Pulseq to Philips (P2P) Interpreter

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Motivation & Outline

Motivation:

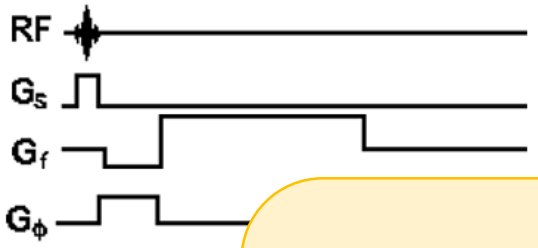
•Lack of Philips interpreter until this year

•The goal of this project is to develop acquisitions and reconstructions primarily for diffusion MRI acquisitions that yield consistent measures across sites and scanner vendors - NIH R01 EB032378

- *Brigham & Women's Hospital Boston*
- *Case Western Reserve University, Cleveland*
- *Department of Radiology, University Medical Center Freiburg, Freiburg, Germany*
- *fMRI Laboratory and Biomedical Engineering, University of Michigan, Ann Arbor*

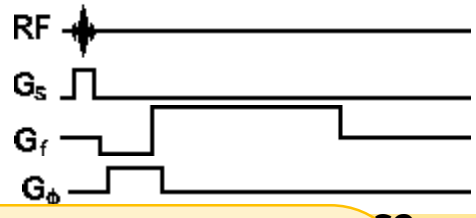
- **Philips sequence programming architecture & interpreter block diagram**
- **Safety evaluation**
- **Results**
- **Interpreter workflow from user perspective**
- **Discussion & Future work**

Philips sequence programming architecture



Sequence (Objects for 1 TR) is built on

Objects, run time scaling factors



ce

on

eter

Proto

param

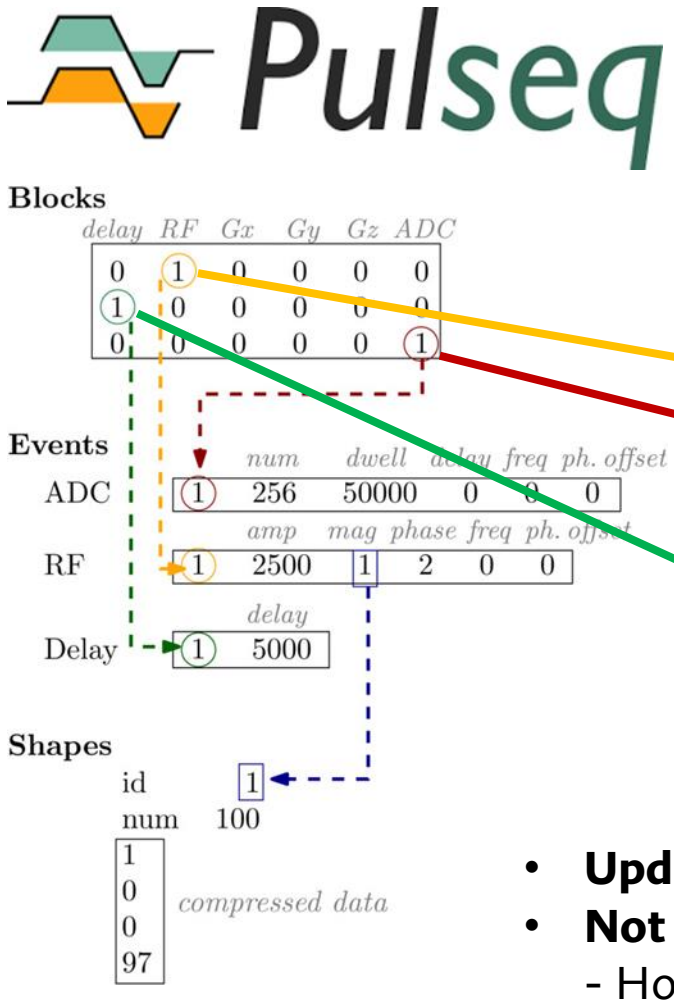
TR, TE, resolution etc initialized on host computer

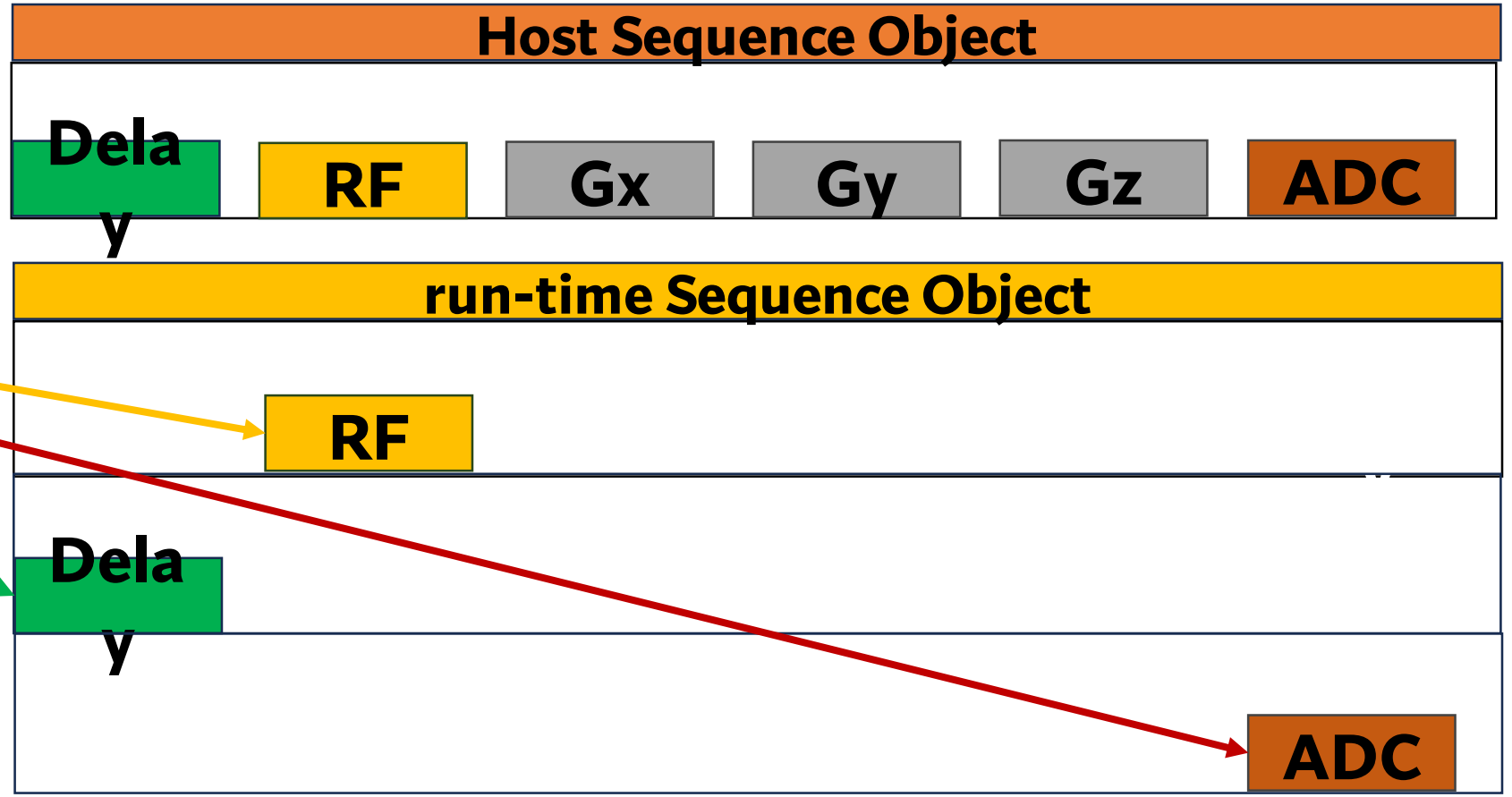
Unlike conventional sequence programming – **instead of a TR, one Pulseq block is played as a sequence object on spectrometer**

Recon

https://www.cis.rit.edu/htbooks/mri/inside.htm

Pulseq blocks mapping to Philips sequence objects





- **Update Object attributes during run time**
- **Not all attributes are run time** – interpreter smartly initializes some of the attributes on - Host
- Gradient delay blocks can be executed without any timing constraint – RF & ADC needs to accommodate **deadTime/ringdownTime**

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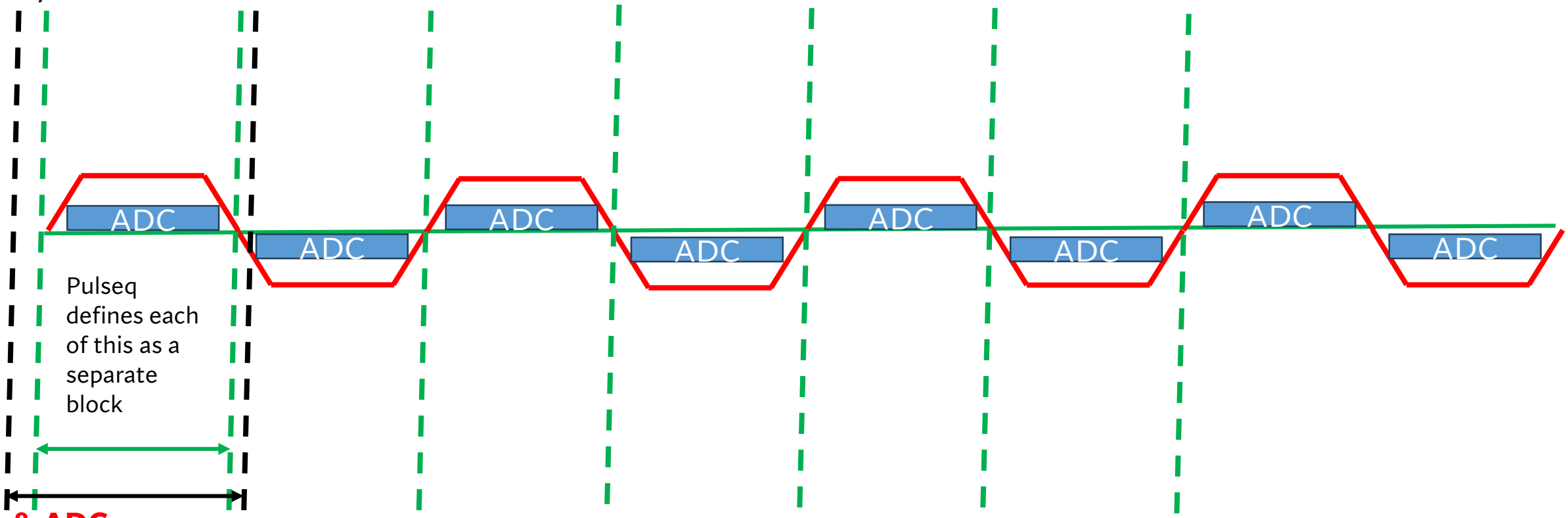
Deadtime/Ringdown time for RF & ADC

EPI sequence plays gradients continuously without any delay between them



RF & ADC needs start and stop time

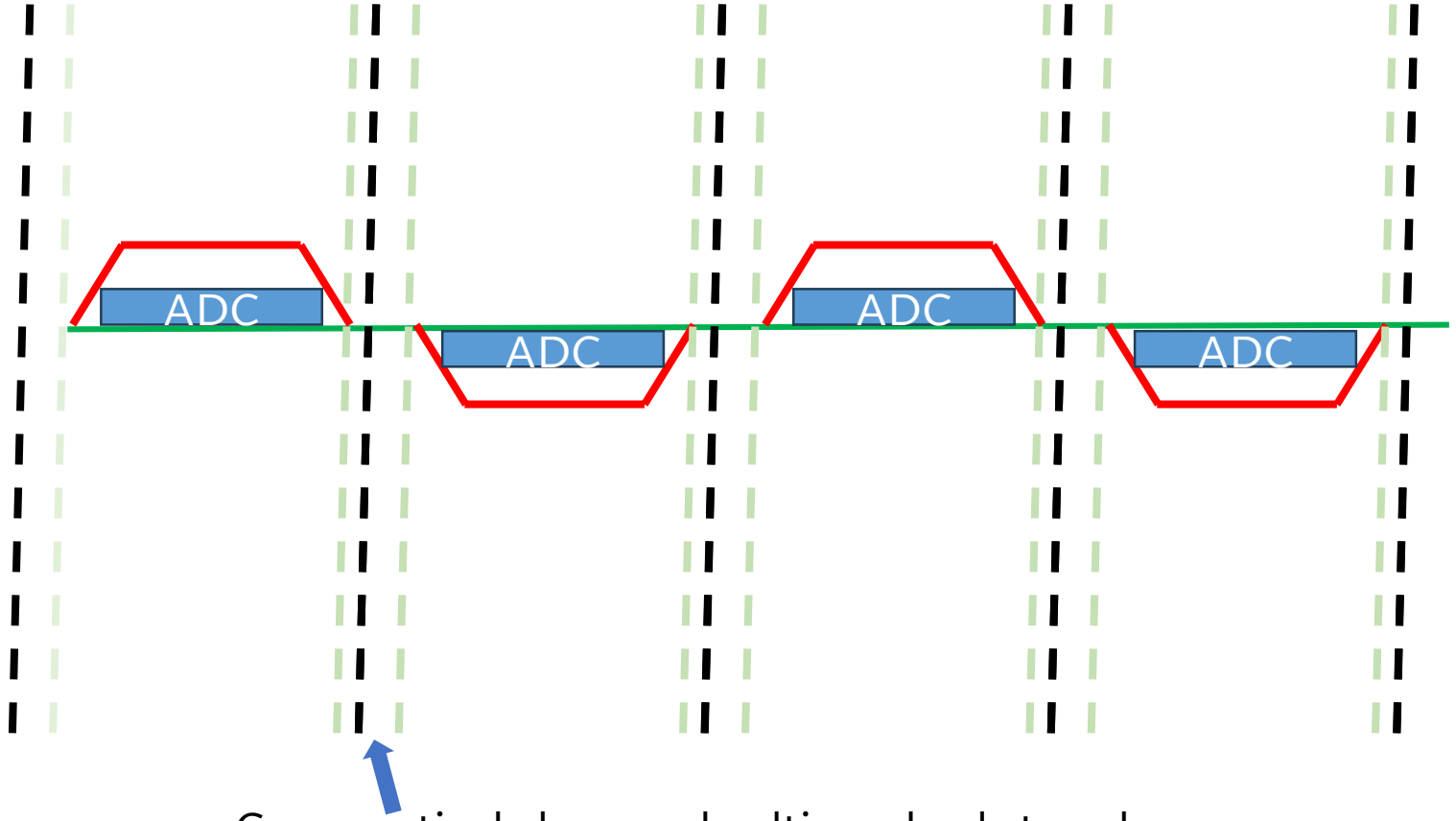
Sequence Object needs to accommodate switching **ON** time & **OFF** time

Deadtime/Ringdown time for RF & ADC

Pulseq framework provides an option for the user to set

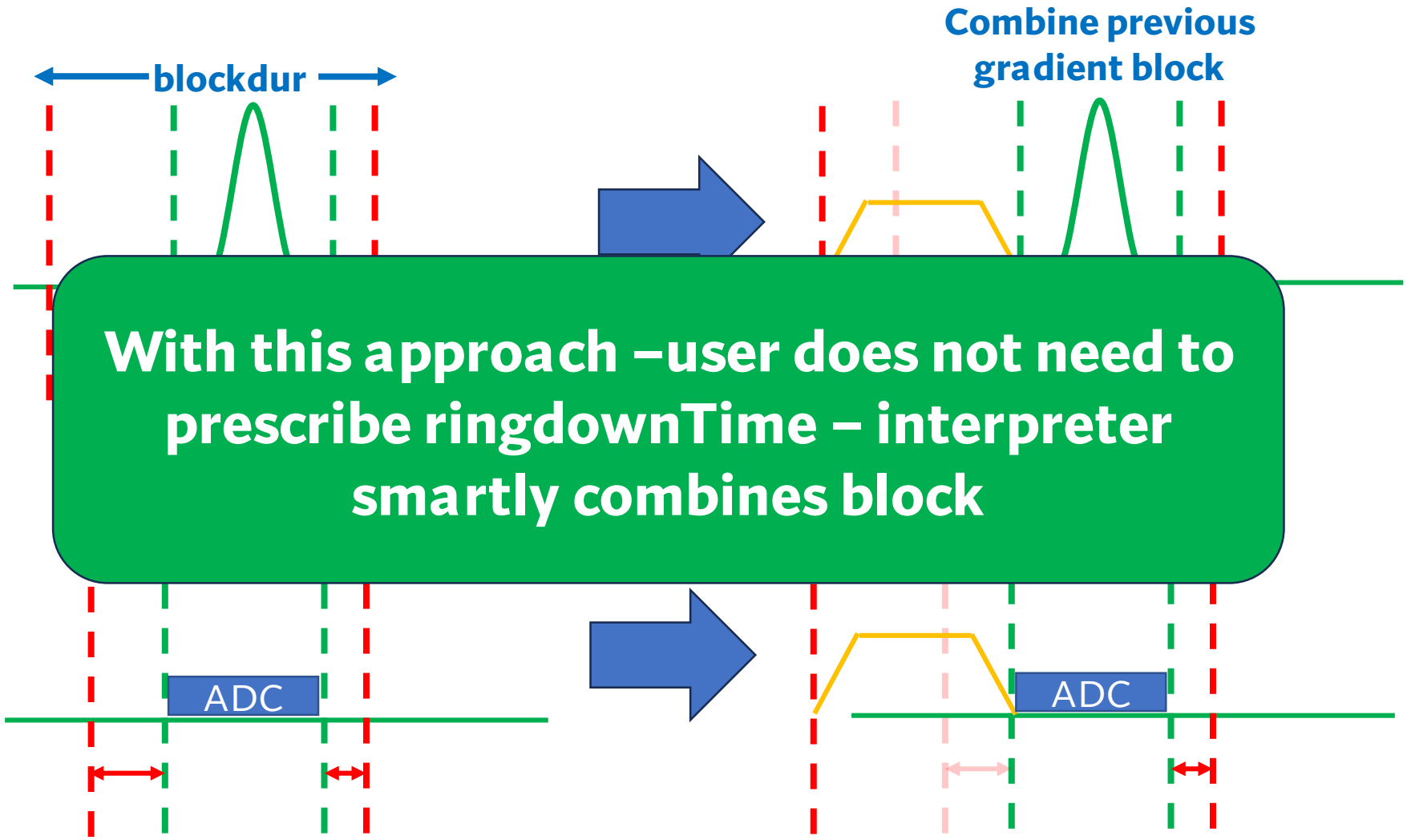
rfDeadTime

rfRingdownTime



Comparatively longer deadtimes leads to sub-Optimal sequences with block-by-block execution – especially for sequences like EPI

Deadtime/Ringdown time for RF & ADC – combine blocks



P2P Block diagram

Mass General Brigham

Pulseq

Case Western Reserve University

MATLAB or Python Code

.seq file

Complies with deadTime requirem-ents?

YES

NO

Host file (build seq blocks)

spectrometer file (run time parameters)

Arbitrary waveforms

Combine Blocks

Blocks combined

Pulseq block 1 | *Pulseq block 2* | *Pulseq block 3*

GR RF GR

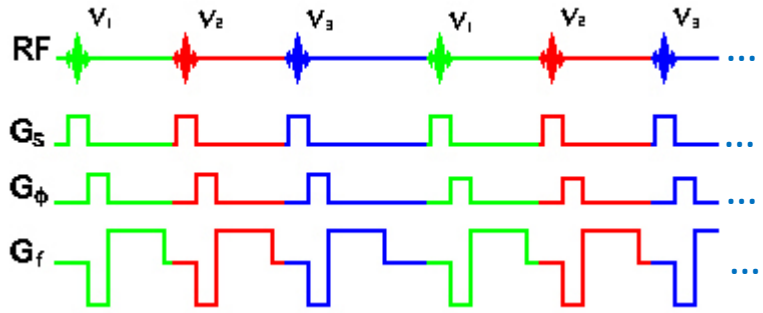
Combine 3 blocks into one

Tx turned on | RF Pulse | Tx turned off

PNS, SAR & HW constraint safety checks

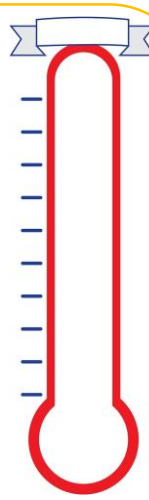
Output files from interpreter

One sequence object – combining 100 blocks



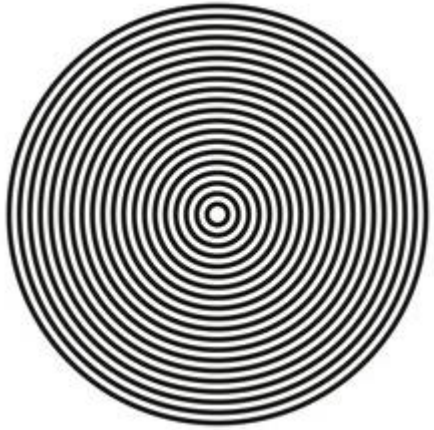
PNS and SAR eval for N iterations

- G_{max}
- Dwell time
- Filter freq
- Number of unique RF shapes



?

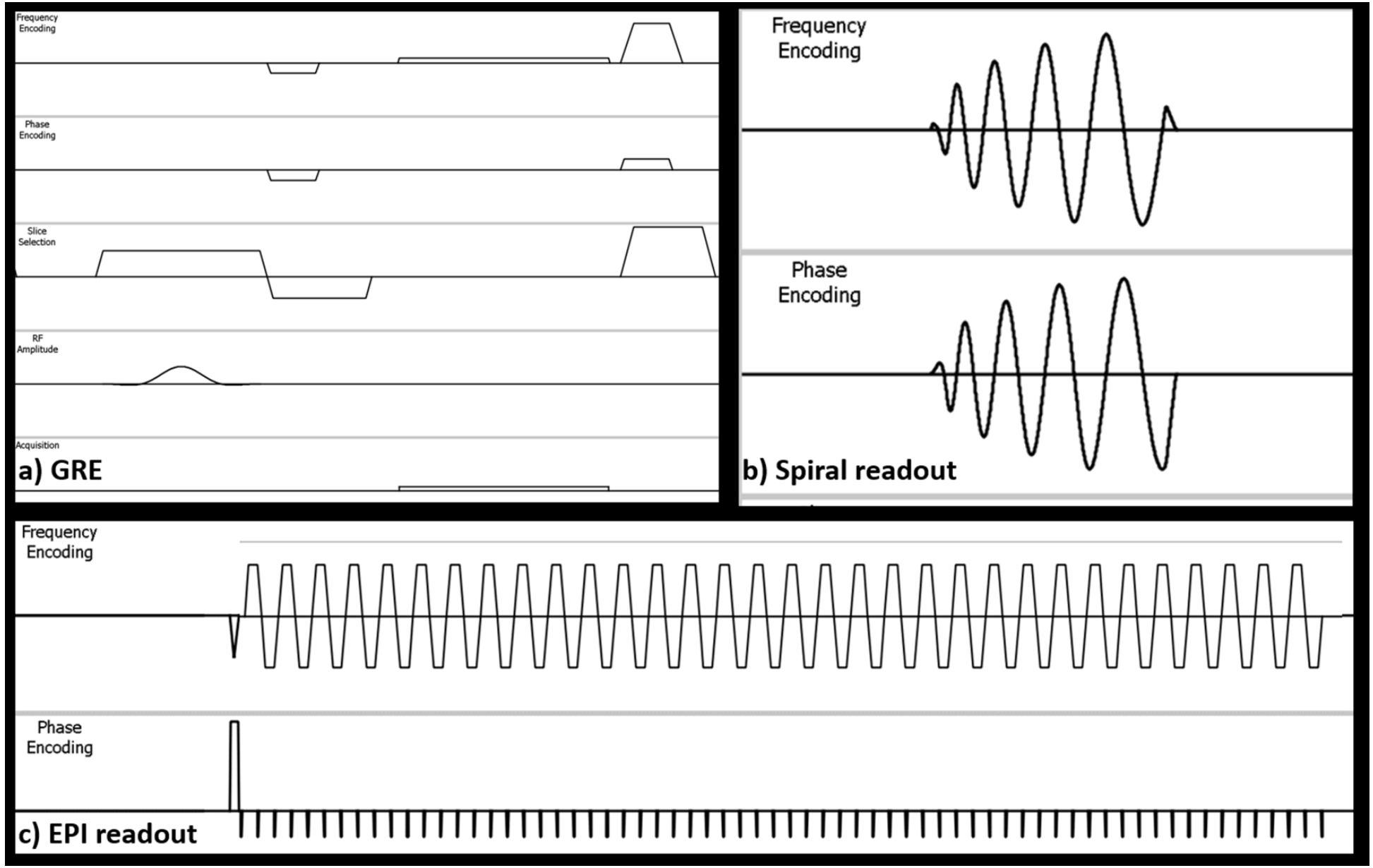
Continue to scan



Conflict raised

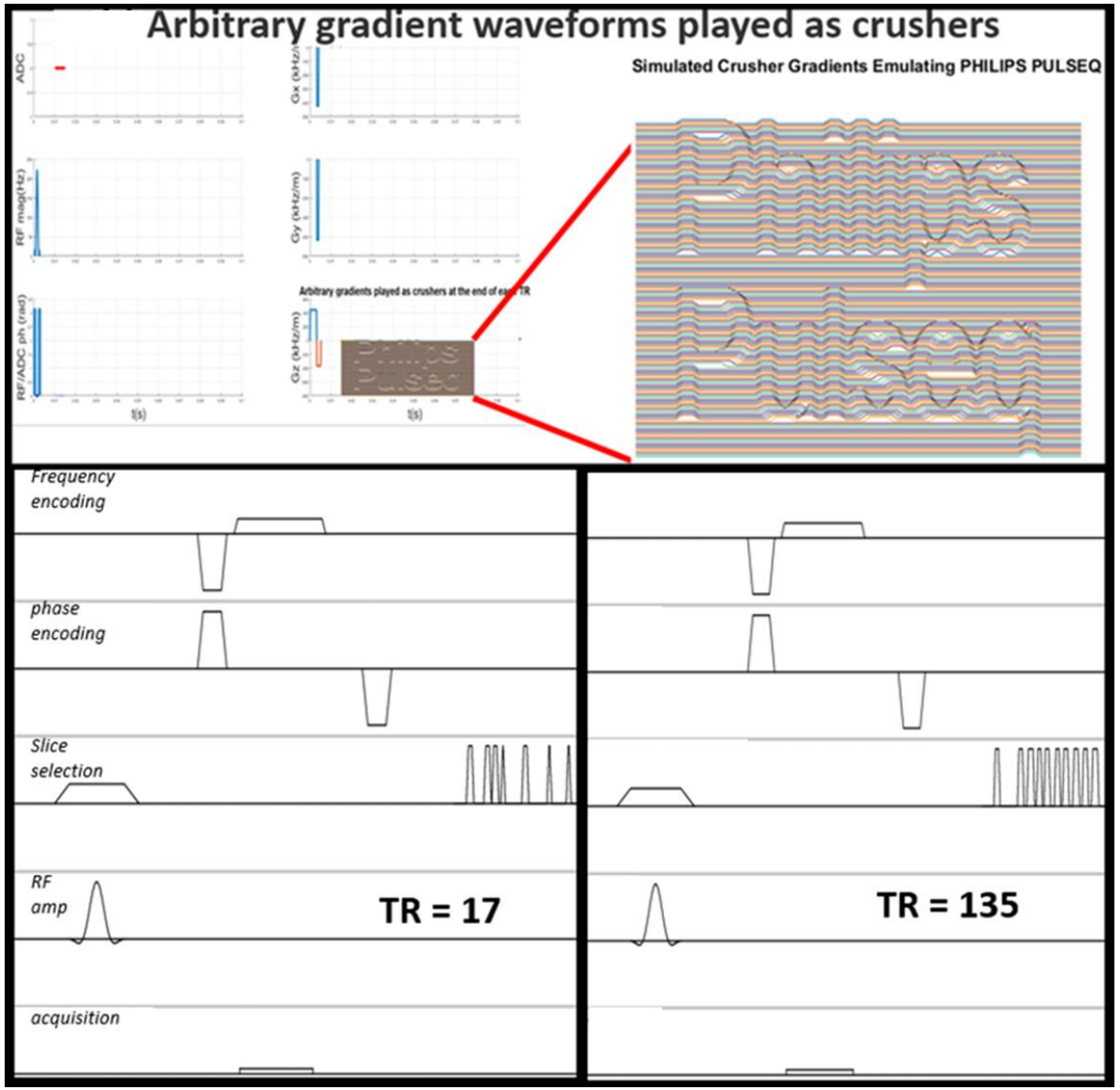
https://www.cis.rit.edu/htbooks/mri/chap-8/chap-8-h5.htm

Different gradient waveforms captured from scanner graphical viewer

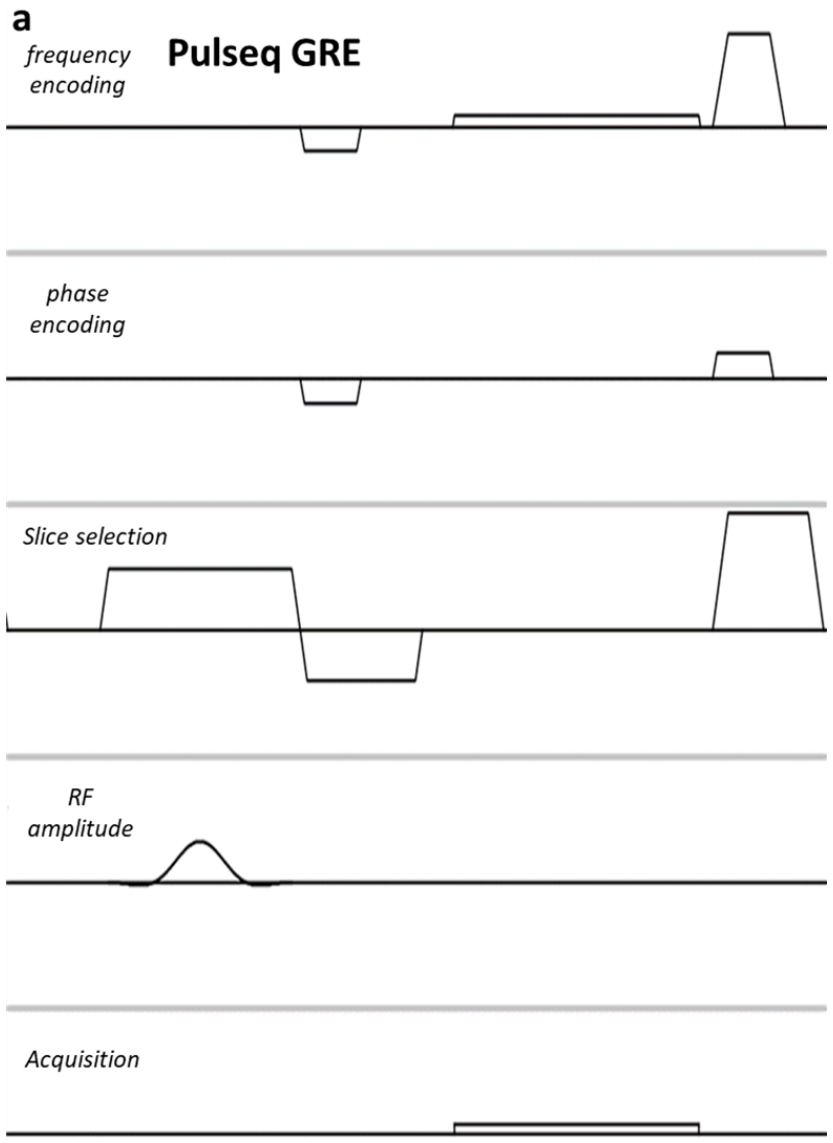


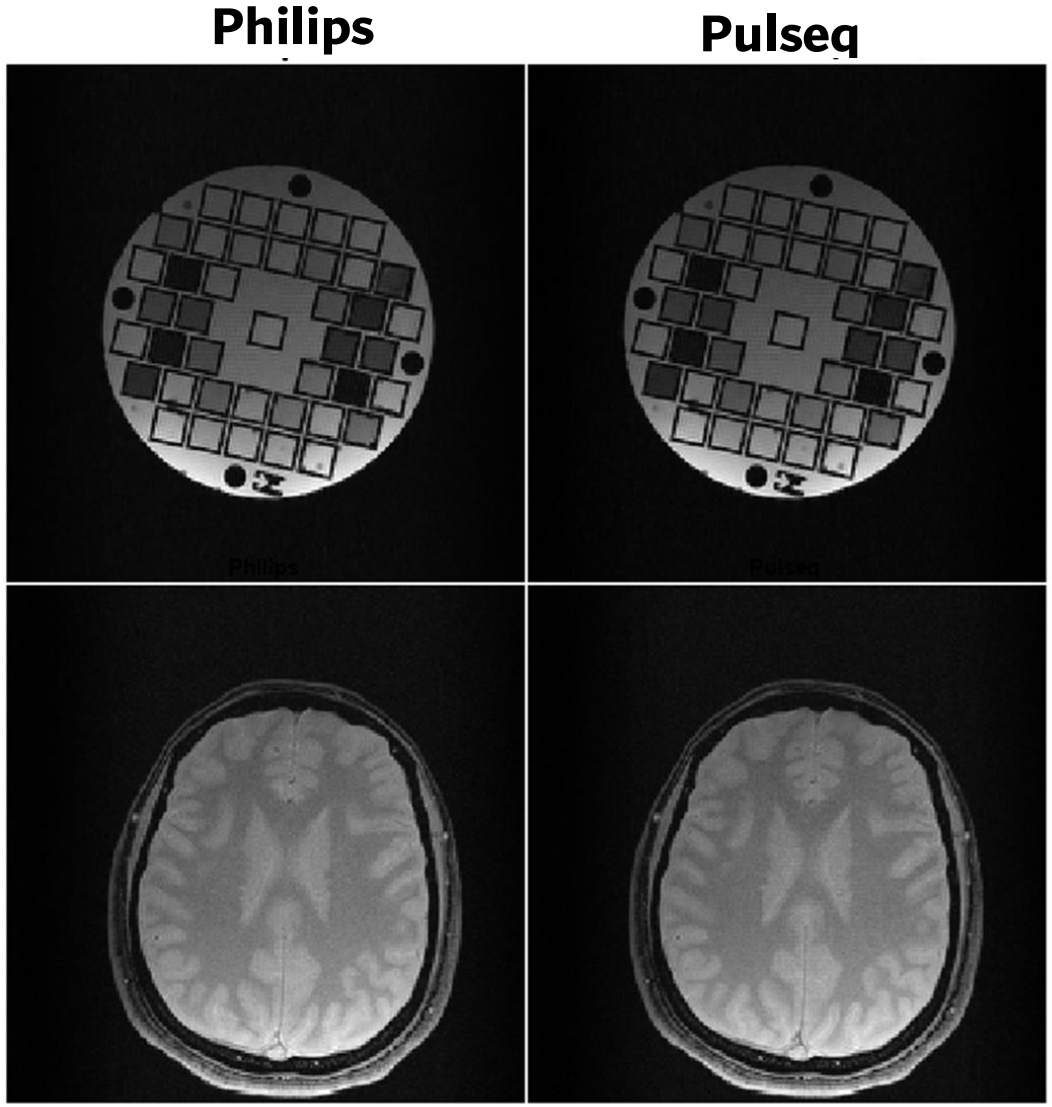
Arbitrary gradient waveforms

- **Any gradient and RF shape designed** for Philips system hardware constraints (Gmax, Slew rate, dwell time etc.) can be played
- Crusher gradients emulating “Philips Pulseq” simulated and played in a gradient echo sequence
- Two TRs – 17 & 135 from vendor provided graphical Viewer

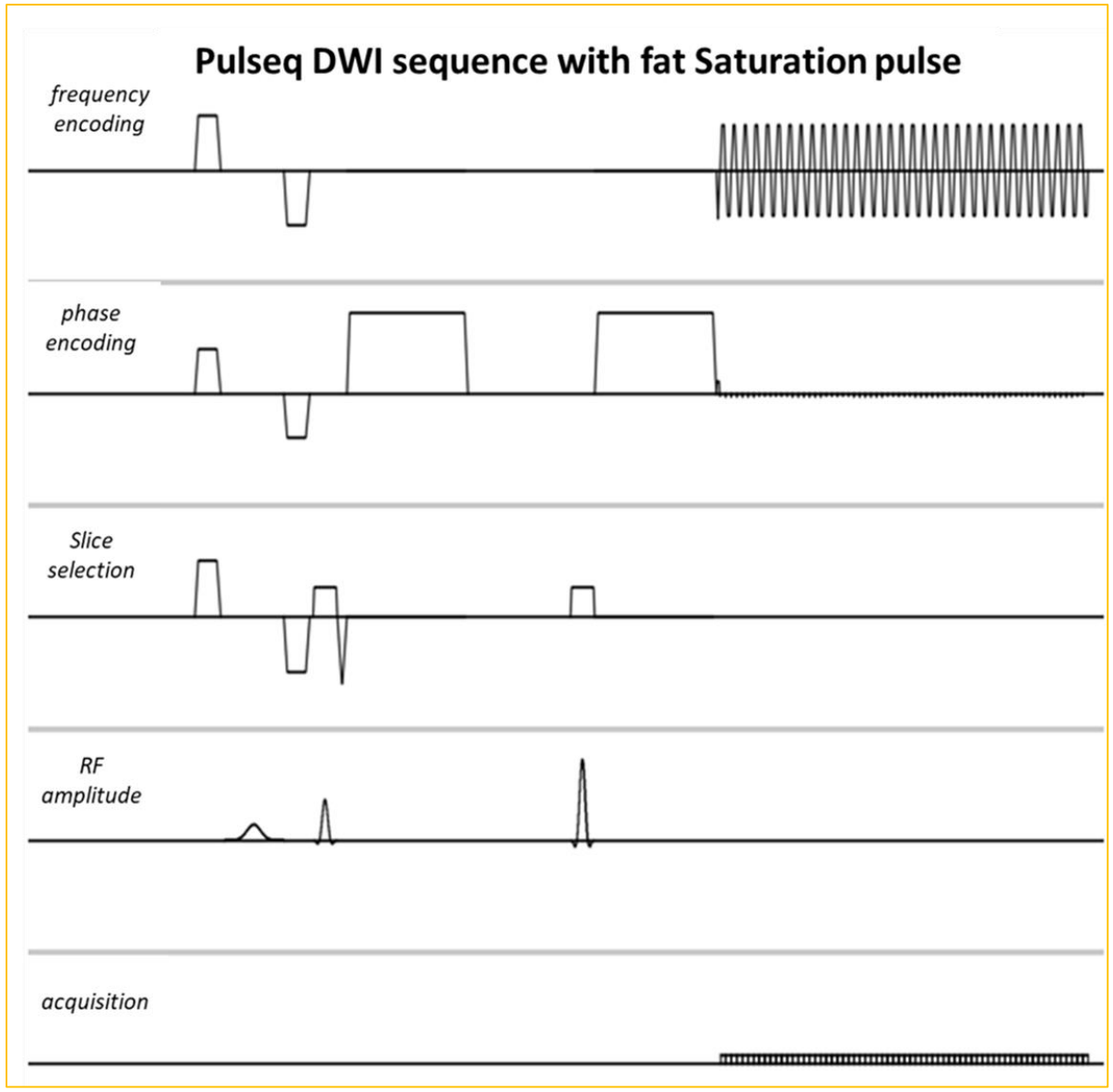


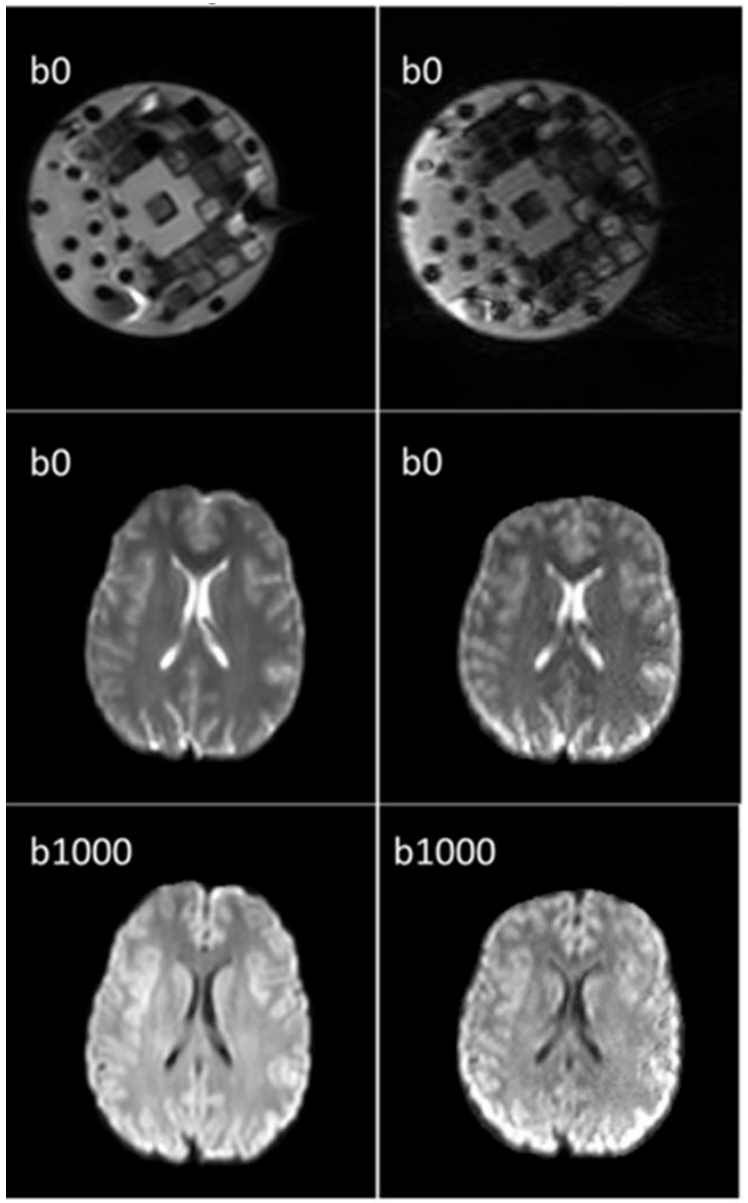
Pulseq GRE comparison with Philips





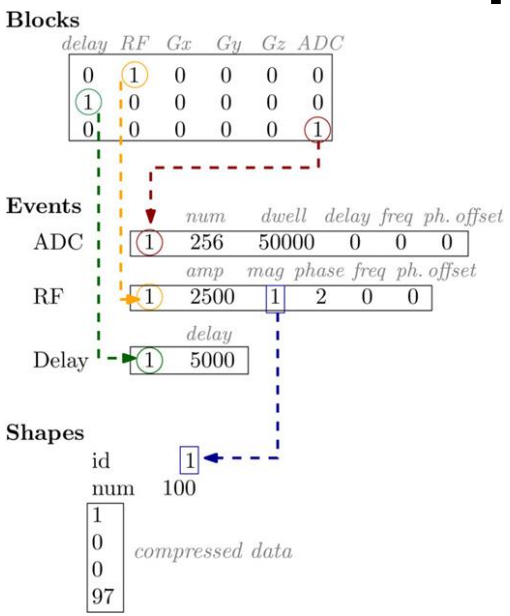
Pulseq DWI comparison with Philips





So what does a user need to do?

p2p interpreter workflow from user perspective



seq2ppe.m

MATLAB

host.csv
runtime.csv
waveforms.csv

Patch

EXE

Raw data

RAW

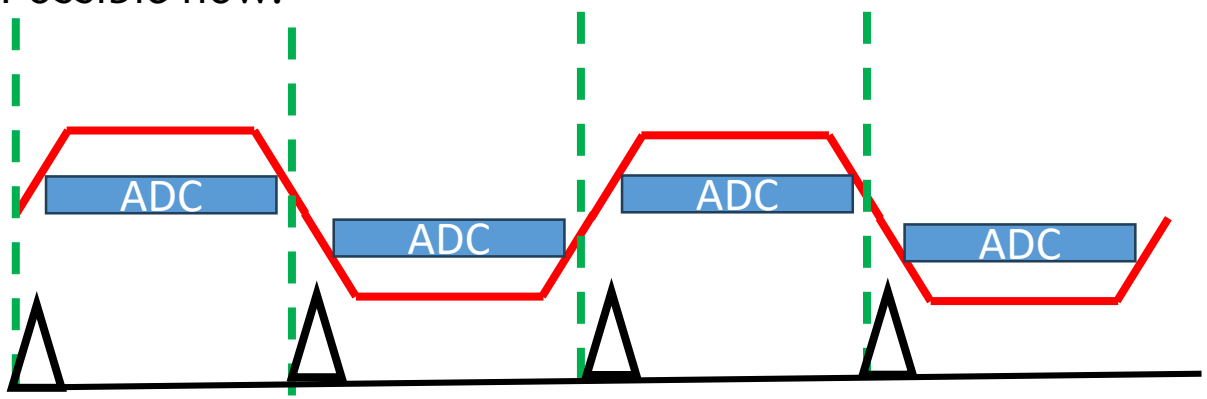
Image

Custom Recon

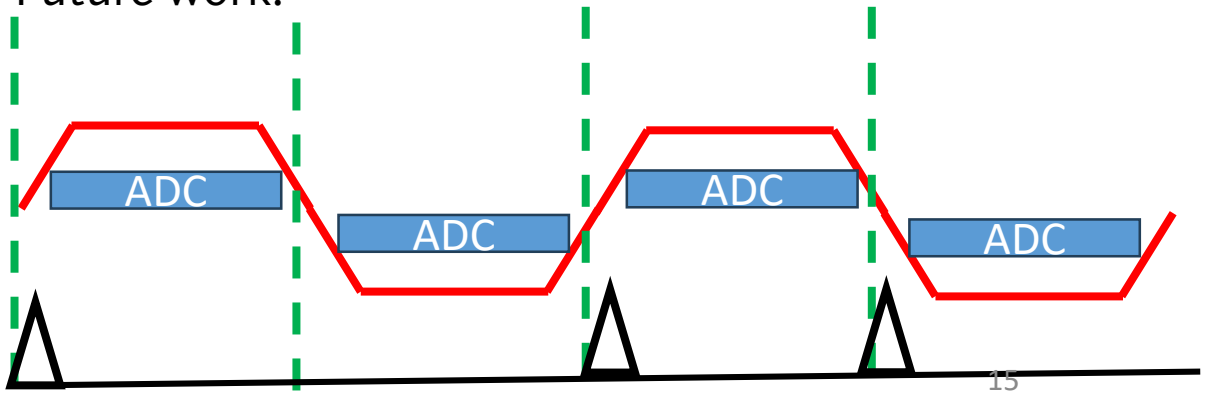
Discussion & Future Work

- Any sequence can be played if the **deadTime and ringdownTime** are set according to Philips requirements
- Up to **256** distinct RF shapes
- Sequence with **100,000** blocks had **12%** CPU usage
- Current limitations and Future Work:
  - Blocks with consecutive RF cannot be combined
  - Geometric **scan planning is not supported** yet – acquisition happens w.r.t **iso-centre**
  - **RF block followed by ADC block** cannot be combined
  - For EPI sequence – Blocks incorporating readout, blip and ADC should iterate by simply altering the sign (readout time, blip duration and number of samples remain same)

Possible now:



Future work:



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Dr. C-F Westin
Dr. Lipeng Ning
Andrew Ellison
Dr. Rushmore Jarrett
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Thank you!

Patch available on request to Philips users

email : ishaik@bwh.harvard.edu

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