Measurement of occupational exposure to RF and gradient fields in an open 1T MR system

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INTRODUCTION: EU Directives 2004/40/EC and 2008/46/EC require a risk assessment of occupational exposure to electromagnetic fields to be carried out. Especially interventional MR procedures may involve exposure of staff to electric and/or magnetic fields and/or magnetic flux density values that exceed action values (AVs) defined in the Directives. Applying current ICNIRP limits within [2] might outlaw any such practice in future. In this work we investigate the use of specifically measurement procedure and analysis to systematically measure field strengths during pre-selected procedures with regard to movements of a radiologist during an interventional procedure carried out in an open 1 T scanner. The results have been compared with the existing AVs of Directive 2004/40/EC.

METHODS: Placing a guide wire in the breast of a patient (fig. 1) requires a radiologist to lean into a 1T open system (Panorama HFO, Philips Medical Systems). To understand if relevant AVs at and around the position of the radiologist could be exceeded it was necessary to map gradient and RF fields on two fixed grids, a single plane designed for operation outside the magnet (fig. 2), and a smaller sub-grid for inside the bore (fig. 3). The probe positioning was manual but supported mechanically. Position identification was done using an image projected on a screen inside the scanner room in order to minimize erroneous measurement location selection. Gradient field distribution was mapped with using NARDA-STS ELT400 low frequency 3-axis magnetic flux meter. The required field mapping space was worked out using the ICNIRP exposure limit feature of the ELT400. In addition, time domain signals have been obtained from the x,y,z-coils for clinical and test sequences.B1 RF fields were measured with SPEAG's EASY4MRI standalone data acquisition system employing high-precision E- and H-probes. The gradient field measurements comprised two elements, firstly measurements of balanced-FFE (sBTFE), turbo spin echo and diffusion weighted single shot (D-SSh) sequences relevant to the type of MRI performed at the site in question and secondly the measurement of a test sequence exciting X, Y and Z gradients individually in order with known amplitude and rise times for all points on the measurement grid down to 0.1 of the AV. The measurements of the RF fields were done using a simple test sequence with nominal 5µT peak field strength with 33% duty cycle or 2.88µT_{rms}. The nominal RF powers were from 450W peak envelope power (PEP) to 1100W PEP.

RESULTS: Fig. 4 shows an example of gradients in the bore assuming excitation of X, Y and Z gradient coils with equal amplitude and vector addition of components. Contours are labeled in T/s. Fig. 5 shows a contour plot of the RF H-field on a horizontal slice (one half of the machine to the front where the patient bed attaches) through the isocentre. The field decays below the AV within the footprint of the machine. The RF fields outside the bore are sufficiently small not be of concern of occupational exposure. Gradient fields exceed the AVs during interventional procedures such as clip insertion or guidewire placements by a factor of 160 for inside the bore and by a factor of 1.5 at the bore edge. RF fields exceed the AVs in the bore by a factor of 15, or by a factor of 1.7 at the bore edge. The combined uncertainties for the measurement results are 1dB for gradient fields and 0.6 dB for RF H-fields and 0.5 dB for RF E-fields.

CONCLUSIONS: Gradient fields and RF fields exceed the AVs as layed out in EU Directives 2004/40/EC during interventional procedures such as clip insertion or guidewire placements. However, this does not necessarily imply that the basic restrictions will be exceeded (induced current density or SAR).

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Fig. 1: Interventional procedure at 1T Panorama

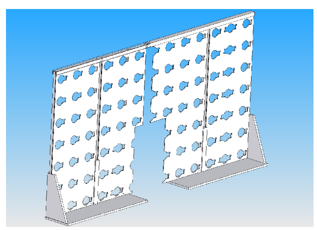


Fig. 2 Measurement wall

Fig. 3 Gradient field probe secured in bore measurement grid

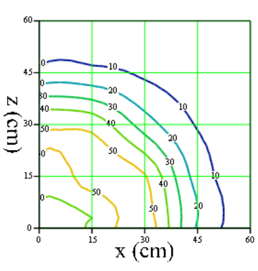
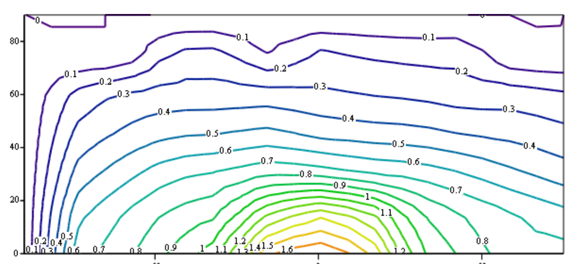


Fig. 4 Gradients in the bore Contours are labeled in T/s.



Fig, 5 H-field in the bore, horizontal cut through isocentre, scale in cm with reference to the isocentre

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