§26. 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 by noninductively driven current. 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 "fishbone" antenna being built for LHD is equivalent to two "combline" antennas [1] stacked vertically, but has only one input and one output. Such a design enables high power operation even with limited port space. This antenna will be placed on the large major radius side of the torus where the plasma is elongated in the vertical direction. The antenna is divided into 10 nearly identical modules, each consisting of a stainless steel half-wavelength resonant structure approximately 1 meter long, grounded at the midplane (T-bar current strap, Fig. 1), a water-cooled stainless steel backplate, and a U-shaped molybdenum Faraday shield. These modules are placed side by side in the toroidal direction, following the helical shape of the plasma surface. The whole assembly is surrounded by carbon protection tiles arranged in a "picture frame" configuration to reduce the plasma density at the Faraday shield. 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 frequency of operation is chosen to be in the neighborhood of 75 MHz, with a bandwidth of about 10 MHz. Electron Landau damping of the fast wave will be used to heat electrons and to drive current in the plasma. In addition, second harmonic heating of hydrogen ions is also possible at a magnetic field of around 2.5 T.

Two types of coupled resonances (symmetric and antisymmetric current modes) are possible in the fishbone antenna configuration. Therefore, controlled excitation of the desired mode (in-phase mode with current in the same direction on the top half and the bottom half) becomes a major issue. Coupling loops linking the top row and the bottom row (added to the first and last elements) have enabled approximately in-phase excitation of the top and bottom rows [2]. A clean bandpass characteristic of the antenna with a 10 dB bandwidth of over 10 MHz centered around 74 MHz was obtained by adjusting the feeder position. Additional measurements using a 10-element mockup antenna (same dimensions as the LHD elements, but arranged on a flat plane) indicated that the coupling loop is not necessary. Final tests will be performed with the 10 LHD antenna modules arranged in a helical configuration.

A test with plasma load was performed on the TST-2 spherical tokamak at the University of Tokyo using a 6-strap combline antenna with a passband (defined as the frequency range where the transmission is greater than –10dB) of 2$\tilde{2}$28 MHz. A low-power (1 kW level) high-harmonic fast wave (HHFW) was excited. A movable limiter was used to reduce the plasma density at the antenna. This is necessary to reduce the radiation resistance low enough to allow excitation of a travelling wave. In LHD, this will be accomplished by installing the antenna sufficiently far away from the plasma, and to reduce the plasma density at the antenna further by the picture-frame antenna protector.

During the next fiscal year, final adjustment of the antenna feeder position will be made before installation of the antenna in LHD. We note that this type of antenna is equally applicable to next generation tokamaks such as ITER, as a simple high power in-port travelling wave antenna.

References

[1] Moeller, C.P., et al., in Radio Frequency Power in Plasmas (Proc. 10th Top. Conf., Boston, 1993), AIP Conference Proceedings 289 (AIP Press, Woodbury, NY), p. 323.

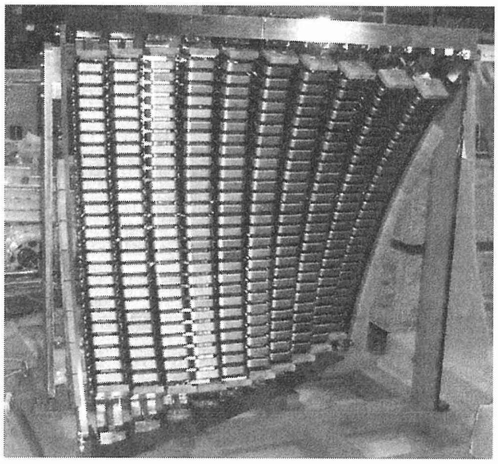

Fig. 1. The LHD "fishbone" antenna assembled for final testing.

[2] Takase, Y., et al., in Annual Report of National Institute for Fusion Science April 2000 – March 2001, p. 236 (2001).