

YuranTestSequence

March 1, 2023

1 Working with Sequence Parameter Sets

1.0.1 Generating Sequence Parameter Sets

```
[1]: from mrftools import SequenceParameters, Perlin, Sequential,
      ↪ ScaledRectifiedSinusoid, types, InversionModule, FISPAcquisitionModule,
      ↪ SpoilerModule, DictionaryParameters, DeadttimeRecoveryModule,
      ↪ T2PreparationModule
      import numpy as np

      # Create a sequence definition programmatically
      numTimepoints=800; numLobes=8; numSpirals=48
      TRs = np.ones(numTimepoints) * 0.010
      TEs = np.ones(numTimepoints) * 0.002

      import scipy.io
      from matplotlib import pyplot as plt
      f = scipy.io.loadmat('FA10.7.mat')
      FA = f.get('FA')
      FAs = np.array(FA.squeeze())
      PHs = np.zeros(numTimepoints)
      IDs = Sequential.Generate(numTimepoints+100, numSpirals)

      timepointsPerModule = int(numTimepoints / numLobes)
      currentTimepoint = 0

      #https://www.sciencedirect.com/science/article/pii/S1053811918321190?via%3Dihub
      sequence = SequenceParameters("YuranMRFTTest", [])

      # Group 1
      sequence.modules.append(InversionModule(totalDuration=0.020))
      acquisitionModule = FISPAcquisitionModule(dephasingRange=360)
      timepointRange = np.
          ↪ arange(currentTimepoint,currentTimepoint+timepointsPerModule);
          ↪ currentTimepoint = currentTimepoint+timepointsPerModule
      acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
          ↪ FAs[timepointRange],PHs[timepointRange], IDs[timepointRange])
      sequence.modules.append(acquisitionModule)
```

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sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 2
acquisitionModule = FISPACquisitionModule(dephasingRange=360)
timepointRange = np.
    ↪ arange(currentTimepoint,currentTimepoint+timepointsPerModule);
    ↪ currentTimepoint = currentTimepoint+timepointsPerModule
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange],PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 3
acquisitionModule = FISPACquisitionModule(dephasingRange=360)
timepointRange = np.
    ↪ arange(currentTimepoint,currentTimepoint+timepointsPerModule);
    ↪ currentTimepoint = currentTimepoint+timepointsPerModule
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange],PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 4
acquisitionModule = FISPACquisitionModule(dephasingRange=360)
timepointRange = np.
    ↪ arange(currentTimepoint,currentTimepoint+timepointsPerModule);
    ↪ currentTimepoint = currentTimepoint+timepointsPerModule
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange],PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 5
acquisitionModule = FISPACquisitionModule(dephasingRange=360)
timepointRange = np.
    ↪ arange(currentTimepoint,currentTimepoint+timepointsPerModule);
    ↪ currentTimepoint = currentTimepoint+timepointsPerModule
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange],PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 6
acquisitionModule = FISPACquisitionModule(dephasingRange=360)

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timepointRange = np.
    ↪ arange(currentTimepoint, currentTimepoint+timepointsPerModule);
    ↪ currentTimepoint = currentTimepoint+timepointsPerModule
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange], PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 7
acquisitionModule = FISPACquisitionModule(dephasingRange=360)
timepointRange = np.
    ↪ arange(currentTimepoint, currentTimepoint+timepointsPerModule);
    ↪ currentTimepoint = currentTimepoint+timepointsPerModule
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange], PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

# Group 8
acquisitionModule = FISPACquisitionModule(dephasingRange=360)
timepointRange = np.arange(currentTimepoint, numTimepoints); currentTimepoint =
    ↪ currentTimepoint+timepointsPerModule
print(timepointRange)
acquisitionModule.Initialize(TRs[timepointRange], TEs[timepointRange],
    ↪ FAs[timepointRange], PHs[timepointRange], IDs[timepointRange])
sequence.modules.append(acquisitionModule)
sequence.modules.append(DeadtimeRecoveryModule(0.500))

from mrftools import SequenceUnits, Units
print(sequence)
sequence.ExportToJson(exportUnits=SequenceUnits(Units.MILLISECONDS, Units.
    ↪ DEGREES), castToIntegers=False)

```

2023-03-01 12:58:08.339113: I tensorflow/core/platform/cpu_feature_guard.cc:193] This TensorFlow binary is optimized with oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-critical operations: AVX2 FMA

To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.

2023-03-01 12:58:08.523355: E tensorflow/stream_executor/cuda/cuda_blas.cc:2981] Unable to register cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has already been registered

2023-03-01 12:58:09.386767: W tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load dynamic library 'libnvinfer.so.7'; dlopen error: libnvinfer.so.7: cannot open shared object file: No such file or directory

2023-03-01 12:58:09.386879: W

```
tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load
dynamic library 'libnvinfer_plugin.so.7'; dlerror: libnvinfer_plugin.so.7:
cannot open shared object file: No such file or directory
2023-03-01 12:58:09.386890: W
tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Cannot
dlopen some TensorRT libraries. If you would like to use Nvidia GPU with
TensorRT, please make sure the missing libraries mentioned above are installed
properly.
```

Unique IDs: 48 || Total Length: 864

```
[700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717
 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735
 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753
 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771
 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789
 790 791 792 793 794 795 796 797 798 799]
```

Sequence: YuranMRFTTest

Modules:

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Module Type: PREPARATION || Preparation Type: RF || RF Type: INVERSION || Total
Duration (s): 0.02000 || RF Duration (s): 0.00000 || RF Phase (degrees): 0.00000
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```

```
Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:
```

```
[(0.01, 0.002, 5. , 0., 0) (0.01, 0.002, 6.427757 , 0., 1)
 (0.01, 0.002, 7.8540764, 0., 2) (0.01, 0.002, 9.277522 , 0., 3)
 (0.01, 0.002, 10.69666 , 0., 4) (0.01, 0.002, 12.110063 , 0., 5)
 (0.01, 0.002, 13.516306 , 0., 6) (0.01, 0.002, 14.913974 , 0., 7)
 (0.01, 0.002, 16.301659 , 0., 8) (0.01, 0.002, 17.677965 , 0., 9)
 (0.01, 0.002, 19.041506 , 0., 10) (0.01, 0.002, 20.390907 , 0., 11)
 (0.01, 0.002, 21.72481 , 0., 12) (0.01, 0.002, 23.041874 , 0., 13)
 (0.01, 0.002, 24.34077 , 0., 14) (0.01, 0.002, 25.620193 , 0., 15)
 (0.01, 0.002, 26.878853 , 0., 16) (0.01, 0.002, 28.115482 , 0., 17)
 (0.01, 0.002, 29.328836 , 0., 18) (0.01, 0.002, 30.517694 , 0., 19)
 (0.01, 0.002, 31.680857 , 0., 20) (0.01, 0.002, 32.817154 , 0., 21)
 (0.01, 0.002, 33.92544 , 0., 22) (0.01, 0.002, 35.004604 , 0., 23)
 (0.01, 0.002, 36.053555 , 0., 24) (0.01, 0.002, 37.07124 , 0., 25)
 (0.01, 0.002, 38.056625 , 0., 26) (0.01, 0.002, 39.00873 , 0., 27)
 (0.01, 0.002, 39.92659 , 0., 28) (0.01, 0.002, 40.809284 , 0., 29)
 (0.01, 0.002, 41.65592 , 0., 30) (0.01, 0.002, 42.465645 , 0., 31)
 (0.01, 0.002, 43.237644 , 0., 32) (0.01, 0.002, 43.97114 , 0., 33)
 (0.01, 0.002, 44.6654 , 0., 34) (0.01, 0.002, 45.31972 , 0., 35)
 (0.01, 0.002, 45.93344 , 0., 36) (0.01, 0.002, 46.505943 , 0., 37)
 (0.01, 0.002, 47.036655 , 0., 38) (0.01, 0.002, 47.525036 , 0., 39)
 (0.01, 0.002, 47.9706 , 0., 40) (0.01, 0.002, 48.3729 , 0., 41)
 (0.01, 0.002, 48.73152 , 0., 42) (0.01, 0.002, 49.04611 , 0., 43)
 (0.01, 0.002, 49.31635 , 0., 44) (0.01, 0.002, 49.541965 , 0., 45)
 (0.01, 0.002, 49.722733 , 0., 46) (0.01, 0.002, 49.858463 , 0., 47)
```

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(0.01, 0.002, 49.94903 , 0., 0) (0.01, 0.002, 49.994335 , 0., 1)
(0.01, 0.002, 49.994335 , 0., 2) (0.01, 0.002, 49.94903 , 0., 3)
(0.01, 0.002, 49.858463 , 0., 4) (0.01, 0.002, 49.722733 , 0., 5)
(0.01, 0.002, 49.541965 , 0., 6) (0.01, 0.002, 49.31635 , 0., 7)
(0.01, 0.002, 49.04611 , 0., 8) (0.01, 0.002, 48.73152 , 0., 9)
(0.01, 0.002, 48.3729 , 0., 10) (0.01, 0.002, 47.9706 , 0., 11)
(0.01, 0.002, 47.525036 , 0., 12) (0.01, 0.002, 47.036655 , 0., 13)
(0.01, 0.002, 46.505943 , 0., 14) (0.01, 0.002, 45.93344 , 0., 15)
(0.01, 0.002, 45.31972 , 0., 16) (0.01, 0.002, 44.6654 , 0., 17)
(0.01, 0.002, 43.97114 , 0., 18) (0.01, 0.002, 43.237644 , 0., 19)
(0.01, 0.002, 42.465645 , 0., 20) (0.01, 0.002, 41.65592 , 0., 21)
(0.01, 0.002, 40.809284 , 0., 22) (0.01, 0.002, 39.92659 , 0., 23)
(0.01, 0.002, 39.00873 , 0., 24) (0.01, 0.002, 38.056625 , 0., 25)
(0.01, 0.002, 37.07124 , 0., 26) (0.01, 0.002, 36.053555 , 0., 27)
(0.01, 0.002, 35.004604 , 0., 28) (0.01, 0.002, 33.92544 , 0., 29)
(0.01, 0.002, 32.817154 , 0., 30) (0.01, 0.002, 31.680857 , 0., 31)
(0.01, 0.002, 30.517694 , 0., 32) (0.01, 0.002, 29.328836 , 0., 33)
(0.01, 0.002, 28.115482 , 0., 34) (0.01, 0.002, 26.878853 , 0., 35)
(0.01, 0.002, 25.620193 , 0., 36) (0.01, 0.002, 24.34077 , 0., 37)
(0.01, 0.002, 23.041874 , 0., 38) (0.01, 0.002, 21.72481 , 0., 39)
(0.01, 0.002, 20.390907 , 0., 40) (0.01, 0.002, 19.041506 , 0., 41)
(0.01, 0.002, 17.677965 , 0., 42) (0.01, 0.002, 16.301659 , 0., 43)
(0.01, 0.002, 14.913974 , 0., 44) (0.01, 0.002, 13.516306 , 0., 45)
(0.01, 0.002, 12.110063 , 0., 46) (0.01, 0.002, 10.69666 , 0., 47)
(0.01, 0.002, 9.277522 , 0., 0) (0.01, 0.002, 7.8540764, 0., 1)
(0.01, 0.002, 6.427757 , 0., 2) (0.01, 0.002, 5. , 0., 3)]

```

Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000

Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:

```

[(0.01, 0.002, 5. , 0., 4) (0.01, 0.002, 5.1586394, 0., 5)
(0.01, 0.002, 5.3171196, 0., 6) (0.01, 0.002, 5.4752803, 0., 7)
(0.01, 0.002, 5.632962 , 0., 8) (0.01, 0.002, 5.790007 , 0., 9)
(0.01, 0.002, 5.946256 , 0., 10) (0.01, 0.002, 6.1015525, 0., 11)
(0.01, 0.002, 6.25574 , 0., 12) (0.01, 0.002, 6.408663 , 0., 13)
(0.01, 0.002, 6.5601673, 0., 14) (0.01, 0.002, 6.7101007, 0., 15)
(0.01, 0.002, 6.858312 , 0., 16) (0.01, 0.002, 7.0046525, 0., 17)
(0.01, 0.002, 7.1489744, 0., 18) (0.01, 0.002, 7.2911325, 0., 19)
(0.01, 0.002, 7.4309835, 0., 20) (0.01, 0.002, 7.568387 , 0., 21)
(0.01, 0.002, 7.703204 , 0., 22) (0.01, 0.002, 7.8352995, 0., 23)
(0.01, 0.002, 7.9645395, 0., 24) (0.01, 0.002, 8.090795 , 0., 25)
(0.01, 0.002, 8.213938 , 0., 26) (0.01, 0.002, 8.333845 , 0., 27)
(0.01, 0.002, 8.450395 , 0., 28) (0.01, 0.002, 8.563471 , 0., 29)
(0.01, 0.002, 8.672958 , 0., 30) (0.01, 0.002, 8.778748 , 0., 31)
(0.01, 0.002, 8.880733 , 0., 32) (0.01, 0.002, 8.978809 , 0., 33)
(0.01, 0.002, 9.07288 , 0., 34) (0.01, 0.002, 9.162849 , 0., 35)
(0.01, 0.002, 9.248627 , 0., 36) (0.01, 0.002, 9.330127 , 0., 37)

```

```

(0.01, 0.002, 9.407267 , 0., 38) (0.01, 0.002, 9.479969 , 0., 39)
(0.01, 0.002, 9.54816 , 0., 40) (0.01, 0.002, 9.611772 , 0., 41)
(0.01, 0.002, 9.670739 , 0., 42) (0.01, 0.002, 9.725004 , 0., 43)
(0.01, 0.002, 9.774511 , 0., 44) (0.01, 0.002, 9.819211 , 0., 45)
(0.01, 0.002, 9.859057 , 0., 46) (0.01, 0.002, 9.894012 , 0., 47)
(0.01, 0.002, 9.924039 , 0., 0) (0.01, 0.002, 9.949107 , 0., 1)
(0.01, 0.002, 9.9691925, 0., 2) (0.01, 0.002, 9.984274 , 0., 3)
(0.01, 0.002, 9.994337 , 0., 4) (0.01, 0.002, 9.999371 , 0., 5)
(0.01, 0.002, 9.999371 , 0., 6) (0.01, 0.002, 9.994337 , 0., 7)
(0.01, 0.002, 9.984274 , 0., 8) (0.01, 0.002, 9.9691925, 0., 9)
(0.01, 0.002, 9.949107 , 0., 10) (0.01, 0.002, 9.924039 , 0., 11)
(0.01, 0.002, 9.894012 , 0., 12) (0.01, 0.002, 9.859057 , 0., 13)
(0.01, 0.002, 9.819211 , 0., 14) (0.01, 0.002, 9.774511 , 0., 15)
(0.01, 0.002, 9.725004 , 0., 16) (0.01, 0.002, 9.670739 , 0., 17)
(0.01, 0.002, 9.611772 , 0., 18) (0.01, 0.002, 9.54816 , 0., 19)
(0.01, 0.002, 9.479969 , 0., 20) (0.01, 0.002, 9.407267 , 0., 21)
(0.01, 0.002, 9.330127 , 0., 22) (0.01, 0.002, 9.248627 , 0., 23)
(0.01, 0.002, 9.162849 , 0., 24) (0.01, 0.002, 9.07288 , 0., 25)
(0.01, 0.002, 8.978809 , 0., 26) (0.01, 0.002, 8.880733 , 0., 27)
(0.01, 0.002, 8.778748 , 0., 28) (0.01, 0.002, 8.672958 , 0., 29)
(0.01, 0.002, 8.563471 , 0., 30) (0.01, 0.002, 8.450395 , 0., 31)
(0.01, 0.002, 8.333845 , 0., 32) (0.01, 0.002, 8.213938 , 0., 33)
(0.01, 0.002, 8.090795 , 0., 34) (0.01, 0.002, 7.9645395, 0., 35)
(0.01, 0.002, 7.8352995, 0., 36) (0.01, 0.002, 7.703204 , 0., 37)
(0.01, 0.002, 7.568387 , 0., 38) (0.01, 0.002, 7.4309835, 0., 39)
(0.01, 0.002, 7.2911325, 0., 40) (0.01, 0.002, 7.1489744, 0., 41)
(0.01, 0.002, 7.0046525, 0., 42) (0.01, 0.002, 6.858312 , 0., 43)
(0.01, 0.002, 6.7101007, 0., 44) (0.01, 0.002, 6.5601673, 0., 45)
(0.01, 0.002, 6.408663 , 0., 46) (0.01, 0.002, 6.25574 , 0., 47)
(0.01, 0.002, 6.1015525, 0., 0) (0.01, 0.002, 5.946256 , 0., 1)
(0.01, 0.002, 5.790007 , 0., 2) (0.01, 0.002, 5.632962 , 0., 3)
(0.01, 0.002, 5.4752803, 0., 4) (0.01, 0.002, 5.3171196, 0., 5)
(0.01, 0.002, 5.1586394, 0., 6) (0.01, 0.002, 5. , 0., 7)]

```

Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000

Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:

```

[(0.01, 0.002, 5. , 0., 8) (0.01, 0.002, 6.427757 , 0., 9)
(0.01, 0.002, 7.8540764, 0., 10) (0.01, 0.002, 9.277522 , 0., 11)
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(0.01, 0.002, 16.301659 , 0., 16) (0.01, 0.002, 17.677965 , 0., 17)
(0.01, 0.002, 19.041506 , 0., 18) (0.01, 0.002, 20.390907 , 0., 19)
(0.01, 0.002, 21.72481 , 0., 20) (0.01, 0.002, 23.041874 , 0., 21)
(0.01, 0.002, 24.34077 , 0., 22) (0.01, 0.002, 25.620193 , 0., 23)
(0.01, 0.002, 26.878853 , 0., 24) (0.01, 0.002, 28.115482 , 0., 25)
(0.01, 0.002, 29.328836 , 0., 26) (0.01, 0.002, 30.517694 , 0., 27)

```

```

(0.01, 0.002, 31.680857 , 0., 28) (0.01, 0.002, 32.817154 , 0., 29)
(0.01, 0.002, 33.92544 , 0., 30) (0.01, 0.002, 35.004604 , 0., 31)
(0.01, 0.002, 36.053555 , 0., 32) (0.01, 0.002, 37.07124 , 0., 33)
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(0.01, 0.002, 44.6654 , 0., 42) (0.01, 0.002, 45.31972 , 0., 43)
(0.01, 0.002, 45.93344 , 0., 44) (0.01, 0.002, 46.505943 , 0., 45)
(0.01, 0.002, 47.036655 , 0., 46) (0.01, 0.002, 47.525036 , 0., 47)
(0.01, 0.002, 47.9706 , 0., 0) (0.01, 0.002, 48.3729 , 0., 1)
(0.01, 0.002, 48.73152 , 0., 2) (0.01, 0.002, 49.04611 , 0., 3)
(0.01, 0.002, 49.31635 , 0., 4) (0.01, 0.002, 49.541965 , 0., 5)
(0.01, 0.002, 49.722733 , 0., 6) (0.01, 0.002, 49.858463 , 0., 7)
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(0.01, 0.002, 49.541965 , 0., 14) (0.01, 0.002, 49.31635 , 0., 15)
(0.01, 0.002, 49.04611 , 0., 16) (0.01, 0.002, 48.73152 , 0., 17)
(0.01, 0.002, 48.3729 , 0., 18) (0.01, 0.002, 47.9706 , 0., 19)
(0.01, 0.002, 47.525036 , 0., 20) (0.01, 0.002, 47.036655 , 0., 21)
(0.01, 0.002, 46.505943 , 0., 22) (0.01, 0.002, 45.93344 , 0., 23)
(0.01, 0.002, 45.31972 , 0., 24) (0.01, 0.002, 44.6654 , 0., 25)
(0.01, 0.002, 43.97114 , 0., 26) (0.01, 0.002, 43.237644 , 0., 27)
(0.01, 0.002, 42.465645 , 0., 28) (0.01, 0.002, 41.65592 , 0., 29)
(0.01, 0.002, 40.809284 , 0., 30) (0.01, 0.002, 39.92659 , 0., 31)
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(0.01, 0.002, 37.07124 , 0., 34) (0.01, 0.002, 36.053555 , 0., 35)
(0.01, 0.002, 35.004604 , 0., 36) (0.01, 0.002, 33.92544 , 0., 37)
(0.01, 0.002, 32.817154 , 0., 38) (0.01, 0.002, 31.680857 , 0., 39)
(0.01, 0.002, 30.517694 , 0., 40) (0.01, 0.002, 29.328836 , 0., 41)
(0.01, 0.002, 28.115482 , 0., 42) (0.01, 0.002, 26.878853 , 0., 43)
(0.01, 0.002, 25.620193 , 0., 44) (0.01, 0.002, 24.34077 , 0., 45)
(0.01, 0.002, 23.041874 , 0., 46) (0.01, 0.002, 21.72481 , 0., 47)
(0.01, 0.002, 20.390907 , 0., 0) (0.01, 0.002, 19.041506 , 0., 1)
(0.01, 0.002, 17.677965 , 0., 2) (0.01, 0.002, 16.301659 , 0., 3)
(0.01, 0.002, 14.913974 , 0., 4) (0.01, 0.002, 13.516306 , 0., 5)
(0.01, 0.002, 12.110063 , 0., 6) (0.01, 0.002, 10.69666 , 0., 7)
(0.01, 0.002, 9.277522 , 0., 8) (0.01, 0.002, 7.8540764 , 0., 9)
(0.01, 0.002, 6.427757 , 0., 10) (0.01, 0.002, 5. , 0., 11)]

```

Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000

Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:

```

[(0.01, 0.002, 5. , 0., 12) (0.01, 0.002, 5.1586394, 0., 13)
(0.01, 0.002, 5.3171196, 0., 14) (0.01, 0.002, 5.4752803, 0., 15)
(0.01, 0.002, 5.632962 , 0., 16) (0.01, 0.002, 5.790007 , 0., 17)

```

(0.01, 0.002, 5.946256 , 0., 18) (0.01, 0.002, 6.1015525, 0., 19)
 (0.01, 0.002, 6.25574 , 0., 20) (0.01, 0.002, 6.408663 , 0., 21)
 (0.01, 0.002, 6.5601673, 0., 22) (0.01, 0.002, 6.7101007, 0., 23)
 (0.01, 0.002, 6.858312 , 0., 24) (0.01, 0.002, 7.0046525, 0., 25)
 (0.01, 0.002, 7.1489744, 0., 26) (0.01, 0.002, 7.2911325, 0., 27)
 (0.01, 0.002, 7.4309835, 0., 28) (0.01, 0.002, 7.568387 , 0., 29)
 (0.01, 0.002, 7.703204 , 0., 30) (0.01, 0.002, 7.8352995, 0., 31)
 (0.01, 0.002, 7.9645395, 0., 32) (0.01, 0.002, 8.090795 , 0., 33)
 (0.01, 0.002, 8.213938 , 0., 34) (0.01, 0.002, 8.333845 , 0., 35)
 (0.01, 0.002, 8.450395 , 0., 36) (0.01, 0.002, 8.563471 , 0., 37)
 (0.01, 0.002, 8.672958 , 0., 38) (0.01, 0.002, 8.778748 , 0., 39)
 (0.01, 0.002, 8.880733 , 0., 40) (0.01, 0.002, 8.978809 , 0., 41)
 (0.01, 0.002, 9.07288 , 0., 42) (0.01, 0.002, 9.162849 , 0., 43)
 (0.01, 0.002, 9.248627 , 0., 44) (0.01, 0.002, 9.330127 , 0., 45)
 (0.01, 0.002, 9.407267 , 0., 46) (0.01, 0.002, 9.479969 , 0., 47)
 (0.01, 0.002, 9.54816 , 0., 0) (0.01, 0.002, 9.611772 , 0., 1)
 (0.01, 0.002, 9.670739 , 0., 2) (0.01, 0.002, 9.725004 , 0., 3)
 (0.01, 0.002, 9.774511 , 0., 4) (0.01, 0.002, 9.819211 , 0., 5)
 (0.01, 0.002, 9.859057 , 0., 6) (0.01, 0.002, 9.894012 , 0., 7)
 (0.01, 0.002, 9.924039 , 0., 8) (0.01, 0.002, 9.949107 , 0., 9)
 (0.01, 0.002, 9.9691925, 0., 10) (0.01, 0.002, 9.984274 , 0., 11)
 (0.01, 0.002, 9.994337 , 0., 12) (0.01, 0.002, 9.999371 , 0., 13)
 (0.01, 0.002, 9.999371 , 0., 14) (0.01, 0.002, 9.994337 , 0., 15)
 (0.01, 0.002, 9.984274 , 0., 16) (0.01, 0.002, 9.9691925, 0., 17)
 (0.01, 0.002, 9.949107 , 0., 18) (0.01, 0.002, 9.924039 , 0., 19)
 (0.01, 0.002, 9.894012 , 0., 20) (0.01, 0.002, 9.859057 , 0., 21)
 (0.01, 0.002, 9.819211 , 0., 22) (0.01, 0.002, 9.774511 , 0., 23)
 (0.01, 0.002, 9.725004 , 0., 24) (0.01, 0.002, 9.670739 , 0., 25)
 (0.01, 0.002, 9.611772 , 0., 26) (0.01, 0.002, 9.54816 , 0., 27)
 (0.01, 0.002, 9.479969 , 0., 28) (0.01, 0.002, 9.407267 , 0., 29)
 (0.01, 0.002, 9.330127 , 0., 30) (0.01, 0.002, 9.248627 , 0., 31)
 (0.01, 0.002, 9.162849 , 0., 32) (0.01, 0.002, 9.07288 , 0., 33)
 (0.01, 0.002, 8.978809 , 0., 34) (0.01, 0.002, 8.880733 , 0., 35)
 (0.01, 0.002, 8.778748 , 0., 36) (0.01, 0.002, 8.672958 , 0., 37)
 (0.01, 0.002, 8.563471 , 0., 38) (0.01, 0.002, 8.450395 , 0., 39)
 (0.01, 0.002, 8.333845 , 0., 40) (0.01, 0.002, 8.213938 , 0., 41)
 (0.01, 0.002, 8.090795 , 0., 42) (0.01, 0.002, 7.9645395, 0., 43)
 (0.01, 0.002, 7.8352995, 0., 44) (0.01, 0.002, 7.703204 , 0., 45)
 (0.01, 0.002, 7.568387 , 0., 46) (0.01, 0.002, 7.4309835, 0., 47)
 (0.01, 0.002, 7.2911325, 0., 0) (0.01, 0.002, 7.1489744, 0., 1)
 (0.01, 0.002, 7.0046525, 0., 2) (0.01, 0.002, 6.858312 , 0., 3)
 (0.01, 0.002, 6.7101007, 0., 4) (0.01, 0.002, 6.5601673, 0., 5)
 (0.01, 0.002, 6.408663 , 0., 6) (0.01, 0.002, 6.25574 , 0., 7)
 (0.01, 0.002, 6.1015525, 0., 8) (0.01, 0.002, 5.946256 , 0., 9)
 (0.01, 0.002, 5.790007 , 0., 10) (0.01, 0.002, 5.632962 , 0., 11)
 (0.01, 0.002, 5.4752803, 0., 12) (0.01, 0.002, 5.3171196, 0., 13)
 (0.01, 0.002, 5.1586394, 0., 14) (0.01, 0.002, 5. , 0., 15)]

Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000

Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):

114.59156 || Timepoints:

[(0.01, 0.002, 5. , 0., 16) (0.01, 0.002, 6.427757 , 0., 17)
(0.01, 0.002, 7.8540764, 0., 18) (0.01, 0.002, 9.277522 , 0., 19)
(0.01, 0.002, 10.69666 , 0., 20) (0.01, 0.002, 12.110063 , 0., 21)
(0.01, 0.002, 13.516306 , 0., 22) (0.01, 0.002, 14.913974 , 0., 23)
(0.01, 0.002, 16.301659 , 0., 24) (0.01, 0.002, 17.677965 , 0., 25)
(0.01, 0.002, 19.041506 , 0., 26) (0.01, 0.002, 20.390907 , 0., 27)
(0.01, 0.002, 21.72481 , 0., 28) (0.01, 0.002, 23.041874 , 0., 29)
(0.01, 0.002, 24.34077 , 0., 30) (0.01, 0.002, 25.620193 , 0., 31)
(0.01, 0.002, 26.878853 , 0., 32) (0.01, 0.002, 28.115482 , 0., 33)
(0.01, 0.002, 29.328836 , 0., 34) (0.01, 0.002, 30.517694 , 0., 35)
(0.01, 0.002, 31.680857 , 0., 36) (0.01, 0.002, 32.817154 , 0., 37)
(0.01, 0.002, 33.92544 , 0., 38) (0.01, 0.002, 35.004604 , 0., 39)
(0.01, 0.002, 36.053555 , 0., 40) (0.01, 0.002, 37.07124 , 0., 41)
(0.01, 0.002, 38.056625 , 0., 42) (0.01, 0.002, 39.00873 , 0., 43)
(0.01, 0.002, 39.92659 , 0., 44) (0.01, 0.002, 40.809284 , 0., 45)
(0.01, 0.002, 41.65592 , 0., 46) (0.01, 0.002, 42.465645 , 0., 47)
(0.01, 0.002, 43.237644 , 0., 0) (0.01, 0.002, 43.97114 , 0., 1)
(0.01, 0.002, 44.6654 , 0., 2) (0.01, 0.002, 45.31972 , 0., 3)
(0.01, 0.002, 45.93344 , 0., 4) (0.01, 0.002, 46.505943 , 0., 5)
(0.01, 0.002, 47.036655 , 0., 6) (0.01, 0.002, 47.525036 , 0., 7)
(0.01, 0.002, 47.9706 , 0., 8) (0.01, 0.002, 48.3729 , 0., 9)
(0.01, 0.002, 48.73152 , 0., 10) (0.01, 0.002, 49.04611 , 0., 11)
(0.01, 0.002, 49.31635 , 0., 12) (0.01, 0.002, 49.541965 , 0., 13)
(0.01, 0.002, 49.722733 , 0., 14) (0.01, 0.002, 49.858463 , 0., 15)
(0.01, 0.002, 49.94903 , 0., 16) (0.01, 0.002, 49.994335 , 0., 17)
(0.01, 0.002, 49.994335 , 0., 18) (0.01, 0.002, 49.94903 , 0., 19)
(0.01, 0.002, 49.858463 , 0., 20) (0.01, 0.002, 49.722733 , 0., 21)
(0.01, 0.002, 49.541965 , 0., 22) (0.01, 0.002, 49.31635 , 0., 23)
(0.01, 0.002, 49.04611 , 0., 24) (0.01, 0.002, 48.73152 , 0., 25)
(0.01, 0.002, 48.3729 , 0., 26) (0.01, 0.002, 47.9706 , 0., 27)
(0.01, 0.002, 47.525036 , 0., 28) (0.01, 0.002, 47.036655 , 0., 29)
(0.01, 0.002, 46.505943 , 0., 30) (0.01, 0.002, 45.93344 , 0., 31)
(0.01, 0.002, 45.31972 , 0., 32) (0.01, 0.002, 44.6654 , 0., 33)
(0.01, 0.002, 43.97114 , 0., 34) (0.01, 0.002, 43.237644 , 0., 35)
(0.01, 0.002, 42.465645 , 0., 36) (0.01, 0.002, 41.65592 , 0., 37)
(0.01, 0.002, 40.809284 , 0., 38) (0.01, 0.002, 39.92659 , 0., 39)
(0.01, 0.002, 39.00873 , 0., 40) (0.01, 0.002, 38.056625 , 0., 41)
(0.01, 0.002, 37.07124 , 0., 42) (0.01, 0.002, 36.053555 , 0., 43)
(0.01, 0.002, 35.004604 , 0., 44) (0.01, 0.002, 33.92544 , 0., 45)
(0.01, 0.002, 32.817154 , 0., 46) (0.01, 0.002, 31.680857 , 0., 47)
(0.01, 0.002, 30.517694 , 0., 0) (0.01, 0.002, 29.328836 , 0., 1)
(0.01, 0.002, 28.115482 , 0., 2) (0.01, 0.002, 26.878853 , 0., 3)
(0.01, 0.002, 25.620193 , 0., 4) (0.01, 0.002, 24.34077 , 0., 5)
(0.01, 0.002, 23.041874 , 0., 6) (0.01, 0.002, 21.72481 , 0., 7)

```
(0.01, 0.002, 20.390907 , 0., 8) (0.01, 0.002, 19.041506 , 0., 9)
(0.01, 0.002, 17.677965 , 0., 10) (0.01, 0.002, 16.301659 , 0., 11)
(0.01, 0.002, 14.913974 , 0., 12) (0.01, 0.002, 13.516306 , 0., 13)
(0.01, 0.002, 12.110063 , 0., 14) (0.01, 0.002, 10.69666 , 0., 15)
(0.01, 0.002, 9.277522 , 0., 16) (0.01, 0.002, 7.8540764, 0., 17)
(0.01, 0.002, 6.427757 , 0., 18) (0.01, 0.002, 5. , 0., 19)]
```

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Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000
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Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:
```

```
[(0.01, 0.002, 5. , 0., 20) (0.01, 0.002, 5.1586394, 0., 21)
(0.01, 0.002, 5.3171196, 0., 22) (0.01, 0.002, 5.4752803, 0., 23)
(0.01, 0.002, 5.632962 , 0., 24) (0.01, 0.002, 5.790007 , 0., 25)
(0.01, 0.002, 5.946256 , 0., 26) (0.01, 0.002, 6.1015525, 0., 27)
(0.01, 0.002, 6.25574 , 0., 28) (0.01, 0.002, 6.408663 , 0., 29)
(0.01, 0.002, 6.5601673, 0., 30) (0.01, 0.002, 6.7101007, 0., 31)
(0.01, 0.002, 6.858312 , 0., 32) (0.01, 0.002, 7.0046525, 0., 33)
(0.01, 0.002, 7.1489744, 0., 34) (0.01, 0.002, 7.2911325, 0., 35)
(0.01, 0.002, 7.4309835, 0., 36) (0.01, 0.002, 7.568387 , 0., 37)
(0.01, 0.002, 7.703204 , 0., 38) (0.01, 0.002, 7.8352995, 0., 39)
(0.01, 0.002, 7.9645395, 0., 40) (0.01, 0.002, 8.090795 , 0., 41)
(0.01, 0.002, 8.213938 , 0., 42) (0.01, 0.002, 8.333845 , 0., 43)
(0.01, 0.002, 8.450395 , 0., 44) (0.01, 0.002, 8.563471 , 0., 45)
(0.01, 0.002, 8.672958 , 0., 46) (0.01, 0.002, 8.778748 , 0., 47)
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(0.01, 0.002, 9.07288 , 0., 2) (0.01, 0.002, 9.162849 , 0., 3)
(0.01, 0.002, 9.248627 , 0., 4) (0.01, 0.002, 9.330127 , 0., 5)
(0.01, 0.002, 9.407267 , 0., 6) (0.01, 0.002, 9.479969 , 0., 7)
(0.01, 0.002, 9.54816 , 0., 8) (0.01, 0.002, 9.611772 , 0., 9)
(0.01, 0.002, 9.670739 , 0., 10) (0.01, 0.002, 9.725004 , 0., 11)
(0.01, 0.002, 9.774511 , 0., 12) (0.01, 0.002, 9.819211 , 0., 13)
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(0.01, 0.002, 8.978809 , 0., 42) (0.01, 0.002, 8.880733 , 0., 43)
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```

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(0.01, 0.002, 7.8352995, 0., 4) (0.01, 0.002, 7.703204 , 0., 5)
(0.01, 0.002, 7.568387 , 0., 6) (0.01, 0.002, 7.4309835, 0., 7)
(0.01, 0.002, 7.2911325, 0., 8) (0.01, 0.002, 7.1489744, 0., 9)
(0.01, 0.002, 7.0046525, 0., 10) (0.01, 0.002, 6.858312 , 0., 11)
(0.01, 0.002, 6.7101007, 0., 12) (0.01, 0.002, 6.5601673, 0., 13)
(0.01, 0.002, 6.408663 , 0., 14) (0.01, 0.002, 6.25574 , 0., 15)
(0.01, 0.002, 6.1015525, 0., 16) (0.01, 0.002, 5.946256 , 0., 17)
(0.01, 0.002, 5.790007 , 0., 18) (0.01, 0.002, 5.632962 , 0., 19)
(0.01, 0.002, 5.4752803, 0., 20) (0.01, 0.002, 5.3171196, 0., 21)
(0.01, 0.002, 5.1586394, 0., 22) (0.01, 0.002, 5. , 0., 23)]

```

Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000

Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:

```

[(0.01, 0.002, 5. , 0., 24) (0.01, 0.002, 6.427757 , 0., 25)
(0.01, 0.002, 7.8540764, 0., 26) (0.01, 0.002, 9.277522 , 0., 27)
(0.01, 0.002, 10.69666 , 0., 28) (0.01, 0.002, 12.110063 , 0., 29)
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(0.01, 0.002, 16.301659 , 0., 32) (0.01, 0.002, 17.677965 , 0., 33)
(0.01, 0.002, 19.041506 , 0., 34) (0.01, 0.002, 20.390907 , 0., 35)
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(0.01, 0.002, 24.34077 , 0., 38) (0.01, 0.002, 25.620193 , 0., 39)
(0.01, 0.002, 26.878853 , 0., 40) (0.01, 0.002, 28.115482 , 0., 41)
(0.01, 0.002, 29.328836 , 0., 42) (0.01, 0.002, 30.517694 , 0., 43)
(0.01, 0.002, 31.680857 , 0., 44) (0.01, 0.002, 32.817154 , 0., 45)
(0.01, 0.002, 33.92544 , 0., 46) (0.01, 0.002, 35.004604 , 0., 47)
(0.01, 0.002, 36.053555 , 0., 0) (0.01, 0.002, 37.07124 , 0., 1)
(0.01, 0.002, 38.056625 , 0., 2) (0.01, 0.002, 39.00873 , 0., 3)
(0.01, 0.002, 39.92659 , 0., 4) (0.01, 0.002, 40.809284 , 0., 5)
(0.01, 0.002, 41.65592 , 0., 6) (0.01, 0.002, 42.465645 , 0., 7)
(0.01, 0.002, 43.237644 , 0., 8) (0.01, 0.002, 43.97114 , 0., 9)
(0.01, 0.002, 44.6654 , 0., 10) (0.01, 0.002, 45.31972 , 0., 11)
(0.01, 0.002, 45.93344 , 0., 12) (0.01, 0.002, 46.505943 , 0., 13)
(0.01, 0.002, 47.036655 , 0., 14) (0.01, 0.002, 47.525036 , 0., 15)
(0.01, 0.002, 47.9706 , 0., 16) (0.01, 0.002, 48.3729 , 0., 17)
(0.01, 0.002, 48.73152 , 0., 18) (0.01, 0.002, 49.04611 , 0., 19)
(0.01, 0.002, 49.31635 , 0., 20) (0.01, 0.002, 49.541965 , 0., 21)
(0.01, 0.002, 49.722733 , 0., 22) (0.01, 0.002, 49.858463 , 0., 23)
(0.01, 0.002, 49.94903 , 0., 24) (0.01, 0.002, 49.994335 , 0., 25)
(0.01, 0.002, 49.994335 , 0., 26) (0.01, 0.002, 49.94903 , 0., 27)
(0.01, 0.002, 49.858463 , 0., 28) (0.01, 0.002, 49.722733 , 0., 29)
(0.01, 0.002, 49.541965 , 0., 30) (0.01, 0.002, 49.31635 , 0., 31)
(0.01, 0.002, 49.04611 , 0., 32) (0.01, 0.002, 48.73152 , 0., 33)
(0.01, 0.002, 48.3729 , 0., 34) (0.01, 0.002, 47.9706 , 0., 35)]

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(0.01, 0.002, 47.525036 , 0., 36) (0.01, 0.002, 47.036655 , 0., 37)
(0.01, 0.002, 46.505943 , 0., 38) (0.01, 0.002, 45.93344 , 0., 39)
(0.01, 0.002, 45.31972 , 0., 40) (0.01, 0.002, 44.6654 , 0., 41)
(0.01, 0.002, 43.97114 , 0., 42) (0.01, 0.002, 43.237644 , 0., 43)
(0.01, 0.002, 42.465645 , 0., 44) (0.01, 0.002, 41.65592 , 0., 45)
(0.01, 0.002, 40.809284 , 0., 46) (0.01, 0.002, 39.92659 , 0., 47)
(0.01, 0.002, 39.00873 , 0., 0) (0.01, 0.002, 38.056625 , 0., 1)
(0.01, 0.002, 37.07124 , 0., 2) (0.01, 0.002, 36.053555 , 0., 3)
(0.01, 0.002, 35.004604 , 0., 4) (0.01, 0.002, 33.92544 , 0., 5)
(0.01, 0.002, 32.817154 , 0., 6) (0.01, 0.002, 31.680857 , 0., 7)
(0.01, 0.002, 30.517694 , 0., 8) (0.01, 0.002, 29.328836 , 0., 9)
(0.01, 0.002, 28.115482 , 0., 10) (0.01, 0.002, 26.878853 , 0., 11)
(0.01, 0.002, 25.620193 , 0., 12) (0.01, 0.002, 24.34077 , 0., 13)
(0.01, 0.002, 23.041874 , 0., 14) (0.01, 0.002, 21.72481 , 0., 15)
(0.01, 0.002, 20.390907 , 0., 16) (0.01, 0.002, 19.041506 , 0., 17)
(0.01, 0.002, 17.677965 , 0., 18) (0.01, 0.002, 16.301659 , 0., 19)
(0.01, 0.002, 14.913974 , 0., 20) (0.01, 0.002, 13.516306 , 0., 21)
(0.01, 0.002, 12.110063 , 0., 22) (0.01, 0.002, 10.69666 , 0., 23)
(0.01, 0.002, 9.277522 , 0., 24) (0.01, 0.002, 7.8540764, 0., 25)
(0.01, 0.002, 6.427757 , 0., 26) (0.01, 0.002, 5. , 0., 27)]

```

Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000

Module Type: ACQUISITION || Acquisition Type: FISP || Dephasing Range (# of pi):
114.59156 || Timepoints:

```

[(0.01, 0.002, 5. , 0., 28) (0.01, 0.002, 5.1586394, 0., 29)
(0.01, 0.002, 5.3171196, 0., 30) (0.01, 0.002, 5.4752803, 0., 31)
(0.01, 0.002, 5.632962 , 0., 32) (0.01, 0.002, 5.790007 , 0., 33)
(0.01, 0.002, 5.946256 , 0., 34) (0.01, 0.002, 6.1015525, 0., 35)
(0.01, 0.002, 6.25574 , 0., 36) (0.01, 0.002, 6.408663 , 0., 37)
(0.01, 0.002, 6.5601673, 0., 38) (0.01, 0.002, 6.7101007, 0., 39)
(0.01, 0.002, 6.858312 , 0., 40) (0.01, 0.002, 7.0046525, 0., 41)
(0.01, 0.002, 7.1489744, 0., 42) (0.01, 0.002, 7.2911325, 0., 43)
(0.01, 0.002, 7.4309835, 0., 44) (0.01, 0.002, 7.568387 , 0., 45)
(0.01, 0.002, 7.703204 , 0., 46) (0.01, 0.002, 7.8352995, 0., 47)
(0.01, 0.002, 7.9645395, 0., 0) (0.01, 0.002, 8.090795 , 0., 1)
(0.01, 0.002, 8.213938 , 0., 2) (0.01, 0.002, 8.333845 , 0., 3)
(0.01, 0.002, 8.450395 , 0., 4) (0.01, 0.002, 8.563471 , 0., 5)
(0.01, 0.002, 8.672958 , 0., 6) (0.01, 0.002, 8.778748 , 0., 7)
(0.01, 0.002, 8.880733 , 0., 8) (0.01, 0.002, 8.978809 , 0., 9)
(0.01, 0.002, 9.07288 , 0., 10) (0.01, 0.002, 9.162849 , 0., 11)
(0.01, 0.002, 9.248627 , 0., 12) (0.01, 0.002, 9.330127 , 0., 13)
(0.01, 0.002, 9.407267 , 0., 14) (0.01, 0.002, 9.479969 , 0., 15)
(0.01, 0.002, 9.54816 , 0., 16) (0.01, 0.002, 9.611772 , 0., 17)
(0.01, 0.002, 9.670739 , 0., 18) (0.01, 0.002, 9.725004 , 0., 19)
(0.01, 0.002, 9.774511 , 0., 20) (0.01, 0.002, 9.819211 , 0., 21)
(0.01, 0.002, 9.859057 , 0., 22) (0.01, 0.002, 9.894012 , 0., 23)
(0.01, 0.002, 9.924039 , 0., 24) (0.01, 0.002, 9.949107 , 0., 25)

```

```

(0.01, 0.002, 9.9691925, 0., 26) (0.01, 0.002, 9.984274 , 0., 27)
(0.01, 0.002, 9.994337 , 0., 28) (0.01, 0.002, 9.999371 , 0., 29)
(0.01, 0.002, 9.999371 , 0., 30) (0.01, 0.002, 9.994337 , 0., 31)
(0.01, 0.002, 9.984274 , 0., 32) (0.01, 0.002, 9.9691925, 0., 33)
(0.01, 0.002, 9.949107 , 0., 34) (0.01, 0.002, 9.924039 , 0., 35)
(0.01, 0.002, 9.894012 , 0., 36) (0.01, 0.002, 9.859057 , 0., 37)
(0.01, 0.002, 9.819211 , 0., 38) (0.01, 0.002, 9.774511 , 0., 39)
(0.01, 0.002, 9.725004 , 0., 40) (0.01, 0.002, 9.670739 , 0., 41)
(0.01, 0.002, 9.611772 , 0., 42) (0.01, 0.002, 9.54816 , 0., 43)
(0.01, 0.002, 9.479969 , 0., 44) (0.01, 0.002, 9.407267 , 0., 45)
(0.01, 0.002, 9.330127 , 0., 46) (0.01, 0.002, 9.248627 , 0., 47)
(0.01, 0.002, 9.162849 , 0., 0) (0.01, 0.002, 9.07288 , 0., 1)
(0.01, 0.002, 8.978809 , 0., 2) (0.01, 0.002, 8.880733 , 0., 3)
(0.01, 0.002, 8.778748 , 0., 4) (0.01, 0.002, 8.672958 , 0., 5)
(0.01, 0.002, 8.563471 , 0., 6) (0.01, 0.002, 8.450395 , 0., 7)
(0.01, 0.002, 8.333845 , 0., 8) (0.01, 0.002, 8.213938 , 0., 9)
(0.01, 0.002, 8.090795 , 0., 10) (0.01, 0.002, 7.9645395, 0., 11)
(0.01, 0.002, 7.8352995, 0., 12) (0.01, 0.002, 7.703204 , 0., 13)
(0.01, 0.002, 7.568387 , 0., 14) (0.01, 0.002, 7.4309835, 0., 15)
(0.01, 0.002, 7.2911325, 0., 16) (0.01, 0.002, 7.1489744, 0., 17)
(0.01, 0.002, 7.0046525, 0., 18) (0.01, 0.002, 6.858312 , 0., 19)
(0.01, 0.002, 6.7101007, 0., 20) (0.01, 0.002, 6.5601673, 0., 21)
(0.01, 0.002, 6.408663 , 0., 22) (0.01, 0.002, 6.25574 , 0., 23)
(0.01, 0.002, 6.1015525, 0., 24) (0.01, 0.002, 5.946256 , 0., 25)
(0.01, 0.002, 5.790007 , 0., 26) (0.01, 0.002, 5.632962 , 0., 27)
(0.01, 0.002, 5.4752803, 0., 28) (0.01, 0.002, 5.3171196, 0., 29)
(0.01, 0.002, 5.1586394, 0., 30) (0.01, 0.002, 5. , 0., 31)]

```

```

-----
Module Type: RECOVERY || Recovery Type: DEADTIME || Total Duration (s): 0.50000
-----

```

1.1 Simulation

```

[2]: import torch
import numpy as np
from matplotlib import pyplot as plt
from mrftools import DictionaryParameters, Simulation, WHITE_MATTER_3T,
    GREY_MATTER_3T, CSF_3T, DictionaryEntry
from mpl_toolkits.axes_grid1 import make_axes_locatable

# Create dictionary definition programmatically
FivePctDict = DictionaryParameters.GenerateFixedPercent("FivePctDict",
    t1Range=(200,3600), t2Range=(1,250), percentStepSize=5)

# Run the simulation
newSimulation = Simulation(sequence, FivePctDict, "newSimulation", numSpins=300)

```

```

newSimulation.Execute(numBatches=10)
newSimulation.results = np.delete(newSimulation.results,0,axis=0) # Temporary,
↳need to fix initial zeros in library

# From https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6263822/
LYMPH_NODE_CORTEX_3T = np.array([(1.435, 0.102, 1.)],dtype=DictionaryEntry)
LYMPH_NODE_HILUM_3T = np.array([(0.714, 0.119, 1.)],dtype=DictionaryEntry)
# From https://mri-q.com/uploads/3/4/5/7/34572113/normal_relaxation_times_at_3t.
↳pdf
FAT_3T = np.array([(0.400, 0.025, 1.)],dtype=DictionaryEntry)

# Find Dictionary Entry Numbers with tissues of interest
WMIndex, WMEntry = FivePctDict.GetNearestEntry(WHITE_MATTER_3T['T1'],
↳WHITE_MATTER_3T['T2'])
GMIndex, GMEntry = FivePctDict.GetNearestEntry(GREY_MATTER_3T['T1'],
↳GREY_MATTER_3T['T2'])
CSFIndex, CSFEntry = FivePctDict.GetNearestEntry(CSF_3T['T1'], CSF_3T['T2'])
LNCIndex, LNCEntry = FivePctDict.GetNearestEntry(LYMPH_NODE_CORTEX_3T['T1'],
↳LYMPH_NODE_CORTEX_3T['T2'])
LNHIndex, LNHEntry = FivePctDict.GetNearestEntry(LYMPH_NODE_HILUM_3T['T1'],
↳LYMPH_NODE_HILUM_3T['T2'])
FATIndex, FATEntry = FivePctDict.GetNearestEntry(FAT_3T['T1'], FAT_3T['T2'])
tissuesIndicesToPlot = [WMIndex, GMIndex, LNCIndex, LNHIndex, FATIndex,
↳CSFIndex];
tissueLabelsToPlot = ["White Matter", "Grey Matter", "Lymph Node (Cortex)",
↳"Lymph Node (Hilum)", "Fat", "CSF"]

# Plot the timecourses in time domain and readout domain
plt.figure(figsize=(20,10))
plt.subplot(211);plt.plot(newSimulation.times, np.abs(newSimulation.
↳timeDomainResults[:,tissuesIndicesToPlot]))
#plt.legend(tissueLabelsToPlot);
plt.title('Magnetization vs Time (s)')
plt.subplot(212);plt.plot(np.abs(newSimulation.results[:,tissuesIndicesToPlot]))
#plt.legend(tissueLabelsToPlot);
plt.title('Magnetization vs Readout')

# Plot the inner product differences of the tissues of interest
plt.figure()
innerProductMatrix = Simulation.GetInnerProducts(newSimulation.results[:
↳,tissuesIndicesToPlot], newSimulation.results[:,tissuesIndicesToPlot])
fig, ax = plt.subplots()
divider = make_axes_locatable(ax)
cax = divider.append_axes('right', size='5%', pad=0.05)
im = ax.imshow(np.abs(innerProductMatrix)**10, 'gray');
ax.set_xticklabels([""]+tissueLabelsToPlot,rotation='vertical');

```

```

ax.xaxis.tick_top()
ax.set_yticklabels([""]+tissueLabelsToPlot);
fig.colorbar(im, cax=cax, orientation='vertical')
plt.show()

```

Dictionary Parameter set 'FivePctDict' initialized with 6825 entries
 Simulating 10 batch(s) of ~682 dictionary entries

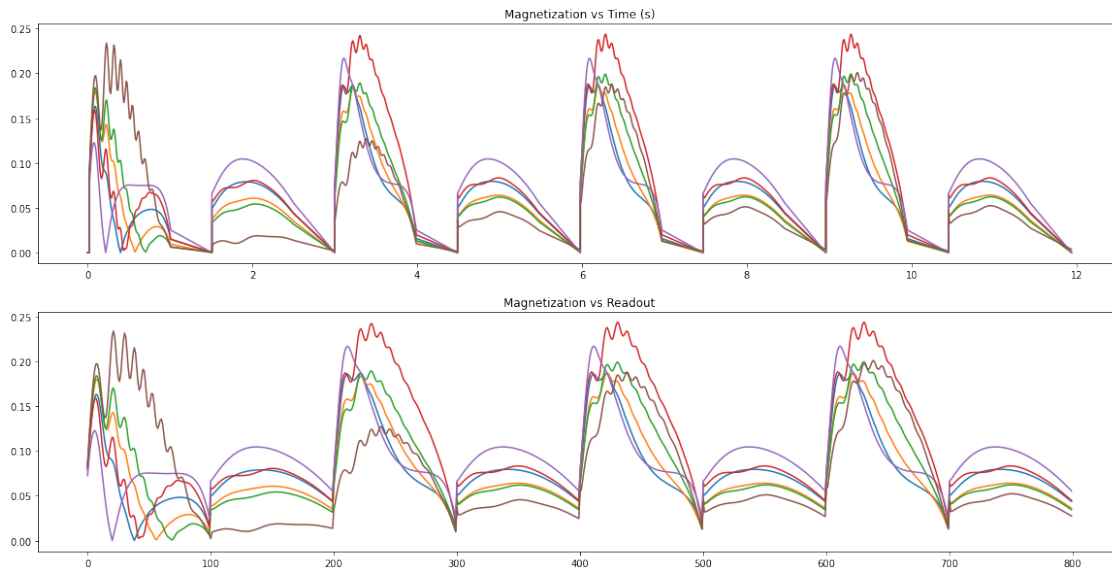
100%| | 10/10 [00:46<00:00, 4.61s/it]

/tmp/ipykernel_1443168/2606074908.py:47: UserWarning: FixedFormatter should only be used together with FixedLocator

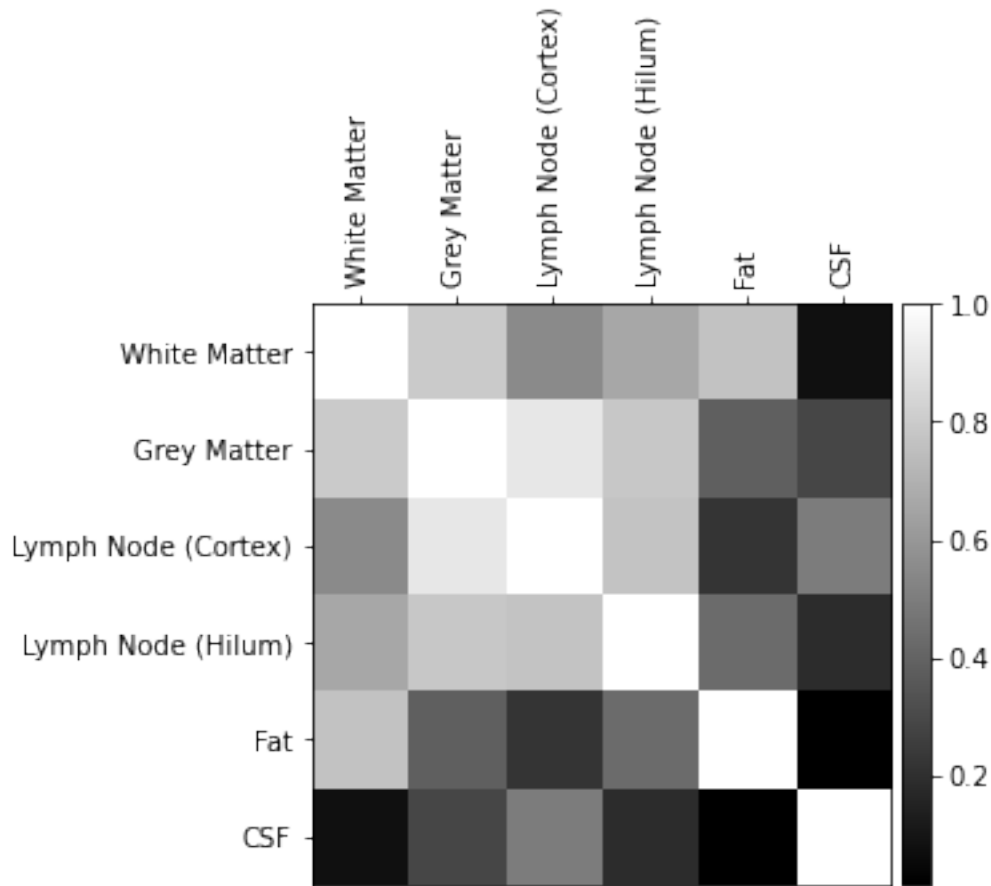
```
ax.set_xticklabels([""]+tissueLabelsToPlot,rotation='vertical');
```

/tmp/ipykernel_1443168/2606074908.py:49: UserWarning: FixedFormatter should only be used together with FixedLocator

```
ax.set_yticklabels([""]+tissueLabelsToPlot);
```



<Figure size 432x288 with 0 Axes>



1.2 Pattern Matching

```
[20]: from mrftools import T1_COLORMAP, T1_COLORMAP_MIN, T1_COLORMAP_MAX,
      ↪ T2_COLORMAP, T2_COLORMAP_MIN, T2_COLORMAP_MAX

f = scipy.io.loadmat('matchingEvos.mat')
matchingEvos = f.get('matchingEvos')
f = scipy.io.loadmat('matchingMaps.mat')
matchingMaps = f.get('matchingMaps')/1000 # convert to milliseconds

dims = np.shape(matchingEvos);
voxelTimecourses = np.reshape(matchingEvos[:,:,:,:0],(dims[0],-1))
patternMatchIndexes = np.reshape(newSimulation.
    ↪ FindPatternMatches(querySignals=voxelTimecourses), (dims[1], dims[2]))
patternMatchDictionaryEntries = FivePctDict.entries[patternMatchIndexes]

mrftoolsDictionaryTimecourses = newSimulation.results[:,patternMatchIndexes]
matlabDictionaryTimecourses = matchingEvos[:,:,:,:1]
```



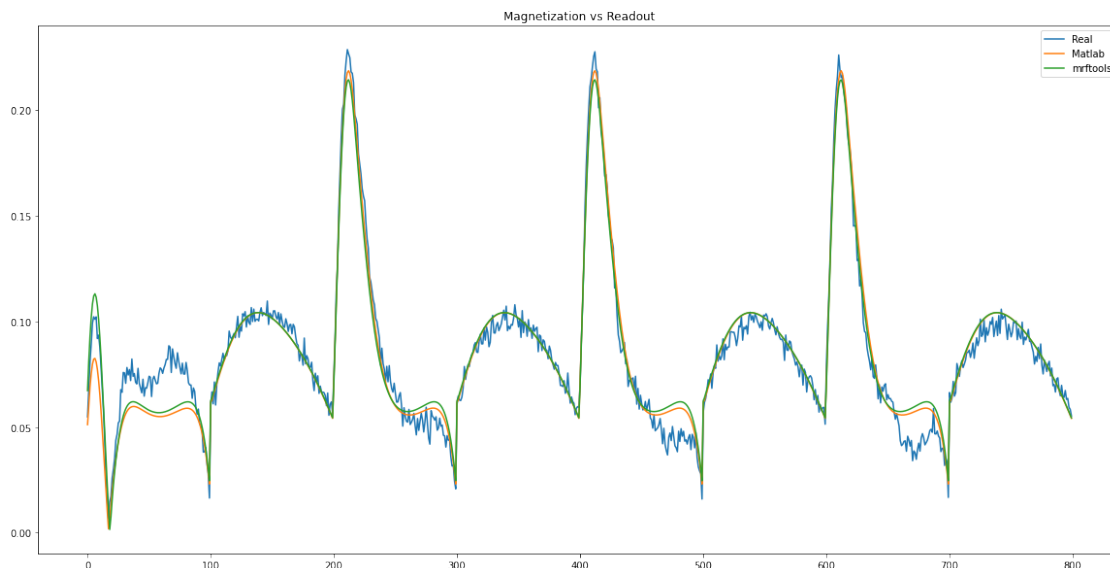
```

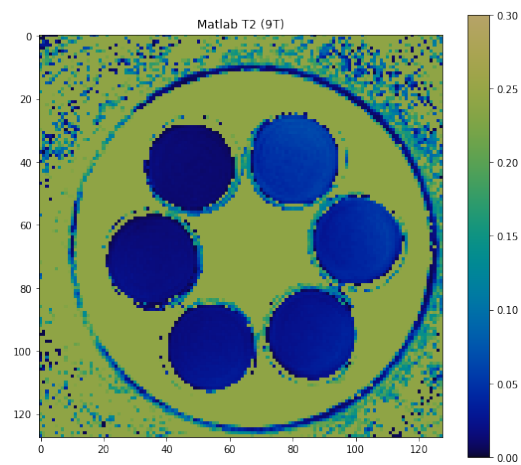
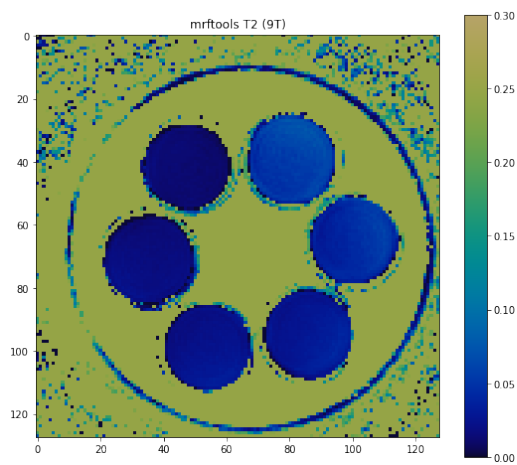
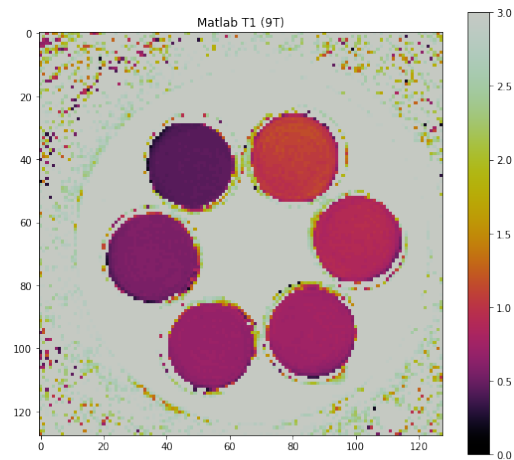
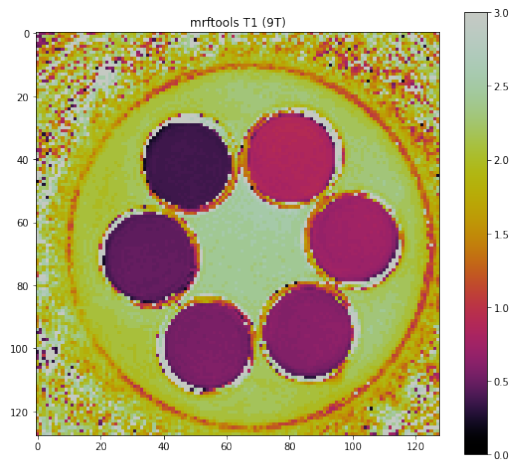
realTimecourses = matchingEvos[:, :, :, 0]

plt.figure(figsize=(20,10))
voxelToPlot = [45,45]
plt.plot(np.abs(realTimecourses[:, voxelToPlot[0], voxelToPlot[1]])/1000000,
        ↪label="Real")
plt.plot(np.abs(matlabDictionaryTimecourses[:, voxelToPlot[0], voxelToPlot[1]])/
        ↪1000000, label="Matlab")
plt.plot(np.abs(mrftoolsDictionaryTimecourses[:, voxelToPlot[0],
        ↪voxelToPlot[1]]), label="mrftools")
plt.legend();
plt.title('Magnetization vs Readout')

plt.figure(figsize=(20,18))
plt.subplot(221); plt.imshow(patternMatchDictionaryEntries['T1'],
        ↪cmap=T1_COLORMAP, vmin=T1_COLORMAP_MIN, vmax=T1_COLORMAP_MAX); plt.
        ↪colorbar(); plt.title("mrftools T1 (9T)");
plt.subplot(222); plt.imshow(np.abs(matchingMaps[:, :, 1]), cmap=T1_COLORMAP,
        ↪vmin=T1_COLORMAP_MIN, vmax=T1_COLORMAP_MAX); plt.colorbar(); plt.
        ↪title("Matlab T1 (9T)");
plt.subplot(223); plt.imshow(patternMatchDictionaryEntries['T2'],
        ↪cmap=T2_COLORMAP, vmin=T2_COLORMAP_MIN, vmax=T2_COLORMAP_MAX); plt.
        ↪colorbar(); plt.title("mrftools T2 (9T)");
plt.subplot(224); plt.imshow(np.abs(matchingMaps[:, :, 2]), cmap=T2_COLORMAP,
        ↪vmin=T2_COLORMAP_MIN, vmax=T2_COLORMAP_MAX); plt.colorbar(); plt.
        ↪title("Matlab T2 (9T)");

```





[]: