



**Title: Radiometer (140-170 GHz) and its essential accessories**

**Tender No.**

**I-I/ET-TPT/24004/24-25**

<b>Title</b>	<b>Procurement of Radiometer (140-170 GHz) and its essential accessories</b>
<b>Sub Title</b>	<b>PART-A (II): Scope of Supply, Scope of Work and Technical Specifications</b>

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## 1 Introduction

Institute for Plasma Research is a premiere research institute pursuing research on plasma science and technology in India. ITER-India is the Indian domestic agency (IN-DA), a centre of IPR, is responsible for Indian in-kind commitments to ITER international project (<https://www.iter.org>). As a part of IN-DA deliverables, ITER-India needs to design, develop and deliver a Radiometer to ITER as Electron Cyclotron Emission (ECE) diagnostic system instrument. The ECE diagnostic is dedicated for measuring plasma electron temperature profile with good spatial and temporal resolution.

For ITER operation, a radiometer in the frequency range 122-230 GHz is required which will be used for the measurement of ITER-core plasma electron temperature (refer Annex-A for more details).

**This tender is to procure a prototype radiometer (140 GHz – 170 GHz), along with its essential accessories, which is to be used at ITER-India, IPR, India.** Detailed technical specifications and requirements are provided in this document to enable the manufacturers/suppliers, to submit their bids with complete details, complying ITER-India requirements.

## 2 Scope of Supply

The scope of supply by the supplier includes the following:

Sr. no	Deliverables	Qty
1	Supply of Prototype Radiometer (140 GHz-170 GHz)	1 set
1.1	All Standard accessories required for the operation of the Radiometer	As needed
1.2	Power supplies compatible with power rating 230 VAC, 50 Hz and required cables & connectors	As needed
2	D-Band Motorized Waveguide switch with power supply	1 set
3	D-Band Noise Source with Full band Isolator (power supply included)	1 set
4	Document Deliverables	
4.1	Detailed design description report	1 set in hard and soft copy
4.2	Operating software/GUI compatible with Linux OS RHEL 8.5 and having EPICS support (LabVIEW based/open source code shall be provided, if available).	-
4.3	Operation/Instruction manuals of all systems	1 set in hard and soft copy



### 3 Scope of Work

The scope of work of Supplier includes the following:

S.No.	Scope of Work
1	Submission of detailed design description report of the prototype Radiometer to ITER-India for its review and approval within 2.5 months after placement of Purchase Order. This design description report shall include configuration of radiometer designed to meet the technical specifications as given in Table 1, details of all interfaces (mechanical and I&C), and details of hardware and software to configure gain control of each channel, and tuning of YIG filter at particular frequency from the GUI.
2	Submission of acceptance test procedure and criteria for review to ITER-India along with #1. This has to be mutually agreed between both the parties. (refer Section 7 for acceptance test criterion). Also, list of equipment required for successful completion of SAT should be provided, so that ITER-India can arrange them, in parallel.
3	Procurement/fabrication and testing of all components of Radiometer in order to meet the required technical specifications given in Table1.
4	Assembly and testing (refer #5 below) of entire system complying with the technical specifications given in Table1.
5	Perform Pre-dispatch tests/Factory Acceptance Tests (FAT) given in Appendix-1 and submit the test reports for dispatch clearance certificate (refer Section 7 for acceptance test criterion).
6	Delivery of items to ITER-India lab as per delivery schedule given in Part-A(III) and as per the delivery terms, with adequate packing to avoid damage during transportation.
7	Provide necessary technical support for the Assembly, Installation, Testing and demonstration of system's performance at ITER-India lab (Site Acceptance Test) either by in person participation or by participating remotely (by the supplier or by their representative).
8	Provide necessary support and undertake prompt actions as needed during the warranty period to fulfil the warranty commitments as per the terms and conditions.

### 4 Technical Specifications of Prototype Radiometer (140 GHz-170 GHz)

ITER-India intends to procure an integrated Radiometer system (140-170 GHz) comprising of RF and IF sections, as represented in Figure 1. Typically, in a Radiometer, first the received RF signal is mixed with a signal from a Local Oscillator (LO). In this stage, the frequency spectrum of

original signal is translated to a much lower intermediate frequency (IF). Here, in the prototype Radiometer, this down-conversion is done using a fundamental balanced biased mixer with desired Noise figure of 8-9 dB for good conversion efficiency. The Local Oscillator at ~138.5GHz should be a phase locked source for better frequency stability. Subsequently the resulting signal is amplified using a low noise broadband amplifier and finally it is detected and processed in a video circuit.

The prototype radiometer is designed to have 14 fixed channels and two tunable channels. The tunable channels have an electrically tunable filter (YIG filter). These filters have 3 dB bandwidths in the range ~200 MHz, and tunable centre frequencies in frequency band 2-18 GHz.

The required technical specifications are given in Table 1 below:

**Table 2 :Technical specifications of prototype Radiometer (140-170 GHz)**

Sr. No.	Parameter	ITER-India Specification
1.	Frequency range	140- 170 GHz
2.	Channel Spacing or Frequency resolution	2 GHz
3.	Fixed Channels	
3a.	No. of fixed channels	14
3b.	IF Filter bandwidth	0.5 GHz
4.	Tunable channels with frequencies tunable between 2-18 GHz	
4a.	No. of Tunable channels	2
4b.	Tunable Filter bandwidth	100 - 200 MHz
4c.	Tuning speed	$\leq 10$ ms
5.	Noise figure	$\leq 9$ dB
6.	Radiometer Sensitivity	$\geq 2 \times 10^7$ V/W
7.	Input power (min. detectable power)	-60 dBm
8.	Max RF Input Power	5 dBm*
9.	Dynamic Range	40 – 50 dB
10.	Channel to channel isolation	> 25 dB
11.	Variable gain amplifiers in each channel which can be tuned remotely.	As per the dynamic range for equalizing the sensitivity in the different channels
12.	Output at each channel	0 to 10 V output voltage proportional to the power at the

		radiometer input, bandwidth from DC to 1 MHz
13.	Input RF connection Port	WR06
14.	Final Output stage interface (at each channel output)	BNC
15.	Supply AC voltage	Single Phase 230V $\pm 10\%$ , 50 Hz Along with required compatible connectors with cables

*\*If needed, attenuator to be used in front of mixer and should be part of delivery*

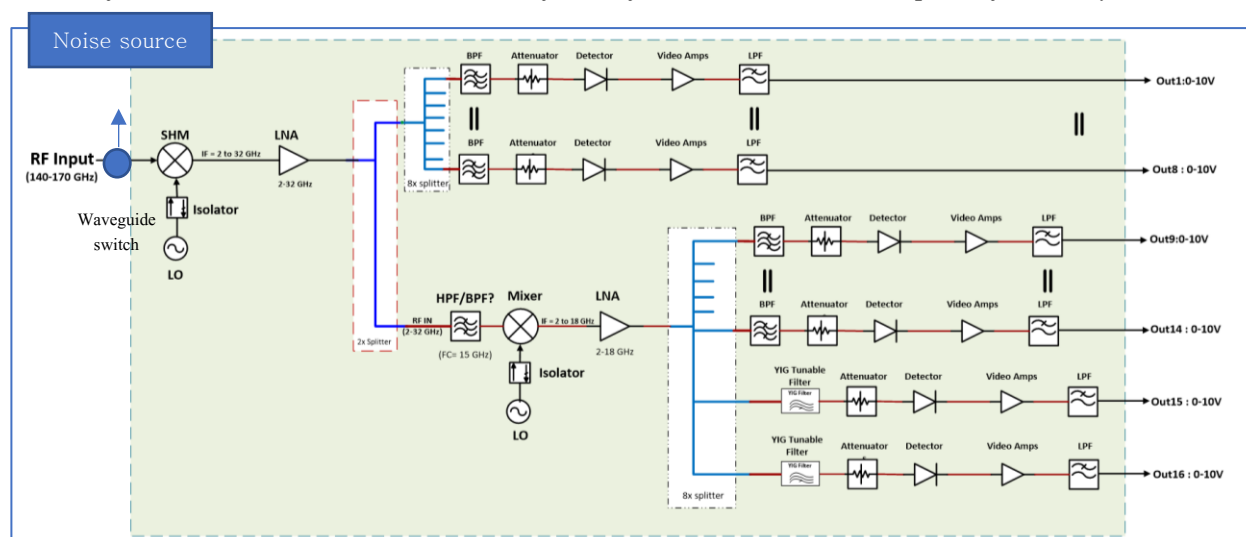


Figure 1 :Schematic representation of Prototype Radiometer (140-170 GHz)

Table 2: Channel details for Prototype Radiometer (140-170 GHz)

Channel Number	Centre Frequency (RF) GHz	Filter BW (GHz)	CF (IF) GHz
1	140.5	0.5	2
2	142.5	0.5	4
3	144.5	0.5	6
4	146.5	0.5	8
5	148.5	0.5	10
6	150.5	0.5	12
7	152.5	0.5	14
8	154.5	0.5	16
9	156.5	0.5	2
10	158.5	0.5	4
11	160.5	0.5	6

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12	162.5	0.5	8
13	164.5	0.5	10
14	166.5	0.5	12
15	Tunable (2 -18 GHz)	Tunable 100-200 MHz	14
16	Tunable (2 -18 GHz)	Tunable 100-200 MHz	16

## 5 Essential Accessories:

### 5.1 D-Band Motorized Waveguide switch with power supply

A motorized waveguide switch for switching between plasma and noise source is needed for performing functionality testing/local calibration of radiometer. The waveguide switch should have low insertion loss, high isolation and TTL control.

**Table 3: Technical specifications of D-band motorized waveguide switch**

Sr. No.	Parameter	ITER-India Specification
1.	Frequency Range	110 GHz-170 GHz
2.	Insertion loss	$\leq 1.5$ dB
3.	Isolation between 2 ports	$> 30$ dB
4.	Switching time	$< 1$ s
5.	Control signal	TTL
6.	RF Port *	WR06
7.	Biasing Power supply	Specify

\*Interface compatible with the radiometer input RF port

### 5.2 D-Band Noise Source with Full band Isolator (power supply included)

A noise source covering the full D band 110-170 GHz in WR06 waveguide including an integral full band Isolator is part of scope of supply as a separate entity to test prototype Radiometer (110-170 GHz).

**Table 4: Technical specifications of D-band Noise source with full band isolator**

Sr. No.	Parameter	ITER-India Specification
1.	Frequency Range	110 GHz-170 GHz
2.	RF Port*	WR06
3.	ENR	15 dB
4.	Power supply	Specify

\*Interface compatible with the radiometer input RF port and waveguide switch

## 6 Other requirements:

- Control and instrumentation –

Gain control for each channel and tuning of YIG filter at particular frequency is needed.

Bidder has to provide all the hardware, software packages to configure these parameters from the GUI, supplied by bidder. All the documentation related to specific protocol interface shall be provided by bidder so that it can be easily interfaced with central control system in future. ITER-India prefers operating software should be compatible with Linux OS RHEL 8.5 and having EPICS support (LabVIEW based/open source code shall be provided, if available).

- All Standard accessories required for the operation of the Radiometer shall be part of the scope of supply and to be specified in the bid.
- Power supplies compatible with power rating 230 VAC, 50 Hz and required cables & connectors.
- Operating temperature: +18 to +40 °C, max relative humidity < 85%
- Long-term drift (3 months) of sensitivity for each channel of Radiometer < 1%
- Operation manual, technical manuals (in English language).
- Optional accessories available from the supplier required for testing should also be quoted separately.
- Applicable codes and standards, if any, to be specified.

## 7 Acceptance test criterion (Factory Acceptance Tests (FAT) & Site Acceptance Test (SAT))

The final acceptance of the integrated systems will be given after the following two tests:

1. Pre-dispatch test at factory site by the supplier (ITER-India reserves the right to do Pre-dispatch Inspection (PDI) of the ordered item by ITER-India personnel at factory site)
2. Final acceptance test at ITER-India lab

### Part I: Pre-dispatch tests/FAT

Before dispatching the Radiometer system, the supplier needs to perform tests and provide sufficient evidence fulfilling the requirement stated above and send a complete test report (details of the proposed tests are given in Appendix-1). The test report will be evaluated by ITER-India and if found satisfactory, ITER-India will send the dispatch clearance note. Delivery shall be effected only after receiving the signed dispatch clearance note from ITER-India. The test criteria





can be mutually agreed between both the parties within one month of placing the purchase order. However, if it is necessary, Factory Acceptance Tests will be witnessed by ITER-India personnel at factory site.

**Part II: Acceptance tests at ITER-India laboratory/Site Acceptance Tests (SAT)**

At ITER-India lab, installation, testing and demonstration of system's performance must be carried out either physically or remotely by the supplier or its principal or by their Indian representative. After successful commissioning at ITER-India, a final acceptance will be given only when it complies with all the technical specifications and requirements.

## **Appendix-1**

### **Proposed Acceptance tests:**

Acceptance test report containing the following information:

1. Component level test- Test reports of all individual parts/modules for gain, insertion loss, noise figure, conversion loss, sensitivity, as applicable, for mixer, low noise amplifier, cavity filters, tunable filters, power divider, detector etc. The report should contain a list of tests done along with results of calibrations and measurements. Test sheets/certificate should be provided for parts which are not manufactured by the company and are procured from some other certified company.
2. Integrated system test: Test reports demonstrating that all parameters of the integrated system, mentioned in Table 1 are achieved. These measurements shall be carried out using the noise source/mm-wave source.

Table 5: Tests for integrated system

Sr. No.	Parameter	ITER-India Specification
1.	Frequency range	140- 170 GHz
2.	Noise figure	$\leq 9$ dB
3.	Radiometer Sensitivity	$\geq 2 \times 10^7$ V/W
4.	Input power (min. detectable power)	-60 dBm
5.	Dynamic Range	40 – 50 dB
6.	Channel to channel isolation	> 25 dB
7.	Output at each channel	0 to 10 V output voltage proportional to the power at the radiometer input, bandwidth from DC to 1 MHz

### **ANNEX-A**

#### **ITER ECE RADIOMETER (122-230 GHz)**

The ITER ECE low-frequency radiometer is one of the two radiometers which will be used for the measurement of ITER-core plasma electron temperature. For ITER operation at high toroidal field ( $B_{0r} \sim 5.3$  T), the 1st harmonic ECE frequencies extend from 122-230 GHz. This low-frequency radiometer will provide measurement of plasma electron temperature profile by measuring 1st harmonic frequency range 122-230 GHz for the full Bt operation.

Wide ECE spectra extending over more than one microwave band need separate receivers for each band in order to ensure good performance. A set of four receivers is used, with IF bandwidth between 16-30 GHz. A frequency splitter unit is used for splitting the ECE radiation frequency band into four receiver bandwidths efficiently.

The low-frequency radiometer shall consist of the following sub-systems as shown in Figure 1:

1. Receiver 1: 122 - 138 GHz bandwidth with sixteen channels of 1 GHz bandwidth
2. Receiver 2: 141 - 168 GHz bandwidth with fourteen channels of 2 GHz bandwidth
3. Receiver 3: 172 - 200 GHz bandwidth with fifteen channels of 2 GHz bandwidth
4. Receiver 4: 205 - 230 GHz bandwidth with thirteen channels 2 GHz bandwidth
5. A Frequency splitter unit which will split the ECE radiation 122-230 GHz into above four receiver bands as mentioned above.

In addition to these, there is a need of 16 tunable channels for real time measurement. The tunable channels have an electrically tunable filter (YIG filter). These filters have 3 dB bandwidths in the range 150 to 250 MHz, and tunable center frequencies. Provision should be made to connect each of these channels to any of the IF sections via fully remotely controlled hardware.

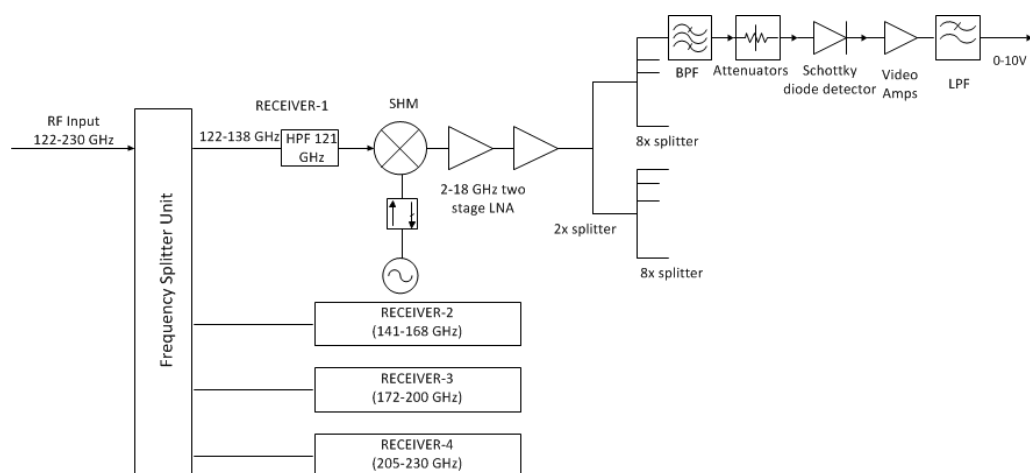


Figure 2 : Schematic representation of low -frequency Radiometer (122-230 GHz)



## **Appendix 2: Technical Compliance Matrix**

Sr. No.	Parameter	ITER-India Specification	Bidder specifications	Bidder's Compliance (Yes/No)
1	<b><i>Scope of Supply: Deliverables</i></b>			
1.1	Supply of Prototype Radiometer (140 GHz-170 GHz)	1 set		
1.2	All Standard accessories required for the operation of the Radiometer	As needed		
1.3	Power supplies compatible with power rating 230 VAC, 50 Hz and required cables & connectors	As needed		
1.4	D-Band Motorized Waveguide switch with power supply	1 set		
1.5	D-Band Noise Source with Full band Isolator (power supply included)	1 set		
	<b><i>Document Deliverables</i></b>			
1.6	Detailed design description report	1 set in hard and soft copy		
1.7	Operating software/GUI compatible with Linux OS RHEL 8.5 and having EPICS support (LabVIEW based/open source code shall be provided, if available).	-		
1.8	Operation/Instruction manuals of all systems	1 set in hard and soft copy		
2	<b><i>Scope of Work</i></b>			
2.1	Submission of detailed design description report of the prototype Radiometer to ITER-India for its review and approval within 2.5 months after placement of Purchase Order.	-		
2.2	Submission of acceptance test criteria for review to ITER-India along with #2.1 above. This has to be mutually agreed between both the parties. (refer Section 7 for acceptance test criterion)	-		



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2.3	Procurement/fabrication and testing of all components of Radiometer in order to meet the required technical specifications given in Table1.	-		
2.4	Assembly and testing (refer #2.6 below) of entire system complying with the technical specifications given in Table1.	-		
2.5	Perform Pre-dispatch tests/Factory Acceptance Tests (FAT) given in Appendix-1 and submit the test reports for dispatch clearance certificate (refer Section 7 for acceptance test criterion).	-		
2.6	Delivery of items to ITER-India lab as per delivery schedule given in Part-A(III) and as per the delivery terms, with adequate packing to avoid damage during transportation.	-		
2.7	Provide necessary technical support for the Assembly, Installation, Testing and demonstration of system's performance at ITER-India lab (Site Acceptance Test) either by in person participation or by participating remotely (by the supplier or by their representative).	-		
2.8	Provide necessary support and undertake prompt actions as needed during the warranty period to fulfil the warranty commitments as per the terms and conditions.	-		
3	<b><i>Technical specifications of prototype Radiometer (140-170 GHz)</i></b>			
3.1	Frequency range	140- 170 GHz		
3.2	Channel Spacing or Frequency resolution	2 GHz		
3.3	Fixed Channels			
3.3a.	No. of fixed channels			
3.3b.	IF Filter bandwidth	0.5 GHz		
3.4	Tunable channels with frequencies tunable between 2-18 GHz			
3.4a.	No. of Tunable channels	2		



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3.4b.	Tunable Filter bandwidth	100 - 200 MHz		
3.4c.	Tuning speed	$\leq 10$ ms		
3.5	Noise figure	$\leq 9$ dB		
3.6	Radiometer Sensitivity	$\geq 2 \times 10^7$ V/W		
3.7	Input power (min. detectable power)	-60 dBm		
3.8	Max RF Input Power	5 dBm*		
3.9	Dynamic Range	40 – 50 dB		
3.10	Channel to channel isolation	> 25 dB		
3.11	Variable gain amplifiers in each channel which can be tuned remotely.	As per the dynamic range for equalizing the sensitivity in the different channels		
3.12	Output at each channel	0 to 10 V output voltage proportional to the power at the radiometer input, bandwidth from DC to 1 MHz		
3.13	Input RF connection Port	WR06		
3.14	Final Output stage interface (at each channel output)	BNC		
3.15	Supply AC voltage	Single Phase 230V $\pm 10\%$ , 50 Hz  Along with required compatible connectors with cables		
	<i>*If needed, attenuator to be used in front of mixer and should be part of delivery</i>			



4	<b><i>D-Band Motorized Waveguide switch with power supply</i></b>			
4.1	Frequency Range	110 -170 GHz		
4.2	Insertion loss	≤1.5 dB		
4.3	Isolation between 2 ports	>30 dB		
4.4	Switching time	< 1s		
4.5	Control signal	TTL		
4.6	RF Port **	WR06		
4.7	Biasing Power supply	Specify		
	**Interface compatible with the radiometer input RF port			
5	<b><i>D-Band Noise Source with Full band Isolator (power supply included)</i></b>			
5.1	Frequency Range	110 -170 GHz		
5.2	RF Port***	WR06		
5.3	ENR	15 dB		
5.4	Power Supply	Specify		
	***Interface compatible with the radiometer input RF port and waveguide switch			
6	<b><i>Acceptance test criterion (Factory Acceptance Tests (FAT) &amp; Site Acceptance Test (SAT))</i></b>			
7	<b><i>Eligibility Criteria for the bidders</i></b>			
8	<b><i>Delivery Date</i></b>			
9	<b><i>Warranty</i></b>			