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Non Invasive Blood Glucose Monitoring using Wideband and Narrowband Antenna

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ABSTRACT: Non-invasive measuring techniques for determining biological parameters are more researched with the growth of the biomedical industry. One of the top areas in noninvasive research deals with diabetes. This disease affects millions of people worldwide. Current glucose monitoring techniques requires blood sample. This paper shows the possibility of wideband and narrowband antenna that can be used to monitor the glucose level in the human body non-invasively. This technique is based on relating an antennas resonant frequency to the permittivity and conductivity of blood which is then related to the glucose levels. A simulation model of layered tissue and blood together with an antenna has been created to study the effect of changing glucose levels. It is noted that the antenna's resonant frequency increases with increase in glucose levels. Thewideband and narrowband antenna has been designed to operate over 500 MHz to 6 GHz and 1 to 4 GHz respectively. Good return loss less than -10 dB is obtained in the frequency band of interest. The patient's blood glucose level was measured by a traditional glucose meter. At the same time, the resonant frequency of the antenna measured by the VNA to create he database.

KEYWORDS: Non-Invasive, Glucose Monitoring, Diabetic, Biological tissues, Wideband, Narrowband

I.INTRODUCTION

The number of people with diabetes has risen from 108 million in 1980 to 422 million in 2014 and it will be the 7th leading cause of death till 2030 [1]. Nearly one-third of the population with diabetes goes undiagnosed because of the invasive testing procedure of blood glucose. It is for this reason that a method for noninvasively monitoring glucose levels is highly desirable for patients with diabetes which would allow for more frequent and possibly continuous monitoring without the pain that is associated with current commercial glucose monitors. Microwaves are used in many applications today, ranging from ground mapping to cell phones, to every type of radar in use. Because microwaves are capable of measuring various parameters inside of a closed volume, through harmless penetration, they have become ideal for advancements in biological measurement applications. Applications of microwaves in the medical field include, and are not limited to, microwave tomography scanning systems, breast tumor detection, RF/Microwave ablation for treatment of cardiac arrhythmias, obstructive sleep apnea and benign prostatic hypertrophy, microwave balloon angioplasty, microwave assisted lipoclastic, and electro thermal arthroscopic surgery. [2] This research presents a microwave resonant sensor for use in non-invasively measuring the glucose concentrations in a patient through the thumb.

This paper gives the possibility of monitoring blood glucose levels non-invasively. The method consists of antenna which would change its resonant frequency depending on the dielectric properties of the human body tissues present in its near fields. We have selected the performance of antenna in the near field because the antenna can be kept on the arm or leg of human body. The antenna has been designed such as to meet the standards of Institute of Electrical and Electronics Engineers which concern with acceptable SAR levels that make the devices harmless to human tissues [3].If blood glucose levels changes, it will affect the dielectric properties of blood and it will shift the resonant frequency of an external antenna [4]. This frequency shift in the antenna can be used to characterize blood permittivity, conductivity, and ultimately the blood glucose levels.

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II.THEORITICAL BACKGROUND

The dielectric properties of any material can be obtained from their complex relative permittivity $\hat{\varepsilon}$and it is expressed as [5]

$$\hat{\varepsilon} = \varepsilon' + j\varepsilon'' \quad (1)$$

Where j=$\sqrt{-1}$$\varepsilon'$is the relative permittivity which is a measure of charge displacement and energy stored in the material,and $\varepsilon''$is the out-of-phase loss factor which is a measureof the electrical energy dissipated. In biological materialexternal field induces ionic and displacement currents. Thecorresponding losses with his currents are in proportion withionic conductivityσ_i. The total conductivity is given by

$$\sigma = \sigma_d + \sigma_i (2)$$

And it is related to the loss factor

$$\varepsilon'' = \frac{\sigma}{\varepsilon_o \omega} (3)$$

But in real it is only possible to measure total conductivityσ. The dielectric properties can be determined as ε' and ε'' or $\varepsilon'$and σvalues, as a function of frequency. The dielectric properties of human tissues are characterized in the studies of previous research group [6] which is described by (1). The frequency-dependent relative permittivity and conductivity [6] of dry and wet skin, fat, muscle, and blood has been shown in the Fig. 1 and Fig. 2 respectively.

$$\hat{\varepsilon} = \varepsilon_r + \frac{\sigma(\omega)}{j\omega\varepsilon_o} \quad (4)$$

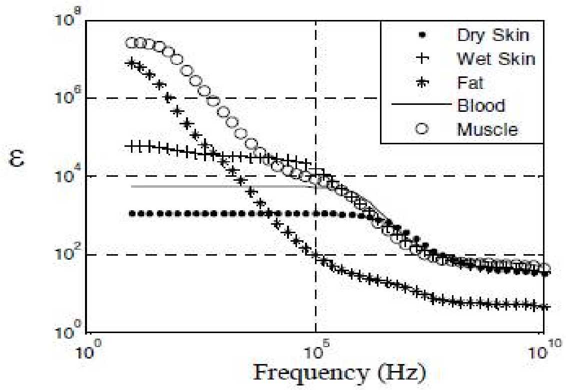

Fig. 1 Biological tissue model with relative permittivity [7]

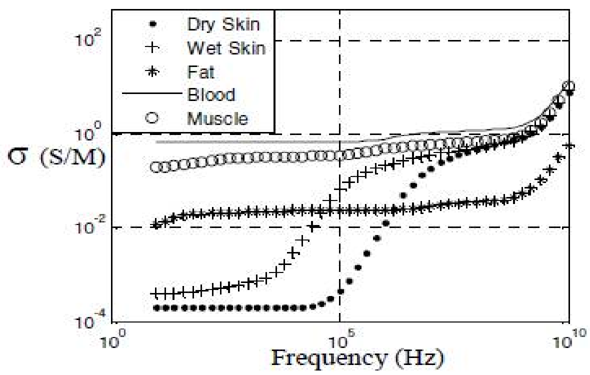

Fig. 2 Biological tissue model with relative conductivity [7]

If the wave is passing through the skin and fat layers at frequency 1 GHz, only 50% of its intensity is transmitted and if the same wave passes through skin and muscle layers it can be transmitted in a 93% of its intensity. Thus, the antenna has to be in touch with more blood i.e. on muscle tissues. But as the layers increased measurement will get more difficult as each layer of tissues has different dielectric and it varies through person to person, gender and age difference etc. So it can be placed on the forearm as only blood vessel has been found in the arm is a branch of the Subclavian Artery, which is very small and surrounded by bone and muscle[7].
Permittivity rises exponentially below 100 MHz This very high permittivity can provide almost complete reflection, so it will be difficult to measure the minor changes in the dielectric properties if tissues. Also at 4 GHz, penetration depth falls to minimum desired level of 1 cm. For our design penetration depth of approximately 1 cm is sufficient as we have

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to observe a blood glucose level and not tumors. So, we can design the antenna in the frequency band of 100 MHz to 4 GHz [8][9].

III.ANTENNA DESIGN

Firstly, we have modified the ultra-wideband antenna [9] to operate 1.3 to 6 GHz and then proposed narrowband antenna to operate 1.2 to 1.4 GHz by removing steps in the design which provided wideband response.
Fig. 3 shows the configuration of the wideband and narrowband antenna.The new antenna is now a narrowband (NB) resonant antenna with a free space resonant frequency of 1.3 GHz.

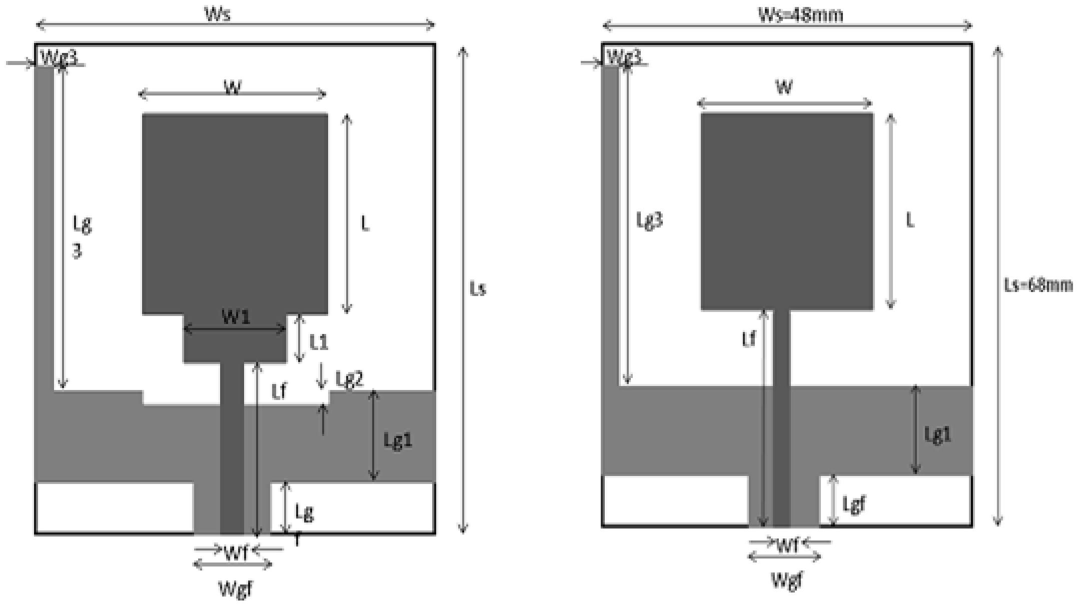

Fig. 3 Configuration of the proposed wideband and narrowband antenna.

The dimensions of the wideband is given in the[11]. The optimal dimensions of the designed narrowband antenna are: Wsub= 48 mm, Lsub = 68 mm, W = 30 mm, L = 30 mm, Wf = 2mm, Lf = 25 mm, Lg1 = 14 mm, Lg2 = 1 mm, Wg3 = 2mm, Lg3 = 42 mm, Wgf = 8 mm, Lgf = 10 mm. It is found that the designed antenna satisfies the requirements in narrow frequency band ranging 1.2 GHz to 1.4 GHz.

IV. RESULTSAND DISCUSSION

Wideband antenna

The wideband antennas with various parameters have been constructed using bandwidth-enhancement technique. The simulated results are obtained using the CST. Fig. 4 shows the simulated and measured return loss curve in free space which is below -10dB over the frequency range 1 GHz to 6GHz.The antenna is resonating for two different frequencies giving large bandwidth and good impedance matching. Simulated return loss is -33.3270 dB at 2.3050 GHz and -29.2365 dB at 3.385 GHz and measured return loss are -42.22 dB at 2.220 GHz and -39.34 dB a 3.63 GHz which is more than accurate.
To check the resonating frequency shift corresponding blood glucose wetookthe samples of different people having different glucose level. For that we kept the thumb of person on the patch of the wideband antenna and saw the response of the antenna on the VNA. We got frequency shift on the VNA but because of the two different resonating frequencies it was difficult to characterize between the responses of frequency shift related to blood glucose level. So we have designed the narrowband antenna which will resonate at one frequency.

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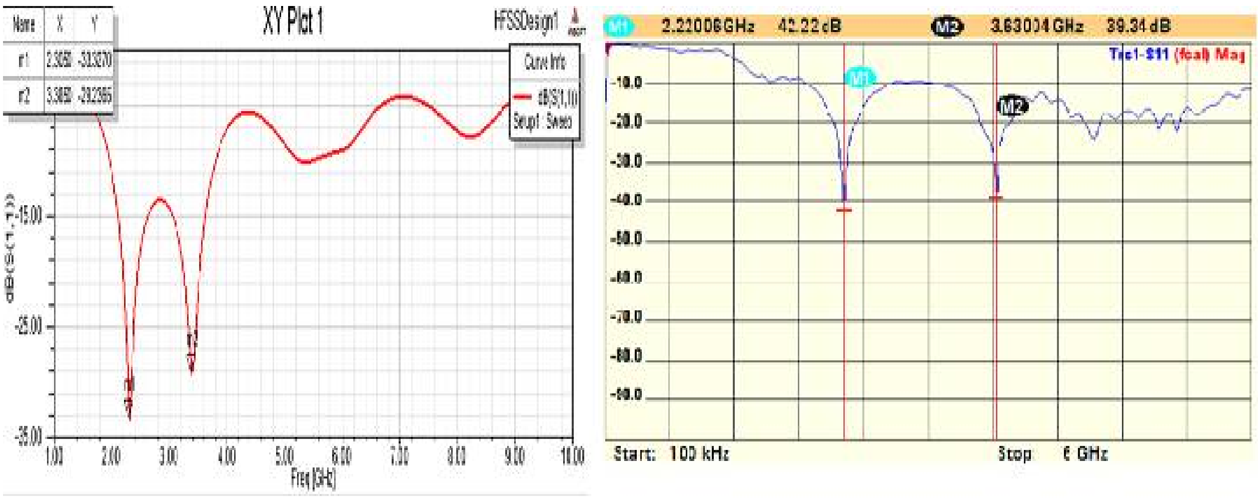

Fig. 4 Simulated and measured Return loss of the proposed wideband antenna.

Narrowband antenna.

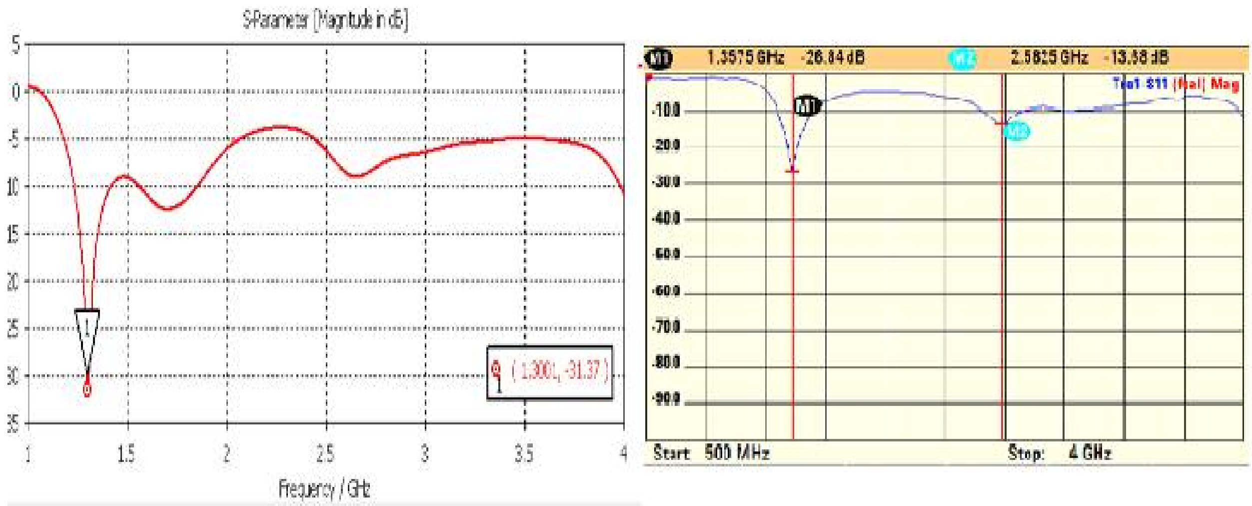

Fig. 5 Simulated and measured Return loss of the proposed narrowband antenna.

Fig. 5 shows the simulated and measured return loss curve of narrowband antenna in free space which is -31.37 dB at 1.30 GHz. The antenna has been designed over the frequency range of 1 GHz to 4GHz. There is good agreement between the simulation and the manufactured antenna. The measured return loss is at 1.3075 GHz which is acceptable. Using narrowband antenna we got better result in frequency shift for same people. We have created the database of frequency shift of narrowband antenna corresponding to glucose level of the body. Using the narrowband antenna it is easy to measure the shift in the resonating frequency related to blood glucose level.

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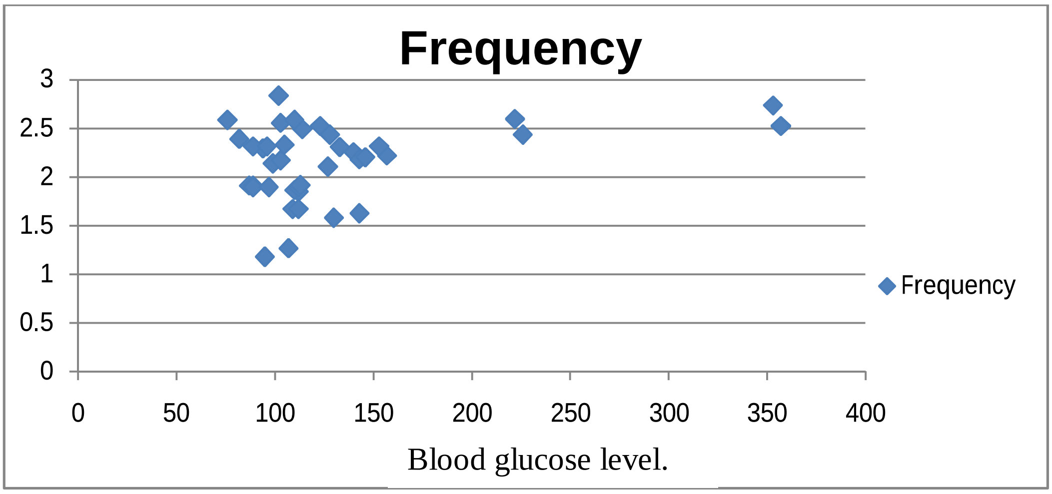

Fig. 6 Plotted graph of frequency shift verses blood glucose level.

Fig. 6 shows the plotted graph is of resonating frequency verses blood glucose level. From the graph we can see that for the higher blood glucose level we are getting higher frequency shift of the antenna and vice versa. The database is created for the different people having different age. It is found that as per the dielectric properties are varies according to gender and age the resonating frequency shift is also varies person to person.

VI.CONCLUSION

Two antennas have been designed to monitor the blood glucose level.These antennas, along with a simulation and hardware model has been created to study the effects of various blood glucose levels.The measured results of the narrowband antenna are better than wideband antenna. Thus narrowband antenna can be used to monitor blood glucose level of the human body frequently. It is resonating at only one frequency i.e. 1.3075 GHz with return loss is -26.84 dB which is more than acceptable value. After taking the samples of different people we have concluded that resonant frequency of the antenna increases with the patient's blood glucose level. This database can be used for further study of the non-invasive blood glucose monitoring technique using narrowband antenna.

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