Frequency & Electrode Separation Recommendations for EDA Measurements

S. Sridhar, T. J. Akl
Biomedical Engineering Team, Analog Devices Inc., Wilmington, MA, USA

Introduction

What is EDA?

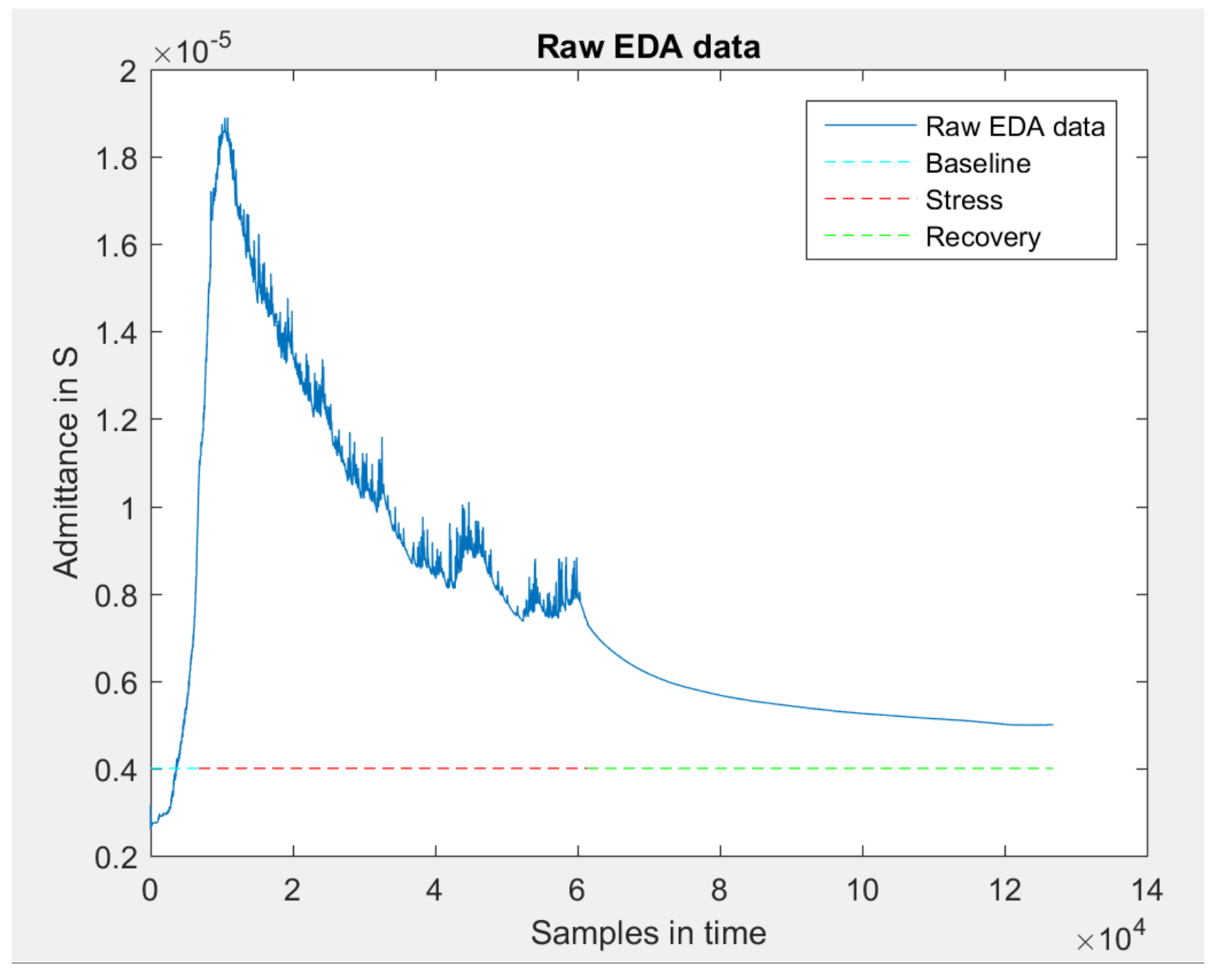
- Electrodermal Activity (EDA) is a measure of **changes in skin conductance**.
- Indicative of the individual's **autonomic nervous activity which is correlated to their stress and emotional state**. [1]

How is it measured?

- By injecting a small **AC electric current directly into the skin** and measuring the induced voltage drop over time.

What is our objective?

- Increase in interest in tracking vitals such as stress through EDA in wearables
- Need to obtained more robust EDA measurements
- **Optimize the design of EDA sensors** by specifically considering excitation frequency and electrode separations



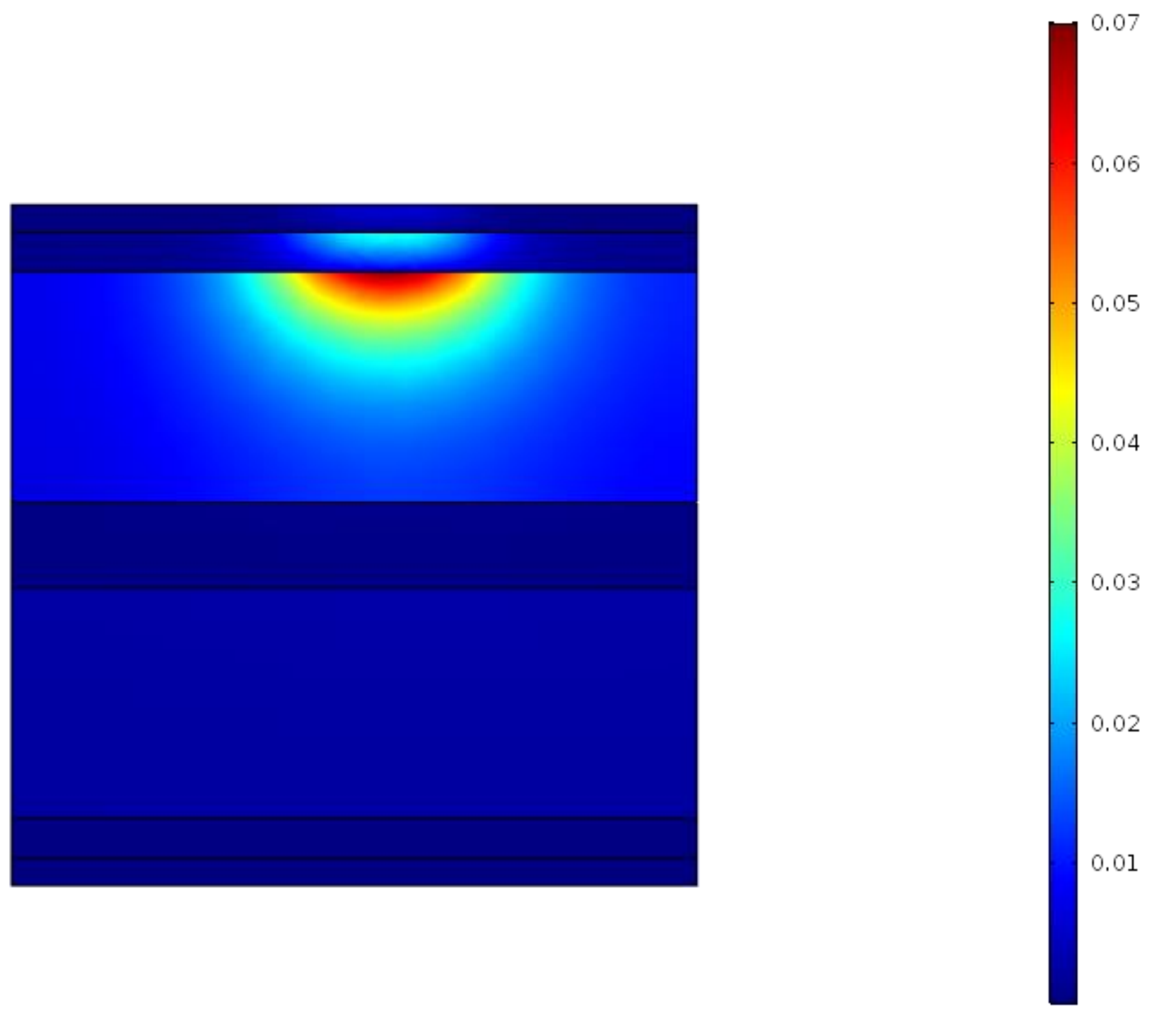


Figure 1: Wrist EDA at 100 Hz and 1 cm separation

Figure 2: Current density in A/m2 at the mid-slice

Methods

- Frequency domain study using the AC/DC Module Electric Currents Physics Interface on COMSOL Multiphysics
- 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. [2]
- 2-electrode method of sensing is employed and modelled through the use of 1 cm^2 square electrodes. 2-electrode methods are used because **EDA relies on the relative changes in skin conductance over time**. (Figure 3)
- **Simulate sweating** by changing conductivity of the skin between dry and hydrated state.

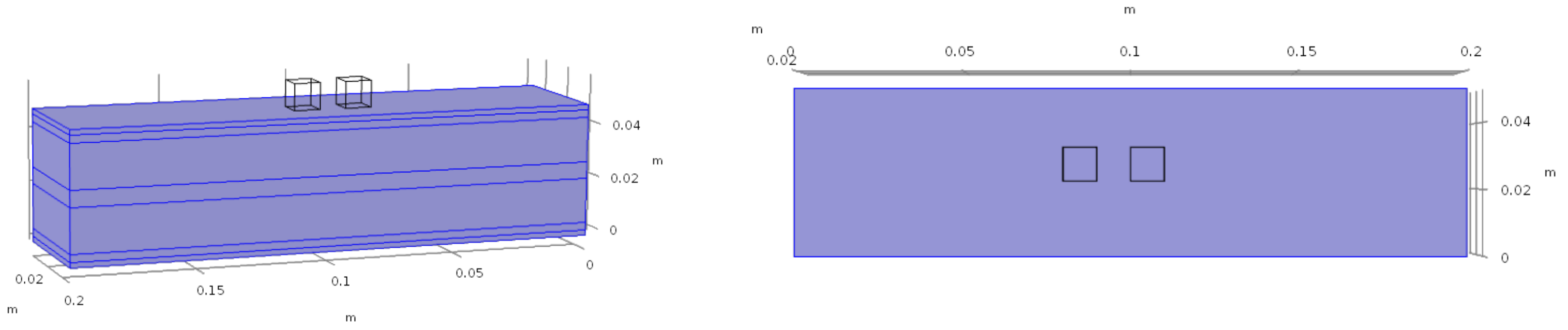


Figure 3: Model of the forearm

- Integral of all the **currents magnitudes, J,** at a mid-slice between two electrodes calculated for each skin conductivity state. (Figure 2)
- **Normalized change in current, k**, due to change in skin conductivity:

$$k = \frac{J_1 - J_2}{J_1}$$

- Where, J_2, J_1 are the two integral current magnitudes at two levels of skin conductivity

Results

- Higher value of k indicates better pick-up of EDA
- k values are **highest at low frequencies** (=100 Hz) and **low electrode separations** (=0.5 cm).
- The effect of choosing the low frequency is a lot more pronounced than using low electrode separation.
  - 99% increase in k as frequencies are decreased
  - 5% increase in k as separations are reduced
- Low electrode separations could lead to shorting of electrodes due to perspiration.
- **Experimental validation** 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.
  - Differences between the simulation and experimental results explained by the model dependence on input conductivity values and experimental dependence on skin prep at the two electrode sites.

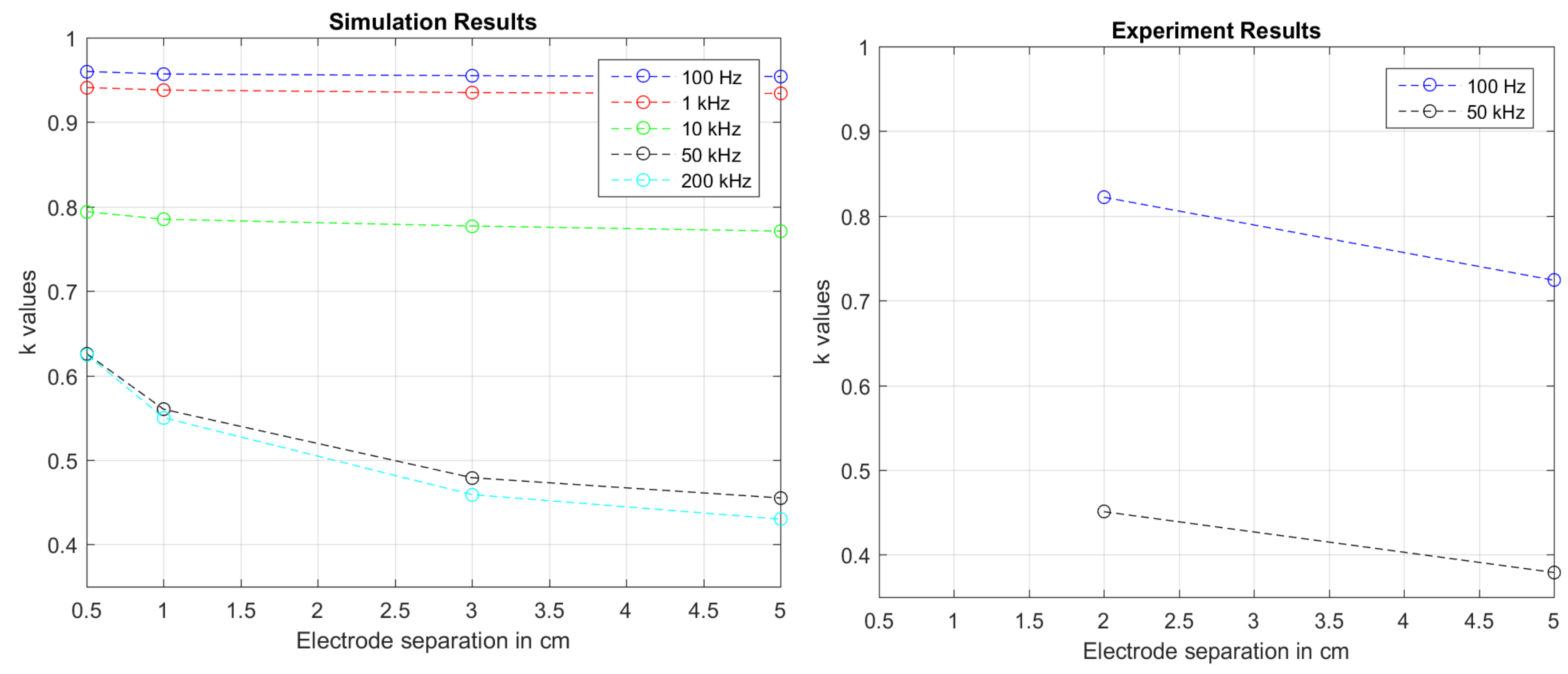


Figure 4: k values from simulations and experiments

Conclusions

We conclude that choosing low excitation frequencies and shorter electrode separations result in optimum 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 (2012): 1017-1034. Web.
2. "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 C.Gabriel et al. in 1996.

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