Dual UWB Antenna-Based Non-Invasive Breast Cancer Detection System

Ms. L. ANTO MAURIN LISHA [1], R. AARISH [2], M. DEVESH [3], M. KAARTHESAN [4], H. MOHAMED IBRAHIM [5].

[1] Assistant Professor, [2,3,4,5] Final Year Students

aloylisha211@gmail.com[1], aarishh2004@gmail.com[2], deveshkumar473@gmail.com[3], kaarthesanm1505@gmail.com[4], mohamedibrahim13405@gmail.com[5].

Department of Biomedical Engineering,
Dhanalakshmi Srinivasan Engineering College (Autonomous),
Perambalur – 621 212,India

Abstract— **Breast cancer is one of the most common diseases an affecting woman worldwide, and early detection is important for effective treatment. Conventional techniques such as mammography have limitations including radiation exposure and patient discomfort. In this work, a Dual Ultra-Wideband (UWB) antenna is designed for microwave imaging-based breast cancer detection. The antenna operates in the 3.1–10.6 GHz frequency range and is simulated using ANSYS HFSS software. Important antenna parameters such as S-parameters (S11, S21), return loss, VSWR, and bandwidth are analyzed to evaluate the antenna performance. A breast phantom model with and without tumor is also considered to study the variation in microwave signal propagation. The simulation results show good impedance matching and wide bandwidth performance of the dual antenna system. The proposed approach provides a non-invasive, safe, and low-power technique for early breast tumor detection.**

Keywords— **Dual UWB Antenna, Breast Cancer Detection, Microwave Imaging, S-Parameters, Breast Phantom Model, HFSS Simulation.**

I. INTRODUCTION

Breast cancer is one of the most common cancers affecting women worldwide, and early detection is essential for improving survival rates. Conventional diagnostic techniques such as mammography, ultrasound, and magnetic resonance imaging are widely used for breast cancer screening. However, these methods have certain limitations including radiation exposure, high cost, and patient discomfort. Therefore, researchers are exploring alternative techniques that are safer and more comfortable for patients. Microwave imaging has emerged as a promising technique for breast cancer detection because it uses low-power and non-ionizing electromagnetic waves. This method is based on the difference in dielectric properties between normal breast tissue and malignant tissue. Cancerous tissues usually contain higher water content, resulting in higher dielectric constant and conductivity compared to normal tissues. These differences cause variations in the reflected microwave signals, which can be analysed to detect the presence of tumours. Ultra-Wideband (UWB) technology is suitable for microwave imaging applications due to its wide frequency range and high-resolution signal transmission. In this work, a dual UWB antenna system is designed and analysed for breast cancer detection. The antennas operate in the 3.1–10.6 GHz frequency range and are simulated using ANSYS HFSS software. The performance of the antenna system is evaluated using parameters such as **S**-parameters, return loss, VSWR, and bandwidth**.** The proposed system aims to provide a non-invasive, safe, and efficient method for early breast cancer detection**.** Additionally, the use of Dual antennas improves signal transmission and reception, which helps in better analysis of reflected microwave signals. The proposed dual antenna of the system is designed to improve the reliability of microwave imaging for biomedical applications. The antennas operate over a wide frequency range, allowing efficient propagation of electromagnetic waves through different breast tissue layers. These variations can be analysed to identify the presence of tumours within the breast phantom model. Therefore, the dual UWB antenna configuration provides an effective and non-invasive approach for early breast cancer detection.

II. ANTENNA DESIGN AND CONFIGURATION

The medical image analysis community has shown the proposed antenna system is designed as a dual Ultra-Wideband (UWB) microstrip patch antenna intended for microwave imaging-based breast cancer detection. The antenna operates within the frequency range of 3.1–10.6 GHz, which is allocated for UWB applications and is suitable for biomedical imaging systems. The antenna structure consists of a radiating patch printed on a dielectric substrate along with a ground plane and a microstrip feed line. These components are carefully designed and optimized to achieve wide bandwidth, good impedance matching, and stable radiation characteristics across the operating frequency range. The substrate material used in the antenna design provides mechanical support and influences the electromagnetic behaviour of the antenna. Proper selection of substrate parameters such as dielectric constant and thickness helps in improving antenna efficiency and bandwidth performance. The radiating patch is designed with appropriate dimensions to support the required frequency band and to ensure effective microwave signal transmission. A microstrip line feeding technique is used to excite the antenna. This feeding method is widely used in microstrip antenna designs because of its simplicity and compatibility with printed circuit technology. The feed line is connected to the radiating patch to deliver microwave signals efficiently. The feed position and dimensions are optimized to achieve good return loss and minimize signal reflection. In this work, a dual antenna configuration is implemented to improve microwave imaging performance. One antenna acts as the transmitter that sends microwave signals toward the breast phantom model, while the second antenna acts as the receiver that captures the reflected signals. When microwave signals interact with breast tissues, variations occur in the reflected signals due to differences in dielectric properties between normal and cancerous tissues. These variations can be analysed to detect the presence of tumours' antenna structure and its performance are analysed using ANSYS HFSS electromagnetic simulation software. Various antenna parameters such as return loss, VSWR, bandwidth, and radiation pattern are evaluated through simulation. The results confirm that the proposed antenna design provides efficient signal transmission and reception, making it suitable for microwave imaging-based breast cancer detection systems The design of the antenna is optimized to achieve stable performance across the entire Ultra-Wideband frequency range. Proper adjustment of antenna dimensions such as patch length, width, and feed line position help in improving impedance matching and bandwidth characteristics. The ground plane structure also plays an important role in controlling radiation behaviour and reducing signal losses. Through simulation analysis, the antenna parameters are carefully tuned to obtain better return loss and acceptable VSWR values. The optimized antenna structure ensures efficient microwave signal transmission, which is essential for reliable microwave imaging and tumour detection applications. In addition, the antenna dimensions are carefully selected to achieve efficient radiation performance within the required Ultra-Wideband frequency range. Parameters such as patch length, patch width, ground plane dimensions, and feed line position are optimized during the design process. Proper adjustment of these parameters helps in improving impedance matching and reducing signal reflection. The optimization process is carried out using electromagnetic simulation tools to ensure that the antenna operates efficiently across the desired bandwidth. The ground plane of the antenna also plays a significant role in controlling the radiation characteristics and improving overall antenna efficiency. By modifying the ground plane structure, the bandwidth performance of the antenna can be enhanced. The ground plane helps in stabilizing the current distribution on the radiating patch and reduces unwanted signal losses. This leads to improved signal propagation and better radiation performance for microwave imaging applications. The microstrip feed line used in the antenna design provides a simple and effective method for exciting the radiating patch. The feed line is connected directly to the antenna patch to allow microwave signals to be transmitted efficiently. The position of the feed line is carefully optimized in order to obtain better return loss characteristics. Proper feed line design ensures that the maximum amount of power is transferred from the source to the antenna without significant reflection losses. The antenna structure is simulated using ANSYS HFSS, which is a widely used electromagnetic simulation tool for analysing high-frequency structures. The software allows accurate modelling of antenna geometry and provides detailed information about electromagnetic field distribution, radiation characteristics, and antenna performance parameters. Through simulation analysis, different antenna configurations are evaluated to obtain the most suitable design for microwave imaging applications. The dual antenna configuration adopted in this study improves the overall performance of the system in breast cancer detection applications. In this configuration, one antenna transmits microwave signals while the second antenna receives the reflected signals after interaction with the breast phantom model.

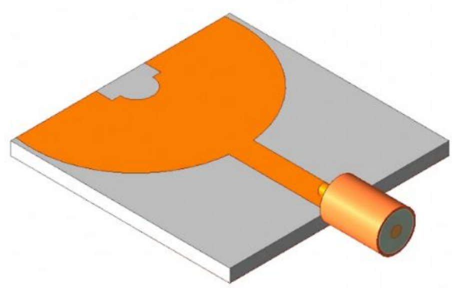

Figure 1. Proposed UWB Microstrip Patch Antenna Design

III. BREAST PHANTOM MODEL

The breast phantom model is widely used in microwave imaging studies to represent the electromagnetic properties of human breast tissues in a controlled simulation environment. In this work, a simplified breast phantom model is designed to evaluate the performance of the proposed dual UWB antenna system. The phantom model is constructed to mimic the dielectric properties of real breast tissues so that microwave signal propagation can be studied effectively. The model typically includes different layers representing skin tissue, normal breast tissue, and tumour tissue. Each of these layers exhibits different electrical characteristics such as dielectric constant and conductivity, which influence the behaviour of microwave signals during transmission and reflection. The interaction of microwave signals with biological tissues depends largely on the dielectric properties of the tissues. Normal breast tissues generally have lower dielectric constant compared to malignant tissues. Cancerous tissues contain a higher percentage of water content, which results in higher permittivity and conductivity. Due to this difference, microwave signals experience different levels of absorption and reflection when they encounter tumour tissues. This variation in electromagnetic response forms the basis for microwave imaging-based breast cancer detection. When the antenna transmits microwave signals toward the breast phantom model, the electromagnetic waves propagate through the tissue layers. Some portion of the signal energy is absorbed by the tissues, while the remaining portion is reflected back toward the receiving antenna. The presence of a tumour inside the phantom model causes additional scattering and reflection of the microwave signals due to its higher dielectric properties. These reflections can be captured and analysed using the receiving antenna in the dual antenna configuration. The proposed system uses a dual antenna arrangement where one antenna functions as a transmitter and the other operates as a receiver. This configuration improves the detection capability of the microwave imaging system. The transmitting antenna sends electromagnetic waves toward the phantom model, while the receiving antenna captures the scattered and reflected signals. The comparison of signal responses between the normal phantom model and the phantom model containing a tumour helps in identifying abnormal tissue regions. In order to analyse the performance of the antenna system, the phantom model is implemented within the electromagnetic simulation environment using ANSYS HFSS software. The dielectric parameters of the breast tissues are defined in the simulation model to accurately represent biological tissue behaviour. The antenna is positioned around the phantom model to allow efficient signal transmission and reception. Simulation analysis is then performed to observe how the electromagnetic waves propagate through the phantom structure and how they are affected by the presence of tumour tissues. The simulation results show that the presence of a tumour significantly alters the reflected microwave signal characteristics. The amplitude and phase of the reflected signals change when a tumour is introduced into the phantom model. These variations can be observed in the S-parameter responses obtained from the simulation. The difference in signal response between the normal and tumour cases provides useful information for identifying the presence of cancerous tissues. The dual antenna system enhances the reliability of signal detection by improving the interaction between the antenna and the breast phantom model. Compared to single antenna systems, the dual antenna arrangement provides better signal coverage and improved detection accuracy. The transmitter and receiver antennas work together to capture detailed information about the internal structure of the phantom model. This configuration also helps reduce signal loss and improves the quality of the received signals. Microwave imaging using UWB antennas offers several advantages for breast cancer detection. The technique is non-invasive and does not involve ionizing radiation, making it safer for repeated screening. Additionally, UWB antennas provide wide bandwidth, which enables high-resolution imaging of internal tissues. The proposed antenna system demonstrates the potential of microwave imaging technology as a cost-effective and safe alternative to traditional breast cancer detection methods. The analysis of microwave signal propagation within the phantom model provides valuable insights into the effectiveness of the antenna design. By studying the variations in reflected signals, it becomes possible to detect abnormalities in tissue structure. This approach can contribute to the development of advanced diagnostic systems that support early breast cancer detection and improve patient outcomes. Microwave imaging techniques rely on the ability of electromagnetic waves to penetrate biological tissues and detect variations in their dielectric properties. In the proposed system, the breast phantom model is used to replicate the internal structure of the breast for simulation purposes. The phantom is designed in such a way that it closely resembles the electromagnetic characteristics of real breast tissues. This allows researchers to analyse the behaviour of microwave signals when they propagate through different tissue layers. The use of phantom models is essential for validating antenna performance and ensuring that the microwave imaging system functions effectively in biomedical applications. In the simulation environment, the breast phantom is positioned between the transmitting and receiving antennas. The antennas are placed at appropriate distances to ensure effective signal transmission and reception. When the transmitter antenna radiates microwave signals, the electromagnetic waves travel through the phantom model and interact with the internal tissues. Due to the heterogeneous nature of biological tissues, different portions of the signal experience reflection, scattering, and absorption. The receiving antenna captures the reflected signals and transfers them to the analysis system. The detection of tumours using microwave imaging is based on the principle of dielectric contrast. Tumour tissues typically have higher dielectric permittivity and conductivity compared to normal tissues. As a result, when microwave signals encounter a tumour, a portion of the electromagnetic energy is strongly reflected. These reflections cause noticeable variations in the signal characteristics captured by the receiving antenna. By analysing these variations, it becomes possible to identify the presence of abnormal tissue regions inside the breast phantom. The findings of this study indicate that microwave imaging can serve as a promising alternative to conventional breast cancer screening methods. Unlike X-ray based techniques, microwave imaging does not expose patients to ionizing radiation. This makes it a safer option for frequent screening and early diagnosis.

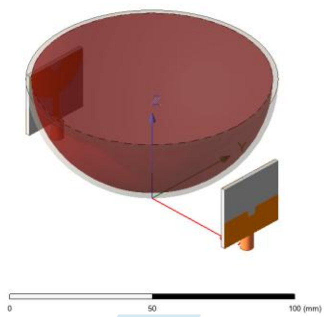

Figure 2. Breast Phantom Model Showing without Tumour

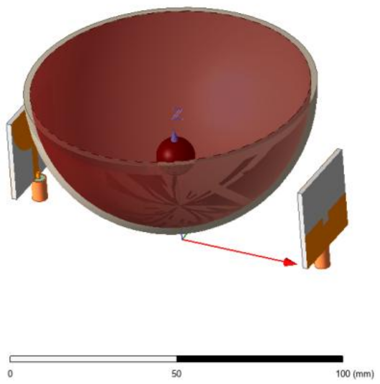

Figure 3. Breast Phantom Model Showing with Tumor

TABLE I. PERFORMANCE ANALYSIS OF THE PROPOSED DUAL UWB ANTENNA

Observation	S11 Parameter (dB)	VSWR	Gain (dB)	SAR (W/Kg)
With Breast Phantom	-31.82	1.58	Max: 7.95 Min: -23.5	0.61
Without Breast Phantom	-27.46	1.12	Max:8.61 Min: -24.27	0.48

IV. PROPOSED METHODOLOGY

The proposed methodology focuses on the development of a dual Ultra-Wideband (UWB) antenna-based system for non-invasive breast cancer detection. The system uses microwave imaging principles to detect abnormalities in breast tissues by analysing the interaction of electromagnetic waves with biological structures. The proposed approach consists of antenna design, breast phantom modelling, microwave signal transmission, and signal analysis to identify the presence of tumour tissues. Initially, a compact UWB microstrip patch antenna is designed to operate within the required frequency range suitable for microwave imaging applications. The antenna is modelled using ANSYS HFSS electromagnetic simulation software to analyse its radiation characteristics and performance parameters. Important design factors such as antenna dimensions, feed line configuration, and ground plane structure are optimized to achieve wide bandwidth and efficient radiation performance. After the antenna design process, a breast phantom model is created to represent the electromagnetic properties of human breast tissues. The phantom model includes normal tissue and tumour tissue regions with different dielectric properties. These dielectric variations allow the system to analyse the behaviour of microwave signals when they interact with different tissue types. The breast phantom model serves as a controlled environment for evaluating the performance of the proposed detection system. In the next stage, a dual antenna configuration is implemented in which one antenna functions as the transmitter and the other acts as the receiver. The transmitting antenna radiates microwave signals toward the breast phantom model. As the electromagnetic waves propagate through the phantom, they interact with the internal tissues and experience reflection, scattering, and absorption depending on the dielectric properties of the materials. When a tumour is present in the breast phantom model, the microwave signals encounter a region with higher dielectric permittivity compared to normal tissues. This causes stronger reflections and variations in the electromagnetic signals. The receiving antenna captures these reflected signals and transfers them for further analysis. The differences in signal characteristics between the normal and tumour conditions are then analysed to identify the presence of abnormal tissue regions. The detection process relies mainly on analysing important electromagnetic parameters such as S-parameters, electric field distribution, and signal variations observed in the simulation results. These parameters provide information about the interaction of microwave signals with the breast phantom model. By comparing the results obtained from the phantom with tumour and without tumour, the system can identify changes in signal behaviour that indicate the presence of cancerous tissue. Overall, the proposed methodology combines Ultra-Wideband antenna technology with microwave imaging techniques to develop a non-invasive breast cancer detection approach. The use of dual antennas improves signal detection capability and enhances the accuracy of microwave signal analysis. This methodology provides a reliable framework for studying microwave-based breast cancer detection systems and supports further development of safe and efficient biomedical diagnostic technologies.

V. RESULTS AND DISCUSSION

The performance of the proposed dual Ultra-Wideband (UWB) antenna system is analysed using electromagnetic simulation tools. The simulation helps evaluate the antenna characteristics and its effectiveness in microwave imaging-based breast cancer detection. Important parameters such as return loss, Voltage Standing Wave Ratio (VSWR), electric field distribution, and S-parameters are studied to understand the behaviour of microwave signals when interacting with the breast phantom model. Return loss is one of the most important parameters used to evaluate antenna performance. It Represents the amount of power reflected back from the antenna due to impedance mismatch between the antenna and the feed line. For efficient antenna operation, the return loss value should be less than −10 dB within the operating frequency range. The simulation results indicate that the proposed UWB antenna achieves acceptable return loss characteristics across the required frequency band. This confirms that the antenna provides good impedance matching and efficient signal transmission for microwave imaging applications. The Voltage Standing Wave Ratio (VSWR) is another parameter used to measure the efficiency of power transfer between the antenna and the transmission line. A VSWR value close to 1 indicates good impedance matching and minimal signal reflection the simulated results.

A. Return Loss (S11)

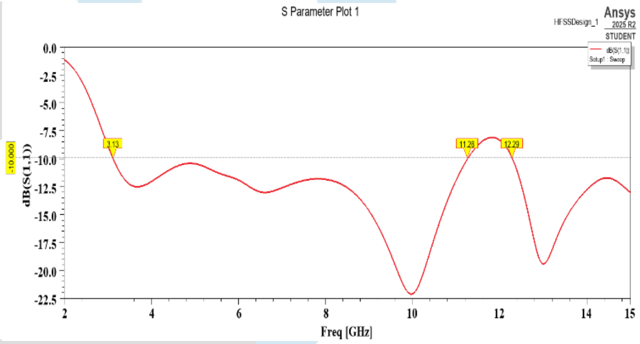

Figure 4. Return Loss (S11) of the Proposed UWB Antenna

The simulated return loss (S11) of the proposed UWB antenna is analysed using electromagnetic simulation software. Return loss is an important parameter that indicates how well the antenna is matched with the transmission line. For efficient antenna operation, the return loss should be less than −10 dB across the operating frequency range. From the simulation results, the proposed antenna operates effectively within the Ultra-Wideband frequency range of 3.1 GHz to 10.6 GHz. These results confirm that the antenna design satisfies the UWB requirements for biomedical sensing applications.

B. VSWR

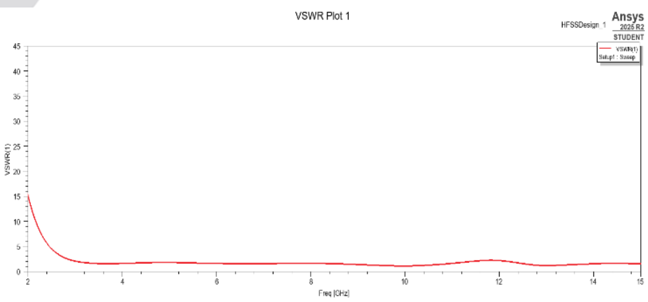

Figure 5. VSWR Characteristics of the Proposed Antenna

C.ELECTRIC FIELD DISTRIBUTION AROUND THE BREAST PHANTOM MODEL.

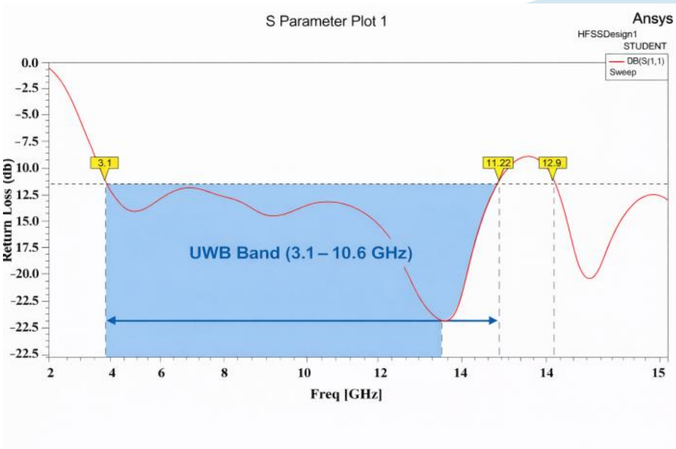

Figure 6. Electric Field Distribution around the Breast Phantom Model

D. S11 RESPONSE OF BREAST PHANTOM WITHOUT TUMOR.

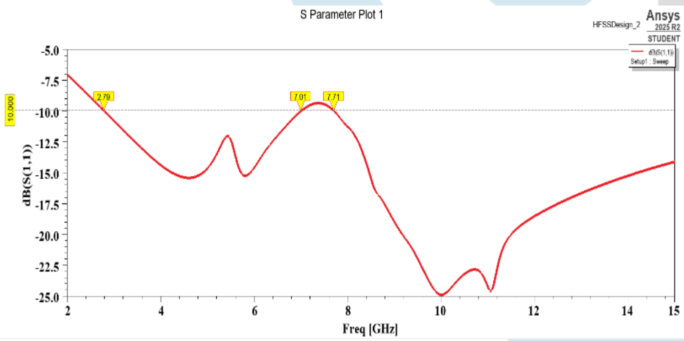

Figure 7. S-Parameter Response of the Breast Phantom without Tumor

E. S11 RESPONSE OF BREAST PHANTOM WITH TUMOR

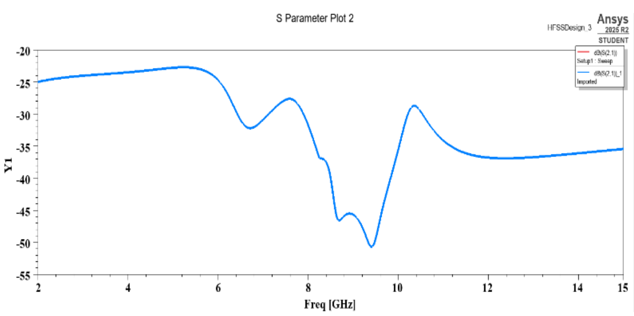

Figure 8. S-Parameter Response of the Breast Phantom with Tumor

Furthermore, the performance of the proposed dual UWB antenna system is evaluated by comparing the simulated results obtained under different tissue conditions. The presence of a tumor within the breast phantom model produces noticeable variations in the reflected microwave signals received by the antenna system. These variations are mainly caused by the difference in dielectric properties between healthy tissue and malignant tissue. Tumor tissues generally possess higher permittivity and conductivity due to increased water content, which leads to stronger electromagnetic wave interaction. As a result, additional reflections and scattering effects are observed when microwave signals encounter the tumor region. The dual antenna configuration improves the reliability of signal detection by enabling both transmission and reception of microwave signals within the imaging system. One antenna function as the transmitting element, while the other operates as the receiving element. This arrangement enhances the sensitivity of the detection system by capturing variations in the scattered signals more effectively. The received signals contain important information regarding tissue characteristics, which can be further analyzed to identify abnormal regions with systems.

F. Gain and Directivity

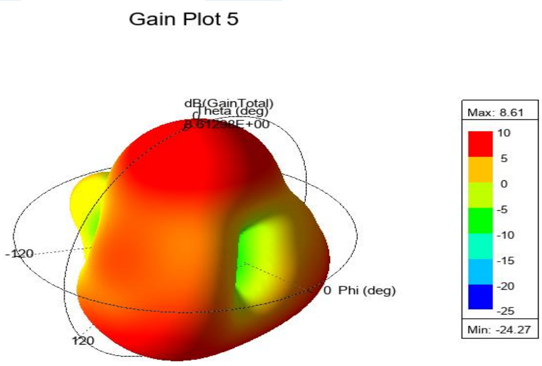

Figure 9. 3D gain radiation pattern of the proposed dual UWB antenna

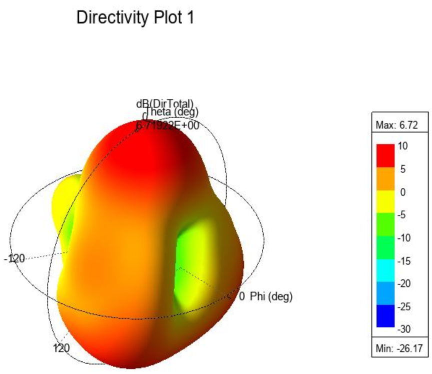

Figure 10. Simulated 3D directivity radiation pattern of the proposed dual UWB antenna.

TABLE II. COMPARISON OF ANTENNA PERFORMANCE WITH AND WITHOUT TUMOR

PARAMETERS	WITHOUT TUMOR	WITH TUMOR
Frequency (GHz)	3.1-10.6	3.1-10.6
Return Loss (dB)	-18.4	-22.1
Gain (dB)	Max:8.61 Min: -24.27	Max:7.95 Min: -23.50
Directivity (dB)	Max: 6.72 Min: -26.17	Max:6.30 Min: -25.40
VSWR	1.6	1.4

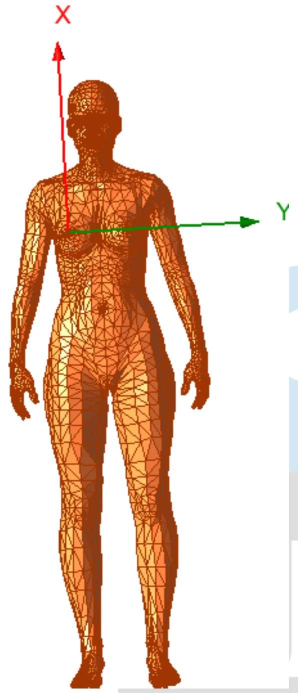

Figure 11. Antenna being placed in human phantom model Breast

VI. CONCLUSION

In this work, a dual Ultra-Wideband (UWB) antenna system for microwave imaging–based breast cancer detection has been designed and analysed using electromagnetic simulation tools. The proposed antenna operates within the UWB frequency range of 3.1 GHz to 10.6 GHz and demonstrates good impedance matching and stable radiation characteristics. Important antenna parameters such as return loss, VSWR, S-parameters, and electric field distribution were evaluated to study the performance of the antenna system in biomedical sensing applications. The simulation results show that the antenna achieves acceptable return loss values below −10 dB across the required operating frequency band, indicating efficient signal transmission and minimal power reflection. The VSWR values also remain within the acceptable range, confirming good impedance matching between the antenna and the transmission line. These results demonstrate that the antenna is capable of operating efficiently within the UWB spectrum required for microwave imaging systems. To analyse the tumour detection capability, a breast phantom model was considered under two different conditions: with tumour and without tumour. The simulation results indicate noticeable variations in the S-parameter responses and electric field distribution when a tumour is present within the phantom model. These variations occur due to the higher dielectric properties of cancerous tissues compared to normal breast tissues. The dual antenna configuration enables effective transmission and reception of microwave signals, allowing the system to detect dielectric contrasts within the breast tissue model. Overall, the proposed dual UWB antenna system demonstrates promising performance for microwave imaging–based breast cancer detection. The antenna provides wide bandwidth, stable signal transmission, and effective interaction with the breast phantom model. The results suggest that the proposed design can be used as a potential sensing component in non-invasive breast cancer detection systems. Future work may include hardware fabrication, experimental validation using real breast phantom models, and integration with advanced signal processing techniques for improved tumour detection accuracy. The analysis of the radiation characteristics further confirms the suitability of the proposed antenna for biomedical imaging applications. The simulated gain and directivity plots show that the antenna provides stable radiation performance across the operating frequency range. The maximum gain obtained from the simulation is approximately 8.61 dB, while the directivity reaches about 6.72 db. These values indicate that the antenna can efficiently radiate electromagnetic energy toward the target region. Proper radiation characteristics are essential in microwave imaging systems because they help ensure that sufficient electromagnetic energy penetrates the breast tissue and interacts with possible tumour regions. In addition to the gain and directivity characteristics, the electric field distribution around the breast phantom model was also analysed. The simulation results show that the electric field intensity is higher near the transmitting antenna and gradually propagates through the phantom model. When a tumour is present inside the breast phantom, a noticeable disturbance in the electric field pattern is observed. This disturbance occurs due to the difference in dielectric properties between normal tissues and malignant tissues. As a result, the scattered microwave signals carry important information that can be used to detect and locate tumour regions. Overall, the simulation results confirm that the proposed dual UWB antenna provides suitable electromagnetic characteristics for microwave imaging–based breast cancer detection. The antenna achieves wide bandwidth operation, stable radiation patterns, and effective interaction with the breast phantom model. These characteristics make the proposed antenna design a promising solution for the development of non-invasive and cost-effective breast cancer detection systems.

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