§6. Test of Phase Control and Impedance Matching of Dummy ICRF Antenna

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We have installed HAS (HAndShake or HAsuu Seigyo: wave-number-control in Japanese) ICRF antennas in LHD from upper and lower ports, which are symmetrical antennas. The wave number parallel to the magnetic field line is controllable by adjusting the phase of the current on the straps for the variation of the experiments. Antenna impedance is not constant even if the plasma parameter remains constant when the complex current ratio is changed due to the mutual coupling between the two antennas. Reflection will increase unless tuners are adjusted.

Figure 1 shows a schematic view of the antenna system including matching devices (liquid stub tuners). The two antennas are characterized by an impedance matrix, Z_a. Currents at the antenna ports of line 1 and 2 are identified as I_{a1} and I_{a2}, respectively. V_{a1} and V_{a2} are the voltages at the antenna ports. These currents and voltages are related as follows:

$$\begin{pmatrix} V_{a1} \\ V_{a2} \end{pmatrix} = \begin{pmatrix} Z_{a11} & Z_{a12} \\ Z_{a21} & Z_{a22} \end{pmatrix} \begin{pmatrix} I_{a1} \\ I_{a2} \end{pmatrix}. \qquad (1)$$

To calculate the impedance for the impedance matching, four components of impedance matrix must be known. Currents and voltages at the antenna ports are deduced from the signal at the directional couplers and condition of tuners. Usually equation 1 cannot be solved since it has four unknown parameters with two equations. However, by assuming geometric symmetry and the reciprocity of the two antennas i.e. $Z_{a11}=Z_{a22}$ and $Z_{a12}=Z_{a21}$, each component of impedance matrix can be solved as follows:

$$Z_{a11} = Z_{a22} = \frac{I_{a1}V_{a1} - I_{a2}V_{a2}}{I_{a1}^{\ 2} - I_{a2}^{\ 2}},$$
$$Z_{a12} = Z_{a21} = \frac{-I_{a2}V_{a1} + I_{a1}V_{a2}}{I_{a1}^{\ 2} - I_{a2}^{\ 2}}. \qquad (2)$$

The phase control together with the impedance matching was tested with a simplified symmetrical two-port dummy antenna consisting of resisters. Two pairs of variable condensers were used instead of liquid stub tuners. Frequency was 30 MHz. The reflection ratios V_r/V_f were large at the initial condition as shown in Fig. 2-(a), but by controlling the injection powers and phase difference together with adjusting tuners, reflection reduced and current phase defined at the points A_1 and A_2 in Fig. 1 approached to the designated value, -45deg. A cable of 27.2 cm in electric length was inserted in one port to make the dummy antenna asymmetrical. The reflection decreased and current phase approached to the designated value, -45deg. as shown in Fig. 2-(b). It suggests that this method will work even if the system includes some errors.

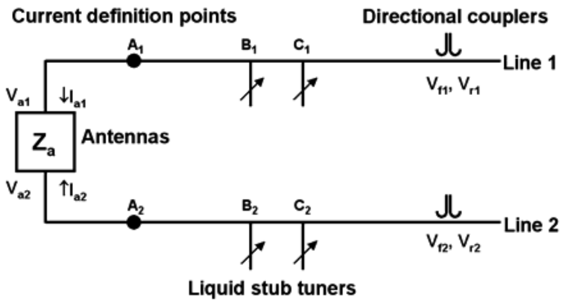

Fig. 1 Schematic view of the antenna system consisting of two lines.

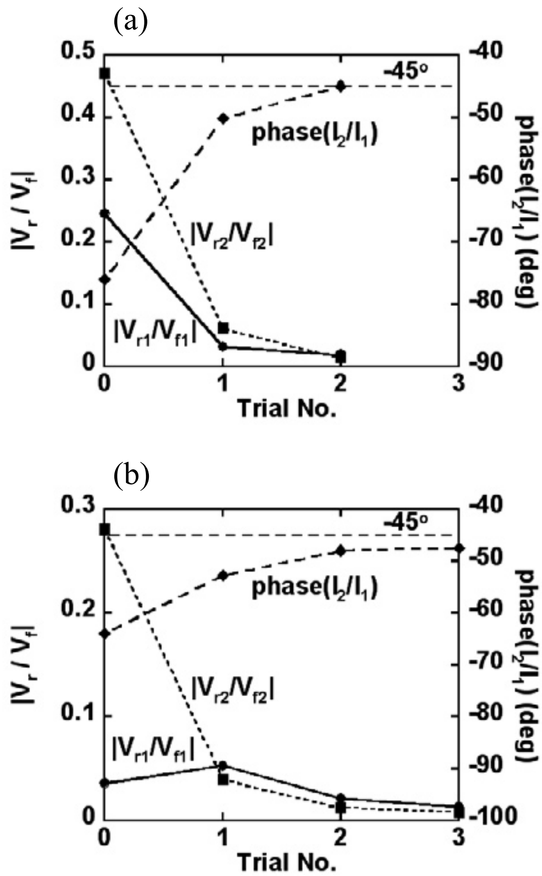

Fig. 2 Convergences of reflection ratio and current phase for the (a) symmetrical and (b) asymmetrical cases.