COMSOL CONFERENCE
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SNCF RÉSEAU

Nonlinear Shielded Multipair Railway Cable Modeling with COMSOL Multiphysics

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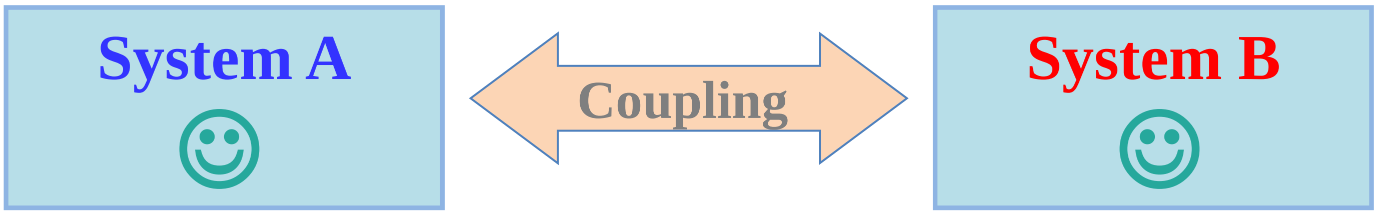
CONTENTS

1.1 EMC in the railway environment

EMC (Electromagnetic Compatibility):



Strong-current systems that produce the disturbance

- High voltage lines (e.g. the Electricity Transmission Network lines)
- Lightning
- Electrical equipments

→ Coupling →

Low-current Systems that suffer the consequences

- Signaling and telecommunication cables
- Cathode screens
- Humans

1.1 EMC in the railway environment

- Signaling cable: transmission of information and connection between the components of signaling system
- Telecommunication cable: communications between the railway systems

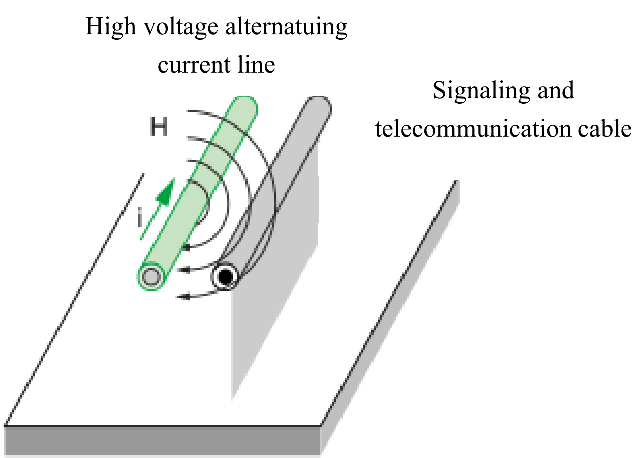


Figure 1. Inductive coupling between two cables

Figure 2. Railway network

Faraday's law:

$$\text{fem} = -\frac{d\Phi}{dt}$$

1.2 Objective

Reduce the risque of inductive interference: Estimate the induced voltage in the cable →
- Decrease the induction loop
- Improve the shielding efficiency of the cable

« Reduction factor k »: shielding efficiency ← results from measurements

Unknown behaviour ← strong electromagnetic fields

Unknown nonlinear behaviour ← material's magnetic property

Study the behaviour of the signaling and telecommunication cables in the face of railway electromagnetic interfernce by COMSOL modeling.

2.1 Shielded cable with reduction factor

Construction of signaling cable ZPAU:

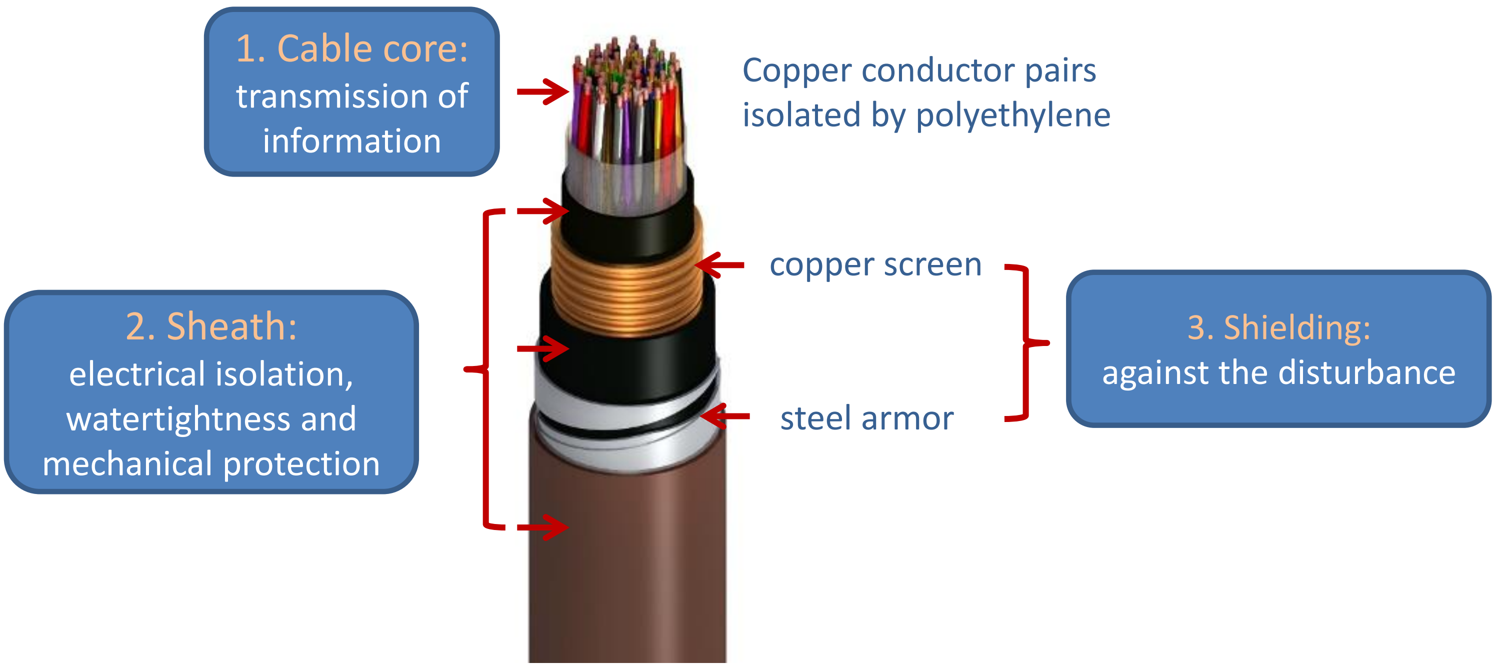


Figure 3. Signaling cable ZPAU

2.1 Shielded cable with reduction factor

Magnetic behaviour of steel (ferromagnetic material)

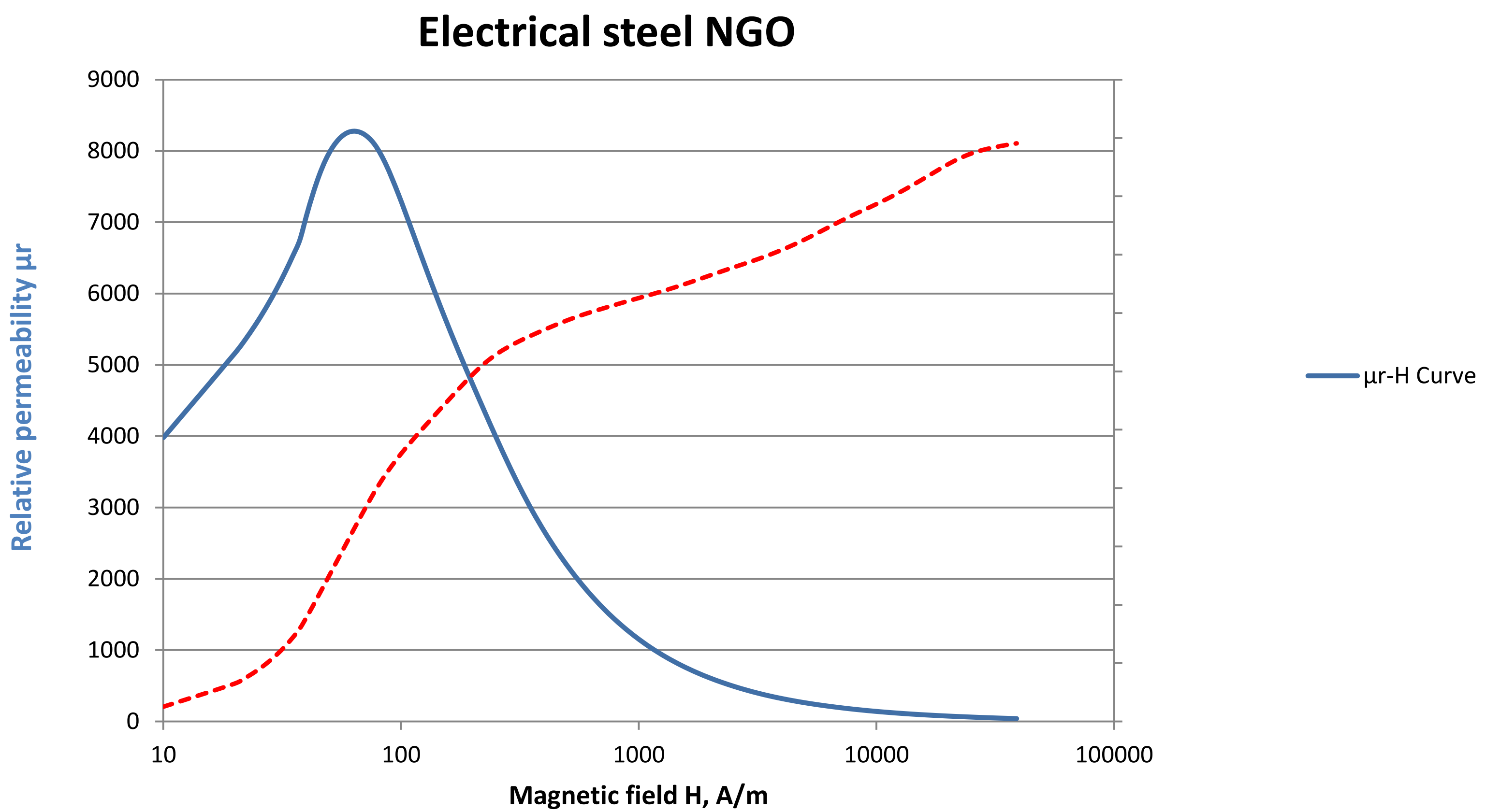
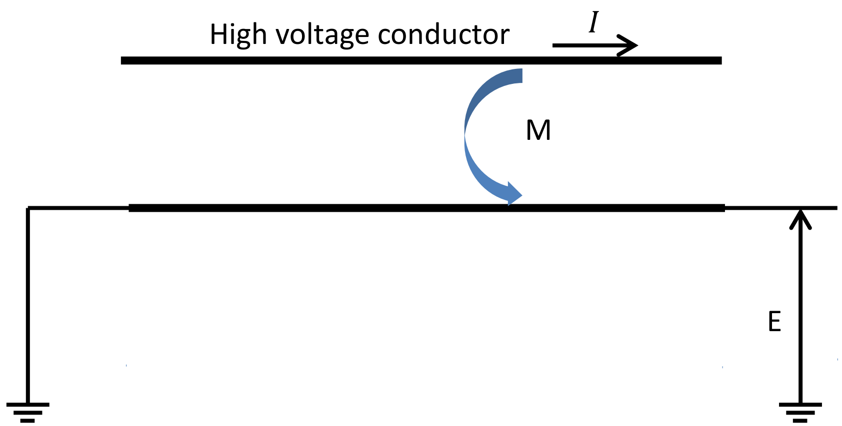
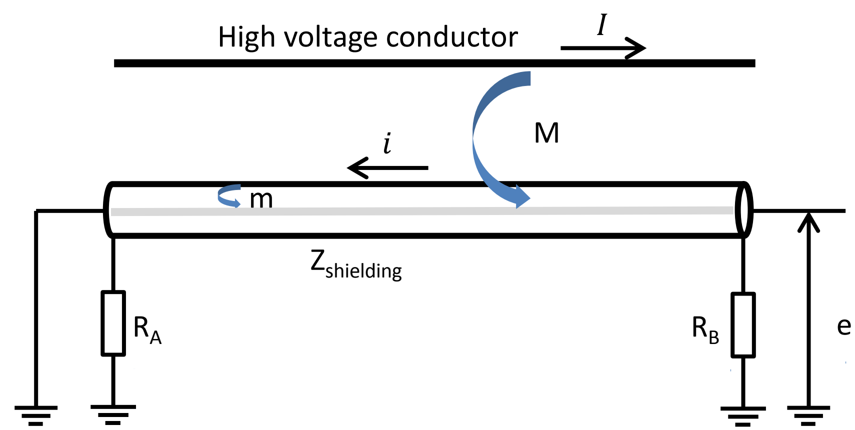


Figure 4. μ_r *and* ***B*** *en fonction in terms of* ***H*** *for mild steel GO*

2.1 Shielded cable with reduction factor

Calculation of reduction factor = $\frac{e}{E}$ = $\frac{\text{induced voltage in the conductors of the cable core with the shielding}}{\text{induced voltage in the cable core without the shielding}}$





- *Without shielding:*

$E = MI\omega j$

- *With shielding:*

$e = E + e' < E$

- Reduction factor

$0 < k = \frac{e}{E} < 1$

$$k = 1 - \frac{m}{Z_{shielding} + R_A + R_B}$$

[1] G. Papaiz Garbini, Contribution to calculation of the soil potential rise in the railway context GeePs, Paris, 2015.

2.2 COMSOL Modeling

- 2D ← Translational symmetry
- AC/DC Module
- Magnetic fields (mf), frequency-domain

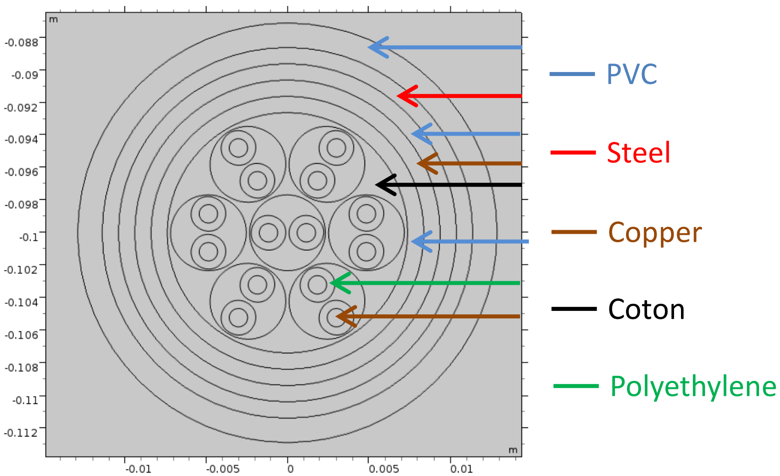


Figure 6. Geometry of signaling cable ZPAU with 7 pairs

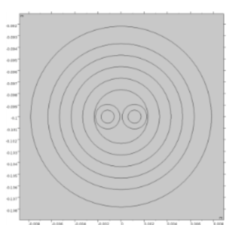


Figure 7. Geometry of cable ZPAU of 1 pair

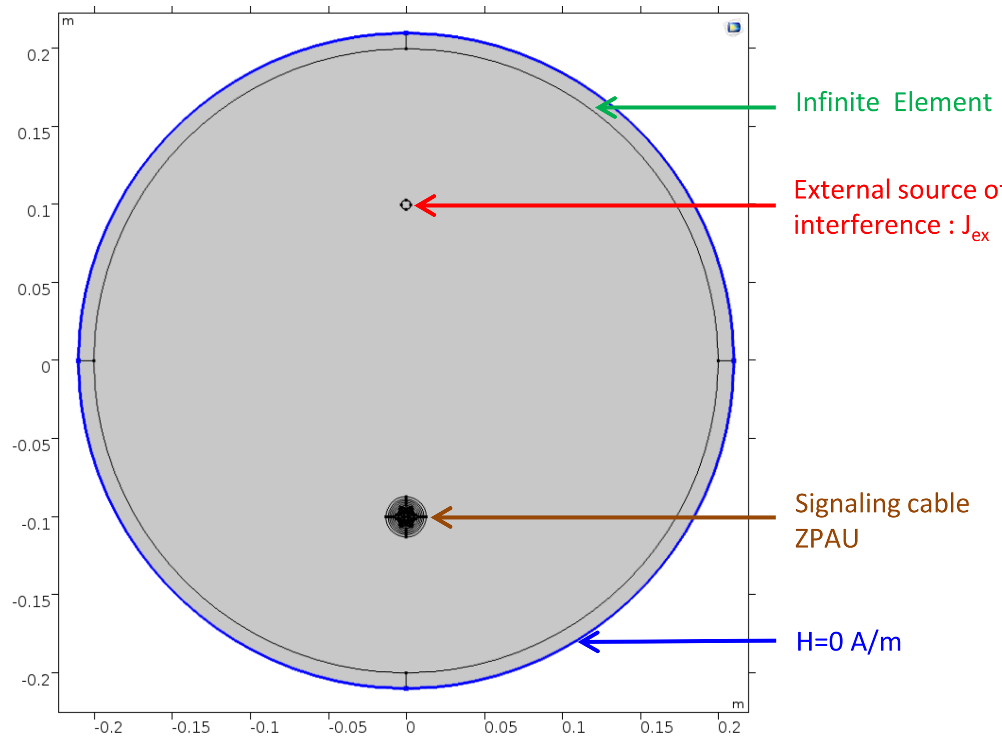


Figure 8. COMSOL Multphysics modeling

3.1 Convergence study

Mesh quality

- Mesh size

Maximum element size : $\frac{X}{nb}$

« nb » : 1 – 10

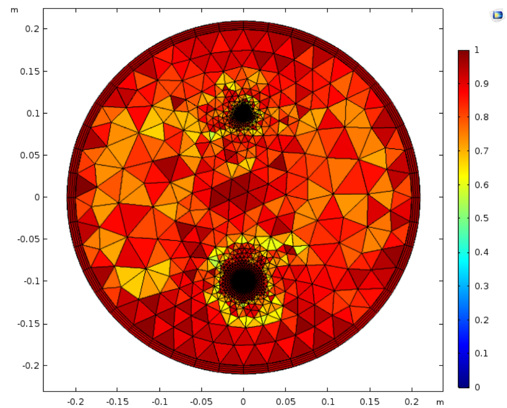


Figure 9. Mesh quality for nb=1

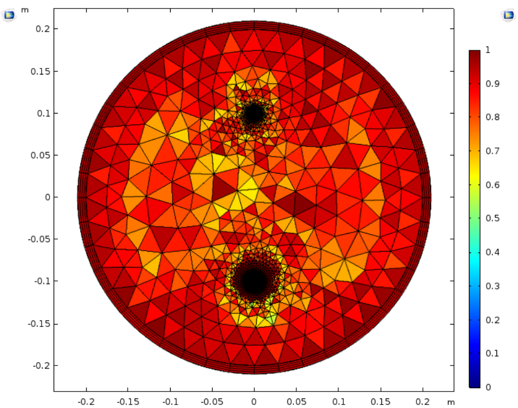


Figure 10. Mesh quality for nb=3

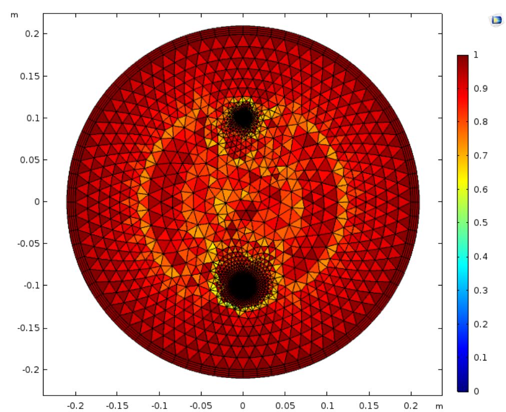


Figure 11. Mesh quality for nb=6

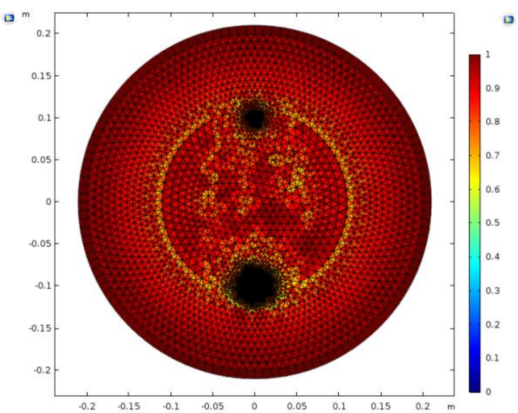
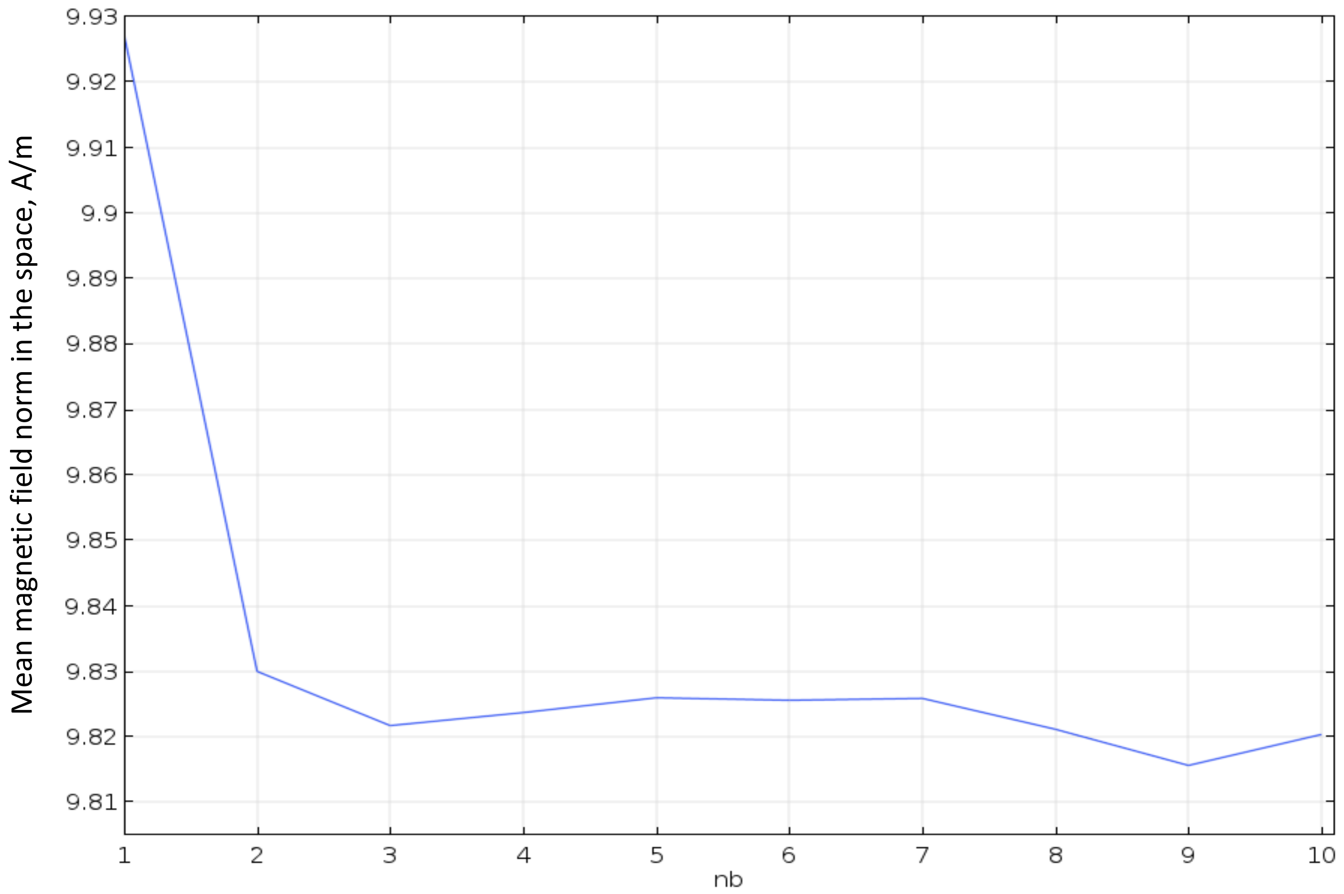


Figure 12. Mesh quality for nb=10

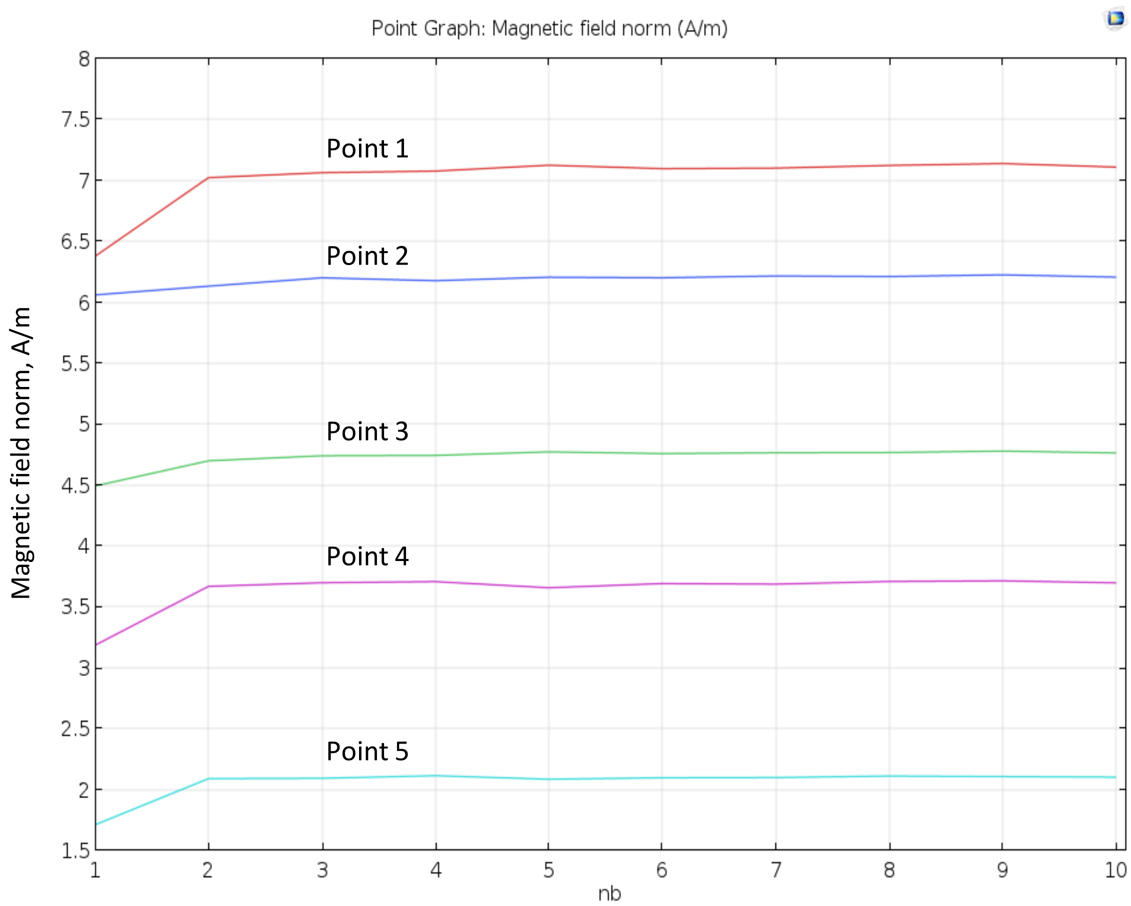
3.1 Convergence study

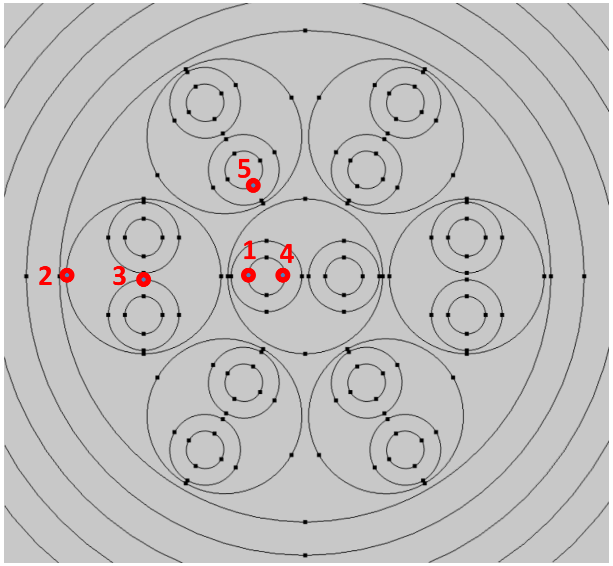
Mean magnetic field norm in the space (A/m) in terms of mesh size



3.1 Convergence study

Convergence of magnetic field norm for several points

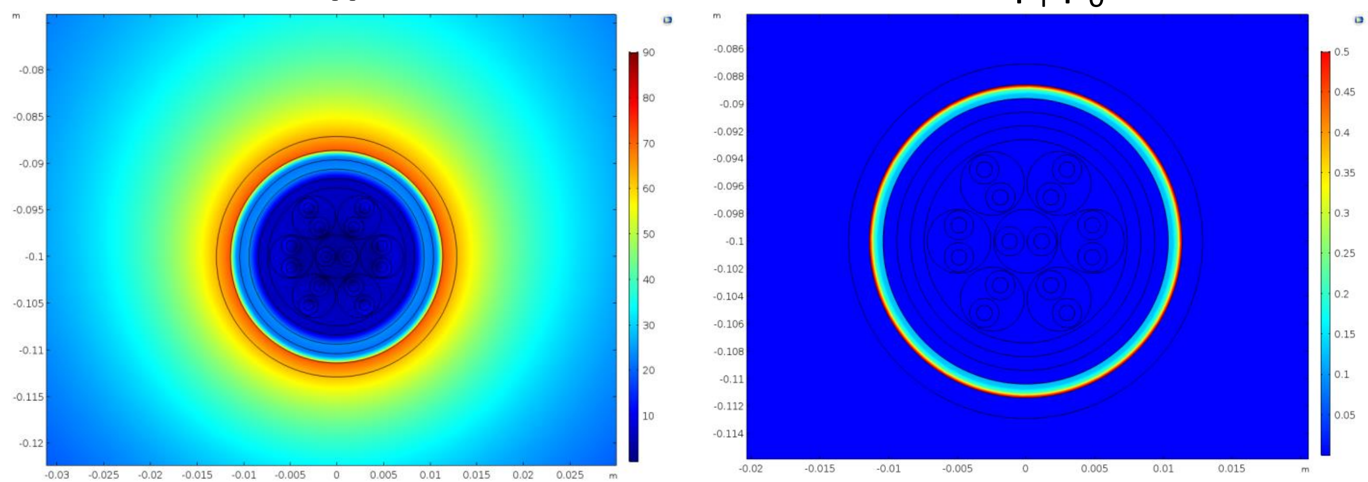




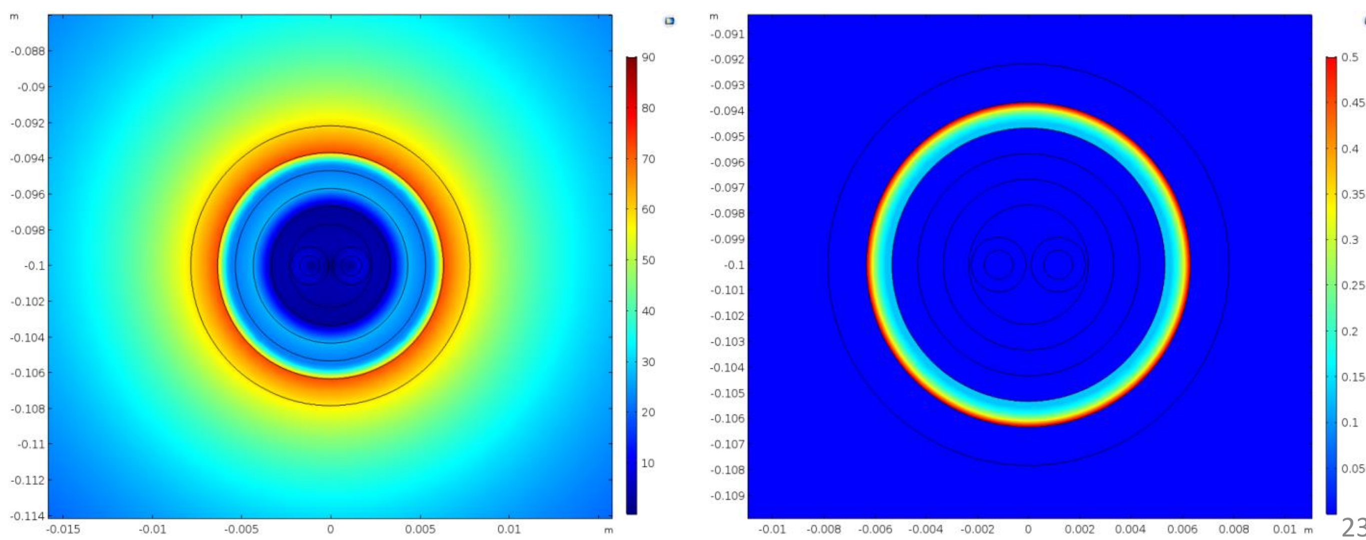
3.2 Shielding behaviour

H | $\mathbf{B} = \mu_r\, \mu_0\, \mathbf{H}$

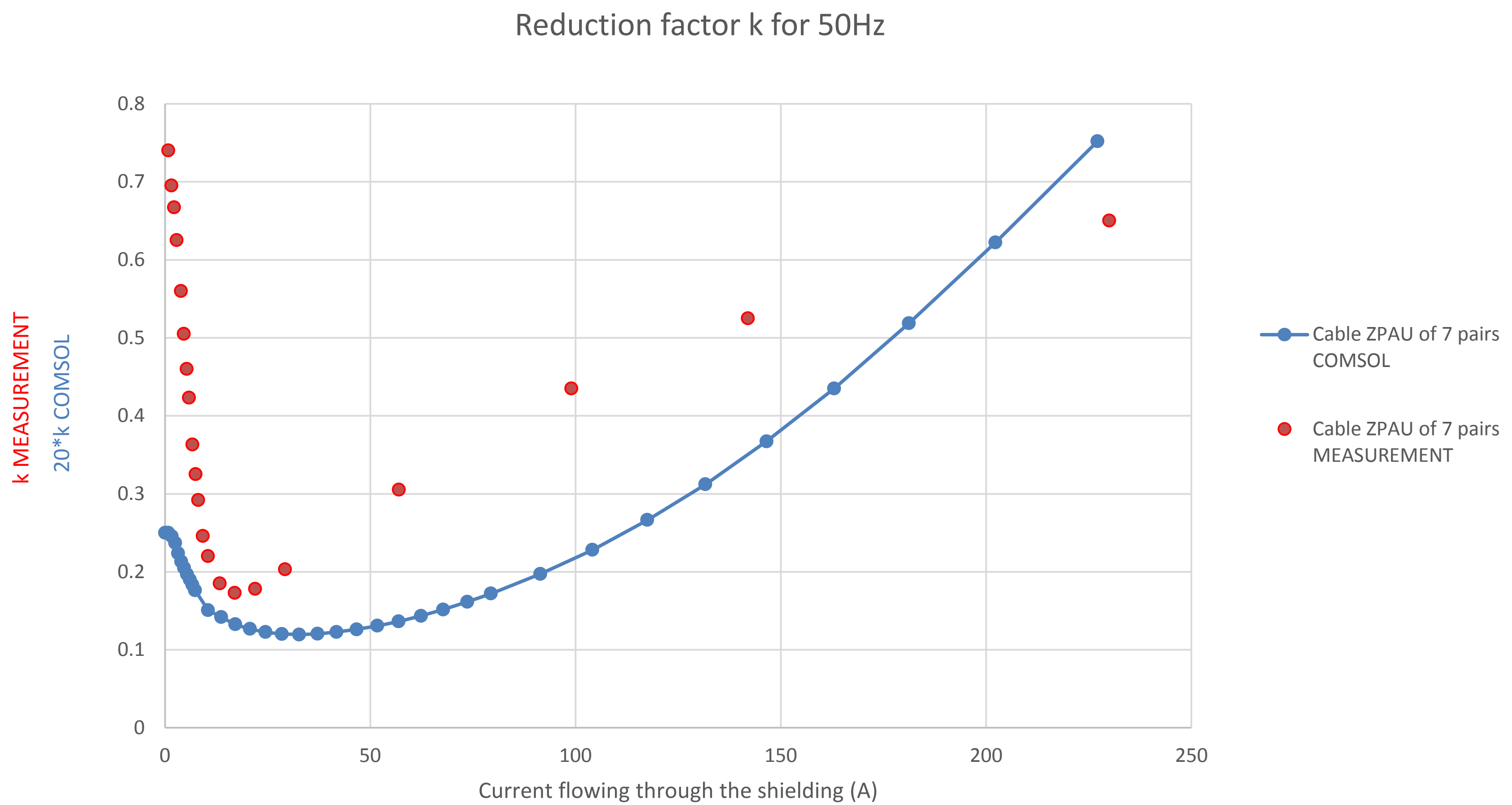
Cable of 7 pairs



Cable of 1 pair



3.3 Reduction factor



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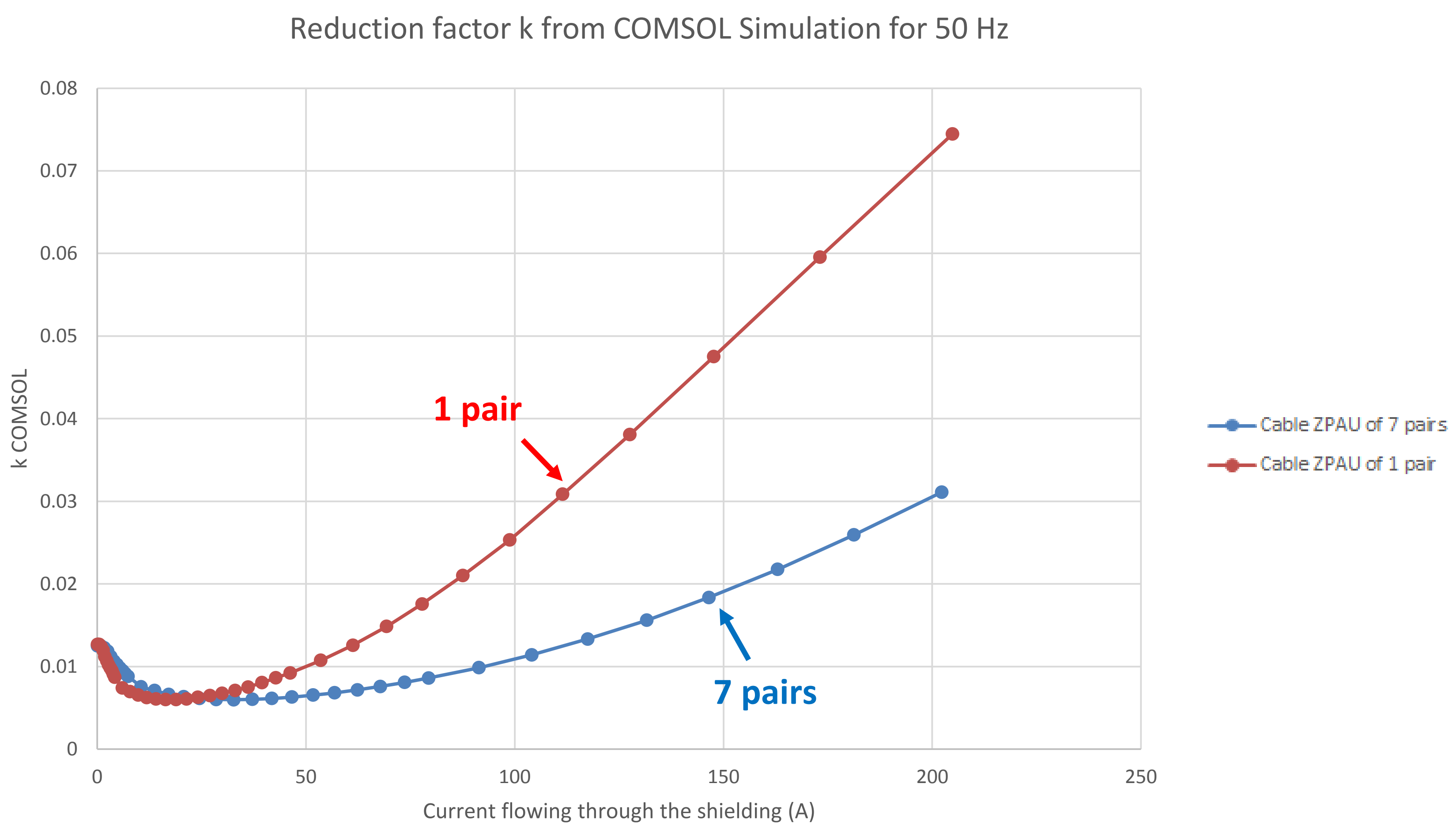

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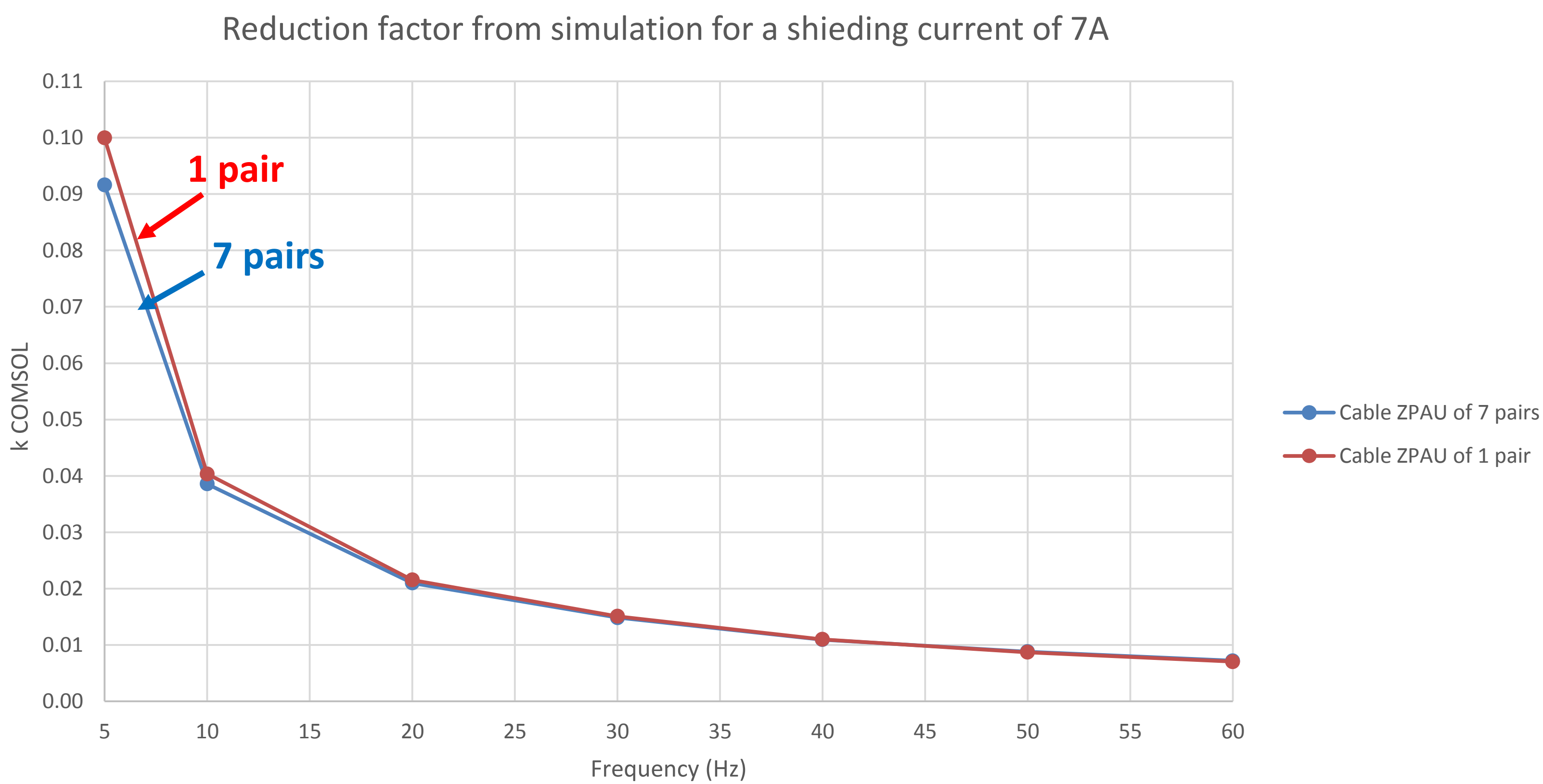

[2] M. Alejandra MORA RIVEROS, *Contribution to the EMC modeling in the railway environment: the influence of infrastructure*, Lab-STICC, 2010.
[3] Schelkunoff, S. A., "The electromagnetic theory of coaxial transmission line and cylindrical shields" *Bell Syst. Technical Journal*, vol. 13, 1934, pp. 352-579.

4. Conclusions

- 2D Shielded railway signling cable model has been built: cable of one pair, cable of 7 pairs
- Nonlinearities of cable’s behaviour have been simulated
- Future work: different cable configurations

THANK YOU FOR YOUR ATTENTION!