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NON-INVASIVE IR-BASED HUMAN BLOOD GLUCOSE MEASUREMENT

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ABSTRACT : Diabetes has become a significant health concern for people worldwide. It is a metabolic disorder characterized by elevated blood sugar levels. Traditionally, blood glucose levels were measured using glucometers and blood tests, which required invasive blood pricking. Although minimally invasive continuous glucose monitoring devices have been introduced in recent times, they still have limitations, such as painful insertion, high cost, and discomfort. As a result, this project focuses on a non-invasive approach to measuring blood glucose concentration using a microwave-based bio-sensor. The sensor design incorporates four cells of an Octal Shaped Complementary Split Ring Resonator (OSCSRR) on a Rogers RO4003C substrate. The key concept is to place a finger on the sensing elements and observe the Reflection-Coefficient S11 S-Parameter with magnitude concentration for the blood layer. By exploring this non-invasive approach, this project aims to develop a blood glucose detection kit that people with diabetes can use, providing a potentially more comfortable and effective way to monitor blood glucose levels.

KEYWORDS: Glucose monitoring; mid-infrared probe; fuzzy logic.

I.INTRODUCTION

Diabetes mellitus is an intractable chronic disease in which abnormal glucose metabolism occurs due to a partial or complete deficiency of insulin secreted by the pan creas. Uncontrolled blood sugar levels or glycemia can lead to health complications for patients. In fact, blood sugar levels in healthy people change before and after a meal. Generally, pre-meal glucose blood sugar concentration is 70–100 mg/dl. Diabetes is diagnosed when blood glucose levels are approximately 126 mg/dL (7 mmol/L) during fasting and 200 mg/dL2hafter eating. Chronic hypoglycemia, a drop in blood sugar, can induce diabetic coma if it drops too quickly. This can lead to brain damage and even death. In order to prevent and avoid the complications associated with the change in the amount of glucose in the blood and the proper monitoring of the development of the dis-ease by health care personnel in order to control the disease effectively, patients need to monitor their blood sugar regularly. In reality, the majority of patients cannot feel the change in their glucose level unless, it is very high or very low, without taking a sample. According to the American Diabetes Association, patients with type 1 undergoing intense therapy should test their blood sugar 4–5 times a day, but those with type 2 require only two measurements per day. Unfortunately, the blood glucose monitoring devices that are available in the market only offer a limited number of measurements per day, while a diabetic needs continuous real-time glucose monitoring (CGM) to be informed in case of severe hyperglycaemia or hypoglycaemia. This is especially true for insulin-dependent patients. In addition to that, conventional glucometers require patients to prick their finger each time a measurement is taken to obtain the amount of blood needed for the sensor to work. These pricks are so painful and affect the fingers in the long term to such a degree that some people reduce the number of measures just to avoid pain. Therefore, it is clear that an ideal CGM device should be non-invasive, portable, accurate, inexpensive, easy to use, and not require extensive calibration. Mid-infrared (IR) radiation, with a wavelength range from 2500 nm to 25 m, offers the highest selectivity for low-concentration compounds in complex organic media. In principle, most approaches using mid-infrared rely on the strong absorption of water in living tissue. Diffuse reflectance spectroscopy can access glucose molecules from the epidermal layer, whereas photothermal detectors can provide information from depths of 20–100 m. A number of portable non-invasive blood glucose monitors have been developed that have demonstrated excellent blood glucose measurement and monitoring capabilities. Most non-invasive devices require frequent calibration, but current research that works on developing non-invasive devices is finding that the calibration process, its duration, complexity, and effectiveness are detrimental and not periodically possible. In recent years, great efforts have been made to reduce or even eliminate the frequency of calibration. This paper presents a fuzzy logic-based calibration system to map the output voltage of IR sensor and Arduino controller into reliable glucose concentration using Clarke error grid. In this study, the fuzzy logic is responsible about estimating the error tolerance using the output voltage from Arduino controller and the estimated glucose concentration.

II. RELATED WORK

Various optical methods, such as diffuse reflectance spectroscopy, Raman spectroscopy, and photoacoustic spectroscopy, have been explored for non-invasive glucose monitoring. These techniques leverage different aspects of IR light interaction with biological tissues to measure glucose concentrations. SPR sensors use IR light to excite surface plasmons, which are sensitive to changes in the refractive index of the surrounding medium. By functionalizing the sensor surface with glucose-binding molecules, SPR sensors can detect glucose concentrations in biological samples. Fiber optic-based techniques offer advantages such as flexibility, miniaturization, and remote sensing capabilities. Researchers have developed IR fiber optic sensors that can be inserted into tissues or placed on the skin to measure glucose levels without invasive procedures. Microfluidic platforms integrated with IR-based detection systems enable the precise control of sample volumes and enhance sensitivity. These devices can analyze small volumes of biological fluids, making them suitable for non-invasive glucose monitoring applications. Advances in smartphone technology have led to the development of IR-based glucose monitoring systems that can be connected to mobile devices. These systems typically utilize smartphone cameras and dedicated apps to analyze IR spectra and estimate glucose concentrations. Combining IR-based measurements with other imaging modalities, such as ultrasound or thermal imaging, allows for comprehensive characterization of tissue properties and glucose distribution. Multimodal approaches enhance the accuracy and reliability of non-invasive glucose monitoring. Non-invasive IR-based CGM systems aim to provide continuous glucose monitoring without the need for frequent fingerstick measurements. These systems typically employ wearable sensors that continuously monitor glucose levels and transmit data to external devices for analysis. Standardization efforts and validation studies are essential for ensuring the accuracy, reliability, and safety of IR-based glucose monitoring devices. These studies involve comparing non-invasive measurements with reference methods and assessing device performance in diverse populations and clinical settings. By advancing research in these areas, scientists strive to develop non-invasive IR-based human blood glucose measurement technologies that are accurate, reliable,

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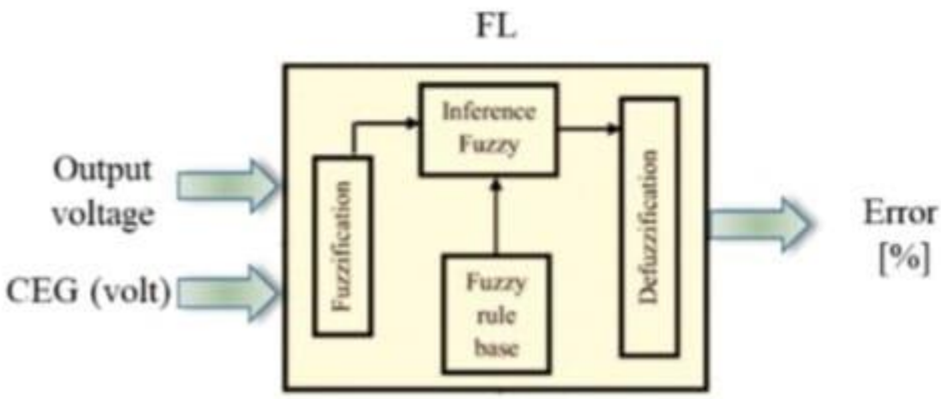
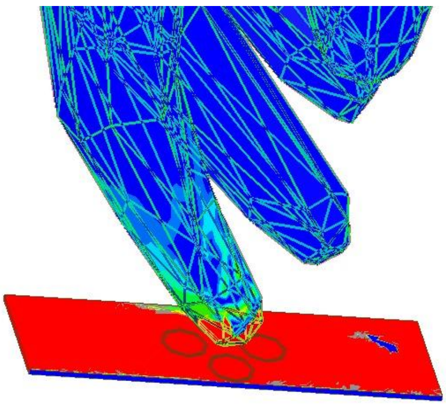
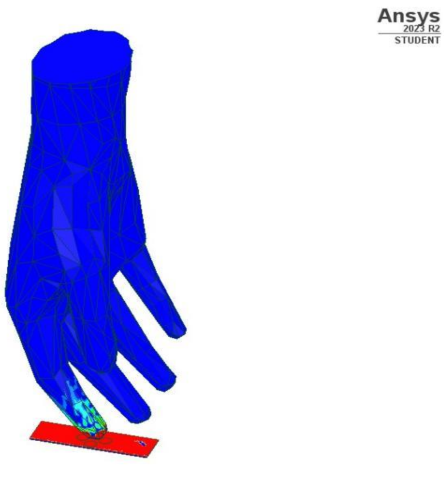
and accessible for individuals with diabetes, ultimately improving disease management and quality of life.

III. **PROPOSED ALGORITHM**

A proposed algorithm for non-invasive IR-based human blood glucose measurement involves preprocessing raw IR spectra to remove noise and artifacts, followed by feature extraction to capture glucose-related spectral characteristics. Machine learning models, such as support vector machines or artificial neural networks, are then trained on labeled spectral data to predict glucose levels. Real-time glucose estimation is achieved by applying the trained model to new spectral data. Continuous refinement and validation of the algorithm are essential for improving accuracy and robustness in clinical applications.



IV. **SIMULATION RESULTS**

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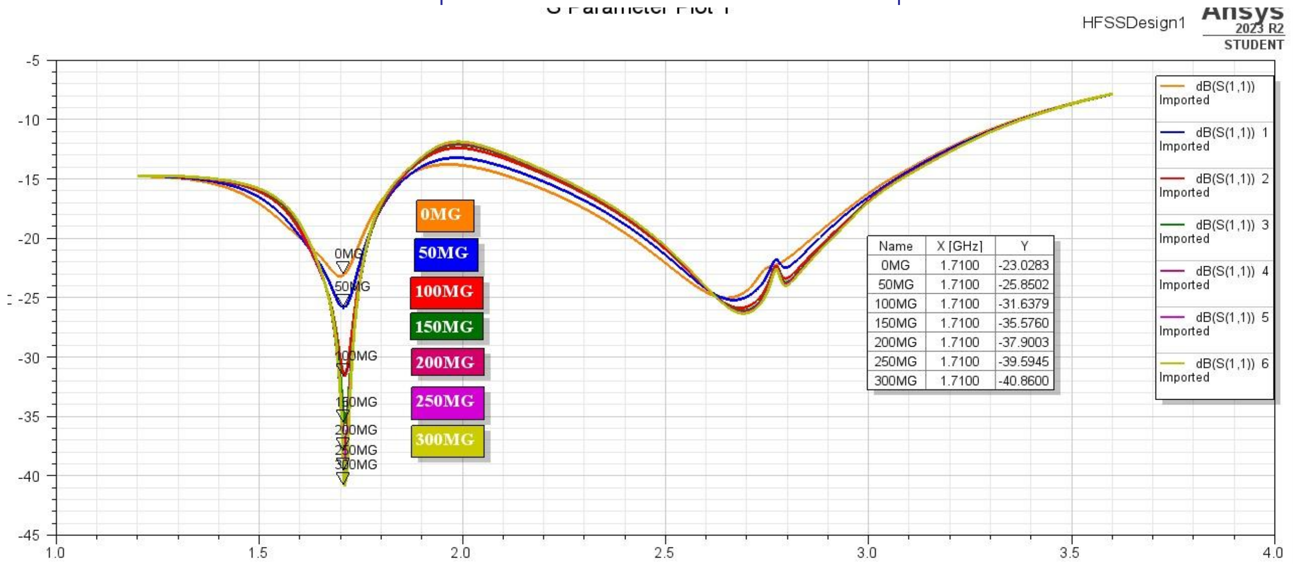

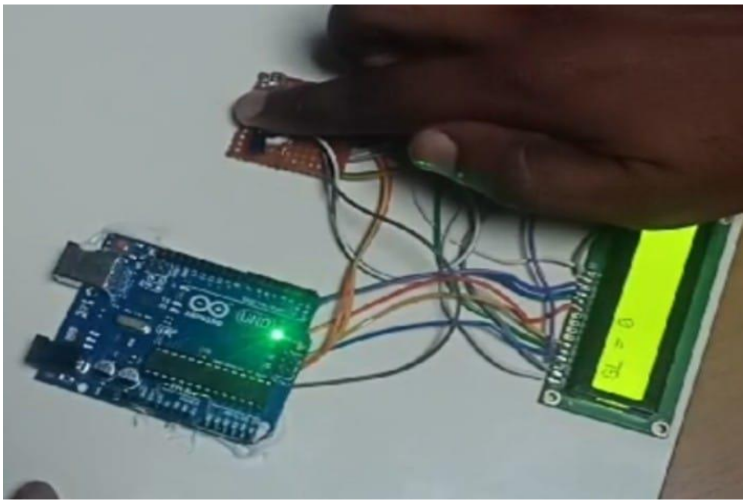

V. CONCLUSION AND FUTURE WORK

In conclusion, non-invasive IR-based human blood glucose measurement shows significant potential for revolutionizing diabetes management. Future work should focus on refining sensor technologies for improved accuracy, miniaturization, and integration into wearable devices. Standardization efforts are crucial to ensure reliability and consistency across different measurement platforms. Additionally, continued research is needed to validate these techniques in diverse populations and clinical settings, addressing challenges such as interferences and biocompatibility. Advancements in machine learning algorithms and data analysis techniques will further enhance the performance of non-invasive glucose

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monitoring systems. Ultimately, these efforts aim to provide individuals with diabetes with convenient, reliable, and continuous glucose monitoring solutions.

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