



UNICO I+D Project
6G-INTEGRATION-01

6G-INTEGRATION-01-E12

Antenna Prototype

ABSTRACT

This document presents the results of the Formal Qualification Test (FQT) defined and performed on the 6G-INTEGRATION-01 antenna prototype for each of its modules. This deliverable focuses on testing and validating the antenna prototype that allows to connect to a LEO satellite constellation in Ku band.

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Contenido

LIST OF FIGURES	5
LIST OF TABLES.....	6
LIST OF ACRONYMS.....	7
RESUMEN EJECUTIVO	8
EXECUTIVE SUMMARY.....	9
1. INTRODUCTION	10
2. TEST PLAN	11
2.1. MANUFACTURING AND TESTING	11
2.2. REQUIREMENTS.....	11
2.3. VERIFICATION METHODS.....	12
2.4. TEST PROCEDURES	12
3. TEST SETUPS.....	13
4. FQT TEST MATRIX.....	15
4.1. MODEM TEST MATRIX	15
4.2. SYNCHRONISM TEST MATRIX	15
4.3. GPS TEST MATRIX.....	16
4.4. PSU TEST MATRIX	16
4.5. ACU TEST MATRIX	16
4.6. RCM TEST MATRIX.....	17
4.7. APERTURE TEST MATRIX	17
4.8. DEMONSTRATOR TEST MATRIX.....	18
5. FQT TEST RESULTS	19
5.1. MODEM TEST RESULTS.....	19
5.2. SYNCHRONISM TEST RESULTS.....	20
5.3. GNSS TEST RESULTS	20
5.4. PSU TEST RESULTS.....	21
5.5. ACU TEST RESULTS.....	22

5.6. RCM TEST RESULTS23

5.7. APERTURE TEST.....29

5.8. DEMONSTRATOR TEST42

6. SUMMARY AND CONCLUSIONS45

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LIST OF FIGURES

FIGURE 1: TX RADIATING APERTURE 13

Figure 2: RX RADIATING APERTURE 13

FIGURE 3: INSTER'S ANECHOIC CHAMBER 14

FIGURE 4: COMMUNICATION MODEM – ANTENNA 19

FIGURE 5: SYNCHRONIZATION SIGNAL 20

FIGURE 6: TRACKING STATUS 21

FIGURE 7: GNSS STATUS 21

FIGURE 8: GNSS DUAL STATUS 21

FIGURE 9: TX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 14.0 GHZ 30

FIGURE 10: TX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 14.25 GHZ 31

FIGURE 11: TX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 14.5 GHZ 32

FIGURE 12: RX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 10.7 GHZ 33

FIGURE 13: RX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 11.7 GHZ 34

FIGURE 14: RX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 12.7 GHZ 35

Figure 15 TX AR (dB) accros TX frequency 39

Figure 16 RX AR - PHI 0 40

FIGURE 17: PANEL AXIS 41

FIGURE 18: DIMENSIONS AND MECHANICAL LAYOUT 42

Figure 19 DIMENSION large measurement 43

Figure 20 DEMOSTRATOR WIDE MEASUREMENT 43

Figure 21 DEMOSTRATOR HEIGHT 44

Figure 22 DEMOSTRATOR WEIGHT 44

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LIST OF TABLES

TABLE 1: REQUIREMENTS.....	12
TABLE 2: MODEM TEST MATRIX.....	15
TABLE 3: SYNCHRONISM TEST MATRIX.....	15
TABLE 4: GPS TEST MATRIX.....	16
TABLE 5: PSU TEST MATRIX.....	16
TABLE 6: ACU TEST MATRIX.....	17
TABLE 7: RCM TEST MATRIX.....	17
TABLE 8: TX APERTURE TEST MATRIX.....	17
TABLE 9: DEMONSTRATOR TEST MATRIX.....	18
TABLE 10: TX ACTIVE GAIN – PHI 0.....	36
TABLE 11: TX ACTIVE GAIN – PHI 45.....	37
TABLE 12: TX ACTIVE GAIN – PHI 90.....	37
TABLE 13: TX ACTIVE GAIN – PHI 135.....	37
TABLE 14: RX ACTIVE GAIN – PHI 0.....	37
TABLE 15: RX ACTIVE GAIN – PHI 45.....	38
TABLE 16: RX ACTIVE GAIN – PHI 90.....	38
TABLE 17: RX ACTIVE GAIN – PHI 135.....	38
TABLE 18: TX AR – PHI 0.....	39
TABLE 19: RX AR – PHI 0.....	40
TABLE 20: EIRP.....	41
Table 21: G/T (dB/K).....	42

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LIST OF ACRONYMS

ACU: Antenna Control Unit
AIM: Antenna Interface Module
AR: Axial Ratio
DC: Direct Current
EIRP: Effective Isotropic Radiated Power
ESA: Electronic Steerable Antenna
FQT: Factory Qualification Tests
GNSS: Global Navigation Satellite System
GPS: Global Positioning System
G/T: Gain over Temperature
IF: Intermediate Frequency
LEO: Low Earth Orbit
LHCP: Left-Hand Circular Polarization
OW: One Web
PCB: Printed Circuit Board
PLL: Phase Locked-Loop
PSU: Power Supply Unit
RCM: RF Converter Module
RF: Radiofrequency
RHCP: Right-Hand Circular Polarization
RX: Reception
SPI: Serial Peripheral Interface
SSM: Satellite Subscriber Module
TX: Transmission

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RESUMEN EJECUTIVO

El presente trabajo se centra en documentar las pruebas realizadas al prototipo de una antena diseñada para el segmento terrestre, específicamente destinada al apuntamiento dinámico de satélites LEO. Estas pruebas se han diseñado y ejecutado con el objetivo de asegurar que los distintos subsistemas del prototipo de la antena cumplen con las especificaciones y requisitos establecidos a lo largo del proceso de diseño.

Las pruebas incluidas en este documento reflejan las mediciones y pruebas llevadas a cabo durante el proceso de ensamblaje de la antena. Los resultados descritos en el presente son los siguientes:

- Definición del procedimiento de pruebas y establecimiento de los distintos métodos de verificación para el diseño de las pruebas.
- Preparación del escenario de pruebas para su correcta ejecución.
- Seguimiento detallado de las pruebas utilizando una matriz para cada subsistema del prototipo, asignando cada prueba a su requisito correspondiente.
- Demostrar el cumplimiento de los requisitos presentando los resultados obtenidos de las pruebas realizadas.
- Proporcionar soporte para la puesta en marcha del prototipo de la antena, asegurando una transición suave hacia su implementación operativa.

EXECUTIVE SUMMARY

The present work focuses on documenting the tests carried out on a prototype antenna designed for the terrestrial segment, specifically aimed at the dynamic pointing of LEO satellites. These tests have been designed and executed to ensure that the various subsystems of the antenna prototype comply with the specifications and requirements established throughout the design process.

The tests included in this document reflect the measurements and tests carried out during the antenna assembly process. The results described in this document are as follows:

- Definition of test procedures and establishment of verification methods for test design.
- Preparation of the test setup for proper execution.
- Detailed tracking of tests using a matrix for each subsystem of the prototype, mapping each test to its respective requirement.
- Demonstration of compliance with requirements by presenting the results obtained from the tests conducted.
- Providing support for the deployment of the antenna prototype, ensuring a smooth transition to its operational implementation

1. INTRODUCTION

This document details the measurements and tests performed to the various subsystems of the antenna prototype. The prototype includes an electronically steerable ground segment antenna with improved beam management for dynamic pointing of LEO satellites. Its components include the following:

- ACU (Antenna Control Unit)
- PSU (Power Supply Unit)
- Synchronism Module
- RCM (RF-IF, IF-RF converters)
- Modem
- Switch
- GPS
- TX and RX apertures

This document presents the unitary tests conducted on the distinct subsystems during the assembly of the antenna prototype. These tests ensure that the various subsystems of the antenna prototype comply with the specifications and requirements established during the definition phase, and they are met throughout the manufacturing and measurement process.

This deliverable addresses the task **T4.5**, which focuses on the manufacturing and testing of the prototype and includes the following subtasks:

1. Fabrication and assembly of the printed circuit boards (PCBs).
2. Conducting measurements in the anechoic chamber to assess antenna performance.
3. Carrying out Factory Qualification Tests (FQTs) on hardware, firmware, and software modules.

2. TEST PLAN

2.1. MANUFACTURING AND TESTING

The following process is carried out to verify and assembly the subsystems of the demonstrator.

- **PCB verification:** The PCBs are verified in the laboratory by performing the necessary FQTs to ensure each PCB meets the required specifications before integration.
- **Mechanical integration:** The PCBs are allocated in the prototype according to the mechanical plans, ensuring all components are positioned as designed.
- **Power supply verification:** The modules are connected to the PSU one by one to verify that the PSU can power on each PCB in the prototype.
- **Module communication verification:** The communication between different modules is verified step by step and module by module, ensuring each module can interact correctly with others.
- **Hardware and aperture communication:** The communication between the HW and apertures is verified, ensuring signals are correctly transmitted and received.
- **Power levels validation:** The power levels are validated, ensuring the system operates within the specified power ranges.
- **Firmware functionality testing:** The firmware is tested to confirm it can command and receive information to and from all modules.

Throughout the document, the FQT of the main system modules will be presented to verify the proper unitary functioning prior to the integration of the modules with each other. Additionally, some mechanical verifications are also done to verify the dimensions and weight of the prototype.

These modules are the following:

- Modem
- Synchronism module
- GNSS module
- PSU
- ACU
- RCM
- Aperture (Tx and Rx)

2.2. REQUIREMENTS

The following table includes the requirements specified for the antenna prototype.

ID	NAME	VALUE	COMMENTS
RF-1	Frequency Range	TX: 14.0 – 14.5 GHz RX: 10.7 – 12.7 GHz	
RF-2	Polarization	LHCP / RHCP Desired SLL: -15dB	

RF-3	Coverage range	Azimuth: 0 – 360° Elevation: 0 – 60°	
RF-4	EIRP @ Plineal	≥ 35 dBW	In all the frequency range, for all the angular range.
RF-5	G/T	≥ 7 dB/K	In all the frequency range, for all the angular range.
RF-6	Axial Ratio	≤ 2.5 dB	In all the frequency range, for all the angular range.
TR-1	Alignment	Electronic	Electronic beamforming.

TABLE 1: REQUIREMENTS

2.3. VERIFICATION METHODS

The verification of each requirement will be presented, indicating the description of each specific test and the verification method used. The test verification method will be indicated using the following notation:

- CI: Certificate Inspection
- DI: Document Inspection
- VI: Visual Inspection
- T: Test
- A: Analysis

2.4. TEST PROCEDURES

The test procedure conducted to verify the requirements is outlined below. The assigned engineer will record the results and determine whether each test passes or fails as part of the testing process.

2.4.1. FORMAL QUALIFICATION TEST (FQT) PROCEDURE

The FQTs encompass the Unitary Tests of the terminal modules. Through these tests, the technical, functional, and quality characteristics of the components are ensured to meet all the requirements necessary for the correct functioning of the system.

3. TEST SETUPS

The evaluation of both the transmission and reception apertures of the antenna prototype is conducted in an Anechoic Chamber. Within this controlled environment, critical parameters such as gain, and axial ratio are measured to ensure compliance with performance specifications.

The following figures show the TX and RX radiating apertures that are tested, along with the testing environment within the Instster's Anechoic Chamber.

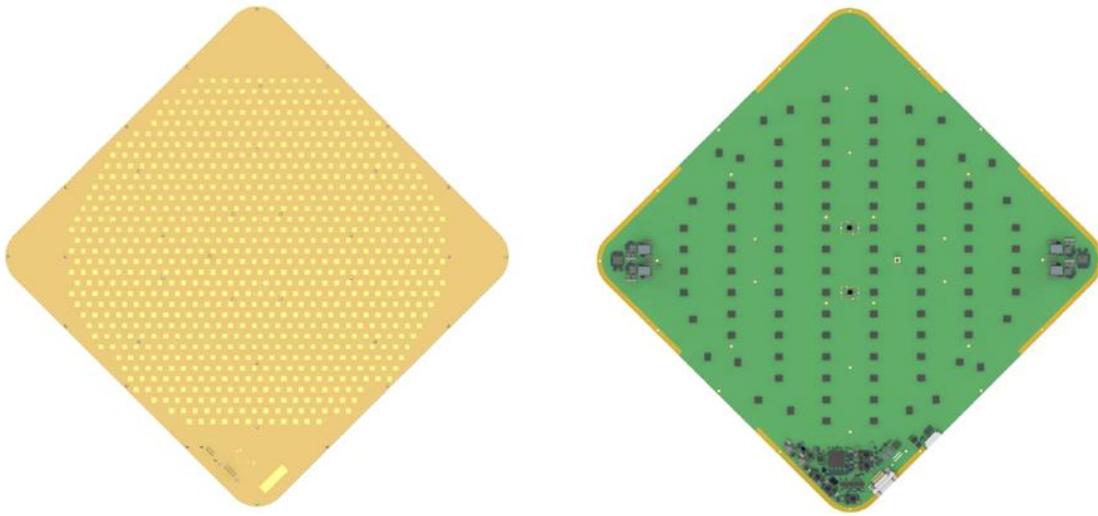


FIGURE 1: TX RADIATING APERTURE

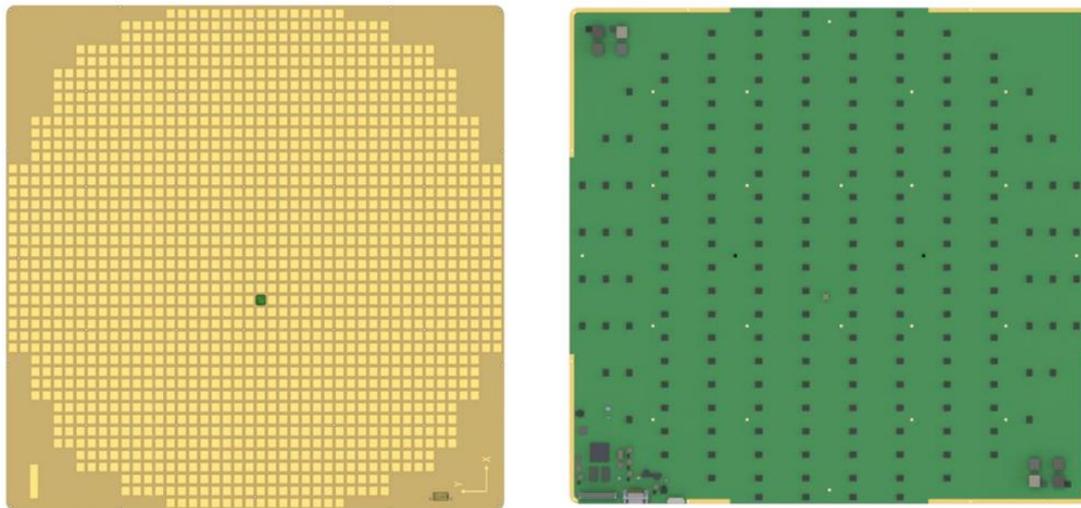


FIGURE 2: RX RADIATING APERTURE

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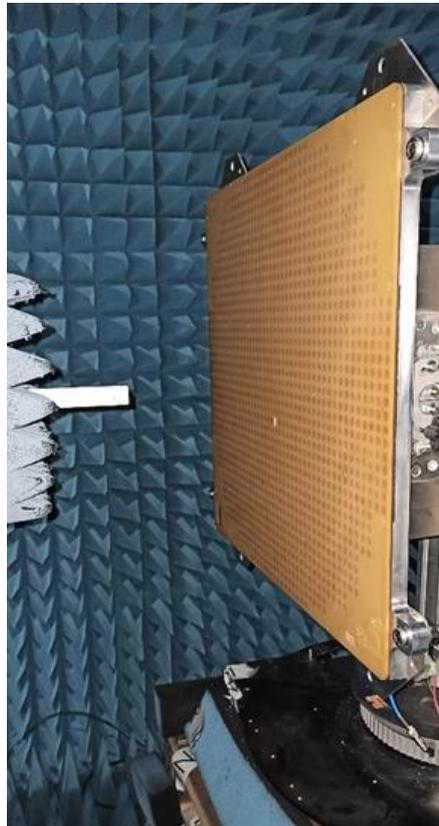
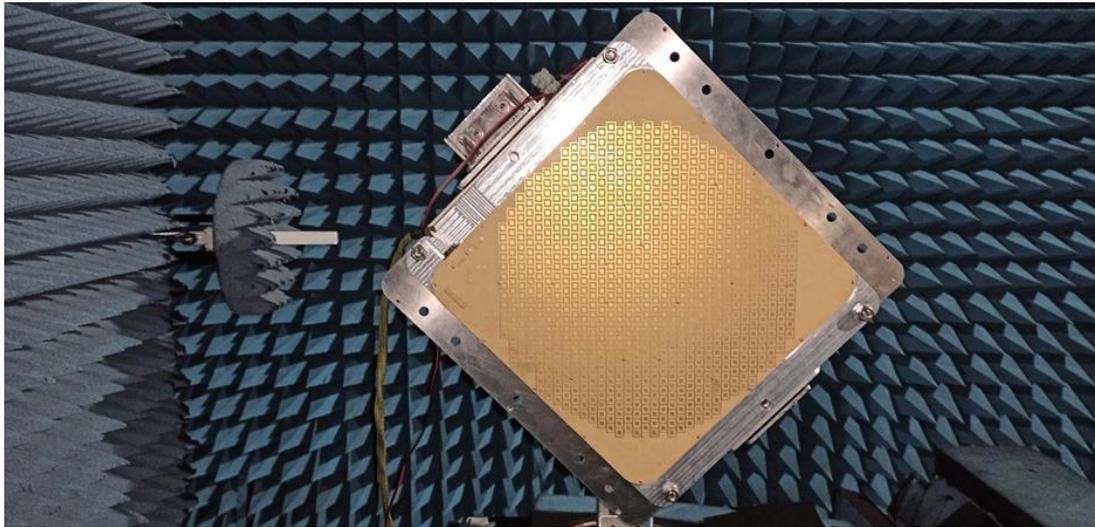


FIGURE 3: INSTER'S ANECHOIC CHAMBER

4. FQT TEST MATRIX

This section lists the FQT tests performed to validate the PCBs and the different modules of the antenna prototype. The traceability of the tests is indicated with each requirement and verification method. Every requirement has been mapped to its respective tests, and additional tests have been considered for each module.

The following tables show the test matrix for each module and their results are detailed in the corresponding test results in Section 5.

4.1. MODEM TEST MATRIX

TEST MATRIX N° 1				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification		Contractual Specification
FQT	Modem	N/A		N/A
N°	Requirement	Test	Description	Method
1	Additional	TEST1	Modem consumption	T
2	Additional	TEST2	ACU – Modem communication	T
3	Additional	TEST3	Sync signal reception	T
4	Additional	TEST4	Modem communication traffic port	T

TABLE 2: MODEM TEST MATRIX

4.2. SYNCHRONISM TEST MATRIX

TEST MATRIX N° 2				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification		Contractual Specification
FQT	Synchronism module	N/A		N/A
N°	Requirement	Test	Description	Method
1	Additional	TEST5	Sync signal delivery	T

TABLE 3: SYNCHRONISM TEST MATRIX

4.3. GPS TEST MATRIX

TEST MATRIX N° 3				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification	Contractual Specification	
FQT	GPS	N/A	N/A	
N°	Requirement	Test	Description	Method
1	Additional	TEST6	Dual GPS reception	T

TABLE 4: GPS TEST MATRIX

4.4. PSU TEST MATRIX

TEST MATRIX N° 4				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification	Contractual Specification	
FQT	PSU	N/A	N/A	
N°	Requirement	Test	Description	Method
1	Additional	TEST7	Power consumption	T
2	Additional	TEST8	Operation voltage	T

TABLE 5: PSU TEST MATRIX

4.5. ACU TEST MATRIX

TEST MATRIX N° 5				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification	Contractual Specification	
FQT	ACU	N/A	N/A	
N°	Requirement	Test	Description	Method
1	Additional	TEST9	GNSS-ACU communication	T
2	Additional	TEST10	Verify Ethernet ports	T
3	Additional	TEST11	Verify SPI protocol	T

TABLE 6: ACU TEST MATRIX

4.6. RCM TEST MATRIX

TEST MATRIX N° 6				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification	Contractual Specification	
FQT	RCM – up converter	N/A	N/A	
N°	Requirement	Test	Description	Method
1	RF-1	TEST12	RF frequency bands	T
2	Additional	TEST13	IF frequency bands	T
3	Additional	TEST14	RF ports	T
4	Additional	TEST15	IF ports	T

TABLE 7: RCM TEST MATRIX

4.7. APERTURE TEST MATRIX

TEST MATRIX N° 8				
Project		6G-INTEGRATION-01 UNICO I+D Project		
Test type	Item Under Test	Applicable specification	Contractual Specification	
FQT	Aperture	N/A	N/A	
N°	Requirement	Test	Description	Method
1	RF-1	TEST16	Frequency bands	T
2	RF-2	TEST17	Polarization	T
3	Additional	TEST18	Gain	T
4	RF-6	TEST19	Axial ratio	T
5	RF-4	TEST20	EIRP	T
6	RF-5	TEST21	G/T	T

TABLE 8: TX APERTURE TEST MATRIX

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4.8. DEMONSTRATOR TEST MATRIX

TEST MATRIX N° 10				
Project			6G-INTEGRATION-01 UNICO I+D Project	
Test type	Item Under Test		Applicable specification	Contractual Specification
FQT	Antenna Prototype		N/A	N/A
Nº	Requirement	Test	Description	Method
1	Additional	TEST22	Dimensions verification	T

TABLE 9: DEMONSTRATOR TEST MATRIX

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5. FQT TEST RESULTS

5.1. MODEM TEST RESULTS

5.1.1. Modem consumption

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST1	Verify that the modem consumption is under the specific level.	≤ 25 W	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the modem consumption remains under the specified level of 25 W.

5.1.2. ACU – Modem communication

Req ID	Test	Test sequence	Test result
Additional	TEST2	Verify the right communication between the modem and the antenna.	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the modem successfully establishes and maintains a stable communication with the antenna. The correct communication between the modem and the antenna is reflected in the graphical interface within the antenna section.

Communications	OK
-----------------------	----

FIGURE 4: COMMUNICATION MODEM – ANTENNA

This field shows the real-time status of the communication between the ACU and the Modem. Additionally, a continuous ping confirms the responsiveness between the modem and the antenna.

5.1.3. Modem communication traffic port

Req ID	Test	Test sequence	Test result
Additional	TEST4	Verify the access to the modem through the Ethernet cable/port	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that access to the modem through Ethernet cable and port is functional.

5.2. SYNCHRONISM TEST RESULTS

5.2.1. Synchronization signal

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST3	Verify the frequency reference of 25 MHz synchronization signal reception	25 MHz	OK x / NOT OK <input type="checkbox"/>
Additional	TEST5	Verify the frequency reference of 25 MHz synchronization signal delivery	25 MHz	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the synchronization signal is delivered by the synchronism module and received by the modem module at the specified frequency of 25 MHz. The correct transmission and reception of this signal is reflected in the graphical interface within the modem section.

RF-LMM 25MHz Clock	
Tx0 RF Path	Enabled
Tx1 RF Path	Enabled
25.0MHz PLL	Locked

FIGURE 5: SYNCHRONIZATION SIGNAL

These fields indicate that the synchronization signal is operational within the system, ensuring that the synchronization module is effectively delivering the 25 MHz signal, which is being correctly received and processed by the modem module.

5.3. GNSS TEST RESULTS

5.3.1. Dual GPS reception

Req ID	Test	Test sequence	Test result
TR-1	TEST6	Verify that when the GPS is connected, the ACU has dual GNSS.	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the ACU successfully operates with dual GNSS reception once the terminal reaches the 'tracking' status. This status is achieved a few minutes after powering on the terminal, indicating that it is operational. Subsequently, the GNSS status can be monitored from both the main page and the antenna section of the graphical interface.

The antenna subsystem status shows that it is in 'tracking' mode, which implies that the GNSS receiver is actively acquiring and processing satellite signals. Additionally, the antenna page confirms that the GPS subsystem is operational, and that positioning is enhanced by the dual GNSS reception. This status is clearly displayed in the graphical interface.

Antenna subsystem status	
Status	TRACKING

FIGURE 6: TRACKING STATUS

GPS status	OK
------------	----

FIGURE 7: GNSS STATUS

Current GNSS DUAL FIX	YES
-----------------------	-----

FIGURE 8: GNSS DUAL STATUS

These indicators collectively ensure that the ACU is effectively using the dual GNSS capabilities, enhancing the terminal's positioning performance.

5.4. PSU TEST RESULTS

5.4.1. Power consumption

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST7	Verify that the PSU power consumption is lower than the specified.	≤ 5 W	OK X / NOT OK <input type="checkbox"/>

Test result:

The test shows a PSU power consumption of 4 W. It is verified that the PSU power consumption is lower than the specified level of 5 W.

5.4.2. Operation voltage

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST8	Verify that the PSU could operate at 18/36 VDC as input power via a 5-pin connector	18 and 36 VDC	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the PSU operates correctly at both 18 VDC and 36 VDC input power via a 5-pin connector.

5.5. ACU TEST RESULTS

5.5.1. GNSS – ACU communication

Req ID	Test	Test sequence	Test result
Additional	TEST9	Verify that the ACU uses UART communication with GNSS receiver.	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the ACU uses UART communication with the GNSS receiver modules.

5.5.2. Ethernet ports

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST10	Verify that the ACU has two Ethernet ports.	<ul style="list-style-type: none"> - RGMII for M&C - RMII for direct communication with the modem 	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the ACU has two Ethernet ports, RGMII for M&C and RMII for direct communication with the modem.

5.5.3. SPI protocol

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST11	Verify that the ACU uses SPI protocol for communication with the apertures	<ul style="list-style-type: none"> - Slave communication with RX aperture. - Slave communication with TX aperture 	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the ACU uses the SPI protocol for communication with the apertures, acting as a slave for both RX and TX aperture communication.

5.6. RCM TEST RESULTS

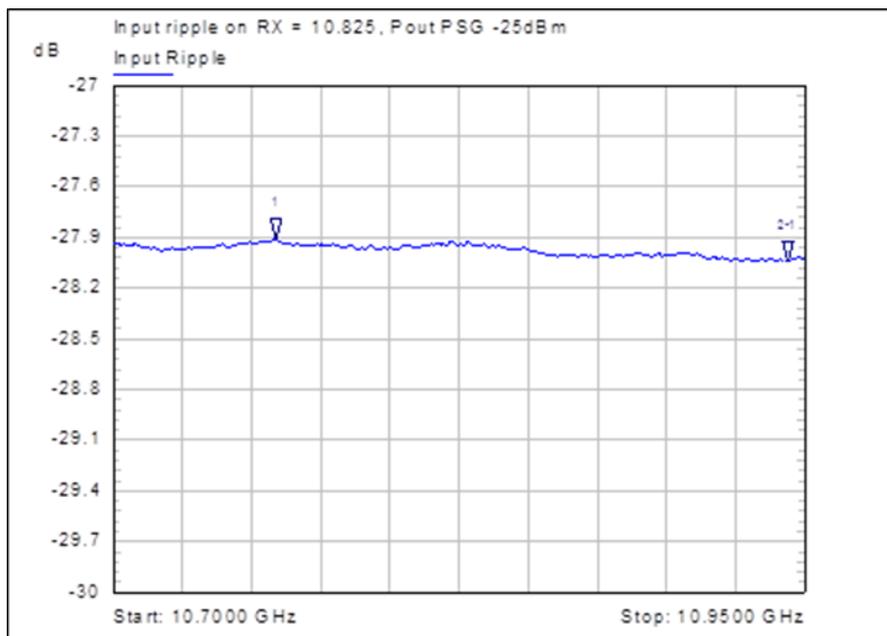
5.6.1. RF frequency bands

Req ID	Test	Test sequence	Specified value	Test result
RF-1	TEST12	Verify that the TX RF frequency is within the specified range.	14.0 - 14.5 GHz	OK x / NOT OK □
		Verify that the RX RF frequency is within the specified range.	10.7 – 12.7 GHz	OK x / NOT OK □

The gain ripple is measured among the expected frequency band with the PSG in RF frequencies (ESG 4438). For IF frequencies, the specific channels of OW are tested.

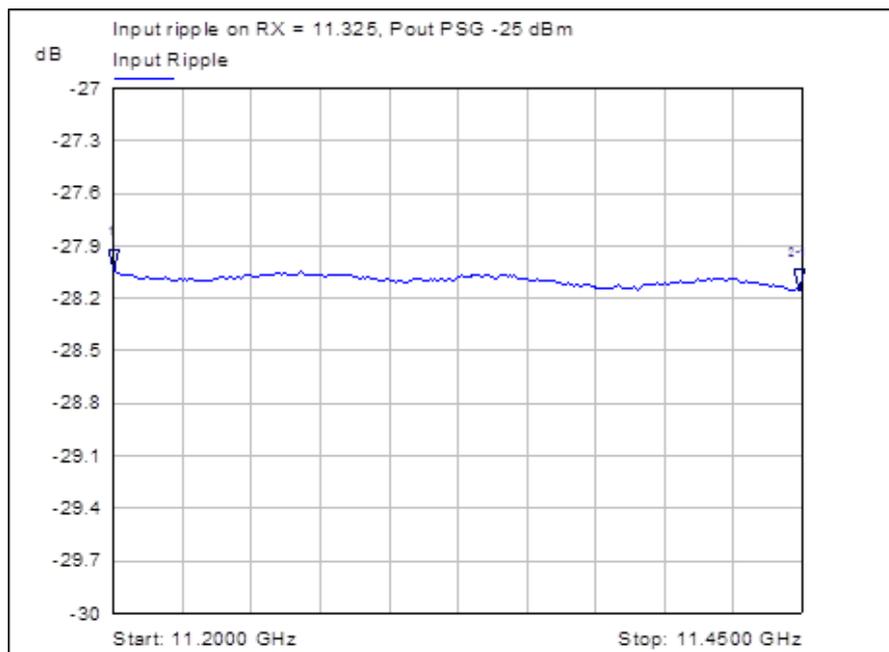
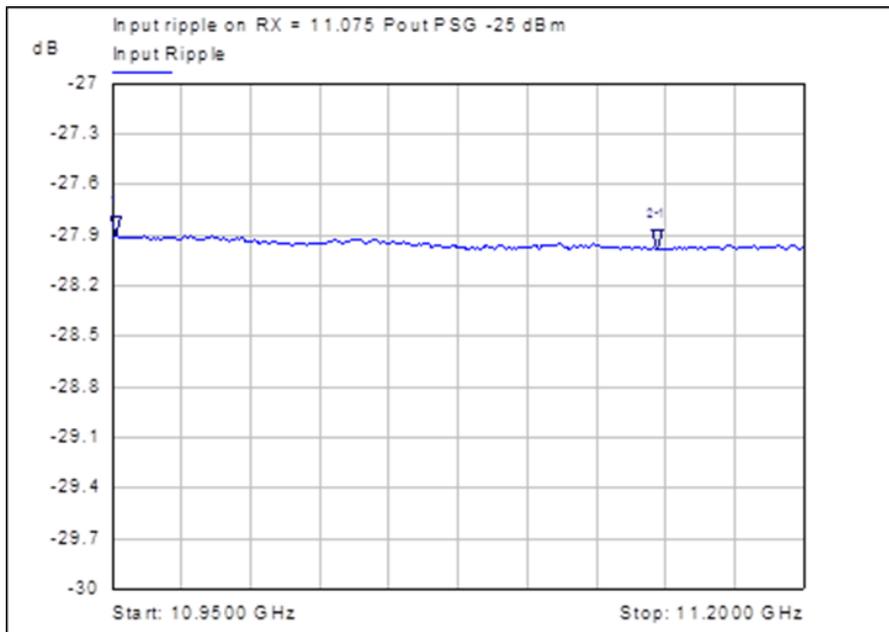
Test result:

It is verified that the transmission RF frequency is within the specified range of 14.0 - 14.5 GHz and that the reception RF frequency is within the specified range of 10.7 – 12.7 GHz. The measurements are done in 250MHz steps:

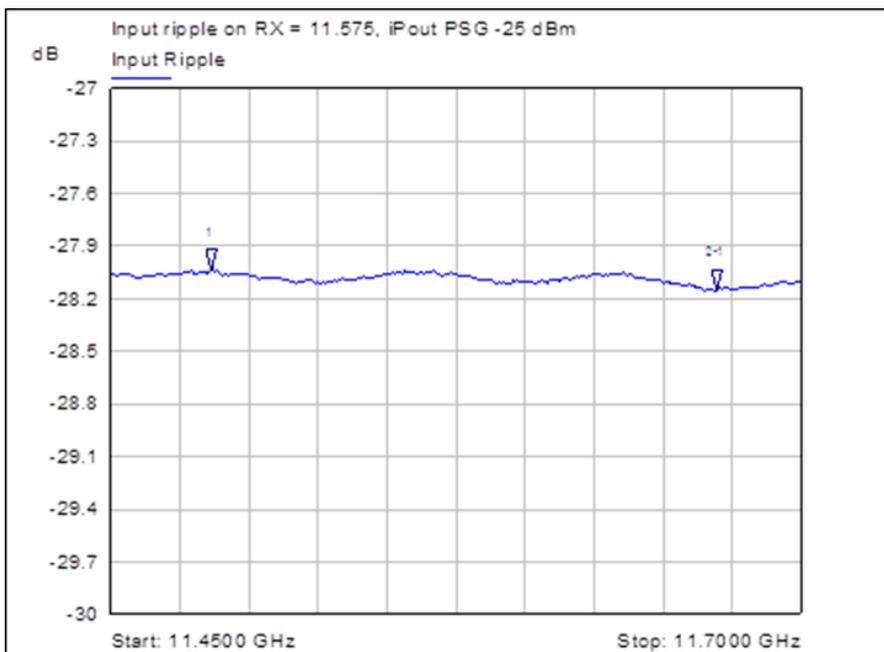
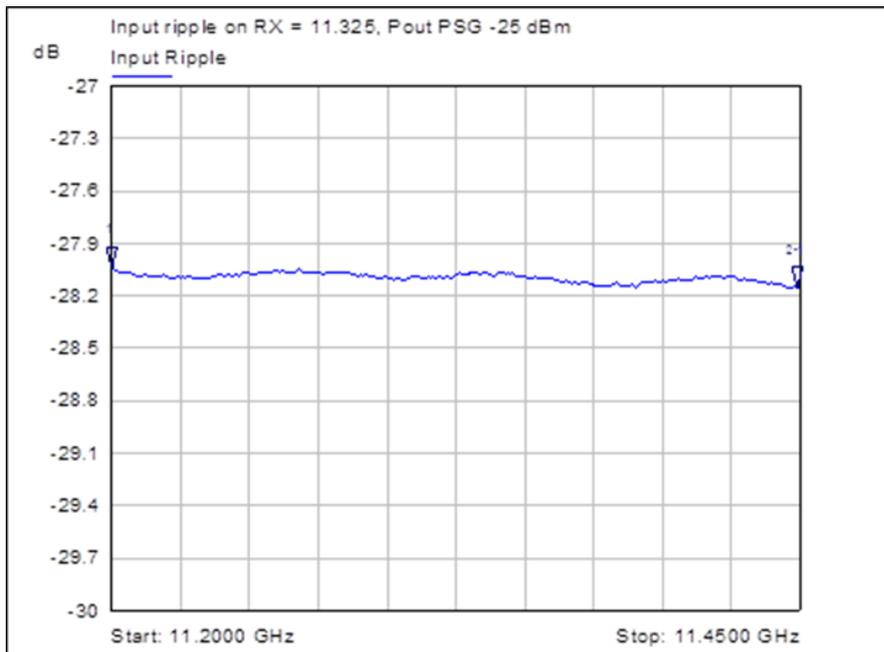


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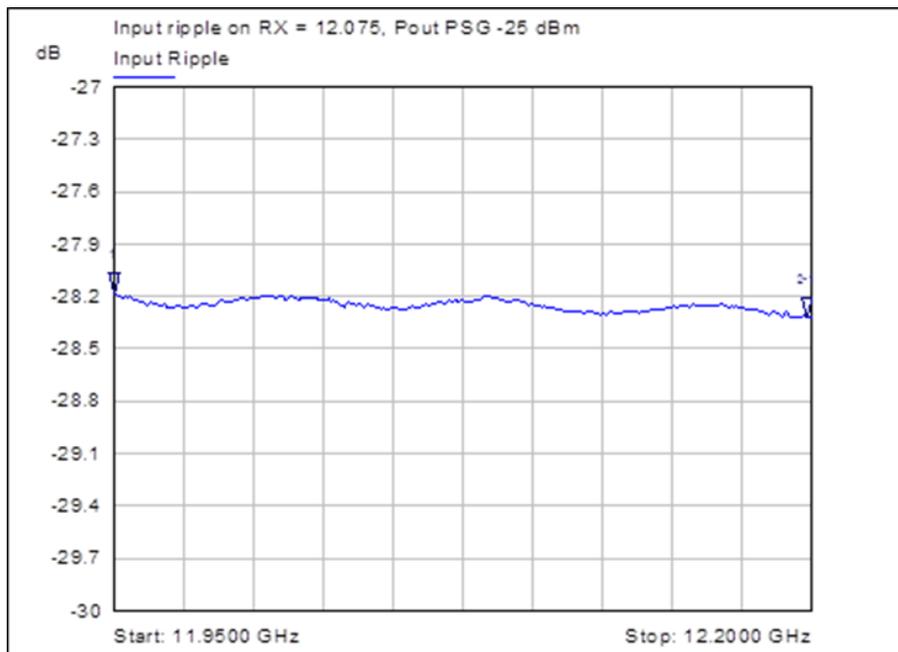
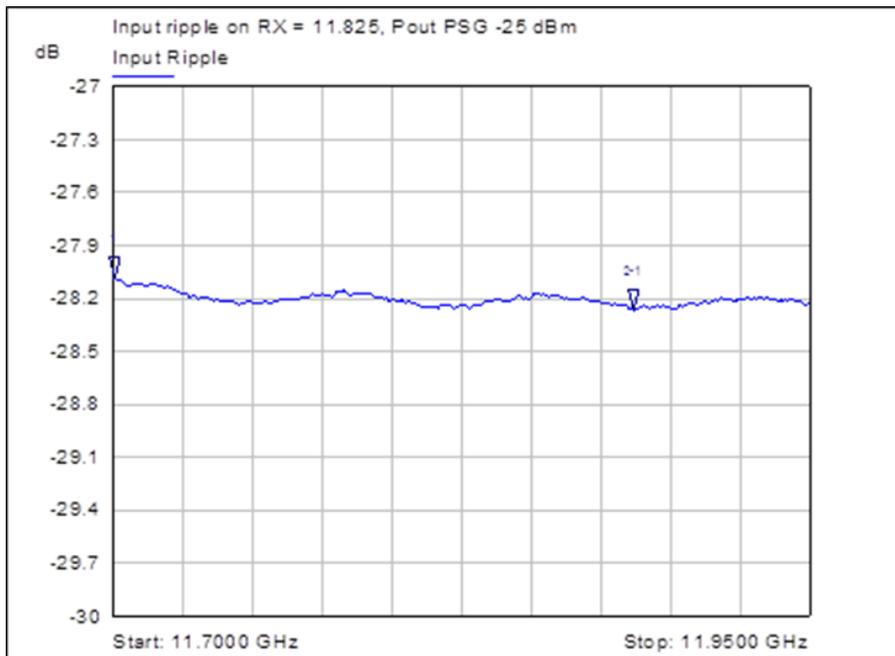
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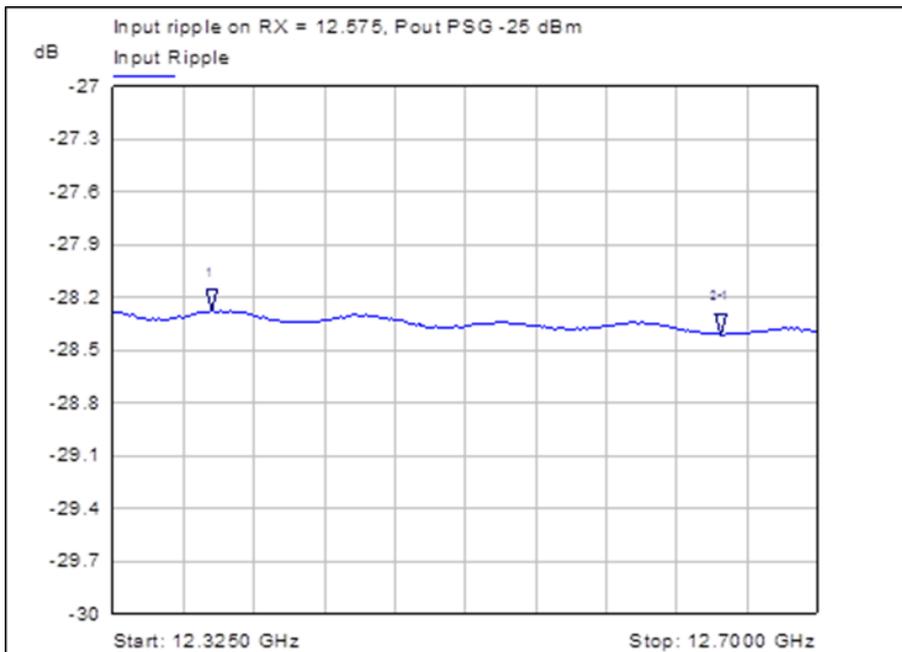
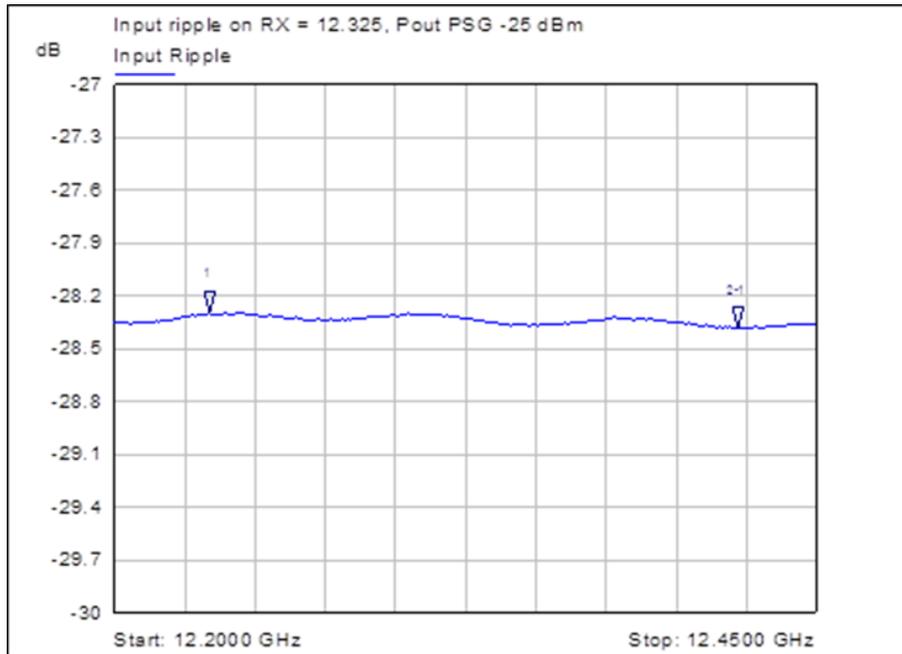
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5.6.2. IF frequency bands

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST13	Verify that the TX IF frequency is within the specified range.	OW IF frequencies	OK x / NOT OK <input type="checkbox"/>
		Verify that the RX IF frequency is within the specified range.	OW IF frequencies	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that both the transmission and reception IF frequencies are within the specified range of OW IF frequency ranges.

5.6.3. RF ports

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST14	Verify that the TX RF port is the specified.	SMA (F)	OK x / NOT OK <input type="checkbox"/>
		Verify that the RX RF port is the specified.	SMA (F)	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that both the transmission and reception RF ports are of the specified SMA (F) type.

5.6.4. IF ports

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST15	Verify that the TX IF port is the specified	SMA (F)	OK x / NOT OK <input type="checkbox"/>
		Verify that the RX IF port is the specified.	SMA (F)	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that both the transmission and reception IF ports are of the specified SMA (F) type.

5.7. APERTURE TEST

5.7.1. Frequency bands

Req ID	Test	Test sequence	Specified value	Test result
RF-1	TEST16	Verify that the TX RF frequency is within the specified range.	14.0 – 14.5 GHz	OK x / NOT OK <input type="checkbox"/>
		Verify that the RX RF frequency is within the specified range.	10.7 – 12.7 GHz	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the transmission RF frequency is within the specified range of 14.0 - 14.5 GHz and that the reception RF frequency is within the specified range of 10.7 – 12.7 GHz. The frequency range of the antenna is verified against its design specifications and checked with its gain response performance across different frequency points within the range.

The following figures represent the horizontal (H) and vertical (V) radiation patterns at three different frequencies within the ranges for both transmission (14 GHz, 14.25 GHz, and 14.50 GHz) and reception (10.7 GHz, 11.7 GHz, and 12.7 GHz). These patterns are shown at boresight with both phi and theta set to 0 degrees.

The antenna's performance is optimized to the satellite operator's requirements. Among these requirements, the most prioritized is the gain ripple across the frequency. By prioritizing these requirements, the SLL is degraded in a contained manner, which is approved by the satellite operator at high frequencies within the reception band.

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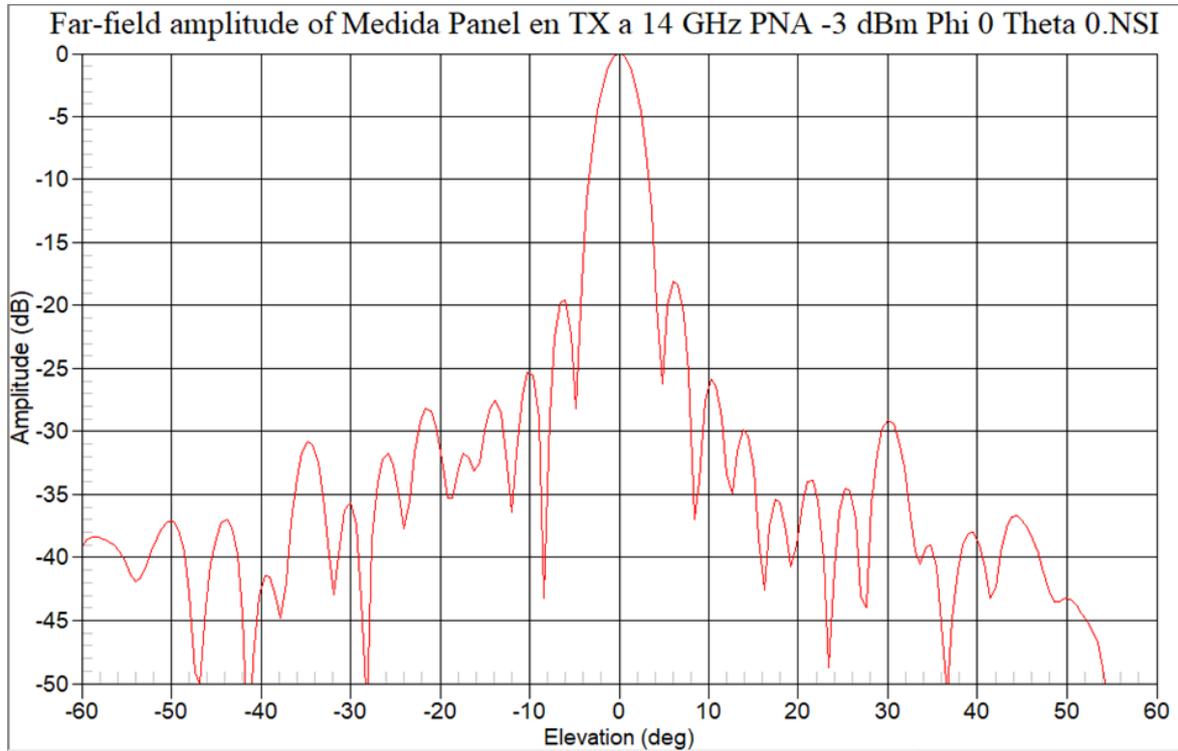
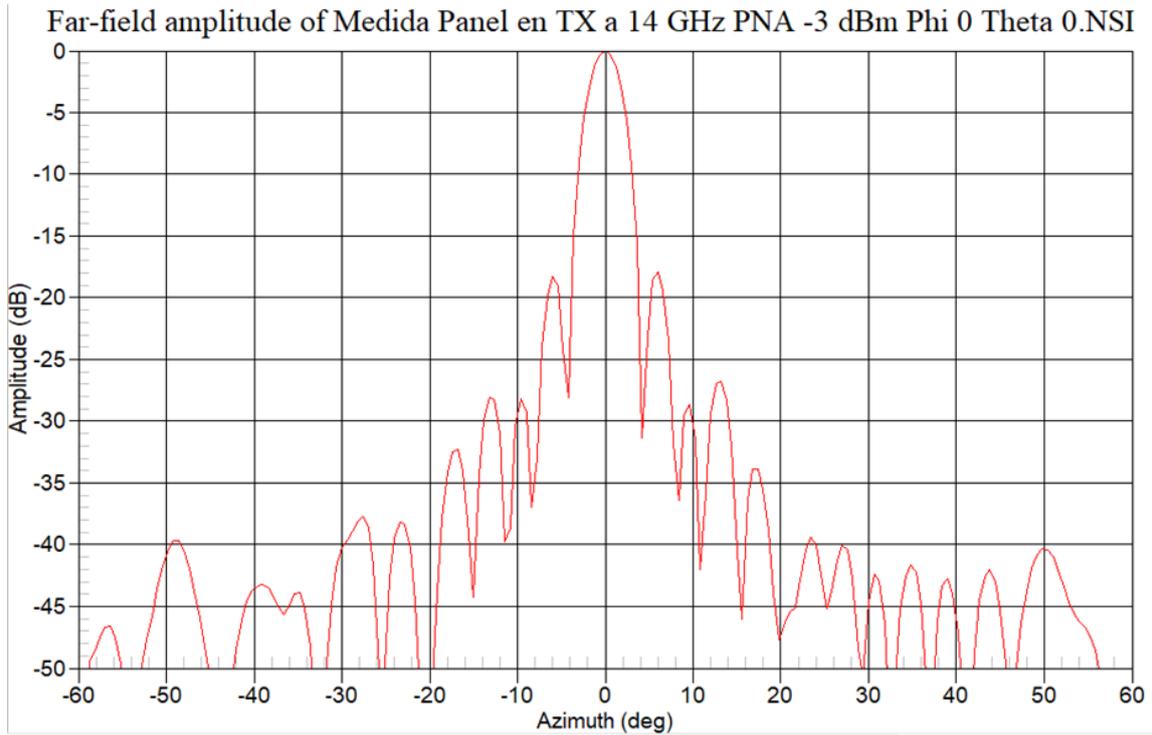


FIGURE 9: TX PATTERNS H (UP) AND V (DOWN) - PHI 0 – THETA 0 – 14.0 GHZ

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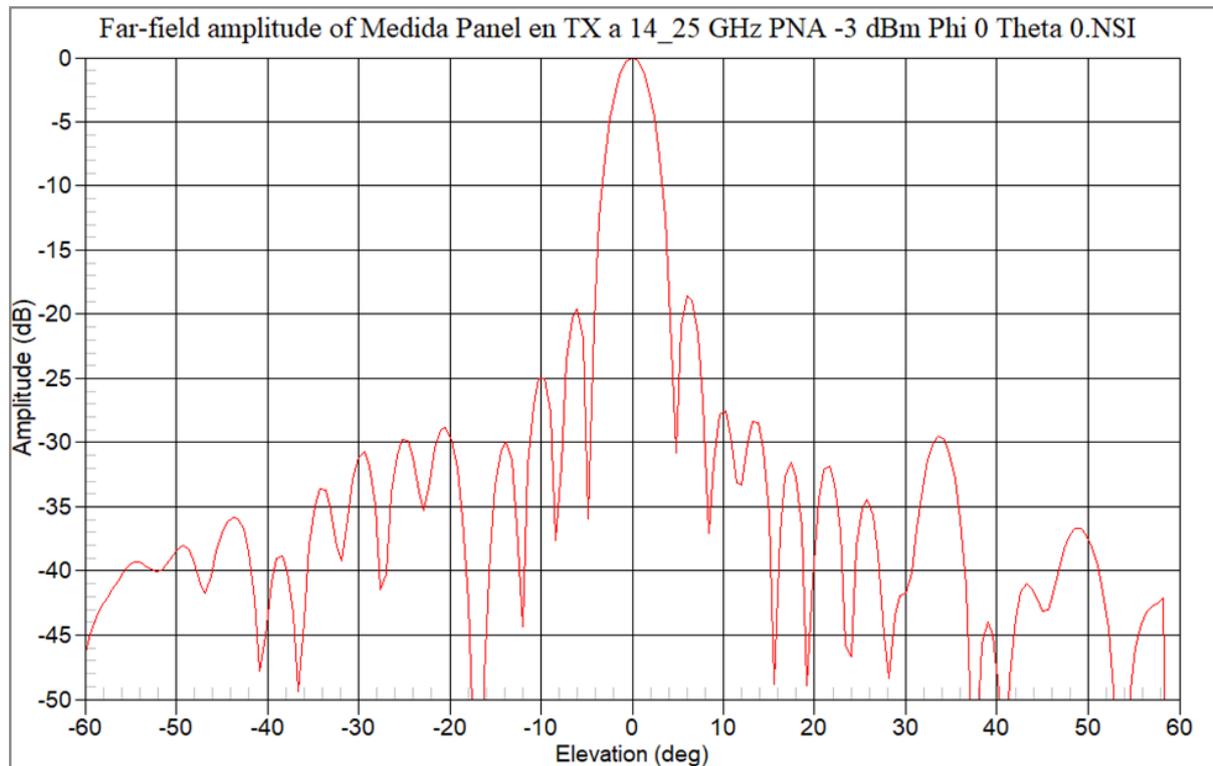
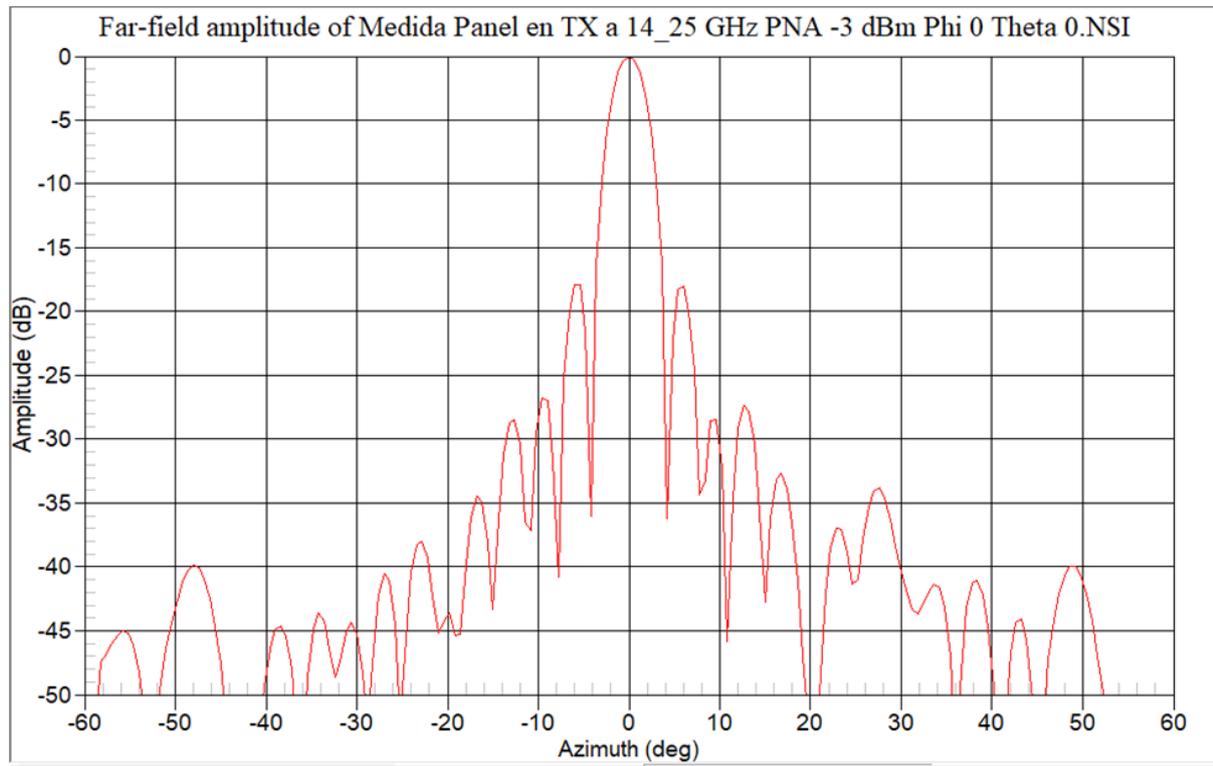


FIGURE 10: TX PATTERNS H (UP) AND V (DOWN) - PHI 0 - THETA 0 - 14.25 GHZ

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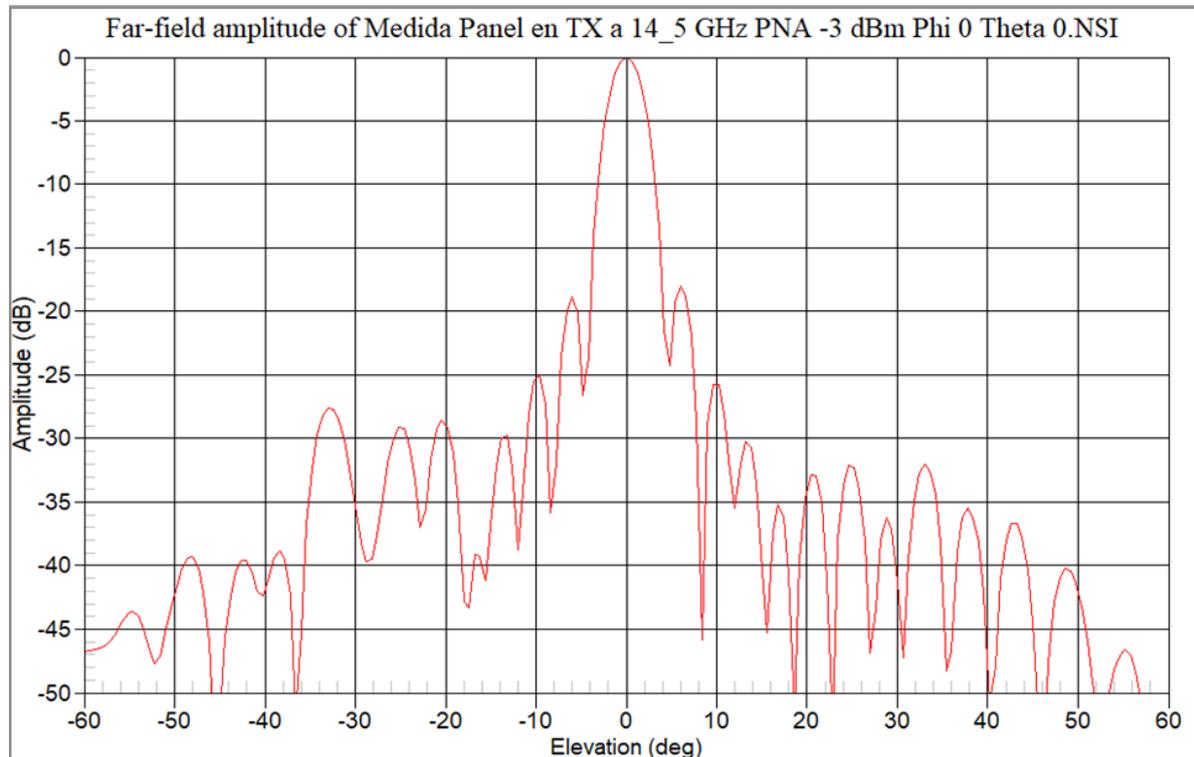
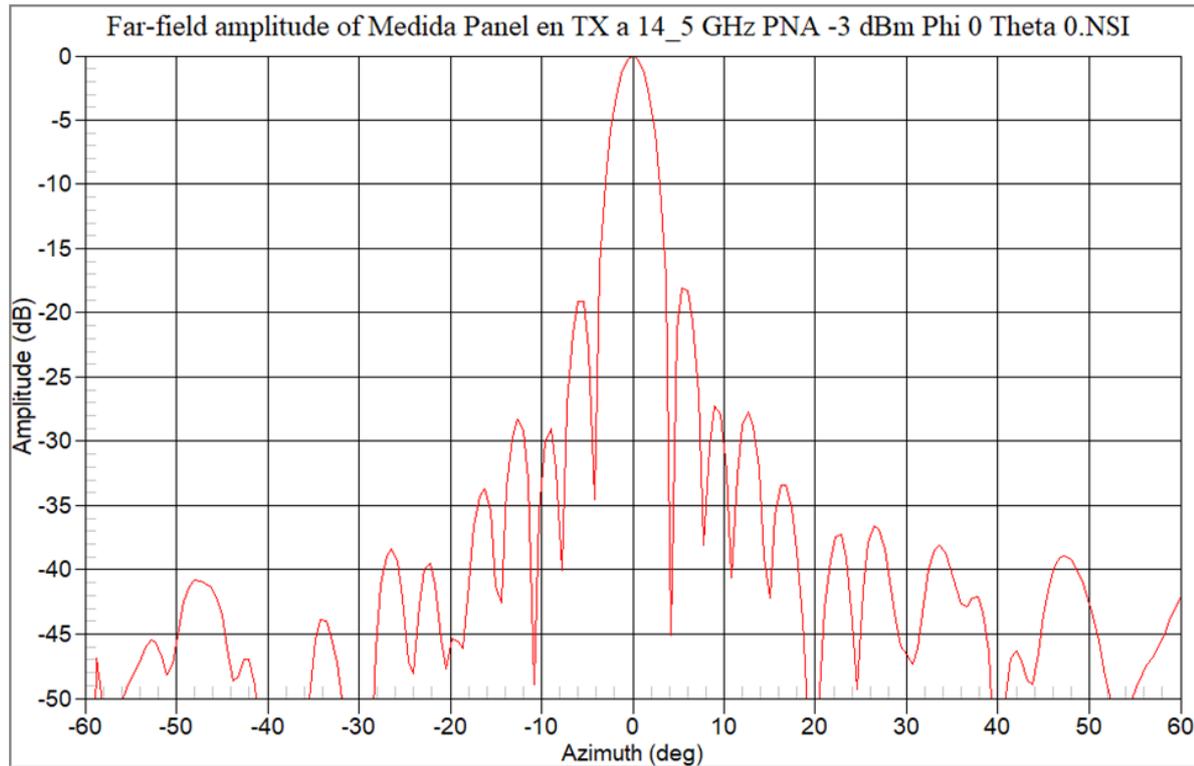


FIGURE 11: TX PATTERNS H (UP) AND V (DOWN) - PHI 0 - THETA 0 - 14.5 GHZ

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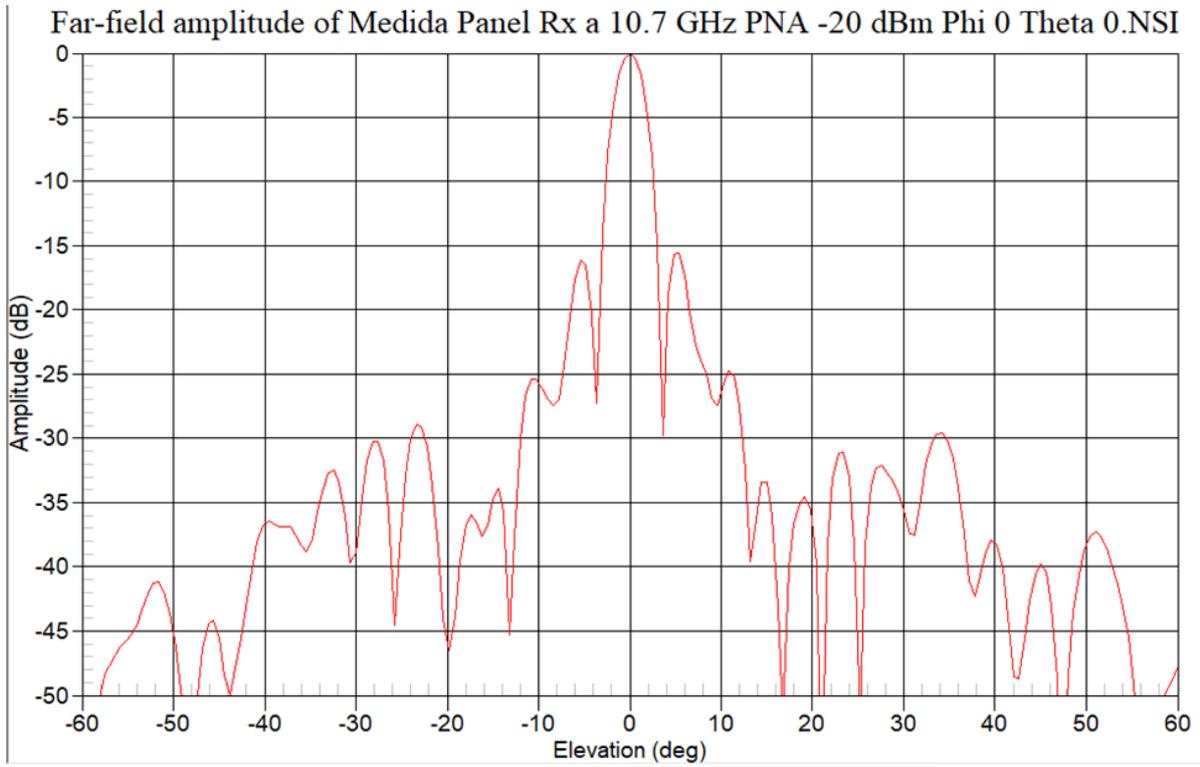
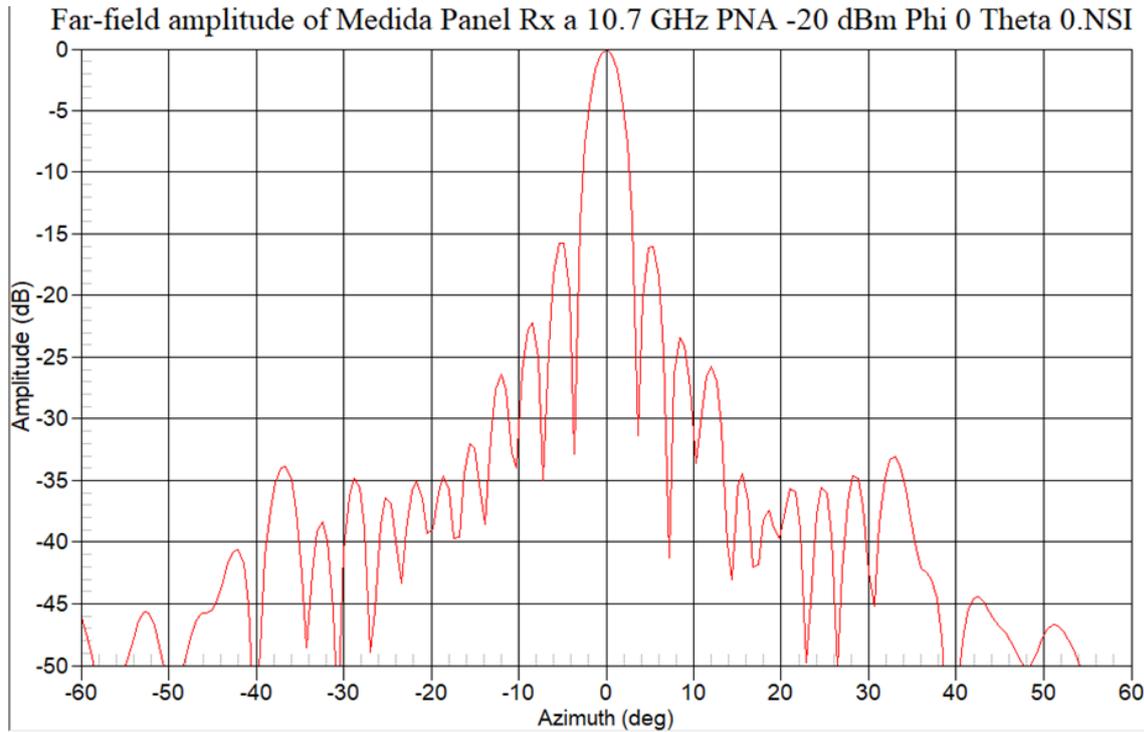


FIGURE 12: RX PATTERNS H (UP) AND V (DOWN) - PHI 0 - THETA 0 - 10.7 GHZ

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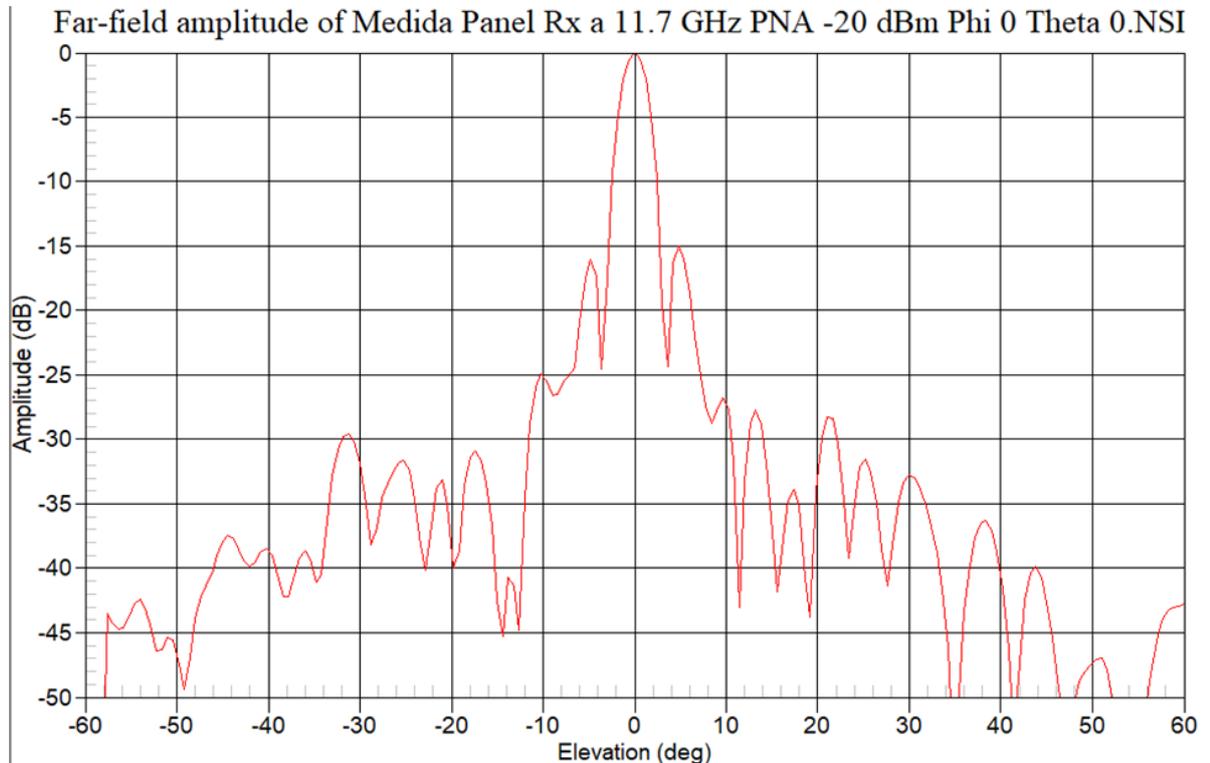
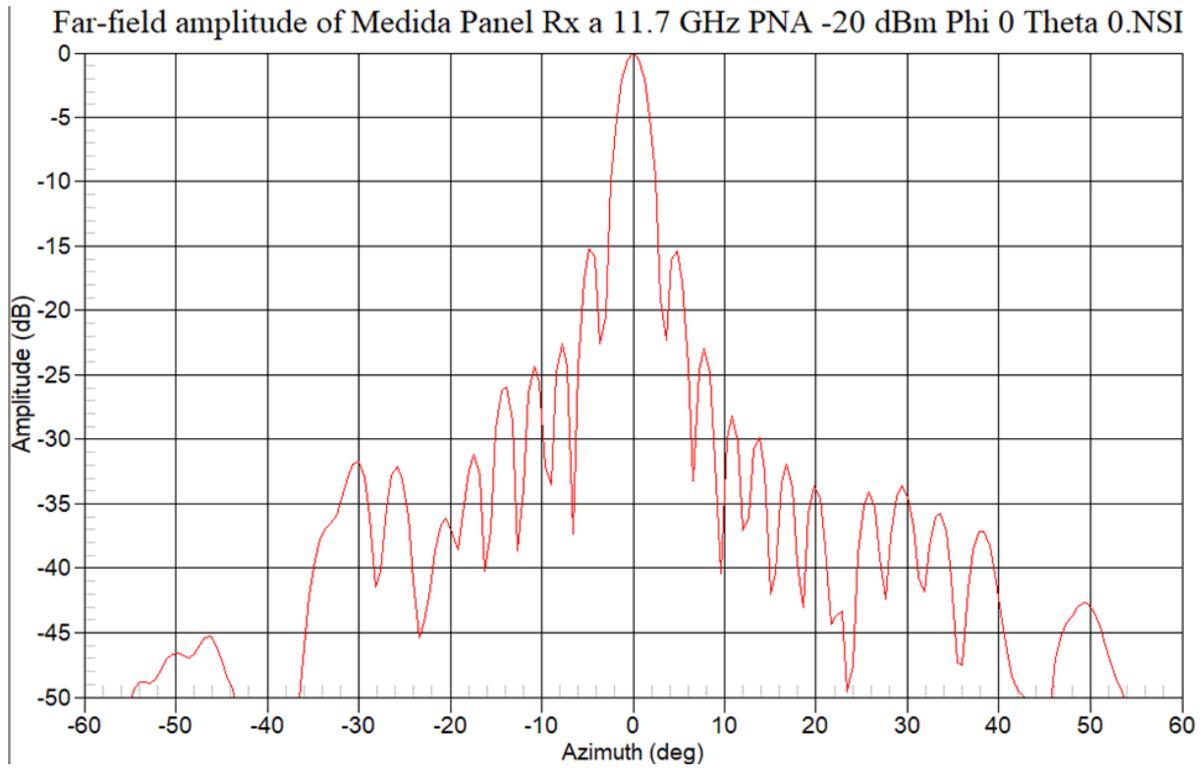


FIGURE 13: RX PATTERNS H (UP) AND V (DOWN) - PHI 0 - THETA 0 - 11.7 GHZ

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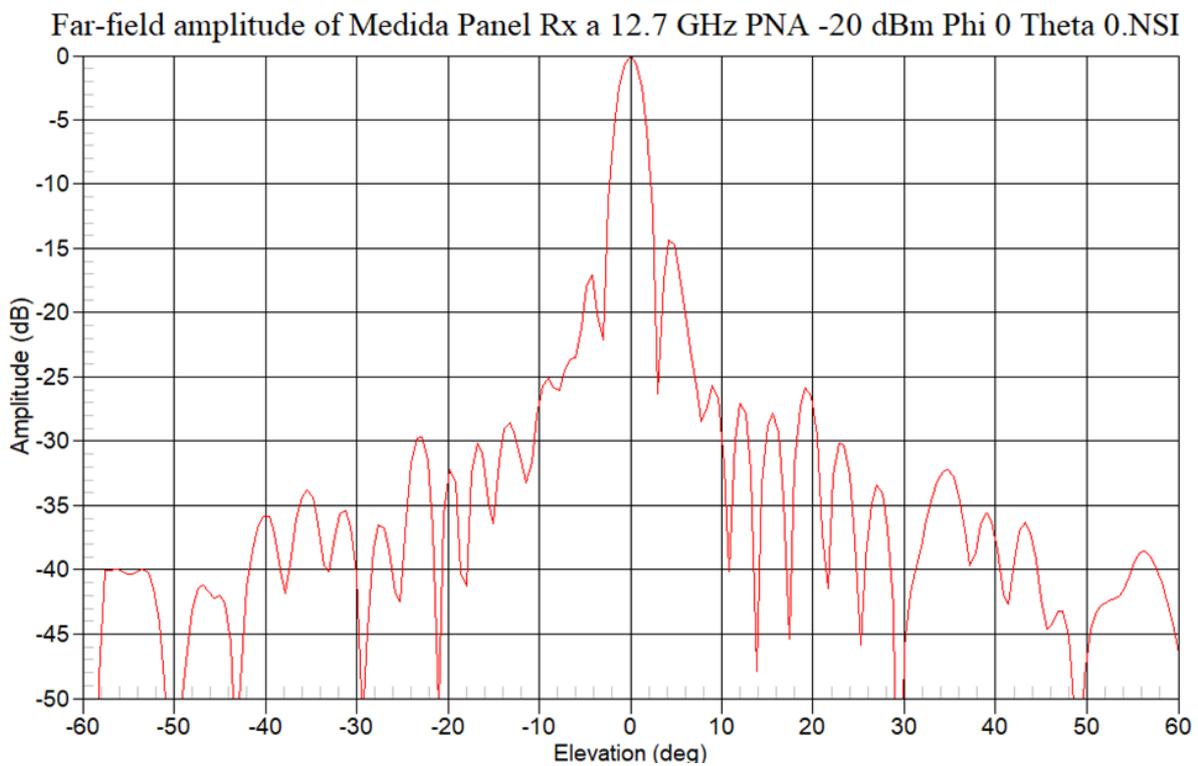
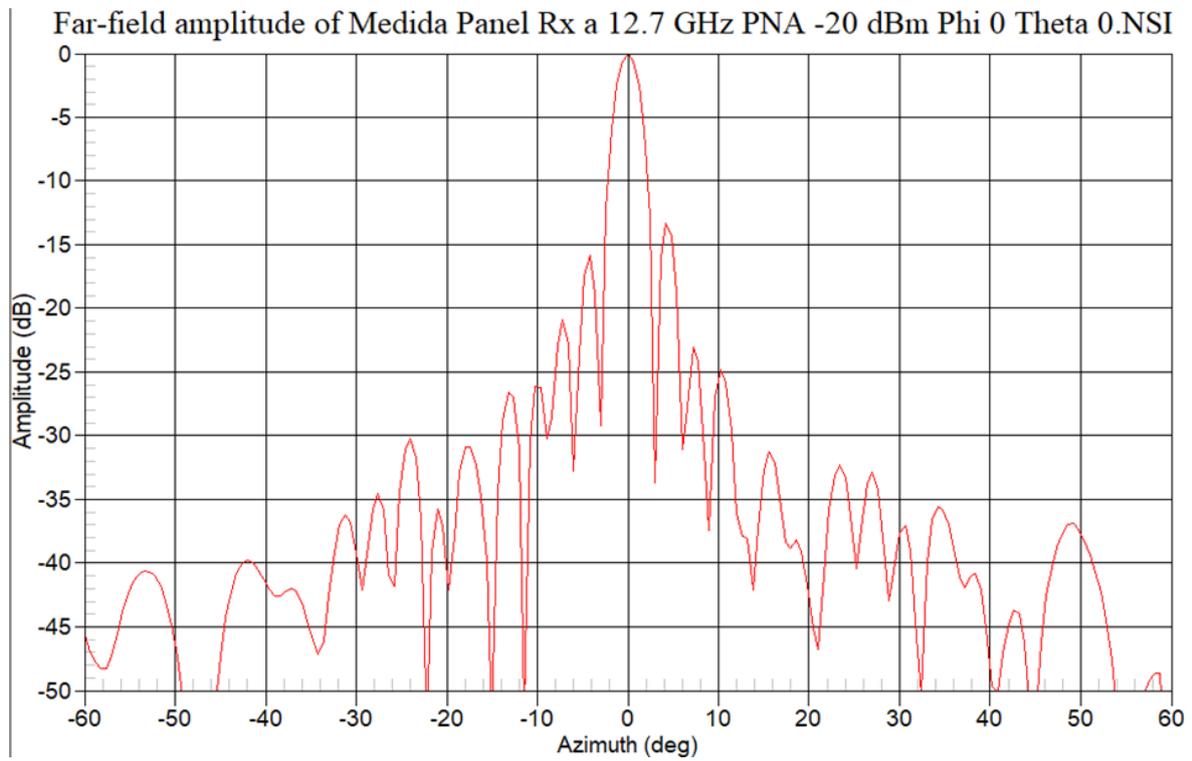


FIGURE 14: RX PATTERNS H (UP) AND V (DOWN) - PHI 0 - THETA 0 - 12.7 GHZ

5.7.2. Polarization

Req ID	Test	Test sequence	Specified value	Test result
RF-2	TEST17	Verify that the TX polarization mode is LHCP.	LHCP	OK x / NOT OK <input type="checkbox"/>
		Verify that the RX polarization mode is RHCP.	RHCP	OK x / NOT OK <input type="checkbox"/>

Test result:

It is verified that the transmitter operates correctly in Left-Hand Circular Polarization (LHCP) mode, meeting design and reception requirements. Similarly, it is verified that the receiver operates correctly in Right-Hand Circular Polarization (RHCP) mode, ensuring it meets design and transmission requirements.

Both polarization tests are validated alongside the gain measurements included in the following test.

5.7.3. Gain

Req ID	Test	Test sequence	Specified value	Test result
RF-3	TEST18	Verify that the TX gain is higher than the minimum expected value.	≥ 63 dB	OK x / NOT OK
		Verify that the RX gain is higher than the minimum expected value.	≥ 69.5 dB	OK x / NOT OK

Test result:

It is verified that the transmission gain values remain higher than the minimum expected value within the transmission frequency range. The test results show the following transmission gain values at the specified frequencies for LHCP.

Gain (dB) Phi = 0°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
14	66,30	69,99	71,03	69,81	66,89
14.25	66,99	70,36	70,95	69,87	67,12
14.50	66,82	70,39	70,64	70,20	66,78

TABLE 10: TX ACTIVE GAIN – PHI 0

Gain (dB) Phi = 45°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
14	66,65	70,13	70,90	69,73	66,30
14.25	67,14	70,14	70,93	70,08	66,68
14.50	67,15	69,78	70,86	69,78	66,82

TABLE 11: TX ACTIVE GAIN – PHI 45

Gain (dB) Phi = 90°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
14	66,88	70,20	71,02	70,20	67,20
14.25	66,78	69,63	71,12	70,30	66,89
14.50	67,11	70,02	70,88	71,39	67,84

TABLE 12: TX ACTIVE GAIN – PHI 90

Gain (dB) Phi = 135°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
14	67,82	70,08	70,91	70,36	67,34
14.25	67,00	69,91	70,90	69,61	67,41
14.50	66,39	69,36	70,76	69,63	66,30

TABLE 13: TX ACTIVE GAIN – PHI 135

Similarly, it is verified that the reception gain values remain higher than the minimum expected value within the transmission frequency range. The test results show the following transmission gain values at the specified frequencies for RHCP.

Gain (dB) Phi = 0°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
10.7	68,7	71,21	71,78	71,16	68,52
11.7	67,18	70,15	70,77	70,39	67,98
12.7	64,88	69,95	70,81	69,97	65,52

TABLE 14: RX ACTIVE GAIN – PHI 0

Gain (dB) Phi = 45°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
10.7	68,62	70,98	71,69	70,69	68,45
11.7	67,92	70,16	70,88	69,57	67,73
12.7	67,55	70,39	70,9	70,18	67,07

TABLE 15: RX ACTIVE GAIN – PHI 45

Gain (dB) Phi = 90°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
10.7	69,21	71,11	71,86	71,77	68,57
11.7	67,73	70,43	70,9	70,45	67,46
12.7	66,02	70,53	70,89	69,56	64,2

TABLE 16: RX ACTIVE GAIN – PHI 90

Gain (dB) Phi = 135°					
Frequency (GHz)	Theta = -60°	Theta = -30°	Theta = 0°	Theta = 30°	Theta = 60°
10.7	68,75	70,63	71,78	71,5	68,18
11.7	68,16	70,05	70,09	70,44	67,52
12.7	67,15	70,24	71,09	70,18	67,77

TABLE 17: RX ACTIVE GAIN – PHI 135

¹ Explanation about the non-compliance for gain measurements at 60° theta:

According to antenna theory, when the spacing between array elements is fixed, the antenna exhibits higher gain at high frequencies, but its 3dB beamwidth becomes narrower. This antenna design is optimized for smaller theta values, which results in decreased gain at larger angles, such as 60°. After the antenna array forms its beams, the gain at boresight increases at high frequencies, while the gain at larger scanning angles experiences a slight decrease.

5.7.4. Axial ratio

Req ID	Test	Test sequence	Specified value	Test result
RF-6	TEST19	Verify that the AR is lower than the maximum expected value.	≤ 2.5 dB	OK x / NOT OK □
RF-6	TEST24	Verify that the AR is lower than the maximum expected value.	≤ 2.5 dB	OK x / NOT OK □

Test result:

It is verified that the transmission AR values remain lower than the maximum expected value within the transmission frequency range. The tests show the following transmission axial ratio measurements at the specified frequencies for a value of $\phi = 0$.

Freq (GHz)	AR (dB)
14	0.69
14.25	0.97
14.5	1.10

TABLE 18: TX AR – PHI 0

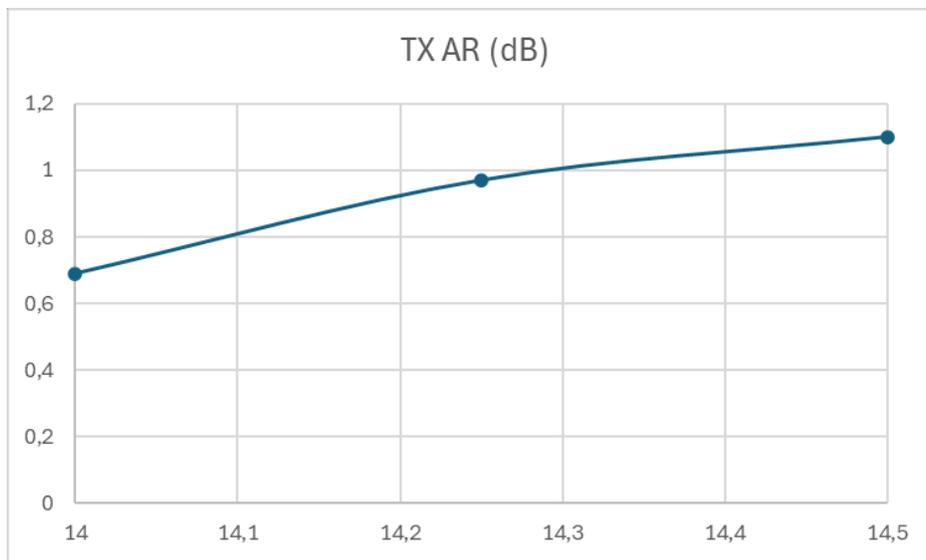


FIGURE 15 TX AR (DB) ACCROS TX FREQUENCY

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Similarly, it is verified that the reception AR values remain lower than the maximum expected value within the transmission frequency range. The tests show the following reception axial ratio measurements at the specified frequencies for a value of $\phi = 0$.

Freq (GHz)	AR (dB)
10.7	0.32
11.7	0.46
12.7	0.29

TABLE 19: RX AR – PHI 0

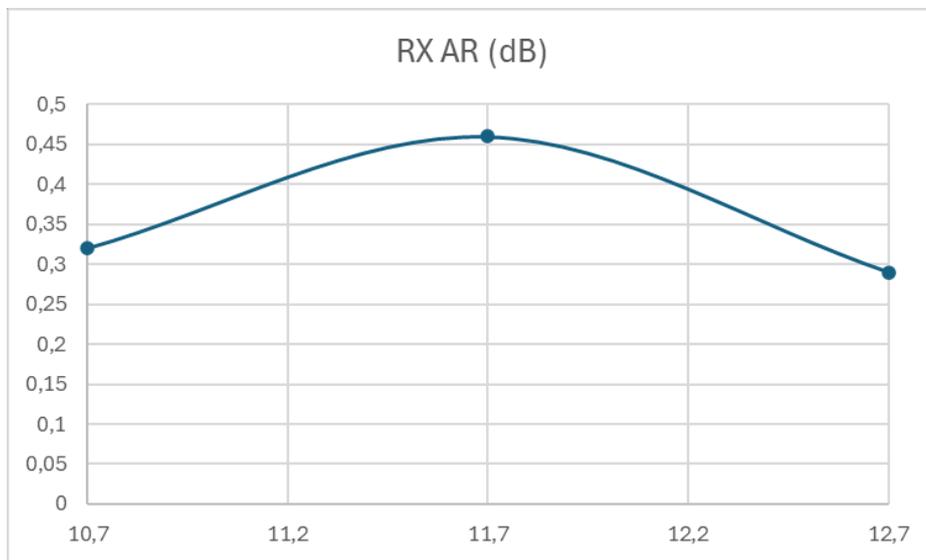


FIGURE 16 RX AR - PHI 0

5.7.5. EIRP

Req ID	Test	Test sequence	Specified value	Test result
RF-4	TEST20	Verify that the transmitter EIRP is higher than the minimum expected value.	≥ 35 dBW	OK x / NOT OK □

Test result:

It is verified that the EIRP values remain higher than the minimum expected value within the transmission frequency range. The tests show the following EIRP measurements at the specified frequencies for a value of P1dB.

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Freq (GHz)	EIRP@P1 dB (dBm)	EIRP@P1 dB (dBW)
14	70.5	40.5
14.25	70.3	40.3
14.5	71.6	41.6

TABLE 20: EIRP

5.7.6. G/T

Req ID	Test	Test sequence	Specified value	Test result
RF-6	TEST21	Verify that G/T is higher than the minimum expected value	≥ 7 dB/K	OK x / NOT OK <input type="checkbox"/>

Test result:

The G/T needs to be measured with radome loss at zenith with the following conditions:

- Antenna temperature of 35 K.
- Tx-chain operating at maximum EIRP level (full-duplex design).
- Receiver reference temperature 290 K.
- RCM at maximum noise figure.
- SSM noise figure.
- Measured gain at 10.7, 11.8 and 12.7 GHz.

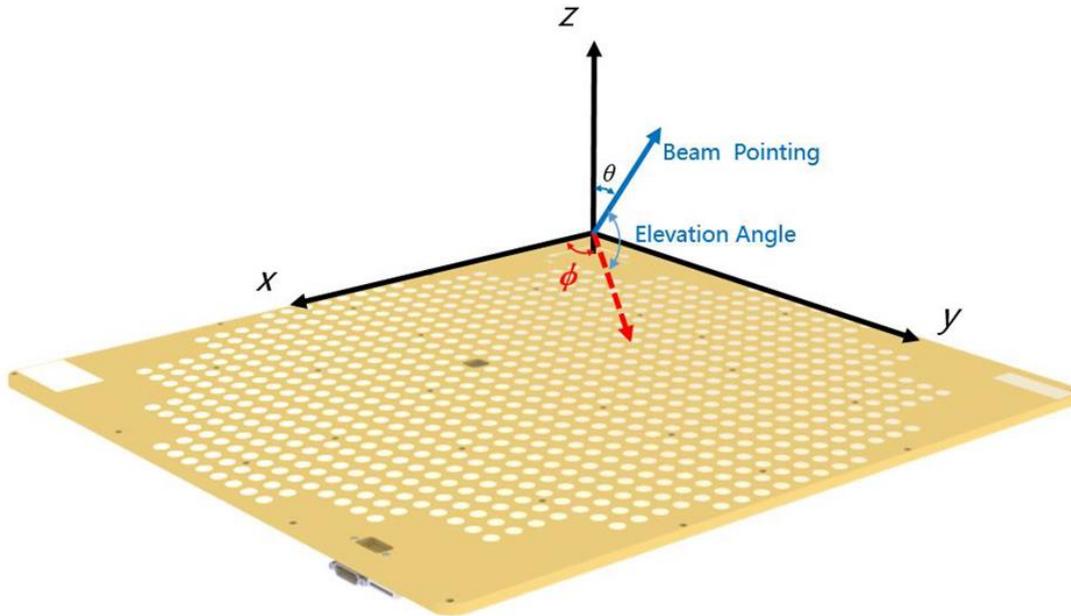


FIGURE 17: PANEL AXIS

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Freq (GHz)	G/T (dB/K)	
	Gain (dBi)	G/T (dB/K)
10.7	71.07	10.87
11.7	70.32	11.44
12.7	70.83	12.56

TABLE 21: G/T (DB/K)

It is verified that the G/T (dB/K) is higher than the minimum expected value of 7 dB/K.

5.8. DEMONSTRATOR TEST

Req ID	Test	Test sequence	Specified value	Test result
Additional	TEST22	Verify that the prototype's dimensions are within the specified limits	L: 1050.2 +/- 10 (5%) mm W:678 +/- 10 (5%) mm H:125 mm +/- 5 (5%) mm	OK x / NOT OK □

Test result:

It is verified that the prototype meets the specified measurements.

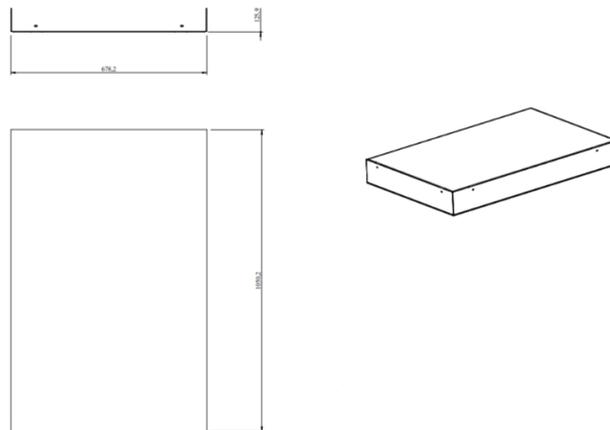


FIGURE 18: DIMENSIONS AND MECHANICAL LAYOUT

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FIGURE 19 DIMENSION LARGE MEASUREMENT

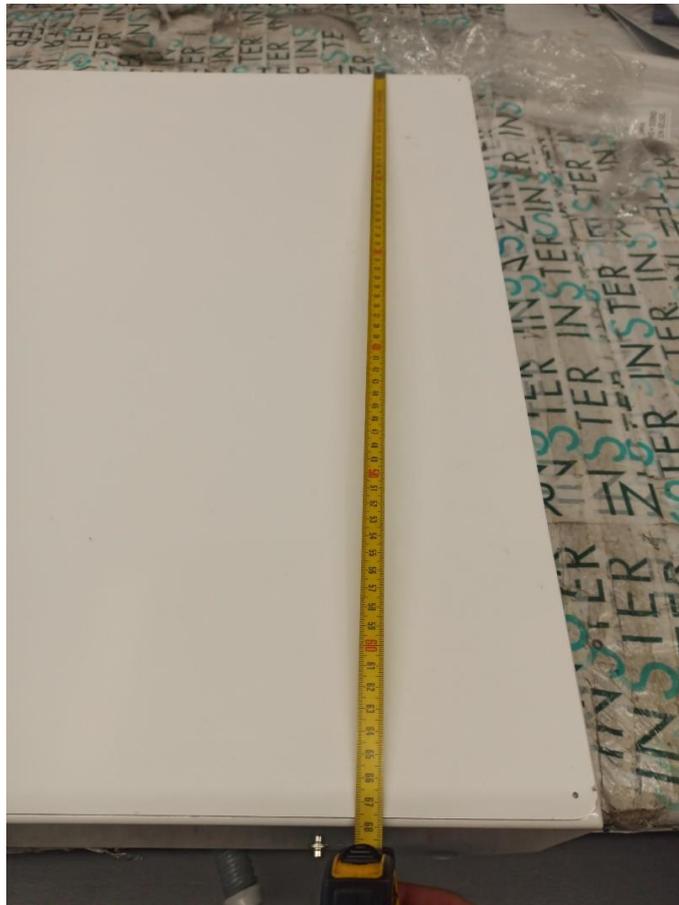


FIGURE 20 DEMONSTRATOR WIDE MEASUREMENT

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FIGURE 21 DEMOSTRATOR HEIGHT

The demonstrator weight is 39.5 kg.



FIGURE 22 DEMOSTRATOR WEIGHT

6. SUMMARY AND CONCLUSIONS

This document outlines the tests and measurements performed to ensure the antenna prototype meets all established requirements. The results confirm that each subsystem, including the modem, Synchronism Module, GNSS, PSU, ACU, RCM, and TX and RX apertures, operates within the expected parameters and is functional.

The positive outcomes of these tests support the completion and validation of the antenna prototype for further operational use and deployment. The successful performance of the subsystems confirms both the design and manufacturing quality of the prototype. Comprehensive testing has ensured that the prototype is ready for its intended application, offering reliable and enhanced beam management for dynamic pointing of LEO satellites.

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