Computation and bench measurements of beam coupling impedance

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Introduction

Beam coupling impedance can cause excessive heat load and coherent beam instabilities in high intensity synchrotrons. Therefore, a quantification of the beam coupling impedance for the components in SIS100 is outlined. We describe the development of a 2D Finite Element (FEM) frequency domain solver for longitudinal and transverse beam coupling impedances for arbitrary relativistic beam velocity. This solver can compute space charge and resistive wall impedances on a triangular mesh. It is based on the open source FEM package FEniCS [1] and mesh generator GMSH [2] and it is available for download at [3].

The beam coupling impedance of different components was also measured by the wire method. The wire method is based on emulating the electromagnetic fields of a particle beam by a TEM mode, i.e. it corresponds only to an ultra-relativistic beam. In the following we show a comparison for a ferrite ring, which is also analytically accessible.

A Ferrite Ring as Example

A ferrite ring of outer diameter 3.05cm and length 2.54cm was chosen for the validation of both measurement technique and our simulation code. The measurement results, together with a 3D reference simulation in time domain by CST Particle Studio®[4] for relativistic velocity $\beta = 1$ can be seen in Fig. 1 (top). The discrepancy visible in the plot originates mostly from the error in the applied material data as given in the frequency domain by the manufacturer of the ring[5], and the fit of these data on a impulse response function, necessary to perform time domain computations. The measurement was performed with a Vector Network Analyzer, where the longitudinal impedance is obtained from the measured S_{21}-parameter by [6]

$$Z_{\|}(f) = 2Z_0 \ln \frac{S_{21}^{\mathrm{REF}}(f)}{S_{21}^{\mathrm{DUT}}(f)}, \tag{1}$$

with Z_0 being the characteristic impedance and S_{21}^{REF} being the transmission in the empty measurement housing.

A 2D simulation with our code, compared to 2D analytic calculations is depicted in Fig. 1 (bottom). Such a simulation in frequency domain allows arbitrary relativistic velocity. The 2D calculations are valid for distributed impedances, i.e. above a certain length, see [7].

Details about our FEM frequency domain solver can be found in [8], and a detailed analysis of the wire measurement method is available in [7]. The wire measurement method was also applied to a SIS18 kicker magnet, see [9].

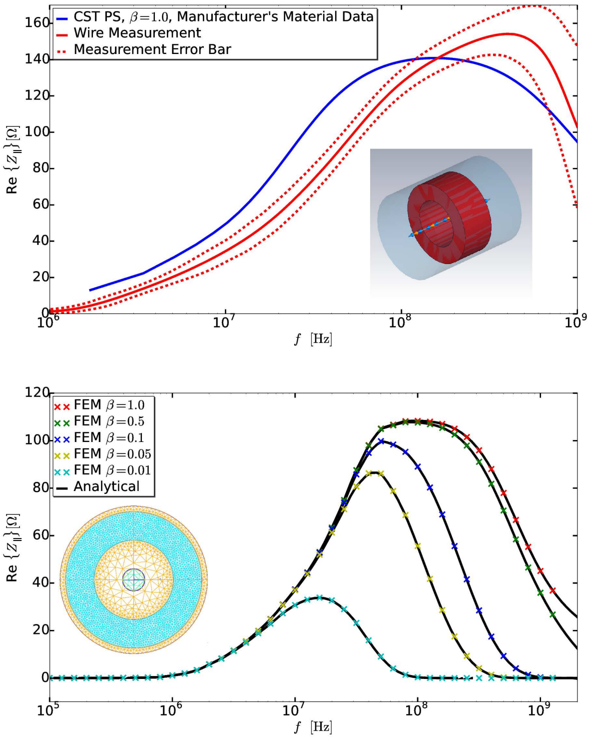

Figure 1: Top: impedance measurement using the wire method [7] vs. 3D numerical computation in the time domain. Bottom: 2D analytical and numerical calculation with the newly developed FEM code [8]. All computations rely on the manufacturer's material data [5], which is specified with 20% error range.

References

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