IDM UID
76HQ9Q

VERSION CREATED ON / VERSION / STATUS
17 Jan 2012 / 2.0 / APPROVED

EXTERNAL REFERENCE

Report

Electron Cyclotron Emission (ECE) System - Panel Final Report

CDR Design Review

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Costley A.**	**18-Jan-2012:signed**	
CoAuthor			
Reviewers	**Kondoh M.** **Udintsev V.** **Walsh M.**	**19-Jan-2012:recommended** **18-Jan-2012:recommended** **26-Jan-2012:recommended**	**IO/DG/DIP/CIE** **IO/DG/DIP/CHD/DIAG/DIAGE** **IO/DG/DIP/CHD/DIAG**
Approver	**Bora D.**	**26-Jan-2012:approved**	**IO/DG/DIP/CHD**
Document Security: level 1 (IO unclassified) *RO: Udintsev Victor*			
Read Access	**RO, project administrator, AD: ITER, AD: External Collaborators, AD: Division - Diagnostics - EXT, AD: Division - Diagnostics**		

Change Log				
Title (Uid)	***Version***	***Latest Status***	***Issue Date***	***Description of Change***
Electron Cyclotron Emission (ECE) System - Panel Final Report (76HQ9Q_v2_0)	v2.0	Approved	17 Jan 2012	Minor text correction
Electron Cyclotron Emission (ECE) System - Panel Final Report (76HQ9Q_v1_0)	v1.0	In Work	17 Jan 2012	

Electron Cyclotron Emission (ECE) System

Panel Final Report

CDR Design Review

	IDM Number: ITER_D_ 76HQ9Q	Date: 17.01.2012
	Name	**Affiliation**
Author	A. E. Costley	External Consultant
Reviewers	M. Kondoh	IO/DG/DIP/CIE
	V.S. Udintsev	IO/DG/DIP/CHD/DIAG/DIAGE
	M.J. Walsh	IO/DG/DIP/CHD/DIAG
Approver	D Bora	IO/DG/DIP/CHD

	IDM Number: ITER_D_ 76HQ9Q	Date: 17.01.2012
	Name	**Affiliation**
Author	A. E. Costley	External Consultant
Reviewers	M. Kondoh	IO/DG/DIP/CIE
	V.S. Udintsev	IO/DG/DIP/CHD/DIAG/DIAGE
	M.J. Walsh	IO/DG/DIP/CHD/DIAG
Approver	D Bora	IO/DG/DIP/CHD

Contents

1. Introduction

The Conceptual Design Review (CDR) of the Electron Cyclotron Emission (ECE) Measurement System (55.F1) was held at the ITER Organization in Cadarache on 8 and 9 December, 2011. The ECE system is intended to measure the electron temperature profile with good spatial and temporal resolutions, temperature perturbations associated with high frequency MHD instabilities, for example, neoclassical tearing modes, and the total radiated power due to ECE. Measurements of ECE are also a sensitive indicator of the presence of non-thermal electron populations and under some circumstances plausible estimates of the parameters that characterise these populations (number and energy density) can be obtained from an analysis of the measured ECE spectrum.

2. Review panel & personnel

The members of the review panel were nominated by the design approver. The chair and external experts were chosen for their knowledge and experience in the field of ECE. The key participants and review panel were:

2.1. Key personnel

V. Udintsev	Design Developer (RO)
M. Walsh	Design Coordinator
D. Bora	Design Approver (DDG)
G Vayakis	Design Review Secretary
A. Guigon	Design Review Manager
Marie-France Direz	Design Review Assistant

2.2. Official review panel

A.E. Costley	Chairman
Park Sungkook	Quality Assurance Division representative
J.B. Lee	Safety Control Division representative
T. Jeannoutot	CIE representative
K.Okayama	Operation Section
W Kasparek	External expert
H Hartfuss	External expert
L Porte	External expert
G Conway	External expert
S Hughes	IO expert
A Loarte	Plasma Operations Directorate representative
D. Johnson	US Domestic Agency representative
P. Vasu	India Domestic Agency representative

One of the panel members (P. Vasu) attended remotely by video link.

3. Agenda and minutes

The meeting agenda is available under ITER_D_6XF7E7 (v1.3). A total of 32 presentations were scheduled over two days, each presentation was followed by questions and discussion. Several presentations were made via video/audio link from the USA. The Panel thanks the presenters for their participation, despite the significant time zone difference. There were two closed sessions for Panel deliberations.

The meeting notes are available under ITER_D_77W6L (v1.0) and general reference documents (DDD and Annexes) under ITER_D_4FJJP6.

4. Procedure

This design review was conducted in accordance with the ITER design review procedure ITER_D_2832CF (v1.12).

5. Diagnostic Requirements

5.1. Measurement requirements

The diagnostic measurement requirements for the ECE system are defined in the Project Requirement ITER_D_27ZRW8v4.6, and extracted in the System Design Description Document (DDD-PBS 55.F1) ITER_D_3WD9Tv1.6. The parameters identified for measurement are listed below for reference. The ECE system is identified as primary contributor for two parameters, backup for one parameter and supplementary for seven parameters. It is noted that some of the parameters will also be measured by other diagnostics.

Measurement	Parameter	Role	Contribution
04. Plasma Energy	006: βp	1a.1 Mach. prot.	Supplementary
05. Radiated power	008: Main plasma Prad	1a.2 Basic contr.	Supplementary
14. H-mode, ELMs, L-H trans.	032: ELM T_e transient	2 Physics	Back-up
15. Runaway electrons	034: Emax	2 Physics	Supplementary
15. Runaway electrons	035: I runaway	2 Physics	Supplementary
23. Electron temperature profile	052: Core Te	1b Advanced cntl.	Primary
23. Electron temperature profile	053: Edge Te	2 Physics	Supplementary
27. High frequency instabilities (MHD, NTMs, AEs, turbulence)	061: NTM δT/Te	1b Advanced cntl.	Primary
27. High frequency instabilities (MHD, NTMs, AEs, turbulence)	063: TAE δN.n, δT/T	Physics	Supplementary

5.2. Diagnostic concept and baseline configuration

The basis of the diagnostic is to measure the full spectrum of the ECE radiation emitted in the radial and near radial directions. If the spectrum is thermal, i.e. the plasma electron velocity distribution is Maxwellian, then the emission in the optically thick lower harmonics of the cyclotron frequency can be used to determine the electron temperature with good spatial and temporal resolutions. In this condition measurement requirements 04, 14, 23 and 27 can potentially be met. If the spectrum is not thermal, then potentially information on the non-thermal electron populations can be obtained, for example measurement requirement 15 can be met. The critical starting point is the determination of the thermal nature of the plasma and the analysis of the full spectrum of the ECE, including the comparison of the emission along the two lines of sight, is required for this determination.

In ECE, the absolute value of the electron temperature is determined from the intensity of the measured emission. The absolute calibration of the measurement system is therefore critically important.

The proposed baseline configuration for the diagnostic has two lines of sight, one radial and one with a toroidal angle of 10 degrees. For each line of sight, front-end optics consisting of two mirrors, one plane and one ellipsoidal, are mounted inside the diagnostic port plug. A shutter and calibration source are also included. The vacuum boundary is a double window arrangement. Beyond the vacuum break, a polariser splitter selects the extraordinary (X) and ordinary (O) mode radiations and an alignment system compensates for movements of the machine relative to the transmission lines. The X and O mode radiations are transmitted along independent transmission lines about 43 m long containing 6 bends (four lines in total). For the pure radial view, corrugated waveguide has been selected for both the X mode and O mode transmission lines. For the oblique view, smooth-walled waveguide has been selected for both lines. In the diagnostic building the lines are coupled to a four channel Michelson interferometer and to heterodyne radiometers. The Michelson will be used to measure the full spectrum of the emission (70 GHz – 1.0 THz) while the radiometers will measure the emission in the frequency range 122 -355 GHz with high temporal and spectral resolutions.

6. Review scope and charges

The scope of the ECE CDR (outlined in the agenda) was to review and assess that:

(1) Design inputs are consolidated:

- Systems requirements are identified
- Interface requirements and schedule are identified
- Horizontal requirements (environmental conditions, etc.) are identified

(2) There is at least one feasible solution concept:

- one or more system level solution concepts are likely to meet the specified objectives,
- design options are assessed and the selected design solution is justified.

(3) Impact of non-achievable requirements have correctly been assessed:

- In case of non achievability, the modifications needed to SRD have been identified
- The impact of identified non achievable systems requirements on the overall project has been assessed.

7. Response to charges: Review findings

In the CDR, the system was divided into nine sections for presentation to the Panel: system requirements, load specifications, physics assessment, front end configuration, interspace/port cell/gallery layout, spectrometer and detector components, interface identification, risk analysis and RAMI, development path and schedule. We summarise our findings in relation to the CDR charges for each section. Reference is made to the Chits that have been raised.

7.1. System requirements

The measurement requirements are clearly identified and well documented in both the DDD and the presentations. They are reasonable requirements and given good system design the ECE system should be able to meet them. Some important requirements should be added, however, and one performance requirement requires review and possible modification.

The baseline design of the system currently permits measurements of both the X and O mode radiation simultaneously along both lines of sight and the intent to meet this requirement is a major driver on the configuration of the system. While it could be beneficial to make all these measurements simultaneously, and it will help particularly in the identification and diagnosis of any non-thermal populations, the requirement to do so does not flow directly from the measurement requirements as specified in the PR or the SRD. A decision on whether this is a requirement that the design should satisfy is needed and the result should be documented in the SRD (Chit 43). The system design should then be developed accordingly. A possible compromise could be to consider this as an optional upgrade and so it only needs to be enabled in the baseline.

A second important design driver is the calibration scenario: how often will a calibration be required, how much time will be available to carry it out and how many times will the hot source be cycled? The specification of the calibration scenario must be compatible with the machine maintenance cycles. It needs to be defined and documented in the SRD (Chits 12 and 53).

There is a functional requirement for the broad-band measurement system to measure the total radiated power due to ECE. The specified frequency for the broad-band measuring system is 70 GHz – 1.0 THz. At Te = 25 keV there is significant emission above 1 THz (as shown in the presentations at the CDR). ITER is potentially capable of operating up to 40 keV and at this temperature possibly all the optically thin emission is above 1 THz. It is recommended, therefore, that the high frequency limit for the broad-band measurement should be reviewed and possibly enhanced.

The Panel was informed that Plasma Operations is in the process of specifying a number of measurements it desires from ECE covering the whole spectrum of measurement roles, from Machine Protection to Physics. What has apparently not been adequately specified is what resolution requirements (temporal and spatial) and what accuracy are required of each measurement parameter to fulfil each of these roles. For example, for the electron temperature profile, the measurement requirements are probably different for the ECE role in Advanced Machine Control versus the requirements for Physics. The precise requirements for the different roles need to be agreed and documented (Chits 20 and 59).

It is of concern that the plasma control definition and designs are so far behind the diagnostic definition and designs. This could require changes to the diagnostic system late in the implementation phase, which could result in increased cost and/or delay.

7.2. Load specifications

The specifications of the structural, electromagnetic and thermal loads on the in-vessel components seem to be comprehensive and certainly adequate for the goals of the CDR, and the plans to deal with them seem to be well in-hand. It is also noted that the IO is treating the stray ECH power as a potential load and the Panel supports this approach. The Panel does have specific recommendations in relation to the stray ECH power and possible mitigating and protecting measures (Chits 26, 39 and 51). However, there is one potentially significant load apparently not yet considered. The ECE system is located in the port together with the exit pipe of the Massive Gas Injection disruption mitigation system, which could cause significant local radiation and gas loads. Similarly, the ECE in-vessel components will be exposed to the radiation loads from ELMs (Chit 38). The impact of these loads should be estimated and, if necessary, protection and/or mitigating measures included in the design. It is also recommended that the loads on the components in the interspace should be addressed (Chits 8 and 15).

7.3. Physics assessment

The basics of ECE as a diagnostic technique are well presented in the DDD but surprisingly there is no mention in the DDD or in the presentations of the methodology of ECE, i.e. how the measurements will be processed and specifically how the required parameters will be derived from the measurements (Chit 36). The method expected to be used on ITER is that the full spectrum will be measured and compared with predictions of sophisticated ECE codes, eg the SPECAC code, with as few fitting parameters (eg vessel reflectivity) as possible. Once fitted, the outputs will be the contribution of ECE to the radiant power loss, the contribution of energy transport due to ECE to the total energy transport (expected to be significant), and a confidence statement on the thermal nature of the plasma, i.e. whether or not there are non-thermal populations. If non-thermal populations are not present then the measurements in the optically thick harmonics can be used for determining Te etc. But if there are non-thermal populations then the measured spectrum can be compared with code predictions in a fit-forward approach to try to obtain information on the non-thermal populations. The additional oblique view will help in this regard and this is the main motivation for that channel. It is expected that the ECE codes will be integrated in the suite of ITER physics codes and it is through these codes that the results of the ECE measurements will be integrated into the experimental output of ITER. It is this methodology that drives the requirement for the measurement of the full spectrum and preferably along both lines of sight.

The Panel supports the inclusion of the oblique viewing line but had some concerns about its use and implementation. Since the angle of view is oblique the X and O mode radiations will be elliptically rather than linearly polarised but a simple linear polariser will be used as the polariser selector. The size of the systematic error that this will introduce should be estimated (Chit 33). The diagnostic designers are also recommended to carry out more simulations to check if useful information can be obtained from only one angle and if the angle chosen (10 degrees) is the optimum (Chits 28). It is recommended that consideration should be given to using a steerable mirror to make measurements possible at different angles (Chit 7).

The oblique view is currently tilted toroidally towards the ECH launchers, especially towards the EQ14 horizontal launcher, which is aimed toroidally towards the ECE port. Consideration should be given to turning the oblique view in the opposite toroidal direction to reduce the coupling of ECH power into the viewing optics (Chit 4).

In ECE measurements the spatial sampled volume is a combination of the instrument resolution, antenna pattern and the natural width of the emitting layer; ideally the instrument design should be such that the natural width dominates. It is recommended that for the chosen front-end optics, the radial resolution should be determined on the basis of the beam waist as function of distance for O- and X-mode radiations and be compared with the emission width of the EC emitting layer to demonstrate that radial resolution is mainly determined by emission properties and to lesser extent by the instrumentation (Chit 23).

The contribution of ECE to the energy transport is likely to be significant under the high temperature conditions of ITER. An estimate of this contribution will be available from the ECE measurement through the use of the sophisticated ECE codes. The scale of this contribution, and how it will be obtained from the ECE measurements should be determined (Chit 34).

7.4. Front end configuration

The front-end components – in-port mirrors, hot source, shutter, first windows, splitter box and active alignment systems – are critical and important components in the system design. Since they will be installed in the vacuum vessel they have to be designed and constructed to high qualification. The integration of these components into port 9 is also important. The Panel was impressed with the level of detail in the designs at this stage, which far exceeds that needed for a CDR, and is confident that the diagnostic designers have a good grasp of the issues. The Panel feels that all CDR objectives have been met for these components.

While the baseline position of the hot-source is inside the port-plug, the Panel was informed in the presentations that consideration is being given to installing the hot-source outside the vacuum vessel close to the double windows. There are advantages for such a location but also disadvantages. Accurate calibration is fundamental to ECE measurements and so the diagnostic designers are encouraged to develop fully the advantages and disadvantaged of both locations so that an informed final decision can be made.

Two detailed points were raised in relation to the first windows. The two wedged discs of the double window feature two pairs of parallel surfaces, which will form a low gain Fabry-Perot resonator and lead to frequency dependant variations in the transmission. A suggestion is made as to how this could be avoided (Chit 25). Calculations of the transmission function for the window arrangement are required. Secondly, it is desirable to make the bond of the two elements of the double window the same geometry. This will simplify the manufacturing (Chit 9).

Access and space at the back of the port plug are severely limited. It is recommended that consideration is given to relocating the splitter box to just outside the bioshield. Enhanced access may be important to recover from ECH-induced damage or to fit in ECH protection mitigation hardware (Chit 35). The main design consideration is the maintenance of the polarisation in the additional waveguide that would be needed.

7.5. Interspace/port-cell/gallery layout including transmission lines

Three topics were covered under this heading. The methods of handling the components near to the machine using remote handling equipment, the details of the transmission lines, and the layout of the diagnostic in the diagnostic building. The solutions being developed for handling the diagnostic components were well presented and are judged to be on a good path. They fulfil the needs of the CDR. The transmission line, on the other hand, has some points of significant concern.

The baseline design uses corrugated guides on the pure radial viewing line and smooth wall guides on the oblique view. It is intended that both broad-band (with the Michelson interferometer) and narrow band (with the heterodyne radiometers) are made along both lines of sight. Accurate broad-band measurements are needed along both lines in order to be able to benefit from the oblique view: comparisons of the emission along both lines of sight are needed, with small differences being significant, to diagnose the non-thermal populations. Corrugated lines provide the lowest loss up to the Bragg frequency (typically 350 GHz) but above this frequency have poor transmission. The radiation in the guide is scattered at high angles leading to sharp frequency dependent changes in the transmission possibly with strong dependence on small changes. It is recommended that this guide should not be used above the Bragg frequency. Candidate alternatives are smooth wall rectangular, smooth wall circular, corrugated metallic with a Bragg frequency approaching 1 THz, dielectric guide, and combinations of dielectric and metallic guide, and possibly others not yet identified. The uncertainty on the choice and performance of the transmission lines, together with the uncertainty of the performance of the interferometer-detector combination (Section 7.6), prevents an accurate determination of the performance of the diagnostic for broad-band measurements. The CDR objective (2) is therefore not met for this component (Chit 56).

The proposed layout of the diagnostic in the diagnostic building looks reasonable. The space allocation for the ECE diagnostic equipment looks adequate.

7.6. Spectrometer and detector components

In the ECE area of the diagnostic building an arrangement of flat mirrors, beam-splitters and wire grid polarisers connects the transmission lines to the measuring instruments.

The baseline design proposes that the narrow-band measurements will be made with heterodyne radiometers (O mode between 122 – 230 GHz and X mode between 244 – 355 GHz), and the broad-band measurements (both O and X modes in the range 70 GHz – 1.0 THz) will be made with a four channel Michelson interferometer and the technique of Fourier Transform Spectroscopy (FTS). The Panel agree that this is a fundamentally sound approach but there are difficulties in the intended implementation and significant shortcomings in the information included in the DDD and the presentations.

Heterodyne radiometers suitable for the low frequency (< 250 GHz) narrow-band measurements are commercially available and no implementation difficulties are foreseen although care must be exercised in the design to ensure protection from stray ECH power and good thermal stability, etc. For frequencies above about 250 GHz heterodyne radiometers are not state of the art and have to be custom built. A brief discussion in the DDD of the availability and performance of heterodyne radiometers for these frequencies is recommended (Chit 31).

No details are given in the DDD or in the presentation of the four channel Michelson interferometer and so the Panel could not assess this instrument. It emerged in discussion at the CDR that the diagnostic designers intend to use a version of the rotating mirror Michelson that has been used on JET; this instrument provides multiple measurement channels. At the heart of the instrument is a small rotating, roof-top shaped, reflector. The instrument has a relatively low optical throughput – probably due to the small reflector – and as a result the time needed for the calibration is long. It may be possible to build a high optical throughput rotating mirror Michelson but this has not been demonstrated. One concern with such an instrument in this application is that, if the rotating mechanism fails, all broad-band measurements would be lost (Chit 19).

The arrangement most commonly used for ECE measurements (and FTS generally) is a reciprocating roof top mirror arrangement where both interferometers outputs are used. This has been shown to be highly reliable over many years of operation on many different tokamaks and stellarators. Instruments of this type would meet the measurement requirements.

The preferred current arrangement for Fourier transform spectrometers is a Mach-Zehnder interferometer, which gives control over all four interferometer ports [1,2]. This would be especially useful for the ECE measurements on ITER since it would enable a reference source to be placed at the second input port thereby making measurements of the performance of the transmission line routinely possible. Existing designs of Mach-Zehnder utilise a reciprocating reflector. The radiation is reflected of both sides of the reflector giving a doubling of the change in optical path difference for a given change in reflector position. This could be advantageous in the ECE application where the reflector has to be moved rapidly.

There is considerable discussion in the DDD and the presentations of the hot-source to be used in the calibration and the plans to provide and install this source are well in hand. However sources at two different temperatures are required for the calibration. Frequently, for ECE measuring instrument calibration, a microwave absorber immersed in liquid nitrogen is used for the cold source since this gives a high difference relative to a hot-source. This possibility should be explored for the ITER system. In any case, the source that will be used for the "cold" measurements needs to be defined (Chit 29).

It is not clearly stated in the DDD how the radiometers will be calibrated. Apparently the current plan is to calibrate the Michelsons using the hot-source and to cross-calibrate the heterodyne radiometers possibly on a shot-by-shot basis (this is the technique currently used on JET). It is recommended that the heterodyne radiometers should be designed and built to be stable and independently calibrated and the calibrated measurements integrated with suitable weighting (Chit 24).

The absence of the details of the Michelson interferometer, combined with the large uncertainty of the performance of the transmission line, means that it is not possible to assess the diagnostic performance relating to the broad-band measurements. This is a major shortcoming since it means that the performance of approximately half the diagnostic cannot be assessed. The performance of the entire measurement system for broad-band measurements should be determined. Key aspects are: the expected signal/noise in the calibration and important plasma measurements; the time to calibrate and the accuracy in the calibration that will be achieved; the accuracy in the important plasma measurements. The results of these estimations should be compared with the measurement requirements and documented in the DDD (Chits 57 and 58).

1) Naylor, D.A., et al., "Mach-Zehnder Fourier transform spectrometer for astronomical spectroscopy at submillimeter wavelengths", Proc. SPIE, Millimeter and Submillimeter Detectors for Astronomy 4855, 540-551 (2003).

Full text available at: http://www.uleth.ca/phy/naylor/documents/pdf/SPIE_Hawaii_MZFTS.pdf

2) Naylor, D.A. and Gom, B.G. "SCUBA-2 imaging Fourier transform spectrometer", Proc. SPIE, Optical Science and Technology, Annual meeting #48, (2003).

Full text available at: http://docs.jach.hawaii.edu/JCMT/FTS2/others/scuba-2_FTS_SPIE_San_Diego.pdf

7.7. Interface identification

Most interfaces have been addressed at the level necessary for the CDR. A few need additional treatment and/or clarification: the potential interface with the Central Safety System (Chit 45); specifications for the building waveguide penetrations i.e. port cell to gallery/gallery to diagnostics building need development (Chit 46); rough pumping of the transmission lines (and perhaps also the Michelson) using the Service Vacuum System (Chit 60). It is also recommended that an overall view of the confinement barrier plan showing barriers at both the port cell to gallery boundary and the gallery to diagnostic hall boundary should be developed and included in the DDD (Chit 40).

7.8. Risk analysis and RAMI

The Panel agree that the approach adopted for the risk identification and assessment are appropriate and that many of the risks to the system performance have been identified. Potentially effective mitigating measures are in preparation. However, further assessment of the risks will be required when the choice and concept design of the hardware for the broad-band measurements are finalised.

7.9. Development path and schedule

Sufficiently detailed and apparently realistic plans were presented for the development and delivery of the front-end in-vessel components (hot-source, shutter, in-vessel optics and first window). The Panel are confident that the diagnostic designers are aware of the difficult issues and have good plans to deal with them. The planned delivery dates will allow timely integration into the relevant port-plug (E9). On the other hand, no plan was presented for the development of the broad-band transmission line and Michelson instrument, or their delivery (Chits 44 and 50). The lack of a realistic development plan is of special concern since these components have significant design issues and require development in order to achieve the performance needed to meet the measurement requirements (sections 7.5 and 7.6). Fortunately, these components are not involved in the integration of the port-plug and so the timing is not so critical but realistic development paths are nevertheless needed. The diagnostic designers are recommended to address this urgently.

It is also recommended that the installation concept should be developed. There appear to be complex metrology and assembly tasks and it is necessary to ensure that installation at the required accuracy is feasible (Chits 47 and 48).

7.10 Other: DDD

It is clear that the diagnostic designers have put much effort into the DDD and indeed it is long with many sections but despite this significant material at the concept level is missing. Important missing material includes: the methodology of measurements of ECE; justification for the choice of the height of the lines of sight; rationale for the choice of 10 degrees as the angle for the oblique view; the concept design of the scanning Michelson interferometer(s); expected performance of the broad-band measurement system (expected signal/noise in the calibration and important plasma measurements, the time to calibrate and the accuracy in the calibration etc); development plan for the broad-band measurement system (transmission line and Michelson interferometers) (Chits 36 and 52). A major topic in current ECE research is the discrepancy in the measurements of Te made by ECE and those made by Thomson scattering at high temperatures, i.e. above about 8 keV. This has been observed routinely on JET and TFTR. There could be implications for the ECE measurements on ITER where the temperatures will be > 20 keV. This discrepancy is not understood – the implications are that it is due to distortions in the velocity distribution that occur at high levels of additional heating power – and if this is indeed the case it could mean that the probing of non-thermal populations using the combination of the radial and oblique channels becomes very important. The existence of this discrepancy and its possible implications for ECE measurements on ITER should be included in the DDD (Chit 41).

On the other hand, there are examples of duplication of material in the DDD and the authors are encouraged to find and remove them.

8. Review findings (chits)

A total of 60 chits were submitted during the course of the meeting by both panel members and observers. The chits were merged, consolidated, grouped and categorized during the final panel session and during the following week according to the prescribed criteria. After this process the number of individual chits is 45 of which 7 are category 1 and 38 category 2. The chits are listed in section 11 and are detailed in full in the IDM document ITER_D_73MTBM.

Category 1 Chits

These are design review contingent issues that must be resolved before proceeding with the next development phase.

Category 2 Chits

These are issues that are not required to be resolved before proceeding to the next development, but are of sufficient significance to require formal tracking relative to a downstream project milestone such as the next design review and design review closure.

Category 3 Chits

Issues for information - not formally tracked.

Because of the importance of the Category I chits we summarise those briefly.

8.1 Category 1 Chits

Chit 19: Design of Michelson interferometers

The design of a Michelson interferometer capable of making the required broad-band measurements was not presented and so the Panel were not able to assess the feasibility of these measurements. The design needs to be developed, assessed and documented.

Chit 38: Loads on ECE associated with disruption mitigation and ELMs

The loads that the disruption mitigating system (DMS) (and ELMs) may place on the front-end components may affect the feasibility of the ECE diagnostic sharing a port with the DMS. If this were not possible, significant rearrangement would be necessary possibly involving other diagnostic port-plugs.

Chit 43: Requirement for O and X mode measurements

The requirement for simultaneous O and X mode measurements is major driver on the configuration of the system and so this requirement needs to be defined, justified and documented, and the system design developed accordingly.

Chit 50: Section 14 in DDD: Development plan required

A plan for the development of the broad-band transmission line, Michelson interferometer(s) and high frequency (> 250 GHz) radiometer needs to be developed, assessed and documented.

Chit 53: Maximum calibration time requirement

The calibration scenario (how often and duration) is a major driver on the design of the in-vessel hot source, and will determine the time available for the end-to-end calibration. It needs to be defined and documented and all aspects of the calibration need to be developed to be consistent with it.

Chit 56: Transmission line component selection and performance

The performance of the long transmission lines is a major driver on the diagnostic design and performance at the concept level. There is currently considerable uncertainty on the performance of the lines selected for the baseline design and as a result the overall performance of the diagnostic cannot be assessed especially for the broad-band measurements.

Chit 58: Performance assessment: Estimates of signal/noise and time required for calibration

The performance of the entire measurement system - estimates of the expected signal/noise in the calibration and important plasma measurements; estimates of the time to calibrate and the accuracy in the calibration; estimates of the accuracy in the important plasma measurements - should be determined. Without these estimates it is not possible to assess the performance of the diagnostic relative to requirements.

9. Conclusions

The ECE system can be divided into four segments: the in-vessel components, the transmission lines, the measurements instruments and detectors in the diagnostic building, and the data acquisition hardware and software. The CDR concentrated on the first three since there are not expected to be conceptual or feasibility issues with the data-acquisition hardware and software.

The Panel found that the designs and preparations for the in-vessel components are, in general, well advanced and there is a high probability that when the detail design stage is completed a system that can meet requirements can be constructed along the adopted lines. There is, however, one concern: that is, that the additional radiation and thermal loads arising from the DMS system which is included in the same port plug will be significant. Potentially they could cause a significant redesign and possibly even a rearrangement of the diagnostic port-plugs. A Category 1 chit is raised on this point. Apart from this concern, it is felt that these components can proceed to detail design.

The transmission lines have to transmit the radiation needed for the broad-band measurements (70 GHz - 1.0 THz) and the narrow band measurements (122 - 355 GHz) to the diagnostic building where the measurement instruments will be located. The baseline design proposes a corrugated metallic guide for the pure radial view and a smooth wall metallic guide for the oblique view. But measurements have shown that corrugated guide has a poor transmission above the Bragg frequency (typically 350 GHz). The attenuation is high and the transmission is strongly frequency dependent and probably sensitive to small changes. In the Panel's view it is not suitable for making broad-band measurements. There are alternatives and these need to be investigated.

The motivation for the oblique view is to provide information that can potentially be used for diagnosing non-thermal populations that might well be present in the plasma especially at high levels of additional heating. The Panel supports the inclusion of this channel. But for such a use it is important that accurate broad-band measurements are available along both lines of sight. It is the differences in the spectrum along these two lines of sight that are used to infer the presence of the non-thermal populations and in attempts to determine their energy and number.

The measurement instruments consist of low and high frequency heterodyne radiometers and broad-band Michelson interferometers. No difficulties are foreseen with the low frequency radiometers. High frequency (> 250 GHz) radiometers exist but are custom built. Given sufficient care it should be possible to realize a high frequency radiometer with the required performance. More details on the high frequency radiometer are required in the DDD.

The broad-band Michelson interferometers will also have to be custom built. No details were presented to the Panel on the instrument(s) and so this instrument could not be reviewed. The combination of the poor performance of the transmission line for broad-band measurements with the lack of information on the Michelson-detector combination means that the Panel was not able to review the performance of the broad-band measurements. Since this constitutes about half the diagnostic this is a serious shortcoming. The CDR objective (2) could not be met for the broad-band measurements.

The measurement of ECE relies on an accurate absolute calibration. The inclusion of a hot-source in the system at the front end is the right approach. However, the intended calibration strategy (how often and duration) could affect the system design and so should be defined at this stage.

The presentations and the DDD provided very little information on the actual performance that could be achieved with the proposed baseline system in the measurement of ECE, probably reflecting the lack of definition of the broad-band transmission lines and Michelson interferometer-detector combination. Parameters such as the expected signal/noise in the calibration and in important plasma measurements, the time to calibrate and the accuracy in the calibration, and the accuracy in important plasma measurements were not presented. It was therefore only possible to judge the performance of the system relative to requirements in a limited way.

The development plans presented for the in-vessel components seem reasonable. On the other hand, the development plans presented for the broad-band transmission lines and the broad-band Michelson interferometers lacked substance: they were more a statement of hope rather than developed plans. The absence of these development plans is a serious shortcoming and the IO is urged to address this urgently.

It is clear that the diagnostic designers have put much effort into the DDD but important material is missing. On the other hand, there is duplication of material in the DDD. A significant improvement of the DDD is needed.

In summary, the Panel feels that the preparation of the in-vessel components and the low frequency radiometers has met the objectives of the CDR. The design of these components could proceed to the detail design phase once the Category 1 chit 38 is resolved. On the other hand, the preparations of the broad-band transmission lines and the Michelson interferometers have not met the CDR objective (2). In view of the importance of these components and the significant design issues involved the Panel recommends that the designs and development plans should be subject to expert review again when the designs and plans have reached the appropriate stage.

The Panel is grateful to the IO and to the external presenters for the quality of the presentations and for their willingness to answer the Panel questions.

10. Chit / Issue summary tables

10.1. Category 1

Chit no.	*Title*
55F1.CH019	Design of Michelson interferometers
55F1.CH038	Loads on ECE associated with disruption mitigation and ELMs
55F1.CH043	Requirement for O and X mode measurements
55F1.CH050	Section 14 in DDD: Development plan required
55F1.CH053	Maximum calibration time requirement
55F1.CH056	Transmission line component selection and performance
55F1.CH058	Performance assessment: Estimates of signal/noise and time required for calibration

10.2. Category 2

Chit no.	*Title*
55F1.CH001	Room allocation in Building 74
55F1.CH002	Philosophy of detecting NTMs
55F1.CH004	Oblique view toroidal angle
55F1.CH007	Oblique steerable mirror
55F1.CH008	Load specification
55F1.CH009	Functional requirements of window arrangement
55F1.CH012	Hot source cycles
55F1.CH013	Structural assessment of the in-port plug components
55F1.CH014	Integrity report
55F1.CH015	Waveguides
55F1.CH020	Consistency of measurement requirements with plasma control requirements
55F1.CH023	Front end optics

55F1.CH024	Integrated calibration
55F1.CH025	Windows and associated containment issues
55F1.CH026	ECH stray radiation
55F1.CH028	Oblique viewing line
55F1.CH029	Calibration source: what is the cold source?
55F1.CH031	RF radiometer technology above 250 GHz
55F1.CH032	In-waveguide power splitters
55F1.CH033	Polarisation in the oblique (10 degree) viewing line
55F1.CH034	Contribution of ECE to the energy transport
55F1.CH035	Position of front end splitter box
55F1.CH036	DDD improvement
55F1.CH039	ECH protection
55F1.CH040	Confinement barrier plan
55F1.CH041	DDD: discussion of Te(ECE) v Te(ThSc) discrepancy should be included
55F1.CH042	O mode radiometer: consider LO stabilization with a PLL
55F1.CH044	R&D Status: development plan needed
55F1.CH045	Interface with the Central Safety System (CSS)
55F1.CH046	Building penetrations
55F1.CH047	Installation planning
55F1.CH048	Alignment requirements
55F1.CH051	ECH protection strategy
55F1.CH052	Viewing height of ECE antennas
55F1.CH054	Four port splitters
55F1.CH057	ECE performance evaluation
55F1.CH059	Improve role and requirement definition
55F1.CH060	Transmission line pumping

ANNEX 1

Agenda for the Conceptual Design Review of the ITER ECE System (55.F1)

ABSTRACT

This document includes Agenda and links to the documentation needed for CDR meeting

Version	Date	Name	What
1.0	21 Nov 2011	G. Vayakis	First Release
1.1	28 Nov 2011	“”	Email and presenter corrections

Responsible Officer: **First and Last name:** Victor Udintsev
Email: Victor.Udintsev@iter.org
Phone: +33 4 42 17 84 07

Design Review Scientific Secretary: **First and Last name:** George Vayakis
Email: George.Vayakis@iter.org
Phone: +33 4 42 17 64 29

Travel: **First and Last name:** Julie Juif
Email: Julie.Juif@iter.org
Phone: +33 4 42 17 64 65

We will be using LiveMeeting only for the slides (not for video or audio). You will find the connection details for LiveMeeting at the end of this email. It is important that you mute your LiveMeeting microphone.

Meeting Room	519/019, Tel:+33442176057
Video Conference (H323)	MCU Number: +33442665207
Slides (Livemeeting)	Join the meeting
Communicator	5207@rmx.iter.org

Remote participants are invited to start testing their remote systems 30mins before for testing

TABLE OF CONTENTS

1. DATE, TIME AND VENUE

Date	from **Thursday 8 Dec 2011**	to **Friday 9 Dec 2011**
Time	(see table below)	
Venue	**Cadarache, Building 519, room 019**	

Server Time: 23 Sep. 2010 16:54					
Moscow GMT+3	**India GMT+530**	**US (Oak Ridge) GMT-5**	**EU (Cadarache) GMT+1**	**China GMT+8**	**Japan / South Korea GMT+9**
11:00	13:30	03:00	09:00	16:00	17:00

2. SCOPE AND OBJECTIVES

The main goals of the System CDR are to check that:

1. Design inputs are consolidated	*the panel should check that:* Systems requirements are identified Interface requirements and schedule are identified Horizontal requirements (environmental conditions, etc.) are identified
2. There is at least one feasible solution concept	*the panel should check that:* one or more system level solution concepts are likely to meet the specified objectives, design options are assessed and the selected design solution is justified.
3. Impact of non achievable requirements have correctly been assessed	*the panel should check that:* - in case of non achievability, the modifications needed to SRD have been identified - the impact of identified non achievable systems requirements on Overall project has been assessed

3. LINKS TO DOCUMENTS

DR presentations material will be available under: 02_Presentations_Meetings
The Input Package will be available under: 02_Technical Documentation

The Engineering data (Plans, Documents, Schematics, CAD Data, Drawings …) provided as Input Data Package (Data/documents to be provided) and the aspects to be reviewed by the Review Panel at each Design Review are detailed in [1]. All the documents should be "approved" before their submission to the Review.

The System Design Description Document (DDD-Folder) gathers DDF and DJF. The DDD folder evolves and gets completed during the Design development.

The Input Package is filed as follows:

In 01_DDD	System Design Description Document (DDD) Diagnostic – Electron Cyclotron Emission (679HW9) (DDD)	
In 02_Annexes	**Section**	**Content**
	01_FunctionalAnalysis & Risk	Functional block diagram, Risk table, etc.
	02_Classification	In DDD
	03_Drawings3DCadModels	Schematics
	04_CMM	
	05_SRD_DCM	Design Compliance Matrix (CDR level)
	06_InterfacesIdentification & Tracking	In DDD
	07_Load & StructureIntegrity	Load Specification and Structural Integrity Report
	08_RemoteHandling(RH)	Remote Handling
	09_Schedule	
	10_OtherAsAppropriate	Empty

Ref	Document	Reference
[1]	Design Review Procedure (2832CF)	ITER_D_2832CF **v. 1.12**
[2]		
[3]		
[4]		
[5]		
[6]		

4. LIST OF ATTENDEES

NAME	MAIN ROLE	UNIT	E-MAIL
Victor Udintsev	Design Developer	CHD/Diag	Victor.Udintsev@iter.org
Michael Walsh	Design Coordinator	CHD/Diag	Michael.Walsh@iter.org
Dhiraj Bora	Design Approver	CHD	Dhiraj.Bora@iter.org
George Vayakis	Design Review Secretary	CHD/Diag	George.Vayakis@iter.org
Alain Guigon	Design Review Manager	CIE/SECM	Alain.Guigon@iter.org
Marie-France Direz	Design Review Assistant	CHD/Diag	Marie-France.Direz@iter.org
PANEL			
Alan Costley	Chairman	EU	Alan.Costley@physics.org
Ce Ye	IO Quality Assurance Division representative	IO/DG/SAS/ QA	Ce.Ye@iter.org
J.B. Lee	IO Safety Control Division representative	IO/DG/SAS/SCD/SCS	JeongBae.Lee@iter.org
T. Jeannoutot	CIE representative	IO/DG/DIP/CIE/TI/DIN	Thomas.Jeannoutot@iter.org
K.Okayama	Operation Section	IO/DG/DIP/CIE/AOP/OPS	Katsumi.Okayama@iter.org
A. Loarte	IO FS&T representative	IO	Alberto.Loarte@iter.org
W. Kasparek	External expert	KIT, EU	kasparek@ipf.uni-stuttgart.de
H. Hartfuss	External expert	IPP-Greifswald, EU	hartfuss@ipp.mpg.de
L. Porte	External expert	EPFL/CRPP, EU	laurie.porte@epfl.ch
G. Conway	External expert	IPP-Garching, EU	Garrard.Conway@ipp.mpg.de
S. Hughes	IO expert	IO	Shaun.Hughes@iter.org
D. Johnson	Domestic Agency rep.	US DA	djohnson@pppl.gov
P. Vasu	Domestic Agency rep.	IN DA	vasu@iter-india.org
PRESENTERS			
M. Austin		University of Texas	max.austin@mail.utexas.edu
A. Encheva		IO/DG/DIP/CHD/DIAG/DIAGE	Anna.encheva@iter.org
R. Feder		PPPL (US)	rfeder@pppl.gov
G. Hanson		ORNL (US)	hansongr@ornl.gov
A. Hubbard		MIT (US)	hubbard@psfc.mit.edu
D. Johnson		PPPL (US)	djohnson@pppl.gov
P. Maquet		IO/DG/DIP/CHD/DIAG	Philippe.Maquet@iter.org
K. Okayama		IO/DG/DIP/CIE/AOP/OPS	Katsumi.okayama@iter.org
H. Pandya		ITER-India, IPR (IN)	hitesh.pandya@iter-india.org
K. Patel		IO/DG/DIP/CHD/DIAG/DIAGE	Kaushal.Patel@iter.org
P. Phillips		University of Texas	p.phillips@mail.utexas.edu
E. Popova		RF DA	l.popova@iterrf.ru
S. Simrock		IO/DG/DIP/CHD/CSD/CDC	Stefan.Simrock@iter.org
P. Vasu		IPR (IN)	parameswaran.vasu@iter-india.org
M. Walsh		IO/DG/DIP/CHD/CSD/DIAG	Michael.Walsh@iter.org
J. Snipes		IO/DG/DIP/POP/SD/PLS	Joe.Snipes@iter.org
Y. Zhai		PPPL (US)	yzhai@pppl.gov

5. AGENDA FOR CDR

CET	List of topics of the presentations	Talk + Q&A	Presenter
09:15	INTRODUCTION		
09:15	Welcome	5' + 0'	M. Walsh
09:20	Chairman's message	5' + 0'	A. Costley
09:25	REQUIREMENTS		
09:25	ECE roles and requirements	20' + 10'	V. Udintsev
09:55	ECE Operational role – Control Requirements	10' + 10'	J. Snipes
10:15	ECE Functional Analysis and control scheme	15' + 10'	V. Udintsev
10:40	COFFEE BREAK		
10:55	LOAD SPECIFICATION		
10:55	Disruption and thermal loads	10' + 10'	A. Encheva
11:15	ECH radiation loads	5' + 5'	G. Hanson
11:25	PHYSICS ASSESSMENT		
11:25	ECE state-of-the-art	30' + 10'	V. Udintsev
12:05	LUNCH		
13:05	Overall system layout, conceptual design overview, and assessed performance relative to requirements	25' + 10'	M. Austin
13:40	End-to-end alignment/calibration stability strategy	10' + 10'	M. Austin
14:00	Utility of oblique view	15' + 10'	A. Hubbard
14:25	ECH protection strategy	10' + 10'	G. Hanson
14:45	COFFEE BREAK		
15:00	FRONT END CONFIGURATION		
15:00	Integration of ECE diagnostic into E9 vertical drawer including interface with diagnostic first wall	15' + 10'	R. Feder
15:25	Disruption loading on ECE components	10' + 5'	Y. Zhai (R.Feder)
15:40	Thermal loading on ECE (EqP09) components	10' + 5'	R. Feder
15:55	Anticipated relative motions	5' + 5'	R. Feder
16:05	Windows and associated containment issues	10' + 5'	P. Maquet
16:20	In-situ hot calibration source	15' + 5'	P. Phillips
16:40	Shutter concepts	10' + 10'	P. Phillips (R.Feder)
17:00	PANEL BREAKOUT DISCUSSION	60' + 0'	
18:00	*End of Day One*		

CET	List of topics of the presentations	Talk + Q&A	Presenter
08:30	Clarification Presentations	30' + 0'	All
09:00	INTERSPACE/PORT CELL/GALLERY LAYOUT		
09:00	ECE interspace/port cell/gallery waveguide components	10' + 5'	H. Pandya
09:15	E9 Interspace/Port Cell support structure	10' + 5'	E. Popova
09:30	DETECTOR COMPONENTS		
09:30	Detection overview	10' + 5'	V. Udintsev
09:45	Waveguide switching unit	10' + 5'	H. Pandya
10:00	COFFEE BREAK	15' + 0'	
10:15	IN DA Michelson design	10' + 5'	H. Pandya
10:30	IN DA O-mode radiometer design	10' + 5'	H. Pandya
10:45	US DA X-mode radiometer design	10' + 5'	M. Austin
11:00	INTERFACE IDENTIFICATION		
11:00	Summary of interfaces	10' + 5'	E. Popova
11:15	RH interfaces	10' + 5'	V. Udintsev
11:30	LUNCH & TOUR OF ITER SITE	90' + 0'	
13:00	I&C interfaces	10' + 5'	S. Simrock
13:15	Vacuum and safety interfaces	10' + 5'	K. Patel
13:30	RISK ANALYSIS AND RAMI		
13:30	Risk Table	10' + 5'	V. Udintsev
13:45	RAMI	10' + 5'	K. Okayama (M-F.Direz)
14:00	DEVELOPMENT PATH		
14:00	Waveguide selection	10' + 5'	H. Pandya
14:15	COFFEE BREAK	15' + 0'	
14:30	Hot source development and qualification	5' + 5'	P. Phillips
14:40	Shutter development plan	5' + 5'	P. Phillips
14:50	Window development plan	5' + 5'	P. Maquet
15:00	ECH rejection development plan	10' + 5'	G. Hanson
15:15	SCHEDULE		
15:15	High-level US milestones	10' + 5'	D. Johnson
15:30	High-level IN milestones	10' + 5'	P. Vasu
15:45	COFFEE BREAK	15' + 0'	
16:00	PANEL BREAKOUT DISCUSSION	105' + 0'	
17:45	Closeout presentation	15' + 0'	A. Costley
18:00	*End of Day Two*		