§ 9. Multi-Frequency Transmission in a Remote Steering Waveguide 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. The theoretical and experimental investigations on the square oversized waveguide antenna with corrugated walls on two sides only and all four sides are being examined. Four corrugated walls have an advantage of geometrical symmetry and this study is being accelerated, because the two smooth walls in a square corrugated waveguide with the cross-section of $a \times a$ could be replaced by corrugated walls in the highly oversized waveguide [1]. Both the experimental observation and theoretical analysis of propagation in a square waveguide with four corrugated walls show good agreement [2].

By analysing the antenna system for different waveguide lengths and various injection angles, in addition to the well-known fundamental branch which includes optimum length of $4a^2/\lambda$ in small angle range, existence of branches with high efficiencies was confirmed [3]. The use of higher branches can extend the scanning angle of the ITER alternative antenna to as large as 25 degrees by switching the waveguide with different path-length. In this paper, we describe that a recursive Gaussian beam with high efficiency radiates in the range of the discrete frequency with the increasing steering angle even in a fixed waveguide length. All the scanning directions in the calculation are perpendicular to the electric field. For the various injection angle of Gaussian beam, recursiveness is examined numerically.

In Figs. 1 (a) and (b), the contours of radiated Gaussian beam power for (a) asymmetric and (b) symmetric directions are plotted in the waveguide length and frequency plane. Here, a is 60.08 mm and injection angle ϕ of Gaussian beam with waist size w_0 = 22 mm is 20 degrees. The contours with high efficiency are almost linear because the optimum length L_{asym} and L_{sym} for asymmetric and symmetric directions are nearly propotional to F [3]

$$L_{asym} = \frac{2s+1}{2m_2+1}\frac{4a^2}{\lambda}\frac{1}{1+(\sin^2\phi)/2},$$
$$L_{sym} = \frac{2s}{2m_2+1}\frac{4a^2}{\lambda}\frac{1}{1+(\sin^2\phi)/2},$$

Here, s is an integer in the vicinity of m_2 and m_2 is the mode number of main mode $m_2 = [2a\sin\phi/\lambda]$ and ϕ is the injection angle [3]. The operator $[u]$ shows the operation which takes only the integer part of u.

The operating range of the antenna system can be extended as a result of characteristics of this branch structure on efficiency.

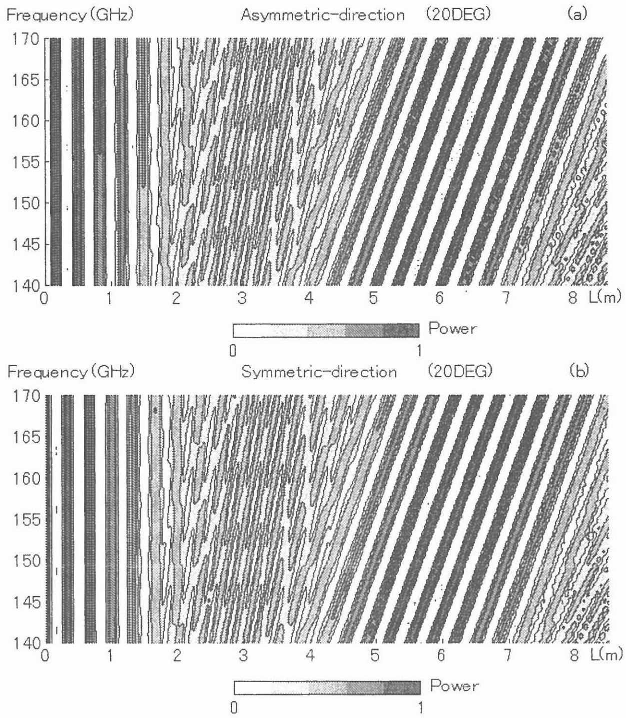

Fig. 1: : The contour plots in the waveguide length and frequency plane of radiated power in (a) asymmetric and (b) symmetric directions with respect to the incident Gaussian beam with w_0= 22 mm and ϕ=20 degrees.

Reference

[1] K. Ohkubo: Int. J. Infrared and Millimeter Waves, vol.22, (2001), 1709-1727.

[2] W. Kasparek et al.: 12th Joint Workshop on Electron cyclotron Emission and Electron Cyclotron Heating (Aix-en-Provence, 2002).

[3] K. Ohkubo et al.: to be published in Fusion Engineering and Design (2003) and 5th Int. workshop in Strong Microwaves in Plasmas (2002).