Coil design for imaging the Uterine Cervix at 3T. Control of r.f. Eddy Currents.

D. J. Gilderdale[1,2], M. A. Schmidt[1], and N. M. deSouza[1]
[1]Cancer Research UK & EPSRC Cancer Imaging Centre, Institute of Cancer Research & Royal Marsden NHS Foundation Trust, Sutton, Surrey, United Kingdom,
[2]Pulseteq Ltd, Wotton-under-Edge, Gloucestershire, United Kingdom

Introduction

For imaging cervical cancer, the high sensitivity of a coil of solenoid structure enveloping the cervix has been demonstrated [1,2]. A single turn short cylindrical structure helps to minimise inductance and hence conservative electric fields. The uniformity of the vertical (y-axis) component of B_1 (receive field) is demonstrated in Fig.1. A receive-only coil must produce minimal disturbance to the uniformity of the B_1 excitation field. The usual priority is to minimise circulating currents around the receive coil loop during B_1 excitation. However, as the copper foil short cylindrical structure presents a significant cross-sectional area perpendicular to the B_1 flux in the x direction, additional field perturbation results even with the coil loop open-circuited. With the short cylinder employed as a surface loop coil [3], this field distortion is usually remote from the volume of interest (VOI) and can be ignored; however, with an enveloping receive coil design, B_1 flux may be partially shielded within the VOI, and field distortions result. Flip angle accuracy is increasingly important for quantitative studies and advanced imaging pulse sequences. The purpose of this work, therefore, was to determine the field perturbations using a short cylindrical coil and document the effects of reducing its cross-sectional area by splitting it into a number of parallel turns.

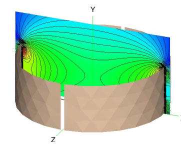

Fig.1

Methods

The orientation of the receive coil ensures that the cross-sectional area presented perpendicular to the circularly-polarised B_1 field will vary throughout each cycle, being maximum with B_1 in the x direction and minimum in the y direction. Faraday's Law dictates that any reduction in the cross-sectional area of copper presented perpendicular to B_1 will commensurately reduce eddy currents. Such a reduction may be achieved simply by dividing the cylinder of Fig.1 into a number of parallel turns.

Simulations: We performed EM simulations using commercial Hybrid Method of Moments software (FEKO, [4]), to explore the possible screening effect and its directional dependency for coils of one, two and four turns. To generate an excitation field, a simple ring coil was modelled, producing a linear horizontal magnetic field component along the x-axis as shown in Fig.2a.

Experiment: Three short cylindrical copper structures were built on 37mm diameter x 12mm deep Acetyl formers consisting of one, two and four parallel turns. These structures were 'open circuits' and therefore presented a high impedance at the resonant frequency, as is desirable for receiver coils during RF excitation. The coils were tested at 3T (Philips Achieva, Best, the Netherlands) by measuring the B_1 excitation field of the body coil, with and without the receiver coils in the excitation RF field. A large test object was used to provide a suitable load to the body coil and a small cylindrical test object placed over it was used to load the short cylindrical test coil structures (Fig.3). B_1 measurements were made using the manufacturer's own tool, using a sequence with two interleaved TRs (30 and 150 ms) [5].

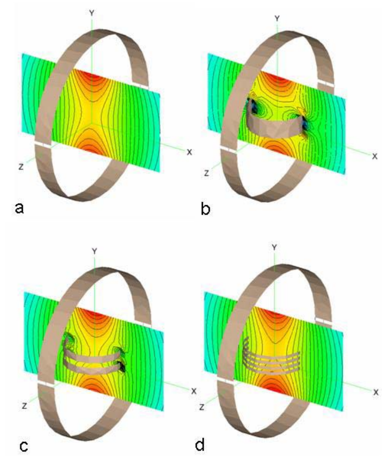

Fig.2

Results

Simulation: Fig.2a represents the reference, undisturbed, B_1 field. Note this is less uniform than a normal transmit field due to the small excitation loop used for modelling convenience. Fig.2b shows the introduction of a single-turn 12mm deep open-circuit receive-only coil. Note the reduction in field throughout the enclosed volume. Using two loops each of 4.5mm depth, there is marked improvement in field distortion (Fig.2c), although an increased fall-off is apparent close to the rings. Finally, use of four rings, (Fig.2d), results in a barely discernible field disturbance.

Experiment: Fig.3 shows trans-axial images of the B1 excitation field without receiver coils in place (a), with a single turn coil in place (b), a two-turn coil (c) and a four-turn coil (d). Without receiver coils, the measured B_1 field at the centre is close to the nominal value. The central B_1 field drops to 89% and 99% respectively when the single turn and the two-turn coils are placed around the cylindrical test object. The single-turn structure produces increasing distortion close to the coil. With the four-turn coil the B1 field of the body coil remains unchanged over the whole VOI shown in Fig.3.

Conclusions

These results demonstrate that for receive-only coils, unwanted screening effects can arise. As anticipated, the importance of these effects depends on the conductor dimensions and their position relative to the VOI. In the specific case of the short cylindrical solenoidal coil, simply dividing a single 12mm deep ring into four parallel loops is sufficient to eliminate the field distortion.

Note that the above discussion is concerned solely with the screening effect of r.f. eddy currents in coil conductors. Lumped capacitors have been deliberately omitted. A practical coil design will almost certainly be segmented, incorporating distributed tuning capacitors. Although these capacitors may help to reduce eddy currents, they will not be eliminated and the issues described will still apply.

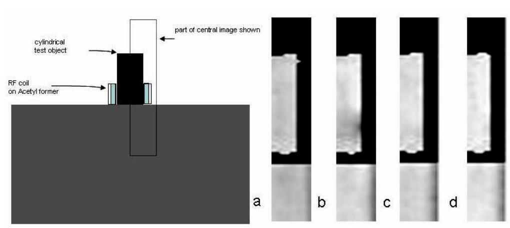

Fig. 3

References

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Acknowledgements We acknowledge support from (1) CRUK and EPSRC Cancer Imaging Centre in association with the MRC and Department of Health (England) grant C1060/A10334, also NHS funding to the NIHR Biomedical Research Centre. (2) MRC Project Grant G0802470.
(3) Philips Clinical Science.