§10. Impedance Matching in Wide Range of Resistance in Conjugate Antenna System

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The conjugate antenna system was introduced in the previous annual report of 2007~2008. In this section the characteristics of the conjugate antenna system are further examined. The impedance at the T-junction is expressed in the following equation,

$$Z = Z_0 \frac{R_N^2(1-2R_{N0}) + R_{N0}(2-R_{N0})}{2R_N(1-R_{N0}^2)} = Z_0 E \qquad (1)$$

It is easily found that when R_N=R_{N0}, E becomes one and therefore the reflected RF power fraction R_{ref} becomes zero in above equation. The above equation is a quadratic equation for R_N for E=1. Therefore there is another solution and the other solution of R_{N1} can be derived using R_{N0} in the following relation,

$$R_{N1} = \frac{2-R_{N0}}{1-2R_{N0}} \qquad (2)$$

For example when R_{N0}=0.26, R_{N1}=3.625, that is, there are two impedance matching conditions. On the other hand the reflected RF power fraction R_{ref} is calculated using the following equation,

$$R_{ref} = \left(\frac{E-1}{E+1}\right)^2 \qquad (3)$$

It is thought that R_{ref} is fairly increased between two impedance matching conditions. Here the normalized resistance R_{Nm} where R_{ref} becomes the maximum can be found between R_{N0} and R_{N1}. Using a differential of R_{ref} by R_N becomes zero when R_{ref} becomes the maximum in the following way.

$$\frac{\partial R_{ref}}{\partial R_N} = 0 \rightarrow R_{Nm}^2 = R_{N0}R_{N1} \qquad (4)$$

The value of R_{Nm} is a geometric mean of R_{N0} and R_{N1}. Then the local maximum R_{refm} is calculated using the equation (3) and derived in the following equation:

$$R_{refm} = \left(\frac{R_{Nm} - 1 + R_{N0}^2}{R_{Nm} + 1 - R_{N0}^2}\right)^2 \qquad (5)$$

Dependences of the local maximum reflected RF power fraction R_{refm}, R_{N1} and R_{Nm} on R_{N0} are plotted in Fig.1. It is found that R_{refm} is decreased with R_{N0} and becomes the minimum value of 12% at R_{N0}=0.26.

The reflected RF power fraction is plotted against RN in the case of R_{N0}=0.26 in Fig.2. When the allowable reflected RF power fraction is employed as R_{ref}=5%, the normalized resistance R_N ranges from 0.18 to 0.45 as also shown in Fig.2. It was reported that the antenna resistance was changed from 2Ω to 8Ω during the H-L mode transition seen in JET [1]. If this conjugate antenna system is applied to the H-L mode transition plasma, the low characteristic impedance of the transmission line such as Z_0=8Ω should be employed. When it is assumed that the maximum RF stand-off voltage is proportional to the clearance between the inner and the outer transmission line, the maximum RF power to be transmitted for the characteristic impedance Z_0 is assessed in the following equation:

$$P_{RF} \propto a^2 \ln\left(\frac{b}{a}\right) \qquad (6)$$

Here a and b are an inner and an outer radius of the transmission line, respectively. The maximum P_{RF} is obtained in the case of b/a=2.72, i.e., Z_0=30Ω. Then P_{RF} at Z_0=8Ω is calculated to be reduced to less than 50% of that at Z_0=30Ω. It is thought that the method of employing the low impedance transmission line is not appropriate for a high power ICRF heating system.

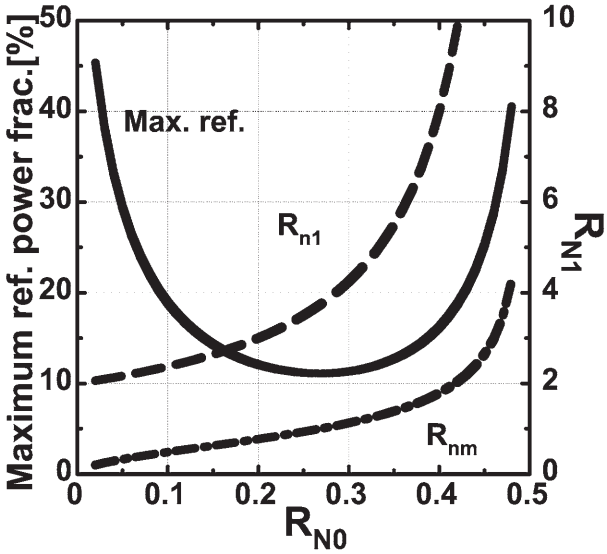

Fig.1 Dependences of reflected RF power fraction, R_{N1} and R_{Nm} on R_{N0}.

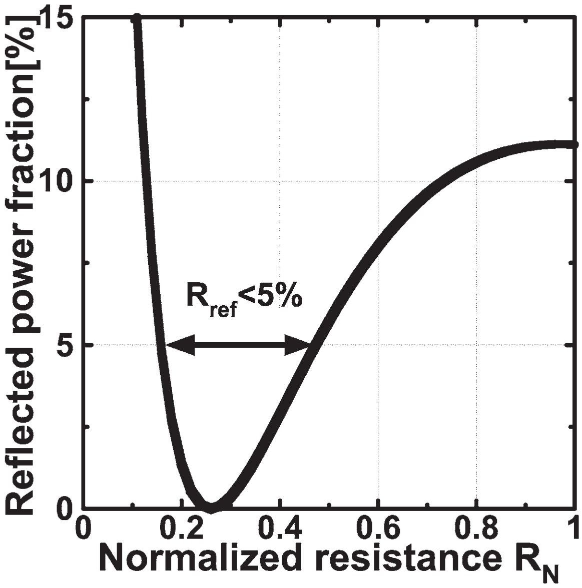

Fig.2 Dependence of Reflected RF power fraction on RN in the case of R_{N0}=0.26. The reflected RF power fraction can be suppressed to less than 5% in the range of 0.18 50 0.43 in R_N.

[1] I. Monakhov et al., 15th Topical Conf. of RF power in Plasmas 2003, AIP Conf. Proc.694, 148