# MAGNETIC WALLS FOR RF COIL ELEMENTS DECOUPLING

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**Introduction:** Transmit-receive RF array coils can be efficiently utilized in high field MRI to improve $B_1^+$ homogeneity and reduce the specific absorption rate (SAR) [1]. To achieve these ends, the mutual coupling intrinsically present between the array elements needs to be overcome. Many methods have been proposed in the past to tackle the mutual coupling problem in MRI RF coil loop arrays; each with its own merits and drawbacks [2]-[4]. This work introduces an essentially lossless new RF decoupling method based on utilizing "magnetic walls" inserted in between the array elements.

**Method:** When two RF loop coils (Fig. 1a), each resonating at frequency $f_1$ are placed in close proximity, their $S_{11}$ response shows two eigenfrequencies ($f_2$ and $f_3$, Fig. 1c.) due to their mutual inductance. An important realization is that the $B_1$ associated with $f_3$ is spatially confined to the region between the two coils, while $f_2$ is associated with the desired $B_1$ produced by each coil. By absorbing the $B_1$ associated with $f_3$, magnetic walls can be used to effectively suppress the mutual coupling between the coils. Because $f_3$ is not associated with the desired Larmor-frequency-associated $B_1$, absorption of the $B_1$ component at $f_3$ removes the coupling and returns $f_2$ to $f_1$. Absorbing only $B_1$ at $f_3$ renders the method effectively lossless as $f_2$ is not interfered with as occurs in lossy methods such as [2]. Magnetic walls are synthesized by embedding small (relative to the RF wavelength ) metallic resonators within a host dielectric. An absorptive magnetic wall is designed with a complex permeability of large and negative imaginary part. When the wall is inserted between coupled loops, evanescent coupled $B_1$ fields at frequencies close to the wall's resonance frequency ($\sim f_3$ in this case) will be trapped and forced to decay within the wall structure. Prototype magnetic walls were constructed to decouple 7 Tesla transceive array elements tuned for proton imaging (RF frequency ~ 298.2 MHz). The magnetic walls were made of two dielectric layers each having three 2-turn square spiral resonators (SR) etched out on printed circuit board with Rogers 4350B substrate of thickness 1/16″ as shown in Fig. 1b. Two of these layers sandwiched two blank layers of the same thickness. The four layers were aligned and screwed together to form the final magnetic wall structure. The SR was made of 5-mil wide copper trace, with 5-mil pitch, and ~ 3/5" external side length. The decoupling performance was assessed by inserting the magnetic wall between two 2-inch square loops as shown in Fig. 1a. Furthermore, the designed magnetic walls were used to decouple a four-element linear Tx/Rx array for high resolution fMRI studies of the human visual cortex (Fig. 2a).

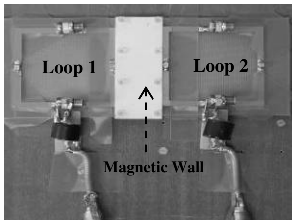

**Fig. 1a**

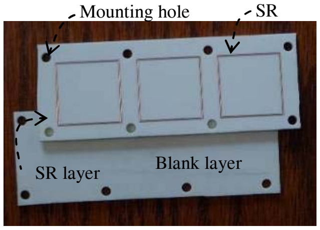

**Fig. 1b**

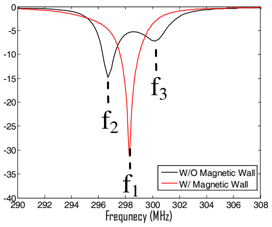

**Fig. 1c**

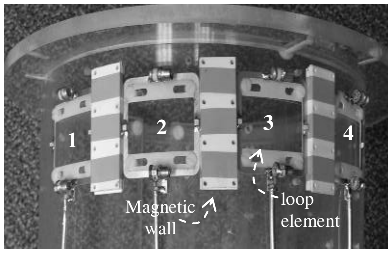

**Fig. 2a**

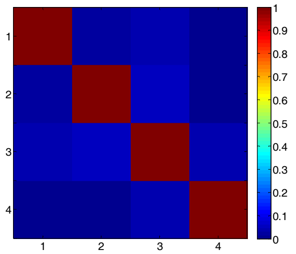

**Fig. 2b**

**Results:** $S_{11}$ measurements for one of the loops in Fig. 1a obtained with (black line) and without (red line) the designed magnetic wall inserted between the loop and its adjacent element were made (Fig. 1c). Besides eliminating mode splitting, i.e. decoupling the loops, the Q factor at $f_1$ was virtually identical to a single coil in isolation, indicating lossless decoupling. The transmission coefficient measurement showed that decoupling of more than –15 dB can be obtained with the magnetic wall. For the 1D array decoupled with magnetic walls (Fig. 2a), the average transmission coefficient between the elements was around –22 dB indicating strong decoupling as desired. The decoupling effectiveness was also evaluated by measuring the noise correlation coefficients between the transceive channels (Fig. 2b). The average noise correlation coefficient for the decoupled array was around 3% with a maximum value of 5.5%. When used for human visual cortex imaging on a 7T scanner, the array enabled efficient $B_1^+$ shimming due to the independence of the individual channels (Fig. 3a). The combined magnitude images (Fig. 3b) showed uniform intensity in the region of interest without any destructive interference that might rise due to RF coupling.

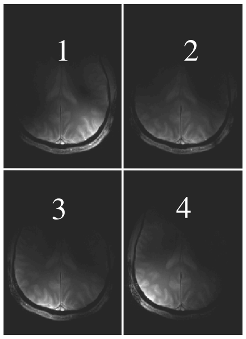

**Fig. 3a**

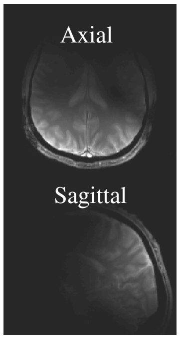

**Fig. 3b**

**Conclusions:** A new RF decoupling method for MRI arrays based on utilizing magnetic walls of complex-valued permeability to isolate the array elements has been proposed and its performance has been evaluated. The proposed method is modular and can be used quite systematically to decouple various array configurations. Although not shown here, the proposed magnetic wall lends itself to optimization, can be used for 2D and 3D arrays, and it can be miniaturized to yield compact arrays. Magnetic walls of only 1/5" (5 mm) width are currently in production using substrates of higher dielectric constant and more turns on the SR.

**References**: [1] C. Van den Berg et al, "Magn. Reson. Med. 2007, 57:3:577-86 [2] K. M. Gilbert et al, NMR Biomed. 2011, 24:7:815–23 [3] P. B. Roemer et al, Magn. Reson. Med. 1990, 16:192-225. [4] R. G. Pinkerton et al, 2005, Magn. Reson. Med., 54:2:499–503.