# Skin Variations Impact on Non-Invasive Measurement of Blood Glucose with Interdigital Electrodes

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**Introduction**: Diabetes affects more than 300 million persons worldwide, by 2030 diabetes will be the seventh leading cause of death in the world [1].

This work investigates the behaviour of an interdigital sensor structure for glucose monitoring in response to distortions in the skin-topology and differences in skin undulation during use. The study further considers a flexible sensor structure which is better able to contour to the skin variations.

**Computational Methods**: The interdigital sensor is a repeated interwoven electrode pattern on an underlying substrate. Consider a pair of positive and negative electrodes as a single entity, utilising the planar nature and repeated electrode pattern the sensor capacitance C would be given by [2]:

$$C = C_{UC}(N-1)L$$

N represents the number of unit cells, L the length of the electrode. The unit cell capacitance $C_{UC}$ represents the collective capacitance effects between the electrodes ($C_1$ to $C_3$):

$$C_1 + C_3 = \varepsilon_0 \left(\frac{\varepsilon_1 + \varepsilon_3}{2}\right) \frac{K\left(\sqrt{1-\left(\frac{a}{b}\right)^2}\right)}{K\left(\frac{a}{b}\right)}$$

$$C_2 = \varepsilon_0 \varepsilon_2 \frac{h}{a}$$

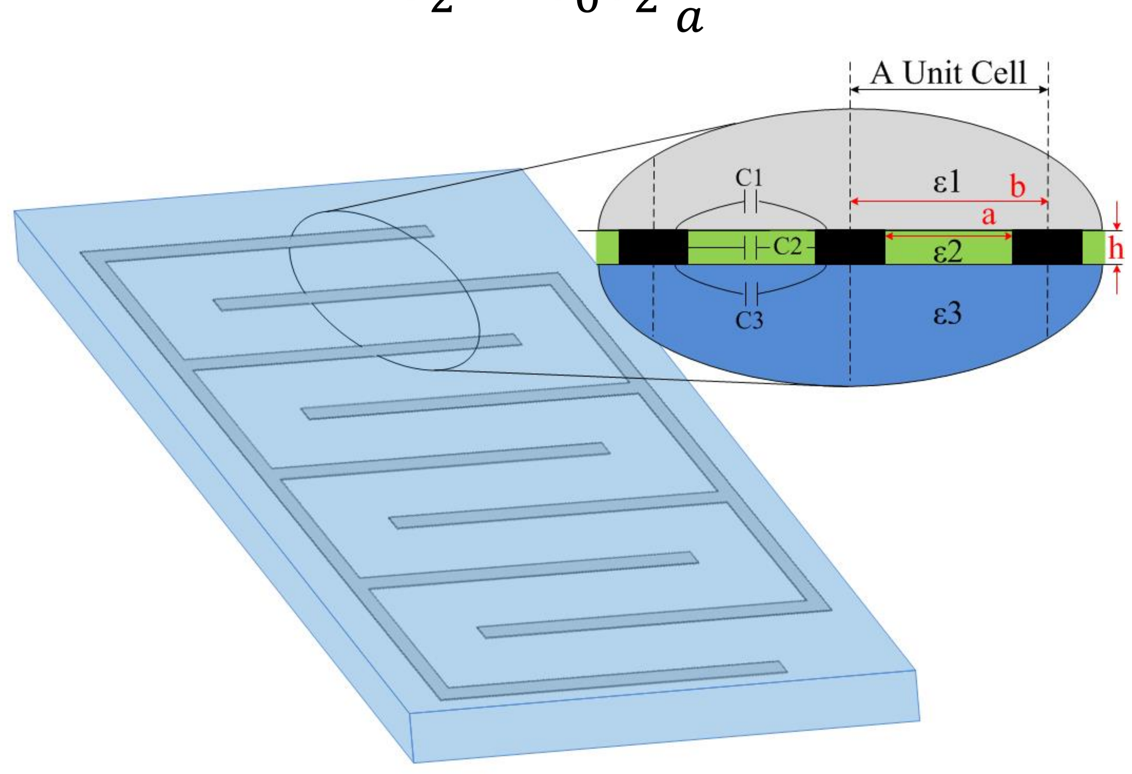


**Figure 1**. Sensor details

**Test cases**: Three (3) scenarios were considered for *skin distortion* :

1. Sensor directly against the skin
2. Electrodes embedded within the skin
3. Sensor embedded 0.4mm within the skin

For *skin undulation*, the skin surface undulation due to the presence of a blood vessel was contrasted with the planar sensor directly against the skin surface. Finally, a *non-planar sensor structure* which contours to the deformed skin surface was considered. The model capacitance was calculated for the frequency range of 10kHz – 1MHz in 10kHz steps.

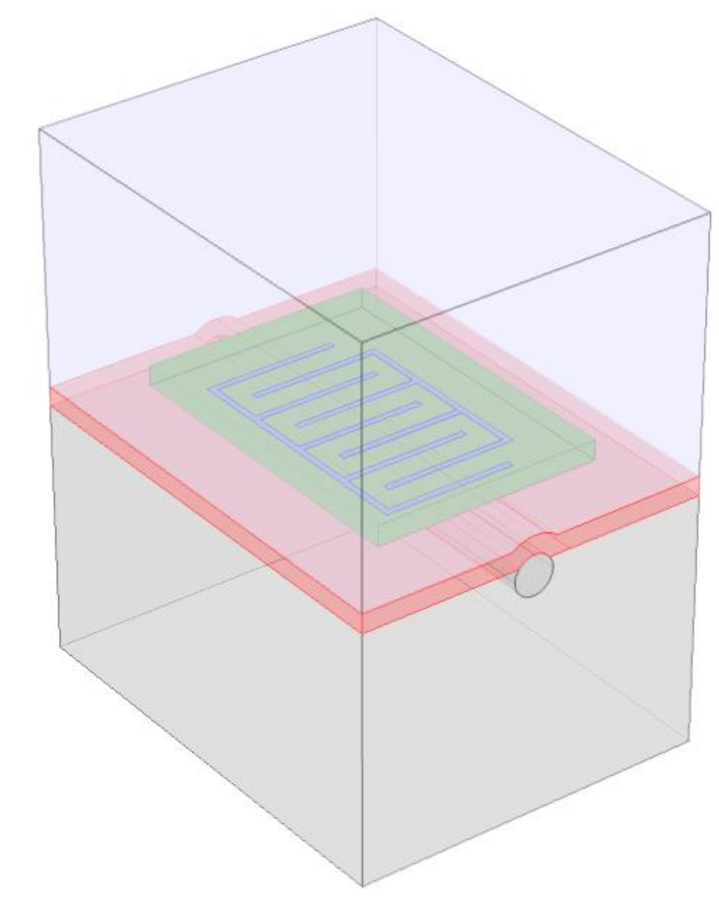

**Figure 2**. Planar sensor

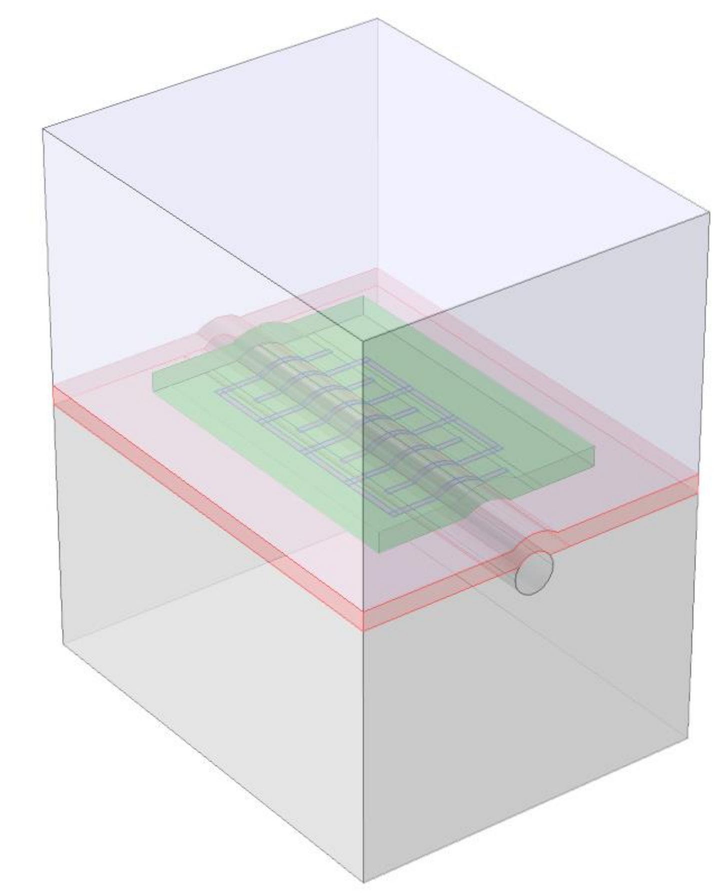

**Figure 3**. Non-planar sensor

**Results**: For all scenarios the measured capacitance decreased as the signal frequency increased. For the skin distortion scenarios, the measured capacitance increased the further that the sensor structure was positioned into the skin's surface. For the skin undulation scenarios, the measured capacitance was significantly smaller for the case of the rigid sensor on the deformed skin's surface compared to the ideal case (rigid sensor and perfectly flat skin surface). However the flexible sensor closely matched the capacitance values of the ideal case.

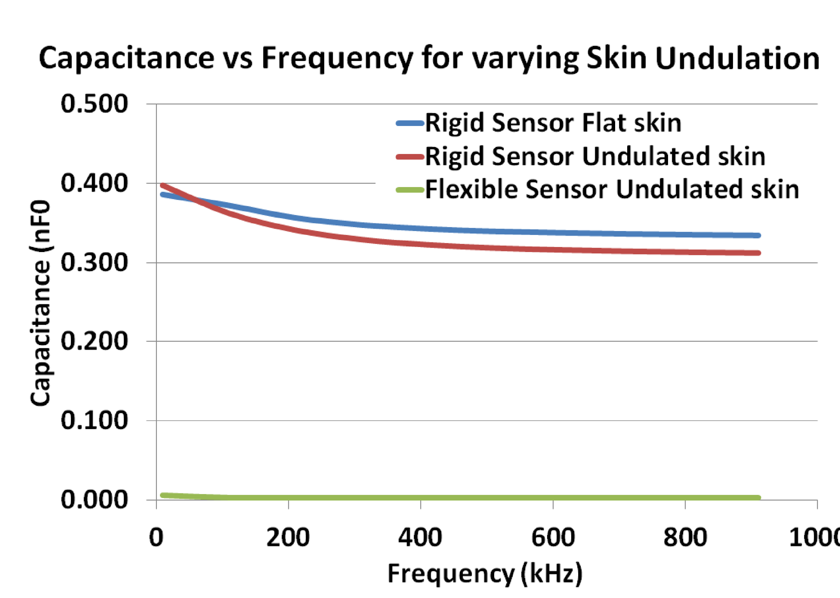


**Figure 5**. Capacitance for Skin Undulation

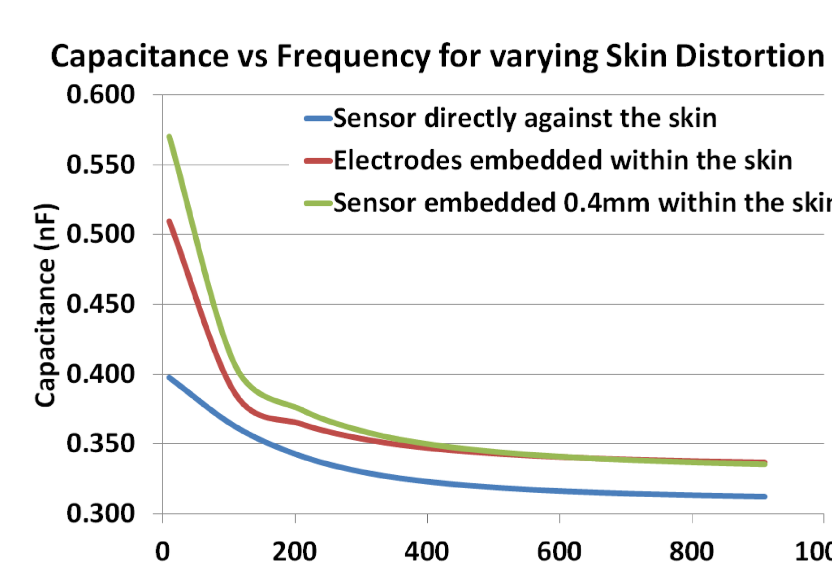


**Figure 6**. Capacitance for Skin Distortion

**Conclusions**: The simulation work shows that skin distortions and undulation significantly affect sensor readings. The flexible sensor shows potential for improved performance in the presence of skin variations.

## References:

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