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Radio Frequency Spectroscopy Using Know Labs Inc Bio-RFID™ Sensor Technology

INTRODUCTION

Since the discovery of chemical compounds, there has been a long interest in identifying and accurately measuring the molecules that make up those compounds. Fortunately, every chemical compound possesses uniquely identifiable fingerprints. This is due to their electronic structure and how the molecules interact with electromagnetic energy. More specifically, molecules will absorb energy with reliable specificity at certain frequencies of the electromagnetic spectrum. Consider that when you see a pair of blue jeans, all of the visible wavelengths of light are illuminating the jeans. However, your eyes see only the reflected blue light because dye molecules in the jeans are actually absorbing the red, orange and yellow light. This is because the visible region of the electromagnetic spectrum is being selectively absorbed by the dye in the cotton fabric. The study of energy absorption by molecular compounds is called spectroscopy. Spectroscopy is the method by which you can identify and quantify any particular molecular compound in the universe by way of its electromagnetic fingerprint.

The electromagnetic spectrum extends well beyond that which we can see with our own eyes. At higher energies, electromagnetic energy is categorized into ranges of frequencies such as ultraviolet and x-ray. At lower energies, electromagnetic energy is categorized in frequencies such as infrared, microwaves and radio waves. In most applications of spectroscopy, it is the electronic component that interacts with the electrons in chemical compounds. Therefore, we can expose an object to certain frequencies of electromagnetic radiation and then measure if that object absorbed any of that energy. If a range of frequencies were used, then the resulting absorbance data would provide information about the compounds within that object, or the amount of a single compound.

Consequently, spectroscopy finds use in clinical measurements because of the high chemical compound specificity, minimal sample preparation and low-cost optical or electronic equipment required to perform the measurements. For example, there is interest to use raman spectroscopy for cancer detection[1], visible-light spectroscopy for oxygen measurements[2,3]

[1] K. Kong, C. Kendall, N. Stone, I. Notingher. “Raman spectroscopy for medical diagnostics – From in vitro biofluid assays to in-vivo cancer detection”, Adv Drug Delivery Rev 2015, 89(15), 121-134.

and even ultra-violet and visible light spectroscopy is used for blood typing[4] amongst other things. Recently, Know Labs developed a novel radio frequency spectroscopy in order to non-invasively determine the amount of glucose in tissue. It does this by sending electromagnetic energy in the form of radio frequency into tissue and then measuring the absorbance of those frequencies that are specific to glucose molecules. In addition, the amount of radiofrequency energy absorbed is dependent on the glucose concentration. This is the fundamental concept behind Know Labs Bio-RFID sensing technology. The following details an experiment using Know Labs Bio-RFID technology to detect differing blood-glucose levels in tissue phantom that mimics the human body.

EXPERIMENT

Materials used to prepare glucose-containing tissue phantoms were used as received with no further purification.

Tissue phantoms mimic the electrical properties (dielectric, conductivity, etc.) of soft tissue. While there are differences in recipes for skin, blood and muscle, the formulation used herein is intended to mimic a blood/skin/muscle ratio of approximately 5%/10%/85% respectively. The formula is based on previously published work.[5] Table 1 shows the basic tissue phantom formulation. Glucose (anhydrous, 99.9%) was also included in the amounts of 2.15 g, 4.30 g, 8.60 g, 17.20 g in the order to prepare 40, 80, 160 and 320 mg/dL test specimens respectively. The phantom was prepared by first dissolving the gelatin and salt into boiling hot water and mixing until no solid gelatin could be observed. The mixture was then let to sit for about 10 minutes. After this, the oil, glucose, interferants and dishwashing soap were added. The mixture was stirred, let sit for 2 minutes, stirred again, then poured into molds, see Figure 1. The complete phantom mixture was let to sit until it gelled before testing. This took approximately 4-5 hours at room temperature.

Water	380 mL
Gelatin	43.43 g (provided pre-measured)

[2] S. Kleiser, et al. "Comparison of tissue oximeters on a liquid phantom with adjustable optical properties", Biomed Opt Express 2016, 7(8), 2973-92.

[3] D.A. Benaron, et al. "Design of a visible-light spectroscopy clinical tissue oximeter", J Biomed Opt 2005, 10(4), 44005.

[4] S. Narayanan, et al. "UV-visible spectrophotometric approach to blood typing II: phenotyping of subtype A2 and weak D and whole blood analysis" Transfusion 2002, 42(5), 619-26.

[5] F. Araujo Cespedes, "RF Sensing System for Continuous Blood Glucose Monitoring"

NaCl	1.00 g (provided pre-measured)
Oil, canola	58.00 mL (~53.30 g)
Dawn brand dishwashing soap	70.00 mL (~72.40 g)

Table 1. Tissue phantom formulation

Equipment data reported herein was collected using Know Labs Bio-RFID sensor prototype system. It comprises a modified Keysight N5171B signal generator, modified Keysight N1913A power meter, custom antenna, custom waveforms and proprietary software/computational algorithms.

General process for Bio-RFID scans. The tissue phantom was placed atop the sensor antenna and tested according to the following process:

1. Place 40 mg/dL glucose sample on sensor
2. Ensure sample is aligned with vessel alignment too
3. Scan sample with custom waveforms
4. Analyze data with proprietary software and computational algorithms
5. Repeat for steps 1-4 with 80 mg/dL, 160 mg/dL and 320 mg/dL samples

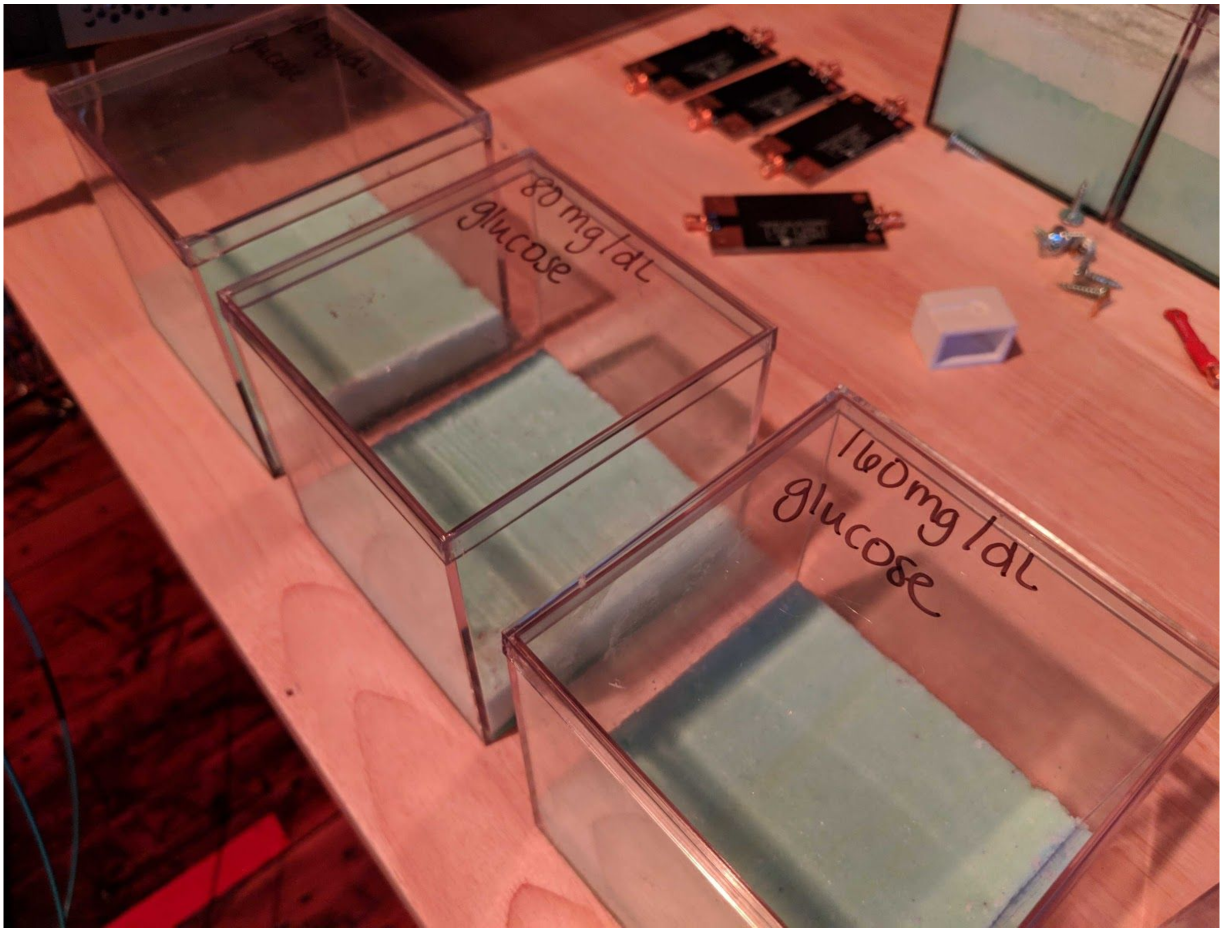

Figure 1. Clear plastic molds holding tissue phantoms, ready to be tested.

RESULTS AND CONCLUSIONS

The Know Labs Bio-RFID sensor system collects an RF spectroscopy signal from the test material. Figure 2 shows the frequency response to four levels of glucose concentration between the frequencies of 1.65 to 1.75 GHz. The observed RF intensity change is approximately 5.3 x 10-3 dB / (mg/dL) of glucose across the frequency range reported herein. When converted to a representative sensor signal, as shown in Figure 3, the linear fit R2 is 0.984 at 1.72 GHz.

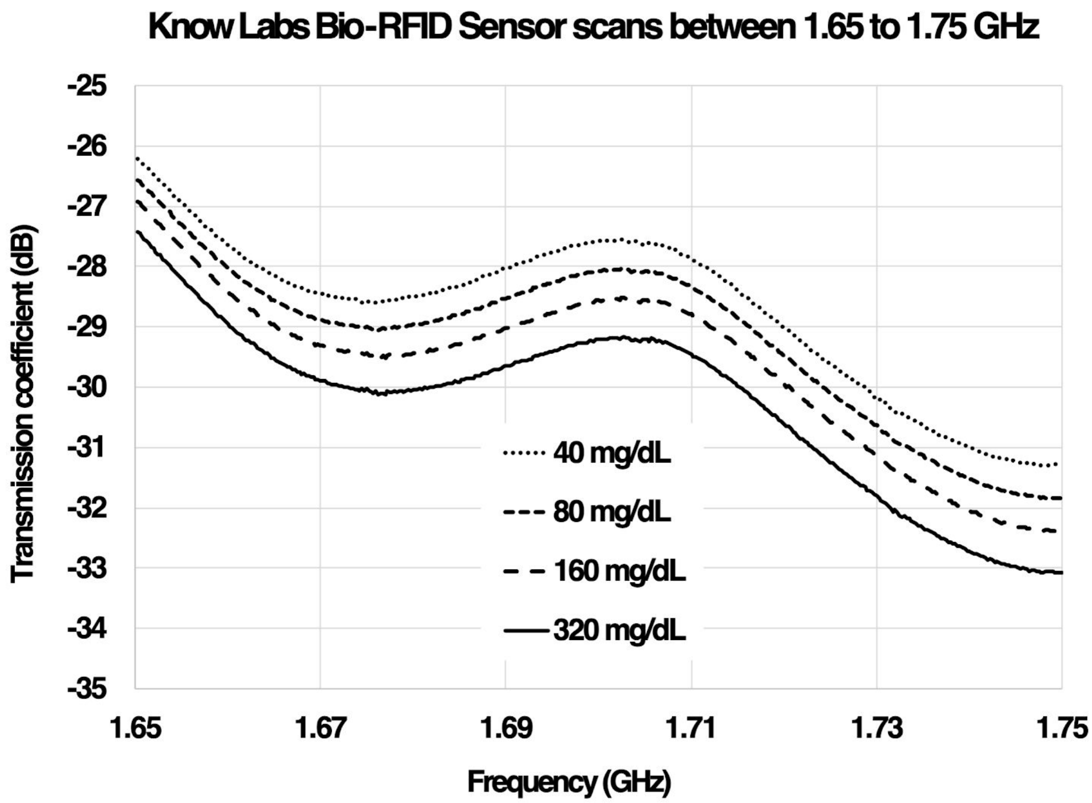

Figure 2. RF spectrum for Know Labs Bio-RFID system between 1.65 and 1.75 GHz for four glucose concentrations.

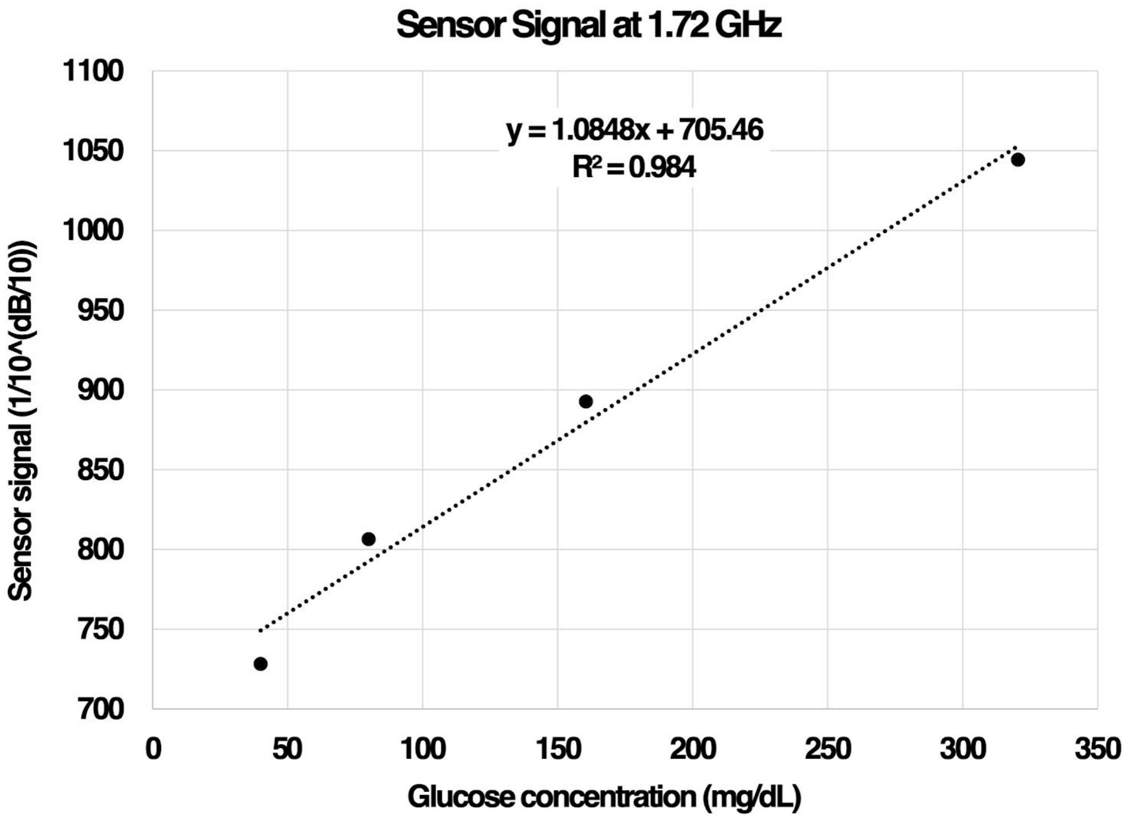

Figure 3. Know Labs Bio-RFID sensor signal versus glucose concentrations plotted at a single frequency, 1.72 GHz.

In conclusion the Know Labs Bio-RFID glucose sensor system was tested in tissue phantoms comprising physiologically relevant glucose concentrations. The sensor system shows strong signal response and linearity. The Know Labs Bio-RFID glucose sensing system effectively uses RF spectroscopy to selectively measure glucose concentrations. This system will enable the creation of a wearable non-invasive blood glucose sensor for consumer and medical use.

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Author Biographies

Mark Tapsak, Interim Assistant Vice President and Dean of Graduate Studies and Research, Bloomsburg University - Tapsak is currently Professor of Chemistry and Biochemistry at Bloomsburg University. He is skilled in spectroscopy, analytical chemistry, polymers, intellectual property, and the design of medical devices. Tapsak is an inventor on more than 50 US patents, primarily focused on medical devices, their design and function. Tapsak received his Ph.D. in Chemistry and Polymer Science from the University of Southern California. Tapsak was previously the 12th employee at Dexcom hired as a scientist for the development of their blood glucose systems.

Phil Bosua, Chief Executive Officer, Know Labs - Bosua is an internationally recognized inventor and innovator. His expertise in lighting lead him to found LIFX (www.lifx.com) where he created the world's first commercial smart light bulb. The 2012 crowdsourcing launch of his smart light bulb raised $1.3 million in six days and attracted $12 million in funding from Sequoia Capital sequoiacap.com. This groundbreaking invention earned him the prestigious Edison Gold Award edisonawards.com presented by Elon Musk to innovators who create products that have a positive impact on the world.

For more information on Know Labs Bio-RFID technology platform visit: knowlabs.co