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ISM Band 2.4 GHz Wearable Textile Antenna for Glucose Level Monitoring

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ABSTRACT- Wearable technology has recently attracted much interest for various uses. An essential component of the wearable system is the wearable antenna. Textile and non-textile materials have both been used to create wearable antennas. Textile antennas are very useful and widely used nowadays, particularly in body-worn applications monitoring health parameters. Fabricated using microstrip technology, textile antennas have various benefits, including small size, lightweight, simple fabrication, and ease of wear. In this study, a microstrip antenna is created utilizing a substrate made of jeans. It works between 2.4 to 2.5 GHz in the ISM (industrial, scientific, and medical) band. High-frequency structure simulator (HFSS) software was used to simulate two antennas, one with an incomplete and the other with a complete ground plane. Wearable antennas can protect the body from the impacts of RF radiation by utilizing the entire ground plane principle. Results from a vector network analyzer were obtained for the fabricated antenna (VNA). This antenna's main function is to track blood glucose levels. Blood's dielectric characteristics change when blood sugar levels fluctuate, affecting the antenna's output frequency. There are two ways to monitor glucose levels. One method requires placing a finger on an antenna patch, while the other involves fixing an antenna to a person's arm and detecting the output frequency fluctuation. The antenna's resonant frequency raises in reaction to increased blood glucose levels. Therefore, these textile antennas are a great choice for non-blood sample monitoring of blood glucose levels.

Keywords: Textile, Jeans, Simulate, Ground plane, Glucose level, Monitoring.

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1. INTRODUCTION

Much interest has grown recently in elastic or non-elastic wearable devices for different applications. The creation of implanted medical devices shows wearable technology advancements [1,2]. As the component in charge of obtaining and sending the signal between the wearable system and the surrounding apparatus, the wearable antenna is a crucial part of the wearable network [3].

The body is a lossy medium for electromagnetic radiation, and a significant amount of this radiation is immersed by the body as power. Hence the antenna should be made as effective as possible. Antenna operating characteristics commonly alter due to contact with the human body [4].

Various conductive and dielectric materials are used to construct wearable antennas. These materials were chosen carefully to offer a suitable level of mechanical curvatures with little impact from weather conditions and appropriate EM radiation safeguard. Wearable antennas have been made using fabric and non-fabric materials. Electro-textiles like Flectron, Nora, etc., are used for the conducting parts of antennas [5]. Silver, gold, and copper are also used in various situations [6]. A critical application of wearable antenna is health parameter monitoring. In this study designed wearable textile antenna is used for glucose level monitoring. A boost or decline in the blood glucose level can result in diabetes, which affects people worldwide. Moreover, the diabetic patient has a significant risk of developing other health issues if this abnormality lasts long [7].

2. ANTENNA DESIGN

A partial ground plane design is used to create the first antenna. As seen in *figure 1*, the antenna is constructed from jeans.

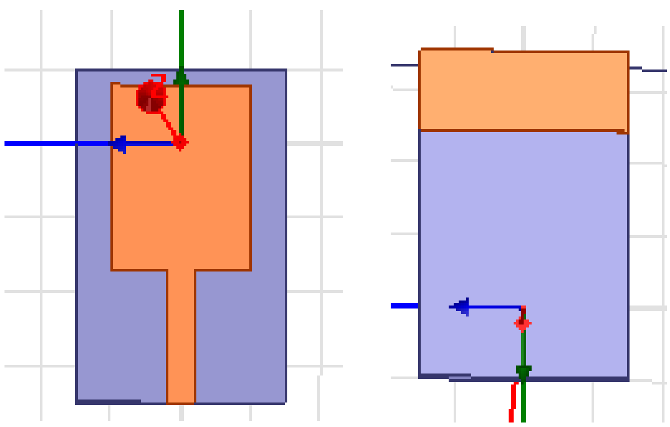

Figure 1: Simulated Antenna

The obtained output frequency of the simulated antenna is 2.4 GHz, which is included in the ISM band [8]. *Figure 2* displays the simulated antenna's reflection coefficient.

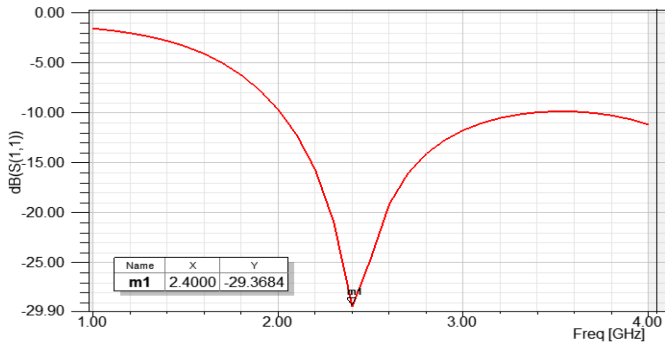

Figure 2: Reflection coefficient

The second antenna is constructed with a full ground plane on the same fabric substrate as the first antenna. Wearable antennas that use the whole ground plane principle can shield the human body from the effects of RF radiation [9]. *Figure 3* depicts a mock antenna.

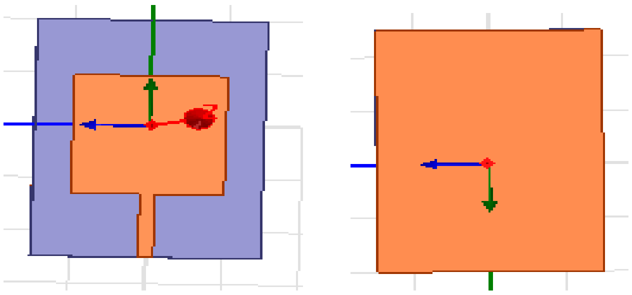

Figure 3: Simulated antenna with entire ground plane

Additionally, this antenna utilizes the ISM band. 2.4 GHz is the obtained frequency. The simulated antenna reflection coefficient is shown in *figure 4*.

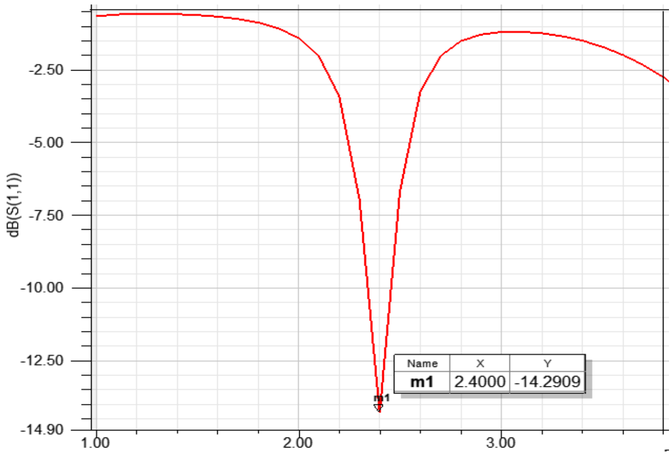

Figure 4: Entire ground plane antennas return loss

Figure 5 shows the radiation pattern of both antennas, *i-e* the first antenna with partial ground plane and the second with the entire ground plane by considering phi = 0.

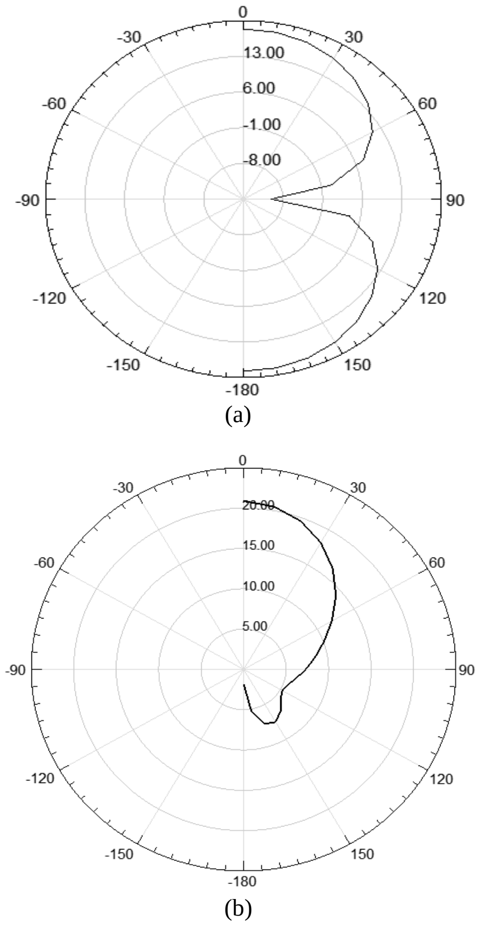

Figure 5: The radiation pattern of (a) partial ground plane antenna (b) entire ground plane antenna

3. FABRICATION RESULT

All Jeans are used as the substrate for the antenna's construction. Copper is used to making both the ground plane and the conductive patch. Then using non-conductive glue, copper material is fastened to the jean's substrate. *Figure 6* depicts the initial antenna that was created.

Figure 6: Made-up antenna

As shown in *figure 7*, a constructed antenna operates at a frequency of 2.406 GHz.

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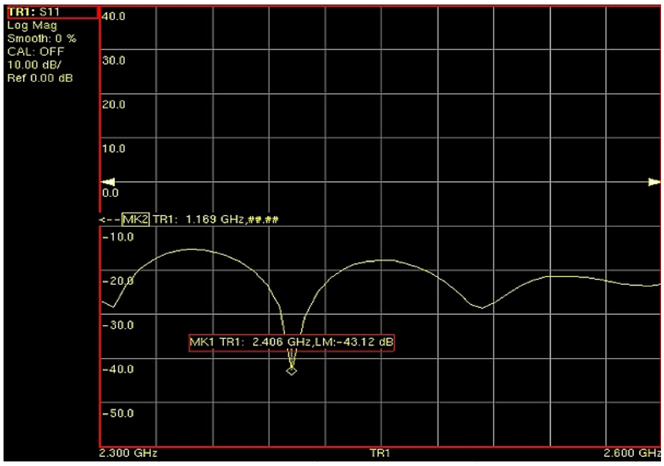

Figure 7: Operating frequency of a made-up antenna

The second antenna is made of the same jeans material, but the complete ground plane concept is used in this design. Figure 8 depicts the fabricated antenna using a full ground plane

Figure 8: Fabricated antenna with full ground plane

As seen in *figure 9*, this fabricated antenna is also used in the ISM band at a frequency of 2.409 GHz.

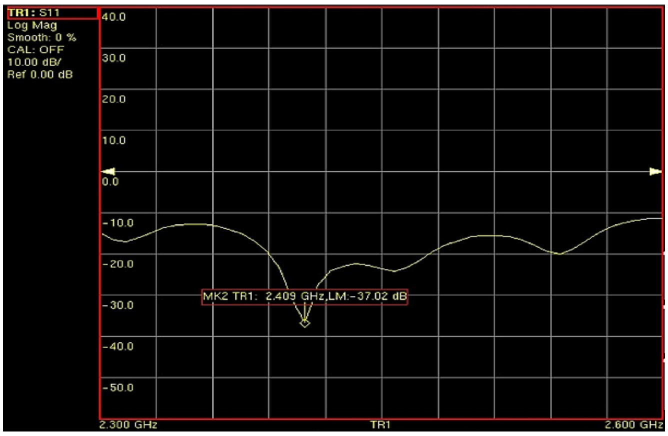

Figure 9: Operating frequency of an entire ground plane antenna

4. FABRICATION RESULTS

The created textile antennas in this study are employed for wearable applications, and glucose level monitoring is one of their essential vital functions. The idea behind glucose level monitoring is that if blood glucose levels rise or fall, blood's dielectric characteristics, or its dielectric constant (Ɛr), will also vary [10].

Blood's dielectric constant decreases when glucose levels rise, affecting the antenna's working frequency. Therefore, as blood glucose levels rise, the dielectric constant drops, and the antenna's operating frequency rises [11-12]. Therefore, if the operating frequency is high when an antenna is located on a human body to monitor glucose levels, there is a high glucose concentration.

There are two ways to monitor glucose levels: placing a finger on an antenna patch and measuring the output frequency fluctuation, mounting an antenna on a person's arm, and measuring the output frequency variation using a vector network analyzer (VNA). In this investigation, both antennas get 1 mw of power [13].

A small partial ground plane antenna is used to measure glucose levels using a finger, while a complete ground plane antenna is used to measure glucose levels using a human arm. HFSS software is used to create an arm and finger phantom, and in each stage of glucose level monitoring, the blood layer's dielectric constant is altered, and the antenna's resonance frequency is measured [14].

4.1 Glucose Level Monitoring using Finger

The HFSS software simulates the finger phantom. Layers of skin, fat, blood, and bone make up this phantom. In the simulation, various blood glucose levels are chosen, as given in *table 1*.

Table 1: BGL Vs. frequency

BGL	Ɛr	σ	f (GHz)	S11 (dB)
100	58	2.5	1.7650	-34.98
160	53.9	2.5	1.7680	-32.98
200	49.1	2.5	1.7700	-30.92
280	43.8	2.5	1.7710	-29.20
300	40	2.5	1.7740	-28.31
68	63.1	2.5	1.7620	-38.50

Based on those numbers, the blood layer's dielectric constant is chosen, and the output frequency of the antenna is measured, as given in *figure 10*.

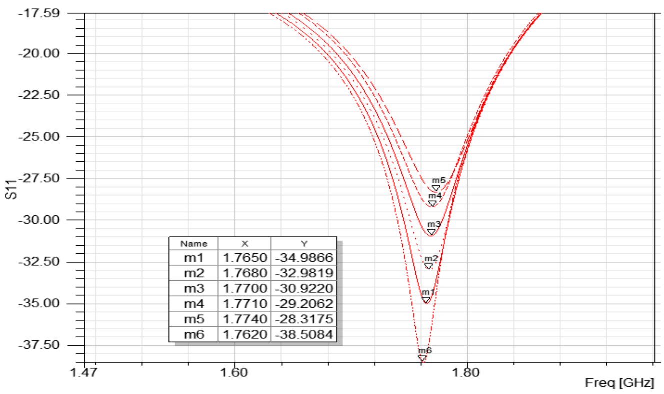

Figure 10: BGL Vs. Frequency simulation results

For a manufactured antenna, 1 mW of power is provided, the patient's finger is placed on the antenna patch, and a VNA is used to measure the output frequency fluctuation. In addition, a glucometer is used to measure blood glucose simultaneously. The obtained results are shown in *table 2*.

Table 2: BGL Vs. Frequency fabrication results

BGL	F(GHz)	S11 (dB)
70	2.5140	-18.91
78	2.5158	-18.61
86	2.5169	-18.58
92	2.5180	-18.02
100	2.5210	-17.62
105	2.5210	-17.48
140	2.5328	-17.28

The different patient's finger is placed on an antenna patch for several tests, and the resulting graph of blood glucose level vs. frequency is displayed in *figure 11*.

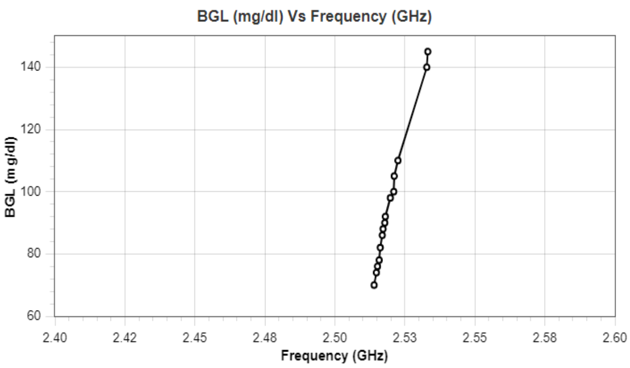

Figure 11: Graph of BGL Vs. frequency

From *figure 11* and *table 2*, it is observed that when glucose levels increase, the antenna's resonant frequency also increases

4.2 Glucose Level Monitoring using the Human Arm

In this case, glucose level monitoring is done by placing an antenna on a human arm. For simulation results, a human arm phantom is simulated using skin, fat, blood, bone, and muscle layers. In each phase of the simulation procedure, an antenna is mounted on an arm phantom, and the blood layer's dielectric constant is altered by a chosen glucose level shown in *table 3*.

Table 3: Simulation results for output frequency

BGL	Ɛr	σ	F (GHz)	S11 (dB)
100	58	2.5	2.1830	-11.63
160	53.9	2.5	2.2030	-11.14
200	49.1	2.5	2.2330	-11.04
280	43.8	2.5	2.2790	-10.72
300	40	2.5	2.3020	-10.46
68	63.1	2.5	2.1610	-12.12

The resultant output frequency graph is depicted in *figure 12* after monitoring the output frequency shift.

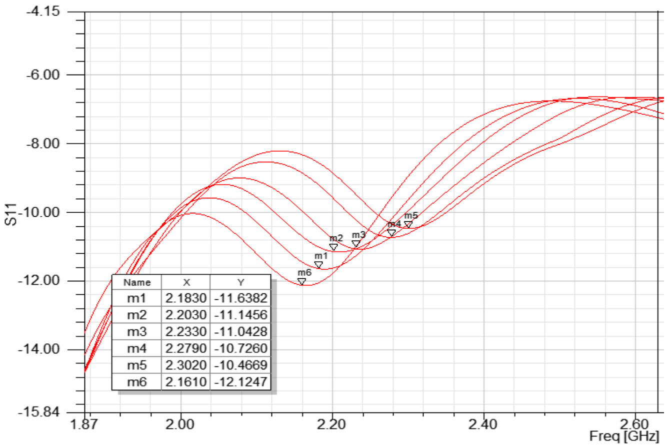

Figure 12: Frequency variation according to the value of Ɛr

A similarly constructed antenna is located on the person's arm, and the frequency shift is measured with a VNA. In contrast, the glucose level is measured with a glucometer and recorded in *table 4*.

Table 4: BGL Vs. frequency using the human arm

BGL	F(GHz)	S11 (dB)
70	2.4227	-20.72
78	2.4235	-20.53
86	2.4241	-20.54
92	2.4247	-20.48
100	2.4252	-20.48
105	2.4252	-20.47
140	2.4263	-20.35

An external device called a glucometer is used to test glucose levels, while an antenna is attached to the arms of several patients to assess frequency shifts. The gathered information is shown in *figure 13*.

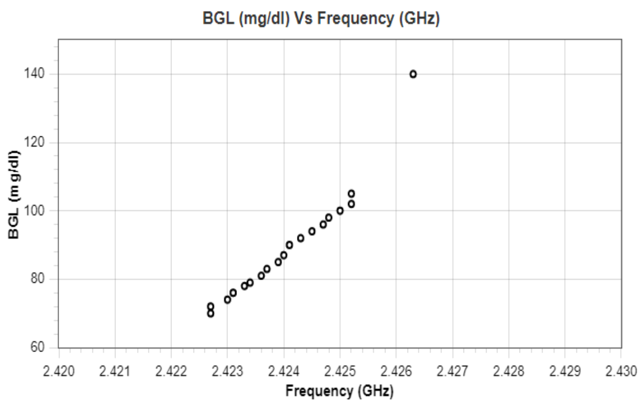

Figure 13: Graph of BGL Vs. frequency (with the entire ground plane)

Maximum frequency variation is obtained when a finger is placed on an antenna patch rather than the antenna being located on the arm.

5. CONCLUSION

Two antennas are designed to operate in the ISM band. Both antennas are used for glucose level monitoring. The principle used in this study is that as blood glucose levels rise, the dielectric properties of the blood change, affecting the antenna's resonant frequency. There are two ways to monitor glucose levels: placing an antenna on a human arm or placing a finger on an antenna patch. As a result, the antenna's output frequency increases along with the glucose level. Both constructed and simulated antennas exhibit frequency variation along with blood glucose variation. Therefore, the created antennas are excellent for monitoring blood glucose levels without drawing samples.

6. PATENTS

Asha Ghodake and Balaji Hogade "Ism band compact jeans wearable antenna for glucose level monitoring," Indian Patent 202221051238 A, October. 7, 2022.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

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