§17. Calculation of Liquid Impedance Matching System with Wide Frequency Range

Kumazawa, R., Mutoh, T., Seki, T., Nomura, G., Shinbo, F., Ido,T., Watari, T.

In the previous section, we formulate the impedance, Z at the inlet of the liquid impedance matching system as a function of A_1, A_L, A_2, A_S and the antenna impedance. The impedance matching can be acquired, when the real part and the imaginary part of Z are 50Ω and zero, respectively. The value of 50Ω is the output impedance of the RF oscillator. When we determined the position of the liquid impedance matching system, the length from the antenna is estimated to A_1, A_L, A_2. Here A_L is a variable. From the imaginary part to be zero,

$$(AZ_I+B)(BX+D-(C-AX)Z_I))=AZ_R^2(C-AX)$$

can be obtained X, which is required condition of the liquid stub tuner. The relation between A_s and X is $X=1/Z_0/\tan A_S$.
Then,

$$X=\frac{ACZ_R^2-(AZ_I+B)(D-CZ_I)}{(AZ_I+B)^2+A^2Z_R^2} \qquad (1)$$

On the other hand, the real part is 50,

$$\frac{AZ_R}{BX+D-(C-AX)Z_I}=50 \qquad (2)$$

By substituting eq.(1) to (2), the normalized length of the liquid, A_L in the phase shifter and X can be determined. As the liquid stub tuner, A_s is a combination of the length of liquid, A_{LS} and the length of gas, A_{GS} as follows.

$$\frac{1}{Z_0\tan A_S}=\frac{1-Z_L/Z_0\tan A_{GS}\tan A_{LS}}{Z_0\tan A_{GS}+Z_L\tan A_{LS}}$$

Figure 1 shows the schematic drawing of the liquid impedance matching system, consisting of the phase shifter and the liquid stub tuner. RF power comes from the right side through D.C.break and goes to the ICH antenna from the left side. Three liquid components are identically same, which is 4 m long. The liquid phase shifter consists of two liquid components and the gas stop, which is inserted between them. The separated liquid component enables to unbalance the liquid levels. On the other hand, the bottom of the liquid stub tuner is electrically terminated.

The impedance matching can be wholly obtained in the wide frequency range, 25-95MHz as shown in Fig.2. The calculation is executed in every 0.1MHz. Here L_{liq} is a required liquid length in the phase shifter, which is less than 8m. This is in the case that the distances between RF antenna and the center of the liquid phase shifter is 25m and the distance between the RF antenna and the liquid stub tuner is 31m, these values are estimated from the allowable location of the liquid impedance matching system in the LHD experimental room. The V_{rf} is also plotted, which is the ratio of the RF standing voltage in the liquid impedance matching system to that near the antenna. In some frequency range, the voltage ratio exceeds to 1.5, which means that the RF voltage is higher than the voltage near the antenna. The method to reduce the voltage ratio will discussed in the next section.

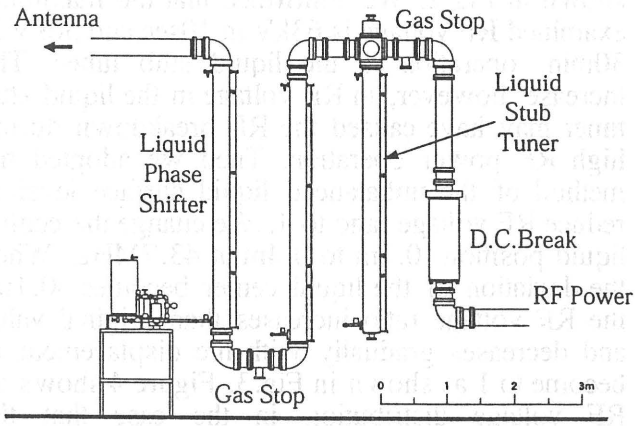

Fig.1 Schematic drawing of the liquid impedance matching system.

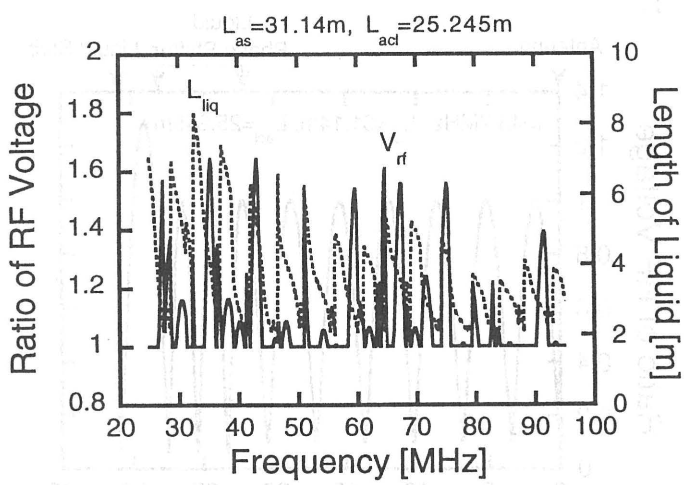

Fig.2 Impedance matching condition of the liquid phase shifter and the RF voltage ratio in wide frequency range, 25-95MHz.