§3. Field Analysis Radiated from Remote Steering Antenna

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A remote steering antenna concept has been proposed and developed for Electron Cyclotron Heating and Current Drive (ECH/ECCD) experiments at the International Thermonuclear Experimental Reactor (ITER). There are two operation modes in a remote steering antenna, anti-symmetric and symmetric modes. The anti-symmetric antenna was considered as the ITER-antenna, and the symmetric antenna with an extended steering-angle capability was developed and used for the ECH/ECCD experiments in the TRIAM-1M tokamak. The radiated field from the antenna was analyzed, based on Gaussian optics, moment and matching coefficient methods [1]. In order to directly evaluate the field radiated from the antenna, the Kirchhoff Integral code has been developed, which has been complied into a integration code to teat issues of coupling of the incident beam into the antenna, transmission in the antenna, and radiation from the antenna.

The remote steering antenna at various antenna lengths has been prepared to study the performance of the antenna in the extended operation regions. The hybrid (m,n) modes, which were coupled into the antenna at the input aperture, were transmitted in the antenna with different propagation constants of β_{mn}. The field at the antenna length L was expressed from summation of the hybrid (m,n) mode components with the phase factor of $\exp(-i\beta_{mn}L)$. The antenna length was one of main parameters to determine the antenna performance. In order to evaluate the field radiated from the antenna aperture, the Kirchhoff integral was used as follows,

$$
\begin{aligned}
E_{x,y}(x,y,z) &= \frac{i}{\lambda z}\int_{-a/2}^{a/2}\int_{-a/2}^{a/2} E_{x,y}(x',y') \\
&\times \left[\exp(-i\frac{2\pi r}{\lambda})/r\right]dx'dy' \\
r &= \sqrt{(x-x')^2+(y-y')^2+z^2}.
\end{aligned}
$$

where a was a side of the squared antenna aperture. The coordinates of (x',y') and (x,y,z) were at the antenna aperture and at the radiated positions, and $E(x',y')$ expressed the fied sumed up the hybrid mode components at the aperture.

The various lengths antenna performance was preliminarily tested in low power test facilities at Kyushu University. The phase profiles as well as the intensity profiles were measured using a vector network analyzer system. Figure 1 shows the measured intensity and phase profiles in the y direction of the beam radiated from the antenna at z=50 mm. The steering angle was 10 degree in the $x-z$ plane, and the anti-symmetric field was plotted in this figure. The antenna length was 3.6m, and the side of square aperture was 0.04m. These antenna length and the side were not optimized for the anti-symmetric antenna performance. The intensity profile had some local peaks, which were result from the interference among the radiated hybrid modes. The phase profile was rather smooth. In the figure, the intensity and phase profiles evaluated using the Kirchhoff integral were also plotted. The complicated intensity profile was also shown, but did not coincide with the measurement. The evaluated phase profile well explained the measured profile. In the evaluation, a pure Gaussian beam was used in the coupling into the antenna, and the coupled hybrid modes were transmitted to the output aperture at L =3.6 m. The measured intensity and phase profiles of the incident beam will be included in the analysis in near future. The comprehensive study of the antenna performance at the various antenna lengths is planed in the extended operation regions.

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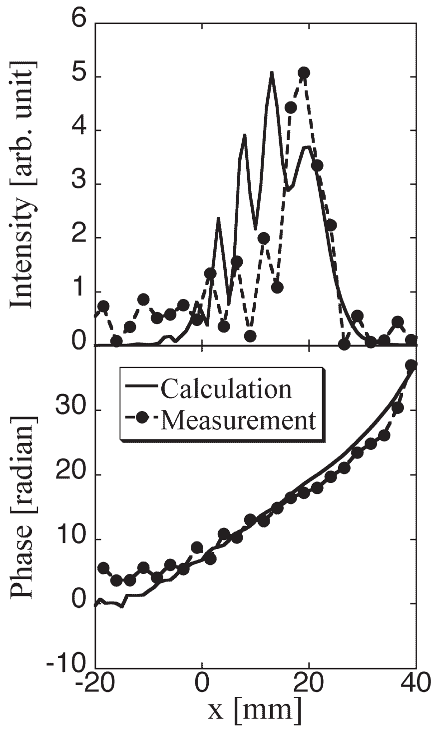

Fig. 1: Measured intensity and phase profiles at the various lengths antenna of L =3.6 m and a =0.04 m. The steering angle is 10 degree. The profiles evaluated from the Kirchhoff integral code are also plotted.

Reference
[1] Idei, H., *et al.*, Nuclear Fusion, **46**, 489 (2006).