Continuous and Noninvasive Microwave Biosensor for Lactate Monitoring

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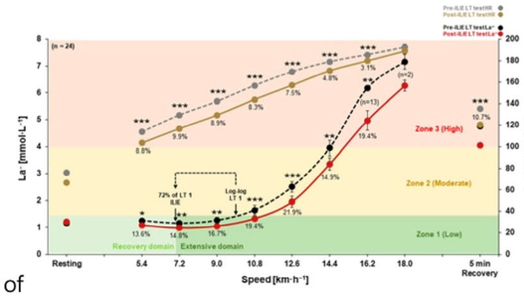
Introduction

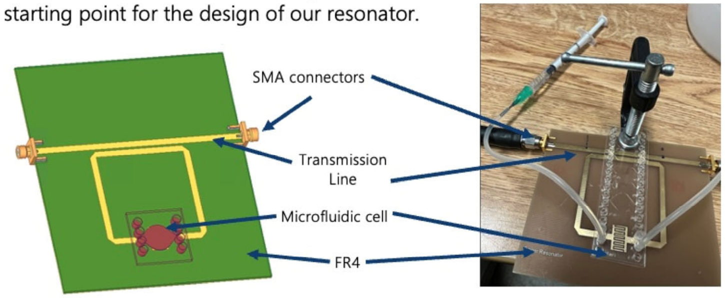
- Lactate is a metabolic byproduct that is generated by the mitochondria as they produce ATP to meet the energy demands of our bodies
- Lactate measurement can be used to assess athletic fitness and, in healthcare, the condition of seriously ill patients
- Project objectives are to analyze the potential of a microwave resonator as a noninvasive, real time lactate monitoring sensor
- A microwave resonator and microfluidic chip assembly were used to evaluate the sensitivity of the resonator
- S_{21} parameters measured changes in resonance
- Results were used to refine the sensitivity of the sensor as we move towards lactate sensor development



Study results showing lactate concentration as a function of intensity of training. After changes to athletes' training plan, fitness levels improved, as verified by lactate and heart rate data. All lactate tests were invasive and required blood samples by lancing fingers [1].

Resonator Design

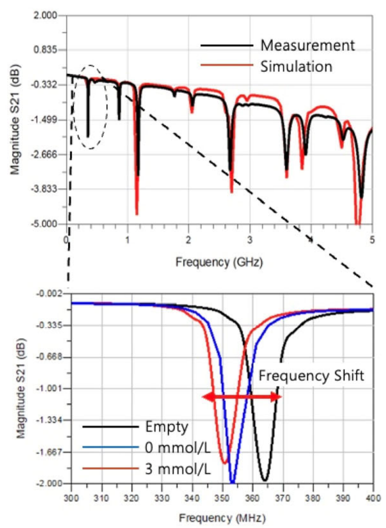
- The design of the resonator was based on work from Reineckie and was configured using the finite element simulator, EMPro, for electromagnetic simulations [2]. This biosensor design was previously used to detect dielectric constant changes for solutions in which protein binding occurred. This served as a starting point for the design of our resonator.



Finite Element Simulation *Manufactured Resonator*

Measurement Results

- In our initial study, we detected salt concentrations within distilled water as lactate and biological testing would require significant investment
- After refinement to sensor sensitivity, we will move towards biosensing
- Solutions consisted of air, distilled water, and 3 mmol of NaCl in 1 L of distilled water
- The microfluidics cell received each solution individually and S_{21} (transmission) was measured
- Each of the 3 solutions resulted in a different resonant frequency



Conclusion and Future Work

Conclusion
- Experiment verified behavior of the resonator design
- Resonant frequency shifted based on amount of salt concentration detected. This will allow us to determine the amount of unknown salt dissolved in a solution.

Future Work
- Test a greater range of salt concentrations
- Refine sensitivity to detect 0.1 mmol salt changes
- Improve mechanical design of clamp to securely hold microfluidic chip in place
- Update the portability of the design so athletes can use during training
- Error analysis

Skills Gained
- VNA measurements
- Use of ADS software
- Microfluidics

References

- [1] J. Hwang et al, "The ability of energy recover in professional soccer players is increased by individualized low-intensity exercise", PLOS ONE, June 30, 2022.
- [2] T. Reineckie, et al, "Design and evaluation of split-ring resonators for aptamer-based biosensors", J. Sen & Sen. Systems, vol 7, p 101-111, 2018.