Webcam-based Distance and Surface Estimation System for Microwave Imaging

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***Abstract*— One of the critical steps in Medical Microwave Imaging (MMWI) algorithms is the calculation of the distances between the antenna and the synthetical focal point, due to the different propagation velocities in the tissues and background medium. In fact, it has a major influence on the image accuracy. As a result, it is very important to have a priori information about the shape of the body part under examination. Here we propose a low cost optical system based on a single commercial webcam. We validate the new system by showing an application to breast imaging, where we reconstruct the scatterers inside the breast using the real and estimated shapes. The results show very good resemblance, thus proving the new system supplies a reliable estimation of the breast shape.**

Keywords*— *balanced antipodal Vivaldi antenna (BAVA), breast surface estimation, medical microwave imaging.

I. Introduction

Microwaves (MWs) are being proposed as an alternative imaging technology for biomedical applications. Examples include breast cancer screening [1] and brain hemorrhage detection [2]. Contrarily to X-rays, used in mammography and computerized tomography, MWs are non-ionizing and present sufficient dielectric contrast between healthy tissues and malignancies to enable their detection.

In MW imaging (MWI) the image is reconstructed by either estimating propagation delays in time-domain [1] or "backpropagating" the wave in the frequency-domain [3]. Regardless, both approaches rely on accurate distance calculation between the antenna and the synthetical focal point.

Yet, in Medical MWI (MMWI) the body is often non-uniform, which makes it much more difficult to obtain precise distances estimation, since different propagation velocities usually have to be considered in and out the body. This may seriously hinder the image reconstruction [4], [5]. Therefore, it is extremely useful to have a priori knowledge of the body surface (i.e. breast or head) and also the distance between the antennas and the skin. Two techniques applied to breast MWI have been proposed. The first uses monostatic backscattered time signals to infer the distance of the skin relative to the antenna [4]. The breast profile is then estimated by interpolating multiple measurement positions. However, to achieve reasonable profile estimation, this technique requires several antennas that may not be available. Alternatively, in [5] the authors present a system based on a laser. Although the precision is very good, the laser set up is quite expensive.

Here, we show how a low cost and fast execution surface and distance estimation system can be used in MMWI applications. The proposed system is based on a single commercial webcam. Moreover, we validate it by showing an application to breast imaging. We emphasize that although we demonstrate the performance of the technique in the context of breast imaging, it can be applied to other applications (e.g. head imaging).

II. Experimental setup and webcam system

We fabricated an elevated styrofoam structure with a circular aperture, in order to replicate the examination posture, where the patient is lying in prone position. The breast pends vertically through the aperture in the examination bed.

We used the breast phantom with ID 062204 from the University Wisconsin-Madison repository, derived from a Magnetic Resonance Imaging (MRI) exam taken with the patient lying on the prone position, with the breast preserving its anatomical shape [6]. We fabricated the phantom in our 3D-printer (Ultimaker 2+ Extended [7]) using silver PLA with 1.2 mm wall thickness. In addition, we have printed an ellipsoidal-shaped tumor. Both the breast casing and tumor container were filled with the liquid corresponding to fatty and tumor tissues, respectively, whose recipe is described in [8]. Note that the PLA interface should not have any major impact on the measurement, given its small thickness and relatively low permittivity [9].

We used the Balanced Antipodal Vivaldi Antenna (BAVA) shown in Fig. 1. This antenna topology was chosen due to its ultrawide bandwidth and low profile. The antenna operates between 2 GHz and 6 GHz. The measured Voltage Standing Wave Ratio (VSWR) in free-space is illustrated in Fig. 1.

In our setup, the antennas are distributed in a cylindrical array around the breast with no coupling medium. Given the non-uniform shape of the breast, the distance between antennas and the breast varies between around 9 mm and 30

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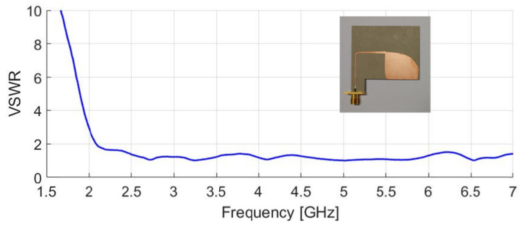

Fig. 1: Measured free-space VSWR of the BAVA used to image the breast.

mm. The non-uniform breast shape and variation of the antenna-breast distance hinder the imaging of the breast.

In order to overcome this challenge, we used an optical system to estimate the shape of the breast. To this end, we utilized a commercial Logitech C930e webcam [10] to capture snapshots of the breast. An example of a snapshot taken by the webcam is represented in Fig. 2. The Red/Green (R/G) markers at each side of the breast were used to relate the pixels-length to the actual distance.

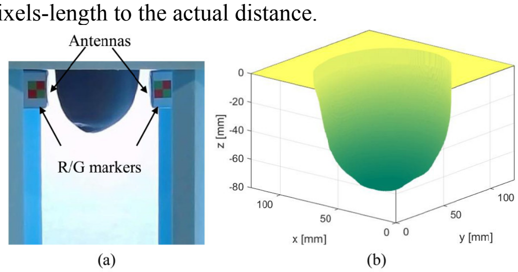

Fig. 2: (a) Example of snapshot taken by the webcam; (b) Final breast surface estimation based on the webcam system.

The proposed system is compatible with real-time image processing and can be implemented using any commercial webcam, thus lowering considerably the costs.

III. IMAGE RECONSTRUCTION

In this section we compare the imaging results obtained assuming the real breast shape and the estimation in Fig. 2 in the distance calculations. To this end, we implemented a wave migration algorithm similar to [3]. The distances from the antenna to each test point were calculated assuming a direct ray between the two points. Since our setup does not require any coupling medium, we have to take into account the different propagation velocities in air and in tissues, respectively. The air/breast interface point is computed based on the breast shape. The imaging results computed assuming the real breast shape and the estimated one are shown in Fig. 3. The skin artifacts were removed by subtracting the corresponding measurement without tumor.

The results indicate that the breast estimation is very close to the real shape, since the tumor pattern is very similar in both images. Moreover, the scale is pretty much the same in both cases, showing very good focusing of the energy.

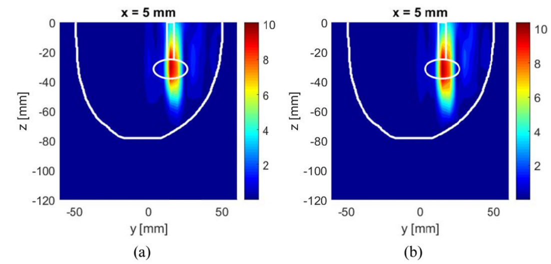

Fig. 3: Image results using (a) the real breast shape (b) and the breast shape estimated from the webcam system.

IV. CONCLUSION

In MMWI it is extremely valuable to have prior knowledge of the shape and distances between the antennas and the body part under undergoing the examination. Here we proposed an alternative low-cost surface reconstruction and distance estimation system based on a single commercial webcam. It is compatible with real-time processing and achieves very good resolution. We demonstrated the concept using realistically-shaped breast model resembling the prone posture taken during the examination. In addition, we compare the image reconstruction quality using the real breast shape and the estimation based on the proposed system. The results show very high resemblance between the two, proving the feasibility of the webcam estimation.

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