Design of Microwave Monopole Patch Antenna for Breast Cancer Detection Implementation.

Izabela Walukiewicz[1], Nabeel AbulJabbar[1], Ibrahim Ghariba[1], Mohammed S BinMelha[1,2], Mohammed Ngala[3], Fuazi Elmegri[1,4]. Atta Ullah[1,5]

i.walukie@bradford.ac.uk[1], N.A.Abduljabbar3@bradford.ac.uk

[1]Faculty of Engineering and Informatics, University of Bradford, Bradford, BD7 1DP, UK.
[2]System Maintenance Controller, Saudi Air Navigation Services, KSA
[4]Heaton Education Bradford, UK
[4]Basrah University College of Science and Technology, Basrah 61004, Iraq

Abstract. A microwave monopole patch antenna was designed to operate at a dual-band frequency of 2.6 to 3.1 GHz (lower band) and 4.3 to 5.8 GHz (upper band) for breast cancer detection. The antenna was created in CST simulation software, and a breast phantom was created to optimize the results. The simulation was conducted for the antenna only and then for the combination of the breast phantom for case one without a tumour and case two with a tumour both exposed to the antenna. The antenna is designed for a characteristic impedance of 50 ohms and is fabricated using FR4 substrate technology.

Keywords: Monopole antenna, breast cancer, breast phantom, dual bandwidth.

1 Introduction

Breast cancer is the 4th leading cause of cancer death in the United Kingdom, accounting for 7% of all cancer deaths. Furthermore, it is the second most frequent cancer among women in the UK, accounting for approximately 11,400 fatalities each year. Diagnosis at the early stage is crucial, as increases survival for 5 years or more in 98% of cases [1]. Currently, there are several techniques for breast cancer screening available. The most common method used worldwide is X-ray mammography. Above 40 years old it is usual for woman to have early breast mammography. Usually as an addition to mammography for further investigation MRI, ultrasound or PET are used. Although effective, each of the existing breast screening methods has inherent limitation and disadvantages. For instance, X-ray mammography uses ionising waves that fail often, with a significant incidence of false positives and negatives. Moreover, requires harmful compression of patient's breast [2]. The limitations of current breast diagnostic imaging technologies motivate the development of alternative imaging modalities. Microwave imaging techniques have lately been proposed as a safe and low-cost alternative to mammography in the diagnosis of breast cancer. Microwave imaging employs the scattering or reflected wave produced by the difference in dielectric characteristics between normal and cancerous breast tissues [3][4].

Radar-based microwave imaging (MWI) is a non-invasive method that utilizes electromagnetic field perturbations to produce two-dimensional (2D) images of the dielectric properties of an object of interest (OI). In the context of breast cancer detection, MWI can distinguish between malignant and benign lesions by analysing the strength of scattered waves. Benign tumours exhibit weaker scattered waves compared to malignant tumours due to their similar dielectric

IMDC-IST 2023, October 25-27, Yola, Nigeria

DOI 10.4108/eai.25-10-2023.2348720

properties to normal tissues. To achieve the necessary resolution, ultra-wideband (UWB) signals are used in radar-based techniques, with a frequency spectrum typically ranging from 1 to 10 GHz. In a UWB radar setup, short-duration microwave bursts are emitted by transmitting antennas into the OI. Reflected waves are then used to construct an image. Radar-based MWI has shown promise in detecting breast cancer, with clinical evaluations demonstrating a sensitivity of 74% in detecting breast masses. This radiation-free imaging method is expected to serve as an alternative to screening mammography, offering a precision of less than 5 mm for early detection and localization of breast cancer. The use of UWB signals enables acceptable signal penetration while maintaining high resolution. The design and characterization of antennas operating in the microwave frequency range, such as miniaturized UWB antennas and circular antenna arrays, have been explored to optimize tumour detection. Overall, radar-based MWI holds potential as an effective and safe technique for breast cancer detection [3][5].

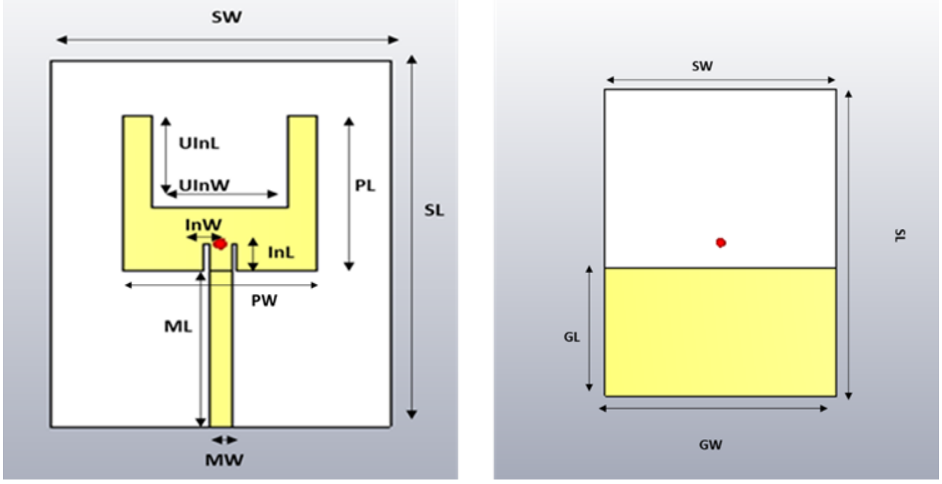

Fig. 1. Proposed antenna design

2 Antenna evaluation

The proposed microstrip patch antenna is designed to operate in the ISM frequency range. The antenna is fed with a coaxial port. The coaxial feeding mechanism ensures a balanced feed to the antenna, reduces radiation from the feed line, and offers a low-loss transmission line. The FR-4 material with moderate dielectric constant permittivity of $\varepsilon r = 4.4$ and 1.6-mm thickness was selected for the substrate. In order to minimize signal losses and achieve good impedance matching ground plane, patch and microstrip line is created out of cooper. The antenna design is as shown in the Figure 1. The patch (P) antenna has a rectangular shape, which is a common shape for patch antennas. The microstrip line (ML) is used to connect the feed line to the patch, providing a low-loss transmission line. The rectangular patch has two arms (U) on each upper edge, which are additional extensions of the patch that can help to improve bandwidth and impedance matching. The patch also has 2 insets (I), which are small rectangular cuts made in the patch to enhance the gain and S11 parameters of the antenna. The rectangular patch is mounted on the front side of substrate material. The ground plane is located on the back side of the substrate material. The specific dimensions are shown in the Table 1.

Table 1. Antenna parameters and their dimensions

Parameter	Dimension (mm)
SL	40
SW	30
GL	16.6
GW	30
ML	17
MW	2
PL	17
PW	17
InL	3
InW	0.5
UInL	10
UInW	12

3 Breast phantom evaluation

The antenna is designed to detect breast cancer therefore spherical shape breast phantom was created in CST software to mimic women breast as in Figure 2 to optime more accurate results. The breast phantom was created out of 2 layers, representing skin tissue which is the top layer, and the second layer of fat was inserted into the skin layer as on the Figure 3. Because the breast dielectric properties various at different frequency range, the properties chosen for the tissues were corresponding to 2.4GHz. At this frequency the properties are as followed in Table 2. For the investigation that the antenna is able to detect breast cancer the simulation was caries for antenna with breast phantom without and with tumour, which was inserted into the fat layer and its dimensions are as shown in Figure 4. The dimensions of each tissue are as followed in the Table 3. However, the size and density may vary depending on age, hormones, genetics, ethnicity etc. Breast size and shape are unique to each individual and can change throughout their lifetime. Hence more investigations are needed to explore how the factors could impact on the results.

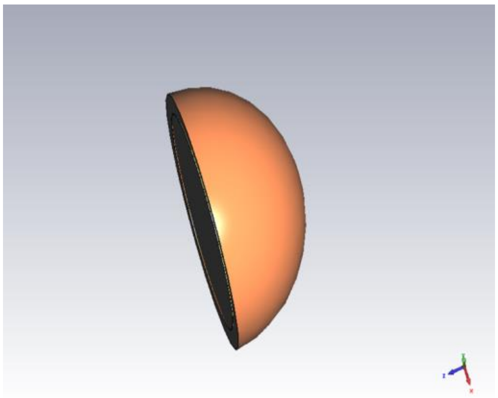

Fig. 2 Breast phantom in CST software

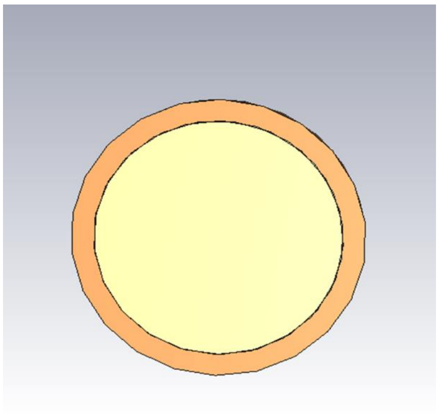

Fig. 3 Skin and fat tissue layers view

Table 2 Dielectric properties of different breast tissues used for breast phantom creation in CST.

Tissue type	Density (Kg/m^3)	Permittivity (F/m)	Electrical Conductance (S/m)
Fat	911	4.84	0.262
Skin	1109	36.7	2.34
Tumour	1058	54.9	4

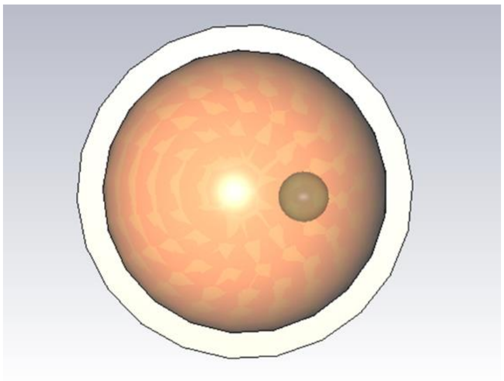

Fig. 4 Tumorous tissue inserted into fat layer view

Table 3 Dimensions of the different tissues used

Tissue Type	Radius dimension (mm)
Skin	70
Fat	60
Tumour	7

4. Analysis and discussion

4.1 Antenna Performance Analysis

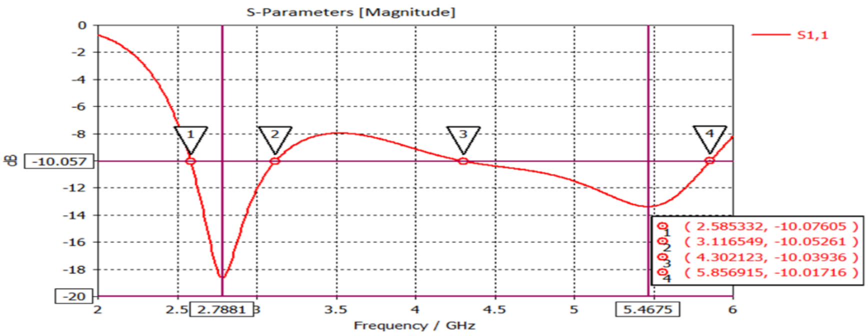

Fig. 5 S1.1 plot for simulated antenna

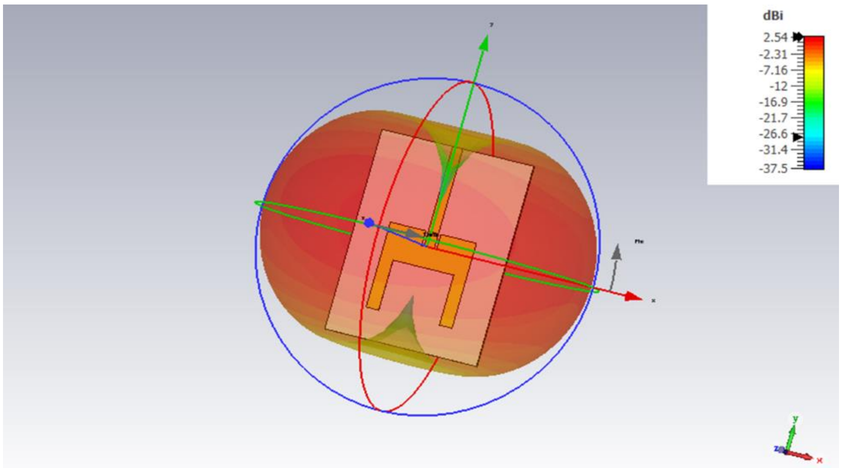

Fig. 6 Gain of the simulated antenna

The antenna was firstly simulated using CST software to establish its performance. The antenna was simulated using CST software to establish its S1.1 and gain performance, as shown in Figure 5 and figure 6 sequently. The simulation results indicated that the antenna has very and dual-bandwidth from 2.6 to 3.1 and 4.3 to 5.8 GHz. The antenna is resonating greatly at the value of 2.78GHz. The far field radiation pattern indicates than the gain of the antenna is approximately 2.54dBi as shown on the Figure 6.

4.2 Antenna exposed to breast phantom without tumour and with tumour tissue

According to the simulation results shown in Figure 7 and Figure 8, there are changes in the S-parameters of the antenna. The S-parameter simulated with the phantom containing the tumour shows a deeper response compared to the simulation without the tumour, indicating a change in the antenna impedance matching or scattering behaviour. The main lobe in the far-field gain at 4 GHz frequency of the antenna decreases from 5.94 without a tumour in the phantom to 5.81 with a tumour, indicating a reduction in the antenna radiation intensity in the direction of the main lobe, shown in the Figure 9 and Figure 10. This suggests that the antenna was able to detect the changes in the breast tissue and detect the tumour. Tumour absorption in the breast phantom may cause absorption of the radiated energy by the tumour tissue. The main lobe direction could possibly allow for estimations of the location of the tumour with respect to the antenna position. The simulation results suggest that the antenna is capable of detecting the presence of a tumour in the breast phantom, which could have important implications for breast cancer detection and diagnosis.

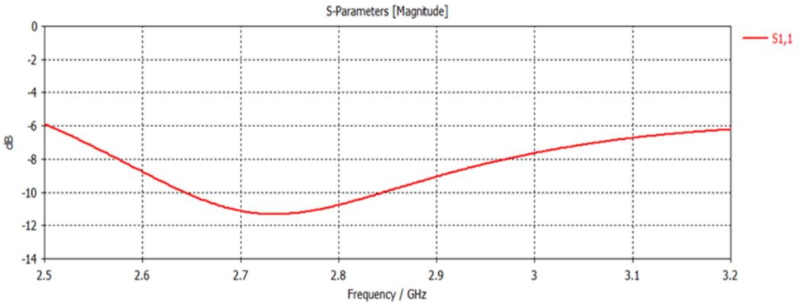

Figure 7. S-Parameter for simulation the antenna with breast phantom without tumour

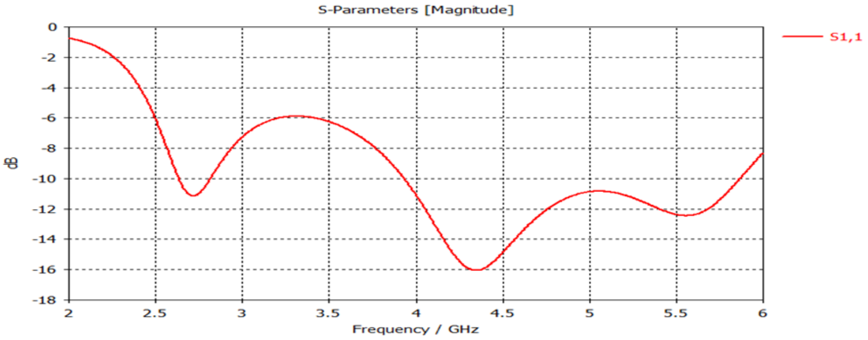

Figure 8. Testing the antenna with breast phantom with tumour

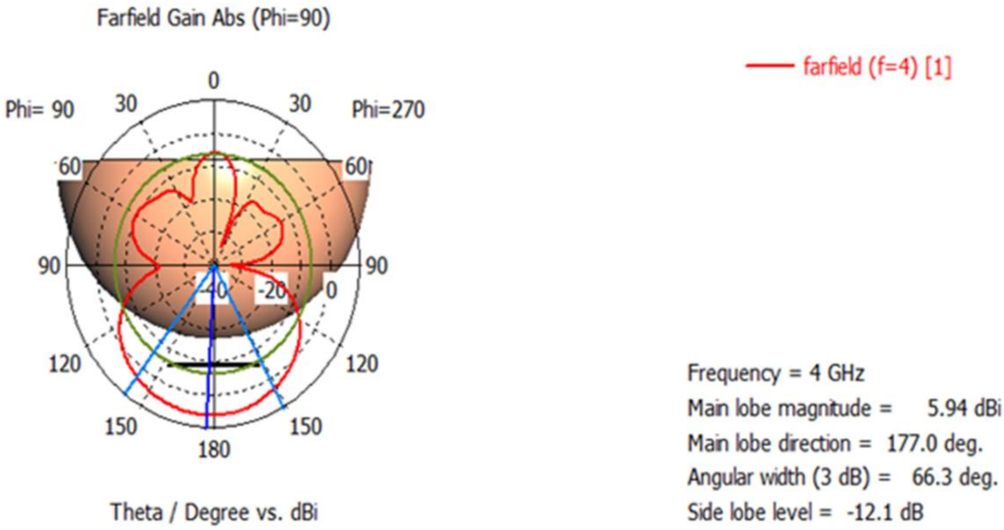

Figure 9 Farfield of the antenna simulated with phantom without tumour

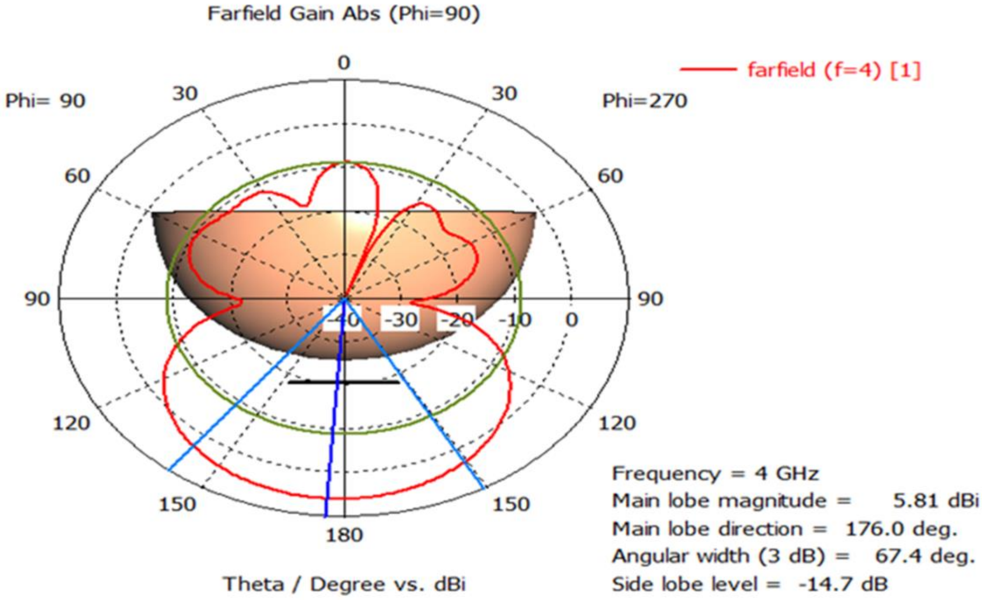

Figure 10. Farfield of the antenna tested with phantom with tumour

5 Conclusions

In conclusion, the simulation results obtained using CST Studio with a breast phantom, both with and without a tumour, provide insights into the performance of the microwave microstrip patch antenna. Comparing the results, it was observed that the antenna performance is affected by the presence of the tumour. Changes in the S-parameter response, such as a deeper response or shifting of the curve, indicate alterations in the antenna impedance matching, scattering behaviour, or interactions with the tumour-affected medium. The main lobe in the far-field gain also showed a slight decrease when the tumour was present. These findings suggest that the antenna characteristics, including impedance matching, radiation pattern, and gain, are influenced by the presence of the tumour. This information can be valuable for understanding how the antenna performs in breast cancer detection scenarios.

Further analysis and experimentation may be required to optimize the antenna design and ensure better performance in the presence of tumours. Fine-tuning the antenna parameters, optimizing the impedance matching, and considering the effects of tumour size and composition can potentially enhance the antenna performance for breast cancer detection applications.

Acknowledgments.

Authors wish to thanks the support of the European fund of the grant application H2020-MSCA-RISE-2022-2027 (ID: 101086492), Marie Skłodowska-Curie, Research and Innovation Staff Exchange (RISE), covering the proposal work: FractuRe Orthopaedic Rehabilitation: Ubiquitous eHealth Solution (Robust Project).

References

[1] Dubey AK, Gupta U, Jain S. Breast Cancer Statistics and Prediction Methodology: A Systematic Review and Analysis. Asian Pacific Journal of Cancer Prevention. 2015 Jun 3;16(10):4237–45.

[2] Tsarouchi MI, Hoxhaj A, Mann RM. New Approaches and Recommendations for Risk-Adapted Breast Cancer Screening. Journal of Magnetic Resonance Imaging. 2023 Apr 11;24(1053-1807).

[3] AlSawaftah N, El-Abed S, Dhou S, Zakaria A. Microwave Imaging for Early Breast Cancer Detection: Current State, Challenges, and Future Directions. Journal of Imaging. 2022 Apr 23;8(5):123.

[4] Amdaouch I, Saban M, El Gueri J, Chaari MZ, Alejos AV, Alzola JR, et al. A Novel Approach of a Low-Cost UWB Microwave Imaging System with High Resolution Based on SAR and a New Fast Reconstruction Algorithm for Early-Stage Breast Cancer Detection. Journal of Imaging. 2022 Sep 28;8(10):264.

[5] Sasada S, Masumoto N, Song H, Kajitani K, Emi A, Kadoya T, et al. Portable impulse-radar detector for breast cancer: a pilot study. Journal of Medical Imaging [Internet]. 2018 Apr 1;5(2). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5997971/