Holographic Radar in Breast Cancer Imaging

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***Abstract*— Breast cancer is one of the leading diseases among women nowadays. As a rule, the routine diagnostic procedure by common methods can not guarantee identification of aggressive tumors. Therefore, there is a need for a new method, which could detect the tumors at the earliest stage possible. This problem may be solved with the help of holographic radar, which detects dielectric inhomogeneities. It is known that the dielectric properties of normal and malignant breast tissues differ even at the earliest stage of a tumor genesis. Thus, frequent scans with holographic radar could be used for safe early stage breast tumor detection. This report presents the results of two series of experiments carried out to confirm the possibility of using holographic radar for the detection of breast tumors. A specially constructed model breast with two dielectrically realistic inclusions of various sizes simulating neoplasm was used in the experiments. It was found out that among holographic radars operating at 4 and 7 GHz the latter is preferable for breast inhomogeneity detection.**

I. Introduction

Early stage breast cancer detection is now one of the most actual problems in medical diagnostics. In some countries this pathology is the leading cause of death among the women. Every 9th female in USA is under the risk of this highly dangerous disease. As a rule, the routine diagnostic procedure consists of 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 can not guarantee identification of aggressive tumors. Also, however rarely, such methods as computed tomography, positron-emission tomography, magnetic resonance imaging, all kinds of biopsy are applied. They allow to purposefully look for certain changes in the mammary glands and specify their cause, nature and prevalence. However, none of them are 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 by an other noninvasive screening method, which could detect the tumors at the earliest stage possible. This problem may be solved with the help of holographic radar, which detects dielectric inhomogeneities. It is known that the dielectric properties of normal and malignant breast tissues differ even at the earliest stage of a tumor genesis [1]. Thus, frequent scans with holographic radar could be used for safe early stage breast tumor detection. Although at present there is a growing interest in literature to the usage of ultrawideband radars for breast malignant tumors detection [2-4], these devices have not yet achieved necessary accuracy and specificity when applied on the realistic breast phantoms. Holographic radars have not been used for this purpose until the present.

In this paper holographic radar RASCAN is proposed for breast screening. A special realistic phantom of a breast is proposed, which allows creating phantoms with different displacement of neoplasm. In section 2 apparatuses, model and experimental procedure are described. Section 3 contains some experimental results.

II. Apparatuses and Methods

During experiments two types of multi-frequency holographic radar RASCAN were compared: RASCAN-4/4000 with frequency from 3.6 to 4.0 GHz and RASCAN-4/7000 with frequency range of 6.4 - 6.8 GHz (Fig. 1) [5, 6].

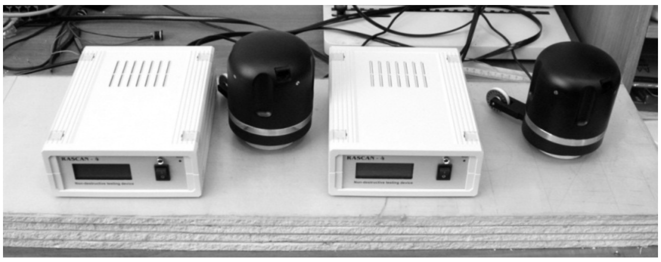

Figure 1. Radars used in the experiments.

Both of them operate at five probing frequencies and two types of polarization (cross and parallel).

Since the reflection of electromagnetic wave radiated by the radar takes place on the boundaries of objects with different dielectric properties, the device can detect tumors by presence of such re-scattered waves. To prove the fact several experiments were carried out on a special breast phantom.

It is always a challenge to construct realistic models of biological objects. In the literature many different breast phantoms are described [7-10]. The main disadvantage of such phantoms is their complexity. In this study a simple in use model proposed by Dr. S. Vesnin, who has been working in the field of breast cancer diagnostics for more that 20 years, was applied. The scheme of the experimental breast phantom with two heterogeneous inclusions of various sizes, simulating neoplasm, is presented in Fig. 2.

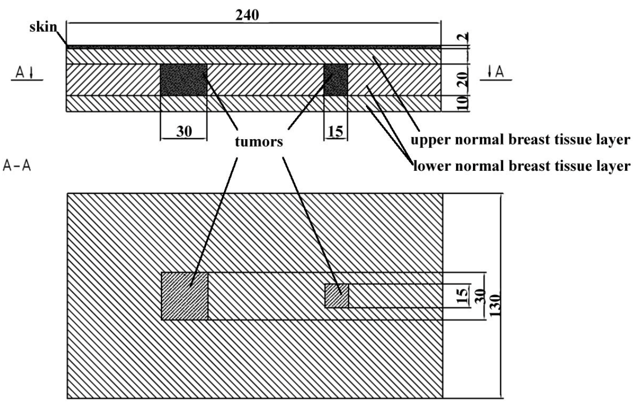

Figure 2. Scheme of the experimental model.

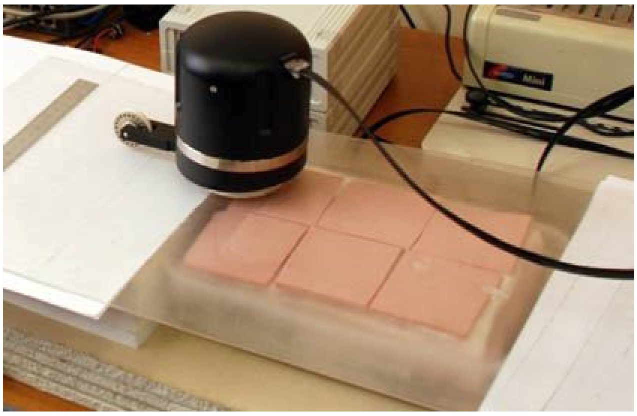

Figure 3. Photo of the experimental setup.

In the experimental phantom normal breast tissue was assumed to have the same dielectric properties as adipose tissue (dielectric constant is about 7 and conductivity 0.5 Sm/m [1]). It was simulated by lard, neoplasm and skin (dielectric constant is about 40 and conductivity 4 Sm/m [1]) - by pudding. Radar head was connected to a control unit and through it to a PC. After that scanning procedure was carried out by the straight movements of the radar in series of 20 parallel lines for the full coverage of the experimental model.

For two of the RASCAN radars the experiments were conducted for next configurations of the breast phantom:

- phantom without inclusion (#1);
- phantom with inclusion and without the skin layer (#2);
- completely assembled phantom: layers of normal breast tissue with inclusions covered with skin layer (#3).

For every experiment 2 images for each of the five probing frequencies are obtained (10 total images). In this paper only the most informative of them are given.

III. Experimental Results

First of all preliminary experiments with phantom #1 were carried out. Their results showed that it is highly important to exclude any air gaps between antenna and breast phantom, because it may be the reason for a false alarm (Fig.4). Obviously, in case of any air gap presence there is a reflection from the surface of the phantom. Its amplitude is much higher than the same parameter for the reflection from the inner inhomogenities of the model.

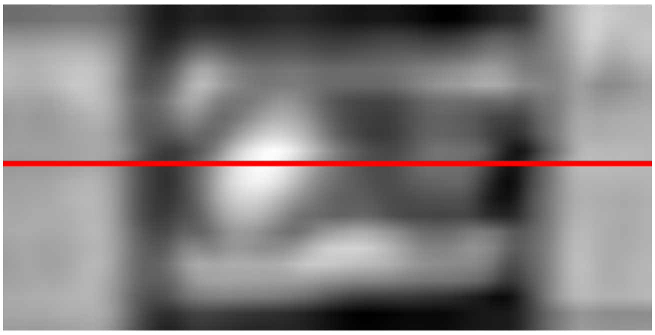

Figure 4. Holographic image of the phantom #1.

This problem was solved by placing a plastic sheet between antenna and breast phantom surface. Thus the gapping was excluded and as it could be seen from the results (Fig. 5) there is not any significant variation of brightness in this case.

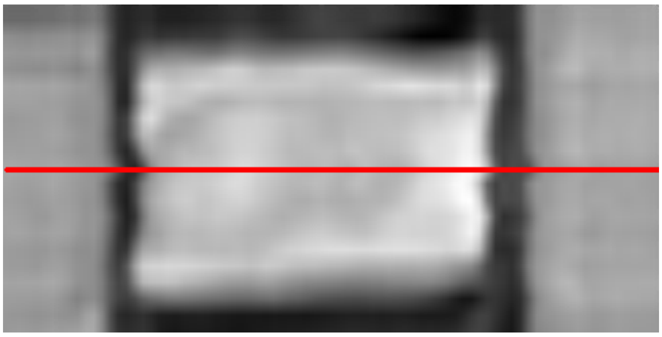

Figure 5. Holographic image of the phantom #1 (air gapping excluded).

It is easy to predict the fact that the contract for the fully assembled phantom #3 should be much lower than for the phantom #2, because the reflection from the skin layer is much higher that from the normal breast tissue layer of the phantom. This statement was proved by the experimental data. For phantom #2 the inclusions are clearly discernible in the resulting image (Fig. 6). Variations in the brightness of the image depend on the transverse coordinate in longitudinal

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sections also indicate the presence of inhomogeneities (Fig. 7, localizations of inhomoginities are circled).

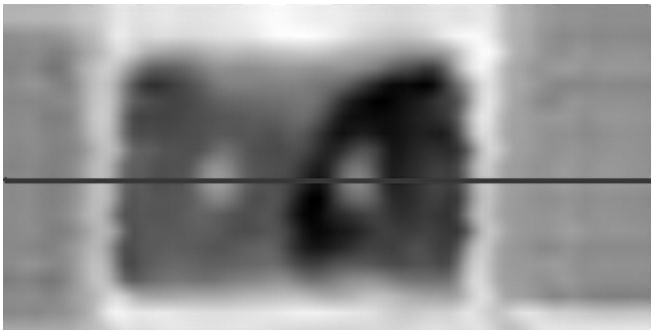

Figure 6. Image of the breast phantom #2 (7 GHz in a parallel channel).

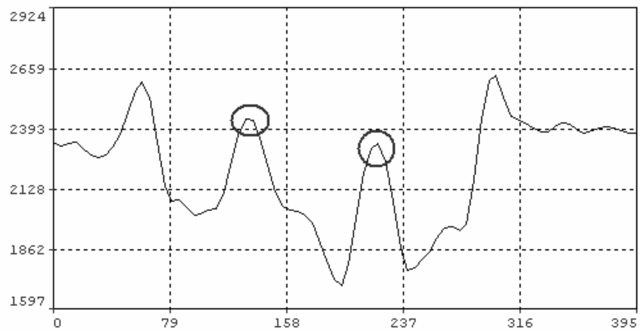

Figure 7. The plot of brightness dependence on the transverse coordinate (section from Fig. 6).

For phantom #3 the results are shown in Fig. 8 and 9. The inclusions can be determined, but not as clearly as in the experiments without skin (Fig.6, 7). That means that the skin layer blocks most of the radar signal.

Data given in Fig. 6-9 correspond to RASCAN4/7000, for RASCAN4/4000 they are quite similar but the resolution is lower.

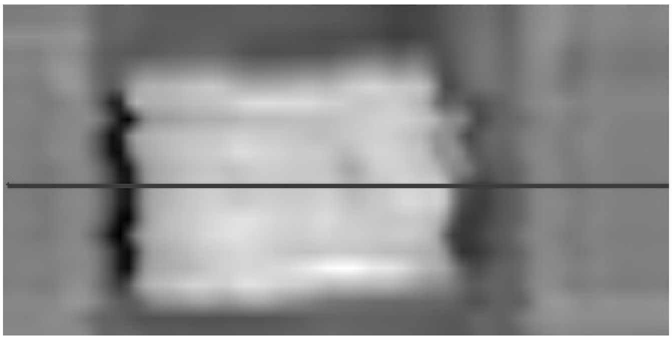

Figure 8. Image of the breast phantom #3 (7 GHz in a parallel channel).

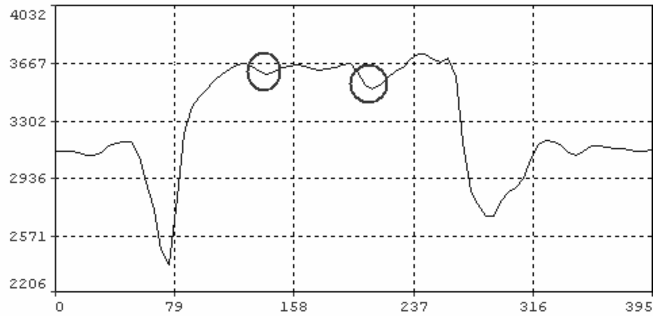

Figure 9. The plot of brightness dependence on the transverse coordinate (section from Fig. 8).

IV. CONCLUSION

Experimental results showed that holographic radars RASCAN, used during the experiments, allow detection of dielectric inhomogeneity in biological tissues, e.g. tumor in normal breast tissue, due to significant differences in the dielectric properties.

Based on these experiments, we can conclude that though the skin layer greatly attenuates radar probing signal, tumor may still be detected by holographic radar. It was found out that among holographic radars operating at 4 or 7 GHz the latter is preferable for breast inhomogeneity detection. In further work it is proposed to apply reconstruction algorithms to the holograms, which may significantly improve the quality of the image and its resolution.

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