Remote Sensing of Blood Glucose Level Using an FMCW Radar Sensor

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Abstract

A novel sensing approach is presented for glucose level monitoring where a robust low-power millimeter(mm)-wave radar system is used to non-invasively differentiate between blood samples of glucose concentrations in the diabetes range through detecting minute changes in their dielectric properties. The processed results have indicated the reliability of using mm-wave radars in identifying changes of blood glucose levels while monitoring trends among those variations. Particularly, blood samples of higher glucose concentrations are correlated with reflected mm-wave signals of greater energy. The proposed system could likely be adapted as a portable non-invasive continuous blood glucose levels monitoring for daily use by diabetic patients.

1. Introduction

Over the recent years, radars have demonstrated success in the health scope for a variety of applications such as sleep monitoring, sensing the respiratory and heart/pulse rates, emotion tracking, and many other aspects of radar capabilities are still under exploration. Continuing these efforts in radar health applications, we are proposing a compact low-cost integrated sensing system that utilizes mm-wave radars to non-invasively detect glucose concentration levels for diabetic patients. In particular, motivated by the results of our prior study in [1] that succeeded in differentiating the amount of sugar in three different drinks (coke, diet coke, and zero coke) using the reflection data from one channel of a 4-port microwave network analyzer; in this study, we employ radar sensing and signal processing for the purpose of identifying the glucose levels in synthetic blood samples of various glucose concentrations typical to the diabetes condition.

2. Proposed Glucose Detection Approach

The glucose detection approach investigated in this study exploits the radar sensor capabilities whereby the characteristics of the object(s) placed in the vicinity of the sensor, right on top or at a definite distance, can be explored by looking into the reflected signals as collected by the radar receiving antennas. These signals represent a rich store of information that describe various attributes (thickness, volume, range, density, surface properties, internal synthesis, etc.) respecting the object(s) on target of the radar transmitted EM waves. For our case, we have liquid samples of homogenous composition of synthetic blood but with different amounts of dissolved glucose. In other words, all the samples have similar shape, volume, placement, and almost the same composition except for the concentrations of the dissolved glucose that have tiny variations from one sample to another. This variation in glucose levels modifies the dielectric properties of the sample in place, thereby make it possible for the radar signals to capture the unique signature of each blood sample of respective glucose concentration. For this purpose, a two-transmitters (Tx) and four-receivers (Rx) high resolution mm-wave radar working in the 57 – 64 GHz frequency range (Bandwidth of 7 GHz) [2], is used as a sensing platform for tracking different glucose concentration levels in blood-mimicking material "fake blood" samples by analyzing the raw data of the reflected radio waves. To do so, we first prepare synthetic "fake blood" samples of assorted glucose concentrations from 0.5 to 3.5 mg/ml at 0.5 mg/ml increment to imitate the practical range of different diabetes conditions (Normal, Hypoglycemia, and Hyperglycemia). The prepared blood samples are loaded at a specific volume inside clinical test tubes, then placed onto a 3D printed fixture device (Fig. 1) that is particularly developed to retain the sample tube position at a consistent distance relative to the radar sensor while mitigating any placement errors. The blood samples under test are illuminated with frequency-modulated continuous electromagnetic waves at very high frequencies and the raw data of reflected mm-waves are collected simultaneously from the four radar channels. The collected raw data is then analyzed using signal processing techniques that correlated the blood samples of higher glucose concentrations with reflected mm-wave signals of greater energy as shown in Fig. 2. These processed results imply the fact that incident mm-wave signals encounter less absorption and attenuation inside higher-concentrated samples compared to those of lower glucose content. This behaviour is also evident by the mm-wave dielectric spectroscopy measurements collected via a characterization system (DAK-TL) that show decrease in the loss tangent when the amount of glucose dissolved in the aqueous solution is increased.

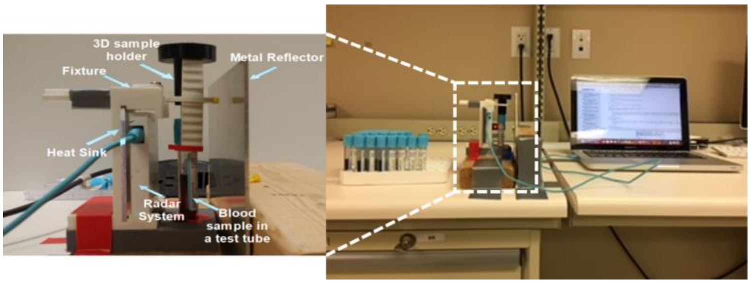

Fig. 1: The experiment setup showing the integrated radar system connected to PC interface where the collected raw data are monitored and processed using DSP algorithms for accurate identification

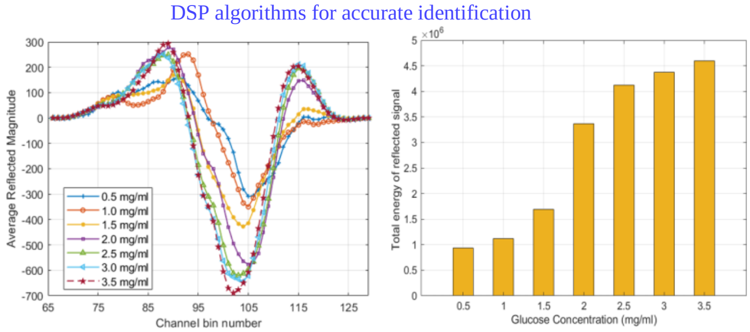

Fig. 2: The processed results by the DSP algorithms.

References

[1] Shaker, G., Smith, K., Omer, A. E., Liu, S., Csech, C., Wadhwa, U., Safavi-Naeini, S., and Hughson, R. Non-Invasive Monitoring of Glucose Level Changes Utilizing a mm-Wave Radar System. *International Journal of Mobile Human Computer Interaction (IJMHCI)* (2018).

[2] Omer, A. E., Shaker, G., Safavi-Naeini, S., Murray, K., and Hughson, R. Glucose Levels Detection Using mm-Wave Radar. *IEEE Sensors Letters* (2018).