Comparison of RF Resonators Using Microstrip for Human Head at 3T

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Introduction

High-field magnetic resonance imaging (MRI) systems (> 7 Tesla) have higher intrinsic SNRs (signal-to-noise ratios), higher resolution, and are currently being investigated for clinical use [1-3]. However, one of the main challenges for these systems is B_1^+ field inhomogeneity. To alleviate this problem, multichannel coils with parallel excitations are used [4] because they provide higher B_1^+ fields in the region of interest, and they optimize the B_1^+ fields by driving the current of individual coil elements [5-6]. Currently, these high-field MRI systems are used for research, and are not applied clinically. To explore clinically viable high-field MRI systems, we used four different RF resonators to enhance multichannel coil performance, with all four being simulated with a spherical phantom to obtain the B_1^+ distribution. 16-channel head coils using a variety of RF resonators were tested on study participants at 3 Tesla, and the penetrated RF magnetic fields were compared amongst four different RF resonators in a spherical phantom. They were verified to be suitable for parallel imaging.

Methods

In order to increase the penetrance of the RF magnetic field, the four different RF resonators had unique top view structures, as shown in Fig. 1. Teflon, a low loss dielectric material Teflon (ε_r=2.08, loss tan.=0.004), was used as the microstrip substrate, which had a height (*h*), length (*l*), and width (*w*) of 20 mm, 150 mm, and 18 mm, respectively. The microstrip line was used as a λ/2 resonator with terminated capacitors at its ends. The terminated shunt capacitors were used to reduce the physical length and to ensure that the resonator operated at the desired Larmor frequency (128 MHz, 3 Tesla). The microstrip transmission lines in the four RF resonators had the same dielectric property, size, and width. The RF resonator meander line width was 3 mm, and the length of the meander line was 129 mm. The RF resonator with two meander lines had a meander line width and length of 1 mm and 12 mm, respectively. For the SIR with four arms, the thin line width and length were 7 mm and 70 mm, respectively. The thick line length of the RF resonator was 40 mm. Each of the four arms of the RF resonator had a width of 2 mm and a length of 20 mm. The thin line width and length of the SIR was 2.6 mm and 110 mm, respectively. The thick line length of the SIR was 20 mm.

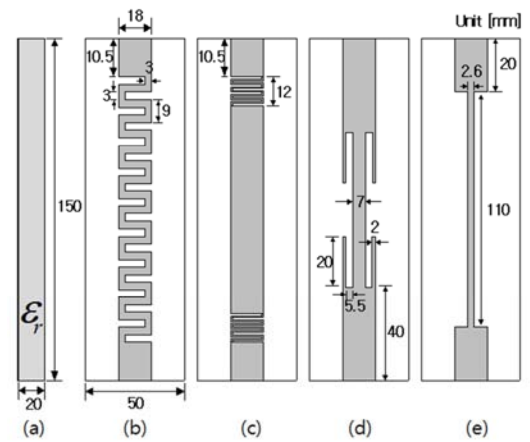

Fig. 1 Side view of RF resonators (Fig. 2a) and a top view of the meander line RF resonator (Fig. 2b), RF resonator with two meander lines (Fig. 2c), SIR with four arms (Fig. 2d), and standard SIR (Fig. 2e)

Results

Based on the finite difference time-domain method, SEMCAD [7] was used to obtain the B_1^+fields with a spherical phantom (ε_r=58.1, σ=0.539 [S/m], radius=100 mm). At the same input power, the SIR with four arms had more highly penetrated RF magnetic field distributions than the other RF resonators. The penetrated RF magnetic field intensities according to penetration depth are presented in Table 1. The SIR with four arms provided the most strongly penetrated RF magnetic field compared to the other RF resonators. RF shimming and homogenization were effectively controlled by using a higher RF magnetic field intensity at the center of the phantom. Note that the input power of all four RF resonators was normalized to 1 Watt. The B_1^+field map generated by the 16-channel coil using each RF resonator are shown in Fig. 2. The B_1^+ map of the 16-channel phased RF resonator was calculated in the phantom, with the exception of when coupling problems between phased RF resonators arose. In the region of interest at the center of the phantom, the and 16-channel coil using the SIRs with four arms provided a more homogeneous B_1^+ field distribution than the other configurations.

Table 1: Comparison of the penetrated RF magnetic field intensity [A/m] according to penetration depths

Resonator \ Position	22 mm	40 mm	67 mm	86 mm	105 mm
Meander line	3.492	1.523	0.611	0.382	0.260
Resonator with two meander lines	3.425	1.454	0.574	0.358	0.243
SIR with four arms	5.069	1.991	0.755	0.465	0.314
SIR	4.813	1.880	0.715	0.440	0.298

Conclusion

3 Tesla MRI system has become a standard technique for imaging the human body and for making diagnoses. However, compared to high-field MRI systems (> 7 Tesla), 3 Tesla MRI systems have a lower, and therefore, worse intrinsic SNR. To overcome this problem, we proposed using a 16-channel coil with a SIR with four arms, and we compared it to other RF resonators based on microstrip transmission lines. The 16-channel coil provided better B_1^+fields and can be effectively controlled for parallel imaging in 3 Tesla MRI systems. Therefore, 16-channel head coils using the SIR with four arms for parallel imaging could be used in hospitals for higher quality imaging.

References

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SEMCAD X by SPEAG, www.speag.com, SMBA-C0141733

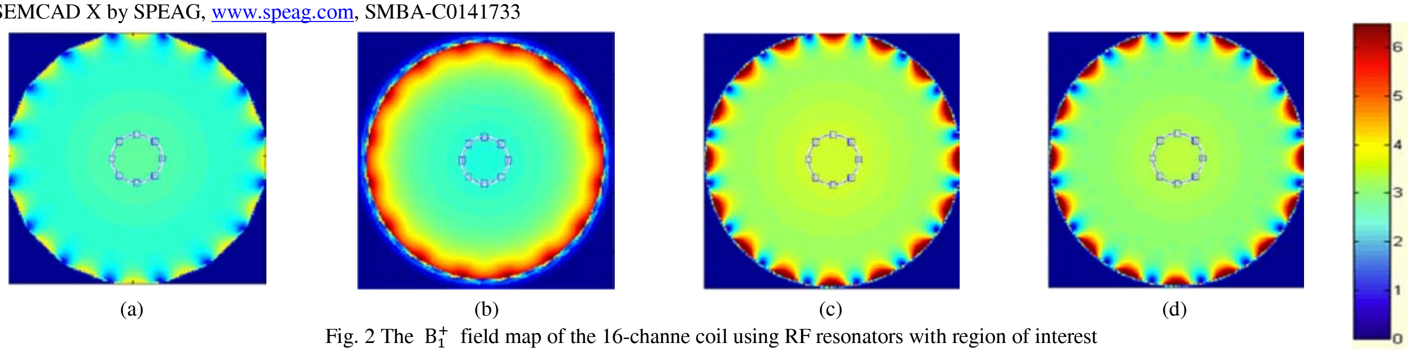

Fig. 2 The B_1^+ field map of the 16-channe coil using RF resonators with region of interest
(a) meander line (b) resonator with two meander lines (c) SIR with four arms (d) SIR