MAGNETIC INDUCTION TOMOGRAPHY: VISUALIZATION OF EXTENSIVE OBJECTS

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ABSTRACT: During recent development the systematic errors of the multichannel measuring system were considerably reduced. These errors were especially noticeable in case of extensive objects visualization. Besides phase measuring accuracy was increased by means of the improvement of the control circuit. The results of imaging of biological objects are presented. The dynamical image of thorax was reconstructed by the filtered backprojection method. The static visualization of human head was carried out using reconstruction algorithm based on artificial neural network. Special experiments were carried out to demonstrate that non-conducting shell dividing two conducting media doesn't influence qualitatively on results of measuring for given geometry and measuring setup. The phantom consisting of tank with NaCl solution and gelatinous cylinder imbedded into it was used. The cylinder had conductivity higher than conductivity of surrounding solution. The MIT measuring system with variable working frequency was developed also. The directly proportional dependence of measured phase shifts on frequency was demonstrated for the material without significant frequency dispersion.

Keywords: inductive methods, conductivity distribution, medical visualization

1. INTRODUCTION

Spatial conductivity distribution inside inhomogeneous media can be visualized by the magnetic induction tomography (MIT) technique. It is a contactless technique in contrast to EIT. As it has demonstrated in the theoretical analysis [1, 2], information about conductivity is contained not in amplitude but in phase shifts between the signals of sources and receivers of magnetic field. In these studies choice of operating frequency was vindicated and numerical simulation results were presented. First measurements with the multichannel system [3] have demonstrated the applicability MIT for investigations of biological tissues. The results agreed with similar one-channel measurements with saline solution that were carried out by the other research group [4] earlier. Unexpected results with conducting and insulating sphere in the saline tank was represented in [5]. Such experiments were carried out here. Now the measurement system was improved: systematic errors were reduced and phase measuring accuracy was increased. The dynamical image of thorax and the static visualization of human head were reconstructed. Dependence of phase shifts on frequency was measured with help of the modified multifrequency MIT system.

2. METHODOLOGY

2.1. Configuration and improvement of the 20 MHz measuring system

The measuring system contains 16 inductor and detector coils. They are arranged along the 35-cm circle on the electromagnetic screen. Each coil is connected to your own transmitter or receiver correspondingly (Fig. 1). During one phase measurement one of the inductors excites 20 MHz magnetic field inside the screen, and all detectors register it. Phase shifts between low frequency signals of each receiver and reference receiver are measured digitally. When the completed cycle with all transmitters has finished we will get an array of 240 numbers. For reconstruction of conductivity distribution it is necessary to measure two such arrays: with sought object for example and without it (reference data array).

Simple low pass filter was added to transmitter control circuit in order to improve signal-to-noise merit. Now the noise level of receiver, which is diametrically opposite to working transmitter, is approximately $\pm 2\times 10^{-3}$ radian. It corresponds to discretization errors with 10 MHz sampling frequency and averaging over 100 periods.

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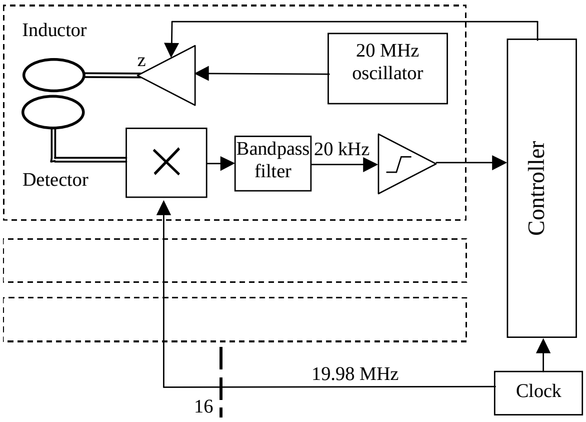


Fig.1. A block diagram of the 20 MHz measuring system

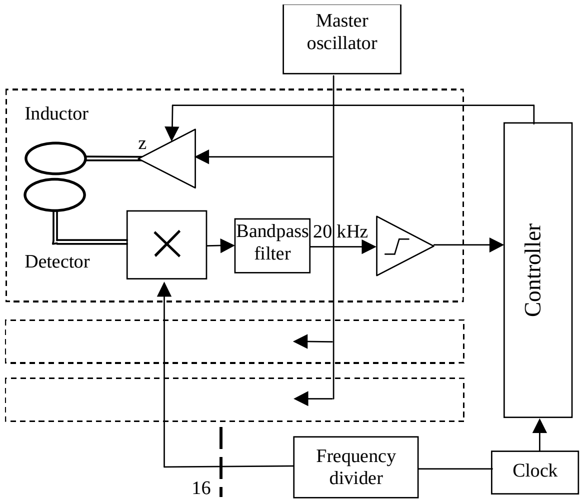
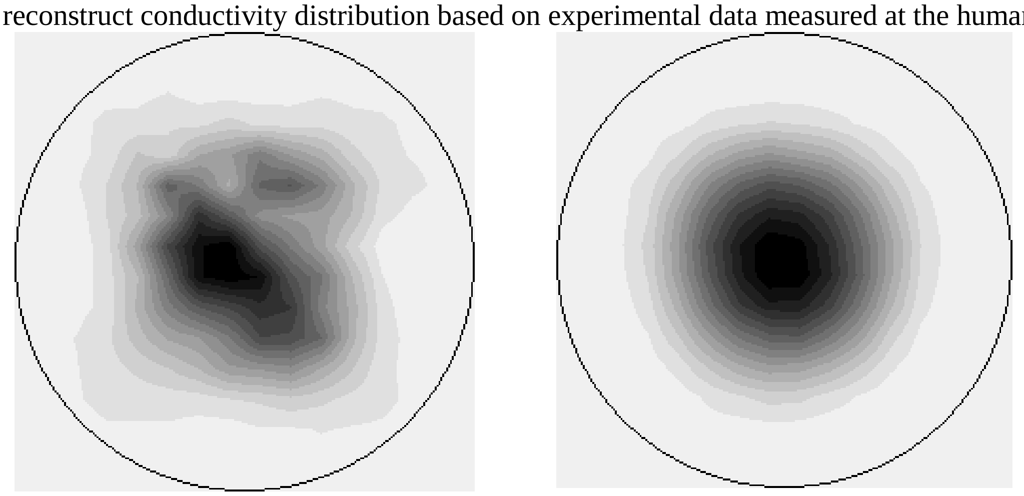


Fig.2. A block diagram of the modified measuring system for working on 5, 10 and 20 MHz

It has found that considerable systematic errors appears when working with massive objects having large permittivity. As a result visualized conductivity distribution of the large tank filled with saline was noticeably asymmetric although the tank was situated in the center of the system. (Fig. 3a). Inductor and detector coils and an immersed object was coupled not only via the magnetic field but via the electrostatic field too, i.e. via a parasitic capacities. In order to reduce the capacitive coupling transmitter coils were rewound with shielded wire and grounded in the midpoint for electrical field component rejection. As a result systematic deviations of phase was significantly reduced. The pattern of conductivity distribution became symmetrical (Fig. 3b). Increasing of measuring accuracy and elimination of systematic errors allowed to reconstruct conductivity distribution based on experimental data measured at the human body.



(a) (б)

Fig.3. Visualization of the large tank filled with saline: (a) – before shielding of inductors, (б) – after shielding

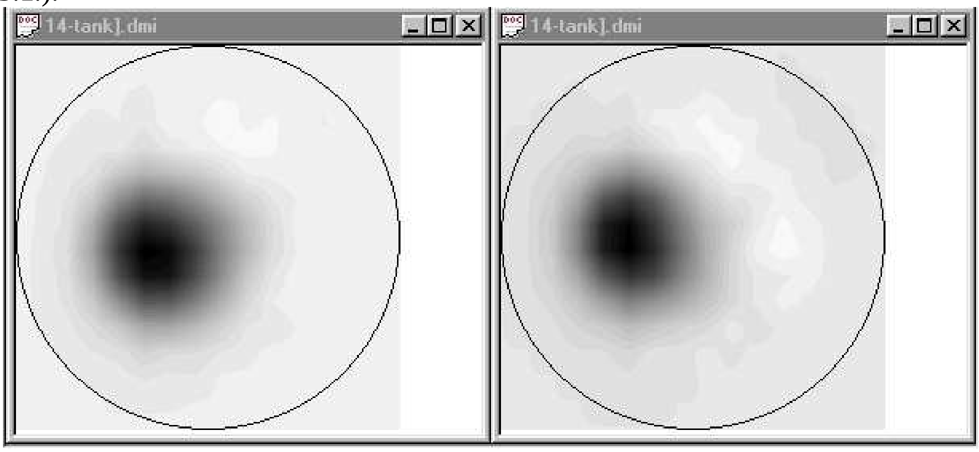
2.2. The measuring system for working on three frequencies: 5, 10 and 20 MHz

The 20 MHz measuring system was modified especially for working on variable frequency. Quartz oscillators inside the transmitters were converted into amplifiers (Fig. 2). Signal of 5, 10, or 20 MHz supplied these amplifiers. Weakness of such modifies was that it has necessity to connect master oscillator output to amplifier input. Signal has not large amplitude (0,3 volts) and that shielded wire was used. But parasitic electromagnetic field adds with transmitter signal and produces systematic deviations of phase.

3. RESULTS

3.1. Measurements on the one frequency

All described in this subsection measurements were performed at the 20 MHz measuring system (see subsection 3.1.).



(a) (b)

Fig.4. Reconstructed image of conducting gelatinous cylinder imbedded into the tank filled with NaCl solution having lower conductivity: (a) – without insulating shell, (b) – with the insulating. shell

Measurements with the phantom consisting of tank with 1% NaCl solution and more conducting gelatinous cylinder were carried out. The conductivity distribution in two versions: the cylinder within insulating shell (a plastic glass) and without the shell was reconstructed by the filtered backprojection method (Fig. 4). There was not found qualitative difference between these versions.

The dynamical image of thorax was reconstructed by the filtered backprojection method (Fig. 5). The image shows the difference between inspiration and expiration states. It easy to see left **-1** and right **–2** lungs in the form of a dark spots. White spot **–3** (in front of the thorax) is the moving artifact caused by displacement of the front side of the thorax when breathing. The static visualization of human head was carried out using reconstruction algorithm based on artificial neural network (Fig. 6). The back of the head was situated in the upper part of the figure. Two light spots (higher conductivity) may be correspond to ventricles of brain. They are situated inside left and right hemispheres and filled with high-conductivity cerebrospinal fluid.

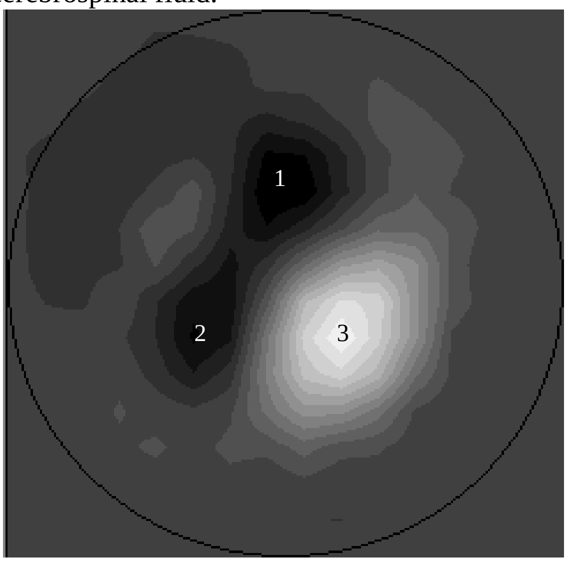


Fig.5. The dynamical image of the human thorax

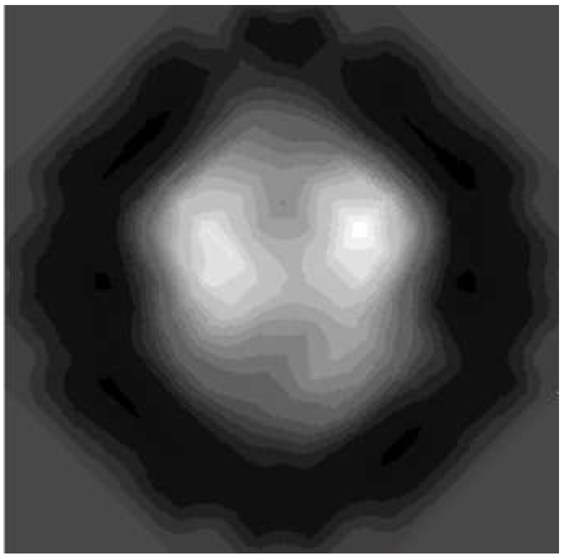


Fig.6. The static visualization of human head..

3.2. Multifrequency measurements

Measurements at three frequencies were carried out using the test object in the center of the workspace (Fig. 7 and 8). The test object represented a 10 cm diameter bottle filled with 5% NaCl solution. The figures demonstrate directly proportional dependence of phase shift from the operating frequency.

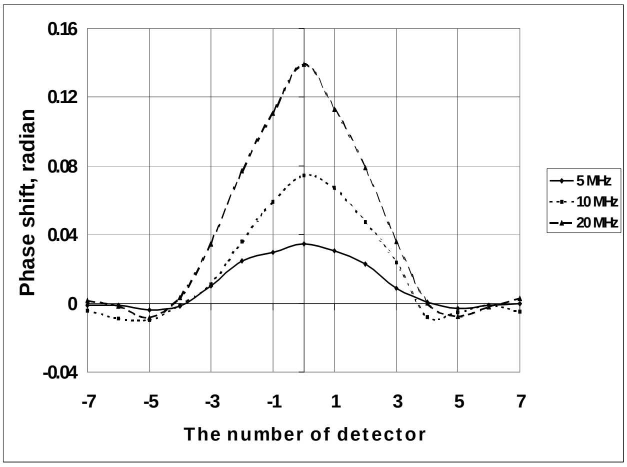


Fig.7. Dependences of the measured phase shift on the detector number at three operating frequencies

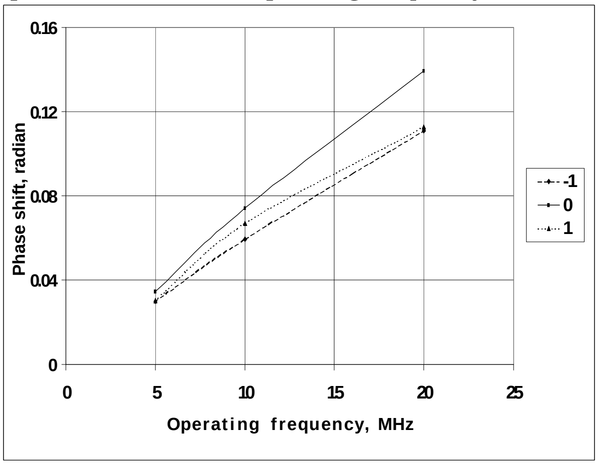


Fig.8. Dependences of the phase shift on the operating frequency measured on the detector which was diametrally opposite to working transmitter (number 0) and on the two adjacent detectors (1 and -1).

4. CONCLUSIONS

Shielding of the exciting coils reduced systematic errors. Phase measuring accuracy was improved by means of control circuit perfection.

Non-conducting shell dividing two conducting media doesn't influence qualitatively on results of measuring for given geometry and measuring setup.

Only imaging of the saline phantoms with MIT was demonstrated experimentally till the recently. The dynamic image of the chest for inspiration-expiration data was reconstructed. The static images of the head demonstrate correct anatomical structure of the brain with high conductive ventricles in the centre. Further optimization of the measuring system, improvement of the measurement accuracy and reconstruction algorithms is necessary to get more detailed images.

Multifrequincy measurements were carried out. Correct data at 5, 10 and 20 MHz were collected in spite of the worsening of accuracy. When frequency varies it may be possible to identify tissues with different frequency dispersion.

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