COMPREHENSIVE BENCHMARK OF ELECTROMAGNETIC 3D CODES IN TIME AND FREQUENCY DOMAIN

V. Serrière, J. Jacob, N. Guillotin, ESRF, Grenoble, France
F. Marhauser, E. Weihreter, BESSY II, Berlin, Germany

Abstract

A comprehensive benchmark of todays most powerful numerical 3D Eigenmode and Time Domain Solvers has been performed using the input geometry of a HOM-damped cavity and a highly lossy waveguide load developed at BESSY. The paper details the simulation results partly compared with existing experimental data.

INTRODUCTION

A normal conducting strongly HOM-damped single cell 500 MHz cavity ("EU cavity") for 3rd generation SR sources has been developed at BESSY. Its first version uses tapered double ridged Circular Waveguide to Coaxial Transitions (CWCT's) with vacuum external RF loads as HOM-dampers. The geometry of the cavity as well as the shape and location of the HOM-dampers were optimized using MAFIA and Microwave Studio (time domain and eigenmode solver) [1-2]. An improved design of the HOM-dampers with circular ridged waveguides loaded by UHV compatible absorbing NiZn ferrite material (C48/Countis Industries) has then been developed with the aim to increase the damping efficiency of the HOMs and reduce the investment cost for the HOM-dampers.

In parallel, the ESRF is currently developing a scaling to 352.2 MHz of the EU cavity, using alternative simulation codes GdfidL and HFSS [3]. It was thus natural to compare the numerical simulation results for a given geometry. This paper summarizes the results obtained with MAFIA, GdfidL, Microwave Studio and HFSS for the 500 MHz EU cavity including studies for the improved HOM-damper. Moreover, the numerical results could be compared to a large extent by existing experimental data.

BENCHMARK MAFIA GDIFDL

A comparative evaluation of MAFIA and GdfidL in time domain computation has been performed using the first design of the EU cavity with the CWCT dampers. The computed longitudinal HOM spectra up to 3 GHz (the TM01 cutoff frequency of a typical 3rd generation vacuum chamber cross-section) are plotted in figures 1, 2 and 3 respectively. The simulations are compared with experimental data obtained with the bead-pull technique [4]. Computations have been performed using half of the complete structure and applying a magnetic boundary condition. The longitudinal impedance spectrum has been evaluated from a Fast Fourier Transform of the longitudinal wake potential computed over 400 m to guarantee a sufficient resolution of the HOMs.

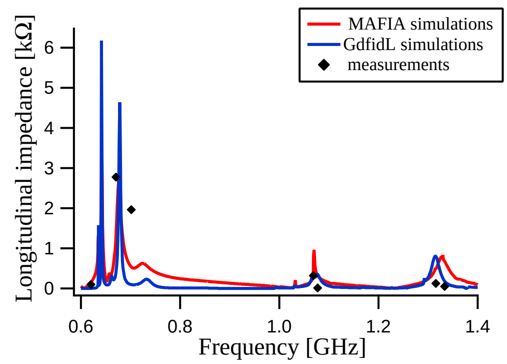

Figure 1: Measured and predicted longitudinal HOMs impedance from 600 MHz to 1.4 GHz.

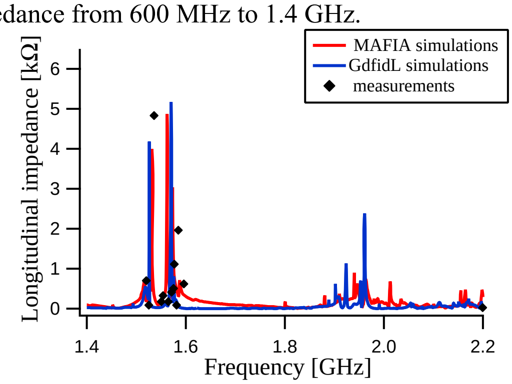

Figure 2: Measured and predicted longitudinal HOMs impedance from 1.4 GHz to 2.2 GHz.

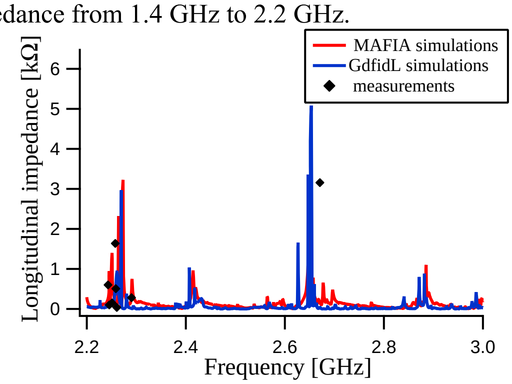

Figure 3: Measured and predicted longitudinal HOMs impedance from 2.2 GHz to 3 GHz.

Simulations with MAFIA and GdfidL show a good agreement. The resonant frequencies of the HOMs are similar and amplitudes are quite close. Measurements carried out on the final prototype indicate smaller HOM impedances than predicted with both codes, except for the HOM at 1.55 GHz. It is worth noting that MAFIA and GdfidL predict some HOMs that where could not be proven experimentally, especially in the ranges around 2, 2.4 and 3 GHz. These modes are probably numerical artifacts attributed to the problem of discretization of the complex tapered shape of the CWCT. However, even when decreasing the mesh size, these modes didn't disappear and are therefore not understood.

A comparison on the transverse impedance has also been done by computing the horizontal transverse wake over 400 m with a horizontal displacement of the beam. In order to exclude longitudinal modes an electric boundary condition was applied to the vertical plane crossing the beam axis. Here too, simulations with GdfidL and MAFIA are in good agreement and compare well with the measurements. Note that the computed transverse HOM spectrum also gives numerical artifacts.

TIME DOMAIN COMPUTATIONS WITH ABSORBING MATERIAL

In the improved design, ferrite loaded circular double ridged waveguides with constant cross-section will be used as HOM absorbers. Figure 4 shows the shape of such a HOM absorber ended by two absorbing C48 ferrite tiles.

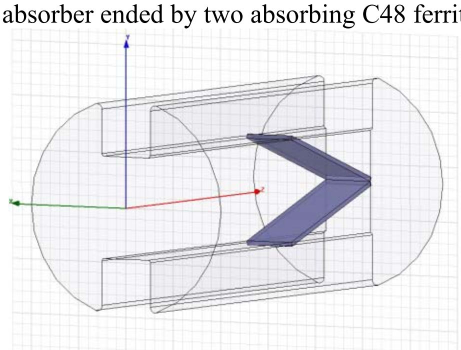

Figure 4: Ferrite loaded circular ridge waveguide.

HFSS has been used to optimize the geometrical dimension of the ferrite tiles. Figure 5 shows the reflection coefficient of the waveguide damper with two tiles of 150 mm length, 51 mm width and 3.9 mm thickness.

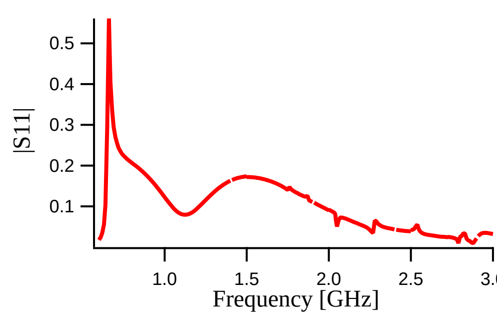

Figure 5: Reflection coefficient of ferrite loaded circular ridge waveguide.

The total reflection coefficient is below 0.2 in magnitude for HOM frequencies above 850 MHz and lies between 0.2 and 0.45 for the first existing HOM in the EU cavity.

One advantage of GdfidL is the possibility to include absorbing material in time domain computation, which is not possible with MAFIA. Only GdfidL could therefore be used to simulate the cavity with this ferrite loaded waveguide. The absorbing properties of C48 ferrite are strongly frequency dependent. However, the time domain code can only handle a fixed absorption coefficient. To compute the HOM impedances, it is therefore necessary to perform simulations for various absorption coefficients, corresponding to the values for the ferrites at different frequencies. Figures 6, 7 and 8 show the superposed longitudinal HOM impedance spectra up to 3 GHz computed for ferrite parameters between 600 MHz and 3 GHz from 400 m long wakes.

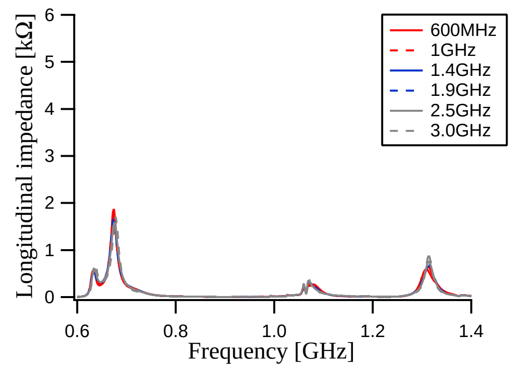

Figure 6: Predicted longitudinal HOM impedances from 600 MHz to 1.4 GHz.

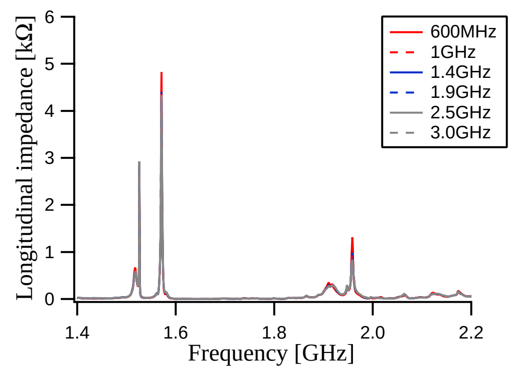

Figure 7: Predicted longitudinal HOM impedances from 1.4GHz to 2.2 GHz.

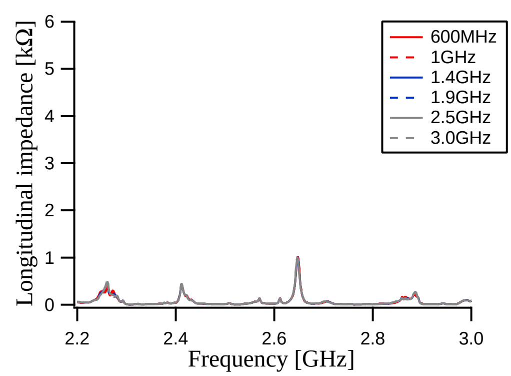

Figure 8: Predicted longitudinal HOM impedances from 2.2 GHz to 3 GHz.

The zooms in figures 9 and 10 show only a little influence of the frequency dependent absorption coefficient. For the optimization process of a structure, it is therefore sufficient to work with a single absorption parameter. Only the final design should then be checked with the complete set of values.

The plots in figures 6 to 8 show a more efficient HOM damping with ferrite loaded dampers as compared to the first CWCT design. The impedances of the first HOMs below 750 MHz and those above 1.8 GHz are reduced by more than a factor two. The HOM impedances between 1 GHZ and 1.6 GHz are in the same range for both designs. It is worth noting that the numerical artifacts disappear with the ferrite loaded dampers and that the HOM impedance at 2.65 GHz is reduced by a factor 5.

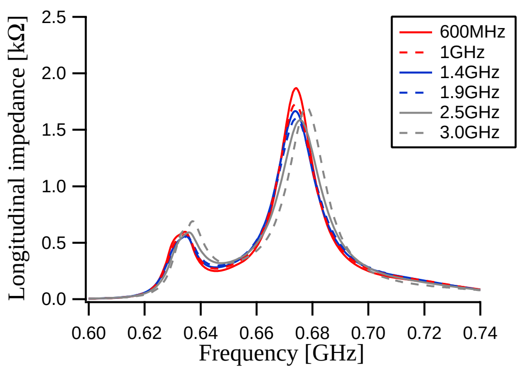

Figure 9: HOM impedance around 680 MHz.

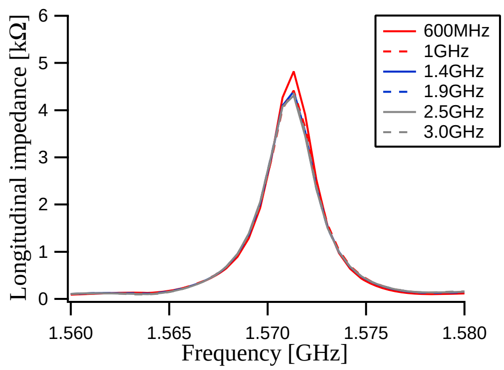

Figure 10: HOM impedance around 1.57 GHz.

HIGH POWER DAMPER PROTOTYPE

A high power prototype of the ferrite loaded HOM-damper has been optimized using Microwave Studio [5]. The shape of this device is shown in figure 11.

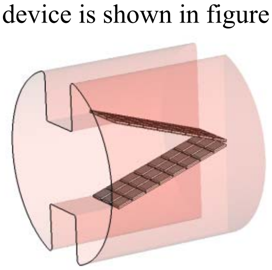

Figure 11: High power model of the ferrite HOM-damper.

In figure 12, the simulated reflection coefficient is compared to TDR measurements. Both compare well, when only one waveguide mode is considered. Taking into account five waveguide modes leads to small discontinuities at the respective cut-off frequencies and to a global overestimation of the reflections as compared to the measurements. Additionally, some of the discrepancies may be explained by the strong dependency of the ferrite material properties on the fabrication process so that these differ from the simulation input.

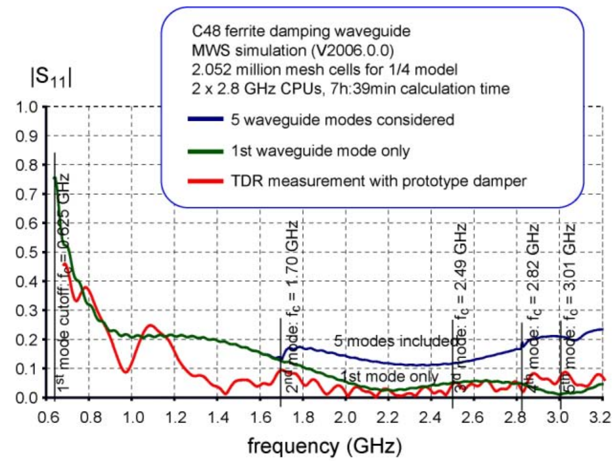

Figure 12: Simulated and measured |S11| of the high power ferrite loaded HOM-damper.

CONCLUSION

A successful benchmark of MAFIA and GdfidL with an existing complex and highly lossy HOM-damped cavity structure has been performed showing a well agreement of simulation results with experimental data. GdfidL has the advantage of allowing time domain computations with the presence of absorbing material. GdfidL was therefore used to simulate the improved HOM damping efficiency when using absorbing ferrite loaded waveguide as HOM-damper. Unfortunately, the results could not be compared with another method. However the expected improved overall HOM-damping efficiency could be proven. Experimental verifications of these findings are planned on both the EU cavity and the scaled ESRF version presently in development.

REFERENCES

[1] F. Marhauser, E. Weihreter, BESSY-016-July-2001, internal report

[2] F. Marhauser, E. Weihreter, D.M. Dykes, P. McIntosh, “HOM damped 500MHz design for 3rd generation SR sources”, PAC’01

[3] N. Guillotin, J. Jacob, V. Serrière, ”Development of HOM damped copper cavity for the ESRF”, these proceedings.

[4] F. Marhauser, E. Weihreter, ”Impedance measurements of a HOM-damped low power model cavity”, PAC’03

[5] E. Weihreter, V. Duerr, F. Marhauser, ”A ridged circular waveguide load for cavity HOM damping”, these proceeding.