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Rapid Prototyping of Radial Ultra-Short Echo Time (UTE) Sequences Using Pulseq and GPI

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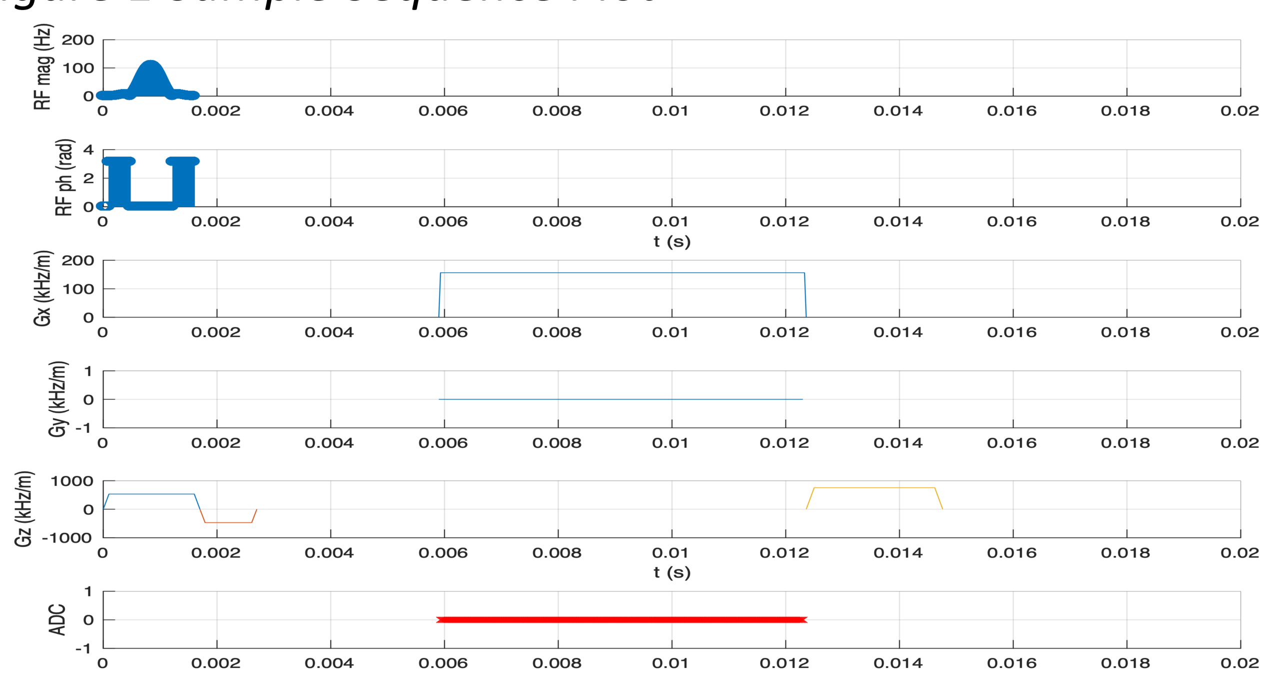
INTRODUCTION

- Ultra-short echo time (UTE) sequence[1] requires rapid switching between transmit and receive coils, which can be challenging to implement without a deep understanding of vendors specific pulse programming environments.
- Some examples of UTE sequence application can be detecting the change of skeletal hydration; detecting the lung tumor based of T2* difference; monitoring pulmonary alveolar proteinosis (PAP) cumulatively.
- Pulseq[2] is an open source tool and file standard capable of programming multiple vendors (including Siemens, GE and Bruker) and multiple hardware platforms. Here, we explore and demonstrate the ability of Pulseq to simplify and enable rapid prototyping of such sequences.

METHODS

- We did not modify the principle of 3D UTE sequence, what we have done is using the Pulseq to replicate the sequence and generate sequence file and k-space trajectory. Then, the sequence played on the scanner and the data was collected for the later image reconstruction.
- Pulseq based MATLAB code was written for the 3D radial UTE sequence to generate Pulseq files and k-space trajectory.
- The sequence was demonstrated on a Siemens 3T Prisma with body coil on the ADNI phantom and knee imaging of a healthy volunteer (as part of IRB approved study).
- After a block RF pulse, the readout gradient starts as fast as possible. The gradient makes a spoke of samples in k-space, with certain polar and azimuthal angle. The spoiler gradient is placed after the acquisition to ensure the previous spin components are removed. After TR, same RF and different gradient repeat to sample another spoke in k-space.

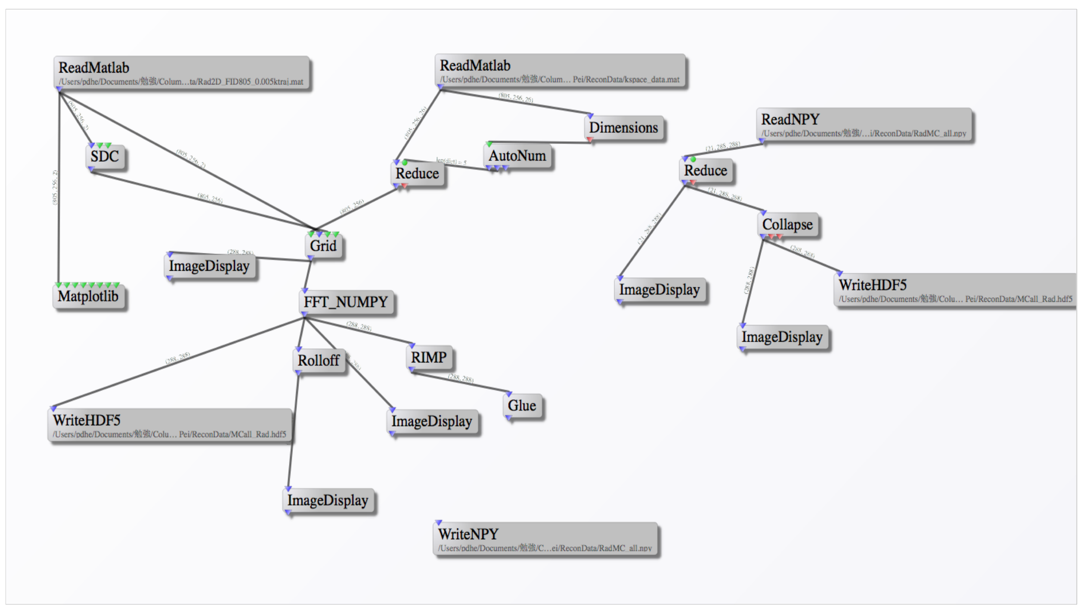
Figure 1 Sample Sequence Plot



METHODS(CONTINUE)

- Acquisition parameters: TR/TE = 20/2ms; 51472 spokes; 256 x 256 x 128mm3; Gmax=32 mT/m; Slew rate= 130T/m/s; Bandwidth= 100kHz ; RF ringdown time= 10µs; RF dead time= 10µs; Flip angle: 15°
- The data was reconstructed offline using Graphical Programming Interface(GPI)[3](Figure 2).The code written by GPI[3] took the k-space data converted from raid data and do the sampling density correction with Krad value =0.8, tapper=0.9.
- The gridding function took k-space trajectory and k-space data to grid the matrix. After gridding, the inverse 3D Fourier transform has generated the images.

Figure 2 The GPI Graphic Code for Image Reconstruction

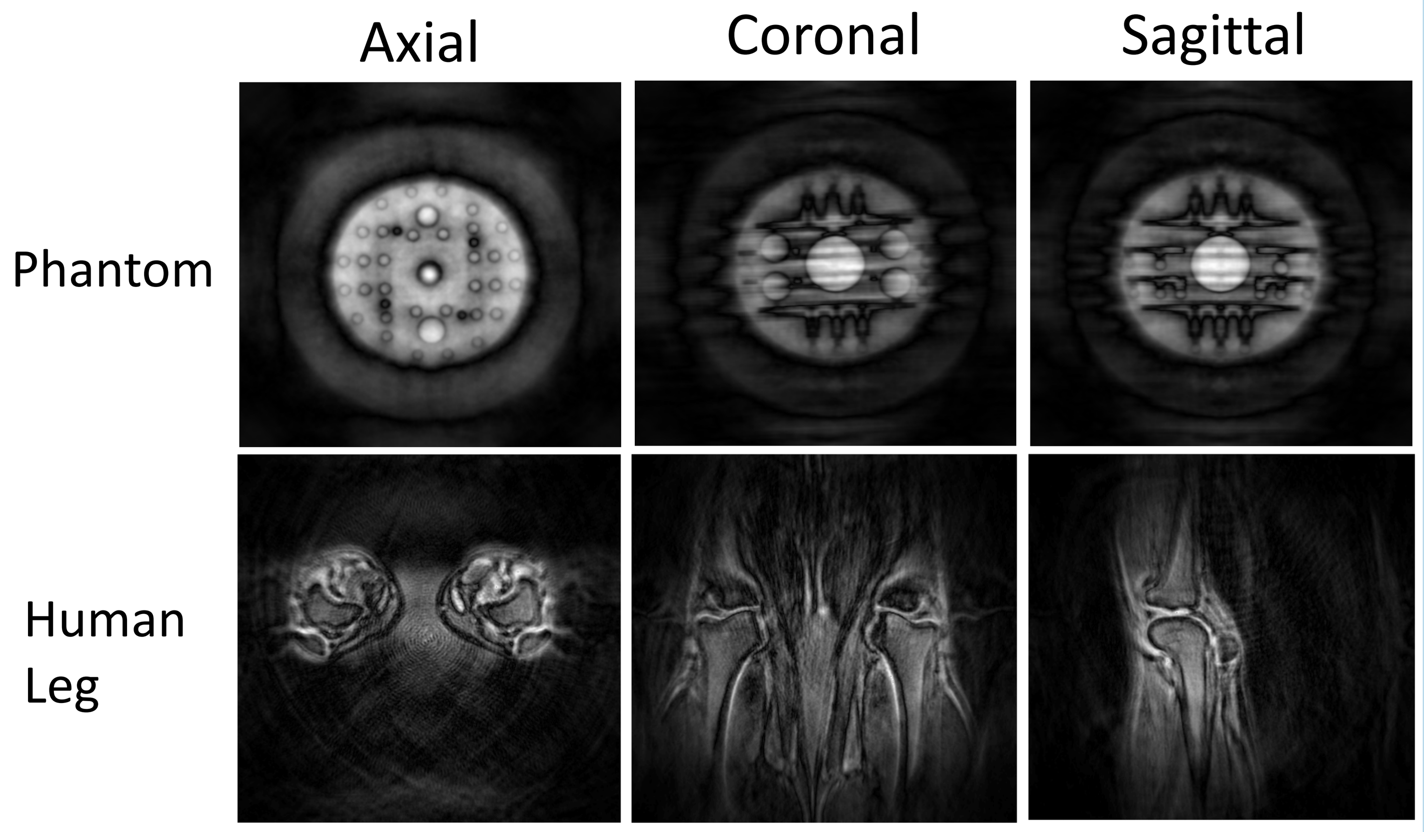


RESULTS

- The body coil switching times dictate the UTE that can be achieved.
- The current implementation is flexible to accommodate other hardware specification as well.
- The current demonstration is not on a knee TR coil which would enhance signal-to-noise ratio but coil selection would not impact the sequence that has been proposed.
- The top three figures in figure 3 show the axial, coronal and sagittal plane of the ADNI phantom. The lower three figures show the subject's knee in the image. The cartilage tissue between the femur and tibia is visible. The code is available in GitHub[4] for reproducing purpose.
- The GPI is able to display the image for every channel when reconstruction is looping through the channels. The reconstructed image can be displayed and saved by different channels and by a combined image.
- In figure 3, the circles in the phantom are being well represented. For in vivo images, the visualization of ACL, MCL and synovial fluid is confirmed.

RESULTS(CONTINUE)

Figure 3 The GPI Image Reconstruction Results



CONCLUSION

- We have demonstrated rapid prototyping of 3D UTE pulse sequence, which is typically employed in MR imaging of the knee. The TE can be as low as 2 ms. In particular, this sequence implementation is completely hardware configurable and can be implemented on Siemens, GE and Bruker systems.
- Pulseq has the property of high-level programming but not sacrificing precise control of the variables and time.
- Pulseq keeps the degree of freedom for the designer in terms of varying the methods, while simplifying the process of coding and transferring between different vendors' machine.
- The GPI is a powerful graphical programming tool that is able to reconstruct images efficiently.
- In terms of UTE sequence, the Pulseq puts no restrict to either the design of the sequence or the performance of the scanner.

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REFERENCES

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[3] Zwart, Nicholas R., and James G. Pipe. "Graphical programming interface: a development environment for MRI methods." Magnetic resonance in medicine 74.5 (2015): 1449-1460.
[4]https://github.com/pdhe/Pulseq3DUTE