Microwave Imaging: CPW Fed Microstrip Patch Antenna with Defected Ground Plane Operating in ISM Band for Breast Tumor Detection

Golap Kanti Dey[1], Tasfia Nuzhat[2], Kumar Priam Das[2], Fariha Ali[1]
Dept. of Electrical and Electronic Engineering[1], Dept. of Computer Science and Engineering[2]
Chittagong Independent University, Bangladesh
golap@ciu.edu.bd, ornitasfia3@gmail.com, kumarpriam92@gmail.com, farihaali1996@gmail.com

***Abstract*— A Coplanar Waveguide (CPW) fed patch antenna with defected ground plane operating in microwave range, i.e. license free 5.8 GHz ISM band is presented for breast tumor detection. The antenna offers a size of 50×50×1.2 mm^3 on a Rogers RT5880 substrate material with a loss tangent of tanδ = 0.0009. The optimized antenna can successfully detect the presence of a tumor cell surrounding with healthy tissues in a breast phantom. The reflection coefficients (S_{11}) of the proposed antenna with and without tumor are -24.11 dB and -23.96 dB respectively. The gain of the designed antenna remains 5.65 dB at 5.8 GHz with tumor cell. The proposed CPW fed microstrip patch antenna operating in license free ISM Band provides us a feasible solution to detect breast tumor successfully through microwave imaging at an early stage.**

Keywords— ***Microstrip Patch Antenna, CPW, ISM Band, Breast Tumor, Microwave Imaging.***

I. Introduction

Breast cancer [1-2] is one of the deadliest cancers and it occurs when the abnormal cells grow in the breast tissue which typically results in the formation of tumors. In the United States, there is a 13% of possibility for a woman to develop breast cancer in her lifetime. Middle-aged and older women are more at risk of developing breast cancer. The likelihood of getting breast cancer also depends on many factors like family history, consumption of alcohol, dense breast, exposure to radiation, etc. The survival rate for breast cancer mainly depends on the stage of diagnosis. If the diagnosis of breast cancer is somehow delayed, the survival chance of the patient drastically decreases and therefore early-stage diagnosis of breast cancer is critical for providing treatment as early as possible. Regular screening is recommended for women above fifty, especially during and after menopause for early detection of breast abnormalities.

Researchers have been trying to develop new and effective breast cancer screening methods for a couple of decades and X-ray mammography, Ultra-Sound (US), and Magnetic Resonance Imaging (MRI) are the most popular screening methods for the detection of breast cancer [2]. But there are also some limitations involved with these existing imaging modalities like X-ray mammography, for example low sensitivity in dense breasts [3] makes this method less reliable as dense breasts have a high risk of developing cancer. Also, X-ray mammography uses ionizing radiation which has many underlying health risks such as cell damage, radiation burns, etc. However, Ultra-Sound is advantageous for women who have dense breasts. But still, a high number of false-positive cases have been reported concerning the Ultra-Sound technique. Magnetic Resonance Imaging (MRI) has several advantages over X-ray mammography and Ultra-Sound such

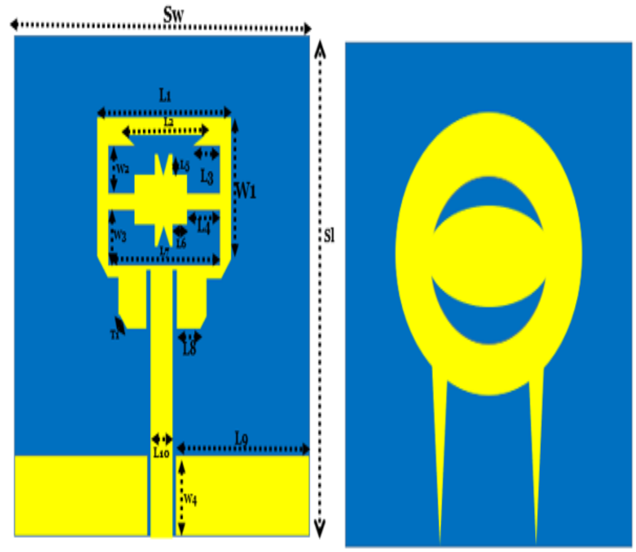


Fig 01. Front view (a) and rear view (b) of the optimized microstrip patch antenna with defected circular ground plane

as high-resolution images, and the ability to detect more aggressive types of cancer [4]. But this technique requires high costs and also has limited specificity. Thus, there is a dire need for a cost-effective and non-ionizing technique for early-stage breast cancer detection.

Microwave imaging is an emerging technique in the field of medical imaging which is also an active area of research. The microwave imaging technique aims to detect tumors based on the variation of dielectric properties of normal and cancerous tissues. The microwave signals are transmitted into the tissue to analyze the backscattered signal and as the tumor tissues have higher permittivity and conductivity than those of healthy tissues that causes significant change in backscattered signal resulting in successful detection of these malignant tissues [5]. The microwave imaging technique is safe and reliable because of the non-ionizing radiation and also the tools used in this system are comparatively cheap. The key component of microwave imaging system is the antenna that transmits the microwave signals through the breast and also receives the scattered signals in a wide-ranging frequency. In microwave imaging system, the antennas are designed maintaining some prototypes such as suitable penetration into the tissue, higher efficiency and gain, simple model architecture [6]. Therefore, it is challenging to design suitable antennas for microwave imaging application. Several types of antennas have been found in existing literature with enhanced bandwidth and radiation efficiency, compatible size such as Monopole antenna, Vivaldi antenna, Bowtie antenna, Horn antenna [7]. In [8], a planar rectangular microstrip patch antenna was designed but the gain is not satisfactory. In [9], a low profile slotted UWB monopole antenna was developed for breast cancer detection. AMC based CPW-fed microstrip patch antenna with improved gain was developed in [10]. A broadband cross Vivaldi antenna for radar-based breast tumor detection was designed in the reference [11].

The main purpose of this research work is to design a novel CPW-fed microstrip patch antenna with defected ground plane working at 5.8GHz. The proposed antenna can successfully detect a 5 mm tumor inside a breast phantom. In addition, the designed antenna composed of low-cost Rogers RT 5880 material with an overall size of 50×50×1.2 mm^3 has been optimized to get the desired response with a high gain at license free 5.8 GHz ISM band frequency.

II. ANTENNA CONFIRUATION WITH BREAST PAHNTOM DESIGN

The geometry of the proposed CPW fed patch antenna (50 mm× 50 mm) with a substrate thickness, S_h = 1.2mm is presented in Fig. 1(a) and 1(b) to detect breast tumor at the early stage. The substrate of the proposed antenna is made of Rogers 5880 with a dielectric loss tangent, tanδ = 0.0009, a relative permittivity, ε_r = 2.2. The main radiating element is truncated at the bottom of the patch to shift the radiation towards the desired license free 5.8 GHz ISM band. Three tapered portions at the middle part of the antenna have been introduced to improve the overall radiation pattern. The CPW and defected ground plane contribute to obtain the desired gain. The detailed dimension of the antenna element is shown in Table I.

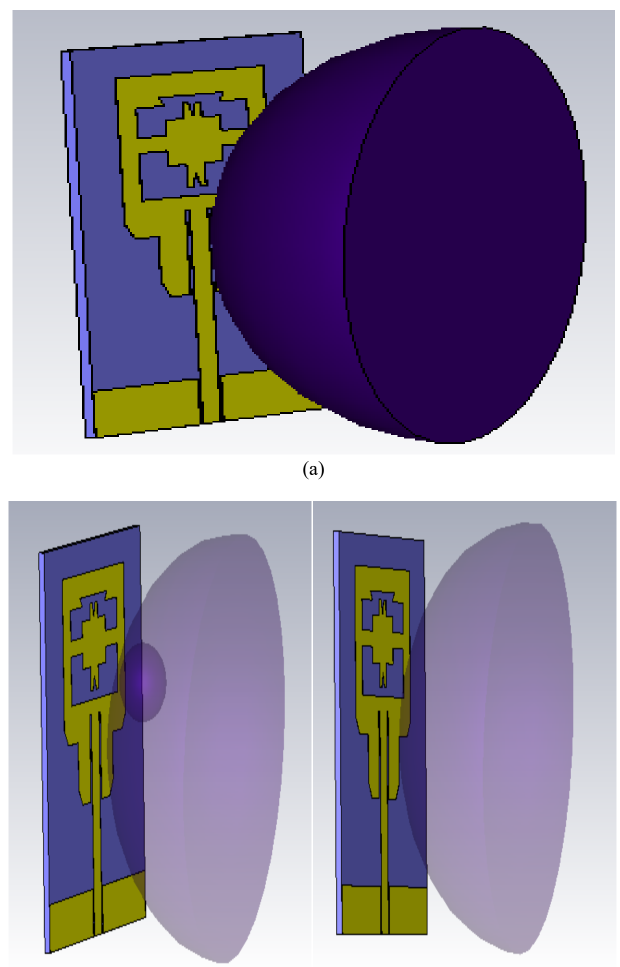
TABLE I. OPTIMIZED PARAMETERS OF THE PROPOSED DESIGN

Dimension	Value (mm)	Dimension	Value (mm)
L_1	32.00	L_{10}	4.00
L_2	14.00	W_1	19.00
L_3	6.00	W_2	3.85
L_4	6.00	W_3	6.15
L_5	2.00	W_4	6.00
L_6	4.00	T_1	1.53
L_7	24.00	S_l	50
L_8	4.20	S_w	50
L_9	22.50	S_h	1.2

A breast phantom [12] having center and bottom radius of 30 mm is placed near the CPW-fed antenna. The breast phantom has a tissue layer that indicates healthy tissue and inside there is a tumor with center radius of 5 mm. Our main focus is to analyze the difference in backscattered signal due to the presence and absence of the tumor. The relative permittivity of the breast tissue and tumor are 9 and 23 and conductivity of the breast tissue and breast tumor are 0.4 and 2.57 S/m respectively.

III. SIMULATED RESULT AND ANALYSIS

The proposed antenna with breast phantom (with tumor and without tumor) is shown in Fig.02.The ultimate goal of this proposed research work is to design an optimized microstrip patch antenna operating in the license free ISM band (5.8 GHz) for breast tumor detection where it is important to analyze the variation in backscattered signal due to the presence of the tumor. Figure. 03 and 04 give us a clear notion that the designed antenna can identify the position of the tumor in the breast phantom with a reflection coefficient (S_{11}) value -24.11dB and S_{11} value keeps at -23.96 dB without tumor. VSWR remains at ~1.14 (Fig. 05) for both cases of the same antenna structure. From Fig. 06 it can be stated that gain of the of the designed antenna remains almost same i.e. 5.65 dB for with tumor and 5.64 for without tumor at 5.8 GHz with a directivity value of 6.716 dBi. Figure 07 and Fig. 08 show three-dimensional gain plots and electric field results of the design antenna (with tumor and without tumor) respectively.



(a) (b) (c)

Fig.02. Proposed Antenna (b) with Breast Phantom (b) Phantom with Tumor (c) Phantom without Tumor

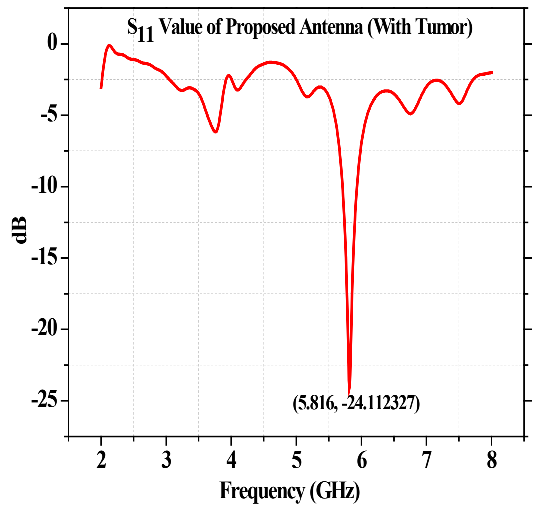


Fig.03. Simulated result of reflection coefficient, S_{11} of the proposed ISM Band Antenna (with tumor)

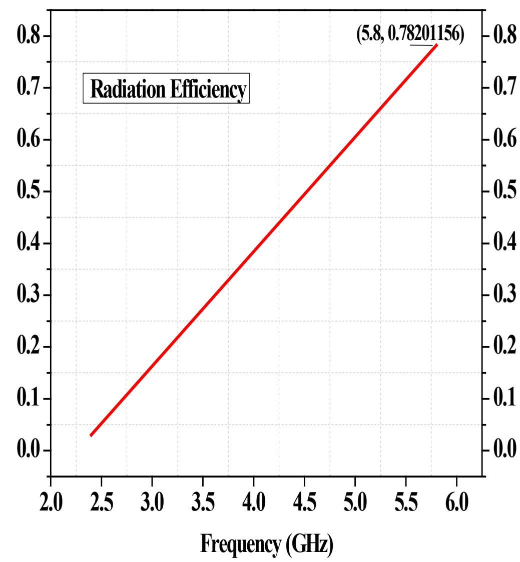


Fig.06. Radiation Efficiency vs Frequency Graph of the designed Antenna

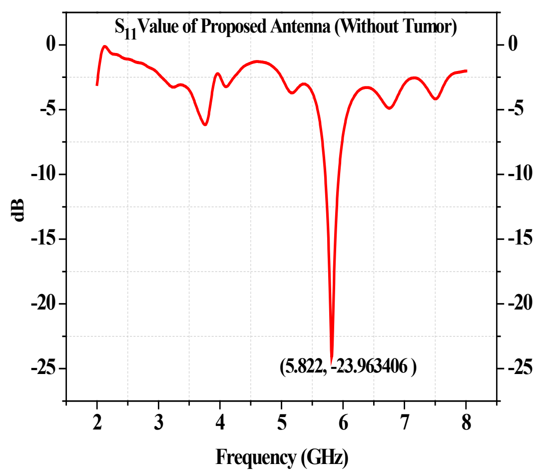


Fig.04. Simulated result of reflection coefficient, S_{11} of the proposed ISM Band Antenna (without tumor)

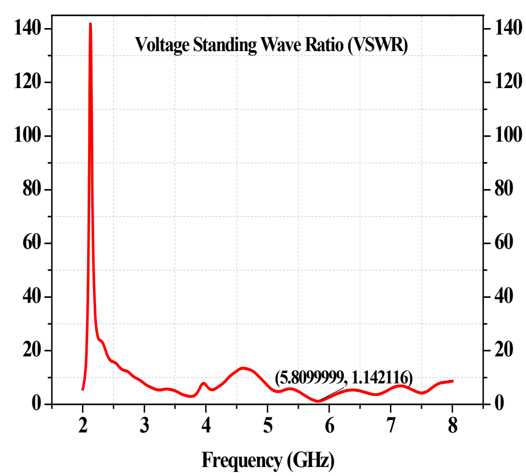
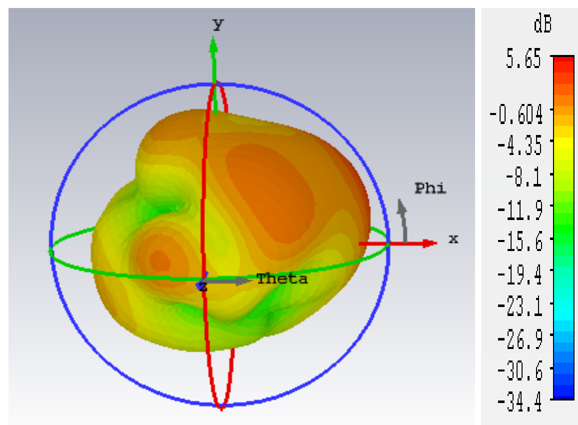
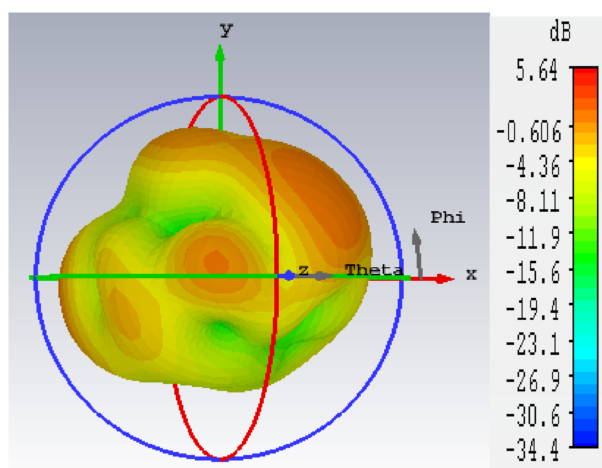


Fig.05. VSWR reading of the designed patch antenna at 5.8 GHz

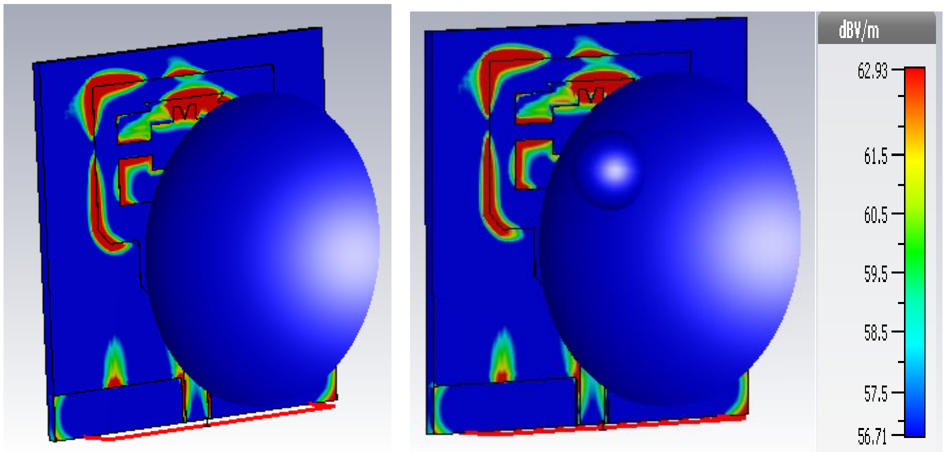


(a)



(b)

Fig.07. Three-dimensional gain plots of the design antenna at 5.8 GHz (a) with tumor (b) without tumor



(a) (b)

Fig 08. Electric field results at 5.8 GHz (a) without tumor (b) with tumor

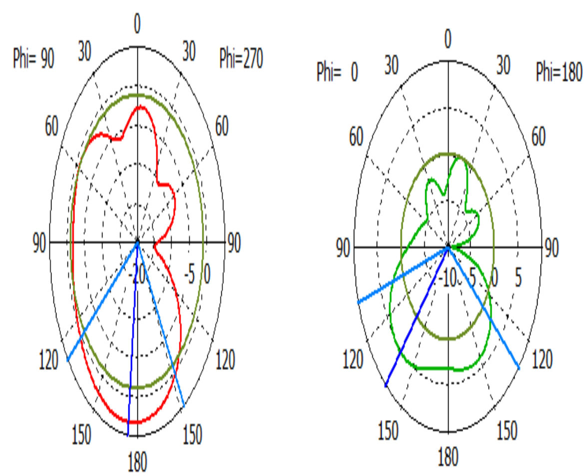
However, Table-II shows the comparative analysis of the antenna dimension, material, frequency and gain of the proposed design with the reference antennas. It is shown that almost all the reference designs used FR4 substrate material except [16] which is working for the range of 1.6 to 11.2 GHz having a gain of 6.17 dB with substrate material of 100% cotton. However, although all of the reference antennas, from [13] to [18] reported in the Table-II operated for a range of frequency but none of the reference antenna reported such an excellent gain ,5.645 dB like our proposed antenna to detect the early stage breast tumor with Rogers RT 5880 substrate material working specifically at license free 5.8 GHz ISM band frequency with an acceptable directivity value of 6.716 dBi. In reference [13] a good antenna gain is spotted but still not reported any desired gain value on the desired 5.8GHz ISM band frequency.2D radiation patterns of E-plane and H-plane of the proposed antenna are presented in Fig. 09.

TABLE II. COMPARATIVE ANALAYSIS WITH PREVIOUS WORK

Reference	**Antenna Dimensions (mm^3)**	**Substrate Material**	**Frequency (GHz)**	**Gain (dB)**
[13]	37× 43 × 4.85	FR4	4.9-10.9	6.32 at 9.1 GHz
[14]	25 × 16 ×0.8	FR4	2.85-13.21	4.33
[15]	45 ×30 ×1.58	FR4	1.3– 6	3.5
[16]	70 × 60 × 1.6	100% cotton material	1.6-11.2	6.17
[17]	26 ×20×0.794	FR4	3.98-17.26	Upper than 2.2
[18]	45 ×40×0.64	Roger RO 3010	4.5	4.26
[Proposed Antenna]	50 × 50 × 1.2	Rogers RT 5880	5.8	5.65

IV. CONCLUSION

In this study, a novel CPW-fed patch antenna with defected circular ground plane has been designed and analyzed to detect early stage breast tumor and most significantly to operate in license free ISM band frequency. To the best of the authors' knowledge, the proposed antenna is a promising one reported with an overall radiation efficiency of 78% with a precise S_{11} response specifically at 5.8 GHz for microwave imaging, having a gain of 5.65 dB with tumor as well as a gain value of 5.64 dB without tumor. The overall frequency responses of the proposed antenna have been observed with and without the presence of a tumor in breast phantom and there are noticeable differences in reflection coefficient with a considerable gain, high directivity, VSWR reading close to 1 and acceptable electric field results which indicates that our proposed antenna can be used successfully for the detection of breast tumor at the early stage. The antenna can be optimized in future to detect breast tumor in other ISM bands as well.



(a) (b)

Fig.09. 2D Radiation patterns proposed antenna at 5.8 GHz (a) E- Plane and (b) H-Plane.

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