§7. ICRF Antenna Characteristics and Comparison with 3-D Code Calculation

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The plasma coupling characteristics of an ion cyclotron range of frequencies (ICRF) antenna in the LHD are studied and compared with the results of 3-D computing simulation code calculation.

Experimental results show clear relations between the antenna loading resistance and frequency and also between the maximum injection power and the loading resistance. High antenna loading resistance is an important element to launch high injection power to the plasma. More than five ohm is needed to launch 1 MW via one loop antenna. There are many components that determine the loading resistance of an antenna. In particular, the loading resistance strongly depends on the frequency, as shown in Fig. 1. The plasma density and temperature profiles and the distance between the antenna and plasma are also important parameters. However the working frequency is the most effective factor at the plasma heating experiment. At the frequency of approximately 20-30 MHz, it was difficult to launch high power to the plasma due to the very low loading resistance below 2 ohm.

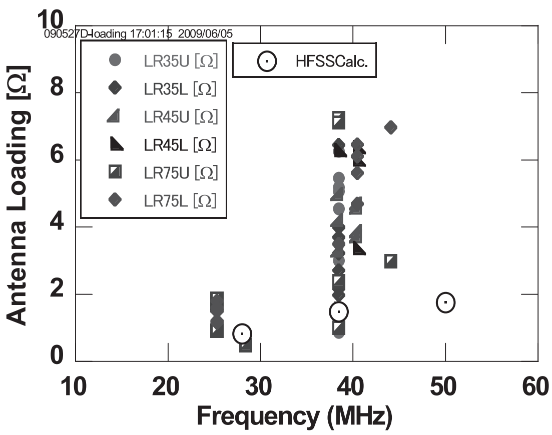

Fig.1 Antenna loading resistances in various frequency experiments in LHD are shown. Six antennas are used and open circles are calculated data by HFSS code.

Figure 2 shows the antenna loading resistance versus injection power to the plasma. These data include many experimental modes and matching conditions. The plasma density is in the wide range, and the magnetic field and the frequency are not fixed. At the low loading region below 4 ohm, the maximum power is limited by peak RF voltage on the transmission lines between the antennas and the impedance tuners. The interlock voltage was set around 35 to 40 kV_{0-p}. On the other hand the maximum injection power with the higher loading resistance condition of over 4 ohm was not limited by the RF voltage interlock, and it was limited by the other hardware problems at the transmitter.

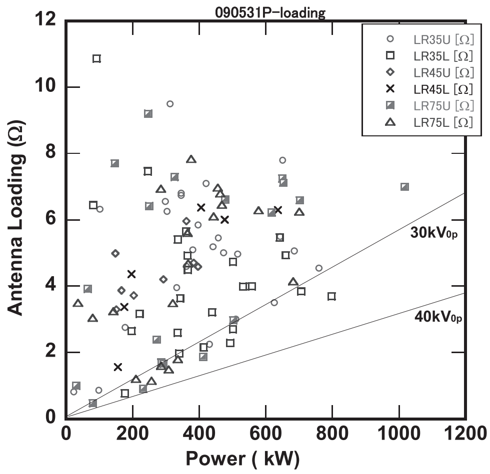

Fig.2 Antenna loading resistances are plotted by changing the injection power. Lines are shows the peak RF voltage on the transmission line near the antennas.

Electro-magnetic field distribution calculation using 3-D computing simulator HFSS code was carried out for the finely detailed model of the LHD ICRF antenna and the surrounding hardware. The realistic configuration included precise replications of the twisted antenna conductors, inclined Faraday screen, and carbon side protectors. The LHD vacuum chamber wall of stainless steel was also realistically modeled and included using CAD data of LHD device. The model material of plasma is artificial water having high permittivity. The calculated impedance of an antenna loop is shown in Fig.1 by the large circles. The increasing character with the frequency is well reproduced by the simulation. The absolute loading resistance value of the simulation is rather small and it should be tuned by adjusting plasma model material.

The RF current distribution on front and rear surfaces of center strap is shown in Fig.3. These calculations are beneficial for the optimization of new antenna design. The absorbed RF power at the antenna structure is well understood by the calculation and this result was compared with the temperature measurement at the long pulse experiment. The temperature increase of carbon side protectors are well explained and it is useful to decide the heat load distribution from the plasma[1).]

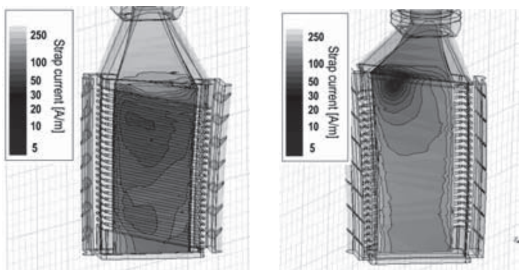

Fig.3 Simulation results of RF current distribution of front surface (left) and of rear surface (right) of center current strap are shown.

1) T. Mutoh, H. Kasahara, T. Seki, et al., to be published in Proceedings of 18th Topical conference on Radio Frequency Power in Plasma, AIP (2009)