§4. Verification of Branch Structure in a Remote Steering Antenna

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There has been considerable interest in a remote steering antenna for local electron cyclotron heating of plasmas in the international thermonuclear experimental reactor (ITER). The structure avoids the use of fast movable mirrors in a vacuum vessel and is advantageous from the viewpoint of maintenance of the antenna. To develop an ECH antenna without a steering mirror in the vacuum vessel, characteristics and optimization of a square corrugated (SC) waveguide antenna with all four sides were examined theoretically and experimentally. In addition to the well-known optimum length of $4a^2/\lambda$ for small-angle injection, existence of many branches was confirmed for large-angle injection. The use of higher branches can extend the scanning angle to as large as 25 degrees [1]. From the viewpoint of small tolerance in the waveguide length, the optimal ratio of an optimal waist size w_0 of injecting Gaussian beam to waveguide size a is found to be $w_0/a = 0.35 \pm 0.1$ [2].

By changing the frequency instead of the waveguide length, the experimental confirmation of branch structure in recursiveness of input Gaussian beam and comparison with the numerical result by the coupling analysis method are carried out. All the scanning directions in the calculation and experiment are perpendicular to the electric field. In Fig.1 , calculated and experimental couplings with incident Gaussian beam component radiated in asymmetric (a) and symmetric (b) directions from the remote steering antenna are contour-plotted. Here, the waveguide length and size are 6.5 m and 60.08 mm. The contours corresponding to optimum frequency $cL/(4a^2)$ =135.0 GHz at the small-angle injection in the fundamental branch are seen at main branch. In the present waveguide size and length, the optimum frequency is 150 and 158 GHz for the second and third branches extending to larger angle. Here, all the experimental and calculated dat are normalized with the value at the normal injection to waveguide mouth. As for the symmetric direction, each branch fills a corresponding gap in the asymmetric direction. Because the observation was carried out for every 2 degrees and 0.05 GHz, the experimental and calculated contours are undulant. Except in the region of lower frequency and large angle, the dependence of efficiency (power) on the frequency and injection angle of incident Gaussian beam is in good agreement with the calculated results.

In conclusion, the agreement between calculated and experimental results enables us to use the symmetric branch and also the higher branches for increasing the injection angle.

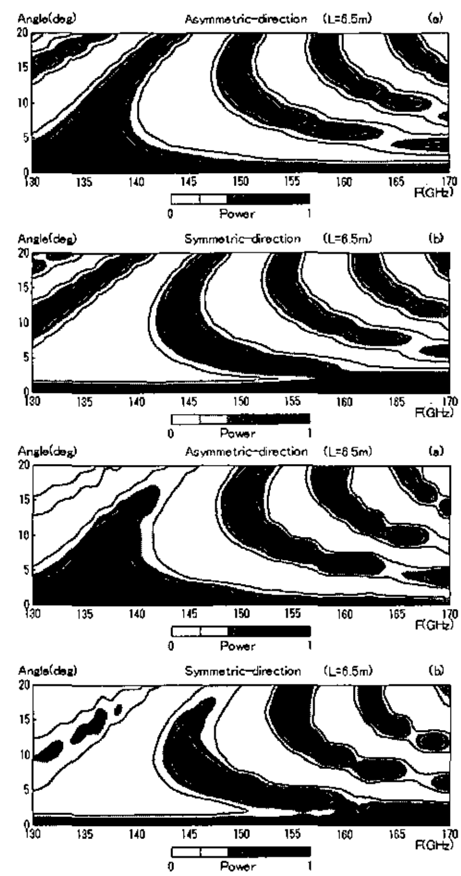

Fig. 1: Calculation (Upper two figures) and Experiment (lower two figures). The contour plots of power in (a) asymmetric and (b) symmetric directions with respect to the incident Gaussian beam with w_0 =22mm.

References

[1] K. Ohkubo et al.: Fusion Engineering and Design vol.65, (2003) 657-677.

[2] K. Ohkubo et al.: US-Japan workshop on RF Heating Technology (Tokai, 2003).