Observation of B1 Field Focusing in Small Homogeneous Phantoms and Biological Samples at 17.6 T

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Introduction: ^{1}H high resolution NMR spectroscopy and MR microscopy at 750 MHz (17.6 T) correspond to an RF wavelength of ~ 4.5 cm in water (dielectric constant ε=80) and 17.9 cm in oil (ε=5) respectively. Consequently, NMR spectroscopy of water-based samples (5-10 mm diameter) and MR microscopy of fixed and in-vivo biological samples could be affected by significant B1 field inhomogeneities due to dielectric B1 field focusing [1-3]. In this study, we observe and quantify dielectric B1 field focusing at 17.6 T in liquid phantoms, as well as in ex vivo and in vivo biological tissues.

Method: All ^{1}H NMR measurements were acquired using a 17.6 T wide bore Avance Bruker spectrometer equipped with a 200 mT/m gradient system. A linearly-polarized Bruker birdcage coil of inner diameter 38 mm was used. All B1 maps were generated from a series of between 60 and 200 gradient-echo images preceded by a square rf-pulse of fixed power but increasing duration. Four homogeneous phantoms of oil, pure water, 100 mM NaCl aqueous solution and 4 % formaldehyde solution were constructed using long glass tubes of inner diameter 8 mm. A small diameter was used in order to keep the coil as well balanced as possible. Gradient-echo images and B1 maps of a fresh thin piece of pork filet (approx. 12x12x40 mm) and of the brain of a living rat were also recorded.

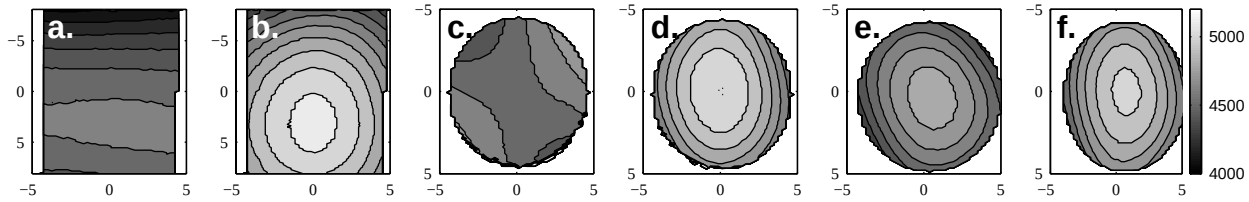

Fig. 1: B1 maps of the phantoms: a) sagittal view, c) axial view of oil (ε =5), b) sagittal view, d) axial view of water (ε =80), e) axial view of 100 mM NaCl solution, f) axial view of 4% formaldehyde solution. All axes dimensions are expressed in millimeters. Absolute B1 contour levels all vary from 4000 Hz to 5200 Hz with a 100 Hz increment, corresponding to a 2 % change of B1 field intensity. For all, FOV=16x16 mm, 128x64 data points. The B1 polarization direction of the coil is orientated top/bottom in the axial B1 maps. Note that this corresponds to the direction of least field focusing as predicted theoretically. The central B1 field intensity of the water phantom is stronger than that of the oil phantom.

Results and conclusion: Significant variations up to 10 % in the B1 intensities are observed in the 8 mm phantoms containing water. These B1 variations are in agreement with the dielectric phenomena of field focusing. One observes a strong field focusing for pure water (Fig. 1b ,1d), no focusing for oil (Fig. 1b, 1d), and a reduced field focusing for the 100 mM NaCl solution due to its increased conductivity (Fig. 1e). The formaldehyde solution (very commonly used to fix samples for ex vivo MR microscopy) behaves very similarly to the saline solution (Fig. 1f). The weak B1 field inhomogeneities inside the oil phantom are due to the intrinsic inhomogeneous B1 field of the coil. Furthermore, applying Tofts analytical equations [ref 2, eq. 10-11] to the calculation of the B1 field inside a long homogeneous cylinder with ε=5 and ε =80 gives good agreement between experimental B1 maps and simulations. In vivo experiments in the rat brain show no visible central brightening (Fig. 2a) and only weak field focusing (Fig. 2b). The pork filet sample shows significant B1 field focusing (Fig. 2d) and moderate amount of image artifacts (Fig. 2c). To conclude, dielectric effects are strong at 750 MHz for samples in polar solvents typically used for ^{1}H high resolution spectroscopy, but appear moderate for in vivo applications to small animals.

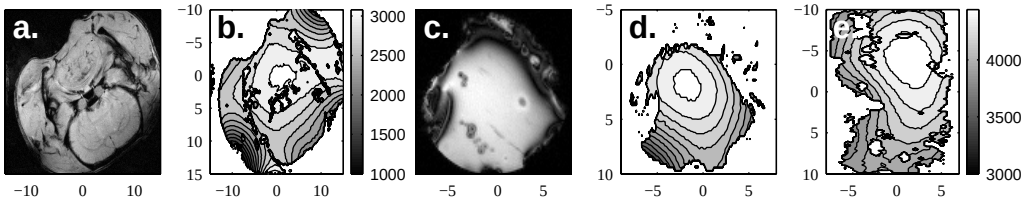

Fig. 2: Axial rat brain: a) gradient-echo image, FOV= 30x30 mm, 256*256 data points, slice thickness = 1.1 mm, b) corresponding B1 map, 128x128 data points. Contour levels every 5 % of B1 field variation. Pork filet sample: axial view c) gradient-echo image, FOV=20x20 mm, 128x128 data points, slice thickness 1.1 mm, d) corresponding B1 map, 128x68 points, e) sagittal B1 map. For d), e) FOV=20x20 mm, 128x64 data points, contour levels every 2% of B1 field variation.

References. [1] Hoult D. I. , J.Magn.Reson.Imag., 12, 46-47 (2000). [2] Tofts P.S., J.Magn.Reson. B, 104, 143-147 (1982), [3] Wang J, Yang Q.X., Zhang X. et al., Magn.Reson.Med., 48, 362-369 (2002).

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