Impact of gas injection on ICRF antenna loading properties on TEXTOR

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Two pairs of antennae are used for RF heating at TEXTOR: the first one is tuned using a stub, a line stretcher and an autotuning system and the second one is matched using a Conjugate-T (CT) matching system [1,2].

The determination of the antenna loading resistances is based on the measurement of the reflection coefficient using directional couplers and on the determination of the standing wave pattern in the transmission lines using capacitive voltage probes[3]. The antenna loading resistances are determined separately for each strap of each antenna pair neglecting the mutual coupling between the straps.

Measurement of the impact of gas injection on antenna loading is carried out in He and in D plasma using respectively injection of He and D.

Impact of gas injection on antenna loading in Helium plasma

When operating TEXTOR in Helium it is possible to measure in the same discharge the change in antenna loading during a density scan with gas injection valve open and closed.

The increase in density is obtained by first opening a fast injection valve located 1.7m away from the antenna CT and by then leaving the density decrease after valve closure. The magnetic field lines connect the gas injection valve to the CT antenna. In figure 1 we present the time evolution of the antenna loading resistance for the 2 straps (3 and 4) of the CT antenna. Helium is injected between t=1.6 and 2.5 s to create a linear increase of the mean central line integrated density $\overline{n_{e0}}$. At t=2.5s the valve is closed and the density slowly decreases. When changing the time of valve closure we change the value of the maximum density reached and, consequently, the range of density decrease after valve closure. The magnetic field is B_T=1.9T and the RF frequency is 29 MHz corresponding to a minority heating scenario of H. The minority concentration was changing between 5 and 10 % and 200 kW of RF power is injected. The evolution of the loading resistance versus density shows peaks when density is increasing monotonically. The existence of those peaks is confirmed by the measurements of the voltage near the antenna and in the transmission line close to the matching capacitors.

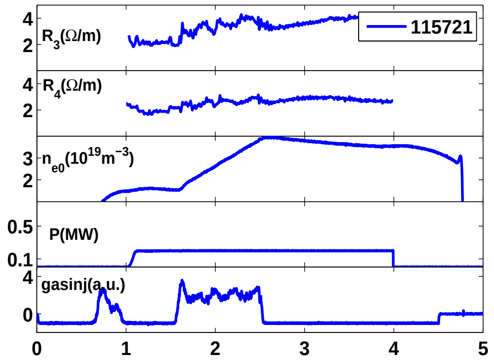


Figure 1 Time evolution of loading resistance (R3,R4) of the two CT antenna straps , line integrated density, RF power and signal indicating gas injection .

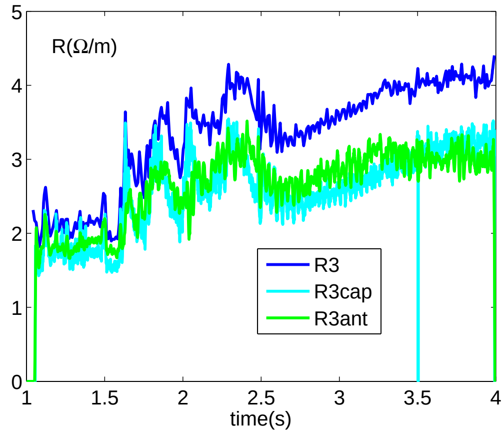


Figure 2 Comparison of the evolution of loading resistance versus time using standard method (R3) or deduced from voltages measured near the antenna or close to the capacitors (R3ant,R3cap)

The loading resistance is deduced from voltages near the antenna and power in the transmission line neglecting the impact of change in inductance. Different estimations of R3 are presented in figure 2. The impact of change in inductance on the uncertainty in R is 4%. The relative change of the loading during gas injection is confirmed.

The values of the loading measured in consecutive discharges are very similar when plotted as function of $\overline{n_{e0}}$. In figure 3 we compare the loading resistance measured during consecutive shots in the phase with and without gas injection. There is no significant impact of the gas injection. At the same density the density profiles measured by interferometry are also very similar.

The measurements were repeated with the plasma displaced 1cm away from the antenna. As expected, at same density the loading is lower than in the shot with plasma closer to the antenna; it is increased when the density increases but again the direct impact of gas injection is negligible.

Analysis of antenna loading in Helium plasma, comparison with modeling

The Antiter code [4] was adapted for TEXTOR and used to analyze the antenna loading measurement. We first compare the results of measurements during plasma displacement 2cm away from the antenna between t=1.5 and 4s. We modeled helium plasma with a low minority of H, neglecting the impact of He^{+}, and full absorption of the wave in a single pass, the density profile is measured by interferometry,.

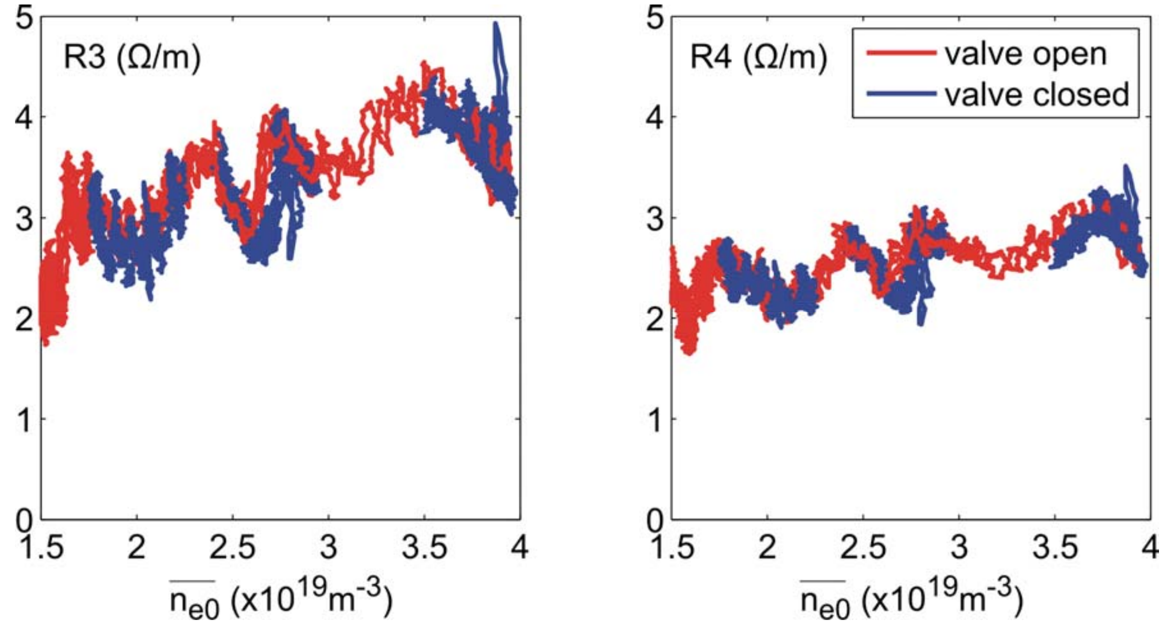
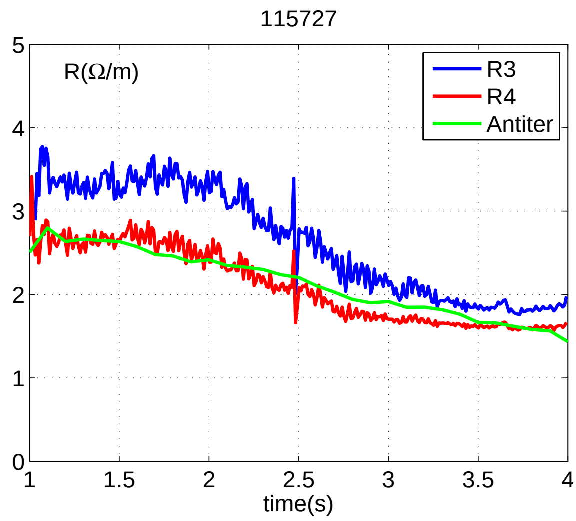


Figure 3 Comparison between the evolution of the loading resistance vs $\overline{n_{e0}}$ with gas injection valves open or closed

Results are presented in figure 4a. In Figure4b the evolution during gas injection of the loading for the shot described in figure 1 is presented.



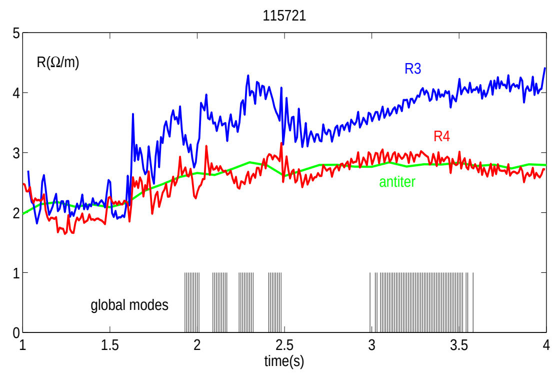


Figure 4b

Figure 4a

Figure 4 Comparison between the measured loading resistance (R3 and R4) and the one predicted by the Antiter code. Phase difference between the straps is $\pi/2$.

The evolution of the loading with the position of the plasma is in agreement with model prediction but the peaks observed during gas injection are not predicted by the model. Similar peaks have already been observed on TEXTOR [5,6] and are attributed to global modes. The Antiter code was used to estimate the densities at which increase of loading is expected if the wave is reflected after one transit. The absorption mechanisms are not modeled in the coupling code Antiter. This prevents its use to model the loading when global modes are present. Simulations with the BRACC code show that excitation of global modes due to poor absorption of the wave by the plasma may be responsible for this behavior and that the amplitude of oscillation is similar to the observed one (figure 5).

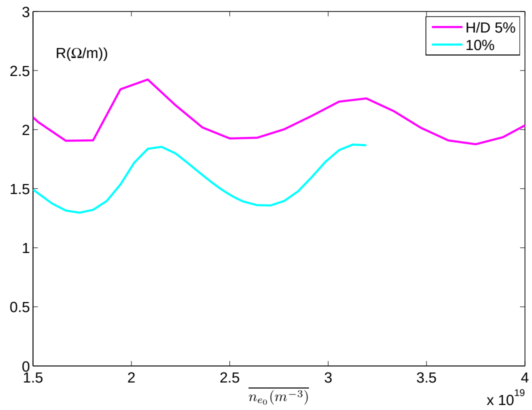


Figure 5 Evolution of loading resistance versus $\overline{n_{e0}}$ for 2 values of Hydrogen minority concentration deduced from run of BRACC code for constant density in the edge.

The change of density profile during gas injection was however not taken into account in the modeling with the BRACC code which prevents good prediction of the evolution of the loading with gas injection and of the exact location of the peaks.

Impact of gas injection on antenna loading in Deuterium plasma

It was not possible to analyze the impact of gas injection in NB heated deuterium plasmas in the same way as in Helium plasmas because due to recycling the density remains almost constant at the end of the gas injection. The loading resistances in Helium and in D plasma are very similar, which it is expected as the role played by He^+ in the edge is negligible. The impact of gas injection using magnetically connected valves with non magnetically connected valves in beam heated plasma is compared and it is found that the impact of the choice of the gas injection valve is very small with respect, for instance, to the perturbation accompanying the sawtooth activity.

Conclusion

ICRH antenna coupling studies at TEXTOR conclude that the impact of gas injection on coupling is mainly due to the change in density profile. No direct impact of gas injection on coupling was observed. Use of a dedicated valve located close to the antenna in combination with density measurements in front of the antenna could be useful to complete this study.

References

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