MICROWAVE TOMOGRAPHY. EXPERIMENTAL IMAGING on TWO and THREE DIMENSIONAL SYSTEMS.

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ABSTRACT.

We have constructed two dimensional and three dimensional microwave tomographic systems. The quantitative experimental images reconstruction has been achieved in 2D case in both low and high dielectric contrast cases. To reconstruct 3D images we generalized the Born approximation into the vector case. The images of the 3D mathematical models and experimental phantoms have been achieved in case of low contrast of dielectrical properties.

Our overall microwave tomographic project involves three major research parts. The biophysical research involves the study of the changes in myocardial dielectric properties in the microwave spectrum caused by various disorders such as ischemia, infarction, hypoxia etc. The mathematical research involves the direct and inverse problems solution of the microwave tomography and spectroscopy. The experimental research involves both the microwave experimental devices construction and experiments on these devices. The design and construction of the microwave tomographic systems and the results of the experimental imaging are presented here.

I. Two-dimensional (2D) and three-dimensional (3D) microwave tomographic systems.

The two-dimensional microwave tomographic system is shown in Figure 1. It operates on frequency 2.45GHz and is composed of 64 antennas (32 emitters and 32 receivers) located on the perimeter of a cylindrical working chamber with diameter of 360mm. The system measures the amplitude and the phase of the electromagnetic field scattered by the object. The achieved signal to noise ratio of about 40dB was estimated as sufficient for the reconstruction of the objects with a spatial resolution of 1-2cm and a contrast resolution of about 5% [1]. We conducted a number of experiments using this system and received quantitative imaging of 2D physical phantoms with various dielectric contrasts [2]. Electronic measurement cycle scanning makes total acquisition time relatively small, about 500msec. It allows us to conduct preliminary experiments with live biological objects, including qualitative imaging of the explanted beating canine heart [1].

As a next step in the experimental microwave tomographic imaging we constructed a prototype of the three-dimensional microwave tomographic system, shown in Figure 2. It operates on frequency 2.36GHz and is composed of 32 emitting antennas

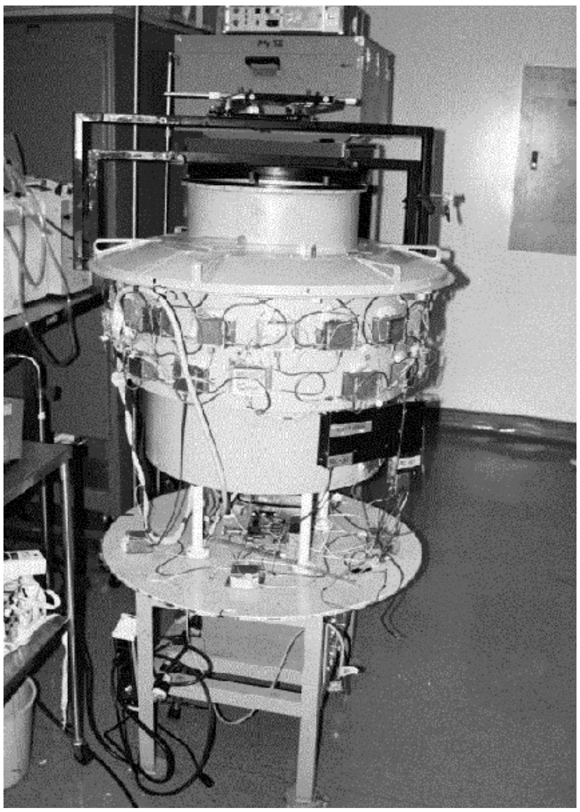

Fig.1. View of the 2D microwave tomographic system.

(located on the perimeter of the working chamber in vertical fashion) and two receiving antennas. The emitting antennas simultaneously radiate an object under the study with polarized (in vertical direction) EM field. The receiving antennas measure scattered (by an object under the study) EM field in both vertical and horizontal polarizations. The receiving antennas are moved by a robotic system inside of the tomographic chamber. The system measures attenuations in the tomographic working chamber up to 120dB having a signal/noise ratio of about 30dB[3].

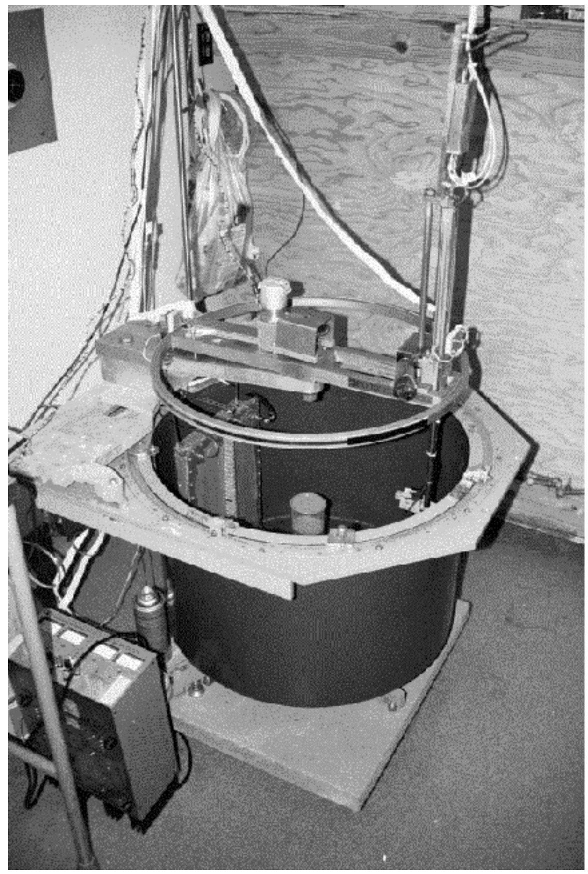

Fig.2. View of the prototype of the 3D microwave tomographic system.

II. Experimental Imaging Results.

Using our two dimensional (2D) microwave tomographic system, we have demonstrated successful imaging of high dielectric contrast objects and live biological objects [1,2]. A full-scale high dielectric contrast mathematical model of the human torso with small (1cm) inhomogeneities (myocardial infarction model) was also quantitatively reconstructed [4]. As an example of 2D experimental imaging, the reconstructed image of the cylindrical phantom (ϵ'~54.0) with two asymmetrical holes located in the center of the tomographic working chamber is presented in Figure 3. The tomographic chamber and phantom holes were filled with deionized water (ϵ'=78.0). Presented experimental image we estimate as almost ideal in terms of spatial (wavelength is about 1.5cm) and contrast resolution. Having both successful 2D images of the high dielectric contrast experimental phantoms and full-scale simulated objects (such as a human torso) we have concluded that in 2D geometry there were no principal questions of MW tomography left to answer.

Three-dimensional (3D) microwave tomographic imaging is not simple generalization of the 2D system and method to the 3D case. It is a much more complicated problem. Despite the spatial and contrast resolution problem, in the 3D case we have to deal with the vector problem.

We generalized the Born approximation for weak scattering to the vector case. We have proved that having measured only one component of the vector electromagnetic field, it is possible to reconstruct 3D image in a weak scattering case. The images of the 3D simple mathematical models were successfully reconstructed by proposed method [3].

The result of the experimental image reconstruction is presented in Figure 4. The 3D elliptical phantom with two chambers inside was located in the center of the tomographic system. The microwave system and phantom chambers were filled with deionized water. As can be seen from Figure 4 the geometrical shape and internal chambers of the phantom were successfully reconstructed. Also, the imaginary part of the complex dielectric properties was qualitatively reconstructed.

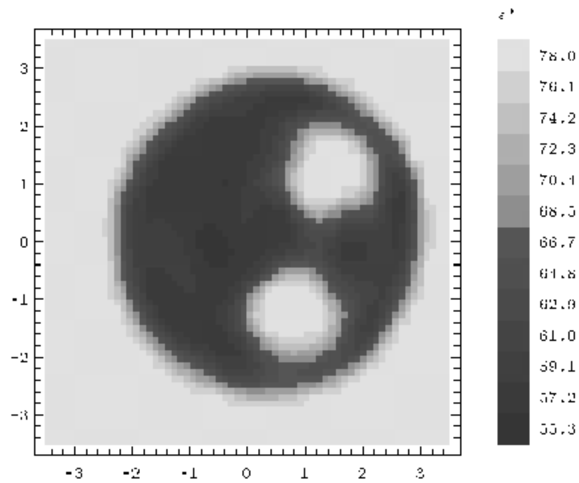

Fig.3. Image reconstruction of the 2D phantom. Axis in [cm].

Practical physiologic 3D microwave imaging will require further progress in the areas of system design, images reconstruction and tissue dielectric properties probing.

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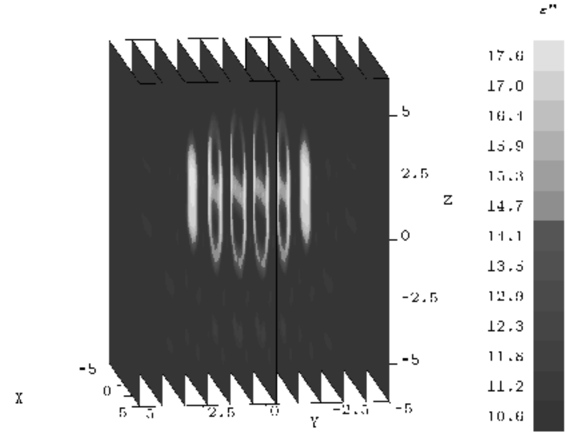

Fig.4. Image reconstruction of the 3D phantom. Axis in [cm].