A 31-Channel Multi-Layer 3T Receive Head Array

W. Loew[1], I. Metzner[2], S. Lindsay[3], L. Blawat[3], F. Wiesinger[1], E. Boskamp[3], M. Menzel[1], M. Vogel[1], R. Schulte[1], P. Loiselle[2], H. Koenig[1], N. Krumme[2], H. Schilling[2], and P. Gross[1]

[1]Imaging Technologies, GE Global Research Europe, Munich, Germany, [2]Schleifring und Apparatebau GmbH, Fürstenfeldbruck, Germany, [3]Applied Science Lab, GE Healthcare, Waukesha, WI, United States

Introduction

The purpose of this study was to build a 31-channel proton head coil for 3 telsa parallel imaging. One common approach to build an overlapped multi coil array is to use single elements, which, after decoupling each element, are fixed on a former. Alternatively, more than one coil element may be printed on a circuit board (PCB) including vias at the coil overlaps. In this design the decoupling was calculated in advance, in order that one multilayer flexible printed circuit board (PCB) could be manufactured including all coil elements and no vias.

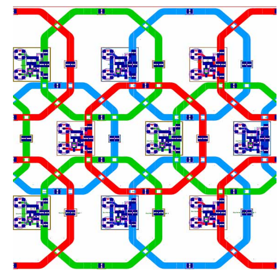

Figure 1: Overlap scheme

Materials and Methods

The substrate used for the coil was a flexible DuPont material with three copper layers, 750mm in length and 218mm in width. The board had 31 octagonal coils. In order to comfortably accommodate various head sizes and shapes the nose, mouth, and a part of the forehead were not covered. Each coil was 82.5mm by 87.5mm and the 31 elements were arranged in three rows. The overlap schema is shown in figure 1. Two types of overlaps were calculated: one in the circumferential and the other diagonal in the z-direction. In order to ensure that the design was robust for simulations and manufacturing tolerances, all trace crossovers were made at 90 degrees and parallel traces were kept at a maximum distance. The overlaps were calculated in advance to achieve minimum (zero) mutual inductance. Additionally the trace at the overlap point had a rectangular slot. This reduces the capacitive coupling between the overlapping traces. A further reduction in capacitive coupling was achieved by placing the overlaps at equipotentials. A big advantage of the multi-layer scheme was that no vias had to be used, reducing coil losses.

The large dimensions of the board made it difficult to fabricate. Nevertheless a tolerance of less than 500µm between the top and bottom layer could be guaranteed. Because of the coupling between neighbor elements, this tolerance was very important to fulfill the calculated coupling values. The overall thickness of the boards was smaller than 1.1mm. To protect the discreet elements placed onto the coil from mechanical stresses due to bending, the board was locally reinforced with an additional 1mm thick layer of FR4. As this re-enforcement was achieved during the multi layer bonding process, it formed an integral part of the board and was predicted to be able to sustain high number of bending cycles.

An isolation of better than 12dB to direct neighbors could be achieved only through overlapping. Other coupling was minimized by the preamp with an input impedance of 2 Ohms, placed a distance of lambda away from the coil. The blocking network of the coil was symmetric, including two air core inductors. For transmit decoupling the coils used standard PIN diode switching, as well as a crossed diodes packages, both integrated to use the preamp-decoupling network. To minimize cable coupling, a balun was placed in the first lambda over 4 segment of the cable towards the preamp, as shown in figure 2.

Receive sensitivity measurements were performed using a fast spoiled gradient echo sequence (single axial slice, TE=3.2, TR=60, 256x256, FOV=31, slice thickness=5, BW=31.25, NEX of 16, imaging time=5'16'') on a GE Signa Excite 3T scanner (GE Healthcare, Milwaukee, WI) equipped with an eight-channel whole-body transmit array. In addition a noise correlation was assessed using an identical examination with RF excitation turned off.

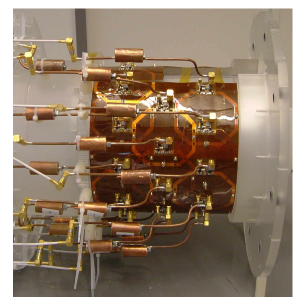

Figure 2: 31 channel array

Results & Discussion

The sum-of-squares image is shown as a 10 based logarithm in figure 3. The decay times of the saline solution restricted the use of high flip-angles at an acceptable TR. While the close proximity of the lossy saline solution ensured a high degree of loading of the small coil elements, this conversely also signified high losses. The sum-of-squares combination prevented destructive interference in the images due to the transmit phases. Nevertheless, the method did not produce an ideal combination in terms of noise or homogeneity. Coil performance needs to be accessed further using homogenously excited receive with higher flip angels and a standard head phantoms.

The noise covariance matrix, shown in figure 4, was scaled with respect to the largest on-diagonal term. It clearly showed the effects of system cabling, with cross talk increasing the covariance for channels of within each cabinet. The largest off-diagonal elements had a scaled value of 16%.

Parallel imaging performance was evaluated for a central axial plane. Figure 5 shows g-factor maps obtained for 1d undersampling with reduction factor of 2.6 (left), 4 (middle), and 5.3 (right) with corresponding mean g-factors of 1.004, 1.06, and 1.19. In addition also 2d parallel imaging was evaluated resulting in significantly improved mean g-factors of 1.001 ($R=2^2$), 1.01 ($R=2.67^2$), and 1.16 ($R=4^2$).

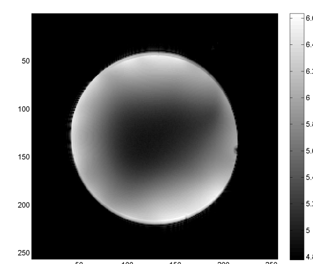

Figure 3: Sum-of-square

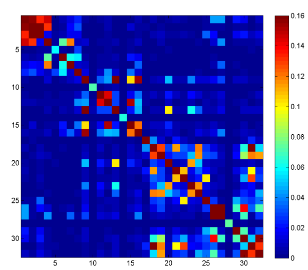

Figure 4: Noise covariance

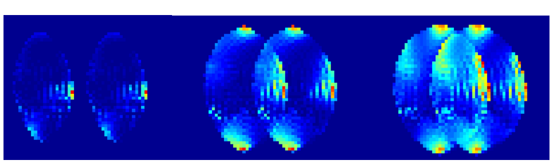

Figure 5: G factors (Mean/ Max) for R=2.67 (1.004/1.09), R=4 (1.06/1.35), R=5.3 (1.19/1.77)

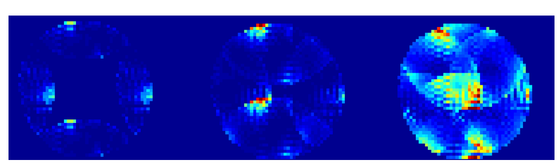

Figure 6: G factors (Mean/ Max) for $R=2^2$ (1.001/1.01), $R=2.67^2$ (1.01/1.26), $R=4^2$ (1.16/1.86)

Conclusion

The research presented both several novel design features all aimed at directly producing a multi-coil array from a simulated design. Furthermore, the novel material and coil design could be used for light and flexible coils. This would make it possible to closely couple the receive coils to the body by draping the patient. The main remaining challenge for this flexible solution is to define another cabling strategy to guarantee total flexibility.

Acknowledgment: Some aspects of this work received co-funding under the Bavarian research initiative "Leading Edge Medical Technology"