§ 15. Development of a Fast Wave Current Drive Antenna

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A fast wave current drive antenna was 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 regime by controlling the rotational transform profile. Current drive by the ICRF fast wave (magnetosonic wave) is suitable fo r such a purpose.

The "fishbone" antenna [1] built for LHD is equivalent to two "combline" antennas [2] 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), 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 operation frequency is chosen to be in the range 70–75 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, with currents in the top and bottom halves either in-phase (even mode) or out-of-phase (odd mode), are possible in the fishbone antenna configuration. Controlled excitation of the desired even mode is a major issue. Several techniques were developed to selectively excite the even mode, including the use of four feeders instead of two, and the addition of a coupling loop linking the top and bottom halves of the antenna.

Final tests were performed with all 10 LHD antenna modules arranged in a helical configuration (Fig. 1). Reduction of the resistive loss by copper plating the stainless steel current straps improved the band-pass characteristic of the antenna. In such a helically twisted configuration, evidence of finite coupling between the even and odd modes was observed. The feeder positions at the first and last modules of the array were adjusted for optimum pass-band characteristics and impedance matching. Predominant excitation of the even mode was achieved without using the coupling loop mentioned above, by selecting an appropriate operating frequency (in the upper half of the pass-band) under the condition in which reflection from the ends of the antenna array is negligible (Fig. 2). This condition was realized by placing an absorbing film in front of the antenna, simulating plasma loading. Installation of this antenna on LHD will be coordinated with the rest of the LHD research program.

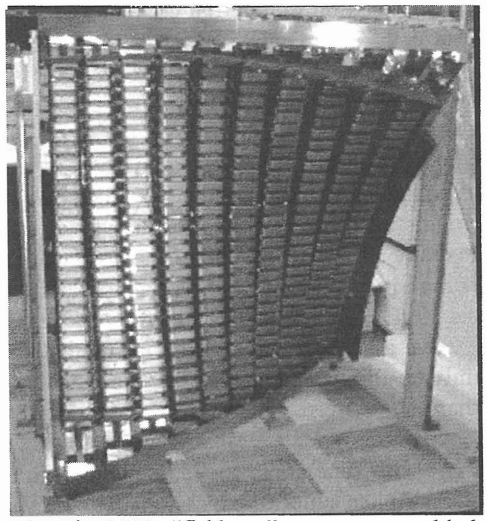

Fig. 1. The LHD "fishbone" antenna assembled for final testing.

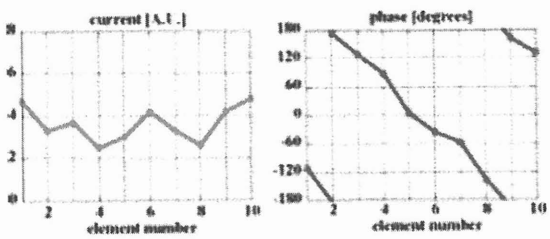

Fig. 2. Current and phase distributions along the 10-element LHD "fishbone" antenna.

References
[1] Takase, Y., et al.: in Fusion Energy 2002 (Proc. 19th Int. Conf., Lyon, France, 2002) paper IAEA-CN-94/FT/P2-05; submitted to Nucl. Fusion.
[2] 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.