Combination of a sodium birdcage coil with a tunable patch antenna for B_0 shimming and anatomical localization at 9.4 T

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Introduction

A homogeneous local static magnetic field (B_0) is important for nearly every MR application. Through field mapping, it is possible to determine adequate shim currents and homogenize the B_0-field over a selected volume up to a certain degree. In the case of X-nucleus imaging, the achievable signal-to-noise ratio (SNR) is in most cases insufficient to produce such maps in a short time and dual-frequency coils [1] and nested-coil designs [2] are then used to exploit the proton signal for shimming and anatomical localization. Here we show that a patch antenna [3] and the traveling wave concept can be used to circumvent the need for these more complicated coil designs, which are normally associated with a loss in SNR for both nuclei.

Methods and Materials

All measurements were performed in accordance with local research ethics policies and procedures on a Siemens (Erlangen, Germany) 9.4 T whole-body MR scanner. Sodium (^{23}Na) images were obtained using a 16-rung high-pass birdcage coil. A capacitively adjustable two-channel patch antenna placed closely behind the X-nucleus coil was used for excitation and reception of the proton signal. The shim currents were calculated based on a B_0 field map acquired with a double-echo gradient-echo sequence using the proton signal. An ultra-short echo time sequence, acquisition-weighted stack of spirals (AWSOS) [4], was used to efficiently sample the sodium signal. Two scanning protocols, achieving different nominal resolution, were chosen for sodium imaging. Some sequence parameters are summarized in Table 1. A cylindrical phantom containing an aqueous 125 mM solution of sodium chloride and a Plexiglas plate with holes of different diameters was used to assess the achieved resolution in the unshimmed (standard preset shim currents) and shimmed case. Moreover, data from two healthy volunteers were acquired.

Protocol	A	B
Resolution [mm^3]	1.5x1.5x3.0	1.0x1.0x5.0
FoV [mm]	240	240
Readout [ms]	9.12	20.48
Flip angle [deg.]	80°	80°
TE [ms]	0.3	0.3
TR [ms]	100	100
Acq. time [min]	27	20

Table 1. Parameters for the AWSOS sequence.

Results

Figure 1a shows the overlay of the B_0 field maps before and after shimming onto proton images of the first subject. The frequency offset initially large in the lower brain could be significantly reduced. Protocol A was used to image the aforementioned resolution phantom (Fig. 1b,c) and the first volunteer (Fig. 1d). In both cases, the improved B_0 homogeneity led to an increased spatial resolution by reducing off-resonance effects, which are problematic especially for non-Cartesian sampling schemes. Protocol B was used to image the second volunteer (Fig. 1e). The longer readout length corresponds to a smaller acquisition bandwidth, which leads to a higher signal-to-noise ratio. Although the readout length for this protocol was more than twice as long as for the previous one, the produced sodium images exhibit only few clearly discernible artifacts due to off-resonances after shimming. In the case of long readouts however, the T_2*-decay of the signal, which acts as a filter on *k*-space, is another factor which reduces the spatial resolution by introducing blurring into the image.

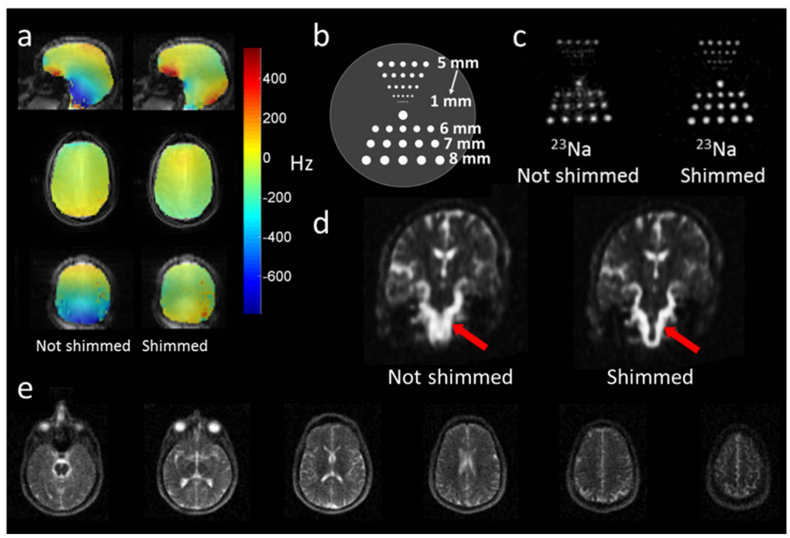

Figure 1. a: B_0 field maps of a healthy human brain before and after shimming showing the off-resonance in Hz for the proton resonance frequency. **b:** Schematic representation of the resolution phantom. Hole diameters range from 1-8 mm. **c:** Sodium images (Protocol A) of the resolution phantom. **d:** Sodium images (Protocol A) from the volunteer shown in (a). The red arrow indicates a region where the off-resonance effects could be clearly mitigated. **e:** Transversal sodium images of a different human subject imaged with protocol B. Although the readout length for this acquisition was considerably longer, image quality is only slightly reduced due to blurring caused by off-resonance effects and T_2*-decay.

Discussion and Conclusion

Although the gyromagnetic ratio of the sodium nucleus is about four times smaller than that of protons, off-resonances can still produce noticeable artifacts and reduce image quality. We have shown that it is possible to use a patch antenna for B_0 shimming and anatomical localization in conjunction with an X-nucleus coil without having to make any modification to either appliance. Numerical simulations and more experiments could be performed in order to assess how much the propagation of the travelling wave is influenced by the X-nucleus coil and if the performance of the antenna or the coil is reduced through the presence of the other.

References

[1] JMR (1985);65:122–129. [2] Design of a Nested Eight-Channel Sodium and Four-Channel Proton Coil for 7T Knee Imaging. MRM (2012) (early view) [3] Human Brain Imaging at 9.4 T Using a Tunable Patch Antenna for Transmission. MRM (2012) (early view) [4] MRM (2008); 60:135–145.