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**POTENTIAL OF ELECTRIC AND  
ELECTROMAGNETIC SIGNAL FOR HYDRIC  
STATE DIAGNOSIS OF BUILDING STRUCTURES.  
CASE OF 2 INNOVATIVE TECHNIQUES.**

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# POTENTIAL OF ELECTRIC AND ELECTROMAGNETIC SIGNAL FOR HYDRIC STATE DIAGNOSIS OF BUILDING STRUCTURES. CASE OF 2 INNOVATIVE TECHNIQS.

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## Context

Raw earth = **environmentally friendly** building materials  
BUT **sensitive to water** (weakening of the mechanical capacity)

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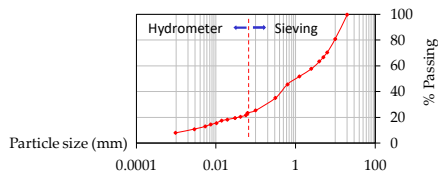
## Objectives

**High necessity to diagnose water content  $w(\%) = m_w/m_s$**

**Non-localized and non-destructive** measurement methods based on :  
- Sinusoidal **electrical investigation** (induced polarization)  
- Sinusoidal **electromagnetic investigation** (free-space radiofrequency)

## Earth sample and drying conditions

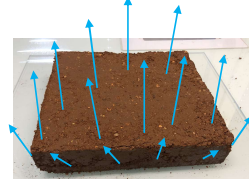
Earth from Orangerie building (Lyon)



Dynamical compaction in layers (like rammed earth)  
**2 samples in drying :**



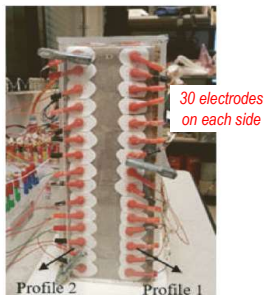
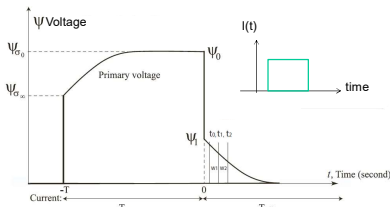
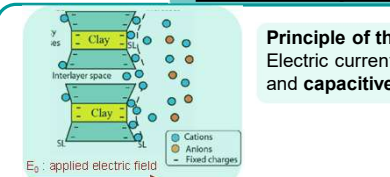
Earth prism  
2 cm sieved  
 $\rho_d = 18,4 \text{ kN/m}^3$   
 $15 \times 15 \times 45 \text{ cm}^3$   
**1D drying**



Earth plaque  
1 cm sieved  
 $\rho_d = 17,8 \text{ kN/m}^3$   
 $30 \times 30 \times 6 \text{ cm}^3$   
**3D drying**

## 1. Induced polarization

**Principle of the measure :**  
Electric current injection and measurement of **resistive and capacitive properties** of soils (electric relaxation).



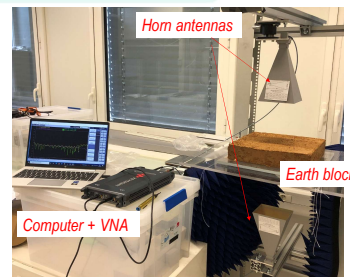
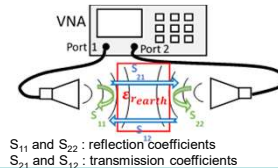
→ Polarization of clay particles surface in DC

## 2. Free-space radiofrequency

**Principle of the measure :**  
Electromagnetic signal injection and measurement of the **attenuation and phase lag** of an electromagnetic signal

VNA + 2 horn antennas  
TRL calibration

S parameters measurement

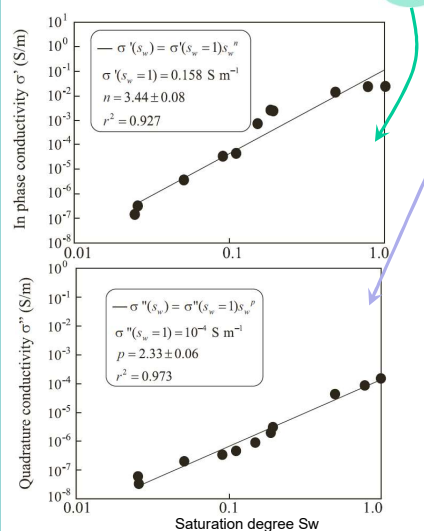


Compromise between sample size and frequency : => **8-14 GHz**

$S_{11}$  and  $S_{22}$  : reflection coefficients  
 $S_{21}$  and  $S_{12}$  : transmission coefficients

→ Results in AC with 1 Hz :

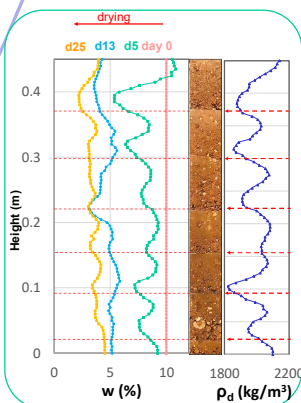
Conductivity = complex function :  $\sigma^* = \sigma'(\omega) + i\sigma''(\omega)$



Dynamic Stern layer model links  $\sigma^*$  with CEC, Sw

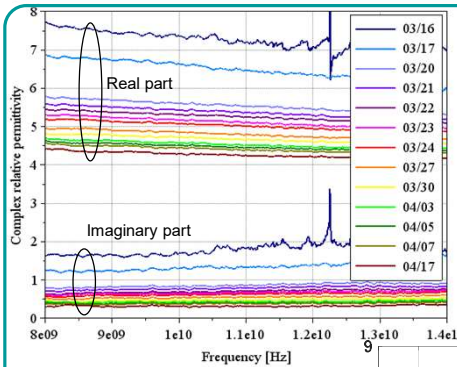
[1] Revil A., et al. Geophysics, (2013) 78(4), D271-D291  
[2] Revil A. et al., Water resour. Res. (2017), 53(8), 7121-7147

In phase conductivity: linked to bulk water  
Quadrature conductivity: linked to CEC, w, porosity  $\phi$



$$M_n \equiv \sigma_\infty - \sigma_0 = \frac{S_w^p}{F\phi} \rho_d \lambda \text{ CEC}$$

$$\sigma_\infty = \frac{S_w^n}{F} \sigma_w + \left( \frac{S_w^{n-1}}{F\phi} \right) \rho_d B \text{ CEC}$$

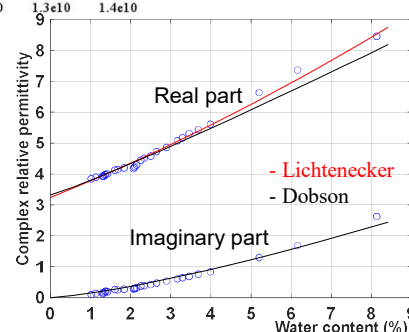


Good agreement with empirical models in the literature:

- Lichteneneker model [3]
- Dobson model [4]

**Measurements :**

- Throughout the drying process :
- weighing
- 4 S parameters => Complex permittivity extraction using Ross-Nicholson-Weir method



[3] T. Zakri et al., J. Phys. D: Appl. Phys. 31 (1998) 1589-1594

[4] M. C. Dobson et al., IEEE Trans. Geoscience and remote sensing, vol. ge-23, no. 1, 1985.

## 3. Conclusion

These 2 methods are promising with -for each- its specificities :

Detection of high water content : >2  
Here 60 electrodes installed on the sample, Time of acquisition : ~1h  
Low frequency 1mHz - 10kHz  
3D reconstruction possible of w  
A data of w is required on a given point

Detection of low water content : ~1h  
Non-contact measurement, instantaneous  
High frequency : 8-14 GHz  
1 average value for w  
A media calibration curve is required