Optimization of B1 field homogeneity along the longitudinal direction for 7T MTL resonators by using a multi-row design

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INTRODUCTION Transmit/receive microstrip transmission line (MTL) array has been widely used for ultrahigh field MRI due to its improved resonance stability and reduced radiation losses [1-4]. However, the $B1^+$ homogeneity of the MTL resonator along the longitudinal direction decreases as its length increases. In this work, we used a double-row MTL design to generate more homogeneous $B1^+$ field along the longitudinal direction by varying the terminated capacitance distribution. The coupling between elements of adjacent rows was reduced by using the induced current compensation (ICE) decoupling method [5, 6]. Full-wave electromagnetic modeling (HFSS, ANSYS, Canonsburg, PA, USA) was used to study and compare the performances of the new design and the conventional MTL resonator.

MATERIALS and METHODS For the double-row MTL design, two identical elements using Teflon (length 10cm, thickness 1.5cm) were placed 1cm apart, as shown in Fig. 1c and 1d. The width of the strip and ground was 1cm and 4cm, respectively. The decoupling element with one capacitor (Cd) at both ends was applied to reduce the coupling between the two elements. A cylindrical water phantom (length 37cm, diameter 16cm, σ: 0.59S/m, ε_r: 78) was placed 4.5cm below the coil element (Fig. 1e). As shown in previous work, the current distribution and magnetic field distribution along the longitudinal direction are stronger near the end with greater terminated capacitance [7]. In this study, we set the Ct2 with

Figure 1: a) Equivalent circuit of a conventional MTL element. b) 3-D model of a conventional MTL element. c) Equivalent circuit of a double-row MTL array with one decoupling element. d) 3-D model of a conventional MTL element. e) Geometrical position of water phantom vs. the coil. element.

different values (30pF, 20pF, 12pF, 8.8pF and 5pF, respectively) to optimize the B1 filed homogeneity along the longitudinal direction. A conventional MTL resonator with the same dimension was also simulated for comparison (Fig. 1a and Fig. 1b). For the conventional MTL element, two capacitors (Ct1, Ct2) were set with the same value to generate a symmetrical $B1^+$ field. 1W was excited for each element of the double-row design with an 180 degree phase shift and 2W was excited for the conventional MTL resonator. The homogeneity of the B1 map was quantified to evaluate the homogeneity improvement of the proposed design. The $B1^+$ homogeneity was defined as: $\mathbf{Homogeneity\_{B1}^+ = (1-(B1^+_{max}-B1^+_{min})/(B1^+_{max}+B1^+_{min}))\times 100\%}$. $B1^+_{max}$ and $B1^+_{min}$ are the maximum and minimum magnitude of $B1^+$. Full wave EM simulation software HFSS was chosen as the 3-D simulation tool and RF optimization software Agilent ADS was used to generate the values of all capacitors [8]. All coil elements were matched to 50 Ohm (S11<-30dB) and the isolation of two elements of the double-row design was better than -20dB.

RESULTS The numerical simulations of the $B1^+$ field in the central sagittal plane of the conventional MTL resonator and double-row MTL designs with different terminated capacitance distributions are shown in Fig. 2. These numerical simulations showed that the $B1^+$ field was largely depended on the terminated capacitance distribution, stronger near the end with greater terminated capacitance as expected. 1D profiles of the $B1^+$ maps in Fig. 2 along two dashed lines (21cm and 14cm long, respectively) are shown in Fig. 3. The $B1^+$ homogeneities of all cases were calculated and marked in Fig.3. For 21cm long 1D profiles, the case of Ct1=Ct2=8.5pF has the best $B1^+$ homogeneity (88%) with an improvement of 40% compared with the conventional MTL resonator. For the 14cm 1D profiles, the $B1^+$ homogeneity of the Ct2=20pF, Ct1=4.81pF case can even achieve 97% with an improvement of 18% compared with the conventional MTL resonator.

DISCUSSION and CONCLUSION Compared with the conventional MTL resonator, the double-row design can provide more homogeneous $B1^+$ field along the longitudinal direction by varying the terminated capacitance distributions. The $B1^+$ homogeneity improvement by using this new design was obvious (40% improvement for the 21cm long case and 18% improvement for the 14cm long case). This new design is easy to build in practice and it has also paved the way for similar designs for human imaging. Further work will focus on multi-channel double-row volume-type array design for human head imaging.

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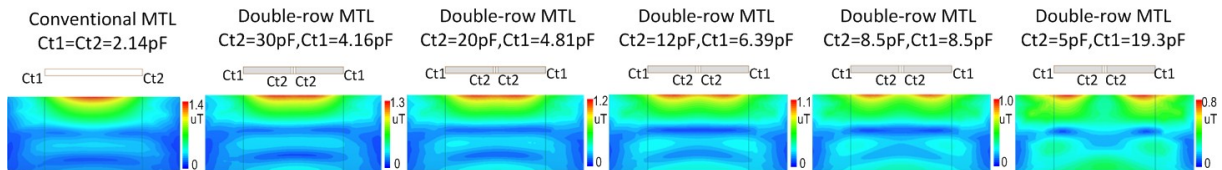
Figure 2: $B1^+$ field in the central sagittal plane of the conventional MTL element and double-row designs with different terminated capacitance distributions.
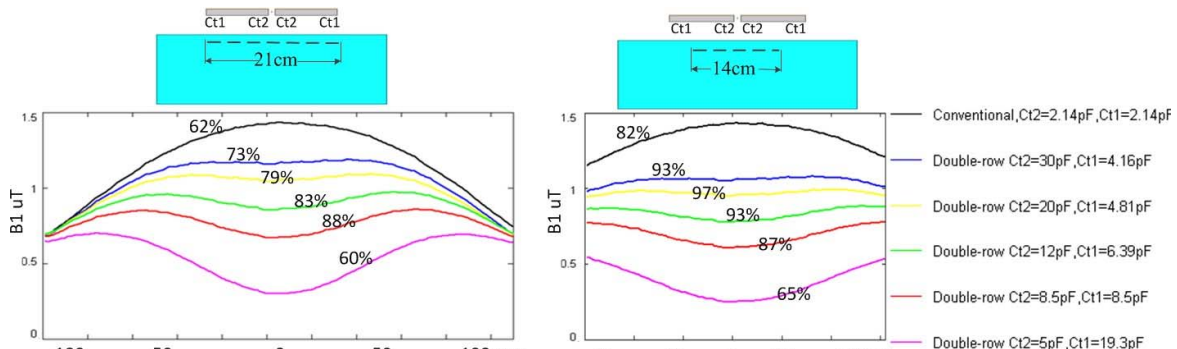

Figure 3: 1D profiles of the B1 field in the central sagittal plane of the conventional MTL element and double-row designs with different terminated capacitance distributions. 100% denotes perfect homogeneity in the region of interest.