Planar Microstrip Antenna Array for Hybrid Electro-Biomechanical Breast Imaging

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***Abstract* — The design of a compact wideband antenna array for use in microwave-mechanical hybrid system aimed at the early detection of breast cancer is presented. The proposed array uses probe-fed planar circular-shaped patch antennas placed on a movable plate. The elements of the antenna array are used to transmit a wideband pulse towards the breast and measure the backscattered pulse before and after compressing the breast by a controlled force applied at the top of the movable plate. To improve the bandwidth of the antenna array, each element of the array uses curved slots located on both the patch and the ground plane, and an annular ring around the circular patch. The presented performance of the antenna indicates wideband operation across the band from 2.4 GHz to 3.9 GHz**

***Index Terms*— Microwave imaging, wideband antenna, biomechanical imaging.**

I. Introduction

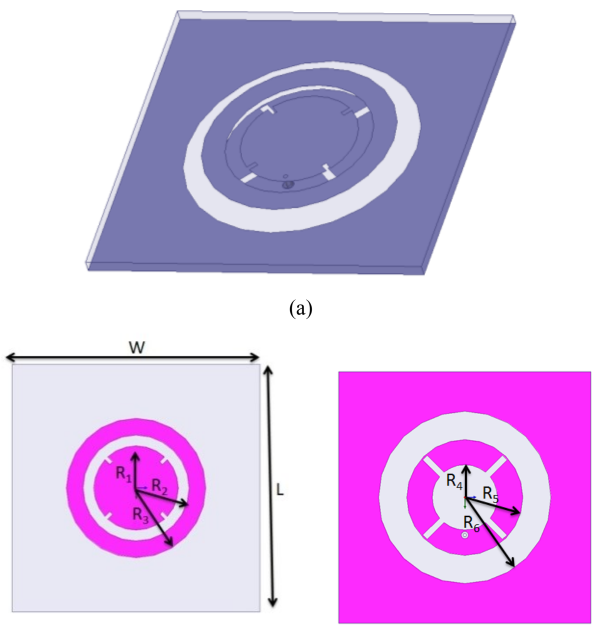
The design of microwave imaging systems for medical applications has attracted a huge interest in recent years. One of such systems is the hybrid microwave-mechanical systems for breast cancer detection [1-6]. In those systems, compact and directive wideband antennas are needed to transmit and receive short duration pulses that are launched into the breast tissues before and after compression. The tumor detection is based on a considerable contrast for the electrical properties (permittivity and conductivity) and mechanical properties (elasticity and Young's modulus) between the normal and cancerous tissues. Because of the difference in the electric properties, the tumor acts as a reflecting object causing the scattering of an electromagnetic wave which is incident upon it. Also, because of the difference in the mechanical properties, the tumor displacement due to the compression is different than the normal fatty tissues displacement.

For the best detection capabilities, the system has to follow suitable guidelines. For example, the antenna elements should be compact in size, low profile, and directive to focus the microwave power in the breast tissues [7-10]. Moreover, the antenna elements should feature low mutual coupling when operate in the array. For the hybrid microwave-mechanical systems, the antenna array should be mounted on the surface of a rectangular plate above the breast. This configuration adds an extra restriction on the antenna array to be planar rectangular array with probe-feed elements.

This paper introduces a novel compact planar microstrip antenna array for the operation in the frequency band 2.5 GHz to 3.9 GHz. The antenna is based on a circular microstrip patch structure designed with suitable modifications to obtain directive and wideband characteristics. To that end, slots in both the patch and the ground plane are introduced to reduce the size of the antenna and increase the bandwidth. The performance of a single element of the designed antenna is optimized. Then, eight elements are arranged to form a rectangular array. The design of the array is optimized using the full-wave simulation package HFSS. The antenna has 48% fractional bandwidth with more than 20 dB decoupling between all the elements.

II. Single Element Antenna Structure

The proposed antenna element is shown in Fig. 1. It includes a circular microstrip patch with four slots. The patch is surrounded by an annular ring. The bottom layer of the substrate includes the ground plane with four rectangular slots and two annular rings. The optimization starts with the traditional circular patch antenna resonate at the center frequency. The size of the patch reduced using slots on the patch and the ground plane. The dimensions of the antenna and slots are optimized using Ansoft HFSS. The optimized dimensions using Rogers RT6010LM (thickness 1.27 mm and ε_r=10.2) as the substrate are: W=40 mm, L=40 mm, R_1=6.5mm, R_2=8.5mm, R_3=11mm, R_4=5mm, R_5=9mm, R_6=13.5mm. Figure 3 shows the optimized return loss of the antenna. The return loss is more than 10 dB in the range from 2.5 GHz to 3.8 GHz.



(a)

(b) (c)

Fig. 1(a) Configuration of the proposed antenna, (b) Top layer, and (c) bottom layer.

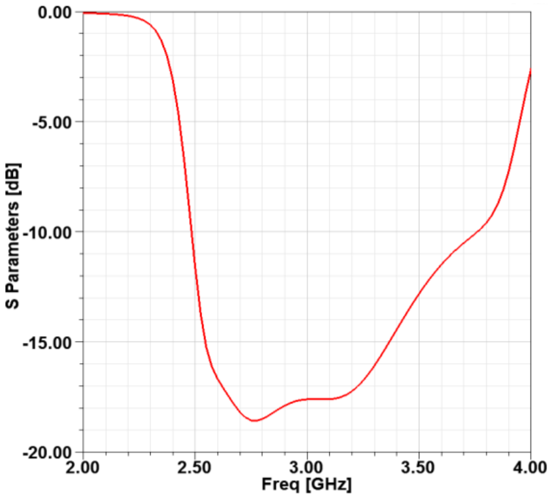


Fig. 2 Return Loss of the single antenna element.

The simulated gain patterns of the antenna at the central frequencies are shown in Fig. 3.

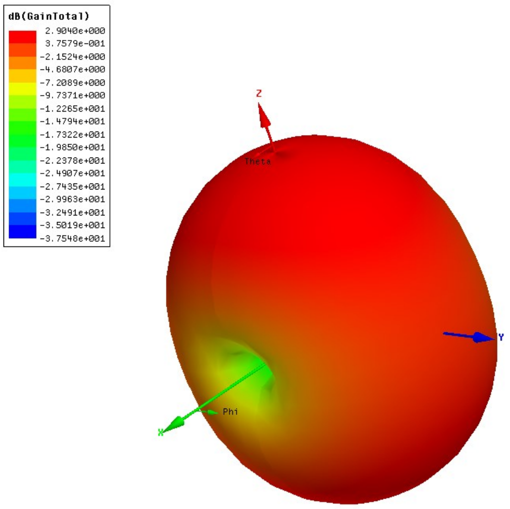


Fig. 3 Total gain of the antenna array.

III. ANTENNA ARRAY

The designed antenna element is used to build an 8-element array as shown in Fig. 4. The dimensions of the whole array are optimized using Ansoft HFSS. The total size off the optimized array is L_a=18.3 cm and W_a=8.9 cm.

The reflection coefficients (S_{11} to S_{88}) as a function of frequency for the eight antennas are shown in Fig. 5. The antenna demonstrates good impedance bandwidth (S_{ii}<-10 dB) across the band 2.5 GHz to 3.9 GHz. Figure 6 shows the coupling between antenna 1 and the rest of the antennas. The graph shows an excellent decoupling (greater than 20 dB) between all the antennas.

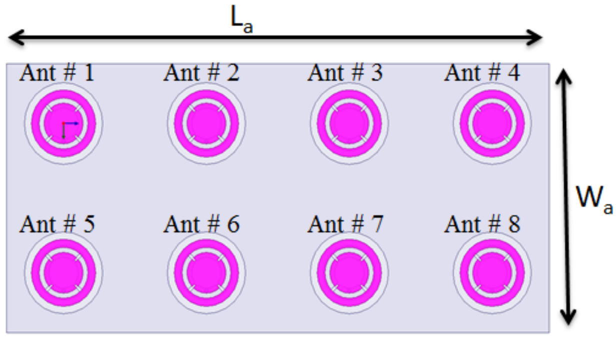


Fig. 4 Configuration of the proposed antenna array.

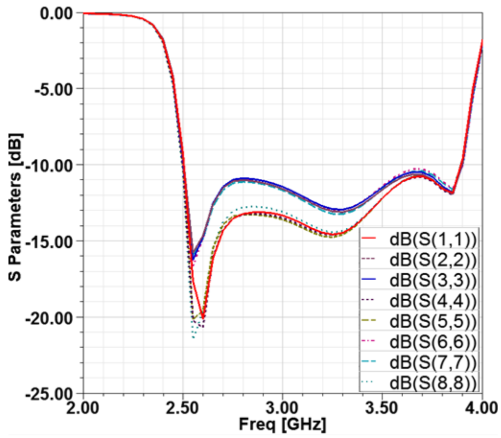


Fig. 5 Reflection coefficients of all antenna elements.

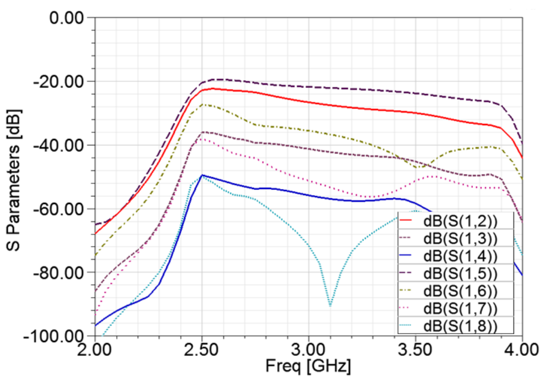


Fig. 6 Coupling between antenna 1 and the rest of antennas.

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