Short hybrid micro-strip coils

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Introduction: Microstrip receiver coils are typically designed as half-wave or quarter-wave resonators that are aligned along the axis of the static magnetic field B0 [1,2]. The relatively long wavelengths at imaging frequencies of 63.8 MHz (1.5T) or 127.7 MHz (3.0T) therefore result in coils that are too long (e.g. ~ 1 m for half wave resonators at 1.5 T) to fit multiple coils in the superior/inferior (S/I) direction, and so these receivers are typically only arrayed in the left-right (L/R) and/or anterior/posterior directions [1,2]. This decreases their utility, because parallel imaging with acceleration in the S/I direction is precluded. In this work, we develop short microstrip receivers for 3 T, and demonstrate their use for parallel imaging with S/I accelerations. The length of the microstrips is reduced using two different methods: 1) a hybrid design incorporating lumped elements and 2) a design that alternates between microstrips and coax lines of the same characteristic impedance.

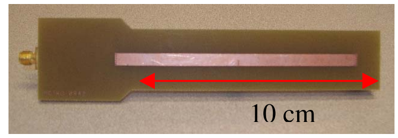

Fig. 1. Hybrid microstrip receiver. Lumped elements are hidden on other side.

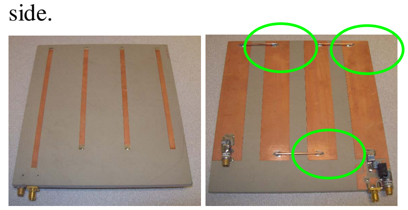

Fig. 2. Microstrip-coax design: Left - imaging side; Right - ground plane and coax sections (green circles).

Methods: The lumped-element microstrip (design #1) is a cascade of two quarter-wave sections, resulting in a half-wave resonator. (This is different from a previous lumped-element design [3] that used air as the dielectric.) Each quarter-wave section was tuned by a lumped capacitor at each end of the microstrip, following a method used to reduce the electrical length of transmission lines [4]. With use of two equal capacitors at each end of a microstrip transmission line, the electrical length can be tuned to a quarter-wavelength, using equations (1) and (2). Here Z and θ are the characteristic impedance and electrical length of the original transmission line, C is the tuning capacitance needed to achieve a quarter wavelength, and Zc is the characteristic impedance of the resulting quarter-wave line [4]. The cascaded half-wave section then has three lumped elements, with equal lumped capacitance at either end and a lumped capacitance of twice that value at the center. The overall length of the resonator is 10cm.

$$Z = Zc / \sin\theta \qquad (1)$$

$$\omega C = \cos\theta / Zc \qquad (2)$$

The microstrip receivers were manufactured using a low-cost substrate material Nelco 4000-6 (Park Electro-chemical, NY, USA). The substrate thickness was 5 mm, the width of the microstrip was 5mm and the width of the ground plane 3cm. The resonator was tuned to a half wavelength and matched to 50 ohms using variable capacitors. A picture of the resonator is shown in Fig. 1.

In the second design, a microstrip is divided into four parallel sections. Neighboring sections are connected with coaxial cables at alternating ends, resulting in a structure that snakes back and forth (Fig. 2). The coaxial cable is selected to have the same characteristic impedance as the microstrip and has a smaller diameter to facilitate a compact design. The lengths of the microstrip sections and the coaxial sections are selected so that the overall electrical length is a multiple of a half wavelength. At the end of the last microstrip section (Fig. 2), an additional variable capacitor to ground can be used for minor adjustment of electrical length. The coaxial sections do not acquire NMR signals or thermal noise from the imaging object due to the outer shield of the cable. The microstrip-coax receivers were manufactured using Rogers RO3210 substrate material (Rogers Corp, CT, USA). The substrate thickness was 5 mm and microstrip width 5 mm. The outer diameter of the coaxial cable was 1.8 mm and the characteristic impedance 25 ohms, which matches the characteristic impedance of the microstrip sections when loaded.

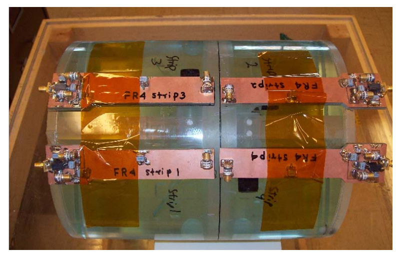

Fig. 3. 2x2 array on phantom.

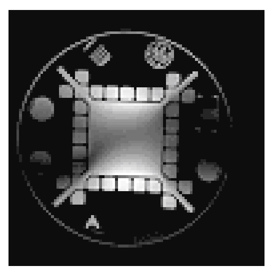

Fig. 4. Image acquired from microstrip-coax design

Four resonators of design #1 were placed in a 2x2 array (in the L/R and S/I directions) on a standard head phantom for imaging (Fig. 3). The phantom and array were placed in a 3.0T scanner (Signa, GE Healthcare, WI, USA) and images from each channel were acquired. Parallel imaging was performed, with an acceleration factor of x2 in the S/I direction. The same phantom was then tilted on its end, and a 2x2 array of design #2 was placed on top, and coronal images acquired.

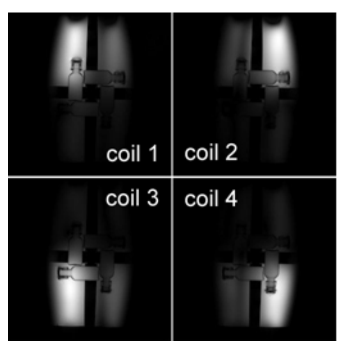

Fig. 5. Images from each of 2x2 array of lumped-element microstrips.

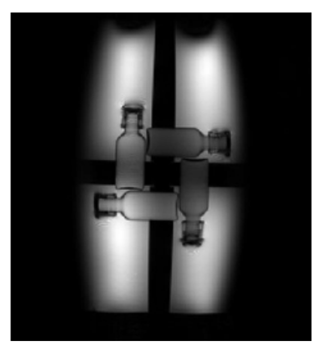

Fig. 6. Reconstructed image with x2 under-sampling in S/I direction.

Results: A coronal plane image acquired from the microstrip-coax design, with the phantom stood on-end, is shown in Fig. 4. Coronal images acquired from each coil of the lumped-element microstrip array are shown in Fig. 5. A reconstructed image, after parallel imaging with a reduction of x2 in the S/I direction, is shown in Fig. 6.

Conclusions: Hybrid microstrip designs allow tuning of the length of the coils by use of lumped elements or interleaved coax sections, allowing them to be arrayed in the S/I direction. This should increase their versatility, making them useful for parallel imaging with acceleration in any direction.

References: [1] Lee, R. F., et. al., Mag. Res. Med., 45:673-683 (2001) [2] Adriany G, et al. Magn Reson Med 53:434-445 (2005). [3] Lee, R. F., et. al., Mag. Res. Med., 51:172-183 (2004) [4] Mongia, R., et. al., "RF and microwave coupled line circuits", Artech House, 1999