Investigation of 7 Tesla Spine MRI with a 5-Channel Stripline Array and an 8-Channel Loop Array

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Introduction: New RF coil and transmit concepts have recently demonstrated the feasibility of 7 Tesla MRI of the human spine [1-3]. However, for a clinical assessment it was found that penetration depth and homogeneity depend heavily on the physique of the volunteers. Especially turbo spin echo sequences (TSE) suffered from severe loss of signal homogeneity in most volunteers depending on the thickness of subcutaneous fat tissue and back muscles [4]. In this study, two transmit/receive RF coil concepts – a 5-channel stripline array [5] and an 8-channel loop array [1] – were investigated with regard to their performance for 7 Tesla MRI of the human spine. Additionally, a combination of these two arrays with separated transmit and receive channels was assessed.

Methods: The 5-channel stripline array has been previously presented as the dorsal part of a 16-channel RF body coil [5]. While the loop array consisted of eight channels aligned in two rows along the z-axis and was fed with optimized but fixed phase settings [1], the stripline array was oriented along the x-axis and was used in combination with RF shimming. Both arrays were compared for homogeneity and maximum signal-to-noise ratio (SNR) and B_1^+ homogeneity and efficiency measured in a phantom as well as in vivo (male, 33 y, 89 kg, 1.86 m), and for specific absorption rate (SAR) performance calculated from numerical simulations [6]. For B_1^+ mapping, the AFI sequence [7] was used with a ratio of TR2/TR1 = 5, TE = 2 ms, and 250 µs pulse length. SNR profiles were obtained with the difference method [8] using two gradient echo images (TR/TE = 100/5 ms, 1.3 x 1.3 x 5 mm^3). The clinical performance was evaluated in vivo with a TSE sequence (TR/TE = 3500/96 ms, 0.6 x 0.6 x 3 mm^3) and by calculating the contrast-to-noise ratio (CNR) between myelin and CSF. A combination of both arrays was tested with the 5-channel stripline array used in transmit/receive mode and placed under the 8-channel loop array, which was detuned during transmit and served only as an additional receive array. Besides the aforementioned tests, a noise correlation measurement was additionally performed for the combined concept.

Results: The loop array yielded slightly higher SNR values compared to the stripline array (Fig. 1A). Although the stripline array achieved lower maximum B_1^+ values (15 µT vs. 22 µT) for the same pulse amplitude and length, it showed a much more homogeneous excitation than the loop array (Fig. 1B and C). For example, over a length of 150 mm in z, the B_1^+ profile showed a max-to-min ratio of 1.11 for the stripline array and 1.38 for the loop array. Additionally, numerical simulations yielded approximately a factor of 2 for the maximum allowed input power for the stripline array compared to the loop array, which can be invested in an optimization of penetration depth by applying higher pulse voltages. Figure 1D shows a strong gain in SNR for the combined array versus the stripline array alone. CNR between myelin and CSF could be more than doubled from 3.4 to 7.2 for the combined concept in the cervical spine (Fig. 1E). Noise correlation between the 5 + 8 receive channels was found to be relatively low (Fig. 1F); residual coupling between the stripline and loop elements might be further reduced through design optimization.

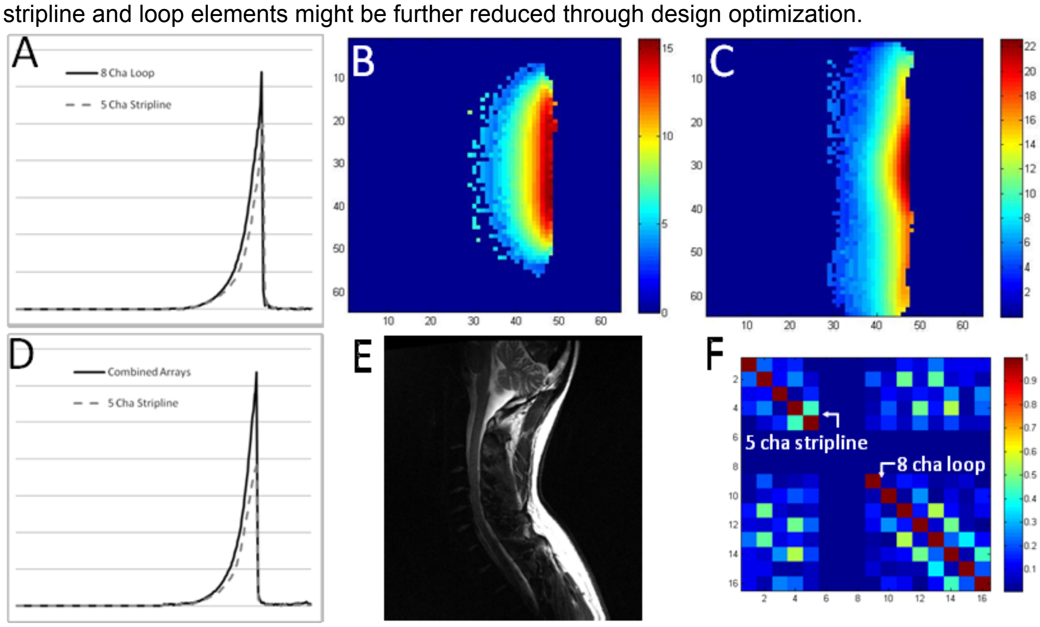

***Figure 1:** (A) shows SNR profiles and penetration depths for the loop (solid line) and stripline array (dashed line). B_1^+ maps are given in [µT] for the stripline (B) and loop (C) array. In (D) the SNR profile of the combination of both arrays (solid line) was compared to the profile of the stripline array alone (dashed line). Measurements for (A) to (D) were performed in a phantom. A clinically usable contrast was achieved with the combined array in vivo in the T2w TSE image of a cervical spine (E). (F) shows the noise correlation matrix for the combination of both arrays with the stripline elements in the upper left corner, the loop elements in the lower right corner, and cross-correlation between arrays in the upper right/lower left corners.*

Discussion: This investigation of 7 Tesla spine MRI with two different RF coil concepts revealed the advantages of the loop array for reception and superior transmit and SAR performance for the stripline array. Hence, a combination of both arrays with separated transmit and receive channels to account for their individual advantages was successfully realized. The in vivo test with a TSE sequence in a healthy volunteer with body mass index over 25 yielded very good contrast in the region of the heavily curved cervical spine. This study may serve as a basis for further optimization of RF coils for MRI of the human spine at 7 T.

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