Performance and safety evaluation of a human sized FFL imager concept

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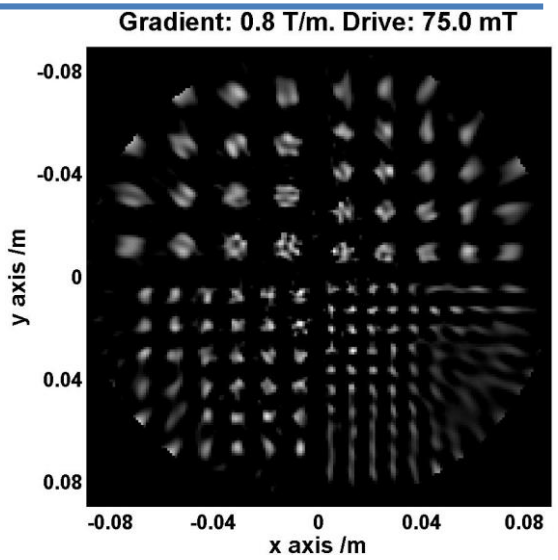
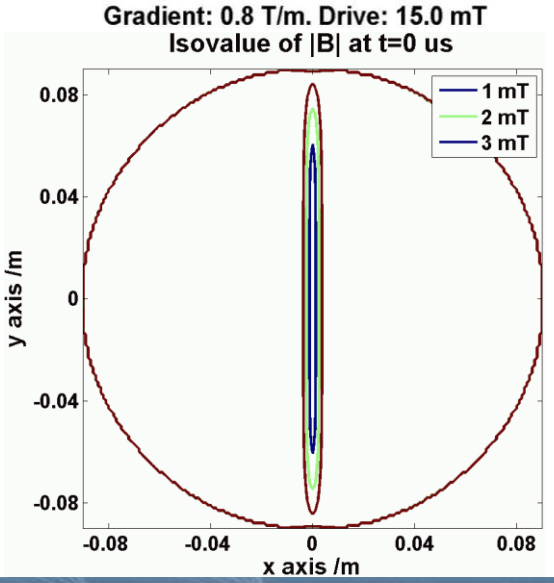
Motivation - I

Two effects limit the Field Of View (FOV) for a Human sized FFL imager:

- the drive field amplitudes are limited to a few mT due to Peripheral Nerve Stimulation (PNS),

- the low field volume looks like a banana when moving the line near the border of the coils.





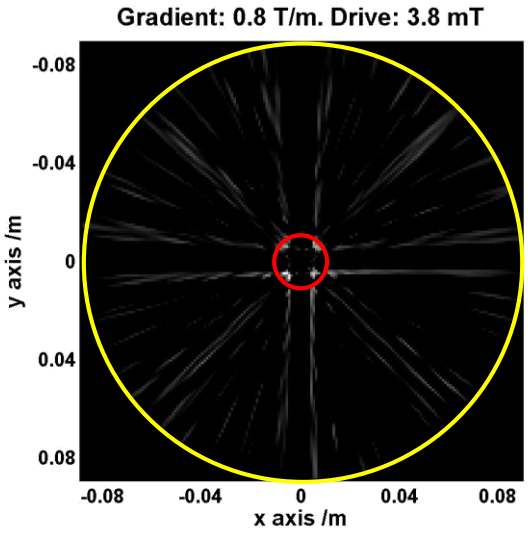
Motivation - II

How could we increase the FOV?

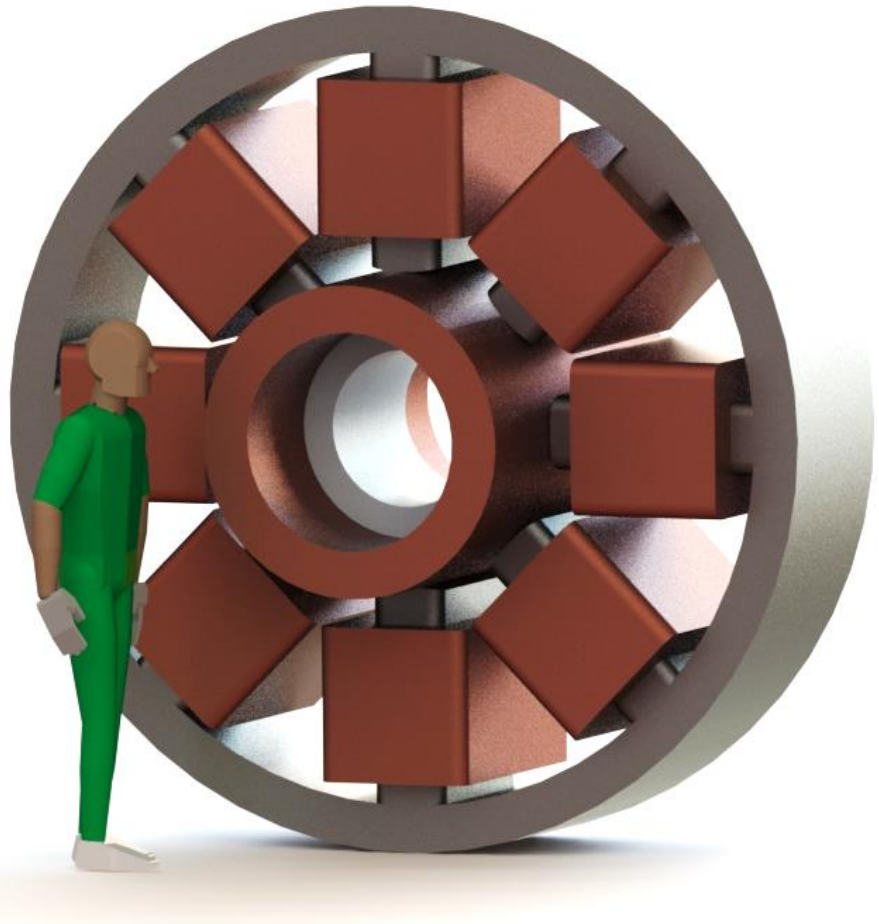
With which sequence?

Does the banana effect play a significant role?

Are PNS likely to happen?



Which imager? Higor



Scanner with a 1 T/m gradient on the line:

Quadrupoles:

- Inner diameter: 1 m
- Magnetomotive force: 81 kAT
- Current density: 3 A/mm²

Solenoid:

- Inner diameter: 0.7 m
- Length: 1.5 m
- Dissipated power: $2 * 65$ kW

Drive:

- 2D
- Inner diameter: ~0.50 m

Focus:

- Using the pole of the quadrupole
- Current density: unknown

An FFL sequence using focus fields

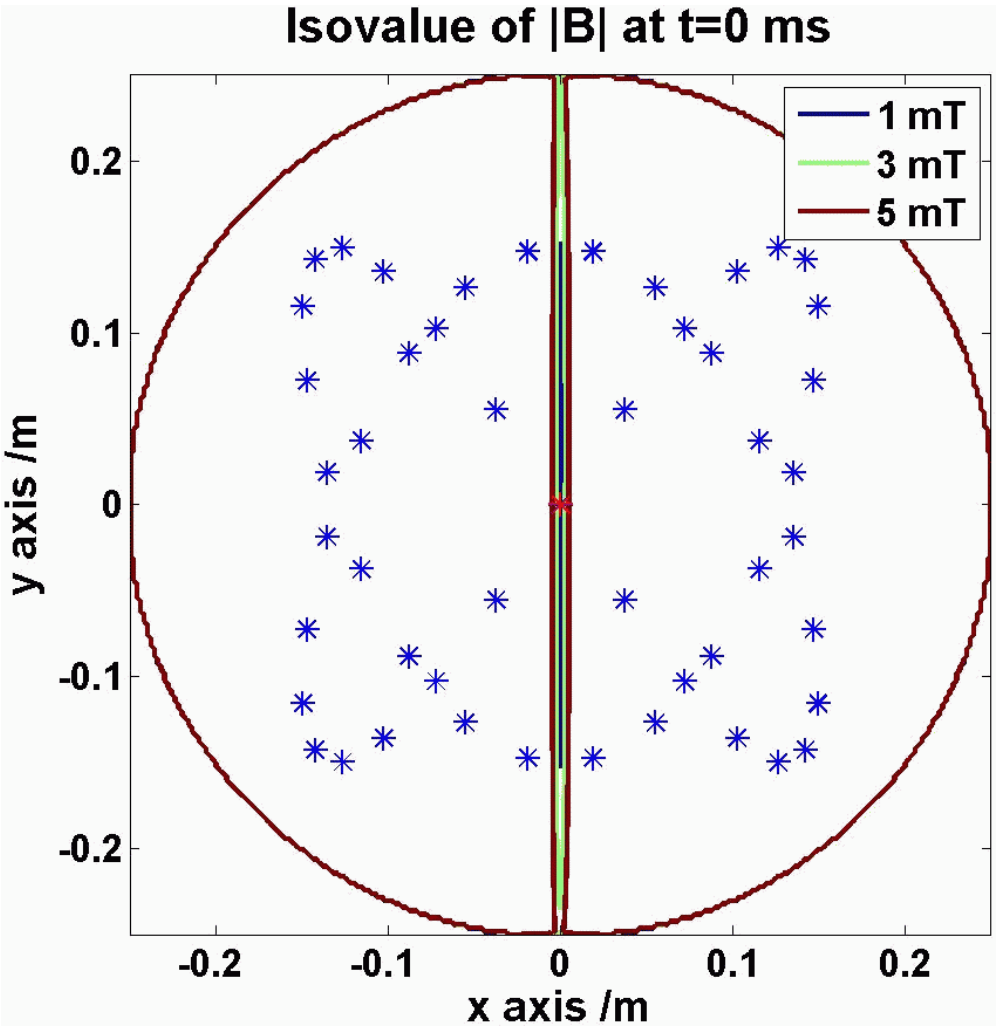
In order acquire one image with a fully resolved spectrum we:

- move the rotation centre 3 times around the Lissajous curves,
- rotate the line 2 times using a 2π rotation.

The Lissajous curve is made with frequencies of 90 and 60 Hz.

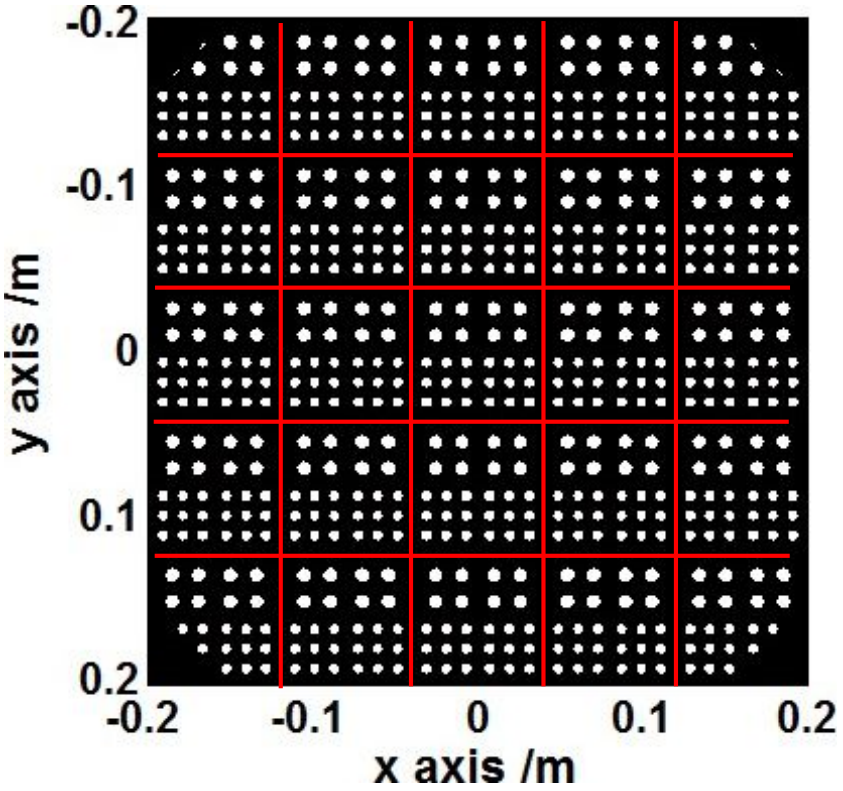
Quadrupoles are used with a frequency of 40 Hz.

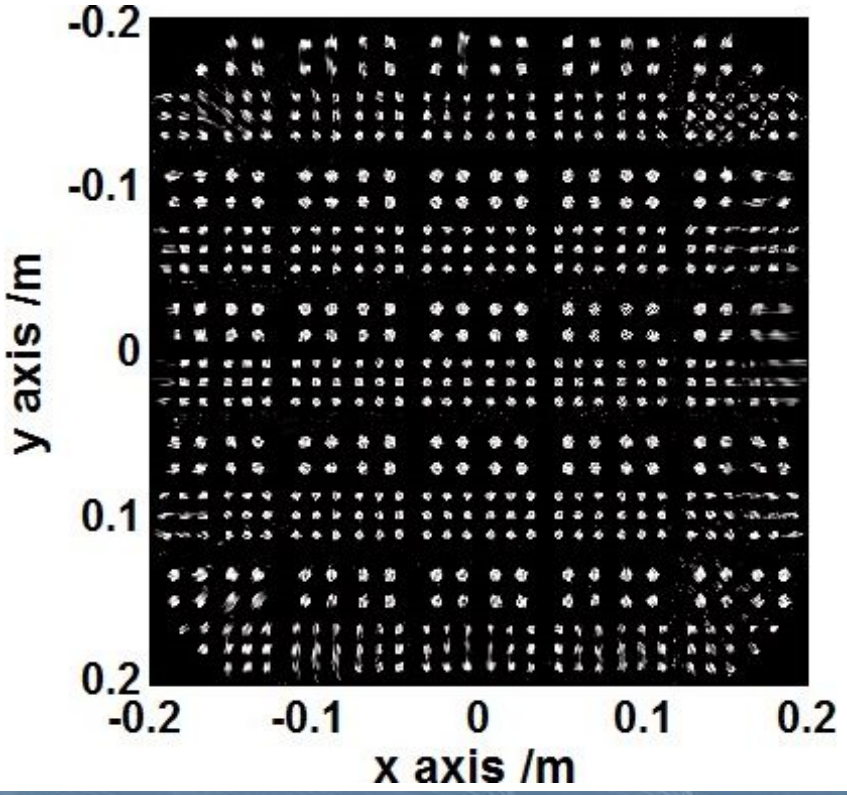
10 acquisitions per second.



Reconstruction

- Area divided in 25 sections (limited by the available RAM – 1 TB)
- Reconstructed with a modified ART (filter imaginary & negative solutions)
- No regularization

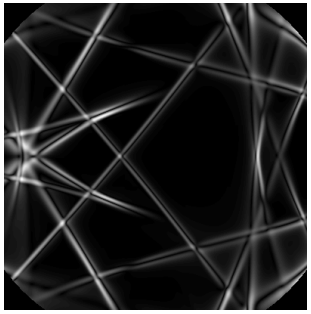




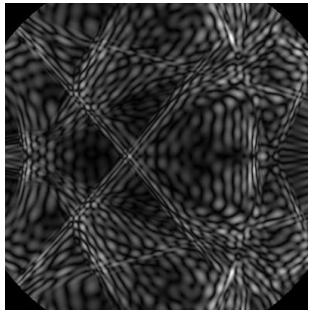
Signal structure

With a drive frequency of 150 kHz, the system matrix looks like:

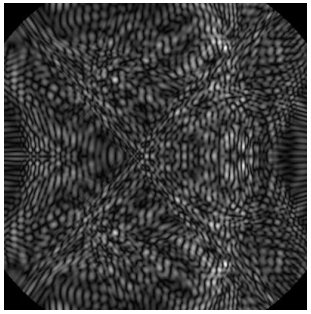
300 010 Hz



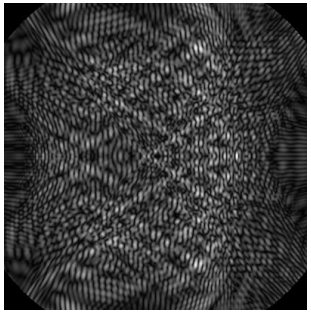
302 040 Hz



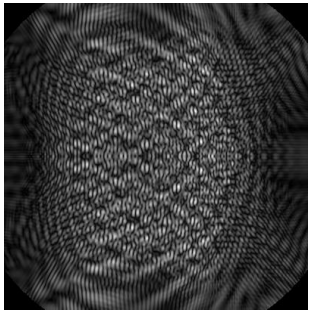
304 100 Hz



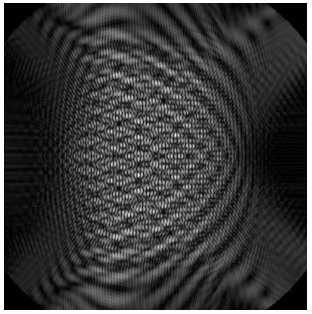
306 100 Hz



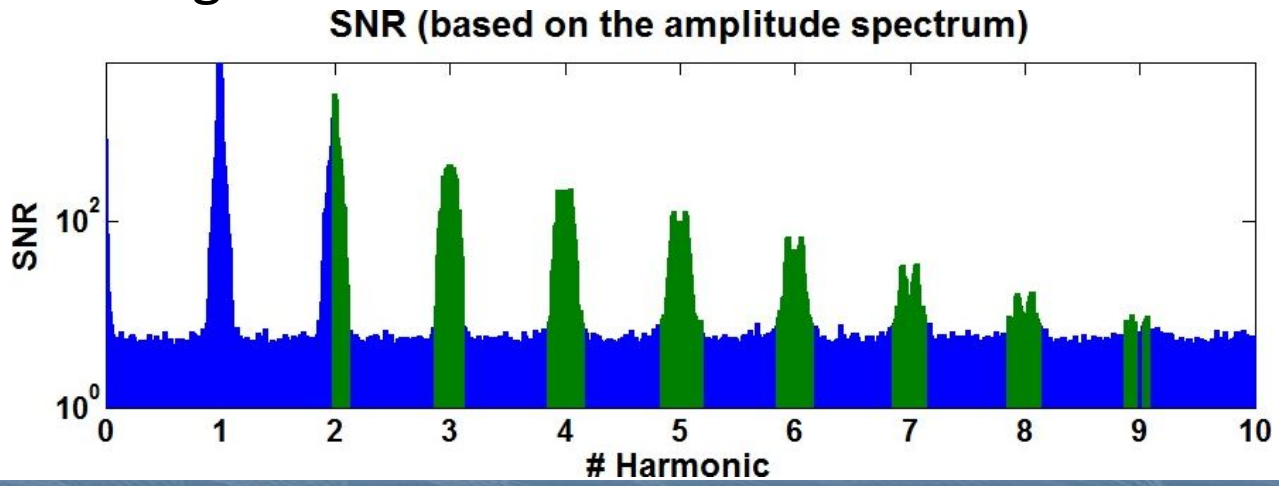
308 620 Hz



312 890 Hz

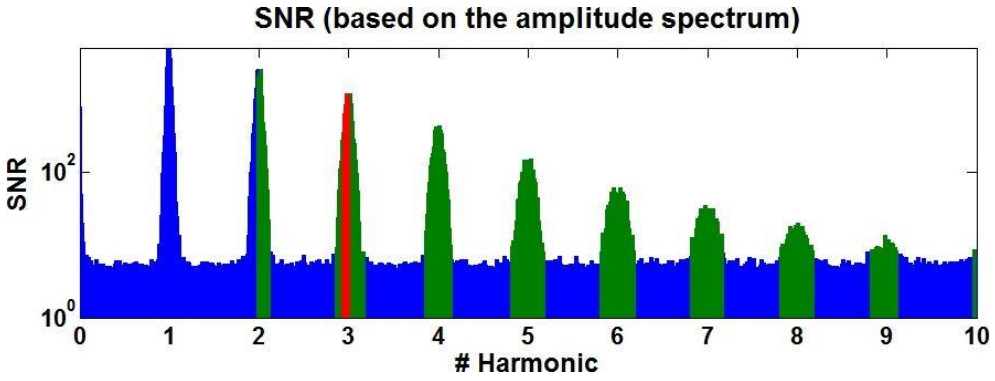


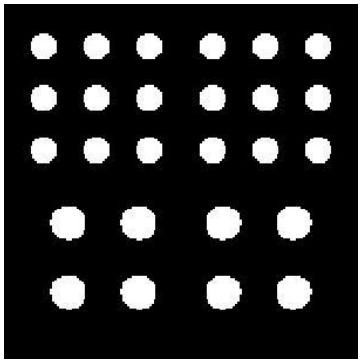
The simulated signal for a section looks like:

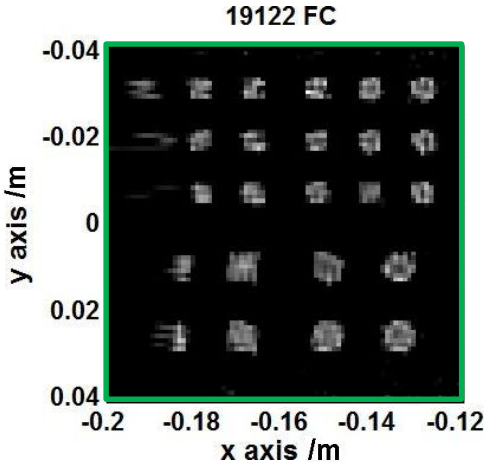


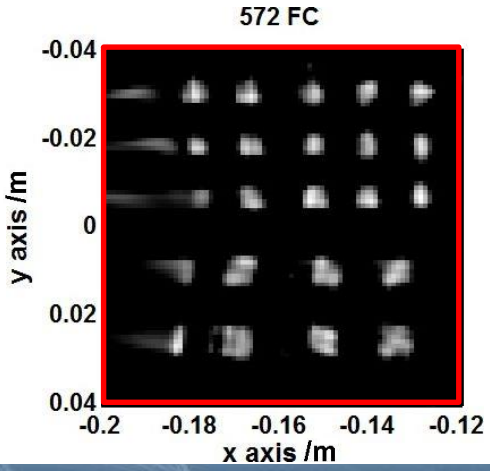
Signal amplitude

Using the FC with an SNR above 1/10 of the maximal SNR around the 3^{rd} harmonic (the red one), 572 FCs are selected.









Safety: Can we put a patient inside Higor?

Drive coils

- 3.7 & 4.8 mT Amplitude peak
- 150 kHz
- Ok

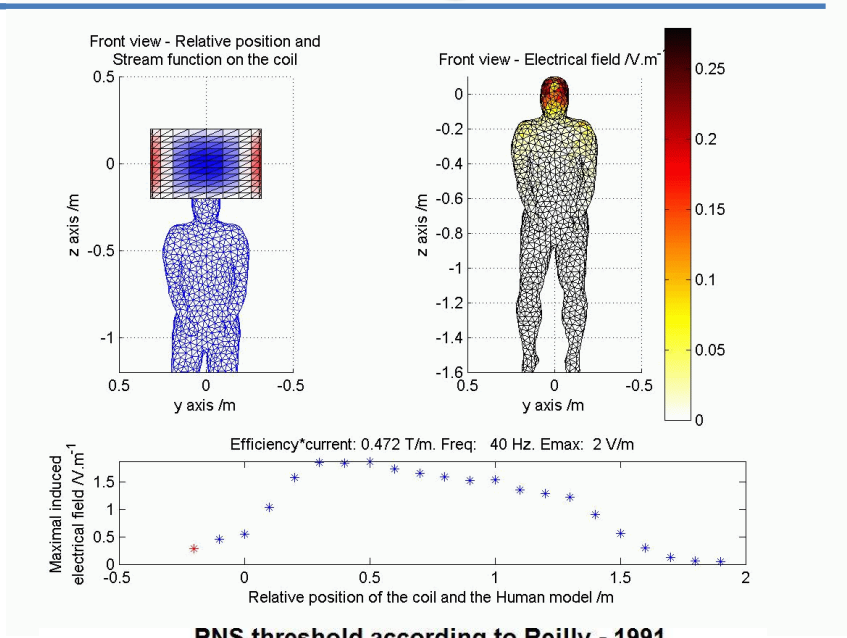
Quadrupole

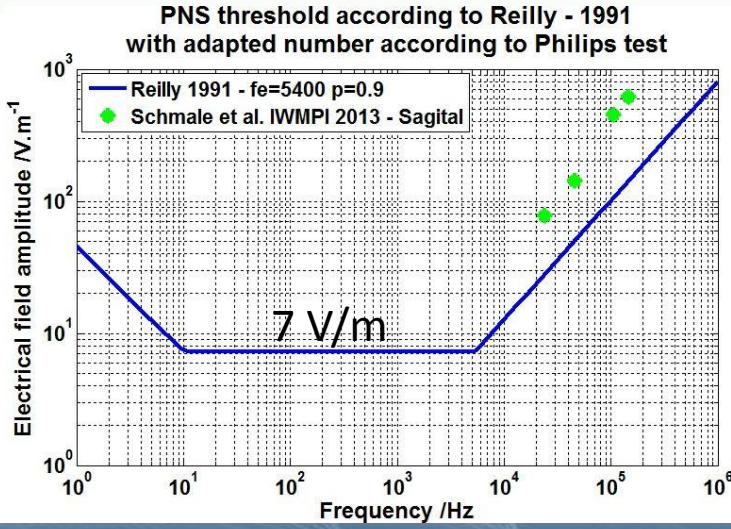
- 0.5 T/m
- 40 Hz
- ~3 V/m: Reilly 1991 – could be ok

Focus

- 320 mT peak
- ~90 Hz
- ~32 V/m: Reilly 1991 – not ok

And together?

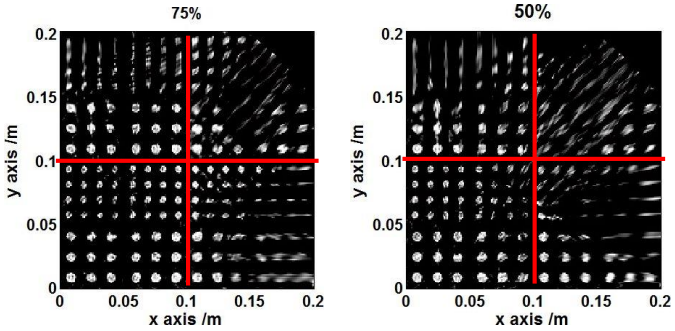


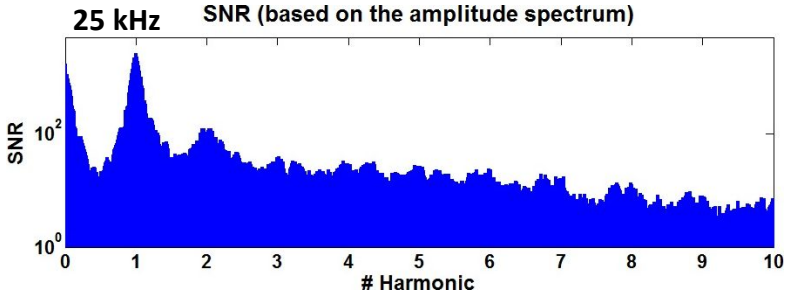


Future work

Explore other possibilities:

- reduce the focus fields amplitudes,
- reduce the drive frequency.





Improve the concept by:

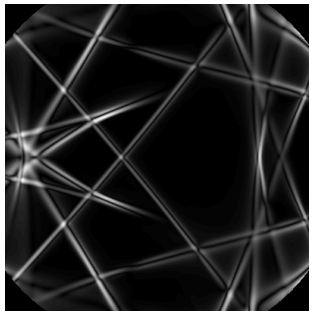
- generating enough magnetic fields for the focus fields. Saturation of the core is a limiting factor,
- experimentally defining the PNS thresholds for low frequencies,
- experimentally defining the PNS thresholds for a sum of fields & frequencies.

Conclusion

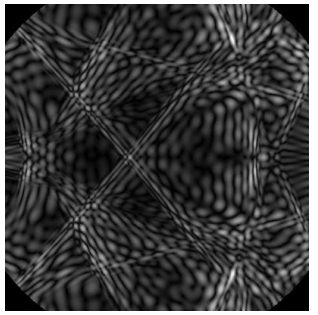
For a human sized FFL imager using focus fields and the presented sequence:

- a large FOV can be covered,
- current functions are continuous,
- 10 images per second could be acquired,
- field quality is not an issue
- more knowledge about the PNS thresholds should be gathered,
- flexibility on the choice of frequencies, huge impact on MPI-signal structure.

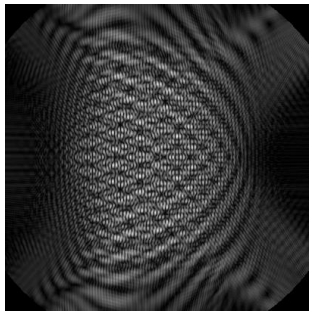
300 010 Hz



302 040 Hz



312 890 Hz



Thanks – Questions?

Federal Ministry of Education and Research
13N11090
01EZ0912
13EZ1140A
13GW0069A

ZUKUNFTSprogramm Wirtschaft
Investition in Ihre Zukunft
122-10-004

DFG
BU 1436/9-1
ER 777/1-1
BU 1436/7-1
BU 1436/10-1

SEVENTH FRAMEWORK PROGRAMME
604448

Federal Ministry of Economics and Technology
03EFT6SH12

DFG GSC235/2
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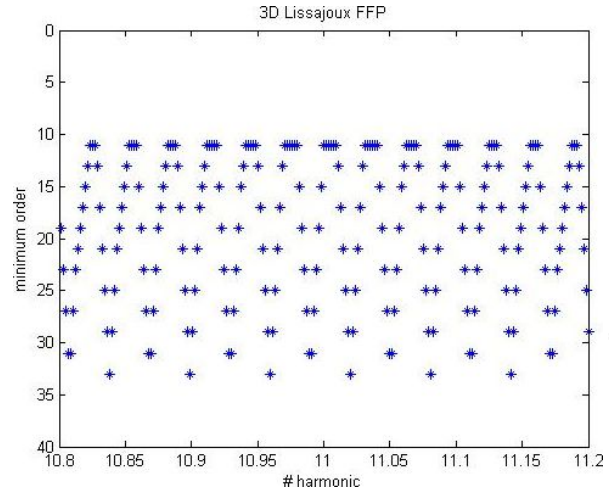
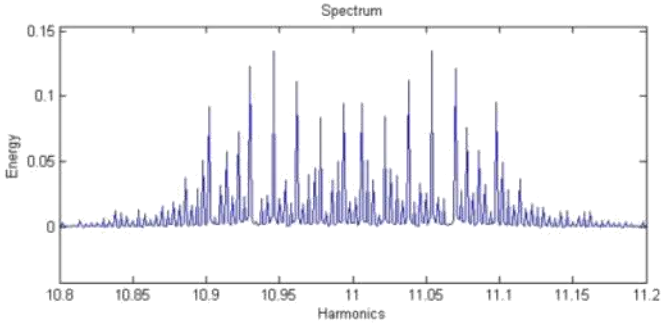
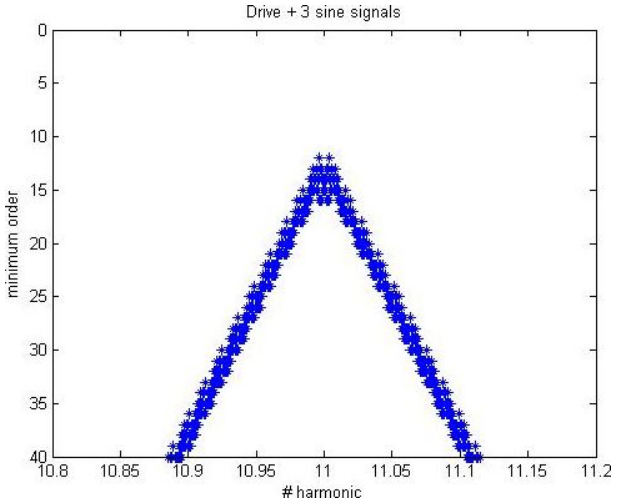
GRADUATE SCHOOL FOR COMPUTING IN MEDICINE AND LIFE SCIENCES

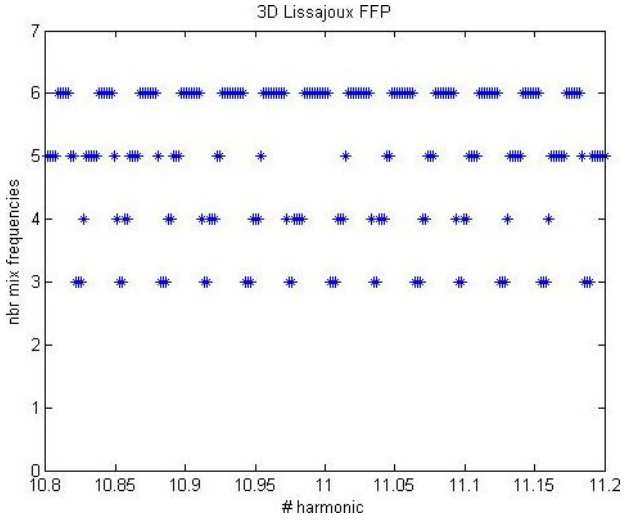
Low and high frequencies mixing

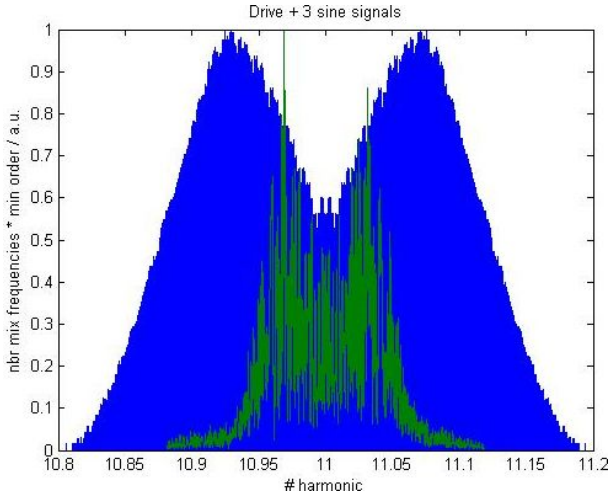
- Does it work as simulated?

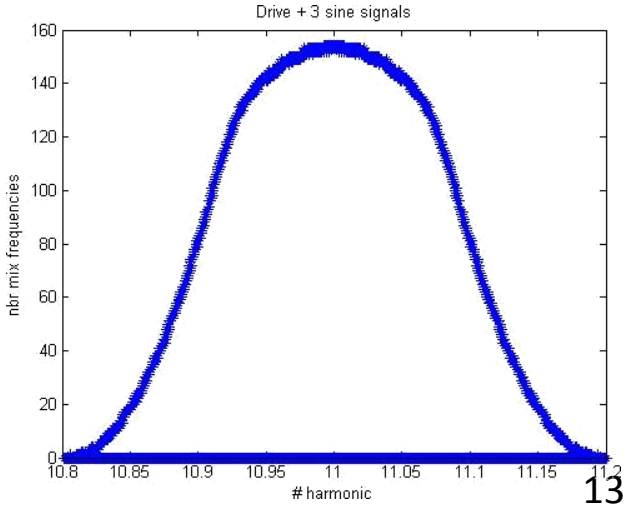


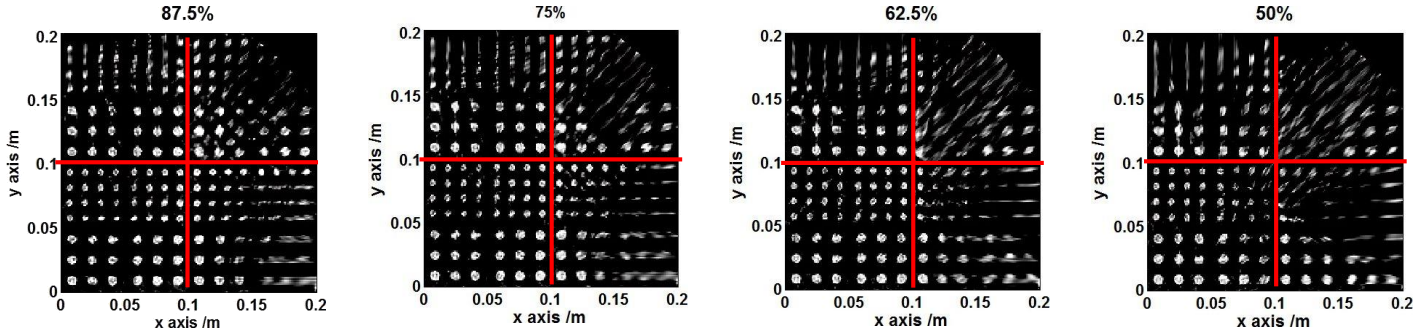


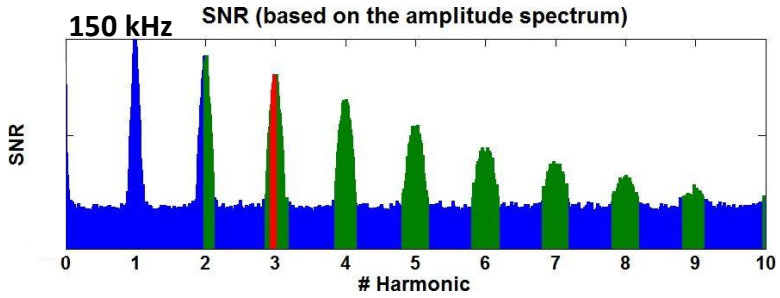


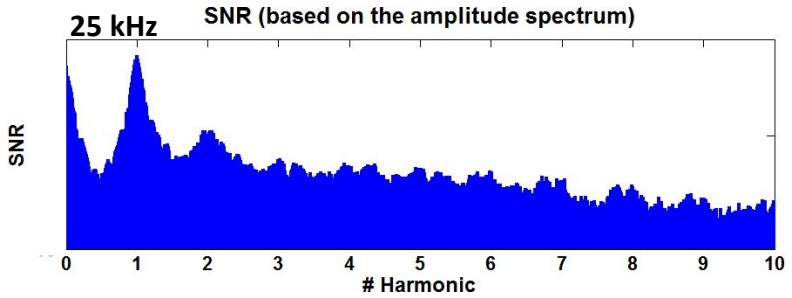







87.5%
75%
62.5%
50%
y axis /m
x axis /m
0
0.05
0.1
0.15
0.2


150 kHz
SNR (based on the amplitude spectrum)
SNR
0
1
2
3
4
5
6
7
8
9
10
Harmonic


25 kHz
SNR (based on the amplitude spectrum)
SNR
0
1
2
3
4
5
6
7
8
9
10
Harmonic

Some reco parameters

- Langevin particle – 30 nm – Fe304
- Concentration phantom: 1.5 mol. m^{-3} (Resovist, 10 times diluted)
- noise's amplitude spectral density: $56\ \mathrm{pV}/\sqrt{\mathrm{Hz}}$
  - 30 times more than the patient noise limits from Weizenecker 2007 – A simulation study […]
- Resolution:
  - System matrix: 1 mm
  - Phantom: 0.5 mm