§3. Reduction of Voltage in Coaxial Line Using Pre-stub Near ICRF Antenna in LHD

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In ICRF heating, one of issues is the high RF voltage in the transmission line between the ICRF antenna and the impedance matching device caused by the low loading resistance compared to the characteristic impedance of transmission line. In LHD 50Ω transmission line is used. The loading resistance is dependent on plasma parameter and antenna condition, and it is normally less than 10Ω. In the case of loading resistance of 5Ω and injected power of 1MW, the RF voltage in the transmission line reaches 32kV. The risk of breakdown at the insulator in coaxial line is high. In order to reduce probability of the breakdown, we tested a pre-stub in LHD for the first time. 7.5U antenna was used. The pre-stub position was selected at the nearest corner of transmission line to ICRF antenna, as shown in figure 1. Figure 2 shows the contour of calculated voltage reduction ratio in the case of loading resistance of the antenna of 0.74Ω. The ordinate denotes stub length and abscissa is antenna-stub length normalized by wavelength. We measured antenna-stub electric length by use of network analyzer without plasma. Assuming that the length is not changed with plasma, three operating frequencies were denoted by dashed lines. In the case of frequency of 41.27MHz, short stub of 45cm can reduce voltage approximately 50% as shown by dot and circle. Figure 3 shows calculated voltage distribution from ICRF antenna. The voltage drop in the upstream region is expected, although two peaks of voltage remains in the downstream between antenna and the stub. Therefore, the probability of breakdown reduced. Voltage reduction ratio is almost same with different loading resistance from 0.2 to 5Ω. For the check of voltage reduction, we attached cables with various lengths. When the length normalized with a wavelength Ls/λ is 0.25, which correspond to transmission line without the stub, reflection ratio was 0.97. When the cable with the normalized length of 0.06 was attached, reflection ratio dropped to 0.88. The reflection ratios agreed well with calculation as shown in Fig.4. Therefore, the voltage reduction ratio also well agrees with the calculation.

A pre-stub of 45cm was installed in the transmission line of 7.5U ICRF antenna for the frequency of 41.27MHz. The loading resistance including the pre-stub and the antenna was estimated from input power and peak voltage between the pre-stub and the impedance matching device. The voltage reduction ratio estimated from the loading resistance was 0.76. Voltage was reduced, although there was discrepancy between the anticipation and the measurement. A tuning by changing stub length would reduce the voltage further.

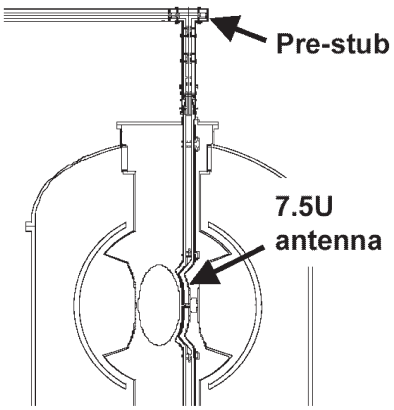

Fig.1 Pre-stub near 7.5U ICRF antenna.

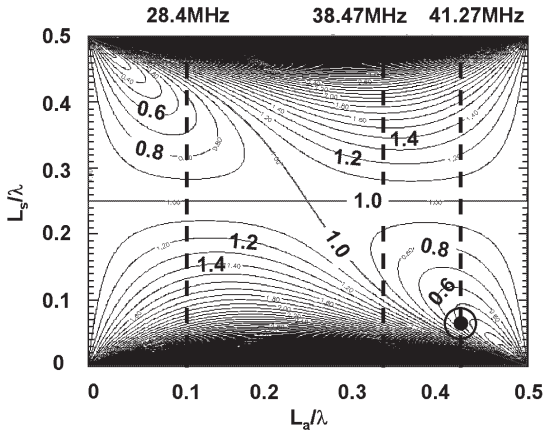

Fig.2 Calculated voltage reduction ratio in the case of antenna impedance of 0.74Ω.

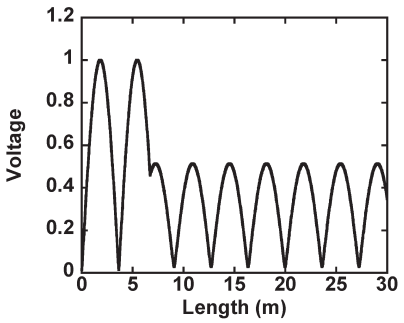

Fig.3 Calculated voltage distribution from ICRF antenna.

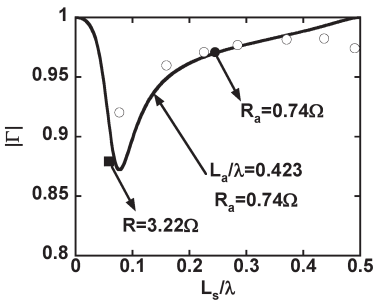

Fig.4 Calculated reflection ratio (line) and measured one (plots).