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A Radiofrequency Coil Based on Hybridized Modes Two Resonant Dipoles

A Radiofrequency Coil Based on Hybridized Modes Two Resonant Dipoles

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Abstract. We propose to use a resonator, consisting of mutually coupled dipoles as a radiofrequency coil with two orthogonal channels for 7 Tesla MRI in parallel trancieve configuration. In this work we show by numerical simulation that the two dipoles being driven symmetrically and anti-symmetrically produce similar field patterns to a dipole and a loop coil. It is shown that this equivalence is achieved for a certain distance between the dipoles.

1. Introduction

Operation of the proposed RF-coil is based on excitation of hybridized eigenmodes [**?**] in a pair of resonators (dipoles in our case). A single dipole is a resonant antenna with a linear current distribution which creates the RF-field distribution mostly described by a dipole electric moment. When used as a RF-coil for body imaging and put horizontally along the MRI bore direction, the dipole moment is parallel to a surface of a subject (i.e. a human body). In contrast, a loop antenna when used as a surface coil for body imaging, can be considered in terms of the field in the subject similarly to a magnetic dipole, directed normally to the surface, when used as MRI-coi. Therefore, a small dipole and a small surface loop produce mutually orthogonal field patterns and may be combined by centering at one position in an array with no mutual coupling. Indeed a pair of straight metal wires may possess an a antisymmetric quadrupole mode (also called odd mode), for which the wires support anti-parallel electric currents. These currents at electrically short distances produce magnetic field similarly to a continuous loop (e.g. a circular or a rectangular one). The same pair of wires may also support currents flowing parallel (even or dipole mode). In this case an electric dipole moment is produced and the near-field patters distantly enough from the dipoles are equivalent to ones of a single dipole. The similarity between the corresponding field patterns is schematically shown in Fig. 1 (a,b,c).

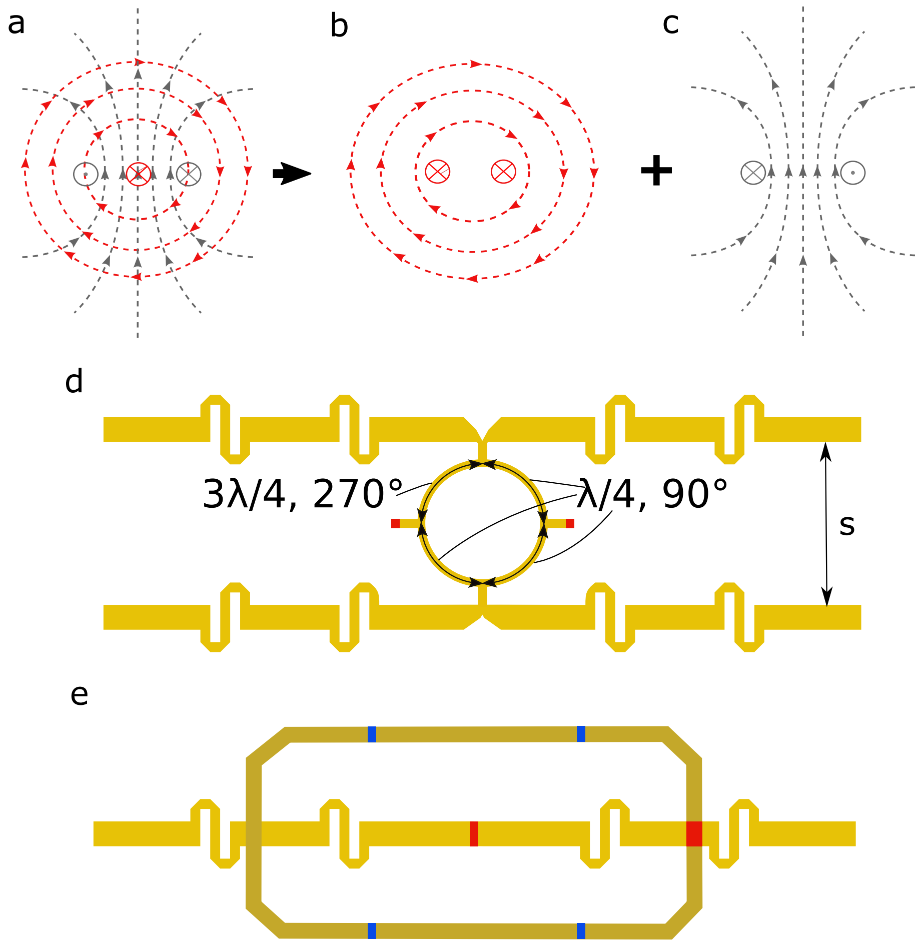

Figure 1. Analogy in the magnetic field created by the combination of a dipole and a surface loop (a) with one produced by the dipole mode (b) and the quadrupole mode (c) of a pair of coupled dipoles (dashed lines represent lines of magnetic field, while circles represent directions of currents of coils). Schematic layout of the proposed coil (d) consisting of two dipoles antennas. Schematic layout of the reference coil (f) consisting of loop and dipole antennas. Feeding points are shown by the red rectangles, lumped capacitors - by the the blue rectangles.

2. Design and simulation

The proposed coil is composed of two identical 300-mm-long fractionated dipole antennas [1] placed parallel to each other with a separation d between them as shown in Fig. 1 (d). The configuration of the reference design is depicted at Fig. 1 (e). The reference coil consists of a single fractioned dipole and rectangular surface loop with four distributed lumped capacitors and with size 89×190 mm^2[2]. The dipoles of the proposed coil have two ports at their middle splits. The even mode can be excited when the ports are driven in-phase, while the odd one is excited by out-of-phase ports. This dual-mode excitation can be realized by using an appropriate 180 hybrid, also known as a rat-race coupler[3].

Numerical simulation software (CST Studio Suite, CST, Darmstadt, Germany) was used to parametrically adjust the separation d between the dipoles by parametric optimization and calculate the electromagnetic fields, produced by the proposed dual-mode array element in pelvis-shaped homogeneous phantom with electrical properties of ε=61.8, ς=0.87 S/m. The goal of the parametric optimization was to obtain the same profiles of the radiofrequency magnetic fields created by both modes of the proposed coil as ones of the reference coil. All channels were

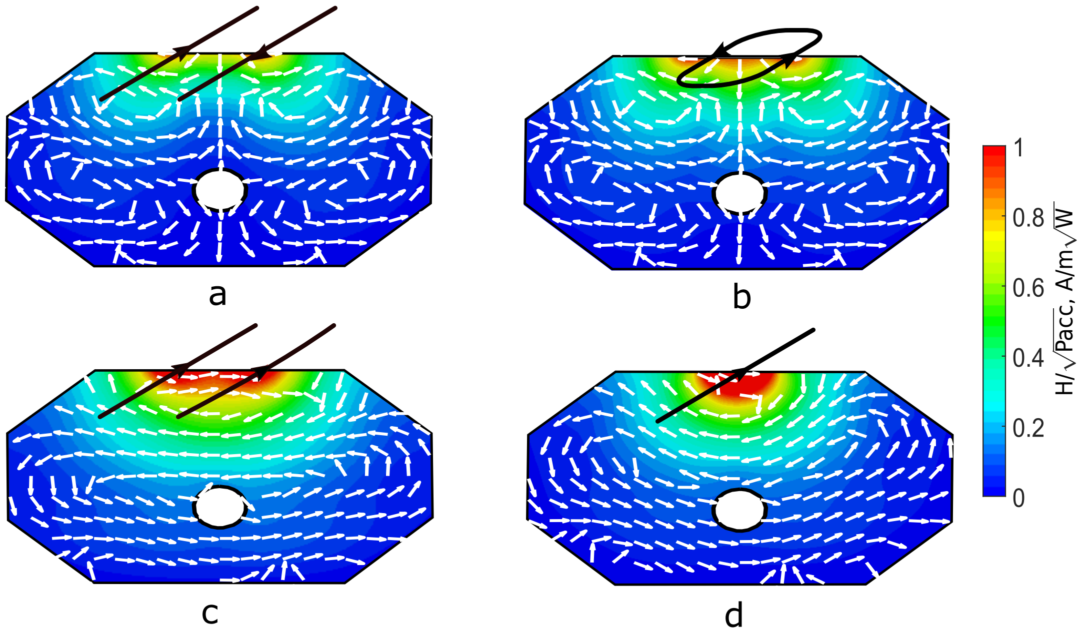

Figure 2. Simulated magnetic RF-field distributions of proposed and reference coils. Color plot demonstrates distribution of B_1^+ magnitude normalized by square root of accepted power. Arrows depict directions of H-field vector in the phantom : (a) odd (quadrupole) mode port of the proposed coil is driven; (b) loop of the reference coil is driven; (c) even (dipole) mode port of the proposed coil is driven; (d) dipole port of the reference coil is driven.

manually matched in CST DS module using lumped elements. The aim of the simulations was to confirm identity of field distributions provided by the proposed coil and dipole and loop coils.

3. Results

The magnetic field distribution normalized by the square root of the accepted power $\sqrt{P_{acc}}$ in the transversal plane in the center of the homogeneous phantom is presented in Fig. 2 both for the proposed coil (with the distance between the dipoles corresponding to the optimized case) and the reference one. The color plots demonstrate the magnetic field magnitude distribution, while the vector plots show the moment directions of the magnetic field vector. That plots demonstrate that the magnetic field distributions of the proposed coil are very similar to ones of the reference coil, especially at the depth of the phantom. As it is seen from Figure 2 (c) the magnetic field of the quadrupole (odd) mode of the proposed coil has the dominating vertical component. These are the same properties as of the surface loop part of the reference coil. From comparison of the Figures 2 a and b as well as Figures c and d, the optimal distance between the dipoles of the proposed coil provides equivalence of the proposed and the reference coils in terms of the RF-field patterns created when both of their channels are fed. Magnetic field magnitude vs. the depth profiles for different distances between the dipoles of the reference coils are compared in Figure 3 with the same curves of the dipole and loop antennas of the reference coils. As one can conclude, the corresponding curves for the proposed and the reference coils fit each other the best for the certain value $d = 6$ cm.

4. Conclusion

In this work, we propose a novel coil for 7 Tesla MRI based on hybridized modes of two coupled resonators. The results have shown an equivalence between the proposed coil and the dipole-

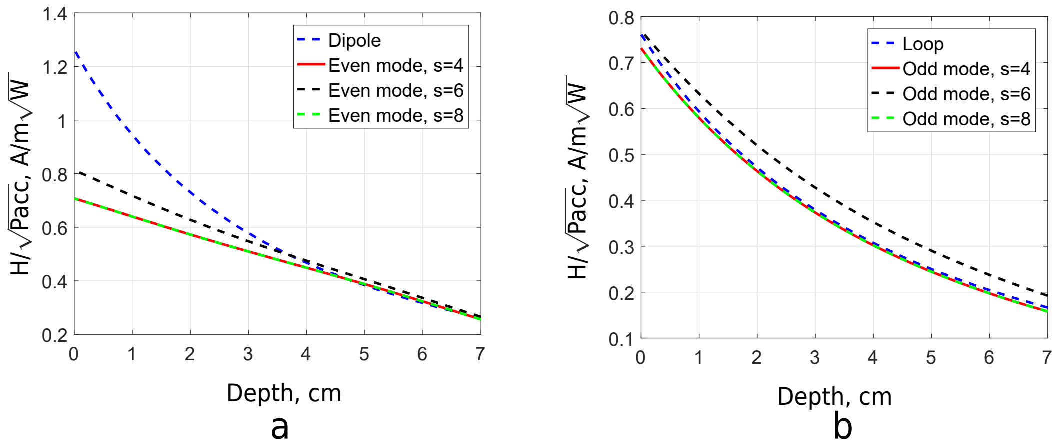

Figure 3. Simulated profiles of magnetic field magnitude vs. depth into a phantom normalized by the square root of accepted power for the even mode of proposed coil v.s. dipole of reference coil (a) and odd mode of proposed coil vs. loop channel of reference coil (b). The depth is measured from surface of phantom along the maximum of radiation inside the phantom.

loop combination in terms of magnetic field pattern created in a phantom. From the presented numerical simulation on can conclude that the proposed coil works similarly to the reference one when the distance between the two dipoles is optimized.

5. Acknowledgment

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