Modelling of Open Boundaries for FIT/FDTD-Simulations of Particle Beams

M.C.Balk*[1], R. Schuhmann, T. Weiland
Technische Universität Darmstadt
Computational Electromagnetics Laboratory (TEMF)
Schlossgartenstr. 8, 64289 Darmstadt, Germany
balk@temf.tu-darmstadt.de

Electromagnetic field simulations with FIT (FDTD-like) provide solutions for a large range of different problems and the corresponding methods are quite sophisticated. However, there still is a need –e.g. in particle accelerator laboratories– of simulating charged particle beams with appropriate boundary conditions.

Existent **P**article **I**n **C**ell (PIC) methods for simulating moving particles are numerically inefficient in case of heavy-ion beams, where the particles show nearly unchanging electromagnetic characteristics throughout the structure. Furthermore, no open boundary condition exists for particles with ($v < c$). Therefore, a method is proposed to simulate charged particle beams in time domain within the Finite Integration Technique (FIT, cf. Weiland, *Int. J. Num. Mod.* **9**, 259-319, 1996).

As first step, the moving charged particles are modeled as a line current along one grid line. This current is implemented using a discrete form of the continuity equation. Hence, the approach ensures the line current to be divergence free and does not introduce unphysical electric charges. At the end of the calculation domain a prediction of the line current via a "Mur"-type open boundary condition is needed.

In the second step – the boundary condition– the electromagnetic field of a charge moving towards the calculation domain has to be considered. Assuming an infinitely long homogeneous beam tube and $v < c$ this field is of infinite extent. Thus, a threshold is discussed, which is a "quasi" limit of the charge's influence on the boundary of the calculation domain.

The electromagnetic field of the moving charge can be found by a combination of a Lorentz transformation and a discrete electrostatic field solution. The Lorentz transformation is applied to the grid where the charge is moving. In the resulting grid, the electric field of the charge can be found by the solution of a discrete Poisson equation. Then this field –after the re-transformation– can be used to impose the boundary fields. The advantage of such a grid based transformation is that the resulting fields obey some consistency laws on the discrete level.

The method will be applied to a typical particle accelerator structure.

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