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Microstrip Antenna for Microwave Imaging Application

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Abstract— A compact microstrip antenna design to be used in breast cancer detection is presented. The antenna consists of a radiating patch mounted on two vertical plates, fed by coaxial cable. A study is carried out on different parameters of the antenna. Simulation results show that the antenna possesses a wide bandwidth and this is confirmed experimentally. In experiments, a homogeneous dielectric box, having similar properties to human tissue is used to study the interaction of the antenna with tissue. Even without added matching medium or lumped loads there is good matching when the antenna is in contact with the tissue. Finally a two-element antenna array is investigated numerically, with promising results.

1. INTRODUCTION

Breast cancer is the most common form of cancer found in women; early detection is the best factor in long time survival. Currently the most popular screening method is X-ray mammography, namely X-ray imaging of the compressed breast. According to reports [1], serious limitations of X-ray mammography provide clear motivation for the development of a new imaging tool to assist in early detection. For a long time, microwave engineers have tried to implement non-ionizing electromagnetic waves to detect cancer in the human body. Over the past several years significant progress has been made in using microwaves for breast cancer detection. Microwave imaging can be defined as seeing the internal structure of an object by illuminating the object with low power electromagnetic wave at microwave frequencies. In the microwave frequency range, passive, hybrid and active approaches to breast cancer detection are being researched [2]. Such methods would be beneficial to patients because both ionizing radiation and breast compression are avoided.

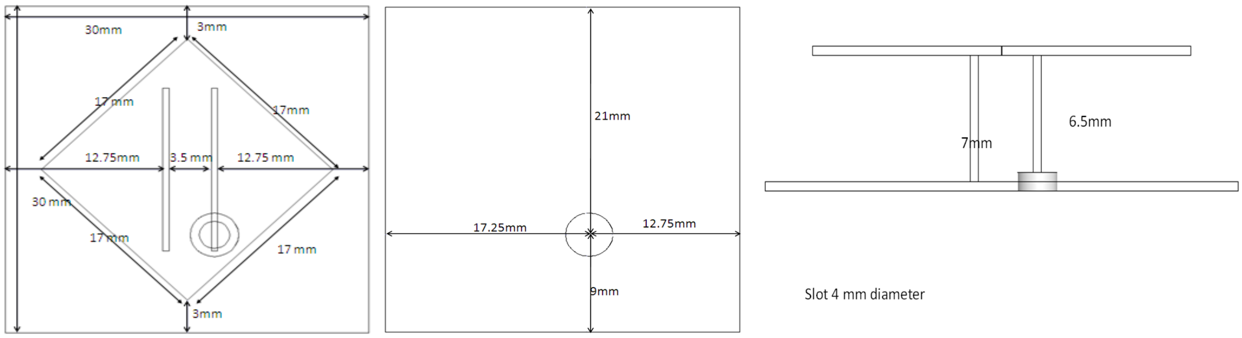
The active method using microwaves radiated into the breast to detect the presence of tumours is the most widely adopted method, and this may be sub-divided into tomography and radar-based approaches [3]. In tomography a single transmitter radiates into the breast while a number of antenna placed around the breast receive scattered waves. The procedure is repeated for various positions of the transmitter. Depending on the acquisition of data these data will be processed to produce a 2-dimensional or 3-dimensional image of the breast [4].

For radar-based microwave imaging, a short pulse is transmitted from a single ultra-wideband (UWB) antenna into the breast and any back-scattering is detected by the same antenna. This process will be repeated for different locations around the breast. The presence of a tumour produces strong scattering, and such a response can be interpreted to estimate the location of the tumour. The travel times of signals at various locations are recorded and computed [3]. As with any radar-based system, this system does not require complex image reconstruction algorithms, and hence offers more detailed information than the tomography microwave imaging method.

The antenna which is used as transmitter and receiver to transmit UWB signals must permit a high level of resolution. This requirement thus limits the class of antenna that can be utilized. Large fractional bandwidth, low side-lobes and low mutual coupling (i.e., when two antennas are used for system operation) are the characteristic factors which must also be considered. The existing antennas used for breast cancer detection require lumped loads as a trade-off for wider bandwidth [5, 6]. Most metallic–type sensors must be immersed in a matching medium with permittivity similar to that of breast tissue so that the reflection between the free space and the breast surface can be minimised [7–12]. However in reality it is difficult to implement the matching medium to surround the patient breast. This paper presents a compact microstrip antenna design for the RF detection system of cancer cells inside the human breast tissue. The operation of two elements including the breast model is also demonstrated.

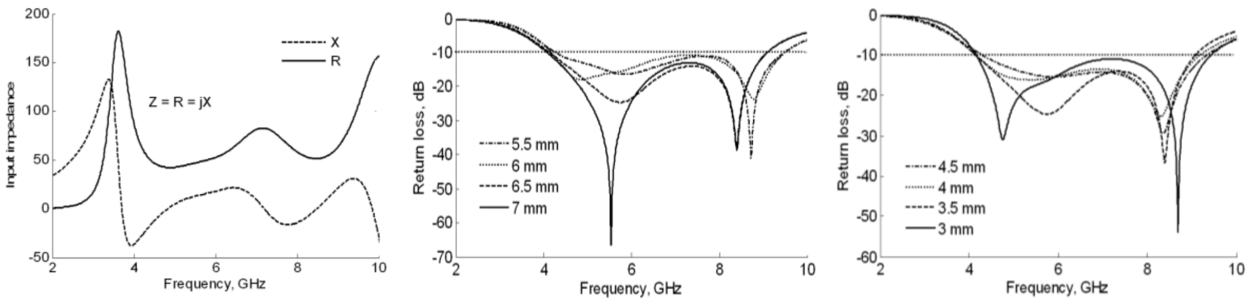
2. ANTENNA GEOMETRY

Figure 1 shows the overall dimensions of the antenna. The antenna consists of a radiating patch mounted on two vertical plates placed on a ground plane of dimension $L = W = 30\,\mathrm{mm}$ and



(a) (b) (c)

Figure 1: Geometry of the Antenna. (a) Top view. (b) Ground plane. (c) Side view.



(a) (b) (c)

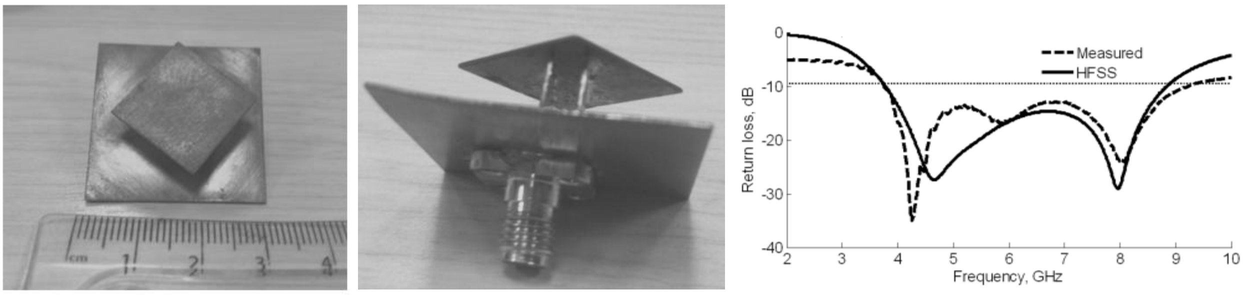
Figure 2: (a) Input impedance. (b) Simulated reflection coefficient of the antenna for different heights. (c) Simulated reflection coefficient for the gap between two vertical plates.

0.5 mm thickness. A 50 Ω coaxial probe excites the antenna, and design parameters are obtained by performing parametric studies with simulation software HFSS [13]. Figure 2(a) shows the input impedance of the proposed antenna, where the real part of the impedance is close to 50 Ω over the targeted bandwidth (i.e., 4 to 8 GHz). Figures 2(b) and 2(c) show the reflection coefficients of the antenna for different heights of the radiating patch from the ground plane and varying gap between the two vertical plates. These show that the reflection coefficient improves with increasing height of the antenna and a narrowing of the gap between the vertical plates.

3. RESULTS AND DISCUSSION

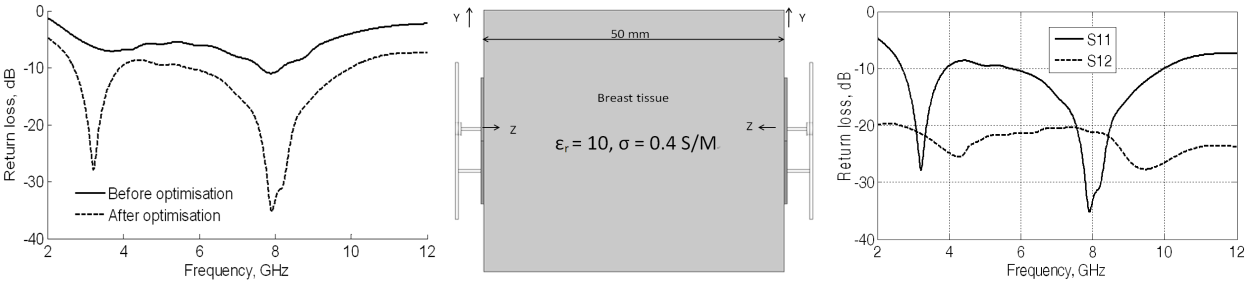
The return loss of this fabricated antenna, see Figures 3(a) and 3(b), is measured using an HP8510 network analyzer. The simulated and the measured return loss of the antenna are compared in Figure 3(c), indicating good agreement. The measured and simulated frequency range covered between 4 GHz and 9 GHz, with $S_{11} < -10\,\text{dB}$, corresponds to a relative bandwidth of 77%.

The antenna is designed to be placed directly on the breast, so the interaction between the antenna and tissue is investigated. A homogenous box with similar properties to breast tissue ($\varepsilon_r = 10$ and $\sigma = 0.4\,\text{S/M}$) [14] is modelled. Figure 4(a) shows the input impedance of the antenna while in contact with the tissue, both before and after optimisation. The results show good matching after optimisation when the sensor touches the tissue, so that more power is penetrating into the tissue. This is obtained without adding any matching materials or lumped loads. After optimisation the new height of the antenna from the ground plane is 4 mm and the gap between the two plates is 8 mm respectively. The remaining dimensions of the antenna remain the same. The configuration of a two-element antenna array in the presence of tissue is illustrated in Figure 4(b). The two antennas are aligned face to face with 50 mm separation. Figure 4(c) shows the return loss (S_{11}) and transmission coefficients (S_{21}) of the antenna elements, indicating wideband characteristics for the impedance and transmission.



(a) (b) (c)

Figure 3: (a) and (b) Antenna prototype. (c) The input return loss of the proposed antenna measured and simulated.



(a) (b) (c)

Figure 4: (a) Simulated reflection coefficients of the sensor in contact with breast tissue before and after optimisation. (b) Configurations of two-element arrays. (c) Return loss S_{11} and transfer function S_{21}.

4. CONCLUSION

In this paper a new compact UWB antenna design has been presented. The effect of the various antenna parameters on the bandwidth and the resonance characteristics were discussed. The operating bandwidth of the antenna achieved at a minimum workable return loss of 10 dB was 4 to 9 GHz. The measurement results show good agreement with simulations. A homogenous box having similar properties to human breast tissue was also used to check the interaction of the antenna with the tissue. The antenna showed good matching without the need to add any lumped loads or introduce dielectric matching media.

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