Annex 1 – Technical information on the tri-band receivers and on the INAF radio telescopes

Three cryogenics radio astronomical tri-band dual-polarized receivers able to simultaneously operate in the frequency bands 18-26 GHz (K band), 34-50 GHz (Q band) and 80-116 GHz (W band) will be installed in early 2022 in the INAF radio telescopes located in San Basilio (SRT), Medicina and Noto.

This set of receivers is required to satisfy the new scientific 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. 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 band (K band) up to the highest band (W band). Phase calibration is of primary importance to avoid the deterioration of the sensitivity and imaging capability in interferometric observations.

For each band and for each circular polarization, 2-GHz wide IF signals are acquired by the DBBC3 (Digital BaseBand Converter ver. 3). This is essentially composed of an Analog Conditioning Module, an Analog-Digital converter, a Data Processing Unit, a Time and Clock board and a Control Computer providing a large exploitable bandwidth for the EVN wideband VLBI and for the VGOS ultra-wide-band VLBI system.

Detailed technical information on the three Italian Radio Telescopes can be found in Chapter I of the report "Receivers for Radio Astronomy: current status and future developments at the Italian radio telescopes" (ISBN: 978-88-9898-504-3), available at the following link: http://pulsar.oa-cagliari.inaf.it/~pulsar/RX2017/review.html.

Finally, the expected performance of the tri-band receivers in the INAF radio telescopes are reported below:

Sardinia Radio Telescope

	K-band			Q-band			W-band		
Frequency (GHz)	**18**	**22**	**26**	**34**	**42**	**50**	**80**	**98**	**116**
System temperature (kelvin)	85,6	109,3	94,1	100,7	115,9	194,2	175,8	173,8	255,9
(Partial) Aperture efficiency (%)	75,9%	76,3%	76,5%	76,8%	77,3%	76,9%	76,0%	76,5%	76,7%
RMS efficiency (%)	98,7%	98,1%	97,4%	95,5%	93,3%	90,6%	77,7%	68,4%	58,8%
Blockage efficiency from struts (%)	97,6%	97,6%	97,6%	97,6%	97,6%	97,6%	97,6%	97,6%	97,6%
(Total) Aperture efficiency (%)	73,1%	73,1%	72,7%	71,6%	70,3%	68,0%	57,6%	51,1%	44,0%
Antenna gain from (total) aperture efficiency (kelvin/Jy)	0,85	0,85	0,85	0,83	0,82	0,79	0,67	0,60	0,51
Insertion loss of quasi-optics and feed system	0,72	0,72	0,72	0,72	0,72	0,72	0,69	0,69	0,69
Gain correction for opacity (at zenith)	0,93	0,90	0,93	0,94	0,94	0,82	0,82	0,82	0,57
Antenna gain including insertion loss and opacity (kelvin/Jy)	0,58	0,56	0,57	0,57	0,56	0,47	0,38	0,34	0,20
SEFD (Jy)	**148,7**	**195,7**	**164,4**	**176,8**	**207,2**	**412,9**	**461,8**	**514,7**	**1262,3**
Sensitivity (mJy)	**2,4**	**3,1**	**2,6**	**2,8**	**3,3**	**6,5**	**7,3**	**8,1**	**20,0**

Medicina & Noto Radio Telescopes

	K-band			Q-band			W-band		
Frequency (GHz)	**18**	**22**	**26**	**34**	**42**	**50**	**80**	**98**	**116**
System temperature (kelvin)	85,6	109,3	94,1	100,7	115,9	194,2	175,8	173,8	255,9
(Partial) Aperture efficiency (%)	76,9%	77,9%	78,2%	77,1%	77,3%	77,6%	79,1%	78,9%	79,0%
RMS efficiency (%)	98,7%	98,1%	97,4%	95,5%	93,3%	90,6%	77,7%	68,4%	58,8%
Blockage efficiency from struts (%)	94,0%	94,0%	94,0%	94,0%	94,0%	94,0%	94,0%	94,0%	94,0%
(Total) Aperture efficiency (%)	71,3%	71,8%	71,6%	69,2%	67,8%	66,1%	57,8%	50,8%	43,7%
Antenna gain from (total) aperture efficiency (kelvin/Jy)	0,21	0,21	0,21	0,20	0,20	0,19	0,17	0,15	0,13
Insertion loss of quasi-optics and feed system	0,72	0,72	0,72	0,72	0,72	0,72	0,69	0,69	0,69
Gain correction for opacity (at zenith)	0,95	0,90	0,94	0,93	0,93	0,82	0,82	0,74	0,55
Antenna gain including insertion loss and opacity (kelvin/Jy)	0,14	0,14	0,14	0,14	0,13	0,11	0,10	0,08	0,05
SEFD (Jy)	**597,4**	**796,5**	**661,3**	**738,8**	**868,5**	**1699,1**	**1843,1**	**2291,1**	**5296,8**
Sensitivity (mJy)	**9,4**	**12,6**	**10,5**	**11,7**	**13,7**	**26,9**	**29,1**	**36,2**	**83,8**