Assessment of the ITER High-Frequency Magnetic Diagnostic Set

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The ITER high-frequency (HF) magnetic diagnostic has to provide essential measurements of MHD instabilities. The Project Requirements [1] specify the measurement of oscillating fields $|\delta B_{MEAS}/B_{POL}|\sim10^{-4}$ (1G) for frequencies up to 2MHz to resolve toroidal (n) mode numbers in the range |n|=10-50. The current design of this diagnostic system includes two main arrays for n-number detection, each one with 2x18=36 equi-spaced sensors located at the corners of the equatorial ports, and one array for poloidal (m) mode number detection, built on 16 un-evenly spaced sensors covering the entire poloidal cross-section but the divertor region, replicated on six machine sectors. Initial provisions exist to add high-resolution arrays on the horizontal and vertical edges of some of the equatorial ports to improve the measurement performance.

The ITER design for the HF magnetic sensor is that of a conventional Mirnov-type pick-up coil, with a target effective area ~0.05-0.10m^2. This sensor is made with 33 turns each on 2 separate layers, wound using a tungsten wire over a hollow hexagonal ceramic former, acting as a wire spacer, with each spacer being made of 6 individual winding guides, kept together by the constraining action of the wire. A slotted stainless steel core supports the former (diffusion-bonded to it), and also improves thermal conduction. Finally, a thermal shield with a thick longitudinal cut is added to protect the entire assembly.

A review of the measurement requirements for HF MHD instabilities in ITER was initiated during the TW4 work-program and led to significant interest for physics and real-time control issues in measuring HF modes with $|\delta B_{MEAS}|$ as low as ~10^{-4}G at the position of the sensors, with $|n|\leq30$ and $|m|\leq60$, but for a lower frequency range, extending only up to ~500kHz [2].

This work reviews the rationale for these more stringent measurement requirements, then focuses on examining the ability of the current design for the individual sensors and the diagnostic system as a whole to meet the more stringent needs, and finally explores what adjustments to the design (of the individual sensors and/or of the system as a whole) or to the requirements would be needed to meet them when considering different hypothesis for the financial costs and risk management over the ITER life-time.

First, we find that the proposed diagnostic layout, with 168 sensors in total, does not meet the more stringent measurement requirements and risk management criteria: these can only be met by a revision of the design, requiring 350-500 sensors, depending on different costing and risk management options, which would also give a much improved redundancy in the n- and m- number measurement capabilities over the machine life-time.

Second, we find that the current design for the ITER HF Mirnov-type pick-up coil could be usefully revised, and this analysis will be reported in more details in a companion paper [3], which will also describe various alternative exploratory designs for the sensor.

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[1] ITER Project Requirements, ITER_D_27ZRW8 v4.5 and ITER N55DDD1_01-06-12_W0.3
[2] see bibliography available at: http://crpp.epfl.ch/itermag/index.php/SCI:Bibliography.
[3] M.Toussaint, D.Testa, et al., to be presented at the SOFT 2010 conference.