New MR-scanner independent B_1 field mapping technique

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INTRODUCTION: The spatial relation between the transmit and receive B_1 fields dramatically affects the results of both MR spectroscopy and imaging experiments. A common approach is to attempt to maximize SNR of the examination at the expense of spatial uniformity of the B_1 field. Unfortunately, this leads to intensity variations in images, and also absolute quantified examinations become less than straightforward. To compensate for these effects, the spatial maps of the B_1 field must be obtained. MR-scanner based methods of B_1 field estimation exist, but their accuracy is very limited [1,2], especially for X-nuclei with low γ. Among the drawbacks is typically the lack of phase information, or the inability of signal acquisition in the direction of the B_0 magnetic field. The aim of this work was to implement a novel, scanner-independent, precise B_1 field measurement method, which would make it possible to acquire both the magnitude and the phase of the RF-signal. It is particularly important to use these methods for the detection of the X-nuclei, such as ^{31}P, for which the limited detection sensitivity makes mapping using direct detection in a scanner inconvenient, highly unpractical, or even impossible.

MATERIALS AND METHODS: The measurement setup incorporates a modified industrial coordinate table (Solectro AB, Sweden), a network analyzer (Rohde&Schwarz GmbH, Germany) and a set of 'near-field probes' (i.e., probes sensitive only to the magnetic component of the EM field; Langer EMV-Technik, Germany). Data was acquired and processed using Matlab (The MathWorks Inc., USA). The actual measurements were performed by automatically moving the near field probe in three orthogonal directions across the surface of an RF coil. Because the coil load affects the B_1 field distribution, a homogeneous phantom (water tank filled with a physiological electrolyte, saline) was used to load the coil. The separate components of the field were then summed to obtain the complete B_1 field map (Eq. 1 and Eq. 2).

$$\mathbf{B} = B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}} + B_z\hat{\mathbf{z}}$$

Eq. 1

$$\|\mathbf{B}\| = \sqrt{|B_x|^2 + |B_y|^2 + |B_z|^2}$$

Eq. 2

While the use of magnitude is straightforward, knowledge of the phase of the signal can be used to determine the orientation of the magnetic component of the field. Compared to methods using MR-scanners to acquire B_1 field maps, we could acquire the phase of the signal, as well as signal from all directions using the off-line arrangement. For lower field strengths, such as at 1.5 T, it is appropriate to use the *Reciprocity Principle* [3] (assuming that the B_1 field distribution is independent of whether the coil is used as a receiver or a transmitter). Thus we assume that the spatial field distribution in both receive and transmit modes may be obtained by a single measurement.

RESULTS: Figure 1 shows the B_1 field maps of a 10 cm diameter Philips ^{31}P MRS surface RF coil, including information on the direction of the flux density vectors, obtained using the automated measuring system. Data were acquired at f = 25.85 MHz at a distance 40 mm above the coil surface. Projected B_1 field map is presented for one particular case for which the coil position was acquired inside the MR-scanner using MR-visible markers.

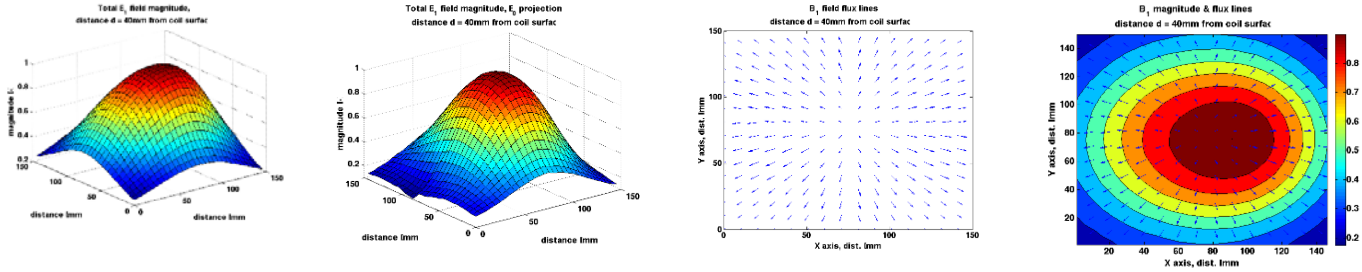

Fig. 1 ***(A)*** *The total B_1 field magnitude at 40 mm above the ^{31}P coil.* ***(B)*** *The B_1 magnitude in the B_0 direction.* ***(C)*** *The flux lines above the surface of the coil.* ***(D)*** *B_1 field magnitudes combined with the flux lines.*

It is apparent from the plots that the B_1 field of the coil is inhomogenous. This highlights the importance of proper coil placement during *in vivo* examinations, as well as the need for performing appropriate compensations for the non-linear detection profile during data post-processing. Moreover, the inhomogeneity causes flip angle variations in the volume of interest, something which consequently abolishes the absolute quantification of metabolites.

CONCLUSION: We have successfully implemented a completely automated off-line mapping method of the spatial uniformity of arbitrary MR-coils. Results of preliminary validation show good agreement to B1 field maps acquired using MR scanner. The method provides complete information, with high spatial resolution, not only of the B1-magnitudes in the transverse plane, but also in the longitudinal direction. Thus the procedure allows for the detailed investigation of B_1 field distribution in three dimensions, as well as field's flux line directions. The advantage of this setup compared to assessing B_1 field distribution inside a MR scanner, is that all field components are acquired as well as their phase. The acquired maps are important for absolute quantification of spectroscopic information, in particular we expect that it will be important for absolute quantification of metabolite concentrations using ^{31}P MRS.

REFERENCES: [1] Weis, J. and Andris, P. and Frollo, I. A simple method for mapping the B1 field distribution of linear RF coils. Magnetic Resonance Materials in Physics, Biology and Medicine, 18:283-287, 2005. [2] Warntjes JBM, Dahlqvist Leinhard O, West J, Lundberg P. Rapid magnetic resonance quantification on the brain: Optimization for clinical usage. Magn Reson Med. 2008 Aug;60(2):320-9. [3] Hoult, D.I. The principle of reciprocity in signal strength calculations - a mathematical guide. Concepts in Magnetic resonance, 12:173-187, 2000.