A mechanically tuned 8-channel microstrip array for parallel transmission at 7T (297MHz)

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Introduction: Microstrip have been developed due to specific features: high Q factor, low mutual coupling (often used at high field MRI for parallel imaging), and radiation losses are significantly reduced (which enhances SNR). Balanced feeding of the microstrip preserves the electrical symmetry with respect to the strip center, making the probe invariant under different loading conditions (different subjects). The aim of this study is to present a novel 8-channel microstrip array designed for RF shimming and parallel transmission. The new design is tuned by adjusting the gap between ground plane and strip, and introduces a symmetric feed via a lattice balun [3] removing the need to match the probe to each subject.

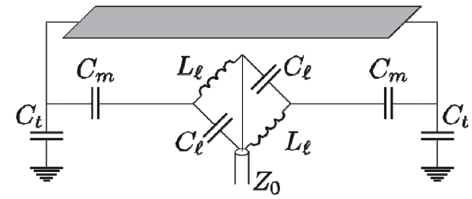

Figure 1: Balanced driving circuit resonating at 290MHz with L_l=26.5pF and C_l=10.5pF.

Materials and Methods: Each strip element consists of a 135×15mm^2 microstrip over an 80×190mm^2 ground plane. The strip is electrically shortened by capacitors at each end. An air dielectric is used to maximize the magnetic field above the strip. Tuning is achieved by adjusting the gap between strip and ground plane (fig. 2). The strip is symmetrically fed from each end using a lattice balun (fig.1) [1]. The lattice is tuned to 290 MHz, which is close to the strip resonance (297.2MHz) but far enough away to avoid strong coupling to the strip. The strip is matched to the balun with fixed capacitors. All components were mounted on the back of the ground plane to reduce interaction with the strip and minimize SAR. Eight strip elements were placed on an octagonal holder (inner Ø235mm, outer Ø285mm). Full wave simulations (Microwave Studio, CST) were used to optimize the strip dimensions using a single strip, loaded with a spherical saline phantom (Ø170mm, ε_r=60, σ=0.5S/m); coupling between strips was then investigated by simulating the full eight strip array. S_{11} and S_{21} were measured with a network analyzer (E5071C, Agilent) and images acquired with a Siemens 7T human scanner using standard Gradient Echo sequence (TE=1000ms, TR=9ms). B_1 maps were acquired using a Sa2rage sequence (TE=1.38ms, TR=2s) [2], transmitting and receiving with one strip in the presence of two neighboring elements (fig. 3.E and F).

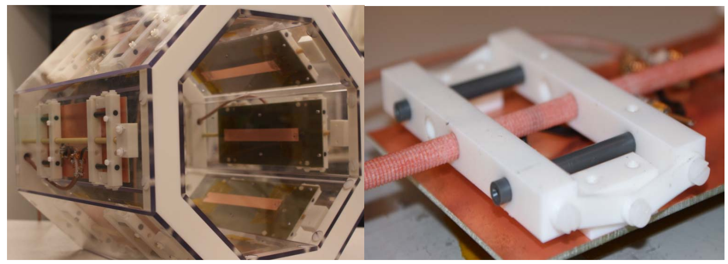

Figure 2: 8-channel microstrip array and the tuning mechanism.

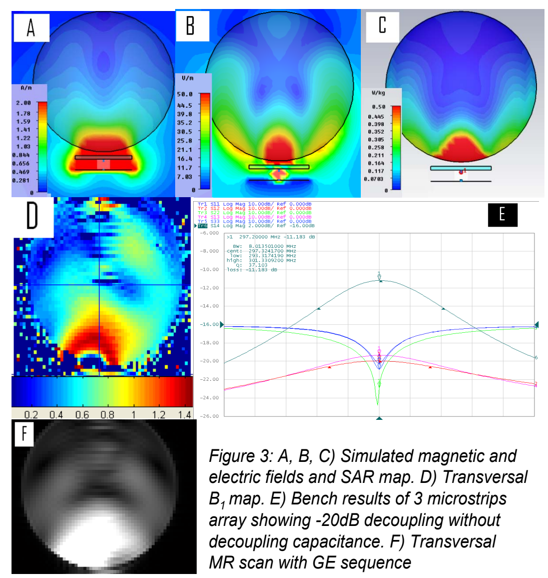

Figure 3: A, B, C) Simulated magnetic and electric fields and SAR map. D) Transversal B_1 map. E) Bench results of 3 microstrips array showing -20dB decoupling without decoupling capacitance. F) Transversal MR scan with GE sequence

Results and Discussion: A single element was first studied using variable tuning and matching capacitors on the bench. We then fixed the capacitor values to C_t=4.8pF and C_m=1.5pF. The gap between strip and ground plane is adjustable from 5-12mm, giving a tuning range of 290-323MHz. Matching (S_{11}) remains at approximately -24dB over this range, without changing the matching capacitors. The three-element array gives a match of -23 to -30dB with Q_L=37 for loaded case (for the middle element, fig. 3.E). If the strip is badly matched, the measured Q will be that of the balun rather than the strip; to avoid this, Q was measured with the sniffer loop (Ø20mm) placed near the strip. A ratio of unloaded to loaded Q_U/Q_L=65/37=1.8 was measured, suggesting that strip loading could be improved. Nonetheless MR images show that the penetration depth is sufficient (fig. 4). Coupling between nearest neighbors was measured at -22dB (loaded), and for the next nearest neighbors at -17dB. These values were obtained without decoupling capacitors between the elements. Figures 3.A, B and C show simulated magnetic and electric fields and SAR map for the strip. B_1^+ penetrates 60mm inside the phantom and the E field is high at the end of the strip end but doesn't penetrate far inside the sample. There is good correspondence between the simulated and measured B_1 map (fig. 3.A and D). B_1^+ values in fig 3.D are presented relative to the intended B_1^+ at a particular reference voltage. The absence of magnetic field above the neighboring strips clearly demonstrated that the strips were sufficiently decoupled (fig. 3.F). To study the strip efficiency, we ran a Gradient Echo sequence (TE=1000ms, TR=9ms) of a cylindrical saline phantom (Ø160mm, L=360mm). The balanced circuit maintains the impedance symmetry and thus current is distributed symmetrically along the strip, as shown by the symmetry of the image profile (fig. 4). Penetration inside the load was around 65mm and the extent of the pattern was 160mm. This suggests that the 8-channel TX transmission line array will be well suited for parallel transmit imaging and RF shimming.

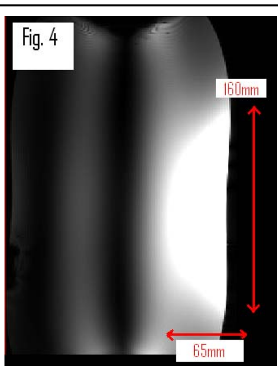

Figure 4: Sagittal MR scan done with GE sequence with one strip element. The pattern is symmetric and penetrates 65mm inside the load.

References and Acknowledgements: [1] A.W. Magill *et al* ISMRM (2010) [2] F. Eggenschwiler *et al* ISMRM (2010) [3] J. Mispelter *et al* IPC (2006).

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