§13. Feedback Control Impedance Matching System Using Liquid Stub Tuner for Ion Cyclotron Heating

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A schematic drawing of the experiment system is shown in Fig.1. The impedance matching system is a double stub tuner, whose distance between stubs is a quarter of the RF wave length. A liquid stub tuner is located at the side of the RF generator. The length of the liquid stub tuner is 2.16m, whose normalized length is 0.26 at the applied frequency of 36.0 MHz. The normalized length of the liquid stub tuner can be changed from 0.26 to 0.45 by shifting the liquid surface level, which was calculated using the equation (5) of reference [1]. An RF power of 1W level is transferred to an antenna through the double stub tuner system. An RF electric resister is inserted at the antenna as shown in Fig.1. The electric resistance can be changed from 1.0 ohm to 7.3 ohm by controlling an externally applied electric voltage. The forward and the reflected power is monitored by a directional coupler and the phase difference between them is an key to know which is a right direction of the liquid surface level, i.e., up or down.

The monitored RF signals, i.e., the forward and the reflected power and the phase difference are acquired to the multi-processing computer system through an A/D converter. The phase difference showing a delay of the reflected power behind the forward power indicates an ascent of the liquid surface, and vice versa in the present experiment setup.

First the optimum condition was found by varying the length of A2A, which is a normalized length between the stub tuner and the antenna as shown in Fig.1. There is the special case where a reflected power can be remarkably reduced in a wide electric resistance range by using only the liquid stub tuner located on the side of the RF generator A1 in the double stub tuner system. The case was found at the fixed normalized length of the stub tuner on the RF antenna side, i.e., A2=0.054; the impedance matching was obtained in the wide electric resistance range, i.e., R_A=1.1~3.8 ohm by shifting A1 only. The reflected power fraction was increased with the increase in the electric resistance and became to 16.5% when R_A was changed from 1.1 ohm to 3.8 ohm without shifting the liquid surface. The liquid surface level was shifted to minimize the reflected power fraction less than 0.1% at each electric resistance.

The real-time feedback control experiment was carried out at the above-mentioned condition employing the multi-computer system with CINOS (CHS Integration No Operating System) method. The liquid surface level was changed using a pulse stepping motor controlled by CINOS. The speed of the liquid surface was 2 cm/sec. Time evolutions of the electric resistance, the reflected power fraction and the shift of the liquid surface are plotted in Fig.2. Here the electric resistance was changed from R_A=1.1 ohm to 3.8 ohm during 70 seconds. The reflected power fraction was reduced to 0.1% in whole electric resistance; the maximum reflected power fraction would have been increased to 16.5% in the absence of the feedback control of the liquid stub tuner. The required shift of the liquid surface was 75cm.

An application of the feedback control to the real ICRF heating system will be carried out to sustain the long pulse plasma discharge for 30 minutes by ICRF heating only at the future experiment on the LHD.

References
[1] R.Kumazawa, et al., Review of Scientific Instruments 70, 2665 (1999).

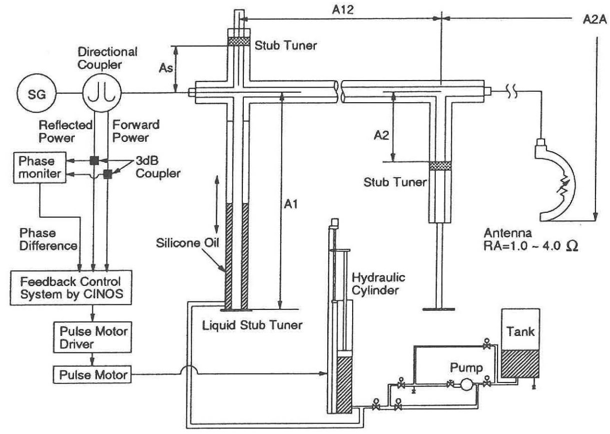

Fig.1 Feedback control system of liquid impedance matching.

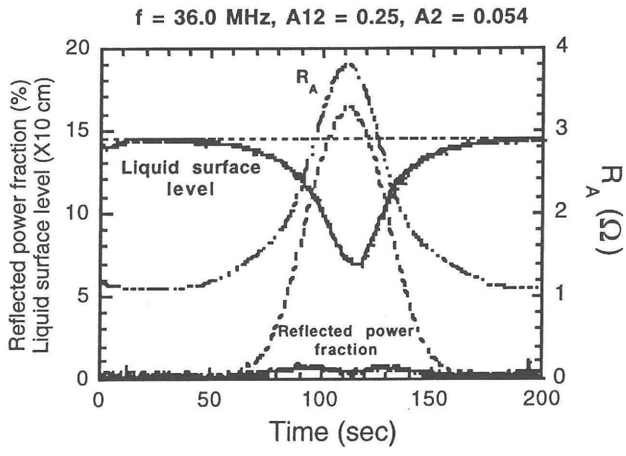

Fig.2 Real time feedback control by shifting liquid surface; electric resistance is changed from 1.1 Ω to 3.8Ω during 70 seconds.