Capacitor/Inductor Decoupling and Its New Application to Microstrip Array

B. Wu[1], and X. Zhang[2,3]

[1]Coil Engineering, GE Healthcare, Wauehsha, WI, United States, [2]Radiology and Biomedical Imaging, UCSF, [3]UCSF/UC Berkeley Joint Graduate Group in Bioengineering, San Francisco, CA, United States

Introduction

Transformer or capacitor is often required to electromagnetically decouple the gapped loops, non-adjacent loops, or microstrip resonators in RF coil arrays when conventional coil overlapping is not applicable. The capacitor decoupling is superior to the transformer decoupling due to its negligible losses and B1 field leakage, thus the better SNR and less B1 distortion caused by the decoupling circuit are expected. Since the mutual inductance between coil elements cannot be canceled (but compensated) by an inductor/capacitor (L/C) decoupling circuit, the decoupling adjustment, especially for coils with high channel count, will be challenging. In this abstract, we analyze the general L/C decoupling circuits and suggest the use of inductor for decoupling at high fields. Based on the circuit analysis, a new inductive decoupling method is proposed for designing microstrip arrays at high magnetic fields.

Method

The general capacitor decoupling circuit is shown in Figure 1 (middle). Both C_{d1} and C_{d2} can be adjusted for decoupling, although only C_{d1} is often used in practice (right insert in figure 1). Like the capacitor in a LC resonator, C_{d1} is proportional to $1/\omega^2$, where ω stands for the resonance frequency. At ultra-high fields, small C_{d1} is usually sensitive to the parasitic capacitance from the loading. To increase the stability of the coil isolation, larger C_{d1} is needed. Larger C_{d2} is helpful to increase the required C_{d1} according to the following equation:

$$C_{d1} = C_{d2}\frac{2\omega^3 LKC_{d2}}{1-2\omega^3 LKC_{d2}}$$, for $1>2\omega3LKC_{d2}$,

where L is inductance of each coil element, K is coupling coefficient.

Further increasing C_{d2} results in $2\omega 3LKC_{d2}>1$. In this condition, interconnecting inductor is required for decoupling. Note that the B_1 flux in the interconnection inductors has no contribution to decoupling such that one can shield each inductor or make it “invisible” to minimize its impact on B_1 field.

When C_{d2} is adjusted to meet $2\omega 3LKC_{d2}=1$, i.e. $C_{d1}=\infty$, it will be the commonly used decoupling circuit shown in figure 1 (left insert).

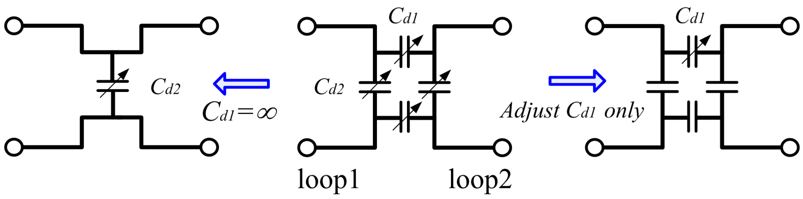

FIG 1. The general capacitor decoupling circuit (middle) can be simplifed into: shared capacitor in a common wire (left) and decoupling capacitors across the loops (right).

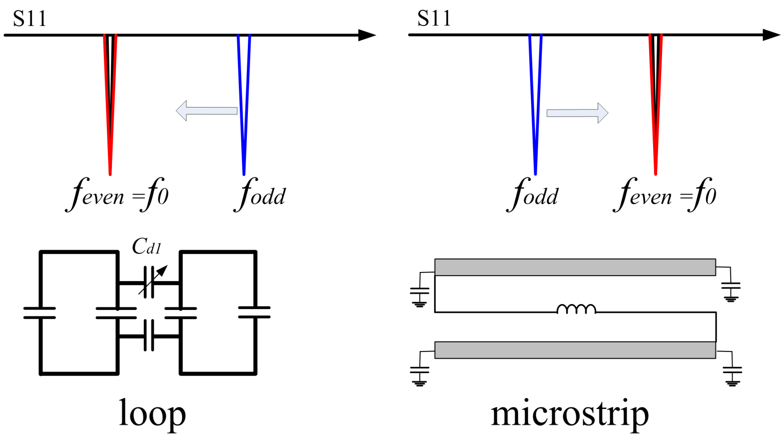

FIG 2. $f_{even}<f_{odd}$ for gapped loops, $f_{even}>f_{odd}$ for microstrip coils

Figure 2 demonstrates how to optimize the decoupling adjustments for gapped loops and microstrip coils. The mutual inductance in the gapped loops is positive. Without placing C_{d1} across the loops, the lower peak in the split peaks is called even mode peak, which will not be changed with C_{d1}. If one tunes each loop individually to a certain frequency higher than f_0, such that the mutual coupling splits the peaks and make the lower peak (even mode) locate at the desired frequency, one can only adjust C_{d1} to make the higher frequency (odd mode) move towards the even mode, and easily achieve the decoupling condition (Figure 2 left).

The decoupling adjustment for microstrip coils is different due to the negative sign of mutual inductance between microstrip coils. Without placing the decoupling circuit between the coils, even mode peak is higher than the odd one. If the even mode peak is at the desired frequency, one can place an inductor across the strips for decoupling. Through adjusting the inductance, the odd mode frequency increases and finally reaches the even mode frequency (Figure 2 right insert).

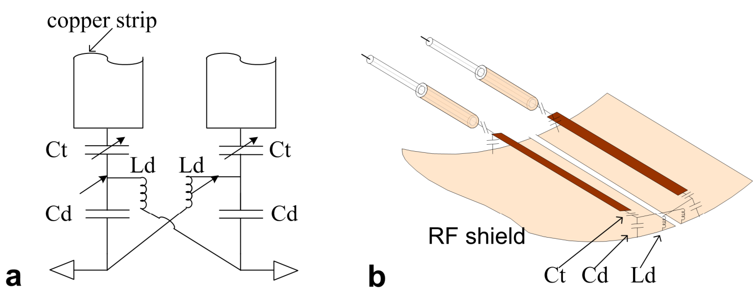

FIG 3. The proposed inductive decoupling method for microstrip array

The use of an inductor has unique advantages for ultra-high field MRI. Unlike capacitors, the decoupling inductance is independent of the resonance frequency, thus the inductor used is expected to be more stable at ultra high fields.

New inductive decoupling for microstrip array

Figure 3 shows an improved inductive decoupling without using long wires shown in Figure 2 right insert. This decoupling scheme is applicable for the nearest coil elements and next nearest elements. Inductor L_d is connected from the shunt capacitor C_d in one element to the ground plane of its nearest neighbor. As what we analyzed in the previous section, C_d, L_d or both can be adjusted for decoupling. Ct is a frequency tuning capacitor, which is used to compensate for the C_d changes in the element. Compared with capacitive decoupling [3], this new method may result in lower cost and higher stability to the loadings at ultrahigh fields.

References [1] U.S Patent 5,804,969 (1998) [2]. JMR 182 (2006) 126-132 [3] MRM 53 (2005) 433-445