Topographic Effects on Radio Magnetotelluric Simulations on Levees: Numerical Modelling for Future Comparison With Fields Results

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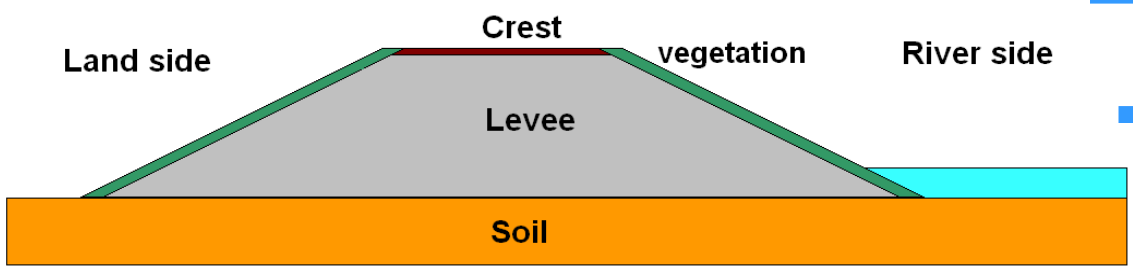
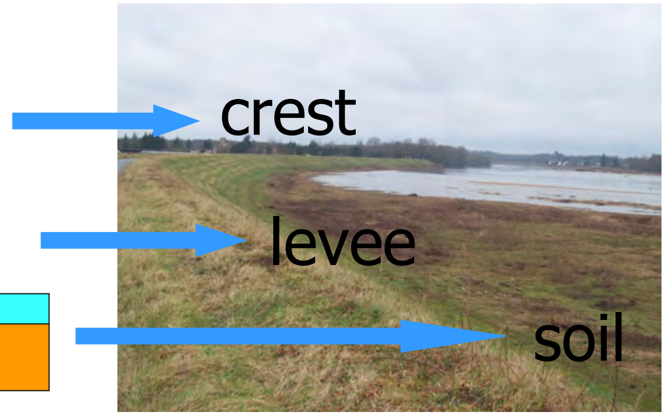
Plan

- 1- Study aim: levee description
  - RMT method
  - Characteristic parameters and values
- 2- Physics modelling:
  - Location of RMT simulated emitters
  - Geometry definition
  - Physics model
  - Physics settings
  - Meshing and solver
  - Post-processing: results
- 3- Results
- 4- Conclusion

1-1 Study aim - diagram of a levee

Study aim: Our work aims at studying the influence of the topography of levees on the apparent electrical resistivity measured with the Radio-Magnetotelluric method (RMT).

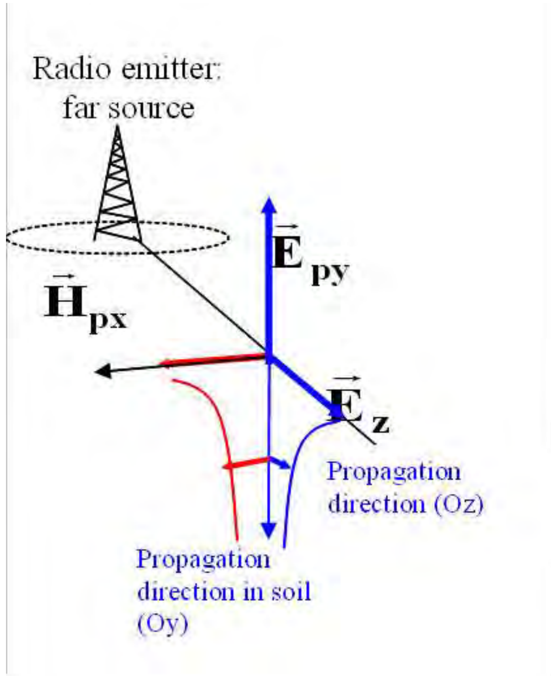




Typical cross-section of a levee alongside a river, like the Loire in France.

1-2 RMT method

RMT method applied on a levee:



Plane waves ⟶ **induced currents** ⟶ **H** field and induced E field

measurement = apparent resistivity: ρ_a

- Radio wave frequency method: source of the electromagnetic wave.
- Maxwell's equation, Ohm's law: propagation equations.

1-3 Characteristic parameters and values

Skin depth: $\delta \cong 2\ p_i$ (depth of penetration)

$$\delta \approx \sqrt{\frac{\rho}{\pi \mu_0 f}} \approx 503 \sqrt{\frac{\rho}{f}} \quad \text{(m)}$$

Wave penetration: $\delta \cong$ levee + soil height

wave length: $\lambda = \dfrac{c}{f}$ (m)

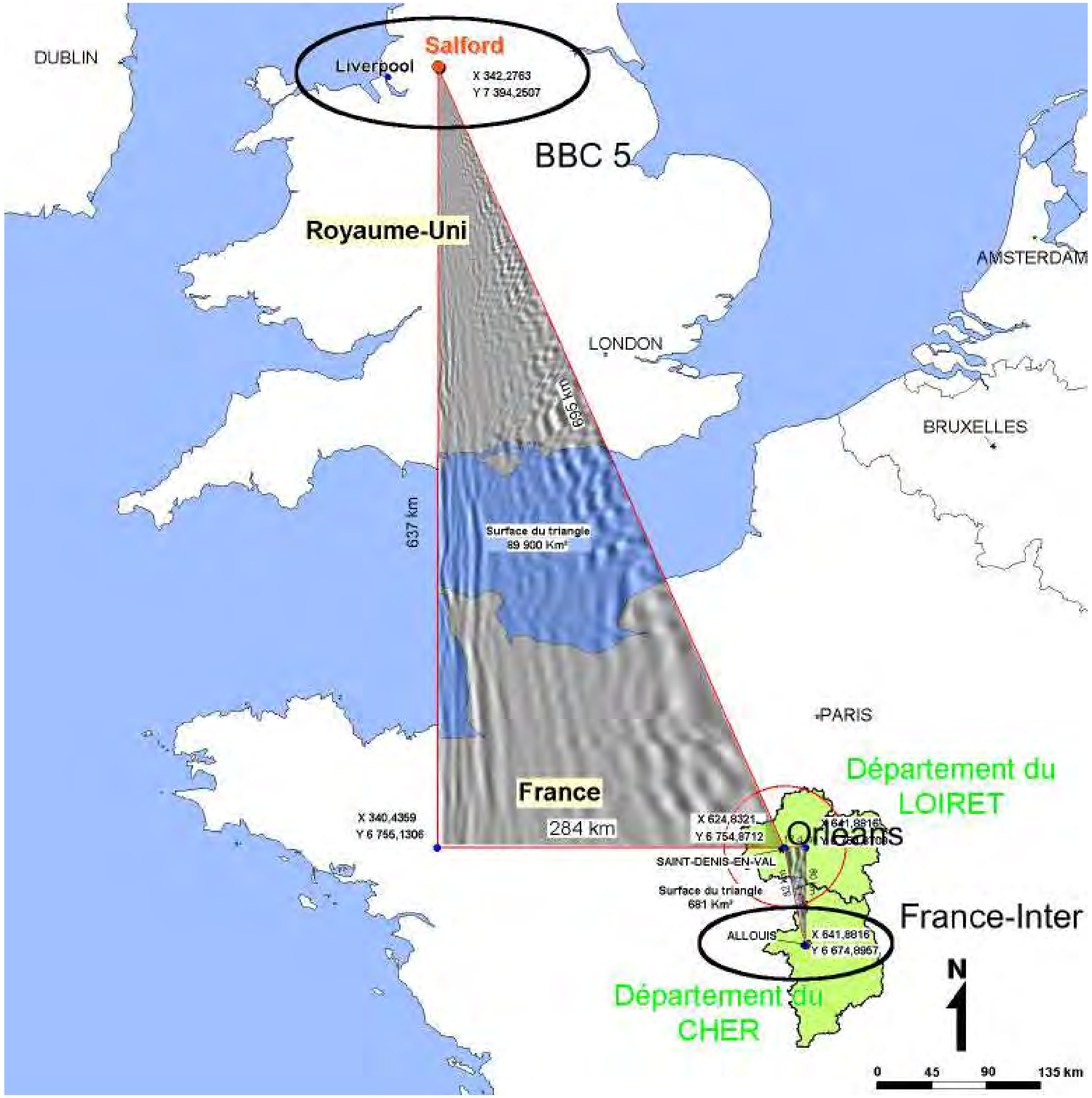
considered as plane and constant:

$\lambda \cong$ geometric model principal dimension

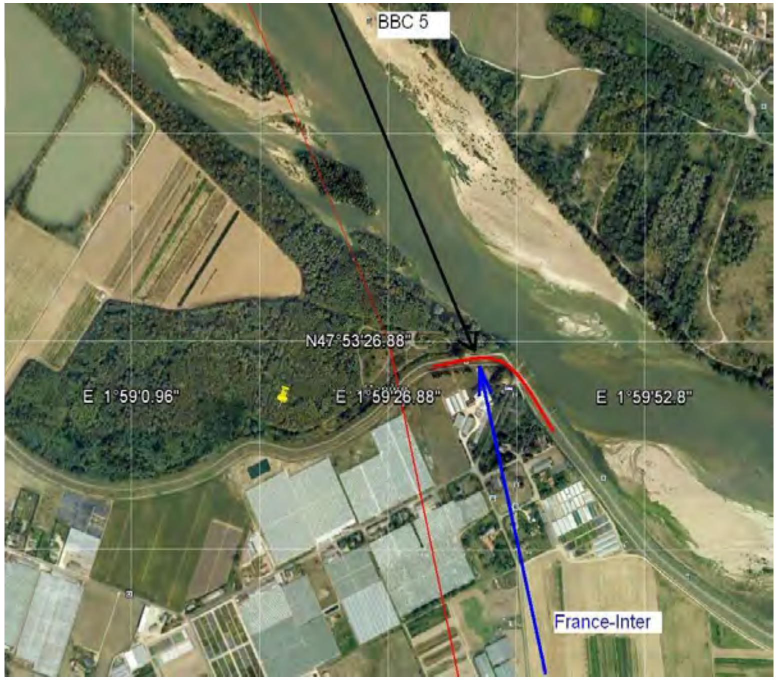
Apparent resistivity estimation : $\rho_a = f(H, E)$

(Cagnard formula)

2-1 location of RMT simulated emitters



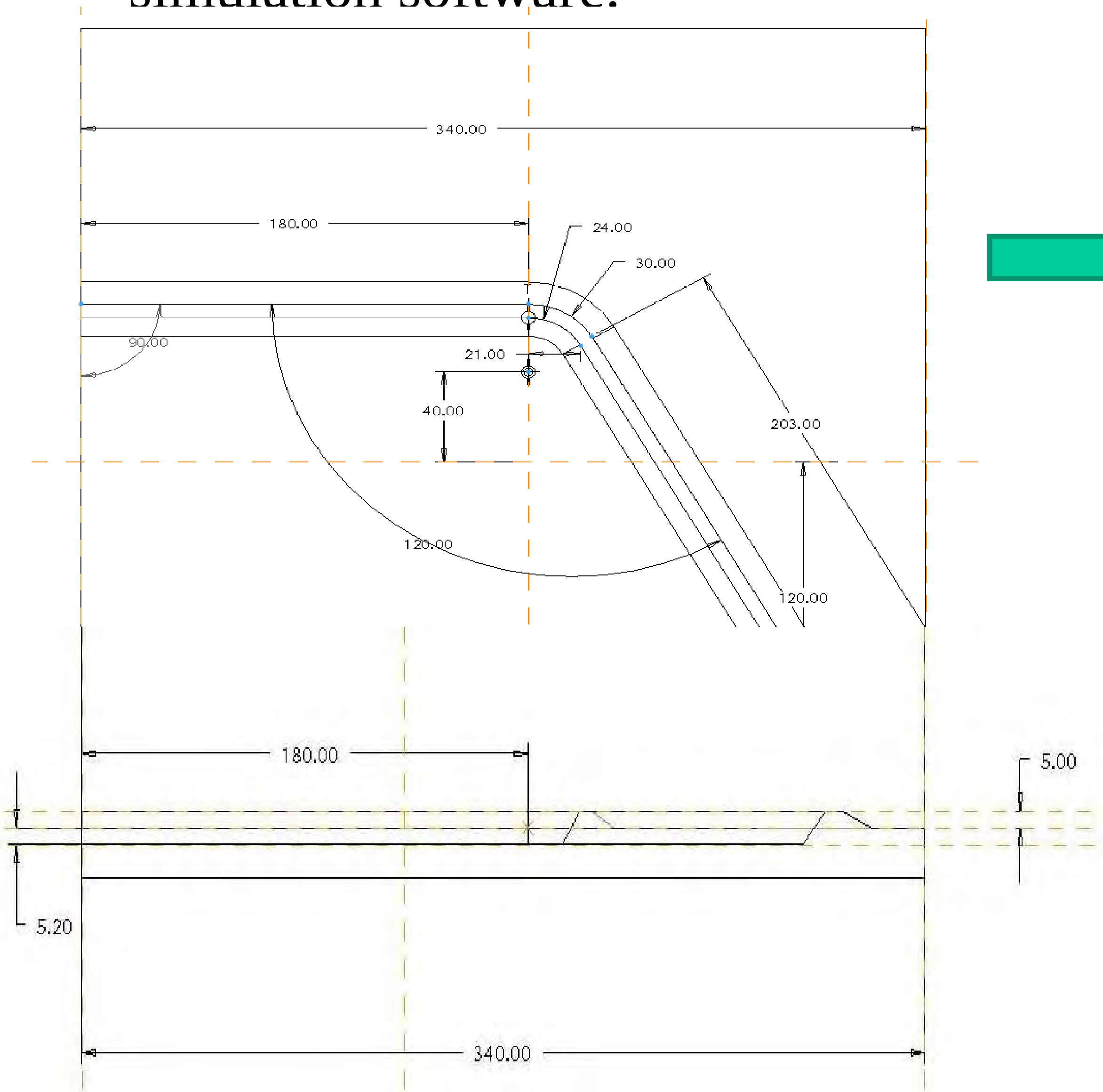
BBC5 freq.
from Salford:
f = 693 kHz
λ_{air} = 433 m

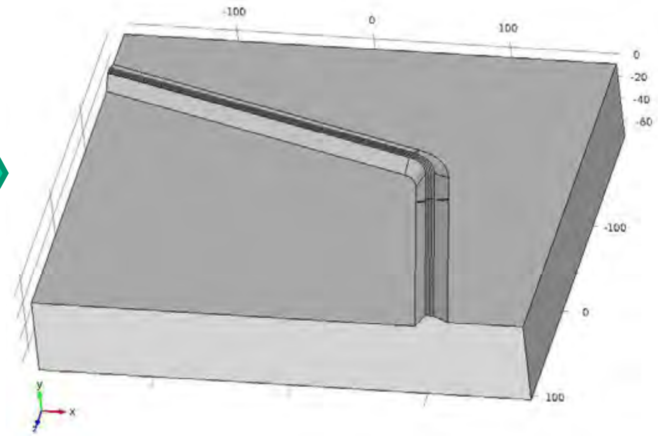


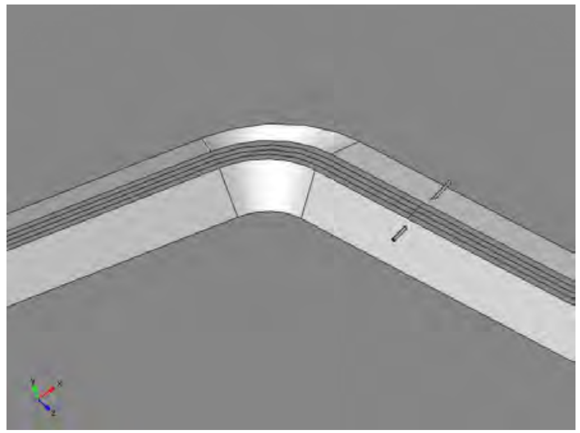
France-Inter freq.
from Allouis:
f = 163 kHz
λ_{air} = 1 840 m

2-2 Geometry definition

- Geometrical CAD model of the levee integrated in Comsol simulation software.





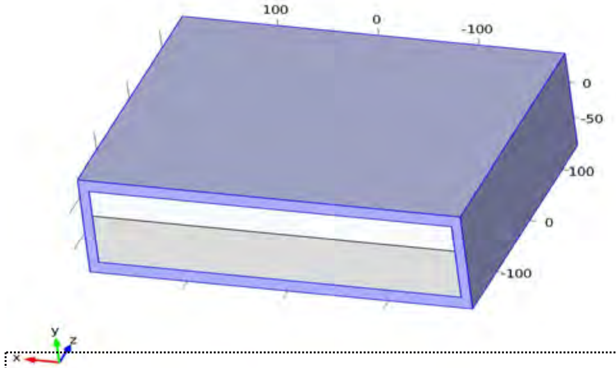


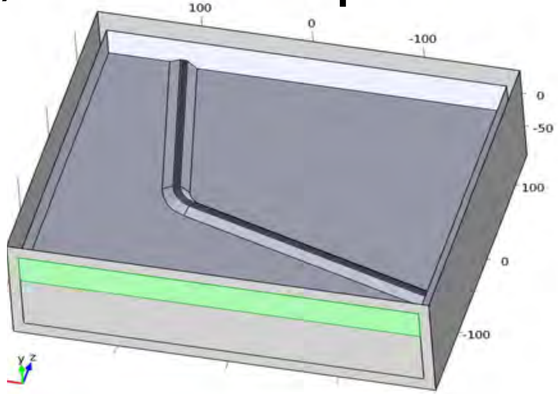
2-3 Physics model selection

2 Comsol modules: RF and ACDC

Comsol RF Module -« electromagnetic waves (emw) »

PML and initialization, the x component of H:

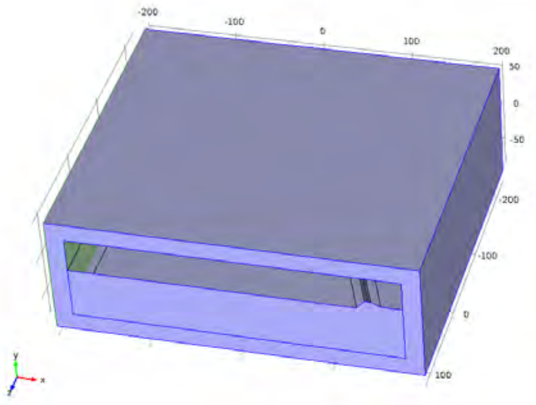


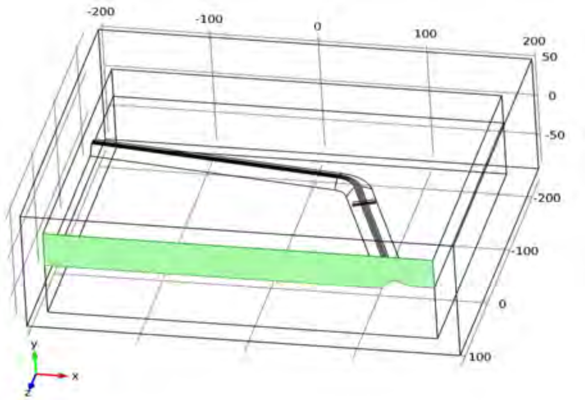


BBC 5 orientation

Comsol AC / DC module - « magnetic fields (mf) »

Magnetic insulation and initialization, the x component of H:





Allouis orientation

2-4 Physics setting

The physics model: scalar variables, physics properties and parameter

For the soil and the levee, different physics properties values:

- relative dielectric permittivity $\varepsilon_r = 8$,
- electrical conductivity $\sigma = {}^1/\rho$, $\rho = 4000$ and 8000 Ω.m
- relative permeability $\mu_r = 1$.

Salford Allouis

The three-dimensional MT responses computed at different frequencies, our parameter for different radio waves.

The induced field $\mathbf{E}_z$ is defined as: $$E_z = E_0 e^{-j k_{0rfw} y}$$

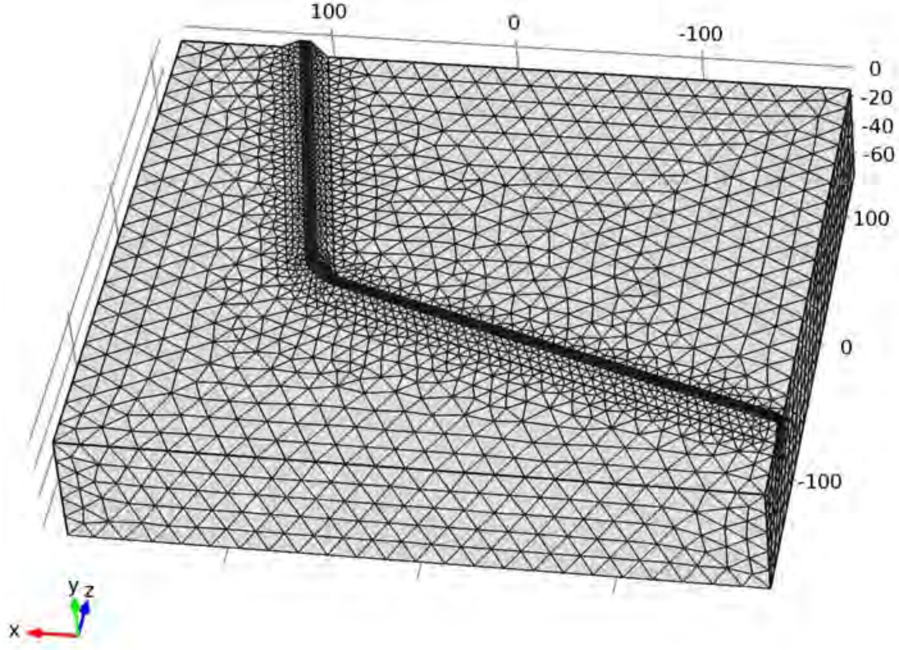
The magnetic field $\mathbf{H}_{px}$ is defined as: $$H_{px} = H_0 e^{-j k_{0rfw} y}$$

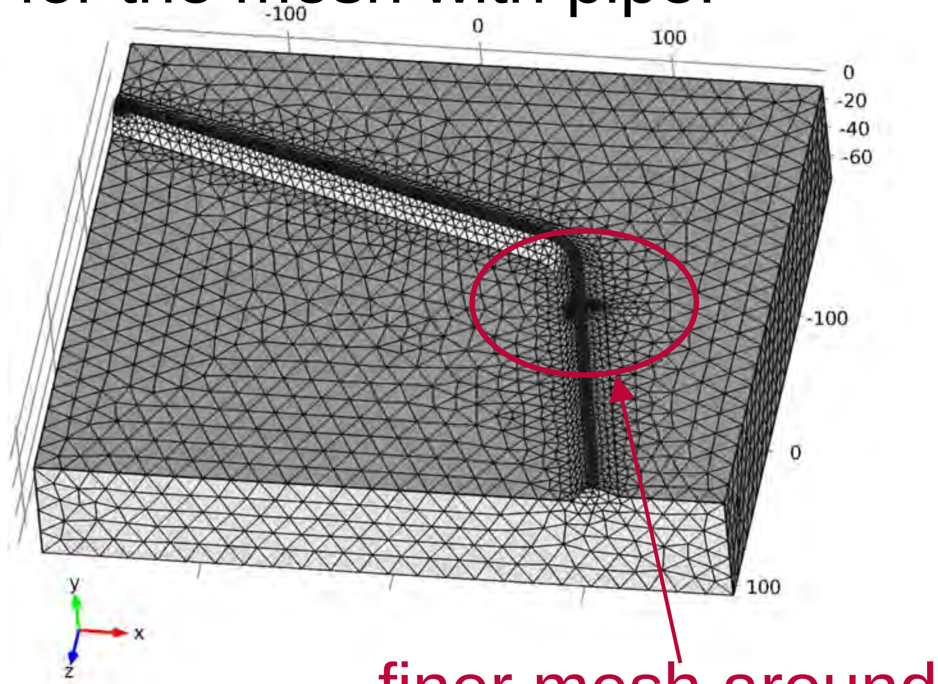
where $k_{0\,rfw}$ is the magnitude of the wave vector.
Both fields exponentially decrease into the soil.

2-5 Meshing and solver with Comsol

Adaptative and refine mesh

90 309 triangular elements for the mesh with pipe:





finer mesh around the gas pipe

In the study : stationary and iterative solver
with frequency domain,

- the relative tolerance sets at 0.0 010
- the degrees of freedom is solved for 572 324

2-6 Post-processing and results:

Solution of apparent resistivity on the levee surface: export in ascii data for treatment;

«Electromagnetic waves (emw)» : $$\rho_a = \frac{1}{\mu_0.\omega} \times \left(\frac{E_z}{emw.H_x} \right)^2$$

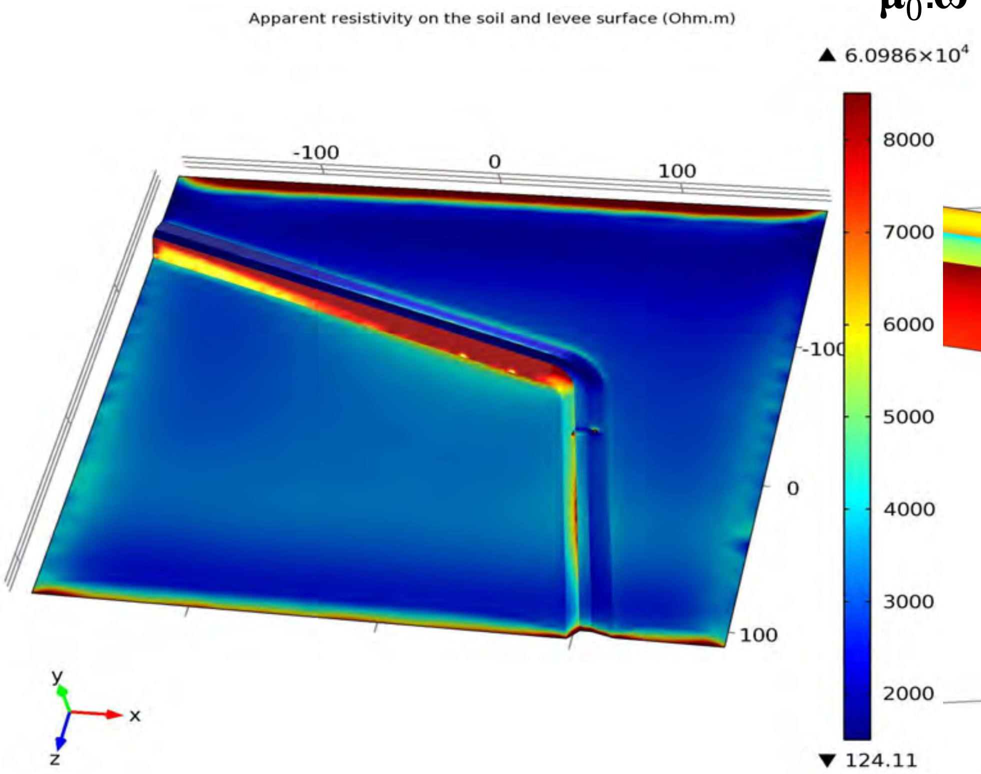
«Magnetic Fields (mf)» : $$\rho_a = \frac{1}{\mu_0.\omega} \times \left(\frac{mf.E_z}{mf.H_x} \right)^2$$

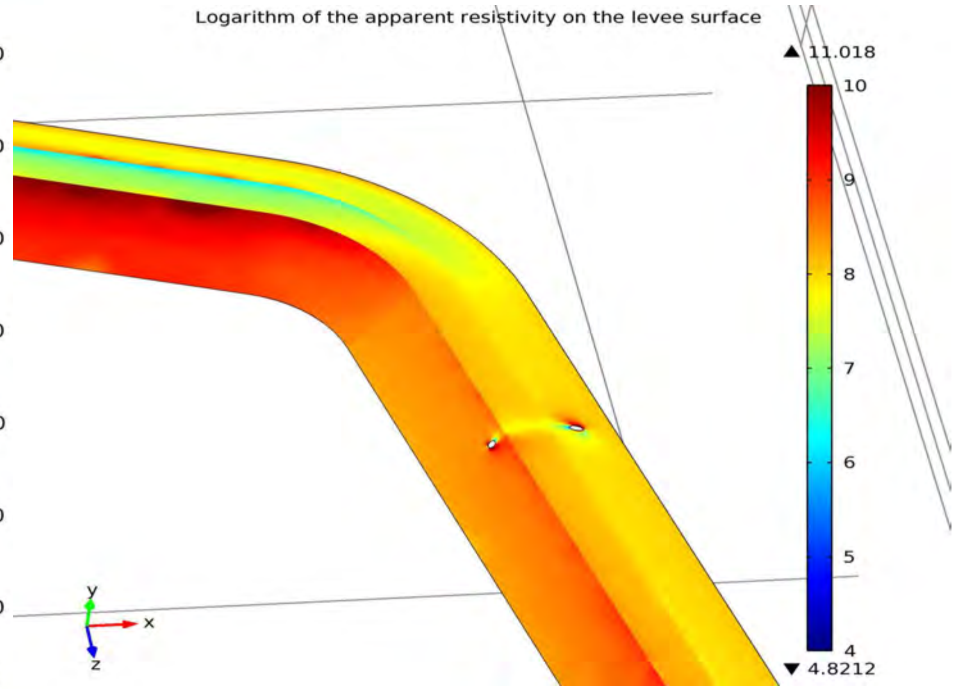
ρ_a : apparent resistivity

E_x : electromagnetic perpendicular field

H_z : magnetic parallel field to the levee

ω : angular frequency

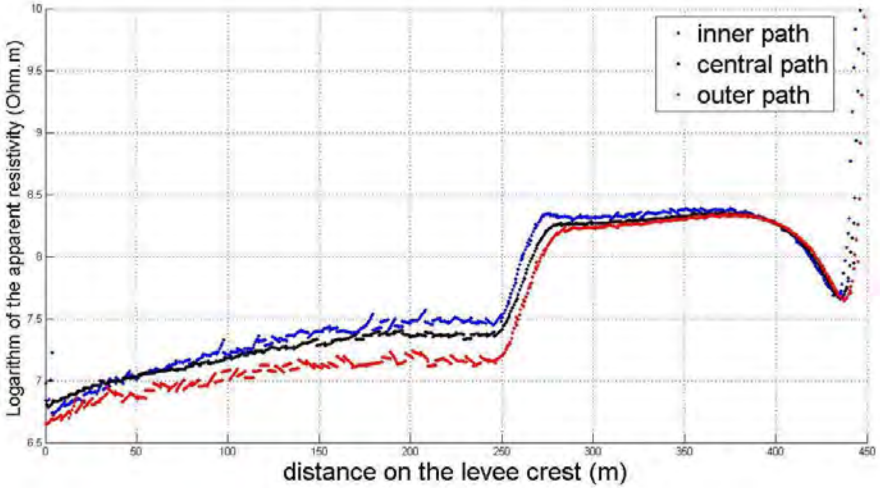


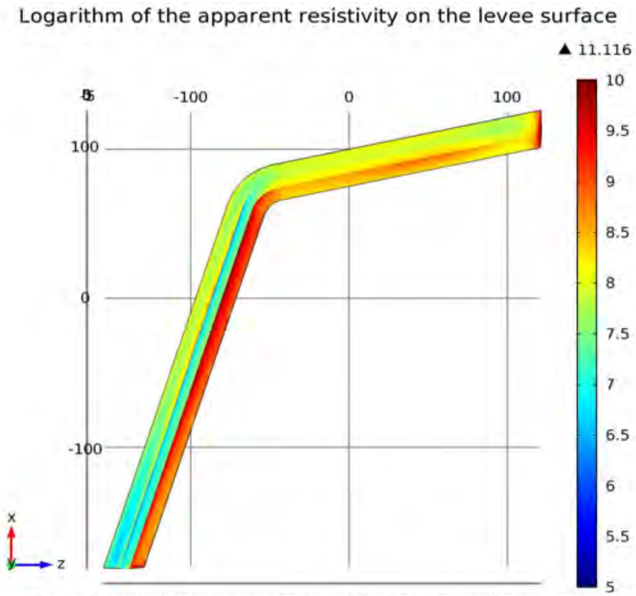


3-1 Results : apparent resistivity on crest

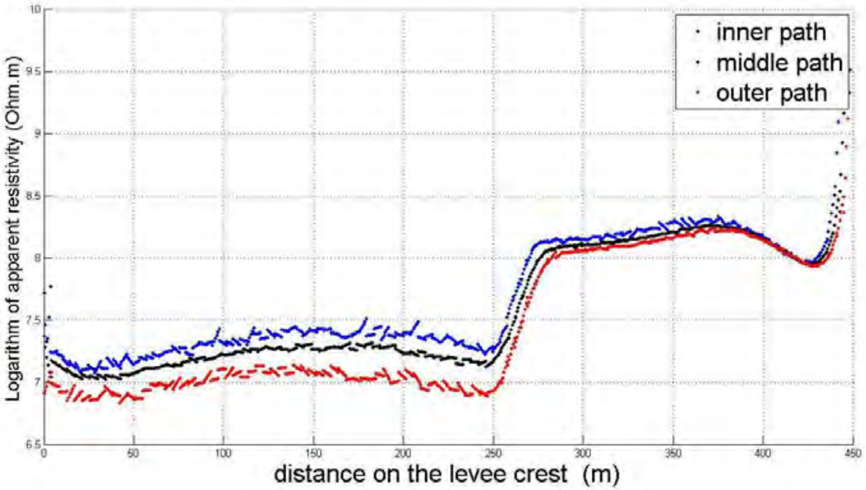
BBC 5 (693kHz) , resistivity levee: 4000 Ω.m

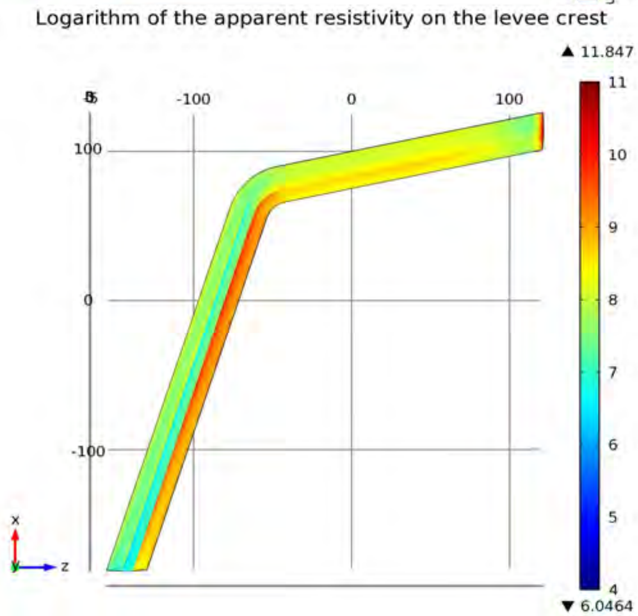
With the RF Module:





With the AC / DC module:

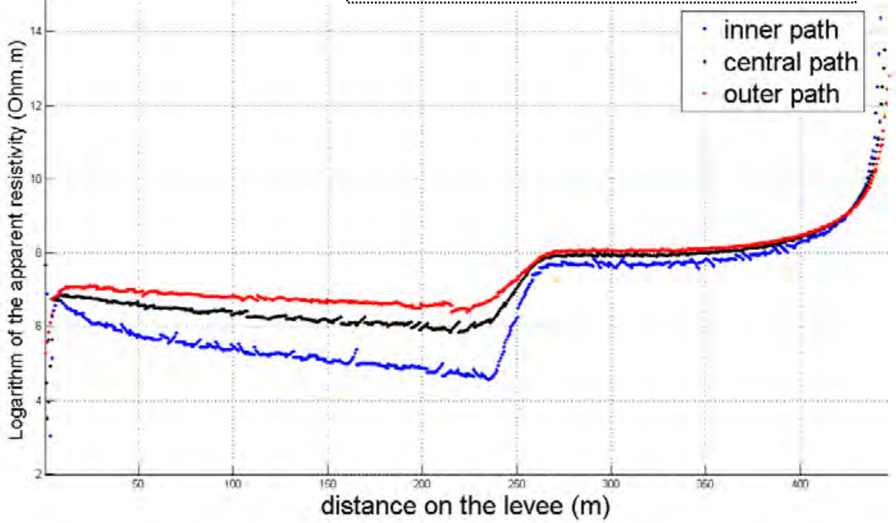


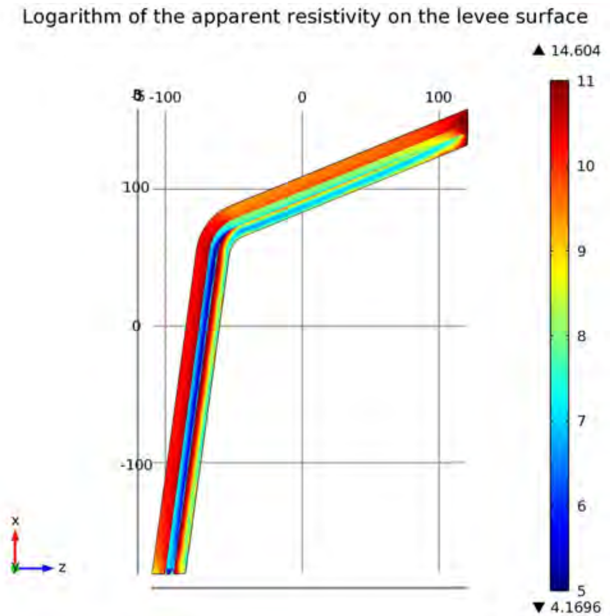


3 -1 Results : apparent resistivity on crest

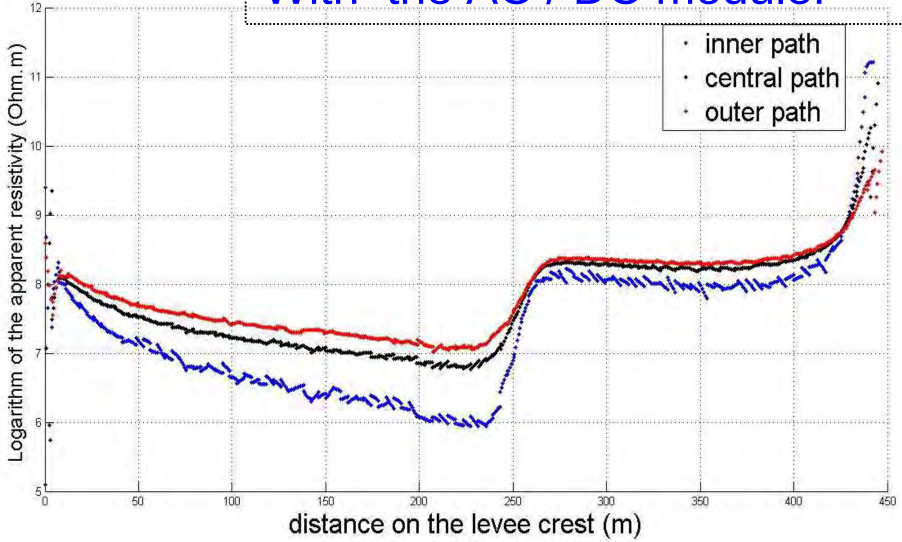
France-Inter (163 kHz), resistivity levee: 8000 Ω .m

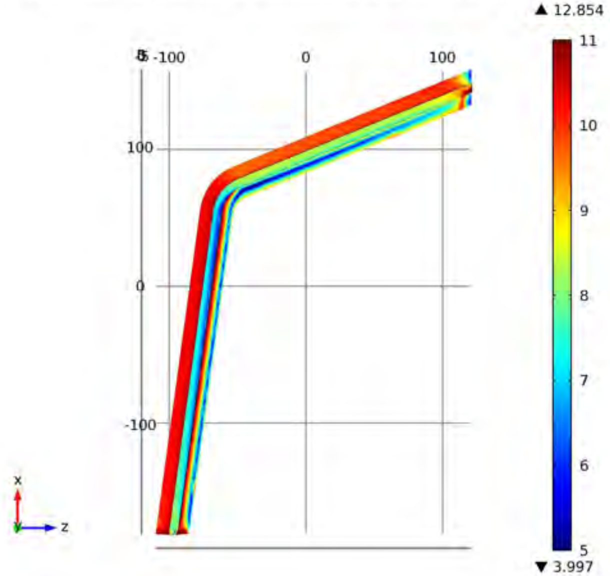
With the RF Module:





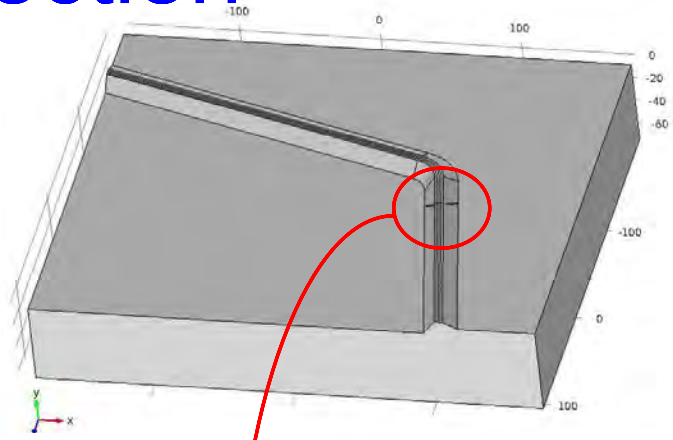
With the AC / DC module:

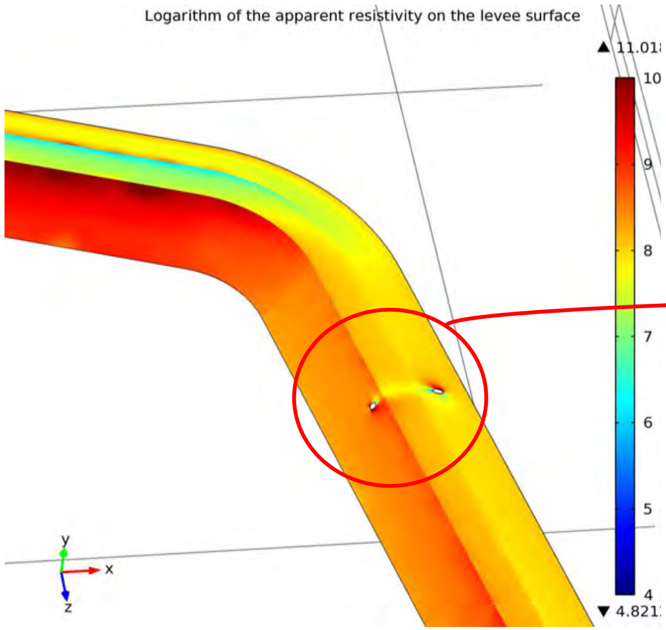


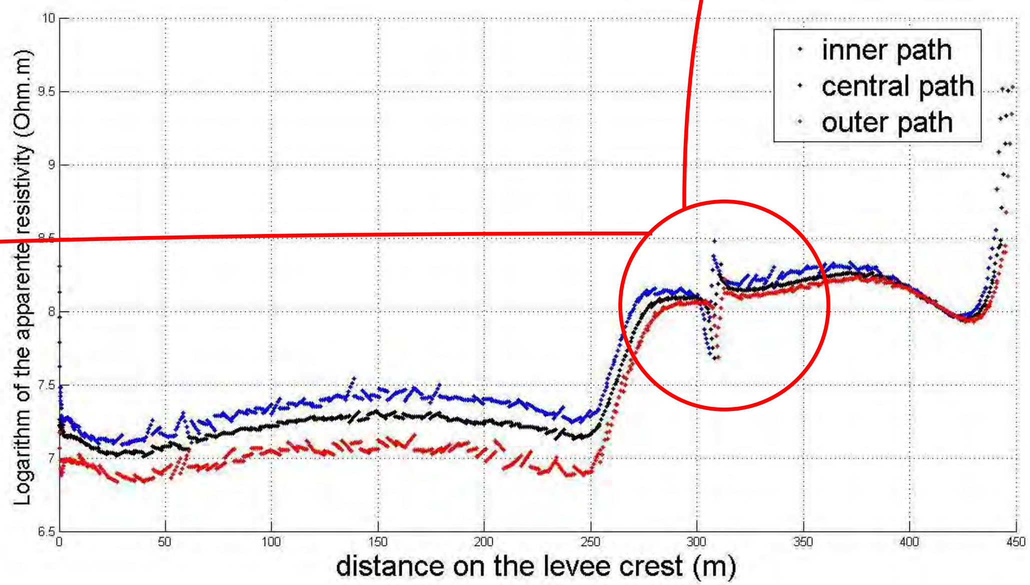


3-2 Results: anomalies detection

The buried gas pipe is located in the levee and beneath the crest paths.







3D modelling of apparent resistivity amplitudes. This show the longitudinal profiles on the levee crest with a typical sinusoidal anomalie of a metallic pipe.

4 - Conclusion

- Apparent resistivity is computed in Comsol.
- Response depends on the direction emitters/levee stretch.
- 3D effects are generated by topography.
- Resistivity anomalies into the levee, like man made structures are accurately simulated.
- Field measurements and simulation values will be compared in further studies.

Simulation results obtained by the two methods are very similar and highlight topographic effects on resistivity measurements in RMT method on levee.

Thank you for your attention !