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Integrated ΔB0/Rx coil array for improved spinal cord imaging at 3T

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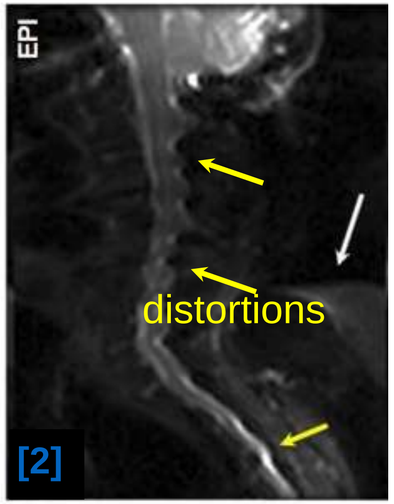
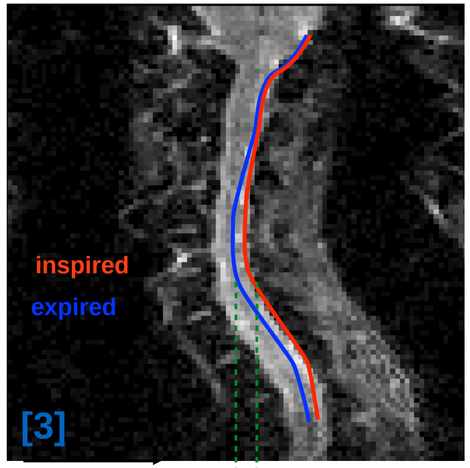
Problems

*"The greatest challenge for acquiring MR images in the spinal cord is **[ΔB_0]** the inhomogeneous magnetic field in this region."* [1]

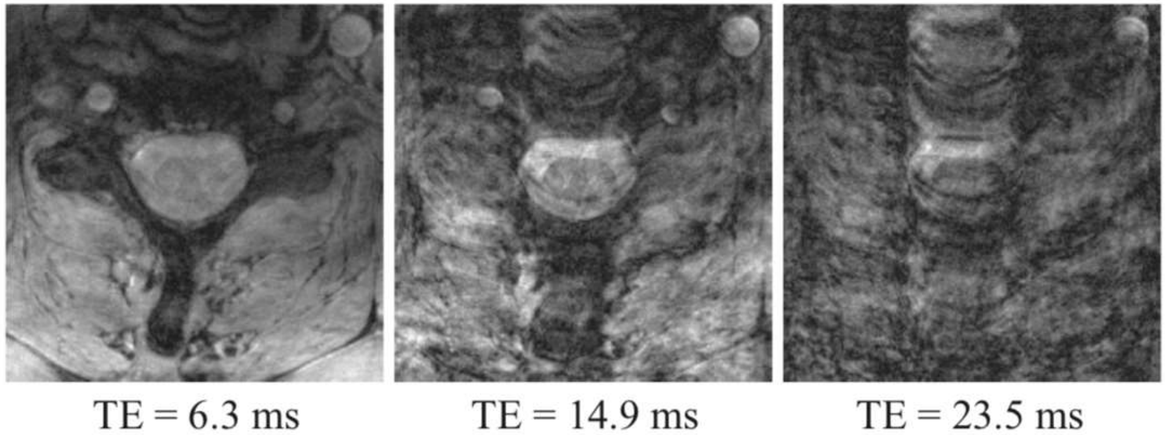
static ΔB_0
(e.g vertebrae, airways)



dynamic ΔB_0
(e.g. respiration & swallowing [3,4])



T2*-w @7T: ghosting from ΔB_0



[4] Vannesjo S, Neuroimage 167:191-202

[1] Stroman P, Neuroimage 84:1070-81
[2] Saritas E , Chapter 2.3 of *Quantitative MRI of the Spinal Cord*
[3] Verma T, Magn Res Med 72:1629-36

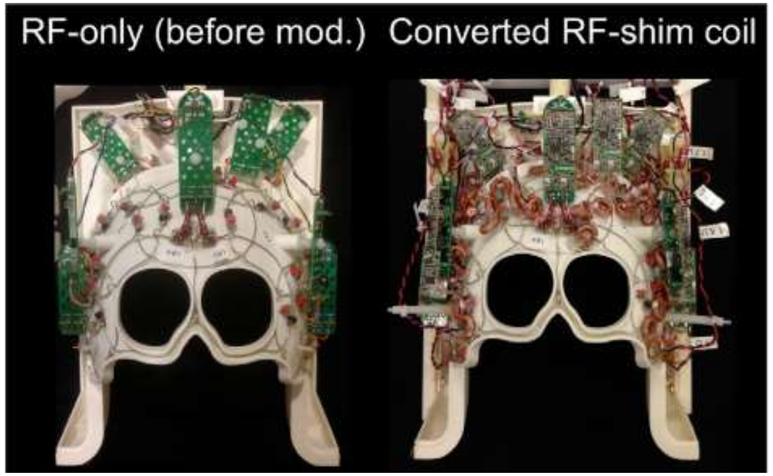
Solutions

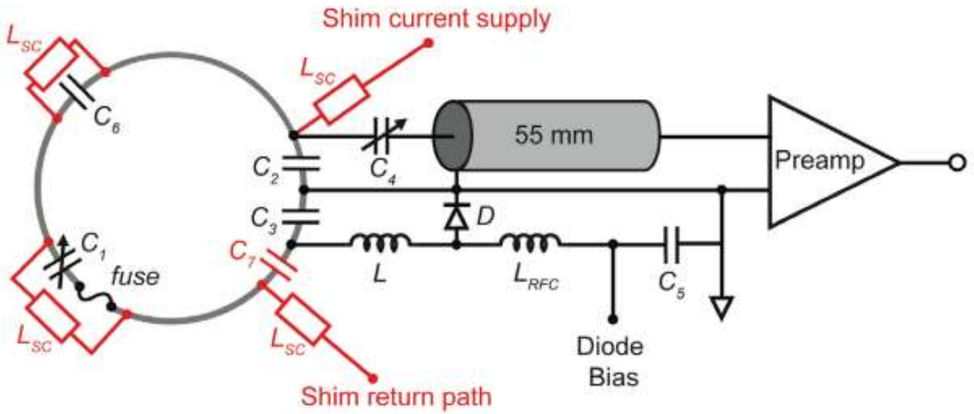
How to address these issues? ⟶ ***Solving the "real-estate problem" [1,2]***

Parallel imaging + high-order dynamic shimming

[1] Stockmann JP, Magn Res Med 75:441-51

Design principle	Rx benefit	Shim benefit
Positioning coils near body	↑sensitivity, ↑SNR	↑efficiency (Hz/A)
Using many coils	enhances parallel imaging	enables higher order ΔB_0 correction [3]





[2] Truong TK, Neuroimage 103, 235–40

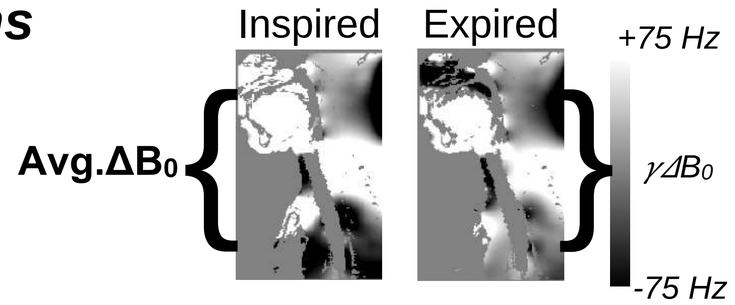
[3] Juchem C, J Mag Reson 236: 95-104

Conceptualization

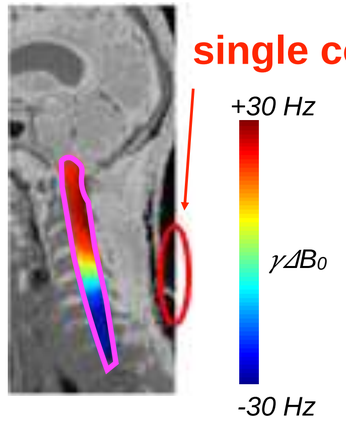
Optimal coil arrangement from simulations

[1] Germain G, ISMRM 2016. Abstract #3490.

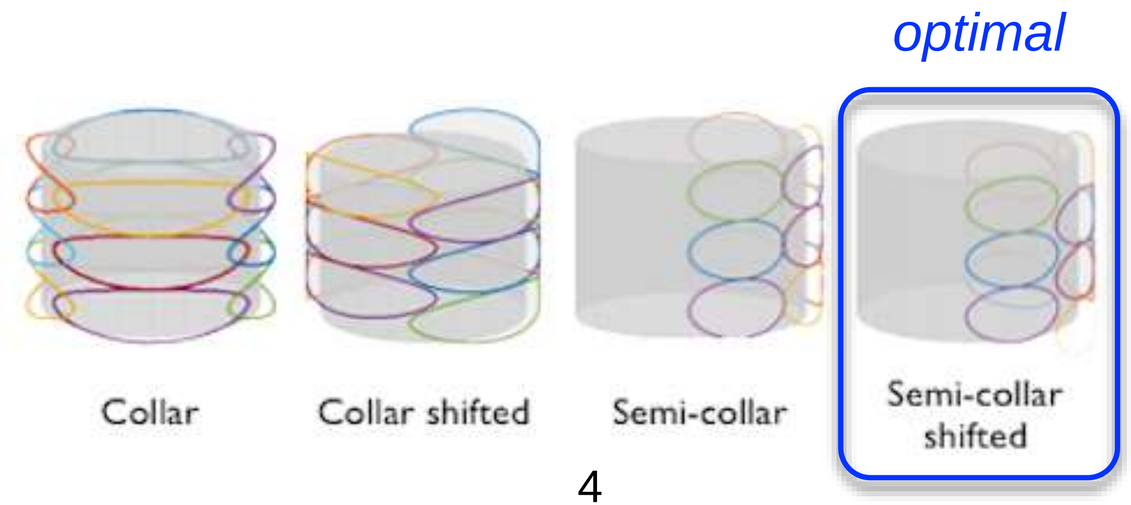
1. Sagittal ΔB_0 maps acquired (n=5)



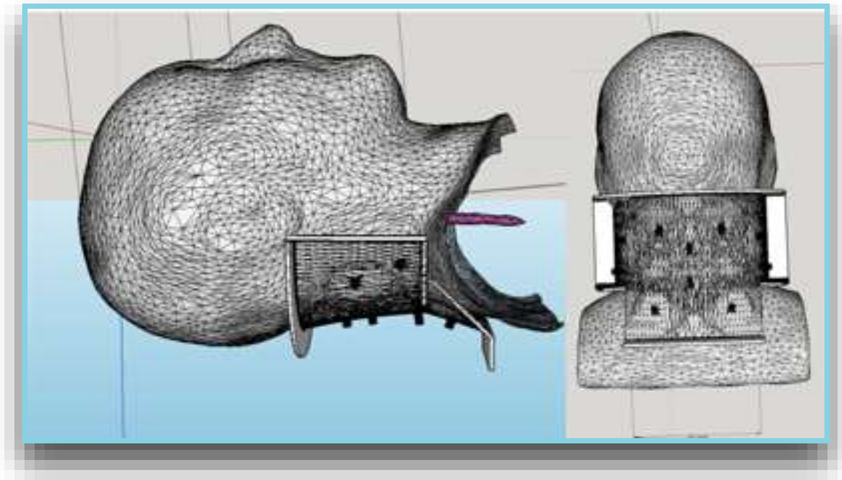
2. Auto-segmentation of cervical spinal cord ROI using the *Spinal Cord Toolbox*



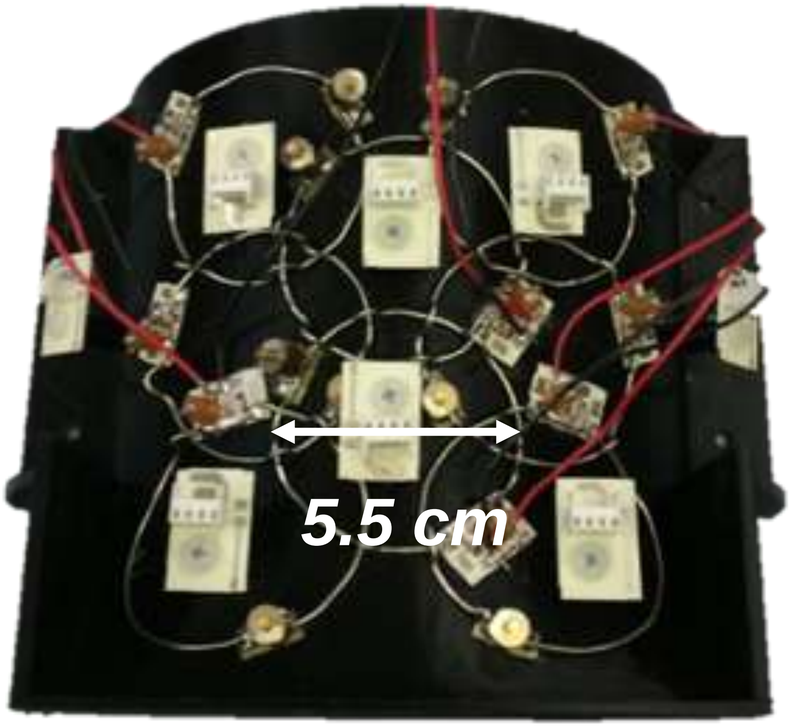
3. ΔB_0 + Rx SNR performance assessed for various coil arrangements

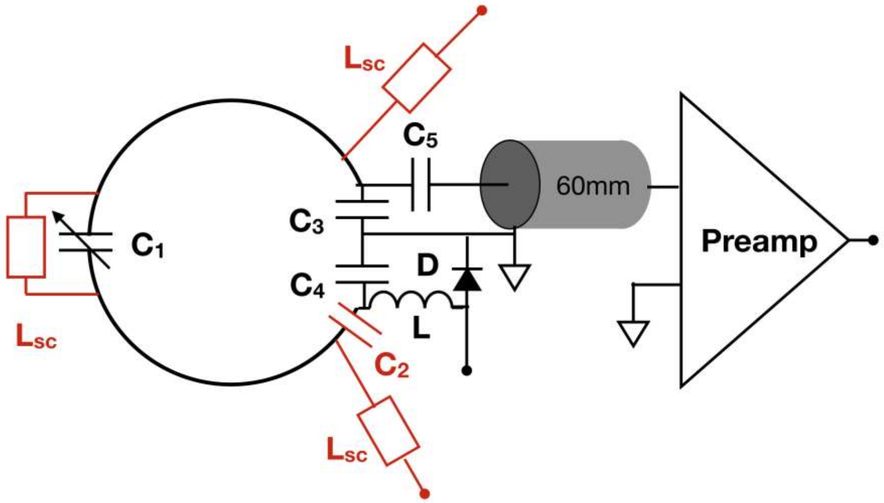


Construction



RF only





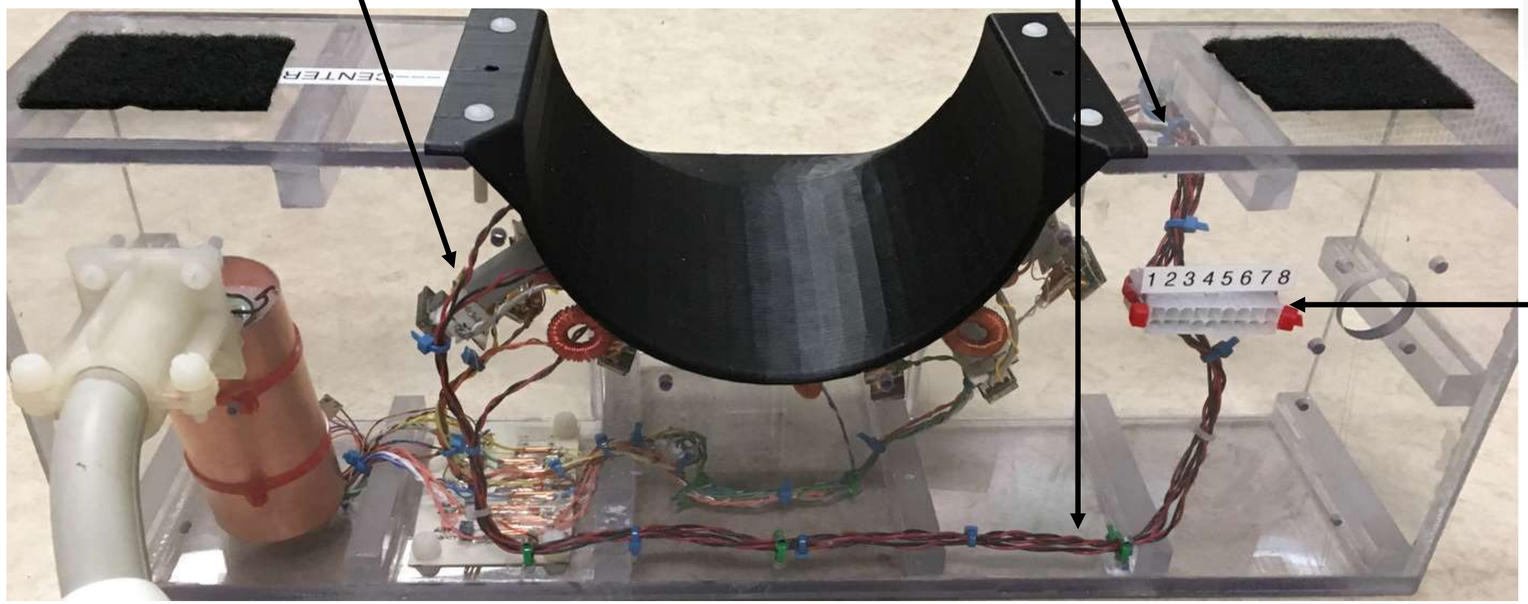
RF + shim

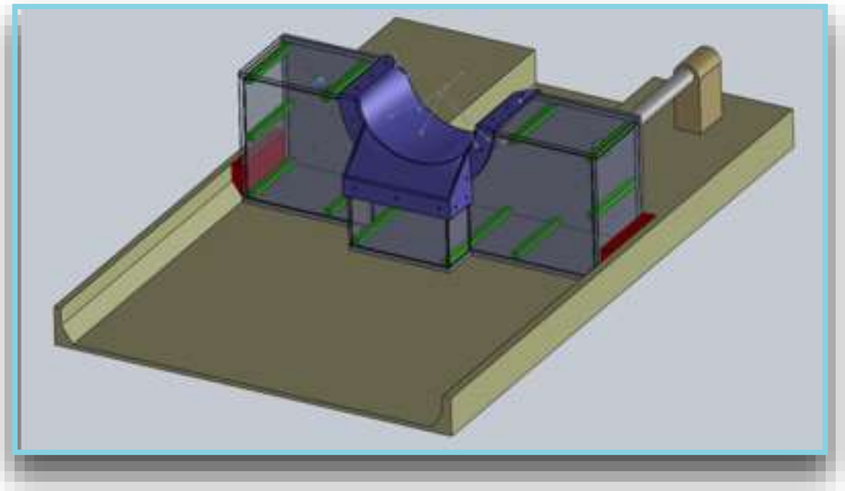
[1] Stockmann JP, Magn Res Med 75:441-51

Construction

Preamps atop plastic supports, away from coils

DC twisted pairs routed away from RF outputs





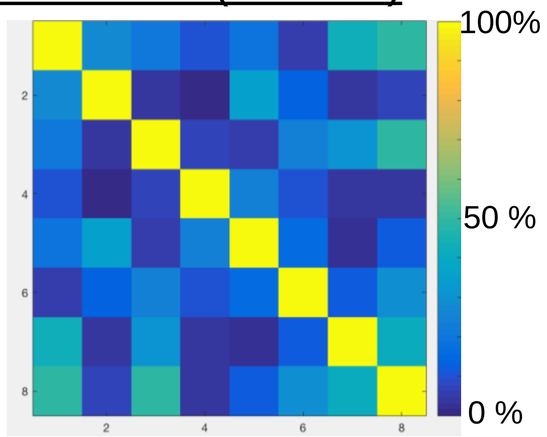
TODO: periodic cable traps + chokes along DC cables [1]

[1] Stockmann JP, Magn Res Med 75:441-51

Coil performance

Rx measurements

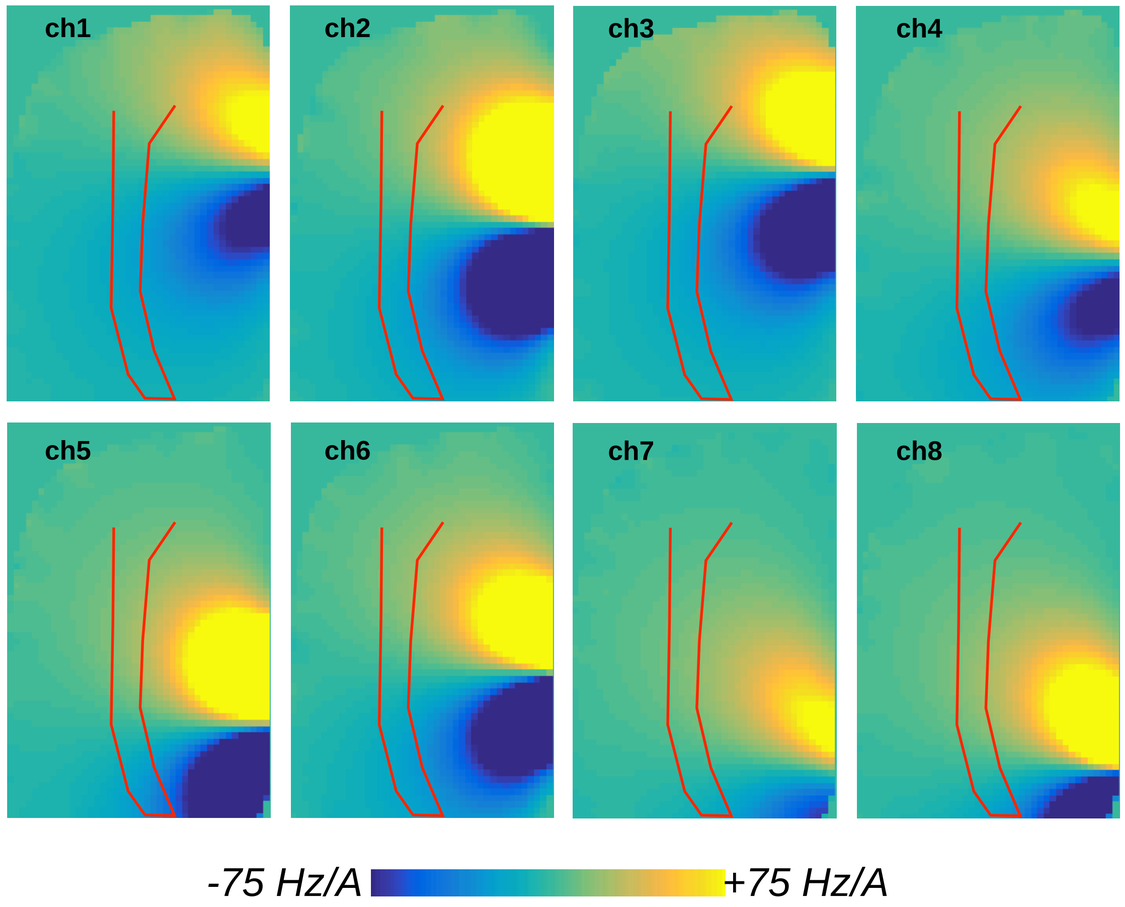
Noise correlation (Tx = 0V)

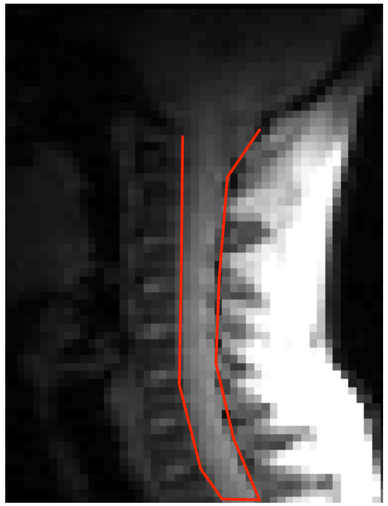


Coupling:
min = 2 %
max = 48 %
avg = 18%

ΔB0 reference maps

used in shim optimization





Max shift per ch.
avg = **±25 Hz/A**
over SC

Experimental setup

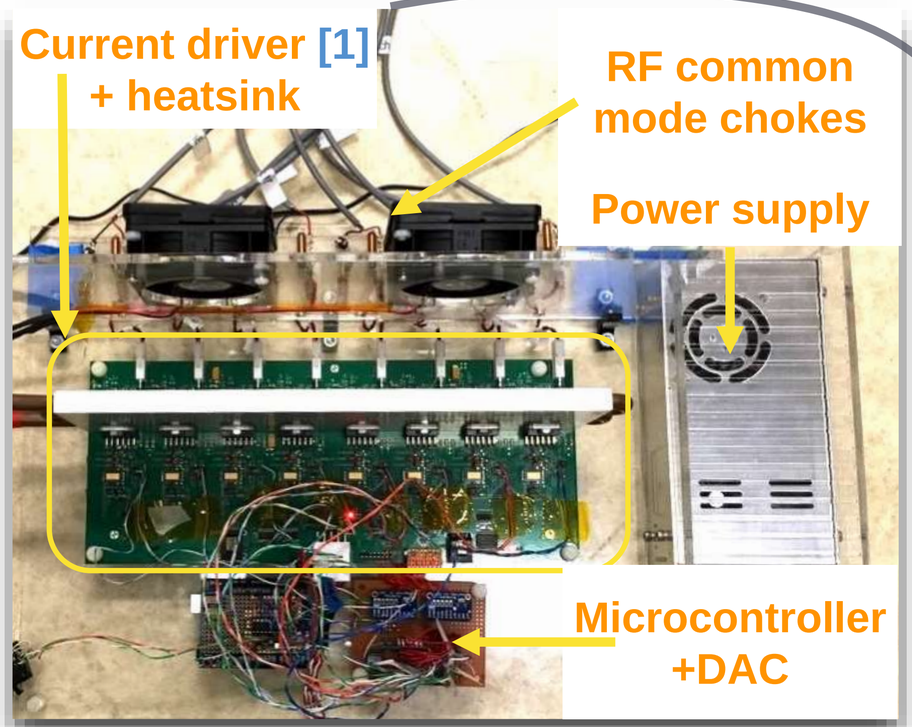
[1] Arango N, ISMRM 2016. Abstract #1157.

Computer in control room

- images transferred over local network
- runs MATLAB + Spinal Cord Toolbox

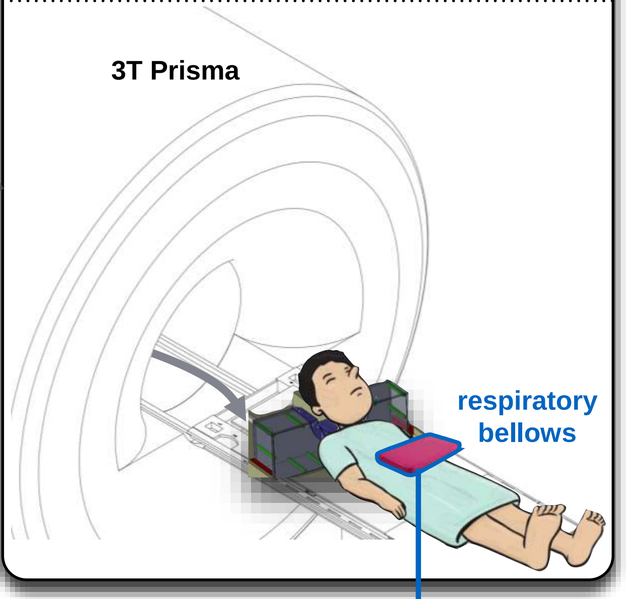
shim update via USB +fibre optic

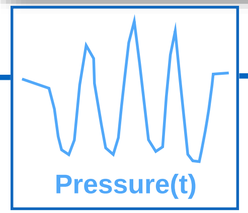
Equipment room



shim DC

MRI room

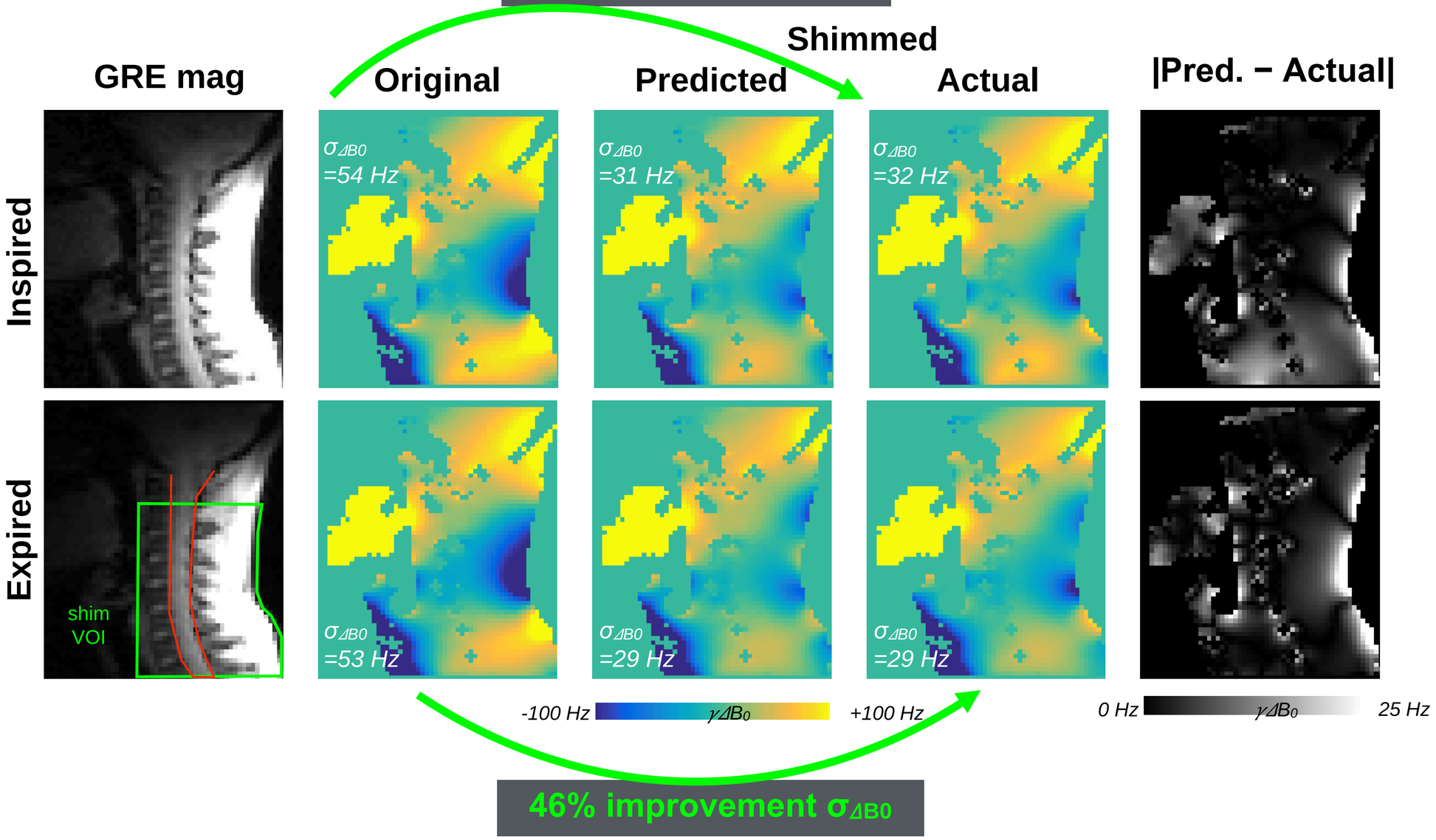




pressure sensor + microcontroller

[2] Topfer R, Magn Res Med 80:935-46

In vivo results



In vivo results

max |shift| = 13 mm

max |shift| = 8 mm

Original

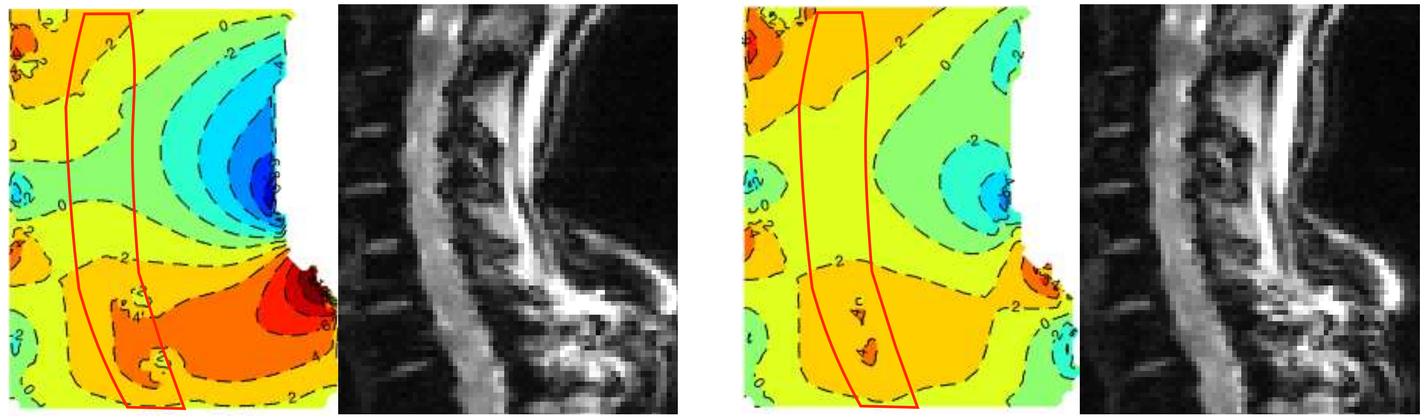
Shimmed

Shift EPI Shift EPI

Inspired

mean |shift| ± st.dev
2.7±2.1mm

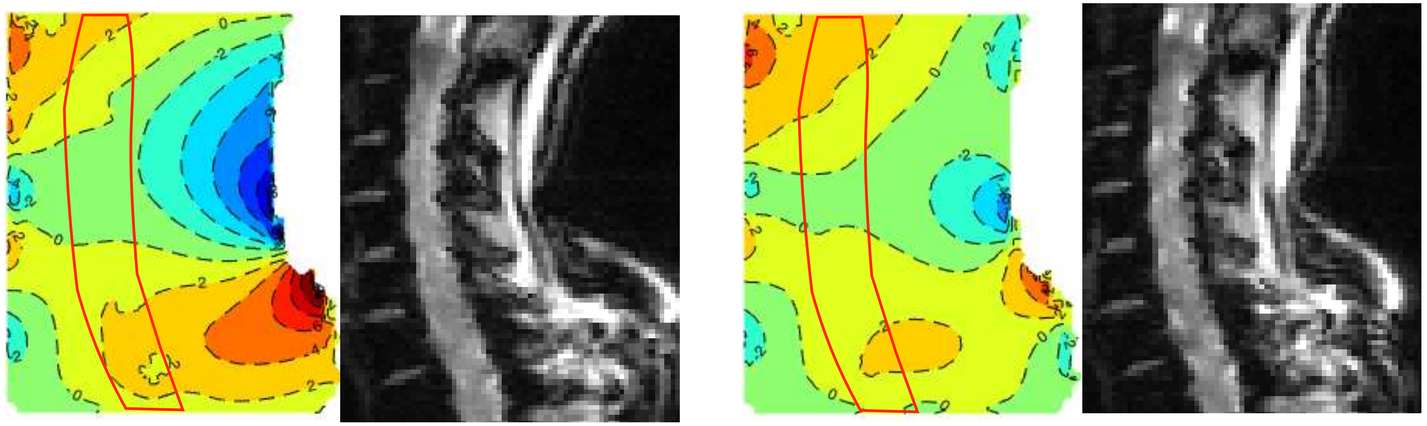
mean |shift| ± st.dev
1.8±1.2mm



Expired

mean |shift| ± st.dev
2.5±2.1mm

mean |shift| ± st.dev
1.4±1.3mm



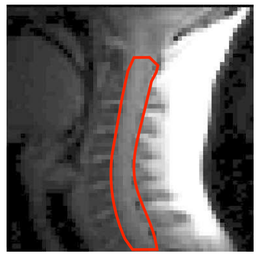
-14 mm *14 mm*

10 cm

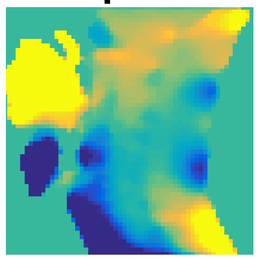
Future directions

1. Real-time shimming

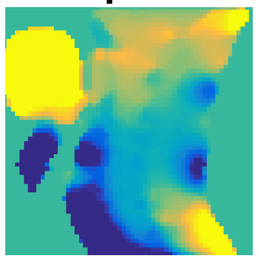
Inputs

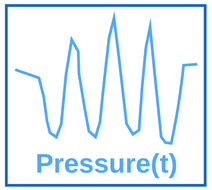


Inspired



Expired





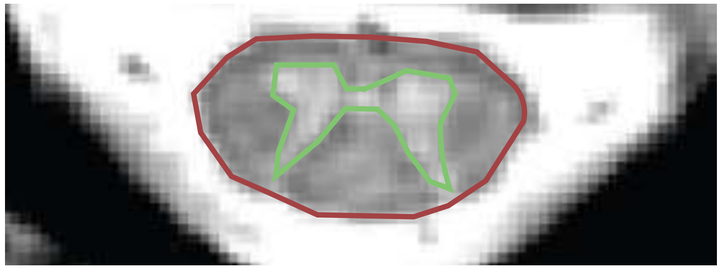
-100 Hz $\gamma\Delta B_0$ *+100 Hz*

2. Making the most of the low inductance coils

—> Potential for slicewise-dynamic shimming

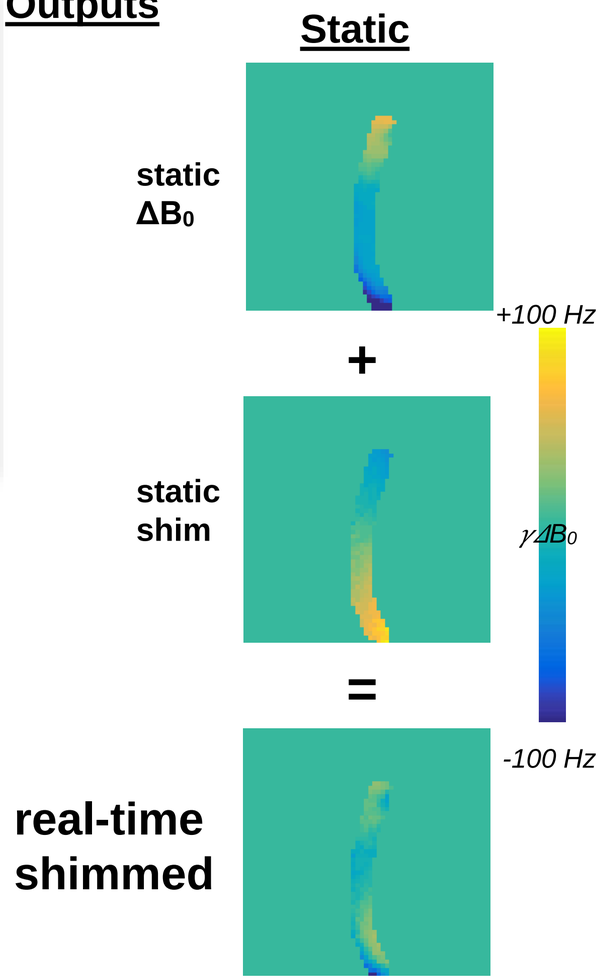
3. Clinical app.: T2 for quantitative spinal-cord assessment*

healthy cord = healthy WM/GM contrast



[1] Martin AR, Am J Neuroradiol 38:1266–73

Outputs



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Thomas Witzel

*See you at ISMRM 2019 in **Montreal***
— Creatively addressing the "real-estate problem" since 1967

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IRSC CIHR
Fonds de la recherche en santé Québec
Fonds de recherche sur la nature et les technologies Québec
Canada Research Chairs / Chaires de recherche du Canada

References

Topfer R et al., 2018, 'Integrated ΔB0/Rx coil array for improved spinal cord imaging at 3T', in ISMRM 26th Annual Meeting, Paris, France
link : http://cds.ismrm.org/protected/18MPresentations/abstracts/0834.html