A Stripline-like Coil Element Structure for High Field Phased Array Coils and its Application for a 8-channel 9.4T Small Animal Transceive Array

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Introduction Ultra-high magnetic field strength, as widely utilised in small animal MRI systems, has advantages of being able to enhance signal-to-noise ratio (SNR) and gain high spectral resolution [1]. However, the homogeneity of B_1 field worsens along with the move to higher RF-frequencies. Methods such as RF shimming and transmit SENSE, which require transceive volume-arrays had been proposed to circumvent the high-field inhomogeneity problem [2]. Currently, the trend in designing transceive volume arrays is to fit the highest feasible number of coil-elements within a given geometry. Consequently, the aperture of each coil element will be small and RF field penetration depth is sacrificed. In addition, with increased number of coil elements, mutual decoupling is harder to control and good channel isolation is difficult to achieve. Therefore, it is very important to consider these two issues when designing a transceive volume-array system. In this work, the development of an optimized, shielded 8-element transceive volume-array for small animal MRI applications at 9.4T is discussed. To take into consideration the mentioned designing issues, a novel radiating structure for the coil element has been proposed. A prototype was constructed and tested in a Bruker 9.4T Biospec MRI system. Simulated and experimental results presented herein demonstrate the potential of the design.

Methods Depicted in Fig 1 is the structure of the prototype transceive volume-array. The coil consists of 8 loop-elements circumferentially positioned on a tube of 75.2mm in diameter and a length of 90mm in z-direction. The RF shield is 200mm long and placed inside the outer protective tube with a diameter of 109mm. An angularly oriented conductive blade, as reported in our former work [3, 4], which could improve RF penetration depth and regulate mutual coupling is used. However, unlike the previous design, we have developed a new stripline-like type of conductor for the coil element. The comparison of the former design and the new 'sandwiched' design of the coil blade is shown in Fig.2. In the new design, a single copper conductor is sandwiched between another 2 copper strips and dielectric material, hence the name sandwiched conductor. Through using this design for the conductor, the capacitance and the inductance are uniformly distributed in the blades, which will therefore contain the electric field and reduce coupling to the sample. Furthermore current is forced to flow nearer to the sample, thus increasing the RF penetration. The angle of the blade relative to the FOV was optimized by numerical calculations using Matlab and EM software FEKO (www.feko.info) with the consideration of an engineering trade off between RF penetration and coil-coil coupling. In addition, a larger sized loop (8.5% increased) coil was used to further increase the RF penetration. For mutual decoupling, a counter-wound inductor decoupling method, which can provide high isolation power [5], is used. Depicted in Fig. 3 is the constructed prototype. To drive the coil, an 8-channel Tx/Rx switch/interfacing unit has been constructed (see Fig.4). Each channel of the switch is equipped with low noise, pulse-protected preamplifiers (input/output impedance matched to 50 ohms, 30 dB gain, NF of about 0.8) and capable of handling 1kW of pulsed transmit power. The unit is designed to improve the SNR, efficiently compensate transmission line losses and is fully adaptable for RF shimming and Transmit SENSE applications.

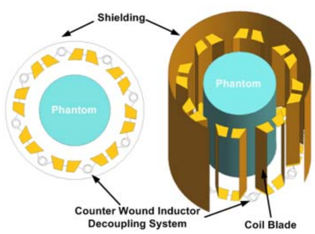

Fig.1 The transceive 8-element array coil model

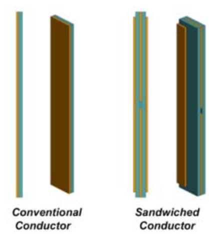

Fig.2. Comparison of the coil element structure between the conventional conductor structure and the novel sandwiched conductor structure.

Fig.3. The constructed prototype of the 8-element transceive array coil

Fig.4. The 8-channel Tx/Rx switching/preamplifier unit

Results and Discussions A comparison study on RF penetration using the sandwiched conductor structure was undertaken. Shown in Fig 5(a) is a coil element using the conventional conductor, Fig 5(b) is a coil element using sandwiched conductors while Fig 5(c) represents the coil element used for the new array, with sandwiched conductor and larger loop size. The effective RF penetration for these three coil elements is plotted and shown in Fig 5(d). It can be observed that through using the sandwiched conductor structure the RF penetration can be increased (approximately 20% increase) and a further increment is noticed for the larger sized loop. The prototype transceive array system and 8-channel Tx/Rx switch/interfacing unit were tested in a Bruker 9.4T Biospec MRI system and MR images of a homogenous phantom and an apple were acquired. Shown in Fig 6 are the sensitivity profiles of each coil element and the SoS image of the phantom. It can be seen that highly homogenous images can be acquired using the constructed prototype. Fig. 7 shows the 3D apple image obtained using the prototype. These MR images show that it is important to design an optimized transceive volume array system so that when used with high field strength magnet it will provide the advantages of high quality MR images.

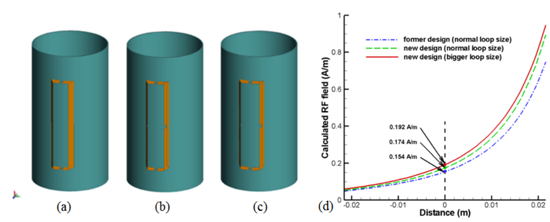

Fig.5 (a), (b) are the former and (c) new coil configuration; and (d) the comparison of H- field along the centre of the phantom

Conclusion In this work, a dedicated, optimized 8-channel transceive volume array for small animal MRI applications at 9.4T with improved RF-penetration was developed. The performance enhancement of the coil is facilitated by using angularly oriented conductive coil elements with stripline-like, 'sandwiched' conductor structures. Both the simulation and experimental results clearly demonstrate the advantages of the proposed design. Future work will investigate the potential of using this design for larger and denser coil array configurations.

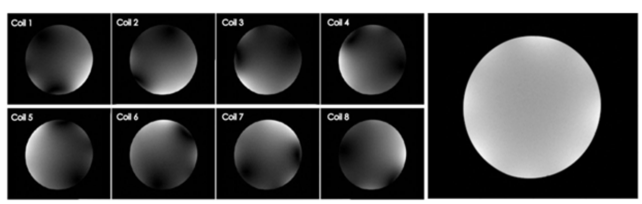

Fig.6. The sensitivity profile of each coil element (left); and SoS imaging (right)

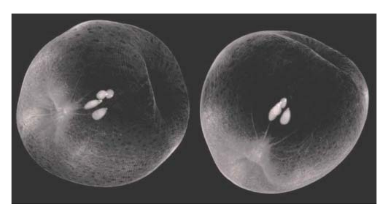

Fig.7. Images of an apple

References

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