Concentrically Shielded Surface Coils - A New Method for Decoupling Phased Array Elements

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Introduction

The latest generation of MR scanners provide a large number of receive channels which can provide close to the ultimate SNR as well as optimal parallel imaging performance. However, arrays with large numbers of coils are difficult to construct since coil coupling becomes more difficult to control. Often a single element has six or more neighboring elements [1]. Each element pair has to be decoupled, which has up to now been accomplished by either overlap or by a shared capacitor. The latter requires potentially significant adjustments for varying loading situations. This coupling problem is exacerbated in situations were a gapped coil arrangement is preferred, since overlap cannot be used. At higher field strengths, microstrip [2] and other shielded coils have demonstrated great potential for array geometries, due primarily to their lack of coupling. This geometry is difficult to use in a dense 2D arrangement of coils, since the tuning and matching circuitry is in general on the sample side of the coil, making adjustment very difficult. Additionally, microstrips have poor performance at clinical field strengths due to the tight coupling to the ground plane that is needed to reduce coupling to neighboring elements. In this abstract we present a new method of decoupling neighboring elements based on the use of concentric shields which is compatible with a gapped coil arrangement and yields good SNR and good isolation between the elements even at 1.5T.

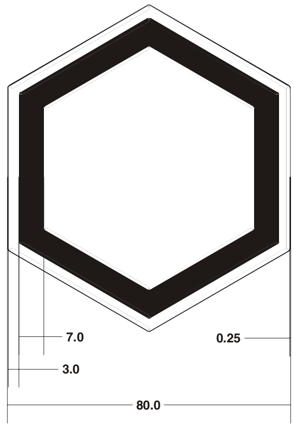

Figure 1: Concentrically shielded coil used in this study.

Methods

The coupling between neighboring coil elements at low frequencies (64 MHz) and small coil sizes mainly comes from B_1 field coupling. In order to reduce this coupling we introduced an additional thin, untuned, copper ring in the coil plane, concentric with the outside of the coil (see fig 1). This copper ring acts as an RF shield for the coil and prevents strong coupling from elements close to the coil. This shield also contains any stray electric fields that may also be present. For evaluation of these shielded coils, several different geometries were built and tested, with various conductor sizes and spacings. In addition, a normal, unshielded coil with the same outer diameter was built. All elements were tuned and matched to 50 Ω for a physiological load at a frequency of 64 MHz. For evaluation a Siemens 1.5T Vision was used.

Results

As an example, the shielded coil shown in Fig 1 demonstrated a Q drop of 170 to 50 when loaded with a physiological load. The unshielded coil showed a drop from 365 to 65. The SNR of individual elements was measured along a profile from the surface of the phantom. The resulting SNR is shown in Fig 2 for the various element geometries, demonstrating the robust SNR performance as well as the potential to adjust the SNR profile of the shielded coil based on judicious choice of element geometry. Additionally, different arrangements of three equal elements were tested to simulate various configurations found in a 2D arrangement of coils. In this case, the elements were simply placed next to one another, with no special care taken to assure a given distance from other elements, etc. The approximate distance to neighboring coils was 2mm. For example Table 1 shows the resulting noise correlation matrix of the linear arrangement of the three shielded coils. The worst case observed for any of the configurations was 23% correlation, with all other values less than 17%.

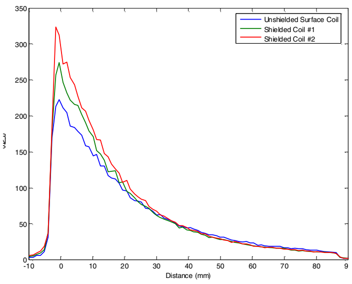

Figure 2: SNR profiles for the various coil geometries

Coil	1	2	3
1	1.00	0.06	0.11
2		1.00	0.10
3			1.00

Table 1: Noise correlation for a linear arrangement of coils

Discussion

The principle of using concentric shields for decoupling array coil elements has been shown to work well. The lower Q drop in the shielded coil elements is due to the fact that the additional shield ring effects the B_1 field throughout all the space. Nevertheless, the Q drop shows that the shielded coil can still be made sample noise dominant and with sufficient SNR for use in an array arrangement. The noise correlation matrix shows that the coil elements have a very low correlated noise, as would be expected for a gapped array with well isolated elements, even though no special care was taken to assure decoupling of these neighboring elements. For this reason, we believe this general concept will be useful for the construction of arrays with a large number of elements.

References

1. Wiggins, et al, ISMRM 2005, pg 671
2. Adriany, G., et. al., ISMRM 2003, pg 474