Repeatability and reproducibility uncertainty assessment in magnetic resonance-based electric properties tomography of a homogeneous phantom

Repeatability and Reproducibility Uncertainty Assessment in Magnetic Resonance-based Electric Properties Tomography of a Homogeneous Phantom

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Key words: electric properties tomography, magnetic resonance imaging, phantoms, quantitative imaging, uncertainty

Magnetic resonance-based electric properties tomography (MR-EPT) is a quantitative imaging technique that non-invasively estimates the electric property values inside a human body [Leijsen (2021)]. Some early clinical applications of MR-EPT have been presented in the literature and most of them rely on the MR-EPT implementation called Helmholtz-EPT, in particular its phase-based approximation [Shin (2015), Kim (2016), Tha (2018, 2021)]. Helmholtz-EPT suffers a large sensitivity to input noise and the presence of systematic errors at tissue boundaries. Recognizing this issue, this contribution presents a repeatability and reproducibility uncertainty assessment in the electric conductivity of a homogeneous phantom estimated by phase-based Helmholtz-EPT.

A homogeneous cylindrical phantom of a known solution of NaCl in distilled water was acquired with a 3 T Ingenia TX scanner (Philips Healthcare, Best, The Netherlands) with a body coil in transmission and a 32-channel head coil in reception using a steady-state free precession (SSFP) sequence with nominal flip-angle of 30° and isotropic resolution of 2 mm. The measured phase of the acquired complex-valued image is a good estimate of the transceive phase from which the electric conductivity is estimated. Repeatability conditions are obtained by acquiring 25 images with the phantom centered at the scanner isocenter. Reproducibility conditions are obtained with 8 additional images acquired by moving the phantom at

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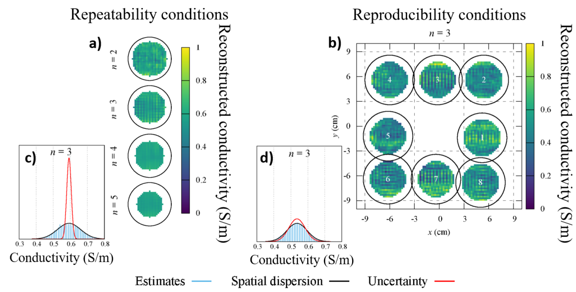

Fig. 1 Estimated maps under repeatability (a) and reproducibility (b) conditions, with kernels of various sizes *n*. Statistical distribution of the estimated conductivity under repeatability (c) and reproducibility (d) conditions, compared with the spatial dispersion and the median uncertainty.

a distance of about 6 cm from the isocenter between the scans (see Fig. 1b). The covariance matrices of the means of the phase and conductivity maps are evaluated according to the James–Stein shrinkage estimator [Schäfer (2005)] and the law of propagation of uncertainty. The EPTlib implementation of phase-based Helmholtz-EPT [Arduino (2021)] and the code for uncertainty propagation published in [Arduino (2020)] were used.

The conductivity maps estimated under repeatability conditions show spatial noise, corresponding to a spatial dispersion of the estimated conductivity, larger than the median standard uncertainty associated with each voxel. Hence, averaging multiple repeated acquisitions does not correct for this, apparently random, spatial noise. On the other hand, the conductivity maps estimated under reproducibility conditions show that the repositioning of the phantom changes the distribution of the repeatable noise, making it random from a practical point of view. Indeed, we observed that the spatial dispersion of the conductivity values estimated under reproducibility conditions is comparable with the median standard uncertainty associated with each voxel (see Fig. 1).

Acknowledgements The results here presented have been developed in the framework of the EMPIR Project 18HLT05 QUIERO. This project 18HLT05 QUIERO has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

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