MISSIONE 4
**ISTRUZIONE RICERCA**

**CHERENKOV TELESCOPE ARRAY PLUS (CTA+)**

MISSIONE 4 COMPONENTE 2, INVESTIMENTO 3.1 IR0000012,
CUP: C53C22000430006

CIG: A034AB5D50

# STATEMENT OF WORK FOR THE SUPPLY OF "TWO MICROWAVE WIDEBAND RECEIVING SYSTEMS FOR THE MEDICINA AND NOTO RADIO TELESCOPES"

OPEN PROCEDURE PURSUANT TO ART. 71 OF LEGISLATIVE DECREE MARCH 31, 2023, N. 36, AND FOLLOWING MODIFICATIONS AND INTEGRATION

**STAZIONE APPALTANTE**
ISTITUTO NAZIONALE DI ASTROFISICA-
ISTITUTO DI RADIOASTRONOMIA
VIA GOBETTI 101, 40129 BOLOGNA (BO)
WWW.IRA.INAF.IT

TABLE OF CONTENT

## Art. 1 Definitions and purpose of the document

### 1.1 Scope & Purpose

This Statement of Work (SoW) intends to address the deliverables, the organisational structure and relative activities requested by INAF (referred alternatively as "Institute") to the Contractor necessary for the successful completion of the work related to [AD1]. The company in charge for the execution of the work (referred to as "Contractor") will be selected by INAF by means of a tender. Consequently, this SoW must be considered as an applicable document during the entire work execution.

### 1.2 Applicable Documents

These documents, and all the documents applicable of these documents, are considered applicable for this SoW.

[AD1] Disciplinare Di Gara - Gara Europea A Procedura Aperta Per L'appalto Della Fornitura Di "Due Ricevitori A Banda Larga Per Radio Telescopi Di Medicina E Noto"

### 1.3 Definition of Terms and Abbreviations

#### 1.3.1 General definitions

- Technical requirements. Requirements that define the characteristics and technical specifications of the supply.
- Functional requirements. Requirements that indicate the purpose and function of the supply.
- Performance requirements. Requirements that define what performance and level of service the supply must have.
- Reward requirements. They identify the characteristics of a technical and / or functional nature and / or performance that improve the minimum requirements set by the contracting station, subject to discretionary or tabular evaluation by the adjudicating commission.

#### 1.3.2 Abbreviations and acronyms

| | |
|---|---|
| AIT | Assembly, Integration and Test |

| | |
|---|---|
| CTA+ | Cherenkov Telescope Array plus |
| CTAO | Cherenkov Telescope Array Observatory |
| EVN | European VLBI Network |
| FAT | Factory Acceptance Testing |
| FDR | Final Design Review |
| INAF | Istituto Nazionale di Astrofisica |
| IRR | Integration Readiness Review |
| LCP | Left Circular Polarisation |
| LNA | Low Noise Amplifier |
| PDR | Preliminary Design Review |
| RCP | Right Circular Polarisation |
| SKA1-MID | Square Kilometre Array phase 1 - mid frequency range |
| VLBI | Very Long Baseline Interferometry |

## 2. EXECUTIVE SUMMARY

The bid is finalised to the acquisition of 2 (two) cryogenic radio astronomical receivers able to simultaneously operate at the frequencies 4.2 to 9.0 GHz. The receivers will be installed in the INAF radio telescopes located in Medicina and Noto.

INAF operates the Medicina and Noto 32m radio telescopes and the Sardinia 64m radio telescope. These instruments observe both in the context of the European VLBI Network (EVN) and as single dish instruments. The EVN is the primary instrument for the Italian community for high angular resolution studies in all astrophysical areas, including transients. Explosive phenomena and transients, as well as synergies with the Cherenkov Telescope Array Observatory (CTAO), feature prominently in the EVN Science Vision Document VLBI20-30. The same document indicates as top-priority in the list of changes and up-grades for the network the development and installation of broad-band receivers compatible with SKA1-MID. With the procurement of such a device, INAF will confirm its leadership in the radio astronomy and multi-wavelength framework. It will also make significant progress toward the development of a national facility based on single dish and VLBI techniques aimed at the screening and monitoring of sources of interest across the energy, distance, and time scales. This will maximise the return of the investment being made towards the strengthening of the CTAO carried out as part of the project CTA+, funded

among the reforms and investments under the recovery and resilience plan, Mission 4, Component 2, Action 3.1.1.

In practice, broadband receivers allow VLBI and single dish simultaneous observations across wide frequency ranges, improving sensitivity through coherent integration of all the data. Another advantage of coherent fringe-fitting is that precise registration of simultaneous images at different frequencies will become possible. Astronomers will be allowed to measure variations of polarised emission as a function of frequency over a wide frequency range with very precise, unambiguous rotation measures. Studies of different maser types in different frequency bands can be made simultaneously with proper alignment of the different maser species. Further opportunities arise for flux variation studies in several bands simultaneously, which is especially interesting for intraday variability investigations. Searches and observations of coherent sources (such as pulsars or fast radio bursts) can be performed over a wide frequency range without timing ambiguities.

This SoW specifically regards the design, production, assembling, and shipping of two receiver units. It applies to all activities and deliverables throughout the various development phases of the receiver production and implementation. In the following chapters, the preliminary design of the broadband receiver and its components, the status of the project, the schedule, the phases, and the task requested to the contractor, the organisation of the team, responsibilities and Customer's right and the document Requirements Definition will be described.

The Proponents, starting from what is requested and described in this SoW, shall produce the final design of the receiver. Furthermore, the Proponents shall describe the complete plans (i.e. management, developments, etc.) in order to achieve what is requested.

Moreover, the Proponents must clearly demonstrate their ability to meet these requirements by providing a full description of their manufacturing and technical capabilities, including a description of the technical equipment and personnel, the average annual staffing levels, and a description of their integration facilities. They shall provide a sustainable AIT plan and evidence of having experience in the design, construction, and implementation (requirements to be considered jointly) in the last ten years of at least one professional receiver for radio antennas of complexity and technical characteristics similar to the requested supply [details in AD1].

## 3. MEDICINA AND NOTO 32m RADIO TELESCOPES OVERVIEW

The optical parameters and the mechanical views of the INAF 32m radio telescopes (Medicina and Noto are identical radio telescopes) are reported in Table 3.1 and Figures 3.1, 3.2, 3.3.

| *Parameter:* | *Value:* |
|---|---|
| Optics | Cassegrain |
| Subreflector geometry | Hyperbolic |
| Prime mirror diameter, D (m) | 32.004 |
| Subreflector diameter, d (m) | 3.2004 |
| Focal length, f (m) | 10.259 |
| Prime focus focal ratio, f/D | 0.32 |
| Secondary focus focal ratio, f2/D | 3.03 |
| Distance from Prime to Gregorian foci (m) | 10.0304 |
| Subreflector eccentricity, e | 1.2357 |
| Magnification, M (m) | 9.48 |
| Prime focus to subreflector vertex (m) | 0.9566 |
| Secondary focus to subreflector vertex (m) | 9.0738 |
| Secondary focus to Prime mirror vertex (m) | 0.2286 |
| Distance from Prime mirror vertex to aperture plane (m) | 6.2697/6.2995 |
| Distance from Prime focus to aperture plane (m) | 3.9893/3.9595 |
| Prime mirror half-angle (degree) | 75.9 |
| Subreflector half-angle (degree) | 9.43 |

Table 3.1 Optical parameters for the Italian antennas

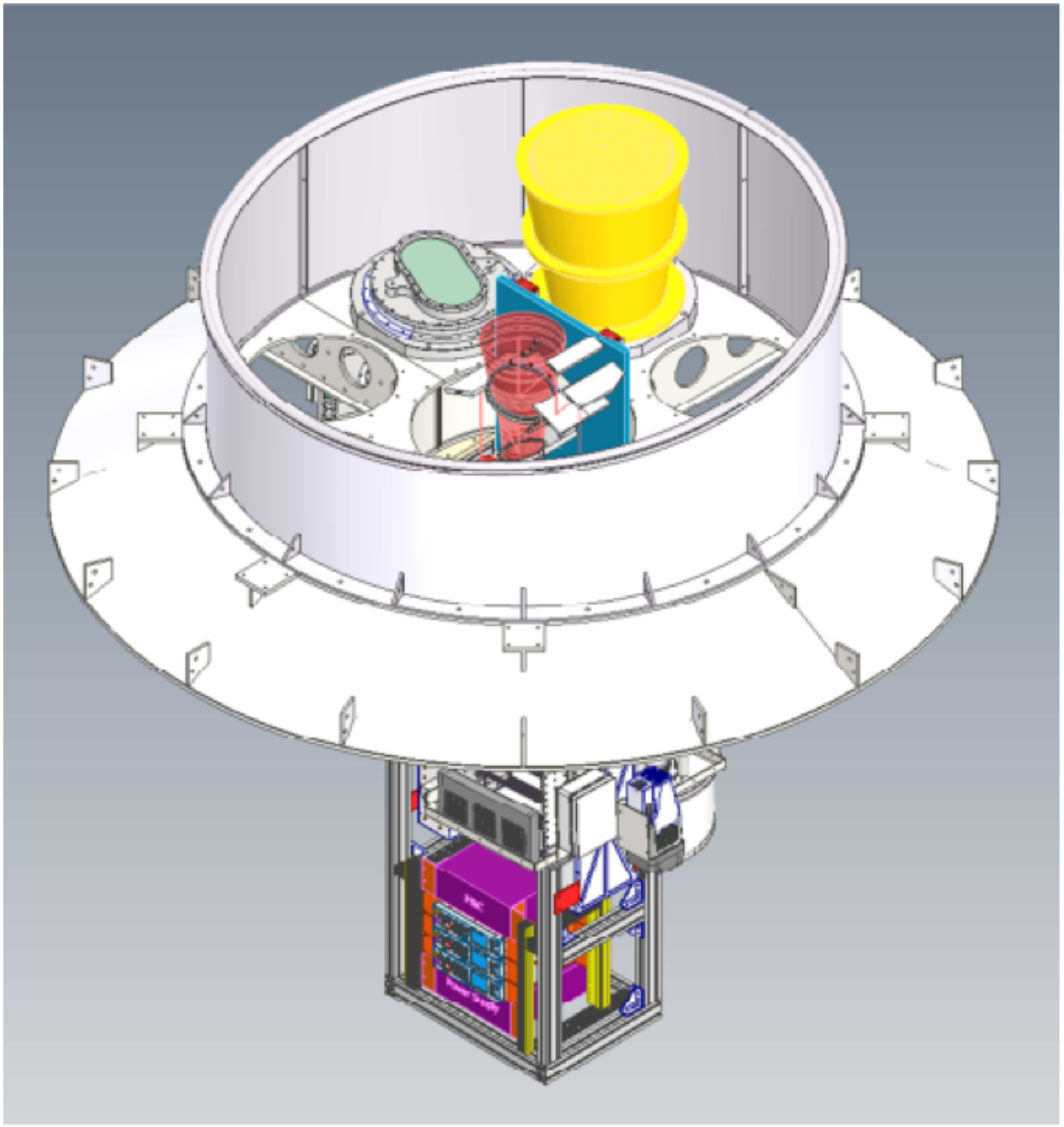


Figure 3.1 Top view of the secondary focus receivers assembling at the radio telescopes: Medicina and Noto

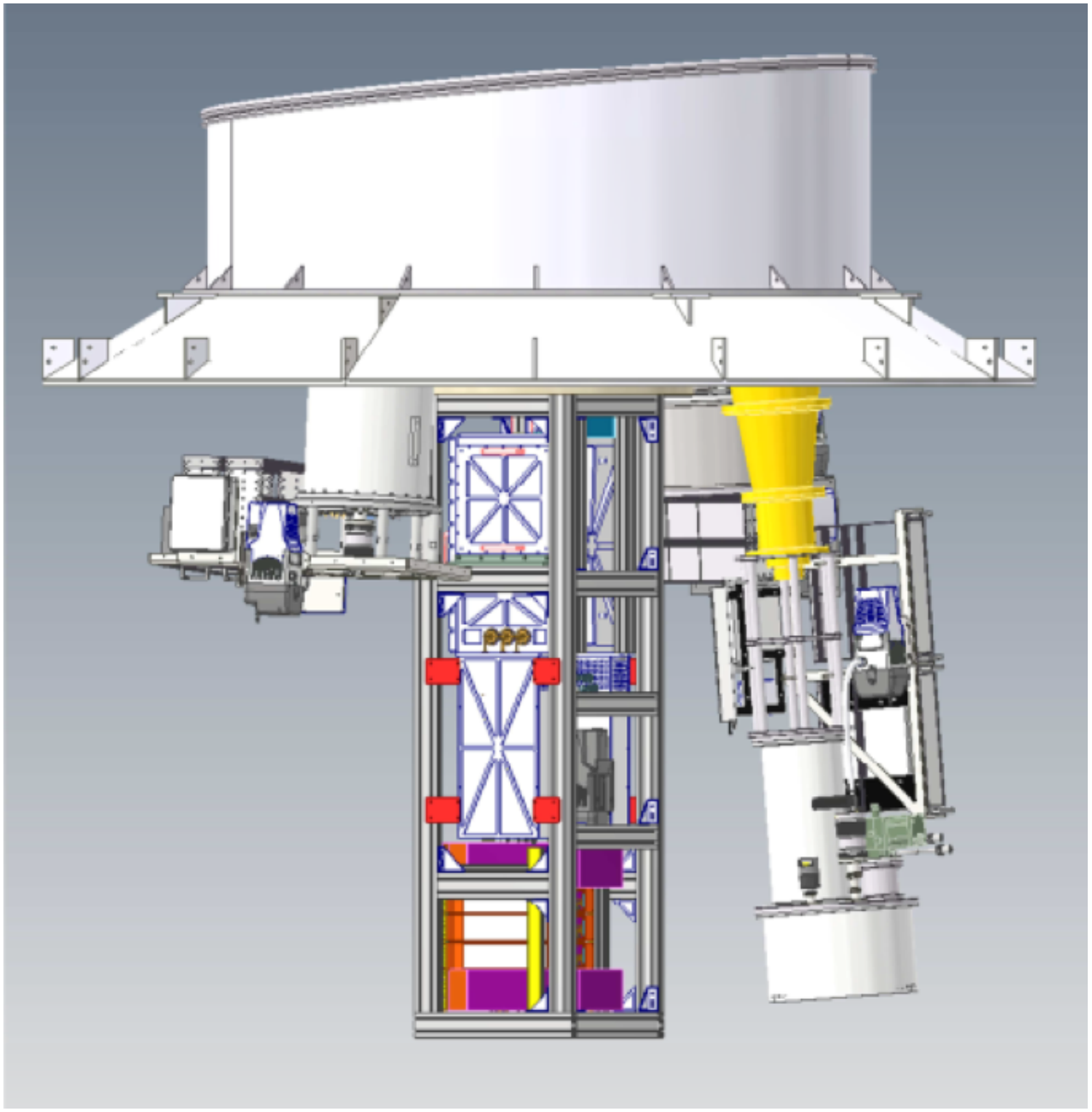


Figure 3.2 Lateral view of the secondary focus receivers assembling at the radio telescopes

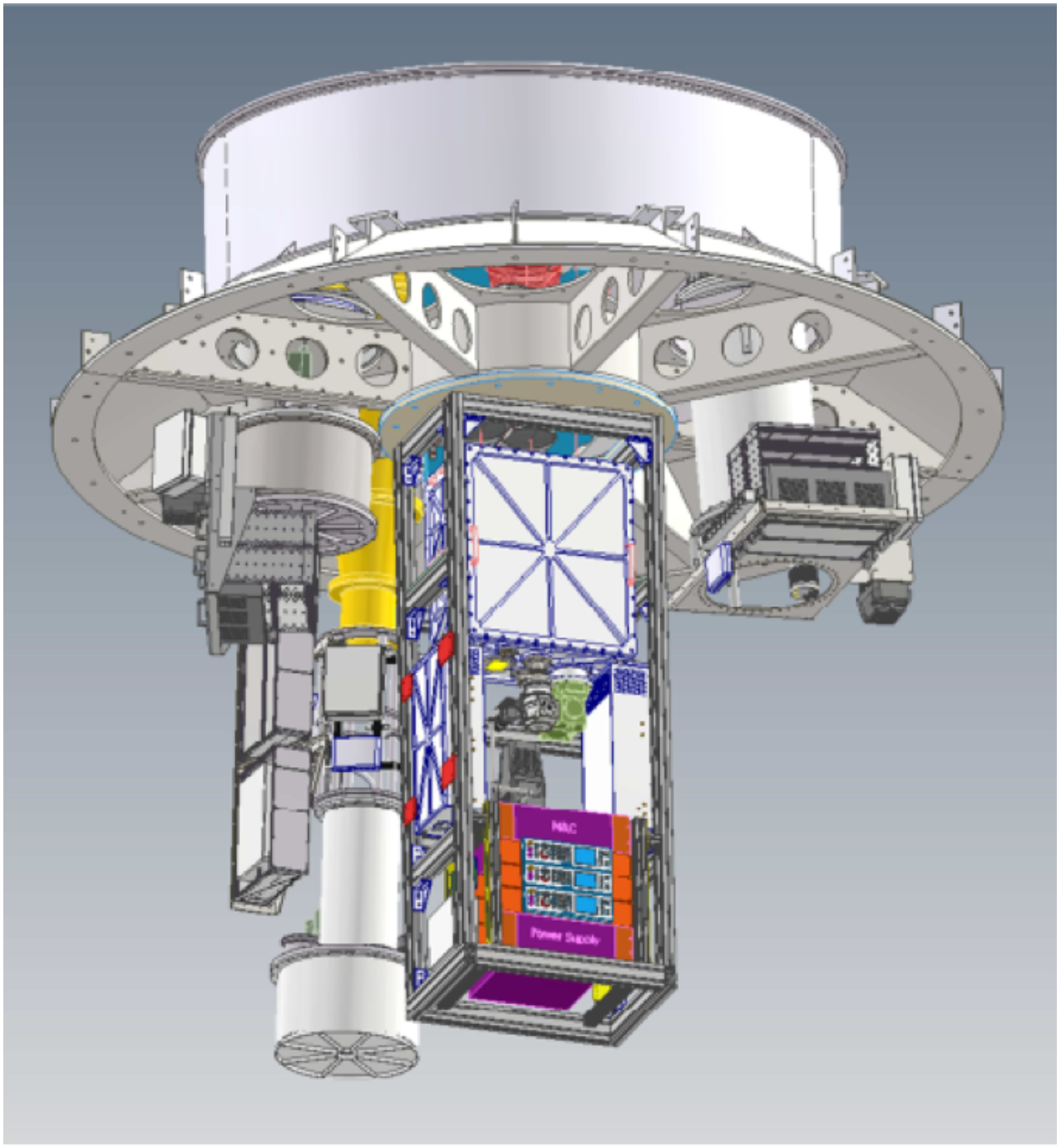


Figure 3.3 Bottom view of the secondary focus receivers assembling at the radio telescopes

# 4. BROADBAND RECEIVER DESCRIPTION AND DEVELOPMENT REQUIREMENTS

## 4.1 Description and functionality of the supply

The receivers will be installed in the secondary focus of the 32-metre antennas of Medicina and Noto. Each receiver includes three circuital sections: 1) the first section is analogue and includes a feed horn followed by one coupler for the injection of a noise mark of known value in the receiver chains. Two circular polarisations will be obtained starting from the linear ones by using a polariser or a 90° hybrid device; 2) a state-of-the-art cryogenic low noise amplifier; 3) appropriate filtering and amplification at room temperature and frequency downconversion into two bands 0.1-2.5 GHz for each polarisation.

Section 1 will be inserted in a common cryogenic system for cooling the components at the physical temperature of 15-20 K. The cooling will be obtained by equipping the system with a vacuum pump and a two-stage cold head based on liquid helium.

A proposed block diagram of the receiving chain is shown in Figure 4.1.

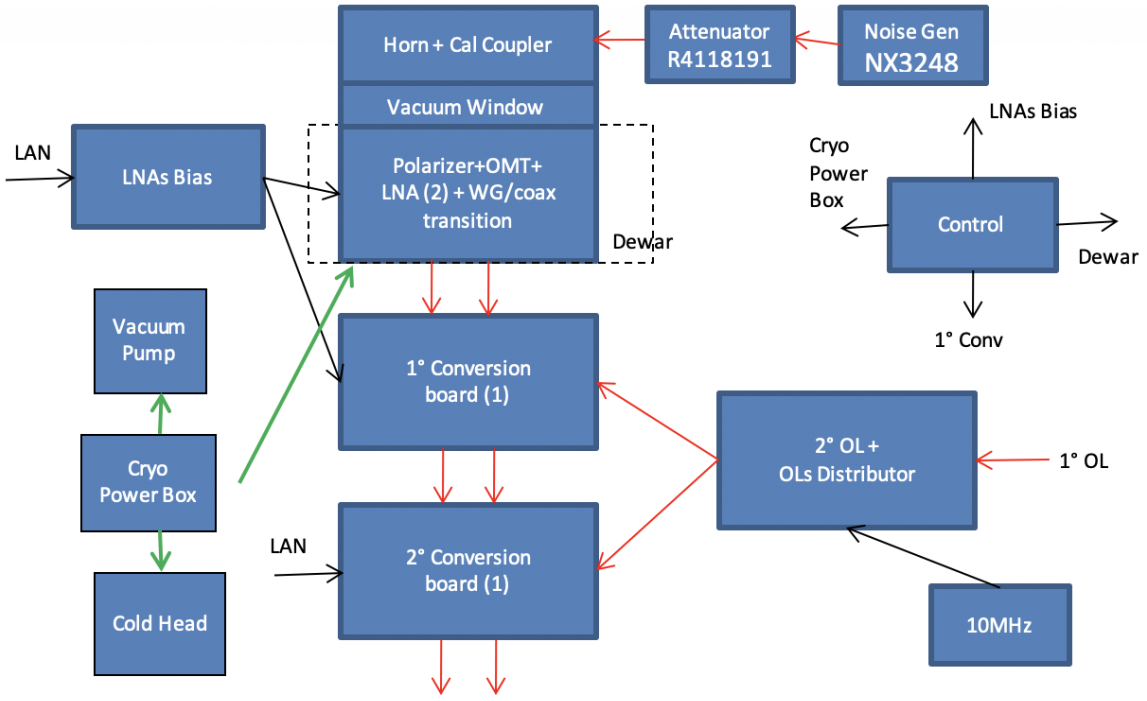



Figure 4.1 A possible block diagram of the broadband receiver

In order for the broadband receiver to be smoothly integrated in the receiving system of the antennas and so avoiding to rewrite the control and monitoring software, the blocks labelled

as 'Control', 'LNA bias', 'Cryo Power Box' will be procured by INAF: the following figure 4.2 shows the units taking care of the job.

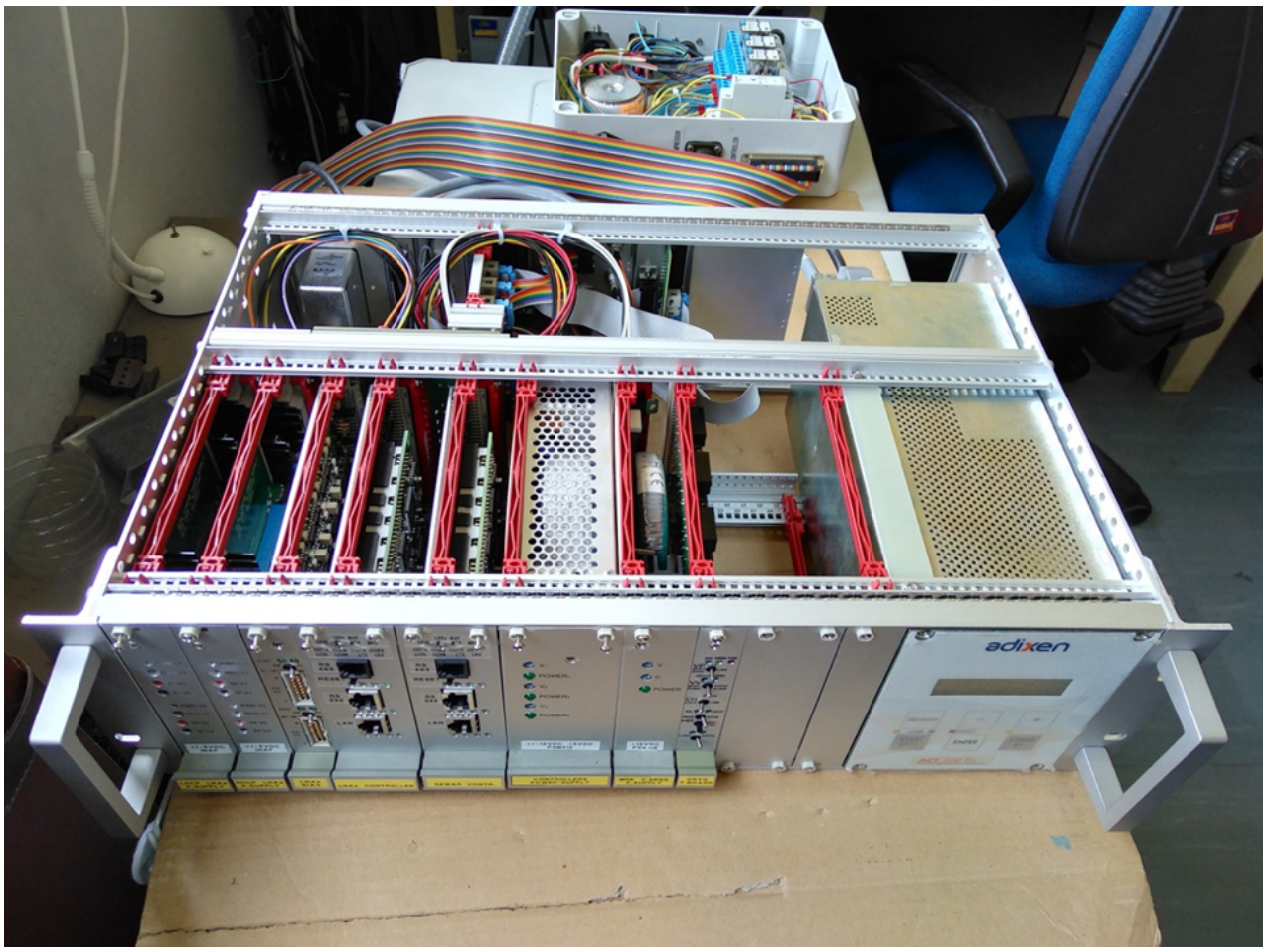



Figure 4.2 M&C unit front panel and Cryo Power Box

## 4.2 Minimum Functional Requirements

The bidder must supply original and new products that correspond to the listed requests in the following articles.

## 4.3 Minimum Technical Requirements

The supply consists of two receivers, each one contained in a box operating at the physical temperature of about 20 K which must have the minimum technical requirements reported in Tables 4.1, 4.2, and 4.3.

Table 4.1 Radio Frequency performance

| *Component* | *Parameter* | *Value* |
|---|---|---|
| Overall performance (1/2) | Frequency range (GHz) | 4.2-9.0 |
| | Instantaneous bandwidth (GHz) | 4.8 |
| | Output polarization | LCP and RCP |
| | Antenna illumination efficiency | Frequency independent |
| Noise calibration | Noise source typology | Commercial component |
| | Switching frequency | ≥ 80 Hz |
| | Coupling level | ON: about 5% of the system temperature |
| Overall performance (2/2) | Receiver noise temperature (K) | <≈ 15 (sky and spillover not included) |
| | Receiver gain (dB) | 70 |
| | Receiver gain flatness (dB) | ±2 or better |
| | Input return loss (dB) | < -20 |
| | Output return loss (dB) | < -20 |
| | Robustness at RFI | take particular care to IP3, P1dB* |
| | Output connectors | SMA-f (for the IF and LO signals) |
| | Crosspolarisation levels (whole receiving system) | out of axis ≤ -30dB on axis ≤ -30dB |
| IF output | Frequency bands | two bands 0.1-2.5 GHz for each polarisation. |
| *) the best proposed value will be rewarded in the tender | | |

Table 4.2 Vacuum and cryogenics performance

| *Parameter* | *Value* |
|---|---|
| Vacuum pump | Commercial system: primary pump Scroll IDP3 Varian + a turbo molecular pump Agilent Twist Torr 74FS. |
| Vacuum level (mbar) | $10^{-6}$-$10^{-7}$ |
| Cold head | Commercial component remotely controllable: CTI350 |
| Compressor | Not requested as already available at the radio telescope |
| Temperature at the two stages | 1st stage : ≤ 70 K typical<br>2nd stage : ≤ 20 K typical |
| Temperature sensors | 4 commercial components distributed in different sections of the dewar: Lakeshore DT470 or DT670. |
| Monitoring and control | INAF will provide one digital unit (3U x 19") to be installed in the receiver for cryo, vacuum, LNA bias, cal switching.<br>The supplier will be in charge to connect the temperature and vacuum sensors to the INAF unit.<br>The ON/OFF of the pump and of the cold head will be controlled by the INAF unit. |

Table 4.3 Physical, environmental and power parameters

| | *Parameter* | *Value* |
|---|---|---|
| **Anchoring system to the secondary focus structure** | Mechanical interface | The receivers shall include flanges for connection to a lateral hole of the secondary focus structure |
| | Mechanical drawing | Annex A |
| **Physical (receiver box)** | Max diameter (mm) | Annex A |
| | Height (mm) | Annex A |
| | Weight (kg) | <= 250 |
| **Environmental** | Ambient temperature (Celsius) | Air-conditioned room, ±2 |
| **Primary power** | Voltage (V) | 230 |
| **Environmental** | Frequency (Hz) | 50 |
| **Primary power** | Consumption (W) | ≤500<br>(excluding the power consumption of the compressor) |

INAF will provide to the supplier for the integration of the receiver the following components:

- One rack 3U x 19'' containing the electronics for the bias and control of the LNA plus a digital board for monitoring and control of vacuum and temperature.

The following mechanical/electrical interfaces between the receiver and the INAF radio telescope infrastructures will be available at the sites:

- two helium flexible tubes to be connected to the cold head;
- a 230 Volt power line to be connected to the receiver;
- one LAN cable to be connected to the Ethernet board of the receiver;

### 4.3.1 Product technical features

The receiver must be shipped together with a documentation set which will include (at least):

- Performance report;
- Detailed set of mechanical drawings and electrical schemes;
- Detailed assembly procedure;
- A maintenance manual that shall be followed in order to allow the buyer to guarantee the optimal performance of the receiver

### 4.3.2 Technical features of accessory services

No ancillary services must be provided.

### 4.3.3 Certificates of product originality

For each receiver a technical report must be provided with detailed information both on the individual performances of the main components and on the overall performance of the entire receiver. Measurements will be made at the operating physical temperature of each component. In the case of commercial components, the technical documentation produced by the external supplier will be valid, while for components developed by the contractor the documentation must be produced by the contractor himself. The minimum set of electrical performances to be included in the technical report consists of the quantities shown in Tables 4.1, 4.2, and 4.3. The results must be provided both as graphs in electronic format using text files (.pdf, .doc) and data in tabular form.

## 5. MINIMUM PERFORMANCE REQUIREMENTS

### 5.1 Commercial guarantee - Duration and extension.

Not less than 12 (twelve) months. A longer duration will be considered a reward.

### 5.2 Lead / Delivery Time.

The supply must be delivered within 15 (fifteen) months from the date of transmission of the purchase / loyalty order on the e-procurement platform U-BUY. A shorter delivery time will be considered a reward.

### 5.3 After-sales technical assistance to be provided.

1) *times for replacement of defective products / spare parts*. The defective component must be replaced within 60 (sixty) solar days from the notification.
2) *mode that will be used to notify the malfunction*. The contracting authority will communicate the malfunction to the contractor using the certified e-mail address or corporate e-mail in the case of a foreign contractor without an operational headquarters in Italy.
3) *charges for replacement of spare / malfunctioning parts*. During the warranty period the replacement of the non-functioning product will be borne by the supplier both for the collection of the defective part and for the delivery of the replacement part. The replacement operation in the receiver will be conducted by the contracting authority remotely assisted by the contractor.

## 6. SUPPLY CONDITIONS

### 6.1 Items / costs included in the price.

With the price requested by the economic operator at the time of the economic offer, it is intended as fully compensated and included, without involving additional costs for the contracting authority:

- the supply of the product

- the charges foreseen by INCOTERM DAP for packaging, shipping, delivery (including insurance coverage).
- the costs incurred by the contractor for the replacement of the products found to be defective during the commercial warranty period and possibly, during the additional period guaranteed by the economic operator during the offer.

6.2 Items / costs not included in the price.

The contracting authority will only pay:

- Import customs duties and expenses (from abroad to Italy)
- VAT

6.3 Terms of payment.

Payments will be made in accordance with the progress status defined in the below reported schedule: a progress meeting will be held for each milestone, and the contractor may issue the invoice only when the technical and administrative contract managers will issue their formal authorization.

6.4 Transport insurance policy.

It must be paid by the contractor.

6.5 Packaging method.

Care and responsibility of the contractor to choose quality external materials, rigid and in good condition. The box must be new and must not have been used beforehand. Choose the size of the box based on the final size of the product you are sending: semi-empty packages can be easily bent and damaged, those that are too full can break. The handling instructions (such as brittle and / or similar) do not guarantee the safety of the goods by the transport company. Take care of the internal packaging, which provides protection for the goods during transport and during delivery. A good internal packaging must be able to protect the product from shocks and vibrations. Seal all possible openings, using quality resistive products. Insert

on the outer edges of the box plastic or cardboard protectors that distribute the pressure evenly and avoid damage to the outer casing.

### 6.6 Progress meetings.

The contracting authority plans to have at least five face-to-face and one online progress meetings. The first and the final progress meetings are expected to be held in one of the INAF Observatories involved, while the second, third, and fourth face-to-face progress meetings will take place at the contractor premises. An online meeting will take place between the first and second face-to-face meetings. A draft schedule of the progress meetings is reported in the GANTT chart in the subsequent Article 9.

## 7. DELIVERY

### 7.1 Location and delivery times.

The receiver must be delivered to the following location:

- One unit to INAF Radio Telescopio di Medicina (Bologna)
- One unit to INAF Radio Telescopio di Noto (Siracusa).

Detailed information will be provided at the time of shipping

### 7.2 Shipping methods.

In accordance with the terms INCOTERMS DAP - Delivered at Place. In the DAP mode the supplier covers the costs and risks of the shipment up to the delivery location indicated above. Shock and tilt sensors are mandatory.

### 7.3 Method of unloading goods.

On the ground floor, by the courier appointed by the contractor.

### 7.4 Presence of specialised contractor personnel.

For the delivery phase, the presence of specialised contractor personnel is optional and not mandatory.

## 8. ACCEPTANCE PROCEDURES

8.1 FAT – Factory Acceptance Testing. Testing in progress at the supplier's headquarters. Modes and times. Required documentation.

The contracting authority will participate in the FAT at the contractor's premises and will verify with its own personnel the compliance of the delivered products with the technical and functional requirements indicated by the contractor at the time of the offer, comparing them with the data sheets associated with each individual product. Documentation will consist of product datasheets with graphs and number tables, as previously requested and specified.

On the other hand, the contracting authority plans to have at least two inspections at the contractor's premises according to the payment milestones.

8.2 OAT – Onsite Acceptance Testing. Test on delivery at the headquarters of the customer. Modes and times. Presence of specialised supplier personnel during the OAT phase. Required documentation.

The contracting authority will verify with its own personnel the compliance of the delivered products with the technical and functional requirements indicated by the contractor at the time of the offer, comparing them with the data sheets associated with each individual product.
OAT will be completed within 20 consecutive calendar days from the delivery date of the product. The presence of supplier personnel during OAT is optional.

At the end of OAT a certificate of regular execution (test certificate) will be issued signed by the Execution Director, if appointed, alternatively by the Responsible for the procedure.

## 9. TIMELINE, MILESTONES

The contracting authority has identified the following six work packages for the execution of the activities and four phases:

Phase 1. WP1 – Design and Final project

WP2 – Overall performance analysis.

Phase 2. WP3 – Purchase and development of devices.

Phase 3. WP4 – Integration

WP5 – Factory characterization and tests.

Phase 4. WP6 – Shipment and On Site Acceptance testing.

The timeline distribution for the work packages together with the planned progress meetings and the payment milestones with the deliverables are described in Figure 9.1 and in Table 9.1.

| Activity/Period | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 | M13 | M14 | M15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 – Design and Final project | | | | | | | | | | | | | | | |
| WP2 – Overall performance analysis | | PDR | FDR | | | | | | | | | | | | |
| WP3 – Purchase and development of devices | | | | | | | | | | IRR | | | | | |
| WP4 – Integration | | | | | | | | | | | | | | | |
| WP5 – FAT | | | | | | | | | | | | | | FAT | |
| WP6 – Shipment and OAT | | | | | | | | | | | | | | | |
| Deliverables | | YES | YES | | | | | | | YES | | | YES | YES | |
| Progress meeting | f2f inaf | on-line | f2f C | | | | | | | f2f C | | | | f2f C | f2f inaf |
| Payment milestones (Keuro) | 122 | | | | | | | | | 122 | | | | 305 | 61 |

Figure 9.1 GANTT chart of the receiver construction, with payment milestones and progress meetings; C means Contractor site

Table 9.1 Workpackages and payment

| Month | Milestone | Deliverable | Amount (€) |
|---|---|---|---|
| 1 | Kick-off | - | 122.000,00 |
| 3 | Conclusion of WP2 | Electrical schemes; Mechanical Drawings; Bill of materials; Technical report with the expected performance of the receiver | |
| 10 | Conclusion of WP3 | Technical report with measurements of each single components | 122.000,00 |
| 13 | Conclusion of WP4 | Pictures of the receiver integration and preliminary test report of the sub-assemblies | |
| 14 | Conclusion of WP5 | Final documents | 305.000,00 |
| 15 | Conclusion of WP6 | Receivers delivered at INAF stations | 61.000,00 |

## 10. OBLIGATIONS OF THE SUPPLIER

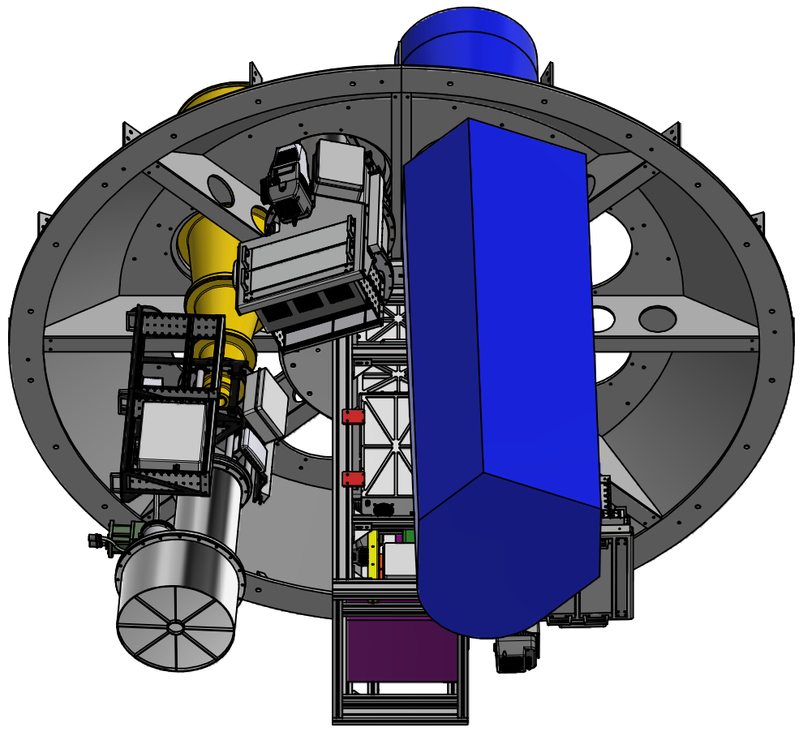
### 10.1 Appointment and duties of the Contract Manager.

The contractor will have to indicate its own Contract Manager with whom the contracting authority will be able to interact until the issue of the certificate of conformity (test certificate) of the supply.

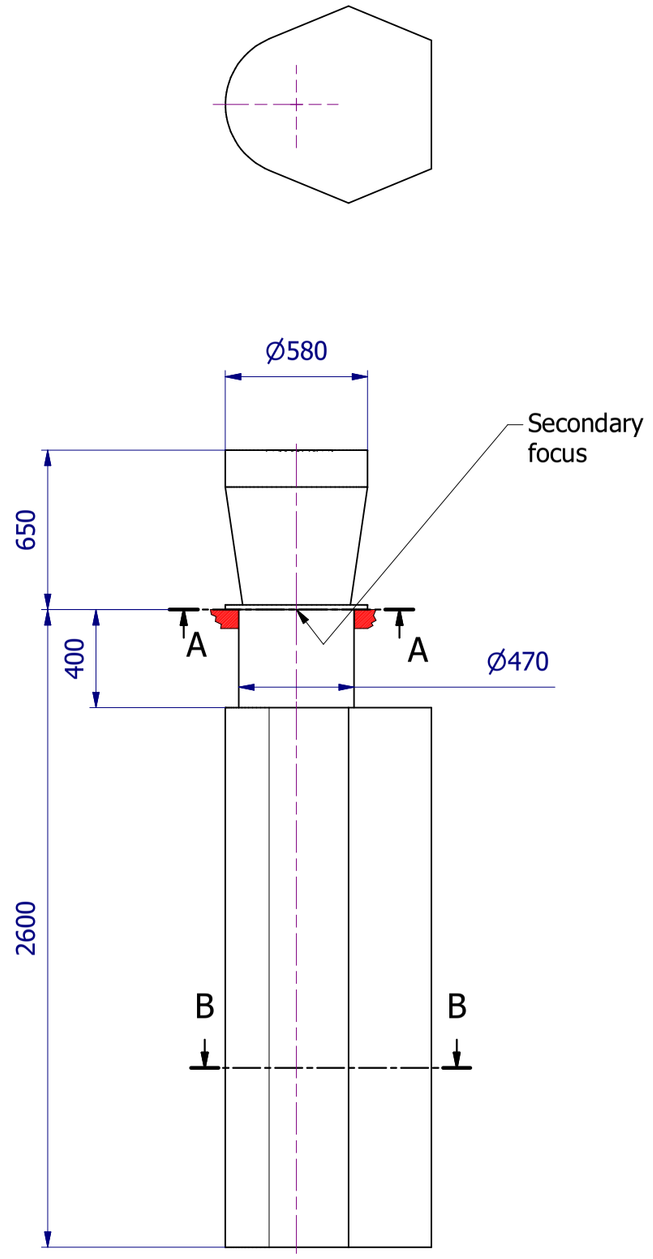
### 10.2 Appointment and duties of the technical manager of the supply.

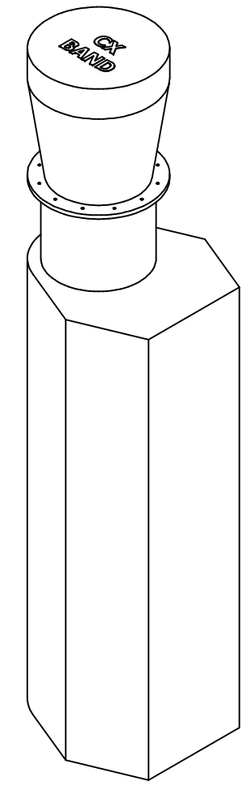
The contractor will have to indicate its own technical manager of the supply with which the contracting authority will be able to interact until the issuing phase of the certificate of conformity of the supply. The figures of Contract Manager and Technical Manager of the supply may coincide.

End of the document

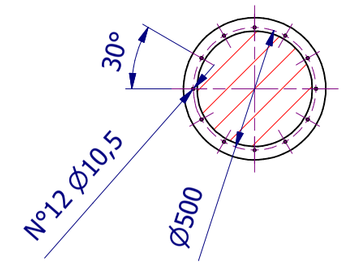


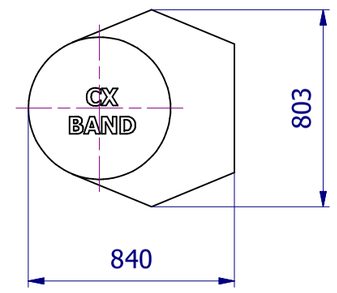
Available volume



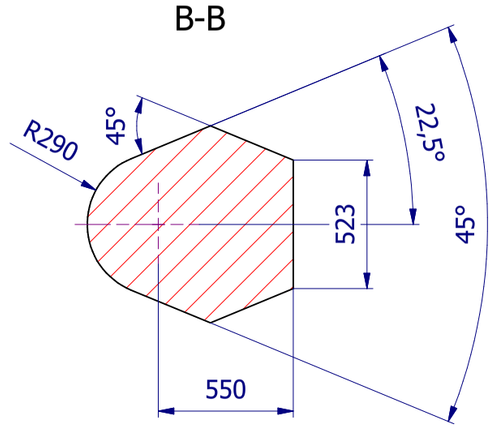




A-A
(fixing holes)




B-B




**ANNEX A**

| | | | | |
|---|---|---|---|---|
| Codice Disegno<br>07112023 | | | INAF ISTITUTO NAZIONALE DI ASTROFISICA<br>**ISTITUTO DI RADIOASTRONOMIA**<br>Radiotelescopio Medicina<br>Via Fiorentina 3508/B - 40060 Villafontana (BO)<br>Tel. 051 6965811 Fax 051 6965810 | |
| Sostituisce dis. N. | | | | |
| Materiale | | | Denominazione<br>Grueff Radio Telescope - 32m<br>Vertex<br>Ric. CX | Disegnatore<br>J. Roda |
| Trat. Term. | | | | Controll.<br>J. Roda |
| Scala Dis. | Scala Plt. | Quantita' | Dimensioni senza tolleranza Foro=H11 Albero=d11<br>Spigoli non quot.Sm 1x45° Raccordi non quot. R=0.5 | Data<br>07/11/2023 |