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Moisture Wall Inspection Using Electrical Tomography Measurements

***Abstract**. This paper presents solutions examining the brick wall dampness using electrical tomography. Different prototype measuring systems based on electrical tomography devices and the laboratory measurement devices were prepared. The prepared constructions contain 16 and 32 electrodes for measuring moisture in the brick wall on one side and two-sided. Electrical tomography, which is based on measuring potential difference, can be used to inspect historical buildings. The way in which we can define state of wall depends on the fact that every material has the unique conductance. To realize this measurement there are necessary electrodes, meters, AC generator, multiplexer and PC with LABview or the tomography device.*

Streszczenie.** W artykule przedstawiono rozwiązania sprawdzające wilgotność murów przy użyciu tomografii elektrycznej. Przygotowano różne prototypowe systemy pomiarowe oparte na elektrycznych urządzeniach tomograficznych oraz systemie laboratoryjnym. Przygotowane konstrukcje zawierają 16 i 32 elektrody do pomiaru zawilgocenia murów z cegły z jednej strony i z obu stron. Do kontroli zabytkowych budynków można wykorzystać tomografię elektryczną, która oparta jest na pomiarze różnicy potencjałów. Sposób, w jaki możemy określić stan murów, zależy od tego, że każdy materiał ma unikalną konduktywność. Do wykonania pomiarów potrzebne są elektrody, mierniki, generatory prądu zmiennego, multiplekser i PC z LABview lub urządzenie tomograficzne (Inspekcja wilgotności murów z wykorzystaniem pomiarów tomografii elektrycznej**).

Keywords: Electrical Tomography, Sensors, Image Reconstruction
Słowa kluczowe: tomografia elektryczna, sensory, rekonstrukcja obrazu

Introduction

One of the major causes of pathologies in historic buildings all over the world is the presence of moisture, particularly rising damp. Moisture transfer in walls of an old buildings, which are in direct contact with the soil, leads to a migration of soluble salts responsible for many building problems. Building porous materials (e.g. brick or concrete), both natural and manufactured have pores (like a sponge) and the moisture can be pulled up against gravity (capillary effect). Rising damp from the soil is a problem in old buildings, especially without adequate horizontal and vertical insulation of foundations. Moisture creates a danger not only to the walls, but also to human health. It promotes progress of rheumatic disorders and formation of fungus on the walls. Fungus can cause allergies and many other diseases. There are many different drainage systems (dry as watertight barriers, injection of hydrofuge products, etc.). Regardless of the method it is very important to continuously monitor the status of damp during the drying process [5].

The models of a brick wall are presented in Fig. 1. The test results obtained by the non-destructive impedance tomography are compared with the results obtained by numerical simulations.

There were prepared two prototype measuring systems (16 and 32 electrodes). First of them is a system contains the 16 electrodes for measuring damp brick wall on one side (Fig. 1a). Second one is a system with 32 electrodes for test on both sides of wall (Fig. 1b).

Measurement systems

The electrical tomography (ET) is a technique of imaging the distribution of material coefficients inside the tested object from measurements of the distribution of potentials on the object surface [1-4,7,8,20]. The test results obtained by the nondestructive electrical tomography are compared with the results obtained by numerical simulations. There were prepared the prototype measuring systems with different number of electrodes systems based on tomography devices and laboratory devices (Fig. 2). The prepared constructions contain 16 and 32 electrodes for measuring damp brick wall on one side and two-sided. Electrical Impedance Tomography, which is based on measuring potential difference [15-18,21]. The way in which we can define state of wall depends on the fact that every material has the unique conductance. There were used necessary electrodes, meters, AC generator, multiplexer and PC with LABview and tomography devices to realize measurements [19].

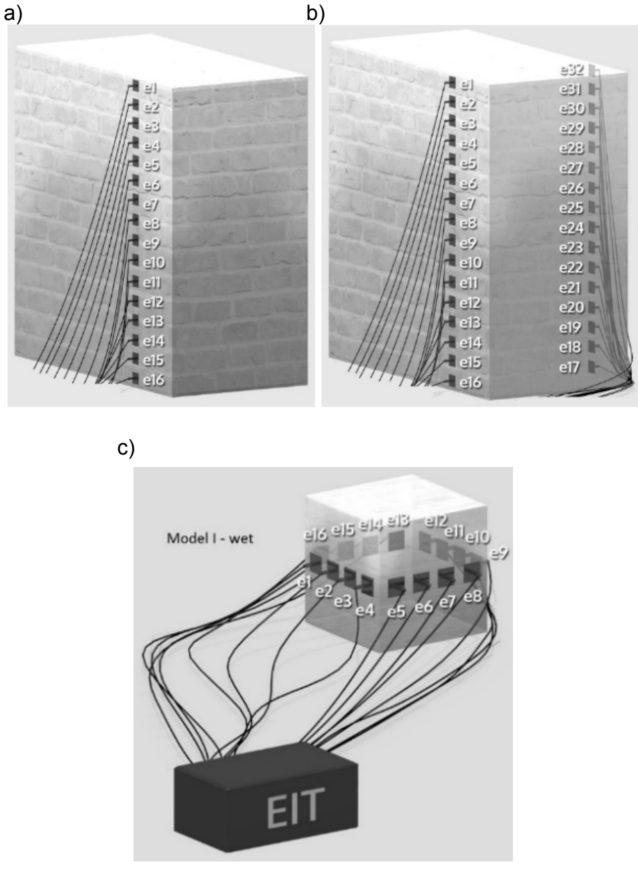


Fig. 1. Measurement EIT systems: a) with 16 electrodes, b) with 32 electrodes on the damp brick wall, c) the model of brick cube

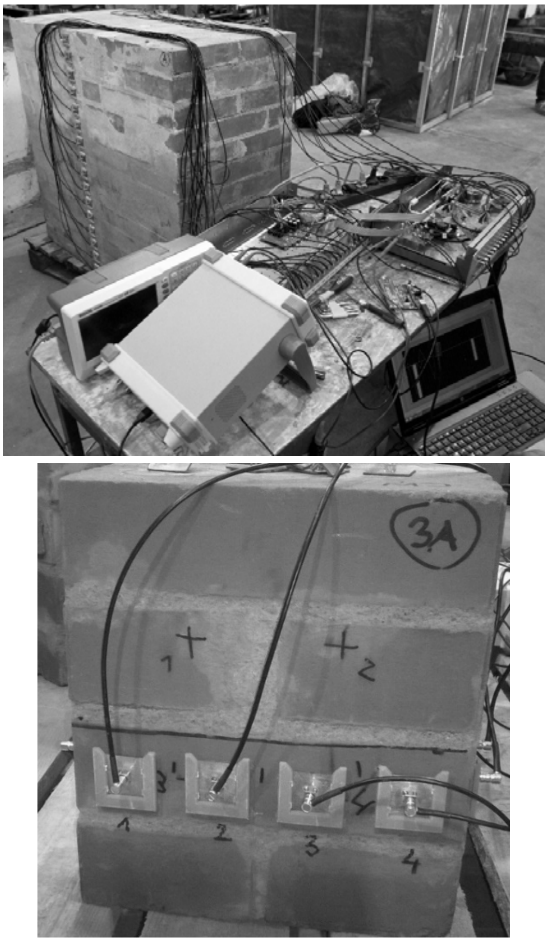


Fig. 2. The measurement system

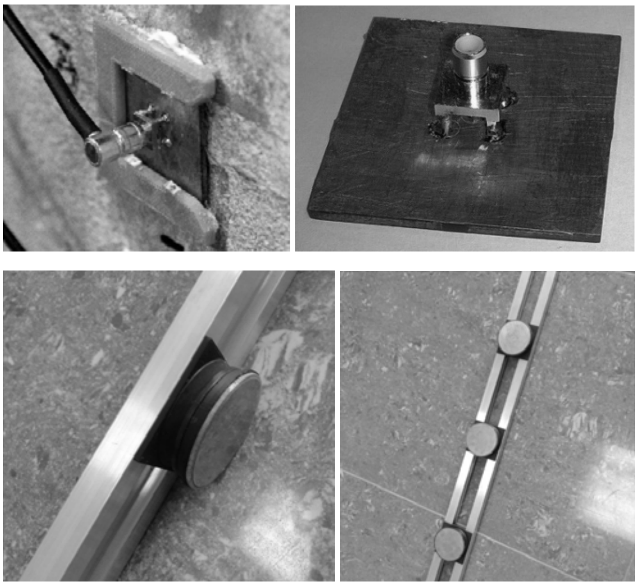


Fig. 3. Surface electrodes on the damp brick wall

Figure 3 shows surface electrodes on the damp brick wall. The concept of measurement model is presented in Figure 4. Next, let us concentrate our attention on airbrick. One should notice, that in this case we have 32 points electrodes. Electrodes have been attached along two opposite sides of airbrick. Professional test-bench have been developed in order to examine the airbrick (Fig. 5).

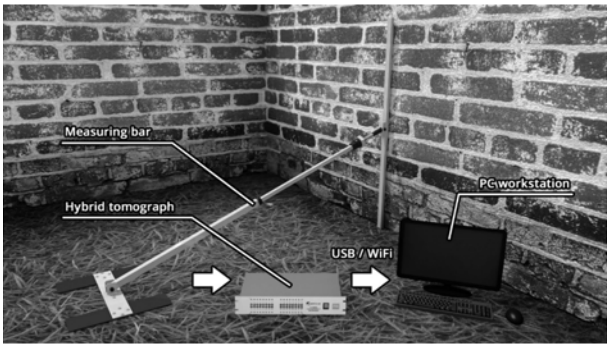


Fig. 4. The concept of measurement model

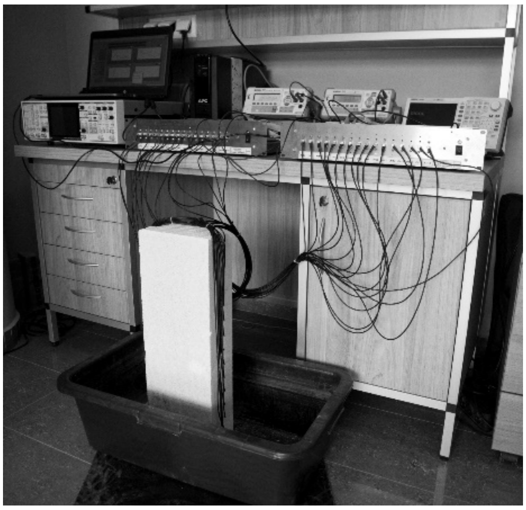


Fig. 5. The laboratory measurement system with measured damp air brick

Measurement device

The project of hybrid electrical tomography device is currently under development. It assumes making use of two measuring methods: electrical capacitance tomography and electrical impedance tomography and allows to perform up to 32-channel measurements. Idea of the measurement system was presented in Fig. 6.

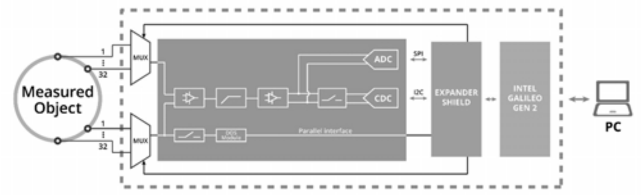


Fig 6. The measurement system

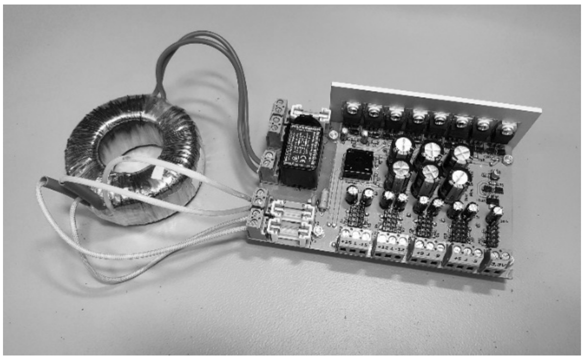
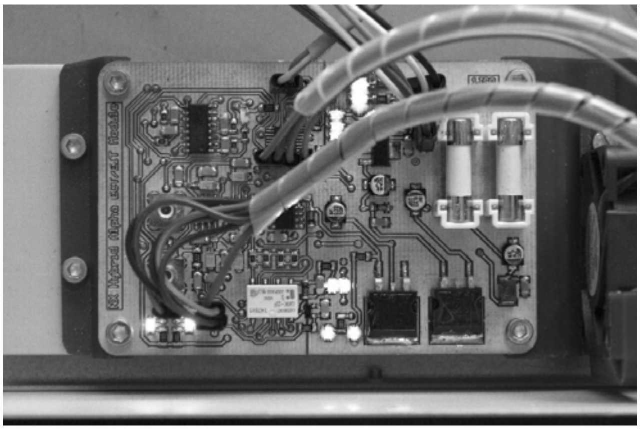
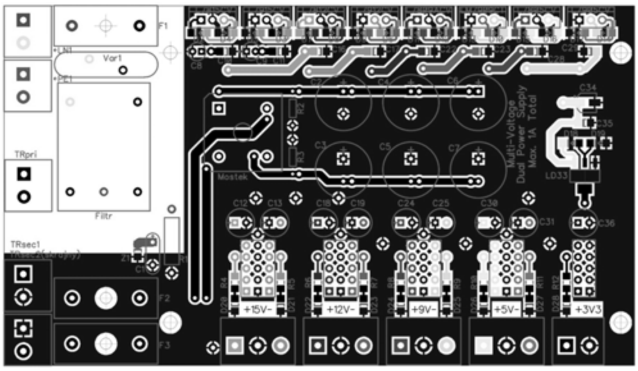
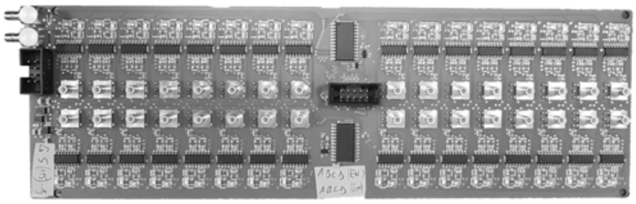


Fig. 7. The block diagram of the data acquisition module

Power supply board is presented in Fig. 7. Schematics of a single channel and a set of decoders driven by logic components are shown in Fig. 8.







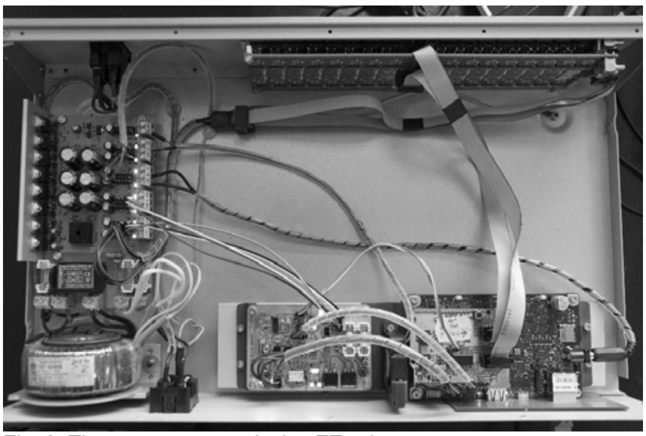


Fig. 8. The measurement device ET schemes

Image Reconstruction

There were built and presented two special models of brick cube "wet" and "moist" with 16 electrodes. In order to solve the inverse problem, we have prepared two-dimensional finite element mesh and using the level set method [6,9-14]. One should notice that surfaces of finite elements which are localized near electrodes are slight. Therefore, solution of the forward problem is accurate. Figure 9 presents the moist building brick (polarization voltage, frequency of 10kHz) - real measurements: (a) the reconstruction by Gauss-Newton method, (b) the reconstruction by hybrid method. Figure 10 shows the reconstruction in moist airbrick. The image reconstruction in models with 16 and 32 electrodes present figure 11 and 12.

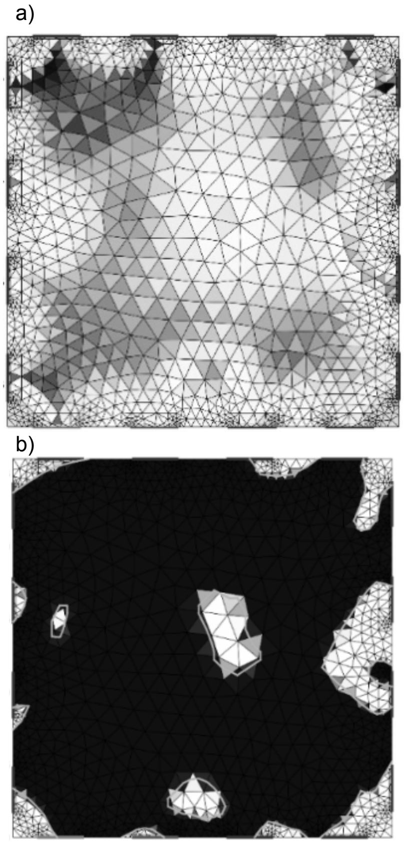


Fig. 9. The moist building brick (polarization voltage, frequency of 10kHz) – real measurements: (a) the reconstruction by Gauss-Newton method, (b) the reconstruction by Gauss-Newton Level Set

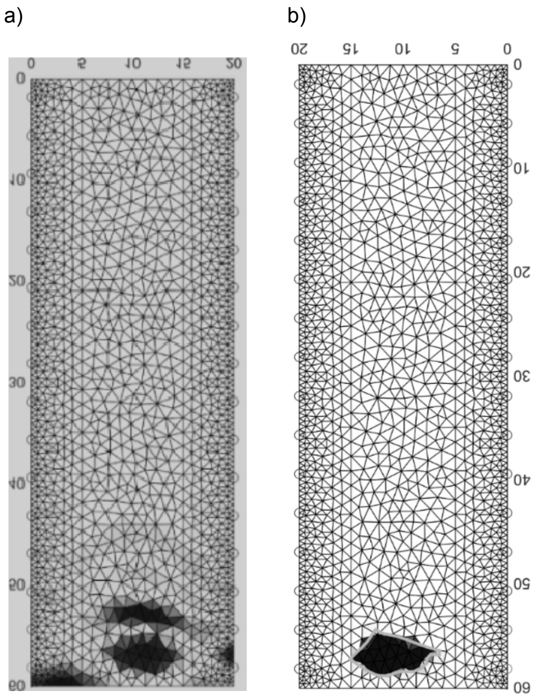


Fig. 10. The image reconstruction of the moisture in the airbrick: (a) Gauss-Newton method, (b) by Gauss-Newton Level Set

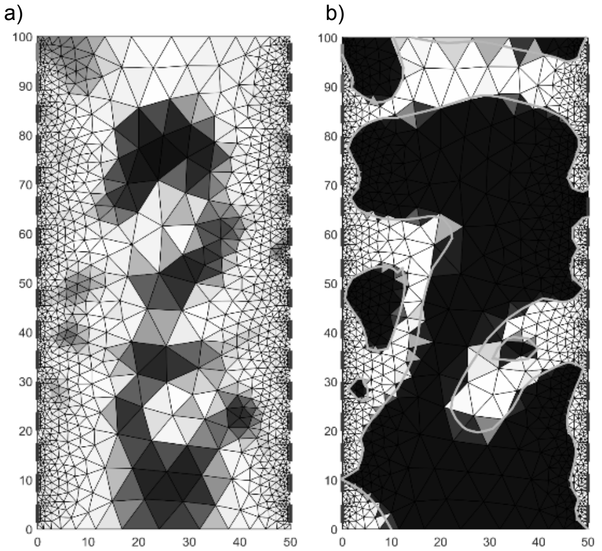


Fig. 11. The wet building brick (polarization voltage, frequency-10kHz) – measurement with 32 electrodes: (a) the reconstruction by Gauss-Newton method, (b) the reconstruction by hybrid method

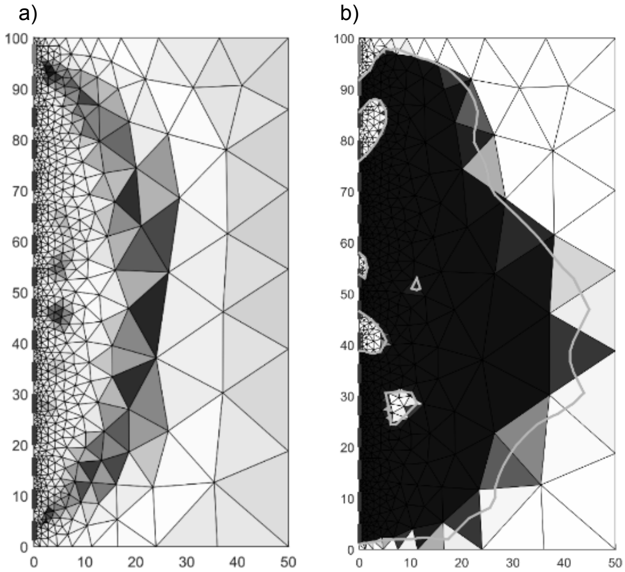


Fig. 12. The wet building brick (polarization voltage, frequency of 10kHz) – real measurement (16 electrodes): (a) the reconstruction by Gauss-Newton method, (b) the reconstruction by hybrid method

Summary

A new nondestructive method of the inspecting the walls in historical buildings system model was presented. Parameters of the device were as there was assumed. According to assumptions it is possible to build effectively the small electrical tomography system. The such solution is measurement speed and its accuracy, however, those are still high enough for practical use. The test results for prototype devices and systems were promising. The electrical tomography is a good technique of imaging the distribution of conductivity and permittivity inside the walls and historical buildings. In conclusion, this solution should be considered just a first step in a research of building effective electrical tomography systems. The device is combining electrical capacitive tomography and electrical impedance tomography to provide a non-invasive way to test the spatial distribution of moisture.

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REFERENCES

[1] Beck M. S., Byars M., Dyakowski T., Waterfall R., He R., Wang S. J., Yang W. Q., Principles and Industrial Applications of Electrical Capacitance Tomography, Measurement and Control (1997), Vol. 30, No. 7

[2] Filipowicz S.F., Rymarczyk T., Measurement Methods and Image Reconstruction in Electrical Impedance Tomography, Przeglad Elektrotechniczny (2012), vol. 88, Issue 6, pp.247-250

[3] Filipowicz S.F., Rymarczyk T., The Shape Reconstruction of Unknown Objects for Inverse Problems, Przeglad Elektrotechniczny (2012), vol. 88, Issue 3A, pp. 55-57

[4] Holder D.S.: Electrical Impedance Tomography: Methods, History and Applications Series in Medical Physics and Biomedical Engineering, (2005) London

[5] Hoła J., Matkowski Z., Schabowic K., Sikora J., Nita K., Wójtowicz S.: Identification of Moisture Content in Brick Walls by means of Impedance Tomography, COMPEL (2012), Vol. 31, Issue 6, pp. 1774-1792

[6] Li C., Kao C., Gore J. C., Ding Z.: Minimization of Region-Scalable Fitting Energy for Image Segmentation, IEEE Trans. Image Processing (2008), vol. 17 (10), pp. 1940-1949

[7] Marashdeh Q.: A multimodal tomography system based on ECT sensors. IEEE Sensors Journal (2007), vol. 7, 426–433.

[8] Marashdeh Q., Warsito W., Fan L., Teixeria F.: Dual imaging modality of granular flow based on ECT sensors. Granular Matter (2008), vol. 10, 75–80

[9] Mumford D., Shah J.: Optimal approximation by piecewise smooth functions and associated variational problems. Comm. Pure Appl. Math. (1989), (42):577–685

[10] Osher S., Fedkiw R.: Level Set Methods and Dynamic Implicit Surfaces, Springer, New York, (2003)

[11] Osher S., Sethian J.A.: Fronts Propagating with Curvature Dependent Speed: Algorithms Based on Hamilton-Jacobi Formulations. Journal of Comp. Physics, (1988), 79, 12-49

[12] Rymarczyk T., Characterization of the shape of unknown objects by inverse numerical methods, Przeglad Elektrotechniczny (2012), vol. 88, Issue 7B, pp. 138-140

[13] Rymarczyk T., Using electrical impedance tomography to monitoring flood banks, International Journal of Applied Electromagnetics and Mechanics (2014), vol. 45, pp. 489–494

[14] Rymarczyk T., New Methods to Determine Moisture Areas by Electrical Impedance Tomography, International Journal of Applied Electromagnetics and Mechanics (2016), vol. 37, Issue 1-2, pp.79–87

[15] Rymarczyk T., Adamkiewicz P., Duda K., Szumowski J., Sikora J., New Electrical Tomographic Method to Determine Dampness in Historical Buildings, vol. 65, Issue 2, Archives of Electrical Engineering (2016), pp. 273-283

[16] Sankowski D., Sikora J.: Electrical capacitance tomography: Theoretical basis and applications (2010), Wydawnictwo Instytutu Elektrotechniki, Warszawa

[17] Sikora J., Wójtowicz S., Industrial and Biological Tomography: Theoretical Basis and Applications (2010), Wydawnictwo Instytutu Elektrotechniki, Warsaw

[18] W. Smolik, "Forward Problem Solver for Image Reconstruction by Nonlinear Optimization in Electrical Capacitance Tomography", Flow Measurement and Instrumentation (2010), vol. 21, pp. 70–77

[19] Texas Instruments Technical Documentation, CMOS Analog Multiplexers/Demultiplexers CD4067B, CD4097B Types, Harris Semiconductor, June (2003)

[20] Wajman R., Fiderek P., Fidos H., Jaworski T., Nowakowski J., Sankowski D., Banasiak R., Metrological evaluation of a 3D electrical capacitance tomography measurement system for two-phase flow fraction determination, Meas. Sci. Technol. (2013), Vol. 24 No. 065302

[21] Zhang C., Electrical resistance tomography (EIT) by using an ECT sensor. Imaging Systems and Techniques (2010), IEEE International Conference