Design and Simulation of Circular Microstrip Patch Antenna for Cancer Detection.

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***Abstract*—Early detection of cancer significantly improves the chances of successful diagnosis and lifelong survival. This project proposes the design and simulation of a circular microstrip patch antenna for biomedical applications focusing on early cancer detection. The proposed antenna designed as a wearable material can be seamlessly integrated into clothing or to the skin offering a non-invasive and portable diagnostic tool. The antenna operates at a frequency of 2.4 GHz to detect abnormal cells in the body that may indicate cancerous growth. The data collected will be transmitted wirelessly to a mobile application. The application will process and display real-time data, providing users with a simple user- friendly interface to monitor their health. The integration of the antenna system with the app aims to make cancer screening more accessible, affordable, and convenient. This work has the potential to contribute significantly to wearable technology and biomedical engineering, paving the way for innovative healthcare solutions.**

***Index Terms*—Cancer Detection, Microstrip Patch Antenna, Biomedical Application, Cells, Frequency, Convenient.**

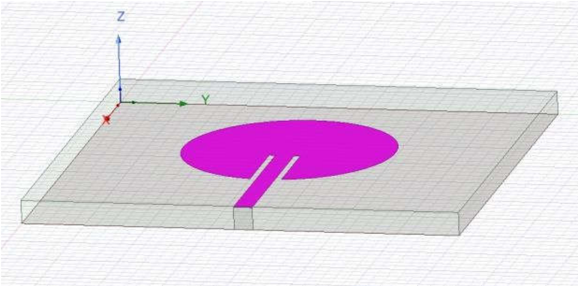
I. Introduction

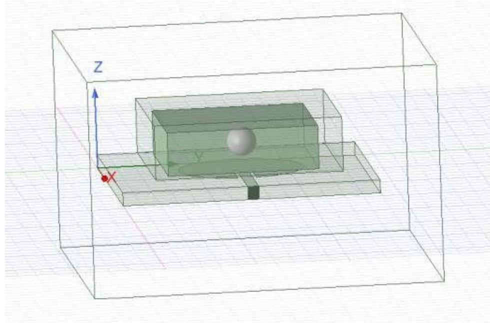
Early detection plays a crucial role in improving survival rates, as treatment outcomes are highly dependent on the stage at which the cancer is diagnosed. Recent research trends emphasize the development of non-ionizing and patient-friendly imaging methods to overcome the limitations of conventional techniques [1]. Tumor cells are basically of two types, of which malignant tumors may be hazardous for life, thus they need to be traced as early as possible. There are various methods available such as PET, X-ray tomography, and ultrasound which can be of use for the detection of cancerous cells [3]. Traditional breast cancer screening methods, such as X-ray mammography, magnetic resonance imaging, and ultrasound scanning, present several drawbacks, making them less than ideal. These drawbacks include high costs, exposure to potentially hazardous radiation, and patient inconvenience. Due to these challenges, researchers have been motivated to seek alternative methods, one of which involves the application of microwave technology [4]. Several studies have demonstrated that the dielectric contrast between malignant and healthy breast tissues can be effectively utilized for tumor localization and size estimation [6]. In 2020, there were 2.3 million new cases of female breast cancer, making it the most frequent cancer in women worldwide [7] Early detection and intervention are most effective in reducing mortality rates, as individuals diagnosed with early-stage cancer have the greatest opportunity for curative therapy and long-term survival [8].

In this work, we present the design of a circular microstrip patch antenna that operates at 2.4 GHz using Ansys HFSS. The antenna is intended for non-invasive cancer detection and can be integrated into clothing or placed directly on the skin. To support the antenna design, we developed a mobile application that shows how the collected data can be processed and displayed for real-time health monitoring. Unlike traditional diagnostic methods, this approach aims to provide an affordable, portable, and user-friendly solution that lowers the need for frequent hospital visits. The uniqueness of this work comes from combining a simulation-based antenna design with a digital health interface. This highlights how wearable technology can help with early cancer screening. Although this study is limited to simulation and application development, it lays the groundwork for future hardware implementation and clinical testing.

II. Circular Microstrip Patch Antenna

The structure of the proposed circular microstrip patch antenna fed by a microstrip line appears in Fig. 1. The antenna is made on an FR4 Epoxy substrate with a relative dielectric constant of 4.4, a loss tangent of 0.02, and a thickness of 3.6 mm. The overall size of the substrate is 30 mm × 28 mm × 3.6 mm, optimized for compactness while keeping acceptable radiation characteristics. A circular radiating patch with a radius of 17 mm is placed on the top surface of the substrate. This design supports multiple resonant modes and offers better radiation efficiency compared to rectangular patches of the same size.





The antenna gets its signal from a microstrip feed line that is 14 mm long and 2.46 mm wide, set to achieve a characteristic impedance of 50 Ω for proper matching with the RF source. A partial ground plane is added to the bottom surface of the substrate, matching the substrate width of 28 mm. To improve impedance bandwidth and reduce return loss, four rectangular slots are cut into the ground plane. These slots work as defected ground structures (DGS) that change the current distribution and boost antenna performance by widening the operating bandwidth and enhancing impedance matching. The optimized parameters of the antenna are listed in Table 1.

To test its use in biomedical applications, a multilayer tissue phantom model was created to mimic human breast tissue. This model included skin, fat, and glandular layers, with a malignant tumor embedded within it. The tumor was represented as a sphere with a radius ranging from 5 to 7 mm, showing different electromagnetic properties ($\varepsilon r \approx 60$, $\sigma \approx 4$ S/m) to simulate the dielectric contrast between cancerous and healthy tissues. The antenna was placed beneath these tissue layers, with its feed excited by a lumped port to launch electromagnetic waves.

The full simulation environment was enclosed in an air box to simulate open-space conditions, and radiation boundary conditions were used to ensure accurate far-field calculations. To reduce computation errors, adaptive meshing and convergence criteria were used in Ansys HFSS to maintain stable S-parameter results across the frequency range of interest. The resonant frequency was set at 2.4 GHz, a common ISM band suitable for safe power transmission and compatible with wearable and wireless medical applications.

Key performance parameters, like return loss (S11), VSWR, bandwidth, gain, and radiation pattern, were reviewed. The interaction between the antenna and biological tissue was examined through specific absorption rate (SAR) analysis to ensure radiation levels stayed within IEEE/ICNIRP safety limits. By combining both Electromagnetic performance and bio-safety evaluation, the proposed antenna design shows promise for non-invasive cancer detection.

Parameter	Value(mm)	Parameter	Value(mm)
Substrate Length (SubL)	30	Ground Length Slot 1(GL1)	2
Substrate Width(SubW)	28	Ground Width Slot1(GW1)	5.5
Substrate Height (SubH)	0.8	Ground Length Slot 2(GL2)	1
Feedline Length(FL)	14	Ground Width Slot 2(GW2)	3.5
Feedline Width(FW)	2.46	Ground Length Slot 3 (GL3)	3
Ground Length(GL)	13	Ground Width Slot 3 (GW3)	7
Ground Width(GW)	28	Patch Radius (r)	7

Fig.1Circular Patch Antenna

III. SIMULATION SETUP

The simulation was carried out using **ANSYS HFSS 2024 R1**, a 3D full-wave electromagnetic simulation software. A **circular microstrip patch antenna** was designed to investigate its capability for breast cancer detection based on changes in the return loss characteristics due to the presence of a tumor model.

Fig. 2 Tumor Model in Biological Tissue Phantom

To simulate a realistic biological environment for cancer detection, a multilayer tissue phantom was designed in HFSS. The outermost layer consisted of a rectangular box representing human skin, assigned with dielectric properties of relative permittivity (εr) approximately 36 and conductivity (σ) around 4 S/m. Enclosed within this skin layer was an inner cuboidal structure simulating healthy tissue, such as muscle or fatty tissue, characterized by εr ≈ 50 and σ ≈ 1.5 S/m. To represent a

IV. MOBILE APPLICATION FOR HEALTH MONITORING

To complement the design and simulation of the circular microstrip patch antenna, a mobile application was developed to provide users with real-time access to the antenna's performance data and health monitoring results. The app was designed using Flutter to ensure cross-platform compatibility, making it accessible on both Android and iOS devices. The primary function of the app is to wirelessly receive data from the antenna, such as return loss, which can be indicative of abnormal tissue, potentially suggesting the presence of a tumor.

The app includes several key features to enhance user experience and accessibility. The **login page** ensures secure access, while the **appointment page** allows patients to schedule consultations with healthcare professionals based on the data received. The **upload scan page** enables patients to upload medical scans, which are analyzed in conjunction with the antenna results. The **About Us** page provides an overview of the research, and a **logout** function ensures privacy and security. By seamlessly integrating the antenna system with the mobile application, this solution offers a convenient, non-invasive method for early cancer detection and health monitoring, making it more accessible to individuals at home and healthcare providers in various settings.

V. RESULTS AND DISCUSSIONS

The primary performance parameter analyzed in this study is the return loss (S11), which indicates the degree of impedance matching and power reflection in the antenna. The simulation was initially performed for the standalone antenna without any tissue or tumor model. Under these conditions, the antenna exhibited a strong resonance at 2.45 GHz, as shown in Figure 3, with a return loss of approximately -33 dB. This value reflects excellent impedance matching and minimal power reflection, validating the antenna's suitability for biomedical applications. Importantly, the 2.45 GHz frequency lies within the ISM (Industrial, Scientific, and Medical) band, which is widely used for non-invasive sensing and medical diagnostics.

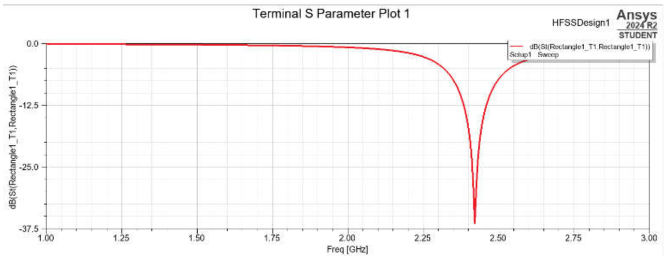


Fig. 3 Return Loss (S11) Parameter of the Circular Microstrip Patch Antenna

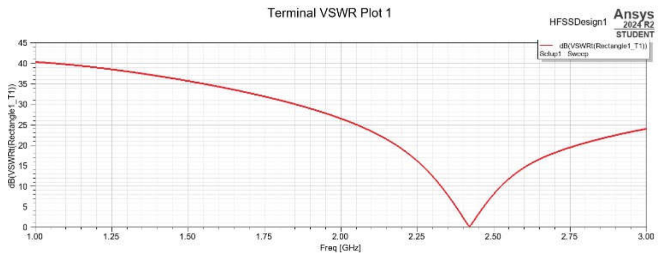


Fig. 4 Voltage Standing Wave Ratio (VSWR) of the Circular Microstrip Patch Antenna

To assess the antenna's response to biological abnormalities, a spherical tumor was introduced into the tissue phantom model. The presence of the tumor altered the dielectric properties of the surrounding medium, which in turn affected the antenna's electromagnetic behavior. This change typically results in a shift in the resonance frequency, a variation in return loss magnitude, and potentially a change in bandwidth. Although only the baseline return loss plot is presented here, future analysis can include comparative plots to highlight the differences in antenna response with and without the tumor. Expected changes may include a frequency shift in the range of 50 to 150 MHz or a reduction in return loss from -33 dB to around -20 dB. These shifts occur due to wave scattering or absorption caused by the tumor's higher permittivity and conductivity. Such observable deviations in the S-parameter response serve as the fundamental mechanism enabling microstrip patch antennas to detect cancerous tissues through electromagnetic characterization

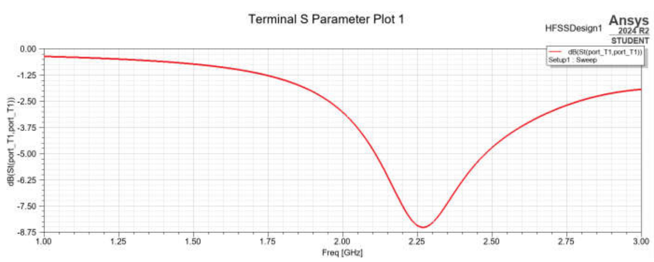


Fig. 3 Return Loss (S11) Parameter of the Tumor Model

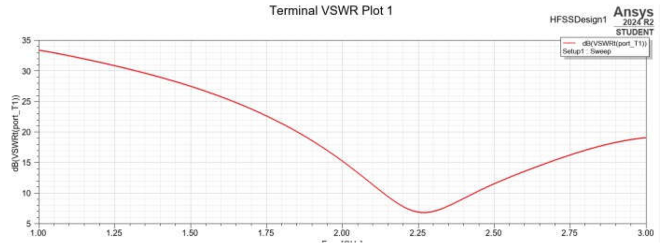


Fig. 4 Voltage Standing Wave Ratio (VSWR) of the Tumor Model

VI. Conclusion

In this study, a circular microstrip patch antenna was designed and simulated using HFSS to explore its potential in Detecting cancerous tumors through electromagnetic interaction. The antenna exhibited strong resonance behavior at 2.45 GHz with excellent return loss performance when simulated in free space, confirming its suitability for biomedical sensing applications within the ISM band. To mimic realistic biological conditions, a multilayer tissue phantom was developed comprising skin, healthy tissue, and an embedded spherical tumor. Simulation results indicated significant variations in the return loss characteristics when a tumor was introduced into the model. These variations, resulting from the altered dielectric properties of the tissue, suggest the feasibility of using electromagnetic sensing for non-invasive early-stage cancer detection.

The promising preliminary findings encourage further development, including experimental validation and integration with signal processing techniques for real-time diagnostics. This approach has the potential to contribute to safer, cost-effective, and early detection systems for various forms of cancer.

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