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Design and operations of a load-tolerant ICRH system in Experimental Advanced Superconducting Tokamak

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Ion cyclotron resonance heating (ICRH) is a significant heating method in tokamak devices, and it is one of the most important heating systems on ITER to heat ions. According to the wave dispersion relationship, we know that the evanescent layer normally exists because the plasma density is relatively low compared to the ICRH wave cut-off density in front of the ICRH antenna. Even if the antenna has good coupling, the coupling impedance is still relatively low compared to the characteristic impedance of the transmission line. This impedance difference will result in a large reflection and high standing voltage in the transmission line, which will reduce the transmitter's efficiency and the stability of the ICRH system. To avoid this undesirable condition, an impedance matching network needs to be designed and installed in the ICRH system to separate the transmitter and antenna. This study reviewed a load-tolerant ICRH system which can achieve and maintain antenna matching with power reflection ratio below 5% for many kinds of operating conditions, which means that this matching network could allow robust high-power operations without fast impedance matching in EAST tokamak.

Ion cyclotron resonance heating (ICRH) has been a dependable tool for sturdy plasma heating with high RF power of several megawatts. However, a sudden increase in the reflected power during ICRH heating experiments is a problem that should be solved for future fusion experimental devices. To solve this issue, the load tolerant matching network have been designed for ICRH system in EAST Tokamak. The matching network includes 3-stub tuner impedance matching system, conjugate-T structure, 30 Ω to 50 Ω transmission line and center grounded antenna strap. By keeping a low reflection ratio in the network for a wide range of resistance, this matching network could allow sturdy high-power operations without fast impedance matching in EAST tokamak. In our matching network, the two arms of a conjugate-T were designed to have the same length which could mitigate current imbalance and antenna poloidal phasing out of control problem. And the T-point corresponds to the maximum point of standing wave voltage, which could greatly improve the input impedance of antenna.

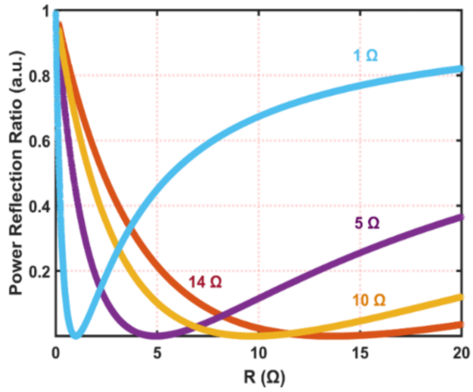

Figure 1 Comparison of reflected RF power fraction after 3-stub tuner impedance matching system with impedance R. The impedance matching is obtained at different resistance R including 1Ω, 5Ω, 10Ω and 14Ω respectively.

The dependence of the reflected power fraction on variable resistance R is shown in figure 3. The abscissa and the ordinate of figure 3 are the resistance R and the reflected power fraction. Here,

$$R = Z_0 * \frac{1 - \left|\frac{Z_A - Z_0}{Z_0 + Z_A}\right|}{1 + \left|\frac{Z_A - Z_0}{Z_0 + Z_A}\right|}$$

The impedance matching is obtained at different resistance including 1Ω, 5Ω, 10Ω and 14Ω, respectively as shown in figure 1. It is clear that the load-tolerance characteristic appeared with larger resistance, as the reflected power fraction is less than 3% in the range of 10–20Ω with the impedance matching at 14Ω.

References

[1] L.N. Liu et al 2024 Nucl. Fusion 64 066025
[2] Rev. Sci. Instrum. 93, 043506 (2022);
[3] Review of Scientific Instruments 72, 2015 (2001