Non-Invasive Monitoring of Glucose Level Changes Utilizing a mm-Wave Radar System

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ABSTRACT

This article discusses recent developments in the authors’ experiments using Google’s Soli alpha kit to develop a non-invasive blood glucose detection system. The Soli system (co-developed by Google and Infineon) is a 60 GHz mm-wave radar that promises a small, mobile, and wearable platform intended for gesture recognition. They have retrofitted the setup for the system and their experiments outline a proof-of-concept prototype to detect changes of the dielectric properties of solutions with different levels of glucose and distinguish between different concentrations. Preliminary results indicated that mm-waves are suitable for glucose detection among biological mediums at concentrations similar to blood glucose concentrations of diabetic patients. The authors discuss improving the repeatability and scalability of the system, other systems of glucose detection, and potential user constraints of implementation.

KEYWORDS

60 GHz mm-Waves, Electromagnetic Scattering, Google Soli, Glucose Monitoring, Non-Invasive

INTRODUCTION

Diabetes is characterized as a breakdown of the insulin production system in the pancreas, which affects cells’ ability to absorb glucose from the bloodstream. Glucose is a very important component of cellular respiration; the process by which cells produce energy. Diabetic people are not able to process glucose properly, and serious complications can arise if diabetics do not monitor their blood glucose levels between 2-4 times a day (American Diabetes Association, 2014). Affected human beings living with diabetes need to continually monitor their blood glucose levels. Care provision and the monitoring of diabetics in Canada, for example, costs millions of dollars each year.
From the device operation perspective, the methods of glucose monitoring can be essentially categorized as invasive, minimally invasive, and non-invasive. Invasive devices detect glucose from subcutaneous or intravenous bodily fluids: besides analyzing glucose level via blood drawn from the finger, there are wireless implants with radio frequency capabilities to communicate glucose data to an external controller for analysis. Minimally invasive devices detect glucose externally via extracted interstitial fluid from skin tissues. They differ from invasive devices in that the techniques to extract interstitial fluid do not cause significant damage to the tissue. There is discomfort and risks of infection from both invasive and minimally-invasive techniques, and researchers in both academia and industry are working on non-invasive techniques for detecting glucose from external body-fluids such as sweat and tear.

There have been thorough investigations on alternative non-invasive methods of blood glucose monitoring over the last decade. Absorbance spectroscopy techniques, such as near infrared and mid-infrared spectroscopy (Vashist, 2012), have been commonly researched where the scattering of light on biological tissue is used to detect the optical signatures of glucose in blood. However, in addition to being costly to implement, these methods are also highly sensitive to changes to physiological parameters, such as body temperature and blood pressure, as well as environmental variations in temperature and humidity. Several research studies have been done on utilizing bodily fluids to correlate blood glucose concentrations in breath (Guo, 2012), saliva (Malik, 2015), sweat (Gao, 2016), and tear fluid (Zhang, 2011). Despite being quite innovative, these proposed methods either show a low correlation between the measured parameters and blood glucose levels or the proposed designs are still in their infancy to judge their applicability (Shaker, 2016).

Currently the leading method for patients to measure blood glucose concentration is using a glucometer, a device that requires blood drawn from a fingertip to be analyzed on a strip of test paper. This method is painful, invasive, and costly to the user. They must prick their finger multiple times a day to draw blood, and must constantly purchase a supply of fresh test paper to analyze the sample. The other leading method of glucose monitoring is an artificial pancreas, which is an invasive device that constantly monitors glucose levels and administers insulin to the patient through a pump inserted in their midsection (Center for Devices and Radiological Health). This eliminates the need for finger pricking, but is also very invasive to the user. Development of non-invasive methods using sweat, tears, and saliva are too susceptible to metabolic changes (Vashist, 2012).

The motivation behind this work is to develop a non-invasive glucose detection system for diabetic patients using mm-wave radar. Using radio frequency (RF) waves to measure the dielectric properties of blood glucose in superficial vessels has been shown to be a viable option (Siegel, 2014). However, the authors of this work are not aware of any work done on using low-cost compact mm-wave radars to potentially monitor blood glucose levels.

RELATED WORK

Current research efforts related to diabetes tracking are extensively exploring non-invasive methods for monitoring blood glucose concentrations. Studies are being done to try and correlate external body fluids such as sweat and tears to blood glucose concentration, however so far results show that there is little or delayed correlation (Guo, 2012, Zhang, 2011, Shaker, 2016). Ultrasound technology has been used in a multi sensor to develop an ear clip detection system, however it requires frequent recalibration to avoid the effects of physiological changes (Gal, 2013). Imaging techniques such as absorbance spectroscopy that can identify glucose concentrations through optical parameters, however these methods are also very susceptible to physiological changes (Vashist, 2012, Amir, 2007).

Recent research has shown correlation between the electromagnetic properties of blood and its glucose concentration. Several systems have been developed using microwave radio frequency (RF) technology to measure these blood parameters and characterize blood glucose concentrations. Most notably systems using split ring resonators (Choi, 2015), microstrip patch antennas (Saha,
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