§34. Optimization of Millimeter-Wave Components Using FDTD Simulation

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It is necessary to provide low-loss transmission of electromagnetic wave for electron cyclotron heating (ECH) system to realize the nuclear fusion generation. To achieve this purpose, a lot of researches have been being done (see Refs. [1-3]) As one of the brilliant successes, it was found that corrugating the walls reduces the loss further not only in straight runs but also at bends and that the corrugation makes the waveguide robust against small deformations[1]. Moreover theoretical calculations, which are based on a space-harmonic analysis of electromagnetic waves, contribute for these properties to be maintained over very wide bandwidths[1]. According to their work[1], the theoretical calculations were validated by the measurements on waveguides.

In order to improve the waveguide to transport with lower-loss energy than the previous design in Ref.[1], we challenge to optimize the waveguide structure by simulating the time evolution of electromagnetic fields in the waveguide by finite-difference time-domain method (FDTD) method (see Refs. [4-6]). In FDTD method, the three-dimensional Maxwell equation is solved numerically, in the perfect matched layer boundary condition[7], for the same situation as the experimental configuration.

Because the corrugated waveguide has the cylindrical symmetry, (i.e., continuous rotational symmetry) for the azimuthal angle φ, the three dimensional simulation can be reduced to the two-dimensional (r,z)-coordinates calculation, where the electromagnetic fields are proportional to a function exp(imφ), where m is an integer (related to the angular momentum of the field). The simulation parameters are as follows: the wave length is 3.57 mm (the frequency 84 GHz), the spatial mesh is 0.025 mm, and the time step Δt = 0.33×10-11 sec. As the initial configuration, the electromagnetic fields are set to zero in the whole space.

In Fig. 1, we draw the isosurfaces of the r component of the magnetic field for the two types of the cylindrical waveguides, that is, (a) "normal" waveguide and (b) corrugated waveguide. In the z direction, the shape of the electromagnetic field seems to the plane wave, i.e., $\exp(ik_z z)$, where kz is the wave number in the z direction. We plot the total electromagnetic energy v.s. time t whose unit isΔt) in Fig. 2. When the time t is less than 100 step, the total energy is increasing. Around t~100, there is a peak. After it, the total electromagnetic field is stabilized. This property denotes the energy is conserved in the simulation.

We performed FDTD simulation with PML boundary condition for cylindrical corrugated waveguide in two-dimensional coordinates. The conservation of the total electromagnetic field in the waveguide is confirmed. In the next step, it is expected to optimize the shape of the waveguide using this simulation.

The present works were supported by Grant-in-Aid for Research (No. 19055005 and No. 23710135) from MEXT, NIFS Collaboration Research program (NIFS09KNSS002, NIFS11KNTS008, NIFS11KNSS020, and NIFS11KNTS010), and NINS Program for Cross-Disciplinary Study. A part of numerical simulation was carried out by the use of the Plasma Simulator at the National Institute for Fusion Science.

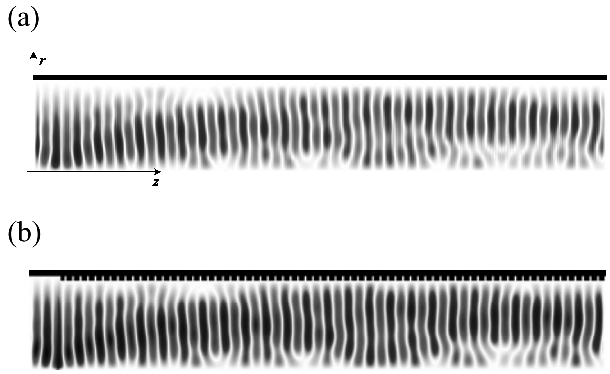

Fig. 1. The *r* component of magnetic field in (*r, z*) plane at time 700× *Δt*. (a) The normal waveguide: (b) The corrugated wave guide.

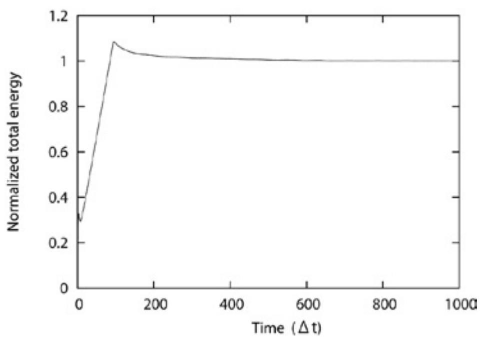

Fig. 2. Time dependence of the total energy for electromagnetic field in the corrugated waveguide. The energy is normalized by the saturated total energy.

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