Optimizing the visibility of a carbon fiber cannula in spin echo sequences using currents induced by gradient switching in an attached copper loop: a feasibility study

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Purpose/Introduction

Cannulae used in MR-guided interventions are often made of titan or other MR compatible materials. At 1.5 T, titan produces pronounced artifacts. Recently, a new cannula made of cfrp (carbon fiber reinforced plastic) with different mandrins for use in iMRI procedures (outer diameter 0.8 mm, lumen 0.34 mm, length 100 or 150 mm) has been introduced [1] and first clinical experiences with therapeutic injections at 1.5 T have been reported [2]. The carbon fiber cannula produces a relatively delicate artifact. Under certain circumstances, however, it would be desirable to optimize its visibility in spin echo sequences (characterized e.g. by the contrast and width of the produced artifact). Gradient switching induced currents in well conducting material (e.g. copper) have been shown to create gradient echo like artifacts in spin echo sequences [3, 4]. Therefore it is proposed to surround the carbon fiber cannula with a loop of thin copper wire and utilize the currents induced in it by gradient switching to individually control the visibility of the cannula according to the prevailing requirements. The feasibility of this approach was evaluated theoretically and practically.

Material and Methods

To demonstrate the desired effect a cfrp tube (outer diameter 5.9 mm, inner diameter 4 mm, length 135 mm) was surrounded by a rectangular loop of 0.5 mm thick copper wire (see fig. 1) and placed along the x-axis in a box with Gd-doped water. Imaging was performed in the transversal plane containing the copper loop at z = y = 0 and x =15 cm using the body coil of a 1.5 T scanner (Siemens, Erlangen) and a spin echo sequence (field of view 256*256 mm^2, slice thickness 3 mm, matrix 256*256, T_R = 1000 ms, T_E = 22 ms, phase encoding direction A>>P). The bandwidth was varied (55, 100, 201, 399, 592 and 781 Hz/Px) and for 201 Hz/Px the encoding directions were swapped. For a systematic assessment 5 mm thick plastic drinking straws (lengths 135, 100 and 65 mm) were surrounded by a rectangular loop of 0.5 mm thick copper wire. Additionally straws (length 100 mm) were surrounded by rectangular loops of 0.4, 0.3, 0.2 and 0.1 mm thick copper wire. The straws were imaged in the same way as described above.

The voltage induced in a wire loop is determined by its area (among other things), while the current – and thus the signal void – depend on the inductive resistance R_L of the loop and its Ohmic resistance R_Ω respectively. The influence of the different parameters was analysed.

Results

Figures 2 and 3 show the increased visibility of the cfrp tube at higher bandwidths caused by the currents induced by gradient switching. Theoretical considerations indicate that while going to smaller dimensions the decreasing area of the loop has a minor influence, rather the Ohmic resistance R_Ω, which increases with decreasing wire diameter, constitutes the current limiting factor. This was confirmed in the phantom measurements: while the desired effect was pronounced for the 0.5 and 0.4 mm thick wires and noticeable for the 0.3 mm thick wire, the currents induced in the 0.2 and 0.1 mm thick wires were not sufficiently high to create clearly noticeable artifacts. Varying the loop area at fixed wire diameter did not have a noticeable influence, as expected from the calculations.

Discussion/Conclusion

Although the proposed approach works in principle the wire thickness required to create sufficient signal void may be too large to be practical. For thinner cfrp cannulae the signal void may further be limited by magnetic field cancellation due to the proximity of the long sides of the rectangular loop. However, it remains to be seen whether the desired effect can be achieved using other geometries of the wire loop, e.g. a dedicated coating, and/or other, more conductive materials.

Fig. 1: Photo of the cfrp tube with the copper loop

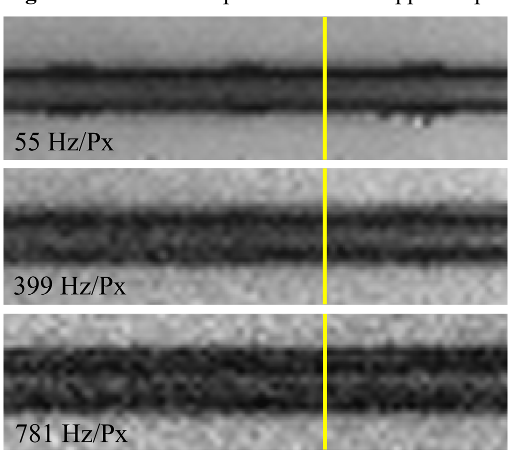

Fig. 2: Spin echo images of the cfrp tube with the copper loop, acquired using different bandwidths
(yellow lines: location of the profile shown in fig. 3)

References
[1] Becker et al., #312 ESMRMB 2009
[2] Thomas et al., EJR, submitted
[3] Shenhav et al., MRM 52:1465–1468 (2004)
[4] Graf et al., MRM 54:231–234 (2005)

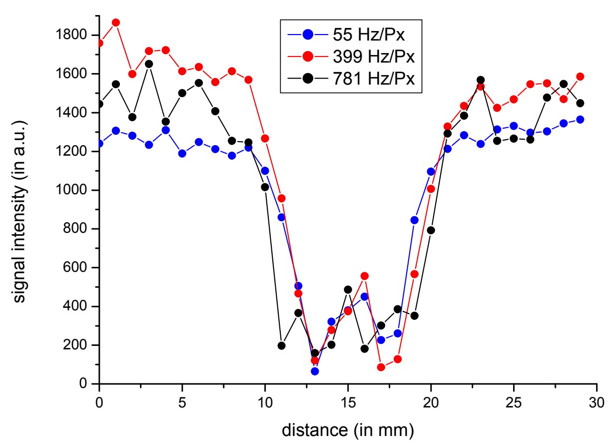

Fig. 3: Profiles of the signal intensities taken perpendicular to the cfrp tube with the copper loop (see yellow lines in fig. 2)