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EXECUTIVE SUMMARY REPORT FOR UHF ANTENNA

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PAG.

1.- SCOPE

This document presents the executive summary for the GSTP activity for UHF antenna contract including all the requested topics following the ESA requirements.

This development has been performed as a result of the need for qualification of a UHF antenna dedicated to environmental satellites for the American market.

2.- UHF ANTENNA DESCRIPTION

The aim of the activity was to design an antenna for environmental satellites able to offer a bi-directional link from a satellite placed in GEO orbit to the corresponding Earth stations placed on the Earth surface. The band selected for this use is UHF; 401-407MHz was used for Rx while 468-470MHz was used for Tx.

From electrical point of view, the main challenge was to design a compact antenna able to offer good values of gain an XPD for global coverage and considering the BW required (more than a 16%).

An array composed by 4 monofilar helices was found as the best solution in terms of gain, compactness and good behaviour against frequency. A trade-off among the different shapes of the ground plane as well as the relative position of the elements was performed in order to obtain the best possible performances.

A feeding network was designed to reach each radiating element, to offer good electrical matching with the helices for both Tx and Rx bands.

Moreover, from electrical point of view, the XPD target was also very challenging, in particular due to the fact that the influence of the surrounding S/C structure had to be considered in the design phase and in the testing campaign.

From mechanical point of view, there were two main challenges. The first one was to achieve a reduced mass figure. Due to the low frequency used, the size of the radiating structure was very large. The second challenge was to increase the first resonant frequency above 100 Hz. This second factor was difficult to achieve as the antenna included a fence surrounding it to improve XPD influence of the S/C

The development program structure was planned to be based on the design, manufacturing and testing of an EQM, in order to prepare the company for future market requests.

The test campaign was exhaustive in order to demonstrate the feasibility of the development to cover electrical and mechanical requirements.

Next tables summarize the antenna requirements.

RF requirements:

PARAMETER	VALUE
Receive Band (RX)	401-407MHz
Transmit Band (TX)	468-470MHz
Coverage half cone	9 degrees
Polarization	RHCP (RX & TX)
Minimum Gain On Coverage	Receive ≥ 13.10dBi Transmit ≥ 13.20dBi
Maximum Gain On Coverage	Receive ≤ 15.00dBi Transmit ≤ 15.20dBi
Axial Ratio On Coverage	Receive < 0.85dB Transmit <1.40dBi
Return Loss (50-Ohm)	<-20dB
RF Input Power Transmit	Nominal 7.5W Multipaction 15W Survival 35W
Side Lobes (40 to 90) Theta angle	Receive <-14dB-peak Transmit <-12dB-peak
Group delay variation	<5ns (RX & TX)
Gain Variation	<0.1dB/MHz
Radiated Power Flux Density Off-Axis (40 to 90) Theta angle	< 0dBW/meter^2 at 1.0 meter
PIM	-140dBm (405MHz) 11th order

Vibration level requirements:

Sine vibration level:

All axis	
Frequency (Hz)	**Level**
10 – 24	± 12.7 mm
24 – 35	± 15 g
35 – 55	± 20 g
55 – 100	± 7 g

Random vibration levels:

Frequency (Hz)	Level (g^2/Hz)	Slope (dB/oct.)
20 - 1000	0.5	
1000 - 2000		-6.0
Overall Level: 27.21 g RMS		

Random excitation in all axes

Shock:

Axis	Frequency (Hz)	Level (g)
All	100	16
	1325	2022
	10000	2022

Shock excitation in all axes

3.- ANTENNA TECHNICAL DESIGN

The selected design concept is based on an Array of four monofilar helices. The helix provides by itself circular polarization (RHCP).

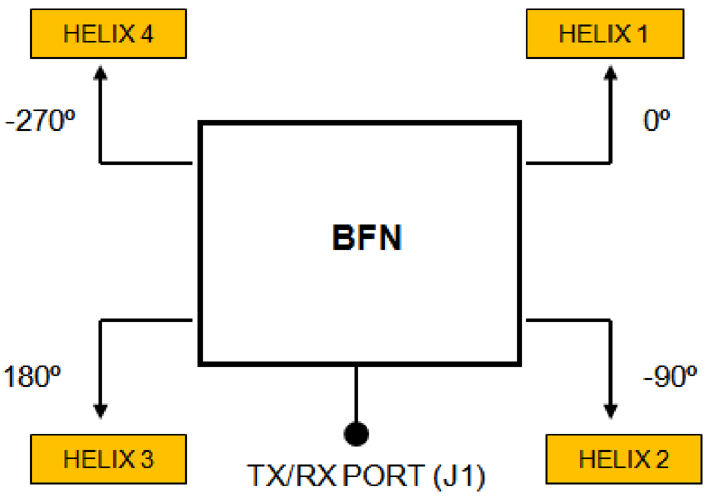
The antenna has a single input connector (TNC-F). This connector channelizes the Transmit and Receive signals.

The helices are fed by a Beam forming Network (BFN) with equal power. The BFN is developed in Bar-line technology and the cross-section size of BFN provides low loss attenuation. (<0.05dB/m)

To improve the on-axis axial ratio, the helices are fed in progressive phase rotation (0º/90º/180º/270º) and mechanically properly rotated in 90º steps to maintain on axis the peak beam. This rotation technique improves the stability on active impedance, because of the cancelation of two coupling coefficients coming from two opposed helices.

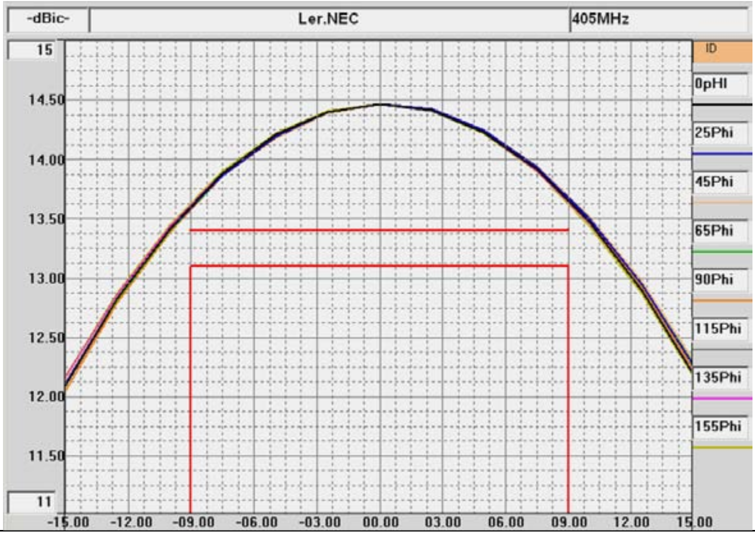
The helices are supported by fiberglass cones. The helix metal is separated from the fiber to minimize the radiating losses.

Figure 3.1 UHFA Scheme

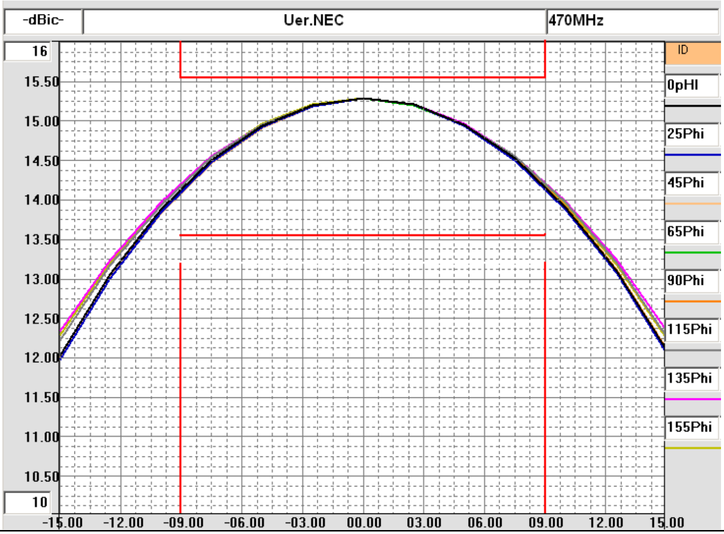


After evaluation of all parameters involved, the radiation patterns were computed in these worst case conditions. At low frequency the design presented a margin of 0.22dB over the minimum Gain at edge of coverage (Theta =9º). For 470MHz, the margin was 1dB. In both frequency bands the maximum specified gain were not over passed.

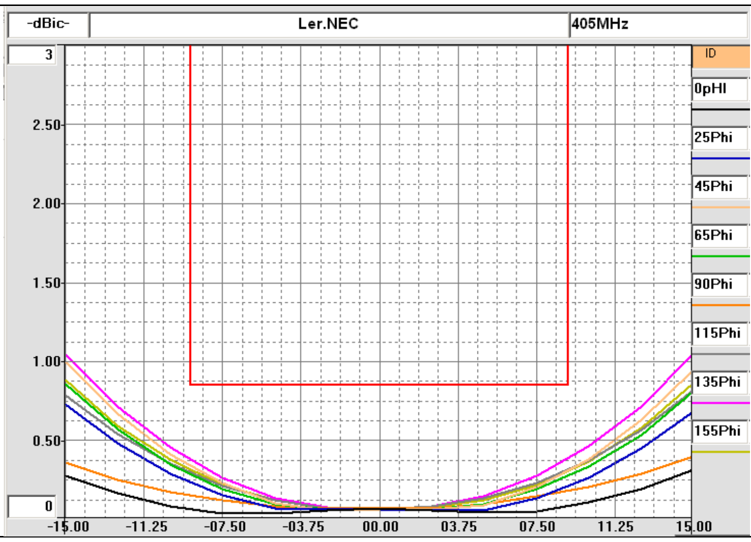
In Axial Ratio, compliance with some margin was achieved.



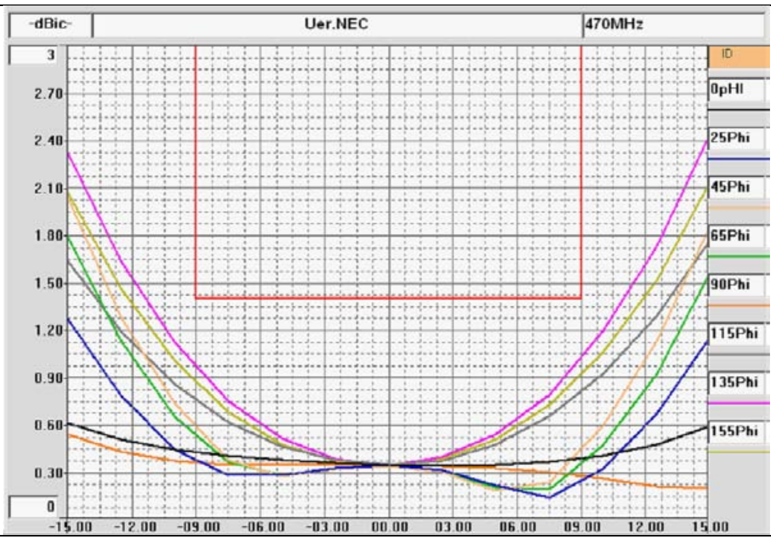
Pattern on Coverage. 405MHz.



Pattern on Coverage. 470MHz.



Axial Ratio. 405MHz.



Axial Ratio. 470MHz.

4.- TEST RESULTS

4.1.- LABORATORY TEST RESULTS.

In Figure 4.1.1, the return loss of the antenna is shown for comparison with initial and post vibration tests results.

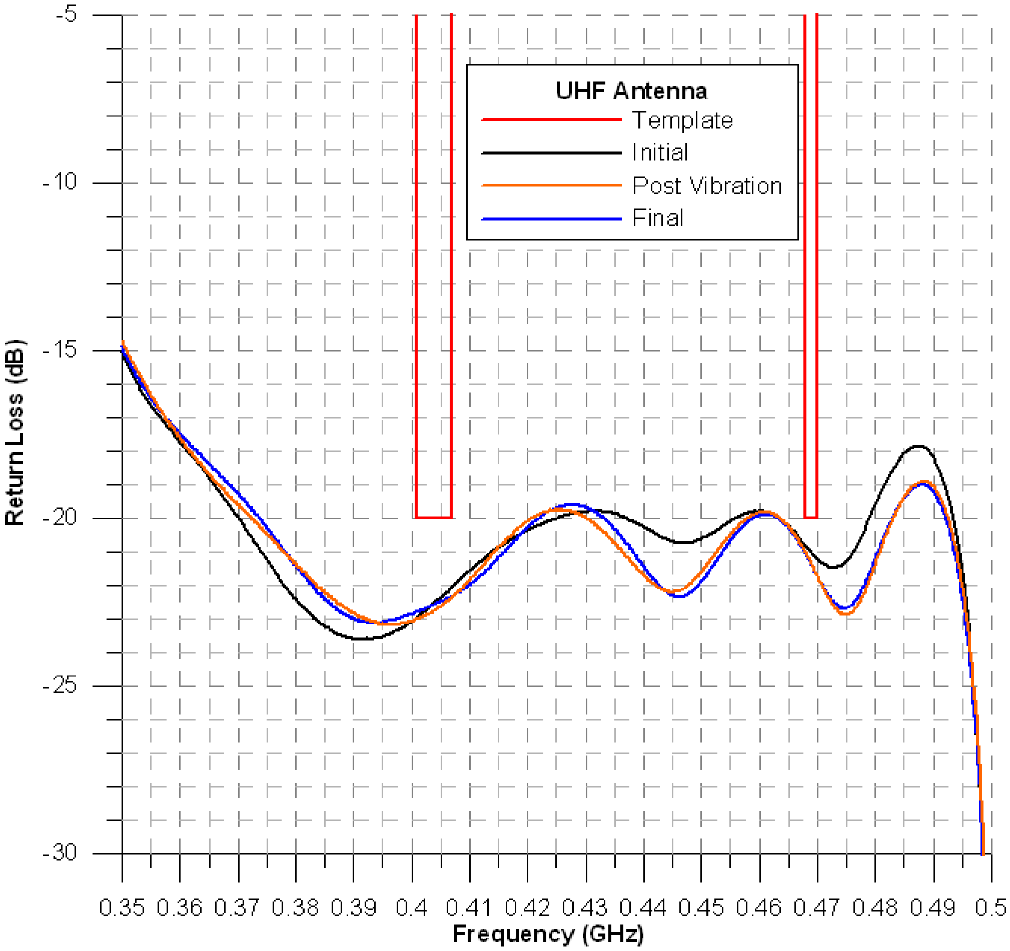


Figure 4.1.1. – Final Test Return Loss

4.2. RADIATION TEST RESULTS.

The radiation pattern measurements were performed on UHF antenna following the Electrical Test procedure.

The radiation performances were measured at 401 MHz, 407 MHz, 468 MHz and 470 MHz.

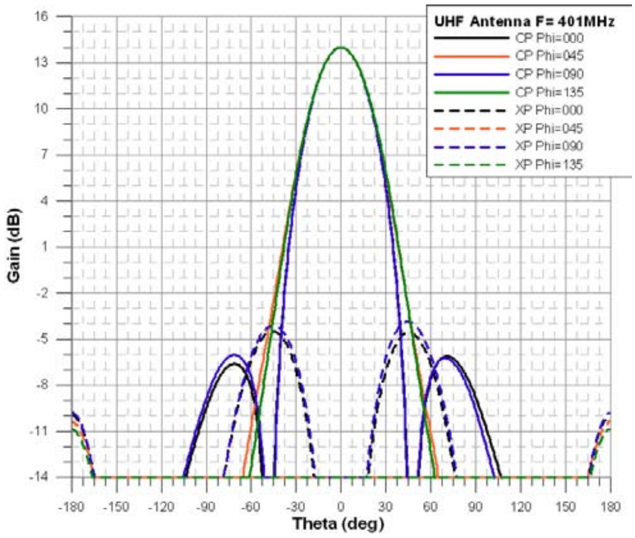


Figure 4.2.1- Final Test Radiation Pattern F=401MHz

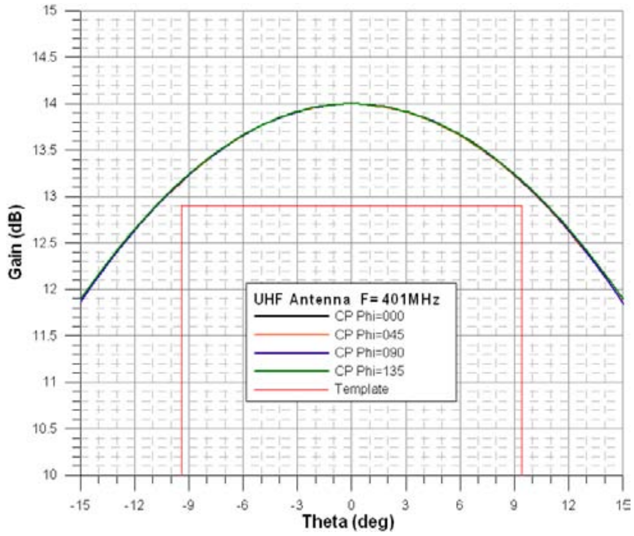


Figure 4.2.2- Final Test Coverage Detail F=401MHz

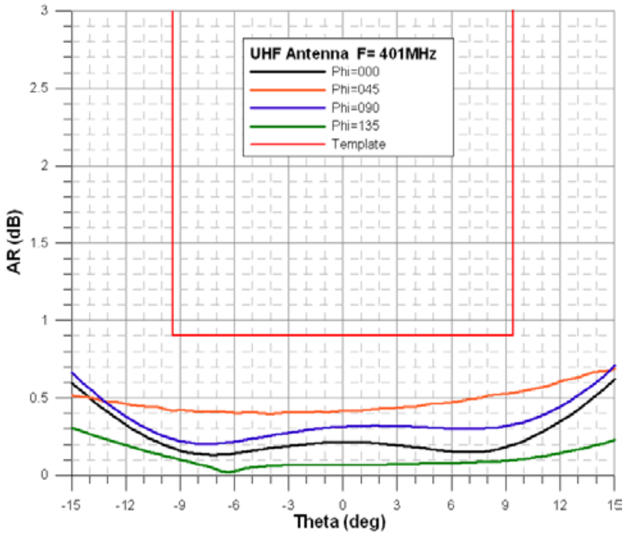


Figure 4.2.3- Final Test Axial Ratio F=401MHz

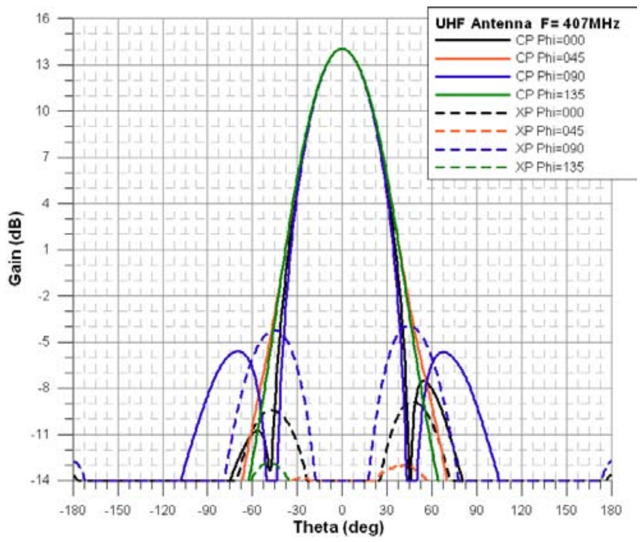


Figure 4.2.4- Final Test Radiation Pattern F=407MHz

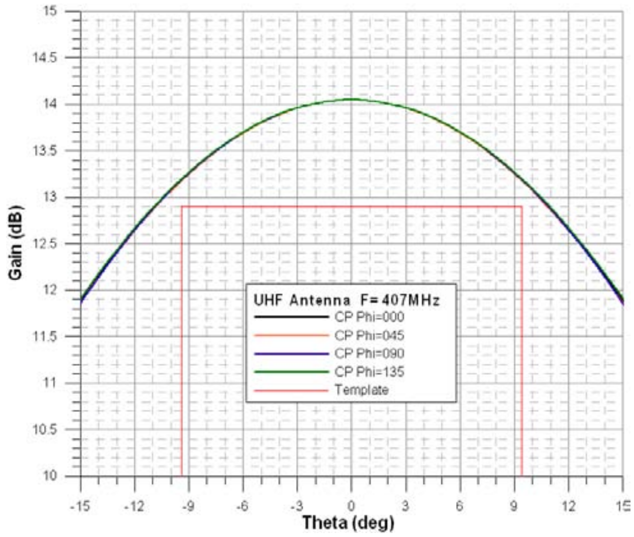


Figure 4.2.5- Final Test Coverage Detail F=407MHz

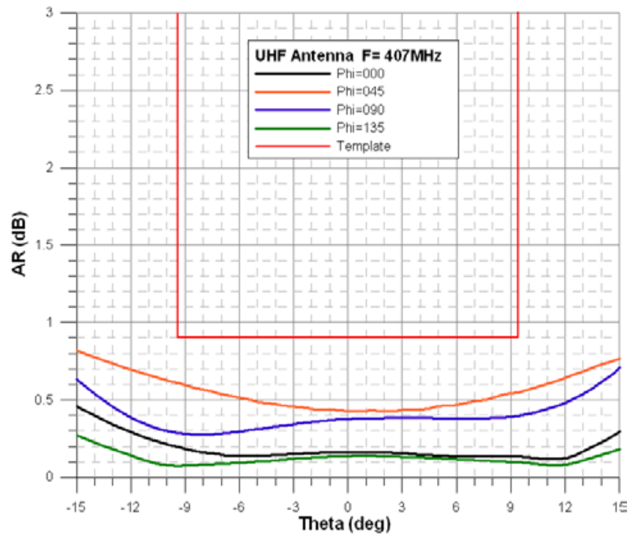


Figure 4.2.6- Final Test Axial Ratio F=407MHz

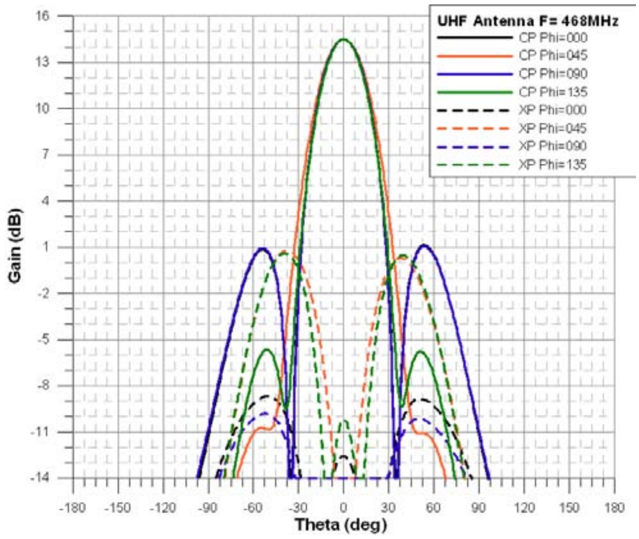


Figure 4.2.7- Final Test Radiation Pattern F=468MHz

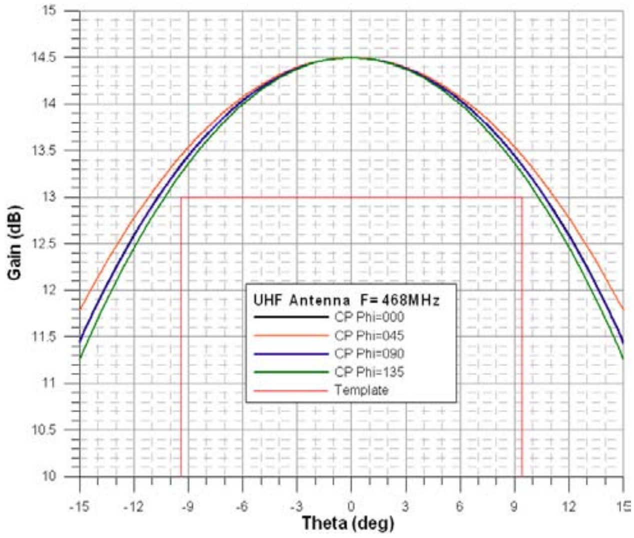


Figure 4.2.8- Final Test Coverage Detail F=468MHz

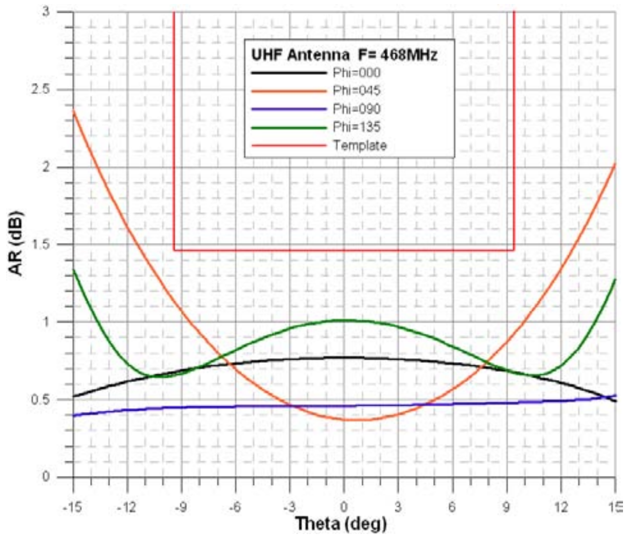


Figure 4.2.9- Final Test Axial Ratio F=468MHz

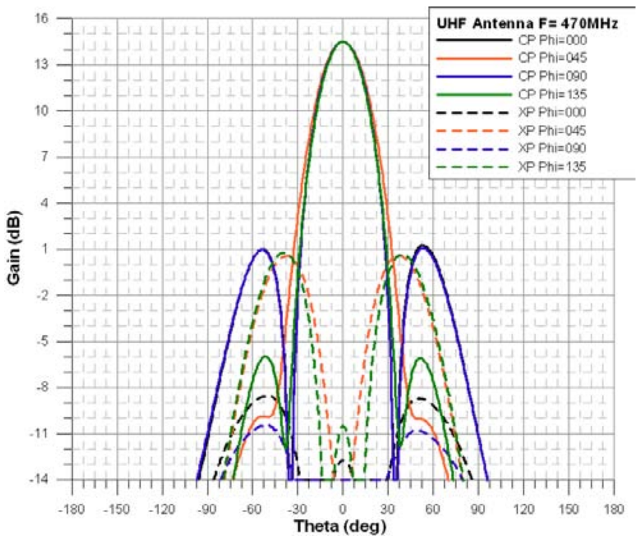


Figure 4.2.10- Final Test Radiation Pattern F=470MHz

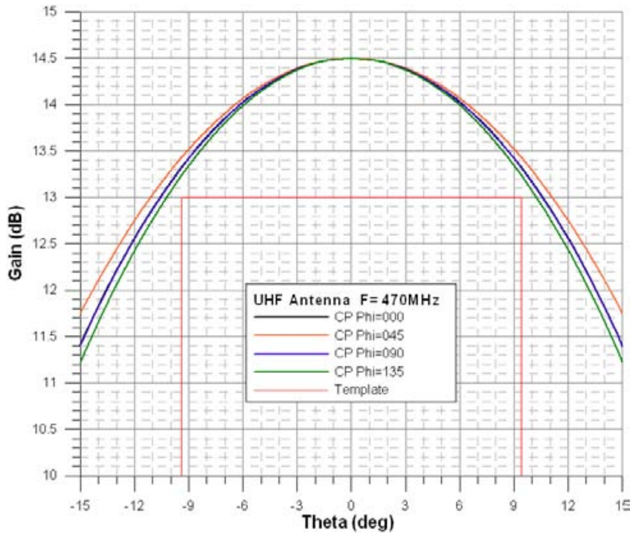


Figure 4.2.11- Final Test Coverage Detail F=470MHz

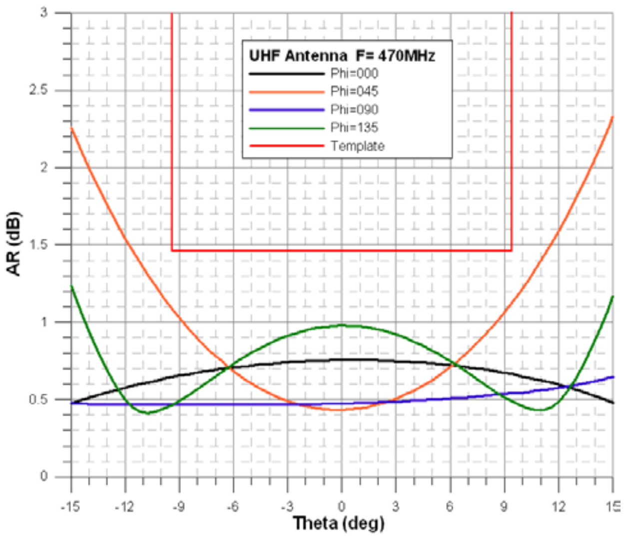


Figure 4.2.12- Final Test Axial Ratio F=470MHz

4.3.- COMPLIANCE TABLE

The statement of compliance of UHF ANTENNA test results is summarised in the following table:

PARAMETER	REQUIREMENT	INITIAL worst case	FINAL worst case	STATUS
FREQUENCY	**RX 401-407MHz** **TX 468-470MHz**			C
COVERAGE	**RX ±9.4 deg** **TX ±9.4 deg**			C
POLARIZATION	**RX RHCP** **TX RHCP**	RX RHCP TX RHCP	RX RHCP TX RHCP	C
MINIMUM GAIN On coverage	**RX >12.9 dBi** **TX >13.0 dBi**	RX >13.0 dBi TX >13.2 dBi	RX >13.1 dBi TX >13.2 dBi	C
MAXIMUM GAIN Peak-to-Edge	**RX NA** **TX <1.7 dBi**	RX NA TX <1.3 dBi	RX NA TX <1.3 dBi	C
AXIAL RATIO On coverage	**RX < 0.90dB** **TX < 1.46dB**	RX < 0.65dB TX < 1.2dB	RX < 0.65dB TX < 1.2dB	C C
SIDE LOBES 40°-90°	**RX <-14dBp** **TX <-12dBp**	RX <-18.0dBp TX <-13.5dBp	RX <-18.0dBp TX <-13.5dBp	C C
SIDE LOBES 115°-145°	**RX <-10dBp**	RX <-28.0dBp	RX <-28.0dBp	C C
HALF BEAMWIDTH 3dB below peak	**RX 16.5°-17.5°** **TX 14.0°-15.0°**	RX 17.5° TX 15.0°	RX 17.5° TX 15.0°	C C
HALF BEAMWIDTH 10dB below peak	**RX 28°-33°** **TX 24°-28°**	RX 33° TX 28°	RX 33° TX 28°	C C
HALF BEAMWIDTH 20dB below peak	**RX 38°-50°** **TX 29°-35°**	RX 50° TX 35°	RX 50° TX 35°	C C
RETURN LOSS	**< -20dB**	< -21.0dB	< -21.4dB	C
G. DELAY VARIATION	**RX <5ns /band** **TX <5ns /band**	RX <1ns /band TX <1ns /band	RX <1ns /band TX <1ns /band	C C
GAIN VARIATION	**RX 0.1dB/MHz** **TX 0.1dB/MHz**	RX <0.1dB/MHz TX <0.1dB/MHz	RX <0.1dB/MHz TX <0.1dB/MHz	C
POWER FLUX 40°-90° off-axis	**<0dBW /m^2**		-1dBW /m^2	C

4.4.- TESTS ON MOCK-UP

Additional testing of the antenna assembled on a representative mock-up was performed. See below a picture of the assembly.

See below the results achieved in tabulated form.

PARAMETER	REQUIREMENT/ GOAL	FINAL worst case	STATUS
FREQUENCY	**RX 401-407MHz** **TX 468-470MHz**		C
COVERAGE	**RX ±9.4 deg** **TX ±9.4 deg**		C
POLARIZATION	**RX RHCP** **TX RHCP**	RX RHCP TX RHCP	C
MINIMUM GAIN **On coverage**	**RX >12.9 dBi** **TX >13.0 dBi**	RX >12.5 dBi TX >13.5 dBi	NC C
MAXIMUM GAIN **Peak-to-Edge**	**RX NA** **TX <1.7 dBi**	RX NA TX <1.3 dBi	C
AXIAL RATIO **On coverage**	**RX < 0.90dB** **TX < 1.46dB**	RX < 1.2dB TX < 1.4dB	NG G
SIDE LOBES **40°-90°**	**RX <-14dBp** **TX <-12dBp**	RX <-14.0dBp TX <-13.5dBp	C C
SIDE LOBES **115°-145°**	**RX <-10dBp**	RX <-30.0dBp	C C
HALF BEAMWIDTH **3dB below peak**	**RX 16.5°-17.5°** **TX 14.0°-15.0°**	RX 19.5° TX 15.5°	NC NC
HALF BEAMWIDTH **10dB below peak**	**RX 28°-33°** **TX 24°-28°**	RX 33.8° TX 28.5°	NC NC
HALF BEAMWIDTH **20dB below peak**	**RX 38°-50°** **TX 29°-35°**	RX 52.9° TX 39°	NC NC

C: compliant
NC: non-compliant
G: goal achieved
NG: goal not achieved

After assessment of the radiation results, Rymsa optimized the relative positions of the antenna and mockup to minimize the impact of the latest. Rymsa run simulations and try to find a better scenario. The proposed correction for the UHF antenna was to tilt it 2 degrees toward the mockup. Further radiation tests were carried out, obtaining the following results.

COPOLAR GAIN	402 MHz	406 MHz	470 MHz
Measured Directivity (by integration of patterns)	**14.63 dB**	**14.47 dB**	**15.85 dB**
Measured Peak Gain (INTA)	**14.07 dBi** (0.56 dB loss)	**14.29 dBi** (0.18 dB loss)	**15.56 dBi** (0.29 dB loss)
Compliance	NC (12.5 dBi)	NC (12.8 dBi)	C (13.4 dBi)
Compliance with 2° correction.	NC* (12.85 dBi)	C (13.0 dBi)	C (13.4 dBi)
Specification	**12.9 dBi**	**12.9 dBi**	**13.0 dBi**

Note.- 0.56dB of loss at 402MHz includes the open range gain measurement error of ±0.6dB. From measurements at laboratory on EQM, the feed loss was estimated in 0.37dB at worst case, with ±0.01dB of measurement error.

AXIAL RATIO	402 MHz	406 MHz	470 MHz
Compliance	NG (0.94 dB)	NG (1.20 dB)	G (1.35 dB)
Compliance with 2° correction	NG (1.01 dB)	NG (1.31 dB)	G (1.35 dB)
Goal	**0.9**	**0.9**	**1.46**

C: compliant
NC: non-compliant
G: goal achieved
NG: goal not achieved

After assesment of the measured radiation patterns of the modified antenna+mockup structure, the customer gave its OK to the results, since the NCs were considered acceptable, not being critical.

4.5.- PIM TEST

The PIM test on GSTP UHF antenna was performed according to the relevant test procedure. The signals applied were the following:

F1=1694.1 GHz. Flux Radiated: 2mW/cm2
F2=1680.2 GHz. Flux Radiated: 2mW/cm2
F3=1686.6 GHz. Flux Radiated: 2mW/cm2
F4= 468.8 MHz. Power Level: 7.5W

PIM Frequency: 405.7 MHz (order 11).

The tests were performed illuminating the AUT port connector with three source antennas (AS), as described in the dedicated Test Procedure. The F4 carrier was applied by means of UHF diplexer. The PIM frequency was detected by spectrum analyser from the AUT port.

The antenna sources (AS) worked in linear polarization: Vertical (V), Horizontal (H) or tilted 45º (X).

Polarization AS1	Polarization AS2	Polarization AS3
V	V	V
V	V	X
V	X	X
V	H	H
H	V	V
H	V	X
H	X	X
H	H	H

The PIM tests were performed at ambient temperature.

The test set-up was checked for PIM reference. The AUT was replaced by a monopole free of PIM. The PIM level was then recorded.
Also, the test set-up was verified to dectect PIM at the desired frequency. A PIM source was used. The controlled generation of PIM was accomplished by means of a small box full of grated metal, placed in the anechoic chamber.

During the test, PIM level over specified value of -140dBm was not detected.

The set-up with the AUT was verified again at the end of the test for PIM detection. The same PIM source was used.

4.6.- MECHANICAL TEST RESULTS.

Vibration test set-up:

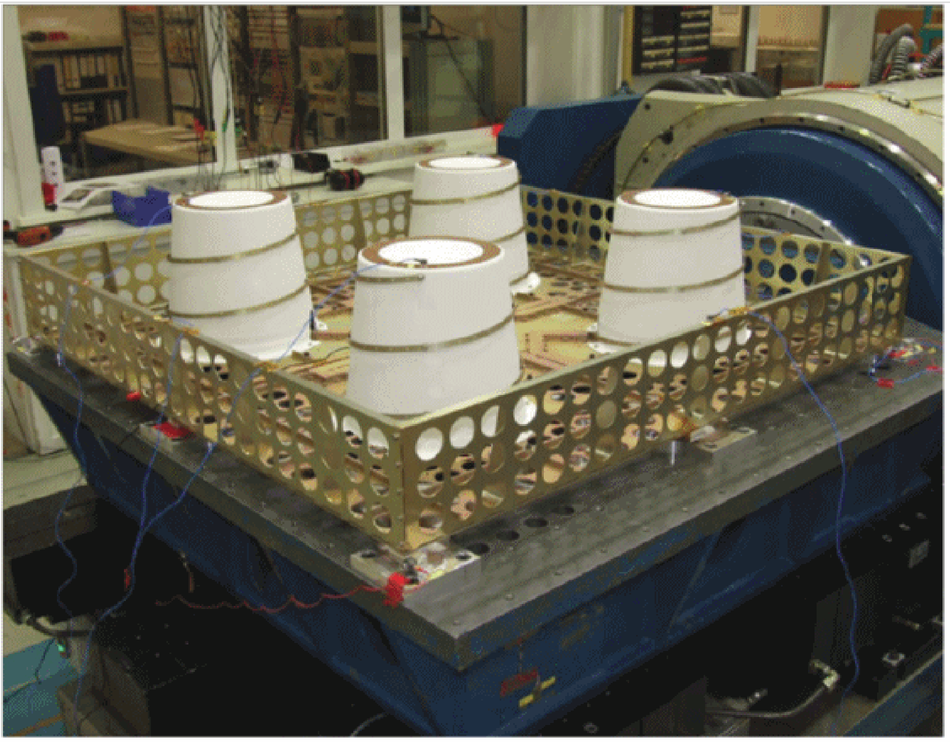


Figure 4.6.1.- Parallel axes set-up

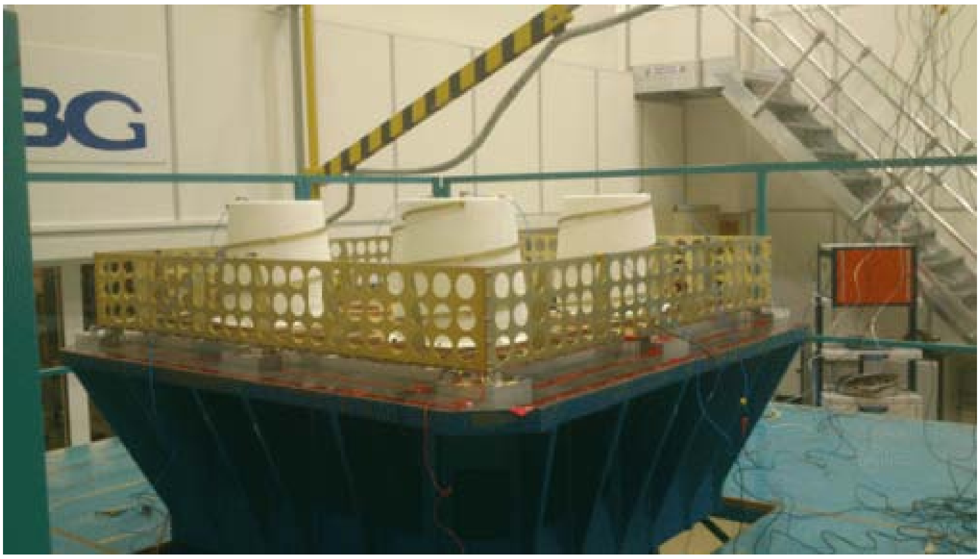


Figure 4.6.2.-Perpendicular axis set-up

Pyroshock test set-up:

Figure 4.6.3.- Pyroshock testing set-up

The vibration test campaign was considered successful since:

- No damage was detected during the overall vibration and shock (qualification levels) test sequence.
- No significant change in the response shape was detected between initial and final modal survey test.
- No significant frequency shifting (higher than 10%) and response amplitude variation (higher than 50%) was measured between each sine survey.
- Visual inspection performed along the test did not show any damage

- Electrical checking performed at the beginning and at the end of the vibration test did not show significant variations.

4.7.- THERMAL VACUUM CYCLING TEST RESULTS

The TVAC thermal cycling test was performed at INTA facilities by Rymsa personnel.

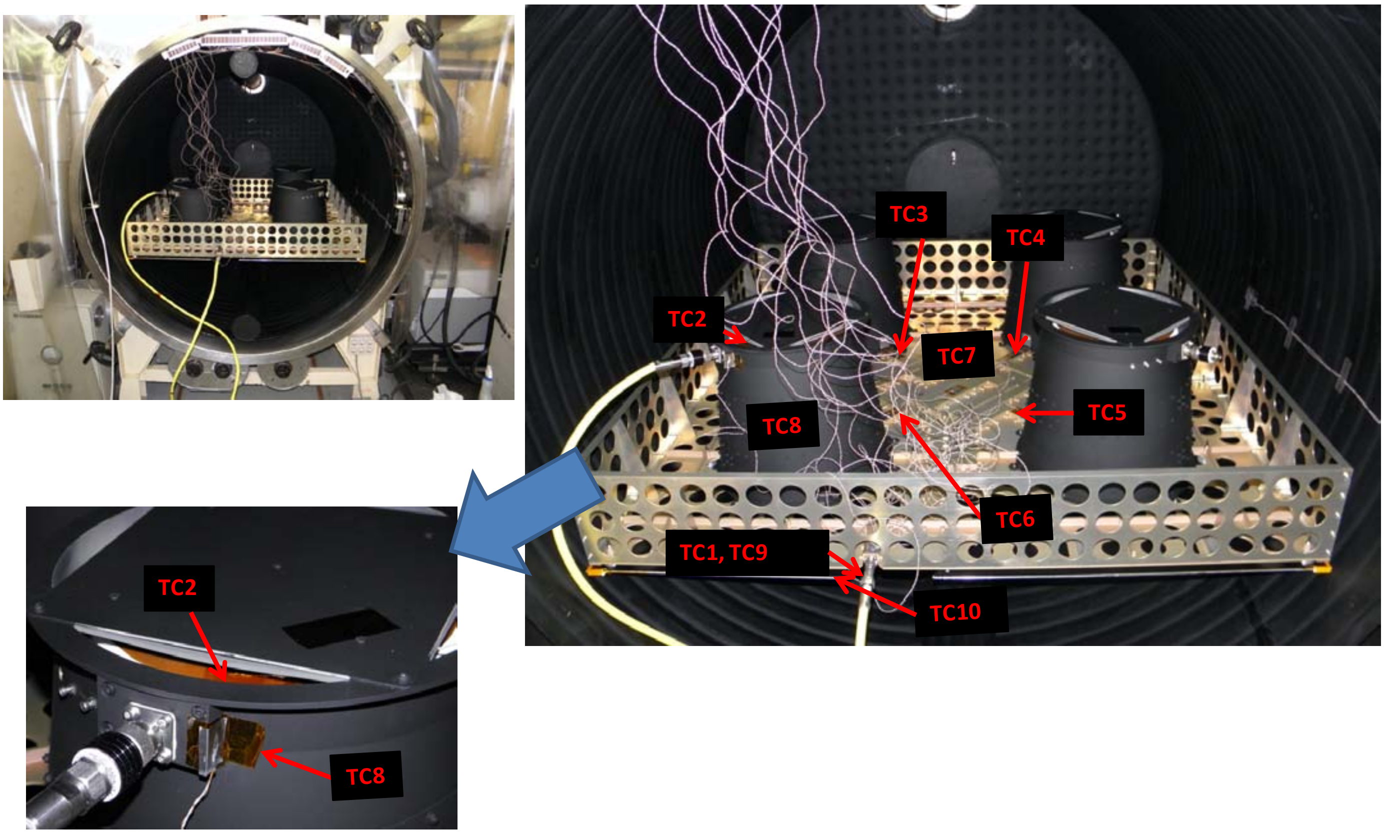


Figure 4.7.1- UHF antenna thermocouples.

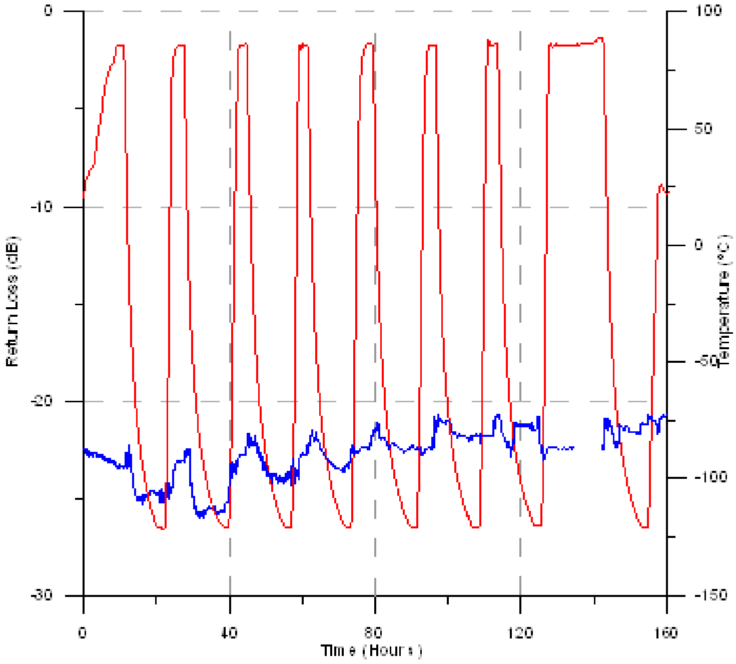


Figure 4.7.2- UHF antenna Continuous Monitoring Results. F: 402MHz.

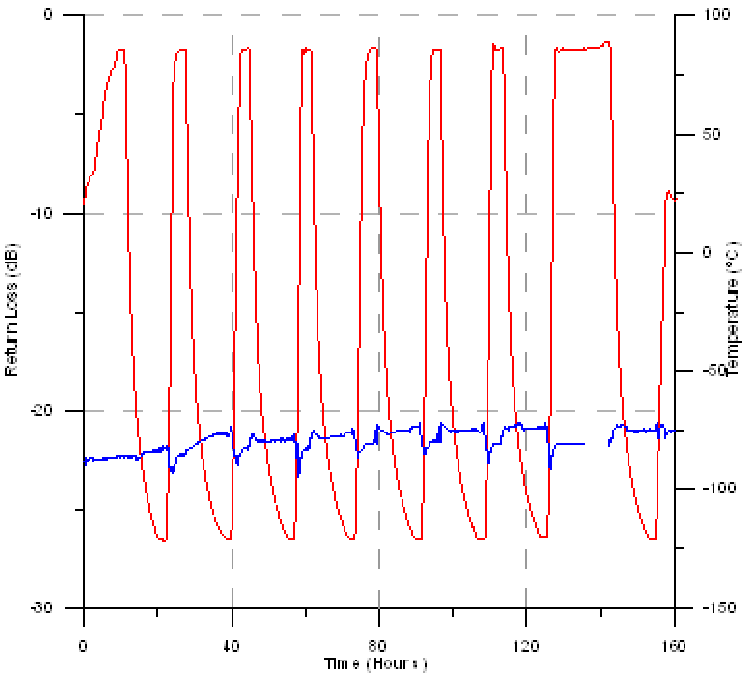


Figure 4.7.3- UHF antenna Continuous Monitoring Results. F: 406MHz.

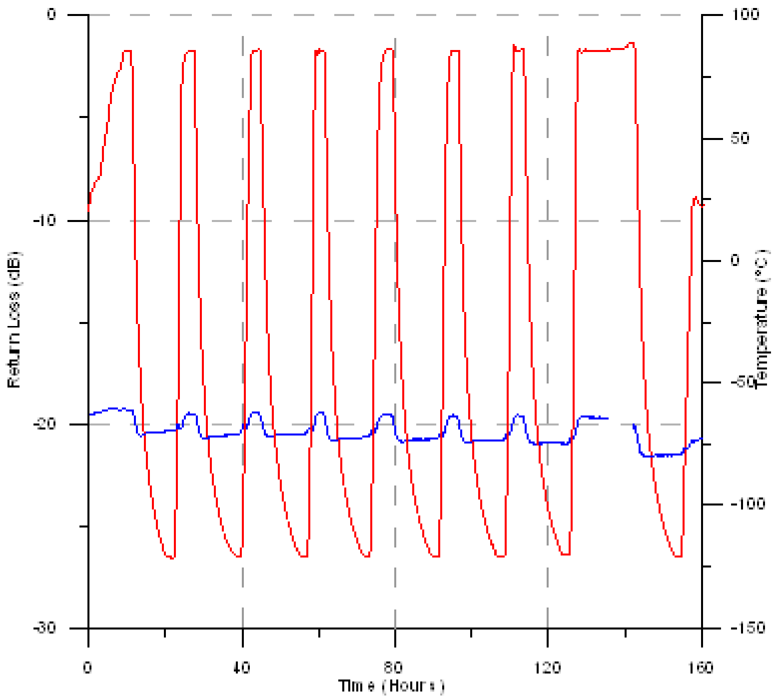


Figure 4.7.4- UHF antenna Continuous Monitoring Results. F: 470MHz.

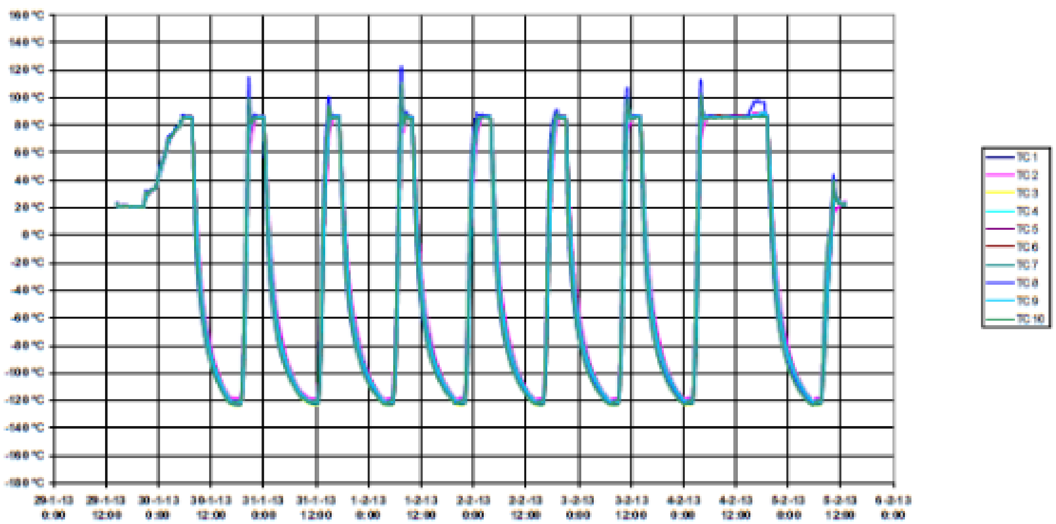


Figure 4.7.5- UHF antenna TVAC Cycle: thermocouples

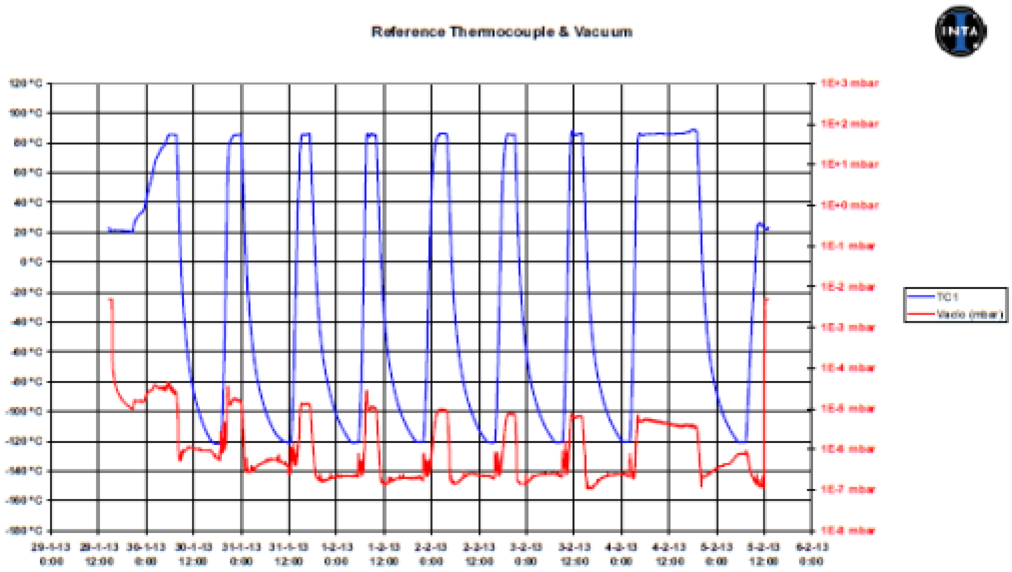


Figure 4.7.6- UHF antenna TVAC Cycle: vacuum

4.8.- POWER HANDLING TEST

The power handling test was performed at INTA facilities by Rymsa personnel.

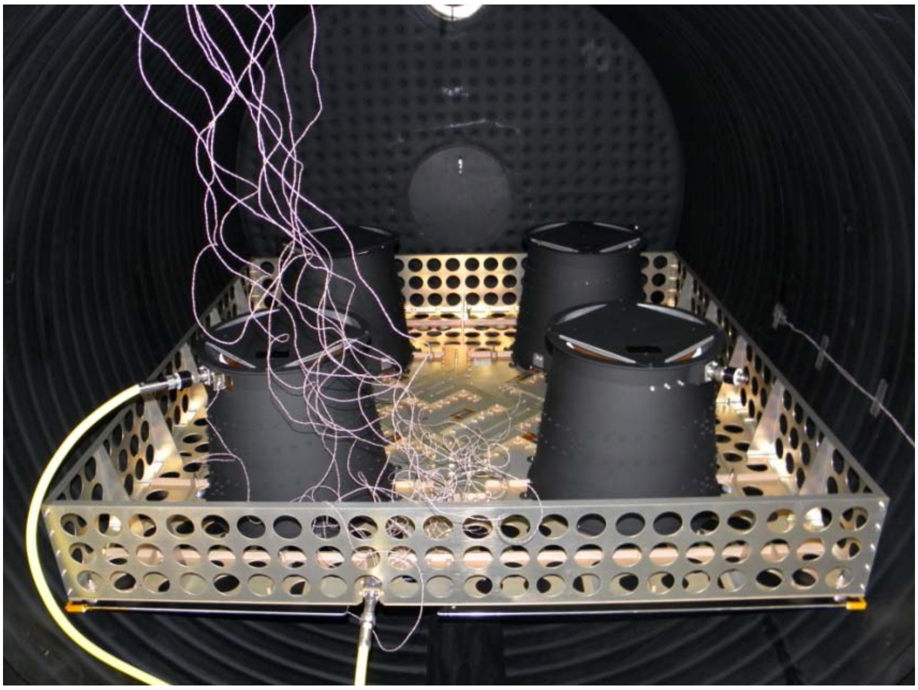


Figure 4.8.1- UHF antenna inside TVAC.

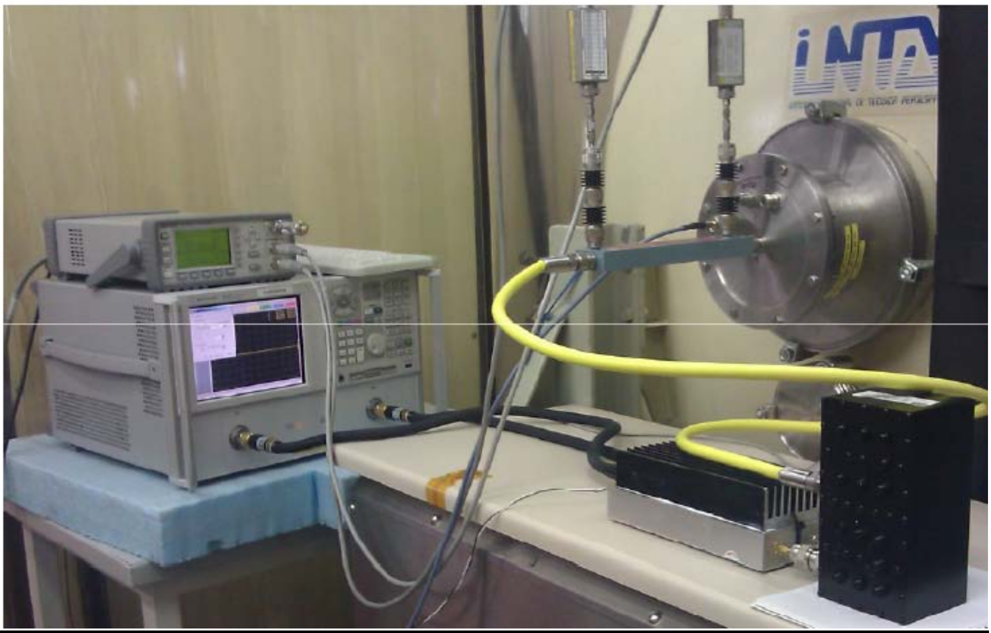


Figure 4.8.2- Detail of Power Handling Test setup.

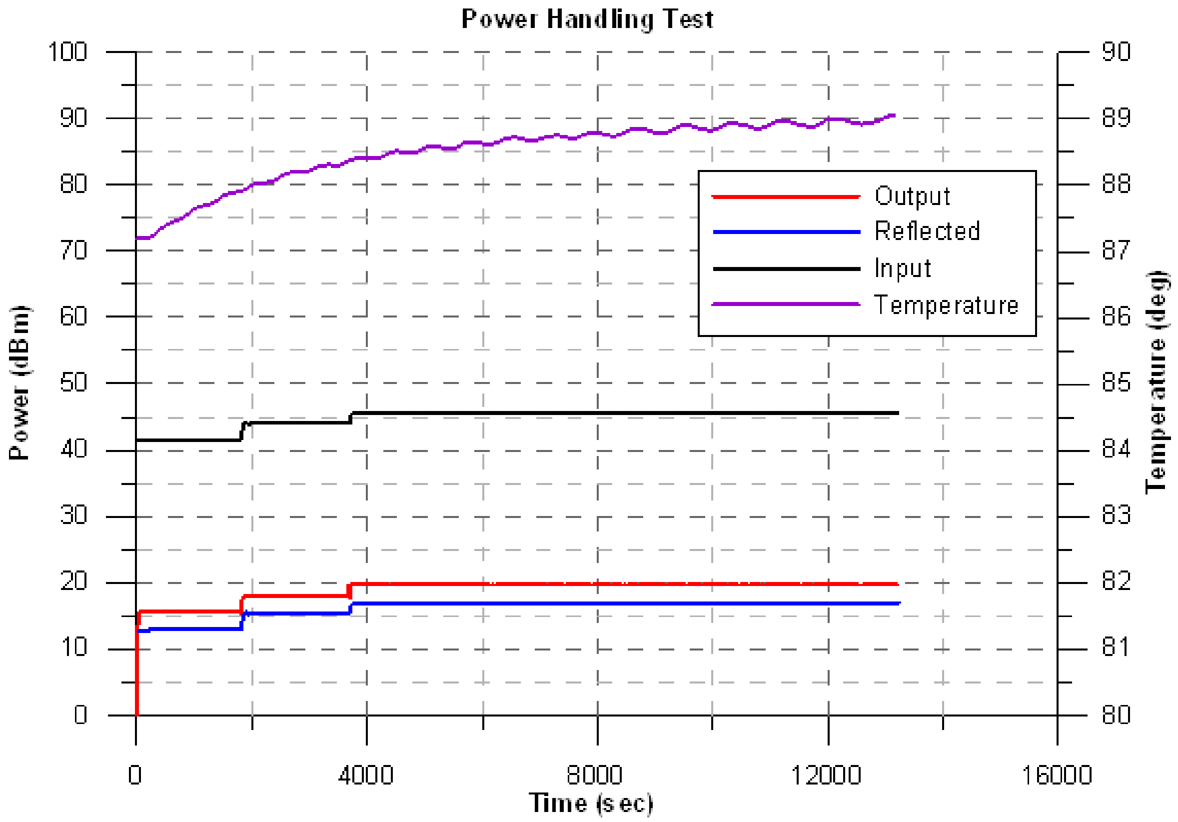


Figure 4.8.3- Power Handling Test results.

	INPUT POWER	TOTAL TIME
STEP 1 → 15W	41.7 dBm	30 min
STEP 2 → 25W	43.9 dBm	30 min
STEP 3 → 35W	45.4 dBm	150 min

The 26dB difference between the input and the Test Cap output signal is due a 20dB attenuator and the division of the input power among the four feeding paths (6dB). The same way, the difference between the input power and the reflected power at that same input is due to the own Return Loss of the antenna with the Test Caps assembled plus the contribution of a 10 dB attenuator.

4.9.- TEST CAMPAIGN CONCLUSION

A successful test campaign has been performed over the UHF antenna.

The UHF ANTENNA has been tested from the RF point of view and all required performances were compliant.

The vibration test campaign can be considered successful since:

No damage was detected during the overall vibration and shock (qualification levels) test sequence:

- No significant change in the response shape was detected between initial and final modal survey test.
- No significant frequency shifting (higher than 10%) and response amplitude variation (higher than 50%) are measured between each sine survey.
- Visual inspection performed along the test had not shown any damage

Thermal test is considered successful as test temperatures have been achieved, obtaining good RF test results after the test.

Power handling and PIM tests were also successful.