LC Decoupling Circuit for Arbitrarily placed Coils

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Introduction

The use of coil arrays has become widespread in applications for parallel MRI. The conventional decoupling technique of coil overlap leads to stringent constrains on how the elements are placed. This fixed overlap may not always be appropriate for parallel spatial encoding [1]. Some alternative decoupling methods are to insert capacitors or LC circuit networks between coils to minimize their mutual coupling [2-7]. To clearly illustrate the LC decoupling circuit, the technique by inserting decoupling-capacitors (*Cd*) or decoupling-inductors (*Ld*) for isolation arbitrary-placed coils was studied. Also we compared the decoupling performance by using *Cd* and *Ld* at different magnetic strengths.

Method

(1) Two coupled cases : The coupled coils can be simplified into two cases according to the current direction in each loop, i.e. the currents in primary and secondary coils have the opposite direction, thus the voltage in secondary coil increases caused by the induced current. In this case, the mutual coupling M has positive sign (M>0). On the contrary when the currents in primary and secondary coils have the same direction, M<0. Two typical examples are listed in fig.1. In fig.1a, when the angle between two loops are larger to 90º (a1), or the two coplanar loops are overlapped too less than the exact overlap, or separated without any overlap (a2), M>0. On the contrary, when angle between loops are less than 90º (b1), or the two loops are overlapped too much (b2), M<0.

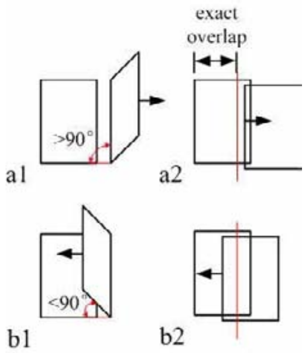

Fig.1. The two coupling cases. a1 and a2: M>0. b1 and b2: M<0.

(2) Decoupling LC circuit for M>0 and M<0: To illustrate the decoupling circuit more clearly, four decoupling methods are applied on loop pair which are overlapped too less (Fig.2a) and overlapped too much (Fig.2b). *C1* is the tuning capacitor defined as the figure shows. *C2* is the equivalent capacitors except *C1*.These methods can be explained by vector analysis [6]. Fig.3a illustrates the methods in fig.2a1-a4 and fig.3b illustrates the methods in fig.2b1-b4. I_i represents the induced current in the second coil, I_d is the additional current introduced by decoupling circuits to diminish I_i. I_t represents the induced current after decoupling. θ is the loss angle of the sample and δ is the loss angle caused by *Cd* or *Ld*.

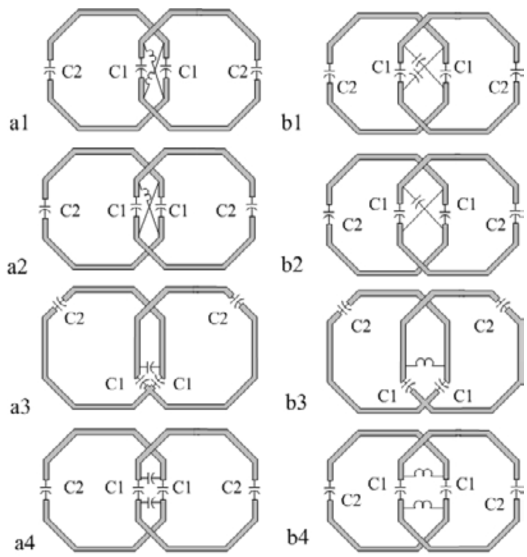

Fig.2. Coil pairs which are overlapped too less (a) and overlapped too much (b) are used to illustrate the decoupling techniques. Four circuits for each case are shown in 1-4.

Result

(1) Cd and Ld vs. resonant frequency: According to analysis models we established, relationships of the required *Cd* and *Ld* vs. resonant frequency are shown in fig.4. *L* represents the self-inductor of each coil. For the method by using inductors (in fig. 2. a1, a2, b1, b2), *Ld* is proportional to *L*. When the material and geometry of coils are fixed, *Ld* is independent of resonant frequency (fig.4c and d). While for decoupling capacitors (in fig.2. a3, a4, b3, b4), *Cd* is proportional to $1/(L\omega^2)$ (fig.4a and b). Thus at ultra-high-field or very-low-field system, *Ld* is easier to implement than *Cd* since in these frequency ranges, the value of *Cd* is sometimes with unreasonable value for choosing.

(2) Coil isolation and SNR by using Cd and Ld: According to fig.3, the loss of the inserting circuits can decrease the coil isolation. Due to δ of *Ld* is usually larger than that of *Cd*, at low field when coil loss is dominant, the isolation and SNR by using *Cd* is better than *Ld*. While at high field when sample loss dominant (θ>> δ), both methods by using Ld and *Cd* have the similar performance.

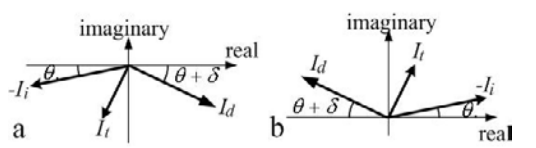

Fig.3. Vector analysis of the decoupling techniques. The explanation of the case when M>0 (fig.3a) and the case when M<0 (fig.3b)

Conclusion

The LC circuits in fig.2 can be used to isolate coil pairs and can be extended to decouple arbitrarily placed multiple coils by inserting the LC circuit between each pair. At low field, *Cd* can provide better isolation than *Ld*. At high field, method by using *Ld* is an alternative of *Cd*.

Reference

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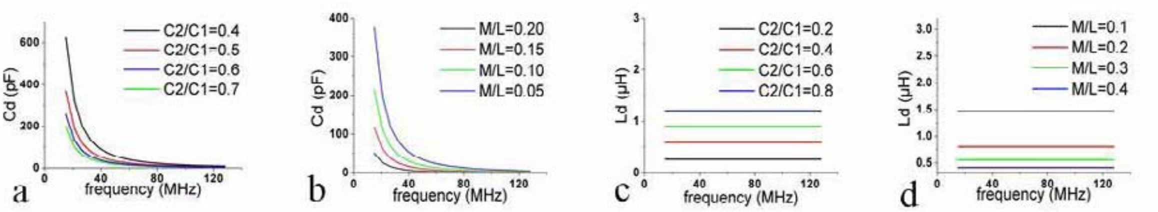

Fig.4. Relationships of *Ld* and *Cd* vs. frequency. Assuming *L*=0.5μH. *M* is absolute value of mutual inductance. In a and c, set *M/L*=0.1. In b and d, set *C2/C1*=1.