Ferroelectric Materials And Metamaterials For A New Approach To ITER-ICRH Loads

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Preliminary laboratory testing of ICRH antennas is a very useful step before their commissioning. Traditionally, ICRH loads used for this task contain pure water, salt water or baking soda water. These "water" loads are convenient because they are cheap, easy to implement and reliable but strongly limited in terms of testing performances because of the relatively low water permittivity ($\varepsilon'_r \approx 81$), far below plasma permittivity values ($\varepsilon'_r \approx 1\ 000$ in the periphery and $\varepsilon'_r \approx 4\ 000$ on the ITER machine axis).

Calculations have been done with the HFSS® (High Frequency Structure Simulator by ANSOFT) code: a baking soda water load facing an ITER-Like antenna does not exceed 3 ohm/m in terms of coupling resistance at 50 MHz. Yet the antenna range, leading to a Standing Wave Ratio less than 1.5, is 2 - 6 ohm/m. Hence, such a load does not permit to test this antenna properly.

HFSS calculations have shown that 6 ohm/m is reached for $\varepsilon'_r \approx 1\ 500$ [1].
Two different approaches are possible for reaching such high values: ferroelectric materials and metamaterials.

Ferroelectric materials, with their inherent high permittivities, are good candidates.
We have selected a Baryum Titanate powder previously measured and presenting an $\varepsilon_r \approx 500$ at 50 MHz [2] and proceeded to the compression of this powder at a high temperature of 700 °C. We have obtained a ferroelectric ceramic presenting a remarkable performance of $\varepsilon_r \approx 1\ 400$ at 50 MHz perfectly fulfilling our needs.

Experiments with loads made of ferroelectric powder, ceramic powder or a mix of both, are planned.

Metamaterials are also very good candidates because they offer the possibility of extended ranges in terms of electromagnetic properties. In collaboration with ONERA, the French Aerospace Laboratory, we have completed a study with numerous calculations and obtained a solution for an array of wires loaded with capacities presenting $\varepsilon_r \approx 1\ 500$ at 50 MHz. We are currently considering an "active" load, e.g. an active resonant absorber [1], able to simulate plasma instabilities such as ELMs that modify strongly and quickly the impedance seen by the ICRH antenna (a coupling resistance exceeding 10 Ω/m is expected within 100 µs).

[1] : H. Bottollier-Curtet et al., Proc. SOFT (2008)
[2] : H. Bottollier-Curtet et al., Proc. RF Topical (2009)