A TWO-DIMENSIONAL NEWTON ITERATIVE SCHEME FOR HIGH CONTRAST FULL-SCALE MICROWAVE TOMOGRAPHY

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Abstract: We propose a variant of the Newton method that uses a fast solution of the direct problem and a dual mesh. Using this method, we are able to obtain good quality images of high contrast experimental phantoms. Our computational experiments show that a full scaled image of a two-dimensional mathematical model of a human torso can be obtained with this method.

Microwave imaging of biological bodies has been of interest for a number of years. Several two-dimensional tomographic systems have been reported to have produced images of relatively simple phantoms and biological objects. In our previous work [1] a two-dimensional prototype of a quasi real-time microwave tomographic system with total acquisition time of 500 ms was reported. This system was quick enough to obtain images of an explanted beating canine heart.

Spectral methods, based on so-called diffraction tomography (DT) [2], prove to be very fast and capable of producing reconstructions with good quantitative accuracy for small contrast objects. If the first order Born or Rytov approximation is not valid however, the reconstructed images are seriously distorted. More than a decade ago a Newton procedure of microwave imaging was introduced that principally did not have contrast limitations [3]. But in spite of recent developments of this method its applications are still limited to relatively small objects with dimensions of a few wavelengths.

Accurate calculations of electric fields, needed by this method, require a mesh that has at least 10 samples per wavelength. For a frequency of 1–3 GHz this sampling rate dictates a mesh with $N = 10^4$–10^5 elements per a slice of a human torso. The many times repeated calculations with a mesh as large as this demand a very effective algorithm of the direct problem solution. In our previous paper [4] we have discussed a fast iterative solution of the Helmholtz equation. Since the number of operations for it is mainly proportional to N in the present paper we are able to use this algorithm in a Newton method for reconstruction of mathematical models of two-dimensional objects as large as a human torso.

We tested our algorithm in physical and computational experiments with simple two-dimensional high contrast phantoms. An experimental reconstructed image of a cylinder with two holes is shown in Figure 1. The phantom has ε' about 56, its diameter is 5.8 cm, and the diameter of holes

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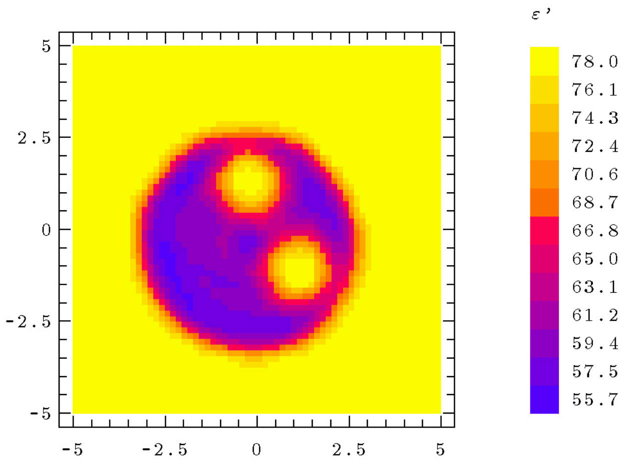

Figure 1: Image of an experimental phantom of a diameter 5.8 cm with two 1.5 cm holes. The phantom has ε' of 56, and is placed in water.

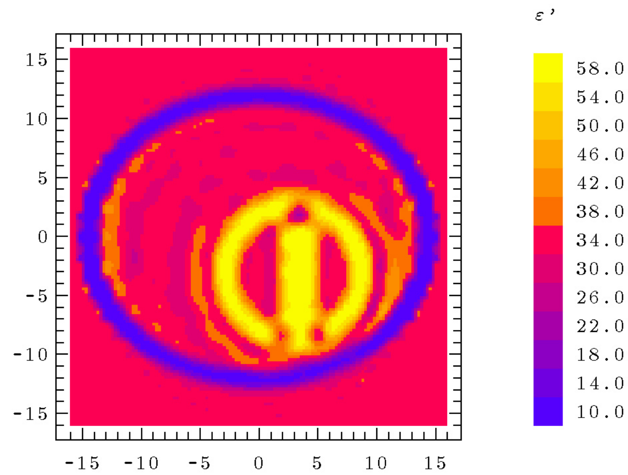

Figure 2: Image of a mathematical model of a torso.

is 1.5 cm. The frequency used in the experiment was 2.36 GHz.

To push our algorithm to its limits we use a mathematical model of a torso with external dimensions 31×26 cm that is composed of an elliptic 1.5 cm thick shell with $\varepsilon = 10 + i2$. A model of the heart with a diameter of 13.5 cm and $\varepsilon = 58 + i21$ is placed inside the shell. The "heart" wall has three small holes of 1.5 and 2.5 cm. The immersion liquid, space inside the shell, heart chambers and holes have $\varepsilon = 33 + i12$. The values of the permittivity are comparable to that of the involved biological tissues at the frequency of 1 GHz. In Figure 2 is shown the result of reconstruction. All mentioned details of the torso can be clearly seen in the picture.

Presented results confirm that our version of the Newton method is capable of imaging two-dimensional high contrast full scale objects.

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