Comparison of Elements Geometries in B_1 Shimming with a 16-channel Whole Body Transmit Array at 3T

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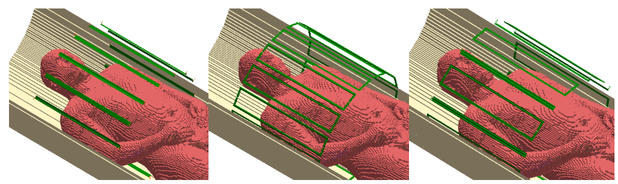
Introduction: A number of groups have demonstrated a variety of benefits to using transmit arrays in MRI. In order to realize these benefits most effectively it is important to determine what array and element geometry will allow for the maximum possible desired benefits. Here we perform a basic comparison of the limitations in B_1 shimming on an axial plane through the human body at 3T with 1) an array composed of stripline elements, 2) an array composed of rectangular loops, and 3) an array composed of both. For the evaluation of each array, homogeneity and SAR are considered.

Methods: Three 16-element whole-body transmit arrays for 3.0 T (128MHz) were modeled for use with the finite difference time domain (FDTD) method using. The matrix size is 193x193x493 in x, y, and z direction and each model contains a human-body model at 5x5x5 mm^3 resolution, RF-coil array, and RF shield. Each strip line element has 50 cm length (z direction) and 2 cm element width. Each rectangular loop coil is composed of loop elements having 50 cm x 5 cm square shape and 1 cm conductor width. The combined type array is composed by alternating between these two basic types of elements. In all arrays, elements are spaced evenly about the surface of a cylinder, and in the strip line and rectangular coil arrays were initially (before optimization) driven with phase equal to azimuthal angle. In the combined type coil array, due to the different field orientations between alternating elements, a 90 degree offset phase was added to the azimuthal angle of every other element. Each element was driven with 2 current sources at opposite ends of the element and in opposite directions connecting the element to the shield (for strip line elements) or across gaps in the coil (for rectangular loop elements). Figure 1 shows the geometry of the three different 16-channel body transmit coil arrays. All simulations were performed using commercially-available software (xFDTD; Remcom, USA). RF shimming was performed using the principle of superposition with home-built software on the Matlab platform (The Mathworks, USA) designed to maximize the transverse magnetization (approach a 90 degree pulse) at all locations in the human body model on an axial plane passing through the heart by changing the amplitude and phase of the current in the 16 elements. After optimization, the maximum SAR in any one cell, in any one gram of tissue, in any 10 grams of tissue, and the whole-body average SAR were evaluated.



(a) (b) (c)

Figure 1 Geometry of the three types of 16-channel body RF coil arrays. (a) Strip line, (b) square loop, and (c) combined types.

Results: Figure 2 shows the transverse magnetization on the axial plane through the heart for all 3 coils after optimization using B_1 shimming. While all three coils can produce homogeneous excitation near the center of the body, the strip line array has the smallest region of inhomogeneity in the arms of the subject. Table 1 shows measures of homogeneity and SAR for all three cases after optimization.

(a) (b) (c)

Figure 2 The transverse magnetizations after B_1^+ shimming for (a) strip line, (b) square loop, and (c) combined type arrays.

Discussion: Two fundamentally-different geometries for array coils are the loop [1] and the strip line or TEM element [2]. It appears that in this particular comparison the strip line array can produce both the most homogeneous excitation and the lowest SAR of the arrays modeled. While other evaluations are possible and while many considerations affect coil-making decisions, due to the great expense of construction it is hoped that the results and methods here may be used to guide design of transmit arrays for the maximum benefit/cost ratio

References:

[1] Hoult DI. JMRI 2000;12:46-67

[2] Metzger *et al*., MRM 2008;59:396-409

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Table 1 The standard deviation, mean of transverse magnetization and SAR values of resultant B_1^+ shimmed field. The field-uniformity information in this table is related to the center axial slice and SAR values are calculated through the whole body. SAR values are during the RF pulse, and would be much lower in practice, depending on TR of actual sequence.

Type of coil element	Before B_1^+ shimming		After B_1^+ shimming		Average SAR (W/kg)	Maximum 1 cell SAR (W/kg)	Maximum 1g SAR (W/kg)	Maximum 10g SAR (W/kg)
	Std(Mt)	Mean (Mt)	Std (Mt)	Mean (Mt)				
Strip Line	0.152	0.858	0.067	0.961	5.619	234.6	109.13	63.30
Square Loop	0.158	0.798	0.117	0.945	5.625	665.6	266.48	154.48
Combined	0.220	0.851	0.105	0.950	6.346	360.7	198.12	161.32