Simple quadrature volume antenna transformed from loop

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Introduction

Quadrature-driven cylindrical volume antennas, represented by birdcage [1] or TEM [2] antennas, can generate a large volume rotational magnetic field in their central regions. They are indispensable hardware for commercial MRI scanners. However, they consist of many parts, e.g., a 24-rung band-pass birdcage coil has at least 121 electrical parts (72 capacitors, 48 conductive elements, and 1 RF shield). Therefore, manufacturing them becomes complex. In contrast, simple loop coils [3] or a micro strip line [4] modified for larger volume excitation or receiving can be made using fewer parts. We introduce a simple quadrature volume antenna that has only five electrical parts (two conductive elements, two capacitors, and one RF shield) by transforming a one-loop antenna. This antenna can produce circular polarization and is applicable to volume antennas for 3T or higher field MRI scanners.

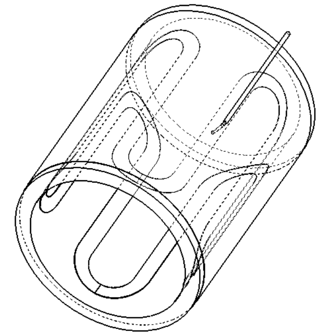

Fig. 1 Simple folded loop for volume excitation and receiving

Method

When a loop on a cylindrical surface is folded 2N times in the axis direction as in Fig. 1 (N=4), and the number of current nodes (minimum points) in the loop is 2(N-1) or 2(N+1), a uniform B_1^+ field is created in the center as shown in Fig. 2. The wavelength between the two current minima is half the RF frequency, so this type of antenna is suited for shorter wavelengths and higher field MRI scanners. If the first port is placed in somewhere on the loop, the port position becomes the maximum current position, and the second port should be placed at the minimum current position of the first port current distribution. Then, quadrature drive can be achieved. There are two possible ways to set the port capacitors: shunt capacitors between the RF shield and the loop, or series capacitors cutting the loop and connecting the gap.

First, a 3T head volume antenna prototype was manufactured. Figure 3(a) shows the prototype; it has a 280-mm inner diameter, 320-mm outer diameter, and 270-mm length. Four 18-pF shunt capacitors were placed with 90° rotation symmetry. The space between the RF shield and loop conductor was filled with acrylic. After a cylindrical phantom image was measured using this prototype, the 3T head antenna design was optimized using an electromagnetic field simulator (CST studio suite®). Much less acrylic was used in the optimized design to avoid dielectric loss. A six-folded design with a 267-mm inner diameter, 312-mm outer diameter, and 280-mm length as in Fig. 4(a), was adopted. Only two 40-pF series capacitors were used for this optimized design.

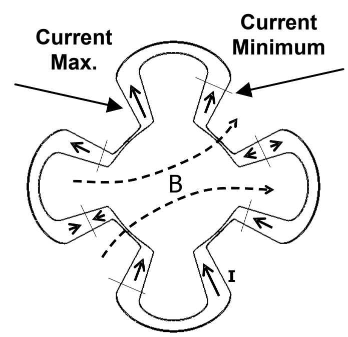

Fig. 2 Current nodes and magnetic field creation viewed from aperture of Fig. 1 antenna

Results and discussion

The measured unloaded S_{12} value of the prototype was -14.5 dB with S_{11} and S_{22} below the -24 dB condition. The phantom coronal (Fig. 3(b)) and axial (Fig. 3(c)) images show reasonable uniformity and verify the feasibility of this type of antenna. The observed phantom image shows good correspondence with the simulated field map (Fig. 3(d)). The measured center magnetic field was 0.45 [$\mu T/W^{0.5}$] for the prototype antenna. A much stronger center magnetic field of 0.84 [$\mu T/W^{0.5}$] (Figs. 4(b) and (c)) was predicted for the optimized design. This value is comparable to those of the birdcage (0.82 [$\mu T/W^{0.5}$]), or the TEM (0.74 [$\mu T/W^{0.5}$]) conventional antennas measured and simulated in our laboratory. Uniform excitation with quadrature drive (Fig. 4(c)) was possible with optimized design. The simulated S_{12} value was calculated to be -18 dB with S_{11} and S_{22} below the -17 dB condition. This simple antenna would be suited for use as a local transmission antenna that should be stored in a small space.

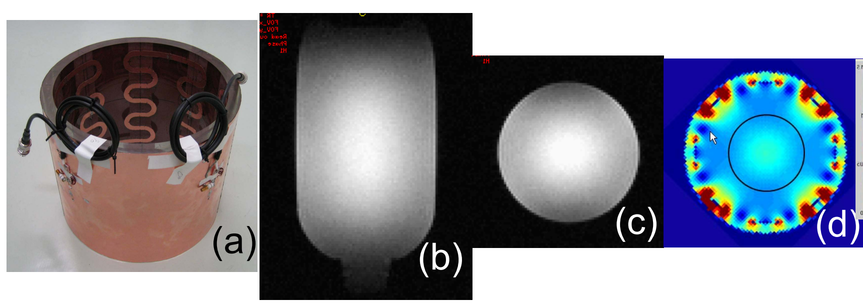

Fig. 3 Prototype for 3T head QD antenna photo (a), phantom image of coronal (b), and axial (c) slices, and simulated B_1^+ field map (d)

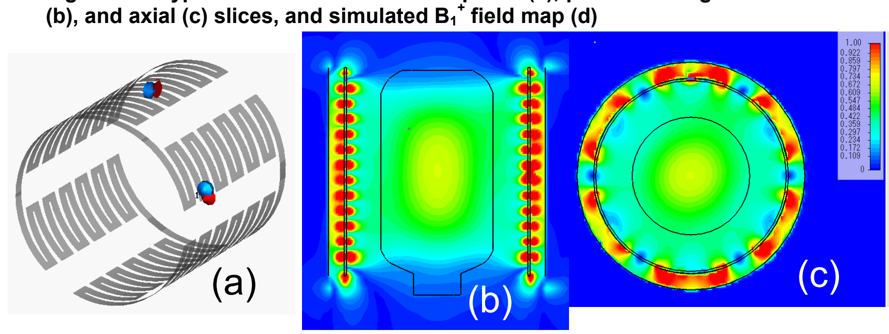

Fig. 4 Schematic view of 3T head optimized design (a) and its B_1^+ field map of sagittal (b) and axial (c) slices

References

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