Review of Non-Invasive Glucose Monitoring Methods

Elizabeth Petersen, Silje Ostrem, Willow C. Reed, Atef Elsherbeni

epetersen@mines.edu, siljeostrem@mines.edu, nj_reed@mines.edu, aelsherb@mines.edu

Electrical Engineering Department

Colorado School of Mines, Golden, CO 80401, USA

Introduction

- Everyone can be affected by changes in their blood glucose levels, especially diabetics and athletes. Many of the current methods to measure blood glucose levels are invasive, where they must prick the skin to test blood glucose levels.
- Although efficient in producing results, the invasive methods are not the most comfortable. This has started a large topic of discussion on exploring non-invasive methods for glucose monitoring.
- A literature review was completed to understand current methods being used for non-invasive glucose sensing.

Use of Radar Modules

- Radar modules have been used as either full sensing system [3] or as signal driver for a separate resonator antenna design [4].
- Studies found that higher frequencies produce greater sensitivity to glucose concentration prediction.
- One concern with the use of a radar module is how the use of high frequencies will affect the human body.

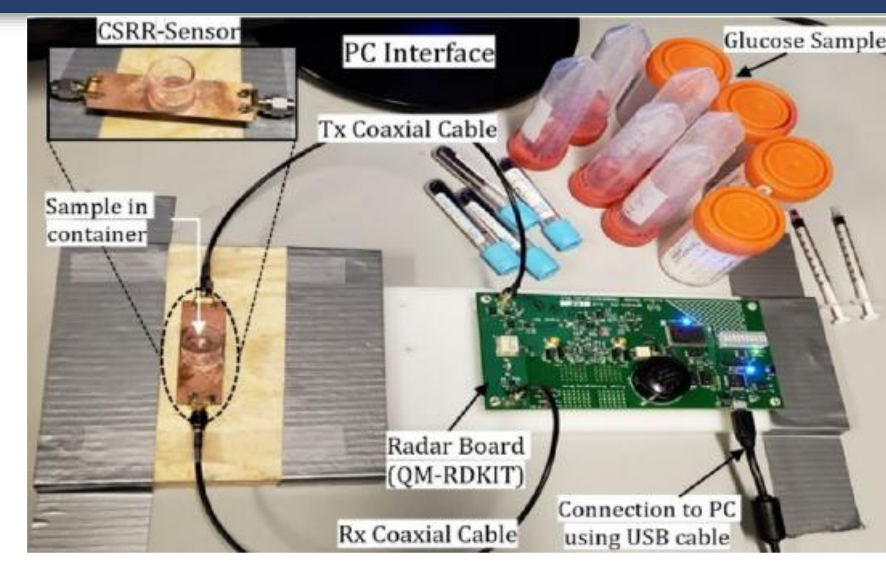

Figure 1 – The set-up for the driving radar module [4].

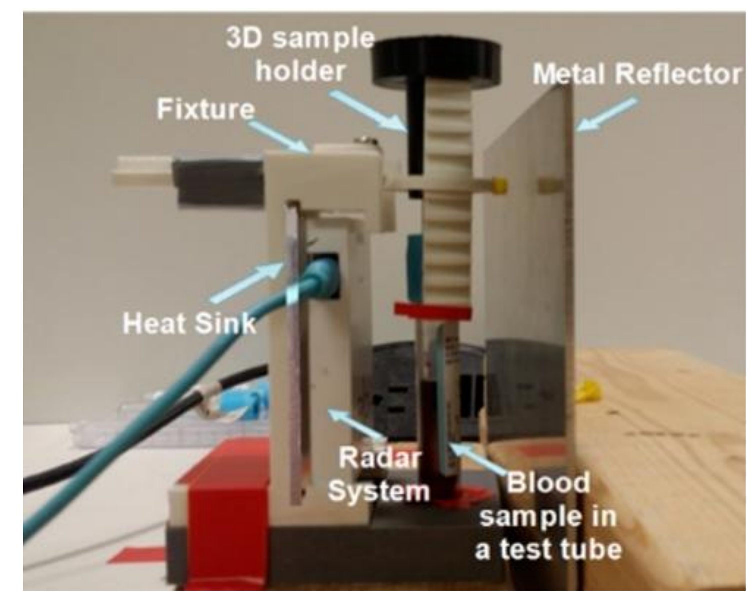

Figure 2 – The set-up for the radar sensing system [3].

Complementary Split-Ring Resonators (CSRRs)

- A triple-pole CSRR design was proposed by Omer et al. [1]

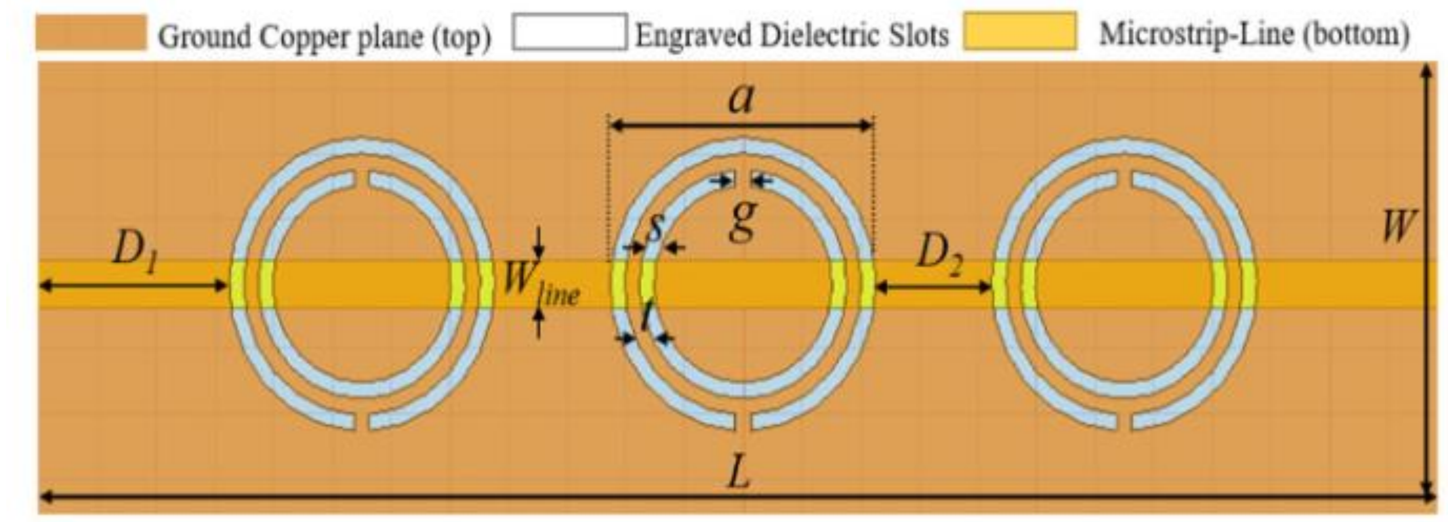

Figure 3 – Triple Pole CSSR [1].

- The gaps act as capacitors and the metal rings act as inductors, where both an electric and magnetic field are produced. Loading the resonator with a skin sample changes the capacitance of the gap, leading to resonating frequency based on:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Wearable and Body-Oriented Designs

- A wearable glove was developed where the slot antenna implanted in the glove would mimic the shape of the veins in the hand [2].
- Figure 6 shows that a strong difference could be seen in the resonating frequency between when the sensor was loaded with a human hand.
- More work will be done to relate the change in resonance frequency to the glucose levels in the skin.

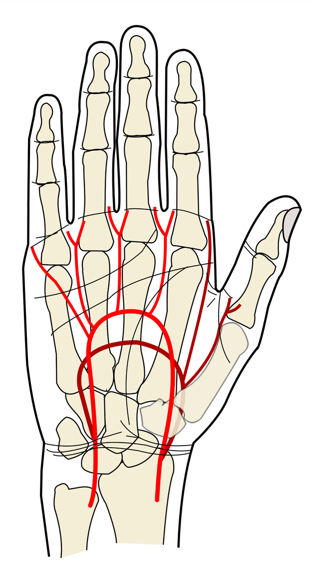

Figure 4 – The vein structure of the human hand.

Figure 5 – Slot antenna design created to mimic the veins in the human hand. [2]

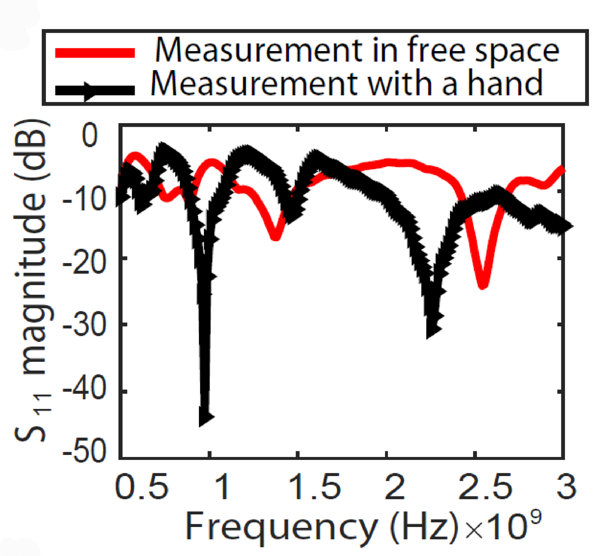

Figure 6 – The comparison of the S11 for the free space and loaded scenarios of the antenna [2].

Conclusion and Future Work

- Current methods for non-invasive glucose sensing tend to work in the 2.3-5GHz range.
- Many of the current designs show changes in resonant frequency when glucose solutions are applied, but the changes are minimal and hard to detect.
- Future work should develop more body-oriented antenna designs such as tracing out the veins of the finger or other easily accessible body parts.
- Further testing should review how different operating frequency ranges will produce stronger or weaker shifts in relative resonating frequency with varying glucose concentrations.

References

[1] A. E. Omer et al., "Non-Invasive Real-Time Monitoring of Glucose Level Using Novel Microwave Biosensor Based on Triple-Pole CSRR," *IEEE Trans. Biomed. Circuits Syst.,* vol. 14, no. 6, pp. 1407–1420, Dec. 2020, doi: 10.1109/TBCAS.2020.3038589.

[2] J. Hanna, J. Costantine, R. Kanj, Y. Tawk, A. H. Ramadan, and A. A. Eid, "A Vasculature Anatomy Inspired Flexible Slot Antenna for Continuous Non-invasive Glucose Monitoring," in *2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI)*, Singapore, Singapore: IEEE, Dec. 2021, pp. 803–804. doi: 10.1109/APS/URSI47566.2021.9704287.

[3] A. E. Omer, S. Safavi-Naeini, R. Hughson, and G. Shaker, "Blood Glucose Level Monitoring Using an FMCW Millimeter-Wave Radar Sensor," *Remote Sensing*, vol. 12, no. 3, p. 385, Jan. 2020, doi: 10.3390/rs12030385.

[4] A. E. Omer *et al.*, "Low-cost portable microwave sensor for non-invasive monitoring of blood glucose level: novel design utilizing a four-cell CSRR hexagonal configuration," *Sci Rep*, vol. 10, no. 1, p. 15200, Sep. 2020, doi: 10.1038/s41598-020-72114-3.

R1.3