1. Purpose of Experiments

The purpose of this experiment is to assess the performance of a possible load tolerant configuration on the ICRF transmission line network. We want to evaluate its ability to reduce the loading variations for the usual operating conditions in C-Mod and, if successful, determine the robustness of the system. Also, potential side-effects of the system on antenna performance and heating efficiency will be monitored.

This experiment is a preliminary investigation for the C-Mod milestone “Design of a load-tolerant ICRF antenna”. To date, it would also be the first experimental test of a load tolerant configuration in the world fusion program.

2. Background

Load tolerant networks are particularly attractive prematching techniques in ICRF transmission line network and have attracted much attention in the last few years. Pre-matching systems are traditionnaly meant to lower the voltage standing wave ratio (VSWR) as close as possible to the antenna structure. They are usually designed to withstand high voltages and therefore cannot be made easily tunable, but they complement tunable impedance matching networks, whose more complex components must be protected against high VSWR at their input.

A load tolerant configuration not only fullfil this task, but it can also maintain the voltage standing wave ratio very low for a wide range of loading conditions. This is an highly desirable feature, since ELM activity and L-H transitions can lead to significant and very rapid ($10^{-4}$s) variations of the loading impedance. These variations are too severe and fast to be handled by existing impedance matching networks and they can result...
in higher voltages in the whole transmission system and the generator, thus lowering the power limits of the system. A system with load tolerant capabilities could effectively lower the negative impact of these variations.

It was realized recently that the resonant double loop (RDL) prematching system, proposed at Oak Ridge in the mid-80’s, could be made load tolerant under certain conditions. The RDL design antenna allow effective prematching inside the antenna structure and keeps the VSWR low in the vacuum feed-through and subsequent lines towards the generator. It has been implemented and used successfully on JET, TFTR and Tore-Supra for prematching. If efficient and robust load tolerant operations could be also achieved with this system, it would constitute a very attractive candidate for future ICRF designs.

Two main issues remain for applicability in next step designs. First, the system requires capacitive components, and the vacuum sealed variable capacitors which have been used so far are inadequate in reactor conditions; work is being done to develop equivalent components with higher voltage standoff and better resistance to neutron radiation. Second, there has been no experimental demonstration of effective load tolerant operations in the world fusion program, and no assessment of potential effects on the overall behaviour of the antenna during such operations. A complete new antenna design is required to perform this test with the RDL scheme, and this work is being done with the JET ITER-like antenna, but it would be desirable to evaluate the load tolerant concept independently. Alcator C-Mod, with its center-grounded design on D and E antenna, can fulfill this objective with relatively simple modifications of the existing setup.

This evaluation is also directly relevant to the Alcator C-Mod program, as a necessary initial step in the design of a new load-tolerant four-strap antenna. If it proves successful, the system could be also kept in place and used for routine operations.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The methodology for the design and tuning of the load tolerant network will be explained separately and we will here only mention the approach for plasma operations. The flattop time for the discharges will be relatively low as we are only interested in the ICRF pulse.

Three steps are required: First, a set of standard ICRF on axis discharges will be used as an early low power test of the system electrical behavior and will allow fine tuning of the stubs in the network. If acceptable operations can be obtained, the power from E antenna will be increased, still with a standard plasma target, to monitor potential degradations of the system on the plasma performance and ICRF heating efficiency. The power limits of the load tolerant configuration will also be determined. If this second step is successful, we will use the remaining time to explore different target plasma conditions (H-modes, L-H transitions, different magnetic fields, different densities) using the D and J antennas. The experiment might be stopped in the first or second stage if the performance is unacceptably poor.
Spectroscopic measurements for the metallic impurities will provide information on potential impurity release from the Faraday Shield or from far-field sheaths effects if the single pass absorption is low.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 5.3 T
Plasma Current: 0.8 MA
Working gas species: Deuterium, Hydrogen minority < 10%
Density: $0.9 \times 10^{20} m^{-3}$
Equilibrium configuration (if possible, refer to database equilibria): Standard diverted ICRF target plasma
Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms: Flattop 1.0 s.

4.2 Auxiliary Systems

RF Power, pulse length, phasing: D, J max power (J in heating phasing).
Pellet Injection (species): None
Impurity blow-off injection: None
Diagnostic Neutral Beam: None
Special gas puffing: None
Other: None

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Standard set plus spectroscopic measurements (Chromex) for metallic impurities.

5. Experimental Plan

Both sections must be filled in.
5.1 Run sequence plan
Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period (10 hours maximum), etc.

1/2 to 1 day. 1-2 days of maintenance will be required before the run to set the system up on the transmission line network. If the performance is not acceptable for usual operations, ohmic runs, ICRF runs with D-port and J-Port only or maintenance should also be considered after this run.

The run might also be finished earlier than expected if performance is unacceptably poor.

5.2 Shot sequence plan
For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

Start with a standard 80 MHz on axis discharge (5.3 T, 1.0 MA, 0.9 \( \times 10^{20} \text{m}^{-3} \)).

Discharges 1-5 are used for step 1: Early evaluation of the system and fine tuning of the stubs. 500 kW from E-Antenna, no demand from D and J.

If the system performance is acceptable, increase power from E by 200 kW increments to determine power limits. Monitor impurity concentrations and heating efficiency. Use D-antenna independently before E in the same discharges with the same power level to provide comparison of the performance. 7-9 discharges (step 2). Repeat as the power limit is reached in order to collect data on the limiting phenomena.

If performance is acceptable at this point, depending on the limiting phenomena, investigate different plasma targets in order to determine the extent to which the configuration can be used for normal operations and compare with performance without the system:

- use D and J antennas to achieve higher input power H-modes (which lead to lower loading). 2-3 discharges.
- increase or lower plasma density 2-3 discharges
- vary the plasma shape, reduce or increase the gap 2-5 discharges

6. Anticipated Results
Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

This experiment will give important results from the milestone “Design of a load-tolerant ICRF antenna”. If the system performance is good and lead to an improvement over the present configuration, it can be used for routine operations during the experimental campaign.

As this is the first test of a load tolerant configuration in the world fusion program, this is very likely to lead to a publication.

7. References
Include references both to external and internal literature or communications which bear on this proposal. See Section 2.