Non Invasive Blood Glucose Measurement through Microwave Resonator

Shiv Kumar[1], Jaspal Singh[2]

[1]Centre for Development of Advanced Computing
A Scientific Society of the Ministry of Communications & Information Technology, (Govt. of India)
A-34, Industrial Area, Phase VIII, Mohali – 160071, India

[2]Centre for Development of Advanced Computing
A Scientific Society of the Ministry of Communications & Information Technology, (Govt. of India)
A-34, Industrial Area, Phase VIII, Mohali – 160071, India

Abstract: ***The paper presented here is an effort to document the design of microwave resonator for non-invasive blood glucose measurement. The sensor was designed on Sonnet lite project editor which is a microwave spiral resonator. Sonnet lite project editor® which is freeware for microwave simulation. The simulation results shows the resonant response of the sensor changes as the body impedance changes and hence may be used for continues non-invasive blood sugar concentration monitoring. Block diagram of the proposed hardware is presented which may be used to interface this sensor for further experimentation.***

Keywords: Non-invasive, Glucose measurement, Diabetes, Impedance.

1. Introduction

For Diabetic care, both painless and Non-invasive and long-term continuous blood glucose monitoring is needed. However, this kind of monitoring procedure has not been accomplished clinically. For other blood constituents, noninvasive monitoring or continuous monitoring without blood sampling is necessary. Today Approximately 8.3 percent of global population is suffering from this Measurement of Glucose concentration in the blood of a diabetic patient should be done 1-4 times a day (at least before injecting insulin in a patient).

The acceptable range of glucose concentration is from 70 mg/dL (milligram of glucose in 100 milli liters of blood) to 110 mg/dL .But soon after eating glucose concentration of a person this level may be rise up to 140 mg/dL The technologies available in the Indian market today require a patient to take blood samples and measure using chemical reactions which are both painful and costly (at least by Indian standards).

Today, a need is felt for such a blood glucose measuring device which may provide continues blood glucose monitoring noninvasively. In this paper presented here Microwave Resonant Impedance Spectroscopy was selected.

2. Design of Microwave Resonator

A microwave resonator was designed in Sonnet- Lite® Microwave Simulation Studio Suite v 13.55. A standard FR4 substrate PCB material with thickness 0.8mm was used for making this resonator. It was made on the two layers PCB. For the ground plate for the micro-strip op layer of PCB was not etched anywhere whereas as the bottom layer

was etched completely. The top layer of PCB was used to make Micro-strip feed lines which were connected to the microwave resonator with copper vias on the bottom layer of the PCB. The Bottom view (Fig. 1) of the sensor hence. Designed is given below:

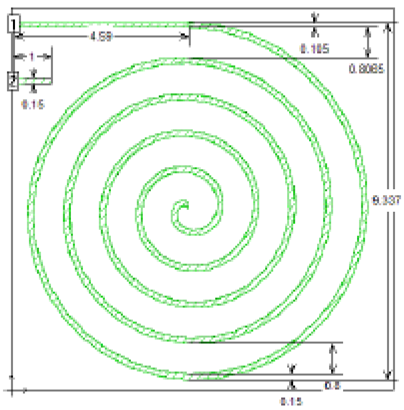

Figure 1: The bottom view of microwave resonator

3. Hardware Design

The hardware implementation of the sensor for measurement of blood glucose the block diagram of the hardware designed is given in Fig-2

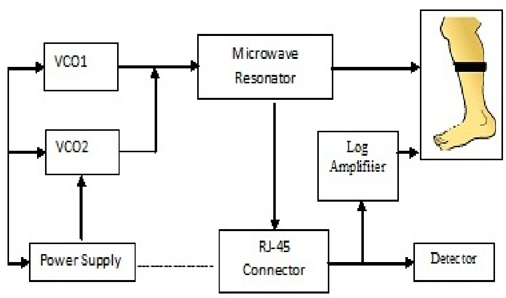

Figure 2: Block diagram of Hardware

To design the hardware the first thing that was designed is the microwave resonator. The circular spiral resonator was designed on a double layer PCB 0.8mm thick FR4 copper laminate sheet as shown in figure 3.

Figure 3: Circular Spiral Resonator

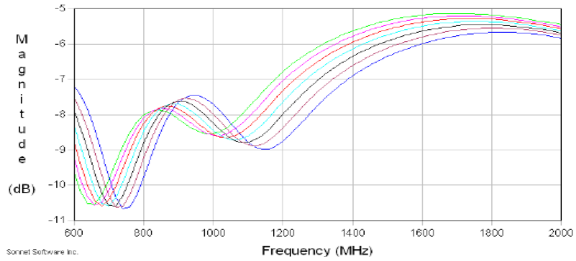

Figure 4: Simulation graph on sonnet lite simulator

After making resonator VCO was designed. The range of the frequency sweep is very wide i.e. 500MHz to 2000MHz we had to use two voltage controlled oscillators. VCOs from RFMD i.e. UMS-1000-A16 and UMS-2000-A16 were chosen due their flexible simplicity and output impedance involved in designing circuit. After that next step was to choose a log amplifier with a wide range of linear output; hence, LT5538 log amplifier was chosen due to its wide linear dynamic range and -72dBm detection sensitivity.

3.1 Design of Load Tissues

Before designing the sensor it was compulsory to design a load where the sensors would be tested hence a load tissue was designed using Sonnet Lite the second order Debye equation and the parameters is shown .

$$\varepsilon(\omega) = \frac{\varepsilon\infty + \sum_{n}^{3} \Delta E}{1 + j\omega\tau}$$

A model of the layers of body was created so that the simulation of the sensor would provide results consistent with those that would be found when used in conjunction with real s of human tissue. The model, shown the fig consist of a layer of cover film , a 0.015 mm layer of dry skin, a 0.3 mm layer of wet skin, a 0.2 mm layer of fat, a 0.5 mm of blood and 2mm layer of muscle.

Table 1: Parameters used in Debaye equation for modeling tissues

Type of Tissue	$\varepsilon\infty$	ΔE_1	τ1(ps)	ΔE_2	τ 2(ns)	ΔE_3	τ 3(μs)
Blood	4.0	56	8.38	5200	132.63	0.0	0.0
Fat	2.5	9	7.96	35	15.92	3.3*104	159.1
Muscle	4.0	50	7.23	7000	353.68	1.2*106	318.3
Skin (Wet)	4.0	32	7.23	1100	32.48	0.0	0.0
Skin (Dry)	4.0	39	7.96	280	79.58	3*104	1.59

3.2 Simulation Result

The response of microwave resonator was simulated on Sonnet lite simulator by changing the dielectric constants. The frequencies range was selected 600MHz to 2000MHz. The results of this simulation are provided in the Fig 4.

From the results it is clearly shown from the simulation is that the first maximum shifts to higher frequencies as the dielectric constant decreases. The shift in maxima was one of the approaches used for design of glucose monitoring device.

4. Conclusion

After simulating various kinds of spiral sensors i.e. rectangular spiral, eight sided spiral and circular spiral for similar load it was found that a circular spiral is best suited for development of permittivity sensor to approximate blood glucose concentration as it ideally has infinite discontinuities. Permittivity which is measured using thing sensor not only on blood glucose but several other factors like Body Temperature, Blood Pressure ,Heart rate etc. To develop a commercially available sensor from such a sensor a lot of experimentation and calibration algorithm through research is required.

References

[1] L. Livshits; A. Caduff; M S Talary; Y. Feldman, "Dielectric response of biconcave erythrocyte membranes to D- and L-glucose," J. Phys. D: Appl. Phys., vol. 40, pp. 15-19, 2007. OlaMartinsson.(2010, April)

[2] Norman Endocrine Surgery Clinic, "Normal Regulation of Blood Glucose," Norman Endocrine Surgery Clinic, 2002. Accessed Oct. 20, 2005.

[3] W. Davis, "Direct & Indirect Costs of Diabetes in the United States," American Diabetes Association, Feb 18, 2004. Accessed Oct. 20, 2005

[4] T. Smith, "Our Deadly Diabetes Deception," *Nexus Magazine*, vol. 11, June – July 2004.

[5] E.C. Green, "Proposed Method for Non-Invasive Measurement of Blood Glucose Concentration: Using Microwaves for Data Measurement and Analysis," Dec. 2004

[6] W.J. Germann and C.L. Stanfield, *Principles of human physiology*, San Francisco, Benjamin Cummings, 2002.

[7] National Diabetes Information Clearing house, *Diagnosis of diabetes*, Bethesda National Institute of Diabetes and Digestive and Diseases, National Institutes of Health, U.S. Dept. of Health and Human Services, 2004.

[8] "Forearm blood samples yield accurate results in home blood glucose monitors, "*Diabetes Week*, pp. 17, November 8, 2003.

[9] Y. Hayashi; L. Livshits; A. Caduff; Y. Feldman, "Dielectric spectroscopy study of specific glucose

influence on human erythrocyte membranes," J. Phys. D, vol. 36, pp. 369-374, 2003.
[10] Harvard Medical School, "Harvard Heart Letter," EBSCO Publishing and Gale Group, pp. 5-6, October 2001.
[11] Burke, Dr. Edmund R., "Hitting the Wall: What Causes Muscle Fatigue?" *Muscular Development*, November, 1999
[12] Turner, A.P.F. and Swain, A. (1988). "Commercial perspectives for diagnostics Using biosensor technologies .American Biotechnology Laboratory, November, 10-18
[13] "Review Criteria Assessment of Portable Blood Glucose Monitoring In Vitro Diagnostic Devices Using Glucose Oxidase, Dehydrogenase or Hexokinase Methodology (Draft Version)," U.S. Food and Drug Administration Center for Radiological Health, Feb. 28, 1997

Author Profile

Shiv Kumar received the B. Tech degree in Electronics and Communication Engineering from C.D.L.M Govt. Engg. College in 2010 and Pursuing in M. Tech from C-DAC Mohali in Electronics. Product Design. His area of expertise is in Electronics product design.

Jaspal Singh received M. Tech degree with distinction from Punjab university and B tech degree with distinction from Thapar University.He is presently working in C-DAC, Mohali since 1998. His area of expertise includes Electronics & Instrumentation for Biomedical applications.