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ICRF antenna coupling in different heating scenarios and impact of phasing during experiments on TEXTOR

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Introduction

Measurements of the impact of plasma conditions on the antenna distributed loading resistance are carried out at TEXTOR to study the coupling of the wave to the plasma for various types of discharges and different heating scenarios. Two different antenna pairs are used: the first one is tuned using a stub, a line stretcher and an autotuning system [1] and the second one is matched using a conjugate-T (CT) matching system [2]. The antennae are not completely covered but are equipped with a protection of the feeder area: graphite plate for antenna 1, partial Faraday shield for antenna 2. The measurements of the antenna resistances at TEXTOR are based on the determination of the standing wave pattern in the transmission lines between the ICRH generator and the RF antennae using voltage probes and directional couplers. Measurements of voltages and currents inside the antenna box of the CT antenna are used to check the consistency of the data.

Impact of heating scenario on antenna coupling

Three heating scenarios were studied during the same day of experiment to insure similar wall conditions: minority heating D(H), heating at the second harmonic of H D(H) and heating at the third harmonic of Deuterium. The frequency of the generators is kept constant and the different absorption layers are located in the center of the plasma by changing the magnetic field. Minority, 2nd harmonic of H and 3rd harmonic of D heating are obtained respectively at B_t=2.6T, 1.3T and 1.75T for a RF frequency of 38 MHz. The evolution of antenna resistance in function of mean line integrated density at R =2.15m shows similar trends and absolute values for the 3 scenarios (figure 1). All resistances in figure 1 correspond to discharges with more than 300 kW power at the generator. At lower heating power (P<300 kW) the loading resistance of the CT antenna depends on the applied power. This is shown in figure 2 where we present the loading resistance as a function of the power for 4 discharges at B_T=1.3T and I_p=240 kA. The power is increased slowly to 4 different maximum powers (upper right box in figure 2). The power dependence of loading is well fitted by $R_t = R_l + \frac{\alpha}{\sqrt{P}}$ where P is the RF power coupled at the corresponding antenna. (The slight rise of resistance observed at high power is due to density increase).

Such loading dependence with power is observed in case of sheath effect. Perturbation of the density profile in the vicinity of the antenna caused by the RF field may also play a role. This decrease of loading resistance is confirmed by independent measurements of decrease of phase difference ($\Delta\Phi$) between the currents in the straps of the CT antenna. This decrease of $\Delta\Phi$ is inherent in the properties of the CT matching system.

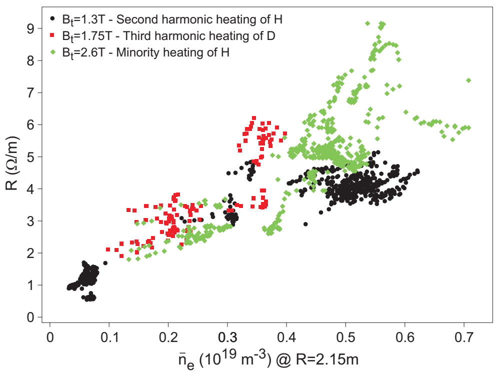

Figure 1 Antenna strap loading resistance as function of line integrated density measured at R=2.15m for different magnetic fields corresponding to 3 different heating scenarios: 2nd harmonic of H, 3rd harmonic of D and minority heating.

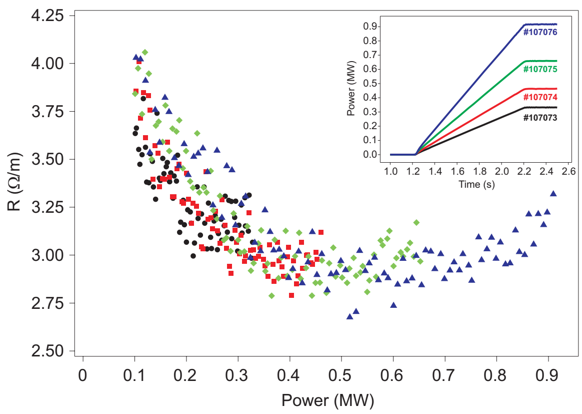

Figure 2 Antenna strap loading resistance as function of power for 4 consecutive discharges .Evolution of power with time is shown in the upper right corner of the figure.

Impact of phasing between the current in the 2 straps of the conjugate-T antenna

In the CT – matching antenna a good resilience to change in loading is obtained but at the expense of a change of the phase difference ($\Delta\Phi$) between the currents in the straps of the antenna pair. It is therefore useful to study the impact of the change of $\Delta\Phi$ on plasma and on coupling properties. By changing the values of capacitors and the lengths of the line stretchers it is possible to control $\Delta\Phi$ at a given loading resistance at the expense of a somewhat degraded loading resilience. In figure 3 and 4 values of $\Delta\Phi$ and loading resilience are presented for some combinations of the tuning parameters. In figures 5-7 the measured values of $\Delta\Phi$, central density and loading resistance obtained for those combinations are presented. In figure 7 the evolution of loading resistance during the increase of the power is also shown. The values of $\Delta\Phi$ directly measured between the currents in the straps are in agreement with the calculated ones and confirm that we are able to control the phase between the straps. The central density modification due to change of phase are modest. Density in the edge of the plasma is higher in case of $\Delta\Phi$=0 or π/2. This may explain the difference between loading resistances. It is observed also that the intensity of the radiation of the metallic impurity is enhanced and that the low power loading resistance is higher (figure 7). Those effects may be due to a higher power absorbed in the edge of the plasma or in the sheath.

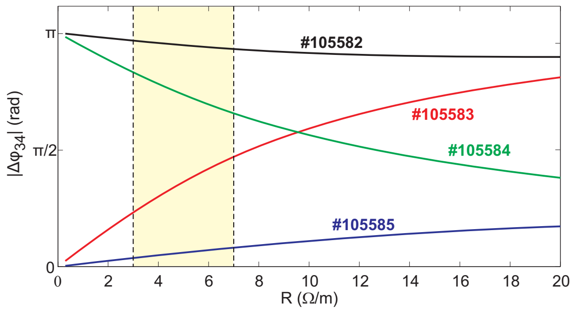

Figure 3 Predicted impact of tuning conditions on phase between the currents in the straps of the CT antenna as function of loading resistance.

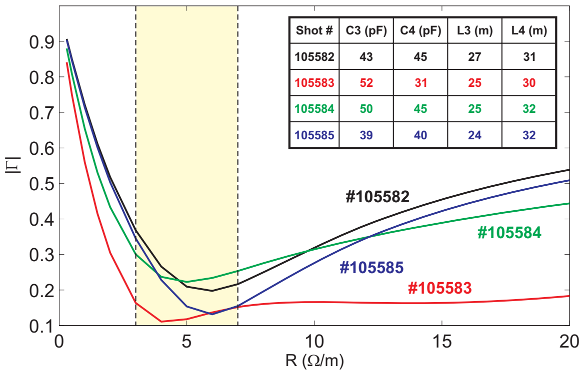

Figure 4 Predicted reflection coefficients for the same tuning parameters showing the loss of resilience.

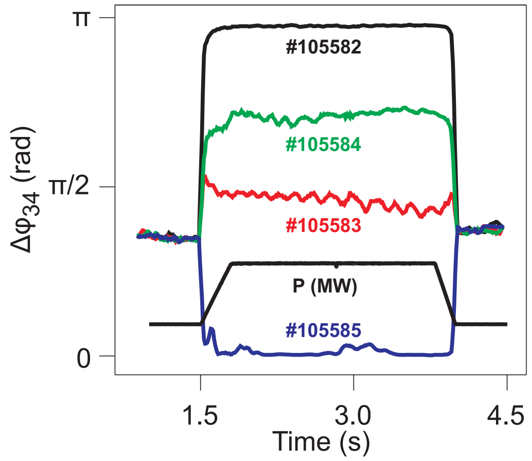

Figure 5 RF power and phasing as function of time

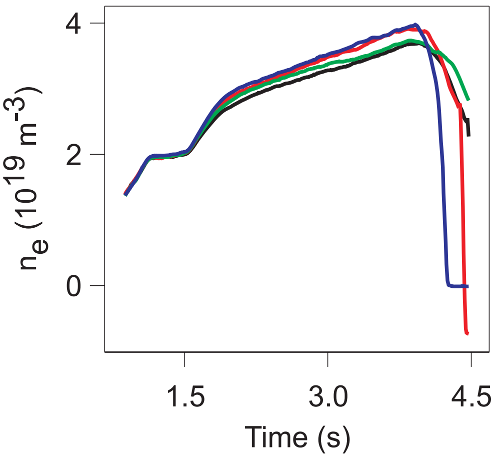

Figure 6 Line integrated central density for the different phasings.

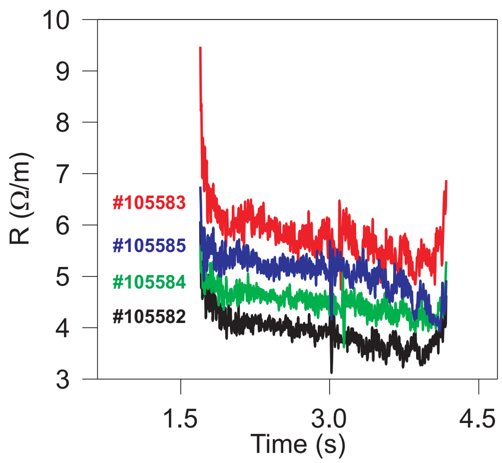

Figure 7 Evolution of the loading resistance during power increase for the different phasings.

Impact of the ELMs on the coupling

In case of ELMy discharges [4,5] the evolution of the loading impedance of the two antennae, located opposite in the toroidal direction, are compared using fast data acquisition for all the voltage and current probes and directional couplers in the transmission lines and near the antennae. A strong increase in the antenna loading resistance is deduced from the evolution of the reflection coefficients in the transmission lines. The change of inductance remains lower than 5%. Due to the increase of coupling a drop of antenna current and voltage at the antenna is observed at the time of the ELM. The ratio of those 2 quantities is rather constant in all types of discharges (directly linked to the antenna inductance) but at the time of an ELM an abnormal drop of the current at the short circuit of the antenna is observed that may be induced by local plasma.

Impact of gas puff on coupling

During H mode experiments or during DED experiments the plasma is pushed to the inner wall far away from the antenna. In this case the antenna loading becomes unacceptably low. To try to improve coupling Deuterium was injected through a valve located close to the RF CT antenna (same toroidal location but 90º away in the poloidal direction; not magnetically connected to the antenna). An amount of 2 mbar litre/s was injected. A ~12 % increase of the loading resistance was obtained. The density of the plasma at R_0 and the line integrated density at R=2.15m were modified respectively by 5% and 9%. The increase of loading resistance obtained by means of gas puffing close to the antenna is small. Further increasing this injection induces arcing in the antenna.

Conclusions

In this study of the antenna coupling in different heating scenarios at TEXTOR with similar plasma conditions it is observed that the antenna loading depends more on the density at the edge of the plasma and on the thickness of the evanescent layer than on the heating scenario. The dependence of loading impedance on power may be due to sheath effect or to change of density in the vicinity of the antenna induced by the RF. To make a clear distinction between the roles played by both effects local measurement of density in front of the antenna will be necessary. Increase of loading resistance by gas puffing in the vicinity of the antenna is small. Injection of Deuterium in a location magnetically connected to the antenna but not too close to the antenna needs to be tried.

References

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