Design of Phased Array RF Coils for MRI Applications

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Abstract—This paper proposes a rotary phased array head coil owing to the phased array coil advantages for rapid imaging with parallel processing and reducing image artifact due to its larger field of view. The array coils consist of eight coils, where each coil is designed from four wide conductor sheets and four small conductor sheets onto which combined with twelve lumped capacitors in order to achieve resonant frequency at 128 MHz for 3T MRI system. Each coil is circularly arrayed to form a volume RF coil in order to achieve homogeneous magnetic field distribution. The simulation results show good reflection coefficient at 128 MHz with relatively uniform magnetic field strength distribution. In addition, specific absorption rate is relatively low in the phantom, which is put inside the array coil.

1. Introduction

Phased Array (PA) RF coils [1] have become a great interest study owing to its very essential component for low to ultra-high field MRI systems due to its ability to acquire high signal to noise ratio (SNR) and large field-of-view (FOV) MR images. Moreover, PA coils have the advantages that they are used for Partial Parallel Imaging (PPI) [2]-[4], to reduce imaging time and in transceive mode they can be used for radiofrequency (RF) shimming [5],[6] and Parallel Excitation (PEX) [7],[8] to mitigate ultra-high field B_1 inhomogeneity effects or to perform selective regional excitation. Due to the advantages in producing homogenous brain images, which is comparable to the birdcage type RF coil and still capable to perform PPI to reduce MRI scan time, therefore in this paper, an eight-elements rotary phased array head coil is proposed. The coil structure and its calculation results will be discussed, including frequency characteristics, magnetic field distribution and specific absorption rate (SAR).

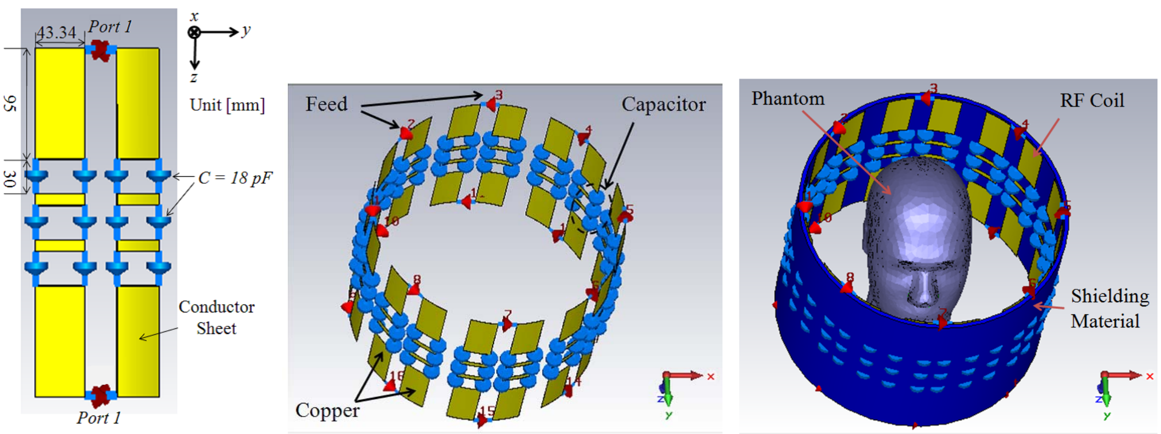
2. Structure of Phased Array Coil

The phased array coil is consisted of eight elements, which is each element is constructed from four-thin copper-sheets to which combined with twelve-capacitors and two in-phase feed ports. The array is enclosed by shielded material from acrylic with ε_r=2.7. The structure of the coil is depicted in Fig. 1(a) for single element and Fig. 1(b) for arrayed construction. The eight elements are formed by circumferential array by the dimension of 400 mm × 300 mm (diameter × height) to scan 360° of the head phantom (Fig. 1(c)). By this configuration, the array coil is expected able to provide homogenously B_1 field, good SNR and possibility for fast imaging in conjunction with parallel MRI technique.

3. Simulation Results

The array is numerically analyzed by using the finite integration technique (FIT) in homogeneous two-layered head phantom, which has electrical properties as follows, ε_{inner} = 42,

σ_{inner} = 0.99 S/m, ε_{outer} = 5, and σ_{outer} = 0.05 S/m. The following results are described particularly at the frequency of 128 MHz.



(a) (b) (c)

Figure 1. RF array coil structure (a) one element coil (b) 8-element array (c) array with dielectric shielding and head phantom

Table 1. Electrical properties of homogenous head phantom.

	Relative Permittivity (ε_r)	Conductivity (σ)
Inner Phantom	42	0.99 S/m
Outer Phantom	5	0.05 S/m

3.1 Reflection coefficient characteristics

The reflection coefficient is characterized in terms of the magnitude of S_{11} versus frequency. Each of the phased array coils resonates similarly at 128.25 MHz where $|S_{11}|$ is -40 dB at the frequency of 128 MHz. The impedance of the coil at input port is 0.84 Ω - j140.16 Ω, showing that it has a conductive property with very low resistance. The simulation result is shown in Fig. 2(a).

3.2 Magnetic field strength distribution

Figure 2(b) shows the magnetic field distribution when the coil no. 1 is active at sagittal plane. The position of the coil no. 1 is set at the right of the head phantom as shown in the figure, allowing to magnetic field goes through the phantom perpendicularly and gets decreased as the distance larger from the coil. The larger field strength is distributed around periphery of the phantom rather than at the center of the phantom. However, in general the uniformity of the field distribution can be achieved, where the discrepancy factor of the contour is about 0.04 A/m from the periphery side up to the center of the phantom.

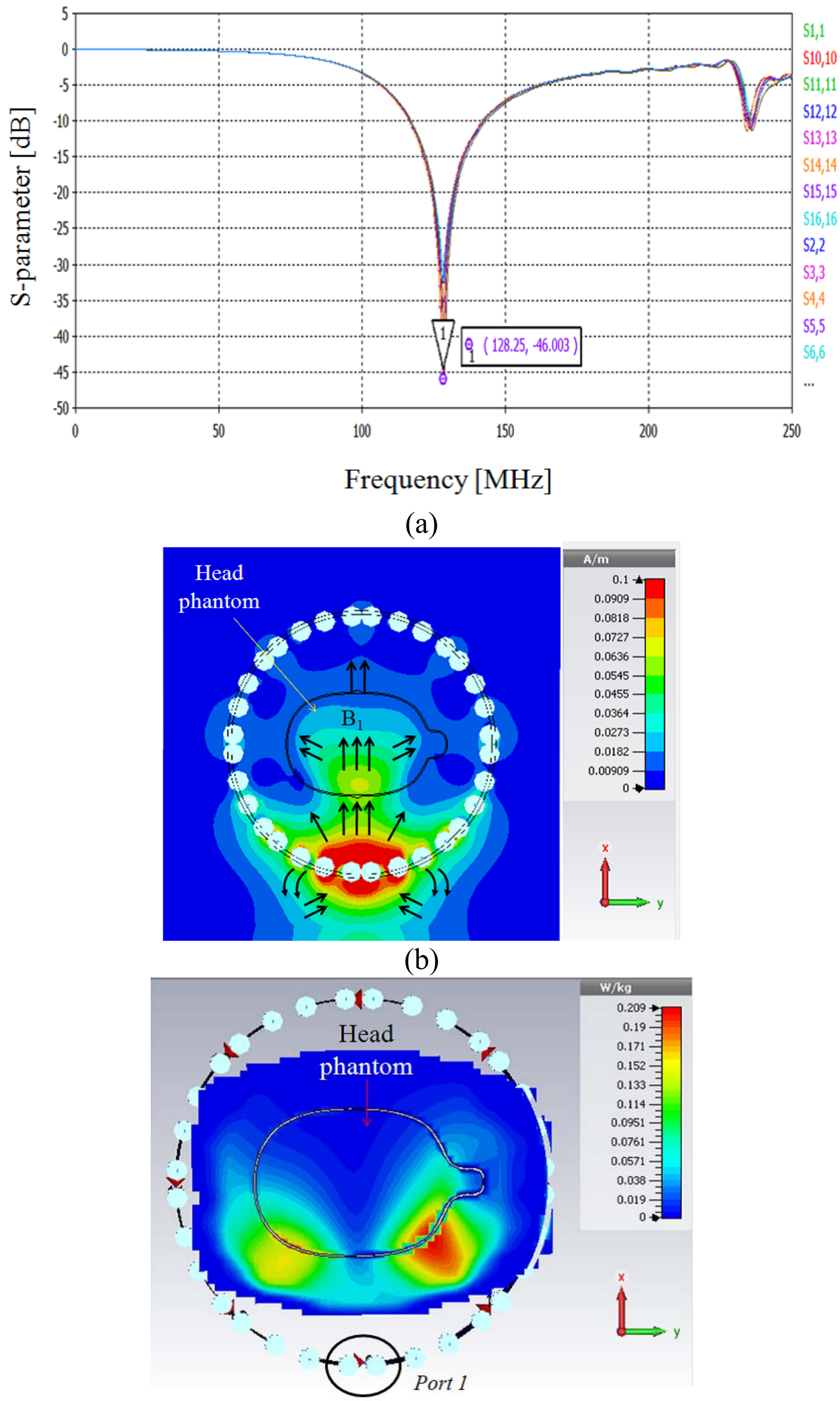


Figure 2. RF array coil performances (a) reflection coefficient caracteristics in terms of $|S_{11}|$ vs. frequency (b) magnetic field distribution (ten contours) (c) SAR inside the phantom (sagittal plane)

3.3 Specific absorption rate (SAR)

The 10g-averaged SAR result is depicted in Fig. 2(c) for input power about 25 Watts at sagittal plane, which is relatively medium power system. According to our simulation, up to 100 Watts of the input power, the peak value of the10g-averaged SAR is about 0.85 W/kg. When the input power is more than 500 Watts, the SAR increases more than 4 W/kg and it will have to be considered for safety due to its relatively high exposure.

4. Conclusions

This paper proposes an eight-elements rotary phased array coil for head scanning in 3T MRI system. The structure is designed from eight surface coils type configuration, consisting some copper sheets combined with lumped capacitors to adjust the resonant frequency at exactly 128 MHz. The numerical simulation is performed and provide satisfactory performances including the reflection coefficient, the magnetic field intensity and SAR distribution. According to the discussed results, it is expected that by this array coil design perspective, a MRI system can have possibility to be applied with the fast imaging technique.

References

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