16-channel microstrip array using 1st and 2nd harmonics for parallel imaging at 7T

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Introduction

High field parallel imaging, as a promising imaging modality, offers high spatial resolution and high temporal resolution simultaneously [1]. However, design of required high frequency parallel RF coil arrays, especially dense-spaced human coil arrays, faces many daunt technical challenges in attaining sufficient EM decoupling, image homogeneity and better geometry factors (g-factor). In this work, we propose a novel technique for the array design using the 1st and 2nd harmonics of microstrip resonators [1-3]. This technique provides an improved image homogeneity, intrinsic element-decoupling that allows of increased channel number, and better parallel imaging performance with reduced g-factor. Based on the proposed technique, a 16-ch microstrip array with alternatively placed 1st and 2nd harmonic resonance elements was designed and tested for 7T parallel imaging applications. Bench test results and 7T MR imaging were shown.

Method

Fig. 1 shows the circuits (left), equivalent circuits (middle) and current distribution (right) of microstrip coils with first, second and fourth harmonic resonances. Based on their equivalent circuits, the mutual coupling among microstrip coils with 2^n (n = 0, 1, 2…) harmonics is equal to zero if they are placed in parallel. The microstrips with 1st, 2nd and 4th harmonic resonance are therefore able to be closely placed without resort to decoupling capacitors or inductors [1, 2] and do not have to obey the microstrip decoupling conditions [4]. Note that n-th order harmonic resonance has n+1 current nodes [3]. The MR images associated with the B_1 fields and the current distributions are shown in Fig 2.

Microstrip coils with combined 2^n harmonic resonances are helpful to shape the B_1 field distribution, so as to obtain better field homogeneity along the strip direction. Fig 3 shows the B_1 fields along strips resonated at 1st, 2nd harmonics and their Sum-of-Square (SoS) combination. The red curve in Fig 3 demonstrates that the combined sensitivity is uniform within the distance of half of the strip length.

To demonstrate the proposed technique, a 16-ch microstrip volume array is then built for 7T human head imaging. This array includes 8 elements with 1st order harmonic and 8 elements with 2nd order harmonic. Array elements with those two resonance modes are alternatively placed around an acrylic cylinder with 22.0 cm inner diameter (Fig. 5). Length of each element is 16.0 cm; Width of strip conductors and ground are 1.25cm and 3.3cm, respectively; Substrate thickness is 1.25cm. The inner gap between the adjacent elements is 3.5 cm. All elements are tuned to 298.1MHz. MR experiments were performed on a GE 7T scanner. A head/neck cylindrical water phantom (length: 40cm, diameter: 20cm) was used for imaging.

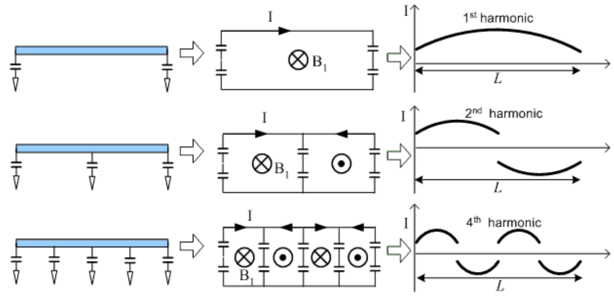

Fig 1. Circuits of microstrip coils with 1st ,2nd and 4th harmonic resonance (left), equivalent circuits based on mirror theory (middle), and current distribution along strips (right).

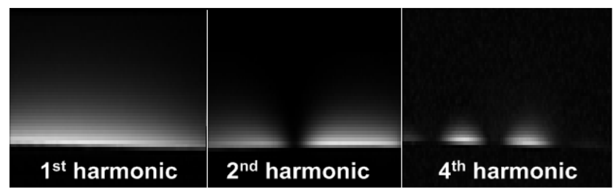

Fig 2. Sensitivity profiles of microstrip coils with 1st, 2nd and 4th harmonics. Images were obtained at GE 7T scanner with an oil photom.

Results

Fig. 4 shows the isolation between the adjacent resonators. After slightly adjusting the elements position, the nearest elements with the 1st and 2nd harmonics were well isolated with more than -22dB. Coupling among non-adjacent elements was minimized by the distance. S21 of all elements were better than -18dB.

Phantom images in coronal plane were collected using each element. Figure 6a shows the images from 8 elements with 1st harmonic resonance, those images were obtained by combining 8 sub-images with SoS method. Its field distribution is similar to a regular 8-element microstrip array [1]. While Fig 6b shows the images from 8 elements with 2nd harmonic resonance. After the combination of all 16 elements (Fig 6c), this array has the same B_1 field penetration as that of a regular 8-element microstrip array but has broader coverage along SI direction.

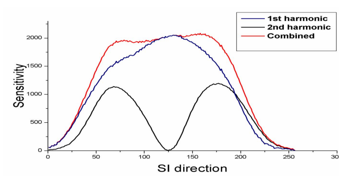

Fig 3. Plot of coil sensitivities (1.5 cm higher than coil planes). The combination sensitivity is homogeneous along strip direction.

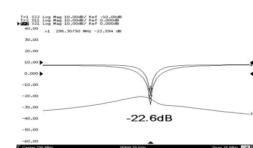

Fig 4. In the 16-ch microstrip array, adjacent elements with 1st and 2nd harmonic resonance are intrinsically decoupled with more than -22dB.

G-factor maps in coronal plane with left-right (L/R) phase encoding direction were calculated based on our simulation results. For fair comparison, g-map from a regular 16-channel microstrip array with the same configuration was also calculated. G-factor maps for reduction factor 3 (R=3) are shown in fig.7. Due to variable sensitivity profiles of the adjacent elements, the head array we proposed is better than the regular microstrip array in terms of average and maximum g-factor values.

Conclusions

This work illustrates that the use of 1st and 2nd harmonic resonators can improve the B_1 homogeneity, EM decoupling among the elements in parallel imaging arrays, and reduced g-factors which potentially enhance the parallel imaging performance.

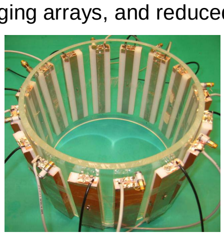

Fig 5. Photo of 16-element microstrip array.

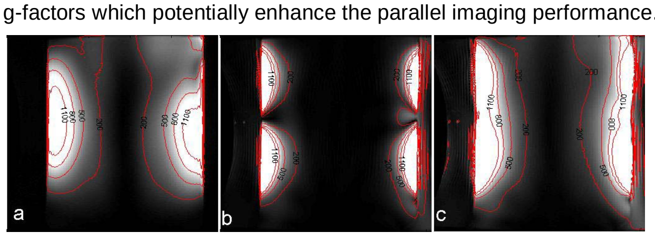

Fig 6. Coronal image of 8 elements with 1st harmonic(a), 8 elements with 2nd harmonic(b), and their combination(c). GRE, 24*24cm, TE6.8ms. TR800ms. Slice thickness=3mm, TG=20 for 1st harmonic resonators and TG=40 for 2nd harmonic resonators. A 10dB attenuator is used.

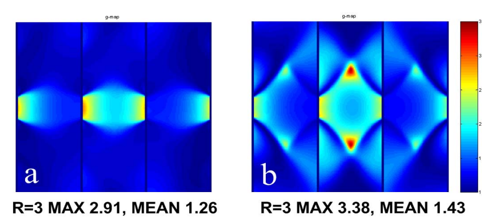

Fig 7. G-factor maps in coronal plane based on simulation. a: g-map from a 16-ch microstrip array with 1st and 2nd harmonics. b: g-map from 16-ch microstrip array with 1st harmonic elements. R=3.

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References [1] Adriany G, et al. MRM 53 (2005), 434-445. [2] Wu B. et al JMR 182 (2006) 126-132. [3] Zhang X, et al, MRM 53 (2005) 1234-1239. [4]Lee R, et al. MRM 45 (2001) 673-683.