Frequency and electrode separation recommendations for EDA measurements

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Introduction

Electrodermal Activity (EDA) is a measure of changes in skin conductance. It has have been found to be indicative of the individual's autonomic nervous activity which is correlated to their stress and emotional state. [1] These changes are tracked by injecting a small AC electric current directly into the skin and measuring the induced voltage drop over time.

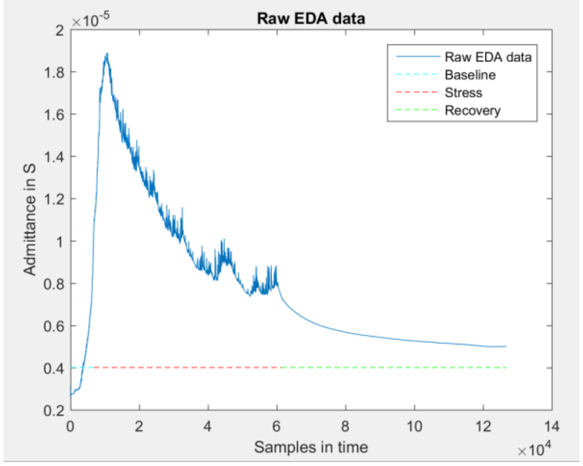

Figure 1. Wrist EDA at 100 Hz and 1 cm separation

With increase in interest in wearable technology and its use in tracking vitals such as stress through EDA, there has been a growing need to optimize the design of dry-electrodes that are used in EDA measurements. The aim of this work was to optimize for the pick-up of EDA signals by dry electrodes by considering excitation frequency and electrode separations.

Methods

In this work, we have used a Frequency domain study using the AC/DC Module Electric Currents Physics Interface on COMSOL Multiphysics to develop a model of the forearm as layers of tissue dielectrics. Tissue layers include the skin, fat, bone and muscle in proportions found in the human forearm. The dielectric properties of these tissues were fed into the model. [2] Since typically, we are interested in changes in relative skin conductivity changes over time, a 2-electrode method of sensing is employed and modelled though the use of 1 cm2 square electrodes. (Figure 3)

To simulate sweating that is picked up by EDA, the conductivity of the skin was changed between two levels simulating dry and hydrated skin. As a part of the post-processing, the integral of all the currents magnitudes at a mid-slice between the two electrodes are calculated for each skin hydration/conductivity state. (Figure 2)

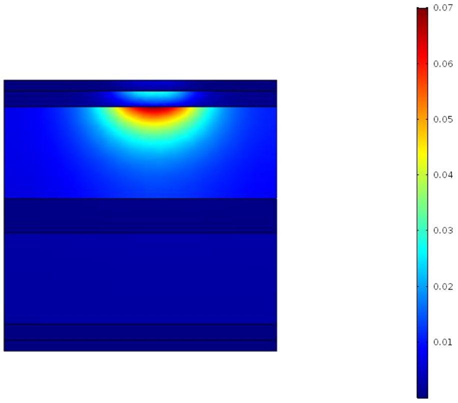

Figure 2. Screenshot of current density profile in A/m2 at the mid-slice between two electrode sites

The normalized change in current, k, caused by the increase in skin hydration is calculated to determine the sensitivity to sweating changes.

$$\mathrm{k} = \frac{Jf - Ji}{Ji} = \frac{\Delta J}{Ji}$$

We computed k for different frequencies between 100 Hz and 200 kHz and electrode separations ranging between 0.5 cm and 5 cm.

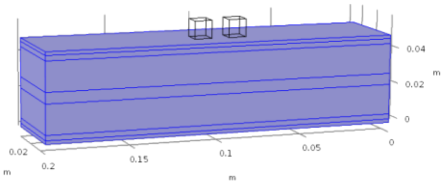

Figure 3. Model of the forearm

Results

The k values computed at different frequencies and electrode separations are shown in Figure 4. For a fixed increase in skin conductivity and fixed voltage drop across the electrodes, a higher value of k indicates a better pick-up of skin conductivity changes. It has been found through the simulations that k values are highest at low frequencies (=100 Hz) and low electrode separations (=0.5 cm). However, the effect of choosing the low frequency (99% increase in k as frequencies are decreased) is a lot more pronounced than using low electrode separation (5% increase in k as separations are reduced).

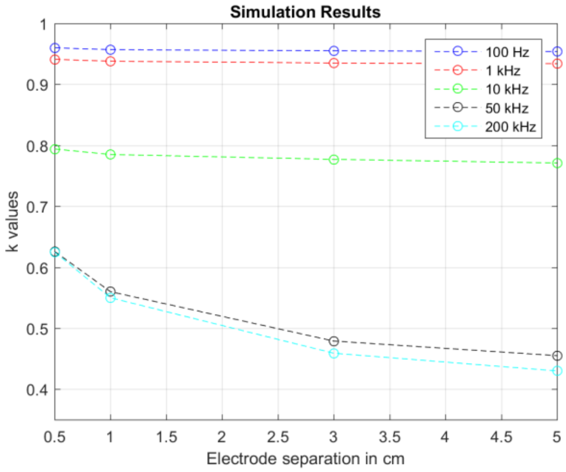

Figure 4. Simulation results

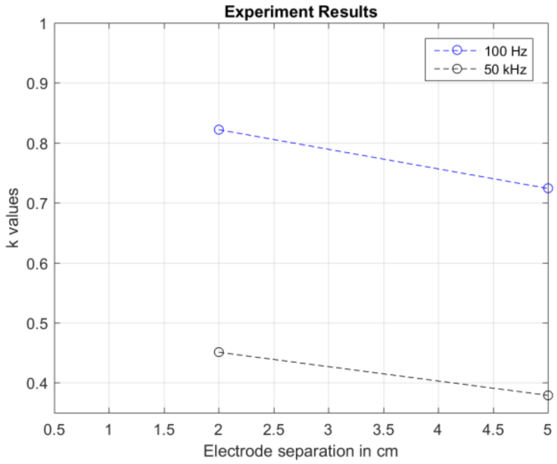

Figure 5. Experimental results

We have also experimentally validated our conclusions by taking impedance measurements at 100 Hz and 50 kHz at 2 cm and 5 cm separations by prepping the skin to induce consistent changes in skin conductivity. The differences between the simulation and experimental results can be explained by the model dependence on input conductivity values and experimental dependence on skin prep at the two electrode sites.

Conclusions

We conclude that choosing low excitation frequencies result in optimizes the sensitivity of EDA pick-up. However, very short electrode separations can lead to shorting due to sweat in a practical application.

References

1. Publication Recommendations For Electrodermal Measurements, *Psychophysiology* 49.8 1017-1034. (2012)

2. C. Gabriel et al. An Internet resource for the calculation of the dielectric properties of body tissues in the frequency range 10 Hz - 100 GHz. Based on data published by in 1996.