Methodology for UHF multichannel coil evaluation

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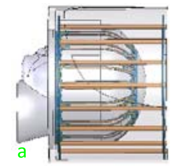
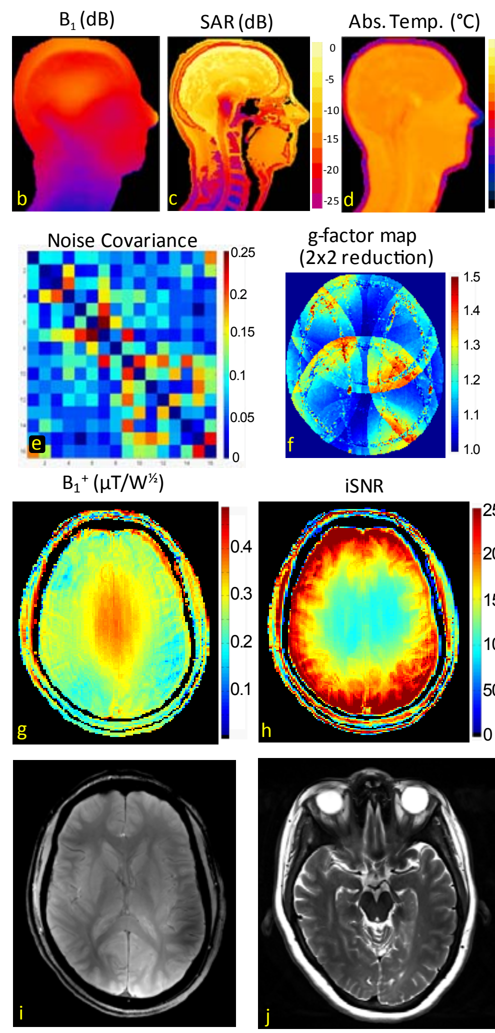
Introduction: Evaluating the performance and safety of high field RF coils with multiple elements is necessary to improve coil designs, but it is challenging due to the complexity of the coil itself. Multiple channel arrays can mask underperforming elements. Subtle design changes can impact coil performance and comprehensive quantification of coil metrics is needed for assessment. Below is the methodology we to test and evaluate new coils for performance, image quality, and safety with a specific coil used as an example.



Materials & Methods: *Simulation and Construction* First, the general design specifications for a coil are drafted, in this example, a 7T inductively coupled TEM transmit coil head coil with 16 receive loops (**a**) for use on a Siemens Magnetom 7T. The coil dimensions serve as the basis for RF simulation. FDTD models (SEMCAD X, Speag) of B- and E-fields, SAR and temperature distribution (**b-d**) allow performance (efficiency) and safety (SAR "hot spots") to be evaluated early in the process, when coil specifications are easily modified and retested. Simulations of the final design will be used for SAR limits. As construction of the coil nears completion, the tuning, matching, decoupling, active detuning, and pre-amplifier operation of each coil is measured on the bench to ensure reliable performance.

Imaging performance metrics The first tests of a coil in the magnet are without transmit power. Thermal noise on a phantom is measured and the receiver channels' mean and standard deviation are calculated to identify any malfunctioning preamplifier circuits. The noise covariance matrix[1] (**e**) is calculated and the coupling of channels with large covariance are corrected on the bench. Still imaging noise, the intensity of the gradients is increased and monitored for spikes indicating unfastened cabling. A 16-channel power monitor constantly monitors and plots the forward and reflected power. Any fluctuation in reflected power on a channel indicates a component is failing at high power and must be replaced. Images excited by individual transmit channels, similar to those from mapping the relative B_1^+ phases for B1 shimming[2] are processed to identify any underperforming transmit and receive channels. EPI images are analyzed for ghosting indicative of eddy currents. At this point, the coil has passed basic quality assurance and is ready for subject testing.

A GRE image (**i**) (0.5x0.5x5 mm, TR/TE = 150/5 ms, α≈35°) is collected to evaluate the geometry factors[3] for parallel imaging performance (**f**). Multi-slice double angle method B_1 maps[4] (4) (1.1x1.1x5 mm, 15 slices, TR/TE = 6000/4 ms) are collected and converted to transmit efficiency maps by calculating the power available at the coil, (**g**). Partial-Fourier acquisition and a TR too short for complete CSF relaxation keep the imaging time (2x11 min) acceptable for occasional coil characterization. The lower flip angle image (α≈60°) is reconstructed in SNR units[5] and normalized voxel by voxel by the B_1^+ map to the signal level that an ideal 90° excitation would have produced[6] (**h**). For alternate reconstructions such as GRAPPA, the pseudo-replica method is used to evaluate the SNR and geometry factors differences due to reconstruction.[8]



Results & Discussion: This method highlights coil deficiencies early in the development process for ease of correction. Reconstructing the B_1^+ maps in iSNR units allows the transmit (**g**) and receive profiles (**h**) to be calculated separately and compared between spectrometers and across field strengths. This coil demonstrates higher central transmit performance and higher receive sensitivity in the periphery, typical of this coil design. These effects can balance each other to produce uniform looking images as in (**i**) or (**j**) (TSE, 0.6 x 0.6 x 4 mm, TR/TE = 6000/96 ms, R=3). Such evaluation methodologies improve quantification of performance and ensure safety.

References:
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