Low eddy current RF body coils

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Introduction

Most MRI systems use a birdcage coil as the main Body RF transmit coil. In order to cut down on coil losses, the rungs and endrings of the birdcage are made of wide copper strip, in which gradient eddy currents can be induced. In order to prevent these eddy currents slits are made in the rungs and ring segments to increase the impedance for the gradient eddy current. They are chosen such that the RF performance of the coil is not affected. It is not clear how to make slits in the areas that connect the rungs to the rings, yet this area is large and is located right underneath the highest current density areas of the X and Y gradient coils. As a result these areas heat up as can be seen in the infrared image (fig 1).

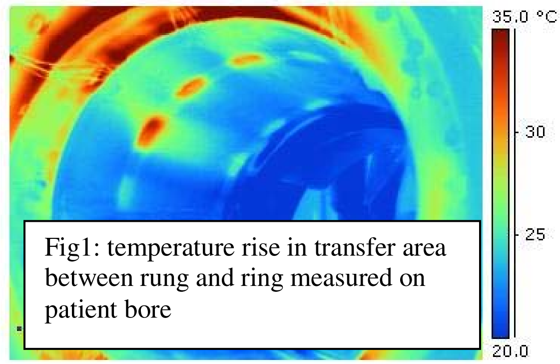


Fig1: temperature rise in transfer area between rung and ring measured on patient bore

Method

Several different shapes of the rung to ring transfer area were built, tested and simulated using a FEM method (HFSS, Ansoft). A 16 rung high pass 64 MHz Body coil was built with an overall length of 620mm, diameter 608 mm, RF shield diameter 650mm. Both rungs and endring segments are 60 mm wide, setting up an area of 36 cm^2 where rung and ring meet, available for eddy currents. The end ring segments have 3 slits in the tangential direction, and the rungs 3 slits in the Z direction to cut down on eddies in rung and ring segments. In an effort to reduce the copper area in the rung to ring transfer zone several cut out shapes were investigated: 1) the uncut version, 6 by 6 cm, 2) a U shaped cut out leaving 1 cm of copper adjacent each ring segment, and 2 cm of copper adjacent to the end of the rung, 3) The same as 2, but now with a > 1 nF capacitor bridging the top of the U. This capacitor has 1 cm wide ribbon leads. 4) The rung is tapered at the ends, so that it is only 1 cm wide, where it meets the endring, The slits in the endring segments are extended so that the copper transfer area is reduced to 6 by 1 cm. In order to test the RF performance with these modifications we calculated the RF current density distribution, and tested the RF coils for SNR and power efficiency changes after they were properly tuned for match and isolation. SNR was measured on a spherical 275 mm phantom surrounded by a load cylinder, 25 mm thick, 275 mm long, OD 340 mm. The load cylinder had 2.1 grams of NaCl per liter. The NEMA SNR standard was used.

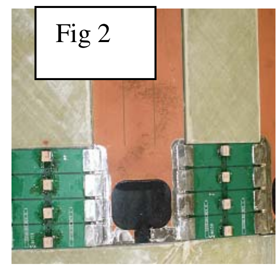
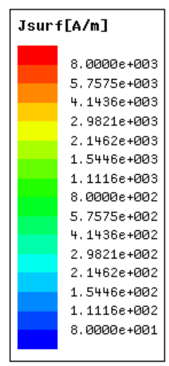


Fig 2



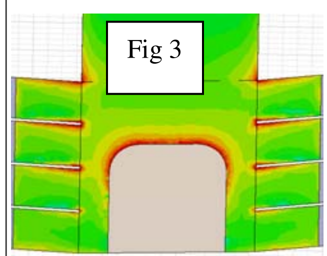


Fig 3

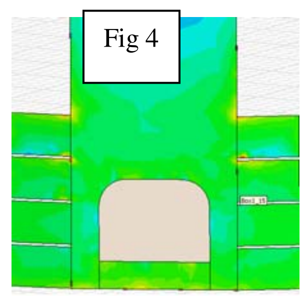


Fig 4

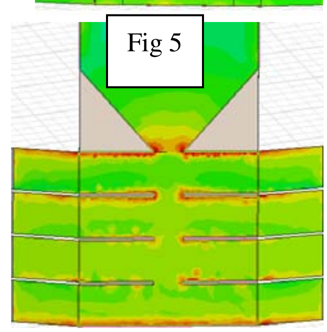


Fig 5

Results

In fig 2 a picture of the transfer area shows location of capacitors and slits. Figs 3, 4, and 5 (all the same scale) show RF current density distributions for the cases described. SNR and empty Q (no load phantom) were unchanged in the case of fig.5 when compared to the original uncut transfer region birdcage. The case of fig 4 showed an empty Q decrease of 10% and a 2% decrease in SNR. The case of fig 3 showed a 11% decrease in empty Q, and a 5% decrease in SNR. Uniformity was the same in all cases. Temperature increase due to gradient eddy currents is reduced by 90% in the worst case due to a 66% reduction in copper surface.

Discussion

The case of fig 5 is slightly better than the others since it has negligible impact on SNR and cost. The RF current density is increased where the rung narrows. Rounded off corners and increased copper thickness can help this issue. The case of fig 4 although having good RF performance requires 32 blocking capacitors (>1 nF) and thus increases cost. The case of fig 3 has some extra losses but they are small. There is no cost increase, but current density plots show that the outermost capacitor gets less current than the others. Instead of evenly distributing capacitance one could increase the outer and decrease the inner capacitances to even out the current density. To decrease current density at the edge of the U shaped cut out one can add copper at that edge in the radial direction.