# Breast cancer detection using an on-body Circular Microstrip Patch Antenna

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**Abstract**.
In medical applications, the early detection of breast cancer plays a vital role in enabling timely treatment and reducing mortality rates among women. With advancements in medical technology, the use of efficient antennas has become integral for imaging, diagnosis, and improving patient outcomes. Since tumors are often small in the initial stages, accurately locating them is essential for effective diagnosis. To address this challenge, various high-precision antennas have been designed. Flexible antennas offer distinct benefits over conventional types, including simple structures, high gain, and cost-effectiveness. The current study introduces an innovative flexible antenna specifically designed for detecting breast cancer at an early stage, applicable for cases both with and without the presence of a tumor. In this design, denim fabric with a dielectric constant of 1.7 is utilized as the substrate to ensure accurate examination and reliability. The antenna structure consists of a circular patch and a copper ground plane serving as the conductive component. We employ a 1 mm thick denim substrate due to its flexibility and suitability for direct application on the breast surface. The design incorporates a microstrip probe feeding technique to enhance overall performance. This wearable textile antenna operates within the Ultra-Wideband (UWB) frequency range of 3.1 GHz to 10.6 GHz. It is modeled and analyzed using CST (Computer Simulation Technology) software. Key performance indicators are looked at in the simulation, such as return loss (S11), gain (dB), radiation pattern, electric field (E-field), magnetic field (H-field), and voltage standing wave ratio (VSWR). Lastly, the results of the simulation are compared with those of existing antenna designs to see if they are better and if they could help find breast cancer earlier.

**Keywords**. CST Software, UWB, Wearable textile antenna, Breast cancer detection

## 1. INTRODUCTION

Breast cancer is a life-threatening disease caused by the uncontrolled growth of breast tissue, contributing to 25% of all cancer cases worldwide [1]. Early detection significantly improves survival rates, making it a priority in healthcare [2]. Regular screening, like X-ray mammography, has problems, like not being very sensitive in dense breast tissue and having trouble finding tumors close to the chest wall. It also exposes people to ionizing radiation and costs a lot [3, 4]. Microwave imaging has emerged as a promising alternative due to its non-ionizing nature and ability to provide physiological and anatomical insights into breast tissues [5][6]. This technique allows non-invasive detection of abnormalities, though the process can be complex during surgical procedures [7]. Wearable technologies, including flexible antennas, are increasingly used for early breast cancer detection due to their comfort, low power consumption, and potential for real-time monitoring [8][9]. Recent advancements have led to the development of flexible microstrip patch antennas for biomedical applications, including breast cancer detection. These antennas can be integrated into wearable fabrics, providing unobtrusive monitoring and reducing patient discomfort [10][11]. For instance, wearable textile antennas made from jeans fabric as a dielectric substrate have been designed for ultra-wideband (UWB) applications ranging from 3.1 GHz to 10.6 GHz [12]. Copper materials are typically used for the conductive elements, ensuring flexibility and durability [13]. Using CST software to run simulations has shown that antennas work well in terms of gain, return loss (S11), radiation pattern, and voltage standing wave ratio (VSWR) [14]. The flexibility and compactness of wearable antennas make them ideal for continuous health monitoring, aiding early diagnosis, and improving treatment outcomes [15]. These improvements are meant to lower the risks of surgery and improve patient care, meeting the growing need for flexible, high-performance antennas in medical settings [16, 17].

The subsequent sections of this research are structured as follows: In Section II, pertinent papers and literature about the planned study are examined and cited. This study examines the advantages and disadvantages of several antennas that are currently designed. The suggested implementation is detailed in Section IV. The experimentation prototype and findings are examined in Section V. Section VI serves as the conclusion, encapsulating the summary of the conducted study.

## 2. RELATED WORK

Abdulla et al. [1] presented a textile-based ultrawideband (UWB) microstrip patch antenna for breast cancer imaging applications in 2024. Simulations evaluated this antenna, operating across 2–11.6 GHz, for its efficiency in early tumor detection. By changing the shape, size, and location of tumors in breast phantoms, its performance was tested using VSWR (between 1.15 and 2), return loss (between −36 and −18.5 dB), and SAR (between 1.6 and 2 W/kg), all of which were within safe medical limits.To detect breast cancer, Fusic et al. [2] created a flexible, wearable polyamide microstrip patch antenna that operates at 2.45 GHz. Simulations showed a gain of 1 dB, a return loss of −14.81 dB, and VSWR ≤ 3. The built prototype showed a resonance at 2.318 GHz and a better return loss of −28.19 dB, which was the same as what the simulation showed.Gour et al. [3] suggested a dual-band wearable microstrip patch antenna with a broken ground structure as a way to find breast tumors. Using an FR4 substrate, the antenna operated at 2.43 GHz and 3.32 GHz with return losses of −35 dB and −24 dB, respectively. SAR values remained within safe limits for wearable applications.Amadaouch et al. [4] made a small, planar, rectangular-shaped UWB antenna system with a high gain for localizing tumors. The frequency range is 3–12 GHz. The system identified tumor locations based on SAR peaks within breast tissue phantoms.For radar-based breast cancer detection, Bahrami et al. [6] created a small, bendable UWB antenna array (2–4 GHz) that can work with either single or dual polarization. The design ensured efficient power transmission and interaction with biological tissues of varying electrical properties.

Wang et al. [7] demonstrated a UWB MIMO antenna for high-resolution imaging that operates between 2.3 GHz and 12.2 GHz. It has unified ground structures that make the coupling loss less than -15 dB.Kaabal et al. [8] proposed mounting a small UWB antenna in the shape of a polygon on an FR4 substrate. This antenna would have dual-band notched properties and a group delay of less than 1 ns. Its effective pulse-preserving properties improve microwave imaging for the detection of breast cancer.Selvaraj et al. [9] looked at how electromagnetic waves interact with breast tissue and transmitting antennas. They found that SAR changes depending on frequency, tumor size, and distance, which helps with pinpointing the exact location of a tumor.Taylor et al. [10] talked about imaging techniques that focused on pixel acquisition times. They said that lung cancer was the most common type of cancer, which meant that better detection technologies were needed.Asha et al. [11] explored the design of microstrip patch antennas for lung tumor detection using CST software. The approach involved monitoring fluctuations in current density, electricity, and magnetic fields to identify malignancies.Shrestha et al. [12] developed a flexible microstrip antenna (32 × 31 mm, 2.45 GHz) for breast cancer imaging and therapy. Experimental validation on skin phantoms confirmed its diagnostic potential.A small microstrip antenna was suggested by Katbay et al. [13] as a way to find breast tumors and make images clearer in different types of tissues.Vidyasree et al. [14] suggested using different kinds of microstrip antennas, like circular, slot, rectangular, hemispherical, and pentagonal arrays that work at different frequencies, to make the process of finding breast cancer more accurate.Susila et al. [15] created a rectangular slot-loaded microstrip antenna using an RT Rogers 5880 substrate. They tested it on breast phantoms to see how the electric (25,167 V/m) and magnetic fields (129 A/m) changed.Gupta et al. [16] created a T-shaped rectangular microstrip antenna to find tumors in the ISM band (2.45 GHz). They proved the effectiveness of the SAR and current density models, and the antenna boasted low losses (32.2 dB). Al Habsi et al. [17] showed a microstrip-fed Vivaldi antenna that was easy to build and had better performance in terms of gain, impedance matching, and VSWR compared to patch designs. Hammouch et al. [18] suggested using an FR-4 substrate with an intelligent UWB antenna (2.96–10.68 GHz) to find breast cancer. We tested this antenna with two electromagnetic solvers to ensure its functionality. Ullah et al. [19] created a 3D folded antenna (1.67–1.74 GHz) for health monitoring. Prototypes showed that it could effectively find malignant tumors in breast phantoms. Singh and his team [20] developed a compact, dual-band textile slot antenna on denim fabric. It has a 5.7 dB gain and works up to 46% of the time (3.01–5.30 GHz) and is good for WiMAX, WLAN, and X-band uses. Using biodegradable materials, Rahman et al. [21] suggested a UWB antenna array (4–6 GHz) that could be worn and built into a "clinical bra" to help find breast cancer early. In tests, this idea worked over 70% of the time. Foroutan et al. [22] created an active sensor system for imaging tissue with microwaves. It uses printed slot antennas with LNAs and active mixers, and its frequency range is from 3 to 7.5 GHz, with 30 MHz of space between the frequencies. The research in [23] was mostly about using microwave sensor technologies to find breast cancer. The imaging quality is based on the quality of the scattering data. Truncated Singular Value Decomposition (TSVD) was used by Mays et al. [24] to make the data quality better in mixed-polarization antenna arrays that were used to find breast cancer. Srinivasan et al. [25] compared different antennas and their characteristics to identify the most suitable designs for early breast cancer detection.

## 3. MOTIVATION AND PROBLEM FORMULATION

Breast cancer is a significant global health issue for women, with mortality rates rising every year. Various strategies and techniques have been devised to mitigate the mortality rate. The efficacy of breast self-examination can reduce female death rates. Various programs are being implemented to educate women on the practice of breast self-examination.

Breast cancer is a prevalent kind of neoplasm identified in women globally. Therefore, it is crucial to identify it at the curable stage as promptly as feasible. Regrettably, it is a leading cause of cancer mortality among women. Consequently, detection and prevention are essential tasks. The surveillance of breast cancer involves obtaining medical data from asymptomatic and seemingly healthy women to facilitate earlier detection of the disease. Another factor contributing to cancer incidence is the unregulated proliferation and aging of the population, with the prevalence of recognized risk factors such as obesity, sedentary lifestyles, and environmental alterations resulting from urbanization and economic advancement. The suggested study employs a low-cost, flexible antenna to detect breast cancer, both in the presence and absence of tumors, to mitigate mortality rates associated with the disease. The antenna utilizes wearable jeans material, with a thickness of 1 mm, as the dielectric substrate, possessing a dielectric constant of 1.7. This research involves the construction of an antenna resembling a sandwich model, using a slot-loaded patch and a copper ground plane as the conductive material. The coaxial feeding approach has been employed for antenna feeding. The engineered antenna functions as a wearable textile antenna for ISM (Industrial, Scientific, and Medical) band applications at 2.4 GHz. The suggested antenna can simulate and implement both software and hardware. The simulation is conducted with HFSS (High-Frequency Structure Simulator) software, incorporating factors such as S11 return loss, gain in dB, and radiation pattern. As a consequence, the simulation yields the VSWR.

## 4. PROPOSED METHOD

### a Design Consideration of CMPA

The suggested antenna is a slender hexagonal patch fabricated on a Jeans substrate with a h = 1 mm thickness. The antenna design necessitates the substrate's permittivity or dielectric constant, as well as the length and breadth of the patch and ground plane. The primary function of the antenna pertains to the substrate's permittivity, εr, which is 1.7 for denim fabric.

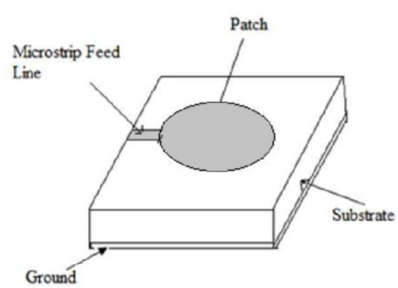



Fig. 1 Circular Microstrip Patch Antenna

Subsequent mathematical formulae are considered when determining the suggested antenna parameters, such as width, effective dielectric constant, and length.

1) Calculation of width

$$w = \frac{c}{sf_0\sqrt{\frac{(\epsilon_0+1)}{2}}}$$

Where

w = Width of Patch in mm

$f_0$ = Resonance frequency in Hz

$\epsilon_0$ = The relative permitivity of dielectric substrate $(\frac{f}{m})$

c = Speed of light ($3 \text{ X}10^8$ m/s)

2) Calculation of effective dielectric constant

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{Pw}\right]^{-\frac{1}{2}} \quad \text{if } \frac{Pw}{h} < 1$$

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{Pw}\right]^{-\frac{1}{2}} + 0.04\left[1-\left(\frac{Pw}{h}\right)\right]^2 \quad \text{if } \frac{Pw}{h} < 1$$

Where,

Pw = Width of Patch in mm

h = Thickness of substrate in mm

$\epsilon_r$ = The relative permitivity of dielectric substrate $\left(\frac{f}{m}\right)$

3) Calculation of effective length

$$L_{eff} = \frac{c}{2f_0\sqrt{\epsilon_{eff}}}$$

Where,

c = Speed of light ($3 \times 10^8$ m/s)

4) Calculation of length extension ($\Delta L$)

$$\Delta L = 0.412h\,\frac{(\epsilon_{eff}+0.03)(\frac{w}{h}+0.264)}{(\epsilon_{eff}-0.03)(\frac{w}{h}+0.8)}$$

5) Calculation of the actual length of the patch

$$PL = L_{eff} - \Delta L$$

Where

PL = Length of patch in mm

6) Calculate the radius of the circular Patch

i. Calculate the radius of a circular Patch antenna from a rectangular Patch antenna.

ii. Calculate the Patch width and Length of the rectangular patch by the above equations. So, by calculations, we get the length and width of the rectangular patch.

iii. Calculate the radius 'r' of the circular patch by following the equations

$$\text{Radius of circular microstrip patch antenna} = \frac{\sqrt{(PL+SH)x(PW+SH)}}{2}$$

Table 1 provides the details of the modeled antenna design. The flexible textile antenna patch is constructed on a 19 × 16 mm² jean substrate, resembling a sandwich model. The microstrip feeding technique has been implemented for the antenna operating in the Ultrawideband at a frequency of 3.1GHz to 10.6Ghz. The Jean material serves as the substrate, while the conductive components (patch and ground) are constructed from copper material. Jeans material is utilized because of its essential properties, including thickness, relative permittivity, and a thickness of only 1 mm. The practical function of utilizing jean fabric lies in its ease when integrated into apparel. The simulation experiment is conducted using CST software. The height and breadth of the substrate and ground are meant to have 23mm X 20mm dimensions.

**Table 1 Design specifications of the proposed antenna**

| Parameters | Symbol | Dimensions |
|---|---|---|
| The relative permittivity of the substrate | εr | 1.7 |
| Thickness of the dielectric substrate | h | 1mm |
| Length of the substrate and ground | Ls & Lg | 20mm |
| width of the substrate and ground | Ws & Wg | 23mm |
| Radius of the patch | r | 9mm |

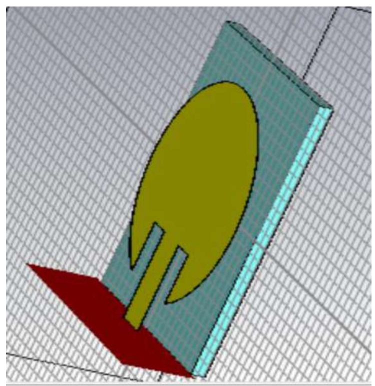


**Fig. 2 Designed antenna using CST software tool**

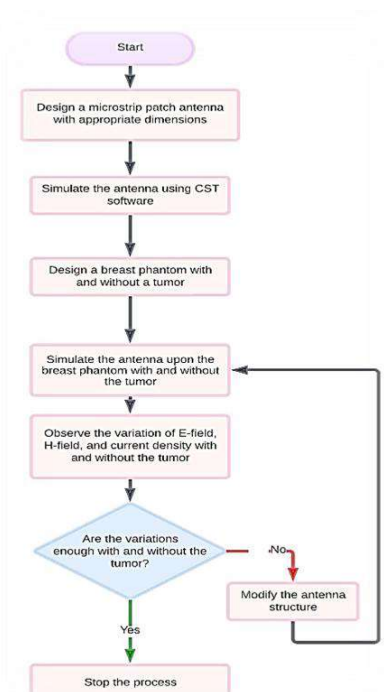



Fig -4: Steps involved in proposed work

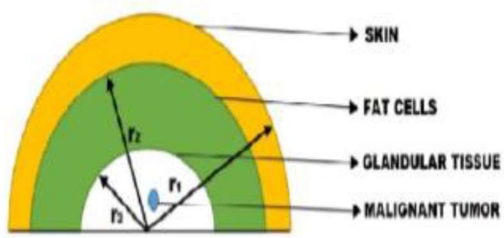
### b *Breast Phantom Design*

A breast phantom is created by modeling a sphere as an internal tumor and a cone as a breast that is covered in breast tissue. Breast skin has a permittivity of 36 F/m and a conductivity of 4 S/m. The tumor has a permittivity of 50 F/m and a conductivity of 7 S/m. For the breast, breast glandular tissue was selected from the CST material library. Compared to healthy tissues, tumorous cells formerly exhibited higher conductivity and distinct dielectric characteristics. The breast tumor has a radius of 2 mm, the breast skin has a radius of 10 mm, and the breast glandular tissue has a radius of 9 mm.

**Table -2: Breast Phantom Design Specifications**

| Breast Tissue | Relative Permittivity | Tangent Delta (Loss) | Thickness (mm) | Distance |
|---|---|---|---|---|
| **Skin** | 17.7 | 0.93 | 5 | 10 |
| **Fatty Tissue** | 3.4 | 0.166 | 15 | 9.5 |
| **Glandular Tissue** | 16 | 0.94 | 40 | 9 |
| **Tumor** | 18 | 1.05 | r=2 to 4 | - |

**Fig. 3: Breast Phantom design**




## 5. RESULT AND DISCUSSION

This section analyzes the performance results of the proposed antenna via simulation using CST software, while the real-time hardware implementation will be addressed subsequently. The antenna developed using CST software is seen in Figure 2. The CST tool is utilized for the design of various antenna types as well as RF electrical circuit components such as power dividers, couplers, and filters. The geometric design, material characteristics, and target output frequency are defined. CST software autonomously produces a solution process and precise mesh analysis for the specified design. The study appropriately considers essential characteristics, including return loss (S11), gain, radiation pattern, and VSWR.

The illustration above depicts the geometric configuration of the adaptable software antenna. Furthermore, the different parameters are studied with and without tumor and the comparison of results is shown in Table II below

**Table III Comparative Study of Different Parameters Like S- Parameters, E-field, H- Field Surface Current Density with and Without Tumor for Jean Substrate for Circular Patch Antenna**

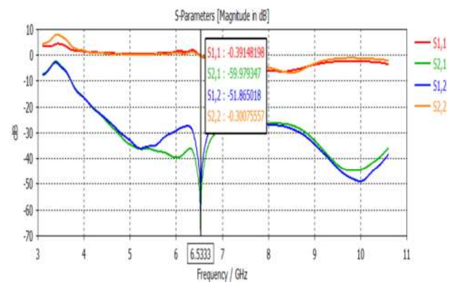
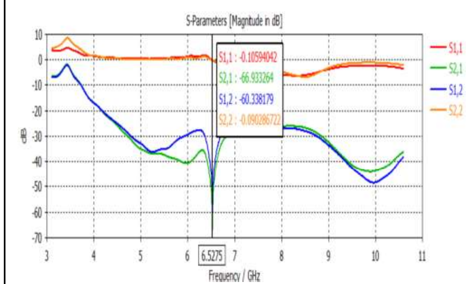
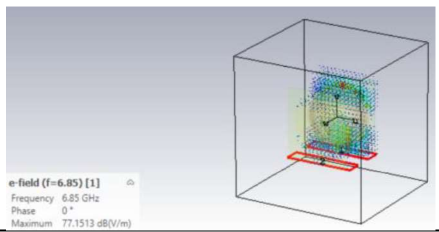
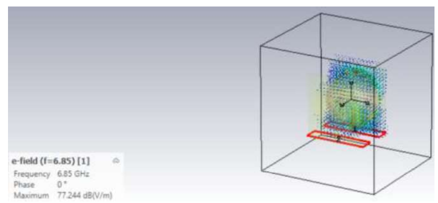
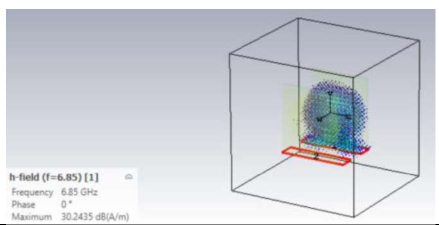
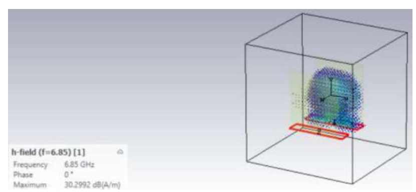
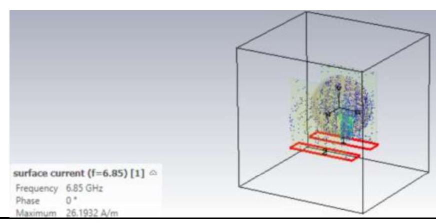
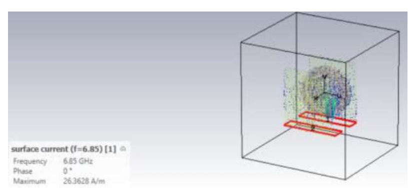
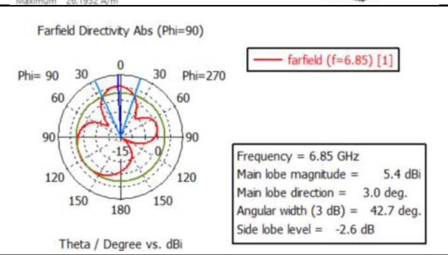
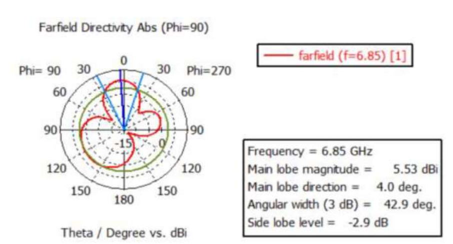
| Sr. No. | Parameter | Without Tumor | With Tumor |
|---|---|---|---|
| | S11 |  |  |
| 2 | E-Field(6.85GHz) |  |  |
| 3 | H-Field(6.85GHz) |  |  |
| 4 | Surface Current (6.85GHz) |  |  |
| 5 | Farfield (6.85GHz) |  |  |

**Table IV Comparison of various parameters with and without Tumor**

| Sr. No. | Parameter | Frequency | Values Without Tumor | Values With Tumor |
|---|---|---|---|---|
| 1 | S11 in dBm | 5.885GHz | 59.60 | 59.89 |
| 2 | E-Field in dBm (uV/m) | 6.85GHz | 77.1513 | 77.244 |
| 3 | H-Field in dBm (uA/m) | 6.85GHz | 30.2425 | 30.2992 |

| | | | | |
|---|---|---|---|---|
| **4** | Surface Current dBm (uA/m) | 6.85GHz | 26.1932 | 26.3628 |

## 6. CONCLUSION

This study aims to build and execute a new, low-cost textile wearable antenna for early-stage breast cancer detection. The engineered antenna can be utilized in the first detection of breast cancer, applicable to both tumor and non-tumor cases. This research utilizes wearable jeans material as a dielectric substrate, characterized by a dielectric constant of 1.7. The antenna is constructed as a sandwich model framework. The ground plane is composed of copper as the conductive substance. The jean fabric with a thickness of 1 mm is utilized for breast cancer examination, while a microstrip feeding technique is employed to provide the antenna. It functions as a wearable antenna, primarily intended for an ultra-wideband at 3.1 GHz to 10.6 GHz applications. The performance of the planned antenna is evaluated using CST software, focusing on Return Loss (S11), E-field, H-field, and surface current density with and without tumor. The examination of the findings demonstrates that the developed antenna offers superior advantages for applications, cost, and time.

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