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Non Invasive Microwave Sensor For Near Field Biological Applications

Avikant B Gadawe[1], Vidya Deshmukh[2]

ME Student, Department of E&TC, AISSMS COE, Pune, Maharashtra, India[1]

Asst. Professor, Department of E&TC, AISSMS COE, Pune, Maharashtra, India[2]

ABSTRACT: In this research paper we introduced rectangular spiral antenna for near field biological application which will work as a non–invasive sensor for glucose monitoring for diabetic patients. We designed and Simulated two sensors one at 2.46 GHz and other is at 4.64 GHz with the help of Ansoft HFSS 11. Diabetic is one of the fastest growing disease in the world and billions of people in all age group are affected with it and glucose level is the major parameter to diagnosis it. We can use this sensor to identify or detect glucose level in a blood non invasively, which will help a Diabetic patients. This analysis will help patient for regular check-up of blood glucose level as it is painless and cheap than the existing technologies for the same.

KEYWORDS: Non-Invasive, Glucose Monitoring, Diabetic, Spiral antenna, Microwave

I. Introduction

Diabetic is one of the common and fast growing health problems. Worldwide total no of diabetic patients expected to rise from 171 million in 2000 to 366 millions in 2030, and it is one of the leading cause of death worldwide. Now a days Glucose monitoring techniques are invasive or minimal invasive in which blood is collected on strip and is it scanned with glucometer and blood glucose measurement is done. For diabetic patient regular glucose monitoring is advisable so that preventive actions can be done for the patient. But regular invasive or non-invasive blood glucose measurement is harmful for the patient and costly too. In this work we designed a Non-invasive microwave sensor for blood glucose concentration. We use microwave frequencies because its have longer wavelengths which make them more capable to penetrate through various body parts. The microwave sensor presented function as a receiver gathering information from the material with which it is in contact. Blood glucose measurements techniques are invasive methods, Minimally Invasive methods and Non-invasive Methods. Invasive Methods are Chemical, Biochemical Method, and Glucometer. Minimally invasive Methods are Reverse Iontophoresis, and non-invasive methods are infrared Spectroscopy, Optical Coherence Tomography, Raman Spectroscopy, Polarization Change, Ultra-sound, Fluorescence, Thermal spectroscopy, Ocular spectroscopy, Impedance spectroscopy, etc.

Most of these non-invasive old methods have drawbacks in terms of calibration, accuracy, in continues monitoring, size of instruments, calibrations and likewise [1][4].

To overcome all this problems and improve the quality of measurements, here we are presenting a microwave technique for non-invasive measurement of glucose.

II Methodology

The frequencies in the radio spectrum between 100 MHz to 100 GHz are typically termed as Microwave frequencies. Permittivity is the most important property monitored by a microwave sensor. Permittivity is the complex number as shown in equation 1 [3].

$$\in = \in' + j \in'' \qquad \text{eq. (1)}$$

Where,

$\in' = \mathit{Dielectric\ Constant}$

$\in'' = \mathit{Loss\ Factor}$

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The relation between the real part of the permittivity and the frequency for some biological tissues is as shown in the fig.1.

Human body is regularly exposed to microwave frequencies via various sources like cell phones, satellites, television stations, wireless routers and like others.

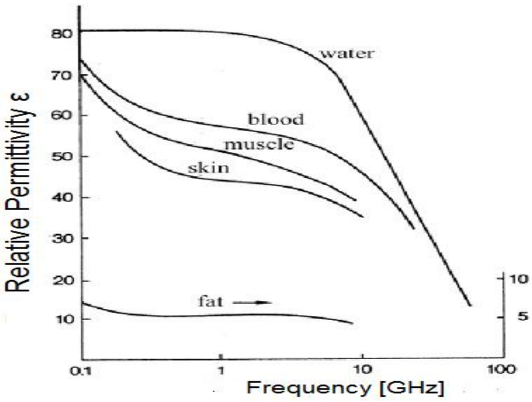

Fig. 1 : Relation between permittivity and frequency.

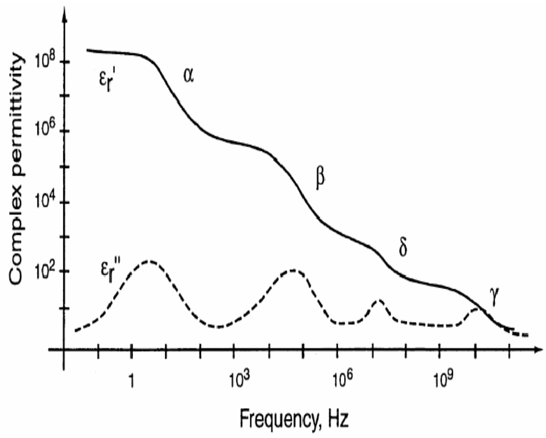

Fig. 2: Graph of dispersion region.

Microwave and living beings have a long history so researcher have considered and studied a effect of microwaves on human body exposure and they came up with results which is validated and approved by IEEE known as Specific Absorption Rate (SAR). This is shown in Table 1. For frequency range of 100 KHz to 6 GHz[10].

Table 1: Specific Absorption Rate by IEEE

Exposure characteristics	Whole body (W/kg)	Partial Body (W/kg)	Hands, Feet & Ankles (W/kg)
Occupational Exposure	0.4	8	20
General Public Exposure	0.08	1.6	4

To understand the microwave radiations from human body and predict its effects, a well understanding of dielectric properties of tissue is necessary. A generalised and standard plot of biological tissue permittivity from near DC to 100 GHz is as shown in fig. 1. This plot has four distinct regions of decreasing dielectric constant called α-dispersion, β-dispersion, γ-dispersion, δ-dispersion[10].

From the plot we can observe that region β and δ fall under microwave frequencies in which we are interested[6]. The relative dielectric constant of tissues have been extensively researched and various mathematical models have been developed. One such model is the cole cole model for multiple dispersion, which is expressed as [6]

$$\in(\omega) = \epsilon_\infty + \sum_n \frac{\Delta\epsilon_n}{1+(j\omega\tau_n)^{(1-\alpha_n)}} + \frac{\sigma_i}{j\omega\epsilon_0} \qquad \text{eq. (2)}$$

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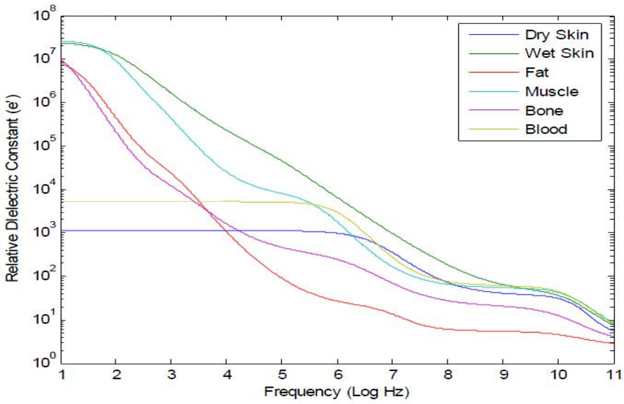

Fig. 3: graph of Dielectric Constant vs frequency (log, Hz)

III. DESIGN CONSIDERATION

1. Operating Frequency:

The design process begins with the selection of the appropriate operating frequency for the sensor design. The operating frequency is majorly affects the penetration depth, which is defined by the equation 3[13][12].

$$\delta = \frac{2}{\omega\mu\sigma} \qquad \text{eq. (3)}$$

Where ,$\omega = fequency$, $\mu = permibility$, $\sigma = conductivity$

For this design penetration depth of approximately 1 cm is sufficient as we have to observe a blood glucose level and not tumours. The graph of penetration depth vs frequency is as shown in fig. 4

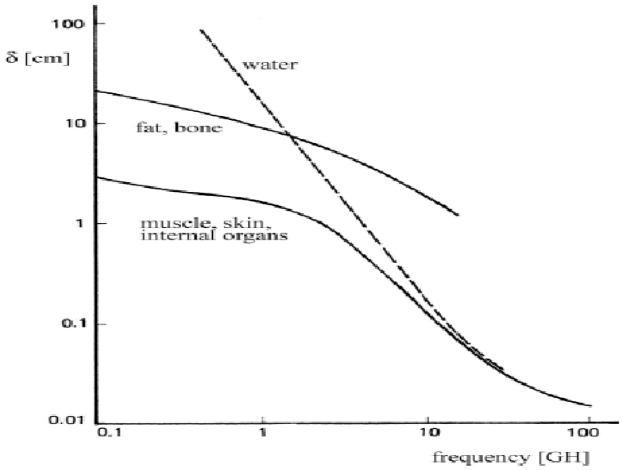

Fig. 4 : Graph of Penetration depth vs Frequency

Another important factor is dimension of antenna aperture and the distance from antenna and MUT should be in its near zone given by equation 4[13][11].

$$R_{ff} = \frac{2D^2}{\lambda} \qquad \text{eq. (4)}$$

Where,

$\lambda = Antenna's\ operating\ wavelength, D = Max\ antenna\ dimension$

So we have to choose a frequency from all the graphs and equations to penetrate at sufficient depth to study glucose concentration in blood. Therefore with the help of all data we choose 4 GHz to 6 GHz as the suitable range for microwave sensor.

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2. Antenna Dimensions

The one of the important factor designing a spiral antenna after deciding the frequency is it dimension. The outer Diameter of a spiral is defined by [12][13].

$$D = \frac{c/f}{\pi} \qquad \text{eq. (5)}$$

Where,

$c = velocity\ of\ light$

$f = frequency\ of\ operation$

We designed antenna by using substrate as standard FR4 with dielectric constant of 4.4 .

3. At 4.73 GHz

$$D = \frac{c/f}{\pi} = 20.2\ mm \qquad \text{eq. (6)}$$

Optimised diameter	17 mm
Number of turn	1.5
Thickness of substrate	1.6 mm
Feed	11,10.7,0
Dimension of boundary	50*50*6

a. Design

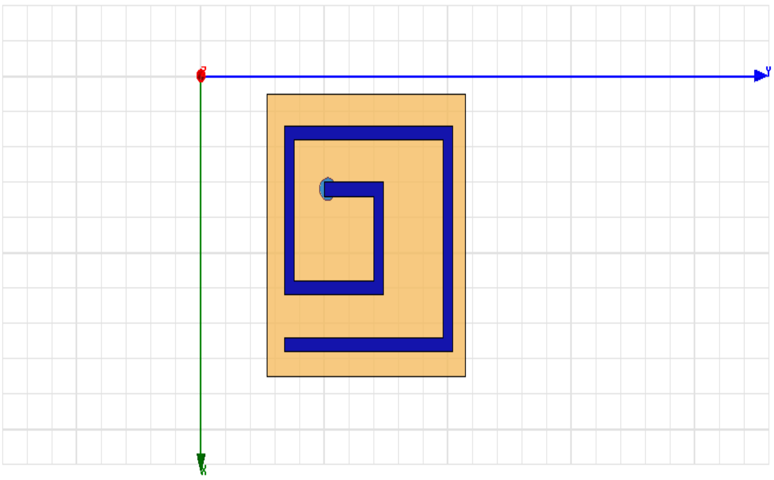

Fig. 5 : Design antenna at 4.73 GHz

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b. Simulations: S11 and Radiation pattern

Fig 6: Simulation Result for S11

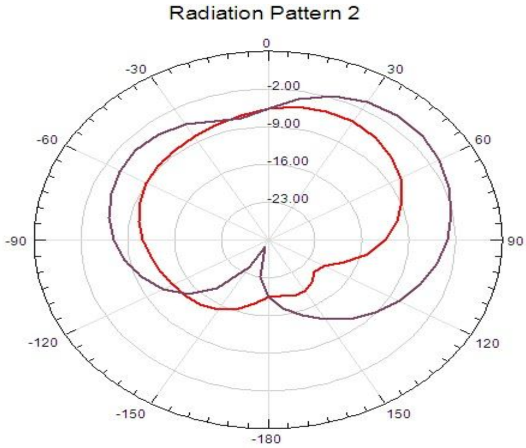

Fig. 7: Radiation Pattern for antenna at 4.73 GHz

4. At 2.63 GHz

$$D = \frac{c/f}{\pi} = 39.3\ mm \qquad \text{eq. (7)}$$

Optimised diameter	38.6 mm
Number of turn	2.5
Thickness of substrate	1.6 mm
Feed	15,15.7,0
Dimension of boundary	60*60*6

a. Design :

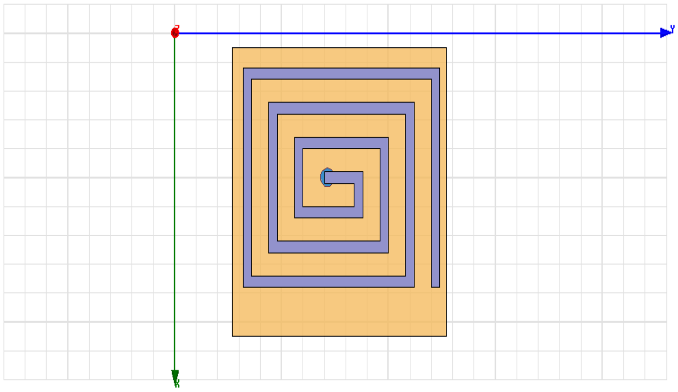

Fig. 8: Design antenna at 2.63 GHz

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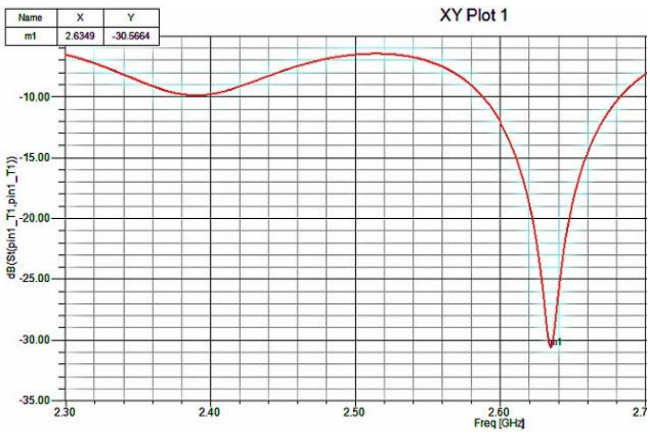

Fig. 9 : Simulation result of S11 for antenna at 2.63GHz

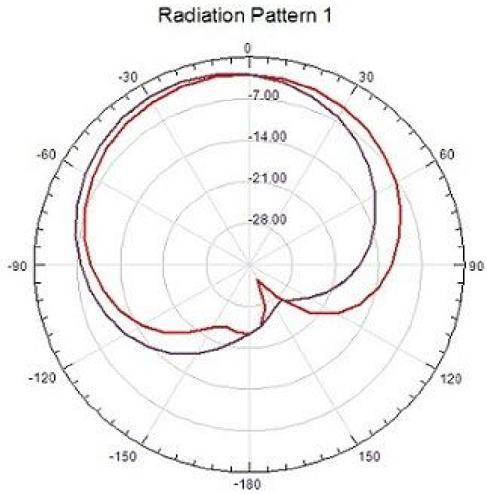

Fig. 10 : Radiation Pattern For the antenna at 2.63 GHz

IV. CONCLUSION

From the simulated result of antennas at a frequencies of 4.73 GHz and 2.43 GHz we observed that the frequency 4.73 GHz is more suitable as we are getting sharp result of -32 dB and as frequency increases, size of antennas and number of turn decreases.

The designed antennas will give the frequency shift on VNA as we change glucose concentration. With the help of these observation we can detect the glucose level in blood. In this way we can have non-invasive glucose monitoring of diabetic patients as here we will not going to make direct contact to the blood.

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BIOGRAPHY

Avikant B Gadawe is Pursuing Master of Engineering in Microwave in the Electronics and Communication Department, AISSMS College of Engineering, Pune University. India. He Received his Bachelor of Engineering

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Degree from Mumbai University in 2012. His Area of Interest is Microwave Communication, Mobile Communication (UMTS , LTE).

Mrs. Vidya Deshmukh received the BE and ME degrees in Electrronics Engineering from Shivaji University in 2004 and 2009 resp. Now she is doing research in biomedical instrumentation in pune University. Currently, she is working as a Assistant professor in AISSMS COE, Pune.