Microwave Imaging of Brest Phantom by Combined Use of Video-tracker and Radar

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Abstract — **This paper discusses an new technique of breast microwave imaging based on combined use of video-tracker and subsurface radar. The feasibility study of the proposed method is done by both mathematical simulation and experiments. A back projection technique used for data processing proved to be reliable while reconstructing microwave images of a breast phantom with a dialectically contrast inclusion imitating a tumor.**

1 INTRODUCTION

At present breast cancer is one of the most common cause of cancer death in women all over the world. The most successful approach of dealing with this problem is the early diagnosis of this decease. Currently used medical screening methods such as mammography and ultrasound scanning are effective only for already formed tumors, and not very effective for early detection of aggressive tumors characterized by high growth speed. That is why it is an up-to-date task to develop new methods, which detect not structural but functional changes in biological tissues taking place from the very beginning of the oncogenesis. One such method is a microwave imaging, which dates back to the 1970s [1].

During last several decades there is a growing interest in application of microwave imaging method in medicine especially in breast tumors detection [2, 3] and brain disease diagnostics and monitoring [4, 5, 6]. The main difficulties in microwave imaging of biological tissue are huge tissue loss, relatively low malignant/healthy tissue contrast and significant variety of the dielectric properties [7, 8]. Furthermore, the individual peculiarities of breast shape cannot be taken into account by existing microwave breast imaging systems because the number of channels and their special position are predefined by hardware design.

At the present work, we propose to overcome this problem by combined usage of a holographic subsurface radar with single transceiving antenna and video-tracking system to reconstruct the microwave image of a 3D breast phantom. Such approach may be applied for surfaces of any shapes. Moreover the procedure of microwave scanning by the proposed system is alike the one with ultrasound sensor, that will make it familiar for an end-user (physician).

The paper is organized as follows. Section 2 contains information about proposed method and data processing algorithm. Section 3 presents the results of mathematical simulation of the method. Section 4 describes the experimental results of its application followed by Conclusion.

2 MATERIALS AND METHODS

In the present work we utilized technique proposed in [9]. According to it, the video-based system for positioning radar uses a web-camera and a contrast graphical marker (an AR-marker). This approach enables positioning the radar in 3D with sufficient precision without any constraints on the sampling pattern. The radar position is calculated using correspondence between the physical coordinates of the marker corners and their projections on the web-camera image.

Reconstruction of the microwave image is performed by a back projection method based on the hypotheses that "The imaging algorithm for any form of frequency and spatial diversity is eminently simple: the image is formed by the integrated product of measured data multiplied by the conjugate phase history postulated for a point located at each pixel in the image space" [10]. In the present work we suppose to use 3D coordinates of each data sample to reconstruct the microwave image of a breast phantom.

A scheme outlining the technique is shown in Figure 1.

3 MATHEMATICAL MODELING

As said above, the problem at hand is concerned with creation of simple microwave scanning technique invariant for the shape of biological phantom which inner structure we want to visualize. To this end, we adopt a very simple model which cross-section is presented in 2. A human breast was mimicked by a cylinder of 5 cm radius with a single reflecting inclusion which coordinate vector is $\bar{r}_0 = [x_0, z_0]$. $E(\bar{r}_i, f)$ is the value of electric-field intensity detected by antenna in i-th point

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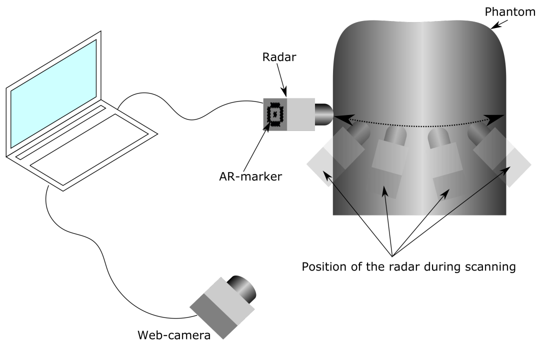

Figure 1: Scheme of the experiment.

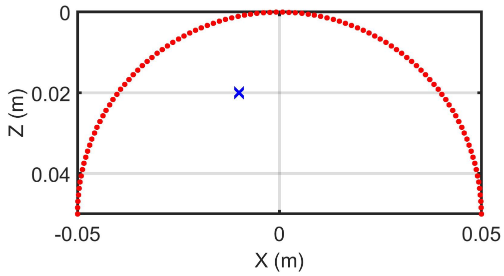

Figure 2: Phantom scheme (red dots represents antennas positions, blue cross - inclusion position).

with coordinate vector $\bar{r}_i = [x_i, z_i]$ for the probing frequency f. It was calculated for $N = 100$ different positions of antenna spread uniformly along the semicircumference of the phantom. The probing frequency value f varies from F_{min} to F_{max}.

The field collected by the radar at i-th point for the probing frequency f is given as:

$$E(\bar{r}_i, f) = \sigma \frac{g^2(f, \theta(\bar{r}_i, \bar{r}_0))}{|\bar{r}_i - \bar{r}_0|^2} e^{jk(f)2|\bar{r}_i - \bar{r}_0|}$$

where σ=1 is a scattering cross section of a target used here for matching the dimension, $g\left(f, \theta\left(\bar{r}_i, \bar{r}_0\right)\right)$ is the antenna radiation pattern, $\theta\left(\bar{r}_i, \bar{r}_0\right)$ is the angle between a boresight direction of the antenna located at (x_i, z_i) and the direction from the antenna toward the point (x_0, z_0), $k(f)$ is a wavenumber for the probimg frewquency f, c is the speed of light. For simplicity, we assume the antenna to be an omnidirectional one. The reconstructed by back projection technique value for the point with coordinates $\bar{r} = [x, z]$ may be represented as [9, 10]:

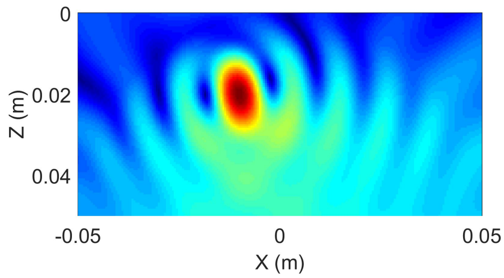

Figure 3: Reconstructed microwave image for phantom from Fig. 2 for a single probing frequency.

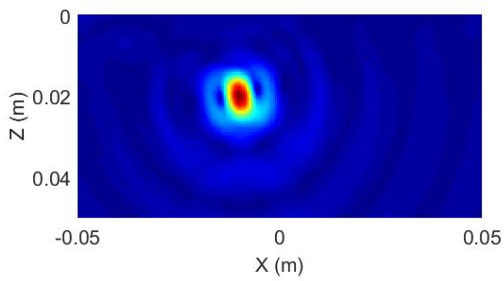

Figure 4: Reconstructed microwave image for phantom from Fig. 2 for probing frequency band of 10 GHz.

$$Q(\bar{r}) = \sum_{f=F_{min}}^{F_{max}} \sum_{i=1}^{N} \frac{\sigma}{|\bar{r} - \bar{r}_i|^2} E\left(\bar{r}_i, f\right) e^{-jk(f)2|\bar{r} - \bar{r}_i|}$$

By utilizing the proposed technique we reconstruct microwave image of the phantom using the values of the field calculated at the single frequency of 6.4 GHz (see Figure 3) and a frequency band 6.4 – 16.4 GHz with a step of 1 GHz (Figure 4).

It can be clearly seen that the usage of a wide frequency band results in more accurate detecting of the inclusion; however, even for a single frequency the coordinates of inclusion may be also estimated.

4 EXPERIMENTS

4.1 Experimental set-up

In the experiments we used a setup consisting of a holographic subsurface radar RASCAN-5/7000 designed at Remote Sensing Laboratory of Bauman Moscow State Technical University, which consists

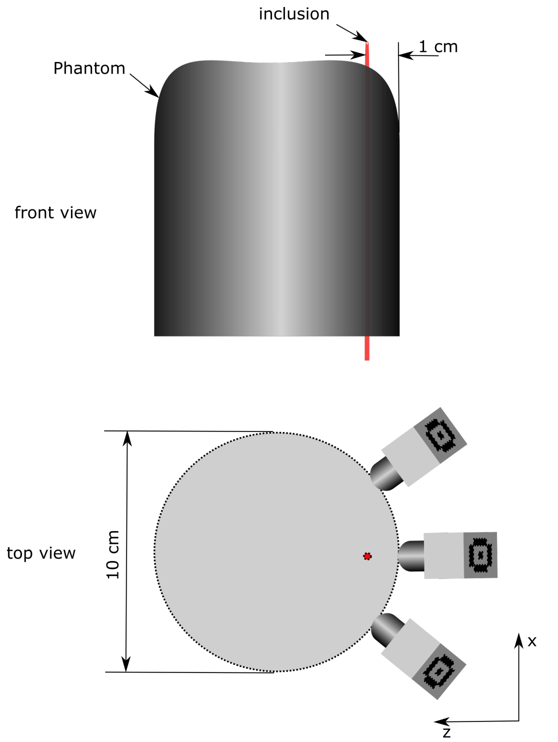

Figure 5: Scheme of the experiment with inclusion.

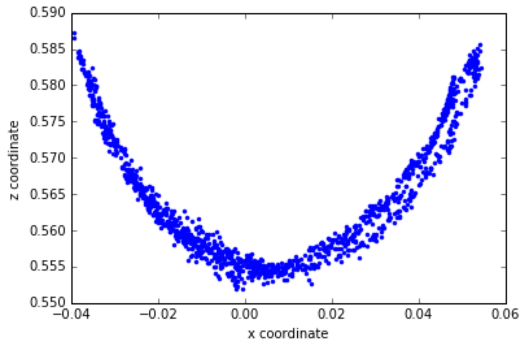

Figure 6: Trajectory of the radar tracked by web-camera.

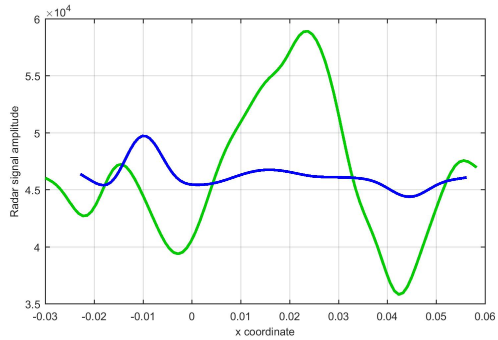

Figure 7: Experimental results for the phantom without (blue line), and with metallic inclusion (green line).

of an antenna with operating frequency band of 6.4 – 6.8 GHz and a control block. An AR-marker was positioned on the top of the antenna. Moreover, a web-camera was mounted on a tripod so to observe the AR-marker while scanning a breast phantom.

The data from the radar and the camera were gathered by the personal computer for further processing. The experiments were carried out for the plastic cylindrical phantom (diameter is 9 cm) with and without a dielectrically contrast inclusion placed inside 1 cm deep from the surface as it is shown in Figure 5. As an inclusion we used a metallic needle of 3 mm diameter. During the experiments the operator was moving the radar over the phantom surface in such a manner that the AR-marker would not disappear from the web-camera field of view.

4.2 Experimental results

Figure 6 presents a trajectory of the radar tracked by the video-tracking system, and Figure 7 shows an amplitude of the hologram $E\left(\bar{r}\right)$ recorded at frequency of 6.4 GHz for the experiments with and without inclusion. Apparently, the inclusion can be easily detected in the radar data.

5 Conclusion

We proposed a technique of breast microwave imaging based on combined use of video-tracker and subsurface radar. The feasibility study of the proposed method is done by both mathematical simulation and experiments. A back propagation technique used for data processing proved to be reliable while reconstructing microwave images of a breast phantom with a dialectically contrast inclusion imitating a tumor. The mathematical simulation showed that wider frequency band allows better spatial resolution; however even for a single frequency it should be possible to detect the presence of an inclusion.

In future we are planning to test the proposed technique on experimental 3D printed phantom circulated among MiMed CostAction group, which are the first step of standard breast phantoms for testing microwave imaging systems.

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