§28. Numerical Calculations and RF Characteristics Measurement of Complex-Conjugate Impedance Antenna System

Kumazawa, R., Kasahara, H., Saito, K., Seki, T., Mutoh, T.

Characteristics of an advanced complex-conjugate impedance antenna system for ICRF (ion cyclotron resonance frequency) heating are discussed in this paper. A large RF power is reflected in such transitions as that of ELMy H-L mode due to the large change in the plasma resistance during the ICRF heating. A conjugate antenna system has been proposed to alleviate the RF reflected power. It consists of two antennas connected to separate transmission lines diverging as shown in Fig.1. An ICRF heating power is divided at the T-junction onto two transmission lines at the T-junction and fed to each antenna. The signs of the imaginary parts of the impedances at the T-junction can be made opposite each other and the impedance at the T-junction has only a real part by selecting proper lengths between the T-junction and the antennas [1]. Here a single stub tuner system is added between the RF power generator and the T-junction to improve the conjugate antenna performance. In the conventional conjugate antenna system without the single stub tuner, the reflected RF power fraction can be reduced only to 27% in the predicted plasma resistance change due to the H-L transition [2].

In the case of $R_1=R_2$, the complex-conjugate condition

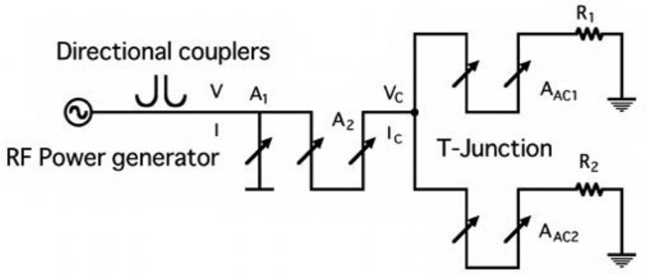

Fig.1 Schematic drawing of a complex-conjugate antenna impedance system with a single stub tuner.

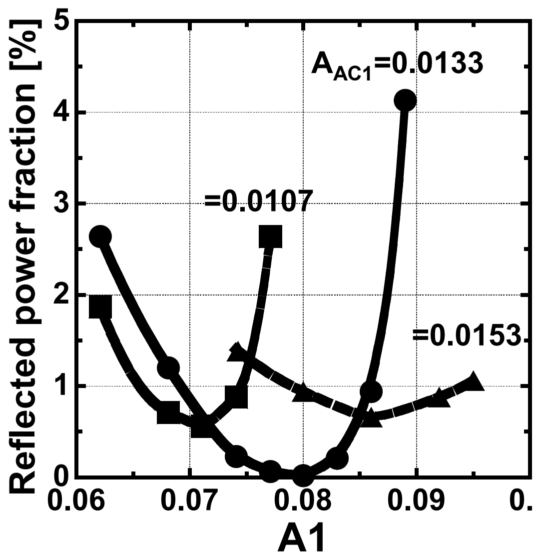

Fig.2 Experimental data obtained in three different A_{AC1}s. The reflected RF power fraction at $R_{N2}=0.164$ is plotted against the normalized length of the single stub tuner at the RF power generator, A1. The initial impedance matching is obtained at $R_{N1}=0.044$.

can be satisfied when

$$\tan(2\pi A_{AC1}) + \tan(2\pi A_{AC2}) = 0 \quad (1)$$

The normalized resistance on the antenna R_N is defined as $R_{N1}=R_1/Z_0$ (Z_0: 50Ω of characteristics impedance of the transmission line). We assume that the resistance change from R_{N1} (H-mode) to R_{N2} (L-mode). The impedance at the T-junction can be the same of Z_{N0} selecting the proper length of A_{AC1} (A_{AC2} is determined in accordance with eq.(1)) in accordance with

$$R_{N1} \cdot R_{N2} = \tan(2\pi A_{AC1}) \quad (2)$$

Then the impedance at the T-junction is calculated

$$Z_{N0} = \frac{R_{N1}^2 + \tan^2(2\pi A_{AC1})}{2R_{N1}\{1+\tan^2(2\pi A_{AC1})\}} \quad (3)$$

The impedance matching is obtained at both resistances, i.e., R_{N1} and R_{N2} with the single stub tuner.

The numerical calculation showed that the reflected RF power fraction could be drastically reduced to 1% in the range of $0.04<R_N<0.16$ [2]. It would have been 27% at $R_{N2}=0.16$ if the single stub tuner were not installed. The effectiveness in this system is experimentally examined.

First the impedance matching was achieved at $R_{N1}=0.044$ in three A_{AC1}s, i.e., $A_{AC1}=0.0107$, 0.0133 and 0.0153. Then at the different $R_N=0.0164$, the reflected RF power fraction was measured with the normalized length of the single stub tuner, A1. As seen in Fig.2 the reflected RF power fraction was almost 0% for $A_1=0.08$ and $A_{AC1}=0.0133$. Then the reflected RF power fraction was measured in the range of $0.044<R_N<0.164$ using five resistors. The maximum reflected RF power fraction was found to be 1%, which agreed with the theoretical calculation.

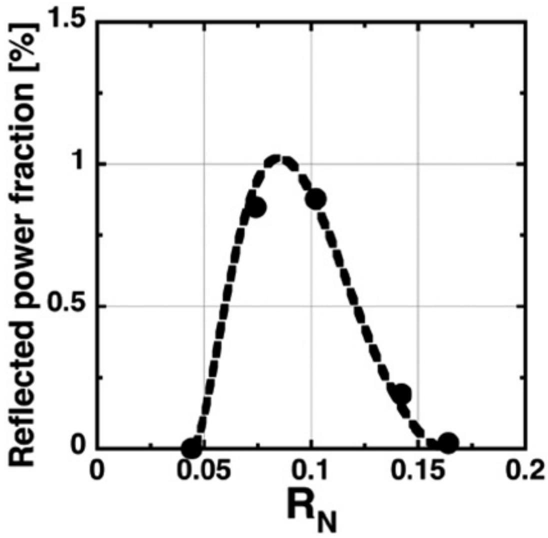

Fig.3 The best condition is obtained at $A_{AC1}=0.0133$ from Fig.2. The reflected power fraction is plotted at five different normalized resistances, $R_N=0.044$, 0.074, 0.102, 0.142 and 0.164, respectively. The calculated result is also plotted in dashed line.

[1] R.Kumazawa et al., J. Plasma Fusion Res. SERIES Vol.8 (2009), 1143-1146.
[2] R.Kumazawa et al., to be published in Nuclear Fusion.