A brain-computer interface inside your earphones

Green-light assessment

Phantom design

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ELECTRICAL ENGINEERING PROGRAMME

Targets and deliverables

Currently, the development of dry electrodes for the in-ear brain-computer interface (BCI) is still being min-maxed [1] [2] and newly developed dry electrodes require testing to determine their functionality [3]. It is unwise to perform these experiments on in-vivo subjects however, as the electrode-skin contact might cause irreversible damage to the skin. Furthermore, in-vitro human tissue is not readily available. Therefore, phantoms are often used. Phantoms are objects that mimic or imitate the electrical and mechanical properties of the human tissues, like skin. This thesis will look into the design of a skin phantom such that the functionality of dry electrodes to be placed inside an ear, can be tested.
To be able to test the functionality of dry electrodes placed inside the ear, the skin phantom will be fabricated as an agar-based ear-shaped phantom. Agar is a jelly-like substance made from algae and has similar dielectric properties as the human skin [4]. An agar-based phantom provides selective "tuning" of the electrical properties by changing its high water content. Besides, fillers can be added to change the conductivity [5]. Varying concentrations of NaCl salt relative to agar powder shift the phase/frequency response profile, whereas aluminium powder contributes to dielectric behaviour and glycine(amino acid) stabilizes dielectric response at higher frequencies.

Currently achieved level

Since the ear is the main part of interest, it is useful to get the phantom in the shape of the human ear. To achieve this, a mould is created to pour the agar into. Since the ear has a very organic shape, it is not possible to pull the result straight out, so the mould is divided into two pieces. Teflon spray can be used to pull the result out easier. The first iteration of the mould has been designed in the free CAD program Fusion 360 and a Creality Ender 3 printer is used with a minimal layer height of 0.12 mm. Figure 1 shows the result of the first printed iteration. An array of elastics around the two sub-moulds keeps the position the same during the moulding process.

Figure 1: Ear mould

Future studies

Experiments have to be done to obtain an agar sample that, as accurately as possible, mimics the electrical and mechanical properties of the human tissue. Therefore, the impedance, conductivity and dielectric properties of samples agar with different concentrations of agar powder, NaCl, aluminium powder, and glycine have to be measured and compared to the properties of human skin over a period of time for the relevant frequency spectrum at room temperature and at body temperature. By placing the agar samples between two conductive copper plates the dielectric/conductive properties of the sample can be measured using a precision LCR meter.
To measure the skin-electrode contact impedance of the newly developed dry electrode, a reference electrode (Ag/AgCl) is to be inserted inside an agar sample. By subtracting the impedance of the agar sample from the electrode-electrode impedance, the skin-electrode contact impedance is found.
The main feature to model is the effect of pressure on the electrode-skin impedance. A real ear can experience various movements and tensions, which affect the skin-electrode impedance [6, 7]. To investigate these effects, impedance measurements will be conducted whilst applying and removing a known magnitude of force to a slab of the agar sample.
The presence of cerumen, sweat or epidermal activity significantly changes the impedance and therefore conductivity of the skin [8]. If time permits, modelling these impedance changes by increasing the water content in the case of trans epidermal water loss (TEWL) and/or adding a mixture comparable to cerumen could contribute to creating a more accurate imitation of the human ear. Another option would be to add sweat ducts to the mould or afterwards add them to the agar phantom using laser ablation for example [9]. The diameter and depth of sweat ducts lie in the range of tens of micrometres, therefore the mould should be printed with a high enough resolution.

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