Earthing Issues at El Roque de los Muchachos Observatory

UCM-ELEC
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Main topics

- Why Earthing?
- The importance of soil resistivity and its influence in earth resistance value
- Representative situations in ORM
- How to improve Earthing systems

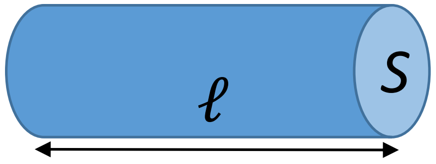
Earthing

Earth Resistance: “Resistance between the electrode and the point of zero potential (the infinite earth)”

Earthing System: Conducting connection between an electrical circuit and the Earth to prevent damage in the case of high discharges. It should be AS LOW AS POSSIBLE. Standards recommend < 10 Ω (low frequency) [IEC-62305-3]. It is influenced by:

- ❑ Resistance of the electrodes
- ❑ Contact resistance between electrode and soil
- ❑ **Resistivity of the soil**

$\boldsymbol{R \neq \rho}$!!



$$R = \rho\frac{\ell}{S} = \frac{\ell}{\sigma\, S}$$

[ρ]=Ohm·m Depends on the material only

[R]=Ohm Depends on the material and geometry

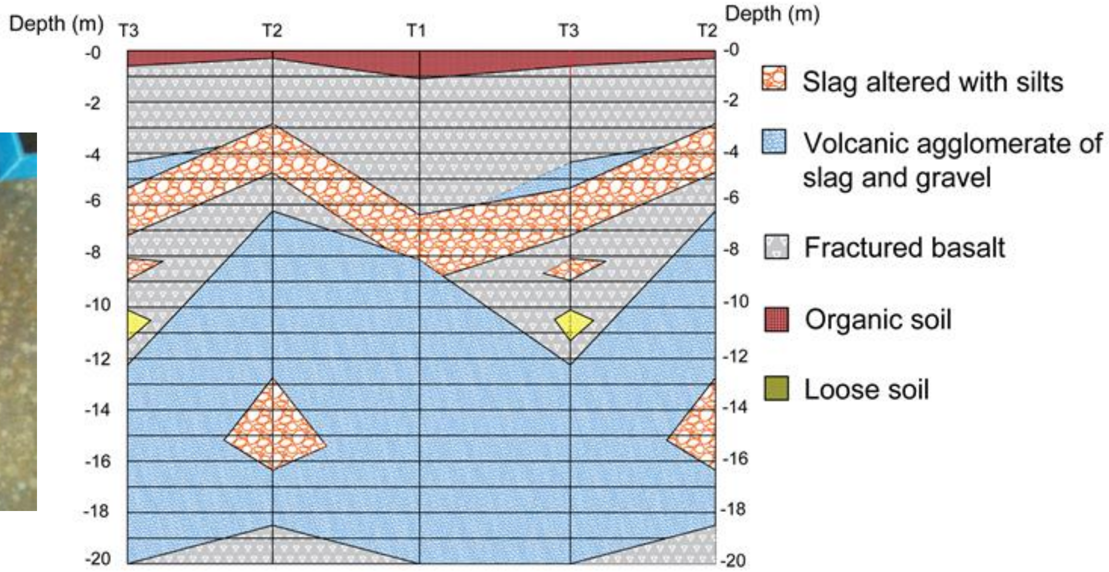
Soil resistivity

Resistivity depends on the type of soil

Soil Type	Resistivity (Ohm-meter)		
	Minimum	Mean	Maximum
Clay	5	27.2	60
Sand/Clay	6.28	215.0	346.83
Limestone	36.4	50.2	95.8
Sand	50	270	476.58
Laterite	961.3	1200	1528.7
Rock	1557	2500	19,012.92

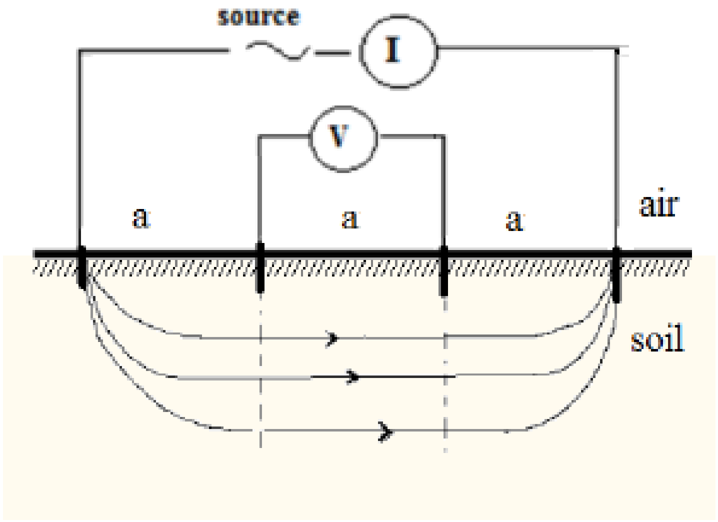
Volcanic terrain

Geotechnical studies



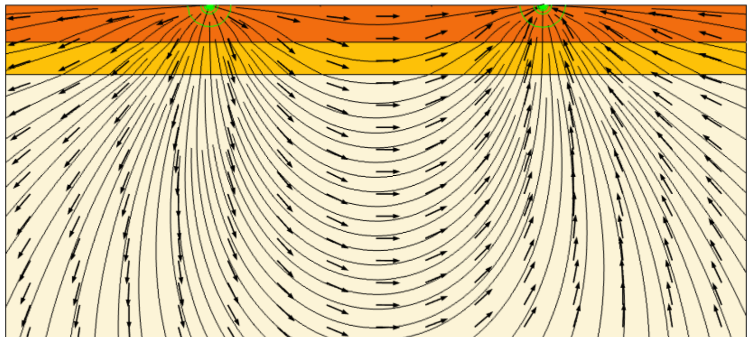
Soil resistivity measurement: Wenner Method

4 electrodes method



$$\rho(a) = 2\,\pi\,a\,R = 2\,\pi\,a\frac{V}{I}$$

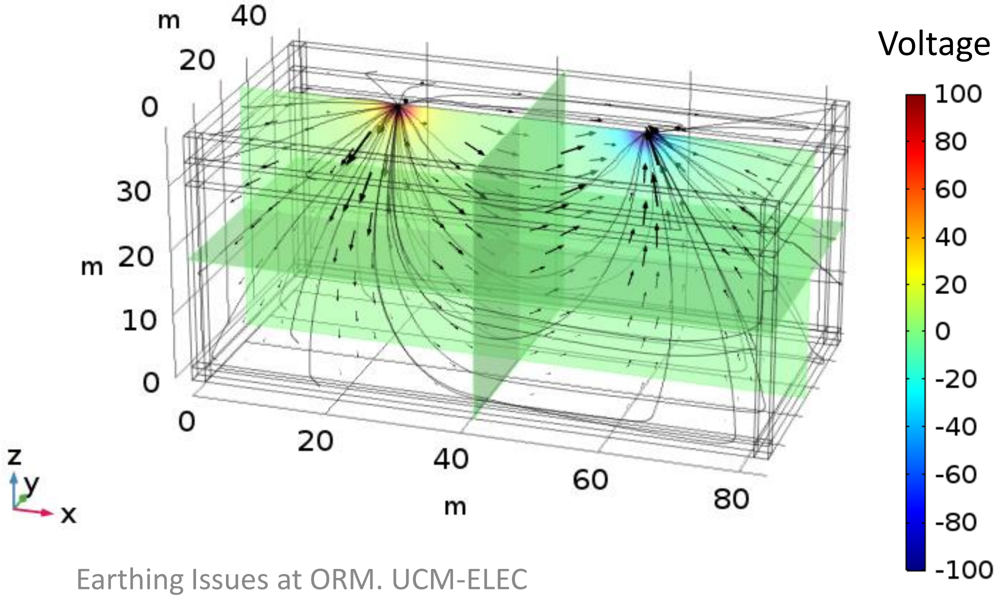
Simulations with COMSOL



Layer 1	σ=1e-3
Layer 2	σ=2e-3
Layer 3	σ=3e-3

Equipotential surfaces

Current density lines and direction



Soil resistivity measurements made in ORM. The numbers correspond to the interelectrode distance in m.

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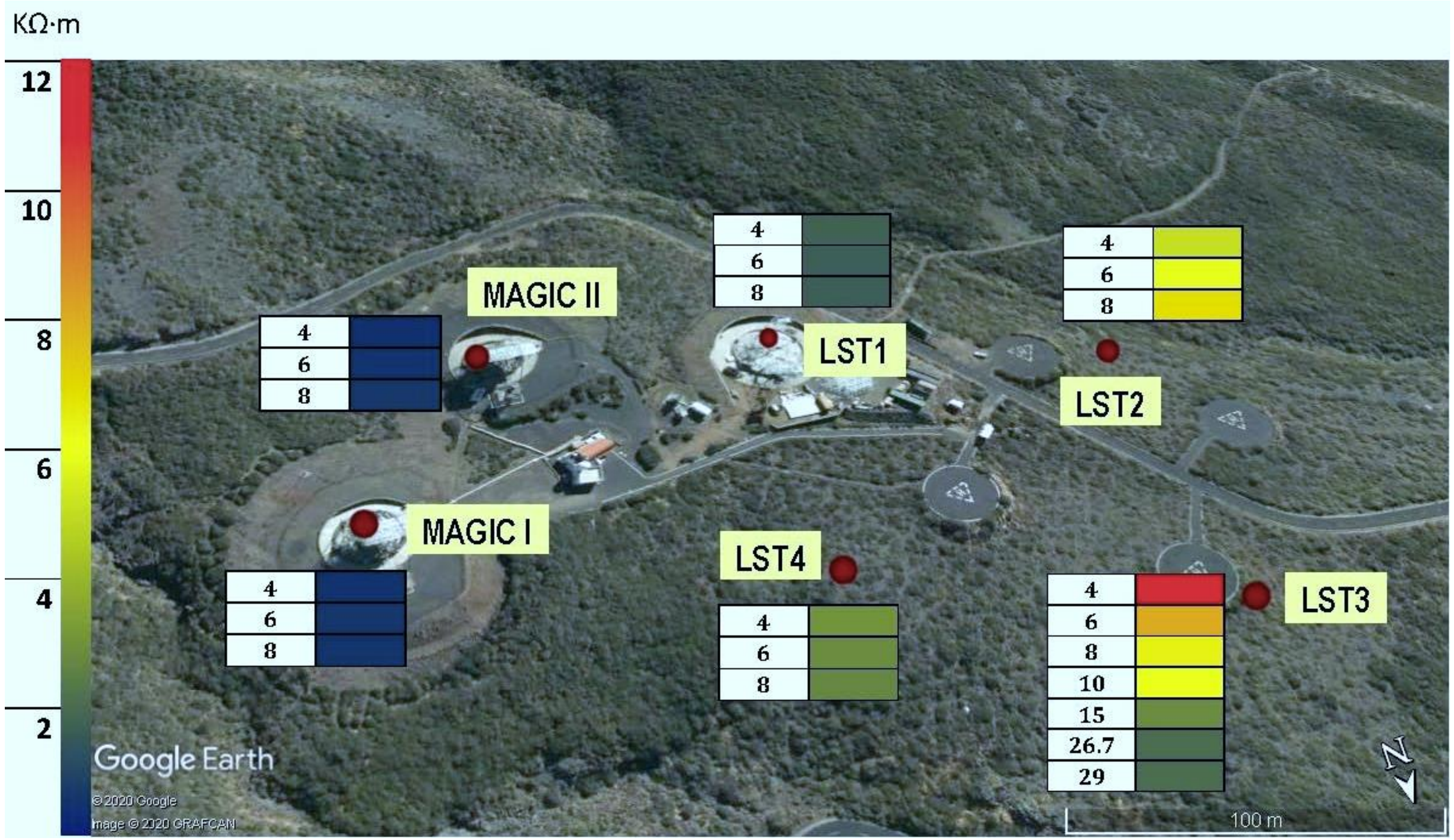
Soil resistivity measurement in ORM



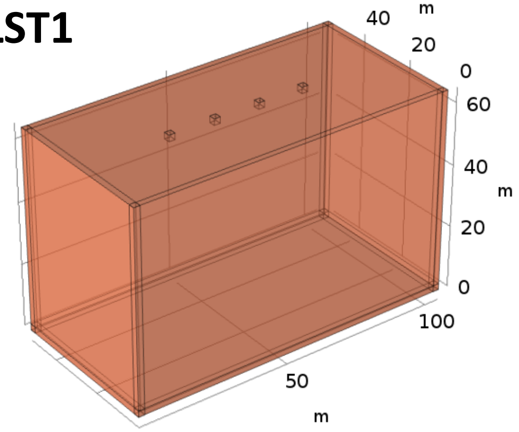
Site	$\overline{\rho}$ (kΩ m)	
MAGIC I	0.57	Homogeneous
MAGIC II	0.53	Homogeneous
LST1	1.44	Homogeneous
LST2	4.3-6.1	Non-Homog.
LST3	1.7-11.5	Non-Homog.
LST4	2.45	Homogeneous

Soil resistivity measurements made in ORM. The numbers correspond to the interelectrode distance in m, roughly equal to depth.

Representative situations in ORM

HOMOGENEOUS HIGH RESISTIVITY SOIL

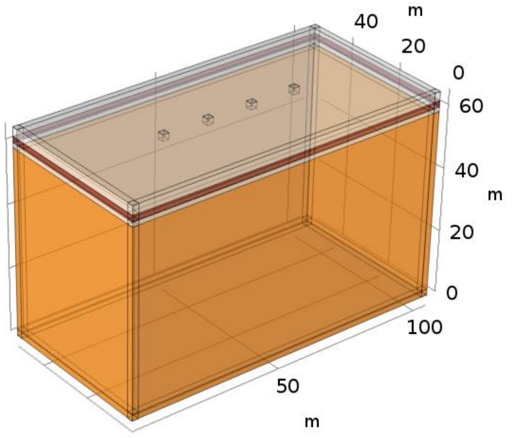
LST1



1.44 kΩ m

NON HOMOGENEOUS SOIL WITH VERY HIGH RESISTIVITY LAYERS

LST3

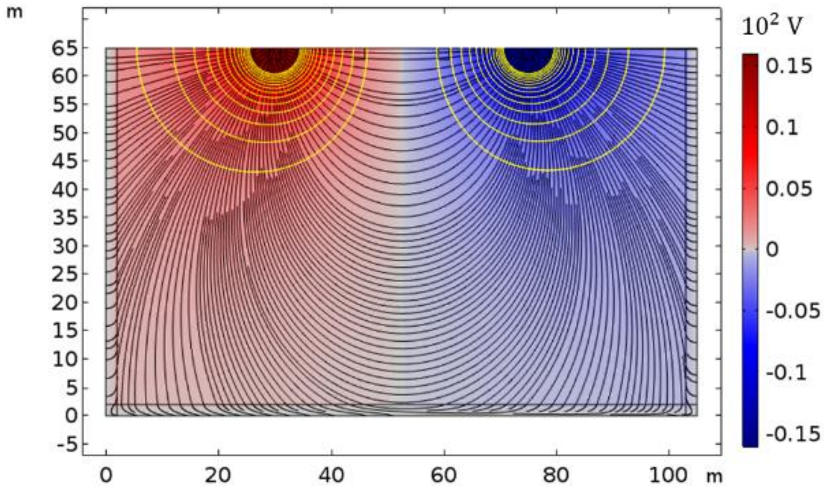


18.4 kΩ m

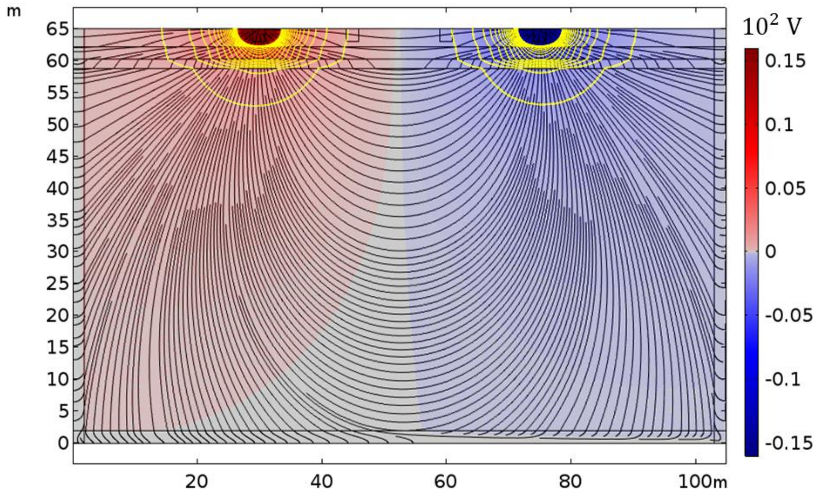
3.5 kΩ m

15.4 kΩ m

1.5 kΩ m



Voltage distribution when resistivity is measured with Wenner method



Possible solutions to reduce earth resistance

- ❑ Chemical treatment of soil or use low resistivity materials ✗
- ❑ Burying metal grids plates (horizontal)
- ❑ Electrodes driven vertical into the ground
- ❑ Electrodes or Earthing Systems interconnection

Design in COMSOL for optimizing the telescopes Earthing

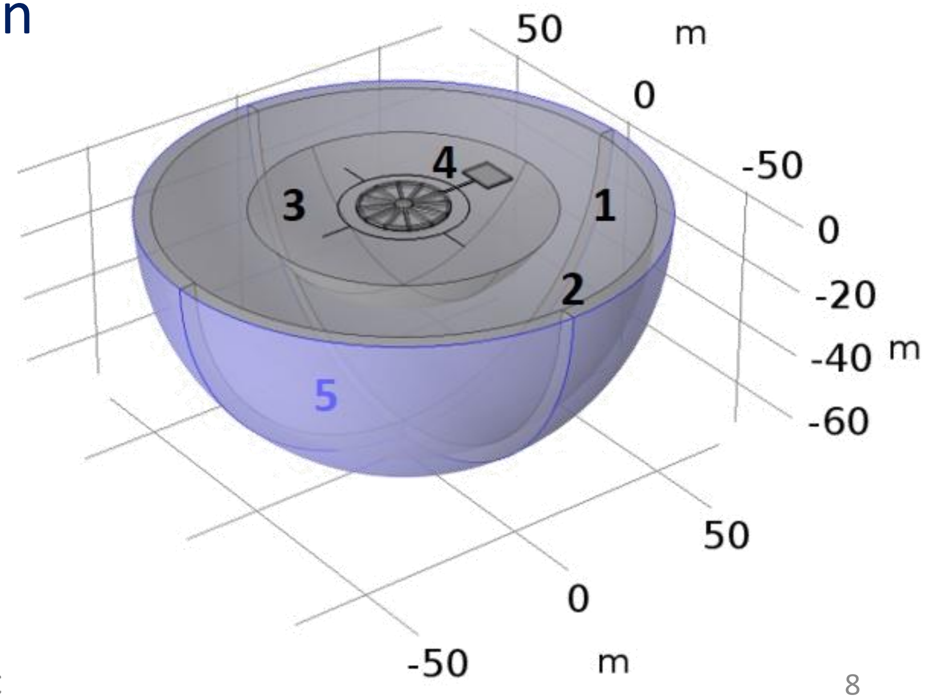
(1) Soil

(2) Infinite Element Domain Layer

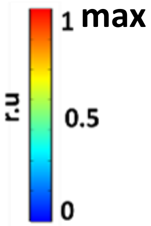
(3) *Extra fine* mesh zone surrounding earth resistance structure

(4) Earth resistance structure

(5) Ground

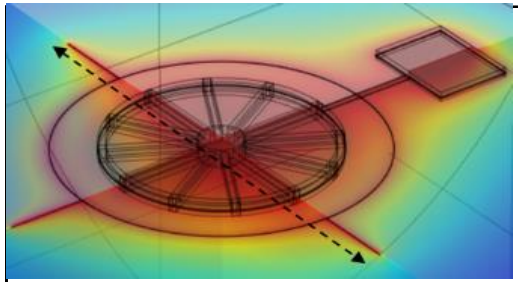
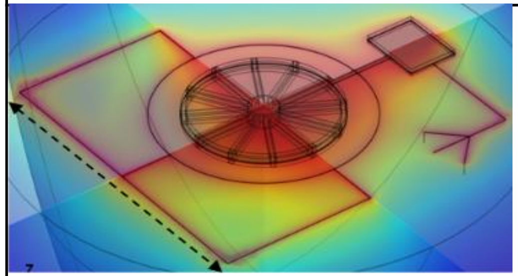
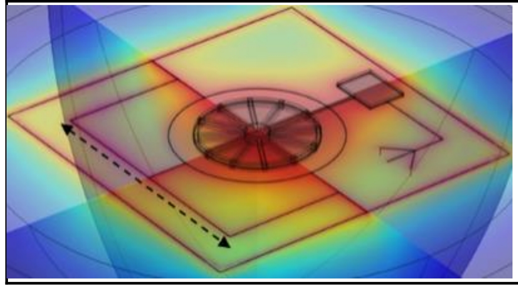


Voltage distribution

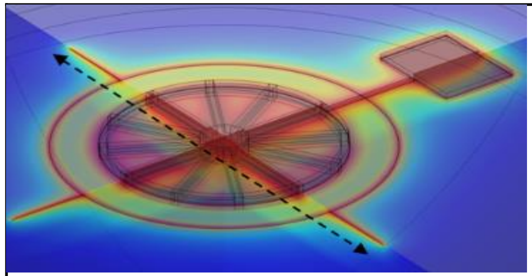
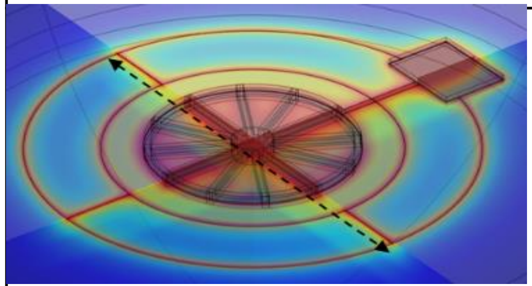
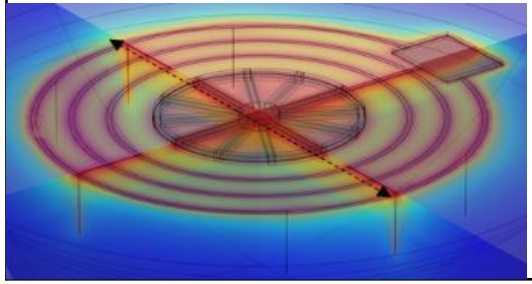


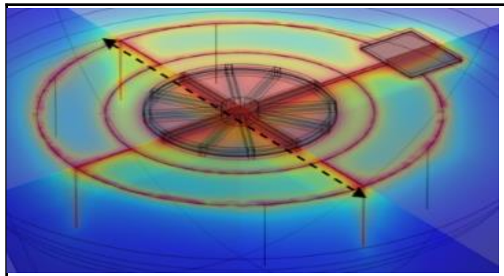
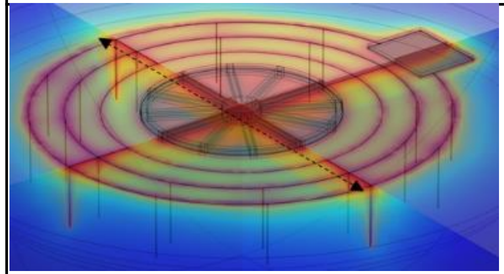
Burying metal plates (horizontal and vertical)

HOMOGENEOUS SOIL

	15.2 Ω
	11.0 Ω
	7.1 Ω

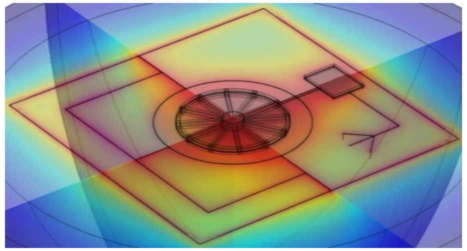
NON HOMOGENEOUS SOIL

	69.2 Ω
	53.5 Ω
	25.5 Ω

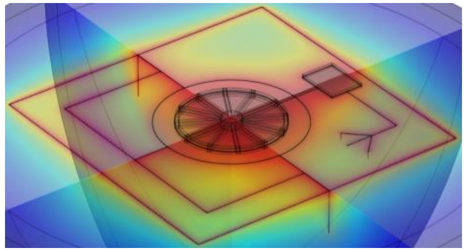
 **7** vertical electrodes	27.9Ω
 **22** vertical electrodes	23.6 Ω

53.5 m

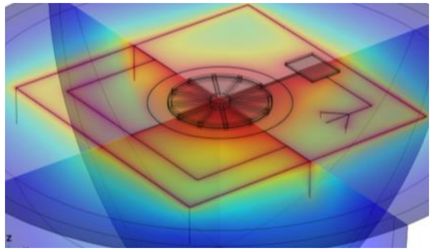
Burying vertical electrodes in homogeneous soil



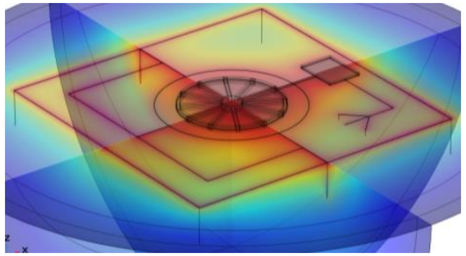
R= 7.14Ω



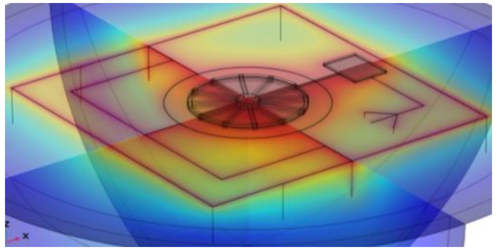
R= 7.06Ω



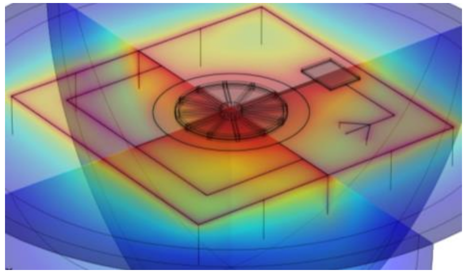
R= 6.79Ω



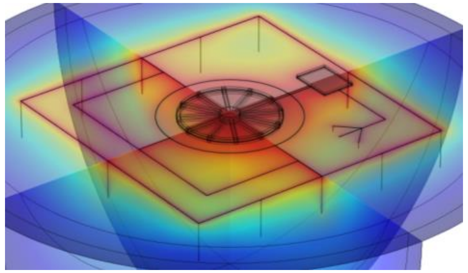
R= 6.54Ω



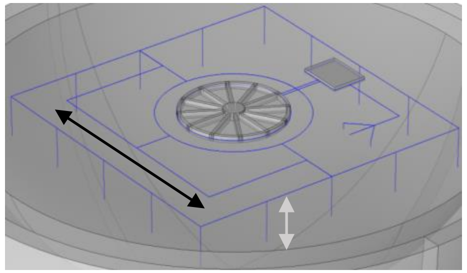
R= 6.43Ω



R= 6.31Ω



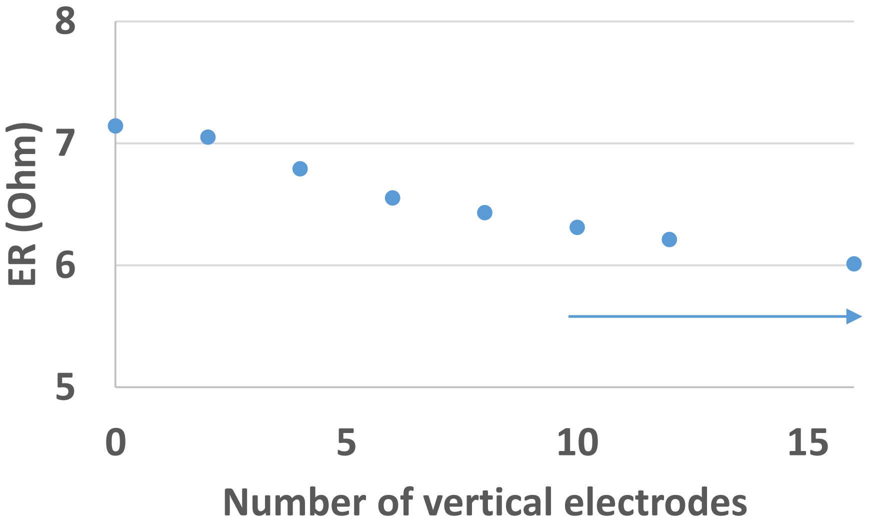
R= 6.21Ω



R= 6.01Ω

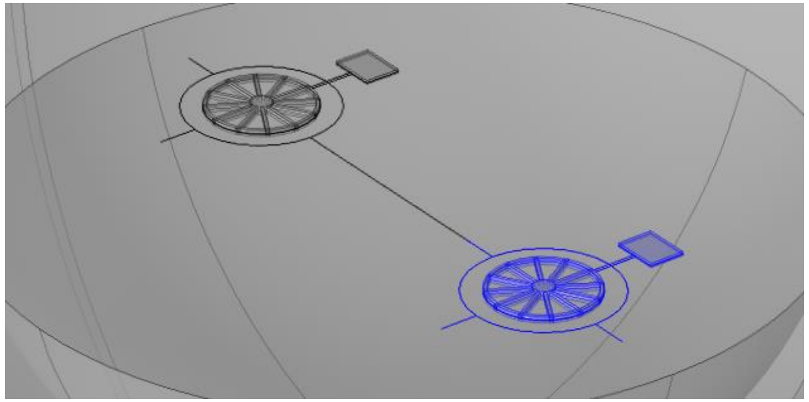
53.5 m

10 m



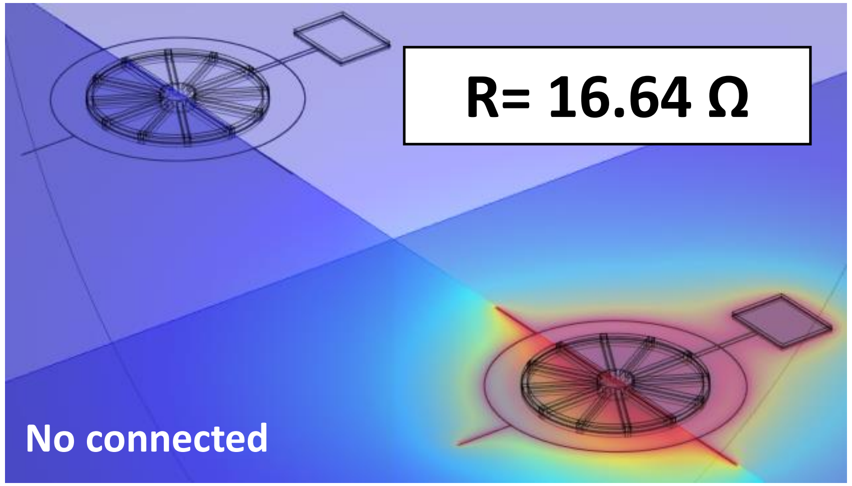
Electrodes or Earthing Systems interconnection

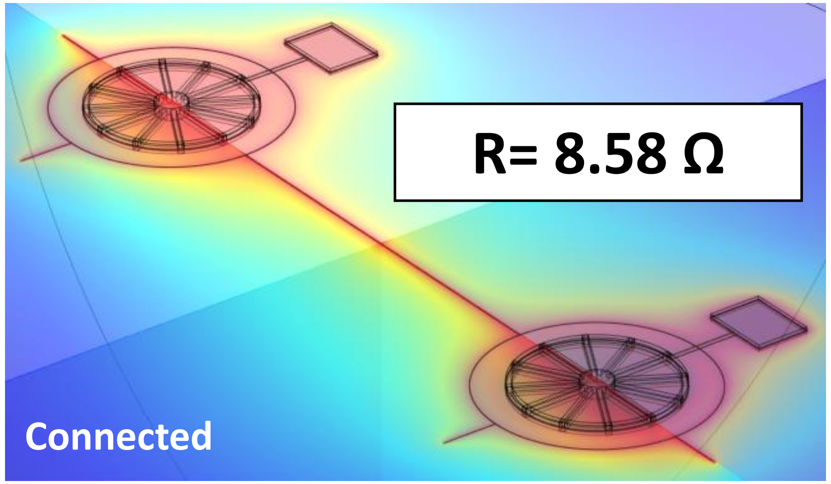
Earthing systems connected



If the resistances work as if they are pararell connected the value expected if we interconnet two LST1 is:

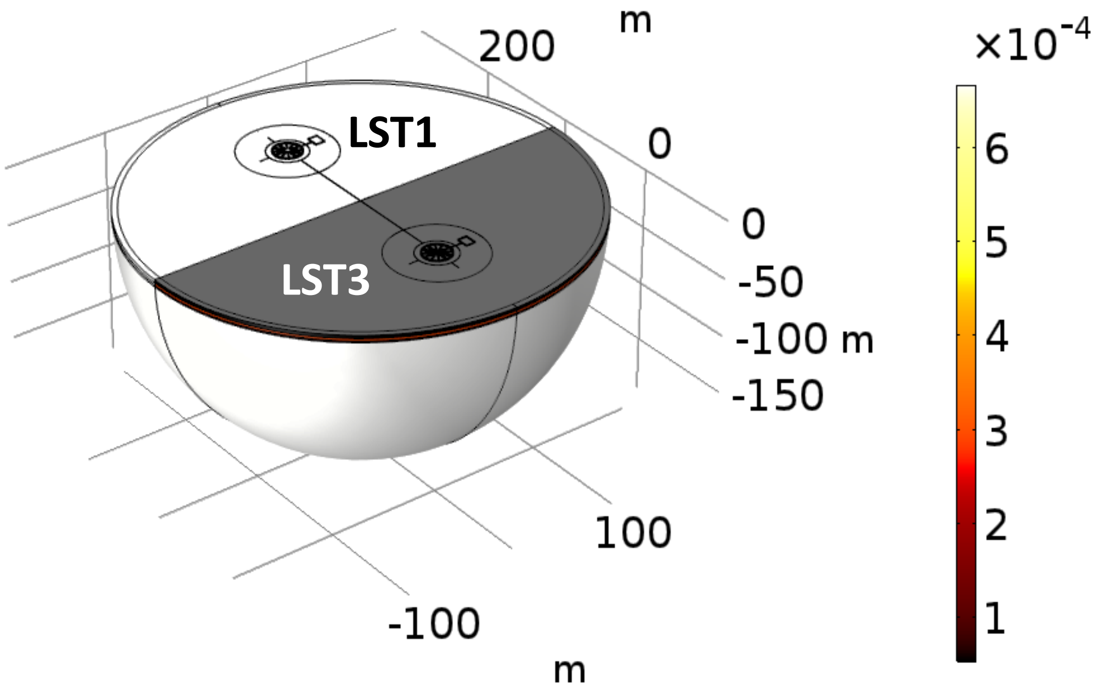
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \cong \frac{2}{15.2} \rightarrow R \cong 7.59\ \Omega$$





This is verifyed with simulation in LST1 (homogeneous soil)

Electrodes or Earthing Systems interconnection



Soil conductivity

No connected

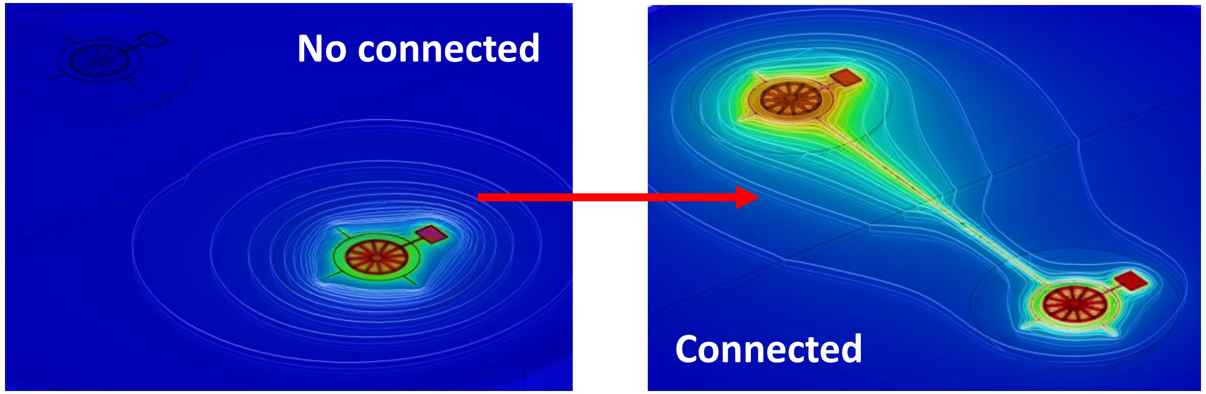
LST1 ~15.2 Ω

LST3 ~69.2 Ω

Expected value for earth resistance of LST1-LST3 interconnection:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \rightarrow R \cong \mathbf{12.5\,\Omega}$$

Simulation of the resitance in LST3



70.7 Ω → **11.6 Ω**

Possible solutions to lowering earth resistance

- ❑ **Soil resistivity is necessary when determining the design of the grounding system for new installations.**
- ❑ **Poor soil conditions (high resistivity) can be overcome with specific grounding designs.**
- ❑ **Our findings might help to efficiently design the future ground structures for the installations under construction and are applicable to other similar sites with soils of volcanic nature.**

Solution	**Homogeneous soil (LST1)**	**Non- homogeneous soil (LST3)**
Low resistivity materials or chemical treatment	✗	✗
Burying metal grids or plates (horizontal)	✓	✓
Vertical electrodes buried into the ground	✗	✓
Electrodes or earthing systems interconnection	✓	✓


Thank You