Introduction: Current treatment of non-communicable diseases (NCDs) present dire problems for healthcare practitioners, as evident for chronic kidney disease (CKD) [1]. The advent of non-invasive sensors and the applicability for microwave engineering provide can ensure efficiency and effective NCD patient management. The authors in [2] highlighted the propensity of a non-invasive microwave plane sensor, in the form of a complementary split ring resonator (CSRR), to be sensitive to changes in the relative permittivity to a material acting as a perturbation to an applied electric field. Given that relative permittivities ($\varepsilon_r$) of blood analytes, such as glucose, show strong correlation to changes in analyte concentration [3], a simulation of the CSRR sensor in [2] sensitivity to extracellular blood permittivity was investigated as a design candidate for a CKD non-invasive sensor.

Computational Methods: A 3D model of the CSRR-based sensor [2] and the human epidermis (blood) was built in the COMSOL Multiphysics® software, with dimensions and material properties highlighted in Table 1 and Figure 1. The RF module was employed to parametrize changes in $\varepsilon_r$ (1 to 100) over frequency using the following Maxwell equation:

$$\nabla \times \mu^{-1}(\nabla \times E) - \omega^2\varepsilon_0\mu_0\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)E$$

At resonance, $S_{11}$ progressively becomes less negative as less reflection of the microwaves occurs at the sensor with increases in $\varepsilon_r$ of the loaded epidermis (blood). This correlation, Figure 4, ($R^2 = 0.8984$) highlight the applicability for CSRR sensor for non-invasive blood analyte monitoring.

Results: The simulation returned $S_{11}$ versus frequency plots for reflection phenomena occurring at the excitation port of the sensor. The results in Figures 2 and 3 show a shift in resonance (2.65 GHz) from the unloaded condition (air) to when a block, modelled as the human epidermis (blood), is factored as a perturbation to the electric field applied at the excitation port of the sensor, over the frequency range of 1 to 10 GHz.

Conclusions: The simulation model shows that CSRR sensors, at least for the form factor investigated, are sensitive to changes in $\varepsilon_r$. As such, these results render the development of a prototype non-invasive device, to detect changes in blood $\varepsilon_r$, as the next step.

References: