Conceptual Design Study

Designing a Next-Generation Radio Facility for Multi-Messenger Astronomy

Deliverable No:	**D5.3**
Deliverable/Document Name:	**D5.3 Front-End Sub-System Design**
Version:	**1.0**
Release date:	**30/06/2024**
Dissemination level:	**Public**
Status:	**submitted**
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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement ***No 101094354***. The content of this material reflects the opinions of its authors and does not in any way represent the opinions of the European Union

Document history

Version	Date	Content and changes	Edited by
0.1	16/02/2023	Contents and Introduction	V. Misirlis
0.2	28/03/2024	Feed Design Data	Dr. Y. Stratakos
0.3	3/05/2024	Market Survey	V. Misirlis
0.4	25/05/2024	Feed Fabrication	Dr. L. Marantis
0.5	20/06/2024	First Review and Corrections	Prof. A. Kanatas
0.6	22/06/2024	Final correction and modifications	Dr. L. Marantis
0.7	26/06/24	Added chapter RF Signal Processing Chain	C. Leinz C. Kasemann
0.8	26/06/2024	Formatting corrections - modifications	V. Misirlis
0.9	26/06/2024	Final review	Prof. A. Kanatas

Peer reviewed by

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Contents

List of Figures

Executive Summary

The overarching objective for the ARGOS conceptual design study is to prepare fully for the subsequent rapid implementation of a leading-edge wide-field interferometer in Europe and ensure its optimal integration into the network of existing and future international astronomical facilities.

A custom feed design that can operate at 1-3 GHz has been made to collect the signal from the reflectors at the required gain and beam levels, to collect as much energy as possible from the faint radio astronomy sources. That feed requires a high-end engineering as a hardware part, to avoid any losses in the efficiency of the RF-front-end, and therefore a breakthrough fabrication solution through 3D printing is described.

Due to the radio-telescope's character that involves small diameter dishes, it was decided to avoid a custom design and fabrication for the dish reflector. Thus, the reflector should be purchased as product that is already in the market and satisfies ARGOS full scale telescope requirements, such as the operating frequency of 1-3 GHz, the 6-meter diameter and a cost-effective pricing in order to realize the low-cost requirement for the ARGOS radio-telescope, that can be easily scalable in the future. This task is described with an extended market survey about reflector antennas, with data from different products and companies. A 6-m reflector, requires also a durable mount, in order to point appropriately such a heavy-weight instrument at the radio sources in the sky, in outdoor environment and strong weather conditions (i.e. severe wind speeds).

Analysing the RF front-end of the telescope, the low noise amplifiers, and the filters should have a specific order in the signal path, and very specific gain levels to amplify the signal adequately and cut off the unwanted frequencies without importing additional noise to the system.

After several scenarios and investigations to create an optimal solution, a final solution has been provided from UPRC and MPIfR, to get the most out of the components. The final front-end RF chain, starts with the feed, which delivers two orthogonally separated polarizations. To avoid losses from cable lengths that could degrade the system performance, a low-noise amplifier is directly connected at each RF output port of the feed-horn. For calibration purposes, a Noise Source is included, which injects a reference signal into both RF downstream paths.

Then, two low-loss coaxial cables will carry the RF signal to an RFI shielded and weatherproofed housing that will be mounted at the back of the reflector. At this place, the housing cannot provide any additional blockage to the reflector, and will not struggle the mount, as it could done if more weight was applied at the feed point, far from the weight center. Inside the housing the RF signal processor, the RFSoC board, a time and reference generator and a power supply are hosted.

This collaborative effort provides a high-performance, low-loss front-end RF chain design that maximizes the capabilities of the chosen components. This design front-end RF chain lays the groundwork for exceptional signal reception and data acquisition for the ARGOS telescope antenna.

1 Introduction

Many of the most fundamental astronomical advances achieved in the past sixty years have been made through radio astronomy, and many more are expected in the following years, since the radio astronomical observations provide the only way to investigate some cosmic phenomena. ARGOS is a concept for a leading-edge, low-cost European astronomical facility that will directly address several fundamental scientific questions, from the nature of dark matter to the origin of Fast Radio Bursts and the properties of extreme gravity, thereby satisfying urgent needs of the community.

To capture and interpret the radio astronomy weak signals, powerful systems are required to resolve all the information and work as a radio-telescope. This leads to a need for the best possible combination of components to receive the waves and transfer them to the digital stage for analysis.

This critical part of the front-end is called RF signal chain which is made from physical components. The signal chain acts as the backbone of the system, a complex pathway where the signals are amplified, filtered, and ultimately transformed into usable data for scientific investigation. This path starts from the feed antenna, the telescope's initial point of contact with the radio waves which is necessary to fulfill both the RF needs, but also the hardware needs to uniformly fit in the chain.

Beyond the intricate electronics, the 6-meter reflector parabola takes center stage, acting as the reflector dish that is responsible for collecting the radio waves. A comprehensive market survey has been made to identify the most suitable solution for ARGOS full scale telescope and its requirements. At the same section, the motorized mount of the reflector plays an equally important role, providing the stable platform that allows the antenna to precisely point towards different regions of the sky for observation. This is an important impact on the radio-telescope's pointing accuracy and overall operational efficiency.

1.1 Scope of the Deliverable

The main scope of the deliverable is to present the whole architecture of the RF front-end of the ARGOS full scale radio-telescope. After several investigations and simulation processes, all the options of components and arrangements were selected in order to synthesize the optimal chain of the system. This task will meticulously dissect each component, from the feed to the digitizers, evaluating their individual functionalities and their combined influence on the overall system's performance. Following the signal's capture, there are described the basic details for the chosen amplifiers responsible for strengthening the weak celestial signals.

Regarding the parabolic dish, there is an extended navigation to the selection process for the reflector and mount system through a comprehensive market survey is that is summarized, outlining the chosen vendors who will provide the foundation and maneuverability for the telescope. This survey will identify and analyze various commercially available options, meticulously considering factors such as technical specifications, performance characteristics, and pricing.

2 Frontend Requirements

The frontend subsystem encompasses several crucial components essential for the ARGOS system's functionality. These include the parabolic dish and its steering mechanism, the feeder containing the antenna elements, as well as both passive and active analog signal components such as filters and amplifiers. Additionally, the frontend subsystem interfaces with the digitization system, facilitating the conversion of analog signals into digital format for further processing.

The following table provides a comprehensive summary of the requirements specifically pertaining to the parabolic dish and its associated steering mechanism. This table serves as a reference point for ensuring that these components meet the necessary specifications and performance criteria essential for the successful operation of the ARGOS system.

Requirement ID	Description	Parents	Issues / Notes
REQ-ARGOS-FE-01	ARGOS shall consist of at least 1200 parabolic reflectors (antennas)	L0_02, L0_22, L0_23, L0_30	
REQ-ARGOS-FE-02	The minimum distance between antennas shall be 23 m	L0_04	L0 requirement will likely be relaxed
REQ-ARGOS-FE-03	1024 of the antennas shall be arranged on a regular 32x32 grid, while the rest shall be randomly placed outside the grid	L0_08, L0_18	Under investigation
REQ-ARGOS-FE-04	The diameter of ARGOS antennas shall be 6m	L0_05, L0_30	
REQ-ARGOS-FE-05	The ARGOS antennas shall have a solid surface	L0_11	
REQ-ARGOS-FE-06	The surface of the ARGOS reflectors shall deviate from a perfect parabola by no more than 50mm	L0_11	
REQ-ARGOS-FE-07	The ARGOS receivers shall be positioned on the prime focus of the reflectors	L0_12, L0_13, L0_29	
REQ-ARGOS-FE-08	The antenna efficiency of the ARGOS reflectors shall be greater than 0.7	L0_02	
REQ-ARGOS-FE-09	The F/D ratio shall be 0.38	L0_05, L0_07, L0_15	Still under investigation, may change to 0.40
REQ-ARGOS-FE-10	The ARGOS feeds shall cover the frequency range from 1 to 3 GHz	L0_06, L0_09	

		L0_15	
REQ-ARGOS-FE-11	The ARGOS feeds shall capture vertical and horizontal polarizations	L0_16	
REQ-ARGOS-FE-12	The ARGOS feeds shall weight less than 10 kg	L0_02	Expected weight 3 - 4 kg
REQ-ARGOS-FE-13	The feed LNAs shall operate at ambient temperature	L0_02	
REQ-ARGOS-FE-14	The feed LNAs shall have a noise figure smaller than 35K	L0_02	
REQ-ARGOS-FE-15	The frontend shall offer a power attenuation mechanism	L0_17	
REQ-ARGOS-FE-16	The frontend shall offer an absolute calibration mechanism	L0_17, L0_18	
REQ-ARGOS-FE-17	The ARGOS antennas shall be mounted on altazimuth mounts	L0_04, L0_12	
REQ-ARGOS-FE-18	The ARGOS mounts shall be motorized	L0_12	
REQ-ARGOS-FE-19	The ARGOS mounts shall offer access to elevation angles between 0 - 90º and azimuth angles between 0 - 360º	L0_04, L0_12	
REQ-ARGOS-FE-20	The ARGOS antennas shall move with a velocity of up to 36º / minute	L0_04, L0_31	
REQ-ARGOS-FE-21	The ARGOS mounts shall position the antennas with an accuracy < 0.1°	L0_12, L0_13, L0_14	
REQ-ARGOS-FE-22	The ARGOS antennas shall operate under a wind load of at least 60 km/h	L0_23	
REQ-ARGOS-FE-23	The ARGOS antennas shall survive wind loads of at least 180 km/h	L0_01, L0_02, L0_03	

Table 2-1: Antenna System Requirements Table.

2.1 Antenna feed & reflector requirements

Starting the design of the RF chain, it is crucial to describe the system specification of the project, to use it as a guideline and as a limit controller. The ARGOS Pathfinder RF chain starts with a parabolic mesh reflector antenna designed for operation within the 1-3 GHz frequency band. Due to budget constraints, a solid surface reflector has been declined. A cost-effective mesh reflector with mesh gap less than 0.9 cm ($\lambda/10$ allowance) can adequately operate up to 3 GHz. The operating frequency band (bandwidth) and polarization are also crucial for the feed design. Dual linear polarization is selected for the ARGOS feed antenna since it is often required in radio-telescopes and allows reception in both vertical and horizontal orientations.

A motorized azimuth-elevation (Az-El) mount is required in order to point the reflector antennas at each part of the sky, with a sidereal tracking that is not affected by Earth's rotation. The antenna's construction prioritizes sturdiness. A reinforced concrete support structure is employed to ensure the antenna can withstand strong winds, with a survival wind speed exceeding 150 km/h. Table 2-2 includes all the antenna system specifications (along with their specific values and critical comments) that were determined during the starting period of the ARGOS full scale telescope project.

Antenna System Specification	Value	Comments
No. of reflectors per antenna element	1	Due to budget constraints
Shape of reflector	Parabolic	
Type of reflector	Solid	Not applicable for Pathfinder due to budget constrains, Mesh will be employ for the Pathfinder with gap < 0.9 cm (3 GHz)
Feeder antenna position	Prime focus / axial – front fed	Due to budget constraints
Diameter of reflector	6 m	
F/D ratio	0.38	(or 0.40)
Frequency bandwidth	1-3 GHz	
Porarization	Dual linear polarization (Vertical - Horizontal)	
Dish gain	> 30 dBi (31.5 - 40.5 dB)	Depending on frequency
12dB feed taper angle	> 70° (75-95°)	Depending on frequency
Sidelobe level	< -25 dB	
Feeder horn gain	> 11 dBi (12-14 dBi)	
Polarization ports isolation	> 40 dB	Estimation
Return losses at both feeder ports	> 13 dB (min)	
Connector type	N-type	For low losses
Maximum power handling	10 W	Could be better if needed
Feeder antenna weight	< 10kg (expected 3-4kg)	
Type of mounting	Polar mount	Azimuth – elevation
Scanning abilities	Elevation range: 0-90° Azimuth range: 0-360°	

Type of motion	Motorized motion	Too heavy antenna system for manual motion
Velocity	> 36°/minute	
Pointing accuracy	< 0.25°	
Operating wind speed	> 60 km/h	
Survival wind speed	> 150 km/h	
Antenna system support	Reinforced concrete support structure	In order to withstand strong winds and mechanical torque

Table 2-2: Antenna Feed & Reflector Requirements Table

2.2 Radio Telescope Feeder Antenna

In order to observe the deep space signals that ARGOS is looking for, a complicated front-end chain is developed. The front-end chain captures the signal, processes it through a series of components and delivers it to the digitizer. The very first stage of that chain is the antenna feed, a custom-made antenna structure that plays a pivotal role in receiving the faint signals, efficiently collecting them and funneling them into the receiver for further analysis.

Through meticulous simulations and comparisons between different feed elements, a design has been made to satisfy the radio-telescope's demanding requirements. Factors like reflection coefficient response, radiation pattern, illumination, and overall system efficiency are evaluated for the best performance of the feed antenna.

By optimizing the feed design, the full potential of the radio-telescope can be unlocked. This translates to increased sensitivity, allowing us to detect fainter signals. A wider field of view enables us to observe a larger swathe of the sky, which is great for phenomena like Fast Radio Bursts. Ultimately, the perfect feed design empowers ARGOS full scale telescope to become a powerful tool for groundbreaking discoveries, pushing the boundaries of our cosmic knowledge.

The feeder system of the parabolic dish (diameter 6 meters and F/D = 0.38) is presented in the Figure 2-1. Based on the F/D ratio the receiver is positioned around 2.28 m away from the reflector center in order to have optimum performance. The antenna feeder is a dual linearly polarized wideband structure which covers the frequency band 1-3 GHz. The whole dish reflector antenna will be properly mounted on a reinforced concrete support structure in order to withstand winds and mechanical torque.

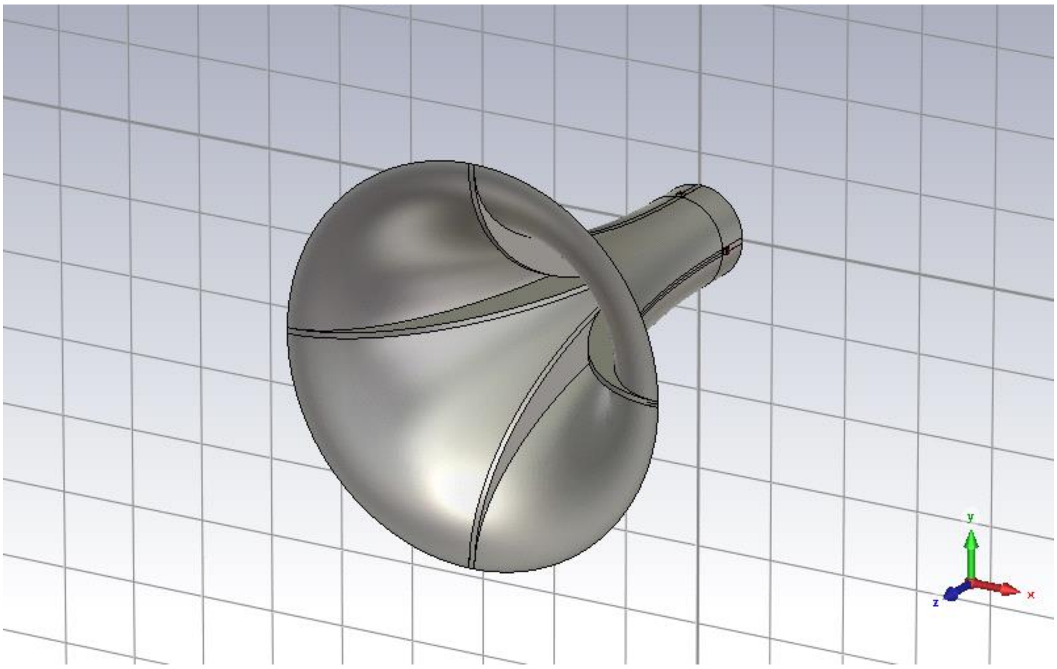

Figure 2-1: Geometry of the feed.

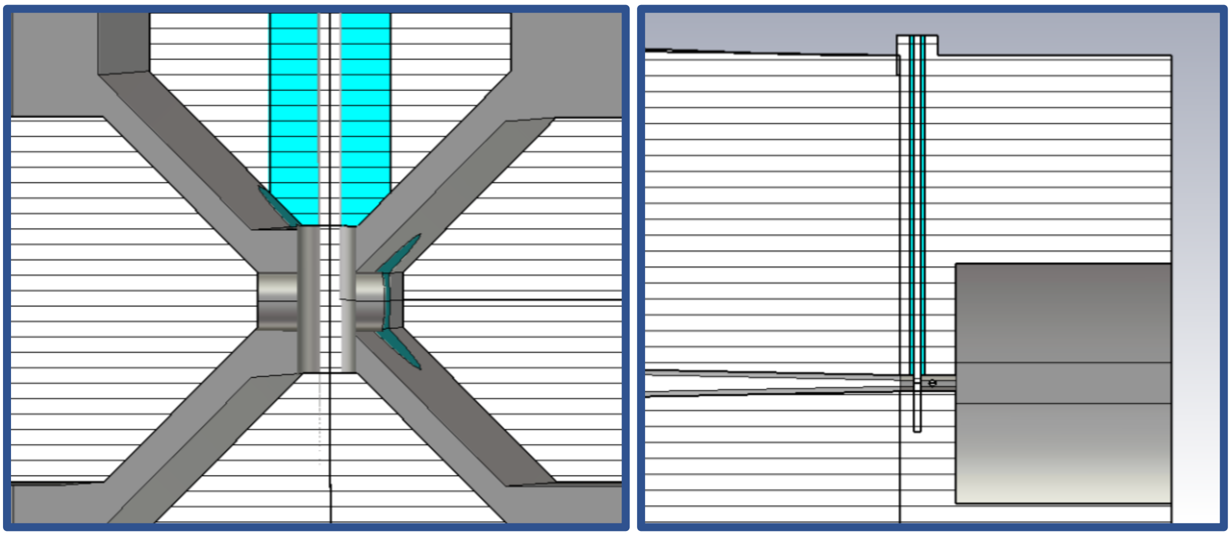

Figure 2-2: Monopole Placement.

3 Antenna Feed Fabrication

To achieve a groundbreaking feed antenna for the ARGOS radio telescope, a modern approach on the fabrication is driven through metal casting of a 3D printed antenna. This method has already been successfully tested in the past from the UPRC TSL lab by designing and manufacturing a simple 10 GHz horn antenna (see on Figure 3-1). First, a prototype of a 3D printed horn antenna has been designed in CST for operating at 10 GHz. Both additive manufacturing techniques (FFF, SLA) were employed in order to print two plastic prototypes. The skeleton of the horn antenna was printed using an acrylonitrile butadiene styrene (ABS) thermoplastic material. The SLA prototype has been selected for metallization due to the smoother surface characteristic that it demonstrated. A standard copper electroplating method has been carried out in order to cover the piece with a thin copper layer. The 3D printed horn antenna has been experimentally verified in the VNA.

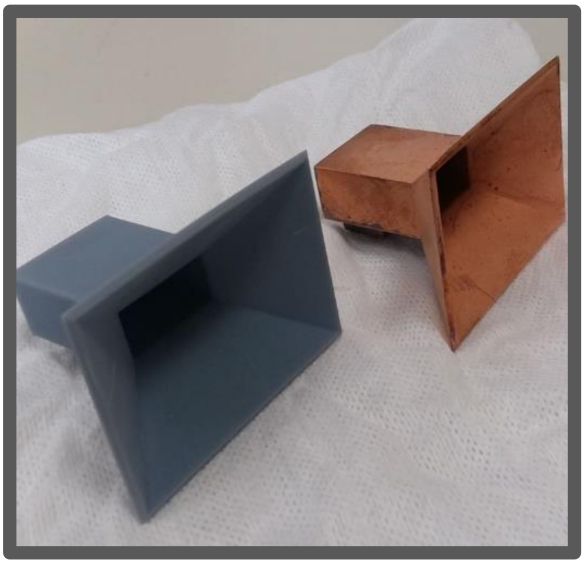

Figure 3-1: UPRC 3D mini feed horn.

The project has established a collaboration with Golden Devices, a recently formed spin-off company from the prestigious Friedrich-Alexander University Erlangen-Nürnberg (LHFT). Golden Devices boasts a strong track record of working with both industry and academic partners, and their vision is to revolutionize millimeter-wave (mmWave) components as you can see in Figure 3-2. Their mission centers around a holistic approach to additive manufacturing, leveraging the combined benefits of 3D printing and metalization in order to (a) create lightweight structures, (b) reduce production time and (c) achieve lower fabrication costs.

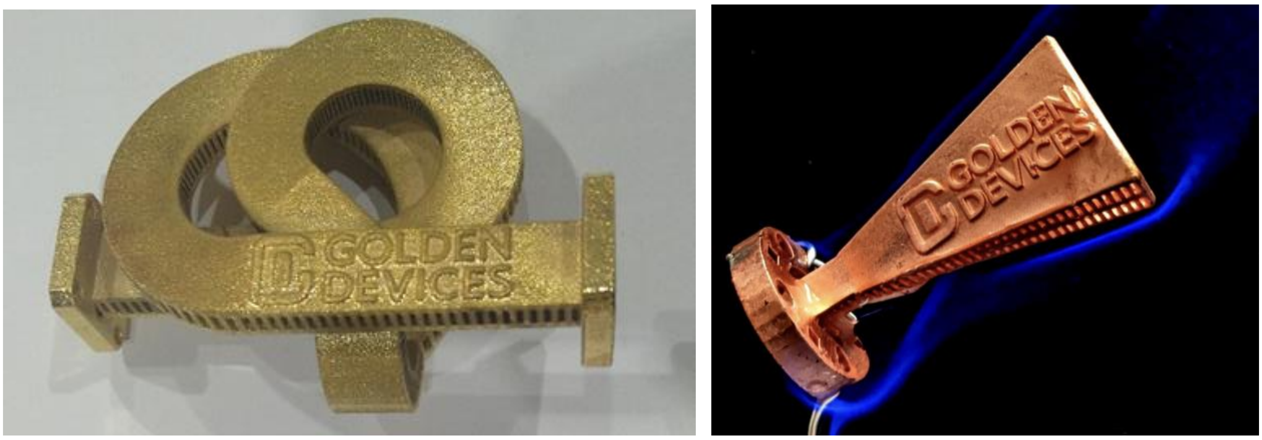

Figure 3-2: Golden Devices RF products.

The fabrication process for the ARGOS radio telescope feed will employ a split-block approach, dividing the model into 4-5 manageable sections. Golden Devices will manufacture and test the crucial feed components utilizing Selective Laser Sintering (SLS) 3D-printing technology, a process that is presented in Figure 3-3. To ensure optimal performance, a nickel coating (7-50 µm) will be applied – opting for nickel over (a) gold for cost-effectiveness, and (b) copper's susceptibility to oxidation. Following this, the individual components will be assembled with N-type connectors, and the feed will undergo strict experimental verification, including measurements of the reflection coefficient (S_{11}) versus frequency and characterization of the far-field radiation pattern. The estimated weight of the finished feed is between 3-4 kg, with the option to increase this for a more rigid structure (up to 5 kg). Finally, a protective plastic front cover will be added, utilizing FDM printing with ASA filament (dielectric constant = 2.8, loss tangent = 7 x 10^{-3}) for optimal electromagnetic transparency. This collaborative effort between UPRC and Golden Devices positions ARGOS radio telescope to achieve a state-of-the-art feed horn antenna that meets both technical and budgetary requirements.

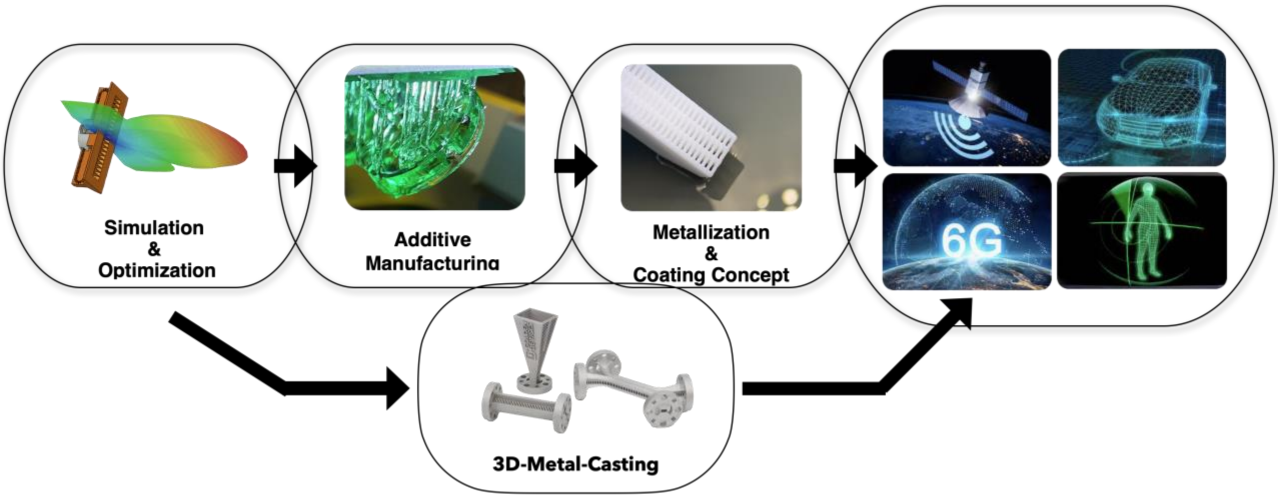

Figure 3-3: 3D Metal casting process.

4 ARGOS Reflectors Market Survey

4.1 Introduction

In this section, we present the offers from the companies we contacted about the reflectors and their mounts for ARGOS Pathfinder. According to the prices and the advantages and disadvantages of each system, the most suitable options that could satisfy our needs for the Pathfinder project, are described. This market survey is designed, depending on factors that include urgency, value for money, complexity, efficiency and capabilities, and therefore, extended information is referred to each offer that is acquired.

4.2 Reflector and mount companies

During the market survey we have contacted the following companies (until 22/03/2023). However, most of them could not satisfy our needs (financial or technical):

- Poam Electronics*
- Kratos*
- Antesky*
- VSAT Antenna
- Antenna - Dish
- SKYCOM Satellite
- AI-SAT
- DH
- RF HamDesign
- RF HamStore
- Vertexant
- Mt-mechatronics
- Medialario.com
- Secantenna
- Aerial Fi Antenna
- CPI
- Oxford Space Systems
- Cospal
- SSTL
- Anhui Bowei Electronics Technology*

(*) Positive Response

4.3 Poam Electronics 7m Solid Reflector RTP70 - Fixed Mount

4.3.1 Description

Our extended market survey identified Poam Electronics as a potential supplier for the ARGOS radio-telescope's reflector dish. They offer the 7m Solid Reflector RTP70 (including fixed mount and a feeder antenna), a dual-reflector antenna with a segmented design (16 segments) for a total diameter of 7 meters as presented in Figure 4-1. This option comes with a one-year warranty and a ten-year guarantee for parts supply. The key specifications include operation across two frequency bands: L-Band (1350 to 1450 MHz) and Ka-Band (21 to 22.5 GHz). It exhibits a gain of 38.32 dBi in the L-Band and an impressive gain of 61.93 dB in the Ka-Band, with corresponding beamwidths of 2.0° and 0.14° respectively. Additionally, the Poam Electronics offer ensures a good signal control with sidelobe levels below -14 dB across both bands. Notably, the price point is listed at £28,500 / $34,900 (excluding VAT).

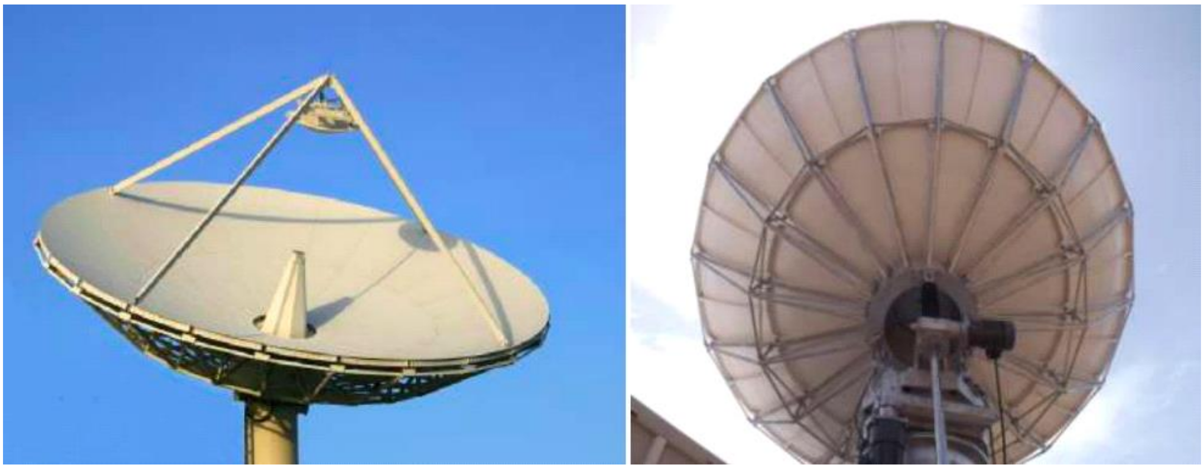

Figure 4-1: Poam 7m Solid Reflector - Fixed Mount.

4.4 Poam Electronics 6m Mesh Reflector - Motorized Mount

4.4.1 Description

Poam Electronics also offers a compelling option for the ARGOS project with their 6 m mesh reflector with a motorized mount as shown in Figure 4-2. This option demonstrates a 6-meter mesh dish designed for prime focus applications and comes with a motorized Az over El mount for precise pointing and tracking. The price is listed at £25,000 / €28,440 (excluding VAT), with a potential discount to £22,000 / €25,030 for orders of 16 units or more. This option includes the mesh reflector itself, feed arms for antenna positioning, the motorized mount, and transportation to Crete at the proposed location of the ARGOS radio-telescope pathfinder.

While the specifications mention operation primarily at 3 GHz (with a gain of 43.8 dBi at 4 GHz), it would be beneficial to inquire regarding the broader operational frequency range capabilities of this mesh reflector. The included motorized mount (depicted in Figure 4-3) support important features, including an elevation range of 0-90 degrees, a full 360-degree azimuthal travel range, and tracking accuracy of less than 0.1 degrees. The mount is designed for harsh outdoor environments with an operational temperature range of -40 °C to +55 °C. Moreover, it can withstand winds up to 100 km/h and it has survival wind speeds of 220 km/h in the parked position at zenith. Overall, the Poam Electronics 6m mesh reflector with motorized mount presents a strong contender, offering a potentially cost-effective solution with a feature-rich motorized mount, though further information on the operational frequency range is recommended for a complete evaluation.

Figure 4-2: Poam Electronics 6m Mesh Reflector - motorized mount.

Figure 4-3: Poam 6m Tracking motorized mount.

4.5 Kratos 6.5m Solid Reflector - Motorized Mount

4.5.1 Description

This antenna system is designed to address the stringent requirements of both the television broadcast industry and telecommunications network operators who demand unsurpassed flexibility and electrical performance in high-quality, cost-effective, and reliable packages.

The 6.5 m dish that is presented in Figure 4-4, is capable of operation at L-, S-, C-, X-, Ku- bands with the selection of feed and combiner systems. The versatile tripod mount, features 180º azimuth coverage in three contiguous 120º overlapping ranges, and 85º continuous elevation adjustment. This large range of adjustment provides non-critical foundation orientation, and the ability to view geostationary satellites, from horizon-to-horizon, from any location worldwide.

Figure 4-4: Kratos 6.5m Solid Reflector - Motorized Mount.

4.6 Antesky 6m Mesh Reflector - Manual Mount

4.6.1 Description

As a budget-conscious alternative, Antesky offers a 6m mesh prime focus reflector with a manual mount that is presented in Figure 4-5. This option, priced at $6,000 / €5,523 (excluding VAT), is significantly more cost effective than the motorized mount options previously explored. It includes the 6-meter segmented mesh dish (12 segments), feed arms for positioning the antenna, a manual kingsport axis mount with a pier for stability, and transportation to Crete. In case the feed antenna is included in the offer, this option exhibits an operational frequency range of 1 to 3 GHz, with a gain increasing from 32.95 dB at 1 GHz to 42.49 dB at 3 GHz. The corresponding beamwidths also decrease with increasing frequency, ranging from 3.3° at 1 GHz to 1.1° at 3 GHz. The F/D ratio is 0.38, with a focal length of 231 cm and a mesh hole diameter of 4.6 mm. The manual mount provides basic functionality with an elevation alignment range of 0-90 degrees and a full 360-degree azimuthal range. While this option lacks the precision tracking capabilities of a motorized mount, it offers a significant cost advantage and might be suitable if manual adjustments are acceptable for the ARGOS project.

Figure 4-5: Antesky 6m mesh reflector - manual mount.

4.7 Antesky 6m Solid Reflector - Manual Mount

4.7.1 Description

For applications requiring a solid dish design, Antesky offers a 6 m solid prime focus reflector with a manual mount at a price point of $14,000 (excluding VAT). This option that is shown in Figure 4-6 falls between the previously explored mesh reflector options in terms of cost. It includes the 6-meter segmented solid dish (12 segments) and feed arms for antenna positioning, but unlike the mesh option, it does not include transportation to Crete. The Antesky solid reflector operates in the C and Ku bands, offering a gain of 46.0 dB in C-Band and 56.09 dB in Ku-Band. It is constructed from aluminum and utilizes a manual kingsport axis mount with a pier for stability. This option can withstand operational winds of up to 20.8 m/s and has a survival wind speed rating of 55 m/s. The operational temperature range spans from -45 °C to +50 °C. The key decision point for this option is the trade-off between the potentially superior performance of a solid dish in certain frequency bands compared to the broader operational range and potentially lighter weight of a mesh dish. Additionally, the lack of included transport to Crete and the limited elevation alignment might need to be factored into the overall cost and suitability for the ARGOS project.

Figure 4-6: Antesky 6m Solid Reflector - Manual Mount.

4.8 Antesky 6.2m Solid Reflector - Motorized Mount

4.8.1 Description

The final option from Antesky presents a significant upgrade in terms of pointing accuracy with their 6.2m solid prime focus reflector with a motorized mount that is presented in Figure 4-7. This offer comes at a premium price of $46,750 (excluding VAT), making it the most expensive option explored so far. It features a slightly larger diameter (6.2 meters) solid dish compared to the previously mentioned solid reflector options. This motorized version includes the reflector itself, feed arms, and a kingsport pedestal motorized mount. Similar to the 6 m solid reflector with a manual mount, it operates in the C and Ku bands with a gain of 46.43 dB in C-Band and 56.18 dB in Ku-Band. The motorized mount offers some improvements over the manual versions, with an elevation alignment range of 0-90 degrees and an azimuthal alignment range of 85 degrees. It can withstand higher operational winds of up to 72 km/h and has a survival wind speed rating of 200 km/h. The operational temperature range remains at -45 °C to +60 °C. While this option exhibits the advantages of a solid dish design and motorized pointing, the decision will hinge on whether the improved pointing accuracy and slightly larger dish size justify the significantly higher cost compared to the previously explored options, particularly the 6m mesh reflector with a motorized mount from Poam Electronics.

Figure 4-7: Antesky 6.2m Solid Reflector - Motorized Mount.

4.9 Anhui Bowei Electronics Technology 6m Mesh - Manual Mount

4.9.1 Description

Anhui Bowei Electronics Technology presents a very cost-effective option with their 6 m mesh prime focus reflector with a manual mount, priced at only $4,200 / €3,864 (excluding VAT). This option that is presented in Figure 4-8, is significantly cheaper than all the previously explored choices. It features a similar design to the Antesky offer, including a 6-meter segmented mesh dish (12 segments), feed arms, and a manual kingsport axis mount with a pier for stability. However, unlike some of the other options, transportation is only included to Athens port (Piraeus), not to the final destination in Crete. This reflector boasts identical specifications to the Antesky mesh reflector, operating in the 1-3 GHz range with a gain increasing from 32.95 dB at 1 GHz to 42.49 dB at 3 GHz, with corresponding beamwidths decreasing from 3.3° at 1 GHz to 1.1° at 3 GHz. It shares the same F/D ratio of 0.38, focal length of 231 cm, and mesh hole diameter of 4.6 mm. The manual mount offers the same functionality as the Antesky option, with elevation and azimuthal alignment ranges of 0-90 degrees and 0-360 degrees, respectively. It can withstand operational winds of up to 25 m/s and has a survival wind speed rating of 60 m/s, with an operational temperature range of -40 °C to +60 °C. The key considerations for this option are the significantly lower price point compared to other offerings and the trade-off between affordability and the lack of motorized pointing capabilities. Additionally, arranging transport from Athens port to the final location in Crete would need to be factored into the overall cost.

Figure 4-8: Anhui Bowei Electronics Technology 6m Mesh - Manual Mount.

4.10 Mechatron Custom Reflector

4.10.1 Description

Mechatron is a company located at Crete with high expertise in motorized solar panels. They have recently been introduced to dish reflectors, and they expressed their interest to be involved in manufacturing a custom parabolic dish for the ARGOS radio-telescope. Their strongest advantage is the experience they have on concrete foundations as it is presented in Figure 4-9 along with the constant service they can provide as a local company based in Crete. However, after several meetings, it turned out, that their lack of experience to dish reflectors cannot satisfy a few technical specifications and their delivery time could not agree with ARGOS timetable. Another disadvantage of Mechatron was the high cost along with the absence of guarantee about the final product, including both the reflector and the motorized mount.

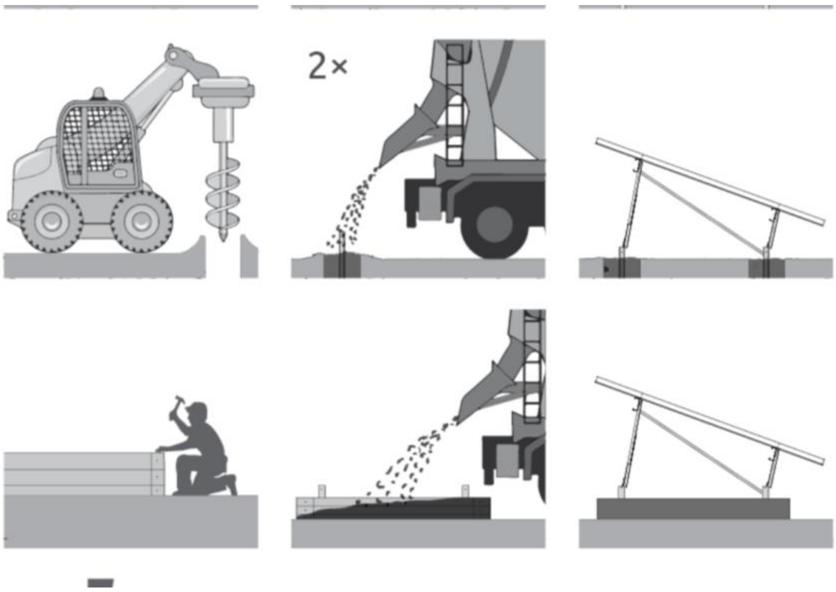

Figure 4-9: Mechatron concrete foundation process.

4.11 Market Survey Conclusion

After considering all the available information for each offer and the minimum cost for each setup, the most suitable options seem to be the following mesh reflectors:

- Poam Electronics 6m Mesh Reflector - Motorized Mount - Price: 25.000£ / 28.440€ (22.000£ / 25.030€ if quantity is to 16) (no VAT included)

- Antesky 6m Mesh Reflector - Manual Mount - Price: 6000$ / 5523€

The second option Antesky 6m Mesh Reflector - Manual Mount - Price: 6000$ / 5523€) is obviously way cheaper than the first one, however the first option provides a motorized mount, which might have a significant role in the experiment. Through the documentation we could also point to the reflector specifications like the F/D ratio, which are critical for the feed design and the overall antenna configuration.

Although the ARGOS Pathfinder requires a mesh reflector due to budget constraints, the solid reflectors that have been presented could be strong candidates for the ARGOS full scale telescope, as they can reach higher frequencies respecting the ARGOS scalable features.

4.12 ARGOS Hybrid Solution

Due to budget constraints, a hybrid solution has been adopted by combining the 6 m mesh reflector from Antesky with the motorized mount offered by Poam Electronics. This approach leverages the advantages of each component to achieve a balance between cost-effectiveness and performance.

Antesky 6m Mesh Reflector:

- **Description:** Manual 6m Mesh Prime Focus Reflector (12 segments)
- **Price:** $6,000 / €5,523 (excluding VAT)
- **Key Specifications:**
  - Operating Frequency: 1-3 GHz
  - F/D Ratio: 0.38
  - Focal Length: 231 cm
  - Material: Aluminum
  - Finish: Spray plastic
  - Advantages:
    - Cost-effective option
    - Broad operational frequency range (1-3 GHz)

Poam Electronics Motorized Mount:

- **Price:** Price not explicitly provided for the mount alone (quoted price included the 6m Mesh Reflector)
- **Key Specifications:** (assuming compatibility with the Antesky reflector)
  - Mount Type: Az over El
  - Elevation Range: 0-90 degrees
  - Azimuth Range: 0-360 degrees
  - Tracking Accuracy: < 0.1 degrees
  - Pointing Accuracy: 0.01 degrees
  - Advantages:
    - High pointing accuracy
    - Enables precise tracking of celestial objects

- **Tracking control:** The mount comes with a software that provides a comprehensive interface for controlling and monitoring the reflector antenna within an azimuth-elevation coordinate system. It displays real-time information including the current time, antenna position in azimuth and elevation angles, and the Sun's position updated every second in both azimuth/elevation and celestial coordinates (right ascension and declination). The software also includes a database of eighteen prominent astronomical radio sources and pulsars, allowing users to easily locate them in the sky. For manual control, the software facilitates movement of the antenna in both azimuth and elevation directions. Additionally, a sky view is presented, visually depicting the positions of the listed sources, the Sun, and the current antenna orientation.

Beyond manual control, the software offers functionalities for automated target tracking and area scanning. Users can select celestial objects to be tracked by the antenna, ensuring the dish remains pointed towards them as they move across the sky. Similarly, the software can be programmed to scan a designated area of the sky, automatically detecting and displaying objects within that region.

Hybrid Solution Benefits:

- **Cost Efficiency:** This approach leverages the affordability of the Antesky mesh reflector while incorporating the precision tracking capabilities of the Poam Electronics motorized mount.
- **Performance:** The combination offers a good balance between affordability and pointing accuracy, which might be sufficient for the ARGOS project's needs.
- **Broad Frequency Range:** The Antesky mesh reflector caters to the 1-3 GHz operational frequency range, potentially fulfilling the requirements of the ARGOS telescope.

Considerations:

- **Compatibility Verification:** While this solution appears beneficial, custom mounting systems should be designed to attach the reflector with the mount.

5 Mount Support

After several meetings with POAM regarding the mount, the company provided all the instructions for the installation of the mount that would hold and track the reflector. The installation is very crucial process, as everything should be exactly as mentioned in the instruction, otherwise a possible mistake can create large issues, e.g. collapsing of the whole antenna system.

A base platform - foundation constructed with reinforced concrete will hold in place the mount which is depicted in Figure 5-1. As mentioned above, the construction company should apply a very specific process, as referred in the mount datasheet and instructions book.

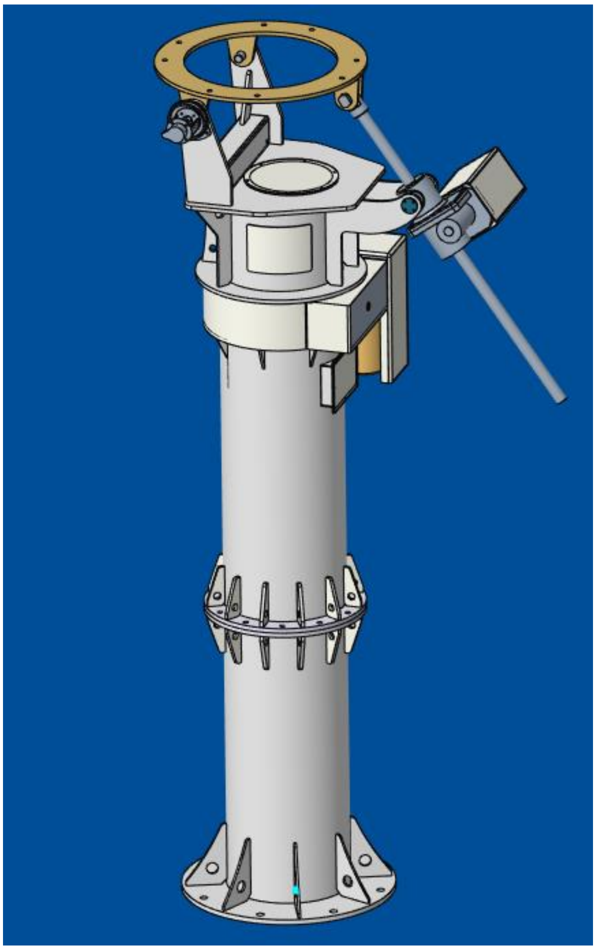

Figure 5-1: Mount sketch.

The antenna mount base is engineered to withstand powerful winds reaching speeds of 33 meters per second, ensuring the antenna's stability even in challenging weather conditions. To guarantee a solid foundation, the base needs to be installed on a surface capable of supporting a minimum soil pressure of 1 kilogram per square centimeter. Careful assessment of the soil conditions at the chosen location is crucial before proceeding. The recommended foundation material is 300# cement, which must be thoroughly compacted using a vibrating spear to create a stable base for the antenna mount. In some instances, minor adjustments might be necessary to the internal layout of steel reinforcement bars if they obstruct the placement of anchor bolts during installation. However, the primary focus should remain on achieving a secure fit for the anchor bolts. Precise vertical alignment is critical for these anchor bolts, with a maximum allowable deviation of only 0.5 millimeters from perfect vertical. Furthermore, the entire base must be meticulously leveled horizontally, with a maximum tolerance of 1.5 millimeters of error per meter across the base's diameter. Finally, after pouring the concrete foundation, a curing period of 21 days is essential for it to reach its necessary strength, which translates to a pressure rating of 210 kilograms per square centimeter. A drawing of the concrete foundation is presented in Figure 5-2. Following these critical specifications will guarantee a robust and reliable foundation for the antenna mount, capable of withstanding wind loads and effectively supporting the weight of the antenna.

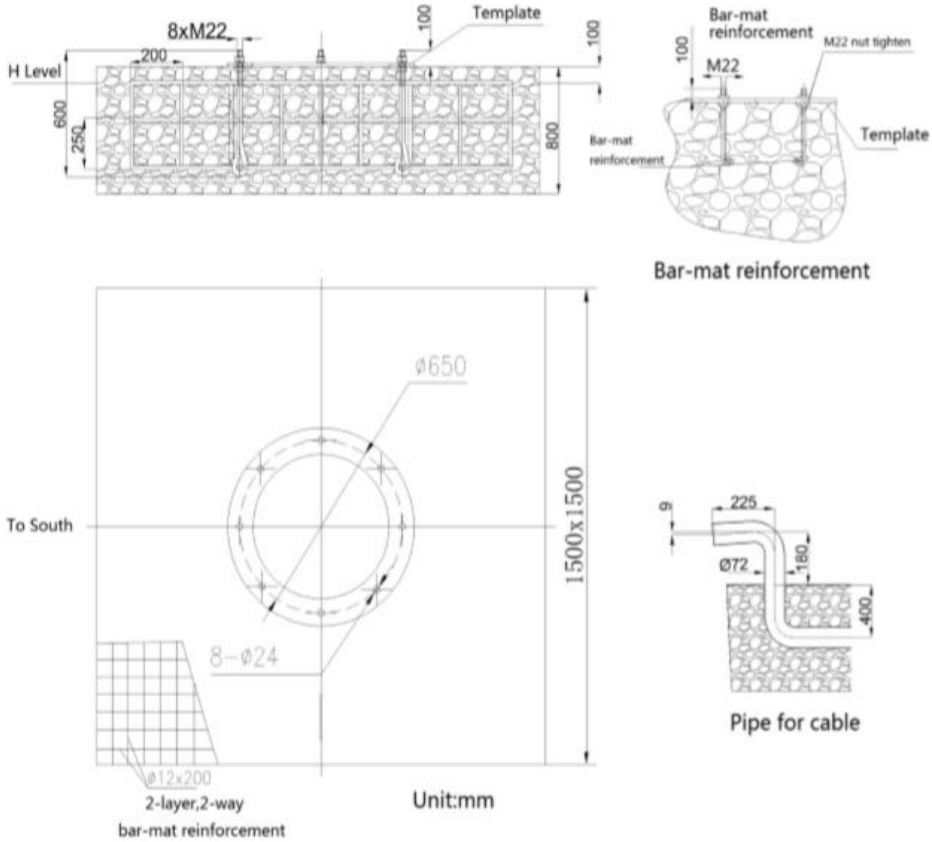

Figure 5-2: Concrete Foundation Drawing.

Figure 5-3: Mount installation.

6 Feed Support

Using a prime focus parabolic reflector, all the collected signal from the dish, concentrate, at a very specific point called focus point. This point has a specific distance from the dish, and it depends on the focal ratio value of the dish. The focal ratio (F/D) of a dish reflector is a critical parameter that defines its ability to focus incoming radio waves. It is calculated by dividing the focal length (F) by the diameter (D) of the dish. Focal length refers to the distance from the center of the dish, where the feed horn is usually positioned, to the focal point where the radio waves converge. Diameter is simply the largest dimension of the dish measured across its curved surface. A smaller F/D ratio translates to a deeper dish with a more concentrated focal point. Conversely, a larger F/D ratio signifies a shallower dish with a broader focal point. That means that each focal ratio requires a specific feed in order to avoid issues like spill-over or under illumination, that can decrease the system efficiency.

Having a custom feed antenna with the desired illumination for a focal ratio of a reflector, requires a custom mounting at the focal point of a reflector antenna, as the reflector is not designed for the feed, but the feed for the reflector. This hardware topic imports new elements to the feed in order to be mounted in a reflector, which lead to investigations for the best possible solution.

6.1 Feedhorn

A circular plate will be imported in the final feedhorn design as a mounting point, that we could add thread and bolts, without affecting its RF characteristics. The feedhorn along with the circular plate is presented in Figure 6-1.

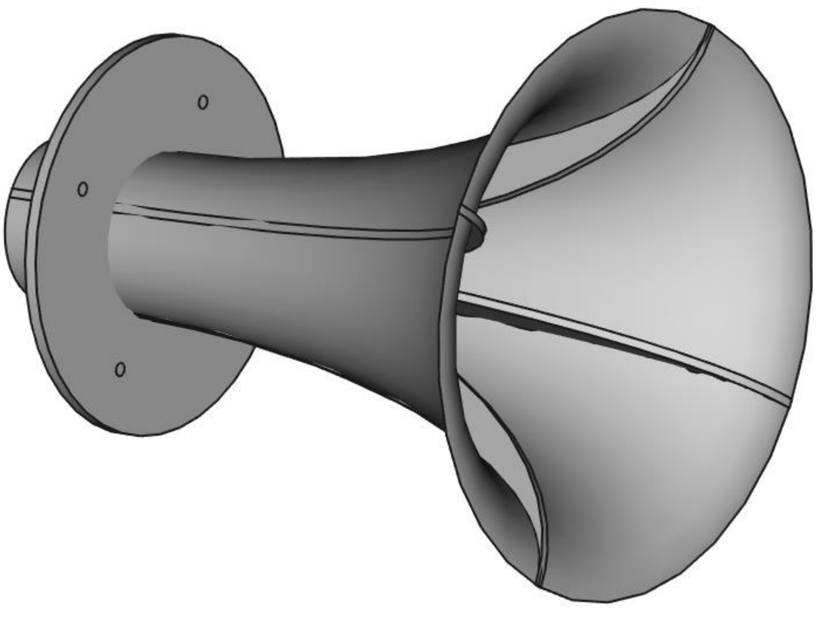

Figure 6-1: Feedhorn with mounting plate.

6.2 Scenario 1

The first idea as presented in Figure 6-2, involves 4 threads for each hole of the plate, to be mounted with angled adapters in the feed arms. Unfortunately, this scenario cannot be adequately durable, especially in heavy outdoor conditions with strong wind speeds. Another issue is that it would be not that easy to mount the feed straight to the reflector, as the angled adapters will not have enough surface for the threads to get tight enough. Over-tightening of the threads could also destroy the 3D printed material employed in the ARGOS full scale telescope feed.

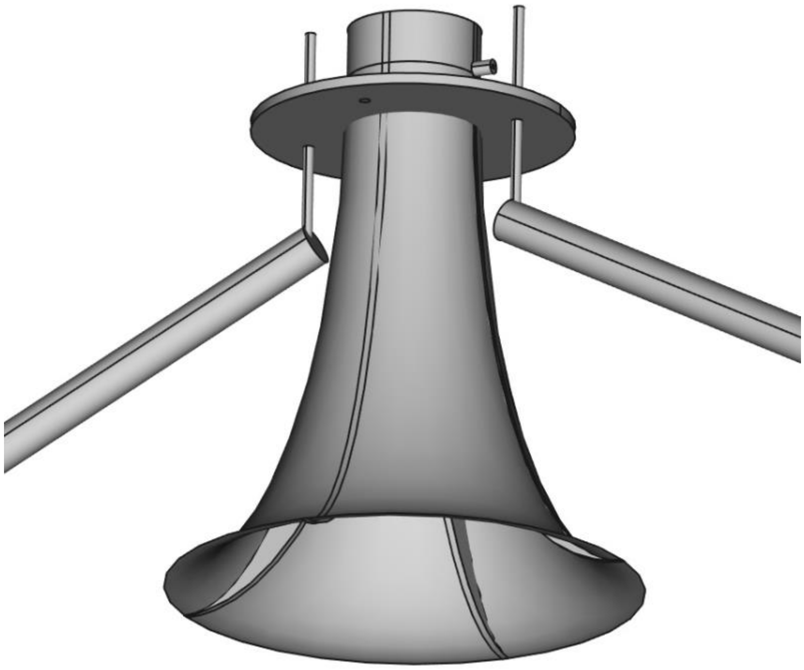

Figure 6-2: Angled adapters scenario.

6.3 Scenario 2

The final idea for the feed support as presented in Figure 6-3, involves an additional circular plate, where the feed arms will be attached. The feed can be perfectly aligned with the help of threads. This scenario has another beneficial characteristic about the phase center of the feed. Having the threads that hold the two circular plates, the feed can slide in space for in or out focus. That means that the antenna feed position is adaptive and the antenna horn feed can come closer or more distant from the focal point (feed's theoretical position), i.e. +-8 cm, achieving the perfect focus and the optimal antenna dish performance. To avoid time consuming thread work, specific extenders/spacers can be applied to each of the 4 threads for each system, after finding the best focus by measurements or observation.

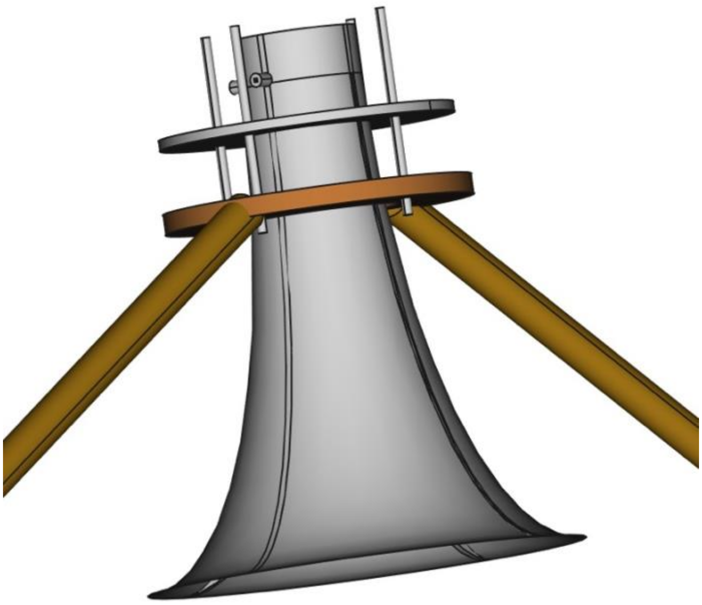

Figure 6-3: Circular plate scenario

6.4 Feed Support Plate Sketch

While the 1st circular plate of the feed will be fabricated along with the feed, the 2nd circular plate of the feed support will be custom manufactured by Antesky, so the ARGOS feed can easily be attached to Anteskys's mesh reflector. In Figure 6-4, sketch dimensions and cuts are presented.

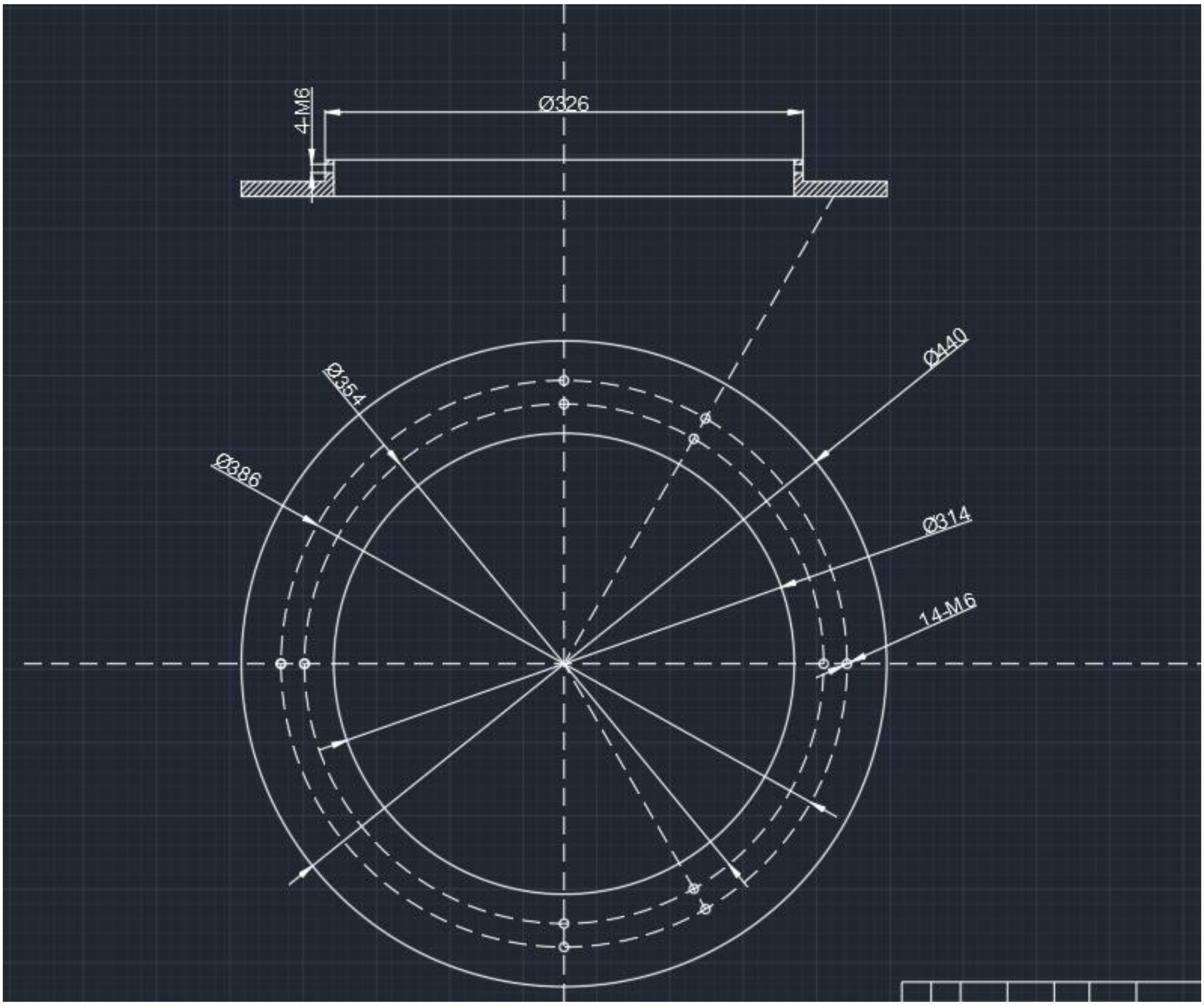

Figure 6-4: Feed Support circular plate sketch.

7 Front-end Architecture

7.1 Basic Structure

The ARGOS radio-telescope will utilize a signal chain designed for optimal performance at the frequency range 1-3 GHz. The feed antenna will be a quad-ridged flared horn, capable of handling dual polarization. To capture faint celestial signals, a low-noise receiver with a wide instantaneous bandwidth will be employed. Due to budgetary limitations, the design avoids cryogenic cooling and instead utilizes a cascade of Low Noise Amplifiers (LNAs) to amplify the weak signal. Band-Pass Filters (BPFs) are strategically placed between the LNAs to mitigate Radio Frequency Interference (RFI), minimize saturation effects, and reduce intermodulation distortion. Various noise injection scenarios were investigated in order to detect the optimum scenario that performs comprehensive noise calibration, ensures accurate signal characterization and improves sensitivity.

7.1.1 Scenario 1 (preliminary idea)

This scenario involves a direct noise injection into the circular waveguide body itself. A coaxial probe will be inserted into the waveguide, oriented at a 45-degree angle relative to the standard horizontal and vertical polarization probes. This angled orientation aims to inject noise power that is independent of the typical signal polarizations. However, this approach has limitations, due to the inherent physics of wave propagation within the waveguide. It seems that it is not feasible to achieve uniform noise power injection across the entire 1-3 GHz operational frequency range using this method. The scenario was dropped at an early stage. However, it highlighted the need to explore alternative noise injection techniques to ensure effective calibration across the desired bandwidth.

7.1.2 Scenario 2

Scenario 2 as presented in Figure 7-1, implements a more controlled noise injection strategy using two 4-arm directional couplers. The incoming RF signal of each polarization (horizontal and vertical) passes through a directional coupler where calibration noise signal is injected. The noise signal is generated by the noise source and is divided into two noise signals by a power splitter before feeding the two directional couplers. The 4th arm of each directional coupler is terminated with a 50 Ohm terminator in order to absorb unwanted reflections. This approach offers greater control over the noise power injected into each polarization path compared to the direct waveguide injection. In addition, the use of directional couplers ensures consistent and predictable noise injection across the 1-3 GHz frequency range.

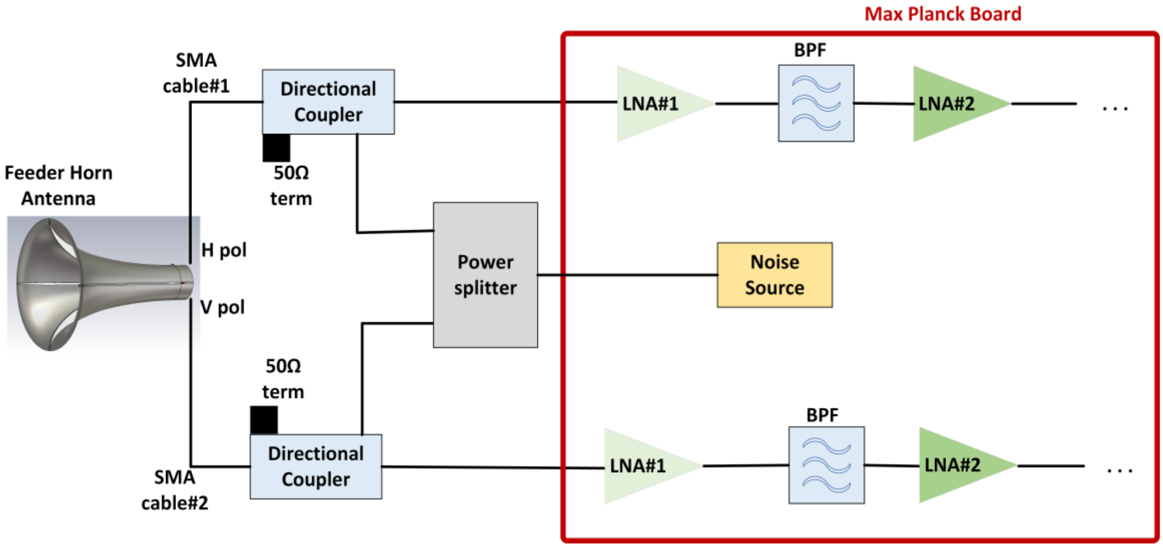

Figure 7-1: RF Chain Scenario 2.

7.1.3 Scenario 3

Scenario 3 as depicted in Figure 7-2, prioritizes minimizing insertion loss within the RF chain to optimize noise performance. It achieves this by utilizing two key components. First, by employing a bi-directional 4-arm directional coupler the power splitter used in scenario 2 is eliminated. Unlike a standard directional coupler, this bi-directional version of coupler allows the noise signal to enter the first coupler and then the second one. Thus, there is no need for a power splitter to split the generated noise signal. Secondly, eliminating the power splitter reduces the number of components in the signal path. This streamlined approach directly translates to a lower overall insertion loss, minimizing the degradation of the weak celestial signal. Minimizing insertion loss is crucial in this application. Every component in the RF chain introduces some level of loss, and in the case of the ARGOS telescope, where the goal is to amplify faint astronomical signals, reducing this loss is paramount. For example, 1 dB increase at the insertion loss can introduce an additional 75 Kelvin to the system noise temperature, effectively reducing the radio-telescope's sensitivity by making it harder to distinguish the weak celestial signal from the inherent system noise.

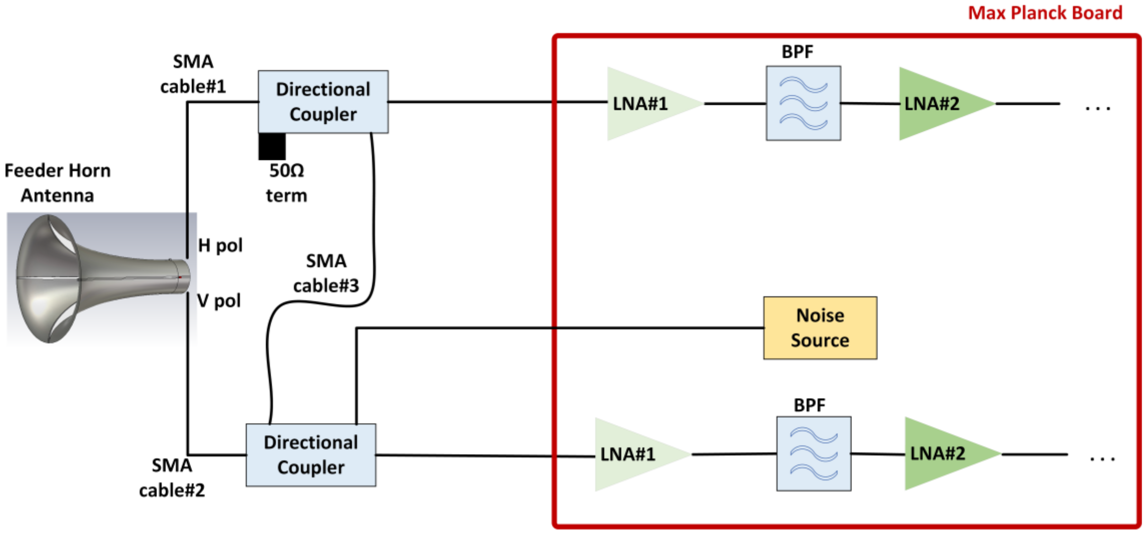

Figure 7-2: RF Chain Scenario 3.

7.1.4 Scenario 4

Scenario 4 as shown in Figure 7-3, introduces a unique approach to noise injection by placing the noise coupler directly before the first Low Noise Amplifier (LNA) and integrating it to the same board along with the LNA matching network. This eliminates the need for separate directional couplers, thereby minimizing insertion losses within the RF chain. The key component here is a noise coupler strategically embedded within the input matching network of the LNA itself. This design allows for controlled noise injection while maintaining a compact and potentially cost-effective solution. The first LNAs, equipped with these embedded noise couplers, are directly attached to the feed horn, minimizing the signal path before the initial amplification stage.

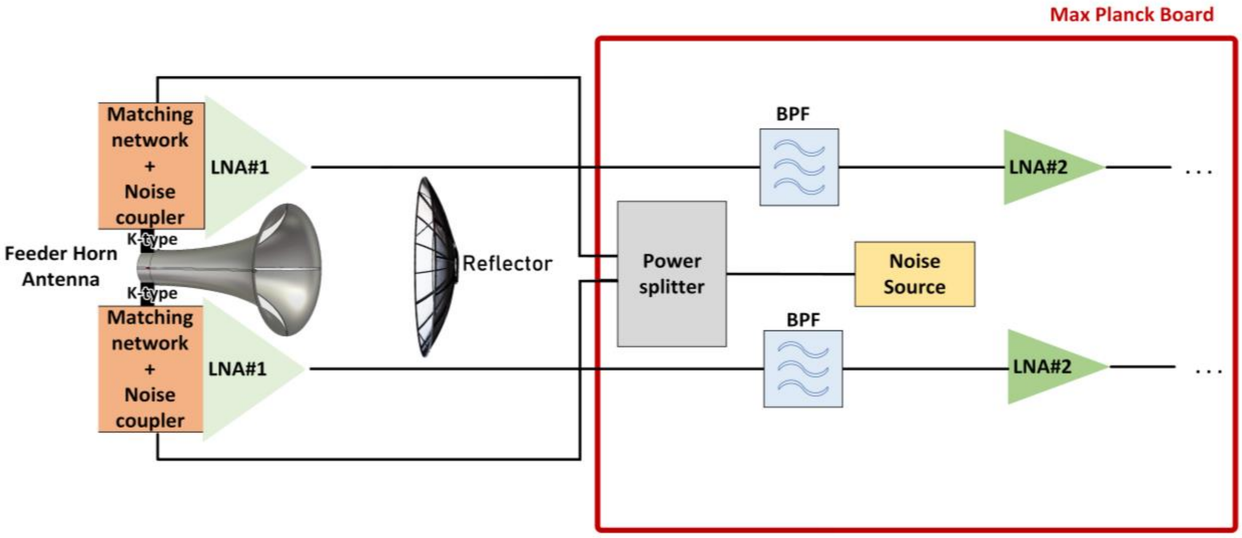

Figure 7-3: RF Chain Scenario 4.

7.1.5 Scenario 5

Scenario 5 as presented in Figure 7-4, aims minimizing signal degradation while maintaining a relatively simple design. Similar to scenario 4, noise injection occurs at the very beginning of the signal chain, directly before the first Low Noise Amplifier (LNA). A power splitter strategically positioned at the back of the feed horn antenna plays a key role. This splitter divides the incoming noise signal into two polarization paths. Calibration noise, with precisely controlled power levels, is then introduced into this dedicated path. The first LNAs, directly attached to the feed horn, amplify the weak celestial signal. ‘

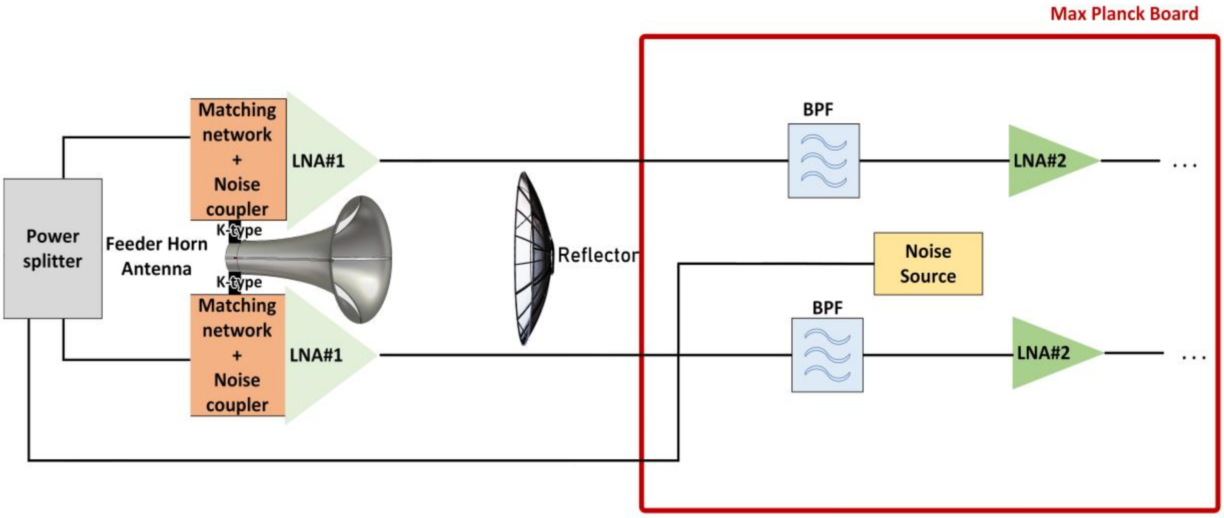

Figure 7-4: RF Chain Scenario 5.

8 RF Signal Processing Chain

An overview of the RF signal processing chain is shown in Figure 8-1. It gives a simplified schematic of all components interacting with each other. Starting from the front-end that receives the RF signal, down to the optical fiber output that delivers the digitized spectral data on a high-speed network towards a central processing cluster. The sky signal is received by the feed which delivers two orthogonally separated polarizations. Signal losses in front of the first active device, the LNA, degrade the overall system noise performance. Therefore, a low-noise amplifier is directly connected at each RF output port of the feed-horn. Additionally, a Noise Source is included here, which injects a reference signal into both RF downstream paths.

Two low-loss coaxial cables carry the RF signal to an RFI shielded and weatherproofed housing. Inside the housing are the RF signal processor, the RFSoC board, a time and reference generator and a power supply. The only interface towards outside world are an AC power and fiber optical cables. Making the interface lean and straightforward to interconnect.

The RF signal processor is split into two chains, one per polarization. Each processor accepts an RF input frequency band of 1-3 GHz and delivers two signal bands 1-2 and 2-3 GHz towards two ADCs of the RFSoC board. A serial peripheral interface (SPI) bus is used to control the digital electronics inside the processor.

To make the interface between LNAs and the Electronic Box (E-Box) simple and lean, we foresee a DC injection scheme that delivers the DC power to operate the LNAs over the coaxial cable.

A good mechanical design for the E-Box is required to ensure a weatherproofed and RFI-free operation when mounted to the rear structure of the dish.

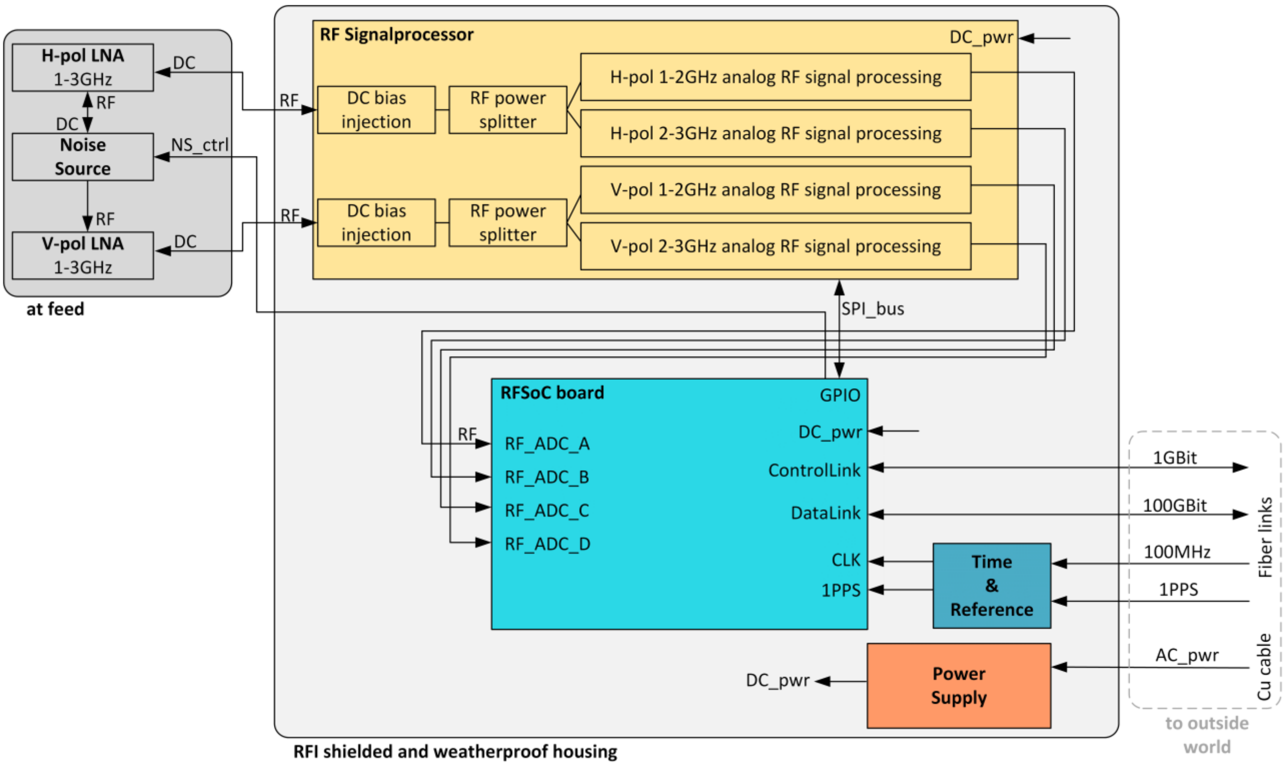

Figure 8-1: Simplified schematic of the full RF Signal Processing Chain located inside the Electronic Box.

8.1 Direct RF Signal Proccessor

The RF Signal Processor is the important link between front-end feed-horn with LNA and the digital back-end. It fulfills several main tasks. One is to bandpass filter the incoming broad-band RF signal from the low-noise amplifier so that only the desired payload band reaches the analog-to-digital converter. At the same time the RF level provided by the LNA needs further amplification and precise level adjustment to drive the ADC at its optimum operation level. Care has to be taken that the signal processor is running linear and that no internal compression occurs. Furthermore, the design has to be chosen in a way that it only contributes insignificantly to the overall noise performance of the full RF signal chain.

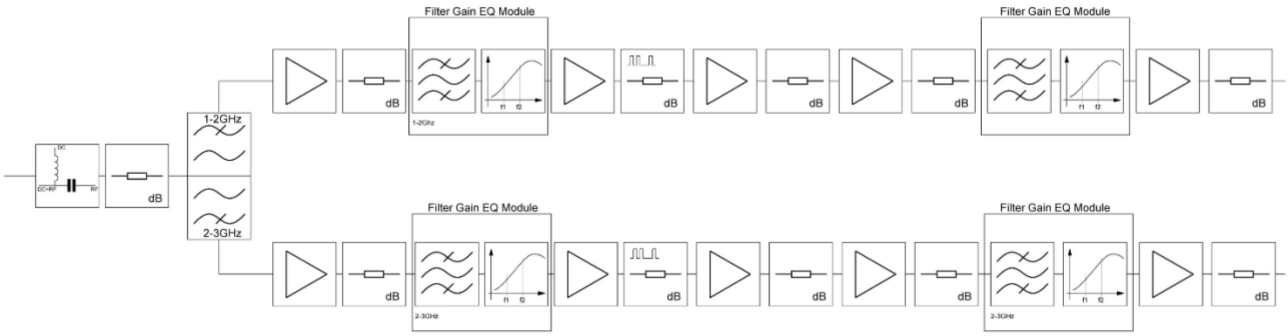

Figure 8-2: Schematic overview of the Direct RF Signal Processor, one chain (1-3GHz input).

Figure 8-2 gives an overview of one complete RF signal chain, processing an input frequency band of 1 to 3 GHz and delivers two filtered signal bands of 1-2 GHz and 2-3 GHz towards the digital backend. All components will be located on a compact designed printed circuit board. Most parts seen in the schematic overview are state-of-the art commercially available off-the-shelf RF components, available on short lead time and with a good price-performance ratio. This includes the SMA end-launch connectors, attenuator pads, the digitally controlled RF step attenuator chips and the surface mount MMIC amplifiers.

Since the signal filters are a crucial component for selecting the desired RF payload bands and to minimize aliasing at the ADC, a market search gave possible candidates that can be used but their performance seems to be inadequate, due to low order and as soon as a custom design is required the cost increases dramatically to provide a high enough filter slope between pass and stop-band. Especially, for the in-band filter edges at 2 GHz where a high isolation between the two output bands is required. We therefore favor in-house designed high-order filters with excellent filter edge steepness, low insertion loss and good input return loss. We would even follow a multi-stage filter scheme, as can be seen in Figure 8-2 where already a frequency selective diplexer and not a power splitter is used to divide the signal into low (1-2 GHz) and high (2-3 GHz) band.

From system design, Figure 8-3 gives the expected signal levels inside one RF chain and band. Starting at the left side of the plot with the LNA and ending at the right side with the power level at the output connector. In order to run the chain linear, a margin of -15 dB towards the 1 dB compression point of each component is chosen. As can be seen, a good margin exists, even when getting closer to the output where the signal level has to be high enough to drive the RFSoC ADCs.

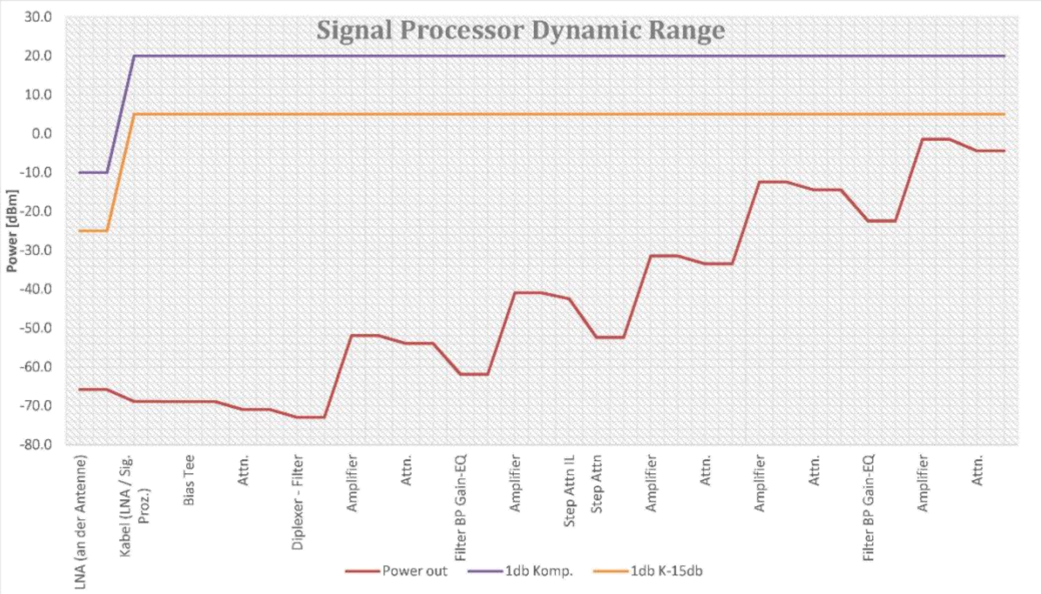

Figure 8-3: Signal Processor Dynamic Range.

The bias tee for DC power injection on the coaxial cable, for supplying power to the LNA, is the first part after the SMA input connector. Despite of commercially available drop-in SMT (surface-mount technology) Bias Tees, the current design foresees the classical approach of using SMT components, a capacitor and inductor combination, see **Error! Reference source not found.**. DC is injected on the RF coplanar waveguide transmission line via an inductor and the capacitor blocks it towards the following parts of the circuit. There are further combinations of capacitors and inductors to ensure that the RF blockage is high enough to avoid RF passing on the LNA DC power line. A low-noise, low drop-out, linear voltage regulator is used to generate the DC supply voltage. This regulator includes an enable/disable functionality so that the LNA can be switched off remotely for testing purpose.

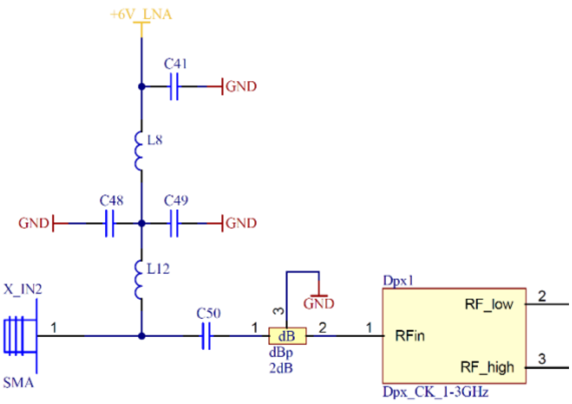

Figure 8-4: LNA DC power injection and diplexer as a signal splitter.

We are currently evaluating two design approaches for the diplexer circuit. One is based on grounded coplanar waveguide transmission lines and the other on microstrip.

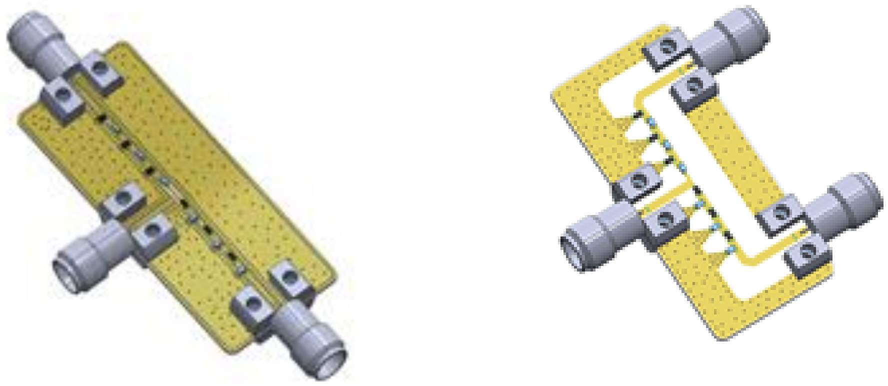

Figure 8-5: diplexer design approaches, GCPW and MS.

The simulation results show excellent return loss of better than -20 dB over the ARGOS frequency range (1-3 GHz, see Figure 8-6) as well as an already good isolation of around 10 dB at the channel separation frequency of 2 GHz (see Figure 8-7). Since the transmission lines on the signal processor board will be GCPW, the microstrip design would have the drawback of adding additional matching structures for interfacing.

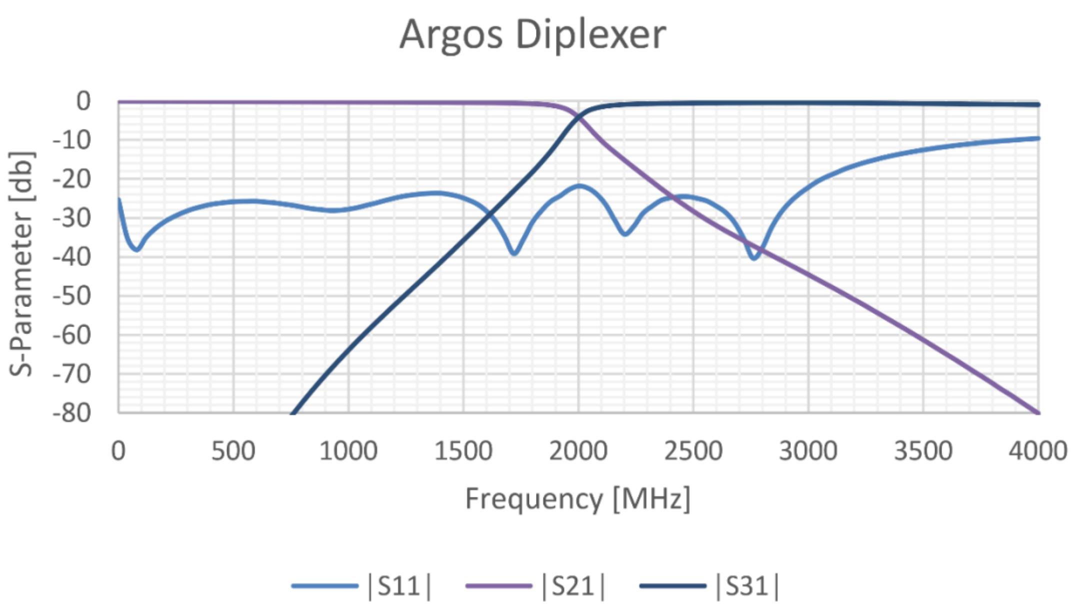

Figure 8-6: RF simulation results of diplexer performance, S-parameters, in the range 0-4 GHz.

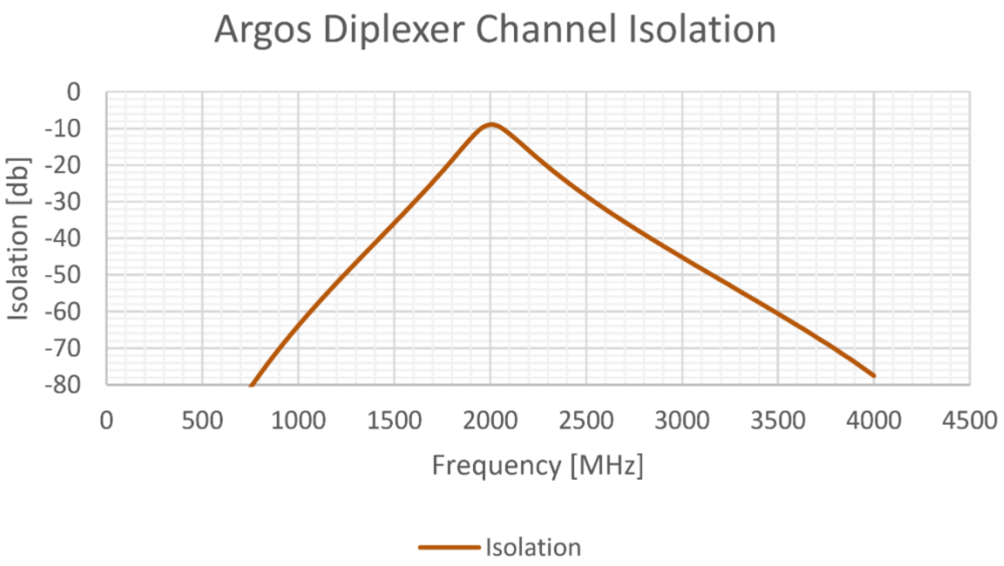

Figure 8-7: RF simulation results of diplexer performance, channel isolation, in the range 0-4 GHz.

We have chosen SMT low noise, wideband amplifiers that operate in the intended 1-3 GHz range. These are commercially off-the-shelf available. The circuit design requires only few external components for biasing. This type of amplifier is already a 50 Ohm impedance design and requires no matching circuitry. In addition, it can be easily cascaded to build amplifier chains. The circuit design and a picture of the part are given in Figure 8-8.

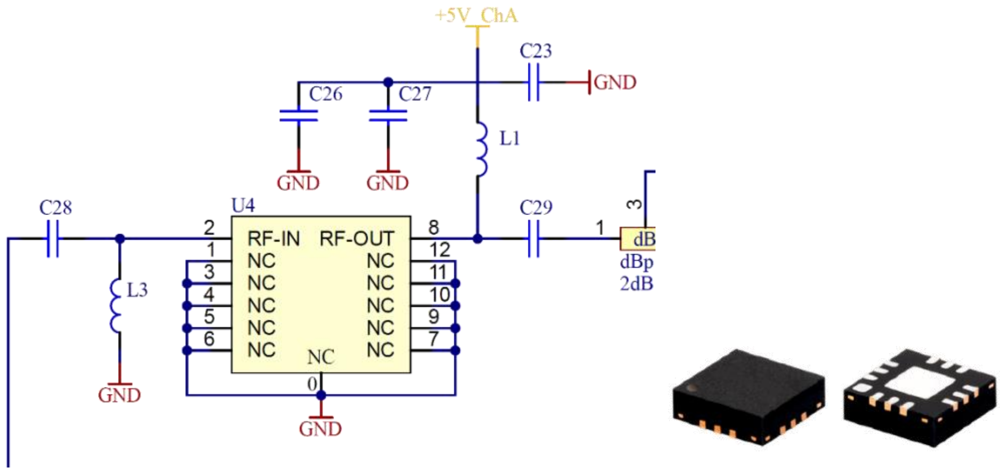

Figure 8-8: SMT mount low noise, wideband amplifiers.

The RF signal filters are a key component for the signal processor´s performance and also at the end of the full signal processing chain. They should ensure excellent out-of-band suppression with a small transition band between pass to stopband. Since the RFSoC ADCs are sampling in the 2nd and 3rd Nyquist zone, the filters also perform as anti-aliasing filters to avoid folding of unwanted frequencies into the desired signal band.

We follow the approach of a cascaded filter scheme. As the first frequency selective element a diplexer splits the incoming 1-3 GHz band into a 1-2 GHz low and 2-3 GHz high channel (see Figure 8-6). Two additional bandpass filters follow in each chain to achieve very good isolation between the channels as well as high suppression of out-of-band signals. Figure 8-9 indicates where the filters are located in the signal flow.

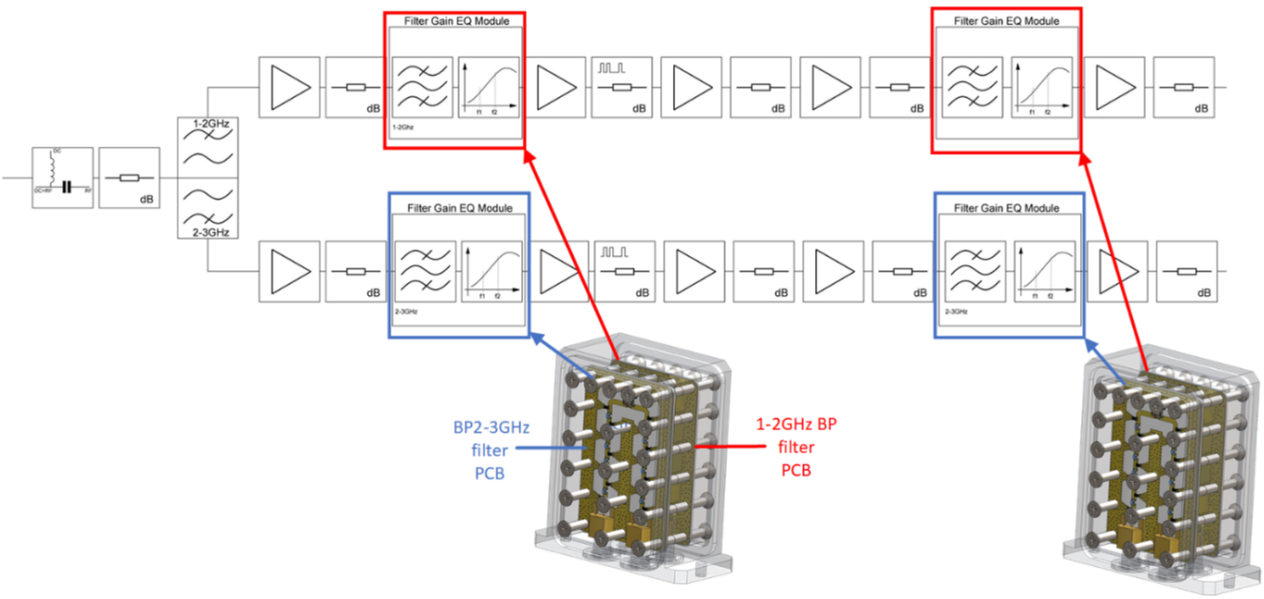

Figure 8-9: combined low and high channel RF signal filters, cascaded filter scheme.

The bandpass filters are of high order, yet with small outline dimensions and are designed to have equal size. This allows for a clever arrangement of the low and high channel filter in a single housing with small footprint (details in Figure 8-10).

An add-on module has certain advantages compared to a fixed filter structure on the signal processor PCB itself. If requirement changes come up, e.g in bandwidth, or additional functionality (like notch suppression of very strong interference signals) is required, only the filter add-on module has to be modified or re-designed. Another benefit is that the RF signal path can be tested and debugged stepwise, since the connectors on the signal processor board can be used as test-ports for piecewise testing of the signal path.

As an additional feature, the filter PCBs have already implemented a gain equalizer to compensate for signal slope of the bandpass and the slope generated by routing the RF signal on the PCB. During the design phase these elements need adjustments, with this approach they are easily accessible without taking the full signal processor housing apart.

We use blind mate RF connectors to interface with the signal processors main circuit board.

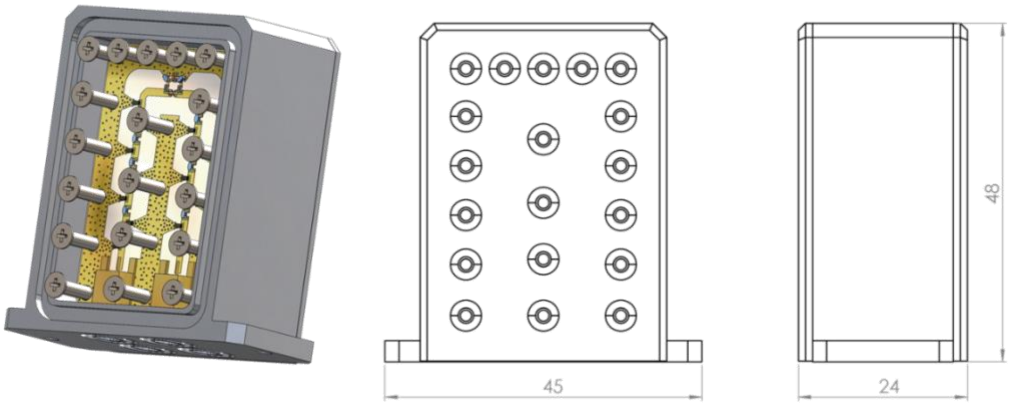

Figure 8-10: Mechanically compact Bandpass Filter housing, containing the low and high channel bandpass filters and gain equalizers.

Our in-house workshop manufactured a first prototype housing. This was populated with a first set of filter PCBs fabricated by our PCB board manufacturer. The filter responses were measured with a Vector Network Analyzer (VNA). The results of the low and high channel bandpass filters are overlaid in Figure 8-11. They show a smooth passband with steep filter edges.

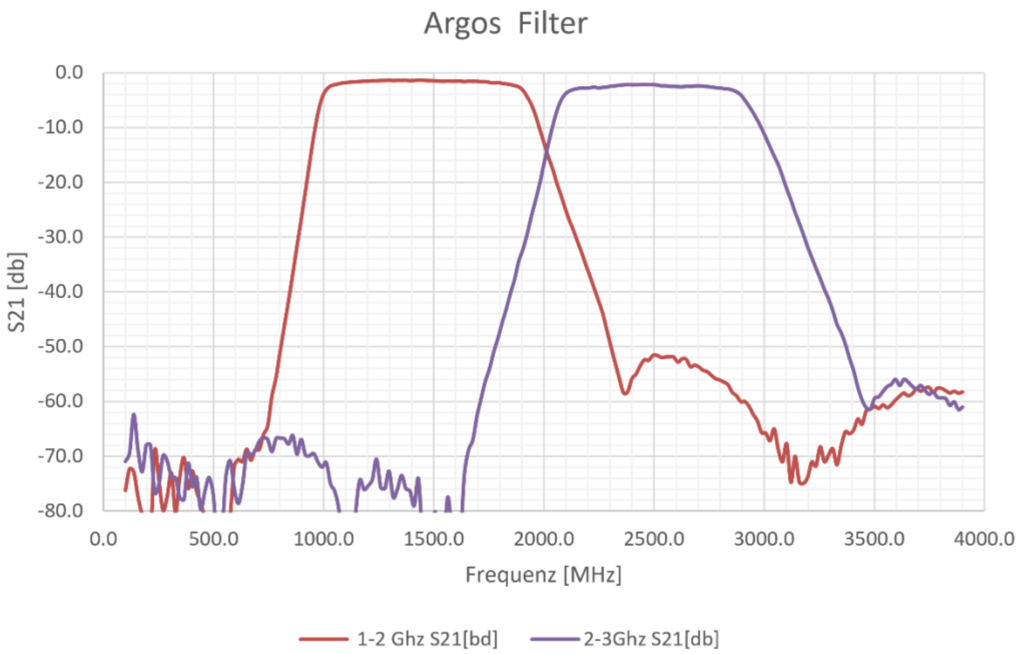

Figure 8-11: VNA measurement of a first prototype filter set, overlay of low and high channel forward gain, S21, in the range 0-4 GHz.

Each signal channel includes a programmable RF attenuator for precise level adjustment. We use a commercially available broadband GaAs SMT mount digital step attenuator with 0.5 dB step size. The attenuator will cover 0.5 to 20 dB of signal attenuation. There are two operational modes for the digital interface, one is SPI and the other is parallel. We aim for the SPI interface since this is a lean bus with only 4 connecting wires. Interconnection scheme of the digital attenuator is given in Figure 8-12.

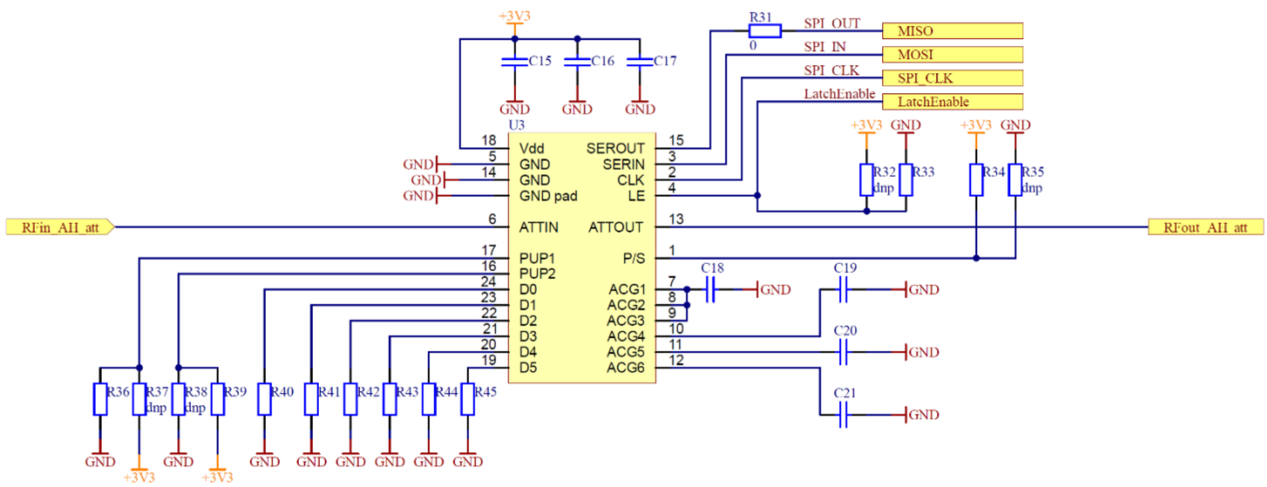

Figure 8-12: Digital step attenuator used per signal channel for precise level adjustment.

As a summary Table 8-13 gives the most relevant RF specifications in short form.

input frequency range	1 to 3 GHz
input connector type	SMA
input level	-70 dBm
RF gain (nominal)	65 dB
internal step attenuator	10 dB nominal with + / - 10 dB in 0.5 dB steps
noise temperature	> 500 K
overall additional noise contribution	< 0.6 K
low-band output frequency range	1 to 2 GHz
low-band output P1dB	+20 dBm
low-band output connector type	SMA
high-band output frequency range	2 to 3 GHz
high-band output connector type	SMA
high-band output P1dB	+20 dBm

Table 8-13: Overview of technical specs for one signal chain.

8.2 E-Box

All relevant receiver electronics will be integrated in a compact metal enclosure. This will be a fully customized mechanical design. The separated compartments ensure a good RF shielding between digital and analog electronics. EMI filters will be used to avoid distribution of unwanted signals between the respective compartments. Mainly three sections can be identified which are the vulnerable analog compartment with the high gain RF signal processor, a digital compartment where all the EMI wise 'dirty' electronics will be located and a separated compartment for the power supply.

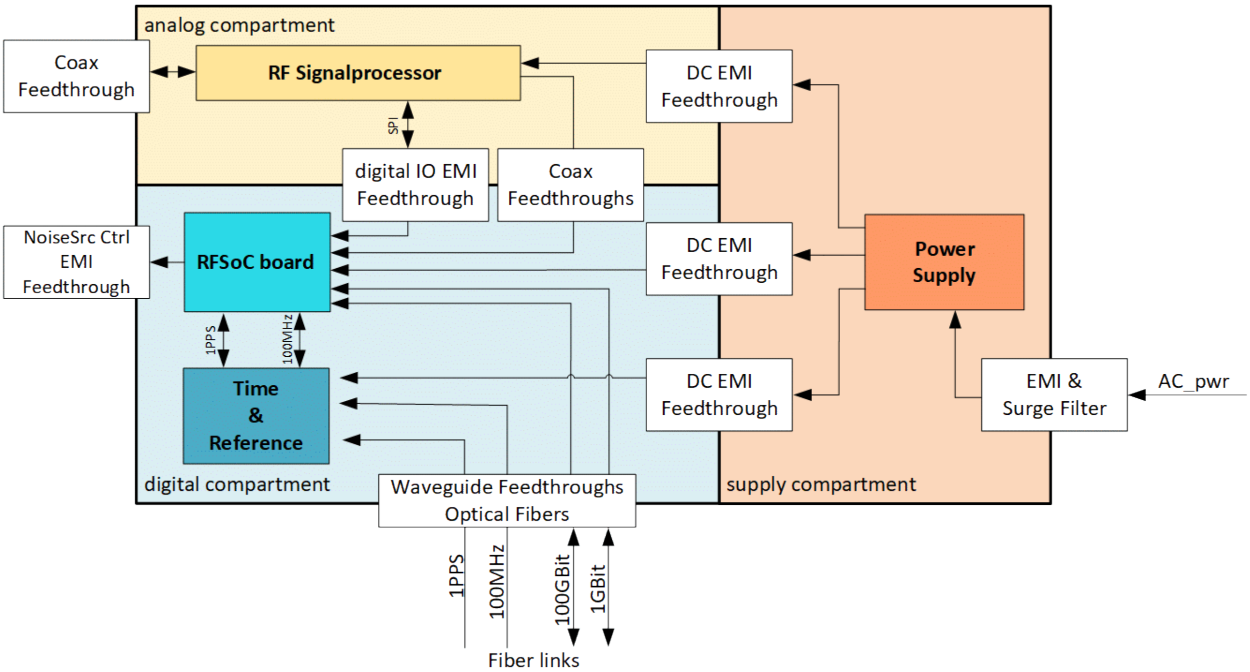

Figure 8-14: Electronic Box, sketch of the mechanical layout using compartments and EMI signal feedthrough filters.

As a short summary Table 8-15 gives the interconnections from the E-box, as identified by now.

H-pol coax connector	N-connector
V-pol coax connector	N-connector
AC input connector	MIL STD type D38999 / 20WC4PN (single phase 230V_AC)
Optical connector	MTP/MPO on Telegärtner TOC LWL flange set

Table 8-15: E-Box interconnections summary.

9 Conclusion

After several scenarios and investigations to create an optimal solution, a final solution has been provided from UPRC and MPIfRM, to get the most out of the components. The final front-end RF chain, starts with the feed, which delivers two orthogonally separated polarizations. To avoid losses from cable lengths that could degrade the system performance, a low-noise amplifier is directly connected at each RF output port of the feed-horn. For calibration purposes, a Noise Source is included, which injects a reference signal into both RF downstream paths.

Then, two low-loss coaxial cables will carry the RF signal to an RFI shielded and weatherproofed housing that will be mounted at the back of the reflector. With this placement, the housing cannot provide any additional blockage to the reflector, and will not struggle the feed point mount, as it could if more weight was applied at the feed point, far from the weight center. Inside the housing the RF signal processor, the RFSoC board, a time and reference generator and a power supply are hosted.

This collaborative effort provides a high-performance, low-loss front-end RF chain design that maximizes the capabilities of the chosen components. This front-end RF chain design lays the groundwork for exceptional signal reception and data acquisition for the ARGOS full scale telescope antenna.

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