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# Design an Antenna for Aqueous Glucose Measurement

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***Abstract* – Diabetes is a disease that afflicts million of people worldwide. Blood glucose measurement is vital to management of diabetes. The technologies available for blood glucose measurement are both painful and costly. A microwave sensor can be useful for the non-invasive determination of blood glucose levels. As the step towards developing a non-invasive blood glucose measurement based on microwave, microwave antenna or sensor is designed and tested with aqueous glucose. In this paper the sensor is designed using Sonnet Microwave Simulation Studio Suite v 13.52, in the form of a microwave spiral resonator and ring resonator. The simulation results show, the resonant response of the sensor changes as permittivity of aqueous glucose changes.**

***Keywords* – Aqueous Glucose, Blood, Diabetes, Dielectrics, Non-Invasive, Resonator, Skin.**

## I. Introduction

Diabetes is a disease that afflicts million of people worldwide. Diabetes is a metabolic disease concerned with the inability of the body to achieve sufficient glucose regulation. The main cause for diabetes is improper regulation of insulin. The primary source of living organism is glucose and insulin is the hormone which breakdown the glucose. Insulin is the key for glucose to enter into cell and energized it. To be healthy, body's glucose concentration must maintain within specific range that is from 70 mg/dL (milligram of glucose in 100 milliliters of blood) to110 mg/dL .But soon after consuming food, concentration of blood sugar may be rise up to 140 mg/dL and blood glucose above 150 mg/dL for prolonged time indicates diabetes or its onset.

The technologies available in the Indian market today require a patient to take blood samples from the fingertip. The user pierces his skin with a lancet and then squeezes his finger until a sufficient amount of blood, usually one large drop, has been collected on a test strip [5] and that strip is inserted into glucometer and blood glucose measurement is done using

Chemical reactions which are both painful and costly [2].There for non invasive glucose measurement is required. In this paper the microwave technique is used for determining concentration of aqueous glucose non-invasively. A microwave sensor is designed such that whose resonance frequency will changes as concentration of aqueous glucose changes.

This paper is organized in the following manner, section II discusses the limitations of invasive glucose measurement. Section III gives idea about the microwave technique, Section IV tells about changes in blood permittivity in microwave region. Section V and Section VI discusses about selection of sensor and designing of sensor, Section VII represents simulation result of antenna without loading with glucose and with loading with aqueous glucose.

## II. Rationale of Work

Approximately 18 million people suffer from diabetes. Measuring glucose level in a diabetic patient on a regular interval and administering insulin are the keys to keep him safe [3].So blood glucose measurement is necessary for administration of insulin. Methods used for determining blood glucose concentration are invasive and non-invasive. Invasive methods are painful, infectious and not easily monitored. So for painless and non-infectious blood glucose measurement, non-invasive approach is considered. The terminologies for non-invasive glucose measurement are near infrared spectroscopy, Optical coherence tomography, Raman spectroscopy, Ultrasound technology, Thermal spectroscopy, Fluorescence technology, Impedance spectroscopy etc [1].

These methods have limitations like size, calibrations problem, effect on body, no continuous monitoring [1]. So new approach to blood glucose measurement is using microwave technique.

## III. Microwave Technique

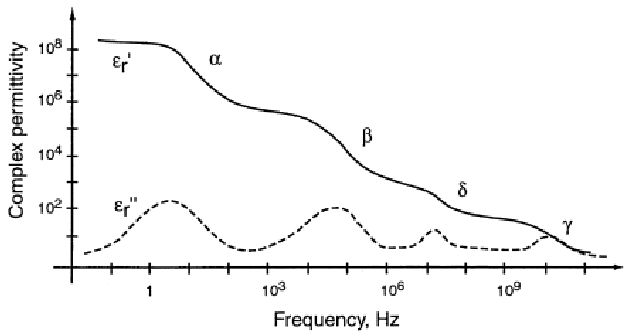


Fig.1. Dispersion regions of an ideal biological tissue [3]

Microwaves are form of EM radiation with wavelength from one meter to one millimeter with frequency between 100MHz to 100 GHz. The microwave energy and biology have had long history together. Ex. diathermy, microwave thermography. Microwave sensor is used to non-invasive determination of blood glucose.To understand microwave first understand how a biological specimen behaves in the presence of microwave and increasingly understand the dielectric properties of biological tissues. this is seen in figure1.a generalized plot of biological tissue permittivity.

Figure1.depicts change in complex permittivity of biological tissue as function of frequency. Complex permittivity of any material is written as $\varepsilon = \varepsilon_r' - j\varepsilon_r''$ where $\varepsilon_r'$ is dielectric constant or relative permittivity, $\varepsilon_r''$ is the dissipation of energy within the material and can be expressed as $\varepsilon_r'' = \frac{\rho}{\omega\varepsilon_0}$ where ρ is the conductivity of the material and ω is the angular frequency, $\boldsymbol{\varepsilon_0}$ permittivity of free space, which is $8.85\text{x}10^{-12}$F/m.

## IV. Effect of Microwave

The $\beta, \delta$ section fall in microwave region. From figure 2 this is observe that bloods permittivity does not change much if the frequency is below 1 MHz. We are rather interested in a dispersion region where the blood permittivity changes owing to a change in frequency [3].Thus the dispersion region allows us to design a sensor whose resonant frequency change depending on the glucose concentration in the blood.

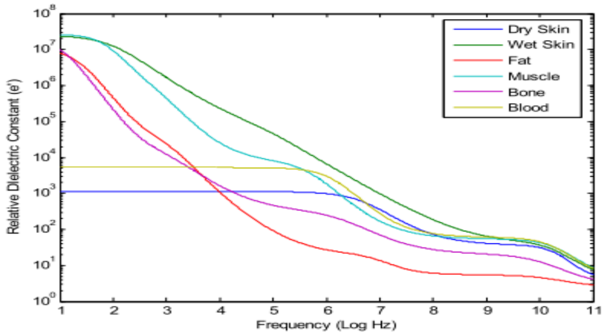


Fig.2. Relative dielectric constants of certain tissues [3]

To compute permittivity of different cells over broad frequency range the Cole-Cole model is used [3].

$$\dot{\varepsilon}(\omega) = \varepsilon_\infty + \sum\nolimits_n 1 \frac{\Delta\varepsilon_n}{\left(j\omega\tau_n\right)^{(1-\alpha_n)}} + \frac{\sigma_i}{j\omega\varepsilon_0} \quad (1)$$

$\dot{\varepsilon}(w)$ is the complex permittivity of the specific tissue
$\tau_n$ is the time constant
$\varepsilon_\infty$ is the permittivity at high frequencies
$\alpha$ is called the distribution parameter, which is a measure of the broadening of the dispersion region .

As the step towards developing a non-invasive blood glucose measurement based on microwave, microwave antenna or sensor is designed and tested with aqueous glucose instead of in vivo measurement**.**

## V. Selection of Topology

The property monitored by microwave sensor is permittivity. There are several ways to measure a materials permittivity like rectangular waveguide, dielectric probe kit, resonant sensor etc[4].Waveguides are used to measure signal transmission and open ended dielectric probes are used to measure signal reflection while resonant sensor can be designed to measure signal transmission and reflection. a resonant sensor is simply sensor whose S-parameter changes as permittivity of material being changes. This paper discuss about Microwave Resonant sensor. Microstrip resonant sensor has a peak or valley in its frequency response at a resonant frequency.

## VI. Design of Microwave Resonator

Among several options that were considered, A microstrip ring resonator and spiral ring resonator were selected to measure the change in concentration of aqueous glucose.

### *A. Ring Resonator*

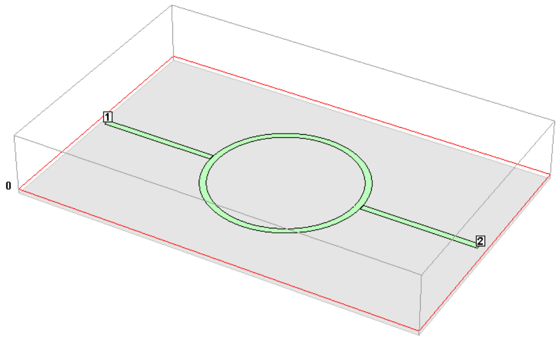

Fig.3 The 3D view of microwave ring resonator

A microwave resonator was designed in Sonnet Microwave Simulation Studio Suite v 13.52. A standard FR4 substrate PCB material with thickness 1.6 mm will used for making this resonator. A Ring Resonator consists of printed micro strip on rigid substrate. A Two board with one dielectric material is used as shown in figure 3.In ring resonator when signal enters the ring from coupling gap on the left, the energy coupled into ring splits equally over the top and bottom of the ring. This produces a standing wave such that when ring is in resonance, the maxima of the wave occur at the coupling gaps and nulls are at the top and bottom [7].

The design formulas relating the dimension and the resonant frequency are as follows:

$$2\pi r = n\lambda_g \quad \text{For n=1,2,3} \quad (2)$$

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_{reff}}} \quad (3)$$

Where r is the radius, f is resonant frequency,$\varepsilon_{reff}$ is effective permittivity of antenna [9].

### *B. Single Spiral Ring Resonator*

The circular-like symmetry of the spiral makes it less sensitive to contact orientation than other configurations and the spiral provides a generous contact area within a small outline [5].

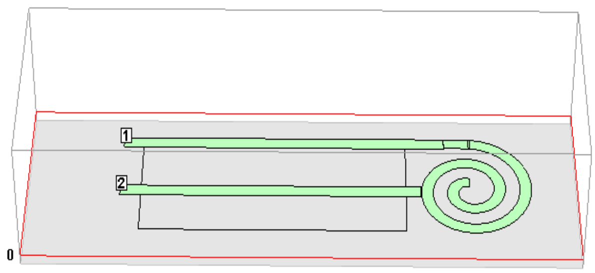

Fig.4. The 3D view of single spiral ring resonator

The microstrip ring resonator is a simple circuit which supports waves that have integral multiples of the guided wavelength equal to the mean circumference. Power is coupled into and out of the resonator through feed lines and coupling gaps. A general sketch is shown in figure 4.

## VII. Simulation Result

The frequencies range was selected 1GHz to 3GHz. The results of this simulation are provided in the Figure 5 and figure 6.

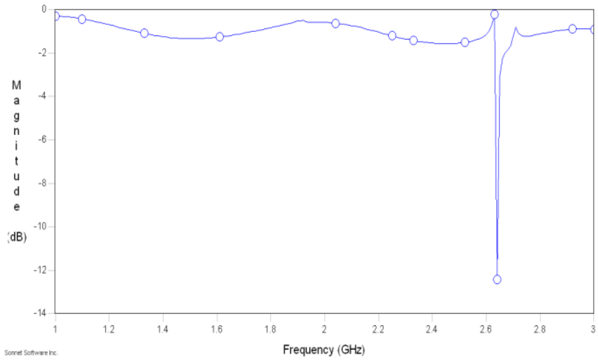

Fig.5. Ring resonator - S21 Response over frequency

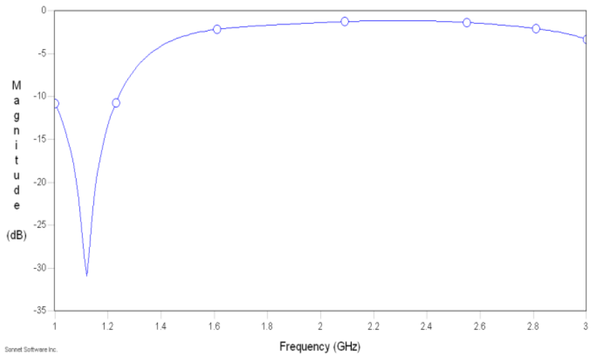

Fig.6. Spiral ring resonator -S21 Response over frequency.

The antenna is fed with stripline embedded within the substrate.In order to find the response of antenna with aqueous glucose load the antenna with 10%,20%, 30%, 40%, 50% aqueous glucose(% of glucose in water).The values of dielecric constants of aqueous glucose explain in table1.

Table I: Dielectric constants of aqueous glucose solution[6].

| Aqueous glucose (wt persent) | Dieletric constant at 25°C |
|---|---|
| 10% | 76.14 |
| 20% | 73.43 |
| 30% | 70.46 |
| 40% | 67.11 |
| 50% | 63.39 |

The microstrip ring resonator gives a good response to changes in load permittivity. When antenna is loaded with aqueous glucose it gives maximum measurable frequency shift. Loading both of antenna with aqueous glucose they gives frequency shift as shown in figure 7 and figure 8.

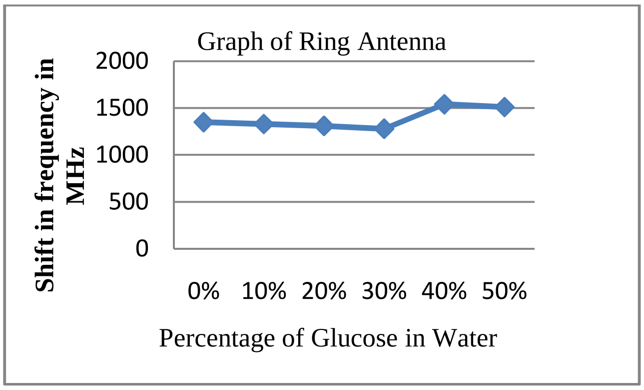

Fig.7 Percentage of glucose in water Vs shift in frequency

Table II: Simulation result of ring resonator

| Aqueous glucose (wt persent) | Maximum shift in S21 | Center frequency of S21 shift |
|---|---|---|
| 0% | 1350 MHz | 1.29 GHz |
| 10% | 1330 MHz | 1.31GHz |
| 20 % | 1310 MHz | 1.33GHz |
| 30% | 1280 MHz | 1.36 GHz |
| 40% | 1540 MHz | 1.1 GHz |
| 50% | 1510 MHz | 1.13 GHz |

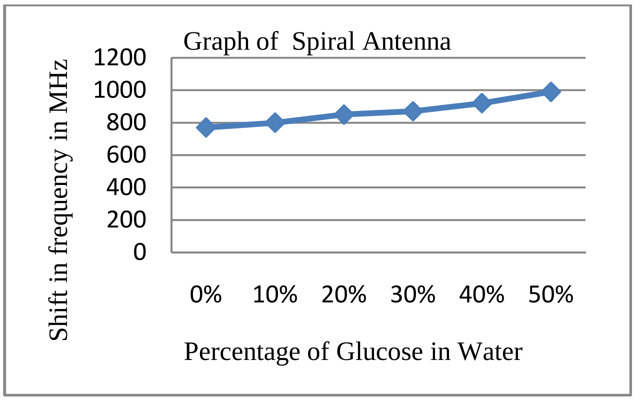

Fig.8. Percentage of glucose in water Vs shift in frequency

Table III: Simulation result of single spiral ring resonator

| Aqueous glucose (wt persent) | Maximum shift in S21 | Center frequency of S21 shift |
|---|---|---|
| 0% | 770 MHz | 1.89 GHz |
| 10% | 800 MHz | 1.92 GHz |
| 20% | 850 MHz | 1.97 GHz |
| 30% | 870 MHz | 1.99 GHz |
| 40% | 920 MHz | 2.04 GHz |
| 50% | 990MHz | 2.11 GHz |

## IX. Conclusion and Future Scope

Simulation result of Microstrip circular spiral and microstrip ring resonator for similar load shows that, a circular spiral is best suited for development of permittivity sensor as it gives maximum measurable shift as per concentration of aqueous glucose changes. to develop a commercially available sensor for glucose measurement a lot of experimentation is required. The future scope of this paper will be designing of sensor which should be able to detect these changes non-invasively i.e without making direct contact to blood. It would be non-invasive glucometer that diabetics can use on daily basis.

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