Topographical effects on Radio Magnetotelluric (RMT) measurements on levees

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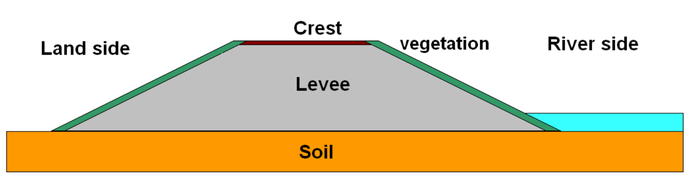
1. RMT method



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

RMT method applied on a levee: study of the topography effect and materials distribution on the recorded Electromagnetic fields

➢Maxwell's equation, Ohm's law : propagation equations

➢Radio wave frequency method : source of the electromagnetic wave,

characteristic parameters and values

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

$$\delta = \sqrt{\frac{\rho}{\pi \mu_0 f}} \approx 503\sqrt{\frac{\rho}{f}}$$

considered as plane and constant :

$$\text{wavelenght}: \lambda = \frac{c}{f}$$

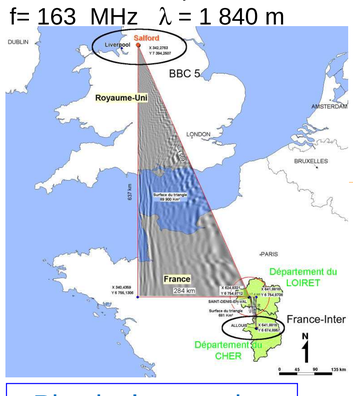
$$\text{Apparent resistivity estimation}: \rho_a = f(H, E)$$

2. Physical modelling

Principle

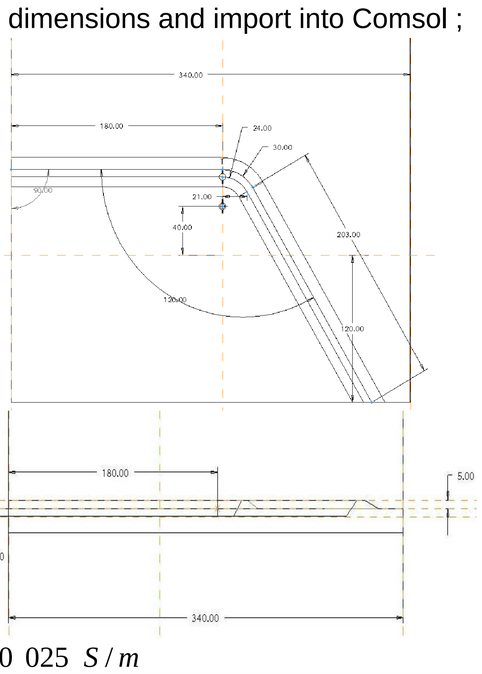
BBC5 freq. from Salford :
f = 693 MHz λ = 433 m

France-Inter freq. from Allouis :
f= 163 MHz λ = 1 840 m



Geometrical model

CAD numerical levee model with dimensions and import into Comsol ;



Physical properties

For the soil and the levee :

$$\text{relative permittivity}: \varepsilon_r = 10$$

$$\text{relative permeability}: \mu_r = 1$$

$$\text{electrical conductivity}: \sigma = 0{,}00\ 025\ \ S/m$$

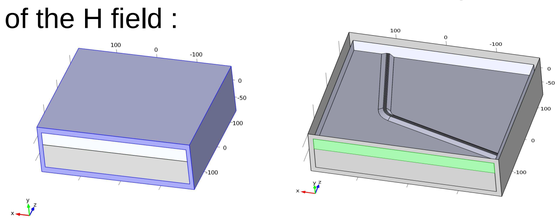
Physical model

2 Comsol modules: RF and ACDC

Boundary condition

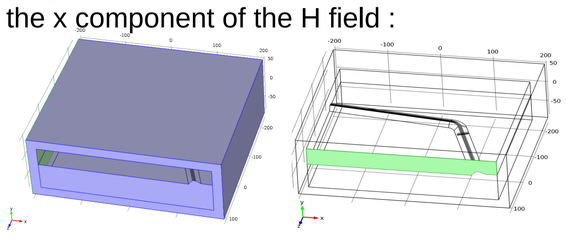
With Comsol RF Module -"electromagnetic waves (emw)« :

PML and initialization with the x component of the H field :



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

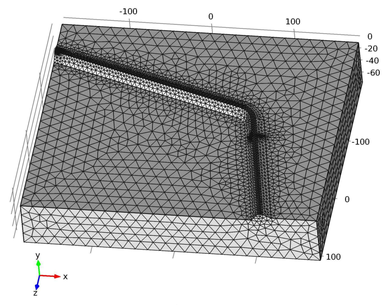
Magnetic insulation and initialization with the x component of the H field :



Post-processing: Results

Adaptative mesh

90 309 elements for the mesh with pipe :

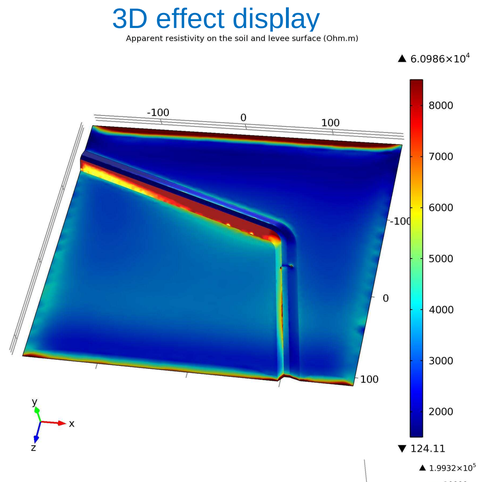


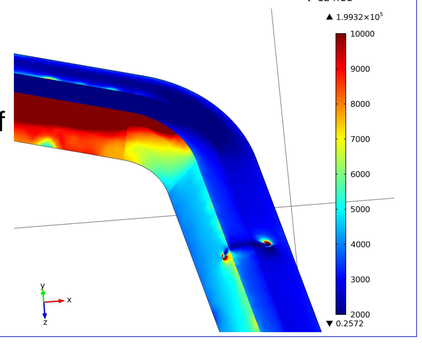
Solveur

In the study : solver with frequency domain, the relative tolerance set at 0.0 010 and the degrees of freedom is solved for 572 324. Type of stationary and iterative solver .

Computation of the apparent resistivity,
Display of the solution on the levee surface and export of ascii data for treatment;

3D effect display





3. Results

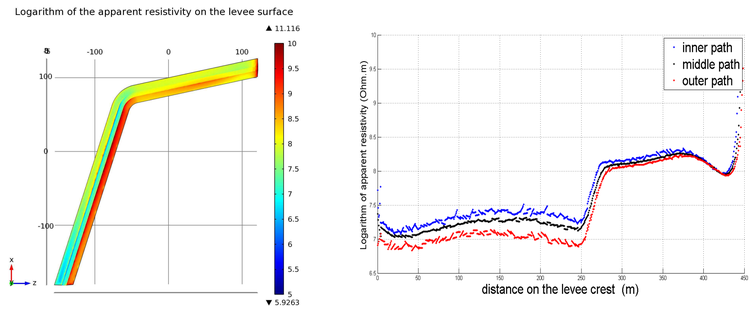
Different frequencies :

Apparent resistivity computation

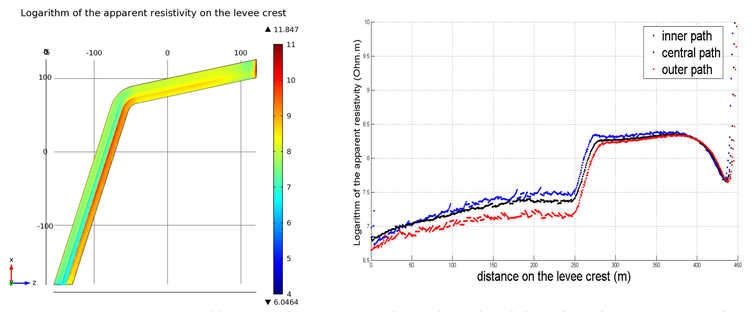
Apparent resistivity logarithm **Longitudinal profiles**

BBC 5 (691kHz) , resistivity levee : 4000 Ω.m

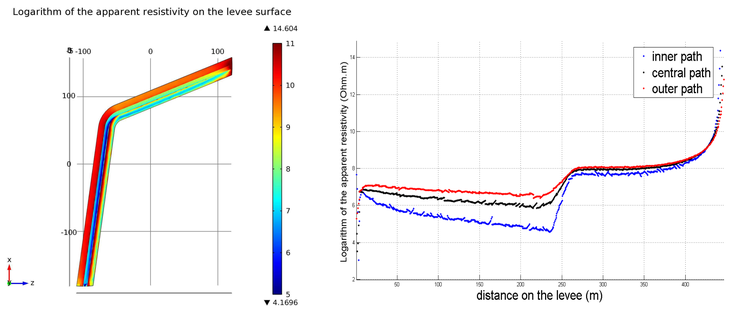
Comsol Multiphysics RF Module -"electromagnetic waves (emw)"

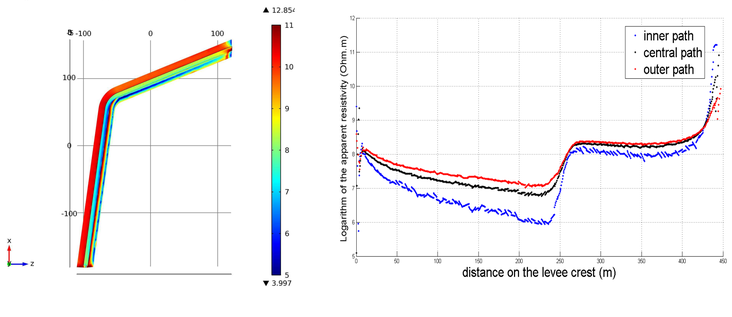


Comsol Multiphysics AC / DC module - « magnetic fields (mf)"

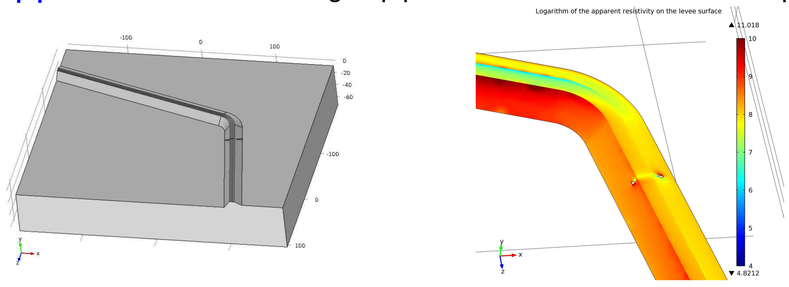


France-Inter (163 kHz), resistivity levee : 8000 Ω.m





Gas pipe detection: Effect of a gas pipe buried in the levee on the apparent resistivity, "electromagnetic wave" model, freq. BBC5;



The apparent resistivity calculation in Comsol :

for the « Electromagnetic waves (emw) » model:

$$\rho_a = \frac{1}{\mu.\omega} \times \left(\frac{E_z}{emw.H_x} \right)^2$$

for the « Magnetic Fields (mf) » model:

$$\rho_a = \frac{1}{\mu.\omega} \times \left(\frac{mf.E_z}{mf.H_x} \right)^2$$

Simulation results by the two methods are very similar and highlight topographical effects on resistivity measurements in RMT method

References:

Fauchard C., Mériaux Patrice, "Geophysical and geotechnical methods for diagnosing flood protection dikes", *éditions Quae, France, 2004*

Eberle D., "A method of reducing terrain relief effects from VLF-EM data", *1981 Elsevier Scientific Publishing Compagny*

Wannamaker philip E., Stodt John A., and Rijo Luis, "Two-dimensional topographic responses in magnetotellurics modeled using finite elements", *Geophysics. Vol.51, NO. 1, November 1986*

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