Update of TL wall with inclusion of roughness

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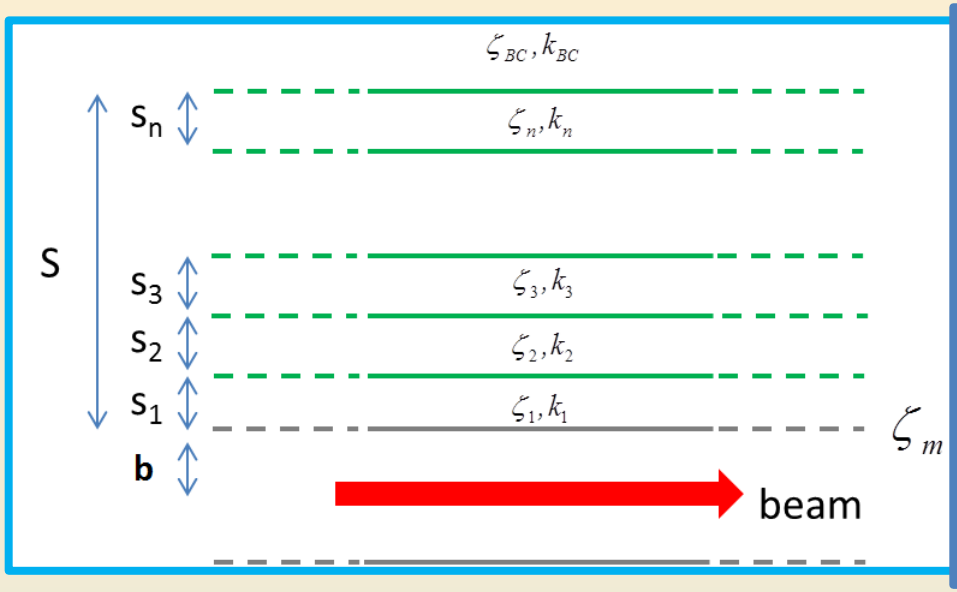
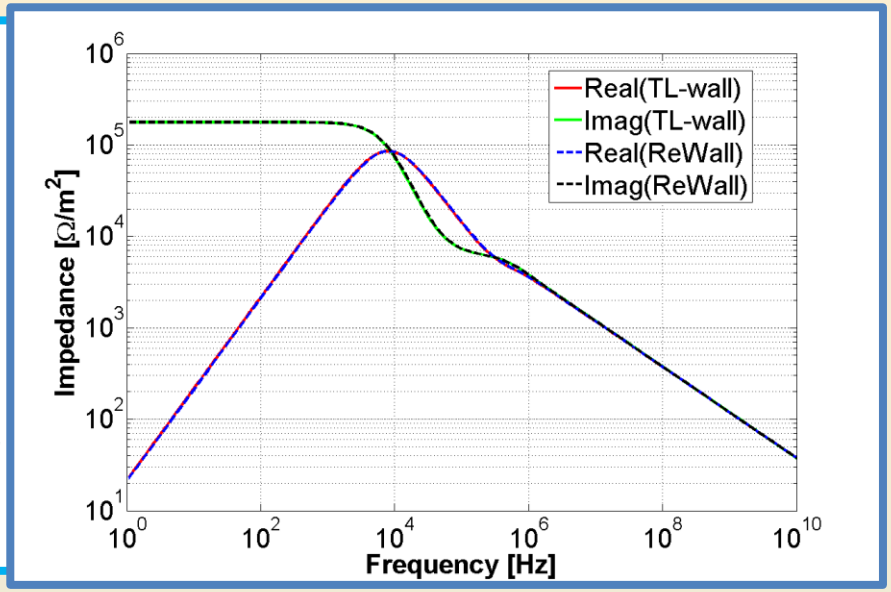
TLwall

- TL based theory to calculate the resistive wall impedance of a multilayer round chamber
- TL equation can be applied recursively to take into account whatever number of layers.
- The code has been implemented in Matlab. A python version has been written by T. Rijoff. The code calculates the wall impedance of a round chamber loaded by a multilayer structure allowing for PEC, Vacuum or Material boundary conditions.
- The code was benchmarked with ReWall/IW2D.

TLwall: code for wall impedance calculations





Advantage

Flexibility, stability, Speed

Disadvantage

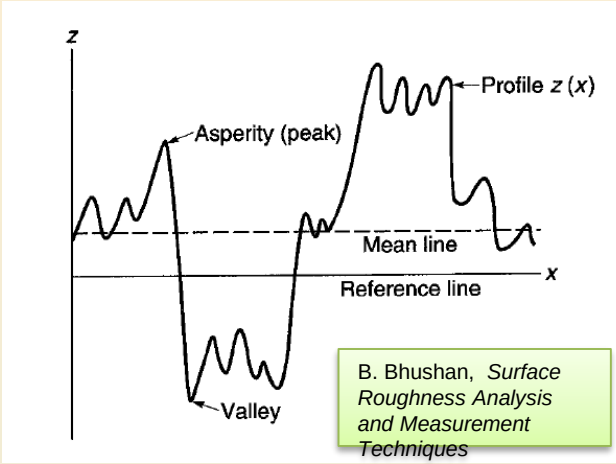
$|\epsilon_1\mu_1| >> \epsilon_0\mu_0$

TLwall: transmission line model for wall impedance calculations.
Presented at the HSC meeting, 18 February 2019

TLwall can cover the major part of practical problem

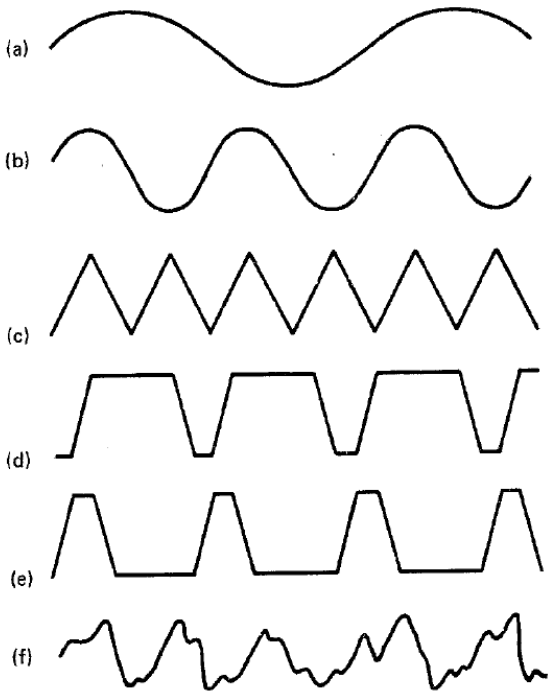
Resistive wall impedance in elliptical multilayer vacuum chambers, Phys. Rev. Accel. Beams **22**, 121001, December 2019

Surface roughness



B. Bhushan, *Surface Roughness Analysis and Measurement Techniques*

Various profiles with the same R_a

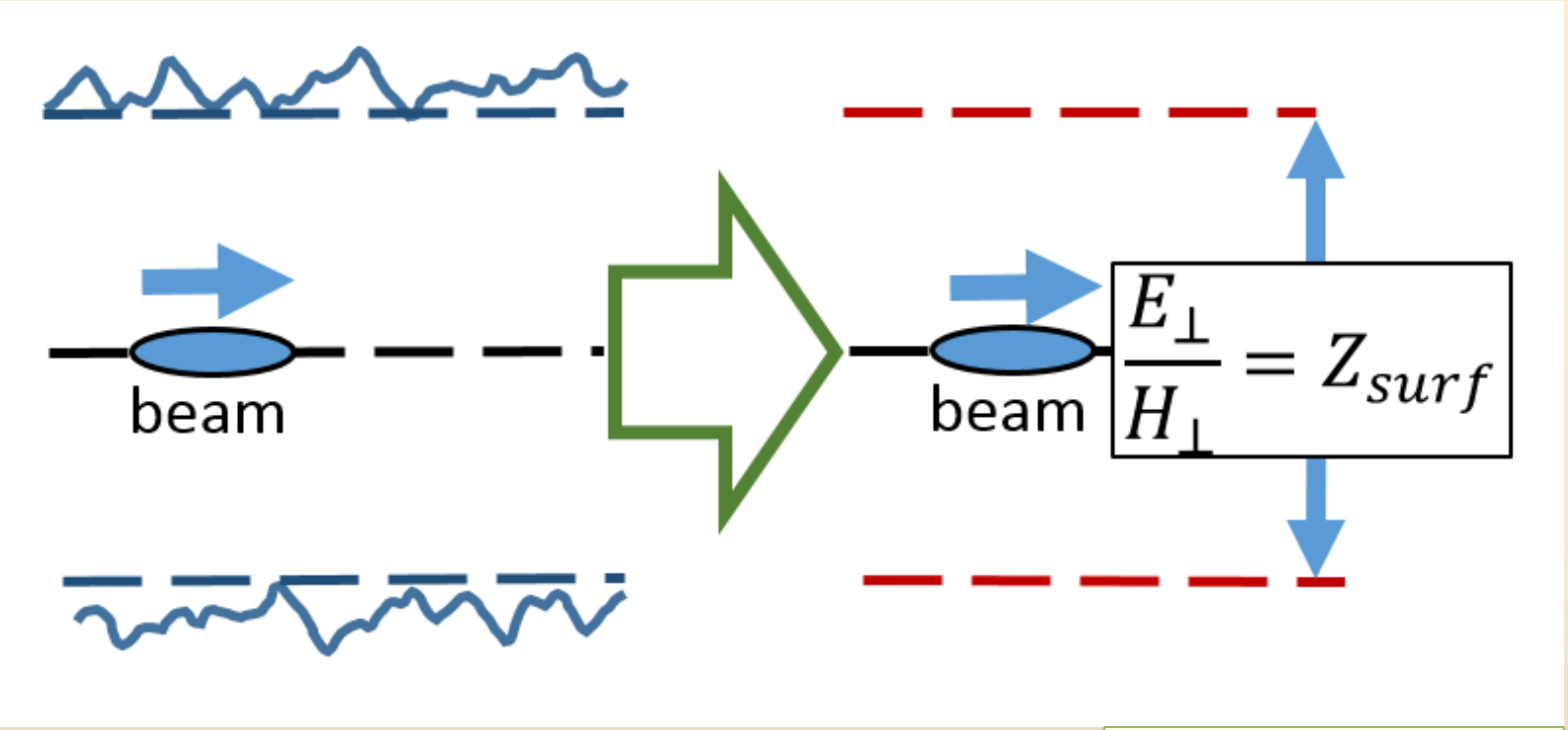


$$m = \frac{1}{L}\int_0^L z\,dx$$

$$R_a = \frac{1}{L}\int_0^L |z - m|\,dx$$

$$R_q^2 = \frac{1}{L}\int_0^L \left(z^2\right)dx$$

Equivalent effect of a rough surface



Picture of S. Arsenyev
ALERT 2019, Ioannina

Inclusion of roughness in TL wall

$$R_s = \sqrt{\frac{\mu\omega}{2\sigma}}\left(1 + \frac{2}{\pi}\arctan\left(0.7\mu\omega\sigma R_Q^2\right)\right)$$

E.O. Hammerstadt, F. Bekkadal, A Microstrip Handbook, ELAB Report STF 44 A74169, University of Trondheim: Norway, 1975, pp. 98–110.

Hammerstadt model is also the default roughness model in CST

$$\sigma_{eff} = \frac{\pi f \mu_0}{R_s^2}$$

$$\zeta_1 = \frac{1+j}{\sigma_{1eq}(\sigma_1)\,\delta_{1eq}(\sigma_1)} \rightarrow \zeta_1 = \frac{1+j}{\sigma_{1eq}(\sigma_{1eff})\,\delta_{1eq}(\sigma_{1eff})}$$

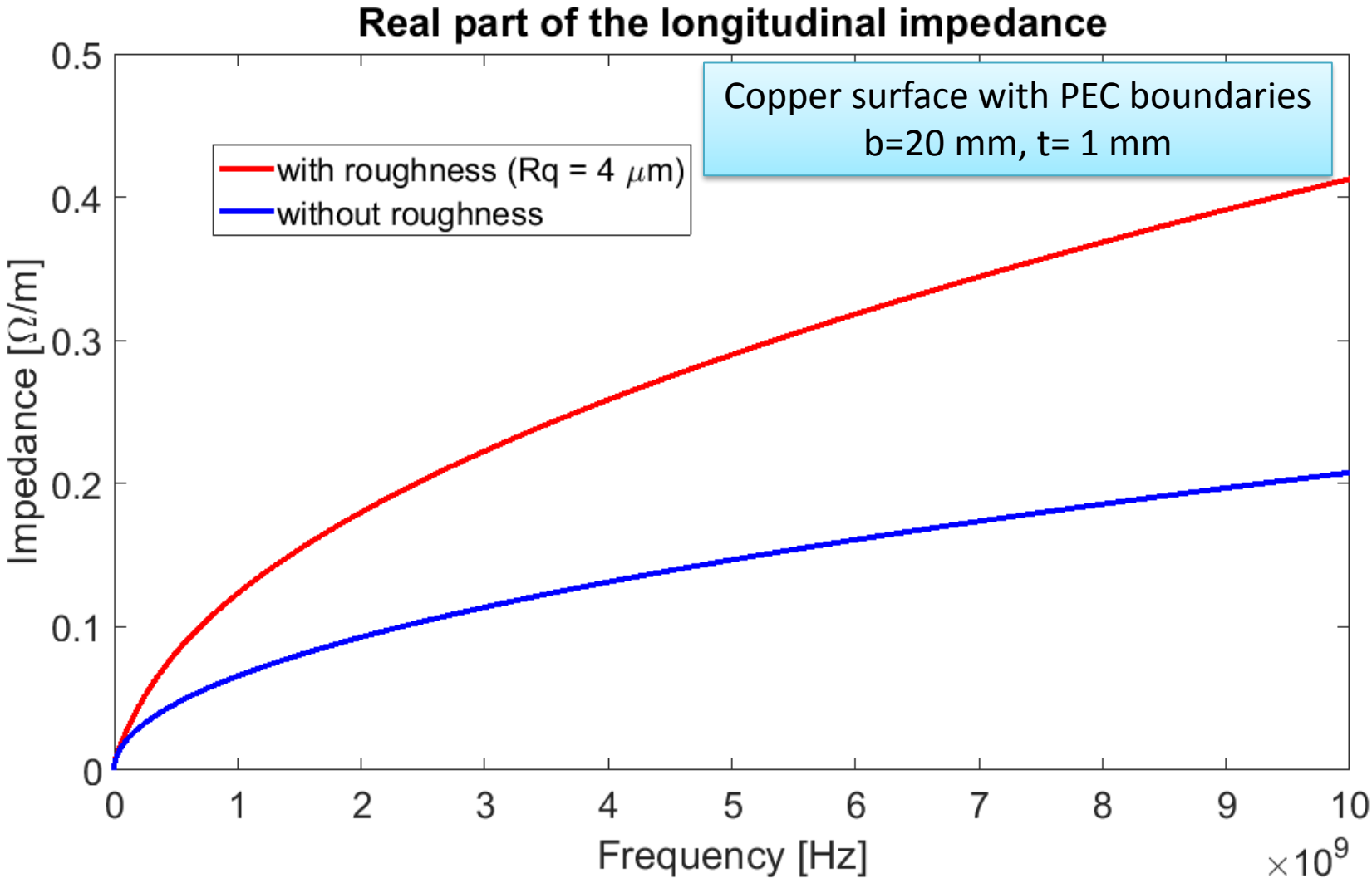
Complex equivalent conductivity

Complex penetration depth

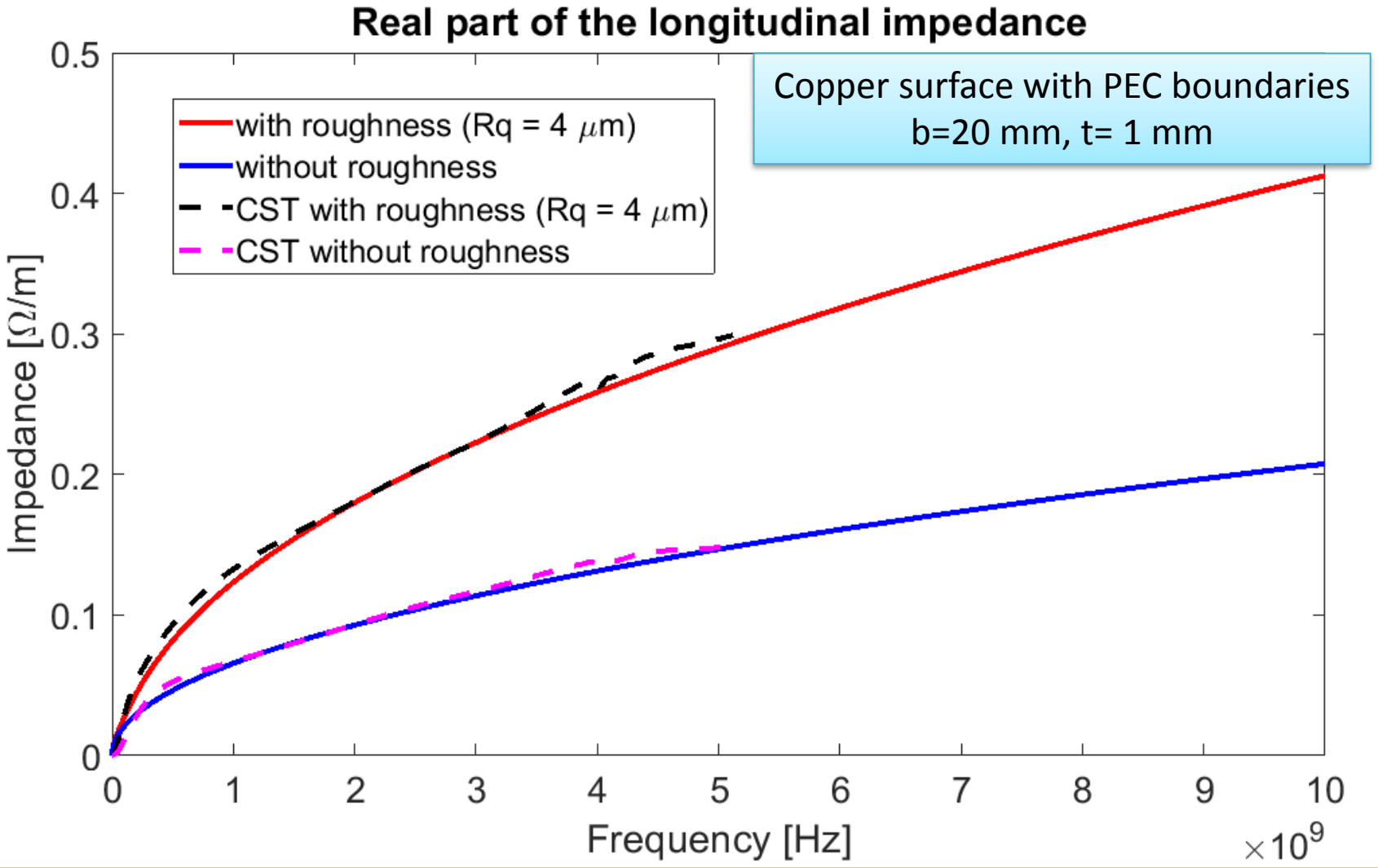
More details in Appendix C of CERN-THESIS-2013-076

More advanced models could be included using the same concept

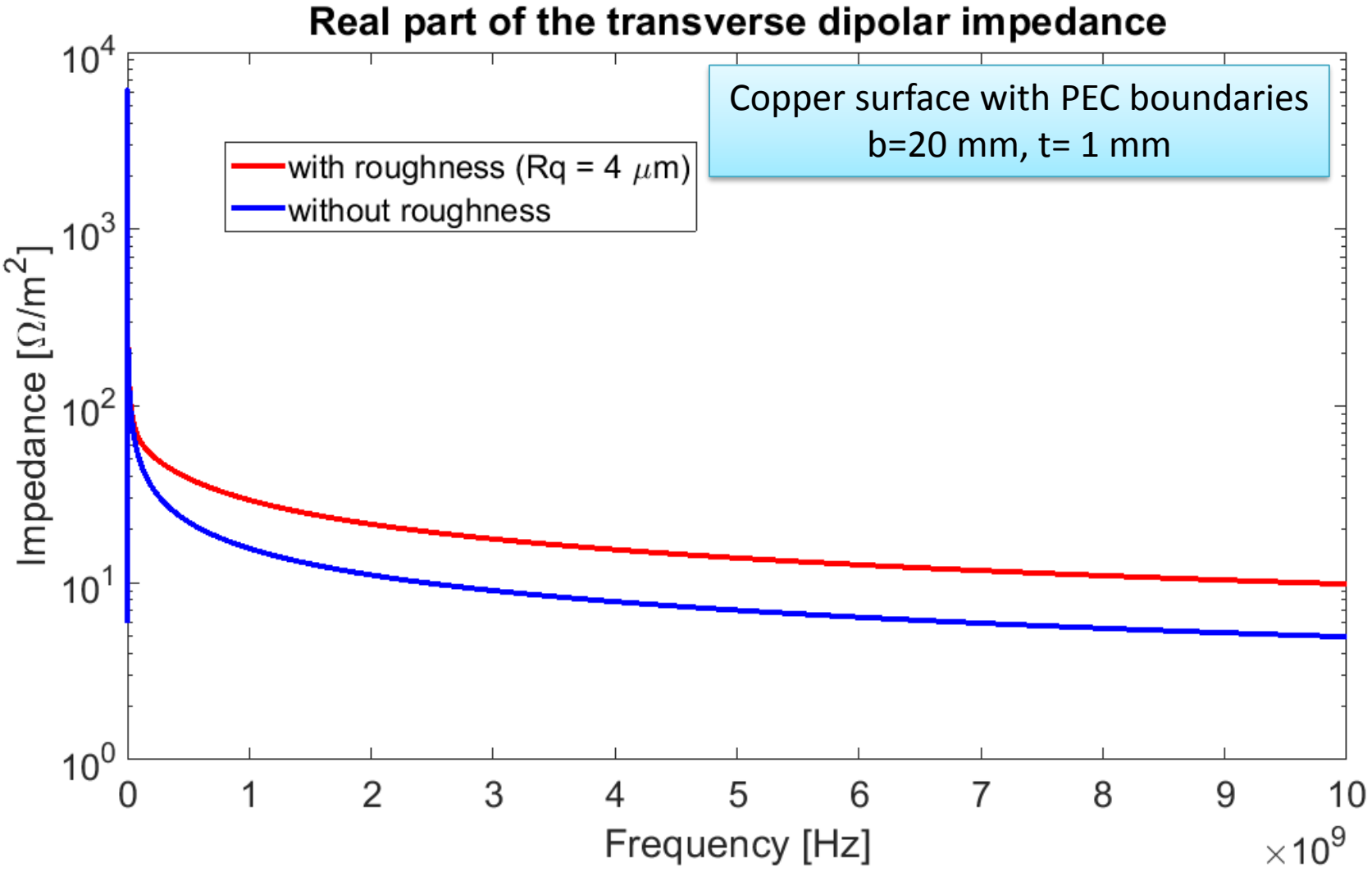
Inclusion of roughness in TL wall: example and comparison with CST



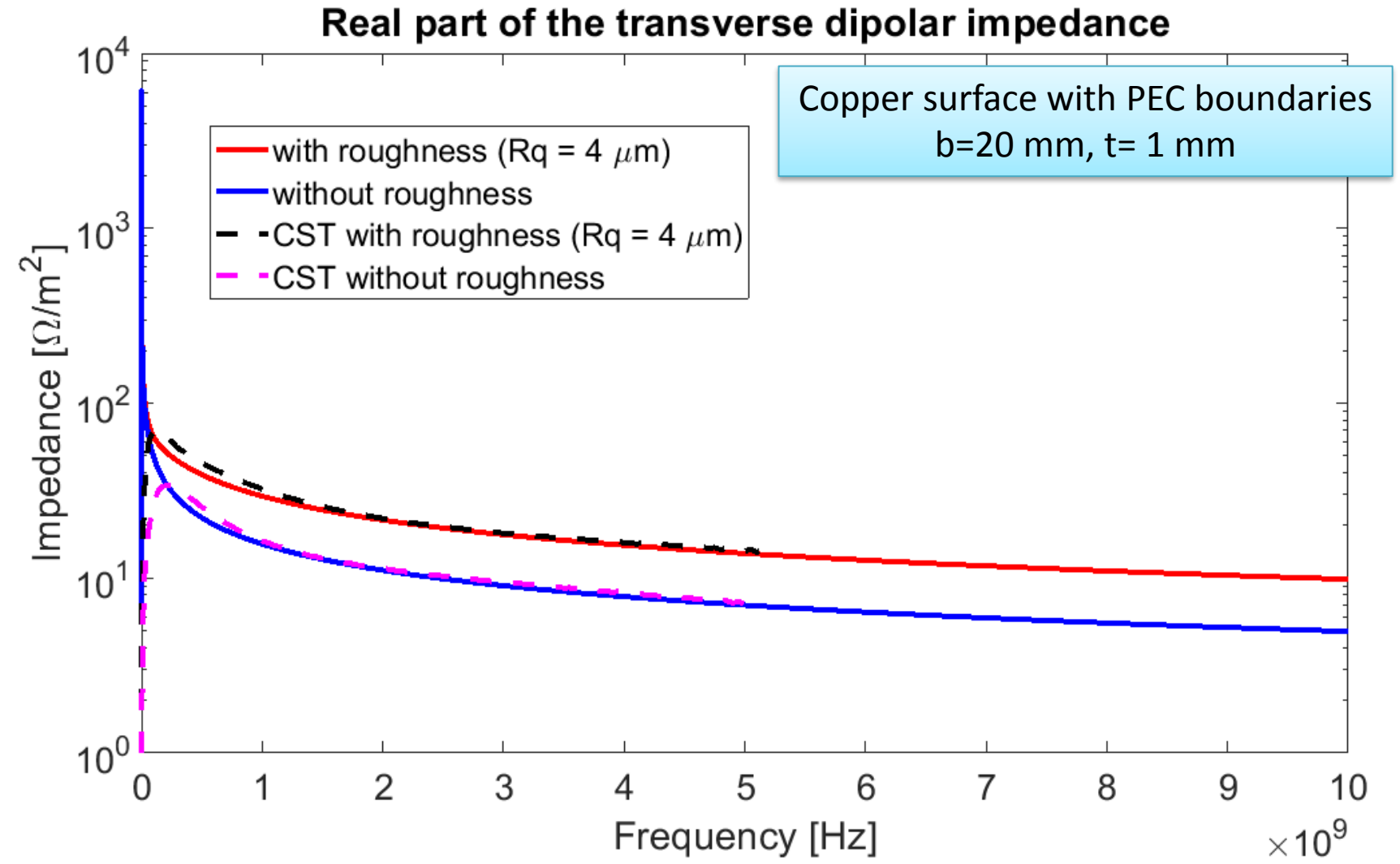
Inclusion of roughness in TL wall: example and comparison with CST



Inclusion of roughness in TL wall: example and comparison with CST



Inclusion of roughness in TL wall: example and comparison with CST



Summary

- A Hammerstaad based roughness model has been included in Tlwall to modify the surface impedance of the first layer.
- The effect of the roughness on a test case has been found in good agreement with the CST

Thank you very much for your attention