Tunable Loop Microstrip (TLM) Coil Array with Decoupling Capacitors

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INTRODUCTION

Minimizing the mutual coupling among array elements is necessary for parallel MRI. Preamplifiers with extremely low input-impedance [1] and capacitive decoupling networks [2, 3] have become the primary techniques for decoupling arbitrarily placed coil array elements. However, the low input-impedance preamplifier is not suitable in transmit mode, and capacitive decoupling networks may cause design difficulties for large number of elements [4]. In this paper, we show that the tunable loop microstrip (TLM) coil array [5, 6] with decoupling circuit can achieve more than *-20dB* element isolation. The decouple circuit in our design is quite simple, only *n* decoupling capacitors are needed for *n* elements. Thus, it is suitable for arrays with large number of coils and for transceivers.

METHOD

The TLM coil array shown in Fig.1 is a series of TLM coils linked by decoupling capacitors. Each TLM coil consists of a conductive loop and ground plane separated by low loss dielectric material. The section in the square box of Fig.1 illustrates the decoupling method, where C_T and C_D are tuning and decoupling capacitors, M and L denote the mutual inductance and equivalent self-inductance of each coil respectively. According to even/odd mode analysis, when two resonant mode frequencies $f_e = f_o$, the mutual inductive coupling of adjacent elements diminishes [7]. Then, the required C_D can be calculated as:

$$C_D = 2C_T M /(L - M) \quad (1).$$

The mutual coupling among non-adjacent elements is much weaker than that of the adjacent pair. If the spacing of the non-adjacent elements is large enough to satisfy the broadband decoupling condition [5], they can be intrinsically decoupled. Thus only *n-1* decoupling capacitors are needed for *n* elements of planar structure.

EXPERIMENT AND RESULT

We built a 4-element receive-only TLM coil array at 1.5T, which is shown in Fig.2. The coils were *9cm×9cm* in size with *2.9cm* coil spacing. All coils were built using *1.27cm* wide copper tape and *10mm* thick teflon as substrate. Without decoupling circuit, the adjacent elements are strong coupled and their frequencies spit, which is shown in Fig.3 (a). After mounting and varying decoupling capacitor C_D, only the f_o is shifted with C_D. Fig.3 (b) and Fig.3(c) show that f_e keeps at 63.88MHz while f_o is shifted. This characteristic is much helpful for decoupling adjusting especially when the number of elements is large. Fig.3 (d) shows that after decoupling, the *S21* between adjacent elements was better than *-20dB*. *S21* between any elements range from *-20dB~-35dB*. This 4-element coil array was tested in GE 1.5T system. Phantom (*0.9%* sodium chloride) with the size of *5.5×8×8cm*^{3} was placed above each element of the TLM coil array. Fig.4 shows excellent decoupling performance between the neighbor elements. When the left element was excited, only *5.6%* signal power was transferred to its nearest neighbor.

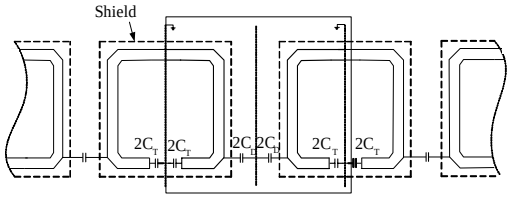

Fig.1. Schematic illustration of the TLM coil array with capacitive decoupling circuit.

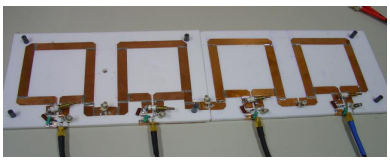

Fig.2. Photo of 4-element receive only TLM coil array.

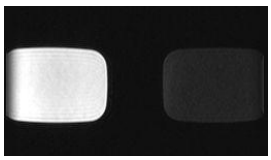

Fig.4. FSE image of phantom by 2 element of TLM coil array. TR=500ms, TE=15ms, 5mm slice thickness, FOV=20×20cm. The left element was excited.

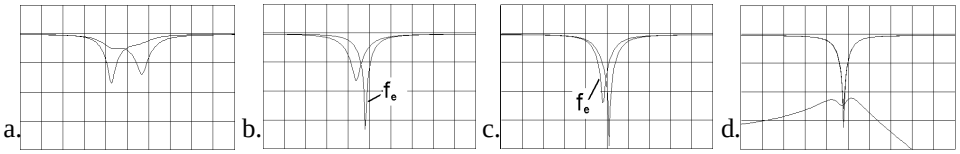

Fig.3. (a): *S11* parameters of 2 adjacent elements without decouple capacitor. (b): and (c): S11 parameters of the 2 elements after mounting and tuning the decouple capacitor. (d): *S11* and *S21* parameters for the pair after decoupling. The horizontal axes in a-d are all frequency-centered on *64MHz*, with a span of 5MHz. The vertical increment is *10dB*.

CONCLUSION AND DISCUSSION

The TLM coil array with decoupling capacitors has been introduced in the paper. It can be not only used for receive-only mode, but an excellent choice for transceivers as well for parallel MRI. The decoupling circuit is quite simple and easy to be adjusted, so it is suitable for arrays with large number of elements. Besides planar structure, it could be wrapped around a cylinder to form a volume coil array.

ACKNOWLEDGMENTS

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