Spurious phase correction in multi-shot CSI

Nour El Sabbagh, Carine Chassain, Hélène Ratiney, Guilhem Pagès, J.-M.
Bonny

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Nour EL SABBAGH[a], Carine CHASSAIN[a], Hélène RATINEY[b], Guilhem PAGES[a], Jean-Marie BONNY[a]

[a] INRAE, AgroResonance, UR QuaPA, F-63122 Saint-Gènes-Champanelle, France, [b] University of Lyon, CNRS, Inserm, CREATIS UMR 5220, U1206, F-69621 Lyon, France

I. Introduction

- Multi-shot CSI : CS study during the TE increments (ΔTE) (refer to Fig1)
- Importance of maintaining a phase coherency during ΔTE
- Phase coherency's loss induces spectral distortion

Fig1: MRSI encoding scheme & frequency switching.

f_e : excitation frequency

f_r : reception frequency
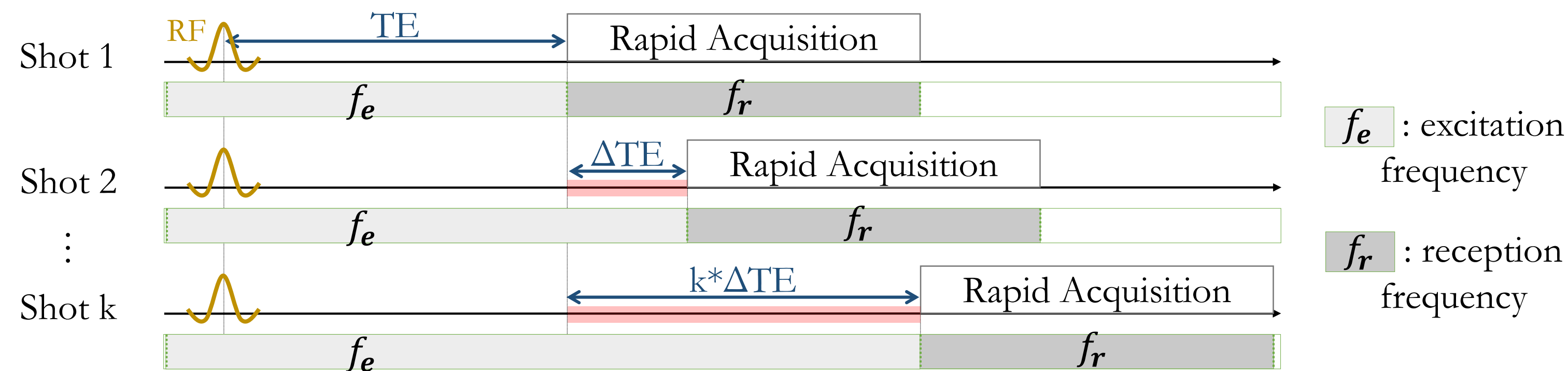
II. Problem

Slice Selection:

- Done with shifting the excitation frequency proportionally to the wanted position z:
$$\Delta f_e(z) = SW \times \frac{z}{FOV_z}. \text{ Ergo, } \Delta f_e = 0 \text{ for centred slice } (z = 0)$$

However:

- Unwanted additional phase can be accumulated during ΔTEs leading to spectral distortion, hence improper images ➡ Correction is mandatory !

III. Two Proposed Solutions

1. Post-Processing Correction (**pP-C**). With S the acquired signal, k the number of shot:
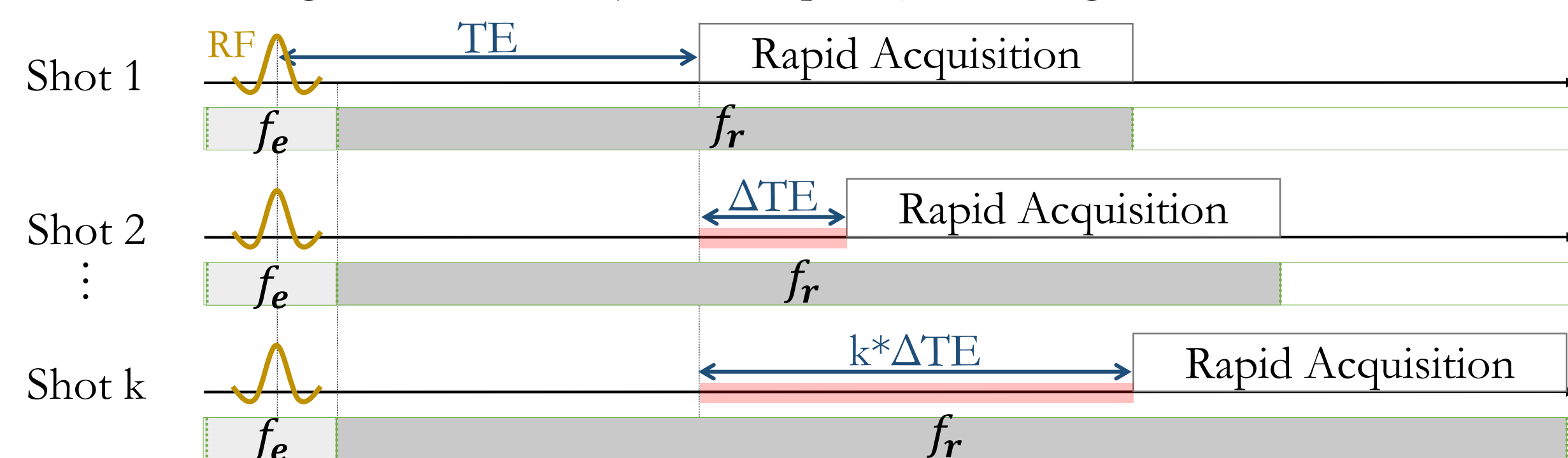$$S_{corrected}(k, z) = S_{raw}(k, z) \times \exp(-i2\pi \times \Delta f_e(z) \times (k - 1) \times \Delta TE)$$

2. Switching from the f_e to the f_r (dependent on the readout position and independent of z) after the excitation pulse (**RF-switch**) :
$$S_{corrected}(k) = S_{raw}(k) \times \exp(-i2\pi \times \Delta f_r \times (k - 1) \times \Delta TE)$$

For non-Cartesian spatial encoding, readout is always centred. Ergo $\Delta f_r = 0$.

Fig2: MRSI encoding scheme with adjusted frequency switching -**RF-switch**.

IV. Application

Correction methods were applied on ^{13}C multi-shot CSI recorded with IDEAL SPIRAL [1] at a static magnetic field of 11.7 T.

Experimental Details:

- Phantom of four syringes containing ^{13}C-labelled Lactate (4 M, 182.2 ppm), Alanine (1.85 M, 175.8 ppm), Pyruvic acid (16.4 M, 174.5 ppm) and Urea (16.4 M, 162.5 ppm)
- Parameter optimisation through effective number of signal averages (NSA) [1] analysis : 7 shots and ΔTE = 0.86 ms
- For non hyperpolarized molecules: TR = 10 s, TE = 1.69 ms and a slice thickness of 15 mm
- Image resolution of (0.78 × 0.78 × 15 mm³)

1. doi 10.1002/mrm.23212

Fig3: ^{13}C metabolite maps of ^{13}C-labelled molecules, for a centred and a shifted slice, superimposed on a ^{1}H reference image.