Silicon-Based **E**lectromagnetic **N**on-Invasive Glucose **Se**nsor (SENSE)

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Abstract

We propose the use of millimeter-wave signals for the non-invasive (continuous) monitoring of blood glucose levels. This revolutionary system eliminates the need of blood samples for glucose measurements since the sensor is placed over the blood vessel on the skin. By sending electromagnetic waves through the skin and sensing the reflection, blood glucose levels are monitored. The radiated wave is of extremely low power (three to four orders of magnitude lower than that of cell-phones) and it does not expose the tissue to any harmful radiation. The device is battery-operated, portable and small-sized (estimated 1cm^2 on sides and 4mm height). Since the system uses a silicon-based chip to gather and process the data, it can transmit the readings to a nearby cell-phone or other electronic device of choice. The cost of the system will significantly reduce with volume due to use of silicon technology. In addition, riding on the economy of scale (as in other electronic markets), costs will further drop with maturity. The overall cost of the system is estimated to be below $20 (one time cost) for the end user. There will be no extra need for extra strips or other recurring monitoring costs besides the device itself.

Background

The National Diabetes Statistics show that 23.5 million, or 10.7 percent, of all people in the age group of over 20 years have diabetes. The prevalence of diabetes increased by %13.5 from 2005-2007. Currently, blood glucose monitoring devices are invasive by nature. This causes burden for the patients especially if the test frequencies are high. Accuracy of the current monitoring devices as well as complications from use of strips and other components further show the need for a new device for glucose monitoring.

Value Proposition

Low cost, non-invasive, accurate and continuous blood glucose level monitoring will improve quality of life for diabetes patients. With this technology, probability of further complications due to misreading or missing glucose level status will significantly decrease. Wireless transfer of data to the desired medium of choice is a desired feature that is included to the design. Since the extracted data is digital by nature, it is easily stored on the memory included in the device.

Unfair Advantage

A completely different monitoring method is proposed that does not require blood samples and can read from an external position to the body with a competitive measurement speed. Millimeter-wave

frequencies allow adequate wave penetration for non-invasive and completely safe continuous monitoring. Use of silicon technology and custom electronics permits flexible system calibration. This increases accuracy and allows for adaptation to environment variables (temperature, altitude). Also, memory size can easily handle years of data points (~20KB or more). Alternate site testing will be possible with appropriate calibration data. We take advantage of the scaling in electronics and hence can reduce costs further than proposed. No additional processing option or complicated manufacturing steps are required with our design and hence use of plain vanilla CMOS process is possible.

Sales/Distribution Strategy

In US 8% of the population (23 million people) have diabetes. 800,000 are newly diagnosed every year. Also, United States spends $174 billion a year for diabetes related issues. Proper and convenient glucose monitoring will reduce health-care costs due to diabetes complications. These factors provide enough incentives for the investors to be interested in this market. For distribution and sales strategy, we need to establish partnership with known drugstores like Walgreens, Longs drugs, etc. This will provides us with the access and exposure to the distribution channels.

	$	Comment
Offered price	**20**	
Distribution channel /Partnership cost	**10**	50% partnership cost
Cost of product (recurring cost)	**5**	Will go down by economy of scale
Net Revenue per device	**5**	

Technology

BWRC is currently involved in the design and development of a low-cost, non-invasive, portable imaging device with the aim of bringing imaging devices from laboratories to bed sides and doctors' offices. The ultimate goal of the project is to reduce health-care costs in the US. This **Time based UWB Synthetic Imager** (*TUSI*) system uses electromagnetic waves to "scan" the object of interest and detect the electrical properties of the tissue. We are proposing a simplified version of *TUSI* for continuous monitoring of blood glucose levels. Inherently, this is an easier technical problem to address than what we originally designed *TUSI* to target. Depth of penetration and detection for glucose monitoring is significantly smaller than that required for other intended applications. Blood glucose will be read from blood vessels close to the skin (e.g. on the finger, wrist, thigh or other relatively exposed parts for vessels).

The final design is currently in development in Berkeley Wireless Research Center (BWRC). The overall architecture is shown in Fig.1. The modified version for blood glucose consists of a 2x2 array and a simple processing unit that is integrated on the chips. A flexible board is used to integrate the whole system together in a 1cm by 1cm by 4mm package (without the display unit). Data is conveyed to a nearby electronic device of choice (PDA, cell phone, laptop, PC or other devices using Bluetooth standard). It is also saved in memory for long-term monitoring purposes.

In terms of the sensitivity, it has been verified that adequate contrast at millimeter-wave frequencies exist with level of glucose concentration in blood. Since our system uses a 12bit ADC with further filtering for SNR improvement at the digital baseband, we can have a 1mg/ml resolution in the 0-300 mg/ml range.

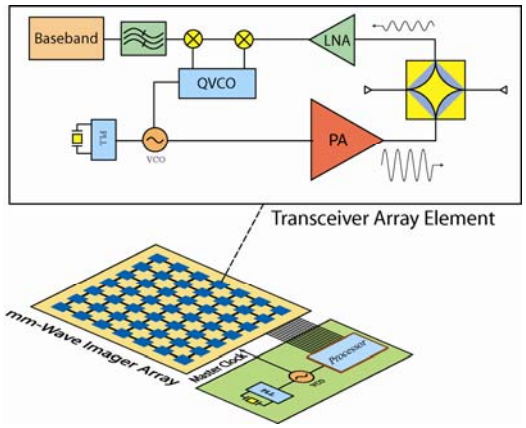
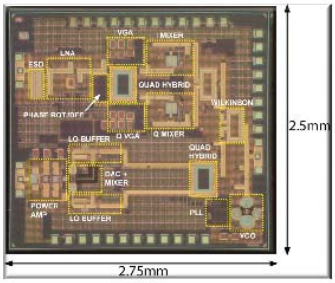


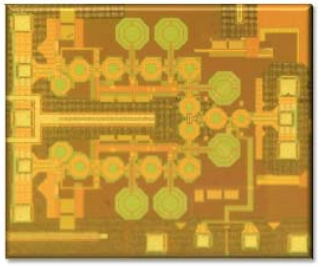
Fig.1: General architecture of TUSI

Background of Project and Research Group

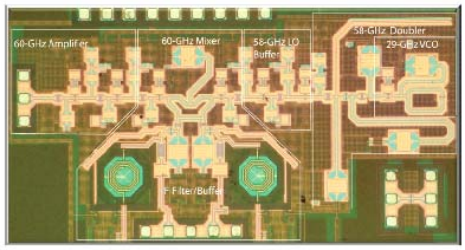
Our research group at Berkeley Wireless Research Center (BWRC) in UC Berkeley has been actively involved with the design and realization of microwave and millimeter-wave circuits and systems in low cost semiconductor technologies. We have been the leader in demonstrating the capability of standard digital CMOS technology in very high frequencies of operation and hence the feasibility of low cost millimeter-wave modules. Several 60GHz operating systems have been demonstrated and published in leading conference proceedings and technical journals (http://bwrc.eecs.berkeley.edu/php/pubs/pubs.php). Previous members of the group successfully launched a venture funded startup company for 60GHz wireless communication (SiBeam, www.sibeam.com). Several of the previous millimeter-wave chips fabricated in BWRC are included below.



60GHz fully integrated transceiver (90nm CMOS, ISSCC 2009)



2-channel 60GHz phased-array receiver (65nm CMOS)



60GHz integrated receiver (130nm CMOS, ISSCC 2007)