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Design and Effective Non-Invasive Blood Glucose Measurement System Based on Electromagnetic Technique

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Abstract: A non-intrusive blood glucose detecting a design for a microwave detector is proposed in our presented paper. It empowers effective interpretation and treatment of diabetic patients. Escorted this cast, three different microwave resonator compositions are analyzed through the basic simulation, and the strength and frailties are high point in each exposition. This paper presents a exceedingly responsive and compact size non-intrusive microwave sensors for parallel blood glucose detecting.This present work in this paper is done to manifest the expedience of noninvasive detecting blood glucose degrees. The approach is based on the correlation of the antenna's resonant frequency to the complex permittivity and conductivity of blood and how they are related to the glucose levels. This present project shows more sensitivity, gain and accuracy than others. The picking resonator is an open formation in which a finger of the sufferer is set down, complying with the part of a sample to be identified by the detector. A prototype detector is simulated in the CST Microwave Studio Suite and auspiciously appraised using several glucose concentrations in glucose-blood solution. Simulated results demonstrate 140 kHz/mgdL^{-1} measurement sensitivity, gain was approximately 9.4093357 dBi which are higher in comparison with available microwave sensors in PCB machinery. It also introduces a higher gain than the previous published prototype sensors. This sensor will try to diminish the diabetes rate as well as the mortality rate around the world. It will encourage people for the diabetes test as there is no fear for the finger pricking. The prototype sensor size is 68 mm×48 mm×1.6 mm.

Keywords*: *NIBGM, Microwave Sensor, Narrow Band Antenna, Wide-Band Antenna, Millimeter Wave Antenna, Beam Forming.

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I. INTRODUCTION

In 2014, 382 million individuals (8.3% of the by and large populace) have been influenced by diabetes mellitus and it is accepted that escalated to the year 2035 the digit of individuals with diabetes mellitus will leap up to 592 million. More than 11% of aid investing around the world is in the treatment of diabetes mellitus[1]. Current methods for blood glucose observation are allobtrusive but it is related to an endless number of self-evident bothers. Standard blood glucose checking by diabetes victims would both essentially move forward their calibre of life and diminish the diabetes reception fetched. In this paper, a straightforward microwave detector deployed on microstrip (MS) monopole fix radio wire standards is created for in glass blood glucose degrees measuring [3]The Microstrip fix feeler has been elected here since it is level and indeed inspite of the fact that the show ponder is performed for in vitro tests, as it where the configuration of the detector may well be with little changes utilized for in vivo tests as well. The preparatoryradio wire measurements were calculated with well-known plan rules (agreeing to the chosen term paper. As it were the body apparition models have been changed here for way better exploratory comes about [4].Measuring glucose within the blood by finger, lower arm, or palm pricking is so excruciating. The drops of blood taken by present sensors pollutes the environment It makes a Solid relationship between HbA1c(Glycated Hemoglobin) estimations normal glucose estimations taken over the same time period.Adolescents and children often face difficulties adhering to the intensive invasive treatment. The complex dielectric consistent switches with the nearness and change of blood glucose levels within the water/glucose framework, that's why glucose amount can be measured super easily.[11]Our proposed sensors deliver microwave wavelengths of between 1mm and 1m. Since of these extended wavelengths run, microwaves are more able of entering through different materials [when the electric field passes through the dielectric medium. The medium has an impact on the electric called permittivity].[12]It recognizes

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electromagnetic radiation. Frequency of the waves is expanded here [when the recurrence increments the water atoms in human tissue lineup exceptionally gradually. It causes vitality putting away in tissue].It has ended up appropriate for expanding recurrence in biomedical building like brain imaging, breast cancer discovery, and blood infection discovery. [13]Microwave sensors are nonionizing low-power exposure (Because microwaves around 1GHz penetrate thebody by a number of centimeters and within the NIBGMapplication microwave control levels of as it were 1mW are needed It could be an inactive sensor because it is utilized as a radiometer or scanner since a receiving wire is utilized toidentify and record the microwave energy.[14]

Microwave method is precise, safe, fast as it provides continuous readings at sub sequent intervals.[15] Our microwave sensor is introduced with a high gain (9.4093357 dBi), high sensitivity(140 kHz/mgdL^{-1}) and also with a compact size. It will also emphasize on the strong bonding between the blood glucose concentration and the blood's complex relativity.

➢ *Related Work*

In this project it presents microwave technique.Related work introduces near infrared spectroscopy sensor(NIR Spectroscopy),Mid Infrared Spectroscopy, Raman Spectroscopy,Thermal Emission Spectroscopy,Metabolic heat conformation, Photoacoustic Spectroscopy,Occlusion Spectroscopy,Optical Polarimetry etc.[3].In microwave technique mm wave enters into the victims after that it creates mixture with the blood molecules.it senses if the patient is having high quality of glucose concentration or not.It basically hits the plasma and try to create relation between blood molecules and di electric permittivity.It shows the result of increasing blood glucose concentration with the increasing or decreasing attenuation.Other works do not find the relative permittivity[5]. These are only able to create different kind of disease in the patients.Some of them are invasive,minimally invasive and fews are non invasive.They cannot be able to show tbhe attenuation.They can only create beam and concentration of analyte.Our work shows how to capture the real picture of blood glucose concentration by situating the sensor on the top of the body phantoms.Some creates shock in the blood molecules and damage the skin but ours doesn't take this type of liability.

➢ *Proposed Work*

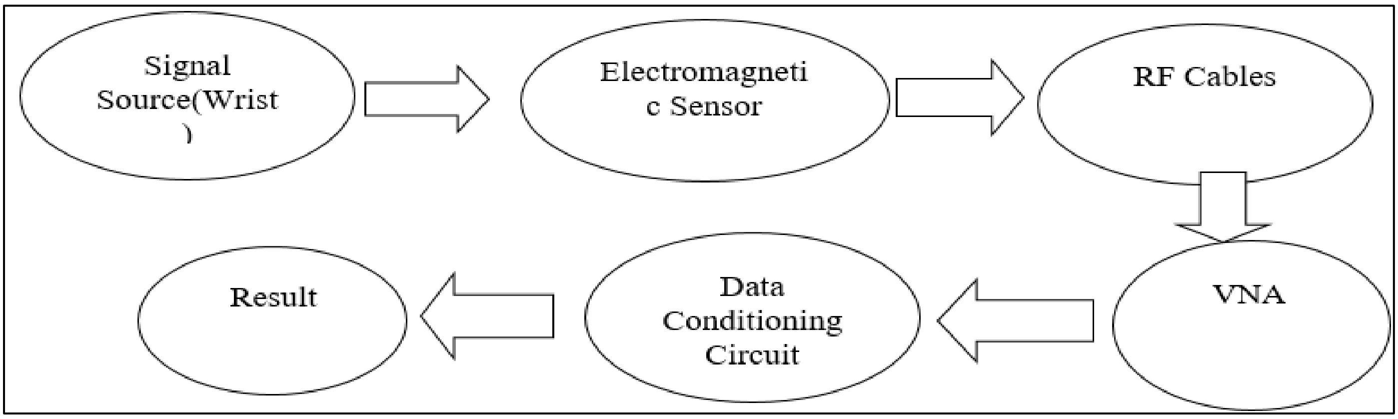

Fig 1 proposed system

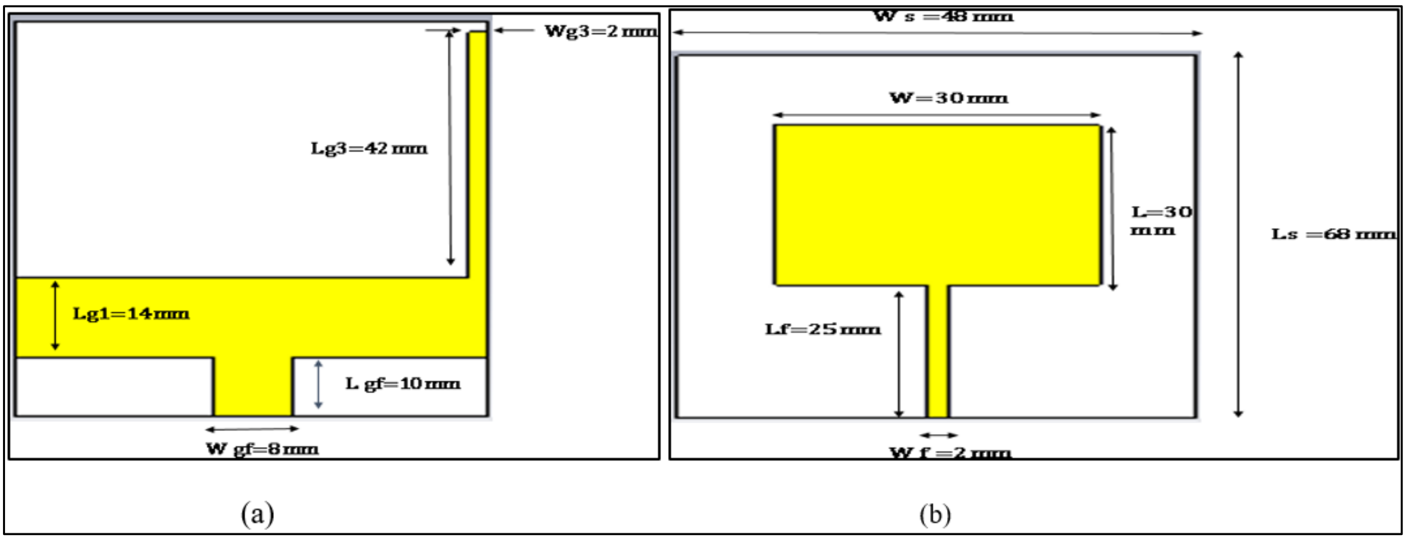

Fig 2 Narrowband Antenna

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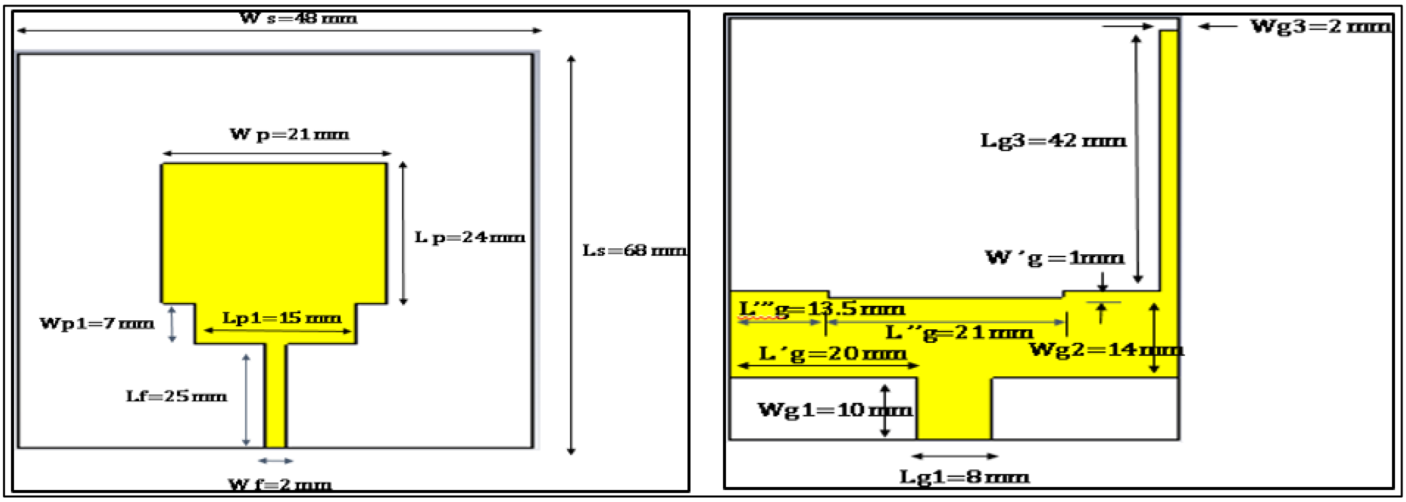

Fig 3 Wideband Antenna

Table 1 Parameters and Values

Parameters	**Value (mm)**
Ws	48
Ls	68
Lf	25
Wf	2
Wp	30
Lp	30
Lg1	8
Wg1	10
Lg2	48
Wg2	14
Lg3	42
Wg3	2
Thickness of the Substrate	1.6
Thickness of the Patch &Feedline	0.035
Thickness of the Ground	0.035

Table 2 Parameters and Values

Parameters	**Value (mm)**
Wp	21
Lp	24
Wp1	7
Lp1	15
L’’g	21
L’’’g	13.5
W’g	1
L’g	20
Thickness of the substrate	1.6
Thickness of the patch & feedline	0.035
Thickness of the ground	0.035

II. METHODOLOGY

The microwave glucose sensing technique/electromagnetictechnique has been strongly used here. It is a non-invasive glucose monitoring technique. The microwave method consists of a dielectric material that is processable with energy in the form of high-frequency electromagnetic waves. The major microwave heating frequencies fall within the 900–2450 MHz range. If frequencies fall under this range, energy will betransferred to material conductive currents which flows withinthe material from the microwave field. As a consequence of this process the ionic component moves. In case frequencies rise higher than the above mentioned range. It gives thepermanent dipole of the molecules .This action potentially overhauls when exposed to a microwave electric field. Energyabsorption then becomes crucial. [8]

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➢ *Microwave Sensor*

In telecommunication, a microstrip radio wire is additionally known as a printed radio wire. It usually means a receiving wire that's defined utilizing photolithographic methods on a printed circuit board (PCB). They are generally utilized at microwave frequencies.[3]

➢ *Working Principle*

Proposed antenna's sensitivity is positively parallelled with both the fill factor and the load quality factor (Q).A high quality factor has been found from our research. In general, thehigh Q value is more favorable to the sensitivity of the sensor as it has the ability to enhance the indigenous electric field strength. At the same time, our Q value also depends on the dielectric loss, transmission loss and parasitic losses of the body phantoms. Advanced micro-fabrication techniques can beused to improve the filler factor. Without ionization and direct contact with biological tissue, the electromagnetic coupling of microwave signal could penetrate hypodermic biological tissueto the blood layer. When blood glucose levels vibrate, the variation in blood and its basal tissues dielectric properties would affect the sensor's reflection-based parameters. They defined a narrative multi-parameter sensitivity factor. It emphasizes to more entirely evaluate the response of the sensorto changes in glucose concentration. The sensitivity factor wasjointly defined by four parameters, naming, input reflection coefficient (S11), resonance frequency (fr), half-power bandwidth (BW) and quality factor (Q). A good corresponding result has been presented between the reflection performance and the D-glucose concentration.[4,5].

III. RESULT ANALYSIS

➢ *Different Algorithms*

$$\mathrm{S(V)} = \mathrm{S\alpha} + \frac{\Delta s}{1+(\mathrm{jvr})^{1-\alpha}} + \frac{\sigma \mathrm{i}}{\mathrm{jvs}^{0}}$$

(w) is the effective permittivity, sa is the relative permittivity, $\boldsymbol{\Delta}$s is the difference between static permittivity and relative permittivity, r is the relaxation time constant, a is the relaxation time and $\boldsymbol{\sigma i}$ is the value for ionic conductivity.

Another mathematical model is given by:

$$u(x) = anX^2 + bnX + cn$$

($\boldsymbol{X}$) is the value of sa,, $r(\boldsymbol{ps})$&$\boldsymbol{\sigma i}$($\boldsymbol{S\ m}$) . $\boldsymbol{X}$ means the glucose concentration. $\boldsymbol{an}$, $\boldsymbol{bn}$ & $\boldsymbol{cn}$ are the co-efficient.

➢ *Linear Regression Model*

$$Y = a + bx$$

Here the Y is the dependent variable (Resonance Frequency) and X is the independent variable (Glucose Concentration)(i.e. it is plotted on the X axis), b is the slope ofthe line and a is the y-intercept. In the figure 6 & 7 this equation has been used. Here the root mean square value is $\mathbf{0.9183}$ & $\mathbf{0.9482}$.

➢ *Quadratic Polynomial Regression Model*

$$y = ax^2 + bx + c$$

In 8,12,13 & 14 the polynomial equations have been introduced. The quadratic formula is a formula that enables one to find the solutions of quadratic equations. The standard form of the quadratic equation is $ax^2 + bx + c$, where a, b and care real numbers and are also known as numeric coefficients. Here the variable 'x' is unknown and we have to find the solution for x. It is called quadratic as here the polynomial degree is 2.

➢ *Observations & Comparisons*

To understand the relation between relative permittivity/effective permittivity and blood glucose levels, a linear regression analysis was done in the CST Microwave Studio Suite software. The glucose concentrations were taken from 0 to 400 mg/dL for the proper investigation of the resonance frequency change during hypoglycemia,hyperglycemia and normoglycemia (one band for the narrowband antenna, dual band for the wideband antenna). Thecontinuous change in the frequencies was found appropriately with the narrowband patch antenna. According to the response relation between the glucose levels and resonance frequencies, resonance frequencies and relative permittivity were plotted in the excel software to investigate.Calculated sensitivity with thenarrowband was higher than the wideband one. It was 140kHz/mgdL^-1 for each 20 mg/dL increment.Estimated resonance frequency changes during hypoglycemia,normoglycemia and hyperglycemia were 2.473GHz,2.491GHz and 2.518GHz at 40mg/dL,120mg/dL & 380mg/dL respectively.

From this study it has been found that the earned realized gain with the narrowband one was higher than the wideband one also than the other previous published sensors. It was approximately 9.4093357 dBi (figure 9).

In the previous published sensor, the sensitivity was foundso low:1.301 GHz, 1.303 GHz, and 1.307 GHz for 72 mg/dL, 95 mg/dL, and 134 mg/dL, respectively. The sensitivity they found was approximately 96 kHz/ mgdL.$^{-1}$ Currently, this microwave biosensor not only possessed a low resonance frequency (1.312 GHz) ,but also exhibited high sensitivity, (140kHz/mgdL^{-1}), linear response(r^2 = 0.9183,extremely low bias (0.0817),0% repeatability, 0% stability & 0% reproducibility. A comparison among the other sensors with the proposedone is given below:

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Table 3 Comparision Among Microwave Sensors

Sensor Type	Frequency(GHz)	SampleType	Sensitivity(per mg/mL)	Error(%)
DiscreteDSRR	4	blood	18.24 kHz	0.5
Resonator	4.8	solution	1600 kHz	3
SRR	4.2	solution	2600 kHz	7.3
TM010 circular SIW	4.4	solution	383 kHz	±0.44
CSRR	2.48	solution	500 kHz	3.3
U-shapedantenna	1.9	solution	1250 kHz	×
Air BridgeType LC Resonator	1.5	solution	117.5 kHz	1.1
Wideband Mono-pole Patch Antenna[**Thiswork**]	2.232	blood	3000 kHz	0.4209
Narrowband Mono-pole Patch Antenna[**This work**]	1.312	blood	14000 kHz	0.0817

➢ *Results*

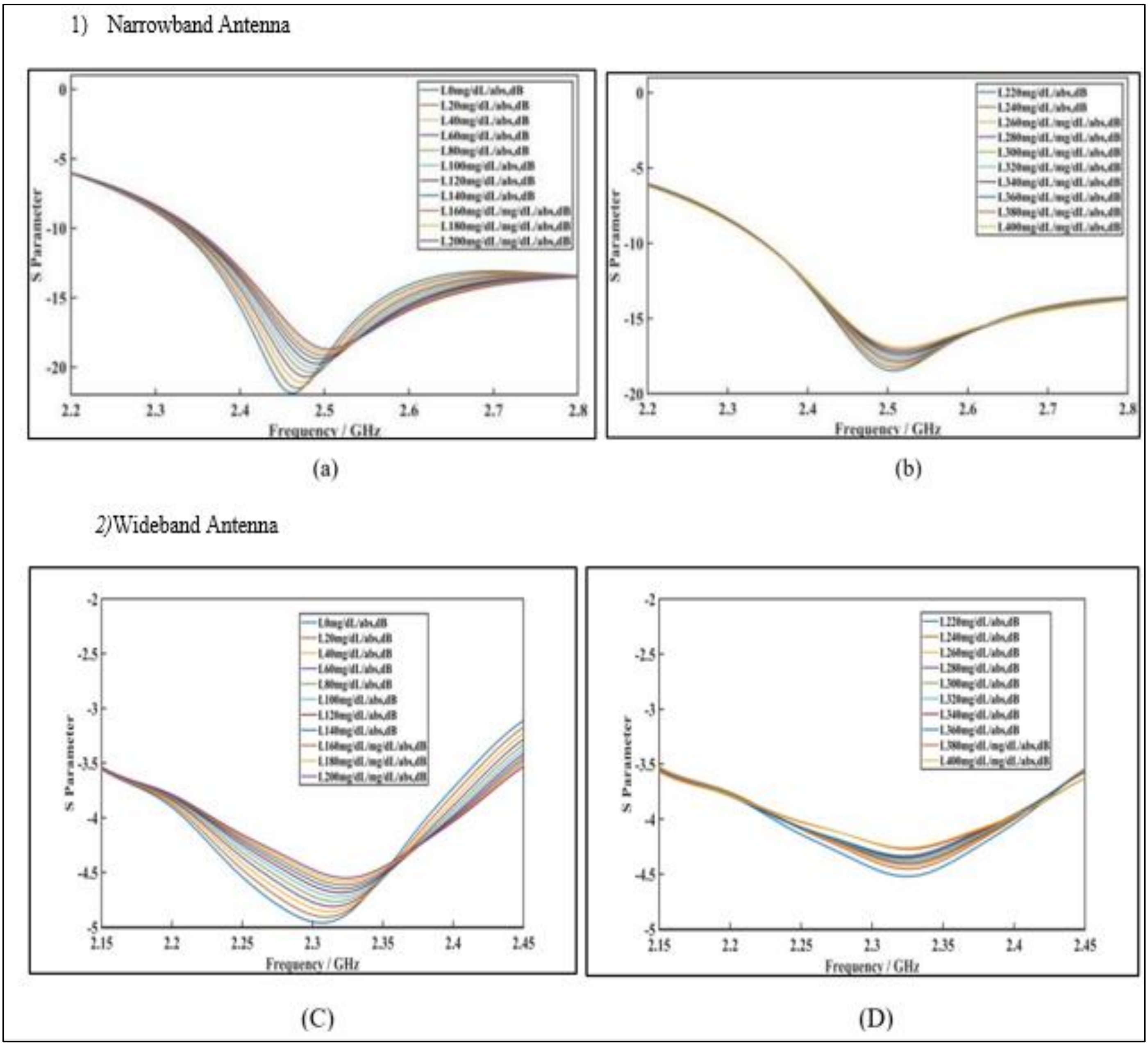

Fig 4 Glucose Concentrations VS Resonance Frequencies (a)&(c) 0 to 200mg/dL (b)&(d) 220 to 400 mg/dL

A proper attenuation was found in the glucose concentration vs resonance frequency related graph.The complex permittivity was changing linearly with the blood glucose concentration.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may069

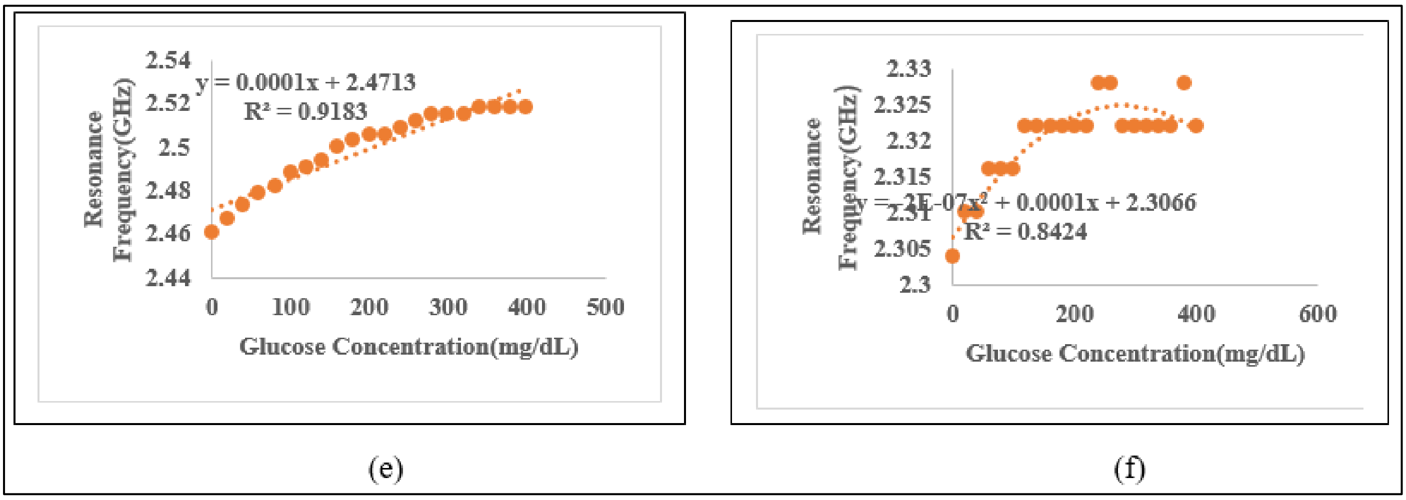

Fig 5 Resonance Frequency VS Glucose Concentration

Resonance frequency was changing linearly(positive) with the increasing blood glucose concentration for both the narrowband antenna and wideband antenna.This indicates that the narrowband sensor will be having of high sensitivity.

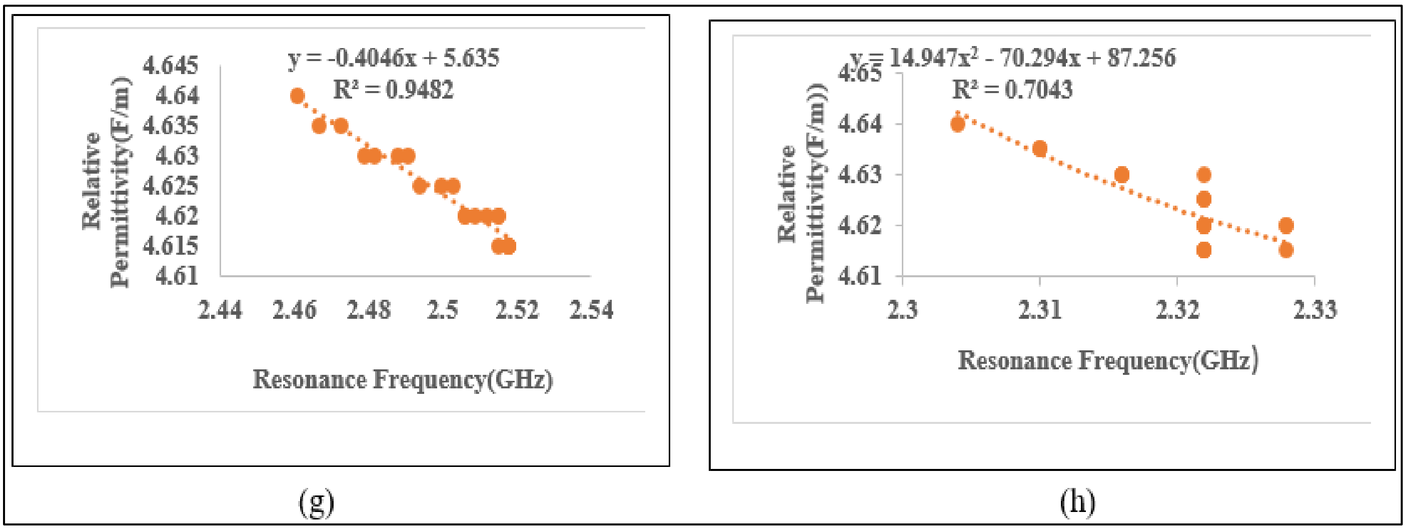

Fig 6 Resonance Frequency VS Relative Permittivity

Relative permittivity was decreasing with time with the increasing resonance frequency of the narrowband patch antenna. That response was non- linear as the blood molecules lines up slowly with the increasing blood glucose concentration.

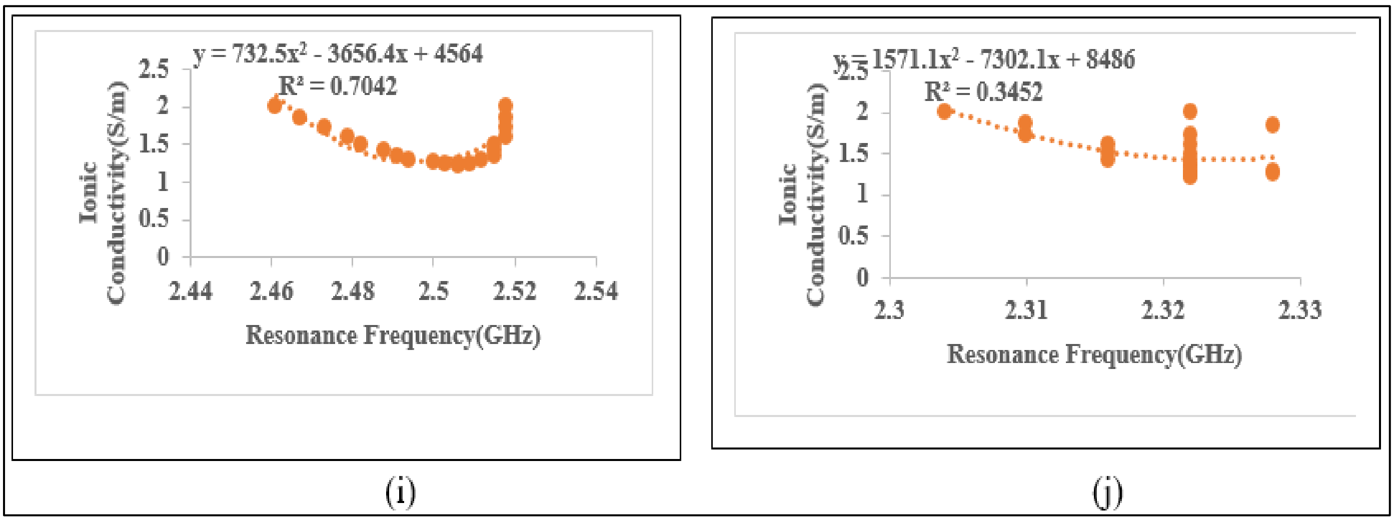

Fig 7 Ionic Conductivity VS Resonance Frequency

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Blood's ionic conductivity was decreasing with the increasing resonance frequency as the declaration in the Cole Cole model due to the increasing temperature of blood.

IV. CONCLUSION

In our presented paper, the glucose-dependent dielectric property changed boundlessly, especially in the microwave region, such that the glucose-dependent changes displayed a significant variation between the frequencies. This indicated that the limited change in blood dielectric properties due to theglucose variations could only be measured by employing a highly sensitive technique. With the narrowband antenna detecting blood glucose was more accurate and sensitive. It was quite an easy, fruitful and continuous process. There we found extremely low bias,0% repeatability,0% reprehensibility and with also 0% stability.It was easier to get proper sensing without any economical hazards. The strong correlation between the microwave and glucose dependent properties was observed very precisely. The higher sensitivity was accreditedto the lower frequency employed. The novelty and advantages of the proposed sensor are highlighted in the high overallsensitivity , the good resolution, the linearity of correlation, the non-invasive, reagent –free, real time operation. A broader band spectroscopy could provide further information from other resonance modes. It is expected however, that tissue penetration (hence, sensitivity) should decrease for higher frequencies, due to the loss in the tissues.

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