GSTP

S-Band Helix Antenna

Executive Summary Report for Development In Printed Substrates or 3D Printed

DOCUMENT NUMBER: GSTP-TR-0212-TA

Issue: 1
DRL Nº: -
Date: 19/12/2018
Pages: 57
Accessibility: Restricted – to be delivered only to project participants or authorized representatives

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CHANGES RECORD			
ISSUE	**DATE**	**WRITTEN BY**	**REMARKS**
1	19/12/2018	E.CELEMIN	Document Creation

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1. AIM AND SCOPE

This document presents the executive summary for the GSTP activity for Developmet of an S-band Helix Antenna in printed substrates or 3D printed contract including all the requested topics following the ESA requirements.

This development has been performed as a result of the need for qualification of an helix antenna dedicated using metallic 3D printing

Two technologies have been developed and compared for the S-band Helix Antenna: printed helix on a dielectric substrate and metallic 3D printed (ALM)helix. For the printed substrates a dedicated breadboard was developed and measured. The results were in line with simulations and confirmed that the technology is valid and understood. For the ALM technology a complete EQM antenna has been designed, manufactured and fully satisfactory tested. The helix radiating element has been manufactured using metallic 3D printing. A procedure for the metallic 3D printed manufacturing process has been developed that guarantees repeatability between pieces by identifying the required samples and the required treatments to achieve the necessary tolerances. The objective was to determine if the current technology, used for the quadrifilar radiating helix element, could be substituted by another technologies that could have advantages. The two alternatives technologies studied have been: printed helix on a dielectric substrate and metallic 3D printing. The first phase of the programme has compared both technologies. For the printed helix on a dielectric substrate, a monofilar design was manufactured and measured. The results were in line with the simulations and the conclusion has been that this technology is well understood and can be used for the manufacture of quadrifilar helix antennas. Regarding the metallic 3D printing technology, the main objective has been achieved if this technology provides benefits respect the standard one, that has derived on the following tasks:

a) Re-design the helix to optimize the metallic 3D printing process but maintaining the performances.

b) Define the type and number of samples during manufacturing process to guarantee mechanical properties.

c) Define a procedure to guarantee repeatability acceptable between different units.

d) Define the thermal treatments to guarantee the required mechanical properties and dimensional tolerances.

e) Define a test campaign that guarantees that the antenna is valid for flight use.

All objectives have been achieved, documented and delivered

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

#	Reference	Document Title
AD01	P3-QS-RS -0010 v4.0	PROBA3 S-Band Antenna Unit TRS
AD02	GSTP-PLN-0195-RYM	GSTP S-Band Helix Antenna Test Plan in Printed Substrates or 3D Printed
AD03	GSTP-ICD-0203-RYM	INTERFACE CONTROL DRAWING FOR GSTP S-BAND HELIX ANTENNA
AD04	GD-TP-0013-RYM	Electrical Test Procedure for Helix and Patch Antennas at RYMSA Facilities
AD05	GD-TP-0014-RYM	RF Measurements under Thermal Vacuum Conditions Test Procedure for Helix and Patch Antennas at RYMSA Facilities
AD06	GD-TP-0001-RYM	Vibration Test Procedure at RYMSA Facilities
AD07	GD-TP-0002-RYM	Thermal Test Procedure at RYMSA Facilities
AD08	GSTP-ANL-0202-TA	GSTP S-BAND HELIX ANTENNA Electrical and Worst Case Analysis

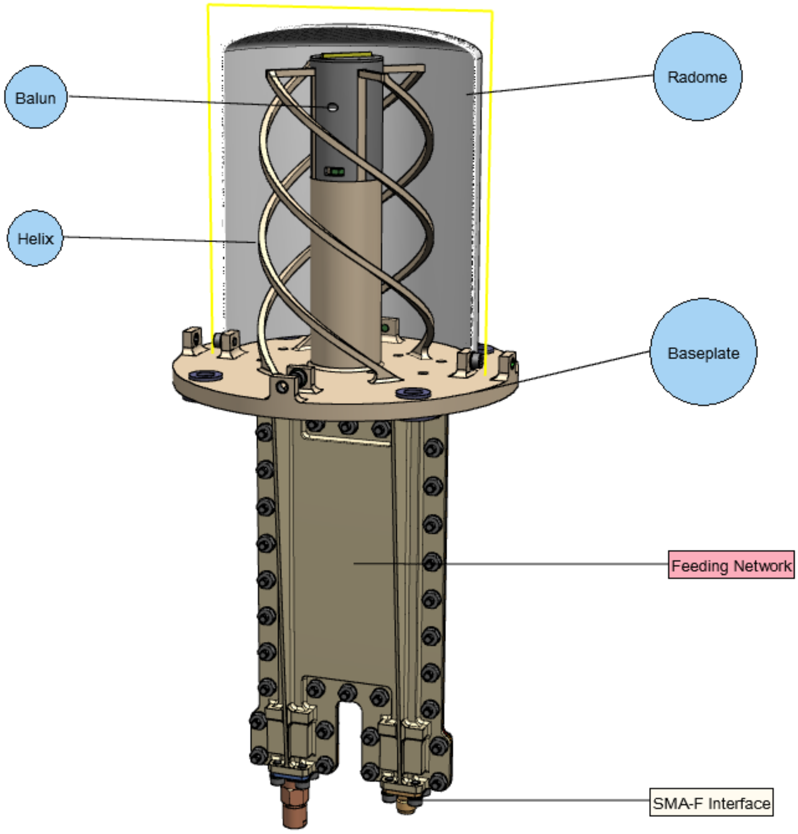
3. ACRONYMS

ACRONYM	
AD	Applicable Document
AR	Axial Ratio
BB	BreadBoard
CoG	Center Of Gravity
CTE	Coefficient of Thermal Expansion
DC	Direct Current
EM	Engineering Model
EQM	Engineering Qualification Model
ESA	European Space Agency
FM	Flight Model
I/F	InterFace
ICD	Interface Control Drawing
LGA	Low Gain Antenna
LHCP	Left Hand Circular Polarization
N.A.	Not Applicable
NC	Non Compliant
NCR	Non-Conformance Report
PFM	ProtoFlight Model
RF	Radio Frequency
RFD	Request For Deviation
RHCP	Right Hand Circular Polarization
RMS	Root Mean Square
S/N	Serial Number
SET	Single Event Transient
SMA	SubMiniature version A (Connector)
SOC	Statement Of Compliance
TVC	Thermal Vacuum Chamber
VSWR	Voltage Standing Wave Ratio

4. ANTENNA TECHNICAL DESIGN

The S-Band antenna is composed mainly of the following parts:

- Resonant Quadrifilar Helix Radiator (Helix, Balun & feed)
- Antenna Ground Plane (Baseplate)
- Feeding network
- Radome



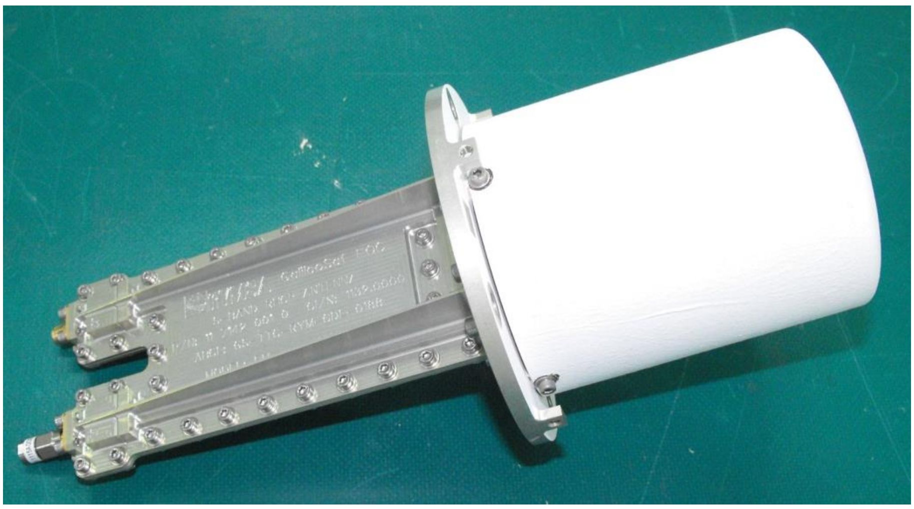


Figure 1 – S-Band antenna overview

Each of the previous parts will be described in detail in this document.

Both simulations and measurements presented in this document include the total antenna loss budget.

Also a frequency shifting, equivalent to temperature operating range influence is taken into account based on the CTE of Aluminum and on heritage programs. This effect is included in the following antenna results by an increasing the frequency bandwidth to comply with the specifications. So ±5.5 MHz will be added to the operation bandwidth.

4.1 RESONANT QUADRIFILAR HELICAL RADIATOR

The current resonant quadrifilar helical antenna consists of four elements (wires) wound in the form of a helix around a support and balun structure. The assembly is mounted over a Ground Plane (see Figure 2).

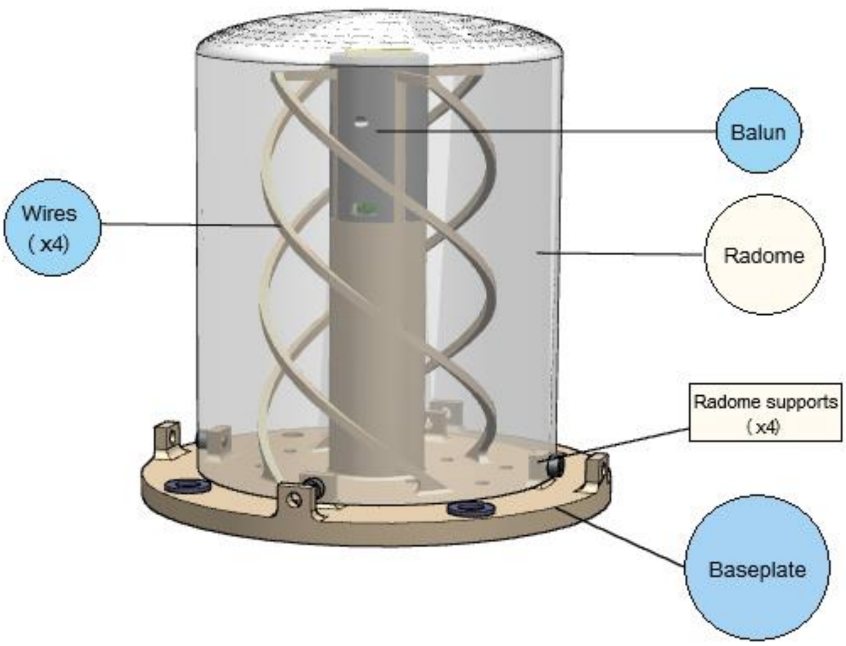


Figure 2 – Quadrifilar Helical antenna

The wires winding sense and the feeding network phase-shift guarantees a **RHCP polarization** in the S-Band antenna.

The feed network is connected to the four antenna wires by means of four radial wires allocated at the top part of the antenna.

Each wire of the antenna has a square section of a convenient size defined by design.

The four antenna wires, the balun mast and the ground plane are manufactured in single Aluminum piece to stiffen the antenna.

At the feeding region (top part of the antenna), opposite elements are fed with a phase shift of 180º to produce two independent bifilar helices. The bifilar helices are fed with a phase shift of 90º to form a quadrifilar antenna. In this way, each antenna wire has a phase shift of 90º with respect to the next wire.

5. ELECTRICAL TEST

5.1 INITIAL ELECTRICAL TEST

5.1.1 Initial Laboratory Test

S-BAND HELIX ANTENNA EQM S/N: 001 was electrically tested before vibration test.

The polarization sense has been checked by means of two helix antennas (LHCP & RHCP) following the AD-4. This test showed that the polarization sense is RHCP as it is specified

Following tests was performed by means of Automatic Network Analyser:

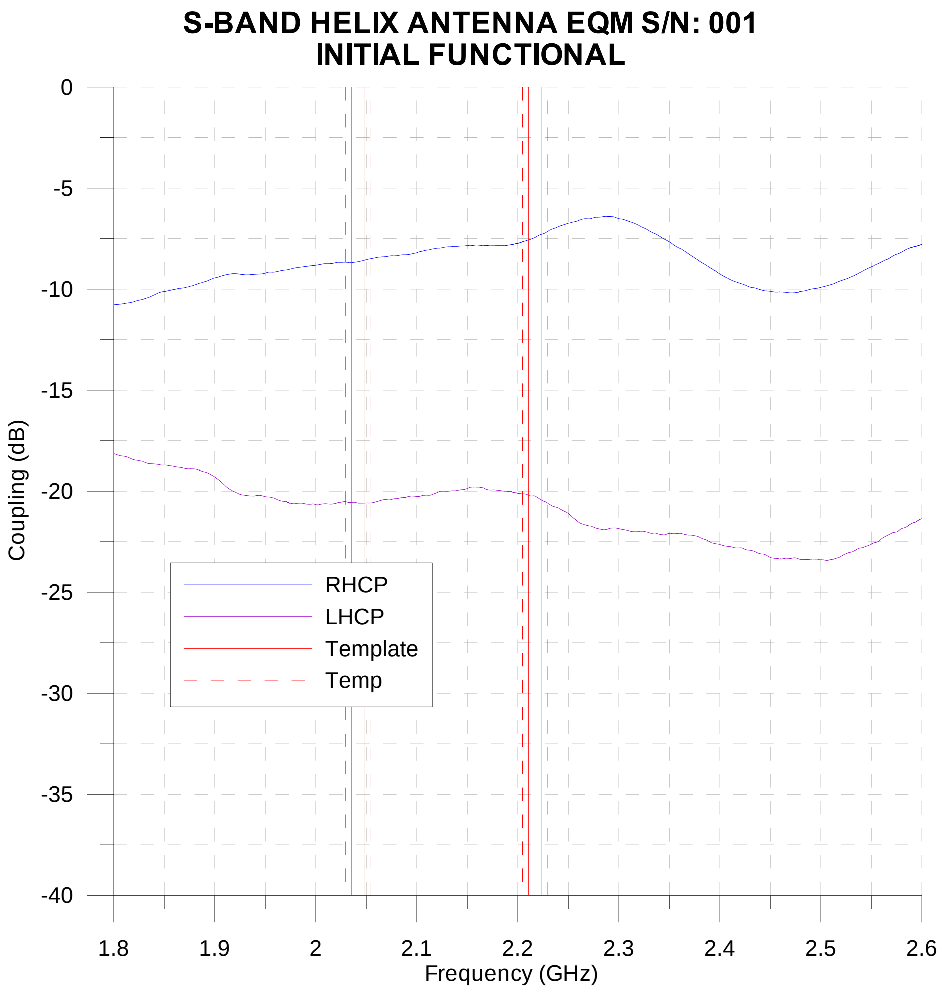


Figure 3 – Polarization. Initial Functional

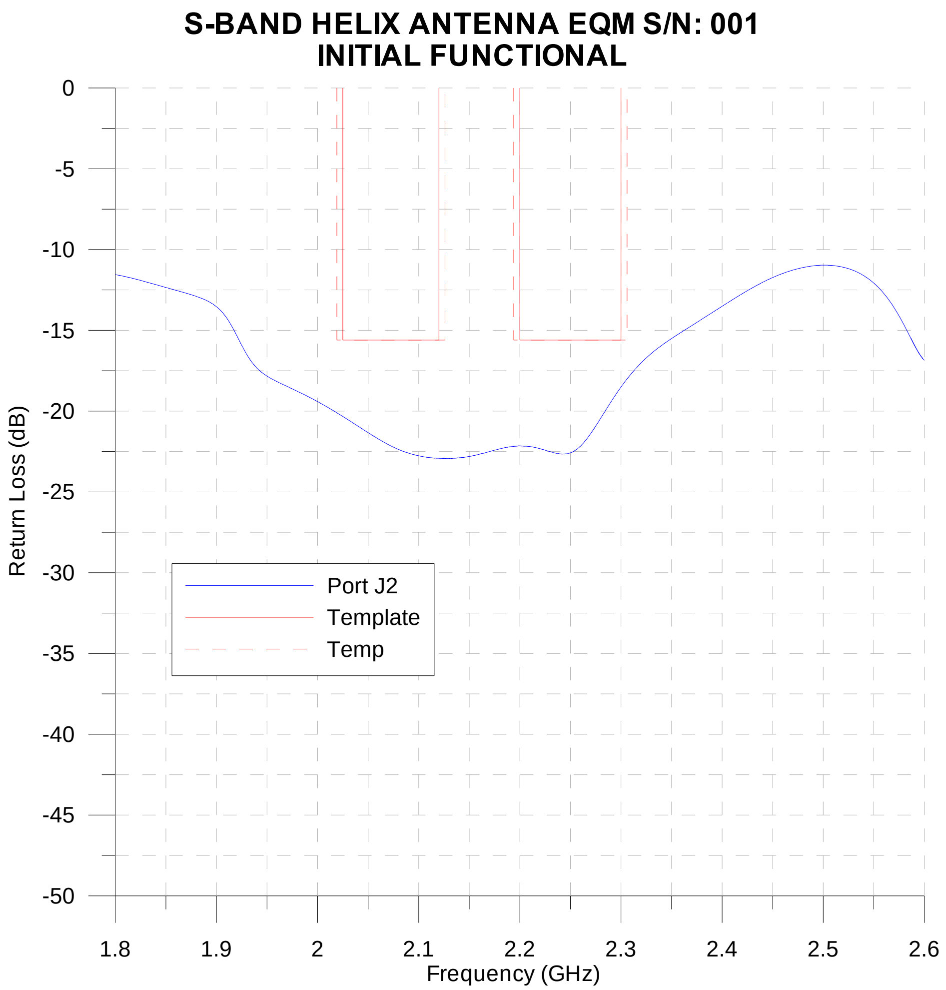


Figure 4 – Return Loss. Initial Functional

5.1.2 Initial Radiation Test

A radiation electrical test has been performed over the antenna at Initial Test.

An Anechoic Chamber at TRYO Aerospace is used for antenna testing of radiation performances (AD-5).

The radiation performances are measured at the frequencies 2.0355941GHz, 2.0477491GHz, 2.2106GHz and 2.2238GHz and those are:

- On Axis Copolar Antenna Gain.

By comparison of the signal levels between AUT and a Standard Horn, the Gain of the AUT is obtained at the operating frequency band

- Antenna Patterns (Copolar and Xpolar).

The radiation patterns are recorded and normalized to the antenna Gain. The patterns are measured in constant φ and θ cuts.

The templates used are the ones expected for the antenna heritage (according to RFD: P3-RY-RFD-004). The values expected for the Additive Manufacturing antenna could be seen in the correspondent plots of AD-08 (paragraph 4.3.3).

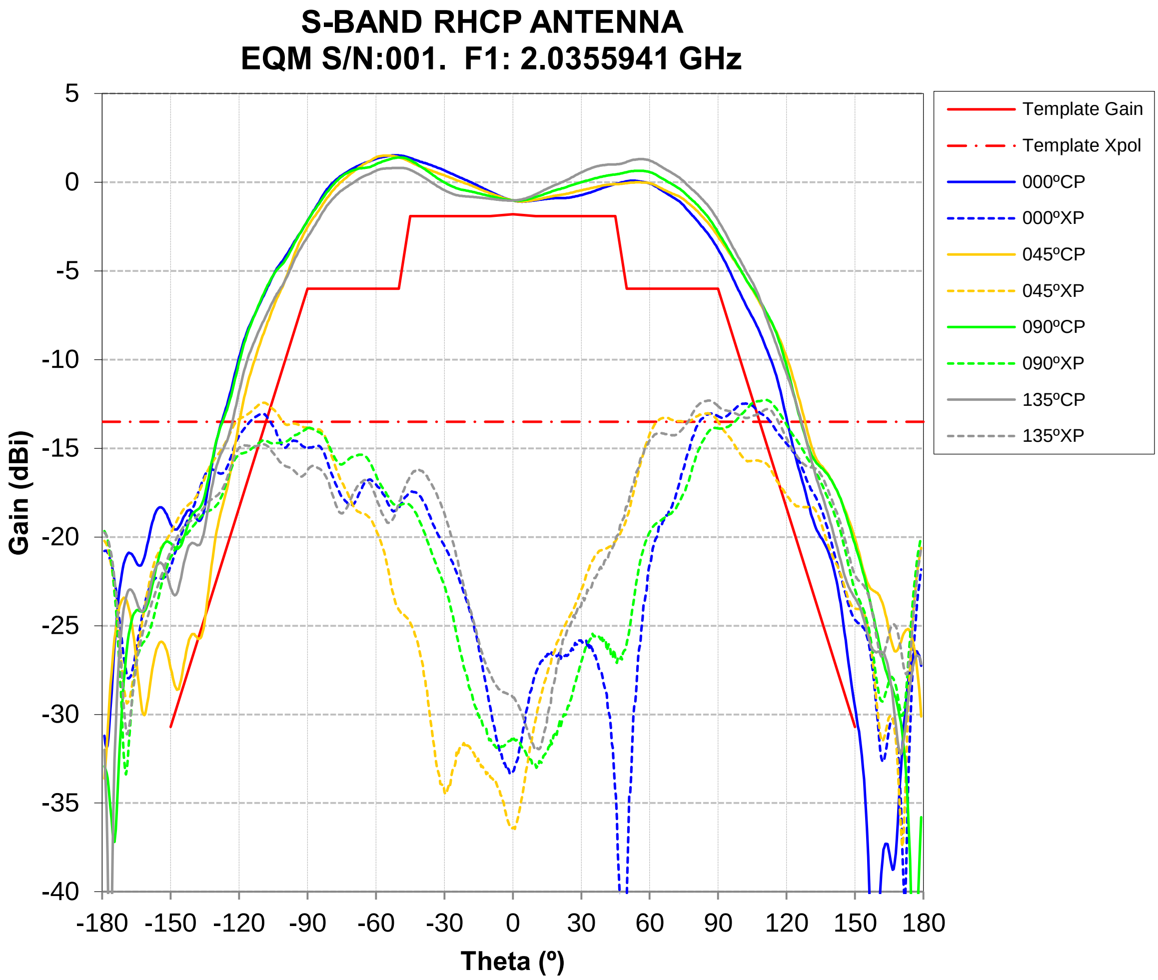


Figure 5 – Copolar and crosspolar patterns in constant phi-cuts. F1: 2.0355941GHz. Initial Functional.

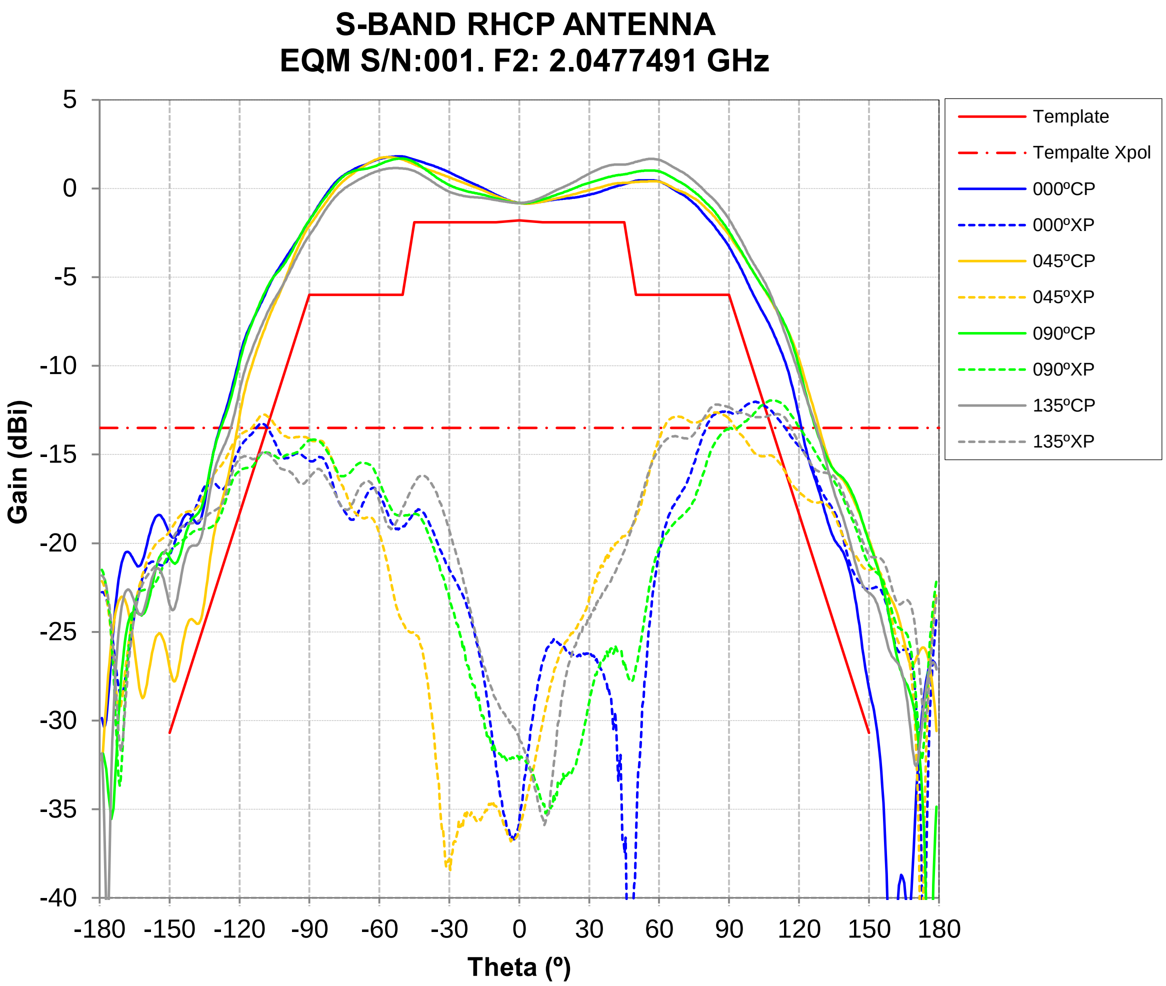


Figure 6 – Copolar and crosspolar patterns in constant phi-cuts. F2: 2.0477491GHz. Initial Functional.

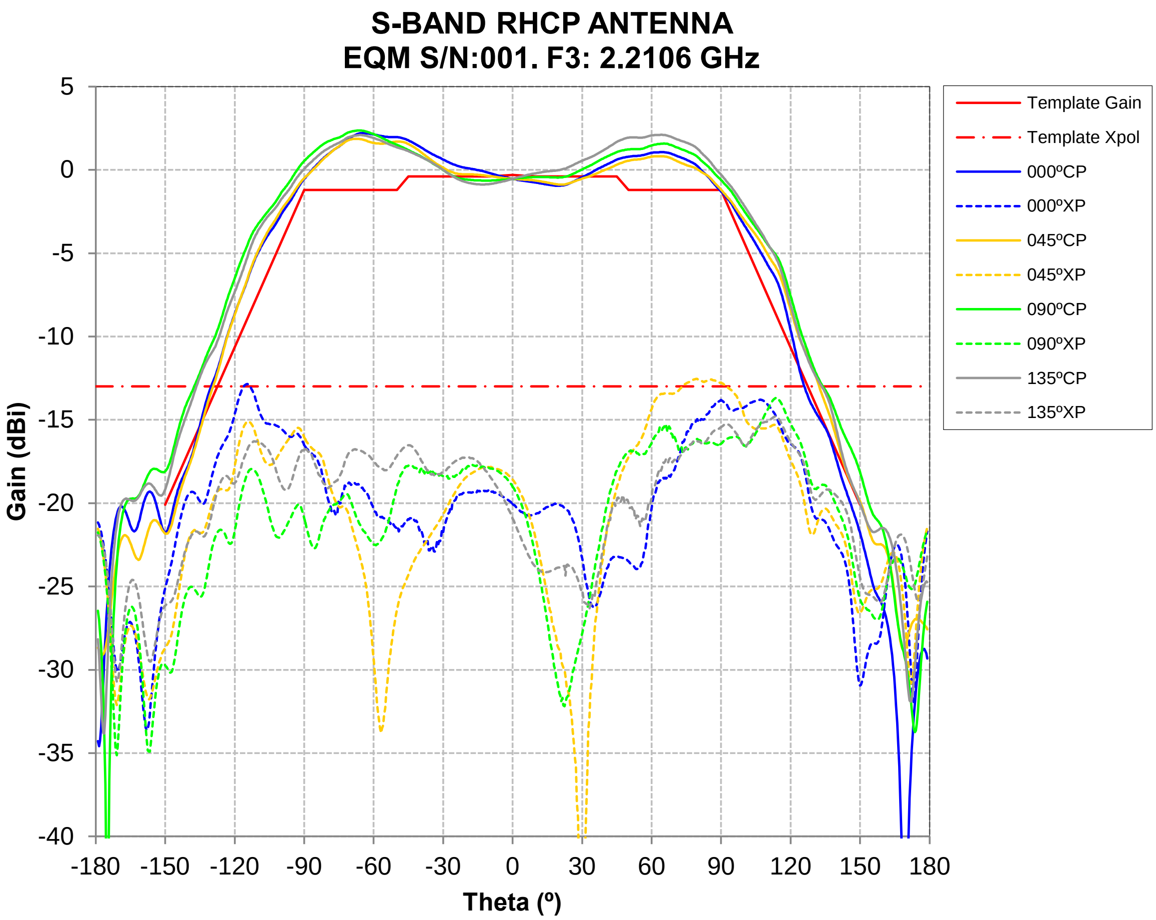


Figure 7 – Copolar and crosspolar patterns in constant phi-cuts. F3: 2.2106GHz. Initial Functional.

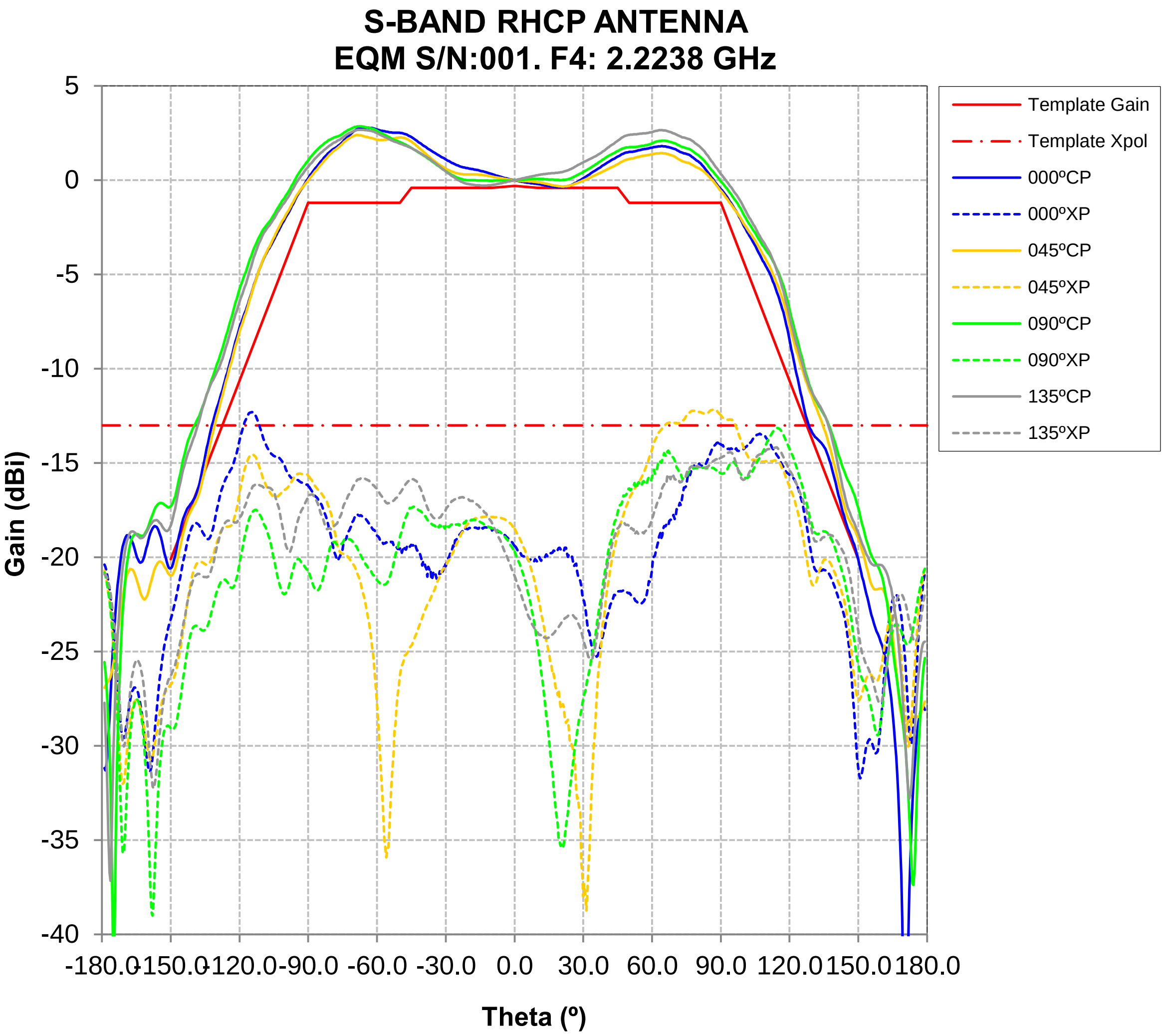


Figure 8 – Copolar and crosspolar patterns in constant phi-cuts. F4: 2.2238GHz. Initial Functional.

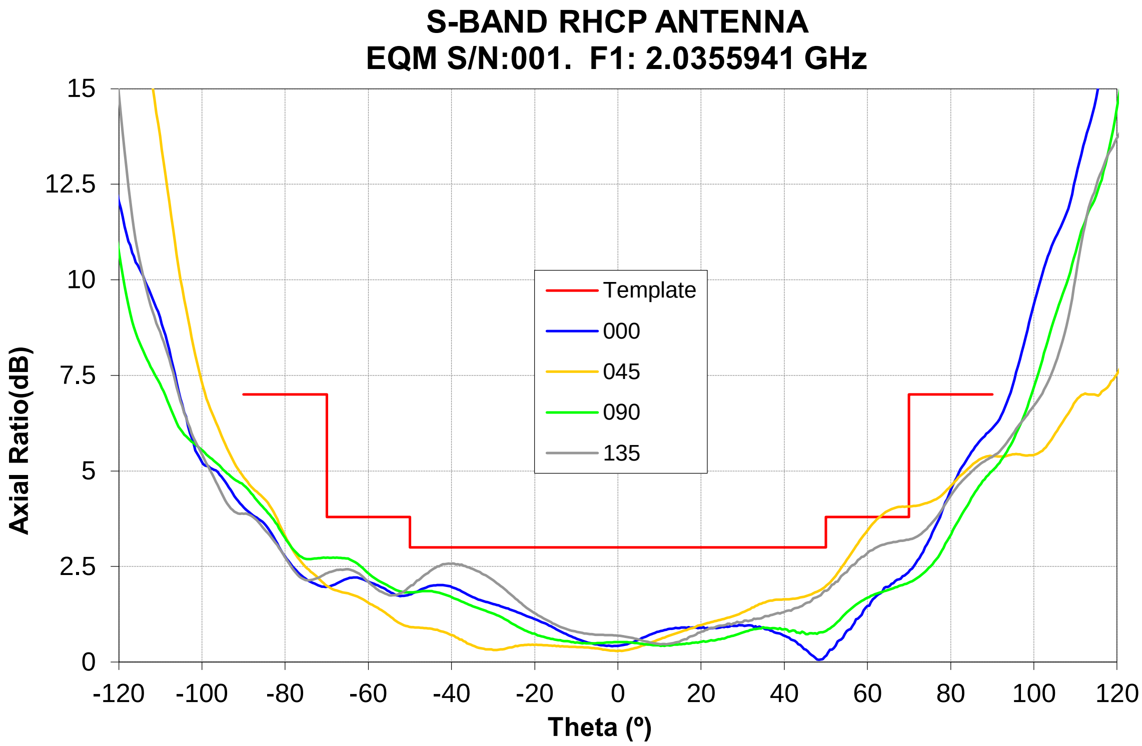


Figure 9 - Axial Ratio in constant phi-cuts. F1: 2.0355941GHz. Initial Functional.

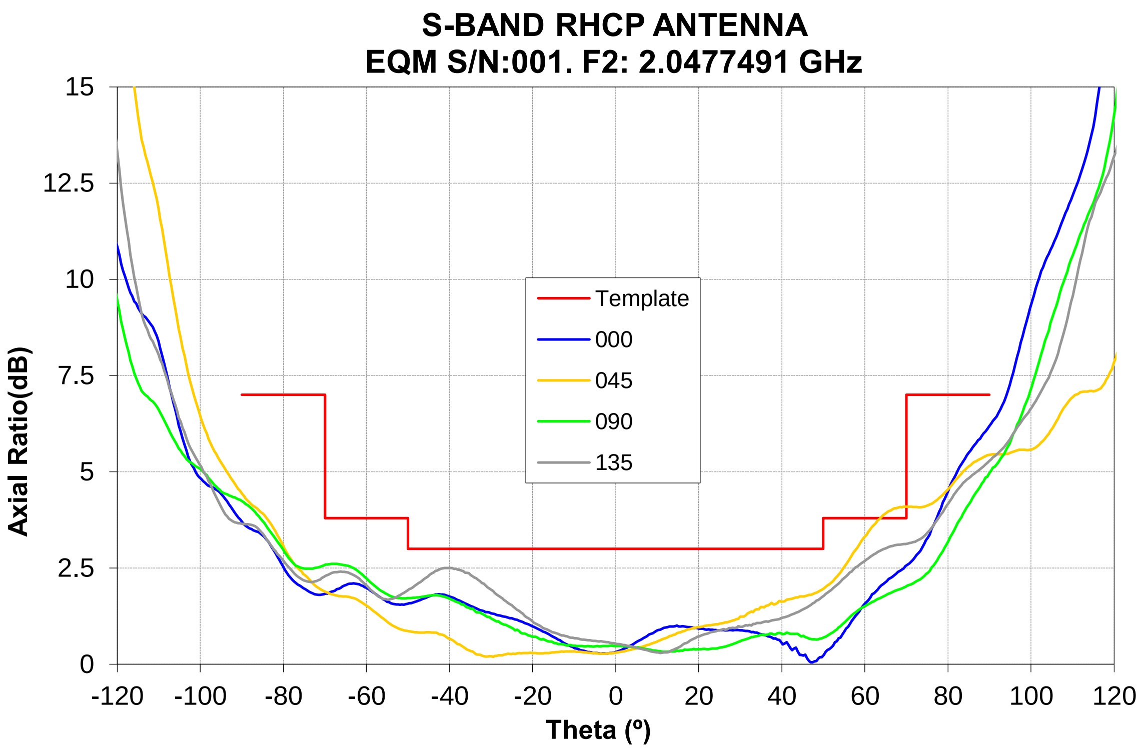


Figure 10 - Axial Ratio in constant phi-cuts. F2: 2.0477491GHz. Initial Functional.

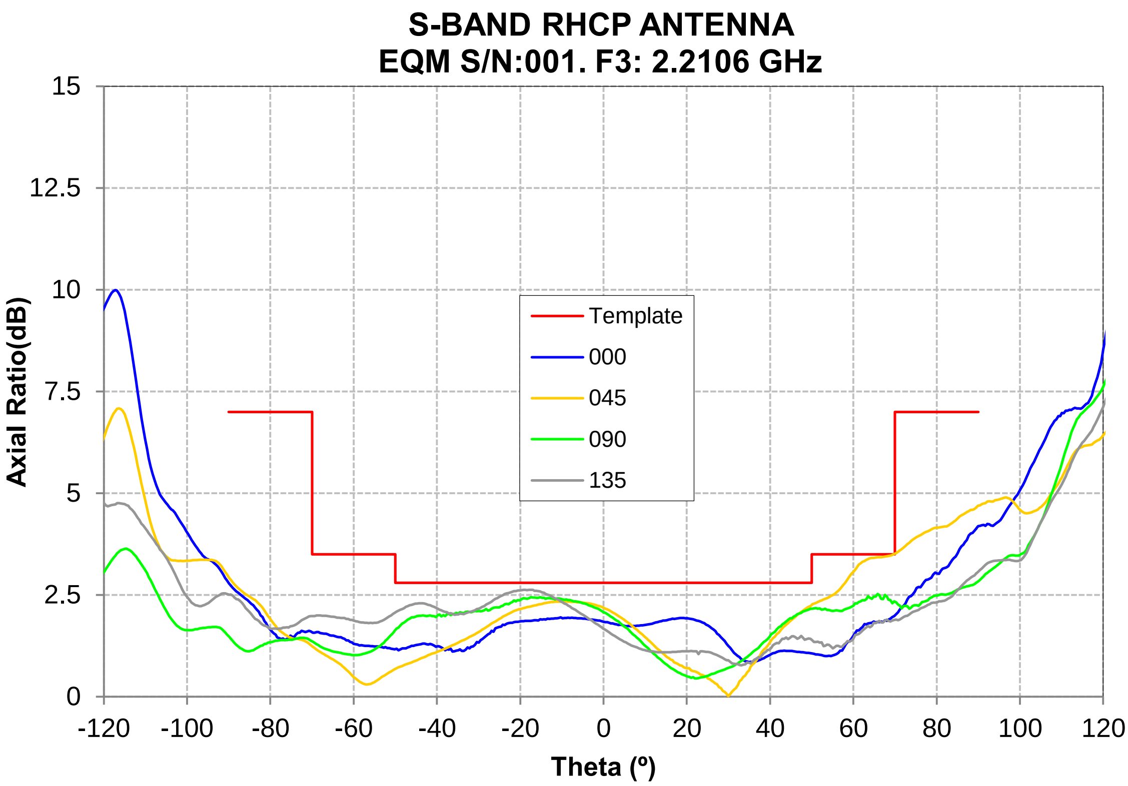


Figure 11 - Axial Ratio in constant phi-cuts. F3: 2.2106GHz. Initial Functional.

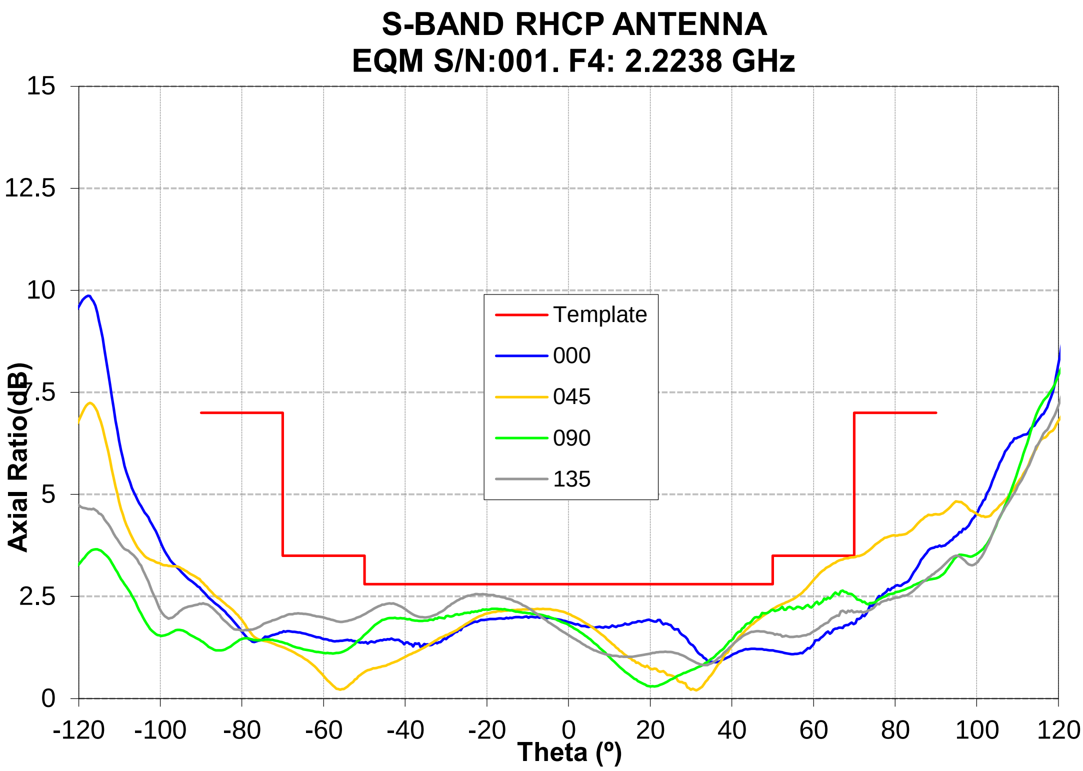


Figure 12 - Axial Ratio in constant phi-cuts. F4: 2.2238GHz. Initial Functional.

5.2 POST VIBRATION TEST

After the vibration test, the S-BAND HELIX ANTENNA EQM S/N: 001 was tested to verify its integrity.

Following tests was performed by means of Automatic Network Analyser:

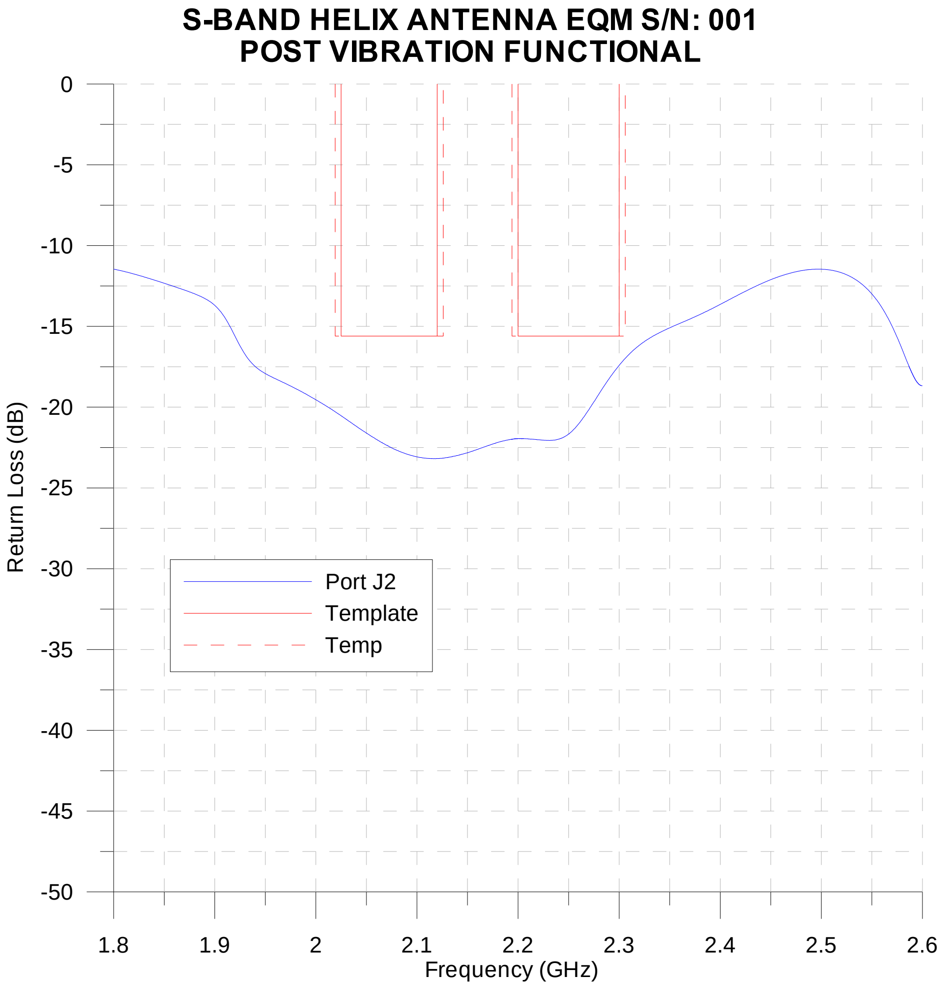


Figure 13 - Return Loss. Post Vibration Functional

5.3 POST SHOCK TEST

After the shock test, the S-BAND HELIX ANTENNA EQM S/N: 001 was tested to verify its integrity.

Following tests was performed by means of Automatic Network Analyser:

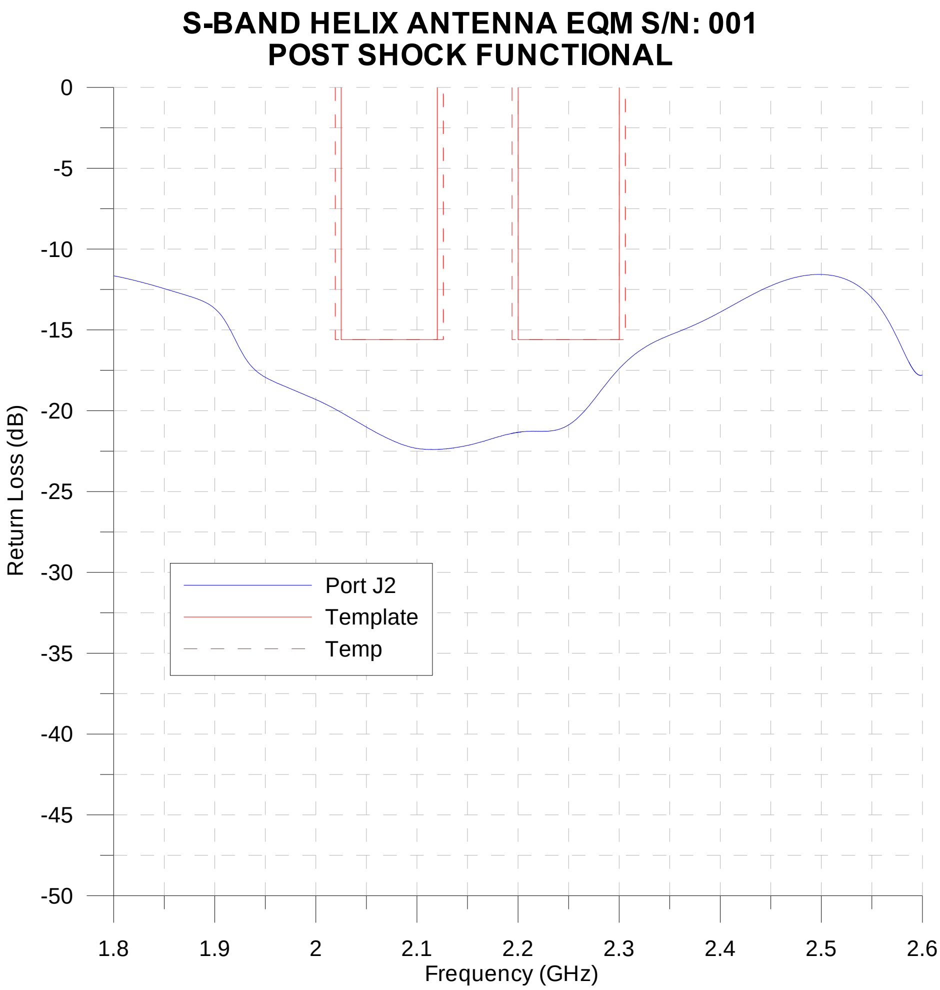


Figure 14 - Return Loss. Post Shock Functional

5.4 RF MEASUREMENTS UNDER THERMAL CONDITIONS

To carry out measurements at thermal chamber it is necessary to mount a very complicated set up. This produces a lot of reflections and losses in cables and connectors. In order to avoid these effects a time windowing is performed to carry out the measurements.

This time windowing produces a distortion in the measurement with respect to the ones obtained at laboratory conditions. Therefore, a variation between laboratory and TVC electrical measurements can be detected.

The information required from this test is the relative variation between hot and cold measurement and ambient one in order to obtain the minimum margin required by the equipment electrical parameters (measured at ambient conditions) to fulfil the specification at extreme conditions.

The results are shown in the following plot:

a) MEASUREMENTS

The temperature calibration procedure, as well as other factors corresponding to measurements, is detailed in AD-5.

The electrical parameter measured during the thermal test is the return loss at the interface port.

This parameter has been checked at the initial ambient conditions, at last cycle for both the hot and cold equilibriums and at the final ambient conditions.

The results are shown in following figure:

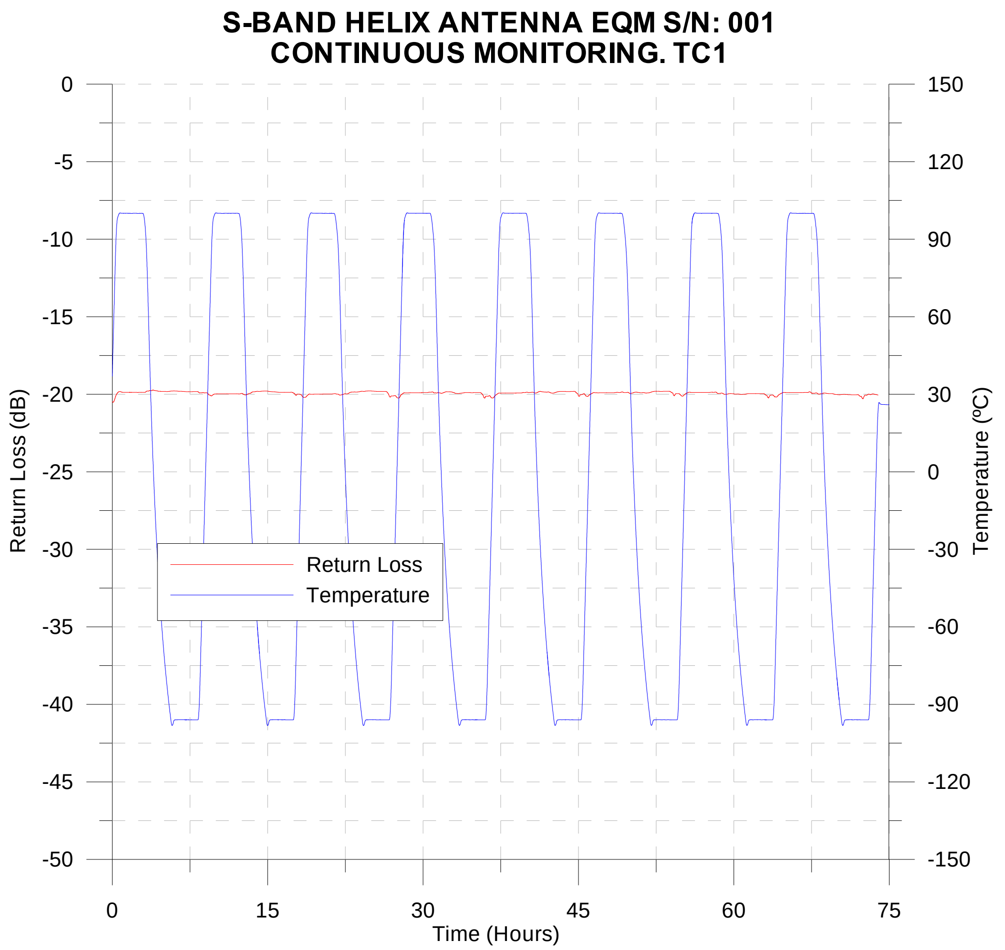


Figure 15 – Return Loss. TC1. Continuous Monitoring. Thermal Chamber Functional

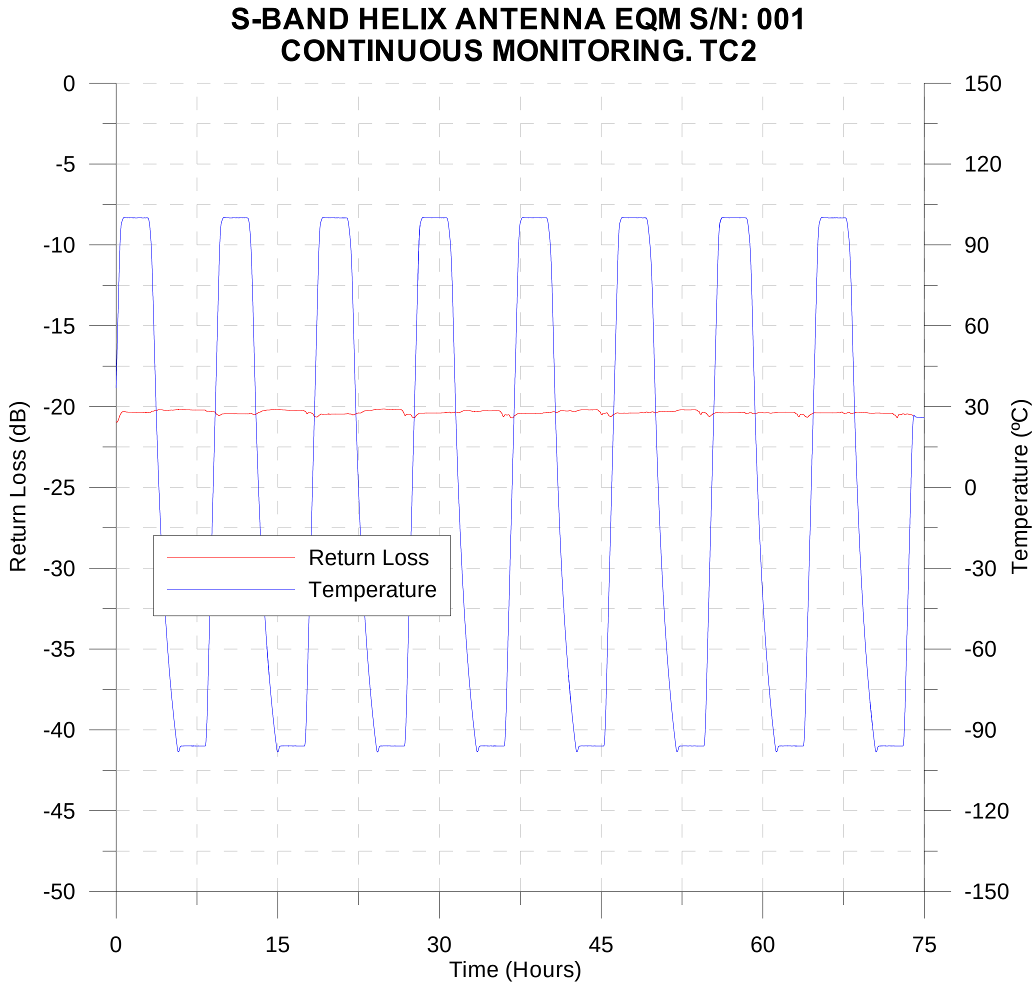


Figure 16 – Return Loss. TC2. Continuous Monitoring. Thermal Chamber Functional

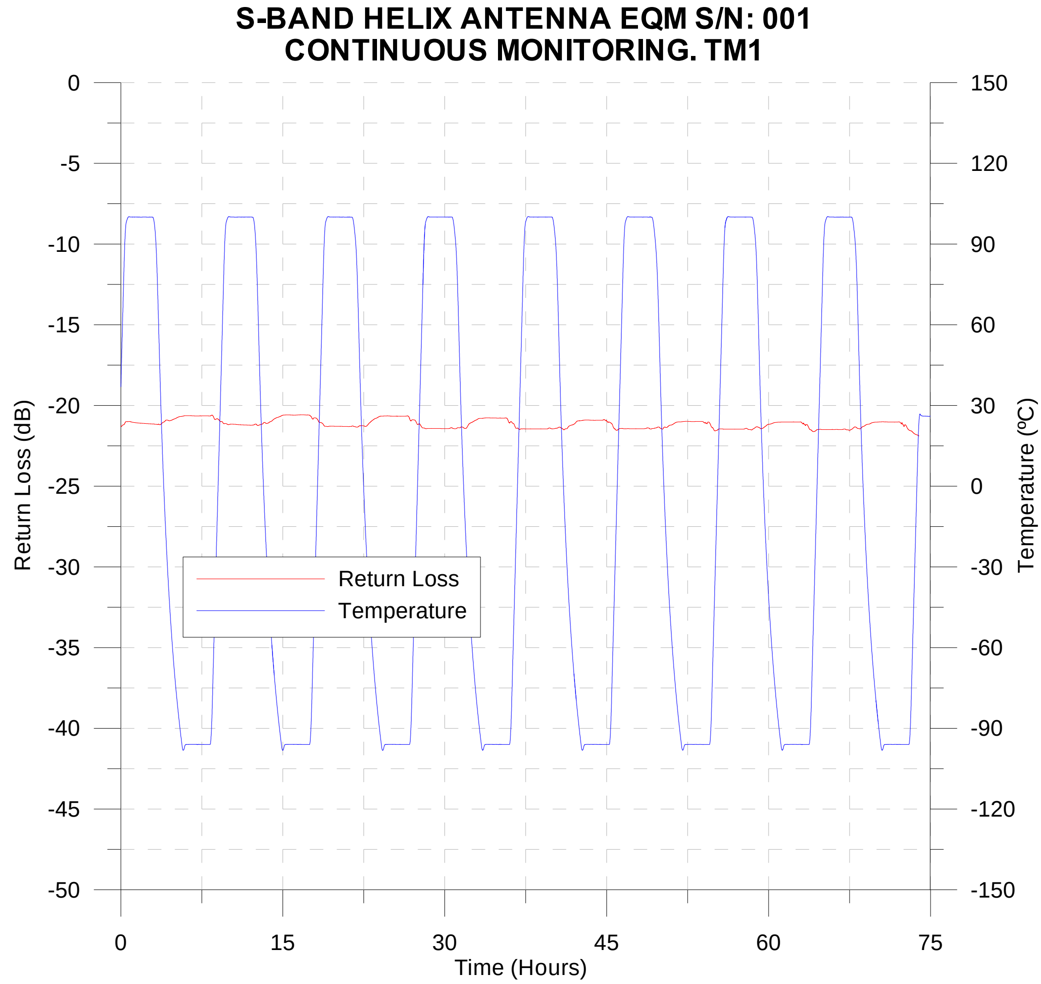


Figure 17 – Return Loss. TM1. Continuous Monitoring. Thermal Chamber Functional

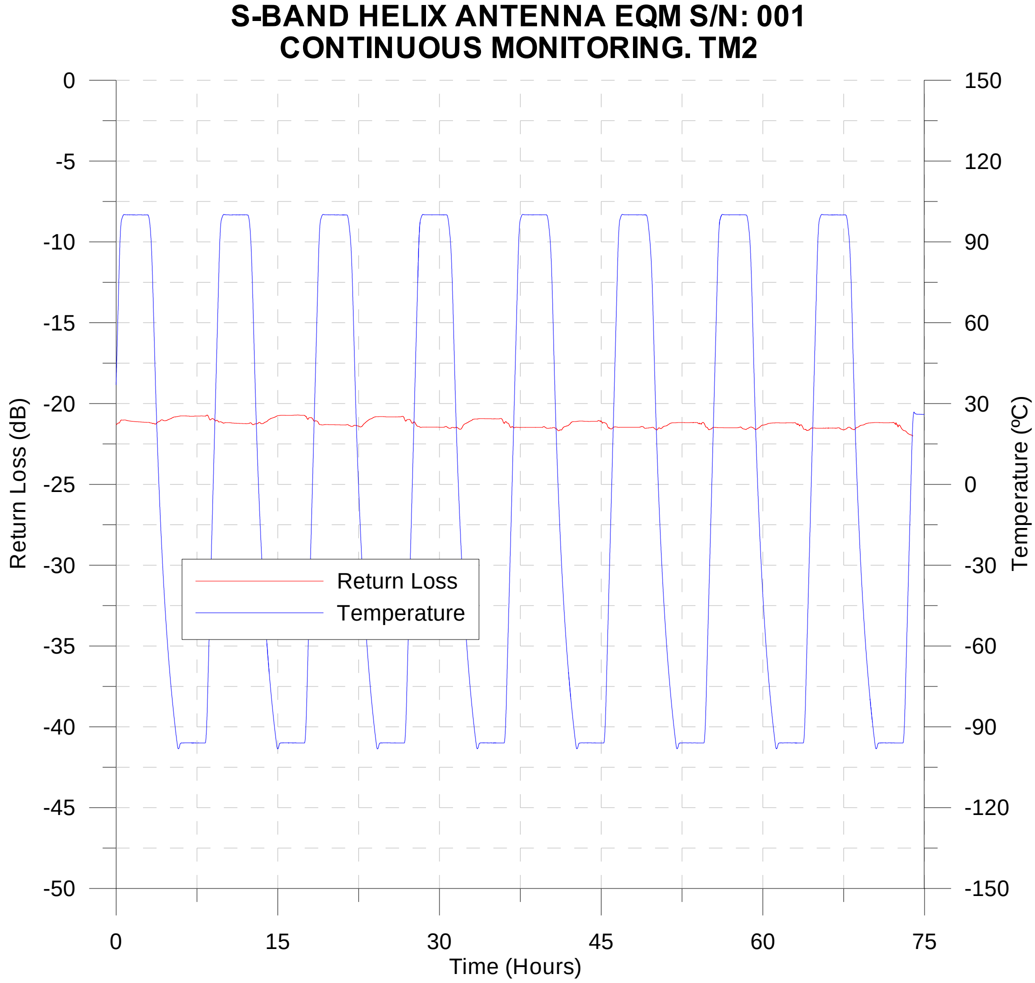


Figure 18 – Return Loss. TM2. Continuous Monitoring. Thermal Chamber Functional

b) ANALYSIS OF RESULTS

To perform the calibration of these measurements the following data process is used (see AD-1).

- MCAL = MNA / MSH reflection

Where:

- MCAL = Calibrated measurement
- MNA = D.U.T. measurement from N.A.
- MSH = Short measurement

In this way, we correct the cable and connector losses with the short measurement. To reduce the impact of the setup on the measurements in the TVC a post-processing has been done, it allows comparing the measurements from the chamber and the measurements at laboratory conditions in absolute values.

Once the test has been performed, the first step is to consider the laboratory measurement performed just before the test as a reference, indeed any discrepancy between the Initial ambient measurement inside the TVC and the measurement in the laboratory is due to the test setup (cables, connectors, transitions, chamber…)

Then the difference in magnitude between the TVC initial ambient measurements and the hot/cold cases is calculated and applied to the reference laboratory measurement. Taking into account that the order of magnitude of the laboratory measurements and TVC measurements are the same, similar variations in magnitude are expected.

5.5 FINAL ELECTRICAL TEST

5.5.1 4.5.1.- Final Laboratory Test

S-BAND HELIX ANTENNA EQM S/N: 001 was electrically tested after environmental test. Following results was obtained by means of Automatic Network Analyser.

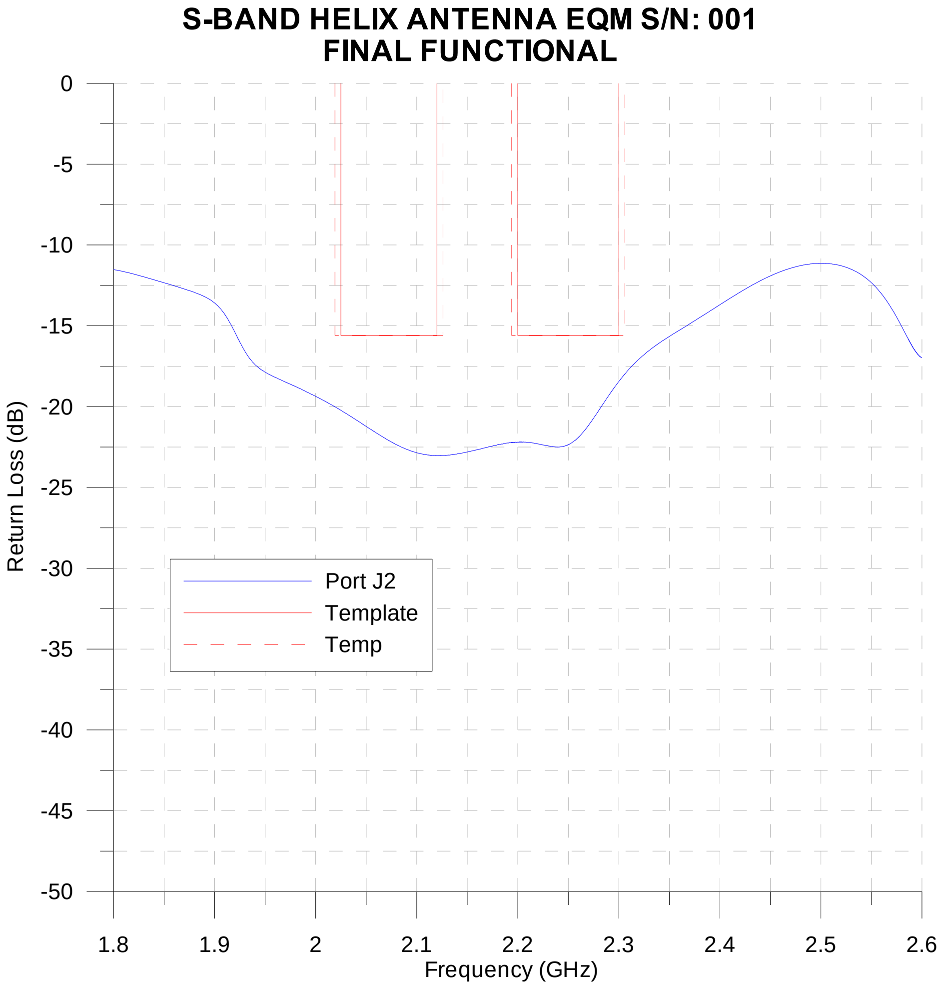


Figure 19 - Return Loss. Final Functional

5.5.3 4.5.2.- Final Radiation Test

A radiation electrical test has been performed over the antenna at Final Test.

An Anechoic Chamber at TRYO Aerospace is used for antenna testing of radiation performances (AD-5).

The radiation performances are measured at the frequencies 2.0355941GHz, 2.0477491GHz, 2.2106GHz and 2.2238GHz and those are:

- On Axis Copolar Antenna Gain.

By comparison of the signal levels between AUT and a Standard Horn, the Gain of the AUT is obtained at the operating frequency band

- Antenna Patterns (Copolar and Xpolar).

The radiation patterns are recorded and normalized to the antenna Gain. The patterns are measured in constant φ and θ cuts.

The templates used are the ones expected for the antenna heritage (according to RFD: P3-RY-RFD-004). The values expected for the Additive Manufacturing antenna could be seen in the correspondent plots of AD-08 (paragraph 4.3.3).

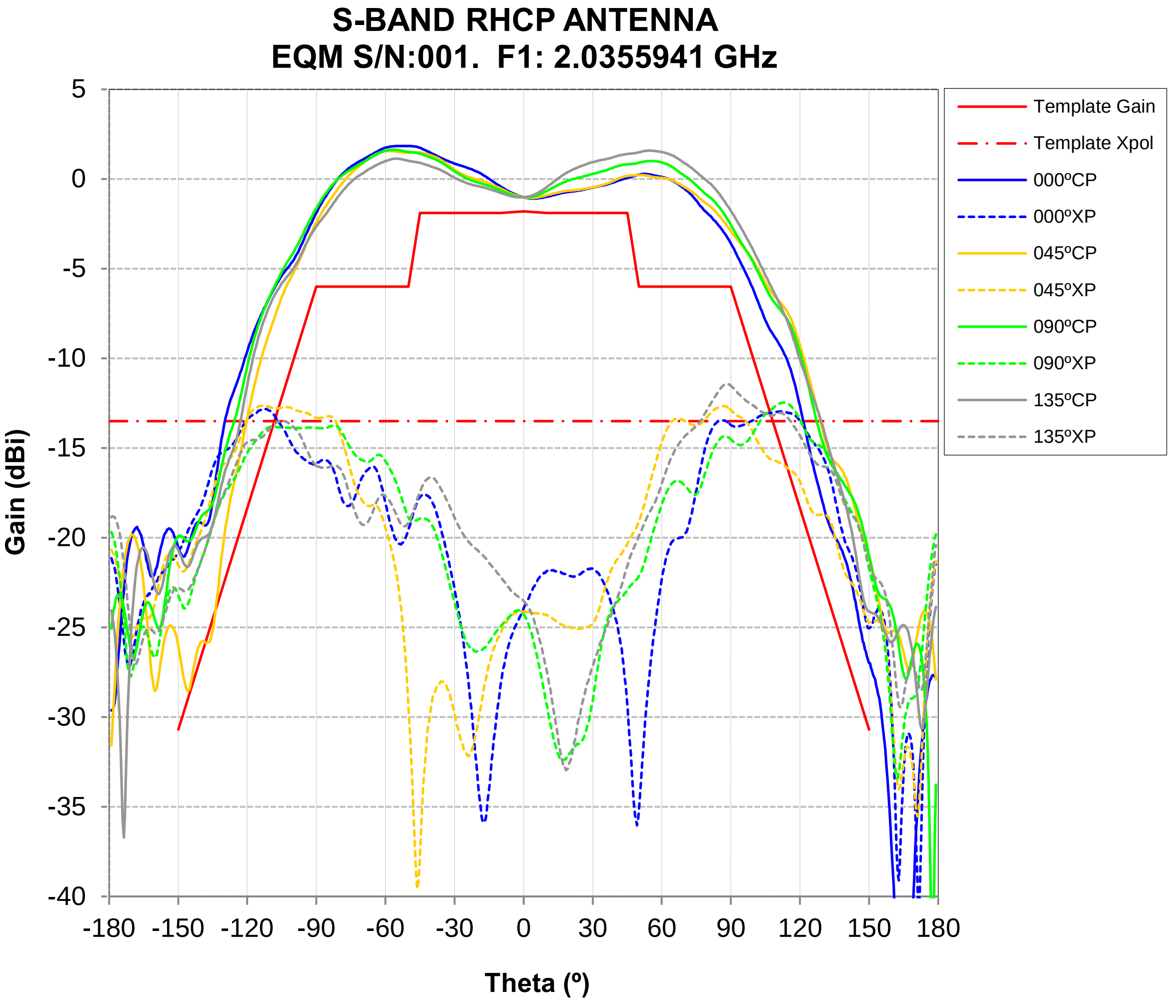


Figure 20 - Copolar and crosspolar patterns in constant phi-cuts. F1: 2.0355941GHz. Final Functional.

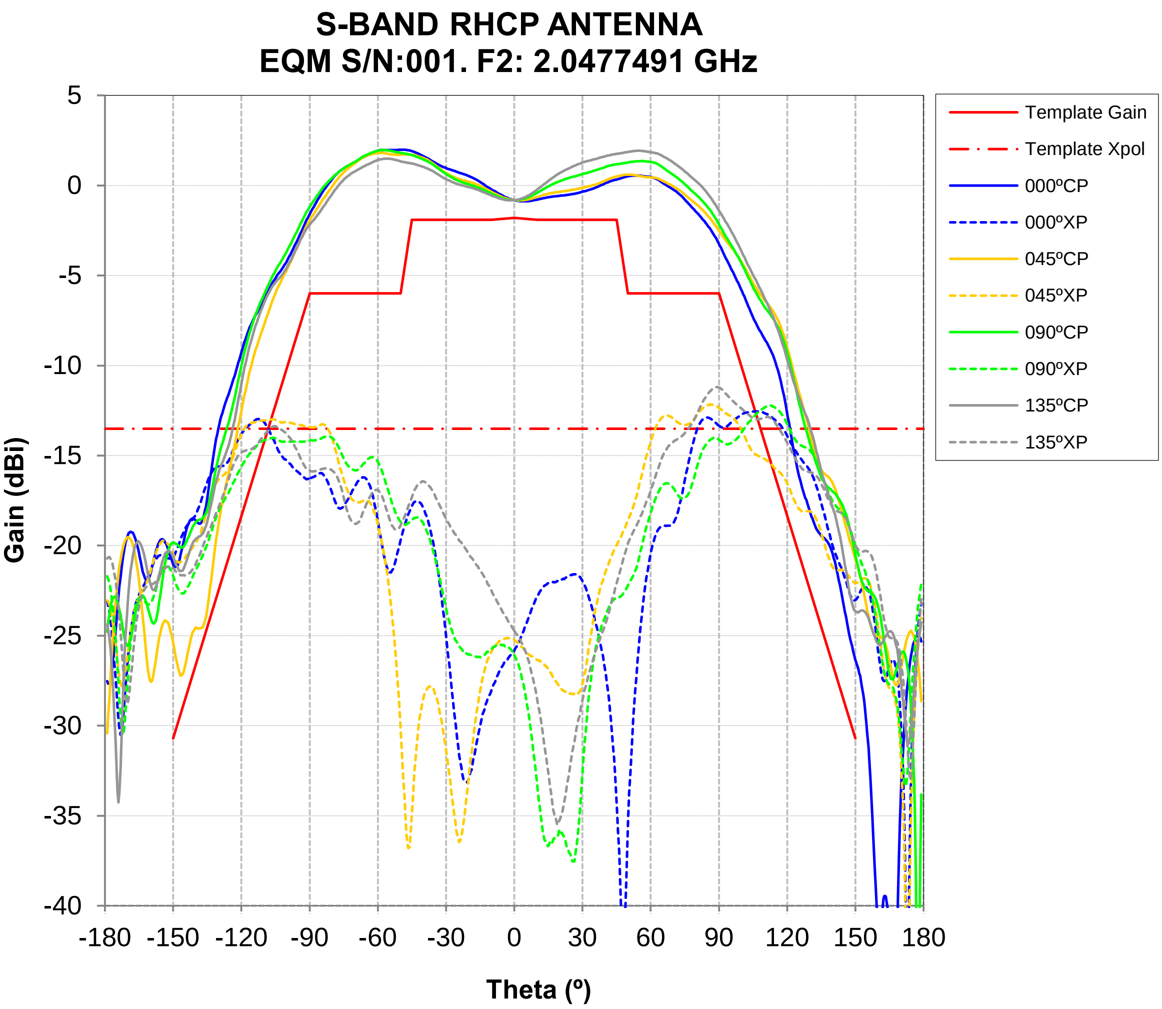


Figure 21 - Copolar and crosspolar patterns in constant phi-cuts. F2: 2.0477491GHz. Final Functional.

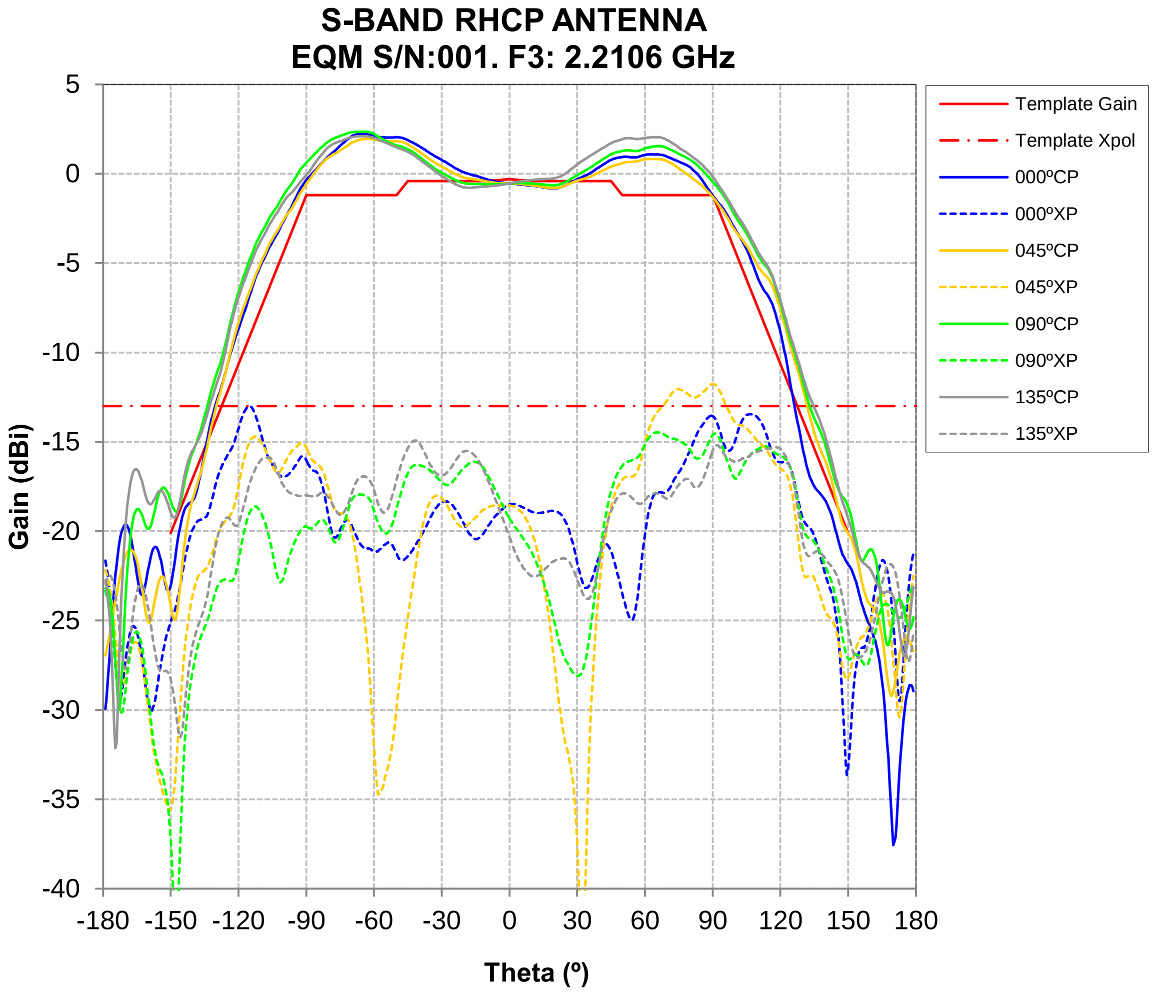


Figure 22 - Copolar and crosspolar patterns in constant phi-cuts. F3: 2.2106GHz. Final Functional.

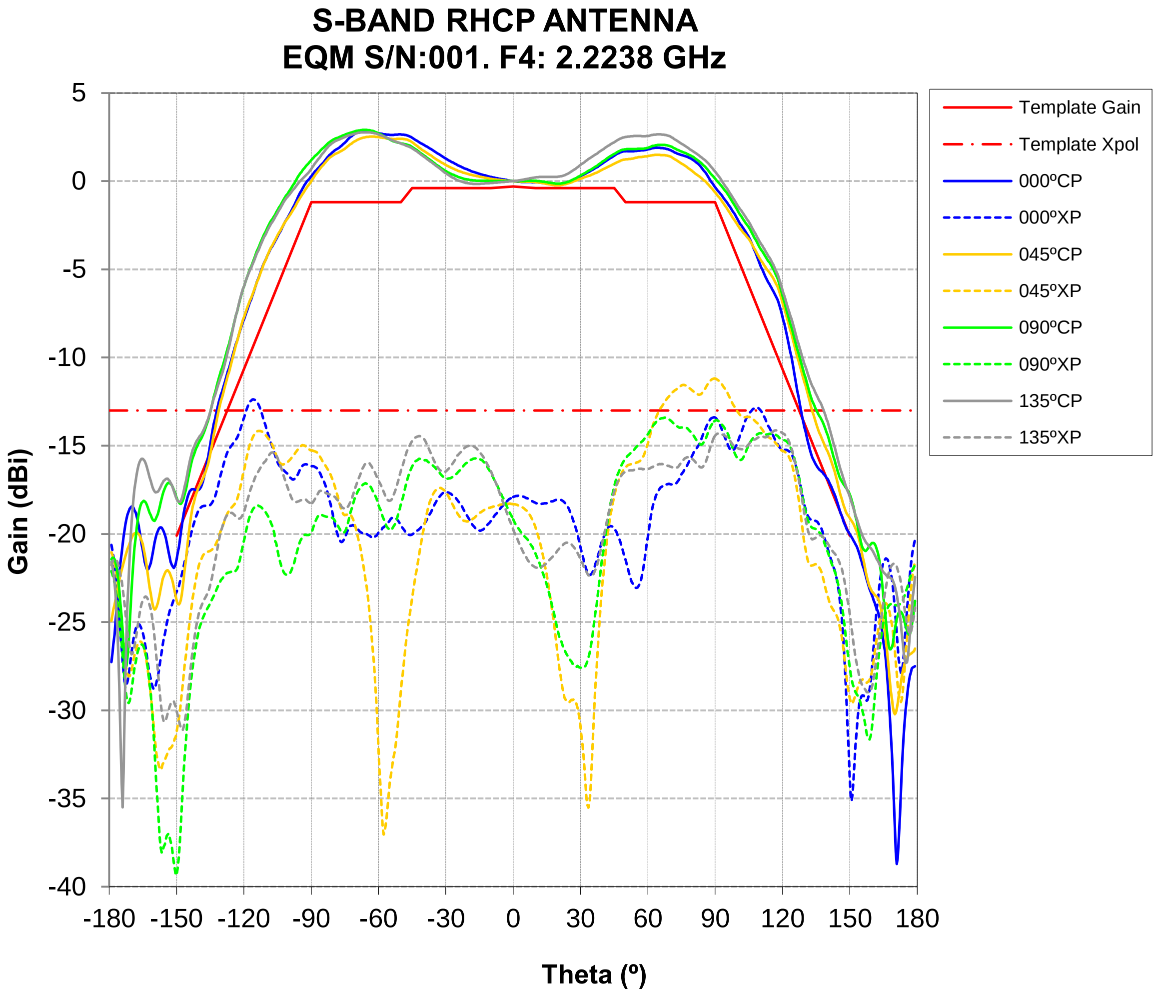


Figure 23 - Copolar and crosspolar patterns in constant phi-cuts. F4: 2.2238GHz. Final Functional.

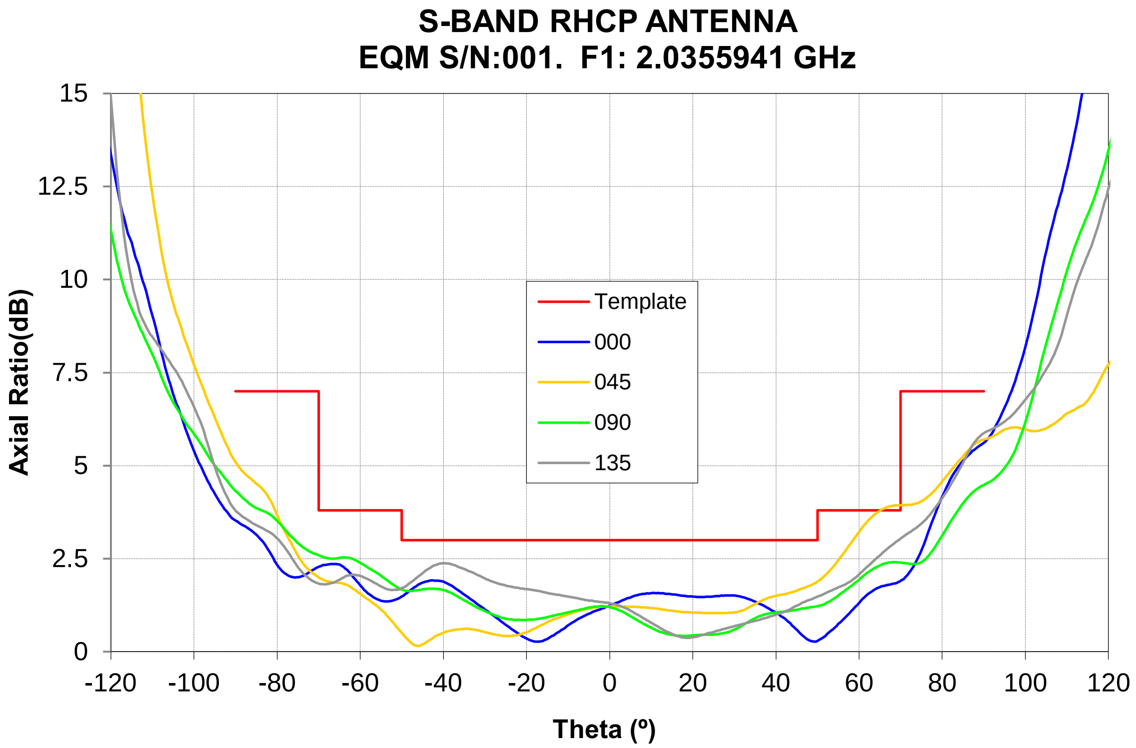


Figure 24 - Axial Ratio in constant phi-cuts. F1: 2.0355941GHz. Final Functional.

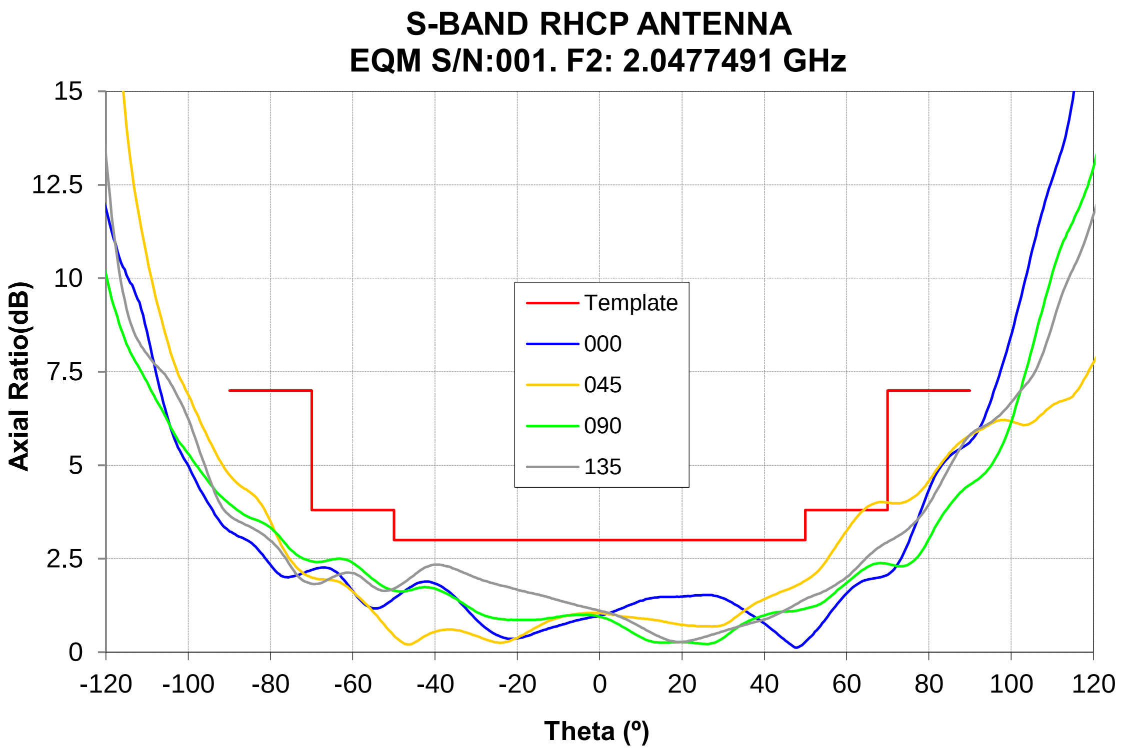


Figure 25 - Axial Ratio in constant phi-cuts. F2: 2.0477491GHz. Final Functional.

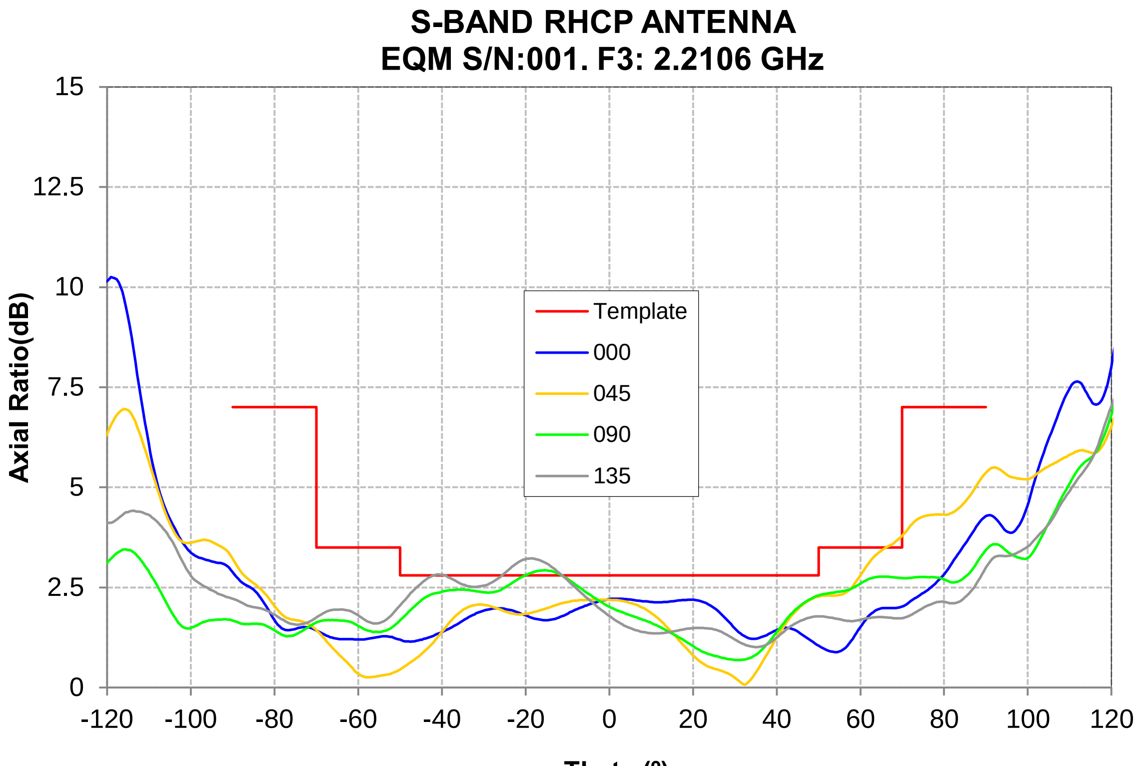


Figure 26 - Axial Ratio in constant phi-cuts. F3: 2.2106GHz. Final Functional.

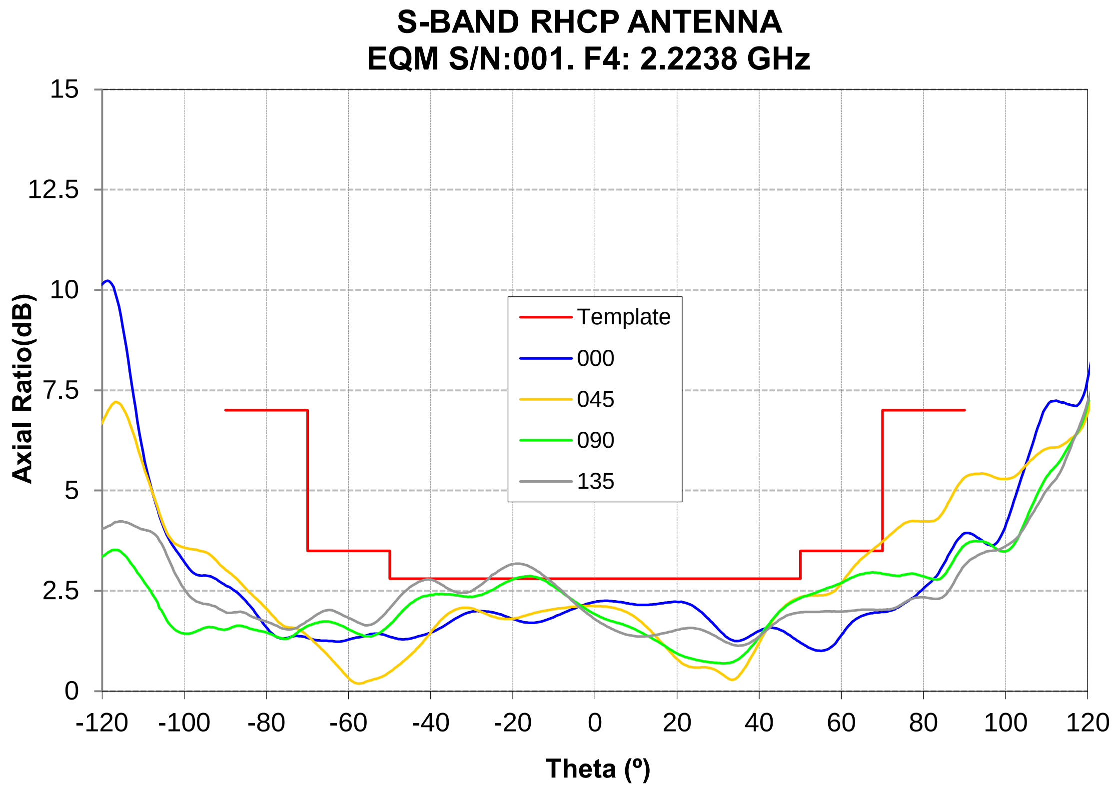


Figure 27 - Axial Ratio in constant phi-cuts. F4: 2.2238GHz. Final Functional.

5.6 DC RESISTANCE MEASUREMENTS

After assembly, we check with a miliohmeter the DC Resistance values between different points.

Results are as follows:

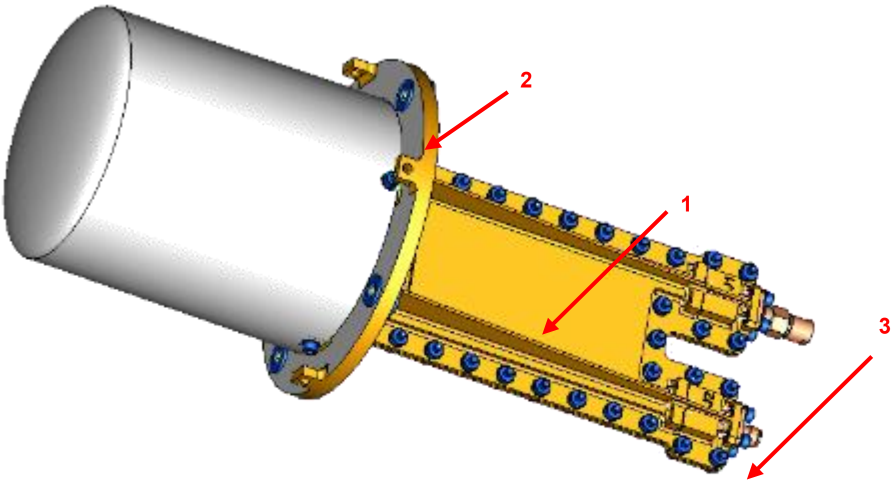


Figure 28 – DC Resistance Measurement points.

DC RESISTANCE TEST RESULTS		
MEASUREMENT POINTS	WORST OBTAINED VALUE	SPECIFICATION
1-2	0.14 mΩ	< 10 mΩ
2-3	0.89 mΩ	

Table 1 – DC Resistance Measured Values

5.7 TEST EQUIPMENT STATUS

EQUIPMENT	MANUFACTURER	MODEL	IDENTIFICATION	CALIBRATED UP TO
NETWORK ANALYSER	AGILENT	N5230A	ES287	FEB 2018
SMA CALIBRATION KIT	KEYSIGHT	85052 D	ES407	APR 2018
MILLIOHMMETER	MEEGGER	BT51	ES086	NOV 2018
ANECHOIC CHAMBER 2	HP ORBIT	8530A, 8340A 8315A, AL-4103-23	ES347, RF010, ES003, ES348	JAN 2018

Table 2 - Equipment Status Calibration

6. VIBRATION TEST

6.1 VIBRATION TEST EQUIPMENT

VIBRATION TEST EQUIPMENT	
Shaker & Slip table	Model: Gearing & Watson V3534/DSA4-32K Sine force peak: 35585 N Random force rms: 35585 N Maximum velocity peak: 1.8 m/s Maximum acceleration peak: 120 g Maximum displacement: 50.1 mm
Amplifier	Model: DSA4
Signal conditioning & Data acquisition	Power supply model: KISTLER 5148 Accelerometers models: KISTLER 8704B500 KISTLER 8763A500 Data acquisition model: VXI – E1432A

6.2 TEST ITEM

The test item is the S-Band Helix Antenna EQM S/N: 001 defined in AD03 drawing.

6.3 VIBRATION TEST LEVELS

6.3.1 Modal Survey Test

Axis	Frequency (Hz)	Level (g)	Sweep rate
All	10-2000	0.5	2 oct./min One sweep up

6.3.2 Qualification Sine Vibration Level

EQM Sine level			
Axis	Frequency (Hz)	Level	Sweep rate
ALL	5-22 22-100	10 mm (0-pk) ±20 g	2 oct./min One sweep up

6.3.4 Qualification Random Vibration Level

EQM Random level ⊥ mounting plane		
Axis	**Frequency (Hz)**	**Level (g^2/Hz)**
Z	20	0.0024
	100	1.5
	500	1.5
	2000	0.0372
Overall Level: 32.31 g RMS		
Duration: 2.5 min/axis		
Alarm level: -0.5 dB / +2 dB Abort level: -1 dB / +3 dB		

EQM Random level // mounting plane		
Axis	**Frequency (Hz)**	**Level (g^2/Hz)**
X, Y	20	0.0024
	100	1.5
	300	1.5
	374	0.5
	500	0.5
	2000	0.0197
Overall Level: 27.09 g RMS		
Duration: 2.5 min/axis		
Alarm level: -0.5 dB / +2 dB Abort level: -1 dB / +3 dB		

6.4 ACCELEROMETERS LOCATION

During all test runs a total number of 1 measurement tri-axial accelerometer and 2 mono-axial control accelerometers were installed.

Those accelerometers were adhered, via kapton tape to avoid direct contact of the fixation cement with the surfaces of the equipment, to the test item/fixture at the measurements locations as show the following figures.

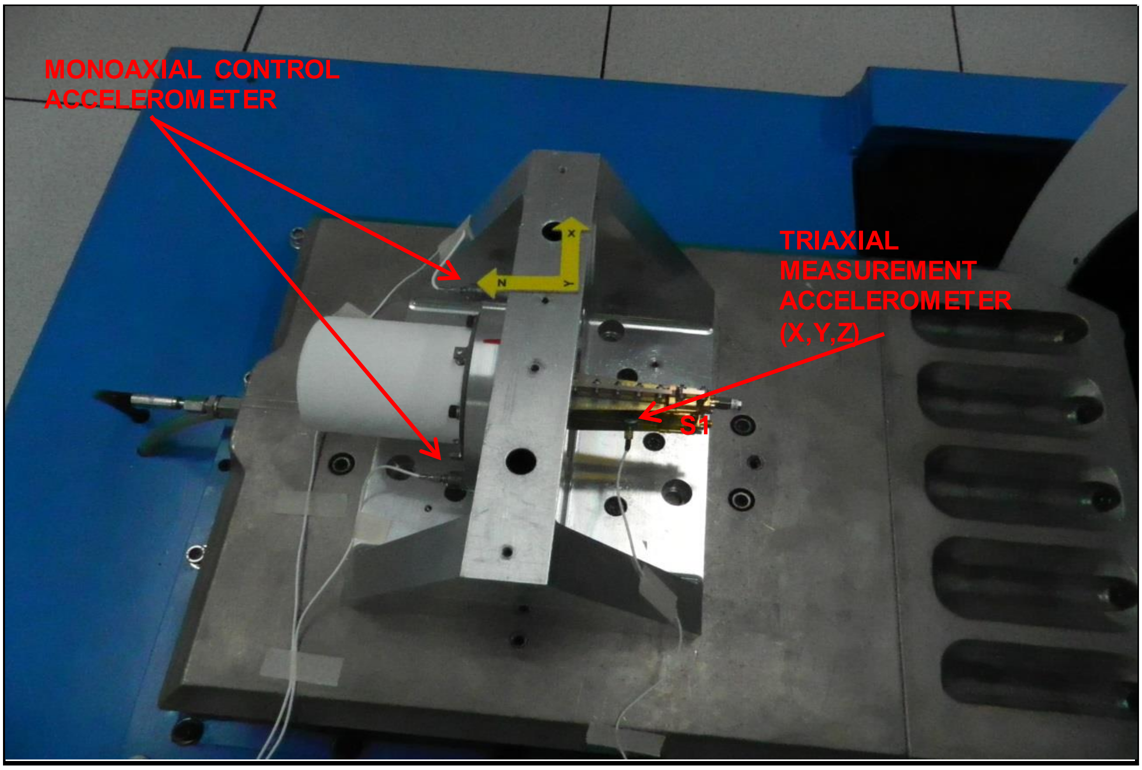


Figure 29 - Antenna accelerometers locations, Z Axis.

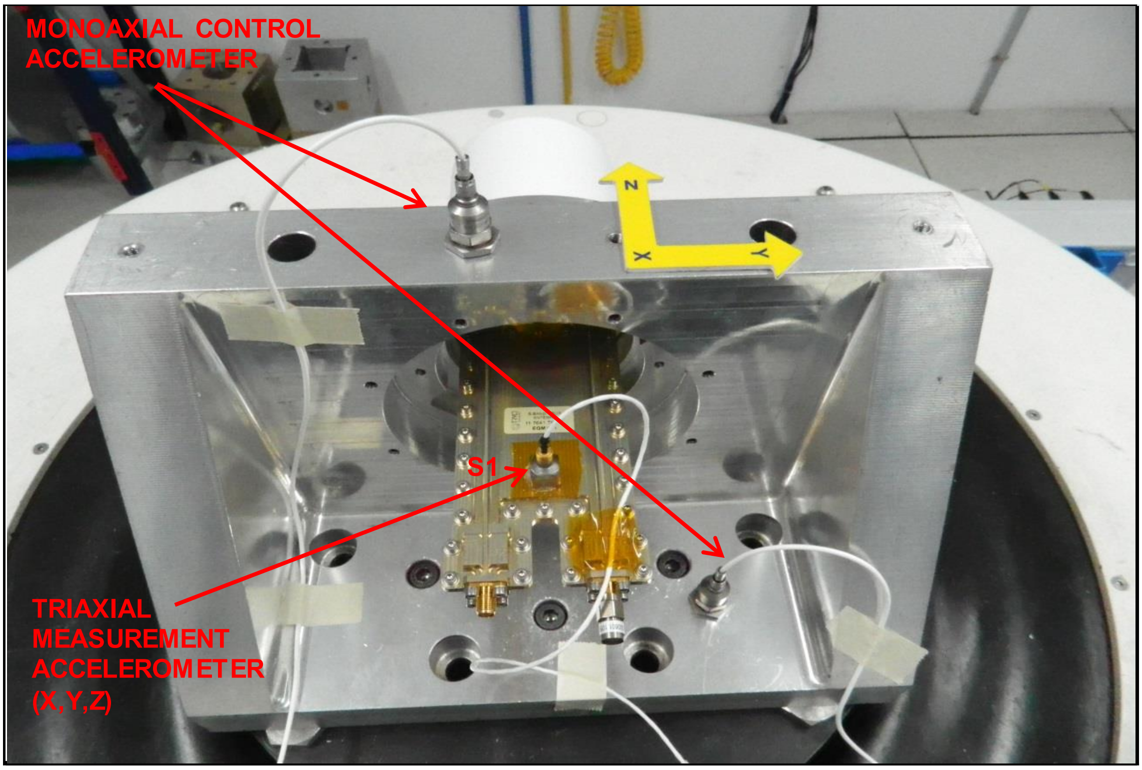


Figure 30 - Antenna accelerometers locations, X Axis.

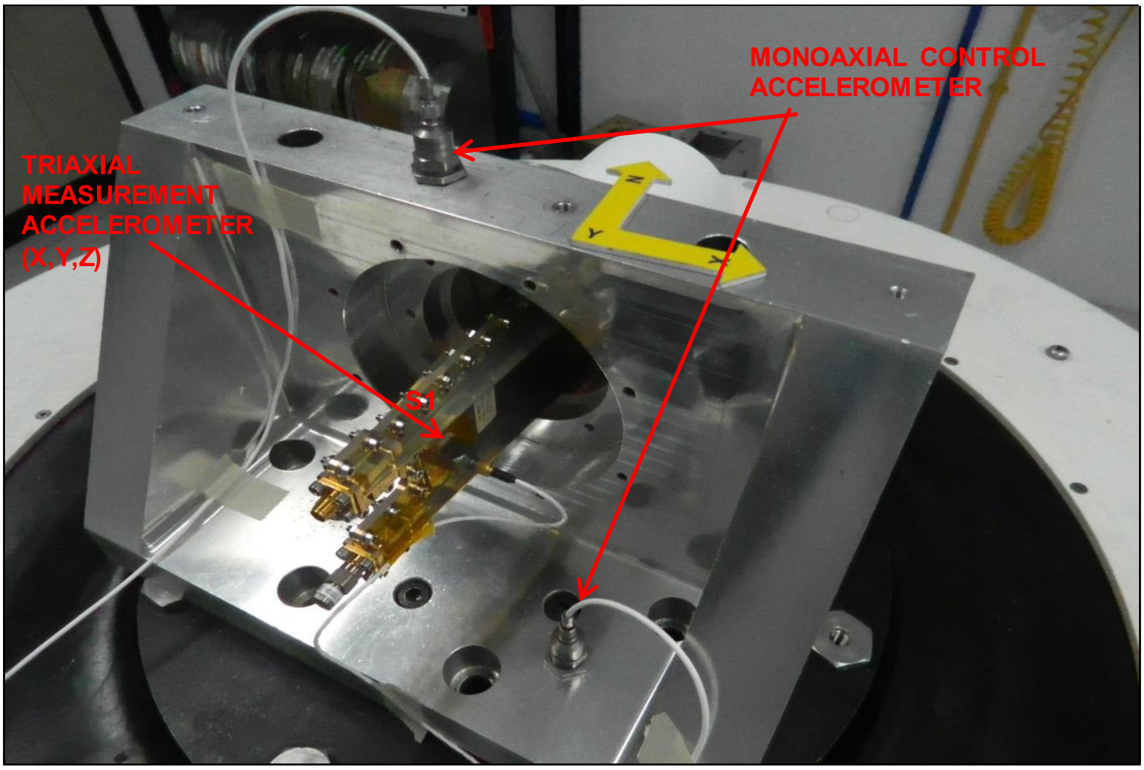


Figure 31 - Antenna accelerometers locations, Y Axis.

6.5 TEST SEQUENCE

The nominal test sequences are given in the following table.

NOMINAL TEST SEQUENCE EQM		
Run Nr	Specification	Remark
I – Z	Signature survey reference test	Reference test
II – Z	Sine test	
III – Z	Signature survey Control 1	Control 1 test
IV – Z	Random test	
V – Z	Signature survey Control 2	Control 2 test
VI – X	Signature survey reference test	Reference test
VII – X	Sine test	
VIII – X	Signature survey Control 1	Control 1 test
IX – X	Random test	
X – X	Signature survey Control 2	Control 2 test
XI – Y	Signature survey reference test	Reference test
XII – Y	Sine test	
XIII – Y	Signature survey Control 1	Control 1 test
XIV – Y	Random test	
XV – Y	Signature survey Control 2	Control 2 test

6.6 TEST PROCEDURE DEVIATION

None.

6.7 TEST RESULTS

Data presentation: See plots attached at the end of this report in Annexe A

6.8 SUMMARY OF TEST RESULTS

AXIS	RUN	TEST	ACCELEROMETER		
			S1(X)	**S1(Y)**	**S1(Z)**
X	**I**	**SINE 0.5 g Reference**	408.99/45.61	-----	-----
	II	**SINE TEST**	20.6	2.22	2.46
	III	**SINE 0.5 g Control 1**	408.99/43.07	-----	-----
	IV	**Random Test**	152.91	7.93	26.02
	V	**SINE 0.5 g Control 2**	409.73/53.08	-----	-----
Y	**VI**	**SINE 0.5 g Reference**	-----	717.05/12.97 1197.6/6.98	-----
	VII	**SINE TEST**	1.80	20.1	2.34
	VIII	**SINE 0.5 g Control 1**	-----	717.81/13.17 1190.65/7.19	-----
	IX	**Random Test**	9.19	51.25	6.13
	X	**SINE 0.5 g Control 2**	-----	718.74/13.68 1192.68/5.39	-----
Z	**XI**	**SINE 0.5 g Reference**	-----	-----	1767.5/7.77
	XII	**SINE TEST**	1.80	1.12	20.0
	XIII	**SINE 0.5 g Control 1**	-----	-----	1770.65/11.67
	XIV	**Random Test**	49.2	68.79	47.67
	XV	**SINE 0.5 g Control 2**	-----	-----	1765.87/9.64

Note: . 1.- Sine 0,5g test: First number corresponds to the eigenfrequency (Hz).

Second one is amplitude value (g).

2.- Random test: the value is the RMS (g).

3.- Sine test: the value is acceleration (g).

The test laboratory conditions and the tolerances of test parameters along the vibration test were every time between the permitted margins specified in AD02.

6.9 TEST EQUIPMENT STATUS

EQUIPMENT	MANUFACTER	MODEL	IDENTIFICATION	CALIBRATED UP TO
32 CHANNEL POWER SUPPLY	KISTLER	5148	ES252/313	FEB-18
DATA ACQUISITION VXI	AGILENT	E1432A	ES248	FEB-18
ACCELEROMETERS	KISTLER	8704B500	ES260-261	AUG-18
ACCELEROMETERS	KISTLER	8763A500	ES242	MAY-18

7. SHOCK TEST

The EQM had been submitted to the shock excitations at INTA facilities (Madrid - Spain).

Test objective was the qualification of the antenna design against the following criteria:

- Application of qualification shock levels
- Verification of structural integrity and electrical performances with respect to qualification shock levels by means of electrical checking performed at the beginning and at the end of the shock test

7.1 SET UP

The test set-up consists of the test fixture, the test item and the accelerometers used for data acquisition.

The test item was joined to the Fixture by means of 4 M5 high strength steel 12.9 screws (yield: 1080 MPa, ultimate: 1200 MPa) and washers with a nominal torque of 5.0 Nm.

7.1.1 Test Fixture

The test fixture was a rectangular aluminium plate used for axes shock testing bolted over the shock table.

7.1.2 Accelerometers

During all test runs a total number of 1 tri-axial control accelerometer was installed close to the I/F of the test item as shows figure 8.2.

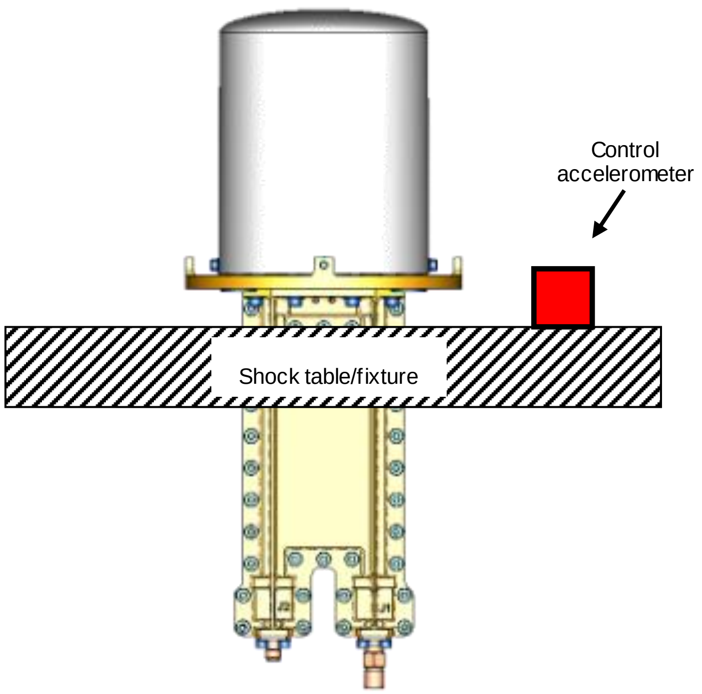


Figure 32 - Accelerometer location for shock test.

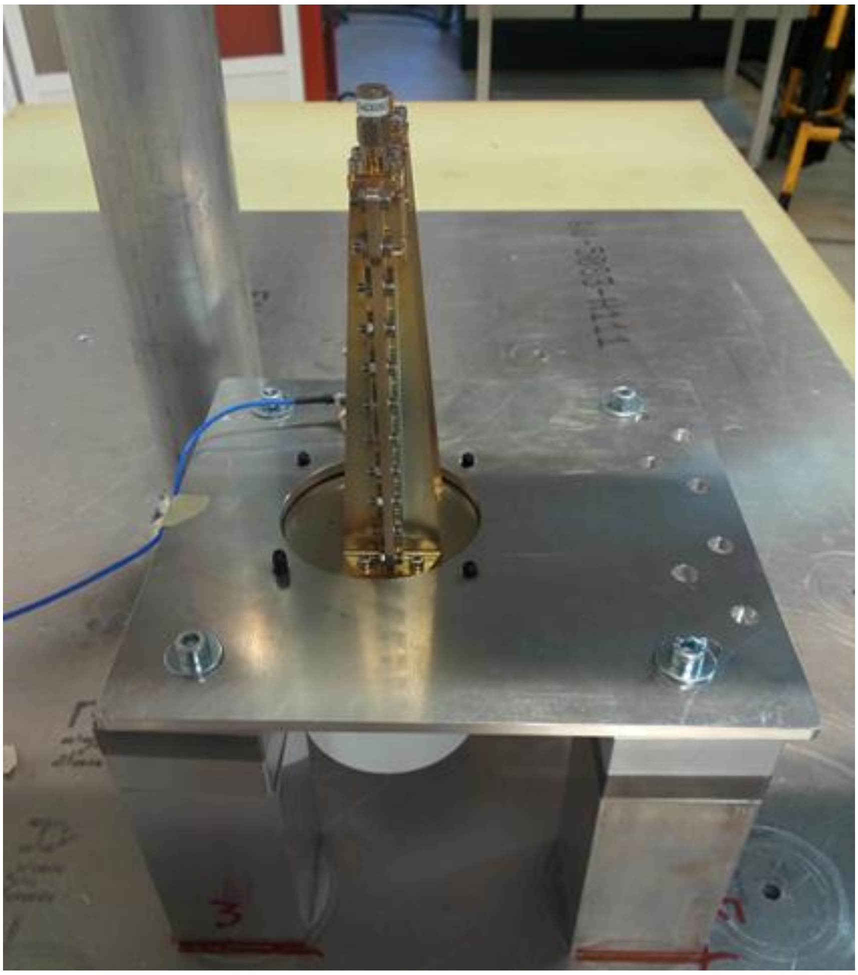


Figure 33 - Antenna Shock Test, Z Axis.

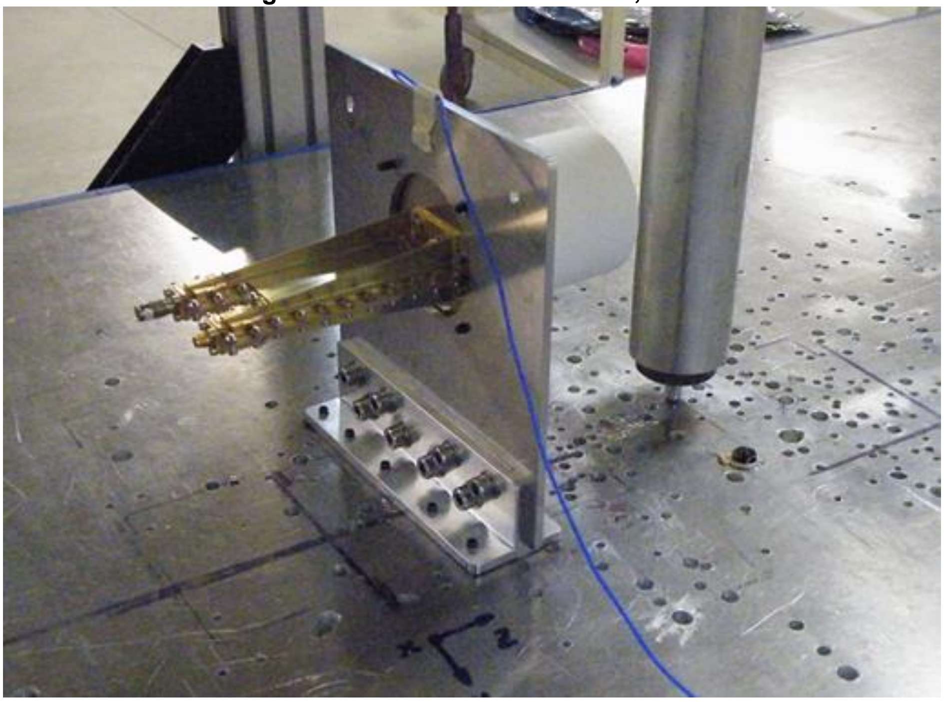


Figure 34 - Antenna Shock Test, X Axis.

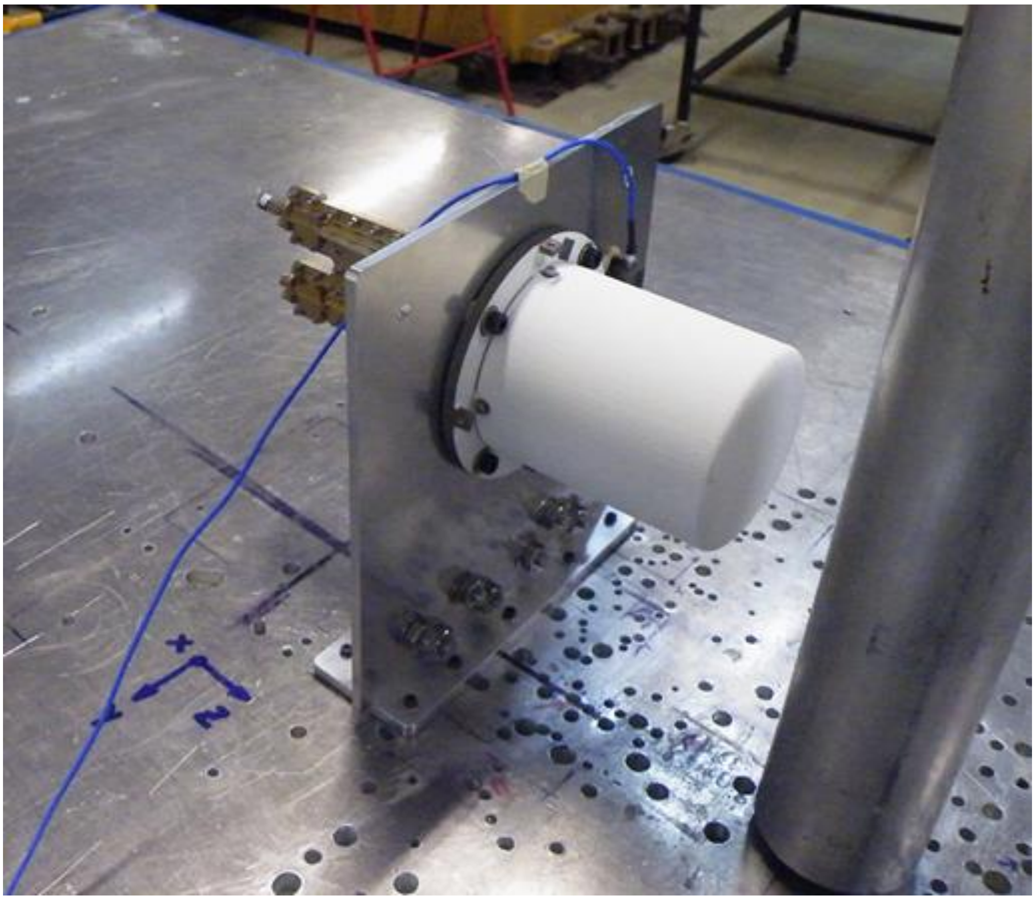


Figure 35 - Antenna Shock Test, Y Axis.

7.1.3 Shock test levels

The shock test was performed one time in each axis (X,Y,Z).

Axis	Frequency (Hz)	Shock Response (g) (Q=10)
1 shock/axis	100	71
	2000	1413
	10000	1413

7.2 TEST PROCEDURE DEVIATION

None.

7.3 TEST RESULTS

Data presentation: See plots attached at the end of this report in Annexe C

7.4 SUMMARY OF TEST RESULTS

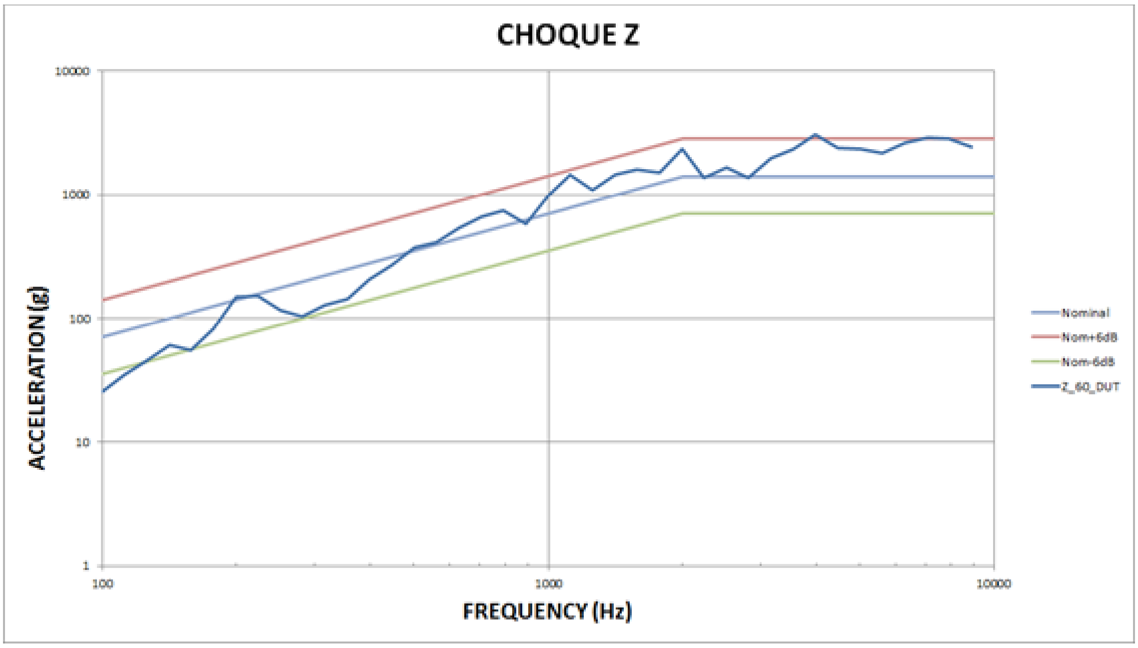


Figure 36 - Antenna Shock Test results, Z Axis

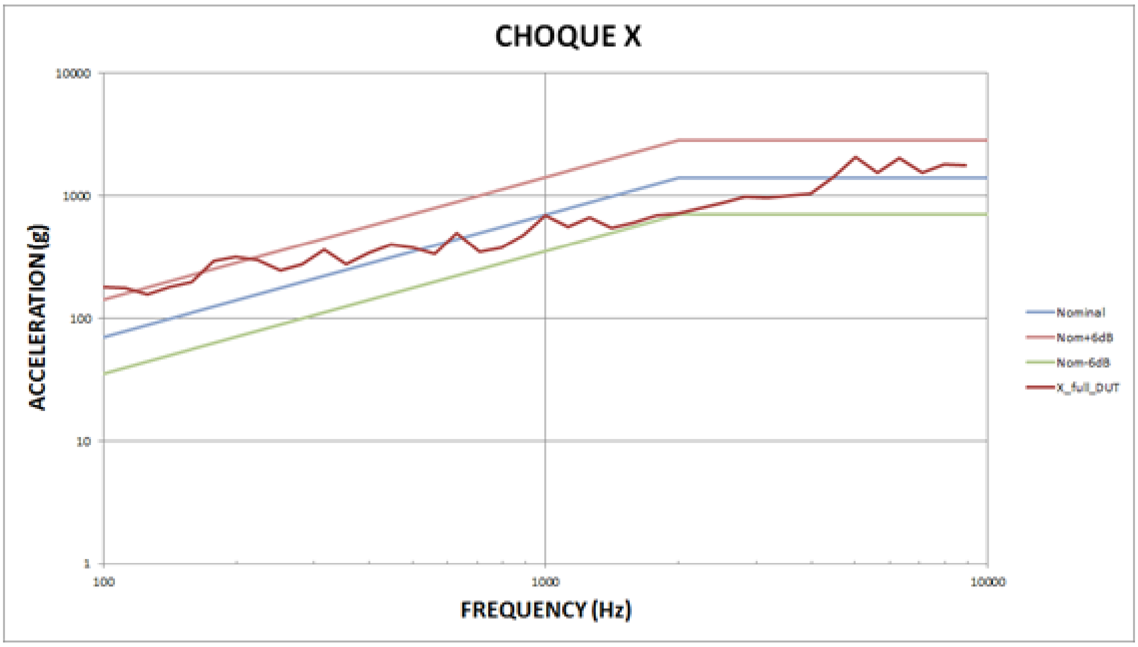


Figure 37 - Antenna Shock Test results, X Axis

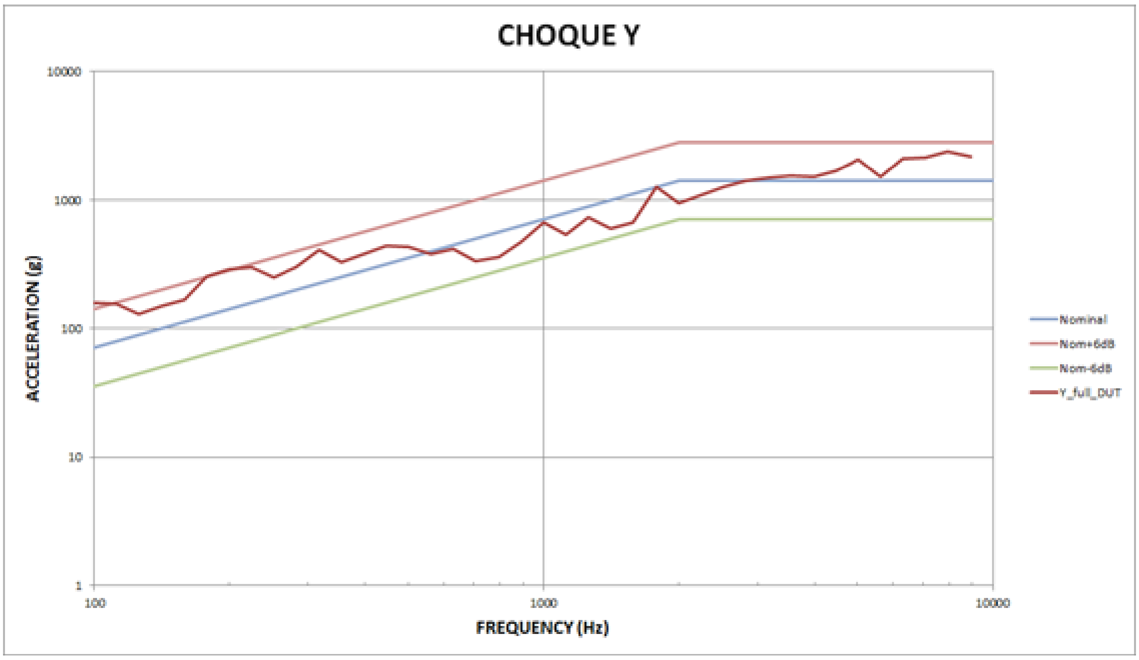


Figure 38 - Antenna Shock Test results, Y Axis

8. THERMAL TEST

8.1 THERMAL TEST EQUIPMENT

THERMAL VACUUM TEST EQUIPMENT Nº. 2	
TVAC Chamber	▪ Model: ANGELANTONI HVT1000LN2 ▪ Volume: Ø800x800 mm ▪ Temperature range: -140 ºC / +160ºC
Programmer controller & Recorder	▪ Model: WINKRATOS 3.20.01 ▪ Specific software: WINKRATOS ▪ Possibility of processing up to 25 temperature signals ▪ Time data acquisition: every 20 seconds
Pressure gauge	▪ Model: LEYBOLD ITR100 ▪ Pressure range: $5x10^{-6}$ mbar / $5x10^{-2}$ mbar
Thermocouples	▪ Type T

8.2 TEST SET-UP

8.2.1 Test Article Configuration.

The test item is the S-Band Helix Antenna RHCP EQM S/N: 001 defined in AD03 drawing.

8.2.2 Test Fixture.

The test set-up consists of the test items and the thermocouples used for data acquisition during thermal cycling test.

8.3 POSITION OF THE THERMOCOUPLES

The following figures show the position of the thermocouples:

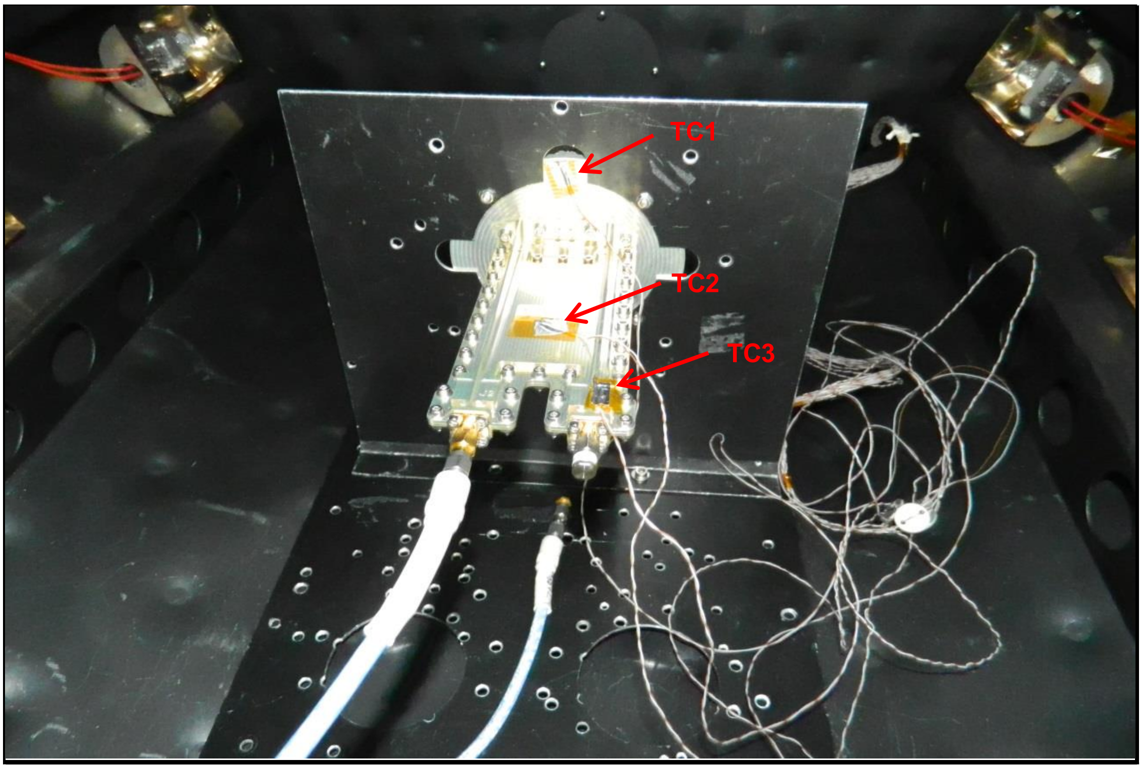


Figure 39 - Thermal Vacuum Test.

8.4 THERMAL CHAMBER TEST LEVELS AND SEQUENCE

Item	Cycles Sequence	Temperature	Pressure	Dwell Time
EQM Antenna	1 to 8	**Qualification** TFQmax= +100 ºC (-0, +3ºC) TFQmin= -95 ºC (-4, +0 ºC)	Vacuum $\leq$ 1.33 x 10^{-5} mbar	2 hours each hot/cold plateau

8.5 TEST LABORATORY CONDITIONS

The test laboratory conditions along the thermal cycles were every time between the permitted margins specified in AD02.

8.6 TEST PROCEDURE DEVIATION

None.

8.7 TEMPERATURE RESULTS

The results of the thermal test are shown in Annexe B.

8.8 TEST EQUIPMENT STATUS

EQUIPMENT	MANUFACTURER	MODEL	IDENTIFICATION	CALIBRATED UP TO
THERMAL VACUUM CHAMBER	ANGELANTONI	HVT1000LN2	ES257	JAN-18
PRESSURE SENSOR	LEYBOLD	ITR100	ES236	NOV-18

9. DIMENSIONAL AND MASS TEST

9.1 DIMENSIONAL AND MASS TEST RESULTS

The following table shows the most important dimensional parameters of S-Band Helix Antenna RHCP EQM S/N: 001 that has been measured to check the requirements of the ICD.

Nominal	Tolerance	Measured	Deviation	Remarks
Ø 0.8	± 0.2	0.8	0.0	2 Venting Holes
Ø 2.5	± 0.2	2.5	0.0	2 Venting Holes
12.0	± 0.2	12.0	0.0	within tolerance
5.0	± 0.2	5.1	0.1	within tolerance
151.8	± 2.0	151.8	0.0	within tolerance
141.1	± 2.0	141.1	0.0	within tolerance
1.0	± 0.2	0.9	-0.1	within tolerance
4.2	± 0.2	4.0	-0.2	within tolerance
1.0	± 0.2	1.0	0.0	within tolerance
259.8	± 5.0	260.1	0.3	within tolerance
37.7	± 2.0	37.4	-0.3	within tolerance
13.2	± 2.0	13.1	-0.1	within tolerance
51.9	± 2.0	51.8	-0.1	within tolerance
Ø 105.8	± 1.0	105.6	-0.2	within tolerance

FOOTPRINT				
Ø 5.5	+ 0.2 - 0.0	5.6	0.1	Worst case of 4 holes
Position	Ø 0.15	0.15		within tolerance
Ø 13.8	± 0.2	13.8	0.0	within tolerance

Roughness & Flatness				
R_0 N8	3.2	0.8		within tolerance
Flatness	0.1	0.0		within tolerance

Nominal	Tolerance	Measured	Deviation	Remarks
374.4 gr	± 5 %	358.1	-16.3	within tolerance

9.2 CENTER OF GRAVITY

The nominal position of the centre of gravity is shown in the ICD.

$X_{cg} = 34.7 \pm 1.5$ mm

$Y_{cg} = 32.7 \pm 1.5$ mm

$Z_{cg} = -9.6 \pm 1.5$ mm

Those values, obtained from 3D model, are given with respect to the reference system shown in the ICD (AD03).

9.3 MOMENTS OF INERTIA

The nominal values of moments of inertia are shown in the ICD.

$I_{xx} = 1479.1 \pm 10\%$ Kg mm²

$I_{yy} = 1426.2 \pm 10\%$ Kg mm²

$I_{zz} = 302.6 \pm 10\%$ Kg mm²

Those values, obtained from 3D model, are referred to a system of axes parallel to the reference system shown in the ICD (AD03) with its origin at the CoG of the antenna.

9.4 TEST PROCEDURE DEVIATION

None.

10. COMPLIANCE OF TEST RESULTS

ID (AD0)	PARAMETER	REQUIREMENT	FINAL WORST CASE	SOC	REMARKS
LGA-7	**FREQUENCIES**				
LGA-8	Receive range Uplink carrier frequencies	[2025-2120] MHz TC1: 2035.5941 MHz TC2: 2047.7491 MHz	TC1: 2035.5941 MHz TC2: 2047.7491 MHz	C	A margin of ± 6 MHz is take into account to comply with Spec. at extreme temperature conditions
LGA-182	Transmit range Downlink carrier frequencies	[2200-2300] MHz TM1: 2210.6 MHz TM2: 2223.8 MHz	TM1: 2210.6 MHz TM2: 2223.8 MHz	C	
LGA-9	**POLARISATION**				
LGA-10	Circular Polarisation. RHCP		RHCP	C	
LGA-13	**GLOBAL COVERAGE**				
LGA-15	Axial Ratio	see Tables 4 & 5		PC	See RFD: P3-RY-RFD-004 See NCR: GSTP-NCR-001-TA
LGA-16	**GAIN AT RECEIVE FREQUENCY**				
LGA-17	Gain in reception band	see Table 6		PC	See RFD: P3-RY-RFD-004
LGA-18	**GAIN AT TRANSMIT FREQUENCY**				
LGA-19	Gain in transmission band	see Table 7		PC	See RFD: P3-RY-RFD-004 See NCR: GSTP-NCR-001-TA
LGA-20	**CROSS POLARISATION ISOLATION**				
LGA-21		see Table 8		PC	See RFD: P3-RY-RFD-004 See NCR: GSTP-NCR-001-TA
LGA-28	**VSWR**				
LGA-29	Input & Output VSWR	1.4:1 (RL≤ -15.56 dB)	-18.0 dB	C	
LGA-245	DC resistance (between metal parts of the structure)	< 10 mΩ	0.89 mΩ	C	

Table 3 - S-Band antenna Statement of Compliance and Worst Case analysis

THETA (°)	AXIAL RATIO (dB)	FINAL WORST CASE	SOC	REMARKS
ϴ ≤ ± 50	≤ 2	2.4 dB	C (*)	(*) See RFD: P3-RY-RFD-004
±50 ≤ ϴ ≤ ± 70	≤ 3.5	4.0 dB	NC	
±70 ≤ ϴ ≤ ± 90	≤ 7	5.9 dB	C	

Table 4 - S-Band antenna. Axial Ratio. Reception band

THETA (°)	AXIAL RATIO (dB)	FINAL WORST CASE	SOC	REMARKS
ϴ ≤ ± 50	≤ 2	3.2 dB	NC	
±50 ≤ ϴ ≤ ± 70	≤ 3.5	3.8 dB	NC	
±70 ≤ ϴ ≤ ± 90	≤ 7	5.4 dB	C	

Table 5 - S-Band antenna. Axial Ratio. Transmission band

THETA (°)	GAIN (dBi)	FINAL WORST CASE	SOC	REMARKS
ϴ = 0	≥ 2.5	-1.0 dBi	C (*)	(*) See RFD: P3-RY-RFD-004
±10 ≤ ϴ ≤ ± 45	≥ 0	-1.0 dBi	C (*)	
±50 ≤ ϴ ≤ ± 90	≥ -6	-3.6 dBi	C	
ϴ =± 150	≥ -26	-27.0 dBi	C (*)	

Table 6 - S-Band antenna. Gain in Reception band

THETA (°)	MIN. GAIN (dBi)	MAX. GAIN (dBi)	FINAL WORST CASE	SOC	REMARKS
ϴ = 0	≥ 2.5	≤ 7.5	-0.5 dBi	NC	(*) See RFD: P3-RY-RFD-004
±10 ≤ ϴ ≤ ± 45	≥ 0	≤ 5	-0.8 dBi	NC	
±50 ≤ ϴ ≤ ± 90	≥ -6	≤ -1	-1.3 dBi	NC	
ϴ =± 150	≥ -26	≤ -21	-17.7 dBi	NC	

Table 7 - S-Band antenna. Gain in Transmission band

THETA (°)	GAIN (dBi)	FINAL WORST CASE RECEIVE BAND	SOC	FINAL WORST CASE TRANSMIT BAND	SOC	REMARKS
ϴ ≤ ± 90	≤ -15	-11.2 dBi	NC	-11.2 dBi	NC	
±90 ≤ ϴ ≤ ± 180	≤ -15	-11.2 dBi	NC	-11.2 dBi	NC	

Table 8 - S-Band antenna. Cross polarization isolation

11. QUALITY ASSURANCE PROVISIONS

See RFD: P3-RY-RFD-004

See NCR: GSTP-NCR-001-TA

12. CONCLUSIONS

The S-BAND HELIX ANTENNA RHCP EQM S/N: 001 has been designed, manufactured and tested at qualification levels.

From the initial to the final RF electrical tests, the performances do not suffer any significant degradation, except for some Co-polar, X-Pol and AR levels (see GSTP-NCR-001-TA).

The antenna has satisfactorily surpassed the qualification test campaign.

No damage has been detected during the overall vibration (EQM levels) test sequence:

- No significant frequency shifting (higher than 5%) and response amplitude variation (higher than 50%) are measured between each sine survey.
- Visual inspection performed along the test has not shown any damage.

No damage has been detected during the overall shock (EQM levels) test sequence:

- Visual inspection performed along the test had not shown any damage.
- Electrical checking performed at the beginning and at the end of the shock test had not shown significant variations.

After performing the thermal chamber test, no damage or degradation had been detected in the equipment.

All dimensions presented on the ICD had been measured obtaining always values within their tolerances.

Total mass of the equipment had been measured within the required values.

ANNEXE A

PLOTS OF VIBRATION RESULTS

(This annexe contains 15 pages)

GSTP

S-BAND HELIX ANTENNA 3D PRINTED

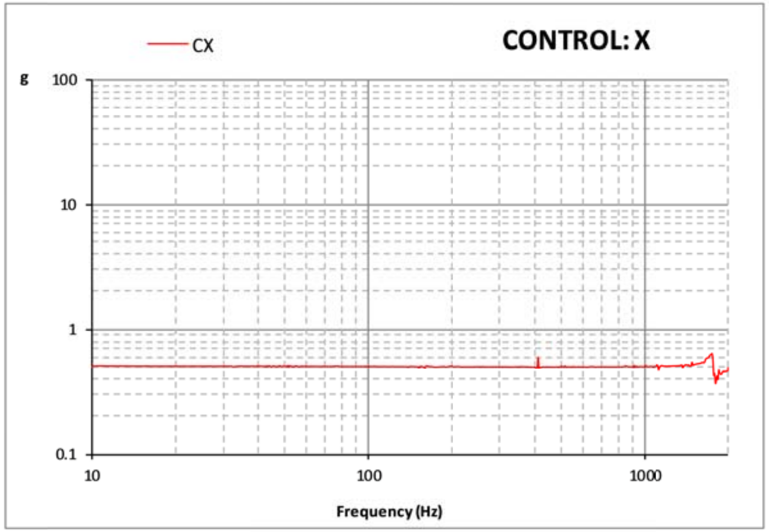
EQM S/N 001

TEST ID: RUN_I

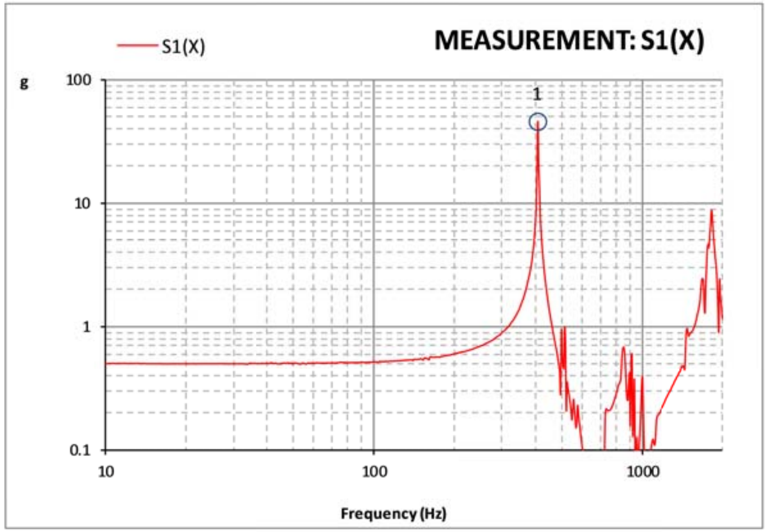
REFERENCE TEST X

SINE 0.5 g

Sweep Rate: 2 oct/min



frequency_spectr

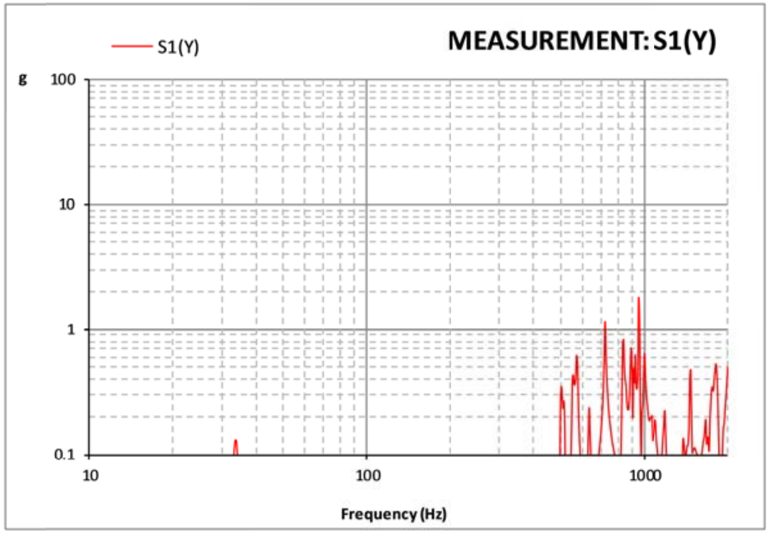


frequency_spectr

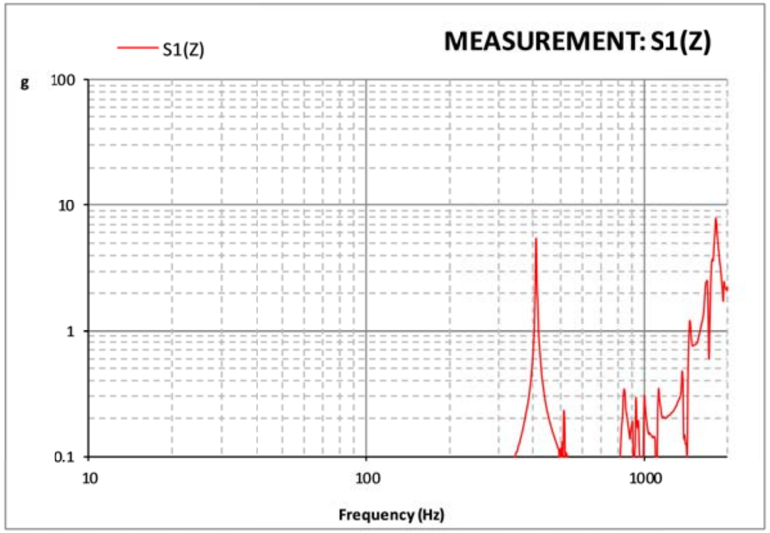
S1(X)

X(HZ) Y(g)

#1: 408.99 45.61



frequency_spectr

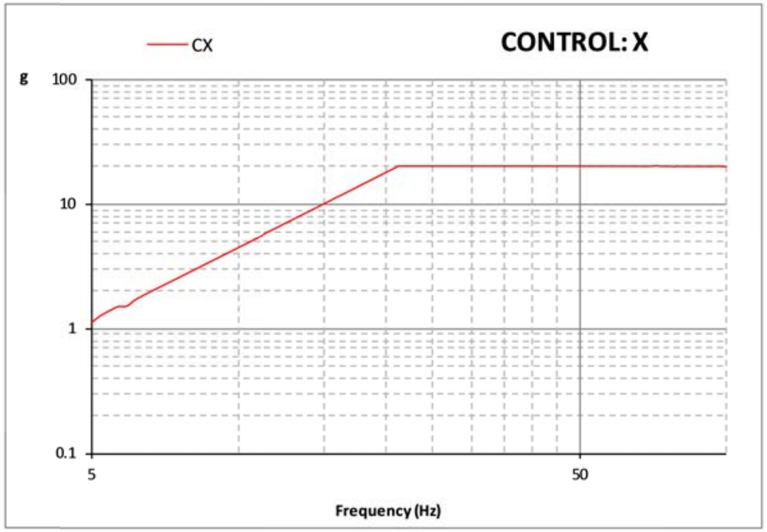


frequency_spectr

GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

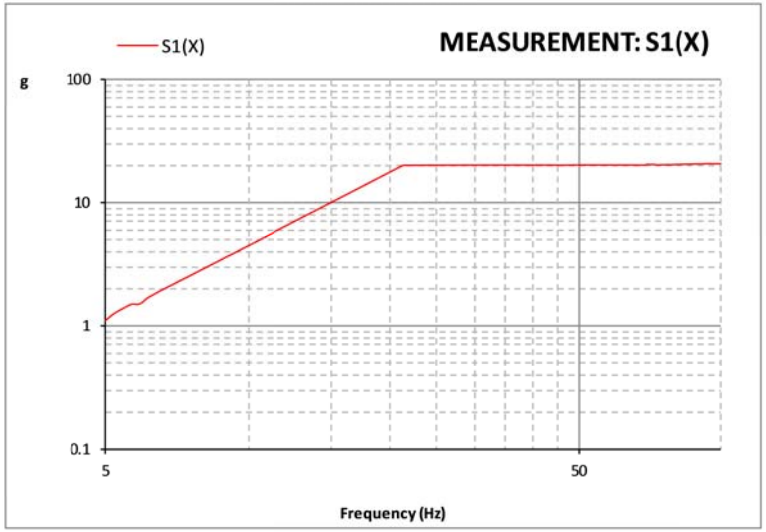
TEST ID: RUN_II
SINE TEST X

Sweep Rate: 2 oct/min



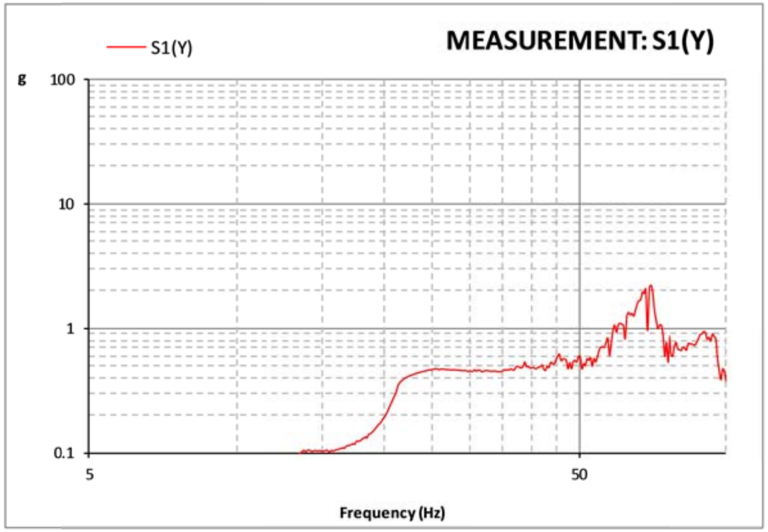
frequency_spectr

20.3 g



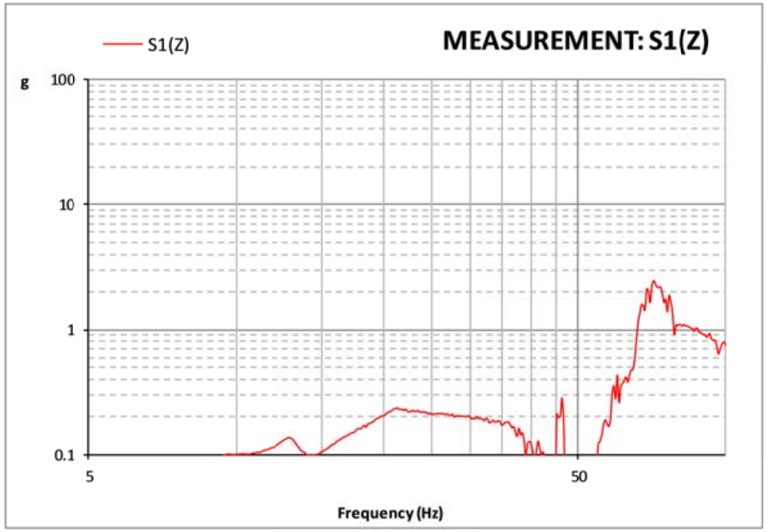
frequency_spectr

20.6 g



frequency_spectr

2.22 g



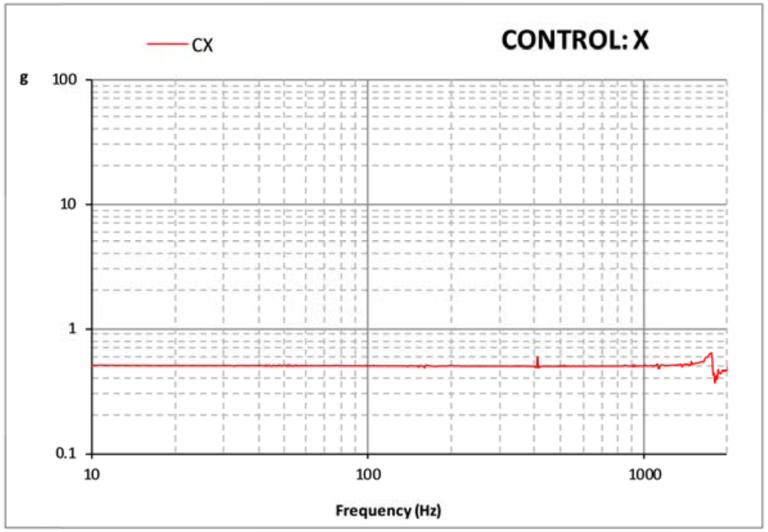
frequency_spectr

2.46 g

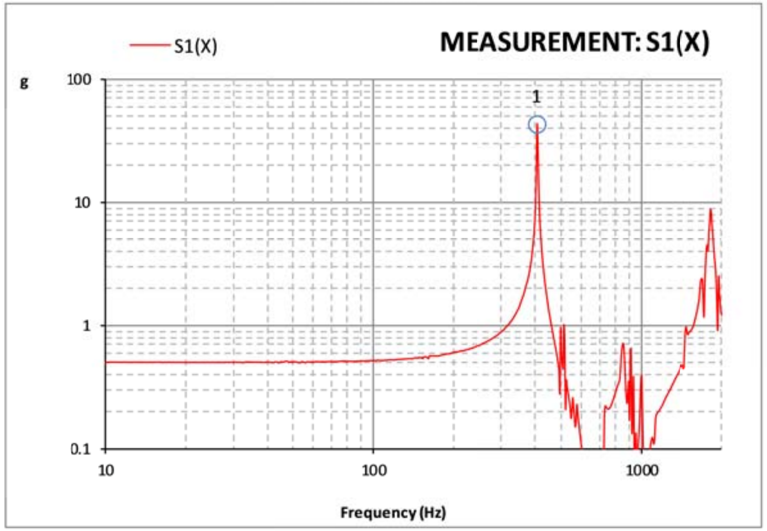
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_III
CONTROL 1 TEST X

SINE 0.5 g
Sweep Rate: 2 oct/min

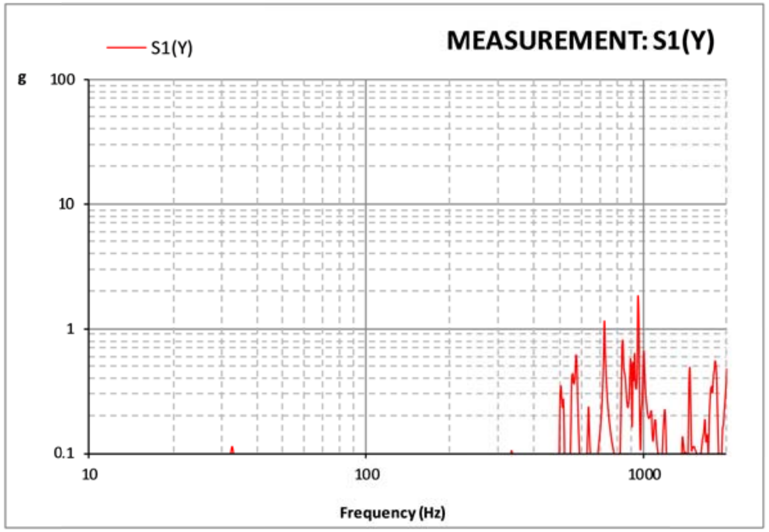


frequency_spectr

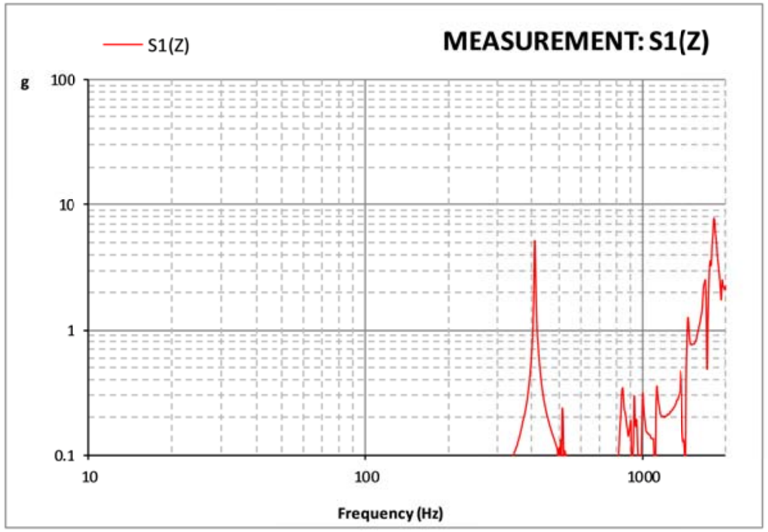


frequency_spectr

S1(X)
X(HZ) Y(g)
#1: 408.99 43.07



frequency_spectr

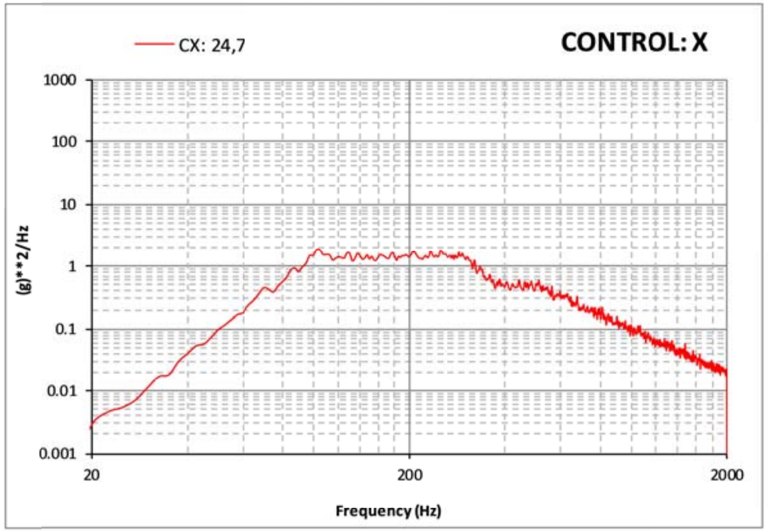


frequency_spectr

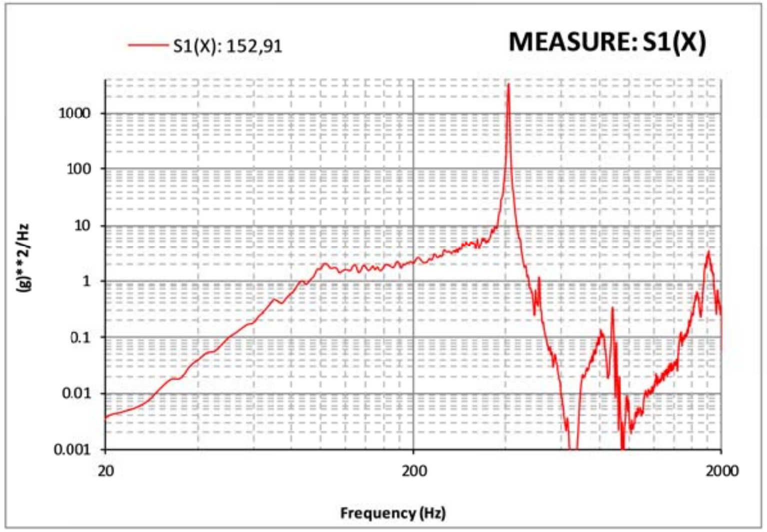
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_IV
RANDOM TEST X

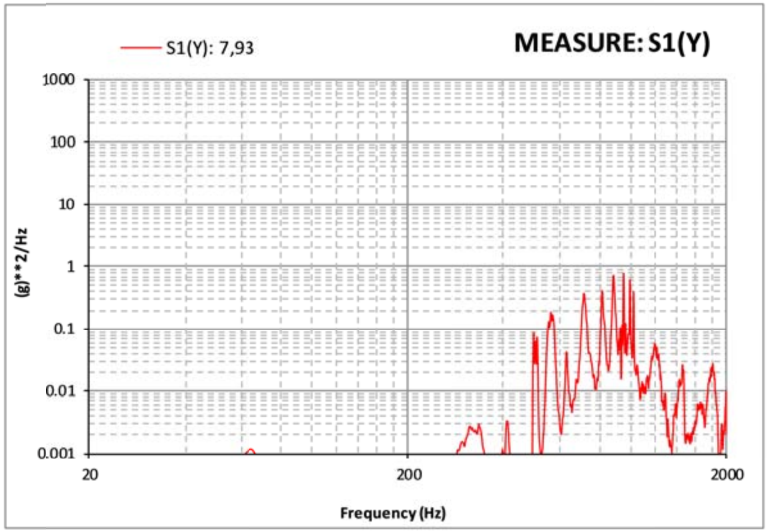
Duration: 150 seg



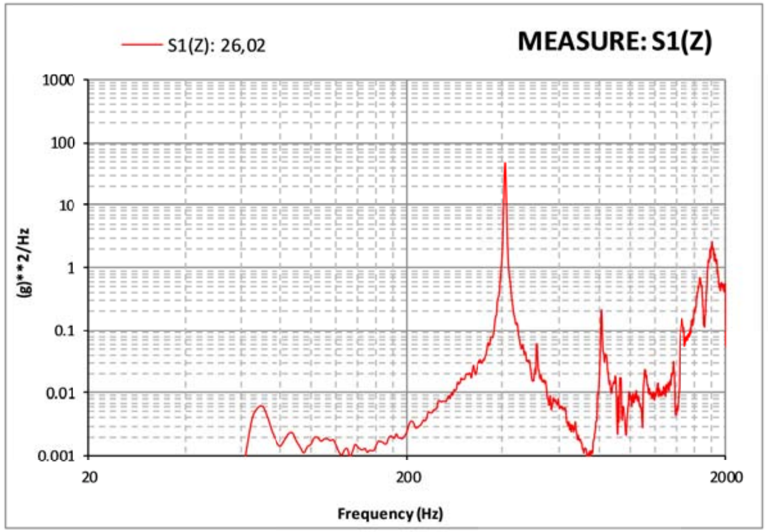
autopower_spectr



autopower_spectr



autopower_spectr

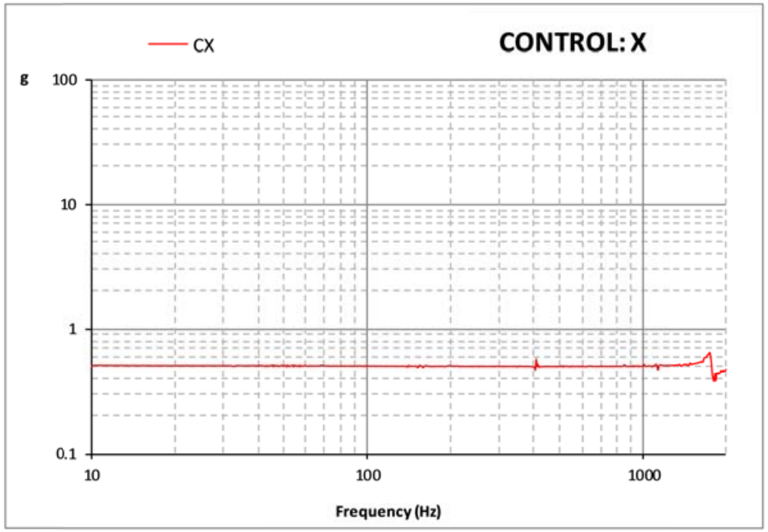


autopower_spectr

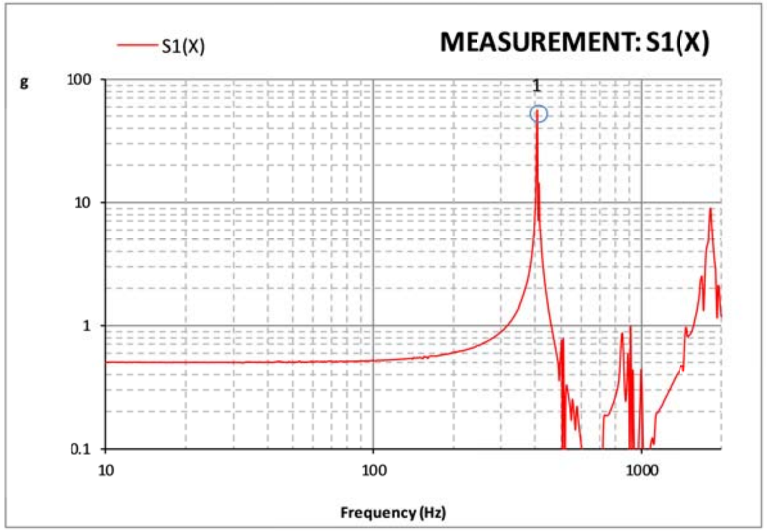
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_V
CONTROL 2 TEST X

SINE 0.5 g
Sweep Rate: 2 oct/min

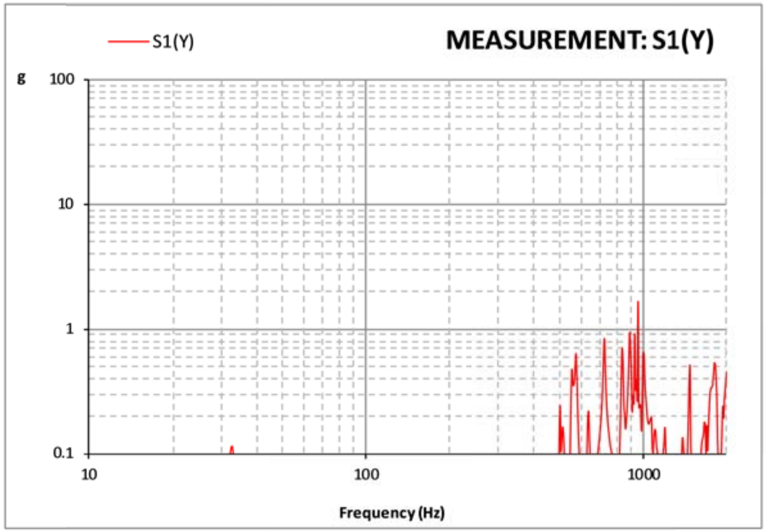


frequency_spectr

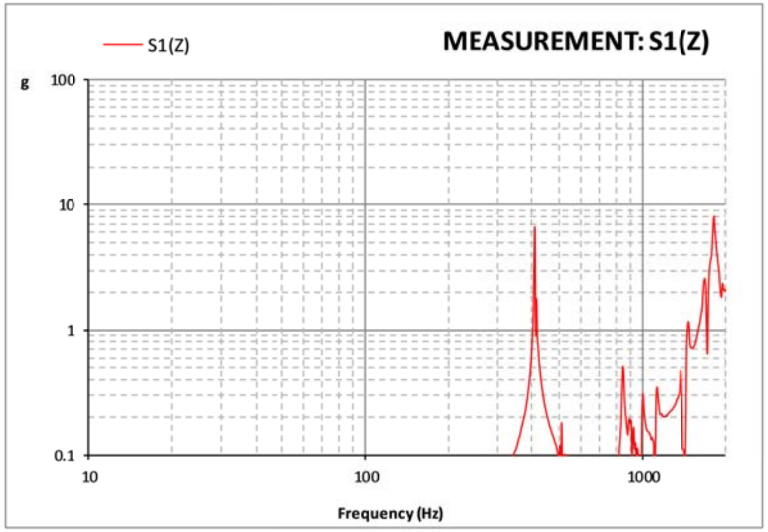


frequency_spectr

S1(X)
X(HZ) Y(g)
#1: 409.73 53.08



frequency_spectr



frequency_spectr

GSTP

S-BAND HELIX ANTENNA 3D PRINTED

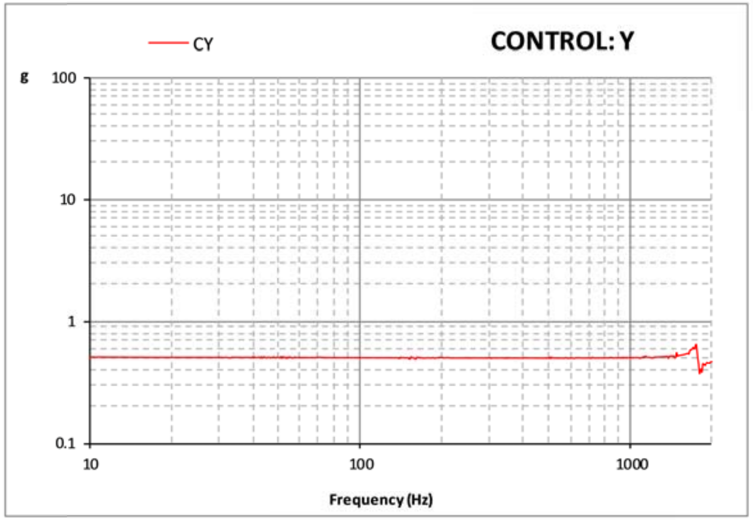
EQM S/N 001

TEST ID: RUN_VI

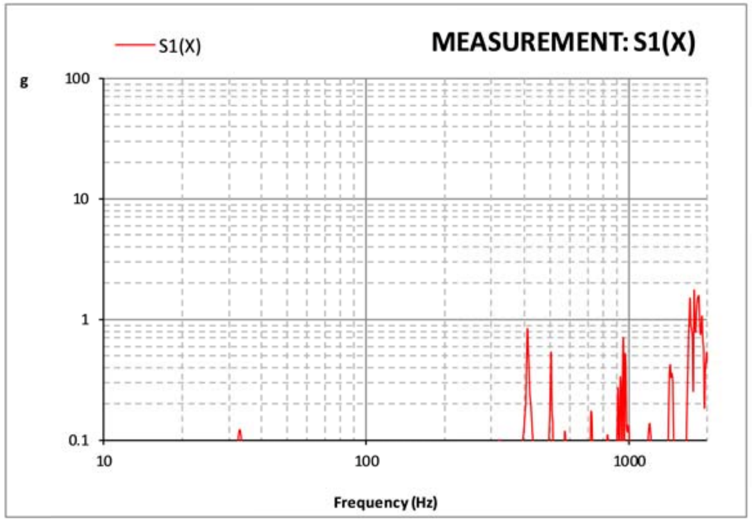
REFERENCE TEST Y

SINE 0.5 g

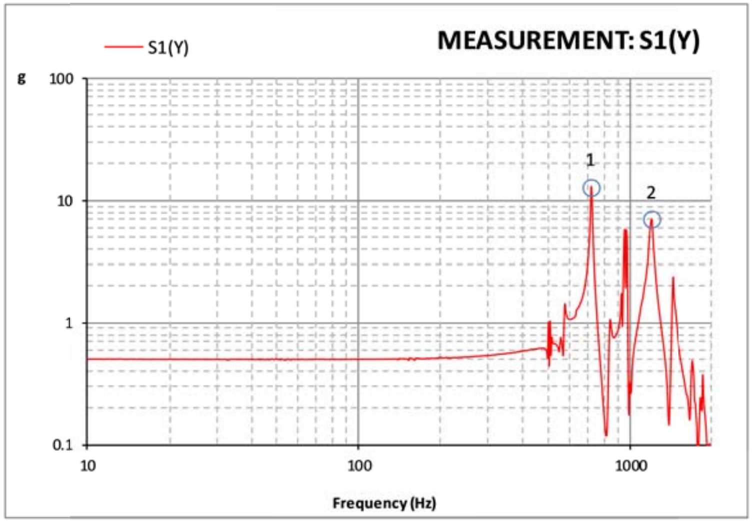
Sweep Rate: 2 oct/min



frequency_spectr



frequency_spectr



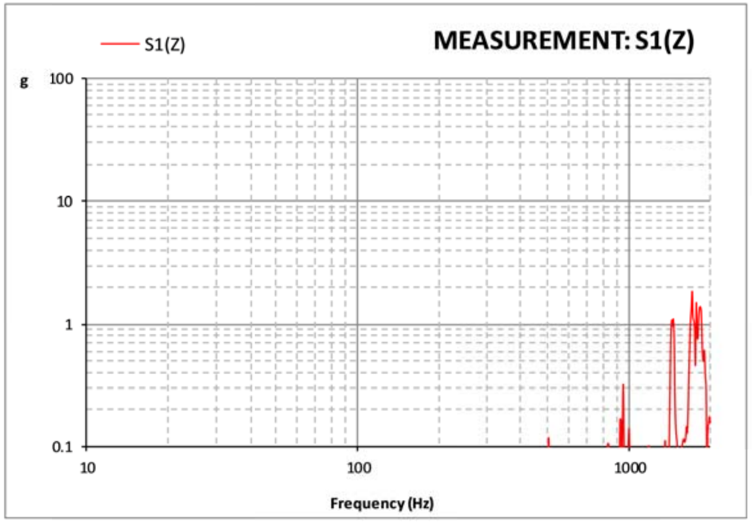
frequency_spectr

S1(Y)

X(HZ) Y(g)

#1: 717.05 12.97

#2: 1197.6 6.98

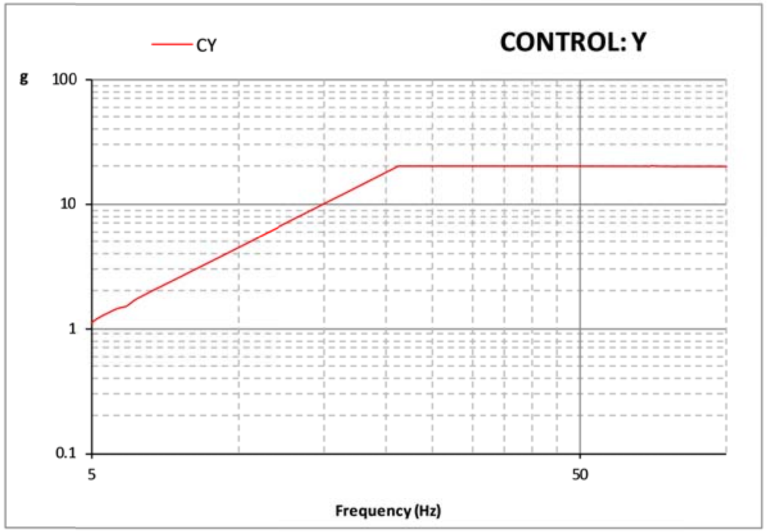


frequency_spectr

GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

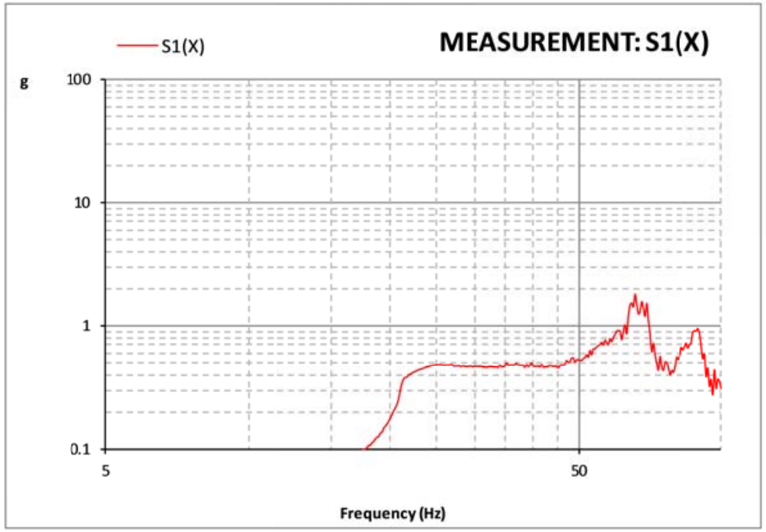
TEST ID: RUN_VII
SINE TEST Y

Sweep Rate: 2 oct/min



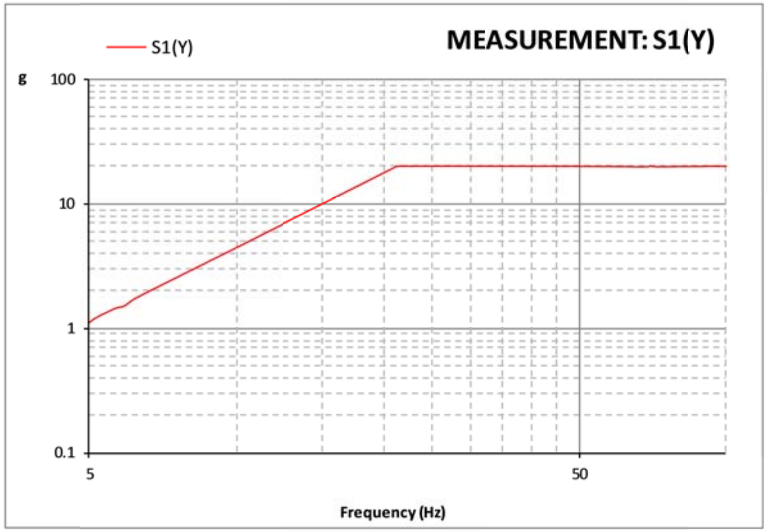
frequency_spectr

20.3 g



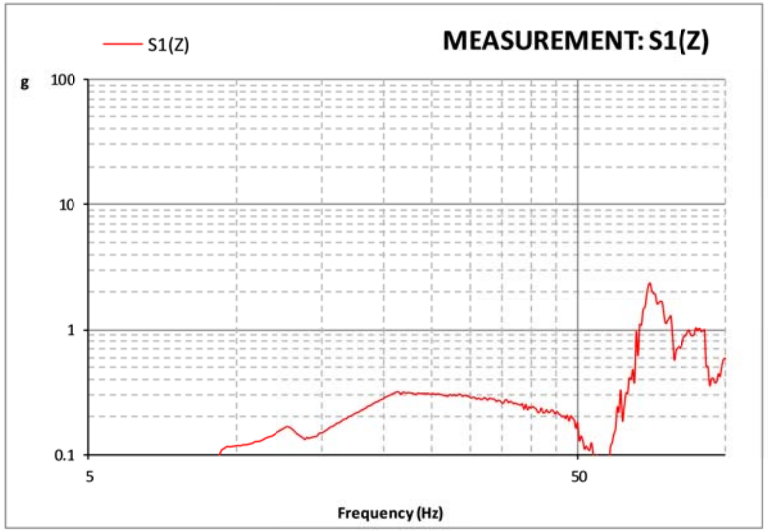
frequency_spectr

1.80 g



frequency_spectr

20.1 g



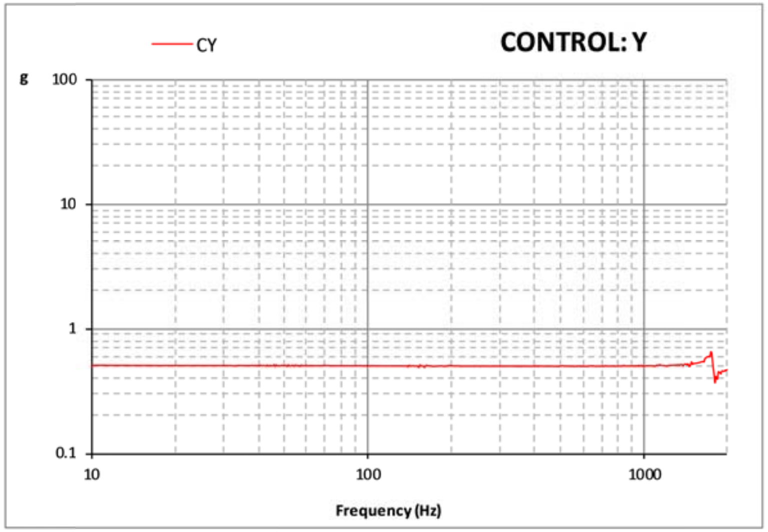
frequency_spectr

2.34 g

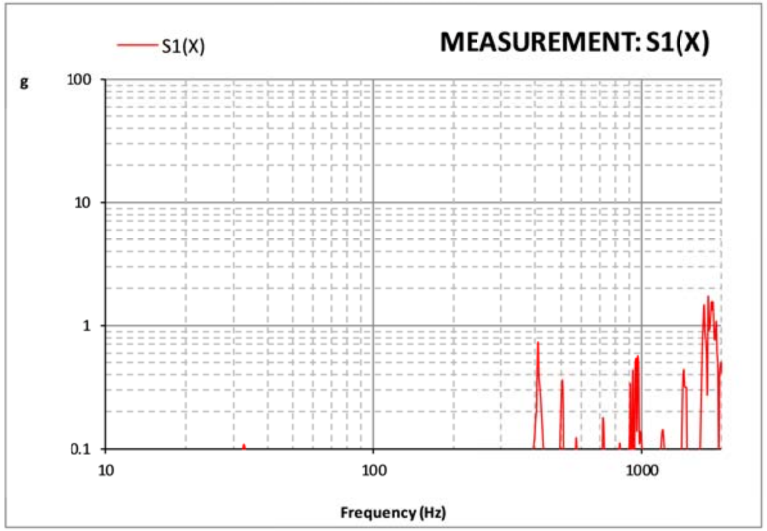
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_VIII
CONTROL 1 TEST Y

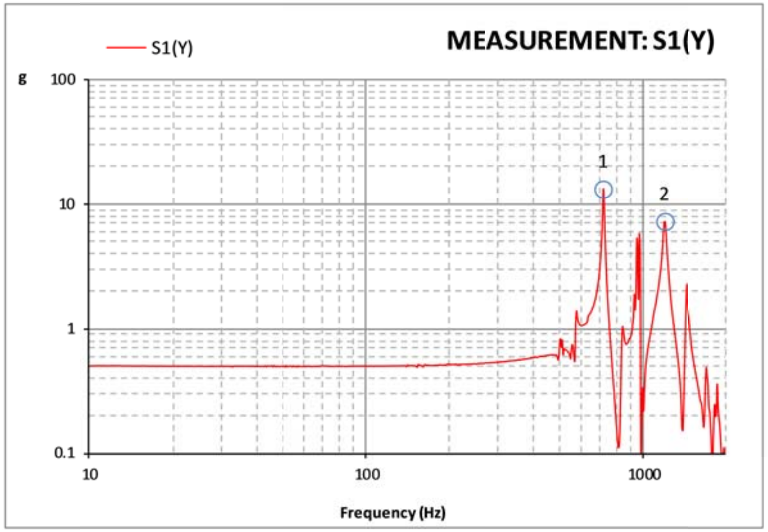
SINE 0.5 g
Sweep Rate: 2 oct/min



frequency_spectr

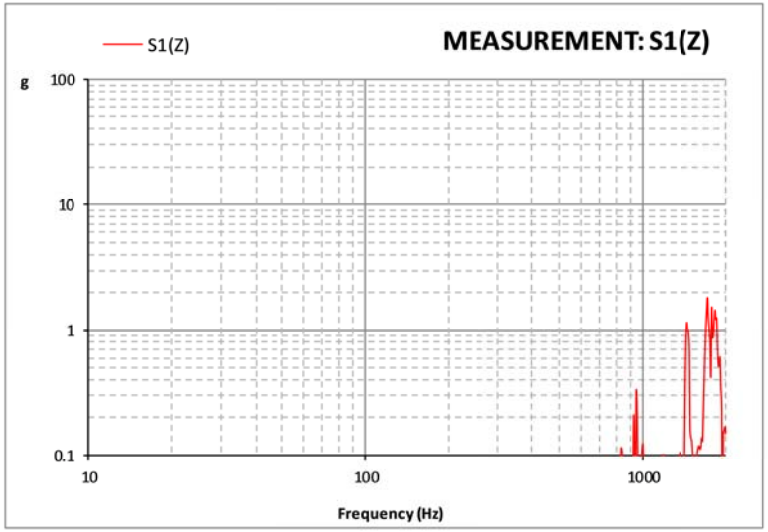


frequency_spectr



frequency_spectr

S1(Y)
X(HZ) Y(g)
#1: 717.81 13.17
#2: 1190.65 7.19

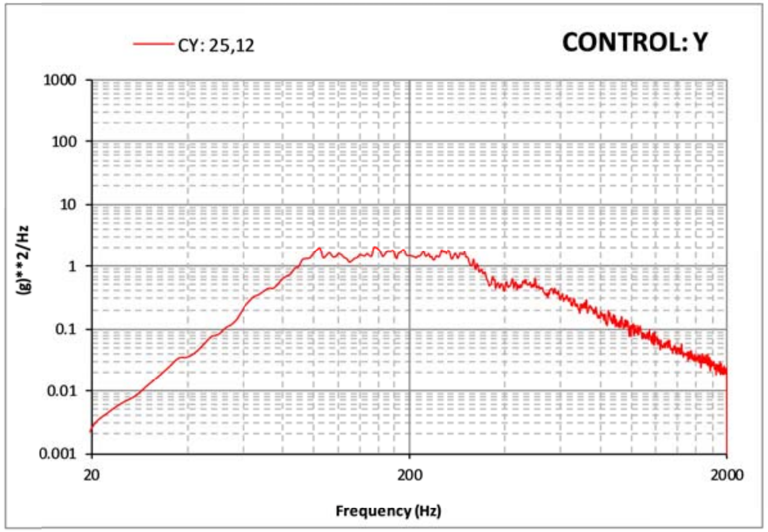


frequency_spectr

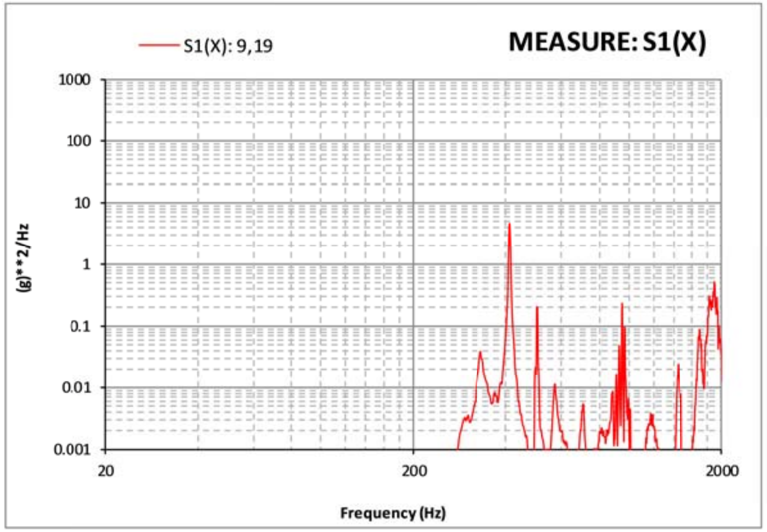
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_IX
RANDOM TEST Y

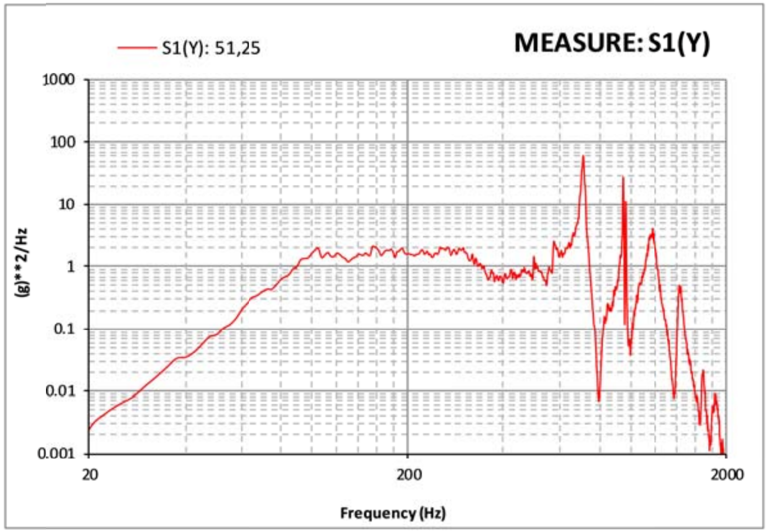
Duration: 150 seg



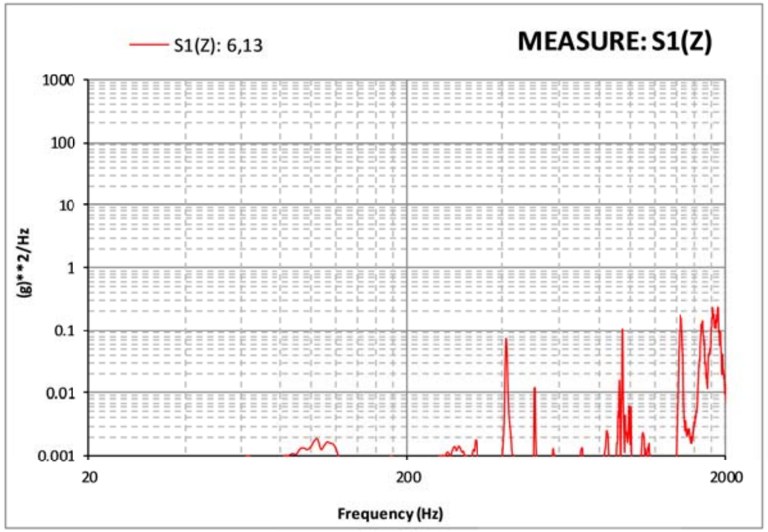
autopower_spectr



autopower_spectr



autopower_spectr

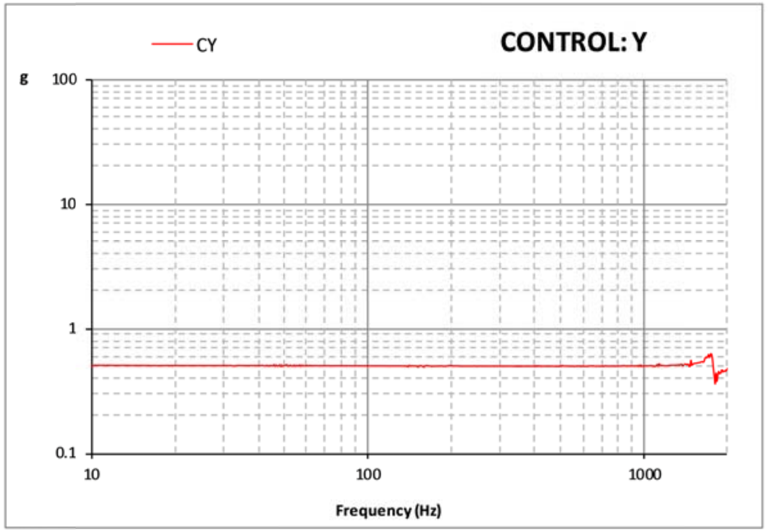


autopower_spectr

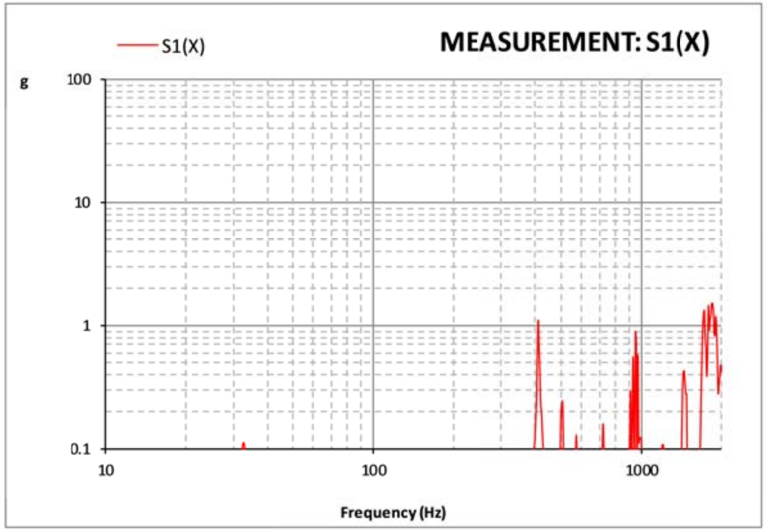
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_X
CONTROL 2 TEST Y

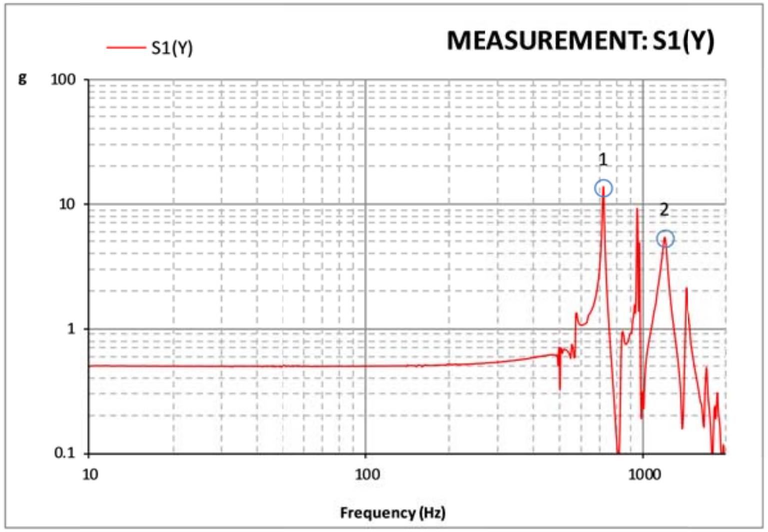
SINE 0.5 g
Sweep Rate: 2 oct/min



frequency_spectr

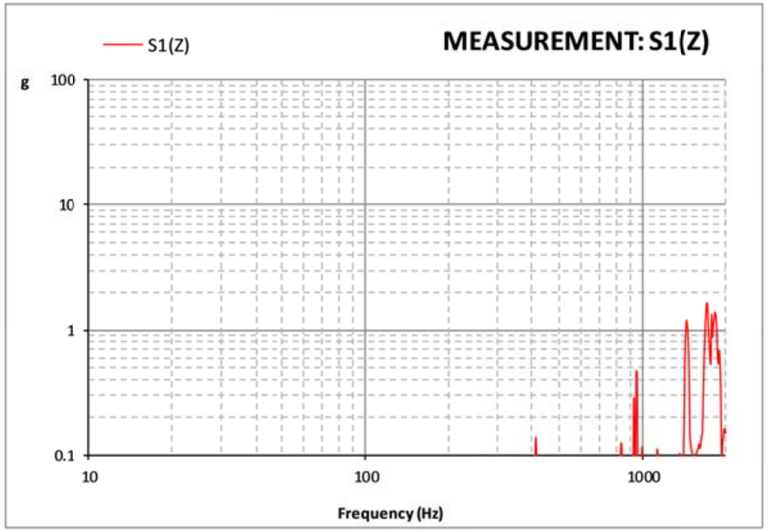


frequency_spectr



frequency_spectr

S1(Y)
X(HZ) Y(g)
#1: 718.74 13.68
#2: 1192.68 5.39

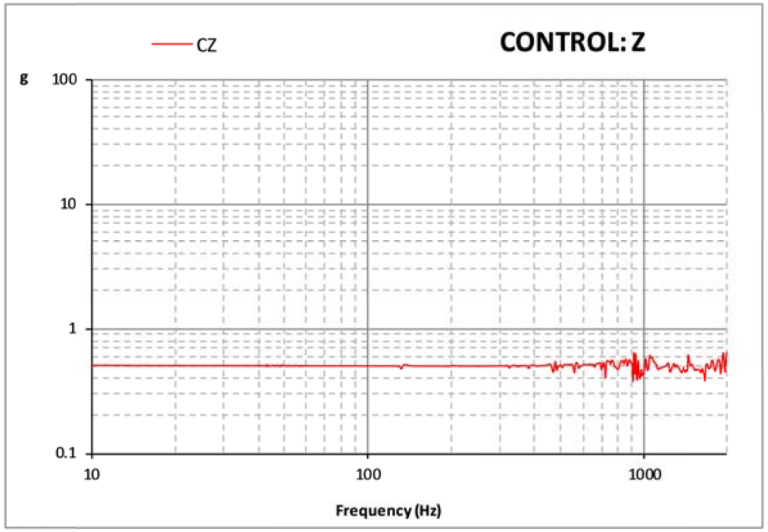


frequency_spectr

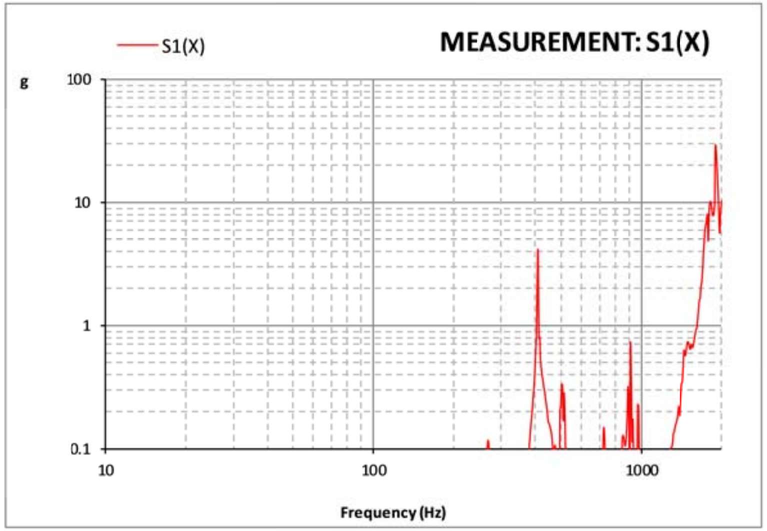
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_XI
REFERENCE TEST Z

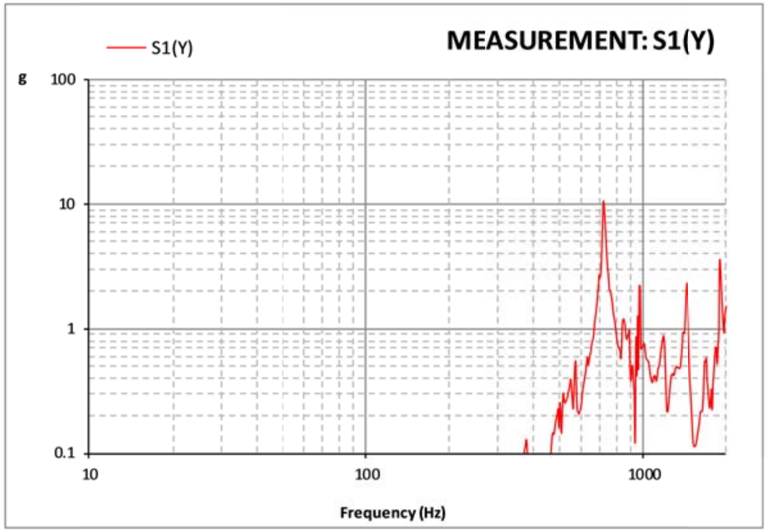
SINE 0.5 g
Sweep Rate: 2 oct/min



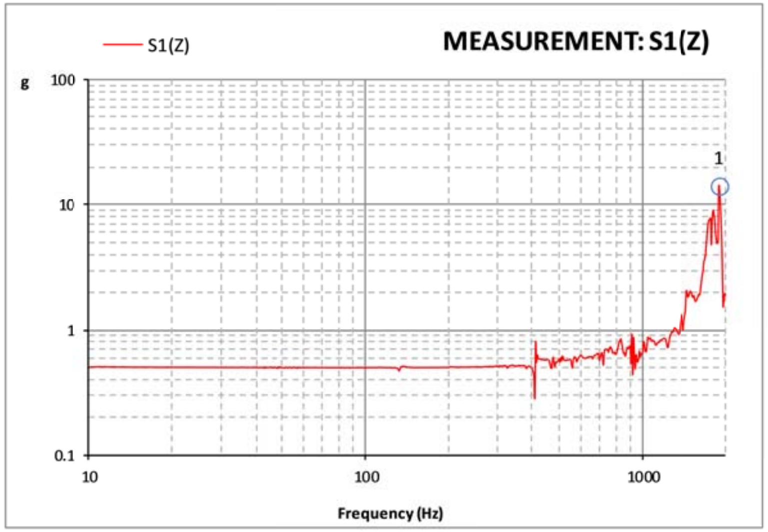
frequency_spectr



frequency_spectr



frequency_spectr



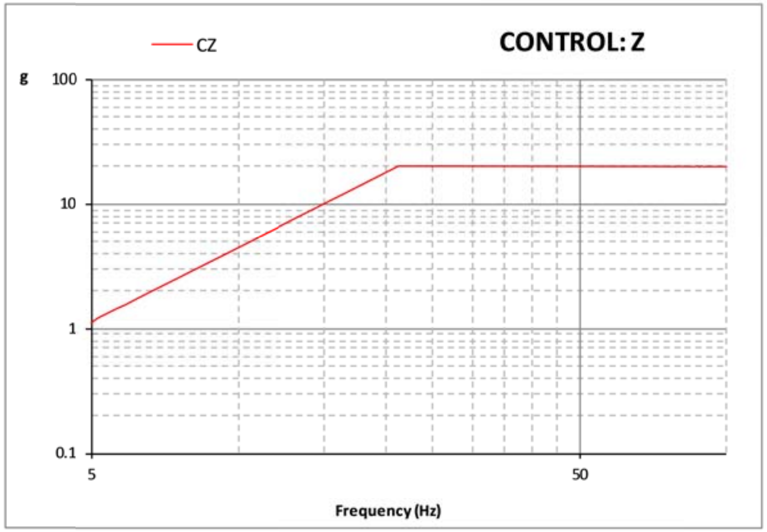
frequency_spectr

S1(Z)
X(HZ) Y(g)
#1: 1894.36 14.31

GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

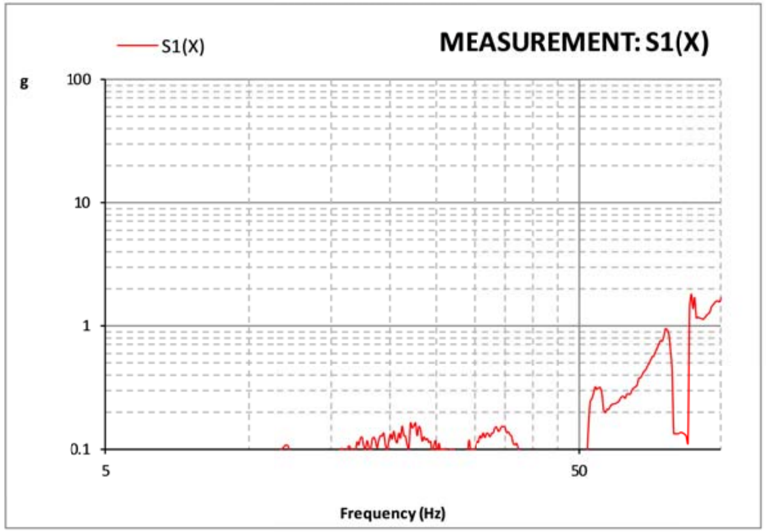
TEST ID: RUN_XII
SINE TEST Z

Sweep Rate: 2 oct/min



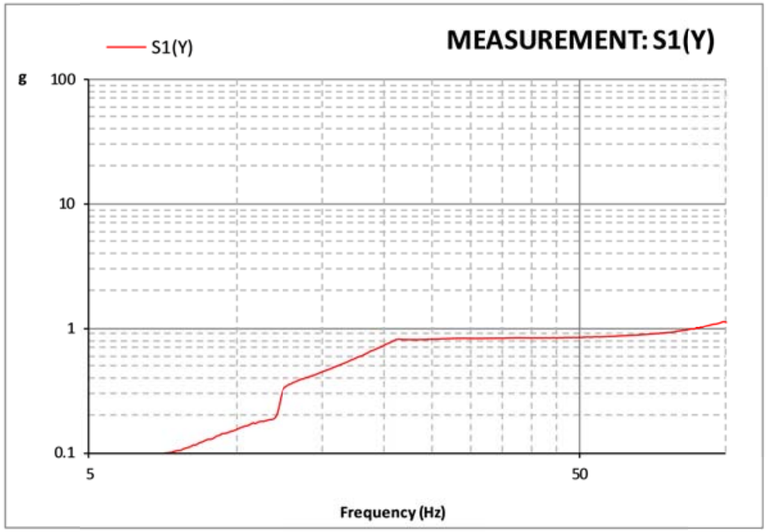
frequency_spectr

20.2 g



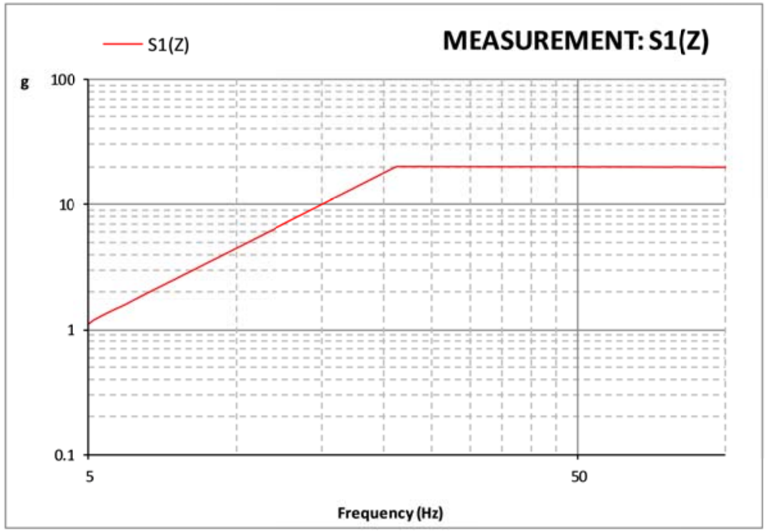
frequency_spectr

1.80 g



frequency_spectr

1.12 g



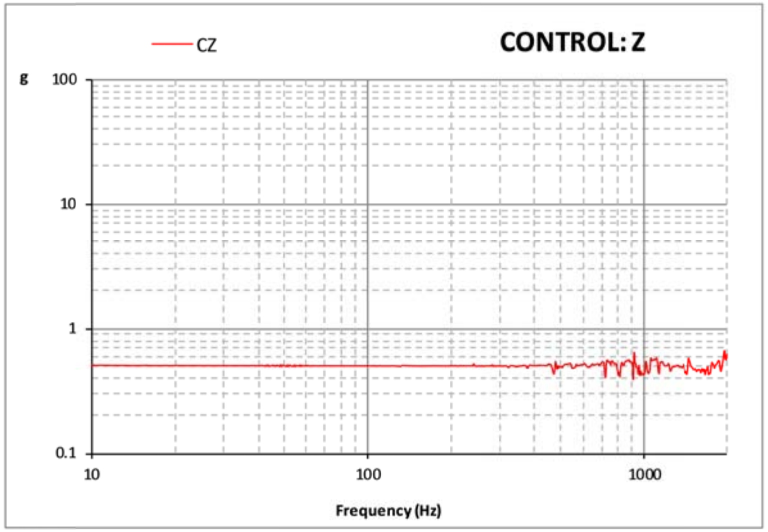
frequency_spectr

20.0 g

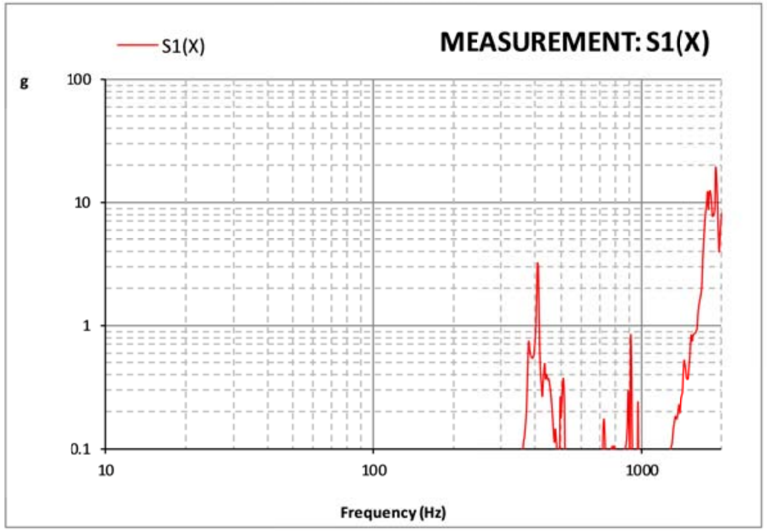
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_XIII
CONTROL 1 TEST Z

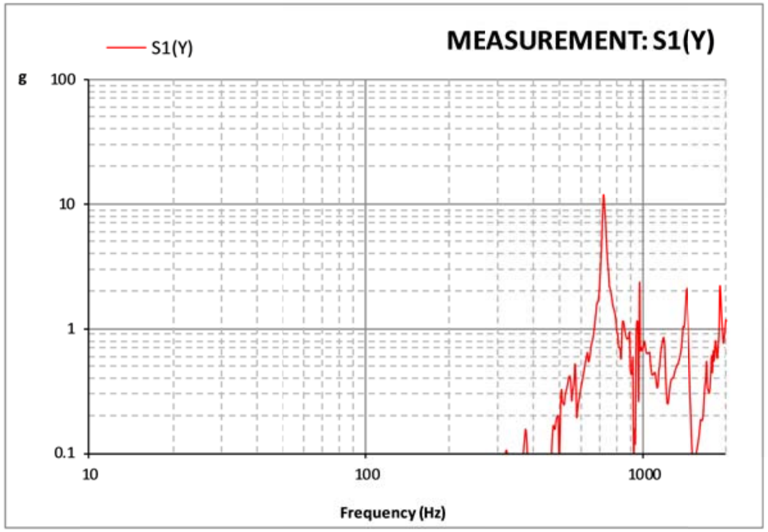
SINE 0.5 g
Sweep Rate: 2 oct/min



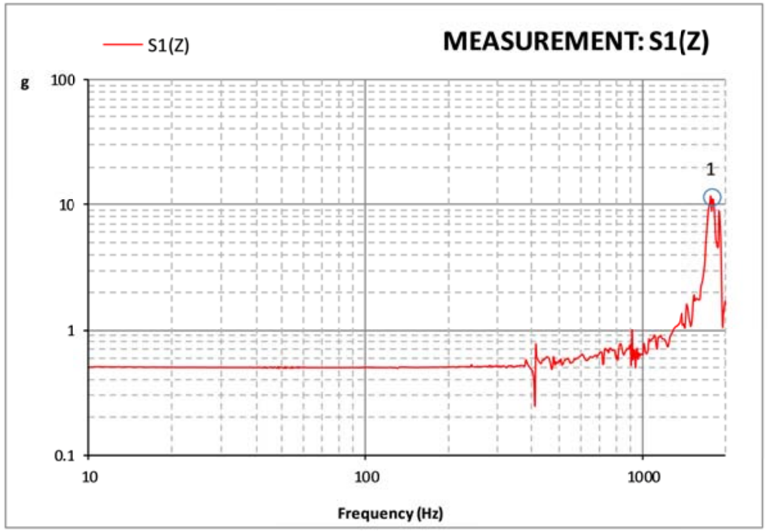
frequency_spectr



frequency_spectr



frequency_spectr



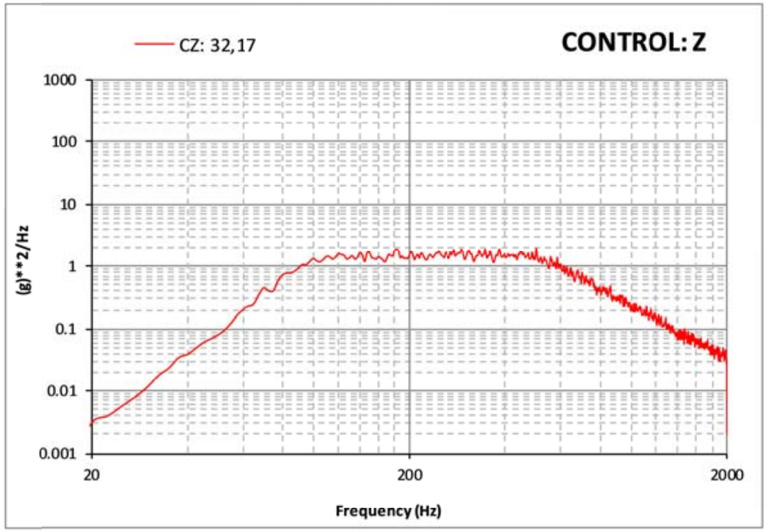
frequency_spectr

S1(Z)
X(HZ) Y(g)
#1: 1770.65 11.67

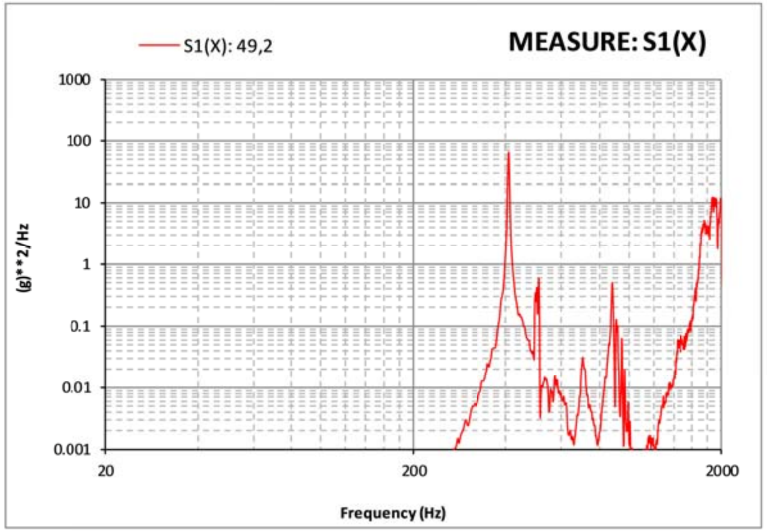
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_XIV
RANDOM TEST Z

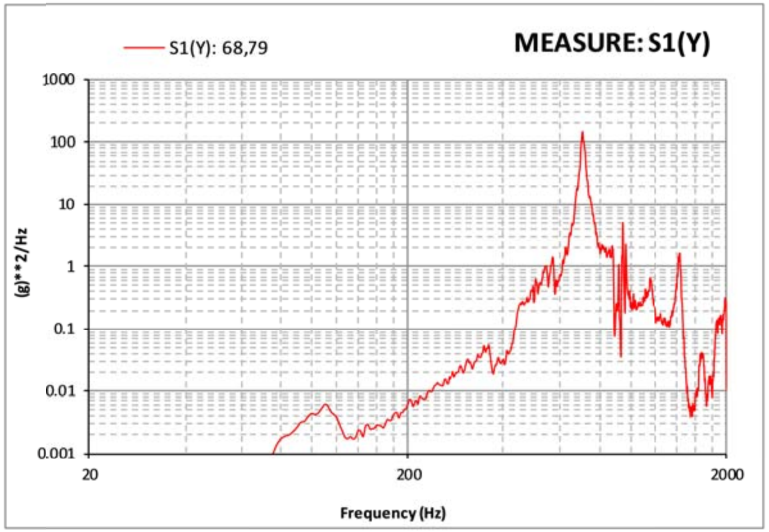
Duration: 150 seg



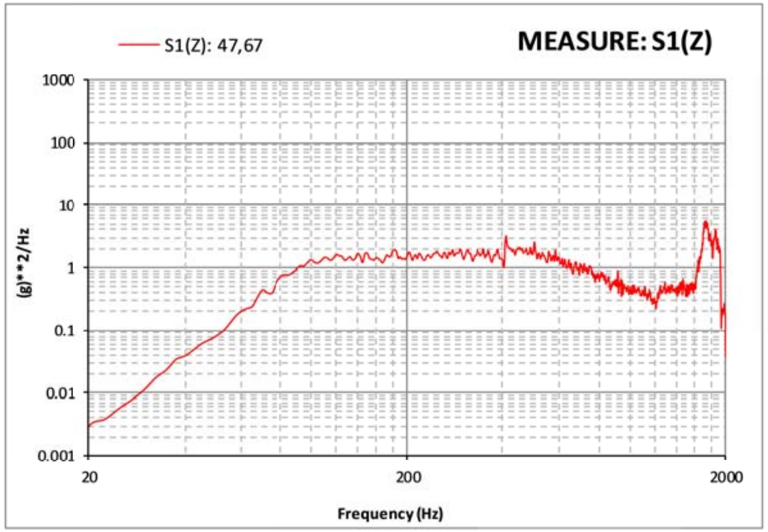
autopower_spectr



autopower_spectr



autopower_spectr

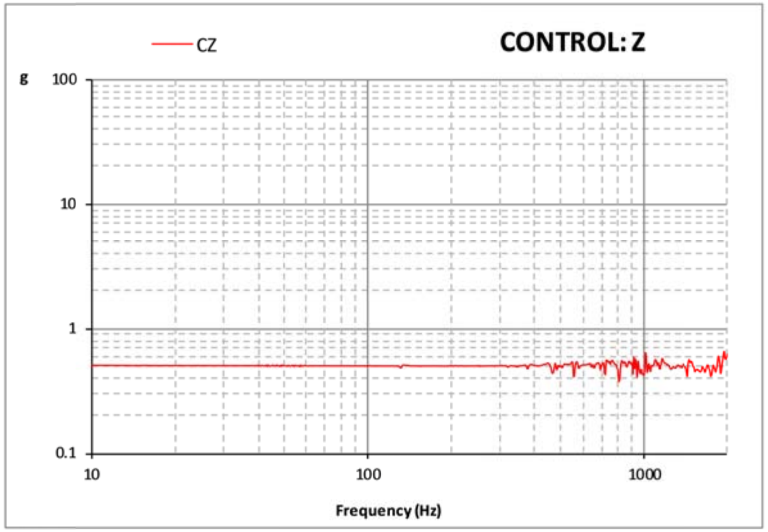


autopower_spectr

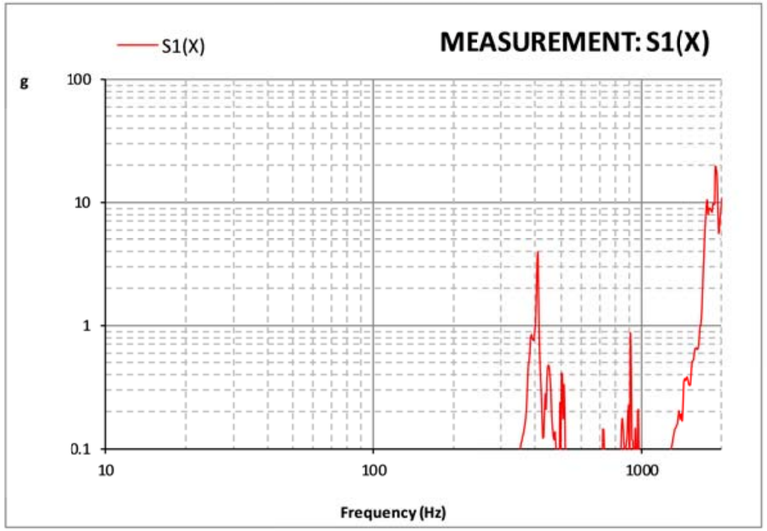
GSTP
S-BAND HELIX ANTENNA 3D PRINTED
EQM S/N 001

TEST ID: RUN_XV
CONTROL 2 TEST Z

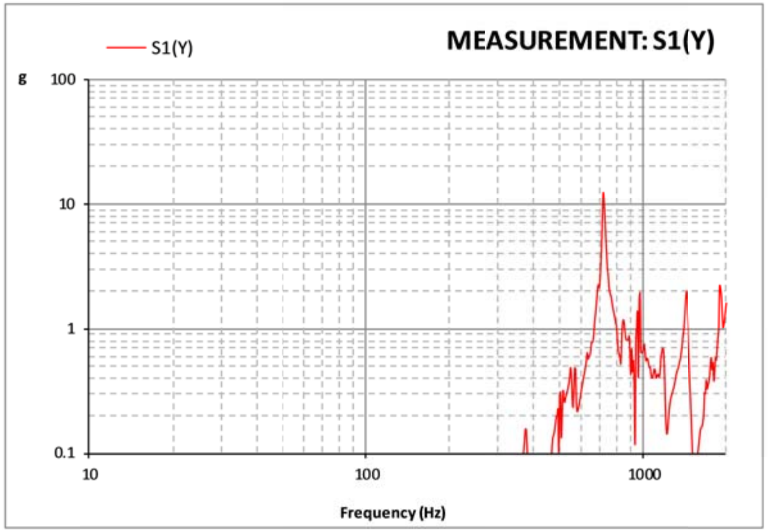
SINE 0.5 g
Sweep Rate: 2 oct/min



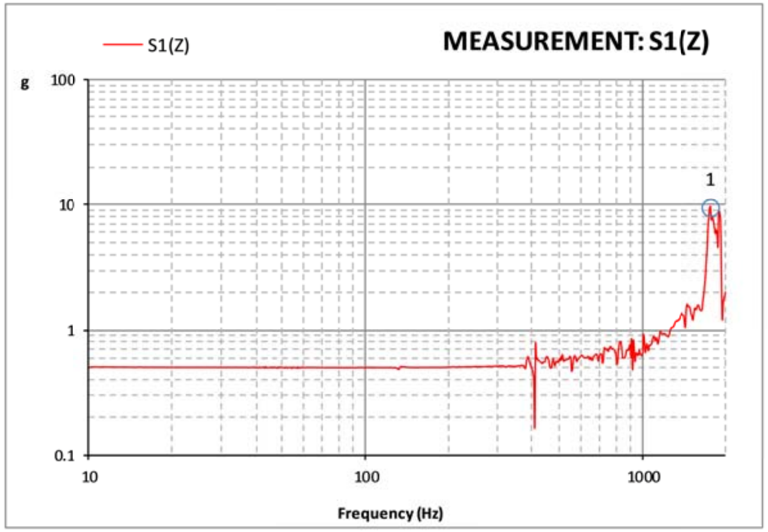
frequency_spectr



frequency_spectr



frequency_spectr



frequency_spectr

S1(Z)
X(HZ) Y(g)
#1: 1765.87 9.64

ANNEXE B

PLOTS OF THERMAL RESULTS

(This annexe contains 1 page)

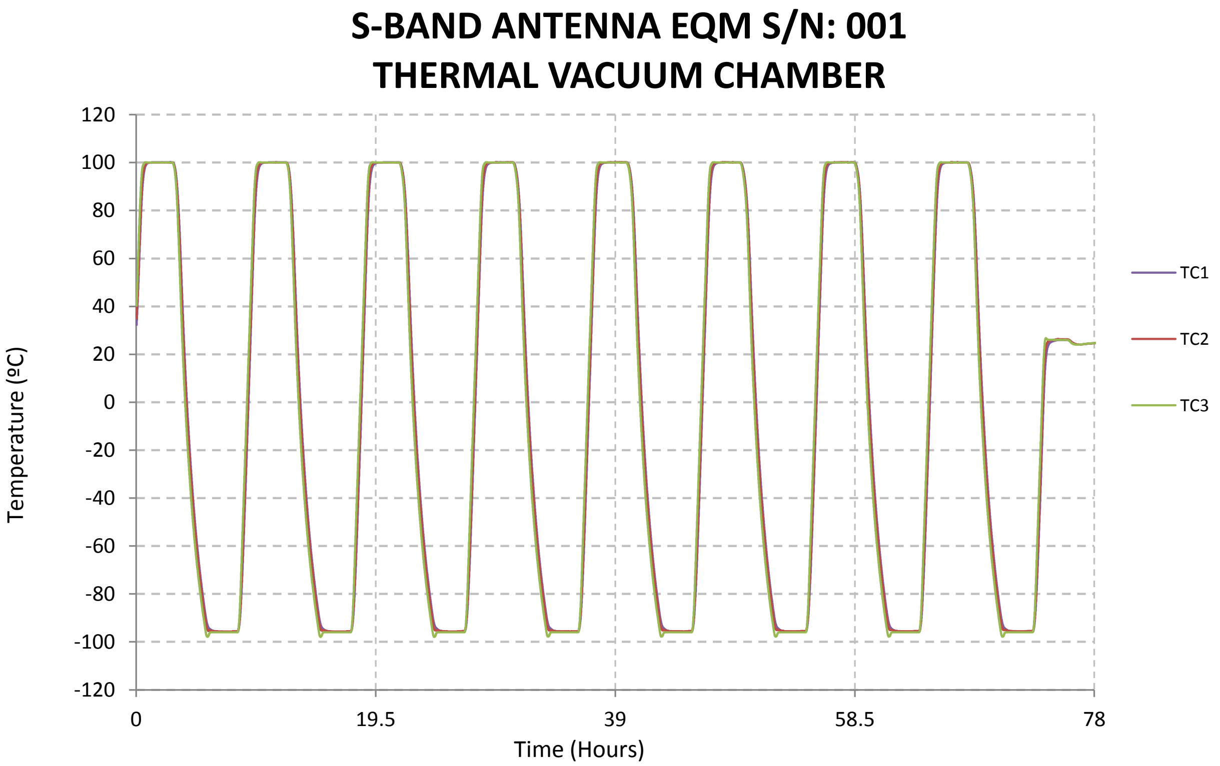


Figure B.1.- Thermal Vacuum Test. Temperature

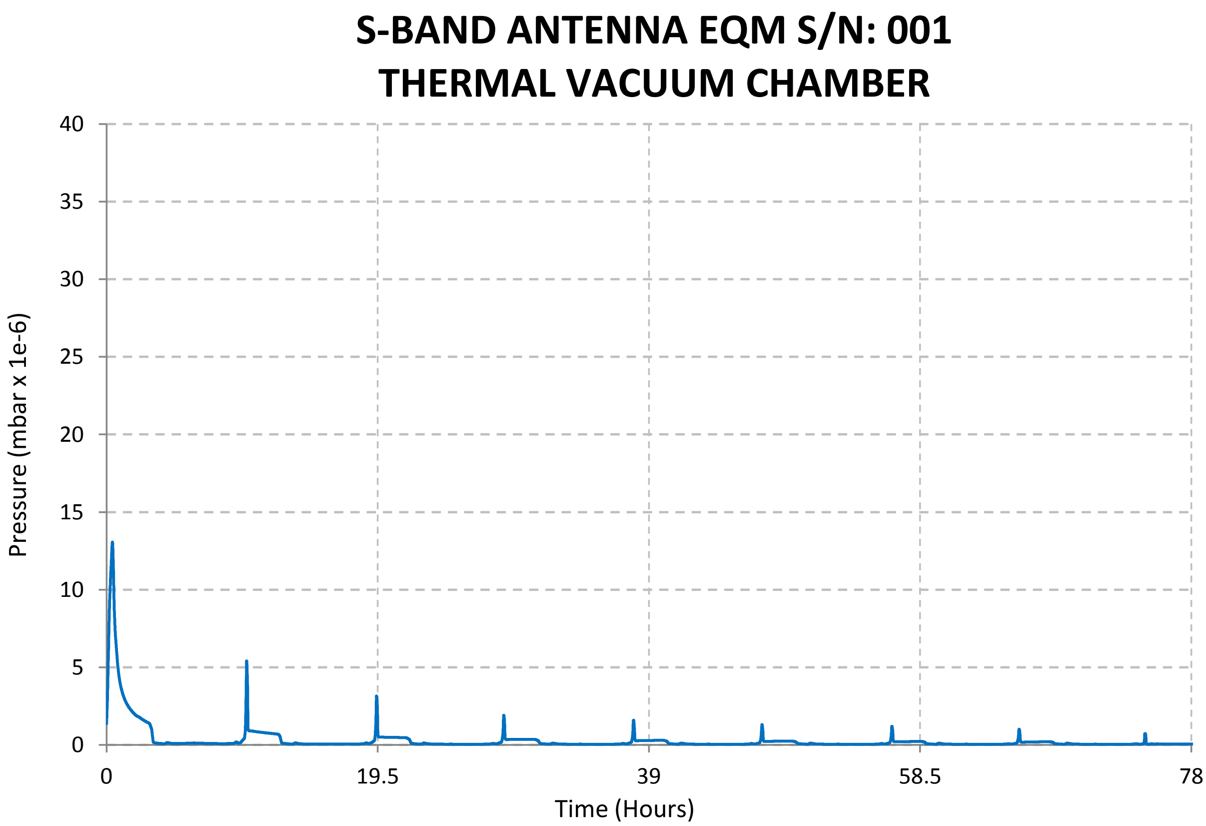


Figure B.2.- Thermal Vacuum Test. Pressure

***** END OF DOCUMENT *****