Development of a Broadband Echo Planar Imaging (EPI) for Hyperpolarized C-13 Imaging on a Siemens Prisma 3T MRI Scanner

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ABSTRACT

Purpose: To develop a broadband echo planar imaging (EPI) for hyperpolarized C-13 imaging on a Siemens Prisma 3T MRI scanner for cross-vendor performance harmonization

Methods: A new graphical user interface (GUI) was implemented to control parameters that are unique for hyperpolarized (HP) C-13 imaging. A metabolite loop was added with controls for metabolite-specific excitation frequency. The GUI also included controls for metabolite-specific flip angle and the number of time frames. A drop-down menu was added to select any custom external RF and gradient waveforms. A spectral-spatial (SPSP) RF/gradient module was programed for excitation, and a symmetric bipolar EPI readout was implemented for signal acquisition. The implementation was developed in C++ on the Siemens IDEA platform and tested using H-1 phantom imaging.

Results: User inputs were successfully translated from the GUI to actual sequence execution. The metabolite loop behaved as intended for multi-slice acquisition with multiple repetitions in both simulation and phantom scans. Using a sinc RF, the spatial shift in the reconstructed image accurately matched the frequency offset as specified in the GUI. The sequence correctly loaded external waveform files and enabled the spectral-spatial excitation mode.

Conclusion: This work demonstrates a new method tailored for HP C-13 MRI studies on a Siemens Prisma 3T scanner. Expanding access to this technique may facilitate harmonizing data acquisition across MR imaging platforms. Future work will evaluate spectral-selective excitation performance of multiple C-13 metabolites (e.g., pyruvate, lactate, bicarbonate, and alanine) under multi-slice and multi-repetition conditions.

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INTRODUCTION

Background: Hyperpolarized C-13 MRI uniquely visualizes real-time metabolism (e.g., the Warburg effect[1]), yet its broader clinical adoption is restricted by limited cross-vendor availability.

Motivation: Harmonizing data acquisition across different MR platforms is critical for accelerating large-scale clinical trials.

Objective: To develop and implement a hyperpolarized C-13 imaging sequence using broadband EPI on a Siemens Prisma 3T system, enabling cross-vendor data harmonization.

METHODS AND MATERIALS

Spectral-spatial (SPSP) module:
- Twenty-two sub-pulses (0.6 ms); the envelope (25.38 ms)
- Oscillating flyback Gz gradient; duration =25.38 ms

Spatial selectivity test:
- Slice profile sequence with different slice offsets were measured using *Pulseq*[2] and a body coil in a Siemens Prisma 3T MRI scanner.

Spectral selectivity test:
- Spectral profile was simulated using the *Spectral-Spatial-RF-Pulse-Design*[3].

Validation in Siemens IDEA:
- Pulse sequence design in XA30A
- Siemens Prisma 3T MRI scanner
- ACR phantom; head and neck 20-channel coil Rx

DISCUSSION & CONCLUSION

The proposed sequence has been further developed since the initial abstract submission. Building upon the frequency offset framework confirmed with a sinc RF pulse, the sequence now **incorporates a spectral-spatial (SPSP) RF pulse**, successfully demonstrating **multi-slice** and **multi-metabolite** loops.

This sequence will serve as an early step toward **harmonizing data acquisition for HP C-13 imaging** across different vendor platforms.

Future work will focus on evaluating performance during **C-13 imaging** of multiple metabolites (e.g., pyruvate, lactate, bicarbonate, alanine, and urea). Furthermore, we plan to develop an **online reconstruction** pipeline within the Siemens ICE environment.

RESULTS

Graphical User Interface (GUI) tailored for HP MRI

- **Metabolite Selection:** Users can enable any subset of five pre-configured C-13 metabolites (pyruvate, lactate, alanine, bicarbonate, and urea), with a real-time display of the total active selections (e.g., “Enable C1 Pyruvate” and “Metabolites selected”).
- **Automated Frequency Calculation:** The pyruvate center frequency is automatically derived using a "Water2Pyr Factor," taking into account the H-1 system center frequency and local H-1 B0 offsets at a tumor target.
- **Metabolite-Specific Controls:** Adjustments can be made for frequency offset and flip angle of each selected metabolite (e.g., “C1 Pyruvate df” and “C1 Pyruvate FA”).
- **Sequence Settings:** The GUI provides direct control over the selection of external RF waveforms (e.g., “Select Ext. RF”) and the number of time frames (e.g., “Timeframe #”).

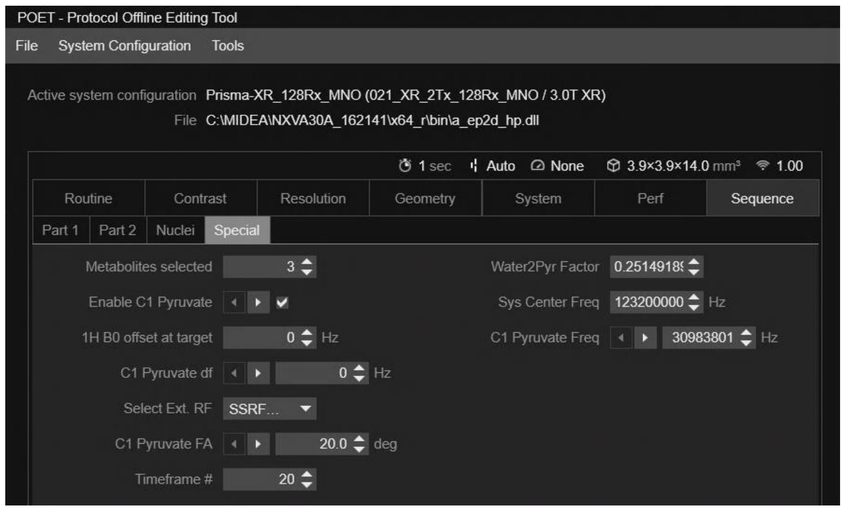


Figure 1. Graphical user interface (GUI) for hyperpolarized C-13 MRI.

The Spectral-Spatial (SPSP) RF and Gradient Pulse

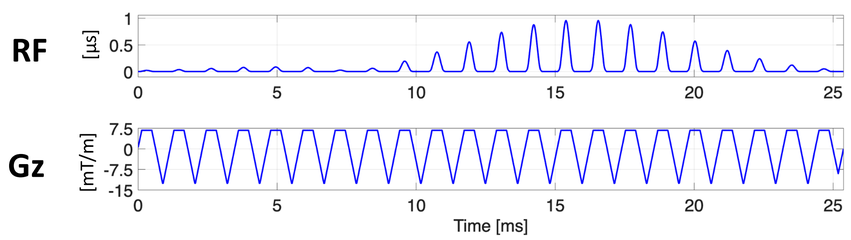


Figure 2. The spectral-spatial RF and gradient waveforms used in both Siemens IDEA and Pulseq environments

Slice Profile Test Result Using Pulseq

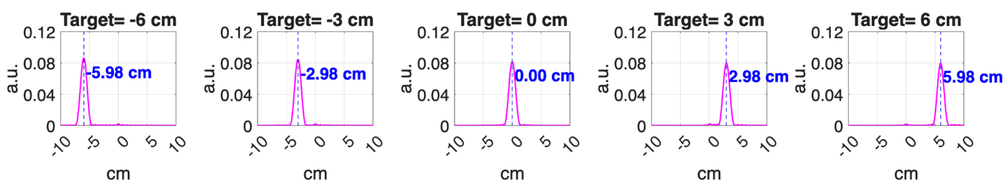
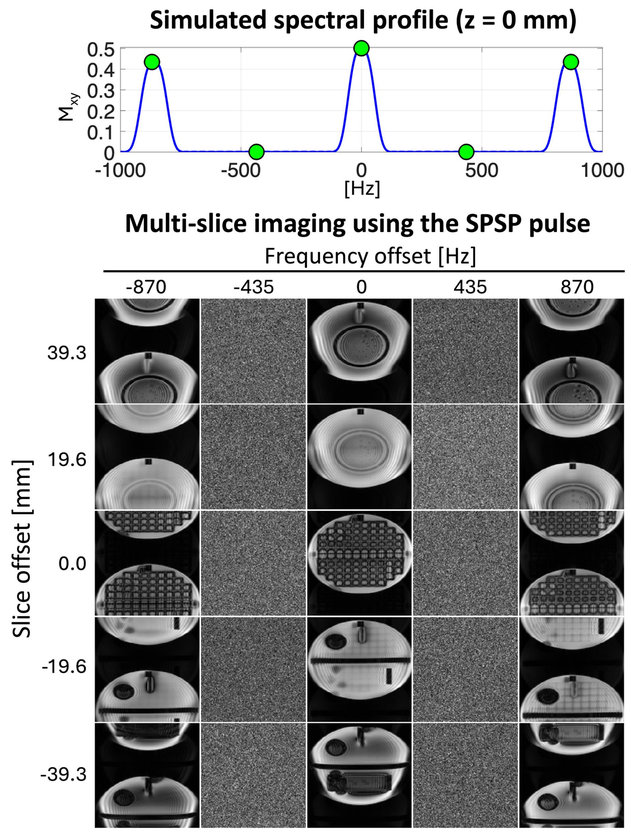


Figure 3. Slice profile evaluation with different slice offsets using Pulseq. The measured slice positions (blue) closely match the prescribed target offsets, demonstrating accurate spatial selectivity (flip angle = 30°).

Validation of the SPSP RF pulse for Multi-slice H-1 imaging



- **Spectral profile** simulation at z = 0 mm demonstrates three passbands and two stopbands.
- Green circle markers correspond to the five **frequency offsets** used in the phantom images, emulating C-13 metabolites.
- **Multi-slice** phantom images were acquired with H-1 imaging at the five frequency offsets. The acquired images confirm that signal excitation is localized to the passbands, in agreement with the simulation. A 30° flip angle was used for both the simulation and phantom experiments.
- Scan parameters:
  TR/TE= 4000/43 ms; flip angle= 30°; FOV= 250x250 mm; resolution= 128x128; slice-thickness= 1.313 mm; readout= single-shot EPI; ESP= 0.55 ms.

Figure 4. Spectral profile simulation using the Spectral-Spatial-RF-Pulse-Design toolbox and phantom scan results acquired using the Siemens IDEA sequence.

REFERENCES

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3. https://github.com/LarsonLab/Spectral-Spatial-RF-Pulse-Design