Everything you always wanted to know about RF bias correction ... but were afraid to ask

Sylvie Clerjon, Jean-Marie Bonny
Centre INRA de Clermont-Ferrand Theix, France

FOODMR 2014 – Cesena, Italy
Thursday 22 May 2014

Spin density measurement affected by RF bias and noise

Measured signal

RF bias

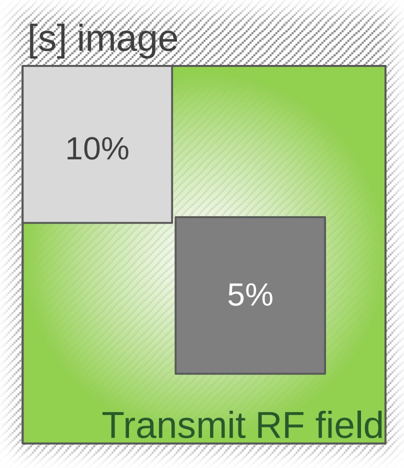
Spin density weighted imaging

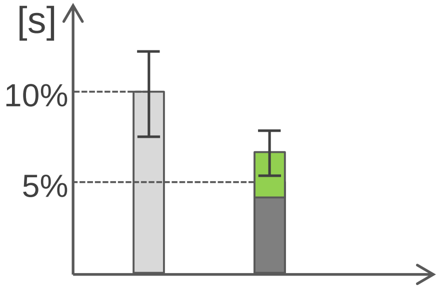
$$S \propto [s].w_1{}^{-}.M_{x,y}(w_1{}^{+})$$

Spin density, what we want to measure

A particular case: *Spin Density Map*

where $M_{x,y}(w_1{}^{+}) = 1$





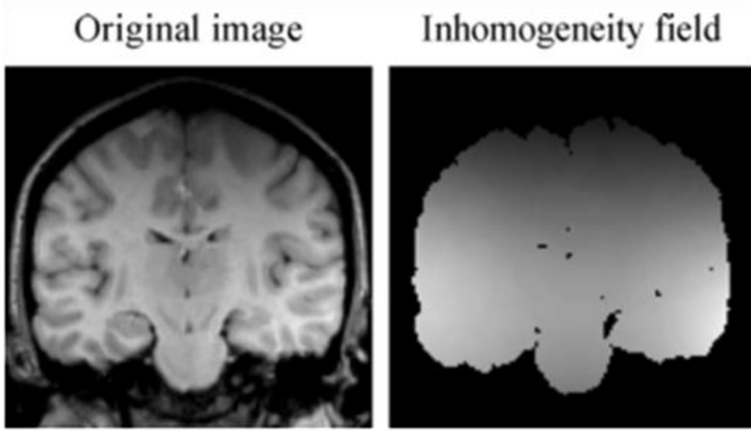
What we can expect concerning coils homogeneity

Manufacturers

→ difficult to find quantified information

Bibliography

In brain transmit RF field bias = w_1^+ variation 30%

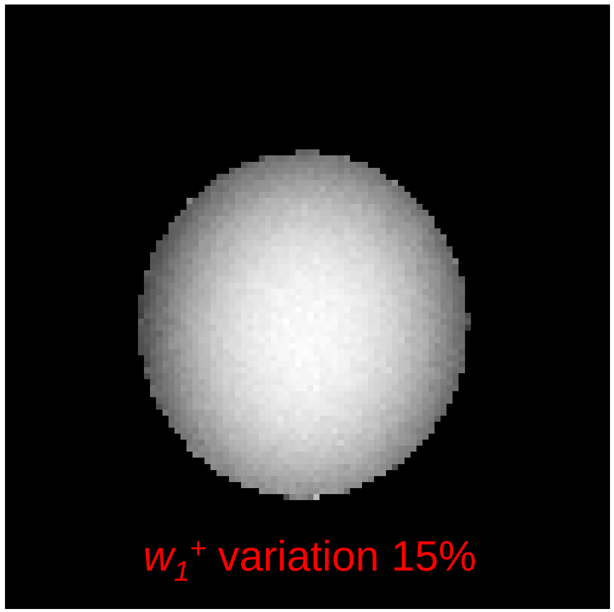


Vovk et al. (2007). A review of methods for correction of intensity inhomogeneity in MRI. *Ieee Transactions on Medical Imaging*, 26(3), 405-421.

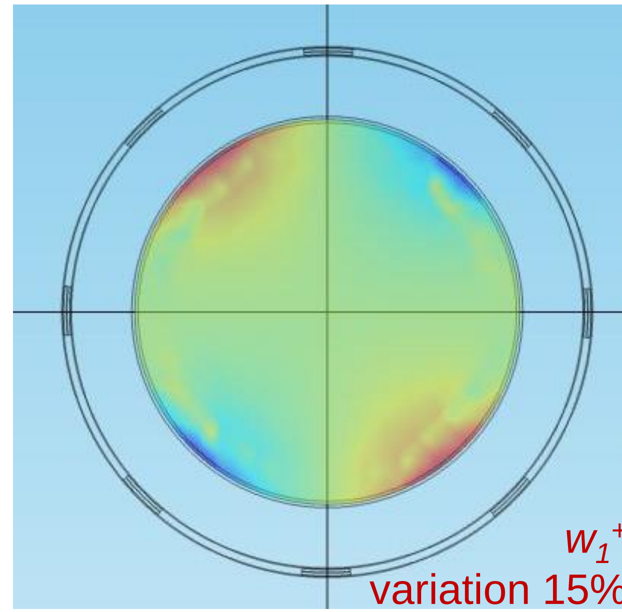
What we can expect concerning coil homogeneities

Our own experiments and simulation

Rapid Biomedical 19 cm birdcage coil. Bruker Biospec 4,7T. Prescribed angle 60°. Sample: 6 cm diameter homogeneous gelatin cylinder



Numerical simulation, birdcage



What we can expect concerning coil homogeneities

Spatial variations of transmit RF field can reach 40%

Spatial variations depend on

- Coil geometry
- Sample (size, shape, dielectric properties)
- Frequency : High field → high RF frequency → small wavelength / sample size → high heterogeneities
- Nucleus

Food science needs quantitative imaging of spin density:

- Products characterization
- Drying, cooking: water mapping
- Salting: sodium mapping

RF bias must be avoid for food quantitative imaging of spin density

1. RF field w_1^+ mapping
2. Image correction

Mapping transmit RF field

DAM-SP for Double Angle Method – Selective Pulse

Principle :

Independent on receive field

$$\frac{S(k.w_1^{+}) \propto [s].w_1^{-}.M_{x,y}(k.w_1^{+})}{S(w_1^{+}) \propto [s].w_1^{-}.M_{x,y}(w_1^{+})}$$

The ratio of two magnitude images at two different prescribed angles

Independent on spin density

The map only depends on transmit field

DAM-SP versus DAM

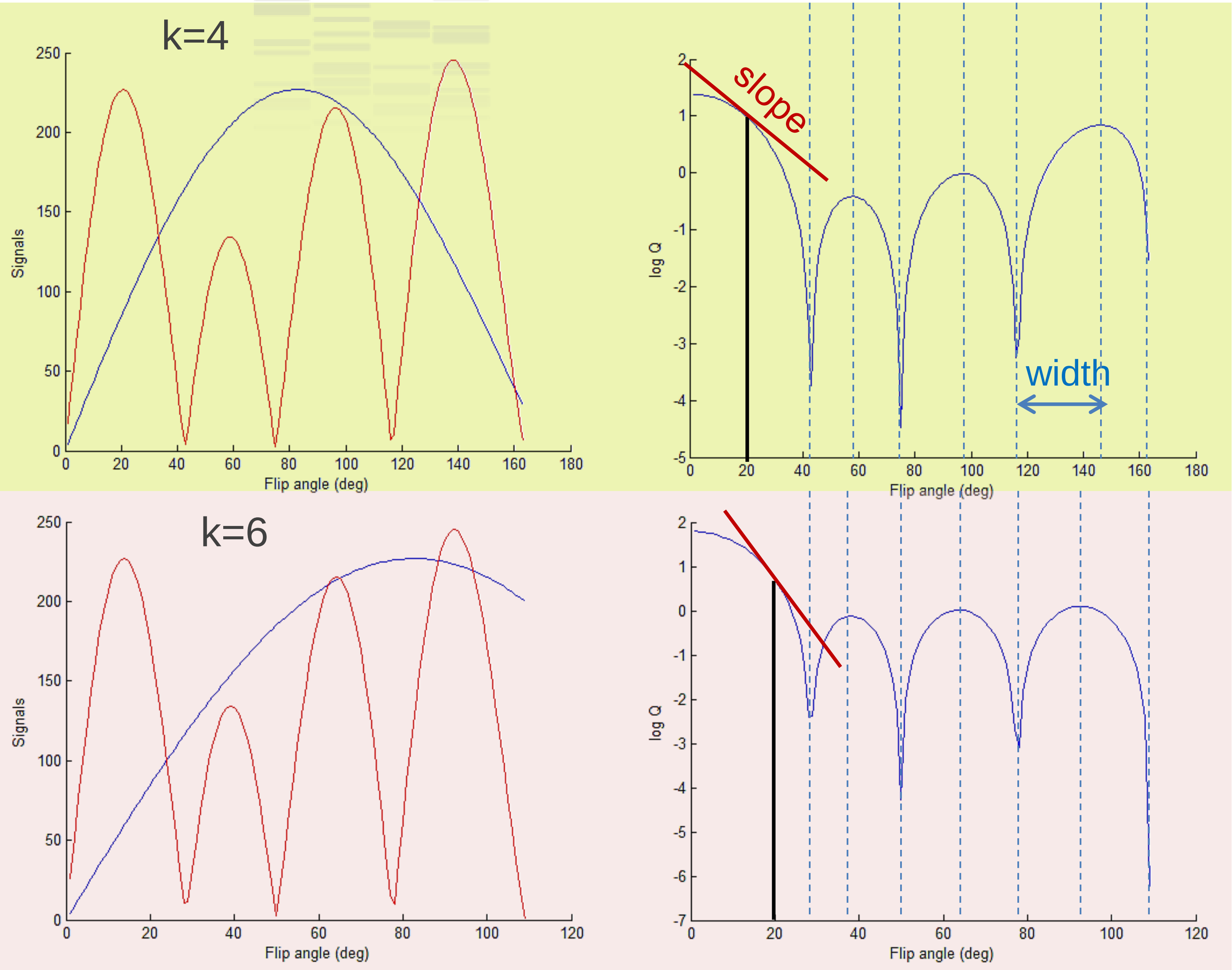
- No bias in $M_{x,y}$ model due to pulse shape
- Can be used in SE imaging
- 2D

Bouhrara M, Bonny JM. B1 mapping with selective pulses. Magnetic Resonance in Medicine (2012) DOI: 10.1002/mrm.24146.

The DAM-SP's 3 experimental parameters

k factor between the two prescribed angles	Have to be optimized
Pulse shape governing $M_{x,y}(w_1^+)$	We choose a Shinnar-Le Roux (SLR) pulse
MRI sequence	We used a Flash

Optimizing the k factor



Width = range

Slope = sensitivity

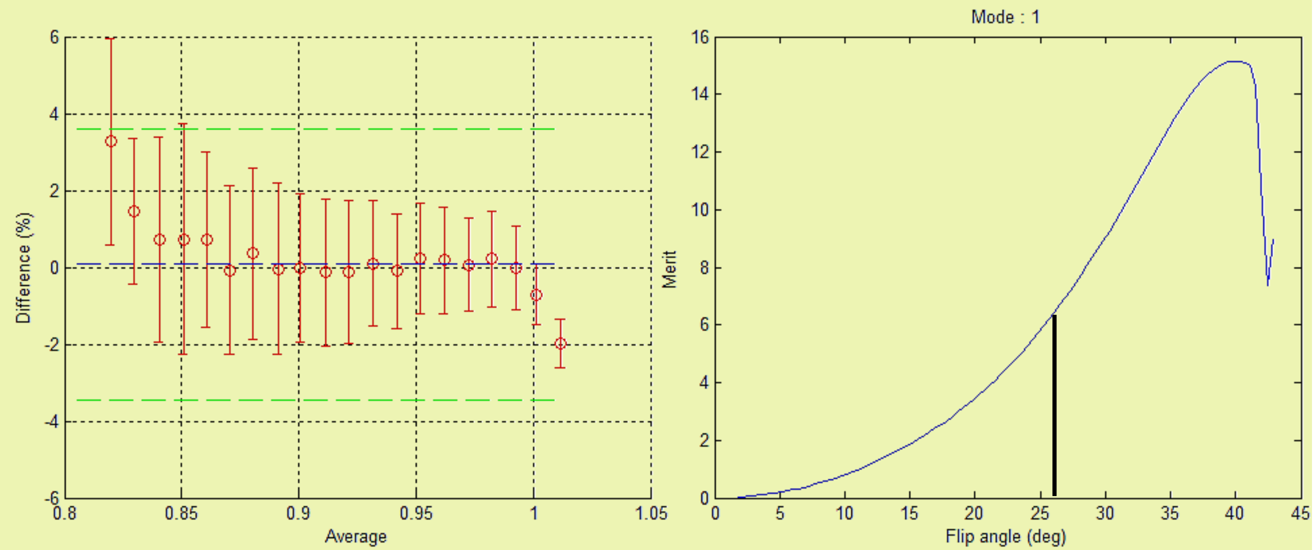
Depends on the pulse

Optimizing the k factor

Measurements on an homogeneous phantom, Flash, Bruker Biospec 47/40, quadrature birdcage coil

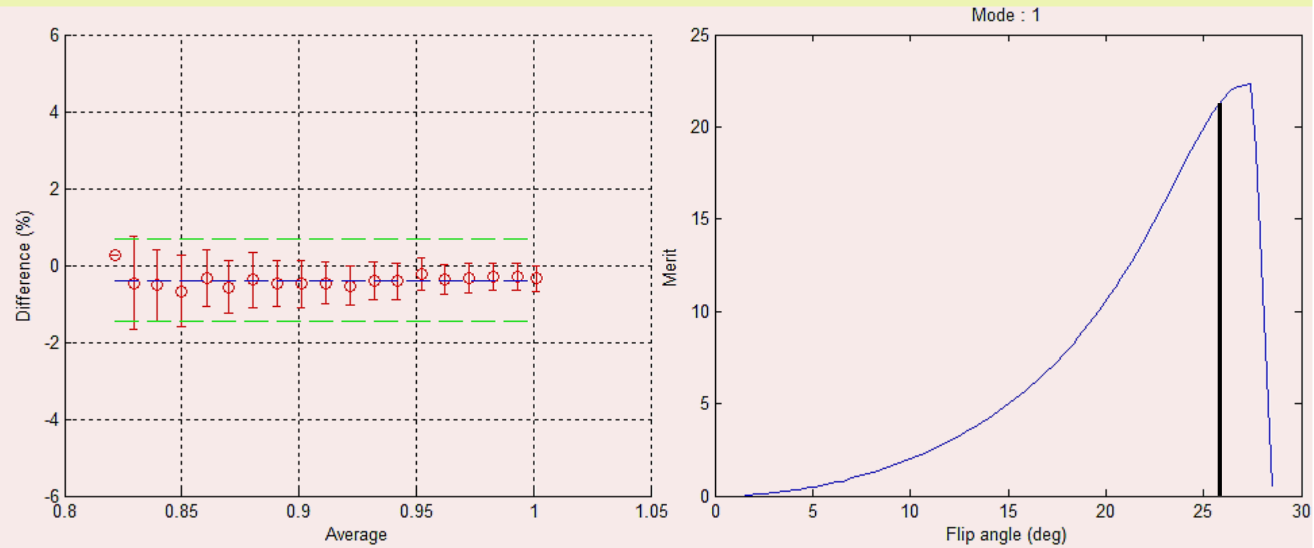
k=4

Transmit RF field map



k=6

Transmit RF field map



Correcting quantitative image from transmit RF field w_1^+ bias

We have an accurate RF field w_1^+ map → **?** How to correct our images ?

$$S^* \propto \frac{[s].w_1^{-}.M_{x,y}\left(\widehat{w_1^{+}}\right)}{\widehat{w_1^{-}}}$$

Correcting quantitative image from transmit RF field w_1^+ bias

We have an accurate RF field w_1^+ map → **?** How to correct our images ?

$$S^* \propto \frac{[s].w_1^-.M_{x,y}(\widehat{w_1^+})}{\widehat{w_1^+}}$$

We have to be sure $w_1^- = w_1^+$

Single coil

Always equal?

Correcting quantitative image from transmit RF field w_1^+ bias

We have an accurate RF field w_1^+ map → ? How to correct our images ?

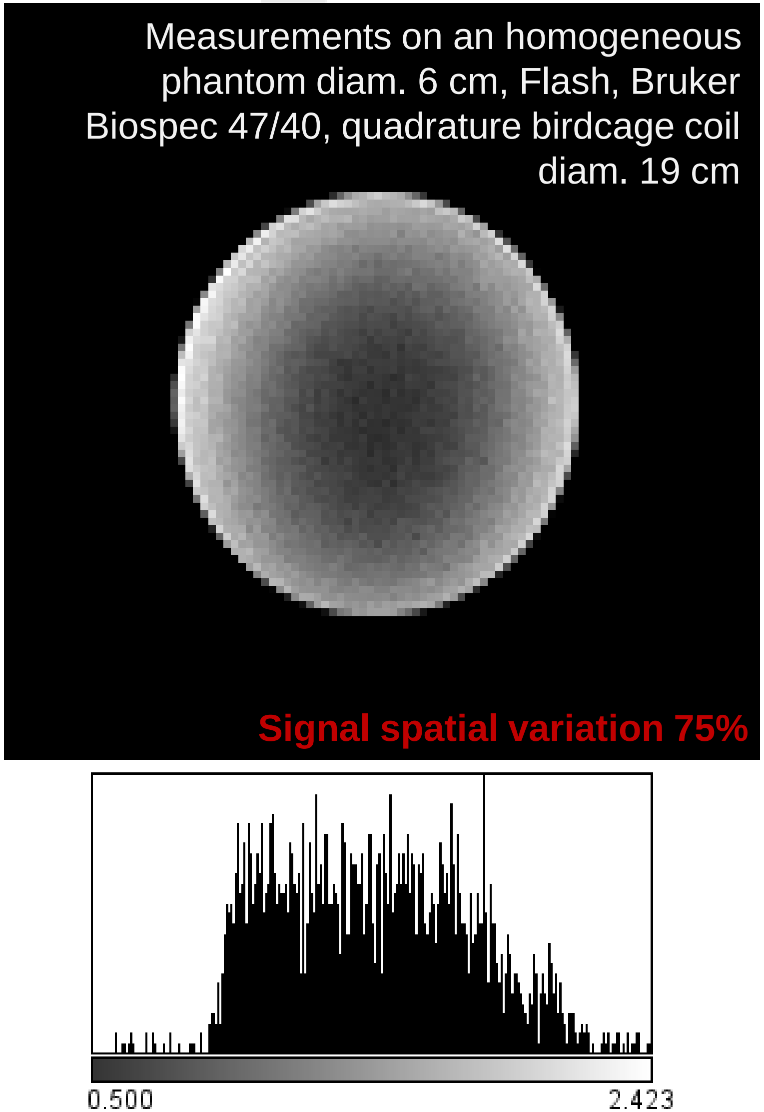
We have to be sure $w_1^- = w_1^+$

$$S^* \propto \frac{[s].w_1^{-}.M_{x,y}\left(\widehat{w_1^+}\right)}{\widehat{w_1^+}.M_{x,y}\left(\widehat{w_1^+}\right)} \propto [s].\frac{w_1^-}{\widehat{w_1^+}} \propto [s]$$

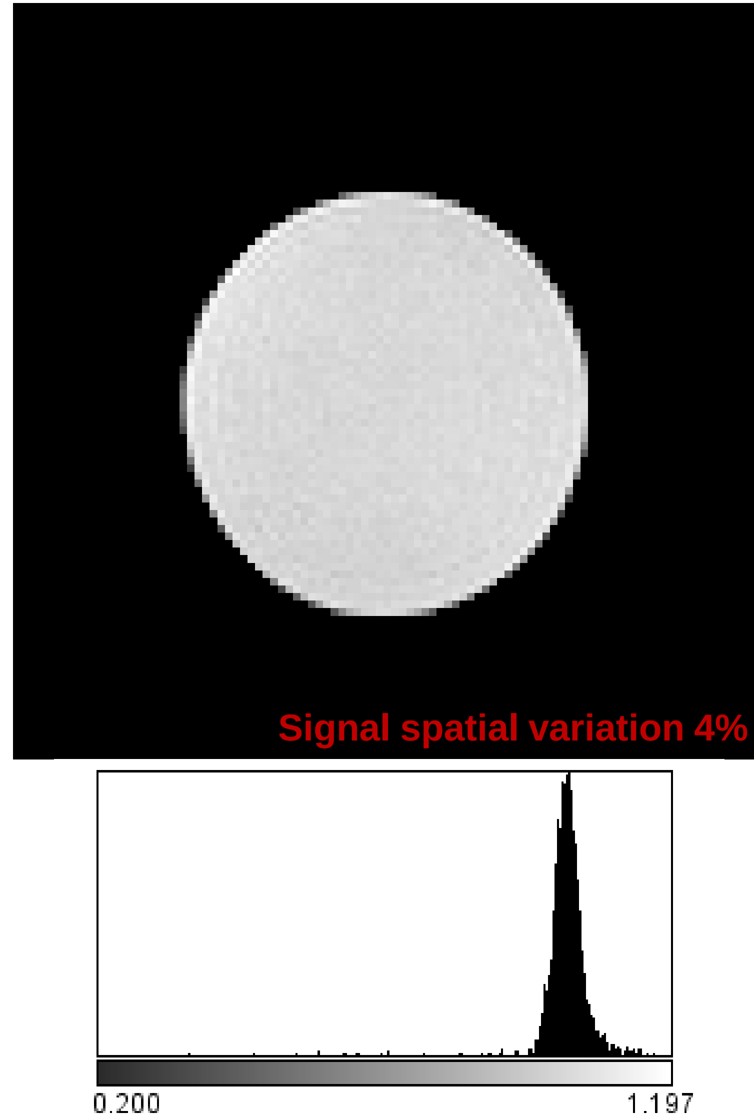
Single coil

Always equal?

Correcting quantitative image from transmit RF field w_1^+ bias

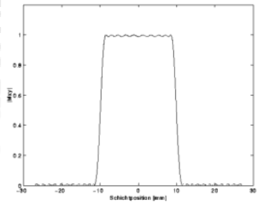


Correction



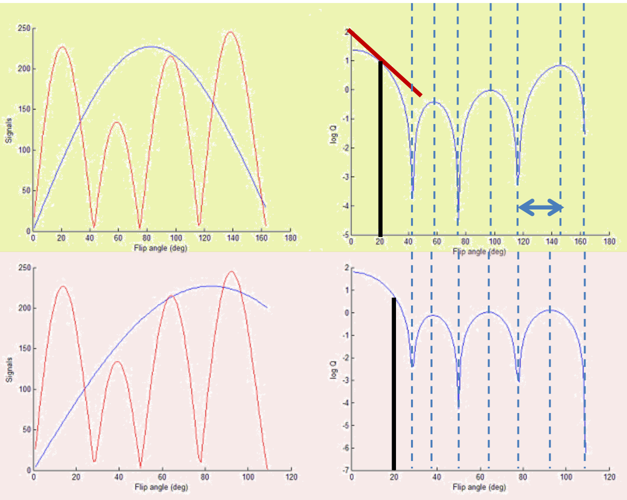
Summarized guide

Choose a pulse



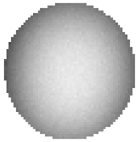
Compromise between measurement range and sensitivity

best polarization point and best k factor for the best w_1^+ map

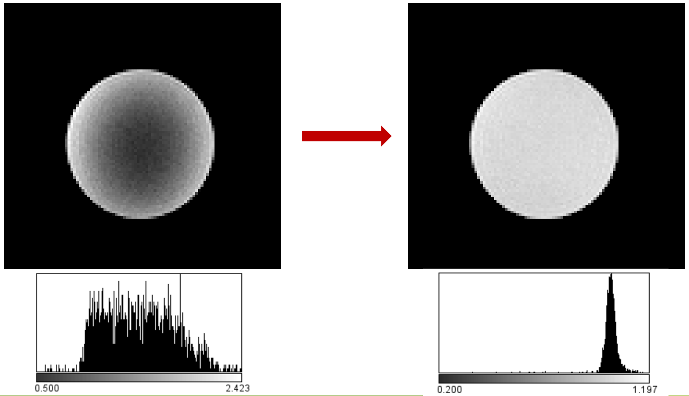


Perform acquisitions at prescribed flip angle and k.prescribed flip angle

Compute w_1^+ map



Correct your raw density weighted images by dividing them by signal due to w_1^+



You obtain quantitative images

Discussion

Transmit and receive RF fields equality (amplitude and phase)

- Sample
  - Dielectric properties (anisotropy, hydration, conductivity due to salt…)
  - Shape and size
- Coil
  - Near field behavior close to coil conductors → position in coil
  - Knowing their coils: **area of fields equality**
  - Coils designers have to work on this parameter

Noise

- Regularization before computing (in DAM-SP and for RF field correction)
- Optimizing acquisition protocol to improve SNR

DAM-SP on each sample before quantitative imaging

w_1^- mapping. How and why?

The MRI experiments were performed at the MR Platform for Biological Systems, INRA Center of Clermont-Ferrand, France.

Thanks to my colleagues,
Jean-Marie Bonny

Thanks for your attention