PERFORMANCE AND SAFETY EVALUATION OF A HUMAN SIZED FFL IMAGER CONCEPT

Gael Bringout, Ksenija Gräfe and Thorsten M. Buzug
Institute of Medical Engineering, Universität zu Lübeck,
Ratzeburger Allee 160, Lübeck, 23562, Germany
Email: {bringout, buzug}@imt.uni-luebeck.de

INTRODUCTION: In the past years, parts of a human sized FFP imager have been presented, whereas other topologies as FFL imager have been kept at smaller sized [1]. In order to evaluate the expected outcomes of a human sized FFL imager, we propose a concept aiming at 2D full body imaging.

METHODS: A multipole expansion technique has been used to design the shape of the dual-quadrupole yoke, in order to maximize the efficiency and the free available inner diameter. To this end, an octupole like geometry is introduced. Six poles of the dual-quadrupole are also used in order to generate the focus fields for each direction. The selection coil is made using a solenoid-like Z-gradient coil, without flux return yoke. Inside, a set of two drive coils are optimized in order to minimize the inductivity using an inverse technique [3], while keeping a free inner diameter of 0.5 m. The induced electrical field of different coil topologies on a human body [4] is used in order to determine the frequency limits regarding the coils. For the drive fields, limits from [5] are extrapolated.

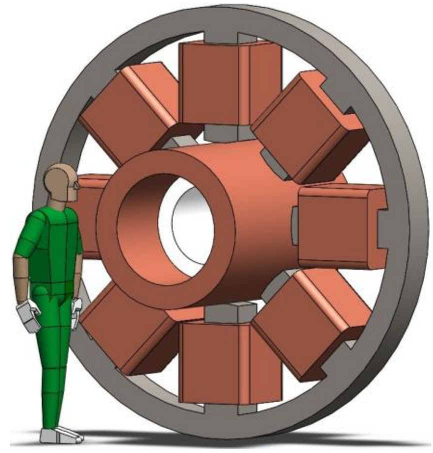

Figure 1. Isometric view of the three main coil systems: an octupole shaped dual-quadruple, a cylindrical Z-gradient coil and a white insert containing the 2D drive coils

RESULTS: To generate a gradient of 1 T/m perpendicular to the line, each pole, winded with 75 loops of 15 parallel hollow copper conductors of 6x6 mm² with a current density of 3.2 A/mm², will dissipate a power of 5 kW. To generate a 40 mT peak focus field in x or y direction, a dissipated power of 450 W (FFDP) should be expected per direction. The selection coil, with a current density of 5.6 A/mm², is expected to dissipate 65 kW. The outer and inner drive coils have an efficiency of $4.25 \cdot 10^{-6}$ T/A and $5.40 \cdot 10^{-6}$ T/A, generates 3.7 and 4.8 mT peak, respectively, and both dissipate a power of 2 kW. Both numbers take into account the effect of a shield placed inside the selection coil, a 5 fold increase of the litz-wire DC resistance at 150 kHz and a working temperature of 30°C. Self-inductivities of 13 and 11 µH are expected, leading to peak voltages at 150 kHz of 11 and 9 kV on the outer and inner coils, respectively. The expected self-inductivity of each pole is in the order of 16 mH, leading to a peak voltage of 9 kV. Using focus fields which move the line rotation point along a square 2D Lissajous trajectory, a surface of 300x300 mm² can be reconstructed, showing promising results. An example using other frequencies in order to reduce the amount of stored data during the simulation are shown in fig. 2. Here frequencies of 25 kHz for the drive, 160 Hz for the quadrupole and 180/120 Hz for the focus are used. All the data needed to redo those simulated images are available on www.imt.uni-luebeck.de and github.com/gBringout/ScannerDesign. From [4], a limit for the induced electrical field of 7.3 V/m is considered, leading to a maximal quadrupole's frequency of 60 Hz. In order to stay around this threshold, the configuration may use frequencies of 64 Hz for the quadrupoles, and 144/96 Hz for the focus fields. This configuration could deliver 16 images per seconds (i/s).

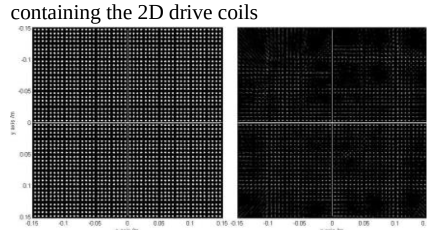

Figure 2. Simulation results. On the left is the phantom used to produce the image on the right. Each quadrands,seperated by whites lines, use different parameters. Each quadrand is simulated in 9 subquadrants. Value are given for a scanner using the frequencies 64/144/96 Hz (16 i/s) and 64/72/48 Hz (8 i/s), but simulated with 160/180/120 and 80/180/120 Hz. **Top left**: 16 i/s, 50% FFDP. **Right**: 16 i/s, 75% FFDP. **Bottom left**: 8 i/s, 80% FFDP. **Right**: 8 i/s, 100% FFDP.

CONCLUSION: A first idea of a human sized FFL imager has been presented, focusing on the magnet design and the acquisition's rate estimation. The acquisition rate has been limited by the induced electrical field in the patient by the quadrupole fields. However, a better thresholds should be derived, taking into account the drive, focus and selection fields variations. Also, the use of continuously varying focus fields of low frequencies in addition to the modulated drive field significantly helps to further reduce the required bandwidth of the MPI-signal, without scarifying resolution. This can be seen as an enhanced narrowband MPI [6].

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