Phased array evaluation using a human body model at 3T

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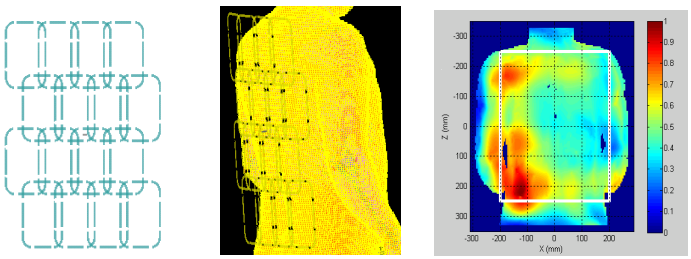
Introduction: Anatomically accurate human body models have been used in estimating the B1 homogeneity, SAR and signal-to-noise ratio (SNR) of a surface coil [1]. In this work, we use an anatomically accurate model for evaluating the SNR of a 16-element phased array used for body imaging at 3T. Using numerical methods, we estimate the electromagnetic fields in the model and calculate an intrinsic SNR metric to evaluate the imaging performance of the array. The results highlight many of the artifacts common in 3T imaging, including left-right shading arising from wavelength effects.

Methods: The 16-element array consists of four rows of four loop coils (Fig. 1a) arranged in a hexagonal overlapped pattern to minimize mutual inductance between all nearest neighbors. This array is placed on the patient table with the body model lying on top of the array in the supine position (Fig. 1b). Using reciprocity, the receiver performance is evaluated by considering the coils as transmitters. In each coil, every capacitor is replaced by a current source with unit amplitude and zero phase angle, and driven at 128MHz. The field quantities at steady state are then obtained using the finite difference time domain method (xFDTD, Remcom, PA, USA). From the steady state flux, the circularly polarized component useful in reception (B1-) [2] for each coil is calculated.

In deriving a metric for the SNR, we follow [3]. The SNR for optimum linear combination of coil outputs is given by $\sqrt{\mathbf{s}^H(i,j)\boldsymbol{\Psi}\mathbf{s}(i,j)}$, where $\mathbf{s}(i,j)$ is the vector of signals from coil elements at location (i,j) and $\boldsymbol{\Psi}$ is the noise covariance matrix. The exact image SNR depends on many factors. In this work we consider a metric that facilitates comparative analysis.

Therefore, we use $s_k(i,j) = B1_k^-(i,j)$. In the estimation of intrinsic SNR, the noise is dominated by the sample thermal noise, which can be represented by an equivalent sample resistance [3]. Therefore we use $\boldsymbol{\Psi}_{l,k} = \sum_{\boldsymbol{\rho}\in Sample} (\sigma_x(\boldsymbol{\rho})E_{l,x}(\boldsymbol{\rho})E_{k,x}(\boldsymbol{\rho})^* + \sigma_y(\boldsymbol{\rho})E_{l,y}(\boldsymbol{\rho})E_{k,y}(\boldsymbol{\rho})^* + \sigma_z(\boldsymbol{\rho})E_{l,z}(\boldsymbol{\rho})E_{k,z}(\boldsymbol{\rho})^*)\Delta x\Delta y\Delta z$, where l and k denotes the coils, and σ and E are the conductivity of tissue and the electric field, respectively, at location $\boldsymbol{\rho}$ with components in the x, y and z directions. The summation is carried out over the human body model. This anatomically accurate male body model (Remcom, PA, USA) has distinct electrical properties to represent dielectric constant and conductivity of different tissue types at 5mm resolution.

Results: The intrinsic SNR metric (normalized to the highest value) has been calculated, e.g., for a coronal plane at a depth of 13cm, as shown in Fig. 1c. The results show a left-right shading due to wavelength effects, similar to that of LISA (local intensity shift artifact) reported for a single coil in [4]. There are also localized regions of lower SNR, which can be attributed to array geometry. For example, the second row in the array is offset from the first row to minimize coupling between diagonal coil elements. This offset leaves a gap in the SNR profile. The typical 40cm x 50cm field of view is also outlined in Fig. 1c.



a **b** **c**

Figure 1: (a) 16-coil array; (b) on human model; (c) intrinsic SNR in a coronal plane.

Conclusions: We have estimated an intrinsic SNR metric for a 16-element phased array receiver coil underneath an anatomically accurate human body model. The results show intensity shift artifacts similar to a single coil, as well as SNR variations due to array geometry. This method can be used to evaluate the imaging performance of a given array, and to optimize array configurations at various field strengths.

References: [1] C. M. Collins, et. al., Magnetic Resonance in Medicine, 45:692-699, 2001. [2] Hoult, D. I., Concepts in Magnetic Resonance, 12(4), 173-187, 2000. [3] P. B. Roemer, et. al., Magnetic Resonance in Medicine, 16, 192-225, 1990. [4] P. H. Wardenier, SMRM Book of Abstracts, 1175, 1989