Experimental Modeling of Breast Cancer Detection by Using Radar Aids

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Abstract— Breast cancer is one of the most common types of cancer among women. Due to this fact, providing methods to assess the early-stage diagnosis and treatment of the breast cancer is of a great interest for researchers in the last decades. The article describes in detail the experiment of imaging breast tumors using radar aids. The development of microwave breast cancer detection and treatment techniques has been driven by reports of substantial contrast in the dielectric properties of malignant and normal breast tissues. During the experiment, two different phantoms of breast were used: one without the dielectric inclusions, another with dielectric inclusions mimicking malignancy of the breast tissue. The materials of the phantoms were selected in such a way as to its dielectric properties were same the dielectric properties of biological tissues of the breast. During the experiments a vector network analyzer (Rohde&Schwarz) with a single helical antenna attached was used for measuring of S_{11} parameters. The antenna was pointed to the phantom behind which radio absorbing material was placed to reduce the clutter. Mechanical scanner controlled by Seeduino was used to move the phantom. We conducted measurements at frequencies from 5.6 to 6.6 GHz, 14 to 15 GHz and from 21 to 22 GHz with a step of 0.2 GHz. Obtained images were processed by using software "RASCAN-Q". It was shown that the applied method allows to detect dielectric inhomogeneities in biological tissues. The results, published in the article, have been obtained in the framework of the implementation of the project part of the Russian Foundation for Basic Research (grant No. 26 16-37-00276\16).

1. INTRODUCTION

Breast cancer is the second most common cancer in the world and, by far, the most frequent cancer among women with an estimated 1.67 million new cancer cases diagnosed in 2012 (25% of all cancers). The range in mortality rates between world regions is less than that for incidence because of the more favorable survival of breast cancer in (high-incidence) developed regions, with rates ranging from 6 per 100,000 in Eastern Asia to 20 per 100,000 in Western Africa [1].

Such high mortality rate is caused, first of all, by the late diagnosis of this disease, delayed treatment of patients, the lack of highly sensitive methods for establishing early (pre-clinical) stages of mammary gland cancer, and insufficiently quality of metastases diagnosis in regional lymph nodes.

As a rule, the routine diagnostic procedure consists of an individual examination by doctors and mammography or ultrasound screening. Screening for early detection of breast cancer is conducted by these methods at 12–24 month intervals, which cannot guarantee identification of aggressive tumors.

In addition, however rarely, methods such as computed tomography, positron-emission tomography, magnetic resonance imaging, all types of biopsy are applied. They allow for the detection of certain changes in the mammary glands and specific to their cause, nature and prevalence [2]. However, none of them is applicable for routine scanning because of high cost, prolonged time of a diagnostic procedure and invasiveness (for biopsy). Therefore, it is advisable to complete a routine diagnostic procedure using a different noninvasive screening method, which could detect tumors at the earliest possible stage.

In this paper we describe the experimental results carried out to confirm the possibility of using radar for the detection of breast tumors. It is known that the dielectric properties of normal and malignant breast tissues differ even at the earliest stage of tumor genesis. Thus, frequent scans with a radar, which detects dielectric in the medium, could be used for early stage breast tumor detection.

2. METHOD

The development and improvement of imaging modalities for the early detection of breast cancer remains an active area of research. Due to their noninvasive nature, reduced system cost, and high potential for early detection of small tumors, breast cancer detection systems which rely on monitoring the dielectrical properties of the breast have gained attention in recent years [3–5].

We propose, in this article, the use of radar to detect the inhomogeneities in breast tissue. Emitted by the radar electromagnetic wave is scattered and absorbed in the media (breast tissue) due to the differences in the dielectric properties between tumors and normal tissues [6]. This principle is a base for the radar usage in visualization the breast internal structure.

During the experiments a vector network analyzer (Rohde&Schwarz) with a single helical antenna attached was used for measuring of S_{11} parameters. The antenna was pointed to the phantom behind which radio absorbing material was placed to reduce the clutter. Mechanical scanner controlled by Seeduino was used to move the phantom (Fig. 1).

We conducted measurements at frequencies from 5.3 to 6.8 GHz, 14 to 15 GHz and from 21 to 22 GHz with a step of 0.2 GHz. Obtained images were processed by using software "RASCAN-Q".

3. PHANTOM DEVELOPMENT

We used two types of materials: adipose and muscular tissues of animal origin. The materials of the phantoms were selected in such a way as to its dielectric properties were same the dielectric properties of biological tissues of the breast (normal and malignant). In addition, the usage of this type of materials is convenient to create different configurations of phantoms, and it allows precise

Figure 1: Photo of the experimental setup.

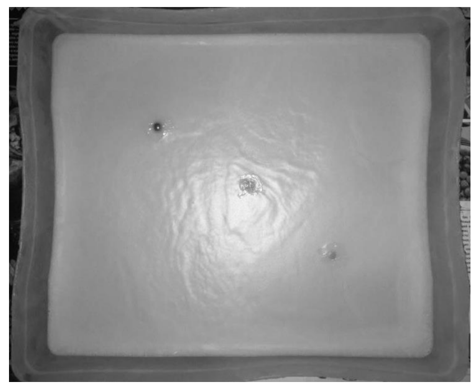
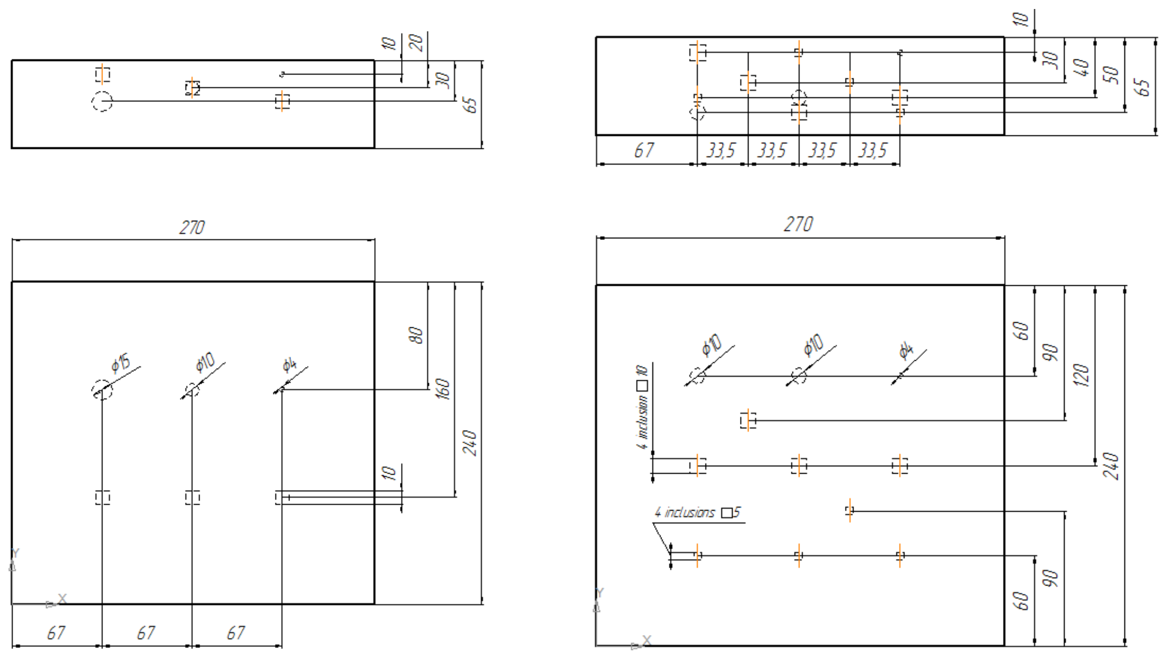


Figure 2: Photo of the phantom.



The first phantom

The second phantom

Figure 3: Arrangement of the inclusions in the breast model.

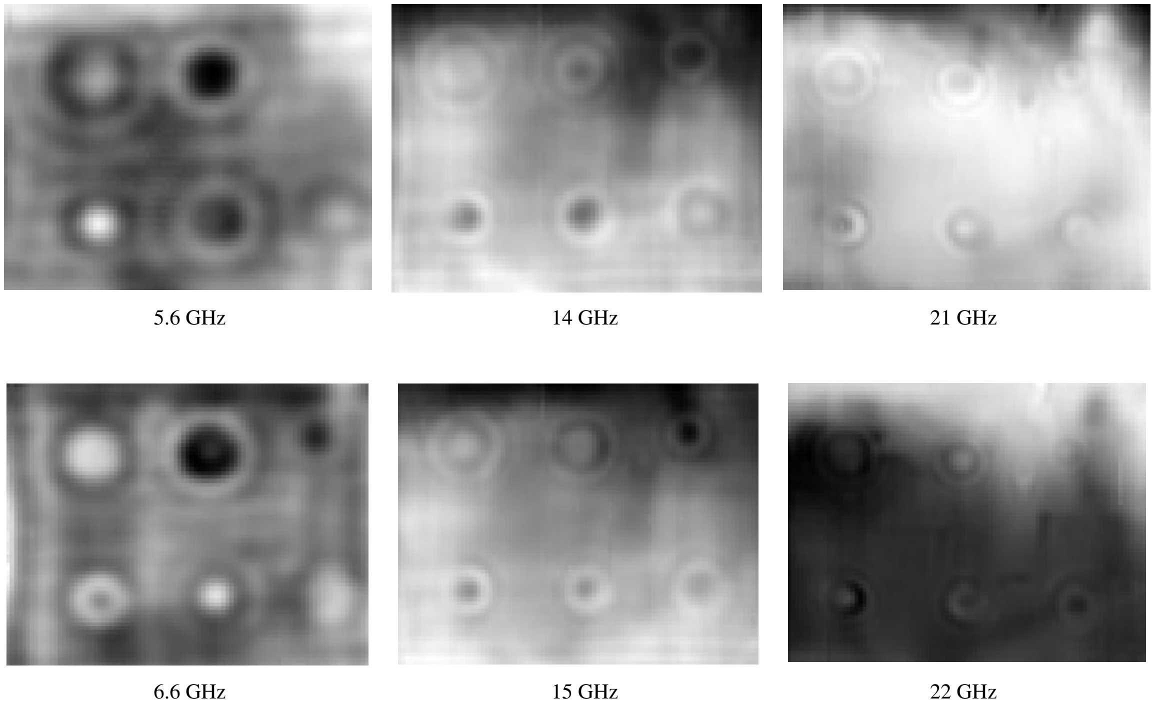


Figure 4: Experimental results.

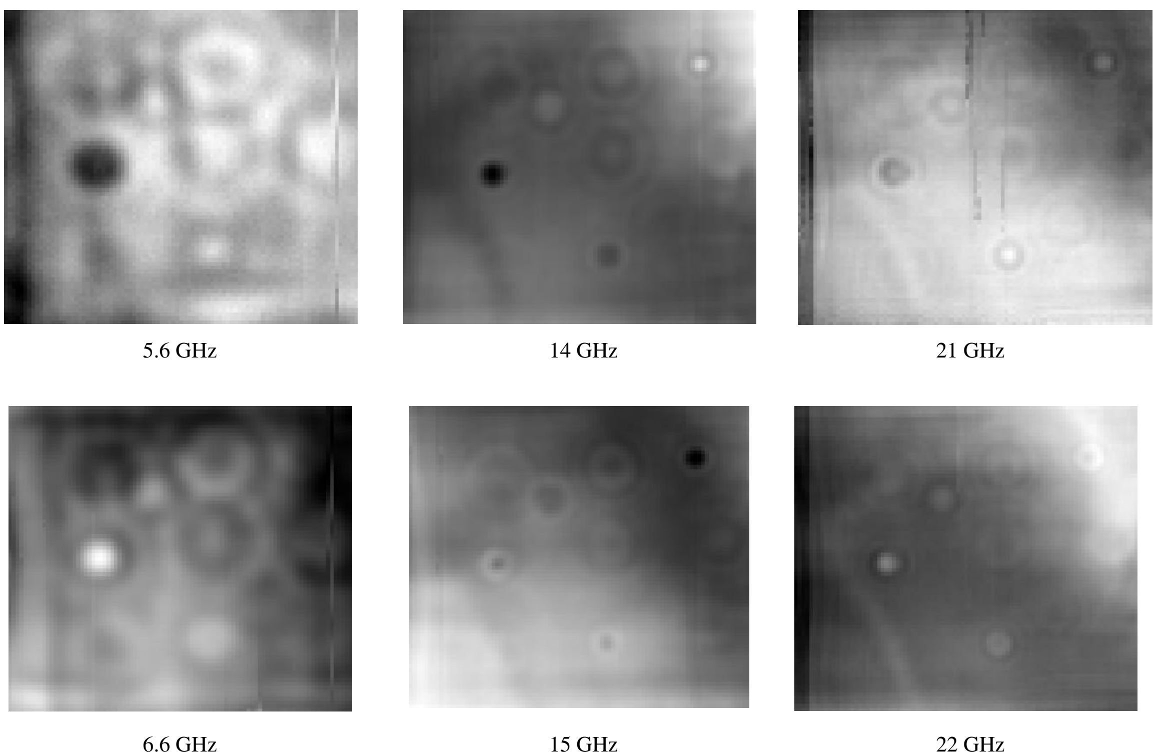


Figure 5: Experimental results.

installation of the inclusions.

The phantom is prepared inside a plastic container with dimensions $400 \times 335 \times 65$ mm. The phantom preparation consists of the following stages. Firstly, the bottom fat layer of the phantom is prepared: it is necessary to melt lard, and then it is poured into the container. The phantom is leaved to solidify for two hours at a temperature of 4–5°C.

The inclusion imitating a tumor of 10 mm diameter and 10 mm height is inserted into the fat layer of the phantom (Fig. 2). We also insert metal ball of 10 mm diameter to compare the contrast between the tissues. The next fat layer of the phantom is prepared and poured into the same mold. Then mimicking tumor inclusion is inserted into this fat layer of the phantom. The process is repeated until the last layer of fat phantom is poured.

We prepared two types of phantoms with different inclusions' configuration. The inclusions were placed as shown on Fig. 3.

4. RESULTS

The performance of the proposed method is evaluated experimentally using the developed phantom materials. In our previous work [7], we found out that edge effects might mask the inclusion. That is why in the present experiment we used a phantom with dimensions of 400×335 mm and scanned the area of only 270×210 mm in the middle of the phantom to eliminate the edge effect.

The results are provided with the help the software "RASCAN-Q", which is design in Remote Sensing Laboratory (Bauman Moscow State Technical University). This software allows to receive the image of I and Q quadrature. The results are list below in Figs. 4 and 5, I or Q-quadratures were chosen based on the quality of the resulting images.

After the experiment with the first model, we wanted to see is it possible to find inclusions at other depths. For this purpose the second phantom (Fig. 3 — right side) was made.

5. CONCLUSION

Experimental results showed that the proposed method allows detecting dielectric inhomogeneity in biological tissues, e.g., tumor in normal breast tissue, due to significant differences in dielectric properties. It was shown that by using the probing signals at 5.6–6.6, 14–15 and 21–22 GHz it is possible to detect the inclusion of 5 mm diameter up to a depth of 30 mm. In details processing methods are described in article by L. N. Anishchenko et al. "Microwave Imaging of Biological Tissue Phantom in Different Frequency Ranges" [in press on PIERS 2016].

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