

Endcap Design for Phased-Array Coils

J. Jevtic^{1,2}, V. Pikelja¹, M. Mercier¹, A. Menon¹

¹IGC-Medical Advances, Inc., Milwaukee, WI, United States, ²Medical College of Wisconsin, Milwaukee, WI, United States

Introduction

The most common application of an endcap or radio-frequency (RF) mirror in MR imaging is at the superior end of a circularly polarized (CP) RF head coil [1]. The RF currents induced in the endcap improve the uniformity of the MR image and extend the field of view of the coil in the superior-inferior (S/I) direction. The design of the endcap should satisfy two conflicting requirements [2]: good RF mirroring and minimal gradient induced eddy currents. Although this problem has successfully been solved for the case of a CP head coil, the conventional approach gives poor RF mirroring performance when implemented as a part of multi-channel phased-array (PA).

Problem

The most commonly used conventional technique is the shield segmentation approach which uses radial cuts in the circular copper plate, as shown in the insert of Fig.1. Very good performance is achieved when this endcap is used in a CP head coil [3], however, when used with a rectangular loop as in Fig.2, typical of a PA coil layout, the mirroring effect is almost entirely absent. This is illustrated in Fig.1, where the normalized measured sensitivity of a rectangular loop is shown along the axis of the endcap in the S/I direction. The endcap is located at 0cm. The main reason for the poor mirroring performance is due to the radial cuts greatly interfering with the natural flow pattern of the RF currents in the endcap. To investigate this point we have used the computational electromagnetics tool, FastHenry [4], to solve for the eddy currents in the endcap. The discretized geometry is shown in Fig. 2 (45 deg by 12 inch loop, 32cm diam endcap, 2cm endcap to loop spacing), representing one rectangular loop of an 8 channel PA head coil. The numerically determined streamlines of the RF current flow in a solid copper endcap are shown in Fig. 3, confirming that the radial cuts are incompatible with the desired flow pattern.

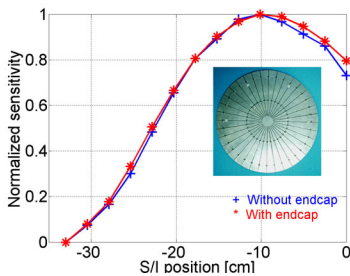


Fig.1 PA sensitivity with conventional endcap.

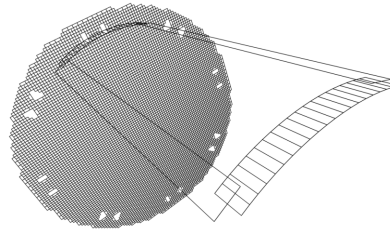


Fig.2 Discretized geometry for FastHenry analysis.

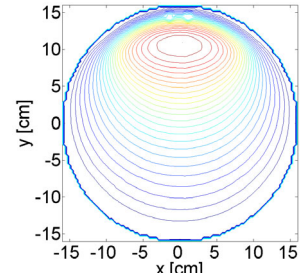


Fig.3 RF current streamlines in the endplate.

Method

A particularly interesting solution [5] to a similar problem in the RF shield design for CP coils is to cut the shield along the RF current streamlines as they would exist in a solid conductor shield. This approach was facilitated by the fact that a CP RF body coil has only two linearly independent RF modes at the Larmor frequency. We extend this reasoning to the case of an endcap for a PA coil. An 8 channel coil may induce 8 different RF current flow-patterns in the endcap. A printed circuit board (PCB) layout compatible with the flow-pattern of Fig. 3 is shown in Fig. 4. The cut-lines simply follow the streamlines. Whenever the distance between the streamlines exceeds 1cm an interposed cut-line is started in order to limit the maximum diameter of a solid copper patch to 1cm.

Results

Fig. 5 shows the top surface of a single channel endcap prototype cut on a double sided G10 board (32cm diam, 10 mils thick, 2 oz./sq.ft. Cu) using a Protomat PCB plotter. The only difference between the top (Fig.4) and bottom (Fig.5) PCB layouts is in the vertical lines which serve to prevent the closed loops for eddy currents but allow the RF current to close thru the capacitance between the top and bottom traces [6]. The measured results, shown in Fig. 6, confirm the strong RF mirroring effect, essentially undistinguishable from the mirroring obtained with an endcap made out of a solid conductor.

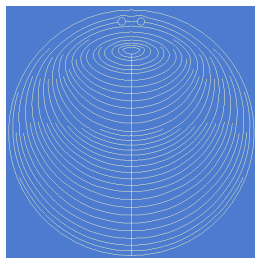


Fig.4 PCB layout for the new endcap (top).



Fig.5 Prototype endcap (bottom).

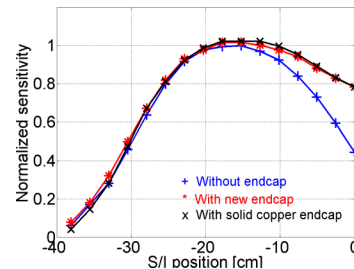


Fig.6 PA sensitivity with the new endcap.

Discussion

An endcap design is presented which provides good RF mirroring, comparable to solid conductor performance, for PA coils, while minimizing the gradient induced eddy currents. A separate circuit layout is required for each channel, obtained by simple rotation about the mirror axis. Although separate PCBs may be used, both the cost and weight of the endcap may be significantly reduced by a multi-layer PCB design.

References

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