§33. Electromagnetic Analysis in Corrugated Waveguide using 3D-FDTD

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i) Introduction In the Large Helical Device (LHD), the Electron Cyclotron Heating (ECRH) system is used for the plasma heating. In ECRH, the electromagnetic millimeter waves are transmitted using long corrugated waveguides, and a miter bend is used to bend the propagation direction of electromagnetic waves at a right angle. The miter bend is primary cause of the transmission loss. In addition, various higher-order modes are generated during the propagation process. It is known that the generated various higher-modes degrades the transmission efficiency.

The polarizer miter bend is implemented for making the polarized waves for efficient plasma heating, and the polarizer miter bend is substantiated by digging rectangular grooves on the miter bend's reflector surface.

The purpose of the present study is to develop the numerical code for analyzing the wave propagation phenomena in the corrugated waveguide by a three-dimensional Finite-Deifference Time-Domain (FDTD) method. In addition, the influence of the miter bend and the polarizer miter bend on the transmission modes are numerically investigated [1, 2].

ii) Results and Discussions The electromagnetic wave propagation phenomena in the corrugated waveguide with the miter bend and the polarizer miter bend are simulated by three-dimensional FDTD. In Fig. 1, we show the spatial distribution of the time-averaged electric field intensity in case of the miter bend. Note that HE_{11} mode that is an eigenmode of the corrugated waveguide is adopted as the source wave. Despite the distortion of the intensity is observed, it can be seen that the intensity distribution is propagated while concentrated near the center of the waveguide. It can be said that the main transmission mode is HE_{11}.

On the other hand, the concentrations of the electric field intensity are confirmed periodically by the beats which are interference between the base mode and the other higher-order modes as shown by dotted circles in the figure. Thus, we can gather from the figure that the beat length is assumed as 60 mm. However, adjacent

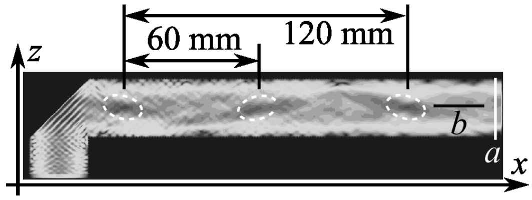

Fig. 1: The Spatial distribution of the time-averaged electric field intensity in case of the miter bend.

shapes of the concentrated parts are different. That is to say, the shape changes downward from left to right to upward from left to right, periodically, and we can also gather from the figure that the beat length is assumed as 120 mm. From this point of view, the candidates of the higher-order modes excited at the miter bend are HE_{22} mode (or degenerated TM_{03} or TE_{02} mode) for the beat length of 126 mm, or HE_{42} mode (or degenerated EH_{23} mode) for the beat length of 60.4 mm.

Finally, the distribution of electric field intensity and the electric field $\boldsymbol{E}$ on output plane a (see Fig. 1) are numerically investigated. From the result, the linear polarization is confirmed in cases of miter bend and polarizer miter bend with $\theta = 0°$. Here, *theta* denotes the rotate angle of the polarizer miter bend. Although the linear polarization is also observed in case of $\theta = 90°$, the direction of the vector is opposite comparing with the result of $\theta = 0°$. On the other hand, the elliptical polarization is clearly confirmed in case of PMB with $\theta = 45°$. From the above results, it is suggested that the polarization can be controlled by changing the rotate angle of the PMB's reflector [2].

Additionally, the wave propagation simulations are implemented by means of meshless based method. Meshless Time-Domain Method (MTDM) is adopted for the wave propagation shimulation in complex shaped waveguide. In the method, we employ the interpolating moving least-squares for the weight functions of MTDM, and the stability of the method increases than the original MTDM [3].

1) Y. Fujita, S. Ikuno, S. Kubo and H. Nakamura, “Electromagnetic wave propagation in waveguide considering influence of induced current”, 24nd International Toki Conference, Gifu, Japan, Nov. 2014

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3) T. Itoh, and S. Ikuno: “Interpolating Moving Least-Squares-Based Meshless Time-Domain Method for Stable Simulation of Electromagnetic Wave Propagation in Complex Shaped Domain”, IEEE Trans. Magn., Vol. 52, No. 3 (2016), 7207404.