A Novel 8-Channel Transceive Volume-Array for a 9.4T Animal Scanner

E. Weber[1], B. K. Li[1], F. Liu[1], Y. Li[1], P. Ullmann[2], H. Sanchez Lopez[1], and S. Crozier[1]

[1]School of ITEE, The University of Queensland, Brisbane, Queensland, Australia, [2]Bruker BioSpin MRI GmbH, Ettlingen, Germany

Introduction

This work focuses on the design of a novel 8-element TX/RX volume-array for high field animal MRI. The magnetic field strength of current small animal MRI systems is increasing in search of higher SNR and spectral resolution [1]. Along with the move to higher field strengths, RF coil design for small-animal MRI is advancing concurrently [2]. At ultra high field strengths, however, RF inhomogeneities become more pronounced, in a similar fashion to clinical scanners [3]. In view of this, transceive volume-arrays developed to ameliorate these high field distortions, employed for transmit SENSE application and also for parallel imaging, have become increasingly popular. In this work, a dedicated, shielded 8-element transceive volume-array for large rat MRI applications at 9.4T, has been developed and constructed. Preliminary phantom images acquired using this prototype show that homogenous B_1 fields can be attained. In addition, the Transmit SENSE images obtained reveal that the design of this transceive volume array is well suited for accelerated spatially-selective excitation (SSE) and that it worked well with GRAPPA.

Methods

Shown in Fig 1(a) is the schematic diagram of the transceive volume-array (only 3 coil elements are shown here) and Fig 1(b) is the picture of the constructed prototype. The active coil length is 100mm, the 8 coil elements are positioned circumferentially around a diameter of 75.2mm, while the RF shield is 200mm long, placed in the inside of the outer protective tube, on a diameter of 109mm. The averaged unloaded Q-factor for all coil elements was measured to be above 90, and the Q-factor was about 52 when loaded with a cylindrical phantom of Ø=56mm (filled with a saline solution resembling a rat of 300g). A rung arrangement with distributed capacitance compatible with the counter-wound, inductive decoupling scheme [4], able to improve the field homogeneity and provide better RF penetration depth is designed. This decoupling scheme is chosen as it can provide high decoupling power (-20dB on average under loaded condition) over a large tuning range, as compared to the overlapping and capacitive decoupling methods, and also maintain the advantage that it can easily be adapted for use in either transceive or receive-only mode. In addition, an 8-channel Tx/Rx Switch as shown in Fig 2 (note that only 2 Tx/Rx Switching units are shown in the figure) has been constructed to drive the 8 elements. Each channel of the switch is equipped with low noise pulse-protected preamplifiers (input/output impedance matched to 50 ohms, 22 dB gain, NF of about 0.6) and capable of handling 1kW of pulsed transmit power. The 8-channel Tx/Rx Switch can improve SNR, efficiently compensate transmission line losses and is fully adaptable for Transmit SENSE.

Results

To test the operation of the prototype transceive volume-array, it was loaded with a cylindrical phantom containing a saline solution (Ø=45mm, ε=76, σ=0.2) and tested in a Bruker Avance III spectrometer MRI system [5]. Fig 3 shows the transmit sensitivity distribution of one coil element. Fig 4 is the acquired sum-of-squared MR image with all 8 elements transmitting simultaneously in a birdcage-like excitation mode, that is with a 45° phase difference between adjacent coil elements and receiving in parallel. Fig 5 shows the GRAPPA reconstructed image of the phantom with a reduction factor of 2 and Fig 6 is a designed checker box image acquired using Transmit SENSE with reduction factor of 4.

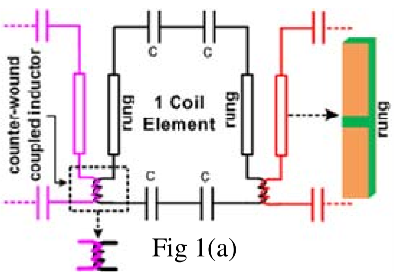


Fig 1(a)

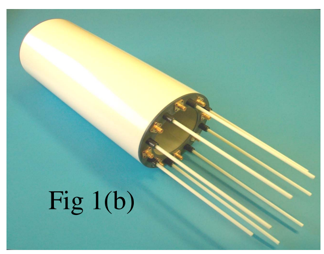


Fig 1(b)

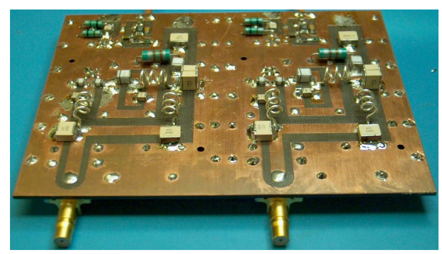
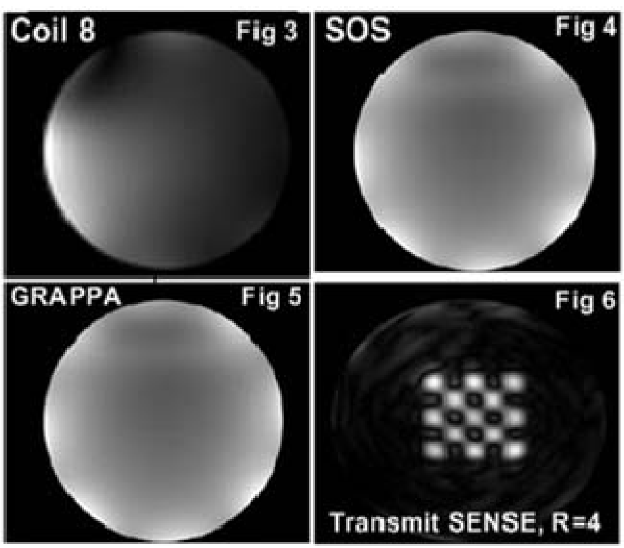


Fig 2



Discussion and Conclusion

As can be seen from Fig 4, homogenous MR images of the phantom at 9.4T can be acquired. The GRAPPA reconstructed image of Fig. 5 shows little loss of information and has an image quality comparable to Fig 4. Hence, parallel imaging techniques function seamlessly with the prototype.

The checker box image of Fig 6, acquired using Transmit SENSE with reduction factor of 4, demonstrates that the prototype transceive volume-array is compatible with accelerated spatially-selective excitation applications. One of the major engineering challenges in developing this system for high field microscopy, is the limited space and this design is specifically engineered to minimize the primary/shield distance, so as to maximize sample space.

The results indicate that high field microscopy systems are capable of being architected for Transmit SENSE applications and also for partial parallel imaging. It is anticipated the transceive volume array can be used for advanced imaging applications, such as cardiac and brain imaging. In addition, the capability to perform Transmit SENSE allows tailoring the B_1 field for dedicated animal applications. Future work will include increasing the number of elements and the extension to higher frequency systems.

References

1.Zhang, Webb, 12th Proc ISMRM 39 (2004)
2. Doty *et al*., NMR Biomed 20:304-325 (2007)
3. Ibrahim, Ranganath, 15th Proc ISMRM 1018 (2007)
4. Weber *et al*, Australia Patent 2007901587 (2007)
5. P.Ullmann, 16th Proc ISMRM Submitted (2008)