Study and Analysis of Trishul Shaped Antenna Performance in Microwave Imaging for Breast Tumor Detection

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Abstract: Any disease is kept at best when it is detected early or as soon as it occurs. It may be covid-19, brain stroke, heart attack, cancer or any kind of disease it is best for survival and further complications when there is no delay in its detection and further procedures are followed for treatment. In this case we are discussing about breast tumor detection which is the second biggest cause of early mortality among women after lung cancer. The ways of detecting breast tumor early by using antenna in microwave imaging (MWI). Attempt is done in designing a trishul shaped antenna and testing its performance in MWI. The Resonance of the broadside pattern of the antenna is optimized at 33 GHz frequency.The Sensitivity of the antenna was recorded as high as 1 GHz which shows high efficiency of the trishul broadside radiation pattern.

1 INTRODUCTION

The major advantage of using antenna in MWI is its effective cost, non-ionizing and non-invasive technique of radiation, high contrast in dielectric properties of healthy tissue and diseased tissue. It is well said that prevention is better than cure but there is not much stress given to early detection if at all anything happens as the means of increasing survival rate. Suppose any abnormality occurs it may be brain stroke, heart ailments, covid-19, or any form of cancer or disease is best when it is detected early or as soon as it occurs. This is the case when it is detected early its survival rate is maximized and the patient is saved with minimum complications and without complicated treatments. MWI is safer compared to X rays. Unfortunately, symptoms are only felt in the last or fourth stage when the patient will go for any form of scans or diagnoses when it is very late which brings with itself very painful treatments and complex to very costly medical diagnoses together as a very bad experience. Even with all of these costly treatments and experiences the survival of the patient is cut to minimum. In this case the discussion is on early detection of breast tumor by microwave imaging method. Microwave imaging has gained popularity due to low cost, safety, simplicity, high image resolution of the scanned tissue, non ionizing radiation and lastly being non-invasive method. The survival rate of a patient in breast tumor when detected in stage I is 97% whereas it is reduced to less than 30% when detected in stage IV or in last stages. Out of every one lakh women it is estimated that 25 develop breast tumor abnormality. Nobody goes for scanning using MRI or CT Scan due to high cost being the main reasons besides high ionizing radiation and the methoid being practically unsitable to be used in scanning purposes. In this research we put forward a scanning mechanism using antenna which will give a hint on breast tumor abnormality if it is present and then the patient can be encouraged to go for more advanced scanning using MRI and CT Scan. This method and research does not propose anything alternative to MRI but alternative to scanning purposes which is not possible by MRI and CT Scan. The design of antenna plays vital role as it directly affects the sensitivity of the antenna in MWI whereas the simulation and fabrication of the antenna for realistic breast phantoms with both simulation and practical designs plays important role in checking the veracity of the design. This area is not much researched and there is lot of scope to be exploited in

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early scanning and detection of breast tumors to save lives. IN the next section we will be reviewing few papers in MWI using antenna design. The design of antenna plays an crucial role in effectiveness of MWI.

2 METHODOLOGY AND DISCUSSION

The key considerations in antenna design in MWI for breast tumor detection is array and scanning antenna in which MWI usually uses an array of scanning antenna which offer advantage such as avoiding mechanical issues and being for practical for self examination, making their topic an important topic in MWI. Besides the antenna performance plays a crucial role in high resolution and high contrast MWI for early breast tumor detection. Considerations include low return loss, high gain and the ability to detect breast tumor with high sensitivity which should not be a defaulter in this work. The range of frequencies are in 1.2 GHz, 3-10 GHz , 2.4 Ghz, 3.6-9.2 GHz range etc. It is noteworthy to discuss the effectiveness of using MWI as compared to other methods as already mentioned again. It is contrast in electrical properties between healthy fatty tissues and diseased tissues, the effectiveness being significant and efficient with high accuracy, even though the antenna location changes with respect to the breast phantom. The other important point is the safety and cost effectivess of this methodology which is obvious a safer and cheaper detection method compared to conventional techniques, as it used low level non-ionizing radiation and offers high resilience to accurate tumor detection. The other important point to discuss is the tumor detection accuracy which is again noteworthy discussion as the design of any antenna is viable as long as the accurate detection takes place which is possible through successful detection of tumors through numerical investigations.

3 RELATED WORK

In a paper consisting of surveys of antenna designs used in breast tumor detection using microwave imaging in (Misilmani, Naous, et al. , 2020) speaks about antenna designs in its oceans. Several antenna designs are being studied to be used in microwave imaging for breast tumor detection. Designs such as vivaldi, antipodal vivaldi, corrugated Vivaldi, circular slotted, balanced antipodal Vivaldi, fractal structure, monopole structure, octagonal shape, bowtie shape, hibiscus shape and horn antenna were successfully designed and their performance tested in microwave imaging. In addition to this a wearable bra is designed to be used in breast tumor detection. Overall different designs and their performance in MWI concludes a thorough performance analysis with tables showing the bandwidth and different antenna parameters. In yet another research paper in (Guetaf, Chaabane, et al. , 2023) discusses about circularly polarized antenna in medical applications for health monitoring. The CPPMA is designed and optimized to function in the ISM band of frequency. A prototype with dimensions of 34 X 28 X 1.5 mm^3 is fabricated on a low cost FR-4 substrate. The range of operation is between 2.425- 2.475 GHz whereas the measured results lie between 2.32-2.515 GHz. The utilization of circular polarization in breast tumor detection is a thing to be researched and pondered. How circular polarization aids and yields in MWI is where not much research is being done. In circular polarization the aptitudes are checked in application of MWI. Circular polarization helps as it reduces indoor multipath-effects and different body postures, reduce polarization mismatch effects, increased tissue penetration and provide robust detection of breast tumors. The antenna design is optimized for best reflection coefficient in ISM band frequency. Similar to paper by Misilmani there is a similar smart bra design implemented by paper in (Elsheakh, Elgendy, et al. , 2023) speaks about biodegradable sensor in MWI applications. The biodegradable circularly polarized antenna has dimensions of 33.5 X 33.5 mm^2 and a coplanar waveguide feedline. The technique is significant in using textile antenna in MWI wearable application. As the antenna design plays an crucial role in effectiveness of sensitivity and MWI we review a few designs done in the past few years. In one of the designs in (Amjadi, Hamedani, et al. , 2012) discusses about double and quad ridged horn antenna operating in the frequency range of 3-10 GHz and the performance show low return loss which makes them effective in breast tumor detection through MWI. Bhargave in his paper in (Bhargava, and, Rattanadecho, 2022) speaks well about a wideband microstrip patch antenna operating between the frequency range of 3.6-9.2 GHz and the performance of the antenna with a minimum return loss of -48 dB and a maximum gain of 4.5 dBi. This design is efficient in creating 2D images of breast tissue by scanning and detecting significant contrasts in reflected signals. Yashaswini in her paper in (Yashaswini, Singh, et al. , 2024) discussed correctly about microstrip inset fed rectangular microstrip patch antenna in MWI with dimensions of 17.75 X

15.16 X 1.21 mm^3 fabricated with RT 6202 which has higher dielectric constant then RT 5880 of 2.94. They have well followed an imaging approach of delay and sum (DAS) for tumor detection and localization. In a fractal peano patch design in (Ahmed, Mahdi, et al. , 2020) discussed about MWI operating in the ultrawideband frequency of 6.744 GHz with an 18 array configuration for better tumor detection facing directly to the breast. Overall 18 antenna array is one of the largest configuration study in this area. Ruhayu in her paper in (Rahayu, Hilmi, et al. , 2019) mentioned to the point on MWI operating between 9-11 GHz range whereas the configuration of the setup was ring configuration for better tumor detection by directly facing the breast phantom in which there is a tumor contained. SAR value of 1.3 W/Kg was below the normal 1.8 W/Kg value. Somethings really well researched in (Amjadi, Hamedani, et al. , 2011) spoke about TEM double ridged horn antenna in MWI operating between the frequency region of 3-11 GHz whereas the performance of the antenna was good with low return loss which was effective in detecting tumor of small sized effectively.

4 DESIGN OF ANTENNA

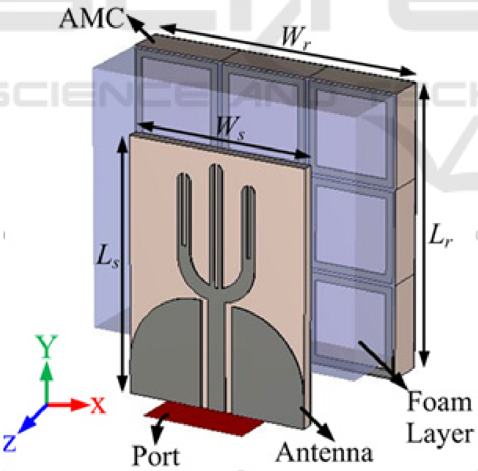

Figure 1: Perspective view of Two Layered Design

Table 1

W_r	7.5mm
W_s	5mm
L_s	9mm
L_r	7.5mm
CPW_l	3mm
CPW_r	3mm
T_s	0.8mm
Microstrip line $patch_l$	1.54mm

FR-4 substrate forms the substrate layer. The width and length of the nine system of AMC back layer is W_r and L_r respectively is 7.5mm and 7.5mm forming a square system to help in broadside system by causing reflection of electromagnetic radiation as discussed later in this research. W_s and L_s which is the width and length respectively of the patch of values 5mm and 9mm forms the front layer of the antenna design. The back layer and front patch is supported by a foam layer as shown in figure 1. The Microstrip line patch is 1.54mm in width.

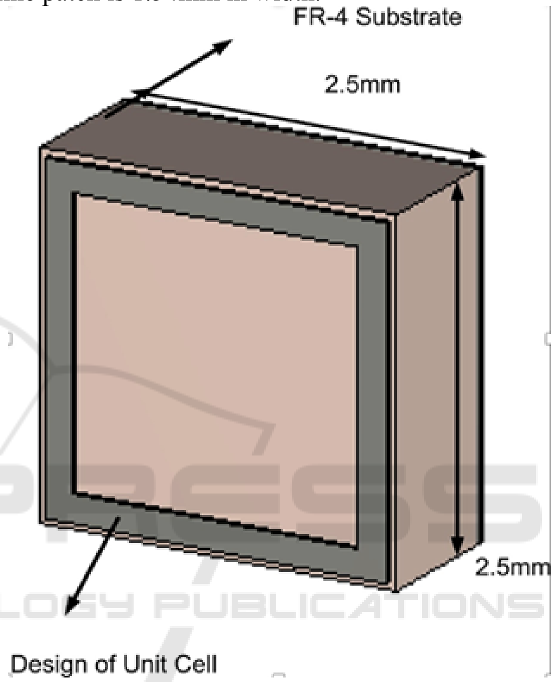

Figure 2: Unit cell Structure Design

Two layers form the back layer. The Artificial magnetic conductor (AMC) and FR-4 substrate. There are nine unit cells and each of the unit cell forms a square shaped layer. The square forms a side length of 2.5mm (width and length) each. The AMC is at the sides bordering the FR-4 substrate.

4.1 Mechanism of Operation of this Antenna

The most important thing behind this design is achieving broadside radiation pattern of the electromagnetic energy which is possible due to the reflection of the electromagnetic energy going from the patch downwards and getting reflected from the back AMC layer. This reduced sidelobes or causes radiation to be in one direction which is the need.

Broadside pattern is important in MWI.

4.2 $S_{1,1}$ Parameters of Trishul Antenna

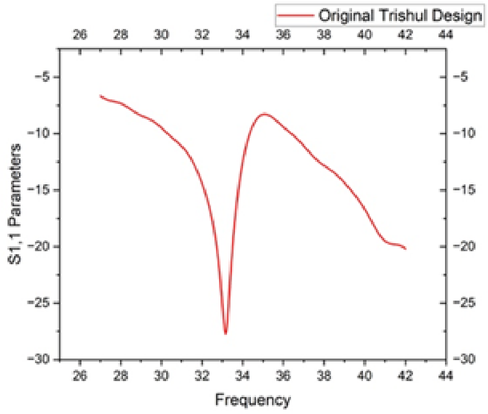

Figure 3:Antenna $S_{1,1}$ Parameters

The resonance is optimized to occur at 33 GHz frequency.

4.3 Experiment of Breast Phantom and Antenna

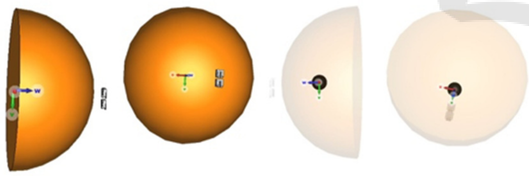

Figure 4: A, B, C and D

Figure A is of Side view of two antenna array with designed breast phantom, Figure B is front view of breast phantom with antenna, figure C is of side view of breast phantom with tumor at location of 35mm from center axis of breast phantom and figure D is of front view of breast phantom with tumor inserted into it for Analysis of MWI respectively.

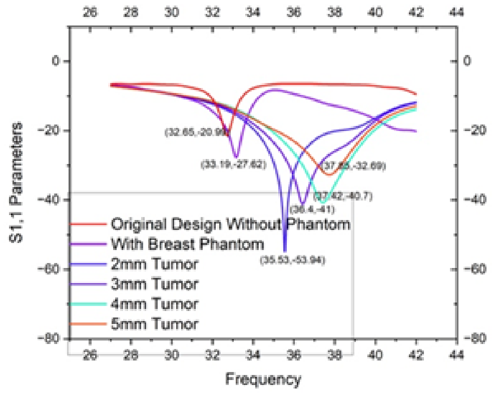

Figure 5: MWI for varying tumor sizes $S_{1,1}$

Figure 5 shows the scattering parameters when the tumor size is varied from 2mm, 3mm, 4mm and 5mm in radius.

The measured sensitivity of the antenna is calculated as follows.

$$\text{Sensitivity}= \frac{Change\ in\ frequency}{Change\ in\ tumor\ radius}$$

$$\text{Sensitivity}=\frac{36.4-35.43}{3-2} = \frac{37.42-36.4}{4-3} = \frac{37.85-37.42}{5-4}$$

Sensitivity=970 MHz/mm, 1GHz/mm and 420 MHz/mm.

The sensitivity recorded is 970 MHz/mm, 1 GHz/mm and 420 MHz respectively for tumor variations from 2mm-3mm, 3mm-4mm and 4mm-5mm respectively.

5 CONCLUSIONS

A trishul shaped antenna was designed and simulated and its performance was tested for MWI. The antenna was designed for mmWave frequency to cause resonance at 33 GHz frequency. Together with the patch a nine cells FR-4 and AMC material layer was designed which changed the propagation of the electromagnetic radiation causing a broadside pattern. This broadside pattern was very much visible in achieving high amount of sensitivity in the antenna's performance which was recorded as 970MHz, 420 MHz and a upper threshold of 1 GHz sensitivity. CST was used for simulation purposes.

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