Status of PSB Impedance calculations: Inconel undulated chambers

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Thanks to: E. Benedetto, J. Borburgh

Overview

- Impedance calculations at $\beta<1$
- Inconel undulated chamber
  - Comparison between Inconel undulated chamber and ceramic chamber
    - Analytical calculation (no corrugation)
    - 3D CST EM simulation
- Summary

Impedance calculations for $\beta < 1$

Analytical calculation (applies only to simple structures)

3D EM simulation (CST Particle Studio: never used for $\beta < 1$)

CST EM simulation are commonly performed in the ultra-relativistic approximation ($\beta = 1$)

$$\beta_{inj}^{PSB} \cong 0.3 \qquad \beta_{ext}^{PSB} \cong 0.9$$

The use of 3D EM simulations for $\beta < 1$ has been investigated

Definition of impedance

$$Z_{\parallel}(x, y, x_0, y_0, \omega)\,[\Omega] = -\frac{1}{q_0}\int_0^L E_s(x, y, s, x_0, y_0, \omega)\, e^{jks}\, ds$$

Longitudinal component of the electric field in (x, y) induced by a source charge placed in (x_0, y_0)

$$E_s^{tot} = E_s + E_s^{SC}$$

Depend only on the source

$$Z_{direct}^{SC}(\beta)$$

EM simulator uses the total fields

$$Z(\beta)$$

contribution due to the interaction of beam and accelerator components

3D CST EM simulation for $\beta < 1$

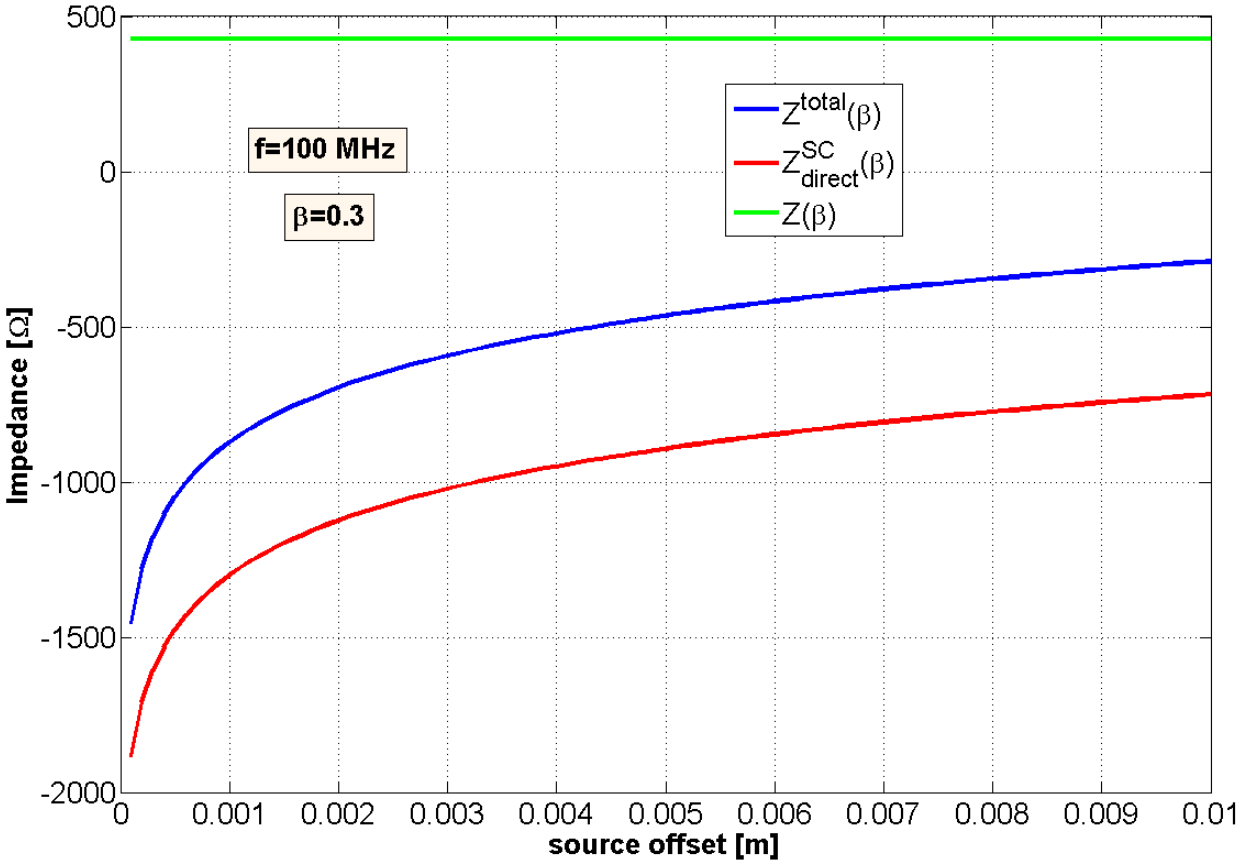
$$Z^{total}(\beta) = Z(\beta) + Z^{SC}_{direct}(\beta)$$

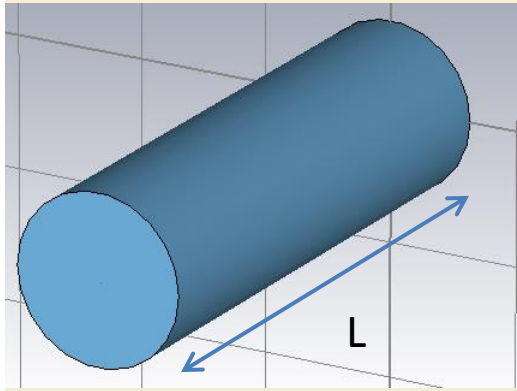
Depend only on the source

contribution due to the interaction of beam and external surroundings

To single out the impedance contribution $Z(\beta)$ the direct space charge is analytically removed

Longitudinal impedance: analytical calculation

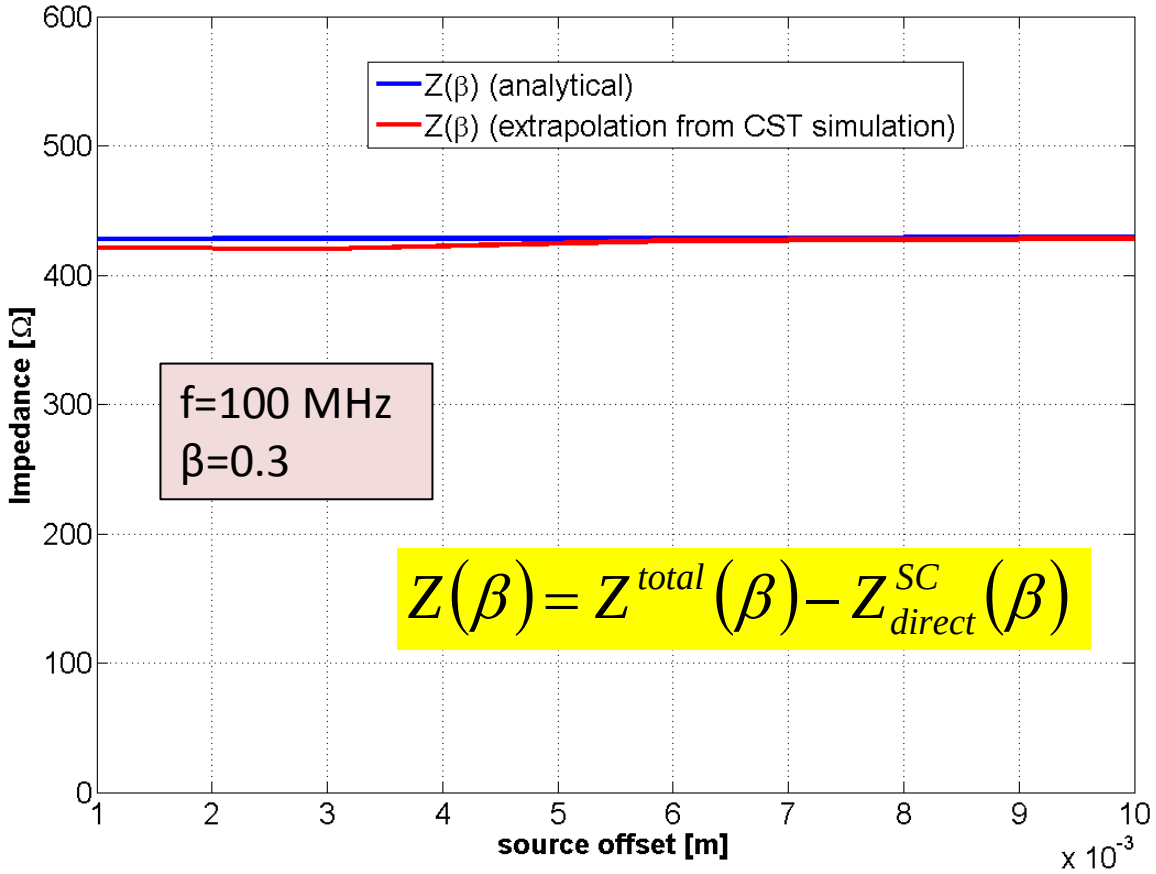


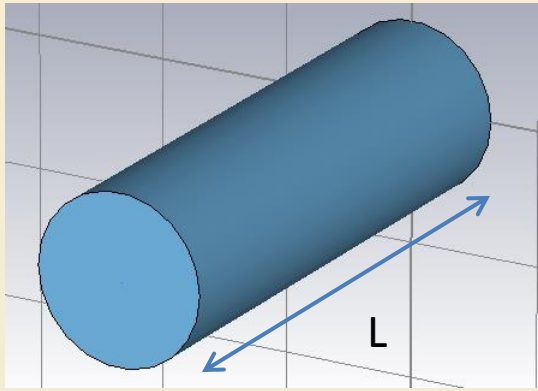


L = 0.2 m

Radius= 0.0315 m

Longitudinal impedance: comparison between the analytical calculation and the CST simulation





L = 0.2 m

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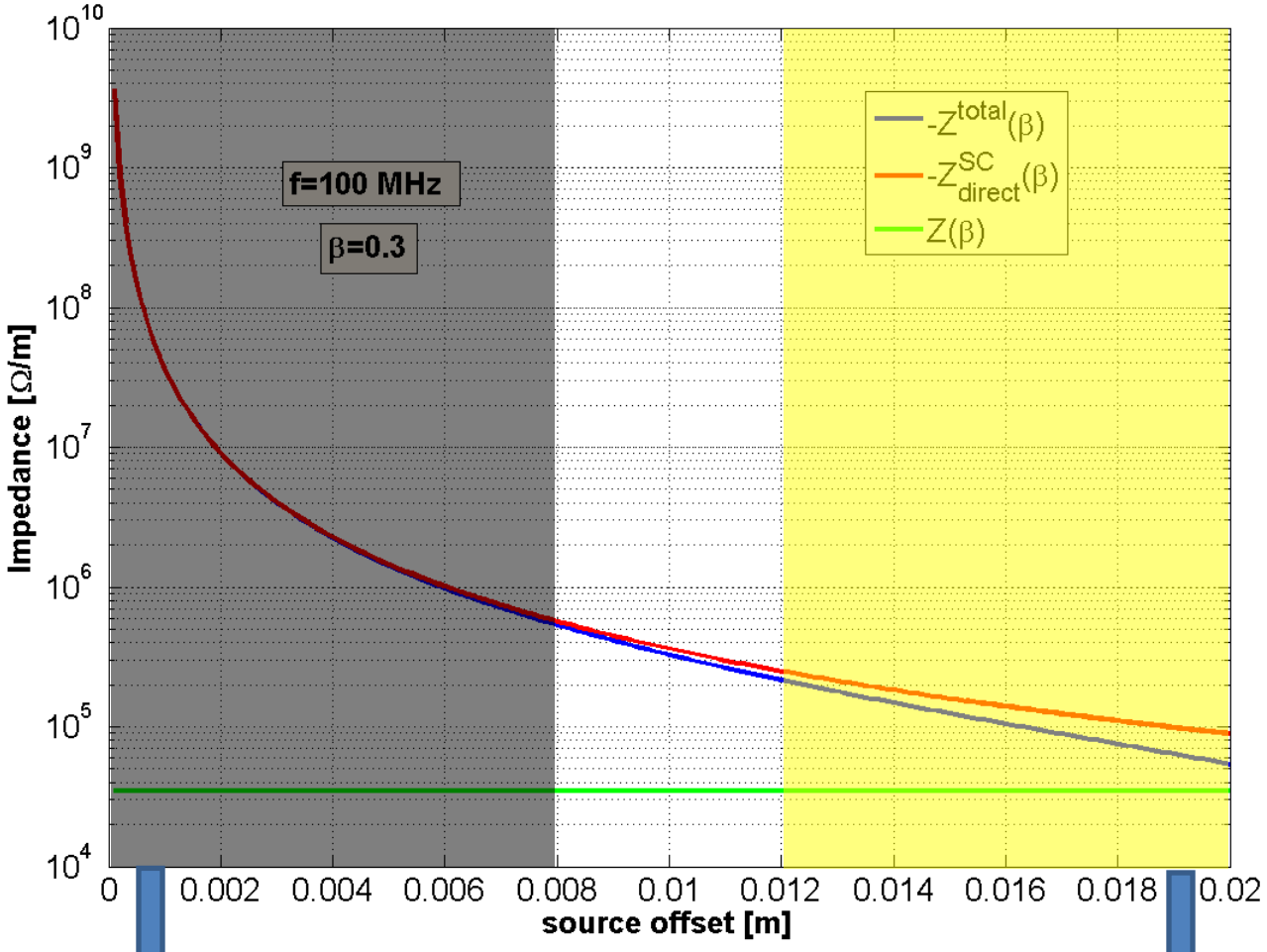
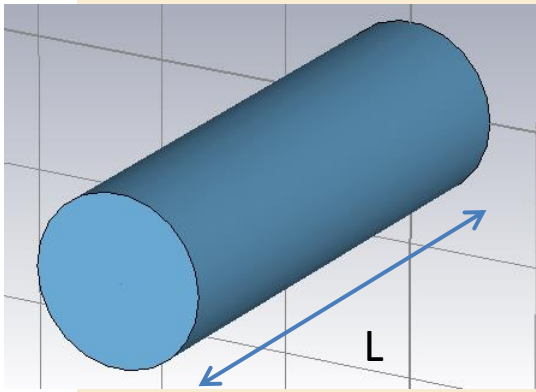
Transverse impedance: analytical calculation



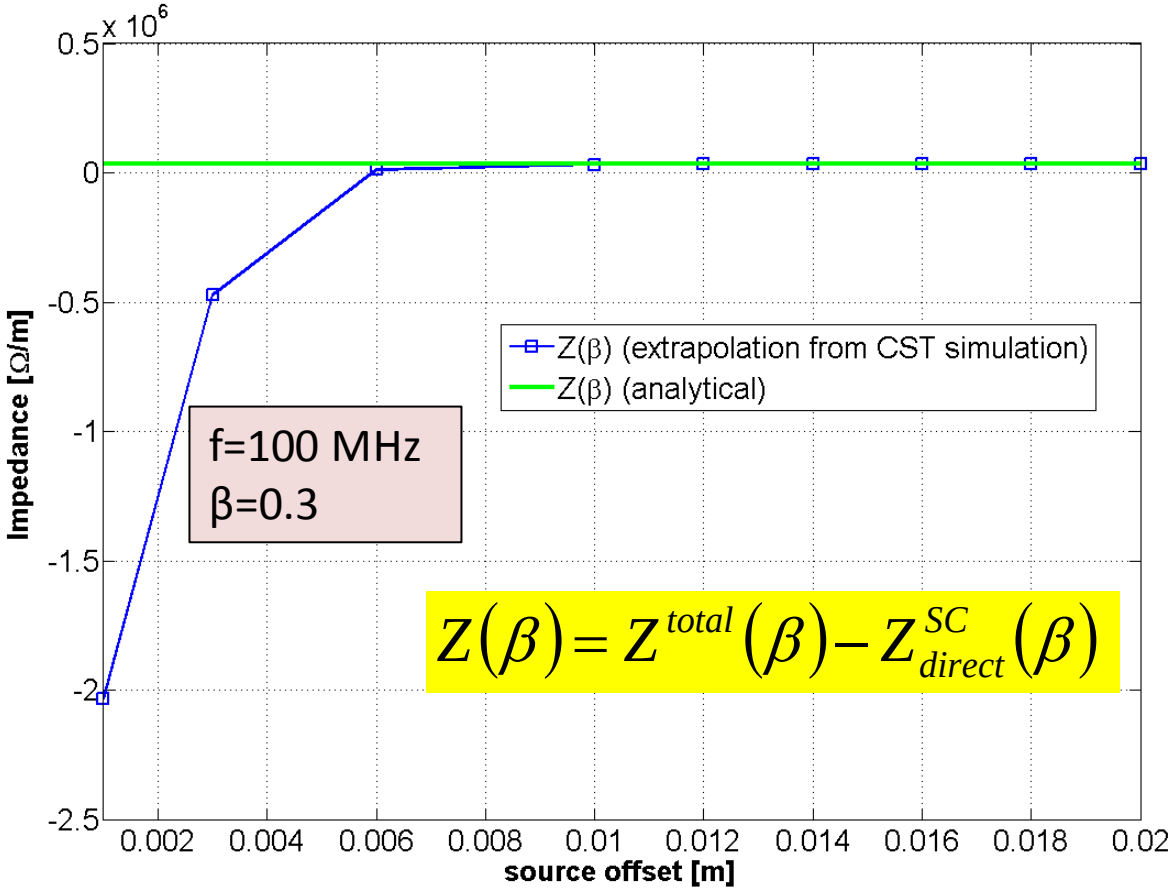


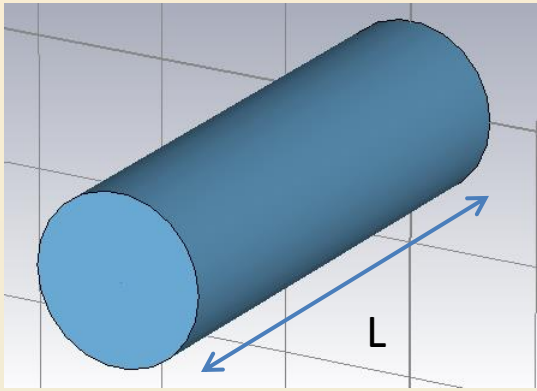
L = 0.2 m
Radius= 0.0315 m

The extrapolation of $Z(\beta)$ would require a very high accuracy of the simulation (impossible to be reached)

The accuracy of the simulation allow the extrapolation of $Z(\beta)$

Transverse impedance: comparison between the analytical calculation and the CST simulation





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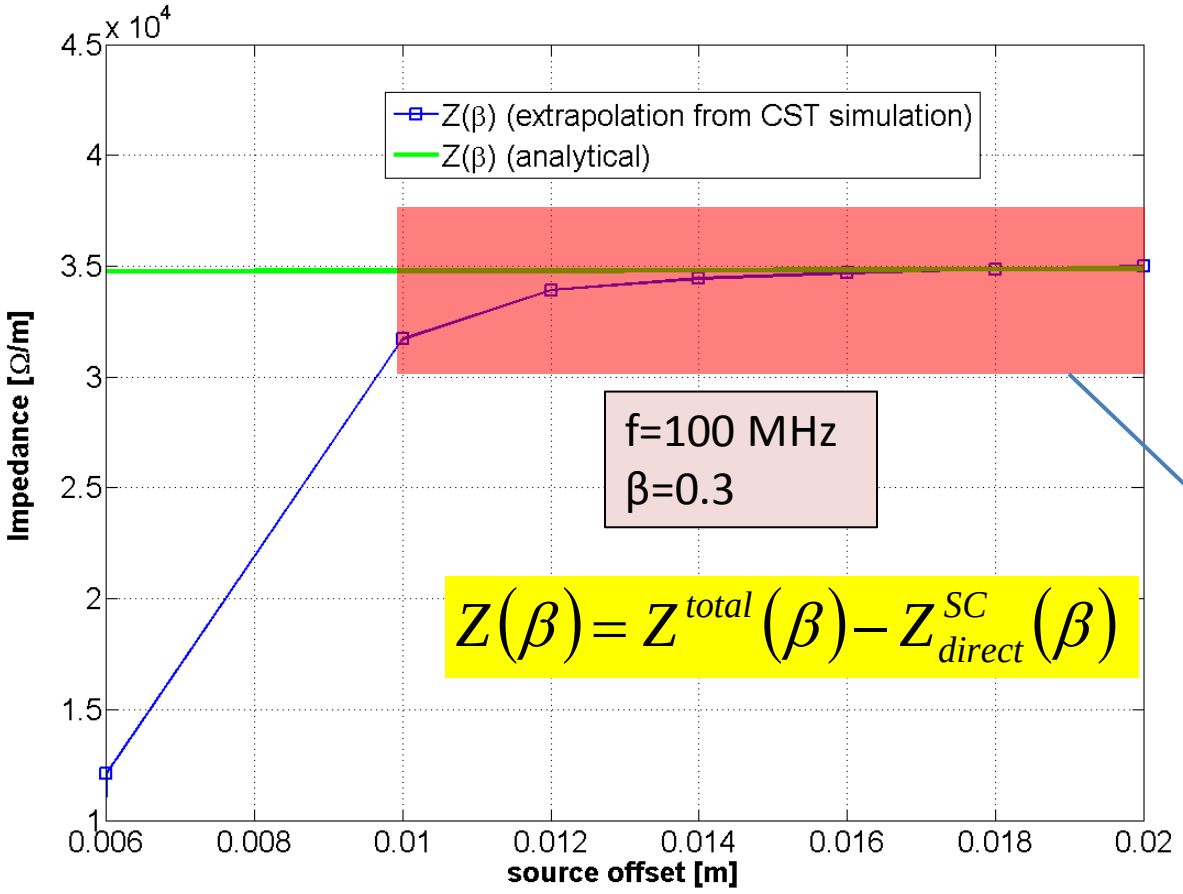
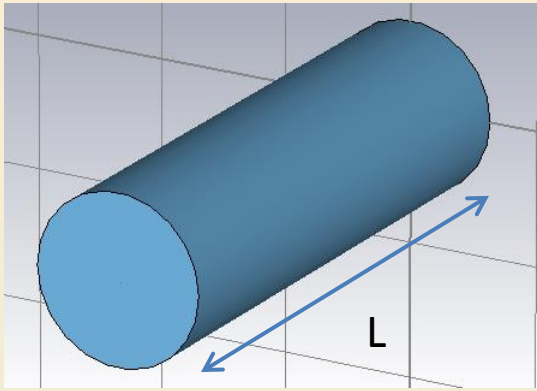
Transverse impedance: comparison between the analytical calculation and the CST simulation





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Error smaller than 10%

The extrapolation method requires the linearity of the impedance with the offset

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Inconel undulated chamber

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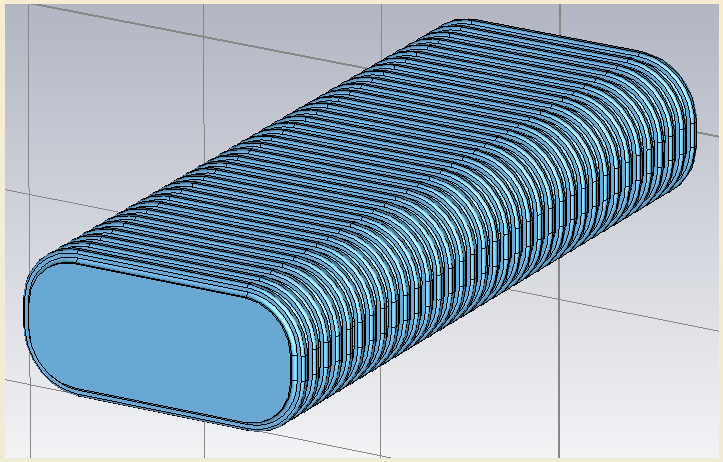


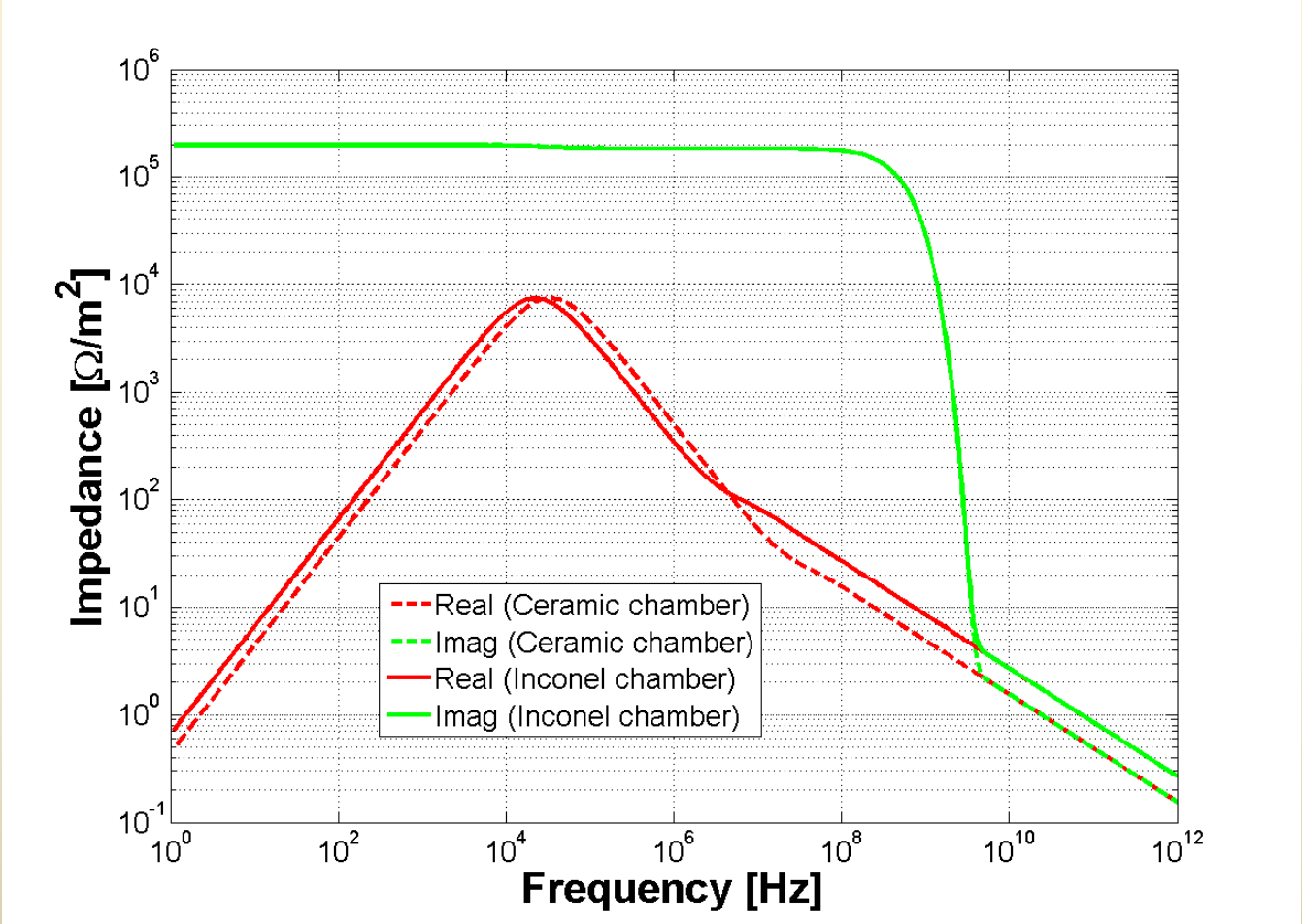
Inconel thickness: 0.45-0.50 mm
Vertical full aperture: 63 mm
Inconel conductivity = 7.89 10^5

Alternative solution

Titanium coated Ceramic (Al2O3) chamber (no corrugation)

Vertical full aperture: 63 mm
Titanium thickness: 100 µm

Analytical calculation (no corrugation): comparison between Inconel and Ceramic chamber



Theoretical calculation made with the TLwall code

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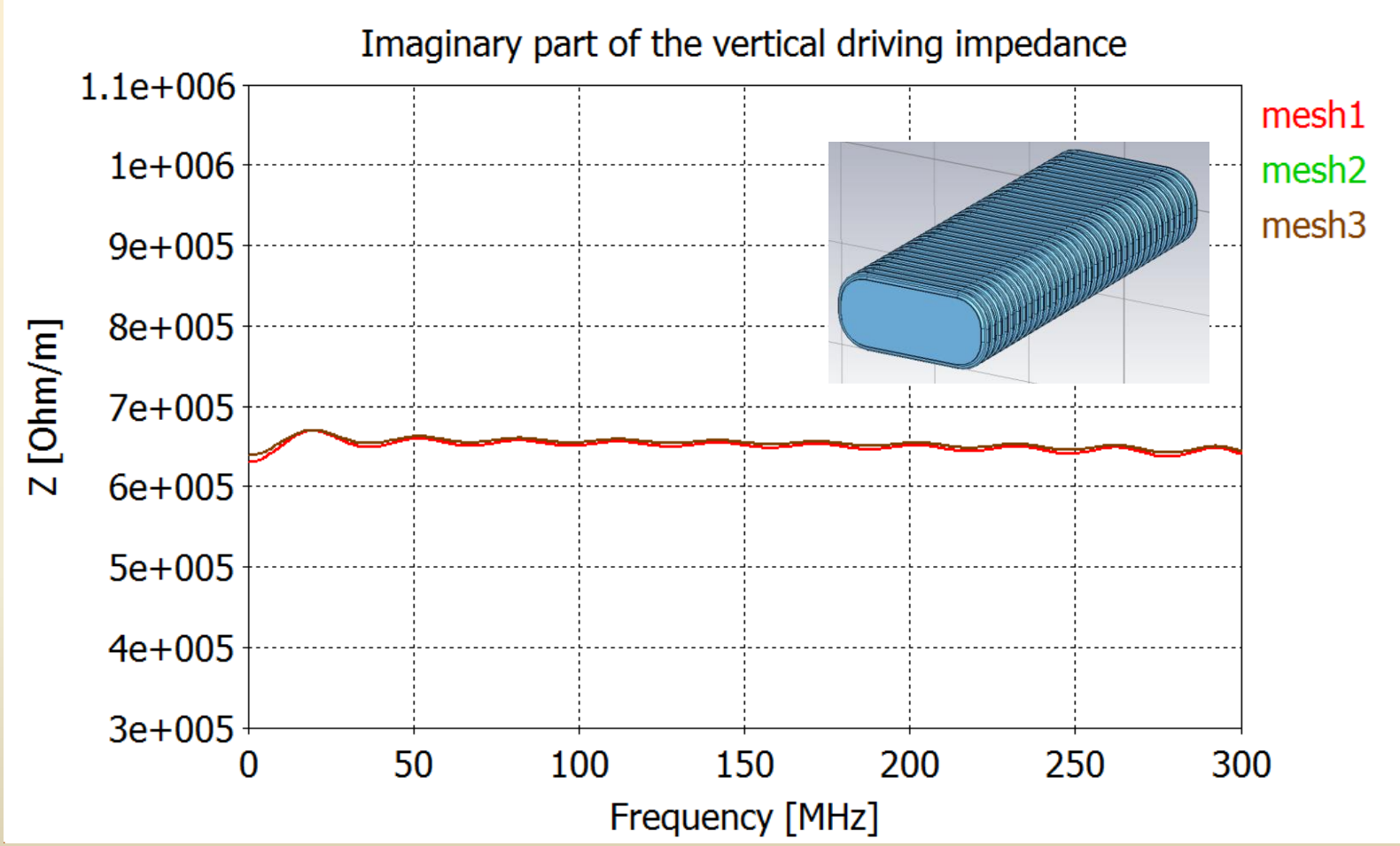
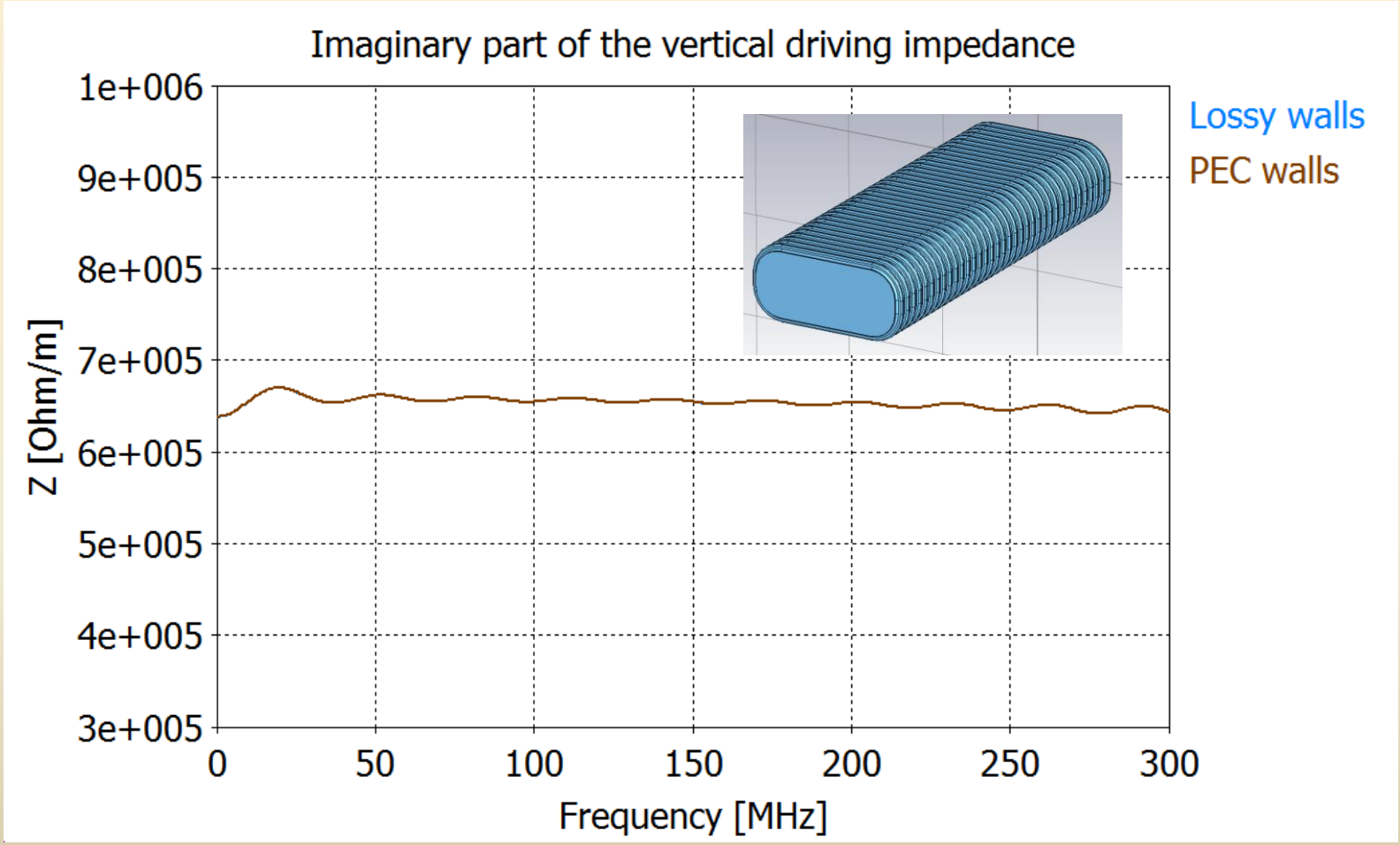
Inconel undulated chamber: CST Particle Studio simulation



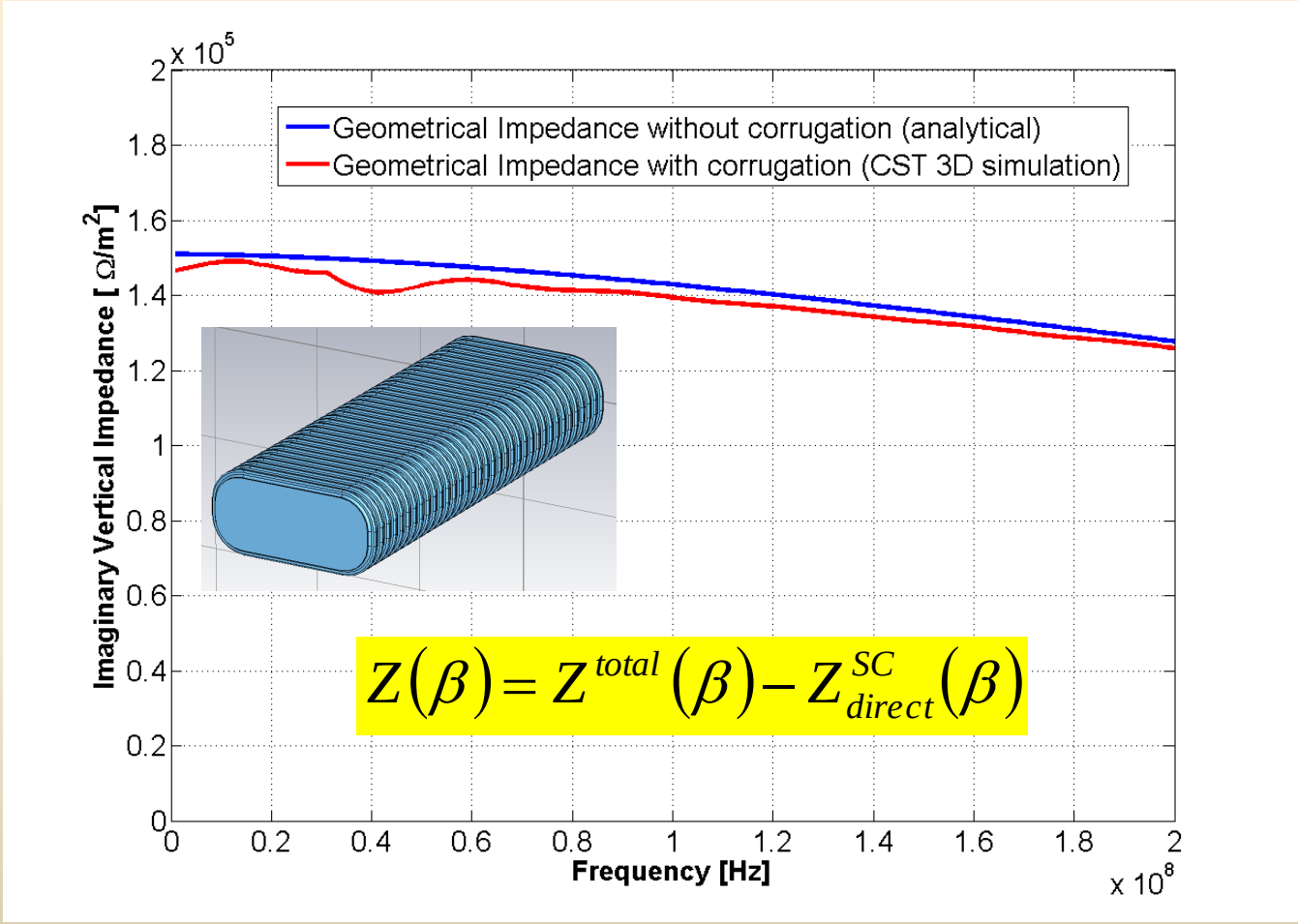
The calculation is stable

Inconel undulated chamber: CST Particle Studio simulation



The resistive wall impedance is insignificant with respect to the total impedance

Inconel undulated chamber: CST Particle Studio simulation



The impedance contribution of the corrugation seems to be negligible

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Summary

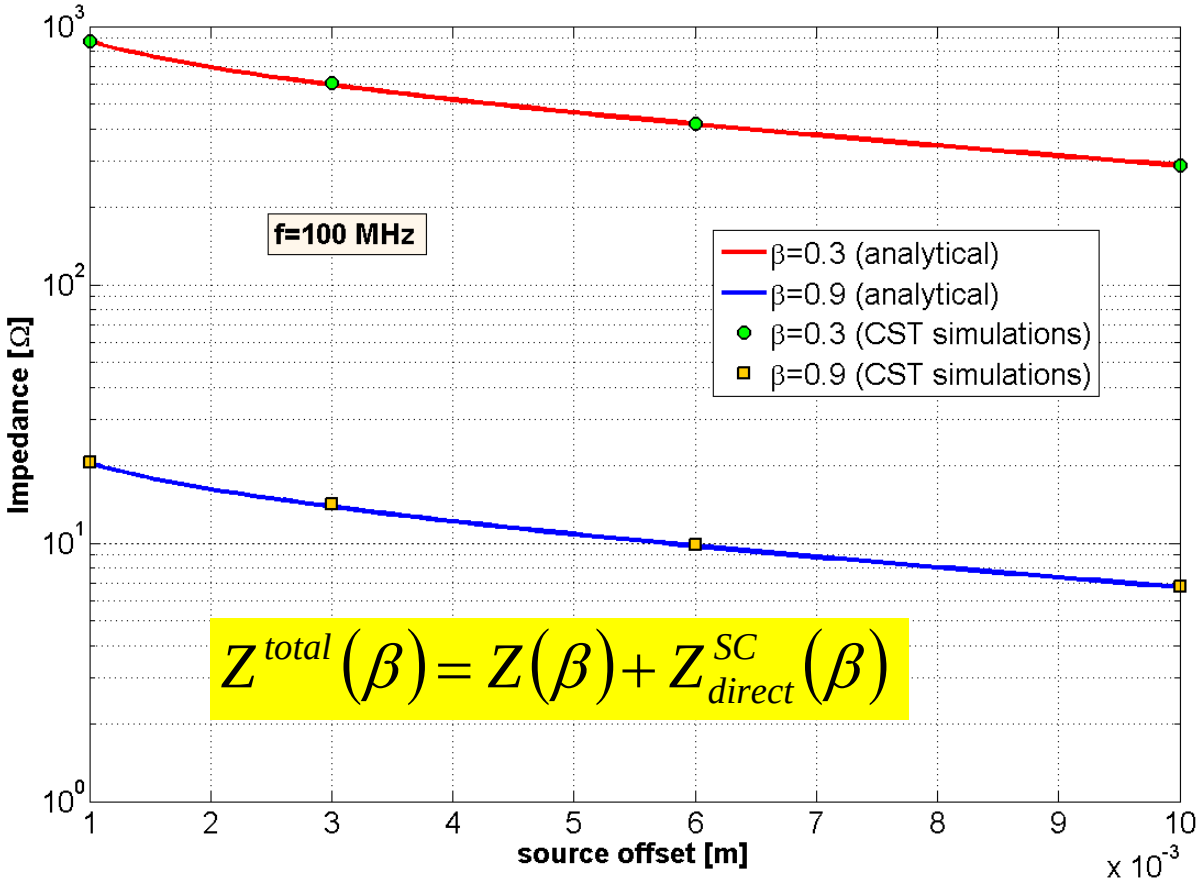
- The use of 3D CST simulation at the PSB energy has been discussed
- From the impedance point of view the Inconel chamber and the ceramic chamber seem to be equivalent

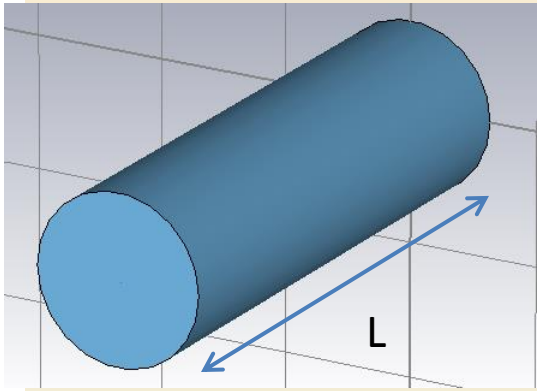
Future plans

- Construction of the PSB impedance model
  - Including all the expected sources of impedance (e.g. kicker)
  - Accurate estimation of the wall impedance
    - I need precise information about the layout of the machine
    - Based on approximate calculations performed by D. Quatraro, the wall impedance represents the 50% of the measured vertical effective impedance at injection (18 MΩ/m)

Thank you very much for your attention

Comparing longitudinal impedance versus source offset





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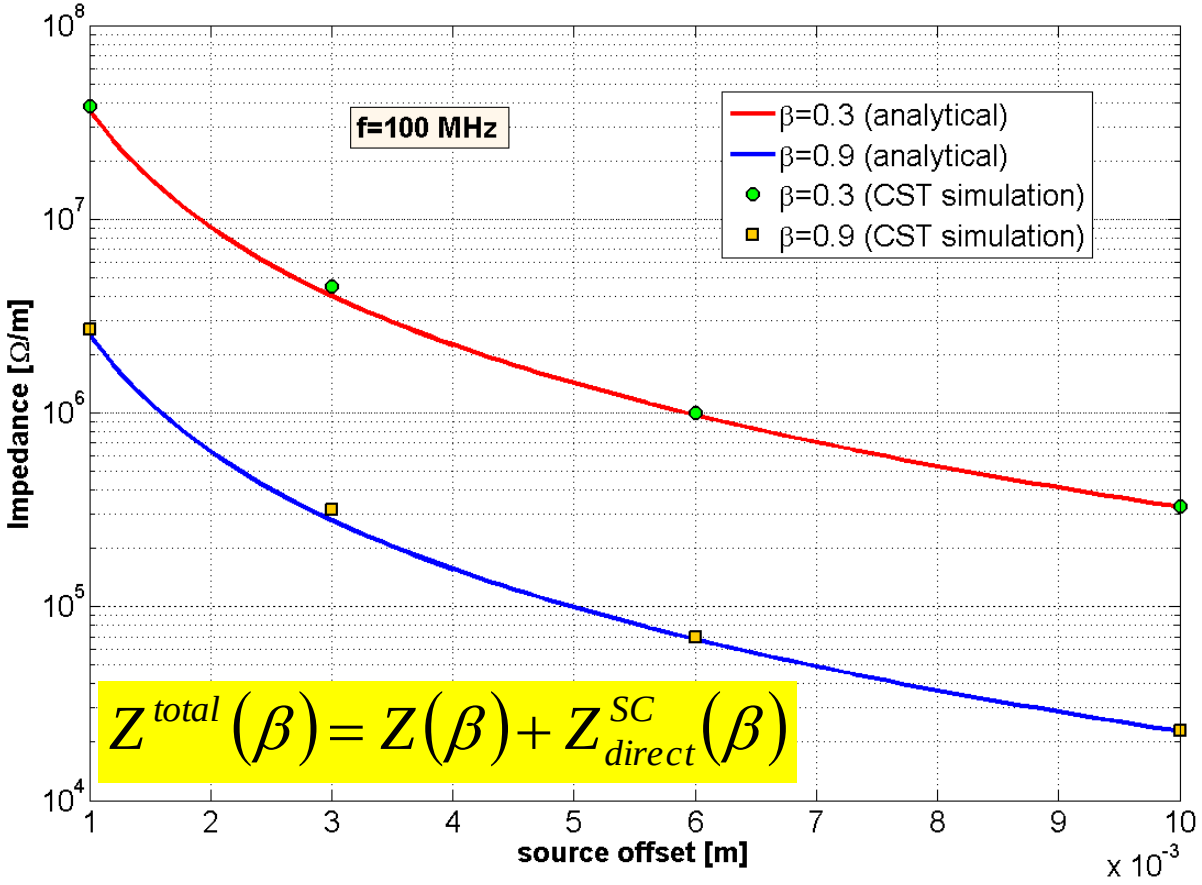
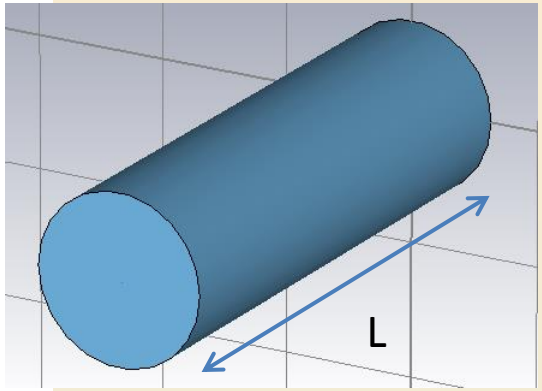
CST simulations and analytical model are in very good agreement

Comparing transverse impedance versus source offset





L = 0.2 m
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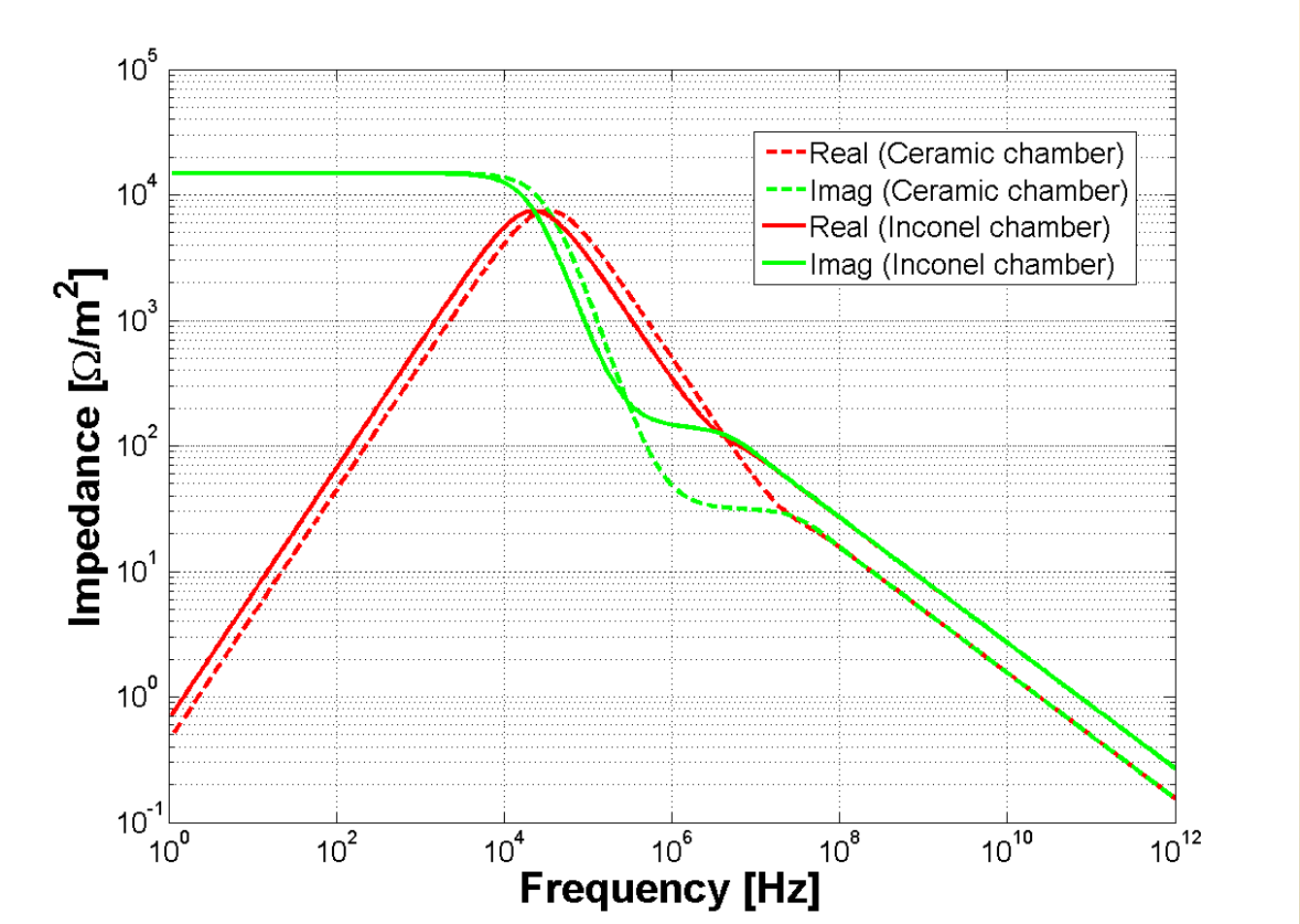
Resistive wall contribution



Theoretical calculation made with the TLwall code

Impedance contribution of the injection region