Specific Absorption Rate (SAR) for a transceive shoulder surface coil at 3T using finite difference time domain (FDTD) electromagnetic simulations.

R. T. Goldberg[1], D. M. Peterson[1], J. J. Caserta[2], J. R. Fitzsimmons[1]

[1]Radiology, University of Florida, Gainesville, FL, United States, [2]Analog Devices, Inc., Greensboro, NC, United States

Abstract: The finite difference time domain method is used to predict Specific Absorption Rate (SAR) values for a quadrature driven surface shoulder coil at 128Mhz (3T). Simulated SAR values were compared to USFDA guidelines.

Introduction: Traditionally, global SAR values for large area body type coils are calculated by measuring the total power delivered to the RF body coil and normalizing that by a patent's mass. For surface coils, localized SAR values are required. These quantities however have to be measured directly with temperature measurement instrumentation, which can be cumbersome and difficult, and sometimes almost impossible to facilitate if the region of interest is inside the human body. The availability of commercial electromagnetic field solving software simulation tools has facilitated the analytical calculation of SAR values, which when shown to be accurate representations of true SAR values, alleviate the need for direct SAR quantification via temperature measurements.

Methods: A two loop quadrature driven shoulder coil was simulated using "XFDTD", a finite difference time domain electromagnetic field solving software package from Remcom Inc., State College Pa. An anatomically correct human "body mesh", with absorption coefficients and dielectric constants representative of the human body supplied by Remcom, was used to load the RF coil. The amount of RF drive voltage was scaled to produce adequate transverse magnetic field strength for 90 and 180 degree angular momentum tip angles according to the equation $\alpha = V(\gamma|B^+|\tau)$, where α is the angular momentum tip angle, V the scaling factor, γ the gyromagnetic ratio, $|B^+|$ the magnitude of the circularly polarized component of the transverse magnetic field, and τ a 1ms rectangular pulse duration [1]. The values of the scaling factors used were V_{90} = 86.9 and V_{180} = 173.8. SAR values for gradient echo, spin echo, and fast spin echo MRI sequences consisting of the 90 degree and 180 degree pulses were calculated according to the equation $SAR_{sequence} = (N_{90}SAR_{90}T_{90}+N_{180}SAR_{180}T_{180})/TR$, where $SAR_{90} = V^2SAR_{1Volt}$, and $SAR_{180} = 4V^2SAR_{1Volt} = 4SAR_{90}$, and N_{90}, N_{180}, T_{90}, T_{180} respectively the number and duration of 90 and 180 degree pulses [4].

Results and Discussion: Figure 1 shows the geometry of the quadrature shoulder coil with overlapping regions used to provide isolation, -17.5dB of isolation between loops was achieved. Each loop contains four series capacitors used to reduce the electrical lengths of the loops as well as tune each one to 128 Mhz. Each loop was driven by a 1 V sine wave voltage source, each 90 degrees out of phase with respect to the other. Figure 2 shows the coil and the body mesh. Figure 3 is a coronal view of simulated SAR values showing highest intensity closest to the coil. Table 1 shows calculated SAR statistics, including the maximum number of slices that can be performed for each MRI sequence under USFDA guidelines for a 1 gram weighted torso SAR of 8 W/kg [5].

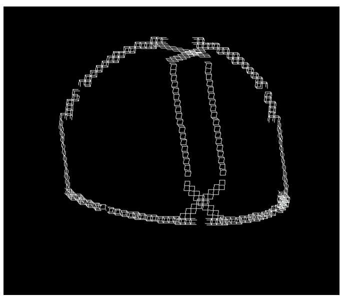

Fig. 1 Coil Geometry

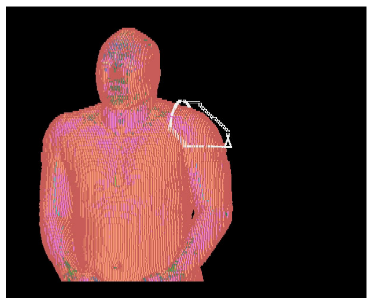

Fig. 2 Location of Coil on Body Mesh

Fig. 3 Coronal slice of SAR distribution

Table 1 SAR Results

	1 Volt Quad Sine Inputs	86.90 Volt Quad Sine Inputs	173.8 Volt Quad Sine Inputs	Gradient Echo Sequence	Spin Echo Sequence	Fast Spin Echo Sequence
# of slices	N/A	N/A	N/A	201	40	4
# of 90 degree pulses	N/A	N/A	N/A	1	1	1
# of 180 degree pulses	N/A	N/A	N/A	0	1	12
τ (ms)	N/A	N/A	N/A	1ms	1ms	1ms
TR (ms)	N/A	N/A	N/A	600ms	600ms	600ms
Max 1 Yee-cell SAR (W/kg)	3.691×10^{-3}	27.87	111.5	9.336	9.292	9.104
Max 1 g SAR (W/kg)	3.152×10^{-3}	23.80	95.20	7.974	7.920	7.776
Max 10g SAR (W/kg)	1.769×10^{-3}	13.36	53.44	4.476	4.452	4.364
Average SAR (W/kg)	0.042×10^{-3}	317.2×10^{-3}	1.269	106.1×10^{-3}	105.7×10^{-3}	103.6×10^{-3}
Total Power (W)	2.918×10^{-3}	22.04	88.16	7.381	7.344	7.196

References:

[1] J Caserta, et. al., 11th ISMRM, Toronto, Ontario (2003)
[2] CM Collins, MB Smith, MRM 45: 684-691, 692-699 (2001)
[3] CM Collins, S Li, MB Smith, MRM 40: 847-856 (1998)
[4] RJ Strilka, et. al., Magnetic Resonance Imaging 16(7): 787-798 (1998)
[5] "Criteria for Significant Risk Investigations of Magnetic Resonance Diagnostic Device", US Food and Drug Administration, (2003)

Acknowledgements:

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