A new array design using tunable loop microstrip (TLM) coil

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Introduction:

Mutual decoupling is an important issue for coil array design. Generally, element overlap, decoupling network and isolating preamplifier are normal approaches for maximizing the decoupling. Recently, parallel planar straight-line strip array, an inherently decoupling design, has been introduced [1, 2]. However, its geometry critically depends on substrate dielectric properties thus its applications are limited. To solve this problem, we have developed a novel tunable loop microstrip (TLM) coil [3], which can achieve higher Q factor and less frequency shift with loading than microstrip straight-line resonator. Capacitance tunning and matching are allowed which makes it much easier to design and fabricate than microstrip straight-line coil, and coil geometry can be selected much more flexible. With the advantage of intrinsical decoupling performance, the TLM arrays have great potential in MRI applications.

Method:

Schematic diagram of 2-element TLM array is shown in Fig.1. C_T and C_M are tuning and matching capacitor respectively. The dimension of each element is 12.0cm × 8.8cm with 1.25cm width copper tape. Teflon with thickness of 6mm is used for the substrate.

(a). Coupling Theory: For 2-element TLM coil, coupling of nonadjacent parallel lines are very weak (<-40dB) that can be ignored. Microstrip coupling between two parallel microstrip lines can be analyzed with quasistatic even/odd mode theory [4]. The scattering parameter, S_{21} represented their mutual coupling can be expressed as the follows,

$$S_{21} = \frac{jC\sin\theta}{\sqrt{1-C^2}\cos\theta + j\sin\theta}, \text{ where } C = \frac{Z_{0e}-Z_{0o}}{Z_{0e}+Z_{0o}},$$

θ is the electric length of coupling section. Z_{0e} and Z_{0o} are the characteristic impedance on even/odd modes respectively. For $C \ll 1$, $|S_{21}| \approx \sin(\omega l\sqrt{\varepsilon_{eff}}/c)$ where l, c, ε_{eff} are coupling length, light speed in free space, effective permittivity respectively. Based on quasistatic even/odd mode empiristic equations [5], the relationship between S_{21} and $g=s/h$ (s is the gap between two parallel lines, h is the thickness of microstrip) is illustrated in Fig. 2. S_{21} is less than –20 dB as g>3.

(b). Experimental comparison: The 2-element TLM array and conventional surface array with the same geometry were implemented for comparison. Both arrays operate at 63.88MHz. Frequency splits with different gaps between elements were measured with HP 8753C network analyzer.

The frequency splits versus gap between elements are shown in Fig.3. The resonant frequency of conventional surface array and TLM array begin to split into two frequencies when the gap is smaller than 13cm and 3.5cm (in unload case) respectively. Comparison results show that the decoupling of TLM array is –10dB to –20dB more than that of the conventional surface array.

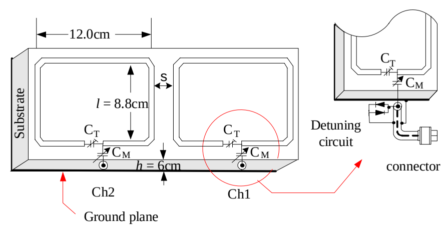

Fig.1. Schematic diagram of 2-element TLM array

In vivo experiment and result:

The 2-element TLM array was tuned and matched for cardiac imaging at GE Signa 1.5T. The gap between elements is 3.8 cm. The array was bent to fit the human chest. The isolation between the coil elements was measured as –22dB with loading. Fig. 4 (a-c) is cardiac images of a healthy volunteer obtained using this 2-element TLM array.

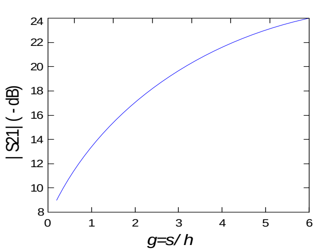

Fig.2. Relationship of S_{21} and s/h. (coupling length l is 8.8cm)

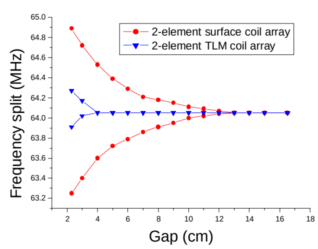

Fig.3. Frequency splits of 2-element TLM array and conventional surface array for different gap between elements.

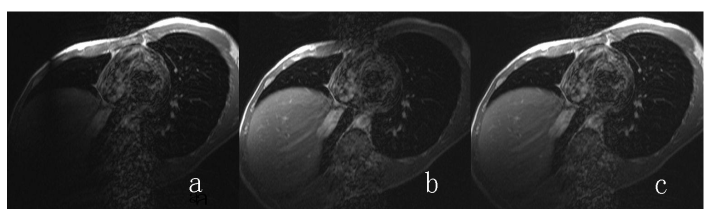

Fig.4. FSE human cardiac image for a healthy volunteer with two-element TLM array at 1.5T. Slice thickness= 5mm, TR= 1018.92ms, TE= 27ms. Fig 4(a), (b) and (c) are the images from left element, right element and their combination respectively.

Conclusion:

Theoretical analysis and experiments show that the decoupling of TLM array is much better than the conventional surface array. This effectiveness of the TLM array is further demonstrated by 1.5T cardiac images. The new design can be easily extended to 4 or more channels array. Without overlap of array elements TLM array will be particularly useful for parallel imaging applications.

Acknowledge:

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