A Shielding-based Decoupling Technique for Coil Array Design

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Introduction

In parallel imaging, one of the principle issues in array coil design is minimizing coupling between coils in order that each element receives independent information and no interference with each other. Conventionally used decoupling techniques includes: (a) geometrical decoupling, such as 'overlap magic'; (b) capacitive or inductive networks; (c) using isolating preamplifiers. [1] These methods either place undesirable constraint on coil geometry or cause less efficiency of the preamplifier. In this work a new decoupling technique which takes advantage of shielding is presented. The shields are placed in two ways: (a) a ground plane; (b) a conductive 'screen track'; both can be easily mounted on conventional surface coils to significantly reduce mutual inductance. Compared with traditional decoupling techniques in phased array design, this shielding-based decoupling technique has two advantages: first, no additional decoupling circuit or modification of preamplifier is required which usually causes signal loss; secondly, it allows more flexible coil geometry, lending itself to geometry optimization in array coil design, especially in SENSE where 'overlap' has been shown unfavorable for g-map and SNR [2].

Method

The presence of a ground plane beneath the coil circuit plane can effectively reduce mutual inductance by reducing the coupling loop area of circuits [3]. At high frequency, a return current is induced in the ground plane due to the local field around the signal conductor. As such, the effective 'coupling loop area' is significantly reduced, as illustrated in Fig. 1. Quantitive analysis shows that coupling of two adjacent loop coils with ground plane can be expressed by Eq. (1).

$$Coupling \approx \frac{K}{1+(D/H)^2} \quad (1)$$

where the constant K depends on the length of the closely adjacent parallel runs. H is the distance between ground and the coil, D is the gap between elements.

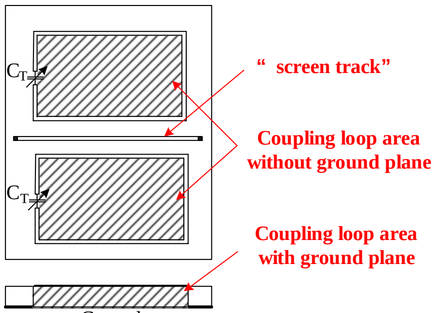


Fig. 1 A ground plane reduces the effective coupling loop area

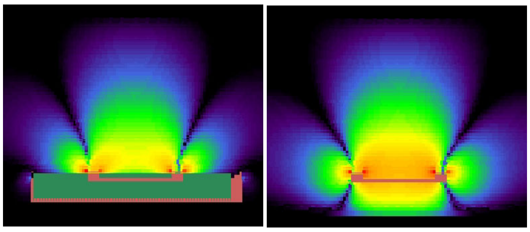
A conductive 'screen track', grounded at both ends, placed between the conductors (shown in Fig. 1) can give extra benefit for isolation, since any current induced in the screen produced a magnetic field which opposes the interference signal.

To further investigate the decoupling performance of shield, the magnetic fields were simulated and compared for two surface coils with and without shield using xFDTD software (REMCOM Inc.). To verify the effectiveness of ground plane and screen track respectively, we built two conventional surface coils (70×80mm, H=7mm) which are both tuned to 64 MHz and matched to 50 Ohm, and the values of S_{21} are measured with different distance for three kind of configurations: (a) without shield; (b) with ground plane; (c) with ground plane and a screen track.

Results

The simulated magnetic fields of a rectangular surface coil with and without ground plane are shown in Fig. 2. The results indicate that the shielded surface coil has more concentrated magnetic field, implying less interference between adjacent elements. Another benefit of the more localized magnetic field is that array elements having more orthogonal sensitivity profiles are more suitable for parallel imaging.

The S_{21} measurement results of three configurations are shown in Fig. 3. The curve shows that unshielded surface coils suffer from strong coupling; when a ground plane was added, S_{21} decrease by 10-20dB; appending the screen track can further reduce mutual coupling by 2-8dB. When the distance between the pair of coils reduce to 5cm, a frequency split appears for unshielded coils, while for shielded configurations, no frequency split is observed at all distances.



(a) (b)

Fig. 2 Simulated magnetic field of a rectangular surface coil: (a) with ground; (b) without ground

Discussion

From Eq. (1), it is clear that the decoupling performance of the ground plane is dependent on the distance H. The smaller is H, the better is the isolation between coils. However, when H decreases, the penetration depth of the coil also slightly decreases. As such, the ground plane should not be placed too close to the coil plane. In our experiment, when H>6mm, the ground plane gains a good decoupling benefit, while the reduction of RF penetration is negligible.

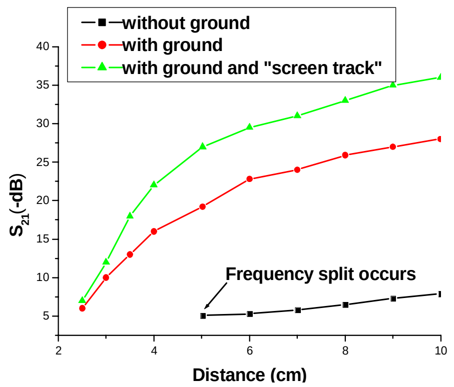


Fig. 3 S_{21} measurement of a 2-element array: (1) without shield; (2) with ground plane; (3) with ground plane and screen track. When distance<5mm, frequency split occurs for unshielded case.

Conclusion

A new decoupling technique which takes advantage of shielding for coil array design is proposed. A ground plane is used to reduce mutual inductance by reducing the coupling area of circuits; in addition, a 'screen track' is placed between adjacent coils to minimize magnetic interferences. This technique requires no modification of circuit and doesn't cause loss of flexibility of coil geometry design. Simulation and experiments were performed to verify the effectiveness of this method. The results show that a ground plane beneath surface coils can reduce mutual coupling by 10-20dB, and a 'screen track' can further provide a 2-8dB reduction of mutual coupling.

Acknowledgement

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