

On the Performance of Metasurface Vivaldi Antenna in Anomaly Breast Cancer Detection Using Artificial Neural Networks for Bio-Signal Analysis

Raya A. Kamil¹, Noof T. Mahmood², Zainab S. Muqdad³, Marwah H. Jwair⁴,
Noor M. Noori⁵, and Taha A. Elwi^{6,*}

¹Public Relations Department, College of Media, Aliraqia University, Baghdad, Iraq

²Technical College of Engineering, Al-Bayan University, Baghdad, Iraq

³Department of Electrical Engineering, Mustansiriyah University, Baghdad, Iraq

⁴International Applied and Theoretical Research Center (IATRC), Baghdad Quarter, Iraq

⁵Department of Information and Communications Technology, Institute of Technology, Middle Technical University, Baghdad, Iraq

⁶Islamic University Centre for Scientific Research, The Islamic University, Najaf, Iraq

ABSTRACT: This paper presents a novel technique to detect tumors in human breasts using a single high-gain antenna and metasurface (MTS) layer. This design is realized to educate artificial neural networks (ANNs) and deliver productive output. We employ an ANN algorithm to classify detected tumors as healthy, benign, or malignant, based on the permittivity of the detected tissues. The method for finding and sorting things uses the fact of normal and abnormal biological tissues having different dielectric properties, which are based on the tissue's actual permittivity. The study focuses on demonstrating the effectiveness of the proposed technique for the detection and localization of malignant tumors within human breasts. The proposed Vivaldi antenna is made to work over 5 GHz to 9 GHz with a gain of 17.7 dBi at 6.5 GHz and a half-power beamwidth of 10°. The electromagnetic analysis is done using voxel datasets from human models. For this, we located the breast tissue with tumor inside phantom between the antenna structure and MTS layer. The obtained numerical results from CST MWS are validated experimentally to be used to realize the training of the considered ANNs for tumor detection. The obtained results from the considered ANNs show minimal average errors and high-performance indices for fat thickness, tumor size, and tumor type. The achieved results are found to realize minimum error percentage rate below 2%. The adopted method is found to be very suitable for tumor detection and localization.

1. INTRODUCTION

Microwave detection is a versatile method that uses electromagnetic waves to assess the properties of objects or materials [1]. These waves can penetrate certain materials and provide valuable insights into their composition, shape, and other properties [2]. This method finds application in various fields, such as medical imaging, remote sensing, object detection, and material characterization [3]. Microwaves also play a crucial role in material characterization, such as dielectric constant and conductivity, which are useful for identifying materials, defects, or irregularities [4]. Breast cancer affects one in eight women, and early diagnosis and treatment are crucial [5]. In 2024, there were 1.67 million new instances of breast cancer globally, resulting in 522,000 fatalities, making it the leading cause of death among females [6]. Proper early detection can lead to a cure rate of almost 98% or five-year survival rate [7]. However, in persistent cases or those whose cancer appears in the entire breast, the survival rate drops to only 15% [8]. Breast imaging for cancer visualization has been proven as a complementary method [8]. Breast cancer is the second leading cause of death in women globally, and early diagnosis ensures an en-

hanced survival likelihood and allows for the use of less costly therapies for curative purposes [9].

In the context of breast cancer detection, microwave technology is employed to identify abnormal tissue growth in the breast, potentially indicating the presence of breast cancer [10]. Researchers have developed advanced techniques, like dual-band microwave sensors, to transmit low-energy microwaves through biomedical tissues, which then reflect back to a detector [11]. The detector can find places in the body that have a different microwave signature from the surrounding tissue by looking at the reflected waves [12]. Microwave detection is currently under investigation as an alternative to mammography, the prevailing method for breast cancer screening [13]. While mammography has drawbacks, microwave detection has shown promising results in early studies, hinting at its potential usefulness in future breast cancer detection methodologies [14]. Important things to think about when making antennas for electromagnetic scanning systems are the operating frequency, bandwidth, and radiation properties like directivity, penetration level, and efficiency [15]. The dielectric constant (relative permittivity) of human tissues depends on the operational frequency; it decreases with an increase in frequency [16]. Existing literature suggests using microwave frequencies, specif-

* Corresponding author: Taha Ahmed Elwi (taelwi82@gmail.com).

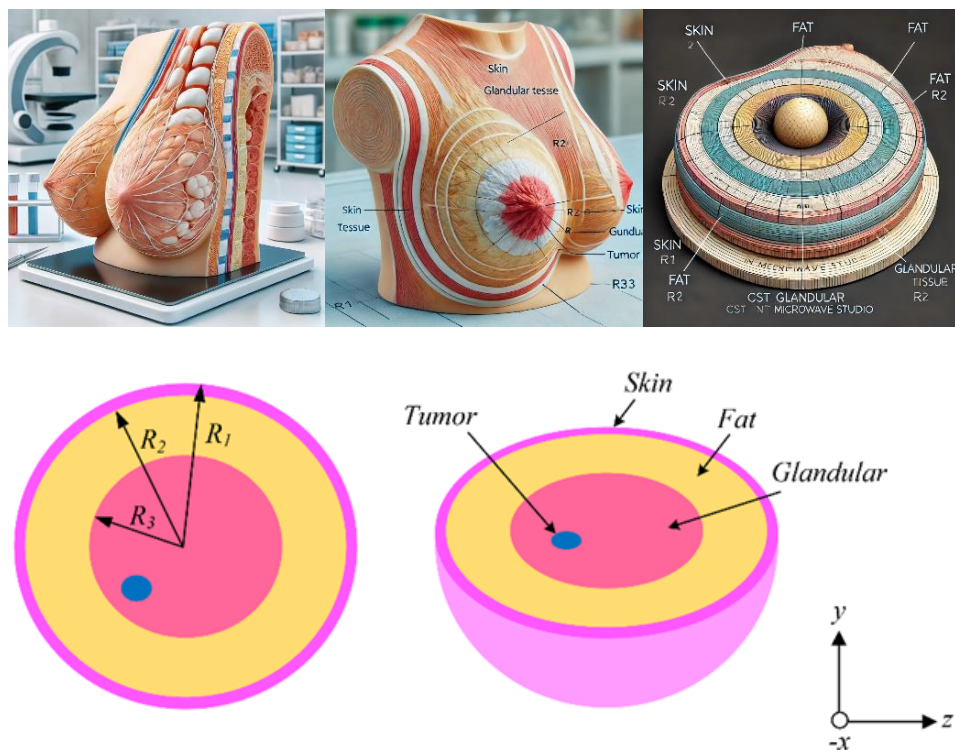


FIGURE 1. The breast phantom structure in 3D image with tissues with a radius ($R_1 = 50$ mm, $R_2 = 48$ mm and $R_3 = 38$ mm) and breast layers.

ically 6 GHz, for electromagnetic torso scanning techniques to address signal loss concerns [17]. However, ongoing research is exploring a range of wideband torso detection and imaging applications [18]. Radar-based imaging algorithms correlate their accuracy with the antenna bandwidth, and electromagnetic scanning systems prefer wideband signals [19]. Focused beam radiation is also an important part of antenna design for electromagnetic scanning systems because it lowers the effect of background noise and electromagnetic fields that scatter signals, which leads to better detection results [20]. Breast cancer is a significant and widely affected disease in women worldwide [21]. Breast cancer cells absorb electromagnetic radiation with surrounding tissue when they grow, and the mass of a cell bond changes, affecting the surrounding tissue's mass [22]. For example, breast cancer cells absorb more electromagnetic radiation when their mass decreases [23].

Recent research has focused on metamaterial (MTM) and MTS antennas due to their unique electromagnetic properties, which enhance overall antenna performance. In a study, an artificial magnetic conductor (AMC)-based microstrip antenna design was used to find breast cancer [24]. Different-sized cancerous tumors with radii of 2.5 mm, 3.5 mm, and 4.5 mm were placed in a phantom at different locations [25]. The principal component analysis (PCA) method and a specific absorption rate (SAR) study for the phantom enabled the detection of malignant tumors [26]. A multilayer ultra-wideband (UWB) patch antenna based on an AMC structure was also shown for finding breast cancer [27]. It has a 3×3 array of modified split ring resonator (SRR) unit cells that are used to build images. Simulation results demonstrated the antenna's capability to detect and locate a 10 mm tumor. We proposed a wearable staircase

antenna based on MTM technology for breast cancer detection, which integrates eighteen MTM unit cells using an altered rectangular SRR [28].

This paper introduces a novel approach for breast tumor detection using a single Vivaldi antenna that emits energy through an MTS layer. The antenna's compact size, expanded bandwidth, unidirectional features, and improved radiation pattern make it a promising and efficient solution for breast cancer detection. The proposed antenna and detection system is different because it uses a single antenna with a single feed point, has a high gain about 17.5 dBi, uses ANN to decide whether a tumor is benign or malignant, and can find tumors with different sizes. Early detection and treatment of breast tumor diseases can significantly increase the chances of recovery. Textile antennas, artificial lymph nodes, and microwaves are all seen as good options for electromagnetic breast imaging (EBI) because they can go through things easily, expose people to low levels of radiation, and do not create ions. The study's goal is to create the first microwave-based imaging system using a fed array of metasurface Vivaldi antennas. This will make breast screening safe, portable, cheap, and quick. The study proposes to detect breast cancer by monitoring patients' circulatory systems using a metasurface Vivaldi antenna and an ANN model.

2. HUMAN BREAST PHANTOM

Based on its dielectric properties, we propose a human breast model for microwave frequencies. The model's volume is similar to the average total volume of both female breasts in adults, with dimensions of 7.444 cm (see Fig. 1). The dielectric values of breast tissue are looked at between 6.0 and 14.9, with

TABLE 1. Dimensions of the proposed antenna in mm scale.

| Parameters | Values | Parameters | Values | Parameters | Values |
|------------|--------|------------|--------|------------|--------|
| W | 60 | $h1$ | 0.15 | $L1$ | 8.9 |
| L | 66 | $h2$ | 1.3 | $L2$ | 3.7 |
| $W1$ | 8 | $h3$ | 2.3 | $L3$ | 2.5 |
| $W2$ | 6 | $h4$ | 2.5 | R | 27 |
| $W3$ | 1.5 | $h5$ | 2 | $R1$ | 13.5 |
| $W4$ | 0.2 | $h6$ | 3.2 | $R2$ | 18.9 |
| $W5$ | 0.2 | $h7$ | 0.35 | $W6$ | 1.3 |
| $W7$ | 6.52 | G | 2.00 | θ_1 | 15° |
| $W8$ | 0.50 | $h10$ | 12.25 | θ_2 | 20° |

a 0.1-step accuracy to see if there are any differences in how they reflect light [29]. The model is established to investigate backscattered breast signals due to the exposure to different types of illumination. Malignant tumors are a common life-threatening health issue for women, and Global Cancer Observatory (GLOBOCAN) states that it has a high influence on causing deaths worldwide. Techniques to detect breast abnormalities include mammography, ultrasound imaging, and MRI. The suggested method dealt with backscattered signals and alerted data using a Unix-like operating system or the right software. It then uses Convolutional Neural Networks (CNN) with ANN to look at and confirm bio-signals by measuring their mean square error, sensitivity, specificity, and accuracy.

The proposed breast phantom is uniform and composed of three distinct layers: skin, fat, and fibro-glandular tissue, illustrated in Fig. 1. The picture clearly shows the radius of each layer in the breast model. We employ a spherical model to mimic tumor circumstances, setting tumor radii at 2.5 mm, 5 mm, 7.5 mm, and 10 mm. It is important to notice that the tumor is located precisely inside the fibro-glandular tissue, since this is the type of tissue from which most breast cancers arise [29]. This breast phantom model is accurate and complete, and it can be used to test microwave imaging methods for finding breast cancer in a range of tumor sizes. Many layers, including skin, fat, and fibro-glandular tissue, comprise breast tissue, each possessing unique electrical properties like permittivity and conductivity [12]. Each layer of the breast exhibits a different electromagnetic field strength due to these intrinsic distinctions [11]. Taking advantage of these differences in dielectric characteristics is an important method for detecting tumors. Table 1 contains the information on electromagnetic characteristics that are particular to the proposed breast phantom. This information is critical for understanding and modeling the electromagnetic interactions that occur inside the breast model.

3. ANTENNA SENSOR FOR DETECTING TUMORS IN HUMAN BREAST TISSUE

Recent epidemics have led to the use of antennas as bio-signal sensors to detect illnesses, particularly cancers. Researchers have developed a 5 to 8.5 GHz UWB-Vivaldi slot antenna using FR4 to address shrinkage, toroidal, and breast tissue issues.

The antenna's range is affected by human skin, epidermis, and fatty tissues. The study focuses on creating a wideband Vivaldi antenna with a gain ranging from 10 dBi to 17 dBi and addressing shrinkage, toroidal, and breast tissue issues. The Vivaldi antennas were designed to send signals between human breast tissue and propagation medium, with a specific design for human breast tissues. The bio-signals received by the antenna sensor were analyzed using ANN algorithms. The Vivaldi antenna sensors were used to identify gaps in honey mixtures and estimate them using ANN, and they can also be used to screen for colon cancer, a growing concern in emerging nations. The Vivaldi antenna was paired with UWB antenna, Reaction Surface Method, and Full Factor Test set to automatically identify collected pictures using deep learning. The hardware was post-processed in Microwave Studio, and 3D simulations were run to offer a new way to find breast cancer. The proposed antenna configuration is based on a Rogers TMM4 substrate with a dielectric constant of 4.5 and a loss tangent of 0.0020. It includes essential components such as grating bowtie electrical dipole, half-ring magnetic dipole, microstrip transition balun, and H-shaped resonators. The antenna design is oriented perpendicular to the MTS plane and incorporates elements from the architecture detailed in [10] and the MTS idea presented in [3].

The antenna construction is bifurcated into two halves on opposing sides of the substrate, connected by a multi-section microstrip transformer. The bowtie antenna consists of three radiating segments spaced at equal angles, connected to a quartering segment. This setup seeks to establish a Huygens source, where the electric and magnetic dipoles are stimulated in both amplitude and phase, yielding an extensive beamwidth and elevated directivity. An H-shaped resonator array is optimally positioned on the antenna to augment its radiation gain to 17 dBi at 8.5 GHz by aligning the antenna with free space. The considered 3D breast phantom is modeled as a hemispherical structure to replicate a human breast, with its several layers simulating a realistic tissue composition that displays frequency dispersive characteristics. The researchers used an ANN to represent different breast configurations with cancers of varying sizes and positions. Reflection coefficient data were gathered using CST Studio Suite across several tumor situations, and the permittivity of the breast phantom was derived using reflection coefficient measurements. Numerical findings from CST Stu-

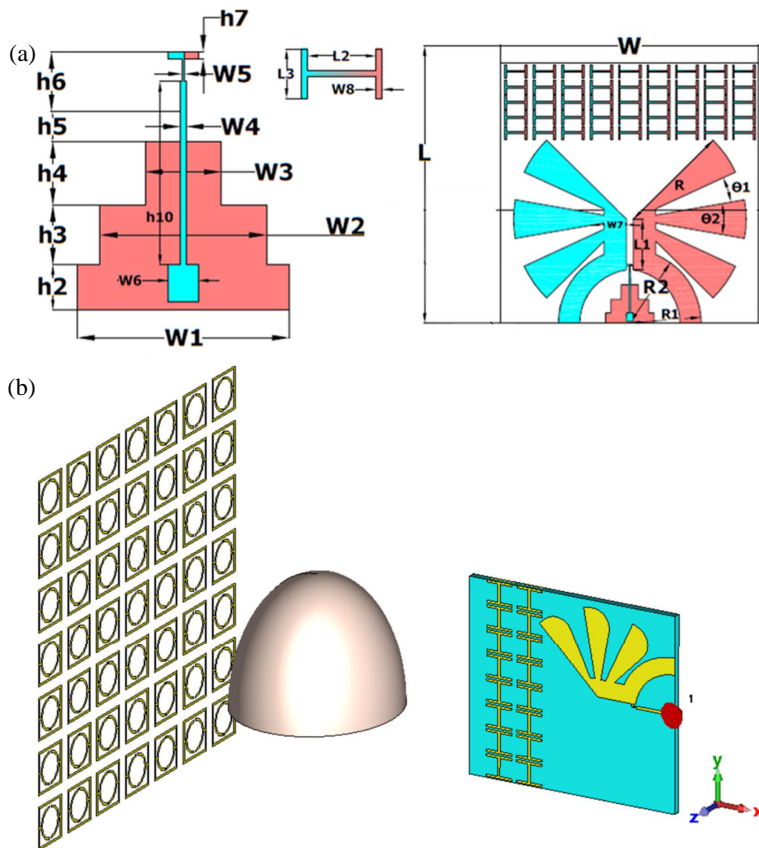


FIGURE 2. Configuration of the proposed antenna: (a) antenna dimensions and (b) antenna and MTS layer with the phantom structure.

TABLE 2. Electromagnetic properties of the breast layers [29].

| Tissue | Conductivity (S/m) | Relative Permittivity (F/m) |
|-----------|--------------------|-----------------------------|
| Skin | 1.44 | 38.1 |
| Fat | 0.133 | 5.16 |
| Glandular | 1.93 | 57.3 |
| Tumor | 1.46 | 47 |

dio Suite were used to train an ANN, and experimental validation results confirmed the efficacy of the suggested technique. The antenna's radiation beam was adjusted in increments to allow for precision measurement of the reflection coefficient data across the breast phantom, enabling accurate characterization of the whole breast. The proposed antenna dimensions of the optimal design are listed in Table 2.

4. ANTENNA PERFORMANCE OPTIMIZATION STUDY

The proposed MTS and Vivaldi antenna, see Figure 2, are optimized for breast cancer detection, with the objective of characterizing miniaturized antennas optimized for higher gain and efficiency at lower resonance and cutoff frequencies. The considered ANN is used for bio-signal analysis, measuring backscattered signals from six different optimized antennas in a breast phantom scanning system. The ANN model successfully detects tumor presence, achieving a high detection rate of 92% at the best -20 dBm of Radio Frequency (RF) power. The increasing number of cancers, particularly in women, has led to

the development of alternative detection methods such as thermal imaging and ultrasound imaging. Early detection of breast cancer can save lives, and many researchers have developed microwave spectroscopy and imaging techniques to diagnose the disease early. In Turkey, computers are also used for early diagnosis, using radiation or sound waves to examine organs and soft tissues. A mechanized process has been developed to detect diseases on imaging, using an ANN to classify images and create numbers for each image. This mechanical learning method ensures robustness to prevent database damage from translation, sensibility, and small distortions of objects. Deep learning methods are used to determine disease by reading complex image outputs.

An MTS Vivaldi antenna structure was developed that works better and more effectively at certain resonance frequencies than other structures. Understanding the impact of rectangular or cuneate notch structures on the impedance response of a Vivaldi antenna is crucial for understanding its effectiveness in breast cancer diagnosis (BCD). Vivaldi antenna is an optimal candidate for bio-signal analysis, especially close to human tissues. It is designed and tested on a metasurface with 60×60 unit cells made up of square metallic loop structures on a flexible adhesive polymer (AP) substrate. The structured metasurface improves the gain and directivity of the antennas. We provide far-field properties of the Vivaldi antenna, both with and without the metasurface. A finite difference time domain solver is used to study how metasurface-structured materials change the antennas' gain, directivity, and effective isotropic radiated power

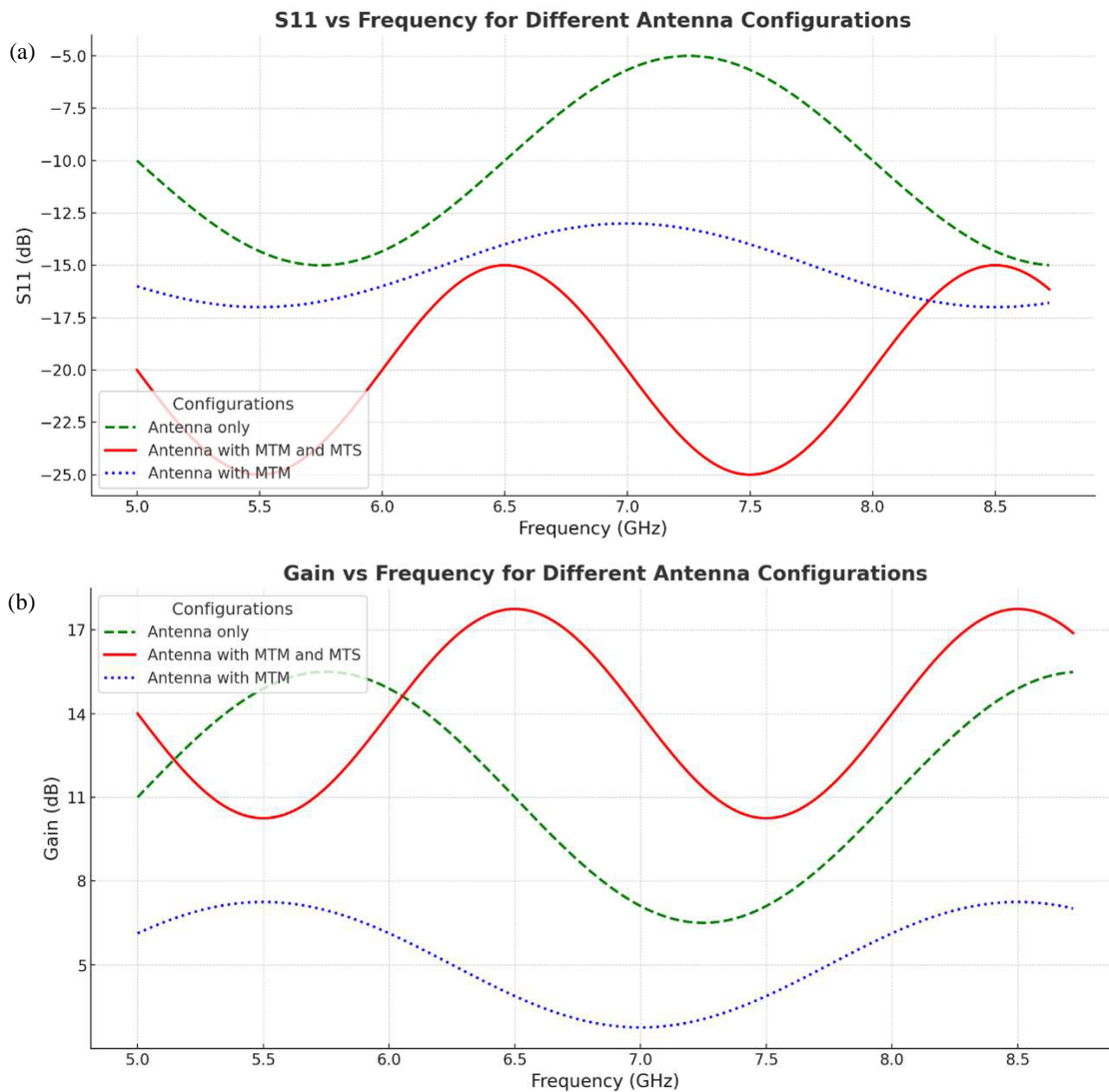


FIGURE 3. (a) Simulated S_{11} and (b) Simulated gain, for the proposed antenna with MTM and with MTS.

(EIRP). It also looks at how well the antennas' radiation pattern works. We designed the suggested MTS layer and Vivaldi antenna using CST MWS. We use a finite difference time domain solver and a parametric scripting approach to do the far-field computation and port excitation of the antennas.

4.1. Antenna Performance with Respect to MTS Layer

This section discusses the use of bio-signal processing in the detection system of breast cancer (BC). The Vivaldi antenna, designed on an FR4 substrate, is used to analyze bio-signal data, which can be electrical, chemical, physical, or logical. Understanding comprehensive LC signals is crucial for doctors and medical officers to make informed decisions. Bio-signal data is gathered from the antenna using CST MWS and ANN using MATLAB tool to improve the understanding of biological status. ANNs can calculate input distribution models and confirm the internal structure of a breast model. The performance of the antenna and MTS Layer is indirectly assessed. Bio-signals can be detected using sensors or probes. The performance of the

antenna before adding breast tissues is recorded with respect to the used MTS layer. The design faces a mismatching problem due to the direct effect of adding breast tissues on the antenna's performance. However, the gain enhancement is evident after adding the MTS layer. Numerical analysis is performed using Finite Integral Technique (FIT) based on CST MWS formulation. Comparing the radiation patterns of the proposed antenna with and without the MTS, it is evident that the problem of scattering pattern and back lobes has been resolved, leading to an improvement in gain. To overcome the mismatch problem caused by the MTS, the grating is introduced to the antenna structure. A grating bowtie is used by adding slots to the bowtie antenna design. This technique has the advantage of enhancing the bandwidth because the bowtie antenna is slotted; in addition, a better radiation pattern is achieved because of the increase of the electrical current path. Fig. 3(a) clearly illustrates a significant impact of the proposed MTM and MTS layers on the antenna transmission bandwidth, which is increased significantly. Fig. 3(b) shows noticeable gain enhancements at higher

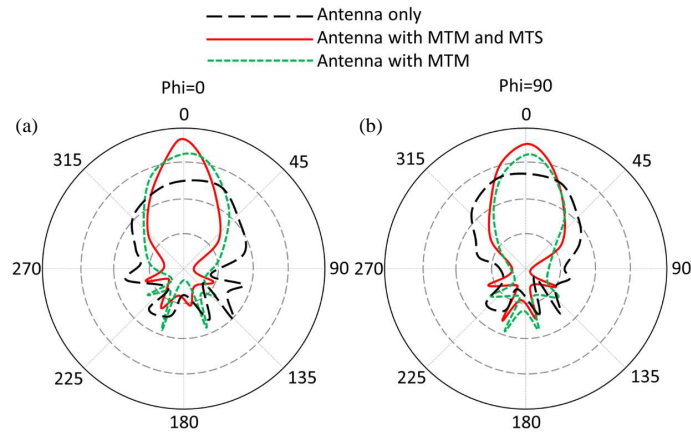


FIGURE 4. Simulated radiation pattern for Phi and Theta at 6.5 GHz and 8.5 GHz, (a) without MTS and (b) with MTS.

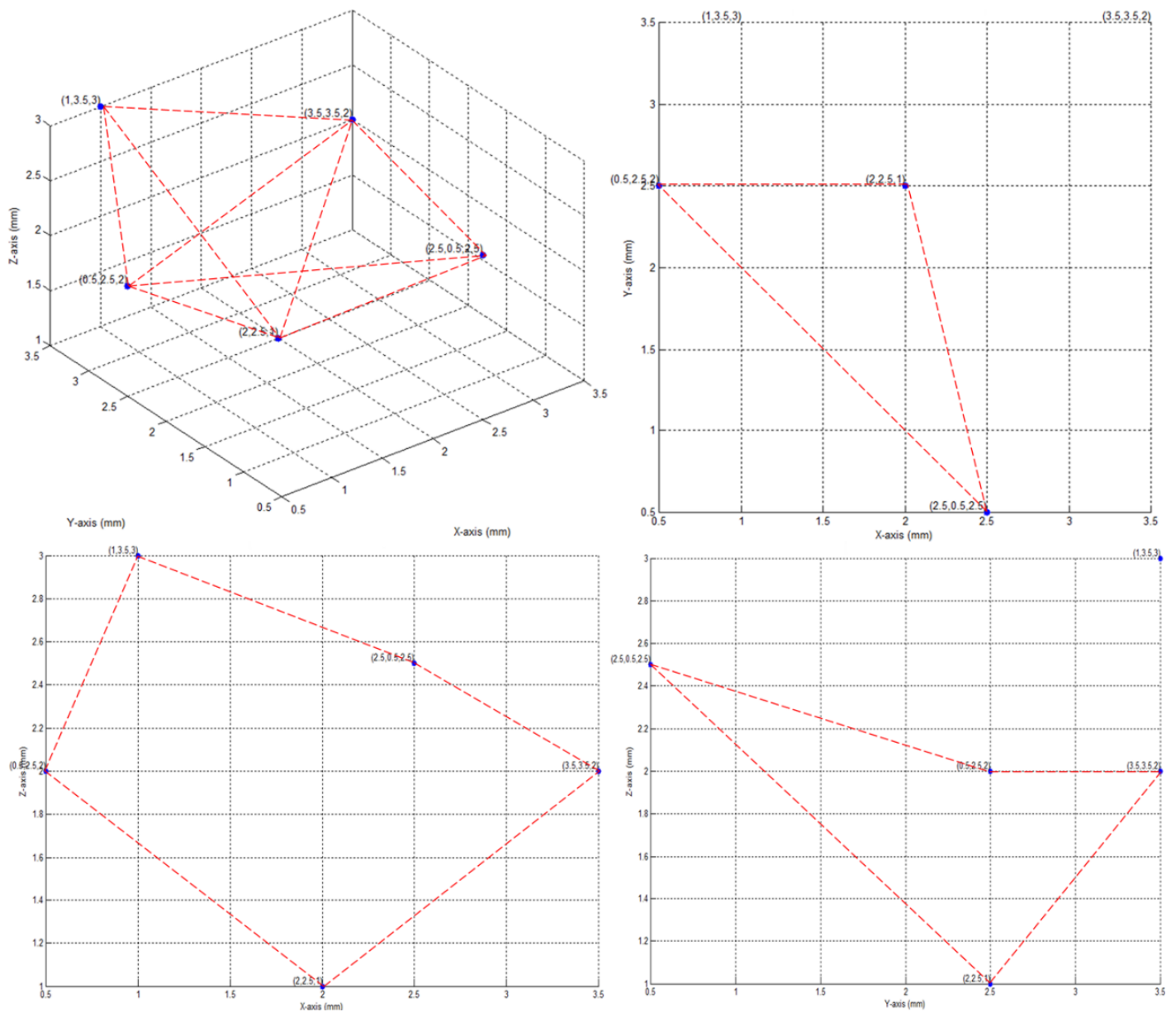


FIGURE 5. Tumor localization in different views of 3D and 2D aspects at x , y , z planes.

frequencies to be realized by increasing the antenna gain up to 17 dBi.

Figure 4 clearly shows noticeable enhancements in the radiation patterns. This enhancement is due to the beam focusing of the electromagnetic radiation to the bore-sight that realizes a traveling wave with TEM modes [24]. It was because of this observation that the proposed MTS layer was added to improve the radiation patterns and antenna gain, as shown in Fig. 4(b).

4.2. Antenna Performance with Respect to Breast Tissue

Breast cancer localization using microwave imaging is a growing field of research that uses electromagnetic waves to detect and locate cancerous tissues. This method leverages the dielectric contrast between malignant and healthy breast tissues, making them detectable. Microwave imaging approaches include passive imaging, active imaging, microwave tomography, radar-based imaging, and hybrid methods. The workflow involves data acquisition, signal processing, image reconstruction, localization and analysis, and machine learning models for malignant patterns. Advantages include being noninvasive and non-ionizing, cost-effective, and portable for bedside or home-based monitoring. Challenges include low resolution, complex inverse problems, breast heterogeneity, and hardware limitations. Researchers are now using artificial intelligence to automatically extract features, reduce noise, and classify tumors. Hybrid imaging has also been developed to improve accuracy, and new materials like metamaterial-based antennas have been used to improve sensitivity and bandwidth. However, challenges remain, such as low spatial resolution, complex inverse problems, breast heterogeneity, and hardware limitations. Recent progress includes using machine learning and deep learning to automatically extract features, hybrid imaging to improve accuracy, and new materials that are more sensitive and have a wider bandwidth.

Visualizing MTS unit cells coordinates can provide valuable insights into the performance of a system. It involves analyzing the spatial distribution, symmetry, and height of the unit cells, which can impact beamforming capabilities. The application context, such as array configuration, can also impact the spacing between unit cells, affecting beamwidth and sidelobe levels. Localization accuracy is crucial, and comparing the coordinates with the intended design is essential. Therefore, the design verification makes sure that the design goals are met and that the coordinates are specified correctly. The simulation feedback can give information about electromagnetic properties like beam steering, gain, and directivity, and how elements are coupled to each other. We can also assess the boundary conditions to determine if the simulated environment affected the accuracy of the exported coordinates. Visual information can help to find boundary of the tumor, and it can also be used to study clusters and how they affect radiation or localization. In Fig. 5, the proposed antenna is used to localize the vertex of the edges of inserted tumor tissue inside a healthy tissue.

5. BREAST TUMOR LOCALIZATION

Breast cancer, the most prevalent type of cancer among women, has been a significant issue for centuries. The proposed antenna is realized to screen the tumor and reconstruct the geometry from the scattered beams on the proposed MTS layer. Therefore, the breast tissue is located between the proposed antenna and the proposed MTS layer. By eliminating the breast tissues by the electromagnetic radiation generated from the proposed antenna, the scattered radiations penetrating the breast tissue can be screened on the MTS layer. The proposed MTS and Vivaldi antenna are used to record scattered signals from a female phantom with tumorous breast conditions using anatomy-related detection mechanisms. A machine learning technique, including ANN, is used to analyze the recorded frequency responses in terms of gain, S_{11} , bandwidth, and frequency resonance to detect tumor emergence. Breast tumor localization using SAR in human breast tissues can be achieved from identifying the electromagnetic intensity with the aid of a smart bio-electronic circuits. The scattered signals are significantly affected by the breast dielectric properties different from the tumor tissues that realize different responses. The antenna receives the bio-signals as inputs and uses time-domain analysis to analyze the received signals for tumor detection and localization. In Fig. 6, the proposed antenna response is used to reconstruct the tumor location and size when being illuminated with electromagnetic radiation with the aid of a MATLAB code based on r2014a version. In this realization, the obtained results are collected from scattering radiations to reveal the tumor location at (30, 35, 25) mm center from the origin with a ball radius of 10 mm.

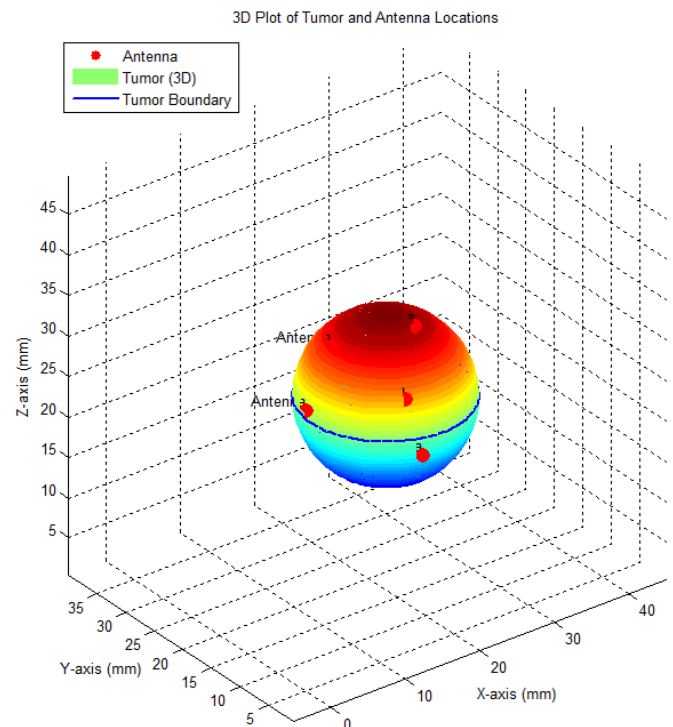


FIGURE 6. 3D reconstructed image of the captured tumor inside the human tissues.

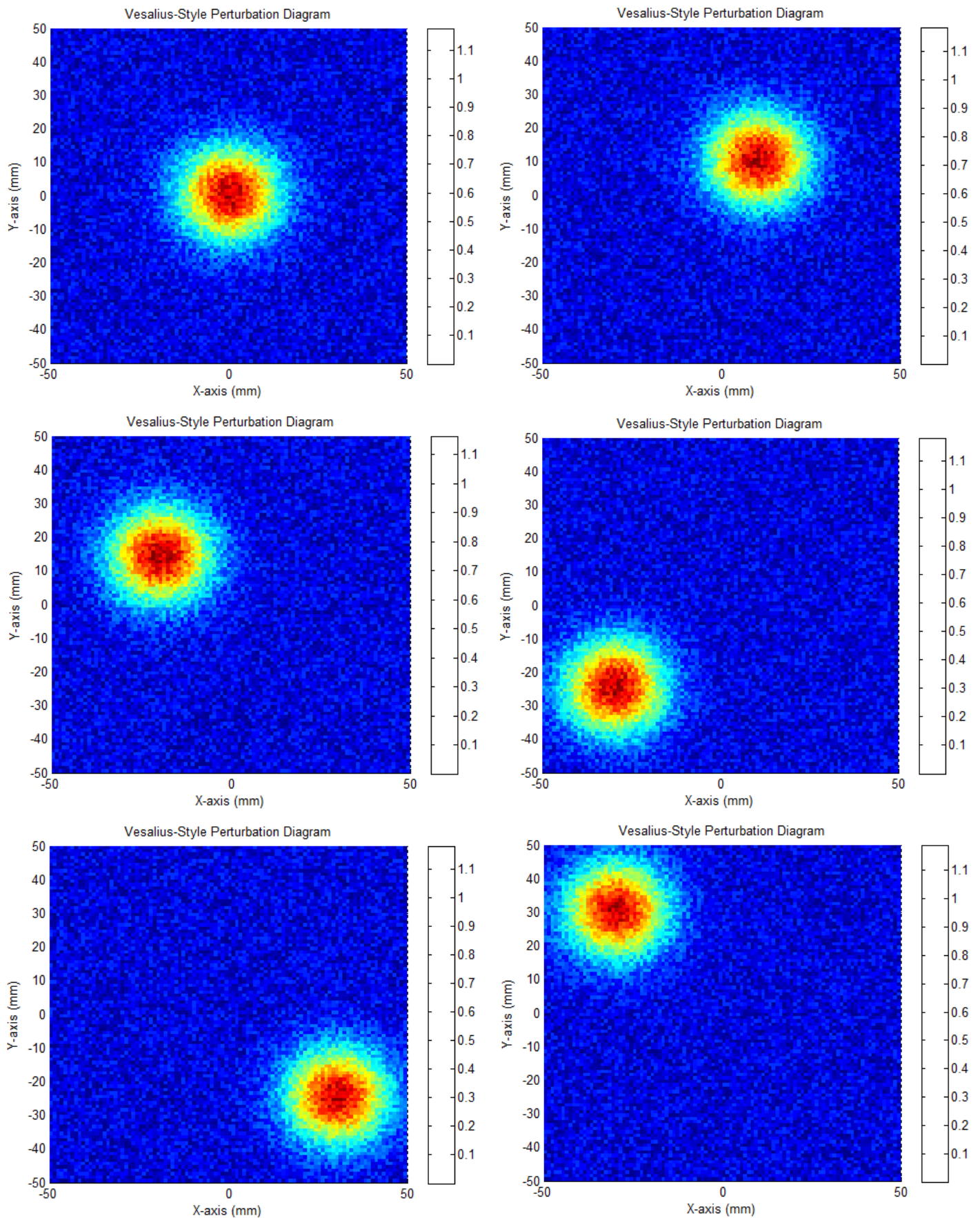


FIGURE 7. The localization of the tumor image at different location with different electromagnetic properties.

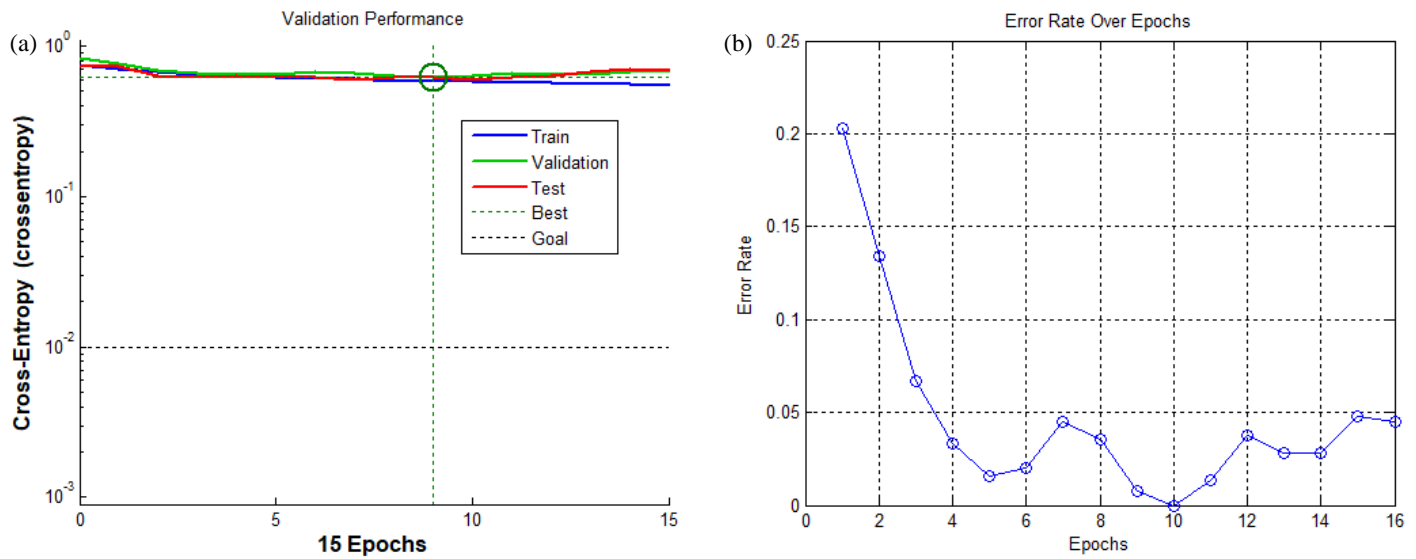


FIGURE 8. KNN classifier performance: (a) Performance matrix based on cross entropy and (b) Error rate.

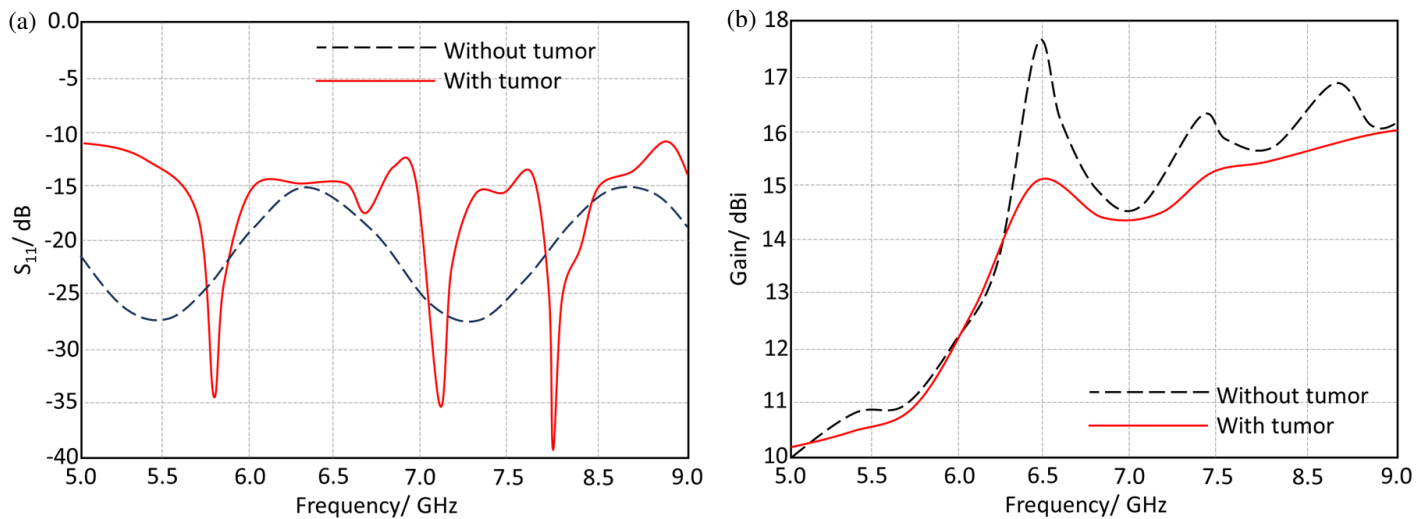


FIGURE 9. Measured results: (a) S_{11} spectra and (b) Gain spectra.

This study proposes the use of MTS and Vivaldi antenna for breast cancer detection and characterization. The Vesalius-Dyagram Perturbation (VDP) analysis was used to explore the sensitivity of the input current of the Metallic Vivaldi Antenna (MVA) with respect to frequency variation of glutamate concentration model phantoms. The results show that the input current of the MVA has high sensitivity with 1.8 g/L of the glutamate concentration model phantom at the center frequency of the bandwidth of 5.25 GHz. The invoked ANN based on VDP method is used as a data processing algorithm to detect breast cancer presence and diagnose its severity level. The diagnosis accuracy of the proposed antenna with the considered ANN using microwave radome phantoms can reach 90% as will be seen later, with a detection sensitivity of 0.88 and a specificity of 0.21. The reconstructed image of the tumor location is presented in a 2D plot in Fig. 7 for six different tumor cases.

These six cases are considered with different tumor properties through varying the permittivity and conductivity with keeping the same size as summarized in Table 3.

To classify the tumor type, an ANN algorithm based on a KNN classifier is invoked. This code is adopted to realize the types of considered tumors in Fig. 7 through the electromagnetic matrices that are generated from CST MWS based on the results for the proposed MTS and antenna model. The classifications among the three different types of the tissues: (Benign, Malignant, and Healthy) are recognized with the aid of the used algorithm based on the fed results from CST MWS. The validation performance matrix of the cross entropy is presented in Fig. 8(a) for the proposed algorithm based on KNN classifier. The error rate over epoch is found to follow a significant reduction in the error rate as seen in Fig. 8(b).

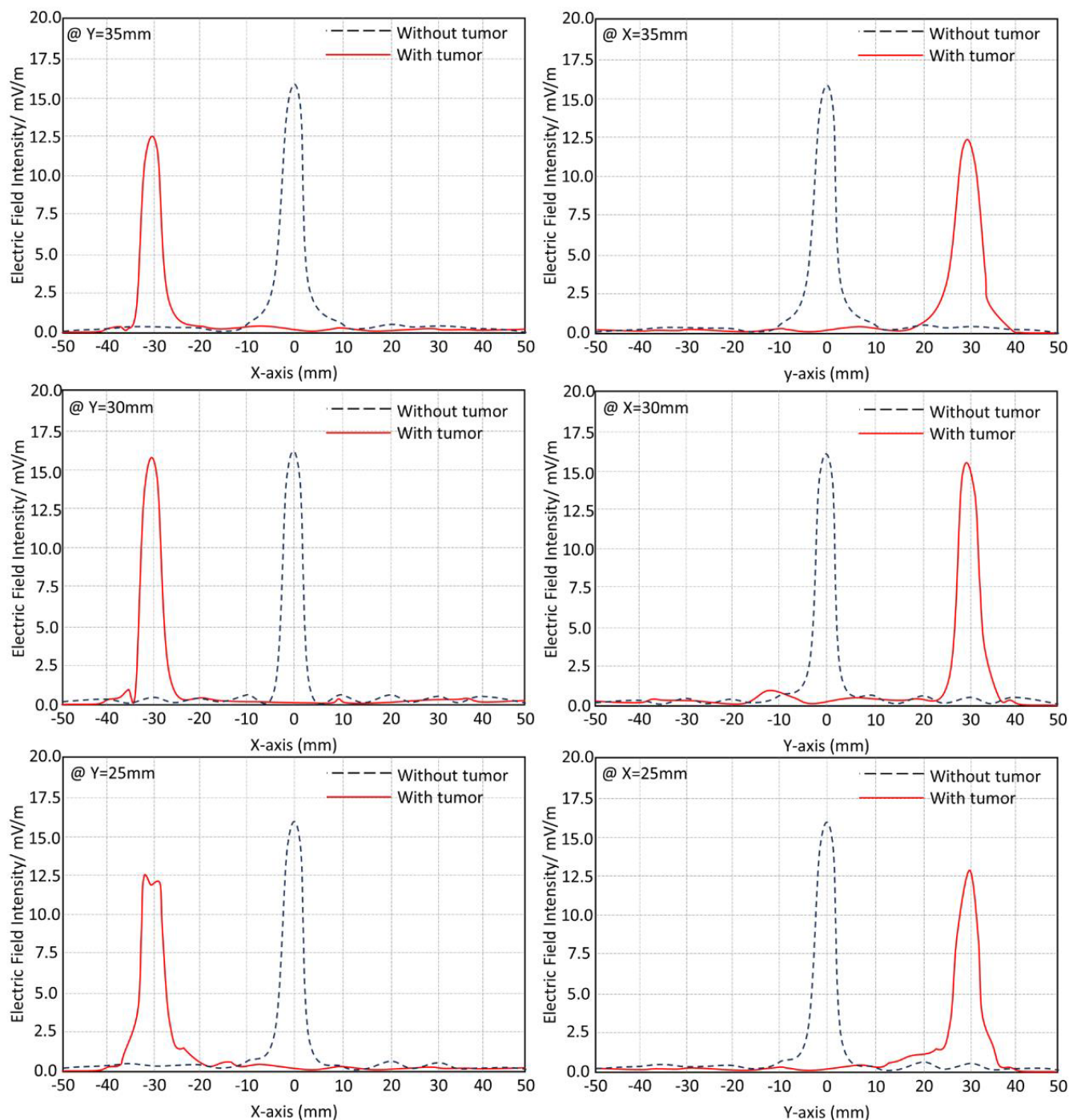


FIGURE 10. Measured electrical field intensity for the proposed antenna with and without breast phantom 6.5 GHz.

6. EXPERIMENTAL RESULTS AND COMPARISON WITH OTHER PUBLICATIONS

This study introduces experimental validations to test the antenna performance first and then validates the feasibility of tumor detection and localization from the measured results of the antenna. The proposed MTS and antenna performances in terms of S_{11} , gain, bandwidth, and frequency resonance are evaluated. These parameters are measured and compared to their equivalent from simulation results as seen in Fig. 9.

The obtained results attracted us to measure the proposed antenna radiation patterns with a phantom structure of breast. Inside the breast phantom, a tumor phantom of a spherical structure is inserted. The measured radiation patterns in 2D Cartesian patterns are presented in Fig. 10. The measured and simulated results are found to agree well to each other. It is good to mention that the tumor is positioned at $(-30, 30)$ from the origin of the x - y plane inside the breast phantom during the measurements process.

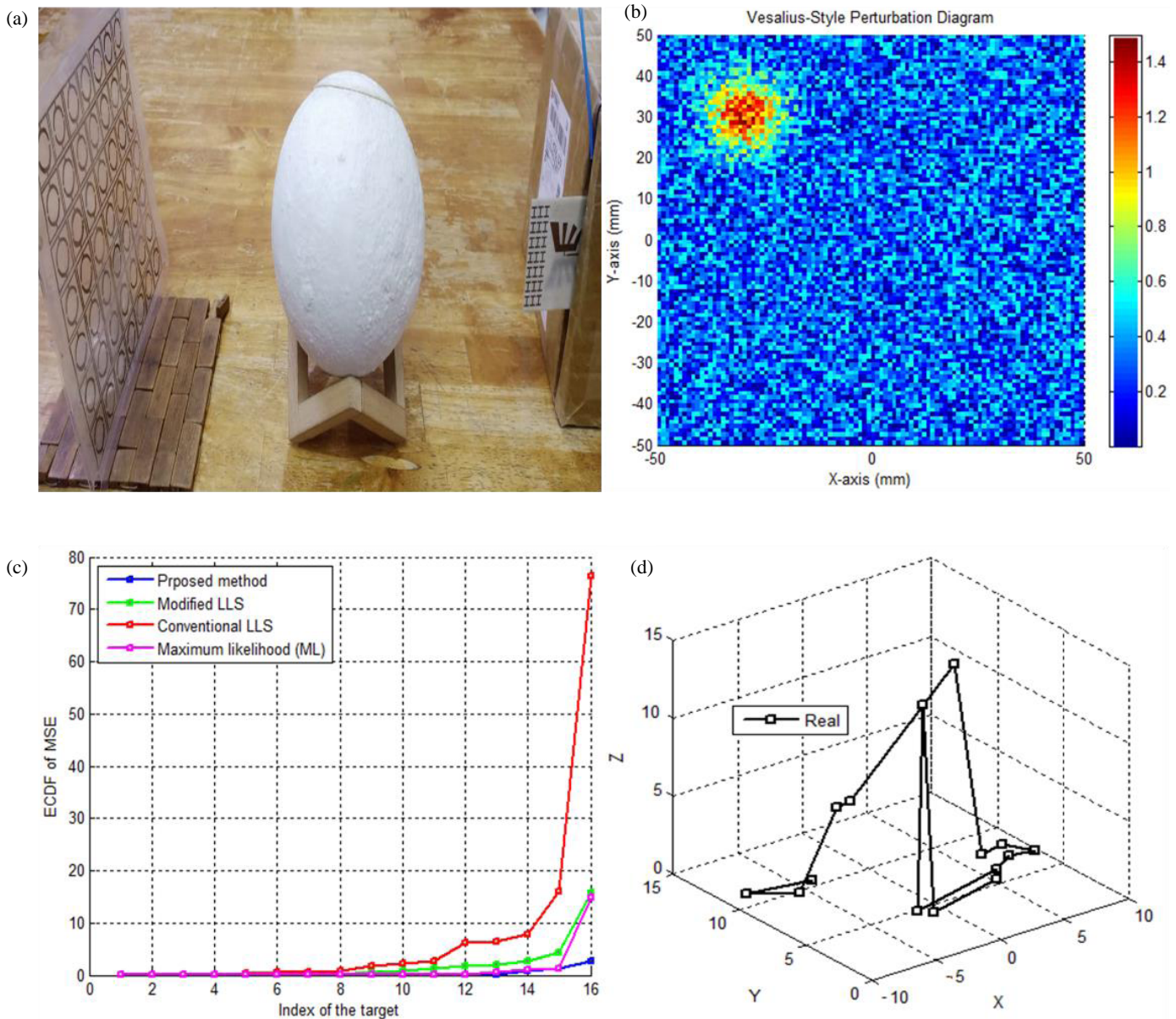


FIGURE 11. The evaluated tumor prediction from experimental measurements: (a) The measurement setup, (b) the reconstructed 2D image, (c) the 3D localization, and (d) performance comparison to other analysis methods.

Next, the obtained results from the antenna performance in Fig. 9 and Fig. 10 are loaded to the MATLAB code to classify the tumor type and reconstruct the tumor image from the screened scattering on the proposed MTS layer. The measurement setup is presented in Fig. 11(a) with the proposed MTS and antenna along with the phantom structure. The image of the inserted tumor inside the phantom structure is reconstructed as a 2D scattering plot as seen in Fig. 11(b). It is found that the considered algorithm for localization predicted the tumor location at $(-27, 30)$ from the origin of the x - y plane. The 3D reconstructed tumor extension location inside the phantom structure is presented in Fig. 11(c). The origin shape of the inserted tumor phantom was a spherical ball; however, the proposed algorithm may determine the location in 3D image, but fail to reconstruct a real 3D sphere image because the shortage of the

measurement points that can be enhanced further in the future. The proposed method performance in terms of Empirical Cumulative Distributed Function (ECDF) of Mean Square Error (MSE) is compared to other considered methods to reveal excellent performance in the localization as shown in Fig. 11(d). It is important to mention that the inserted tumor under test is classified by the proposed method to Malignant which is the same sample that we considered for test. In Table 3, we summarize the obtained results in terms of size, type, location, etc.

Finally, this paper presents the development of MTS Vivaldi antennas for biomedical experimental studies on breast cancer detection using bio-signals. The bio-signals use electromagnetic signal acquisition system to be analyzed with the aid of ANN algorithm. The use of the proposed MTS and Vivaldi an-

TABLE 3. The detected tumor properties.

| Parameters | Real | Detected | | | |
|---------------|-----------|--------------|--------------|-----------|-----------|
| | | Modified LLS | Conventional | ML | VDP |
| Radius (mm) | 10 | 15.5 | 16.7 | 17.2 | 11.6 |
| Type | Malignant | 20.3 | Healthy | Malignant | Malignant |
| Location (mm) | (-35, 39) | (-33, 36) | (-23, 34) | (-33, 38) | (-27, 30) |

tenna improved the experimental setup sensitivity and quality of measured bio-signals. The large arm region of the antennas created a bio-signal acquisition system with high gain and low far-field sensitivity. Four different ANN algorithms are used in this work based on bio-signals of the 3D model to realize the effective tumor size. For each considered model, a strong relationship is observed between the bio-signals and the breast tumor biological tissue properties. Additionally, when the relationship is modeled locally, the proposed MTS and Vivaldi antenna located near the affected area are determined. This setup is thought to be useful in medicine to detect abnormal tissues presenting bio-signals different from the bio-medium.

7. CONCLUSION

In the Asia-Pacific region, efforts are underway to eliminate breast cancer without the need for additional time or surgical procedures. We have used artificial intelligent for evaluating male organs and Vivaldi antennas for observing and detecting female breasts. In this work, a design of Vivaldi antenna-based MTS layer is realized for the applications of biomedical applications. ANNs have been explored for their potential in cancer detection, classification, and prediction. However, there is limited research on the bio-signal composition of a noninvasive approach. MTS and Vivaldi antenna are used to capture electromagnetic backscatter signals from healthy and cancerous tissues. These structures are developed with the aid of CST MWS to cover the frequency band from 5 GHz to 9 GHz converted pulse using short-time Fourier transform in simulation process. The generated signals are subjected to the phantom structure to train our proposed algorithms with the generated data from six different samples to ensure the validity of considered algorithm. It is found that the proposed algorithm based on our developed antenna system realizes excellent detection features compared experimentally to other considered algorithms in the literature. The antenna gain based on the proposed MTS layer is found to be 17.6 dBi that realizes a narrow beamwidth of 10° . The output results are used as the data for considered ANN algorithms. We found that the proposed algorithm of VDP approach realizes a significant quality of detection over other published results in the literature. This output dissipated data is used to create a power distribution along the MTS plane, resulting in a matrix data to reconstruct the tumor image. The resulting data is used to obtain spectral images of cancerous tissues through a 2D portal. The spectral images are fed into the ANN to train a model that can predict the existence of cancerous tissue based on unseen power distribution data of a specific patient. Finally, the proposed method is found as an excellent approach to realize a valid candidate for breast cancer detection.

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