DIAGNOSTICS

PROCUREMENT PACKAGE # 55.PF

MICROWAVE DIAGNOSTICS

Contents

1 Introduction

This document describes the specification for the cost estimate for the ITER-FEAT microwave diagnostics. This document and its Annexes will form the basis of a future Call for Tender for these systems and has been written to allow the assessment of the cost of the future procurement. The Supplier provides the information required in this Cost Estimation Package (PP). The Supplier will provide the deliverables described in section 3 during the construction phase.

The deliverables are defined in accordance with the strategy assumed for procurement of the microwave diagnostics. In particular, the respective responsibilities of the JCT and the Supplier are given in section 3.1. Furthermore, a procurement schedule consistent with the overall ITER-FEAT schedule is presented in section 4. The detailed technical specification is given in Annex 1.

As far as possible, an industrial cost estimate has to be provided by the Supplier on the basis of the information provided in this document considering the requirements given in section 5 and following the format specified in Annex 4. Due to the specialised and diverse nature of tokamak diagnostic equipment, it is expected that the Supplier shall be a fusion laboratory, with appropriate sub-contractors. Annex 4 therefore expects professional manpower used in a design or supervisory role to be accounted for in professional person-years (PPY).

2 System Description

2.1 System Functions

The microwave diagnostic systems provide measurements of

- The electron temperature profile in the core;
- the amplitude and mode structure of quasi static, slow and fast fluctuations of temperature in the core;
- The electron density profile and fluctuations in the main regions of the plasma – core, edge and divertor;
- divertor pressure;
- core D/T ratio.

Different combinations of the measurements are used for:

- control of plasmas in specific high performance scenarios;
- understanding important physical phenomena which may limit ITER performance.

The system operates in all phases of the discharge and in a wide range of parameters outside the planned scenarios to be able to recover from abnormal events.

2.2 System Features

The main design requirements and the description of the reference design of system and major components are given in Annex 1 (Technical Specification). The list of equipment and tables with technical data for the major components are available in Annex 2.

2.2.1 F.01 Electron Cyclotron Emission

The Electron Cyclotron Emission (ECE) is one of several diagnostic systems proposed for ITER. Its objective to provide the electron temperature with good spatial and temporal resolutions. Secondary objectives are to obtain information on non-thermal electron populations and the power loss due to ECE.

The system divided into three main parts:

- the front end, which collects the radiation from the plasma and transmits it through to the pit;
- the transmission system which transports the ECE emission from the front end to the instrumentation and
- the instrumentation which is housed at a distance from the tokamak in an ITER provided building.

The ECE front end uses two collection antennas. The antennas are staggered vertically to give access to the core for a variety of plasma heights near the nominal plasma centre height. All antennas are Gaussian beam telescopes. For each antenna, there are built-in calibration hot sources at the front end. The sources can be intermittently viewed through a shutter.

The radiation from each antenna is transmitted to the pit using wide band corrugated waveguide with suitable assemblies to take up machine movements. There, the signal is split into X and O mode components using a polarising beam splitter, before transmission to the diagnostic hall by a dedicate evacuated corrugated waveguide system. In the diagnostic hall, the signal is divided between two survey spectrometers and two fixed multichannel spectrometers.

2.2.2 F.02 Reflectometry (Main Plasma)

This sub-system is comprised of

- **LFS X** : an extraordinary mode (X-mode) launch system, reflecting off the upper cutoff is used on the low-field side to provide measurements of the scrape-off layer (SOL) profile;
- an ordinary (O-mode) system is used to provide the inboard (**HFS O**) and outboard (**LFS O**) density profile in the gradient region; and
- **HFS X-l**: an X-mode system reflecting of the lower cutoff and launched from the high field side is used to provide the core profile.

The LFS X system employs an array of 2 pairs of broad-band antennas of typical diameter 90 mm, mounted on a diagnostic block in an equatorial port and view the plasma through apertures in the blanket/shield. The antennas do not protrude in front of the diagnostic block. As a result, the front ends of the antennas are at least 0.8 m away from the plasma during operation, with the first mirror at least 1 m away from the first wall. Broad-band overmoded corrugated circular transmission lines (63.5 mm dia) couple the front ends to the system electronics. Components such as swivelling mitre bends, expansion joints and long elastic sections are used to accommodate vessel movement with respect to the bioshield whilst preserving mm-wave performance. The LFS O system is implemented in the same way, and employs 4 antenna pairs.

The HFS X-l system consists of two antenna pairs, mounted on the backplate and viewing the plasma between blanket modules. Radiation is routed to these using small bore (<35 mm typ.) rectangular or circular corrugated waveguide depending on the frequency range. This waveguide is routed in the diagnostic conduit paths on the vacuum vessel. The waveguides are brought out through an upper horizontal port and the cryostat to electronics located in the pit on a removable trolley or in the diagnostic hall, depending on the frequency range. The HFS - O system is implemented in the same way.

2.2.4 F.03 Reflectometry (Plasma Position)

This diagnostic is designed to act as a stand-by gap measurement, in order to correct or supplement the magnetics for plasma position control, during very long (>1000 s) pulse operation, where the position deduced from the magnetic diagnostics could be subject to substantial error due to drifts. To meet the ITER requirements for accuracy of the location of the gaps, density profile recovery to a density comparable to, or exceeding the separatrix density is necessary.

An ordinary mode reflectometer operating in the frequency range 15 to 60 GHz is being proposed, which can measure the location of a plasma density surface near the separatrix with sufficient accuracy to be used to supplement the magnetics for position control. A swept frequency (FM-CW) is used. Such a system can be implemented using the same frequency range at each poloidal control location, and it is possible to consider many common components. A bistatic (separate transmit and receive units) antenna arrangement his used.

As for the HFS of the main reflectometer with which it shares one antenna pair, the antenna pairs are mounted on the vacuum vessel and view the plasma between blanket modules. Radiation is routed to them using small bore waveguide. The waveguide resides in the space allocated within the VV and blanket structure for the diagnostic conduit. The waveguides are brought out through two of the upper ports to electronics residing in the pit. Expansion joints and elastic sections are used to accommodate the vacuum vessel movement.

Labyrinths in the transmission lines reduce neutron streaming outside the vacuum vessel and bioshield. Vacuum windows of fused quartz directly bonded to metal structures and inclined at the Brewster angle for the appropriate polarisation provide robust, low mm-wave loss, pressure boundaries.

2.2.4 F.04 / F05 Reflectometry and ECA for the divertor

This sub-system is comprised of front end antennas, waveguides and mm-wave transition pieces mounted on specific divertor cassettes, a removable in-vessel transmission line set, a permanent interspace transmission line set, a short ex-cryostat transmission line set and self-contained electronic transmit/receive assemblies mounted on trolleys in the pit.

The divertor reflectometer is a density profile measurement system for the divertor. It is the only divertor system potentially able to provide good (sub-cm) resolution across the divertor legs for selected sightlines. The waveguide set for this system will also be used for electron cyclotron absorption (ECA) and interferometric measurements.

The design is for multiple sightline, low transmission line diversity system. Once the limitation on the total number of sightlines is taken into account, it is possible to accommodate 5 sightlines on the outer leg, and 3 sightlines on the inner leg by making full use of two ports (40 waveguides).

The antennas view the plasma between divertor modules. The waveguides in the insert are brought out through conversion boxes to a size suitable for long distance transmission to electronics residing in pit. Expansion joints and elastic sections are used to accommodate the vacuum vessel movement. Labyrinths in the transmission lines reduce neutron streaming outside the vacuum vessel and bioshield. Vacuum windows of fused quartz directly bonded to metal structures and inclined at the Brewster angle for the appropriate polarisation (where possible) provide robust pressure boundaries.

2.2.5 F.07 Fast wave reflectometer

This sub-system is comprised of a wide-band RF generator unit, RF transmission lines, in-vessel transmit and receive antennas and RF heterodyne receivers phase locked to the transmitter unit.

This system is aimed the measurement of the fuel ratio in the core (n_D/n_T). It can also supply an estimate of the line integral density. Both measurements are performed by launching and receiving RF radiation in the ion cyclotron range, and measuring the return phase and amplitude.

A broad-band RF system, operating in the range 20 – 60 MHz is required. The transmission antenna is a single strap mounted on a diagnostic port. The receive antennas are coils mounted in filler and blanket module gaps. There are 8 receive antennas in the same sector as the transmitter, and an additional 9 antennas at toroidal intervals of 40°.

3 Definition of Deliverables

3.1 General Approach to Procurement

A single procurement package is foreseen for the microwave diagnostics. The procurement will be performed as follows:

i) Components within the vacuum vessel: at the detailed design level.
ii) Transmission system components, and remote diagnostic equipment: at the functional specification level.
iii) Specialised signal processing electronics: at the functional specification level.
iv) Analysis and system control software: at the functional specification level.

Note that windows and feedthroughs are specifically excluded from this procurement. These are included in another PP.

As a result, the responsibilities of the JCT and the Supplier are given below.

3.1.1 JCT Responsibilities

i) Components within the vacuum vessel

The JCT will supply a functional specification, including interface aspects such as space limitations, access restrictions, services available, etc. and reference outline design.

The JCT will supply the reference detailed design. Deviations from the detailed design that satisfy the functional specification and outline designs will be considered by the JCT in the acceptance of the offer.

The JCT will install the components (machine assembly workers under JCT supervision).

ii) Transmission system components and remote diagnostic equipment and

iii) Signal processing electronics

The JCT will supply a functional specification, including interface aspects such as space limitations, access restrictions, services available, etc. and a reference outline design. Deviations from the outline design that satisfy the functional specification and outline designs will be considered by the JCT in the acceptance of the offer.

iv) Analysis and control software

The JCT will supply a functional specification, including interface aspects such as protocols used, available hardware and network services as well as a reference outline design. Deviations from the outline design that satisfy the functional specification and outline designs will be considered by the JCT in the acceptance of the offer.

3.1.2 Supplier Responsibilities

The Supplier will provide a detailed project plan with key milestones to be reviewed and agreed by the JCT at the start of the contract.

The Supplier's responsibilities for specific components are as follows.

i) Components within the vacuum vessel

The Supplier is responsible for the manufacturing design and fabrication of these components in accordance with the technical specifications (see Annex 1) and all related documentation provided by the JCT. Further, the Supplier is responsible for factory testing and delivery.

The Supplier is responsible for the performance of the components, subject matter of the contract, in accordance with the technical specifications.

The Supplier may place sub-contracts for the procurement of major subsystems or components. In this case the JCT will review and approve the technical specifications prepared by the Supplier for its sub-contractors and will participate in the technical assessment of the offers. Finally, the sub-contractors selected by the Supplier have to be approved by the JCT.

The Supplier shall provide:

- the manufacturing design (including manufacturing drawings) of the system and components, if non-standard;
- fabrication and/or purchasing of the components;
- factory testing;
- packing and transport.

ii) Transmission system components and remote diagnostic equipment

The Supplier is responsible for the detailed design, manufacturing design and fabrication of these components in accordance with the technical specifications (see Annex 1) and all related documentation provided by the JCT. Further, the Supplier is responsible for factory testing and delivery.

The Supplier is responsible for the performance of the components, subject matter of the contract, in accordance with the technical specifications.

The Supplier may place sub-contracts for the procurement of major subsystems or components. In this case the JCT will review and approve the technical specifications prepared by the Supplier for its sub-contractors and will participate in the technical assessment of the offers. Finally, the sub-contractors selected by the Supplier have to be approved by the JCT.

The Supplier shall provide:

- the manufacturing design (including manufacturing drawings) of the system and components, if non-standard;
- fabrication and/or purchasing of the components;
- factory testing;
- packing and transport.
- on-site tests

ii) Signal processing electronics

The Supplier is responsible for the detailed design, manufacturing design and fabrication of these components in accordance with the technical specifications (see Annex 1) and all related documentation provided by the JCT. Further, the Supplier is responsible for factory testing and delivery.

The Supplier is responsible for the performance of the components, subject matter of the contract, in accordance with the technical specifications.

The Supplier may place sub-contracts for the procurement of major subsystems or components. In this case the JCT will review and approve the technical specifications prepared by the Supplier for its sub-contractors and will participate in the technical assessment of the offers. Finally, the sub-contractors selected by the Supplier have to be approved by the JCT.

The Supplier shall provide:

- the manufacturing design (including manufacturing drawings) of the system and components, if non-standard;
- fabrication and/or purchasing of the components;
- factory testing;
- packing and transport.
- on-site tests

iv) Analysis and system control software

The Supplier is responsible for the layout, implementation, debugging, installation, integration and documentation of the code required to provide the quantities shown in the technical specifications (see Annex 1) and all related documentation provided by the JCT. Further, the Supplier is responsible for the layout, implementation, debugging, installation, integration and documentation of the code required to operate the diagnostic hardware remotely through the ITER-FEAT Control and Data Acquisition system (CODAC). The Supplier is also responsible for factory testing and delivery of these codes.

The Supplier is responsible for the performance of the software, subject matter of the contract, in accordance with the technical specifications.

The Supplier may place sub-contracts for the procurement of major subsections. In this case the JCT will review and approve the technical specifications prepared by the Supplier for its sub-contractors and will participate in the technical assessment of the offers. Finally, the sub-contractors selected by the Supplier have to be approved by the JCT.

The Supplier shall:

- write and debug the codes;
- install them;
- perform on-site tests and debugging;
- integrate the system into CODAC;
- at all stages during installation have available detailed, up-to-date documentation on code operation.

3.2 Hardware

A detailed description of the equipment to be provided is given in Annex 1; a summary of the component numbers is given in Annex 2. The main subdivisions of the microwave diagnostic systems are as follows (the WBS subdivision follows in brackets).

ECE (5.5.F.01)

- In-vessel QO antenna systems
- Port interspace waveguide
- In-vessel shutter/mirror mechanism
- Port interspace mechanical transmission
- Ex-cryostat waveguide
- Diagnostic hall signal distribution
- Diagnostic hall equipment
- Software

Reflectometry for the main plasma (5.5.F.02)

- LFS-X sub-system
- LFS-O sub-system
- HFS –O and Xl, high frequency sub-system
- HFS –O and Xl, low frequency sub-system

Position reflectometry (5.5.F03)

- HFS –O low frequency sub-system
- Software

Divertor Reflectometer (5.5.F.04) and Divertor ECA (5.5.F.05)

- In-vessel components
- Interspace components
- Pit components
- Software

Fast Wave Reflectometry (5.5.F.07)

- In-vessel components
- RF Tx/Rx equipment
- Software

3.3 Manufacturing Processes

These vary by sub-system. Key processes include:

4 Machining (waveguide flanges, corrugated waveguide sections, in vessel mirrors).
5 Polishing (in-vessel mirrors)
6 Electro-plating (Waveguide inner surfaces)
7 Electro-forming (Waveguide special bends)
8 Spark erosion (Precision tungsten components)
9 Precision mechanical assembly (Waveguide runs, Spectrometers)

10 Wiring (Electronics)
11 Welding (cooling connections in primary vacuum)

3.4 QA Procedures

A QA organisation will be implemented as required for fabrication and installation in conventional systems. (See Annex 6.) Points of particular importance for the microwave systems are:

- On the completion of any waveguide sub-assembly, a transmission test of the sub-assembly must be performed and documented. A visual inspection of joints (using endoscopy) is required for all assemblies in primary vacuum, interspace vacuum, or embedded in concrete.
- On the completion of a waveguide transmission system, reflection and cross-talk checks using reflectometry (time of flight equivalent) techniques should be performed and documented.

3.5 Documents

Throughout the procurement contract, the Supplier shall provide bi-monthly progress reports. These shall included a report on progress with the key elements agreed at the start of the contract. In addition, the Supplier shall provide the following documents:

- Manufacturing Design Report. This shall include all calculations supporting the design and system performance and manufacturing drawings of the system.
- Factory Test Procedure. This shall include the list of all type and routine tests to be performed on the various components. Copies of test certificates for type tests on standard components are acceptable.
- Factory Test Report. This shall include the results of all factory tests mentioned above.
- Site Test Procedure. This shall include the list of all tests to be repeated on site on the various components; the list of all signals for the end to end commissioning; the test procedure for the integrated acceptance tests on dummy loads.
- Site Test Report. This shall include the results of all site tests mentioned above.
- Operation Manual.
- Recommended Spare Parts. This shall include the list of spare parts for the first year of operation, for the following five years and finally for the following fourteen years.
- Maintenance Manual

4 Construction Schedule

The procurement schedule of the contract proposed by the JCT is as follows (in months from date of contract):

	Start of month		End of month
Project planning	01 st	-	01 st
Manufacturing Design	02 nd	-	14 th
Fabrication and Factory Tests	15 th	-	39 th

Delivery	40 th	-	43 rd
Installation	44 th	-	47 th
Comm. and on Site Acceptance Tests	48 th	-	54 th

The Supplier should consider and propose modifications to the schedule which can reduce cost, improve efficiency or accelerate the schedule.

5 Requirements for the Cost Estimates

Cost estimate

The Supplier shall consider and cost the reference design provided in Annex 1; alternative designs, that satisfy the functional technical specifications, could be proposed but will need to be agreed with the JCT in advance of the submission of the final report.

The Supplier shall use the cost estimate spreadsheet given in Annex 4. Line item additions / removals are permitted. General guidelines for the presentation of costs may be found in Annex 5 to this document. Neither cost for R&D or contingency has to be included in the cost estimate.

The Supplier shall assume that site installation and commissioning take place in the country where the he resides.

Packing and Transport

For this cost estimate, it is assumed that equipment is to be packed and delivered FOB at a port of export for transoceanic shipment, in the Supplier's country. The transport cost to be included in the cost estimate should only be from the Supplier factory to the port of export.

Procurement Schedule and Annual Cash Flow

The Supplier shall review the procurement schedule as requested in Section 4 and shall provide an estimate of the annual cash flow. The Supplier has to assume that payments are made to meet the cash flow requirements according to the planned work, therefore no interest costs are to be charged.

6 Contact Arrangements

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Inquiries:

Written inquiries by Estimators should be sent to the ITER Supervisor. Both the inquiry and the response will be shared with the Estimators of other ITER Parties.
Estimators may contact directly the ITER Responsible Officer to obtain additional information or clarification. However amendments of this document can be made only in writing by the ITER Supervisor.

Date for the submission of the cost estimate package:

Draft: no later than 13 October 2000
Final: no later than 30 November 2000

Annexes

Annex 1: Technical Specifications.
Annex 2: Equipment List and Quantities.
Annex 4: Cost Estimate Spreadsheet.
Annex 5: Guidelines for the filling out of Annex 4.
Annex 6: Procurement Quality Specification for Cost Estimation Purposes.
Annex 7: Guideline for ITER Dedicated Plant Control Subsystem.

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