Abstract No. : **4017**

Computer No. : **68**

Correction of Dynamic Off-resonance in Spiral 2D Real-time MRI of Speech

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Background - Human Articulators

- Organs that are used for speech
  - The lips, palate, tongue, velum, and epiglottis …

- Information about dynamic function can be used to…
  - Understand language
  - Improve speech synthesis and recognition
  - Clinical applications such as swallowing, glossectomy, velopharyngeal insufficiency
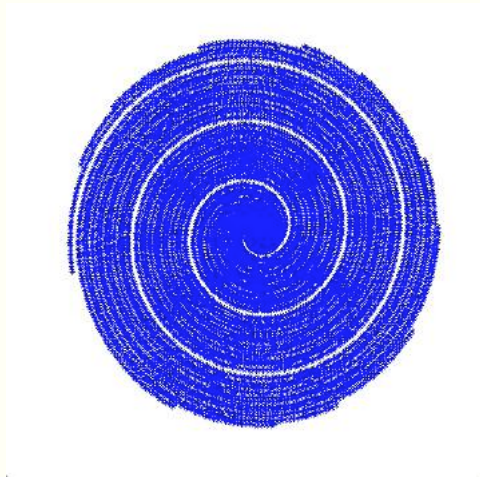
Spiral 2D RT-MRI of speech
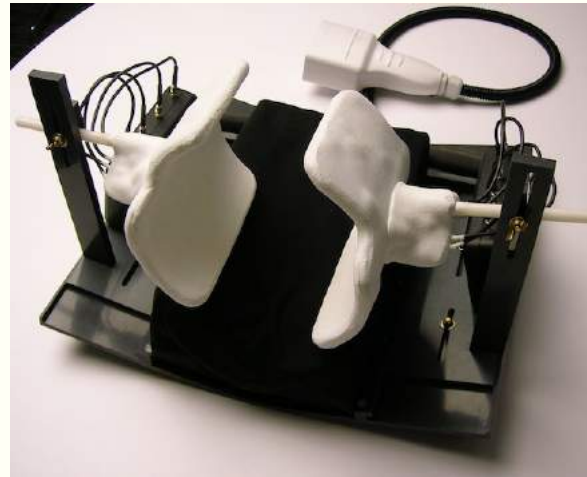

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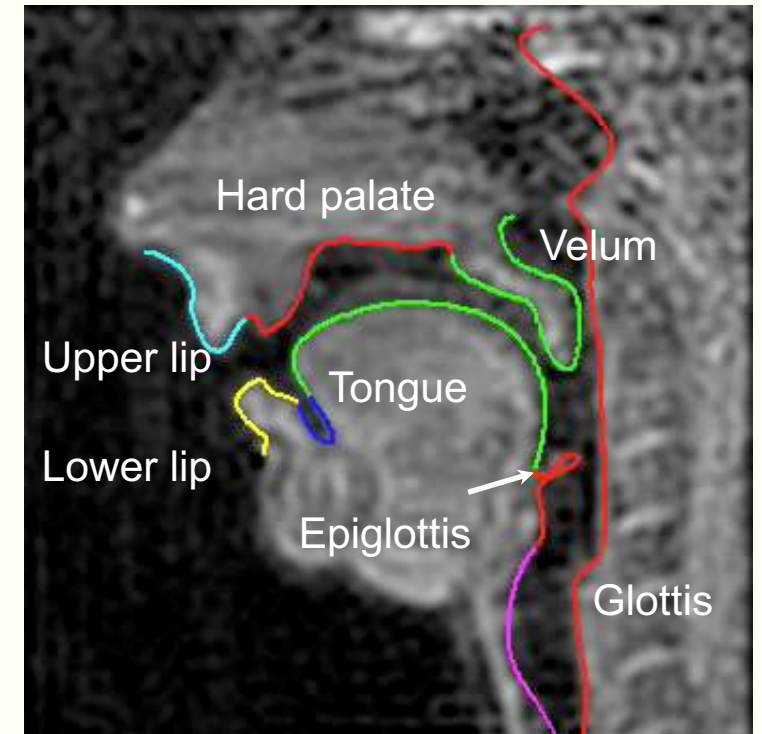
Background - Spiral 2D RT-MRI of Speech

- 2D real-time MRI (RT-MRI) based on a spiral sequence is used to study dynamic function of the articulators non-invasively[1]
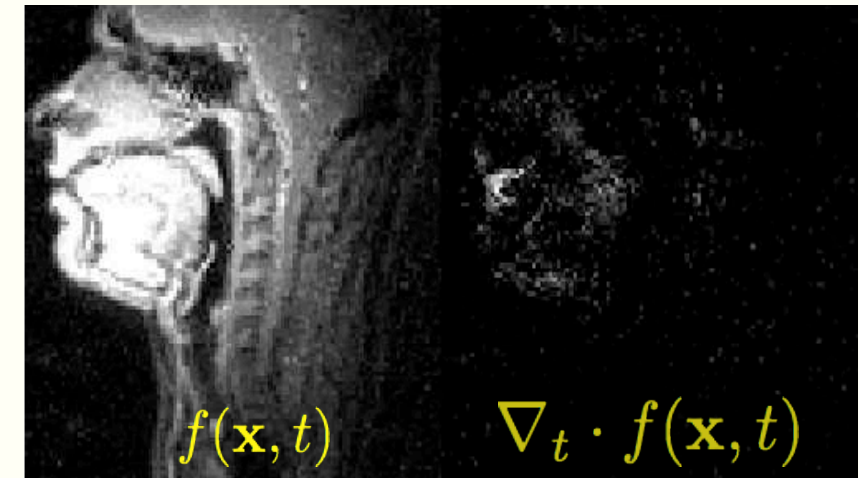
Multi-shot spiral sequence

Novel custom upper-airway coil design

Constrained reconstruction with prior knowledge

$f(\mathbf{x}, t)$ $\nabla_t \cdot f(\mathbf{x}, t)$

1. Lingala S, et al, MRM, 2017; 77:112–125

Background - Off-resonance Blurring Artifacts

- A key drawback in **spiral imaging**

- Due to

  1. Large magnetic susceptibility difference between air and tissue ($\Delta\chi$ = 9.41 ppm)

  2. Phase accrual during the spiral readout

- <u>Blurring or signal loss</u> appear at the boundaries of articulators of interest

  - The lips, tongue, and palate

Spiral 2D RT-MRI

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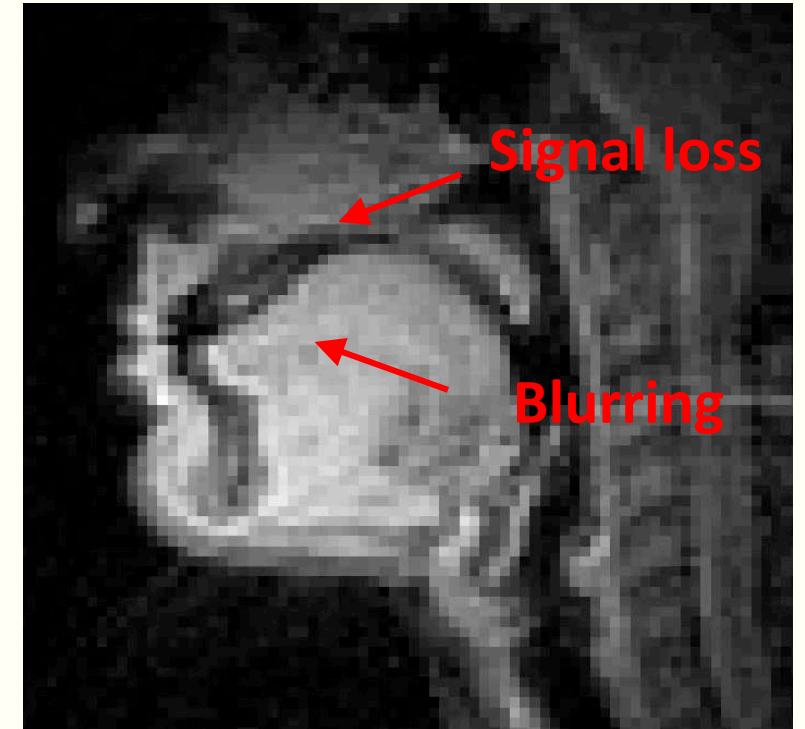
Goal

- To estimate dynamic changes in off-resonance directly from phase of single echo-time dynamic spiral images

- To correct for off-resonance induced blurring artifacts

Method – Estimation of Dynamic Field Map

- Approximation of image equation

$$m_i(\boldsymbol{r}, t) \approx m_0(\boldsymbol{r}, t) C_i(\boldsymbol{r}) e^{-j2\pi f(\boldsymbol{r},t)TE}$$

i-th coil image

Transverse magnetization (real)

Coil sensitivity (complex)

Field map

- If we know $C_i(\boldsymbol{r})$, the field map $f(\boldsymbol{r},t)$ can simply be estimated by

Multi-channel combination

$$\hat{f}(\boldsymbol{r}, t) = \frac{\angle[\sum_{i=1}^{Nc} m_i(\boldsymbol{r}, t) C_i^*(\boldsymbol{r})]}{-2\pi TE}$$

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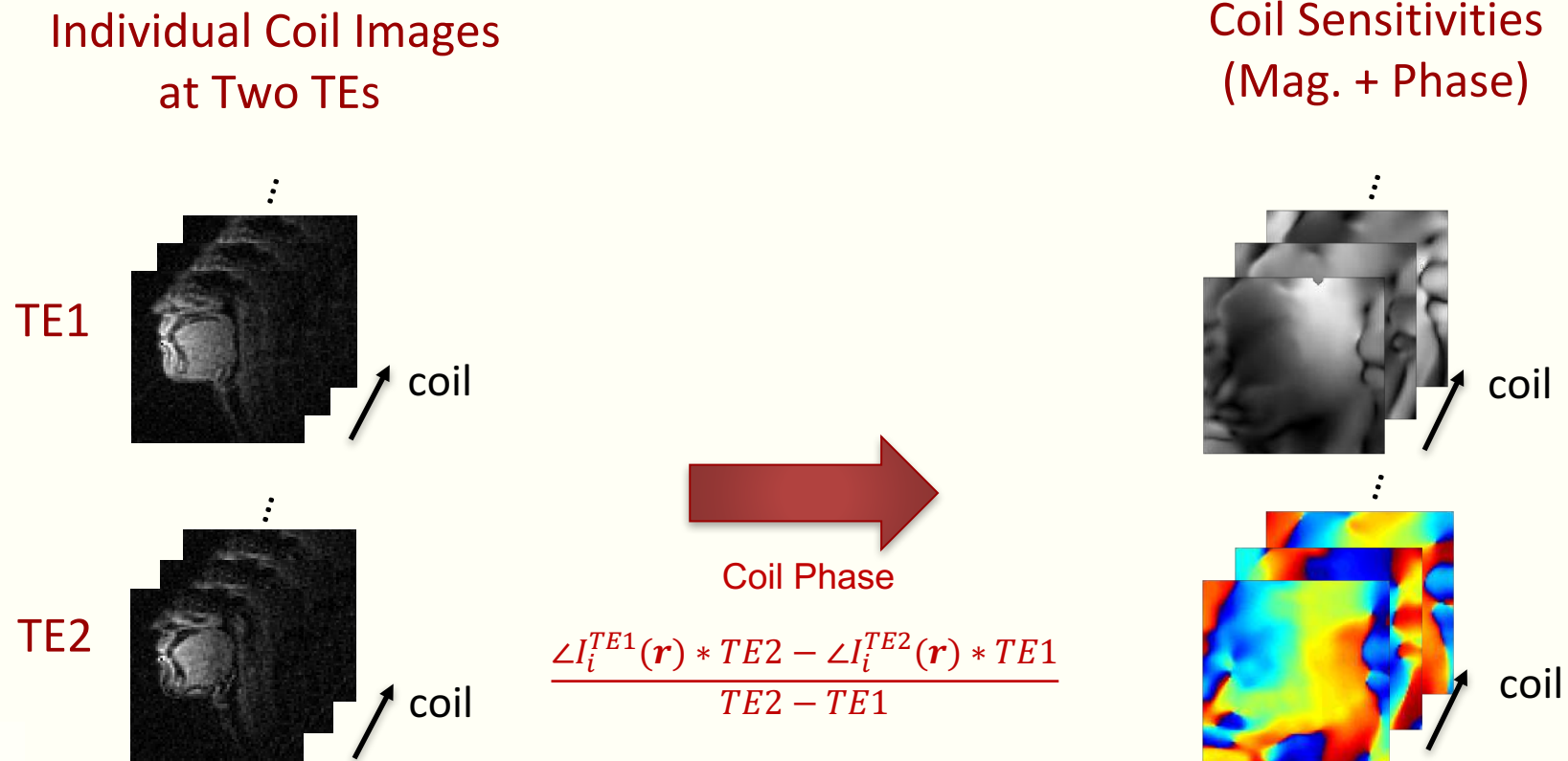
Method – Estimation of Coil Sensitivities

- Coil sensitivity maps can be obtained from either

  - Method A[1]: a dual-TE scan at a static posture

  - Method B: a single-TE scan itself (auto-calibration)
   - If the dual-TE scan is not available

1. Robinson S, et al, MRM, 2011; 65:1638–1648

Method – Estimation of Coil Sensitivities

- **Method A**[1]: <u>A dual-TE scan</u> at a static posture

Individual Coil Images
at Two TEs

Coil Sensitivities
(Mag. + Phase)

TE1

coil

TE2

coil

Coil Phase

$$\frac{\angle I_i^{TE1}(\boldsymbol{r}) * TE2 - \angle I_i^{TE2}(\boldsymbol{r}) * TE1}{TE2 - TE1}$$

coil

coil

1. Robinson S, et al, MRM, 2011; 65:1638–1648

Method – Estimation of Coil Sensitivities

- <u>Method B</u> : a single-TE scan itself (Coil sensitivity auto-calibration)
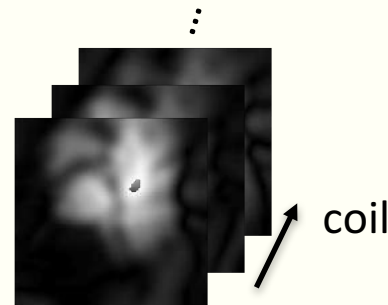 - If the dual-TE scan is not available

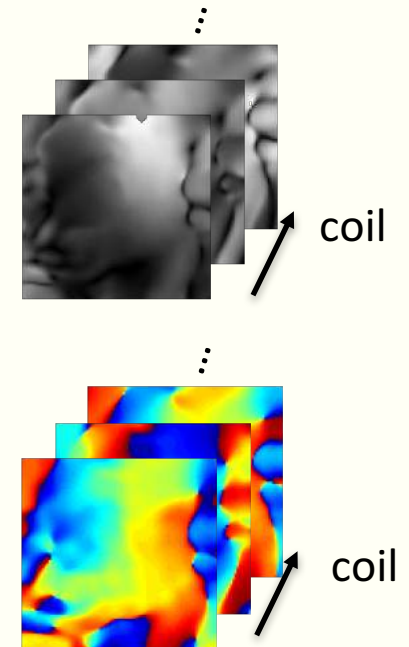Continuously Acquired
Golden-Angle Spiral Data
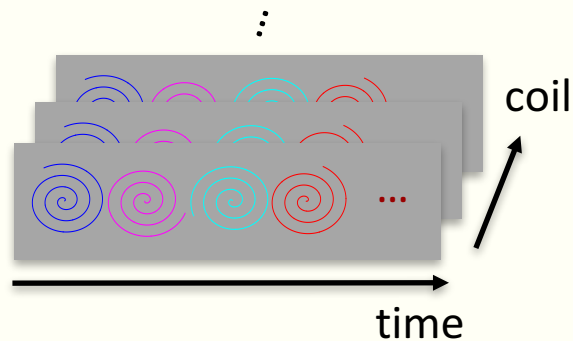
NUFFT

Time-Averaged
Low-Resolution
Individual Coil Images

$$\hat{C}_i(\boldsymbol{r}) = \frac{I(\boldsymbol{r})}{\sqrt{\sum_i |I(\boldsymbol{r})|^2}}$$
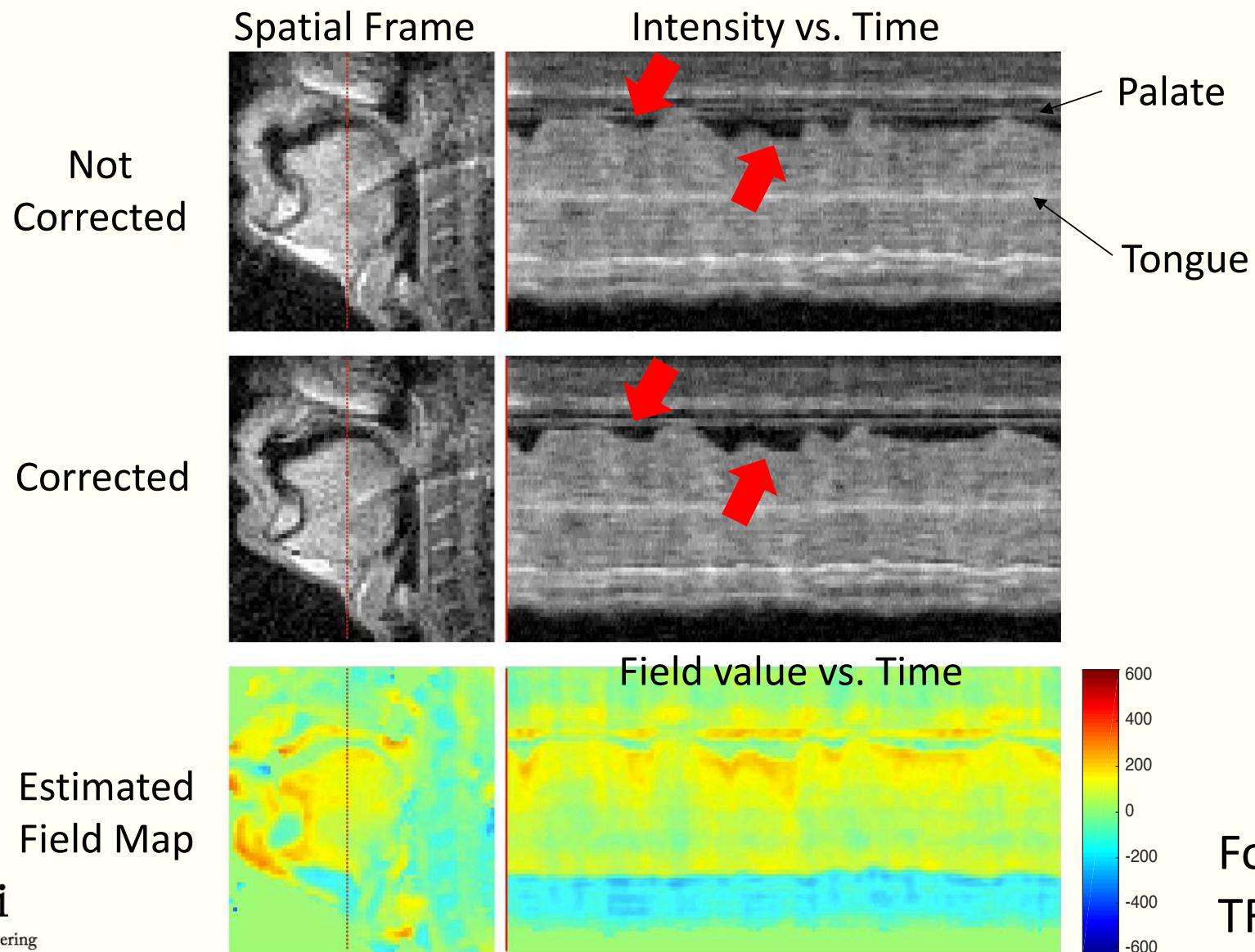
Coil Sensitivities
(Mag. + Phase)

Method – Acquisition and Reconstruction

- MRI Protocol
  - GE Signa 1.5T scanner
  - 13-interleaf spiral sequence
  - A 8-ch custom upper airway coil
  - TR/TE/Tread = 6/0.8/2.52ms
  - Spatial resolution = 2.4 x 2.4 mm^2
  - Temporal resolution = 42 frames/s

- Coil sensitivity maps are estimated from either Method A or B.
- Iterative image reconstruction was used to correct for off-resonance

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Results – In-vivo Experiments (Method A)

Results – In-vivo Experiments (Method B)
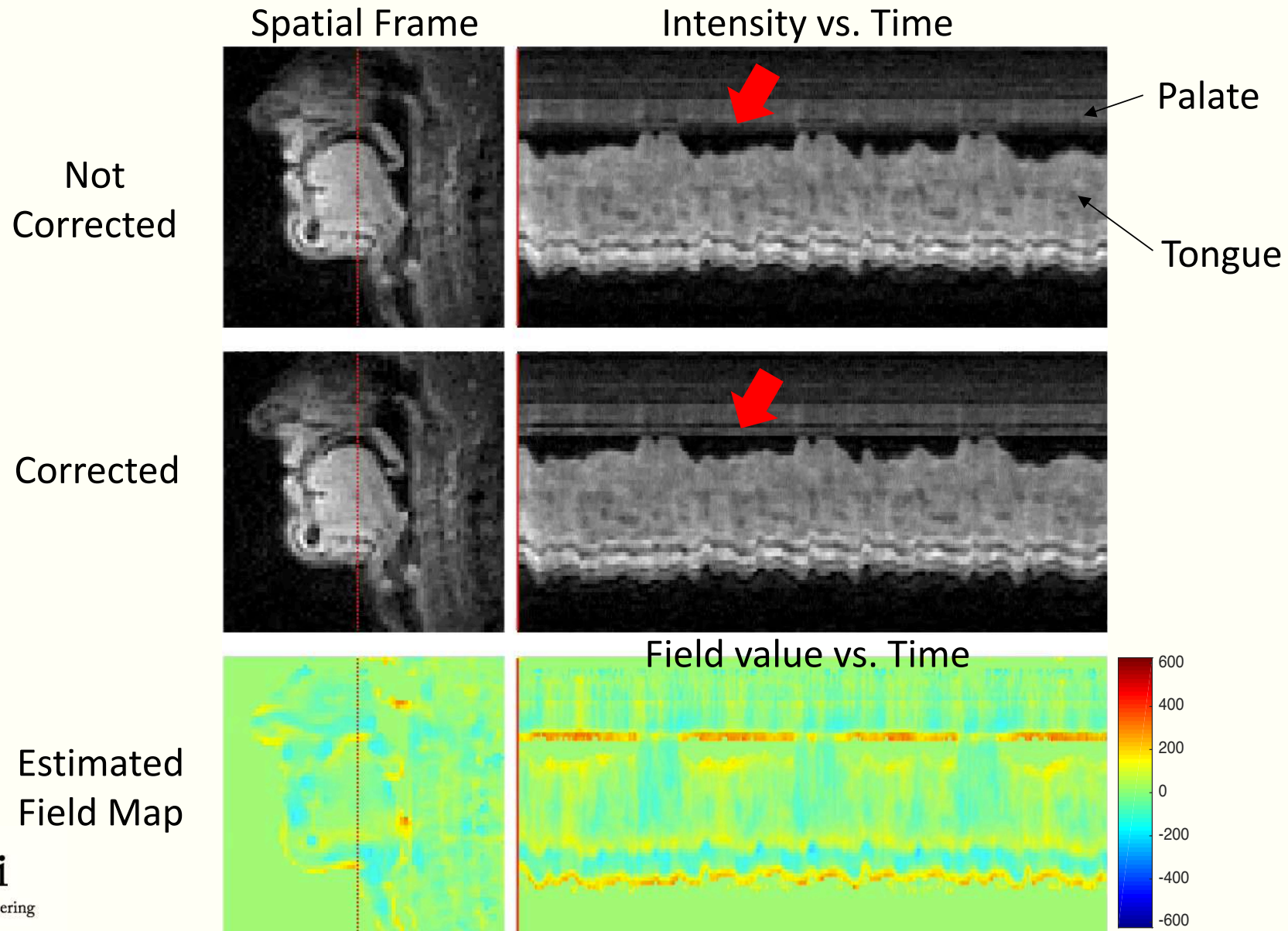
Conclusions

- Proposed a simple method for estimating dynamic off-resonance in spiral 2D RT-MRI

- Estimated a dynamic field map from phase of the image after coil sensitivity compensation

- Method B is also applicable if a dual-TE scan is not available

    - Any previously collected spiral RT-MRI datasets

- Provided considerable improvement in sharpness at articulator boundaries such as the tongue and palate

Acknowledgement

- USC Magnetic Resonance Engineering Laboratory (MREL) group

- USC Speech Production and Articulation kNowledge (SPAN) group