

Design and Analysis of U slot Microstrip Patch Antenna Sensing for biomedical application

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Abstract This paper describe a modeling of a blood glucose sensor using HFSS and COMSOL Multiphysics. Si will be material for biomedical application, but for long term it is required to need of biocompatible device material. A continuous glucose monitoring employing RF signal using SiC is proposed. Initially antenna is fabricate multiband U slotted microstrip patch antenna Si substrate with Ti/Au metallization for medical implantable application with frequency range between 1.8 GHz to 4.76 GHz. It is based on shift of resonance frequency as a function of glucose concentration, which itself change permittivity and conductivity

Glucose concentration in a diabetic patient may vary between 30mg/dl to 400mg/dl, sodium(310-330 mg/dl), chloride (337-372 mg/dl) slot antenna can be used in biomedical application such as hyperthermia tumore treatment, drug delivery system. The antenna is designed to radiate into the tissue and the emphasis was in near field, SAR, and penetration depth. An antenna-based biocompatible implantable sensor for continuous glucose monitoring is proposed using a SiC substrate with Ti/Au metallization. The long-termgoal is to develop an implantable antenna sensor operational for extended periods of timeusing the proven biocompatible material SiC for continuous glucose monitoring

Keywords — U slot Microstrip patch antenna, sugar, Radiation Pattern, reflection coefficient, dielectric properties

I. Introduction

Diabetes a medical condition in which the body is unable to control the level of sugar in the blood. Current reports indicate approximately 5-7% of the world's population is affected by this widespread disease and it is one of the leading causes of morbidity and mortality.

Antennas have long been used in many medical applications including, microwave imaging, medical implants, drug delivery, cancer detection, hyperthermia treatments, and wireless wellness monitoring. Microwave measurement technique are used for determination of dry substances in sugar industry typically have frequency of approximately 2.5 GHz[10]. Microwave measurement instrument, microwave from a transmitter irradiate wave and detected by a receiver, its acts as a resonator or scattering sensor. Microwave measurement system consist of two component 1. Evaluation unit with high digital processor and microwave generation with DSP technology. 2. Microwave sensors in the form of an insertion probe, pipe probe or with patch antenna. Most of people . The change level of glucose concentration from normoglycemia to hypoglycemia shift resonance frequency , which affect dielectric property of blood , muscle, fat and skin in which antenna and biomedical devices are located. [4]. Fasting

blood glucose test are painful method.[5]. Biosensor technology for implantable medical devices(for heart and brain) which need to transmit diagnostic information. FCC safety issue related to implantable device in terms of maximum available power at receiver location must be obtain. This limit protect human tissue from being damaged from exposed radiation. Designing antenna that would operate inside the human body is a challenging task. Factor such as human tissue dielectric property, conductivity, impedance matching, antenna size , SAR requirement and biocompatibility play an important role in the design

Silicon carbide as a biocompatible Material.: Semiinsulating Silicon Carbide(SiC) is substrate for patch antenna with gold patches. Future work, a possibility of utilizing highly conductive (Heavily doped) SiCepitaxial layer which has potential to replace existing antenna.Computer simulation using HFSS were conducted . Radiation performance of SiC based antenna was as good as FR4 and Roger. Corrosion resistance under normal biological condition(Neutral,pH and body temp) is excellent.

II. ANTENNA DESIGN

The bands are obtained for the center frequencies 1.84 GHz, 2.4 GHz, 3.6 GHz, 3.98 GHz, 4.22 GHz and 4.76

GHz. The proposed sensor is u slot shape with dimension 37.2x48x3 as shown in Fig 1.A 4H-SiC semi insulating substrate is as it has no microwave loss this yielding the maximum possible gain[9]

By using HFSS and IE3D different shape of U slot patch antenna is simulated. The desired reflection coefficient by each antenna is -10 dB. At 2.45 GHz as shown in fig 4 &5 Other factor needs to be consider i.e. dimension of patch, shape of patch and location of feed point. The simulated return loss and radiation patterns for each of the center frequencies are plotted. Proposed antenna structure is a cost effective solution since it comprises a commonly used Roger substrate or SiC substrate with Ti/Au metallization with size 37.2x48x3 mm³ and it work over 1.8 GHz to 4.6GHz with VSWR <2. A prototype of the designed antenna was fabricated and tested for performance verification of proposed switch and antenna Characteristic of proposed antenna like group delay, radiation pattern, return loss and VSWR have been measured and presented along with simulated result.

For the dominant TM₀₁₀ mode, resonant frequency of Microstrip patch antenna is a function of its length usually given by

$$(fr_{010}) = \frac{1}{2L\sqrt{\epsilon_r\sqrt{\mu_0\epsilon_0}}} = \frac{\theta_0}{2L\sqrt{\epsilon_r}} \quad (1)$$

Resonant frequency is dependent upon on the relative dielectric constant, as well as conductivity of the material surrounding material. The Ansys HFSS and COMSOL software is used for SiC antenna design and simulation.

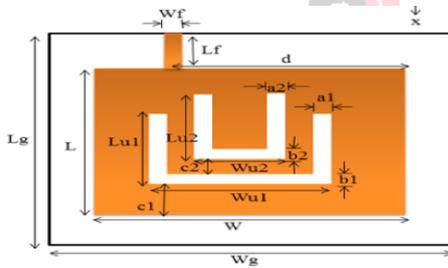


FIGURE 1.Geometry of U slot antenna



FIGURE 2:Fabricate prototype U slot antenna

The conductivity of SiC is depends on the doping concentration of the materials

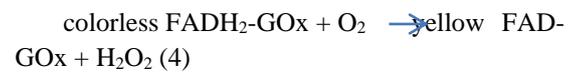
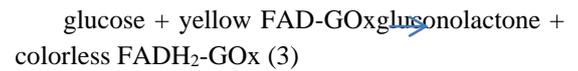
$$\sigma = q\mu N \quad (2)$$

Where σ is the conductivity in S/m, q is the electric charge in Coulombs, μ is the mobility in cm²/V-s and N is the doping concentration in cm⁻³.

III AMPERIMETRIC SESNOR

Electrochemical glucose sensors use amperometric methods to measure the concentration of glucose in a sample. An applied voltage causes oxidation of glucose and current due to this oxidation is measured at electrode. In this model three species are modeled :active redox coupled ferricyanide and ferrocyanide anions as well as concentration of the glucose.

Glucose Sensing



Most sensors use enzyme called glucose oxidase (GO)

- Most sensors are constructed on electrodes, and use a mediator to carry electrons from enzyme to GO Fc = mediator, ferrocene, an iron complex

These reactions occur in the sensor:

The rate of reaction(mol/m³) is given by a Michaelis-Menten rate la as

$$R = \frac{c_{\text{glucose}}V_{\text{max}}}{(1+K_m c_{\text{glucose}})} \quad (5)$$

FR4 substrate U slot 20mm X X29mmx3mm at 2.4 to 4.6GHz6

Here parameter Vmax is max rate of enzyme-catalyzed reaction. Km is Michaelis-Menten constant[13]

The current density for electrochemical reaction is given by Butler-volmer equation for an oxidization

$$i_{oc} = nFk_o \left(c_{\text{ferri}} \exp\left(\frac{(n-a)F\eta}{RT}\right) - \left(c_{\text{ferr}} \exp\left(\frac{(a)F\eta}{RT}\right) \right) \right) \quad (6)$$

The sensor gives a linear response over a suitable range of concentrations. The Electroanalysis interface is used to couple the chemical species transport to the electrolysis at the working and counter electrodes, and the glucose is oxidized by the glucose oxidase enzyme in solution according to Michaelis-Menten kinetics.

Total current recorded at the electrode can be extracted by integrating the local current density across the electrode surface.

$$I_{c1} = \int_S i_{oc} dA \quad (7)$$

As seen from figures,3b the dielectric constant and conductivity decreases with the glucose concentration in

the sample increases. Concentration of the ferrocyanide redox mediator species when a steady-state current is drawn in the sensor.

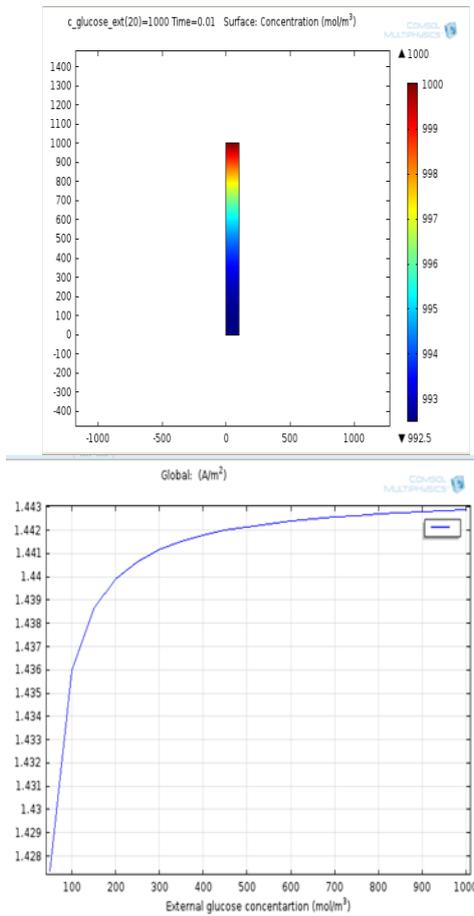


Figure 3: A)ferrocynide concentration for a n external glucose concentration of 1 mol/m³B)Current density versus glucose concentration

Fig 3 b shows Current against glucose concentration for a working sensor (blue line), demonstrating that the response of the idealized sensor is linear in the studied range of glucose concentrations. Enzyme to be a factor of 10 slower at oxidizing the glucose itself, by lowering the coefficient for the enzyme kinetics. Then, the linear response fails over the same concentration range[11].

IV Si/SiC Based Antenna Simulation and Design

The simulation of antenna design would work on SiC substrate (Ti/Au as metal patch) having $\epsilon_r = 10$.

The response of the antenna in term of resonance frequency and return loss is as shown in figure 4,5

Here antenna electrode-heavily doped SiC top layer. A prototype of the designed antenna was fabricated (Fig. 1,2)

In this paper, the simple strip line fed multiband antenna integrated with RF switch is designed, two U- slots are introduced one by one and optimized so that to provide multiband response. Since, edge feeding is used, the impedance matching is provided by varying the feed

position along the y- axis. Thus, the antenna exhibits good reflection response for the 6 different bands, exhibiting the reflection coefficient to be less than -10 dB[3]

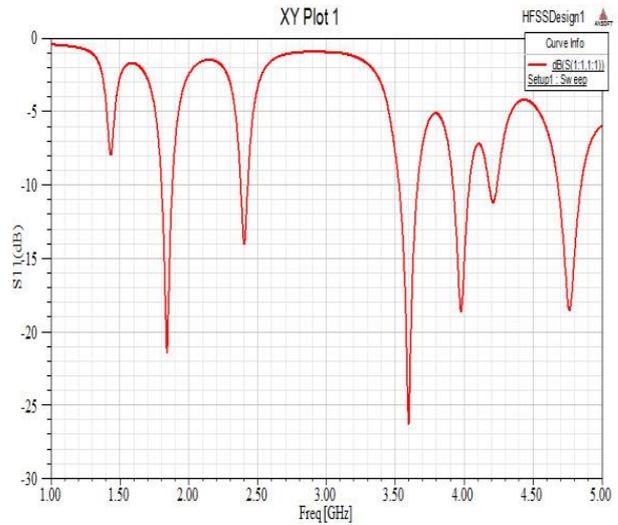


FIGURE 4 : Simulated Return Loss of the antenna SiC

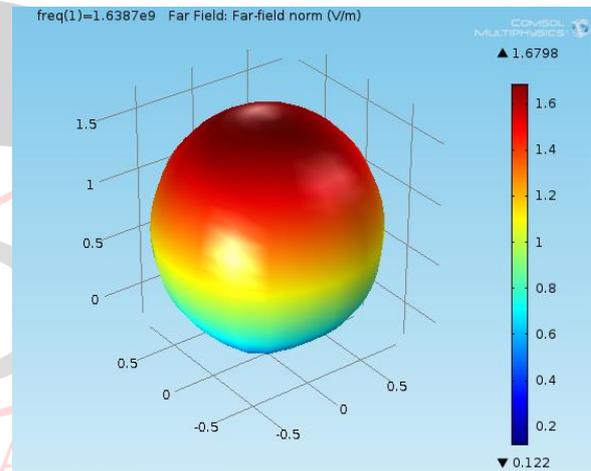
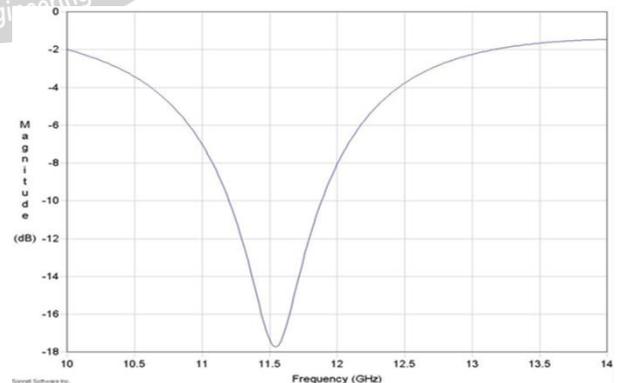


FIGURE 5. Simulated radiation pattern measured at freq1.84 GHz



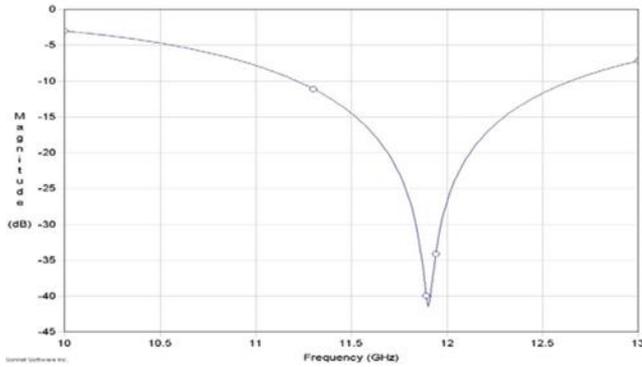


Figure 6 a) (SiC Based Ti/Au Antenna –Resonance frequency shift Vs Permittivity b) Resonance frequency shift due to change in permittivity The resonance frequency shifted according to the glucose levels. [Dr.ErdemTopsakal, Mississippi State University]

Comparison of antenna

Antenna	Dimension [mm]	ϵ_r	σ	Gain(dBi)
Spiral PIFA	17x17x4	49.6	0.51	-30.6
Cavity Slot	1.6x4x2.8	35	1.6	-22
U slot antenna	5x7x1	10	0.	-15

Radiation pattern: The designed antenna is radiating all its power in one direction and therefore the optimized antenna has result with the effective radiation pattern and therefore the side lobes or nulls in the pattern has been minimized and the better directivity is achieved. The radiation pattern for the proposed system antenna figure has angles in phi and theta. The antenna is radiated from the angle of 45 degrees and has the magnitude of 7.108dB.

V Result

In this study, we reported an in vitro study performance Si and SiC substrate Ti/Au metallization glucose sensor designed with frequency from 2.4, GHz to 10 GHz has simulated .A n implantable antenna operating from 1.8 GHz to 4.6 GHz multiband intended for biomedical devices. At 3.67GHz, the antenna has a gain of 5.64dB and return losses of -22.60dB that states it can be used for practical applications like the monitoring of glucose levels.. The measured antenna had dimension 29mm X 20mmx3mm at 2.4 GHz to 4.6 GHz as well as 5 x7 mm at 10 GHz has been simulated

The microstrip patch antennas are designed by using HFSS and fabricated by using FR4 substrate. The antennas are simulated by SiCsubstrate , in order to obtain the optimum dimension for this work

The antenna sensor was able to determine glucose concentration by observing a well defining shift in the resonance frequency. Ferrocyanide is generated in the solution between electrode and enzyme –catalyzed oxidation of glucose. It react at the anode in the center of the unit cell to provide the working electrode current used to measure the concentration of glucose.

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REFERENCES

- [1] ErdemTopsakal ,TutkuKaracolak , and Elaine C. Moreland ,”Glucose-Dependent Dielectric Properties of Blood Plasma” IEEE 2011
- [2] C. Bircan and S. A. Barringer. “Salt–Starch Interactions as Evidenced by Viscosity and Dielectric Property Measurements,” Journal of Food Sciences, 63, pp. 983-985, 1988
- [3] Ali Daliri, Amir Galehdar, Sabu John, Wayne S. T. Rowe and Kamran Ghorbani.“Circular Microstrip Patch Antenna Strain Sensor for Wireless Structural Health Monitoring.” Proceedings of the World Congress on Engineering 2010 Vol II, WCE 2010, June 30 - July 2, 2010, London, U.K.
- [4] N. Z. Yahaya and Z. Abbas.“Determination of Moisture Content of Hevea Rubber Latex Using a Microstrip Patch Antenna, PIERS Proceedings, pp.1290-1293, 2012.
- [5] Chung JH, Verma LR, “Measurement of rice moisture during drying using resistance-type sensors,” American Society of Agricultural Engineers, 1991, 7(5): 630-635.
- [6] Thomasson JA, “Cotton moisture measurement with a black-and-white video camera,” American Society of Agricultural Engineers, 1995, 11(3): 371-375.
- [7] Jayanthy T, and Sankaranarayanan P., Measurement of dry rubber content in latex using microwave technique,” Measurement Science Review 5: 3, 2005.
- [8] Theory of Electrochemical Kinetics based onNonequilibrium ThermodynamicsMartin Z. Bazantmoisture content in oil palm fruits.”EurPhys J-Appl Phys. 40: 207-210, 2007.
- [9] Ghretli M, Khalid K, Grozescu I, Sahri M and Abbas Z, “Dual frequency microwave moisture sensor based on circular microstrip antenna,” IEEE Sensors Journal 7 (12): 1749-1756, 2007.
- [10] E.M. Cheng*,et “Development of Microstrip Patch Antenna Sensing System for Salinity and Sugar Detection in Water”,International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol:14 No:05 31
- [11] Peter H. Siegel,” Compact Non-Invasive Millimeter-Wave Glucose Sensor of two varieties of corn (Sc 704 and Dc 370),” Aust J AgricEng 1(5): 170-178, 2010