUB 1 Telecom 1. Radiation Pattern 19.700 GHz


TUB 1 Telecom 1. Radiation Pattern 20.200 GHz

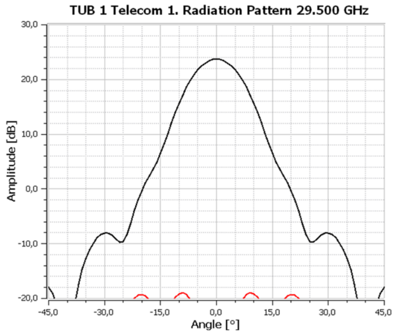
- **HORN TUB-1 TELECOM#2:** Radiation Patterns. TX Band

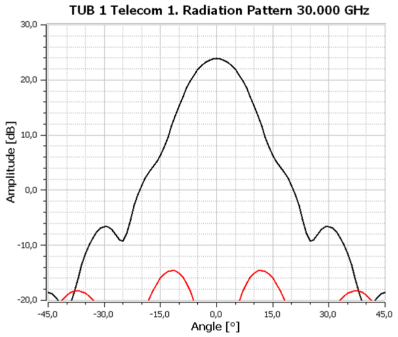

TUB 1. Radiation Pattern 19.700 GHz


TUB 1. Radiation Pattern 20.200 GHz

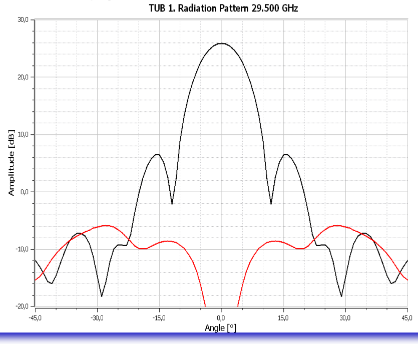
2.3) Horn electrical design.
"Tub1 Telecom1-2". Radiation Pattern RX Band.

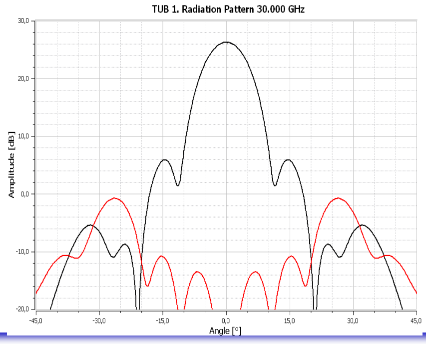
- **HORN TUB-1 TELECOM#1:** Radiation Patterns. RX Band


TUB 1 Telecom 1. Radiation Pattern 29.500 GHz


TUB 1 Telecom 1. Radiation Pattern 30.000 GHz

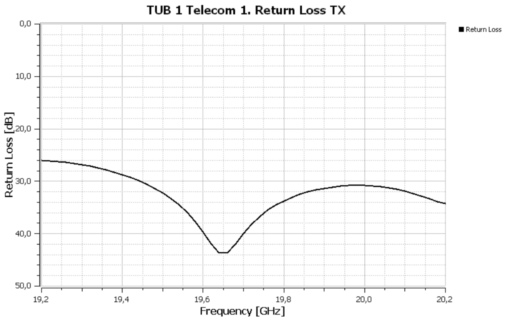
- **HORN TUB-1 TELECOM#2:** Radiation Patterns. RX Band

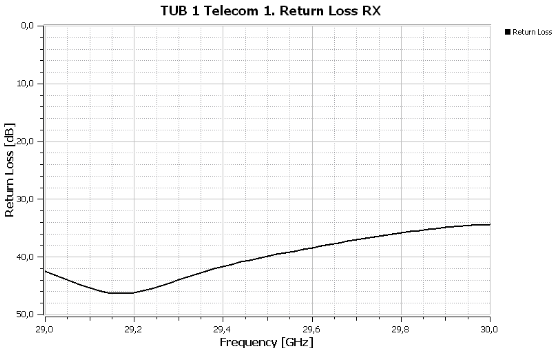

TUB 1. Radiation Pattern 29.500 GHz


TUB 1. Radiation Pattern 30.000 GHz

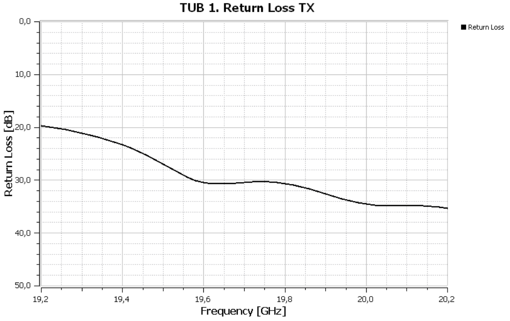
2.3) Horn electrical design.
“Tub1 Telecom1-2”. Return Loss.

- **HORN TUB-1 TELECOM#1:** Return Loss.





- **HORN TUB-1 TELECOM#2:** Return Loss.



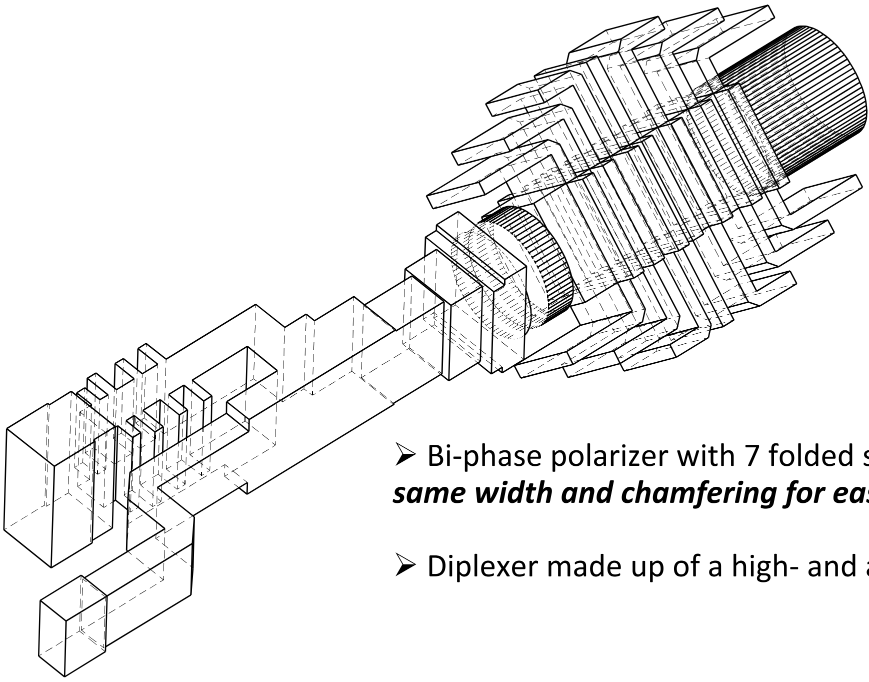
2.3) Horn design. Combined Performance

- Next table summarizes the combined best performances for both Telecom#1 and Telecom#2 horns.
- Green highlighted cells shows the proposed horn to be used on each band.

	TX Band		RX Band	
Operating Frequencies (GHz)	**19.2 - 19.7**	**19.7 – 20.2**	**29.0 - 29.5**	**29.5 – 30.0**
Return Loss (dB) TUB 1 Telecom #1	> 26.0	> 30.0	> 40.0	> 34.0
Return Loss (dB) TUB 1 Telecom #2	> 20.0	> 30.0	> 26.0	> 36.0

- In the RX band, the use of both horns can validate the polarizer performances as return loss is always better than 36 dB and there are large parts of the band with return loss better than 40 dB.
- In the TX band, the situation is more difficult as the use of both horns ensures a return loss better than 32 dB in 75% of the band, better than 35 dB in 40% of the band and better than 40 dB in 10% of the band. It is proposed to perform a prediction of the feed chain with the actual performances of these horns. Then, the proposed validation methodology for the polarizer performances will be carried out through a correlation between SW prediction and test measurement of the chain.
- For the validation of the prototype, the feeder chain Radiation Pattern has been measured only with Horn TUB-1 Telecom#1. Horn TUB-1 Telecom#2 has been used only to check the return losses.

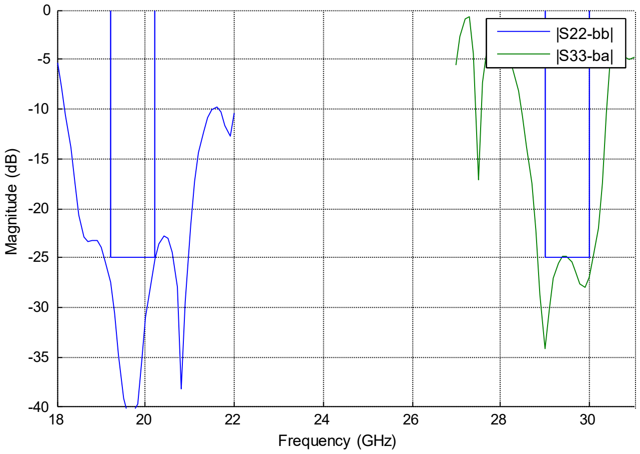
2.4) Diplexer+Bi-phase Polarizer.
Final Design: “**dplex_shifter_20170629**”.



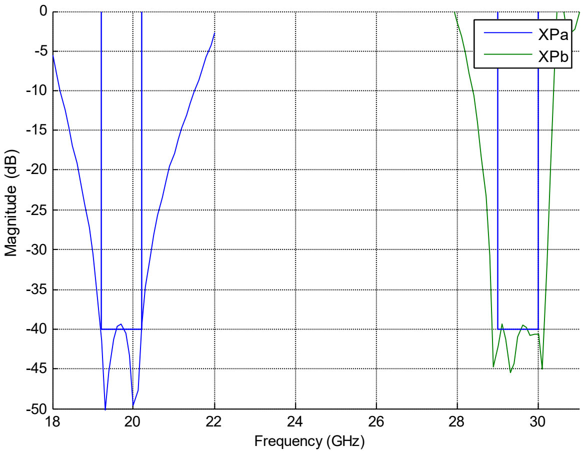
- Bi-phase polarizer with 7 folded stubs, all ***having same width and chamfering for easier manufacturing.***
- Diplexer made up of a high- and a low-pass filter.

2.4) Diplexer+Bi-phase Polarizer.
Final Design. Full Antenna Feed Electrical Design.
Simulated Performance. (I)

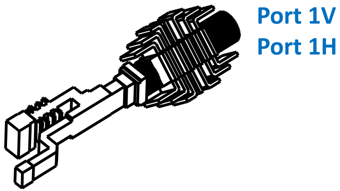
Return Loss at the dedicated ports



Cross Polar Discrimination



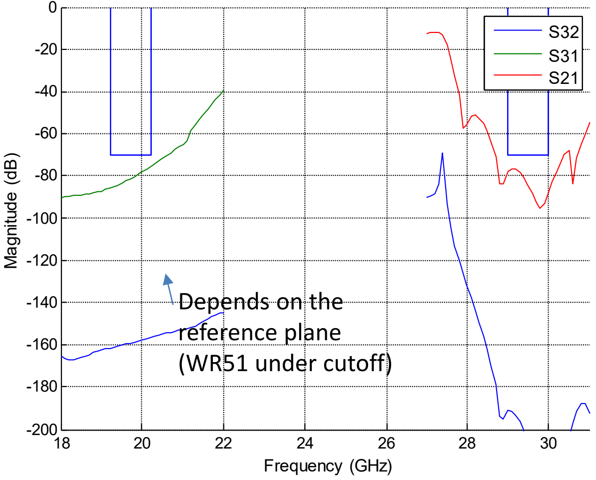
Mask at -25 dB **(Specs are -24dB)**



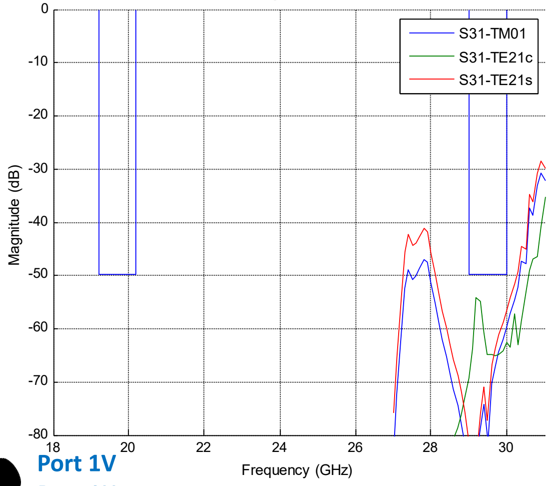
Mask at -40 dB
(Specs are -38.8 dB <->axial ratio 0.2 dB)

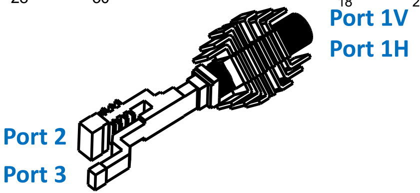
2.4) Diplexer+Bi-phase Polarizer. Final Design. Full Antenna Feed Electrical Design. Simulated Performance. (II)

Isolation between rectangular dedicated ports



Level of higher order modes

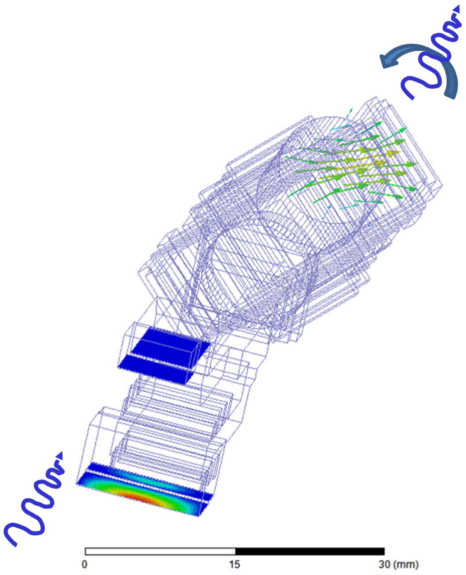


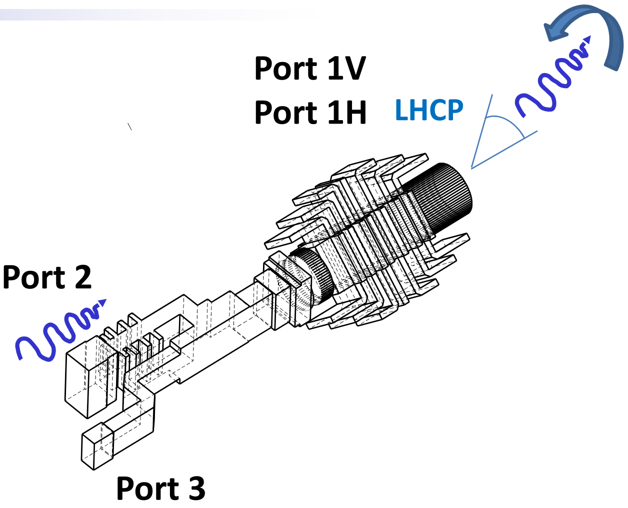


Mask at 70 dB **(Specs are 60 dB)**

Mask at 50 dB
(Specs are 40 dB)

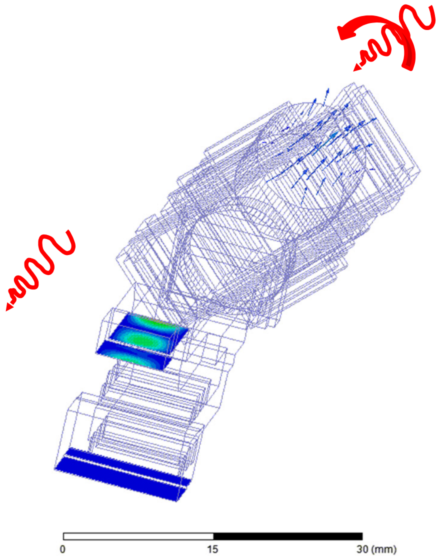
2.4) Diplexer+Bi-phase Polarizer. Field Animation (I). Port number 2 is for Transmission in LHCP (TX for 19.2 - 20.2 GHz).

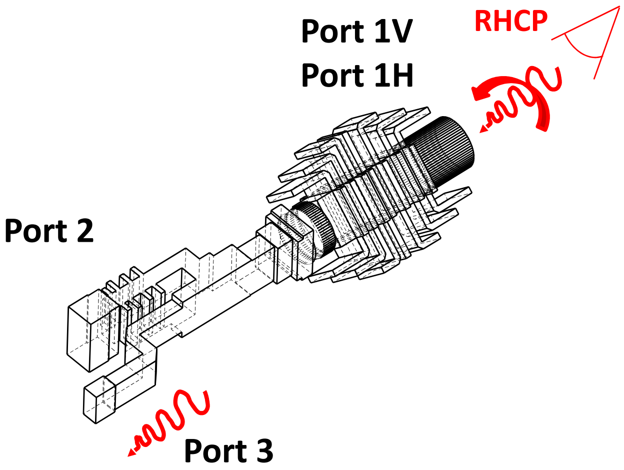




(LHCP at TX Port 2 - WR51 with given relative rotation diplex-polarizer)

2.4) Diplexer+Bi-phase Polarizer. Field Animation (and II). Port number 3 is for Reception in RHCP (RX for 29.0 - 30.0 GHz).





(RHCP at RX Port 3 - WR28 with given relative rotation diplex-polarizer)

2.4) Diplexer+Bi-phase Polarizer. Final Design. Conclusions.

Electrical

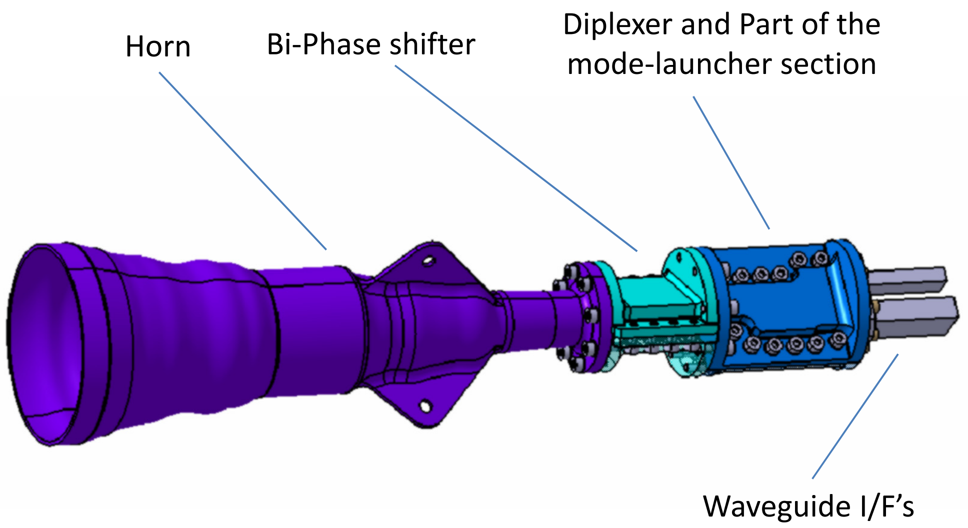
	Spec. TX/RX	Actual Design
Return Loss	> 24 dB / > 24 dB	✓ 25 dB
Inter-band isolation	Tx-Rx: > 60 dB	✓ 70 dB
Insertion Loss	< 0.15 dB / < 0.15 dB	✓ 0.1 dB (*)
On-axis Axial Ratio	< 0.20 dB / < 0.20 dB (38.8 dB XP)	✓ XP 40dB
Level of Higher order modes (TM01-TE21)	-40 dB	✓ -50dB

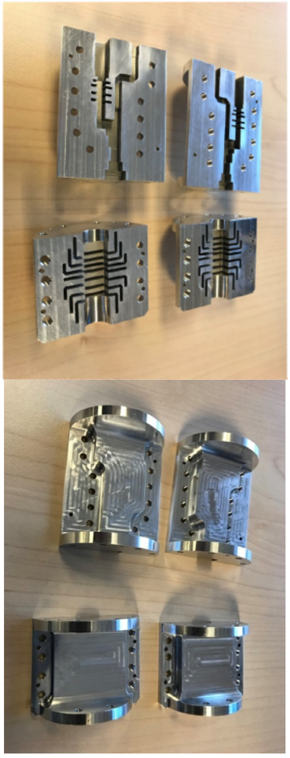
(*) see Annex I

Mechanical

Diplexer + Bi-phase Polar.	diameter	< 30 mm	✓ 29.3 mm
	Length	< 90 mm (for diplex). Total < 140mm	✓ 42.2 mm (diplex) ✓ Total 85 mm (92.5 with stub.) 44.3 mm (pol., 36.5mm shifter)
Additional restrictions by Airbus during WP2500 (Limit for wall separation and for smallest dimensions, flange positions centered)			✓

2.5) Mechanical design. Components.





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3) Manufacturing. Actions.

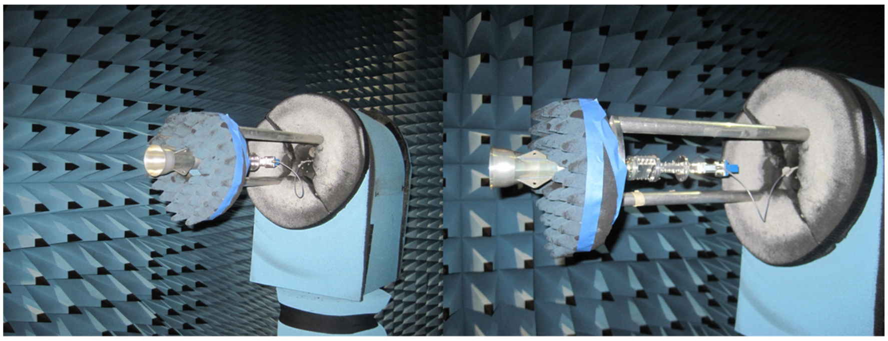
- This project implies the manufacturing of a compact EM polarizer that it is going to be measured in order to validate its RF performances. This compact design implies some dimensions and tolerances in its internal path that are in the limit of its manufacturing in terms of robustness for flight missions.
- Alter manufacturing the breadboard, an internal check has been performed to validate the component.
- Some deviations has been detected:
  - Dimensionally deviations
  - Extra material presented in its internal path

- In order to analyze the final component as it was manufactured, a new step model was created including these dimensionally deviations.
- As the extra material presented in the internal path could not be analyzed, it was removed.
- Extra care was taken when realign the two halves of the polarizer in order to avoid issues due to it.

3) Feed assembly.

- Manufactured breadboard was mounted with both proposed horns in order to validate RF performances of the compact K/Ka antenna feed.
- Extra care was taken when aligning the polarizer to the diplexer and to the horn.

- Following pictures show the feed assembly mounted in the anechoic chamber.



4.1) S-Parameters test

- Manufactured breadboard was mounted with Horn Tub-1 Telecom#1 in order to validate RF performances of the compact K/Ka antenna feed.
- Extra care was taken when aligning the polarizer to the diplexer and to the horn in order to avoid any issue due to misalignment.

- The radiation test has been measured with Horn Tub-1 Telecom#1 two times, the first time as manufactured at Airbus facilities, as some discrepancies were found, the components were opened and adjusted removing some burr that was seen in the internal path.
- Radiation patterns have been measured at TX and RX Band each 100MHz.
  - TX Band: From 19.200 GHz to 20.200 GHz
  - RX Band: From 29.000 GHz to 30.000 GHz
- Radiation patterns of both measurements are included in Annex II.
- Analysing all the radiation patterns, it is observed that the accuracy of the second measurement, for levels below -35 dB wrt the peak, is better than that of the first one, mainly in RX Band.

4.2) Radiation test.

- Next tables presents a summary of results in the TX and RX Bands

(only values at Th=0º are presented in RX as the maximum XP values are very similar)

Tx	XP at TH=0º (dB)		Max XP (dB)	
F	First meas.	Second Meas.	First meas.	Second Meas.
19200	-20	-21	-20	-21
19300	-22	-24	-22	-23
19400	-26	-30	-25	-25
19500	-32	-36	-28	-27
19600	-30	-32	-28	-27
19700	-31	-33	-29	-27
19800	-40	-36	-31	-29
19900	-38	-30	-32	-27
20000	-34	-27	-29	-26
20100	-32	-27	-27	-24
20200	-31	-28	-27	-26

Rx	XP at TH=0º (dB)	
F	First meas.	Second Meas.
29000	-19	19
29100	-19	-19
29200	-20	-19
29300	-20	20
29400	-20	-20
29500	-21	-21
29600	-23	-22
29700	-23	-23
29800	-23	-22
29900	-23	-22
30000	-22	-22

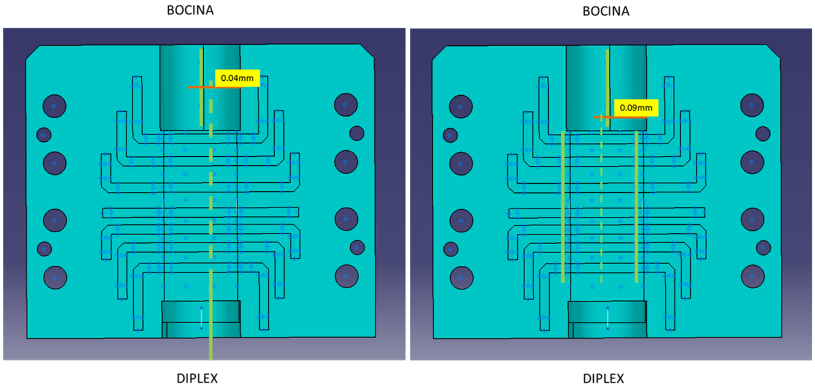
TX: It can be observed that there are significant variations between both measurements, both at boresight (contribution of polarizer) and in the maximum level (contribution of the horn). This seems to indicate that the re-work and subsequent assembly/alignment have had an impact in the XP. High levels are observed in the lower frequencies in both measurements anyway.

RX: In this band, results of both measurements are much more similar, with high XP contribution coming from the polarizer or its interaction with the horn. In this case, the rework/assembly has not affected significantly to improve the XP.

5.1) **Deviations** from the nominal structure when manufacturing the antenna feed.

- The manufacturing of the breadboard feed was addressed in WP3000.
- The model, shown in the photographs of this slide, was measured by Airbus (2018-02-14). However, since measured results were not as expected, a dimensional analysis was done over the fabricated device.
- Two main deviations were found: 0.04/0.09 mm at input/output axis of polarizer and waveguides .

Photo from Airbus, November’17



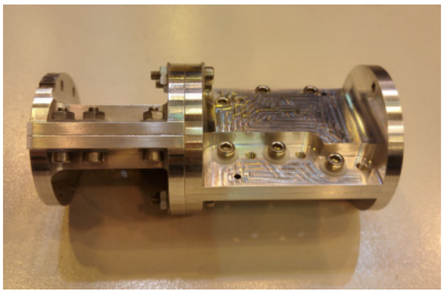
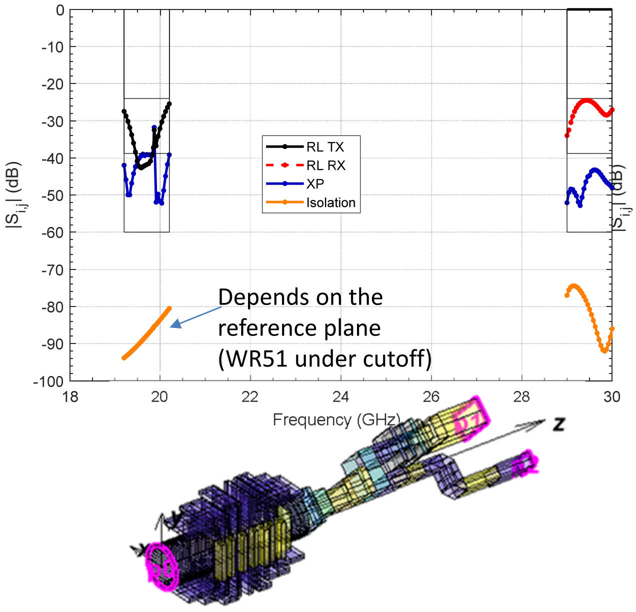


Photo from Airbus, January’18

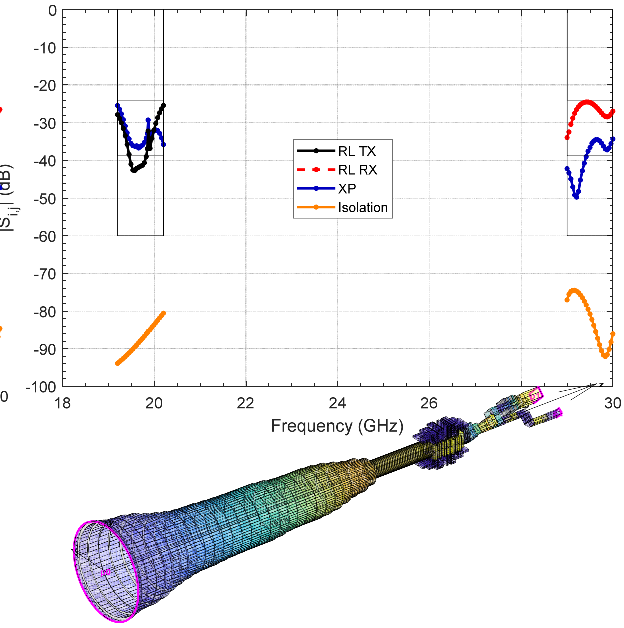
5.1) Feed **with deviations + *Horn “Tub1 Telecom1”***. Simulated Performance.

Mode-matching simulation of Feed (**Model with deviations**) ***Alone***

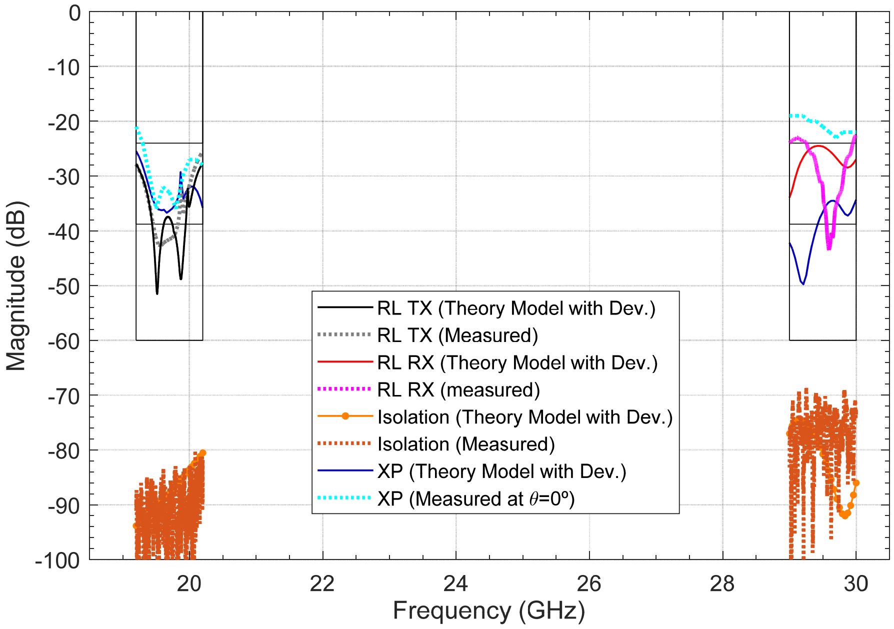


Depends on the reference plane (WR51 under cutoff)

Mode-matching simulation of Feed (**Model with deviations**) ***+ Horn “Tub1 Telecom1”***



5.1) Feed **with deviations + *Horn “Tub1 Telecom1”***. Comparison of Simulations with Measured results.



5.1) Comments to the simulations of the model with the deviations provided by Airbus.

- As a general comment, response for both the return loss and cross-polar discrimination are affected less than changes made in the previous analyses as in Annex I for Sensitivity. The responses in previous slides with the deviations incorporated into the simulations are very close to the specified requirements.

- The main change coming from ***the deviation***s is in ***the level of the higher order modes***, much larger now due to the misalignment between the axes, and showing a ***peak in the TX lower band for the TM01*** that is under cutoff. These modes can affect the cross-polar out of the horn axis, but not on the main axes.

- Therefore, the two deviations detected by Airbus do not seem to explain by themselves the first set of measurements. Additional deviations may be found.

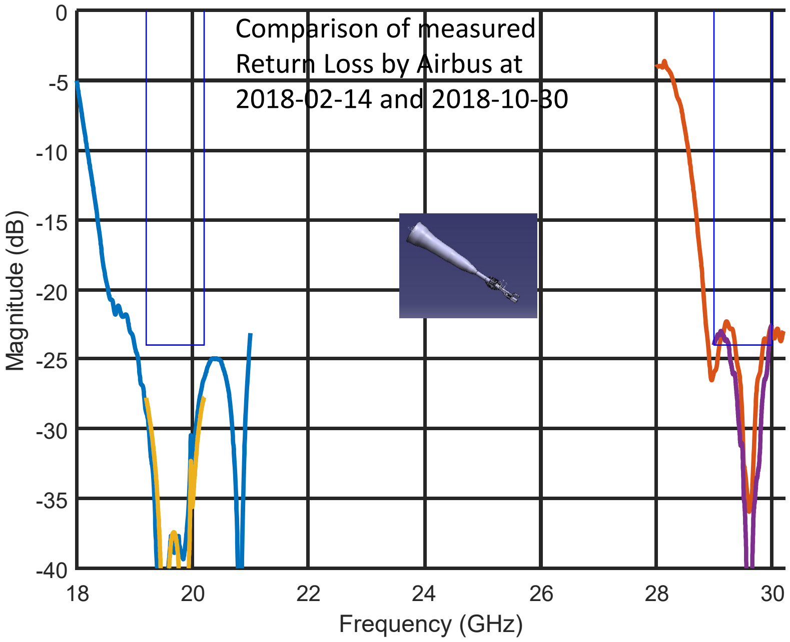
5.1) Second set of measurements.

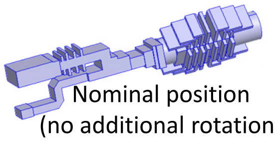
- First set of measurements by Airbus (2018-02-14) had: radiation pattern (at Airbus anechoic chamber) and S-parameters (nominal position, i.e., for normal use).

- As explained before, to have more information and explain the discrepancies with the measured data, a second set of measurements was done by Airbus (2018-10-30): radiation pattern (at UPM anechoic chamber) and three sets of S-parameters:
  a) nominal position (i.e., for normal use).
  b) diplexer and polarizer with additional -45º rotation.
  c) diplexer and polarizer with additional +45º rotation.

- The second set of measurements came after:
  a) Re-open and re-work the polarizer to remove some extra-material.
  b) Re-alignment of the two halves of the polarizer.
  c) Re-alignment of the polarizer with the diplexer and horn.

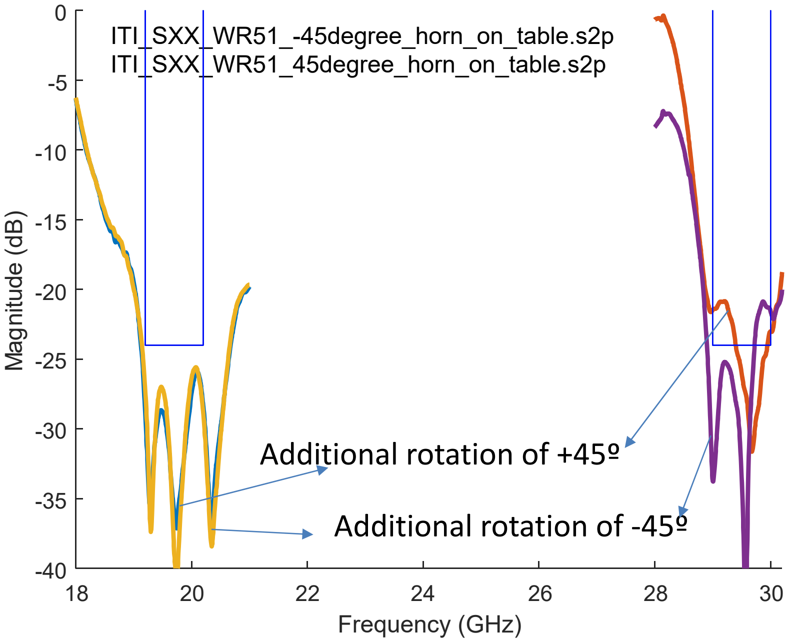
5.1) Measurements of return loss of the feed loaded with horn “Tub1 Telecom1”. (and II). Coherence of the return loss measurements.



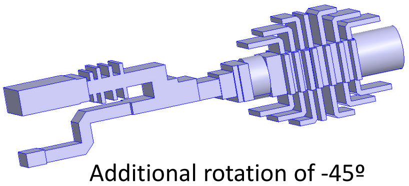

Nominal position
(no additional rotation)

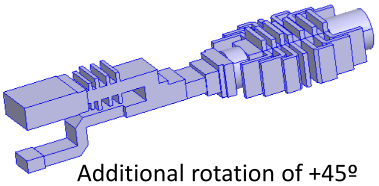
- ➢ Both measurements by Airbus at 2018-02 14 and 2018-10-30 agree very well.
- ➢ Perhaps a slight variation at higher band.

5.1) Measurements of return loss of the feed loaded with horn “Tub1 Telecom1” with additional rotations: -45º and +45º.



Measured Return Loss
(2018-10-30, Airbus)


Additional rotation of -45º

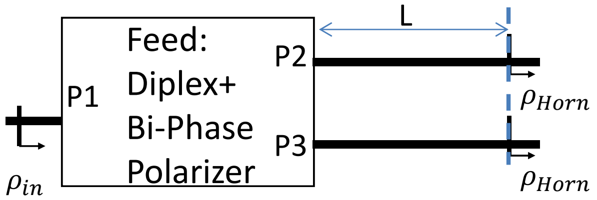

Additional rotation of +45º

5.1) Measurements of return loss of the feed loaded with horn “Tub1 Telecom1”. Comments on the measured results of feed with nominal position and with additional rotations of ±45º

- No significant differences were found between measured return losses in 2018-02-14 and 2018-10-30, in spite of the additional work done to the second set (a) Re-open and re-work the polarizer to remove some extra-material; b) Re-alignment of the two halves of the polarizer; c) Re-alignment of the polarizer with the diplexer and horn.
- The measurements of nominal (no additional rotation), +45º and -45º are very similar in the low frequency band.
- More significant differences are observed in the high frequency band.
- The measurements of +45º y -45º do not show the spike of TM01 mode.

5.1) Simulation of the feed (with deviations) loaded by irises emulating different horns. (I)

- In order to take into account the loading of the possible horns used in the application into the simulations, a model of feed + “iris-replacing-the-horn” has been used. It is described in next slides.
- Proposed model:



L= distance between feed and horn

- P1: input port of the diplexer under analysis.

WR51 for lower frequency band (19.2-20.2 GHz), and
WR28 for higher frequency band (29.0-30.0 GHz)

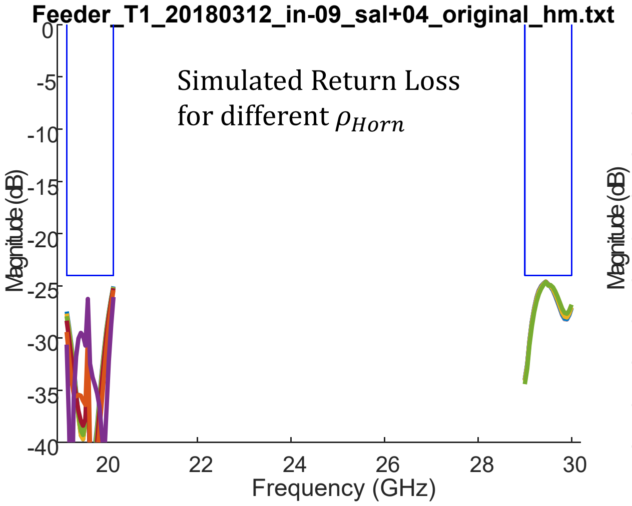
- P2: Vertical polarization at circular waveguide output port of the Bi-Phase Shifter.
- P3: Horizontal polarization at circular waveguide output port of the Bi-Phase Shifter.
- Different return loss of the horn ρ_{Horn} (***same loading in magnitude and phase for P2 and P3***), emulated by means of a circular iris in the output circular waveguide:

- Radius of the output circular waveguide is 5.6 mm.
- Radius of the iris (with 1mm thickness) is changed as: 5.3 - 5.2 - 5.1 - 4.95 - 4.7 mm

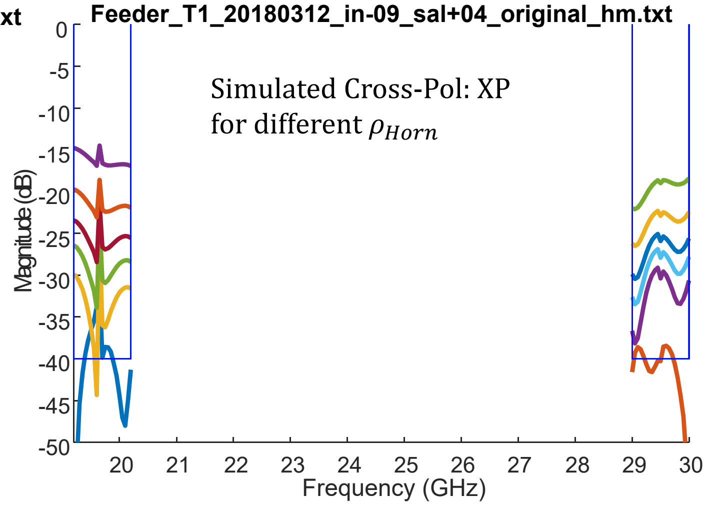
ro1 - ro2 - ro3 - ro4 - ro5

- The return loss ro1 to ro5 of the considered circular iris gives a range from -35dB to -15dB.

5.1) Simulation of the feed (with deviations) loaded by irises emulating different horns. (and II)


Feeder_T1_20180312_in-09_sal+04_original_hm.txt

Simulated Return Loss for different ρ_{Horn}


Feeder_T1_20180312_in-09_sal+04_original_hm.txt

Simulated Cross-Pol: XP for different ρ_{Horn}

- The return loss at input P1 is not affected by the different ρ_{Horn} at the output (***equal for loading P2 and P3***).
- This behavior is fully coherent with a feed very well designed as its shown in the analysis in next slide.
- The cross-polarization is strongly affected by the different ρ_{Horn} at output.
- Cross-polarization levels of the measured -20 dB requires a horn return loss of -20 dB.

5.1) Comparison between predicted and measured S-parameters of the feed (with deviations) plus horn. Comments.

Reference model plus different horn models (emulated by irises)

The return loss at input is not affected by the different return loss of the horn at the output.

This behavior is fully coherent with a feed with values resembling the ideal performance (see circuital analysis).

The cross-polarization is strongly affected by the different return loss at output.

Cross-polarization levels of the measured -20 dB requires a return loss for the horn of -20 dB (seems not very likely).

Reference model with additional rotation of -45º plus different horn models

The return loss at input is strongly affected by the different return loss of the horn at output, particularly at lower band.

The spike at lower band generated by the deviation in the manufacturing by the TM01 mode is seen in the curves.

Comparing with the measured values could be concluded that the used horn has a return loss level of -24 dB approx.

Reference model with additional rotation of +45º plus different horn models

The spike of the TM01 mode at lower band has disappeared.

The measured return loss levels could be explained with a horn having 24 dB of return loss at lower band.

The return loss at higher band is barely affected.

5.2) Comparison with other alternatives.

T2: Bi-Band and Single-Polarization Antenna Feed (Two port)

	A. Asymm. OMT + Mono-Phase Polarizer	B. Septum-OMT	C. Self-diplexed Union (Six-port-Turnstile)	D. Diplexer + Bi-Phase Polarizer (AFeNSat) *Solution for this ESA- ITI project*	
Bandwidth **Low-band** **High-band**	+ (50%) + (4%) - (3%)	+ (42%) - (3.5%) -- (2.5%)	++ (57%) ++ (13%) ++ (8.7%)	+ (42%) + (4.8%) + (3.3%)	++(49%) ++ (10%) ++ (7%)
Interconnected degradation	--	--	++	++ Launcher_T1 - Launcher_T2	- Launcher_T2
Additional Loads	NO	NO	YES	YES Launcher_T1 NO Launcher_T2	
Axial Ratio	< 0.25 dB	< 0.3 dB	< 0.15 dB	< 0.25 dB	< 0.17 dB
Isolation Tx—Rx	< - 50 dB	< - 38 dB	< - 60 dB	< - 80 dB	< - 100 dB
Higher order modes	+	--	++	++	
versatility	+	-	-	++	
Volume	+	++	--	++	
Manufacturing complexity /price	-	++	--	++ Launcher_T1 + Launcher_T2	+ Launcher_T2

5.2) Comparison with other solutions.

- Multiple spot beam systems are expected to be the most common scenario in new generation satellite communications.
- The tendency is to increase the operation frequency bands with very stringent mechanical constraints.
- User feeder is expected to be the most used configuration. This is a two port feed, for dual-band single circular polarization. It is intended to support the downlink and uplink frequency band with an orthogonal circular polarization for each band.
- This new concept proposed improves the electrical performances provided by the classic feed chain option considering in a dual-band OMT and polarizer.

There are many opportunities for this concept:

- To avoid the use of much cumbersome and expensive antenna feeds that are not intended, in principle, for single polarization applications.
- To improve intrinsic limitations of conventional OMT and polarizer in terms of bandwidth and separation between bands.
- To provide better electrical performances (isolation between bands and axial ratio) when elements are connected in order to be compliant to the required performances of new communication satellites.
- To reduce axial length that means a reduction in mass.
- To provide a more compact and low cost solution.

5.3) Recommendations for improvements.

- The addressed Bi-Phase Polarizers are very sensitive to the return loss of the horn, since they convert the signal reflected by the horn into cross-polarization. Therefore, a very well matched horn is needed.
- In addition, the full design can be done including the load of a dedicated horn for the feeder. The design of the bi-phase polarizer + horn incorporates in this case the return loss of the horn in the design process, in order to obtain the desired levels of cross-polarization.
- The manufacturing process must be very accurate, in K/Ka frequency band, since design is very critic with respect to mechanical tolerances: difficulty has been confirmed with the experimental results.
- Some internal dimensions and tolerances are in the limit of its manufacturing in terms of robustness for flight missions and this implies that it is necessary to manufacture the component with a very accurate process.
- It is very important to chose a qualified mechanical workshop in order to avoid issues in the expected RF performances of the feeder chain.
- A possible improvement would be to increase its internal mechanical tolerances.

ESA Innovation Triangle Initiative (ITI)
Contract No.
4000114624/15/NL/MH/GM
Title: Compact K/Ka band antenna feed for multi-beam satellite communications

Final Presentation

ESA ITI proposal B00016918

Reference: Final_Presentation_Draft_v0

Date: 2018-12-05