A human skin model for body hydration monitoring by electrical impedance measurement

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Introduction

The purpose of the study is to monitor human body hydration for medical monitoring. It has been shown that the hydration of the deep layers of the skin could reflect the hydration state of the body. Therefore a bioimpedance spectroscopy approach is developed in order to evaluate the skin hydration state by electrical measurements. A numerical model is used to aid the design process of the electrodes. Various design efficiencies are compared.

Bioimpedance measurement

A four electrodes setup is used to scan the different skin layers [1]. Two electrodes inject the current and the two other ones measure the voltage.

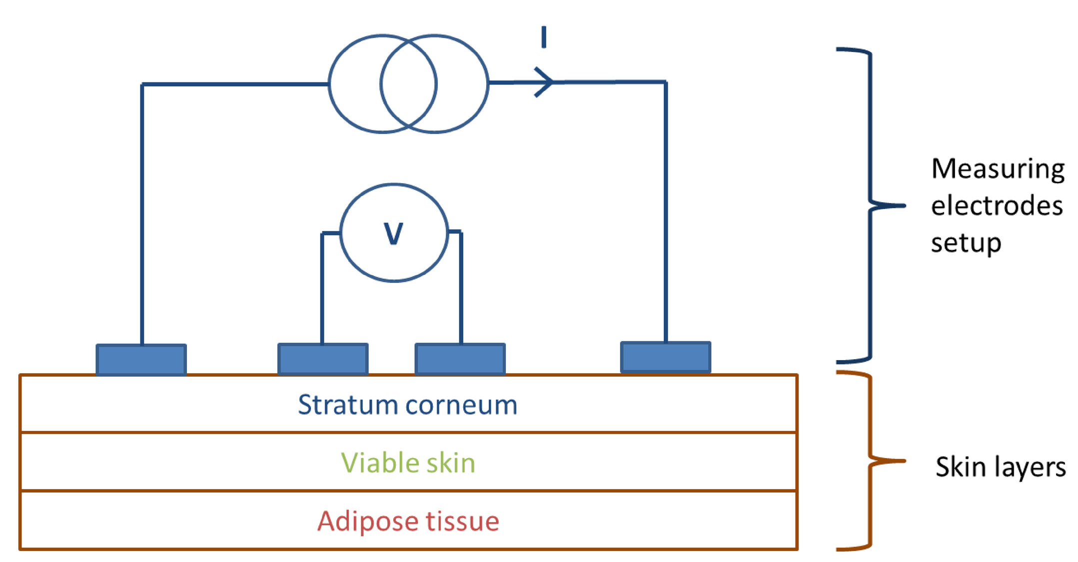

Figure 1. Skin bioimpedance measurement setup.

Numerical model

A classical electrical formulation in harmonic is used:

$$\vec{\nabla}\cdot\left(-\sigma^{*}\vec{\nabla}V^{*}\right)=0, \text{ with: } \sigma^{*}=\sigma+i\varepsilon\omega,$$

Where V is the complex electrical potential [V], σ is the electrical conductivity [S/m], ε is the electrical permittivity [F/m], ω is the puolsation [rad/s] et i is the imaginary number.

The interfaces between the skin and the electrodes are modeled as capacitance layers.

The complex bioimpedance [Ω] is given by: $Z^{*}=\frac{U^{*}}{I^{*}}$.

The main difficulty of biological tissues modelling lies in their electrical properties that are frequency dependent because of the cellular structure (composite material of conductive and dielectric medium).

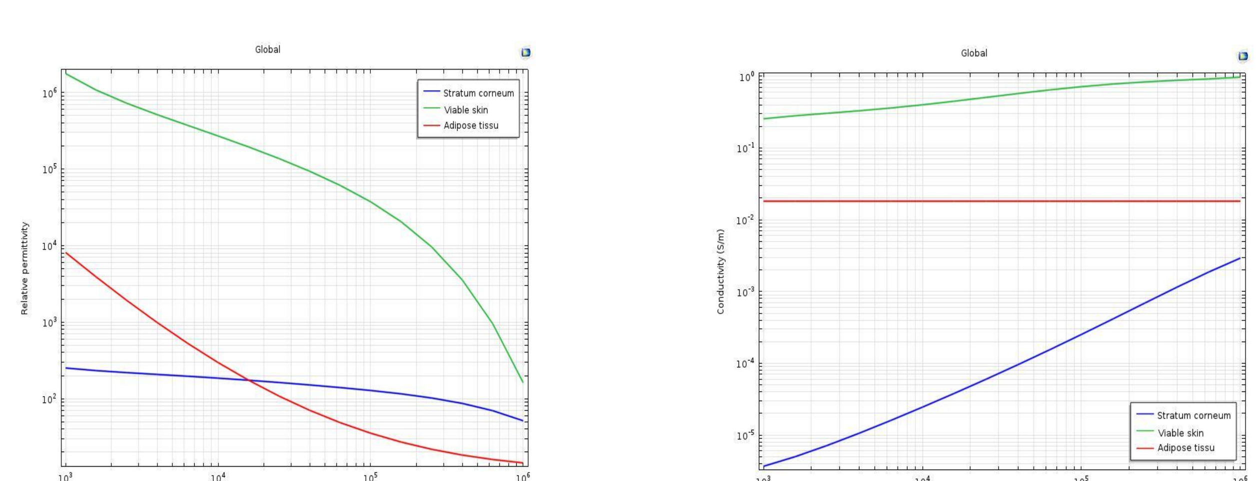

Figure 2. Electrical properties of skin layers [1], [2], [3].

Electrode designs

Various designs are tested, there are presented in the next figure.

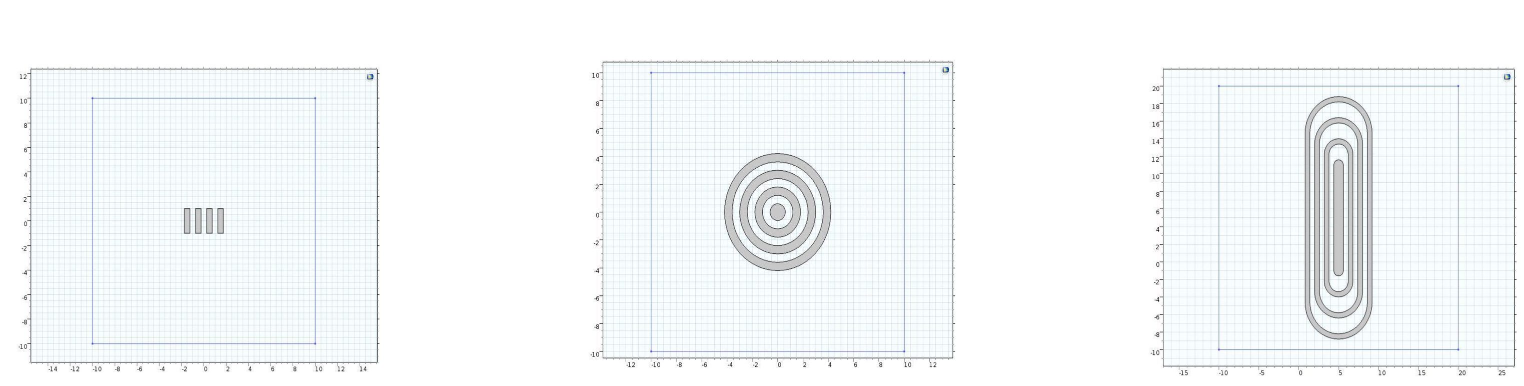

Figure 3. Electrode designs: on the left: rectangular [1], on the middle: ring [2] and on the right: elliptic [3].

Results

The study is run in multiple parametric mode. Frequencies are swept between 1 KHz and 1 MHz, and different sets of electrodes sizes and spacings are tested.

1. Current penetration inside the skin depending on the frequency

The deep layer of the skin is more sensitive to bioimpedance measurement at high frequencies than at low ones.

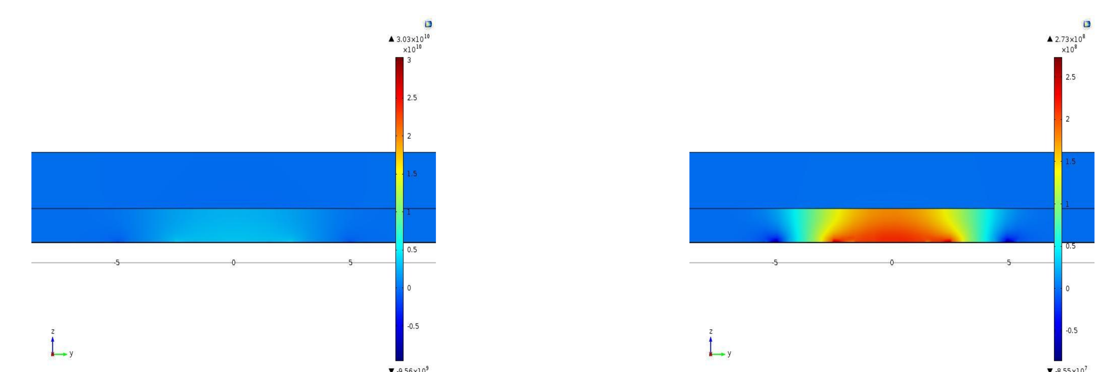

Figure 4. Sensitivity depending on the frequency (left 1 kHz, right 1 MHz). Ring electrode.

2. Skin sensitivity depending on the frequency and electrode spacing

Sensitivity of deep layer of the skin are maximum from a electrode spacing of 7 mm at high frequencies. This result is consistent with experimental data [1].

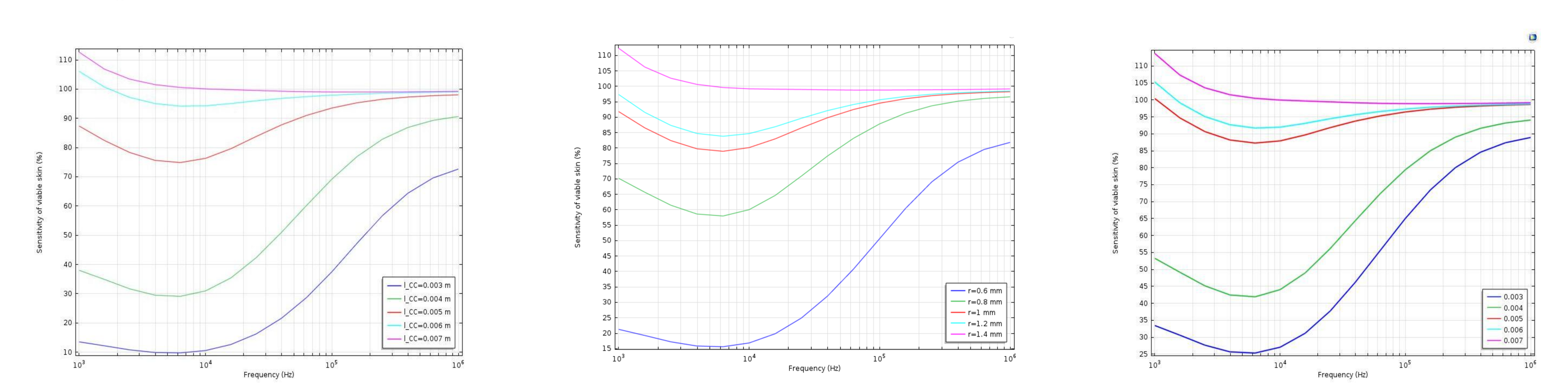

Figure 5. Sensitivity of viable skin for the different geometries for different spacings. From left to right : rectangle, ring and elliptic.

3. Experimental validation

The shapes of the curves are similar between the experimentally measured and simulated data (except argument at low frequencies).

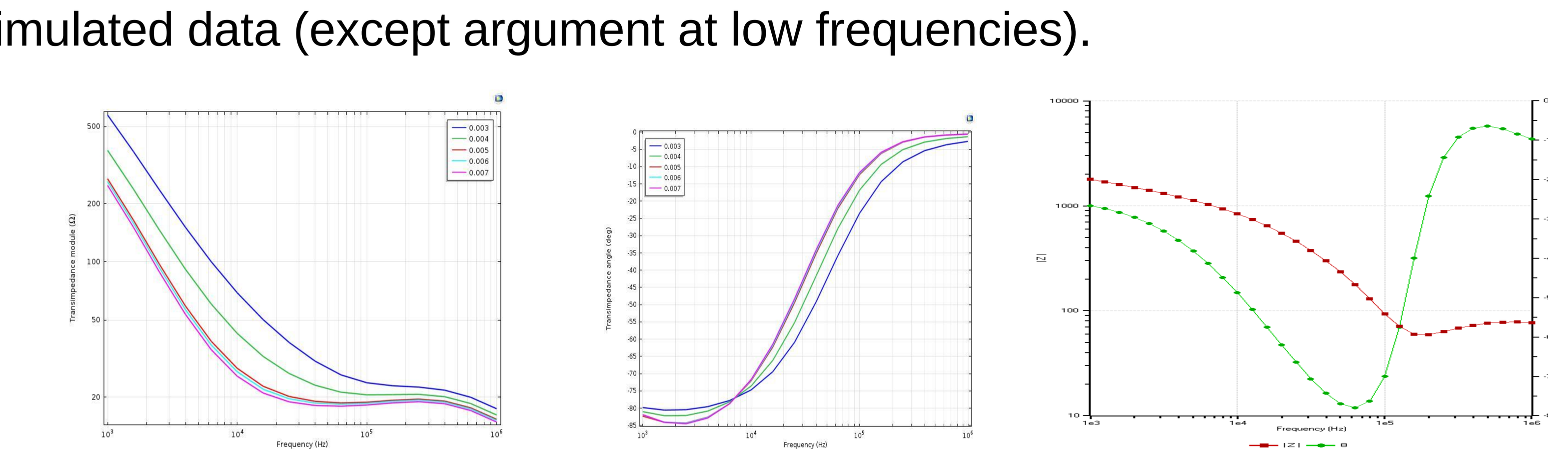

Figure 6. Bode diagrams of bioimpedance in absolute value and argument. Modelisation on the left, experimental on the right,

Conclusion

A numerical modelling of the human skin is developed. Various designs of electrode are tested in order to be sensitive to the deep layers of the skin.

Acknowledgement

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References

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