MONACO

Executive Summary Report

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1 INTRODUCTION

1.1 Purpose and Scope

This is the Executive Summary Report that according to Statement of Work, concisely summaries the findings of the contract. It is written with a content adapted for non-experts and it is appropriate for publication.

This document summarizes the activities performed to develop a multifunctional antenna that incorporates high data rate communications with the lunar orbit and PNT capabilities. The concept has been validated by means of a breadboard, which has been designed, manufactured, and tested in the frame of this activity.

1.2 List of abbreviations and acronyms

Acronym	Description
AD	Applicable Document
AR	Axial Ratio
CSR	Change Status Report
EQM	Engineering Qualification Model
LGA	Low Gain Antenna
NC	Non Compliant
RD	Reference Document
RF	Radio Frequency
SOW	Statement Of Work
TRB	Test Review Board
TRR	Test Readiness Review

Table 1-1: List of abbreviations and acronyms

2 APPLICABLE AND REFERENCE DOCUMENTS.

2.1 Applicable documents

The following documents are applicable to this document in the following table:

AD#	Title	SENER Code	Rev	Client Code	Rev
[AD 01]	Antenna for Assets Navigation on Planets, Integrated in Communication Systems	-	-	ESA Contract No. 4000136209/21/NL/AS	-
[AD 02]	COMMUNICATION AND POSITIONING, NAVIGATION, AND TIMING FREQUENCY ALLOCATIONS AND SHARING IN THE LUNAR REGION			REC SFCG 32-2R3	3
[AD 03]	Preliminary Design Description	DOC00298558	1		
[AD 04]	Detailed Design Description	DOC00310919	2		
[AD 05]	Test Plan for MONACO Antenna	DOC00310925	1		
[AD 06]	Electrical Test Report for MONACO Antenna	DOC00330221	2		

Table 2-1: Applicable Documents

2.2 Reference documents

The following documents are reference to this document in the following table:

RD#	Title	SENER Code	Rev	Client Code	Rev
[RD 01]					

Table 2-2: Reference Documents

3 TECHNICAL SCOPE AND OBJECTIVES

Accurate localization of assets on planetary bodies will be crucial in future exploration missions when it comes to autonomous vehicles navigation and accurate positioning. On Earth, dedicated systems in L-band are typically used for navigation and localization. For exploration missions, it is desirable to integrate the navigation antenna in a communication system operating at higher frequency (such as S-band or Ka-band).

The advantage of this solution is a reduction of the required hardware, corresponding to relaxed requirements on mass and volume to be transported to the planet, as well as reduced complexity of the deployment mechanisms. Specifically, the use of higher frequencies, even in the S-band, will help reducing the size and mass of the navigation system.

The objective of this activity was to focus on the design and development of a high gain transmit and receive antenna for terminals (e.g. landers, rovers, etc.) integrating PNT and communication capabilities, corresponding to TRL 4.

The main target of the project is to develop a multifunctional antenna that incorporates high data rate communications with the lunar orbit and PNT capabilities. Among the different PNT options, two-way is selected. In this case, the PNT antenna receives a signal from a positioning satellite, and this signal is transmitted back to the satellite to estimate the position of the asset.

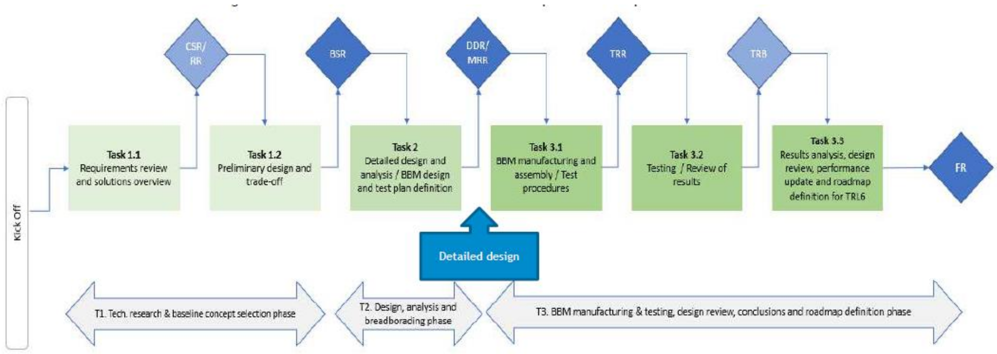
4 SUMMARY OF ALL ACTIVITIES CARRIED OUT DURING THE PROJECT

The work is organized as follows:

TASK 1: Antenna requirements review and preliminary design.

TASK 2: Detailed antenna design.

TASK 3: Manufacturing and test of the antenna breadboard and development roadmap



4.1 Task 1: Antenna requirement review and preliminary design

The objective of this task 1 was to provide an overview of possible solutions, several scenarios, terminals, and antenna configurations. A trade-off analysis was performed, among the identified possible solutions.

Based on this trade-off analysis and considering, as a minimum, the following aspects: RF performance, mass, mechanical and thermal requirements, manufacturing techniques, materials; one candidate architecture was proposed for a preliminary design.

Concerning the requirements of the mechanism, the design was based on other flight proven APMs, such as BepiColombo, Juice or EUCLID, upgrading the design in order to be compatible with lunar dust and low temperature requirements. This is specifically related to the modifications on actuators, by including seals and dust filters to avoid contamination and by changing the type of lubrication in order to be able to operate at cryogenic temperatures without the need of power to heat it up.

Different link budgets scenarios have been considered for communication between a lunar orbiter and an asset (rover, lander, hub…) on the lunar surface. The link budgets included downlink and uplink datalinks at Ka band for communication and at S-band for communication and navigation as well. From these initial system assessment, the radiofrequency requirements of the antenna are obtained to guarantee a datalink of 10/25 Mbps at Ka band and 8 Kbps at S-band. As an output of this task 1, a consolidate requirement document was issued.

4.2 Task 2: Detailed Antenna design

This task is a detailed RF design of the baseline antenna chosen in Task 1, including: S-Parameter analysis, co- and cross-polar pattern analysis for both antennas, S-band LGA and Ka-band HGA.

The complete antenna is composed manly by these two radiating elements:

- A HGA Ka-band reflector antenna for high data rate communications with the lunar orbit.
- A S-band conical helix antenna for two-way PNT and low data rate communications.

Both antennas will be integrated at the same assembly and using the same antenna pointing mechanism (APM). The helix antenna is accommodated at the rim of the main reflector to reduce coupling between radiators and to point to the same direction. In this way, both antennas will take advantage of the APM to maximize the throughput of the data link, with communications at Ka and S-band simultaneously. The HGA antenna relies on the well-known ADE configuration but using a dielectric support between feed and sub-reflector (splash-plate).

For the two-way PNT antenna the most promising solutions is based on a conical log-periodic helix that provides low/medium gain performances for the operating bands Tx: 2200-2290 MHz and Rx: 2025-2110 MHz. The advantages of this solution are:

- Low loss compared to cavity backed absorber spirals.
- Higher gain that a planar radiator.
- Low-profile at S-band.

In addition, two-way PNT uses the same frequency range as for communications allowing the option of implementing both services, as well as taking advantage of the APM for throughput optimization.

A detailed RF design have been performed for both antennas. Also, a mechanical, thermal, and steerable design description have been carried out (see [AD 04]).

In addition, a test plan and an update of the statement of compliance to the full technical specifications have been issued.

4.3 Task 3: Manufacturing and test of the antenna breadboard and development roadmap

This Task includes the next activities: Manufacture the antenna breadboard, perform all relevant RF tests of the antenna breadboard, compare test results with predictions and issue all the closure documentation of this project.

4.3.1 Manufacturing topics

A breadboard has been manufactured. The complete antenna assembly consists of the following elements:

- Ka-band HGA antenna
- S-band LGA antenna (metalized PEEK)
- Mock-up of the representative APM: This mock-up is a simplified version using plastic ALM, and metallic parts. It allows to adjust manually the antenna to different fixed positions Below, several pictures of the manufactured separate pieces and of the complete structure are shown.

Figure 4-1. S-band LGA antenna

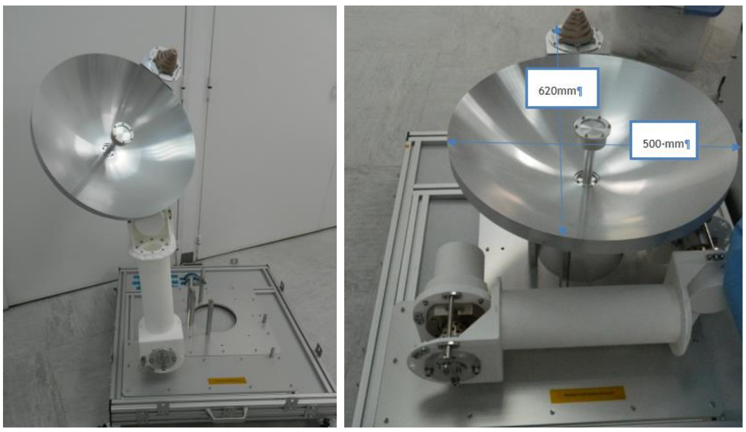


Figure 4-2. MONACO Breadbord Antenna

4.3.2 Test results

A test campaign has been carried out according to the test matrix show below and following the AD-5.

All the radiating electrical tests were carried out at Universidad Politécnica de Madrid (UPM). For radiation patter testing, the UPM facilities used spherical near-field acquisition system. The laboratory test was carried in SENER facilities.

MONACO Antenna Model: BB TEST MATRIX	Nº	1	2	3	4	5	6	8	9		
TEST	TEST PARAMETERS	VISUAL INSPECTION	FREQUENCY BAND	POLARIZATION	RADIATION PATTERN	RETURN LOSS	ISOLATION	MASS	DIMENSIONAL VERIFICATION	OPERATING	NON-OPERATING
INITIAL INSPECTION		X							X		X
MASS PROPERTIES								X			X
PERFORMANCE TEST			X	X	X	X	X			X	
FINAL INSPECTION		X									X

Figure 4-3. MONACO Breadbord Antenna

4.3.2.1 Test results

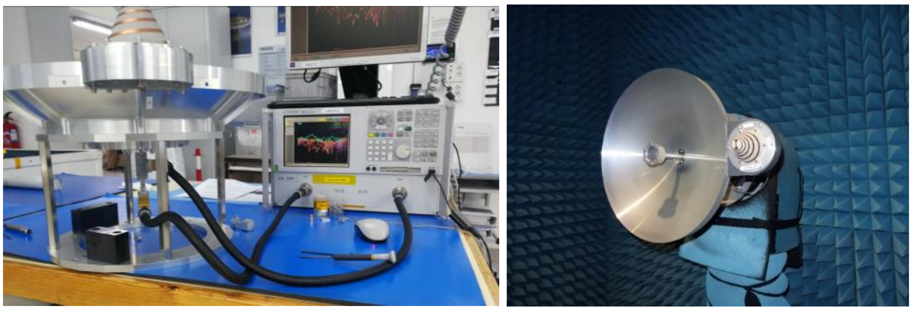


Figure 4-4: Antenna Measurements.

Parameter	Requirement	Current results	SoC	Comments
Frequency S-Band	Tx: 2200-2290 MHz Rx: 2025-2110 MHz	Tx: 2200-2290 MHz Rx: 2025-2110 MHz	C	
Frequency Ka-Band	Tx: 27-27.5 GHz Rx: 23.15-23.55 GHz	Tx: 27-27.5 GHz Rx: 23.15-23.55 GHz	C	
Return loss	>20dB	S-Band: 20.6 dB Ka-Band: 26.8 dB	C	
Polarization	Single circular	Single circular	C	
Gain S-Band	>2.5 dB For $\vert\theta\vert \leq 0.3°$ and all ϕ.	4.8 dB	C	Including 1.5 dB expected added loss from the cable through the APM.
Gain Ka-Band	Tx: >38.2dB Rx: >34.2dB For $\vert\theta\vert \leq 0.3°$ and all ϕ.	Tx: 39.0dB Rx: 36.0dB	C	Including 0.92 dB expected added loss from the APM and thermal effects by simulation.
Axial Ratio S-band	<1 dB For $\vert\theta\vert \leq 0.3°$ and all ϕ.	Stand-alone < 1.45dB Assembly < 2.25dB	NC	Stand-alone helix and mounted on the reflector rim.
Axial Ratio Ka-band	<1 dB For $\vert\theta\vert \leq 0.3°$ and all ϕ.	0.85dB	C	

Table 4-1: Compliance of Test Results for MONACO Antenna.

4.3.3 Development roadmap

A development plan, including development cost, up to TRL 6 has been issued [AD-XX]

As a summary, future activities related to this project are the next:

- A detailed design of the APM: mechanical, thermal and RF.
- An RF re-design of the antenna (if necessary due to system values consolidation).
- Manufacturing and testing of an EQM.

4.4 Milestones and reviews

MILESTONES	*REVIEWS*
MS-1 → BSR (at the end of TASK 1)	*CSR/RR (during TASK 1)* *BSR (at the end of TASK 1)*
MS-2 → DDR (at the end of TASK 2)	*DDR (at the end of TASK 2)*
MS-3 → FR (at the end of TASK 3)	*TRR (during TASK 3)* *TRB (during TASK 3)* *FR (at the end of TASK 3)*

5 CONCLUSIONS

MONACO Antenna has been designed, manufactured, and tested, following the required work to be performed in the specific SOW.

All the requirements are in line with the designed values. The Ka-band reflector is fully compliant with the requirements and the results in line with the simulations. There are only minor deviations at the AR values of the S-band, that do not impact the system performances.

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Task summary

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