§19. Optimization Research for A Fishbone Antenna

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A fishbone antenna is being developed for current drive and 2nd harmonic heating in the ion cyclotron range of frequency in order to change of the rotational transform profile and to improve the magneto-hydrodynamics (MHD) stability. Each antenna element consists of an antenna strap, a back plate and Faraday shields of 27 pieces. The fishbone antenna is an array of ten antenna elements in the toroidal direction. The antenna strap is a T-character shape and is supported at the center. There were two resonance frequencies referred to as an even mode ω_e and an odd mode ω_o. A mock-up antenna was manufactured (see Fig.1) so as to acquire the best performance and to design the LHD fishbone antenna in detail. A flat configuration was used in the test, while LHD fishbone antenna is a curved configuration fitted to the last closed magnetic surface.

The RF current on each antenna element was measured using a 3-dimensional movable RF magnetic probe. The even mode and the odd mode of the RF current pattern were found in the different frequency; the even and the odd frequency were f_{even}=72.77MHz and f_{odd}=62.34MHz in the one antenna element. It was compared with calculated results solved in a recurrence formula of an electric circuit consisting of the electrical parameters, *i.e.*, L_1, L_2, L_a, L_b ($L = L_1+L_2 = L_a+L_b$), L_C, C, M_{ee}, M_{oo}, M_Z, and I_Z [1]. The electrical parameters of the mock-up antenna were determined from the resonance frequencies except for L_1 and L_a. The tap positions at the inlet and the dummy load, *i.e.*, L_1 and L_a affect the reflected power fraction of two modes, therefore the ratio of current of the even mode to that of the odd mode is changed. When the even mode current is the same order as the odd mode one, the difference between adjacent RF currents is increased. Therefore the absolute value of $(I_{k+1}-I_k)/(I_{k+1}+I_k)$ was employed in order to evaluate the purity of the mode. The direction of the driven current can be changed in accordance with the experimental purpose by choosing the same tap position of the inlet as that of the dummy load. When the normalized tap positions of L_a/L and L_1/L were 0.36 with the termination resistance of 50.7Ω, the absolute value of $(I_{k+1}-I_k)/(I_{k+1}+I_k)$ became the minimum as shown in Fig. 2.

In the optimized tap positions, the fraction of the RF power transmission P_{out}/P_{in}, and that of the RF power reflection at the electric power supply P_{ref}/P_{in} were measured as the function of the frequency. P_{ref}/P_{in} was lower than 0.2 and P_{out}/P_{in} was higher than 0.5 in the frequency range of 70-85MHz. At 75.01MHz the phase of the RF current was changed by about 72 degrees between adjacent antenna elements as shown in Fig. 3.

For simulating the plasma loading R_p, an electrical resistance of 1kΩ ($R=1/\omega^2C^2R_p$) was inserted between the Faraday shields and the antenna strap. The relation of the absolute value of $(I_{k+1}-I_k)/(I_{k+1}+I_k)$ and plasma loading is shown in Fig. 4. It is expected the purity of the mode to be better in the presence of plasma than in the vacuum.

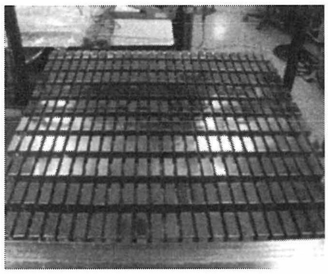

Fig.1 The mock-up of LHD fishbone antenna

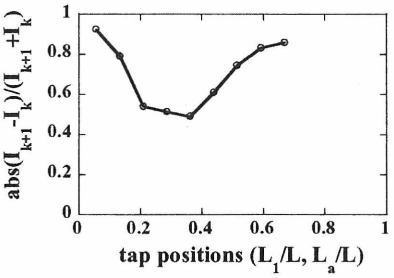

Fig.2 Optimization of outlet tap position with termination of 50.7Ω (f=72.77MHz)

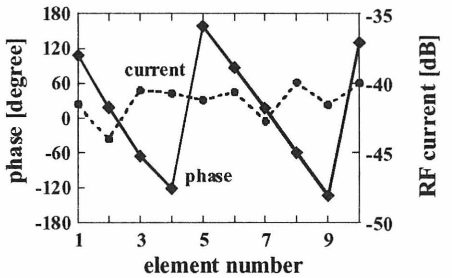

Fig.3 RF current and the phase in each antenna element (f=75.01MHz)

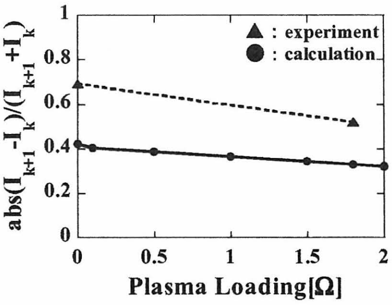

Fig.4 RF current and the phase in each antenna element with plasma imitation (f=72.77MHz)

Reference

1) Takeuchi, N., *et al.*, Annual Report of National Institute for Fusion Science April 2000 – March 2001, p. 135-136 (2001)