Image reconstruction in magnetic induction tomography without using a phase reference channel

Hermann Scharfetter, Sinan Issa and Doğa Gürsoy

Institute of Medical Engineering, Graz University of Technology, Kronesgasse 5, A-8010 Graz, Austria

E-mail: hermann.scharfetter@tugraz.at

1. Introduction and Methods

Magnetic Induction Tomography (MIT) is a low-resolution imaging method which aims at the 3-D-mapping of the electrical conductivity and correlated pathological processes in living tissues [1]. MIT is based on the measurement of the perturbation of AC magnetic fields by the body. In practice not the magnetic fields but instead the voltages induced in coils are measured. A conducting perturbation causes a relative voltage change ΔV/V which possesses both a real and an imaginary part with respect to the unperturbed magnetic field. The reference phase for synchronous demodulation must therefore be derived from the primary field either by measuring the excitation current (in phase with the magnetic field) or a voltage induced in a reference coil (-90 deg out of phase). In the latter case the biological conductivity information is mainly reflected in the imaginary part of ΔV/V, at least up to moderate frequencies. In a practical MIT hardware it is necessary to provide the reference phase to the demodulator, which requires a separate measuring channel. In transmit/receive configurations with 8, 16 or 32 transmitters one usually employs commercial DAC/ADC boards with 8, 16 or 32 channels. An extra reference channel is not very practical because one ADC channel must be sacrificed and the number of available measurement channels is reduced to 7, 15 or 31. Moreover it is never guaranteed that the reference channel provides the correct phase because the respective pickup and amplifier chain also contains phase errors. We have developed a signal preprocessing method which does not require an extra reference channel. Several noise sources affect mostly the real part, e. g. the relative movement of transmit and receive coils due to mechanical vibrations [3]. Therefore the correct reference phase Ψ_{ref} is the one which minimizes vibrational noise in the imaginary part of the data z. Denoting as U and V the variances of the real and imaginary parts, respectively, and W their covariance the optimization yields the following analytical solution for Ψ_{ref}

$$\cot(\psi_{ref}) = -\left(\frac{U-V}{2W}\right) \pm \sqrt{\left(\frac{U-V}{2W}\right)^2 + 1}$$

whereas that solution has to be used which corrsponds to the minimum of the variance of the imaginary part. State differential images were reconstructed from experimental data produced with the 16-channel Graz multifrequency MIT system [2]. The measured object was a plastic bottle (5 cm diameter, height 15 cm) filled with saline (conductivity 8 S/m). U, V, W and the reference angles were calculated for

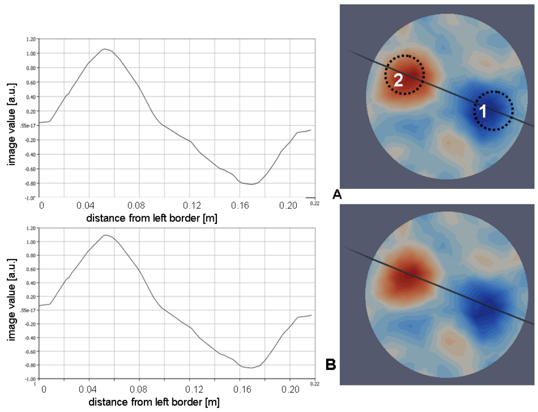

Figure 1. reconstructed images and profiles along the solid line from data with fixed reference phase (A) and with reference phase derived from the new method. The dotted circles denote the original positions of the bottle before (1) and after (2) the shift.

all individual channels from 15 calibration frames while sinusoidal vibrations (20 Hz) were applied with a loudspeaker. During acquisition of the following 26 measurement frames the vibration was stopped and the saline bottle was shifted from position 1 to position 2 (see fig. 1). DAQ parameters: 12 bit, 7.5 MSamples/s, 20 ms window length. Injected current: Two superimposed sinusoids, 0.85 App @ 200 kHz and 0.31 App @ 450 kHz. Alternatively the same fix reference angle was assigned to all channels in such a way that the bottle provided a purely imaginary signal. This phase was assumed to be the ideal Ψ_{ref} because, according to theory, it should provide virtually no real signal. Image reconstructions were done with Tikhonov-regularization using the unit matrix as regularization matrix.

2. Results and Discussion

Fig. 1 shows the cross-sectional images and profiles along the shown line reconstructed in a plane parallel to the median plane and 2.2 cm below the origin of the coil system with the ideal Ψ_{ref} (A) and with Ψ_{ref} calculated with the new method (B). The difference between the images is marginal, which demonstrates the validity of the new method. One beneficial side-effect of finding the correct reference phase is a minimization of vibrational noise in the reconstructed images in case that only the imaginary part of the data is used for the inverse problem.

Acknowledgements

This work was supported by the SFB project F32-N18 (Austrian Science Fund9.

[1] Griffiths H 2001 *Meas. Sci. Technol.* **12** 1126-31
[2] Scharfetter H, Köstinger A and Issa S 2008 *Physiol. Meas.* **29** 431-43
[3] Scharfetter H, Casaas R and Rosell J *IEEE Trans. Biomed. Eng.* **50** 870-80