Document ID	**PON-OR4-01-SOW**
Revision	**01**
Document classification	*Statement of work*
Tender name	***Supply of three compact and simultaneous three-band microwave receiving systems for the three Italian radio telescopes.***
Type of tender	***Open procedure*** pursuant to art. 60 of Legislative Decree April 18, 2016, n. 50, and s.m.i.
Decision Act	**Determinazione n. 188 del 14 agosto 2019**
Tender value	**€ 2.400.000,00**
Funding source	**PON "Ricerca e Innovazione 2014-2020" - Avviso D.D. 424 del 28/02/2018** PON FSE FESR / PIR01_00010 "SRT_HighFreq - *Potenziamento del Sardinia Radio Telescope per lo studio dell'Universo alle alte frequenze"*
CUP	C87E19000000007
CIG	8014329183

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Art. 1 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.

Art. 2 Subject of the contract

The bid is finalized to the acquisition of ***3 (three) cryogenics radio astronomical tri-band receivers able to simultaneously operate at the frequencies of 22, 43 and 86 GHz***. The three tri-band receivers will be installed in the INAF radio telescopes located in San Basilio, Medicina and Noto. This set of receivers is required to satisfy the new scientifical requirements to allow interferometer simultaneous observations at high frequencies. The simultaneous multi-frequency observations are essential to study variable (e.g. active galactic nuclei, maser sources) and transient (e.g. supernova remnants, gamma-ray bursts, micro quasar) objects. Moreover, the *simultaneity* simplifies calibration both in single-dish mode and, most of all, in VLBI mode (in co-operation with other antennas). Indeed, removing phase fluctuations due to the presence of water vapour in the troposphere is more difficult the higher is the frequency. With the proposed receiver, it will be possible to transfer the phase calibration from the lower frequency (22 GHz) up to the highest frequency (86 GHz), where is typically quite difficult. Phase calibration is of primary importance to avoid the deterioration of the sensitivity and imaging capability in interferometric observations.

The optical parameters and the mechanical views of the INAF radio telescopes (Medicina and Noto are identical radio telescopes) are reported in Table 1and Figure 1.

In the framework of an agreement between INAF and the Italian Space Agency (ASI) it is foreseen that the SRT will be equipped with transmitters operating in X-band and Ka-band for spacecraft communication (Sardinia Deep Space Antenna). Therefore, all receivers and equipment to be installed near the SRT transmitters beam propagation path, including the tri-band receiver, might potentially be exposed to electromagnetic fields of significant intensity when the telescope is operated in transmission mode. At the moment, it is not possible to foresee the exact power levels and electromagnetic environment at which the receiver will be exposed. For this reason, if possible without performance degradation and delay on the delivery time, it is requested that the tri-band receiver be designed for maximum protection from strong X-band and Ka-band signals in all its sensitive parts. In all cases, whether proper shields are applied or not, it is requested that the supplier provides the maximum tolerability threshold of the various receiver components to allow INAF and ASI to prepare appropriate countermeasures to preserve their integrity and performance.

Parameter	**MEDICINA/NOTO**	**SRT**
Optics	Cassegrain	Shaped Gregorian
Subreflector geometry	Hyperbolic	Numerical[1]
Prime mirror diameter, D (m)	32.004	64.008
Subreflector diameter, d (m)	3.2004	7.9060
Focal length, f (m)	10.259	21.0236
Prime focus focal ratio, f/D	0.32	0.3285
Secondary focus focal ratio, f2/D	3.03	2.342
Distance from Prime to Gregorian foci (m)	10.0304	17.4676
Subreflector eccentricity, e	1.2357	-
Magnification, M (m)	9.48	7.13
Prime focus to subreflector vertex (m)	0.9566	2.8524
Secondary focus to subreflector vertex (m)	9.0738	20.3200
Secondary focus to Prime mirror vertex (m)	0.2286	3.5560
Distance from Prime mirror vertex to aperture plane (m)	6.2697/6.2995	12.1415
Distance from Prime focus to aperture plane (m)	3.9893/3.9595	8.8821
Prime mirror half-angle (degree)	75.9	74
Subreflector half-angle (degree)	9.43	12

Table 1- Optical parameters for the Italian antennas

[1] The two shaped mirrors have revolution symmetry around the optical axis. The numerical files of the two shaped profiles are available on request.

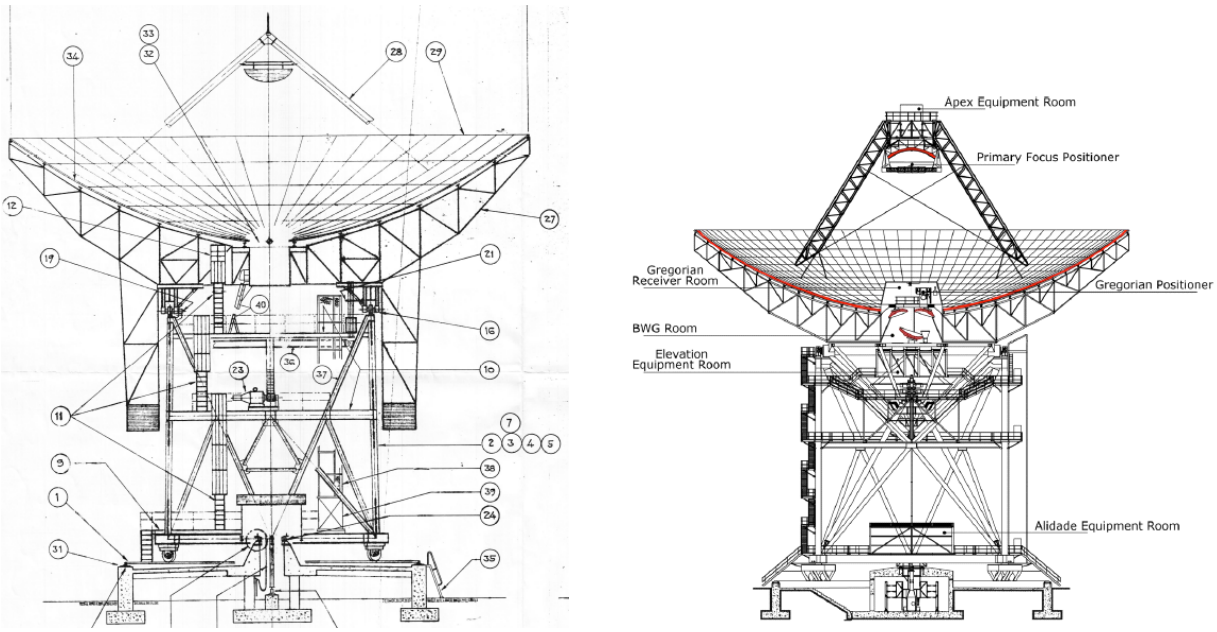

Figure 1 – Mechanical structure (side view) of the INAF radio telescopes: Medicina and Noto (left), SRT (right). For Medicina and Noto, the tri-band receiver will be installed in the room identified by label 32, while for SRT in the Gregorian positioner

Description and functionality of the supply. The three receivers will be installed in the secondary focus of the 64-meter antenna (Sardinia Radio Telescope) and of the two 32-meter antennas of Medicina and Noto. Each receiver will consist of two main sections: **i)** a quasi-optic frequency selection system able to split and refocus the incident beam through the use of dichroic filters and mirrors; **ii)** three distinct front-ends each operating in one of the three frequency bands of the receiver (18-26, 34-50 and 80-116 GHz), with very low noise, double-polarization and based on a super-heterodyne scheme capable of converting the sky frequency in the band (2-18 GHz) processed by the external modules. The three front-ends will consist of a chain of microwave components composed by a feed-system (circular horn antenna, polarizer and ortho-mode transducer) and a pre-amplifier for each polarization. The supply must include the following sub-systems: local oscillator for the down-conversion mixers and calibration noise. The three front-ends will be inserted in a common cryogenic system for cooling at the physical temperature of about 15 k the microwave components. The cooling will be obtained by equipping the system with a vacuum pump and a two-stage cold head based on liquid helium.

By way of example only, a schematic diagram of the receiving chains is shown in Figure 2, while Figure 3 illustrates the receiver installed inside the focal cabins of Medicina and Noto (left side) and SRT (right side).

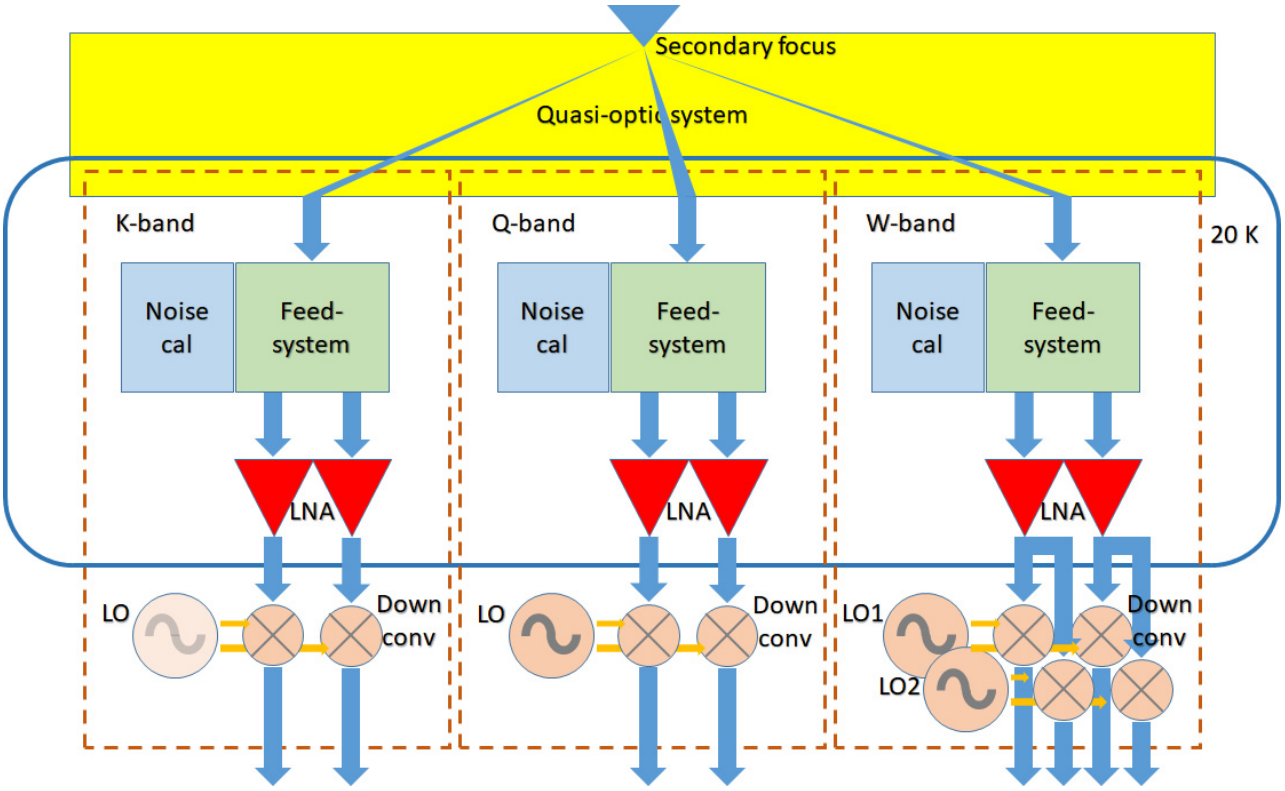

Figure 2 - Conceptual electrical scheme of the receiver

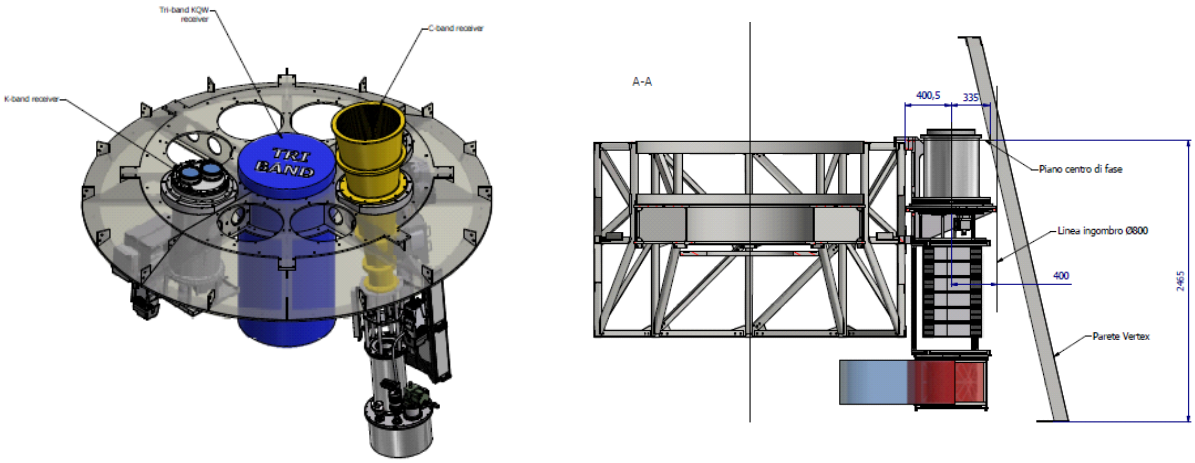

Figure 3 - Tri-band receiver installed in the secondary focus mechanical structures of the INAF radio telescopes: Medicina and Noto (left), SRT (right)

Art. 3 Minimum Functional Requirements

The bidder must supply original and new products that correspond to the below listed requests.

Art. 4 Minimum Technical Requirements

The supply consists of 3 (three) receivers operating at the physical temperature of about 15 K which must have the minimum technical requirements reported in Table 2, 3 and 4.

Table 2 - Radio Frequency performance

Component	Parameter	K-band	Q-band	W-band
Overall performance (1/2)	Frequency range (GHz)	18-26	34-50	80-116
	Instantaneous bandwidth (GHz)	8	16	2 x 16
	Frequency coverage	Simultaneous observation capability in the three bands		
Quasi-optic system	Insertion loss (dB)	0.4	0.4	0.2
	Cross-pol (dB)	< -25	< -25	< -25
	Illumination Taper (dB)	-9 @ 12° for SRT -12 @ 9.43° for Medicina/Noto	-9 @ 12° for SRT -12 @ 9.43° for Medicina/Noto	-9 @ 12° for SRT -12 @ 9.43° for Medicina/Noto
	Illumination efficiency	Frequency independent		
Feed-system	Output Polarization	Left and Right Circular	Left and Right Circular	Left and Right Circular
	Return loss (dB)	< -20	< -20	< -20
	Cross-pol (dB)	< -30	< -30	< -30
	Polarizer axial ratio (dB)	< 0.5	< 0.5	< 0.5
Noise calibration	Noise source typology	Commercial component	Commercial component	Commercial component
	Injection mode	Through waveguide after the OMT component	Through waveguide after the OMT component	Through waveguide after the OMT component
	Switching frequency	> 100 Hz	> 100 Hz	> 100 Hz
	Coupling level	ON: around 10% of the system temperature	ON: around 10% of the system temperature	ON: around 10% of the system temperature
Low Noise Amplifier	Typology	Commercial waveguide component	Commercial waveguide component	Commercial waveguide component
	Gain (dB)	35	34	24
	Gain flatness (dB)	± 2	± 2	± 2

	DC power	Three wires single supply	Three wires single supply	Three wires single supply
	Bias and monitor	INAF will provide the electronics to power supply the LNA	INAF will provide the electronics to power supply the LNA	INAF will provide the electronics to power supply the LNA
Frequency down-conversion	Local oscillator generators	Commercial synthesizer (provided by INAF)	Commercial synthesizer or YIG/PLL system	Two commercial synthesizers or two YIG/PLL systems
	Frequency of the local oscillators	Not applicable	Tunable	Tunable
	Control and monitor	Not applicable	The LO generator must be remotely controlled and monitored	The LO generator must be remotely controlled and monitored
	Phase noise (dBc/Hz)	Not applicable	As appropriate for the VLBI application	As appropriate for the VLBI application
	Amplitude temperature stability (dB/°C)	Not applicable	< 0.05	< 0.05
	Reference signal for local oscillator	Not applicable	10 MHz (provided by the hydrogen maser available at the radio telescope)	10 MHz (provided by the hydrogen maser available at the radio telescope)
	Mixer	Commercial component	Commercial component	Commercial component
	Output frequency range (GHz)	6-14	2-18	Two frequency channels: 2-18 each
	Image rejection (dB)	> 25	> 25	> 25
	Intermodulation products and harmonics (dB)	-20 wrt the minimum output power	-20 wrt the minimum output power	-20 wrt the minimum output power
Overall performance (2/2)	Receiver noise temperature (K)	≤ 40	≤ 50	≤ 70
	Receiver gain (dB)	35	35	35
	Receiver gain flatness (dB)	± 3	± 3	± 3
	Output power levels (dBm) over the instantaneous bandwidth	From -50 to -10	From -50 to -10	From -50 to -10
	Output return loss (dB)	< -15	< -15	< -15
	Output 1 dB compression point (dBm)	> 0	> 0	> 0

	Output third-order intercept point (dBm)	> 10	> 10	> 10
	Output connector	2 x SMA-f (one for each singular polarization)	2 x SMA-f (one for each singular polarization)	4 x SMA-f (one for each singular polarization and one for each frequency channel)

Table 3 - Vacuum and cryogenics performance

Parameter	**Value**
Vacuum pump	Commercial system
Vacuum level (mbar)	10^{-6}-10^{-7}
Cold head	Commercial component remotely controllable
Compressor	Not requested as already available at the radio telescope
Temperature at the two stages	1st stage : < 70 K typical 2nd stage : < 20 K typical
Temperature sensors	3-4 commercial components distributed in different sections of the dewar
Monitoring and control	INAF will provide one digital board to be installed in the receiver. The supplier will be in charge to connect the temperature and vacuum sensors to the INAF board. The ON/OFF of the pump and of the cold head will be controlled by the INAF board.

Table 4 - Physical, environmental and power parameters

	Parameter	**MEDICINA/NOTO**	**SRT**
Anchoring system to the secondary focus structure	Mechanical interface	The receivers shall include a circular flange to be connected to the central holes of the secondary focus structures	The receiver shall include a commercial aluminum profile system based on the INAF design
	Mechanical drawing	Annex A	Annex B
Physical (receiver plus anchoring system)	Diameter of the top part of the receiver (dewar) (mm)	< 760	< 600
	Diameter of the bottom part of the receiver (mm)	< 800	< 600
	Focus position within the space assigned to the receiver (transversal view)	Fixed at the center of the circle	See dashed-dotted curve in Appendix B
	Height (mm)	≤ 2600	≤ 2450

	Weight (kg)	< 250
Environmental	Ambient temperature (Celsius)	Air-conditioned room, ±2
Primary power	Voltage (V)	230
	Frequency (Hz)	50, European standard
	Consumption (W)	≤ 500

INAF will provide to the supplier for the integration in 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;
- eight coaxial cables (SMA-m) to be connected to the receiver outputs;
- one coaxial cable (SMA-m) coming from the K-band local oscillator generator to be connected to the LO receiver input;
- three coaxial cables SMA-m coming from the H-maser to be connected to the reference input of the LO generators;
- one LAN cable to be connected to the Ethernet board of the receiver;
- cables to be connected to the LO generators for its control;
- the receiver cabins of each radio telescope for the installation of the receivers.

- **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;***
  - ***A maintenance manual that shall be followed in order to allow the buyer to guarantee the optimal performance of the receiver***
- **Technical features of accessory services.** No ancillary services must be provided.
- **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 2, 3 and 4.

Measurement must include, as a minimum, the three pass bands of each receiver. The results must be provided both as graphs in electronic format using text files (.pdf, .doc) and data in tabular form.

Art. 5 Minimum Performance Requirements

- **Commercial guarantee - Duration and extension.** Not less than 12 (twelve) months. A longer duration will be considered a reward.

- **Lead / Delivery Time.** The supply must be delivered within ***25 (twenty-five) 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.

- **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.

Art. 6 Supply conditions

- **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.

- **Items / costs not included in the price.** The contracting authority will only pay:
  - Import customs duties and expenses (from abroad to Italy)
  - VAT

- **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.

- **Transport insurance policy.** It must be paid by the contractor.
- **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.
- **Progress meetings.** The contracting authority plans to have at least five face-to-face progress meetings. The first two progress meetings and the final one are expected to be held in one of the INAF Observatories involved, while the third and fourth progress meetings will take place at the contractor premises. A draft schedule of the progress meetings is reported in the GANTT chart in the subsequent Article 9.

Art. 7 Delivery

- **Location and delivery times.** The three receivers must be delivered to the following locations:

  - INAF Sardinia Radio Telescope – San Basilio (SU);
  - INAF Radio Telescopio di Medicina (Bologna);
  - INAF Radio Telescopio di Noto (Siracusa).

  Detailed information will be provided at the time of shipping

- **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.

- **Method of unloading goods.** On the ground floor, by the courier appointed by the contractor.

- **Presence of specialized contractor personnel.** For the delivery phase, the presence of specialized contractor personnel ***is required***.

Art. 8 Acceptance procedures

- **FAT – Factory Acceptance Testing. Testing in progress at the supplier's headquarters. Modes and times. Required documentation.** The contracting authority does not plan to carry out FAT. On the other hand, the contracting authority plans to have at least two inspections at the contractor's premises according to the payment milestones.

- **OAT – Onsite Acceptance Testing. Test on delivery at the headquarters of the customer. Modes and times. Presence of specialized 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. *Terms and conditions*: OAT will be completed within 20 consecutive calendar days from the delivery date of the product. *Documentation for OAT*: product datasheet with graphs and number tables, as previously requested and specified. *Supplier personnel*: the presence of supplier personnel during OAT is required. 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.

Art. 9 Timeline, milestones

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

WP1 – Design and Final project

WP2 – Overall performance analysis

WP3 – Purchase and development of devices

WP4 – Integration

WP5 – Factory characterization and tests

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 4 and in Table 5.

Activity / Period (year - bimester or month)	Y1						Y2						Y3
	B1	B2	B3	B4	B5	B6	B1	B2	B3	B4	B5	B6	M1
WP1 - Design and final project													
WP2 - Overall performance analysis													
WP3 - Purchase and development of devices													
WP4 - Integration													
WP5 - Characterization and tests													
WP6 - Shipment / On site final acceptance test													
Progress meetings (f2f)	@ INAF				@ INAF				@ Factory		@ Factory		@INAF
Payment milestones (keuro)	480				620				500		500		300

Figure 4 - GANTT chart of the receiver construction, with payment milestones and progress meetings

Month	Milestone	Deliverable	Amount (€)
1	Kick-off	-	480.000,00
10	Conclusion of WP2	Electrical schemes; Mechanical drawings; Bill of materials; Technical report with the expected performance of the receiver	620.000,00
18	Conclusion of WP3	Technical report with measurements of each single components	500.000,00
22	Conclusion of WP4 and preliminary activity in WP5	Pictures of the receiver integration and preliminary test report of the sub-assemblies	500.000,00
25	Conclusion of WP6	Receivers and final documents	300.000,00

Table 5 - Workpackages and payment

Art. 10 Obligations of the supplier

- **Appointment and duties of the Contract Manager.** The contractor will have to indicate his 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.
- **Appointment and duties of the technical manager of the supply.** The contractor will have to indicate his 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.