Approaching the inverse problem of the multi-layer skin system

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The problem of solving the electromagnetic inverse problem for skin (i.e. evaluation of the dielectric properties for various skin layers) is being investigated by comparing capacitive fringing field sensors of different geometry. The sensors are attached to the surface of the skin and therefore are relevant for non-invasive practical applications in healthcare. In contrast to coaxial probes typically used to determine the permittivity of biological materials, the shape of the capacitive fringing field sensors used in this project is thin circuit board (~3mm) so that it can easily be integrated into small portable devices. As a first approach, we have considered a two layer skin model. For the experimental investigation of the influence of the different model parameters on the measured signal we have built an artificial testing system with the ability to vary dielectric properties and thickness of the layers. In particular, the conductivity of the first layer is changed to test how the conductivity influences the prediction of the dielectric properties of the second layer that is kept constant.

In a future application relevant to the problem of non invasive in vivo glucose monitoring, we will be mainly interested in changes occurring in the deeper skin layers where the glucose-induced changes on the dielectric properties are occurring. However, these alterations can be obscured by dielectric changes in the upper layer and on the surface of the skin, (e.g. following sweating events). In the two layer systems we have therefore used solutions of water and sodium chloride with a concentration varying from 10 mmol/L to 100 mmol/L as a first layer. This range covers the normal range that are expected in the sweat of a healthy individual.

To separate the influence of the two layers we need a sensor with at least two different "penetration depths". We then use numerical simulations to predict the effective (mixture) permittivity and conductivity of the two layered medium by the different sensors. The effective bulk properties are predicted for a large number of combinations of dielectric properties of the two layers. The predicted values are collected in a four dimensional table for the various combinations of permittivity and conductivity of the two layers. This table can then be used as a look up table to determine the dielectric influence of the two layers separately by measuring the bulk at two different "penetration depths".

The results using the look up table were also compared with analytical formulas used to predict the permittivities of each of the two layers from a measurement of the effective bulk permittivities by two different sensors. These results will form an addition to the development of a dielectrics based algorithm applied to the experimental/clinical data for deriving continuous glucose related information.