Using Embroidered Interdigitated Electrodes (IDTs) To Monitor Biomarkers Present In Human Sweat

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IDT – Design and Operation

IDTs (Fig 1a) have been embroidered onto textile substrates as resonators for sensing applications. The resonators are coupled with loop antennae to measure resonant frequencies using a VNA (Fig 1b). The resonant frequency of the IDTs (Fig 1c) shifts in the presence of different concentrations of molecules, e.g. glucose.

IDTs were simulated using CST Microwave Studio. The structures have been excited by plane waves to obtain their resonant frequencies. The water droplet was then placed on the IDT with varying permittivity, resulting in frequency shifts. The simulated geometry is based on the design geometry. Inevitable geometrical alteration due to the embroidery process results in frequency shifts (Fig 1d).

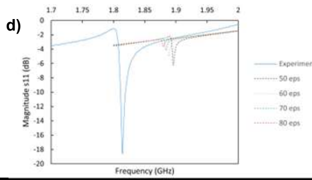

Figure 1:
a) IDT embroidery design with associated dimensions
b) IDT and antenna in test conditions, with droplet on the surface
c) Antenna position placed over the IDT and the experimental resonant frequency response
d) Simulation (CST) and experimental comparison for varying dielectric constants of the material being measured (the simulation does not consider the construction of the embroidered threads)

Frequency Response to Water

Droplet measurement positions (Fig 2a) were chosen to provide optimal coverage of the IDT without encroaching on the previous 10 μl DI droplet's position. The antenna position was fixed according to the optimal coverage and frequency response determined in Fig 1b). The surface of the IDT was initially covered with Kapton tape to show that any frequency response was due to the presence of water rather than an object placement effect (Fig 2b). The surface of the IDT was then uncovered and 10 μl droplets placed onto the surface individually (Fig 2c) and cumulatively (Fig 2d) with both methods showing a higher frequency response along the left-hand edge of the IDT and a greater change between the resonant frequency and frequency measured in the presence of water towards the right-hand side and centre of the IDT.

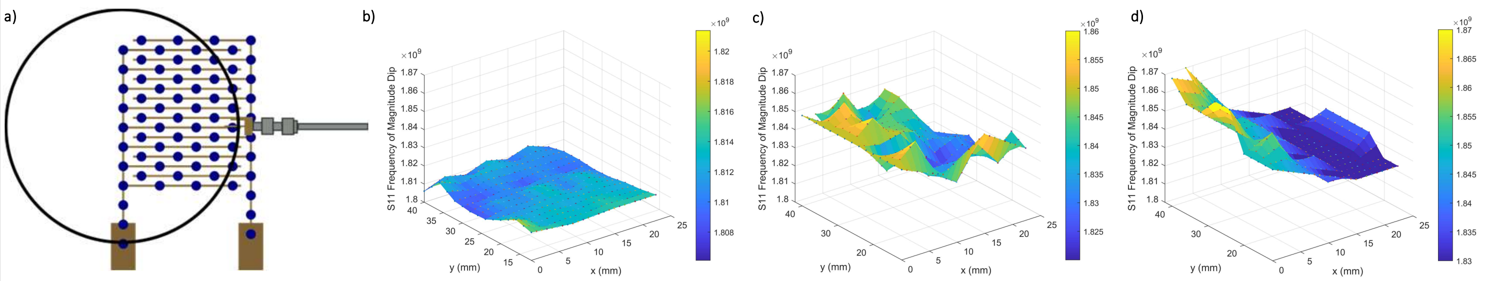

Figure 2: a) Relative water droplet measurement positions with fixed antenna position, b) frequency response of the IDT in the presence of individual 10 μl water droplets when the IDT surface is sealed and covered with Kapton tape, c) frequency response of the IDT in the presence of individual 10 μl water droplets for an uncovered surface and d) frequency response for 10 μl droplets cumulatively placed

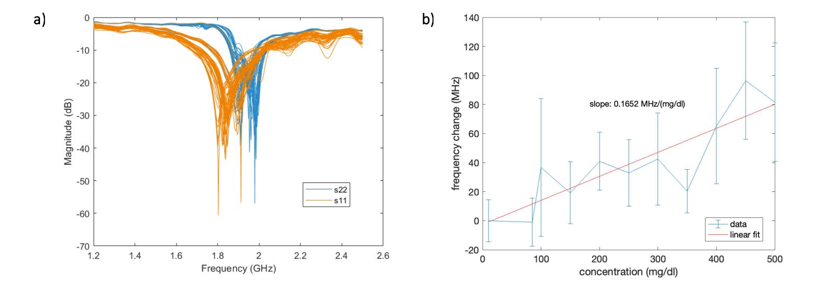

Figure 3: a) S11 (Glucose) and S22 (Control) frequency responses, b) Differential frequency shift of S11 in response to changing concentration of Glucose within the physiological range

Response to Glucose

To test the detection sensitivity of the sensor, concentrations of glucose over the physiological range (10 mg/dl to 500 mg/dl) were placed in the form of 10 μl droplets onto the sensor surface and the frequency was measured (Fig 3a). The measurement setup includes a reference IDT without exposure to glucose for differential sensing. The differential signal shows an increase in resonant frequency with increasing glucose concentrations with a sensitivity of 0.165 MHz(mg/dl) (Fig 3b).

Future Study

Gold coating provides the underlying scaffolding onto which specific functionalising chemical can be attached for selectivity purposes. This means that these sensors can be functionalised to selectively detect different biomarkers in sweat for whatever their required application. Furthermore, an array of these sensors could be used in tandem to provide a full suite of real-time biosensors. To make the sensors truly portable, a potentiostat will be used, removing the need for a VNA.

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