The Twisted Phased Array: A New Array Design for Improved SNR and g-Factor

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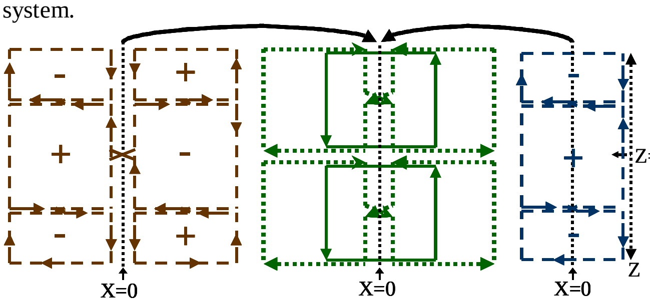
Introduction

In addition to SNR gain, array coils are now being designed for optimum g-factor performance in parallel MRI. For surface arrays, to limit the number of array elements used, the size of individual array elements is chosen to provide maximum SNR at the depth of interest. Recently, both volume and surface array designs were introduced with separation between array elements as opposed to the traditional overlap to the zero mutual inductance position [1]. G-factor improvement through increased separation is limited due to SNR loss between separated elements, and thus typically there are no separations in the z-direction [2]. To address this, a new type of phased array design is proposed, using "twisted" array elements that have substantially orthogonal B1- and associated E-fields to standard loops and butterfly elements. We will investigate the SNR gain and g-factor improvement using such a Twisted-Array coil and compare to standard array designs.

Theory/Methods

Quasi-static numerical simulations were performed, corrected for typical conductor-to-sample resistance ratios for realistic SNR predictions. In order to achieve SNR gain while stacking array elements over the same FOV, they must be orthogonal in resistive/noise properties. Twisted array elements contain loop-lobes with both co- and counter rotating currents, which when overlapped appropriately with standard loops and butterfly elements (Fig.1), exhibit zero coupling and hence zero noise correlation. The twisted loop and twisted butterfly elements (Fig.1) are not centred along the long axis with a single loop-butterfly pair as in previous designs [3], but in the gaps between the standard loop-butterfly elements of extended FOV arrays. The lobe dimensions are chosen such that the twisted array element is naturally isolated from all loop and butterfly elements, leading to SNR gain at the depth of interest. Standard and twisted array elements were constructed and SNR images (SE, TR/TE=500/10ms) were collected on a GE 1.5T 4-channel MRI system.



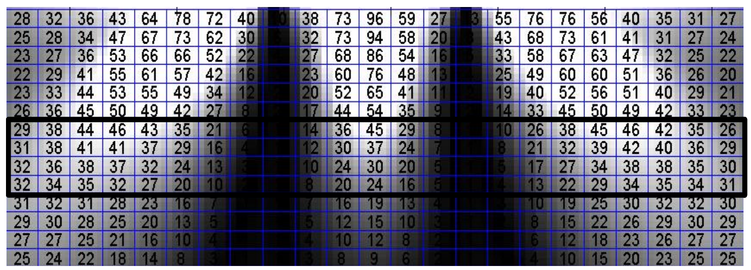


Fig. 1: Coil geometry used in simulations and experiments: Spine-style standard separated Loop-Butterfly structure (***centre-left***), Twisted-Butterfly (***far-left***), Twisted-Loop (***centre-right***). Sum-of-squares SNR % gain of the Twisted-Array over the standard 30cm long loop-butterfly array (zero separation in this example), with spine region identified (***far-right***).

Results and Discussion

Both simulated and experimental (*Fig.2:left*) SNR from Twisted-Loop and Twisted-Butterfly array elements show significant inherent SNR at the depth of interest, leading to significant SNR gains (25%-45%) in the separation region when combined with standard loop-butterfly elements in a standard spine array (*Fig.1*:*far-right*). This is because the lobe sizes (in particular the central lobe) within the twisted array element are comparable to the optimum loop-size for a particular depth. Additional SNR gain at the ends of the array (35%-45%) gave improved FOV coverage and a squarer z-profile. Many higher order twisted array elements can be added that are also naturally decoupled from the loop-butterfly elements, but the SNR benefits of higher order twisted elements are not as significant at the depth of interest, because the lobe sizes become smaller.

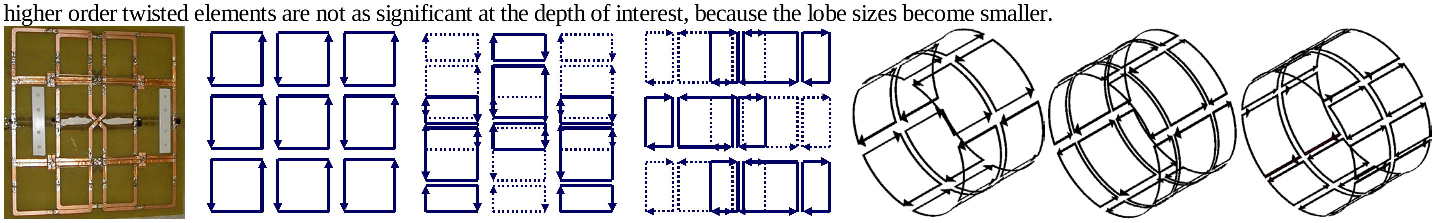


Fig. 2: Twisted-Loop and Twisted Butterfly array elements (***left***), Other Twisted-Array design strategies: 2D cardiac-style surface array (***middle***) or volume array (***right***).

Conclusions

Both simulations and experiments were performed with small (2mm) z-direction separations between standard loop-butterfly elements, where between 25%-45% SNR gain was achieved at the depth of interest with the addition of the twisted array. Further separation would result in increased SNR loss between standard elements that would be recovered using the twisted array. The addition of Twisted-Array elements should allow one to optimize g-factor through array element separation in both transverse and z-directions, while retaining maximum SNR of ideal phased arrays. The only downside is that the extra array elements require more receivers, but this will likely not be a problem as the number of receiver channels on MRI systems is increasing rapidly.

References

[1] M. Weiger et al. MRM 45:495-504(2001). [2] C.J. Hardy et al. MRM 52:878-884(2004). [3] M.A. Ohliger et al, Proc. ISMRM p.11(2004).

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