The SNR of Spiral Birdcage Coils

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Introduction

Recently, a new type of volume phased array was proposed, referred to as Fourier Array Coil Technology (FACT^{TM}) [1]. Here volume coils with substantially orthogonal fields are stacked such that each coils spatial sensitivity distribution covers the same volume. A particular geometry proposed was to stack spiral birdcage coils [2] of different "twists". With proper choice of twists, the B1 and associated E-fields can be made orthogonal so that SNR gain may be possible. This abstract reports upon investigations of the inherent SNR of various spiral birdcage coils.

Theory/Methods

In order for a spiral birdcage to be completely isolated from a standard birdcage, one must consider both quadrature modes from both coils. For instance an ideal $+\pi$ spiral birdcage will not be isolated from both of the degenerate birdcage modes. Therefore, if one were to stack spiral coils on top of a standard birdcage coil and operate all coils in quadrature, there must be a 2π difference in the twisting (neglecting end ring coupling). That is, all modes of a quadrature $-\pi$ and a quadrature $+\pi$ are isolated (inductively and resistively orthogonal). Similarly, a standard birdcage and a $+2\pi$-quad in addition to a -2π-quad are all isolated. All quasistatic Matlab simulations and experiments were performed with coils 27 cm long and 25 cm in diameter and a cylindrical phantom 30 cm long and 20 cm in diameter. Bench SNR equivalent B1 measurements were made using a small search probe and a cylindrical phantom with a narrow air tube in the center. Image SNR was calculated from the central pixel mean and the standard deviation of pixel values in signal-free background ROI of a large FOV axial SE image.

Results

As expected, the B1 field produced from a spiral birdcage ($+2\pi$ in this case), demonstrates a phase variation consistent with the amount of twist applied. For sample lengths similar to the coil lengths (indicated with vertical dashed lines in *Fig. 1-left*), you can see that both modes of the 2π spiral coil are not perfectly isolated from the standard birdcage because the B1 field is weaker near the ends of the coil and hence the share resistance integral is not zero. The simulated center SNR of $\pm\pi$, $\pm2\pi$, $\pm3\pi$, and $\pm4\pi$ spiral birdcage coils is 0.80, 0.62, 0.46, and 0.12 respectively, relative to a standard birdcage coil (*Fig. 1-right*). At the ends of the spiral coils, the SNR is not decreased relative to the standard birdcage, suggesting that spiral array coils may be used not only for SNR gain but also for creating more uniform B1 fields in the z-direction. Experimental results (*Fig.2*) from both bench measurements and from axial images collected on a 3T scanner shows similar SNR behavior to those predicted with simulations.

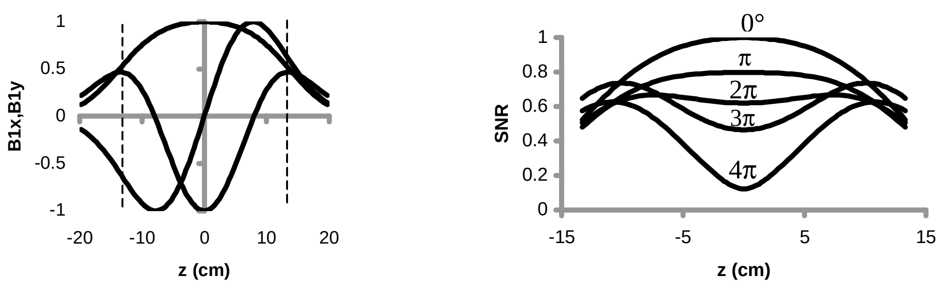

Fig. 1: Simulations: Linearly driven B1x- and B1y-fields for a 2pi Spiral and a standard birdcage coil (left). SNR comparison for 0, $\pm\pi$, $\pm2\pi$, $\pm3\pi$, and $\pm4\pi$ birdcage and spiral birdcage coils (right).

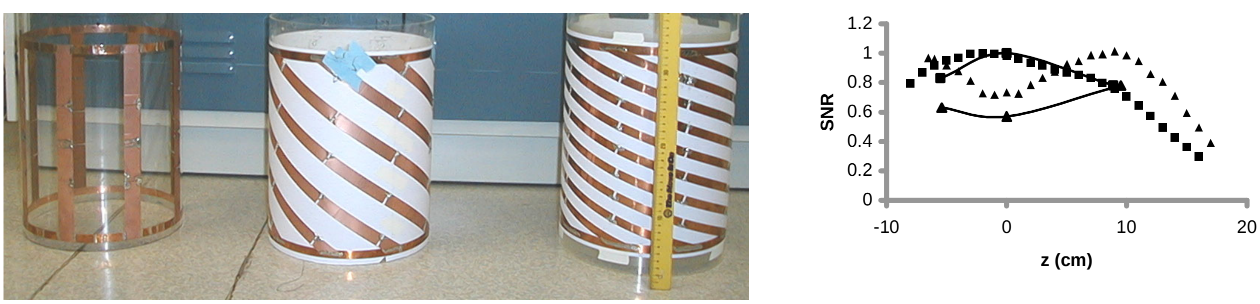

Fig. 2: 0, π and 2π birdcage coils (left). Bench(markers-only) and image(lines) SNR for the 0°(squares) and 2π (triangles) birdcage coils (right).

Conclusions

Although the use of spiral birdcage resonators as elements of a volume array coil may seem very promising, realistic SNR gains will be minimized by the inherently decreasing SNR of higher order spiral coils. The SNR in the center of spiral coils of length equal to the sample length are 1.0, 0.80, 0.62, 0.46, 0.12 for twists of 0°, $\pm\pi$, $\pm2\pi$,$\pm3\pi$,$\pm4\pi$ respectively. The SNR loss at coil center for higher order spiral coils suggests that gains in SNR over comparable length standard birdcage coils would be limited to 30%.

References

[1] G.R. Duensing, et al, Proc. ISMRM p.771 (2002), [2] Alsop, D. et al, MRM 40:49-54 (1998).