Novel Inductive Decoupling for Single- and Double-Tuned Transceiver Phased Arrays to Compensate for both Reactive and Resistive Components of the Mutual Impedance.

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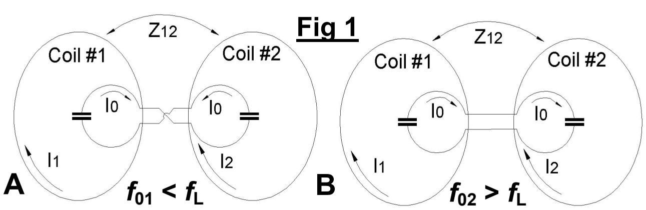
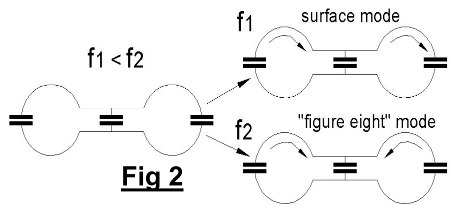
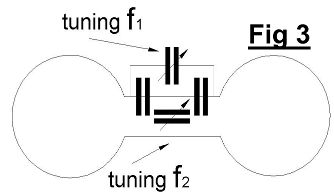
Introduction: Decoupling is one of the most critical aspects in constructing transceiver phased arrays. Insufficient decoupling can disturb the RF field profile and compromise both transmission performance and SNR. Previously described decoupling techniques have focused on eliminating the reactance of the mutual impedance Z_{12}, which can limit the obtainable S_{12} to -10 to -13 dB due to residual mutual resistance, R_{12}. Recently we introduced a double-tuned 7T ^{31}P/^{1}H transceiver array. Due to frequency dependence of the mutual inductance two separate decoupling circuits are required between each array element. Double-tuning of the decoupling coils can significantly simplify the design. In this work we described a novel inductive decoupling technique, which addresses both of these issues.

Methods: Figs.1A,B show two resonant decoupling circuits resonating at f_{01}, f_{02}. Solving the Kirchhoff equations shows that they can decouple a pair of surface coils (#1,2) when resonating either below (Fig.1A, "figure 8" coil) or above (Fig.1B, surface coil) the resonance frequency of the surface coils, f_L. When f_{01}, f_{02} approach f_L the decoupling circuits generate an

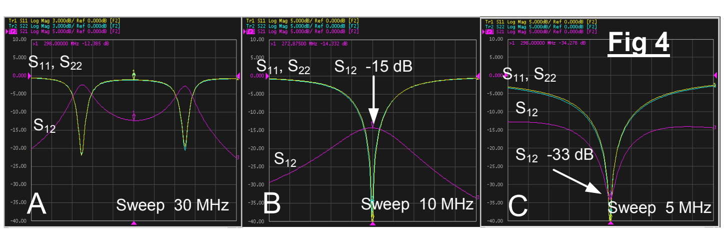


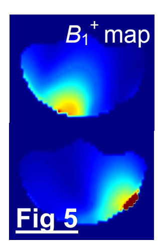


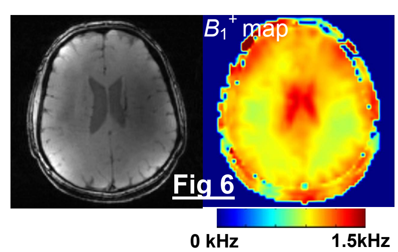


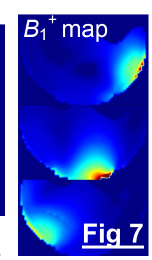
additional resistive coupling R_{12}'. While the surface coil (Fig.1B) adds to R_{12} by generating positive R_{12}', the "figure 8" coil produces negative R_{12}' compensating the R_{12}. Thus the "figure 8" coil can cancel both the reactive and the resistive components of the Z_{12}. Two current patterns shown in Fig.1 can be realized simultaneously using a double-tuned (f_1,f_2) 2-mode detuning coil. Figs. 2 and 3 present a low pass version of such coil. The higher mode ("figure 8") can be used to decouple adjacent double-tuned surface coils at ^{1}H frequency and the "surface" mode can provide decoupling at the lower X-nuclei frequency. However, only the higher mode can compensate the R_{12}. To verify the concept we constructed several ^{1}H arrays (2-coil array with two types of inductive decoupling; 8-coil array (19.5cm - width, 23cm - height) circumscribing the head with "figure 8" decoupling) and a 3-coil ^{31}P/^{1}H (120.7/ 298 MHz) double-tuned array based on the common LC-trap design. All arrays were constructed using non-overlapped surface coils of the same size (7.5 x 9cm^2).

Results: Fig.4 shows results obtained for ^{1}H 2-coil array with the surface coils: A) unloaded and coupled; B) loaded and decoupled using a common inductive (reactive only) decoupling; and C) loaded and decoupled using the "figure 8" resonant decoupling coil. When the array was loaded with a phantom located 4-5 cm away we could not obtain decoupling better than -15 dB using common inductive decoupling (Fig.4B). Using the "figure 8" decoupling coil (~20 mm dia., ω_L-ω_0 ≈10MHz) decoupling better that -30dB was obtained (Fig.4C). Fig.5 shows B_1^+ maps of individual surface coils









demonstrating excellent decoupling. For the 8-coil ^{1}H array we obtained decoupling on a human head better than -27dB for all adjacent surface coils and better than -20dB for all other surface coils. Figure 6 shows image and corresponding B_1^+ map demonstrating very good homogeneity. For the ^{31}P/^{1}H array we obtained decoupling better than -17dB at ^{31}P (120.7MHz) and better than -22dB at ^{1}H (298MHz) frequencies between all surface coils in the array using the double-tuned decoupling coil (Fig.3). Fig. 7 shows B_1^+ maps of the individual surface coils of the ^{31}P/^{1}H array obtained at 300 MHz.

Conclusions: We have developed and experimentally verified a novel inductive decoupling method using additional resonant coils, which compensates for both reactive and resistive components of the mutual impedance Z_{12} between two adjacent surface coils. We also demonstrated that this method can be utilized for decoupling of adjacent double-tuned surface coils at both frequencies simultaneously using a single double-tuned resonant decoupling circuit.