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International Journal of Electrical and Electronics Research (IJEER)
Research Article | Volume 13, Issue 2 | Pages 381-385 | e-ISSN: 2347-470X

Design Patch Antenna at Wi-Fi Applications for Detection Breast Cancer Tumors

lham H. Qaddoori[1], Ahrar al-khafajy[2], Luma Abdulkareem Hussein[3], and Israa Hazem Ali[4*]

[1]*Department of communication Engineering, College of Engineering, University of Diyala; Iraq, ilhamhqaddoori@gmail.com*
[2]*Department of communication Engineering, College of Engineering, University of Diyala; Iraq, Ahrar.Alkhafajy@uodiyala.edu.iq*
[3]*Department of communication Engineering, College of Engineering, University of Diyala; Iraq, luma.abd.alkareem@uodiyala.edu.iq*
[4]*Department of communication Engineering, College of Engineering, University of Diyala; Iraq, israa_hassan_eng@uodiyala.edu.iq*

***Correspondence:** *israa_hassan_eng@uodiyala.edu.iq*;

ABSTRACT- The development in the science of communications technology in the medical fields has led to the use of patch antennas for applications in biomedical applications and for the Wi-Fi band, which ensures reliable results for detecting tumors. Antenna is deliberate using Rojers R03203 with 0.75 mm for thickness of the substrate and 3.02 for the permittivity. The actual size of this antenna is (36·58 ·0.75) mm. For the patient's health safety, the patch antenna was designed at the frequency of WiFi applications and placed above the human breast phantom, which was designed with two homogeneous layers, skin and fat, with different electrical properties, and all of these designs and simulations were done by Microwave Studio cst 2021. The designed antenna displays the current density, electric field, standing wave ratio, specific absorption ratio, and return loss. Through changing these elements during the simulation, it was observed that there was a small tumor in the imaginary breast the first time and two tumors the second time.

General Terms: Breast Cancer Tumors, Design of Patch Antennas, Specific Absorption Rate (SAR) Analysis, Microwave technology.

Keywords: Wi-Fi Patch Antenna, Reflection coefficient, Tumor, breast tissue, current density distribution, SAR.

ARTICLE INFORMATION

Author(s): lham H. Qaddoori, Ahrar al-khafajy, Luma Abdulkareem Hussein, and Israa Hazem Ali;

Received: 11/03/25; **Accepted:** 11/06/25; **Published:** 30/06/25;
E- ISSN: 2347-470X;
Paper Id: IJEER250110;
Citation: 10.37391/ijeer.130223
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-13/ijeer-130223.html

Publisher's Note: FOREX Publication stays neutral with regard to jurisdictional claims in Published maps and institutional affiliations.

1. INTRODUCTION

The rapid advancement of wireless communication has created a demand for low profile, low-cost antennas, which poses challenges for traditional resonant antennas like patch and slot antennas [1-3]. Additionally, breast cancer remains a significant global health issue, affecting the nervous system and characterized by abnormal cell growth in the breast. Tumors can be either cancerous or noncancerous and may spread to other body parts [4,5]. Early detection is crucial for successful treatment, with Magnetic Resonance Imaging (MRI) being a common diagnostic technique. The text discusses various imaging techniques for cancer detection, including CT scans, PET, X-ray screening, Ultrasound is less effective for young patients compared to MRI, while MRI is expensive [6-9]. Microwave technology is presented as a non-ionizing and cost-effective alternative that can effectively identify malignant tissue amidst healthy tissue, offering significant advantages over existing methods.

Recent advancements in brain cancer detection have highlighted safety. The text describes a method that is economical and provides high accuracy. That falls into two primary categories of microwave imaging: Radar-based Microwave Imaging and Microwave Tomography [10-14]. It highlights that microwave imaging delivers quantitative information about the dielectric properties of tissues. to identify tumors, while the radar-based method is noted for its safety and high sensitivity [15,16]. The dielectric properties of human cells can vary significantly at different frequencies, necessitating the creation of experimental phantoms to mimic the brain's dielectric characteristics [17,18]. Additionally, modern technology has enabled the creation of compact devices with small antennas, particularly microstrip patch antennas, which are widely used in biomedical applications [19-20].

This paper presents a compact patch antenna designed to scan a two-layer breast phantom model to assess differences between healthy and tumor tissues. The antenna utilizes a coaxial cable feed and features a small thickness, yielding practical results. Sections 2&3 detail the antenna geometry and the human breast phantom, while Section 4 discusses various metrics such as

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electric field, SAR, return loss, and the amount of electric current for both healthy and cancerous breast models. The conclusion of the study is provided in *section 5*. These details have been illustrated in the flow chart in the *figure 1*.

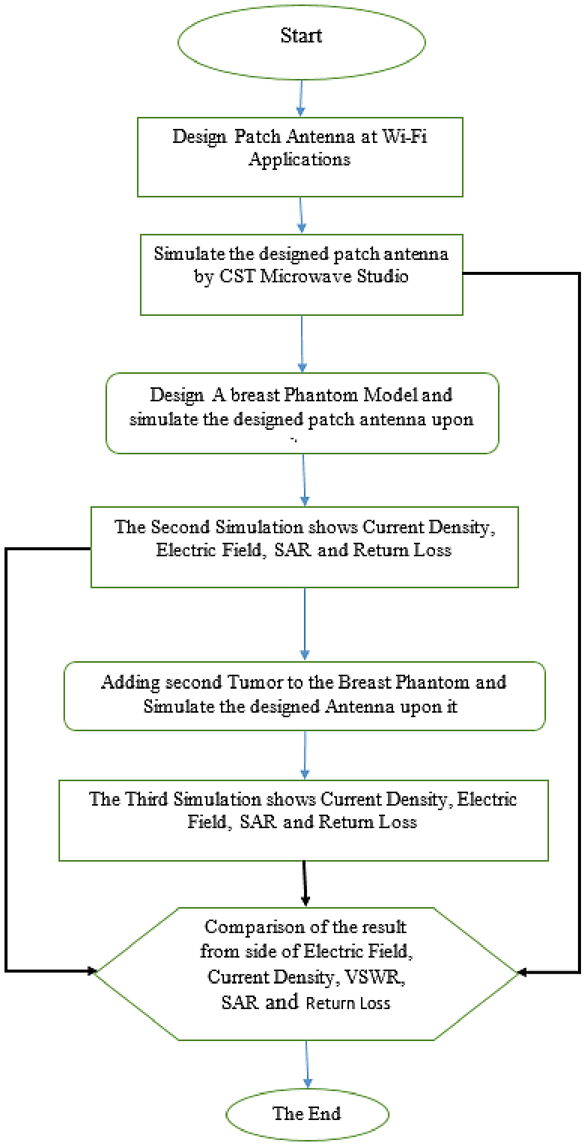

Figure 1. An illustrative diagram of the paper

2. ANTENNA DESIGN

The paper presents the design and simulation of a simple rectangular radiator antenna, depicted in *figure 2*. The antenna features a ground and patch made of pure copper and is designed using CST Microwave Design Studio (2021) with dimensions of (36×58 ×0.75) mm. A Rojers R03203 substrate with a permittivity of 3.02 is utilized. The antenna's dimensions are determined through various mathematical equations, specifically for calculating the radiator width, patch length (considering fringing effects), substrate dimensions, and feed dimensions.

$$P_W = \frac{v_o}{2f_o}\sqrt{\frac{2}{\mathcal{E}_r+1}} \quad (1)$$

Where P_W is the radiator width, f_o is the resonator frequency, $\mathcal{E}_r$ is the dielectric constant and v_o is the velocity [9-12].

$$\mathcal{E}_{reff} = \frac{\mathcal{E}_r+1}{2} + \frac{\mathcal{E}_r-1}{2}\left[1+12\frac{h_s}{P_W}\right]^{-\frac{1}{2}} \quad (2)$$

Where, $\mathcal{E}_{reff}$ is effective permittivity and h_s is the height of the substrate.

$$\frac{\Delta L}{h_s} = 0.412\frac{(\mathcal{E}_{reff}+0.3)(\frac{P_W}{h_s}+0.264)}{\mathcal{E}_{reff}-0.258)(\frac{P_W}{h_s}+0.8)} \quad (3)$$

Where ΔL is the extended length of the patch.

$$P_L = \frac{1}{2f_o\sqrt{\mathcal{E}_{reff}}\sqrt{\mu_o}\sqrt{\mathcal{E}_o}} - 2\Delta L \quad (4)$$

Where P_L is the length of patch

$$S_L = 6h_S + P_L \quad (5)$$

$$S_W = 6h_S + P_W \quad (6)$$

Where S_L and S_W is length and width of substrate layer respectively. Note that length and width of the ground is equal to length and width of substrate [13-16].

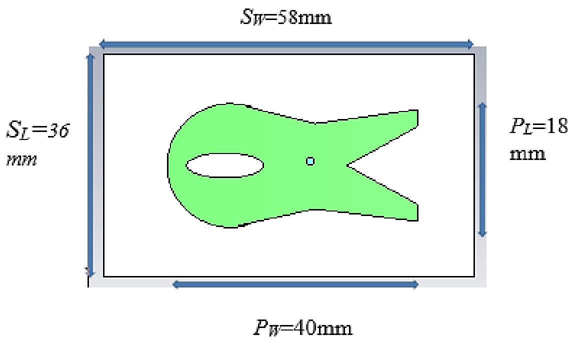

Figure 2. The proposed antenna and its dimension

The antenna's parameters and dimensions are detailed in *table 1*, with modifications made to the rectangular patch and feed to function within the ISM band. The ground plane measures 36 x 58 mm, and the antenna is centered at coordinates (X = Y = Z = 0) in the simulation. The return loss, depicted in *figure 2*, indicates the antenna resonates at 2.452 GHz with a reflection coefficient of -29.95 dB, which is acceptable as it is below -10 dB. The antenna has a bandwidth of 13.56 MHz, ranging from 2.445 GHz to 2.459 GHz. *Figure 3* shows that the antenna achieves a gain of 2.2 dBi at 2.452 GHz.

Table 1. The proposed Antenna's Dimensions

Parameter	Values (mm)
The length of substrate *(S_L)*	36
The width of substrate *(S_W)*	58
The radiator length *(P_L)*	18
The radiator width *(P_W)*	40
The height of patch & ground *(t)*	0.035
The height of substrate *(h_S)*	0.75

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3. PHANTOM MODEL OF HUMAN BREAST

The text debates the design of a human breast phantom model using CST microwave studio to study the effects of radiation on body tissues, particularly in the context of biotechnology applications. The model consists of two spherical layers, with a cancerous tumor included within the breast. Each layer has varying electrical properties, specifically permittivity (Ɛ) and conductivity (σ), which are crucial for identifying malignant cells. The electromagnetic field values differ based on these properties. Additionally, the structure of the model and details about the conductivity, permittivity, and thickness of the coats and tumor are provided in accompanying in *table 2*. The tumor 15 has a significantly larger 'Ɛ' value compared to other model layers, and its electrical conductivity 'σ' is notably high at 4 S/m. These electrical properties distinguish the tumor from normal body cells, while the skin has a minimal thickness of 4 mm.

Table 2. Ch/s of Breast Phantom

Tissues	Permittivity	Radius(mm)	Conductivity(S/m)
skin	37.5	90	1.74
fat	10.7	86	0.344
tumor	54.9	15	4

The Phantom is positioned at coordinates (X =Y = 0 mm and Z = 100 mm) to conduct measurements of electric field (V/m), current density (A/m³), return loss (dB), and SAR (W/Kg). A significant difference in these results indicates the presence of a cancerous tumor.

4. RESULTS AND DISCUSSION

A breast phantom model was designed for simulation, positioned 5 mm below an antenna to minimize the negative effects of the electromagnetic field. The model was simulated three times: once without a tumor, once with a single tumor located at coordinates (X = 0 mm, Y = 30 mm, Z = 60 mm), and the third time with double tumors located at coordinates (X = 0, Y = 30 mm and Z = 60 mm) and (X = 0 mm, Y = 20 mm, Z = 70 mm) as shown in *fig 3*. The parameters of the model are thoroughly discussed for clarity.

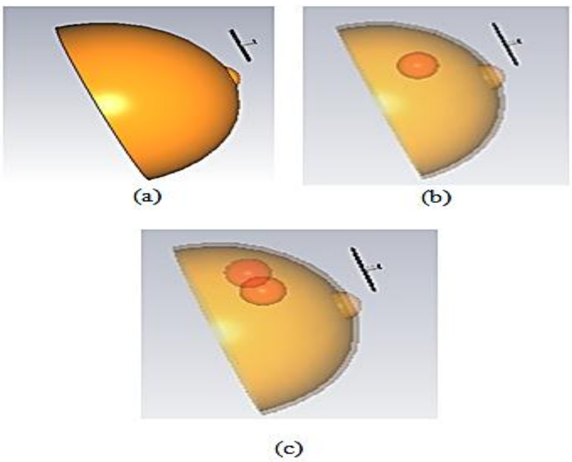

Figure 3. A breast phantom model (a) without tumor, (b) with single tumor, (c) double tumor

4.1. Reflection Coefficient Analysis

The phantom model exhibits a maximum return loss of -29.95 dB at 2.452 GHz, while the presence of a cancerous tumor results in a maximum return loss of –24.12 dB at 2.455 GHz and the presence of double cancerous tumors results in a maximum return loss of –22.285 dB at 2.455 GHz as in *fig. 3*. This indicates a difference of 5.1 dB in return loss and a shift of 3 MHz in the resonant frequency for single tumor and 7.664 dB of 3 MHz for double tumor.

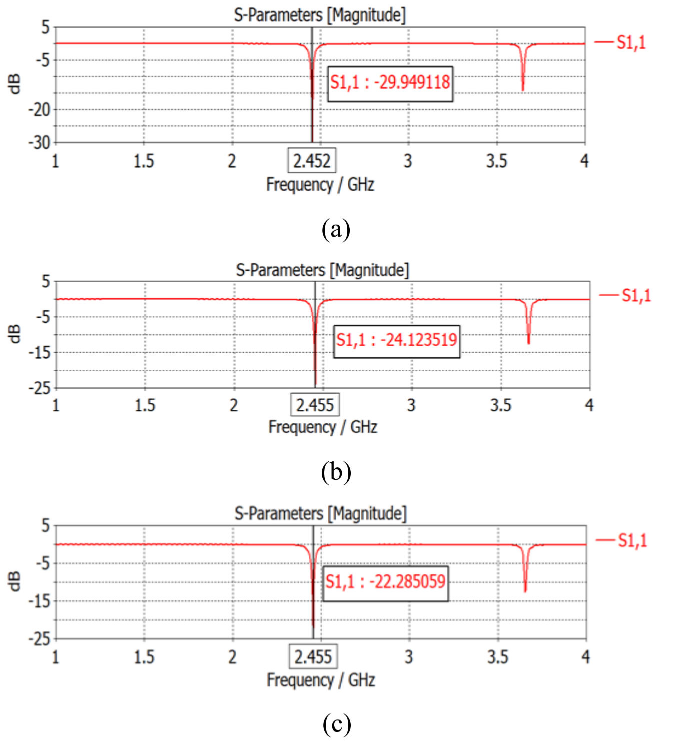

Figure 4. Farfield properties for proposed antenna (a) without tumor, (b) with single tumor, (c) double tumor

4.2. Analysis of Electric Field (V/m)

The text discusses the electric field intensity around living body cells, noting that a simple phantom model achieves an electric field of 16.2 V/m, while a phantom with a single tumor has an electric field of 15.6 V/m and a phantom with double tumor has an electric field of 15.7 V/m. This results in a difference between the three cases, as illustrated in *figure 4*.

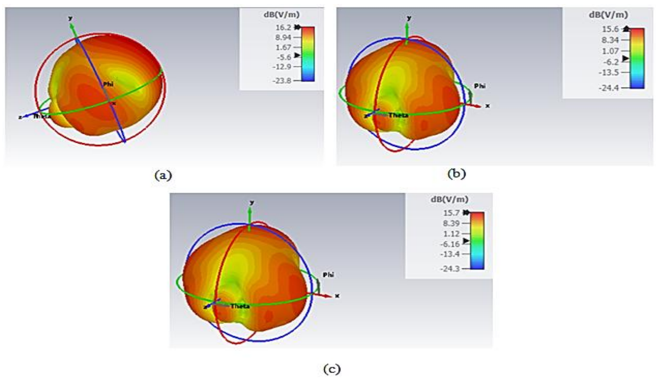

Figure 4. Electric field intensity at 2.445 GHz for proposed antenna (a) without tumor, (b) with single tumor, (c) double tumor

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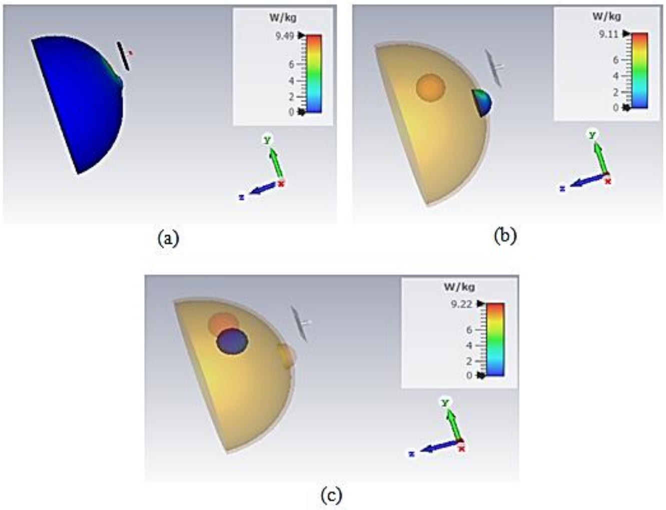

Figure 5. SAR (1g) at 2.445 GHz for proposed antenna (a) without tumor, (b) with single tumor, (c) double tumor

4.3. Analysis of SAR

The Specific Absorption Rate (SAR) measures the power absorbed per kilogram of human body tissue, which is important for assessing safety. In a normal breast model, the SAR is measured at 1g is 10.5 W/Kg, while in the presence of a single tumor, is 9.11 W/Kg and it is 9.22 W/Kg at a double tumor. At 10 g are 4.31,3.37 and 3.78 respectively as show in the *figures 5&6*.

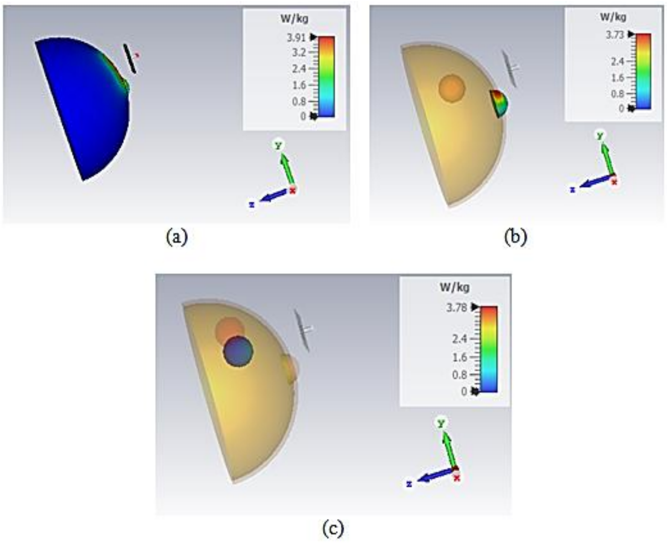

Figure 6. SAR (10 g) at 2.445 GHz for proposed antenna (a) without tumor, (b) with single tumor, (c) double tumor

4.4. Analysis of current density

The maximum of the amount of electric current reached is 293 A/m² for the simple model and 295 A/m2 for the single and double tumor model. *Figure 7* illustrates the current density values for models, while *table 4* highlights the significant differences between the three simulation methods.

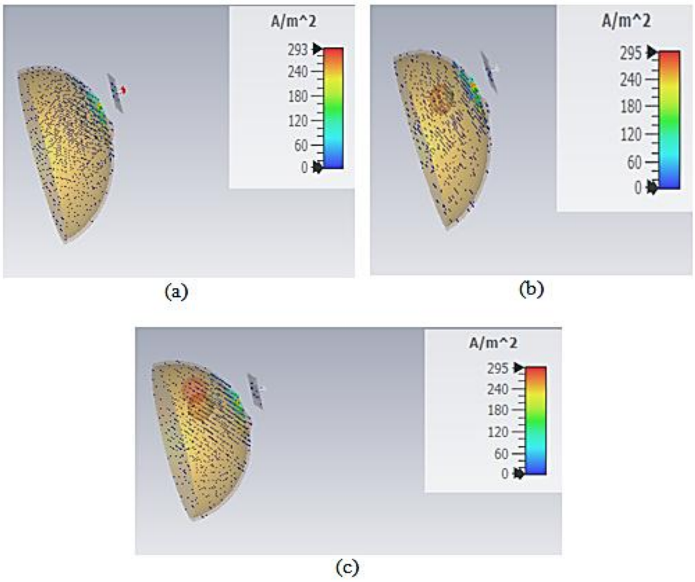

Figure 7. The current density at 2.445 GHz for proposed antenna (a) without tumor, (b) with single tumor, (c) double tumor

Table 3. Comparison between three cases of tumor presence and absence

Results parameters	Without tumor	With single tumor	With double tumor
Resonant frequency GHz	4.452	4.55	4.55
Return loss dB	-29.95	-24.12	-22.28
Electric field V/m	16.2	15.6	15.7
Current density A/m2(max)	293	295	295
SAR (1g) W/Kg	10.5	9.11	9.22
SAR (10g) W/Kg	4.31	3.73	3.78

Table 4. Comparison with existing literature

References	Resonant frequency (GHz)	Reflection coefficient dB	VSWR	Gain (dBi)
[21]	2.4	-25.44	1.128	--
[22]	2.555	-19.05	1.251	2.16
[23]	2.45	-22.40	1.164	--
[24]	2.45	-17.5	<2	--
[25]	2.885	-12.470129	--	--
This work	4.452	-29.95	1.065	2.2

The *table 4* shows a difference for the better between the previous work and this work by VSWR, return loss and the gain.

5. CONCLUSION

The letter discusses the design of a simple rectangular geometry radiator for microwave imaging to detect breast tumors, operating at a frequency of 2.452 GHz. It presents measurements for a phantom without a tumor, showing return loss of -29.95 dB, electric field intensity of 16.2 V/m, SAR of 10.5 W/Kg, and current density of 293 A/m². For the phantom with a single tumor, the values are -24.12 dB, 15.6 V/m, 9.11 W/Kg, and 295 A/m² and with a double tumor the values are -22.28 dB, 15.6 V/m, 9.22 W/Kg, and 295 A/m² indicating a significant difference that suggests tumor presence. Additionally, the radiator's geometry can be miniaturized and adapted for flexible substrates, making it suitable for on-body surgical medical applications. Future proposals: It is preferable to manufacture the antenna to compare simulation and practical results

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