§23. Development of a Fast Wave Current Drive Antenna

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A fast wave current drive antenna is being developed for LHD, motivated by the need to provide a capability for rotational transform profile control. Stability calculations suggest that it is possible to increase the beta limit and obtain access to the second stability region by controlling the rotational transform profile. Current drive by the ICRF fast wave (magnetosonic wave) is suitable for such a purpose.

The LHD antenna consists of two combline antennas [1] stacked vertically (Fig. 1), and will be placed on the large major radius side of the torus where the plasma is elongated in the vertical direction. The frequency of operation is chosen to be in the neighborhood of 85 MHz. Electron Landau damping of the fast wave will be used to drive the plasma current. In addition, second harmonic heating of hydrogen ions is also possible at a magnetic field of 2.8 T.

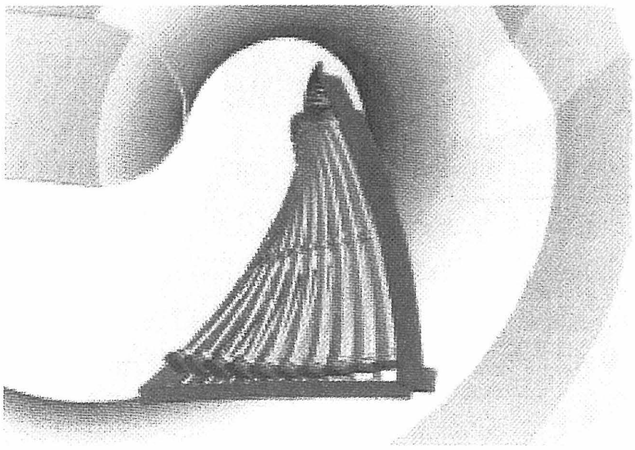

Fig. 1. A drawing of the stacked combline antenna inside the LHD vacuum vessel. The grounded ends of the top and bottom comblines are located on the midplane. The Faraday shield elements and the side protection tiles are removed for ease of viewing.

The antenna is divided into 10 nearly identical modules for ease of fabrication and adjustment. Each module consists of the upper and lower straps (with the grounded ends on the midplane), a backplate, and a U-shaped Faraday shield. A "back Faraday shield" may be added to increase the capacitance of the strap. Ten of these modules are placed side by side in the toroidal direction, following the helical shape of the plasma surface. The spacing between adjacent straps (center to center) is 0.11 m, which corresponds to a wavenumber of 14 m^{-1} when the phase difference between adjacent current straps is 90°. The antenna is surrounded by carbon protection tiles arranged in a "picture frame" configuration.

Electrical measurements using two types of mock-up antennas were performed at the University of Tokyo. The first mock-up antenna (MP1) was built to examine the effects of geometry on the pass-band characteristics of the antenna. Adjustable parameters were the strap length, the distance from the strap to the Faraday shield, Faraday shield geometry, the distance from the strap to the backplate, and the strap spacing. In addition, a discrete capacitance could be added to the open end of each strap. The radiation resistance in the presence of the plasma was simulated by placing a resistive film in front of the antenna. The intensity and the phase of the RF magnetic field (toroidal component) in front of the Faraday shield were measured using a loop probe, approximately 1 cm in diameter. As expected, the field intensity peaked in front of each strap, and the phase varied monotonically in a step-wise fashion, confirming that a traveling wave was excited.

The second mock-up antenna (MA2) was built to test the stacked combline configuration. This was a 2 × 2 array. Each pair consisted of two current straps, connected to each other at their grounded ends. Two types of coupled resonances, corresponding to the top-to-bottom pair and the side-to-side pair, were observed. The desired mode had the highest frequency and was well separated from other resonances. The LHD antenna was designed based on the results of these measurements and model calculations.

A test with plasma load was performed on the TST-2 spherical tokamak using a 6-element combline antenna. A low-power (1 kW level) high-harmonic fast wave (HHFW) in the frequency range of 20–30 MHz was excited. As expected, the loading resistance increased as the plasma current increased and the plasma grew to its full size. RF magnetic probes showed that the wave field detected on the center post was rather uniform both toroidally and vertically (variation within 5 dB), but were much weaker than the wave field detected on the outboard limiter (by 10–15 dB). This result is consistent with the wave field distribution calculated by the TASK/WM full-wave code [2].

A prototype antenna, consisting of 4 modules of the LHD antenna, was fabricated. A final optimization of the LHD antenna will be made based on electrical measurements of the prototype antenna.

References

[1] Moeller, C.P., et al., in Proc. Europhys. Top. Conf. Radiofrequency Heating and Current Drive of Fusion Plasmas (Brussels, 1992), Vol. 16E, EPS, Geneva (1992) p. 53.

[2] Fukuyama, A., et al., Comp. Phys. Rep. **4** (1996) 137.