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Early detection of breast cancer using microwave imaging

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Abstract: Microwave imaging for medical applications is mapping the electrical property distributions in the body which have been paid close attention for several years. Breast cancer detection with microwave imaging is based on the contrast in electrical properties of cancerous tissues compared to normal tissues. A previously designed PCMA antenna has been used here along with its enhanced version SCPCMA antenna. Both antennas have been used with a hemisphere shape breast phantom model consisting with two models; skin and fatty phantoms. The skin and fat tissue are used as a simulation for normal tissues, and muscle tissue as a simulation for malignant tissues or tumors. Simulation results show improved results of SAR analysis in detecting more cases due to the higher values of max SAR for SCPCMA antenna as compared with PCMA antenna, and this is back to the fact that SCPCMA has higher gain compared to PCMA antenna.

I. Introduction

Breast cancer has become one of the most widespread diseases worldwide making it a threat to the nowadays women. The technological boom in every aspect has made researchers to ponder over a screening tool that can be used to detect tumor in its developing stage, which can be used by the surgeons for further diagnosis.

Recently, significant progress has been made towards breast cancer detection via using non-ionizing electromagnetic waves. Breast tumors have electrical properties at microwave frequencies, which are different in contrast to normal breast tissue. X-Ray being a known technology to detect breast cancer has reportedly caused side-affects to the breast tissues of the patient under examination. Accordingly, researchers have implemented ultra-wide band radar-based microwave imaging techniques for early detection of breast tumor. The advantages can be noted as follows [1]; low-cost implementation, exposure to non-harmful radiation, high accuracy, and better patient comfort compared to the currently used X-Ray mammography.

I.I. Designed Antennas

A planar circular monopole antenna (PCMA) has been designed in a previous work as illustrated in Fig. 1(a) [2]. The PCMA antenna has been modified in [2] by utilizing the self-complementary technique, which lead to self-complementary planar circular monopole antenna (SCPCMA) antenna. Both of these antennas have been simulated by using CST Microwave Studio™ software package (Dassault Systèmes, Vélizy-Villacoublay, France).

Simulation results for the reflection coefficient of both PCMA and SCPCMA antennas show the improvement of performance for SCPCMA antenna as compared with PCMA antenna as depicted in Fig. 2 [2]. Also, the gain of SCPCMA antenna show an improvement at certain frequencies especially around 4 GHz, which has been noticed in previous works [2], as good frequency for SAR simulations. The Simulated realized gain of PCMA and SCPCMA antennas, are shown in Fig. 3.

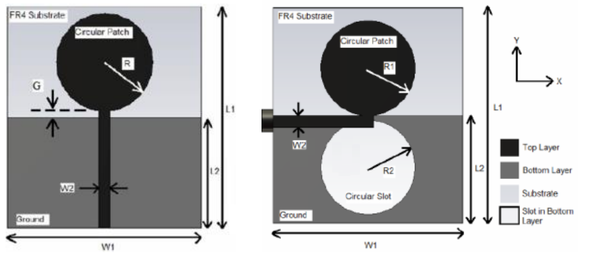


Figure 1: Antenna Geometry (a) PCMA and (b) SCPCMA [2].

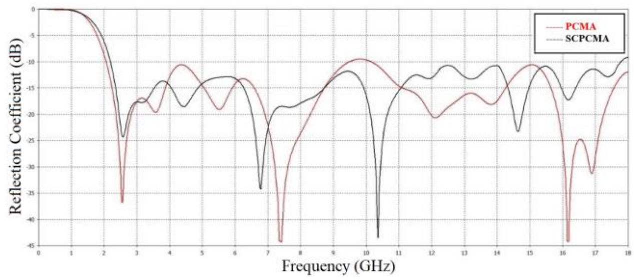


Figure 2: Ref. Coeff. of PCMA and SCPCMA Antennas [2].

I.II. Microwave Imaging Technique

Microwave imaging is a non-ionizing technique which is without doubt inexpensive compared to MRI and X-ray, and therefore it is considered as an alternative imaging technique for breast cancer detection in the future [3]. And it has three different types; Passive, Hybrid and Active. In this paper the active technique has been utilized.

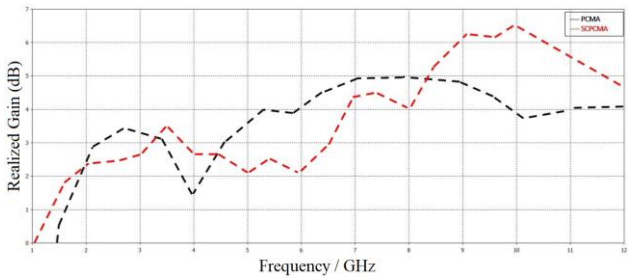


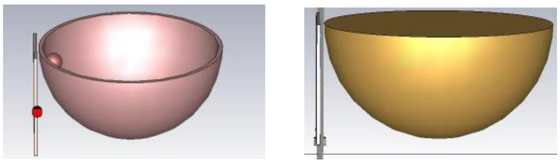
Figure 3: Simulated realized gain of PCMA and SCPCMA [2].

II. Specific Absorption Rate Calculations

SAR is a measure of the rate at which energy is absorbed by the human body when exposed to electromagnetic field, it can be calculated from electric field in tissue as [4]:

$$\boldsymbol{SAR} = \frac{|E|^2\sigma}{\rho} \quad (\frac{W}{kg}) \qquad (1)$$

where E is the internal electric field (V/m), σ is tissue conductivity (S/m) and ρ is tissue mass density (Kg/m^3). The simulated breast taken as shown in Fig. 4 [4], includes two models; skin and Fat phantoms, with 50 mm radius, and 5 mm diameter of tumor, beside the ultra-wideband (UWB) antenna. Tumor having different dielectric properties (permittivity, conductivity) have different electromagnetic field values. Differences of dielectric properties provide the opportunity for detecting that simulated tumor.



(a) *(b)*

Figure 4: Simulated breast phantoms with tumor inside; (a) Skin (b) Fatty [4].

III. Results and discussion

Simulation results show that the Max SAR values using SCPCMA antenna were higher than those of using PCMA antenna. Table 1~6 shows different cases of tumor location, the green color cells show the correct detection.

Table 1: SAR values of 10g for Skin Phantom and PCMA Ant.

Tumor size of 5 mm, and its location is at (1.5, 9, 9)		
f (GHz)	Max SAR (W/kg)	Max at (x, y, z)
4	27.2152	-13.2197, 9.22727, 3.75
4.5	26.0684	0.155, 10.5909, 13.7727
5	26.8402	0.155, 10.6732, 13.7443
6	48.6411	-0.155, 17.25, 1.21958
7	34.9911	0.155, 17.75, 1.21958

Table 2: SAR values of 1g for Fatty Phantom and PCMA Ant.

Tumor size of 5 mm, and its location is at (1.5, 9, 9)		
f (GHz)	Max SAR (W/kg)	Max at (x, y, z)
4	32.6452	(2.47, 8.038, 4.19)
4.5	28.5449	(2.1, 8.42, 4.96)
5	21.7001	(2.1, 9.18, 5.35)
6	17.8406	(2.1, 11.08, 5.73)
7	10.6933	(3.99, 9.56, 6.12)

Table 3: SAR values of 10g for Skin Phantom and SCPCMA Ant.

Tumor size of 5 mm, and its location is at (1.5, 9, 9)		
f (GHz)	Max SAR (W/kg)	Max at (x, y, z)
4	38.12	(-11.43,8.49,2.99)
4.5	29.12	(0.23, 10.48, 12.31)
5	27.95	(0.23, 10.31, 12.82)
6	45.76	(-0.12, 15.54, 1.37)
7	41.88	(0.12, 16.85, 1.36)

Table 4: SAR values of 1g for Fatty Phantom and SCPCMA Ant.

Tumor size of 5 mm, and its location is at (1.5, 9, 9)		
f (GHz)	Max SAR (W/kg)	Max at (x, y, z)
4	42.6452	(2.12, 8.14, 5.92)
4.5	25.9872	(1.93, 8.63, 6.15)
5	22.8821	(2.13, 9.23, 5.47)
6	16.5143	(2.11, 10.86, 5.91)
7	12.7383	(1.84, 9.41, 7.34)

Table 5: Max SAR for Fatty Phantom and PCMA at 4.5 GHz.

Tumor Loc. (x,y,z)	Average Mass 1 g		Average Mass 0.5 g	
	Max SAR (W/kg)	Max at (x,y,z)	Max SAR (W/kg)	Max at (x,y,z)
(0, 9, 9)	28.31	- 0.15, 8.42, 4.96	40.80	0.15, 9.18, 9.19
(0, 9, 15)	16.78	0.15, 9.18, 14.80	26.37	0.15, 9.18, 15.57
(7, 6, 20)	11.73	6.80, 6.56, 20.57	18.44	6.80, 6.18, 20.57
(-15,12,24)	13.23	-14.81,11.81, 24.19	20.57	-14.81, 11.81, 24.19
(-12,4,35)	9.54	-0.15, 21.79, 1.80	10.58	-0.15, 21.79, 1.80
(-10,10,40)	9.73	0.15, 21.79, 1.80	10.84	0.15, 21.79, 1.80

Table 6: Max SAR for Fatty Phantom and SCPCMA at 4.5 GHz.

Tumor Loc. (x,y,z)	Average Mass 1 g		Average Mass 0.5 g	
	Max SAR (W/kg)	Max at (x,y,z)	Max SAR (W/kg)	Max at (x,y,z)
(0, 9, 9)	32.54	-0.12,9.23,5.13	43.26	0.12,9.08,9.15
(0, 9, 15)	17.89	0.12,9.08,14.97	30.73	0.12, 9.13,15.43
(7, 6, 20)	14.75	7.1, 6.43, 20.14	20.35	6.91,6.25,20.37
(-15,12,24)	15.42	-15.2,11.95,24.05	24.79	-15.11,12.02,24.22
(-12,4,35)	8.46	-0.124,21.87,1.67	10.84	-0.12,21.87,1.67
(-10,10,40)	9.62	0.124,20.91,1.63	11.14	0.12,20.91,1.63

IV. Conclusions

The improved gain especially around 4.5 GHz, and stable Omni-directional radiation pattern for SCPCMA makes that antenna suitable for microwave imaging. It has been also reflected to increase the Max SAR value which increase the chance for detection more than that for PCMA antenna.

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Author's statement

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