Example of calculating ADC spectra of one restricted compartment

This example shows how to calculate frequency-dependent OGSE ADC spectra of one restricted compartment based on analytical equations. The restricted compartments can be parallel planes, cylinders, spheres, or spherical shells (hollow spheres). NOTE: diffusion is perfectly restricted without surface relaxation or permeability. There are two independent microstructural parameters:

1. compartment size d: distance between planes, diameters of cylinders or spheres. NOTE: spherical shells need two diameters din and dout.
2. intracompartment diffusion coefficient: D_{in}

Reference

The main reference that should be cited when using the code in this script is

1. Xu J, et al. Quantitative characterization of tissue microstructure with temporal diffusion spectroscopy. J Magn Reson. 2009;200(2):189-97. PubMed PMID: 19616979.
2. Xu J, et al. Magnetic resonance imaging of mean cell size in human breast tumors. Magn Reson Med. 2020;83(6):2002-14. PubMed PMID: 31765494.

Comments or questions?

Please send your comments or questions to Junzhong (JZ) Xu (junzhong.xu@vanderbilt.edu)

Contents

Preliminary

```
clear ; clear obj ;
```

Generate a PulseSequence object

Set pulse parameters

```
delta = 20 ;                            % each gradient duration [ms]
fs = [25:25:1000]*1e-3 ;        % the range of gradient frequencies [kHz]
ns = floor(delta .* fs) ;           % the range of number of oscillating cycles
Nacq = length(ns) ;               % total number of data acquisition points

% Create the object
pulse = mati.DiffusionPulseSequence(sum(Nacq) , ...
                    'delta',           delta , ...         % gradient duration [ms]
                    'Delta' ,         delta+5 , ...     % gradient separation [ms]
                    'shape',         "cos" , ...        % gradient waveform shape, a single string or a string array
                    'b' ,               1 , ...               % b value [ms/um^2]
                    'n' ,               ns ...               % number of gradient oscillating cycles
            ) ;
```

Example#1: ADC spectrum of restricted diffusion between parallel planes with different distances

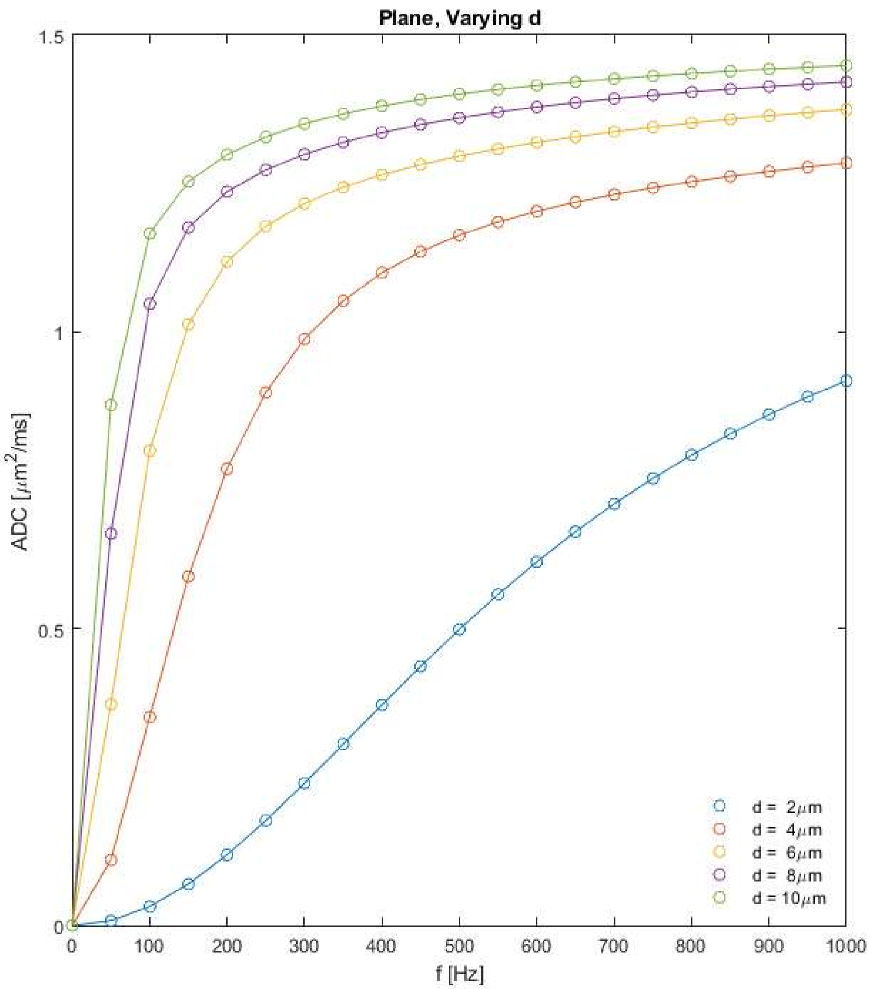
```
% Generate a structure object
structure.modelName = '1compt' ; structure.geometry = 'plane' ;
plane_model = mati.IMPULSED(structure, pulse) ;

% Set microstructual parameters that are of interest
d = [2:2:10] ; Din = [1.56] ;

% Calculate restricted dMRI signals based on analytical equations
signal_plane = plane_model.FcnSignal({d, Din}, plane_model) ;

% Calculate ADC based on signals and b values
ADC_plane = -log(signal_plane) ./ pulse.b ;

% Plot ADC spectra of restriction between parallel planes with different distances
figure(1) ; clf ;
plot(pulse.f*1000, ADC_plane, 'o-') ; xlabel('f [Hz]') ; ylabel('ADC [\mum^2/ms]') ;
legend('d =  2\mum','d =  4\mum','d =  6\mum','d =  8\mum','d = 10\mum','Location','Southeast') ; title('Plane, Varying d')
```



Example#2: ADC spectrum of restricted diffusion perpendicular to cylinders with different intra-cylinder diffusion coefficients

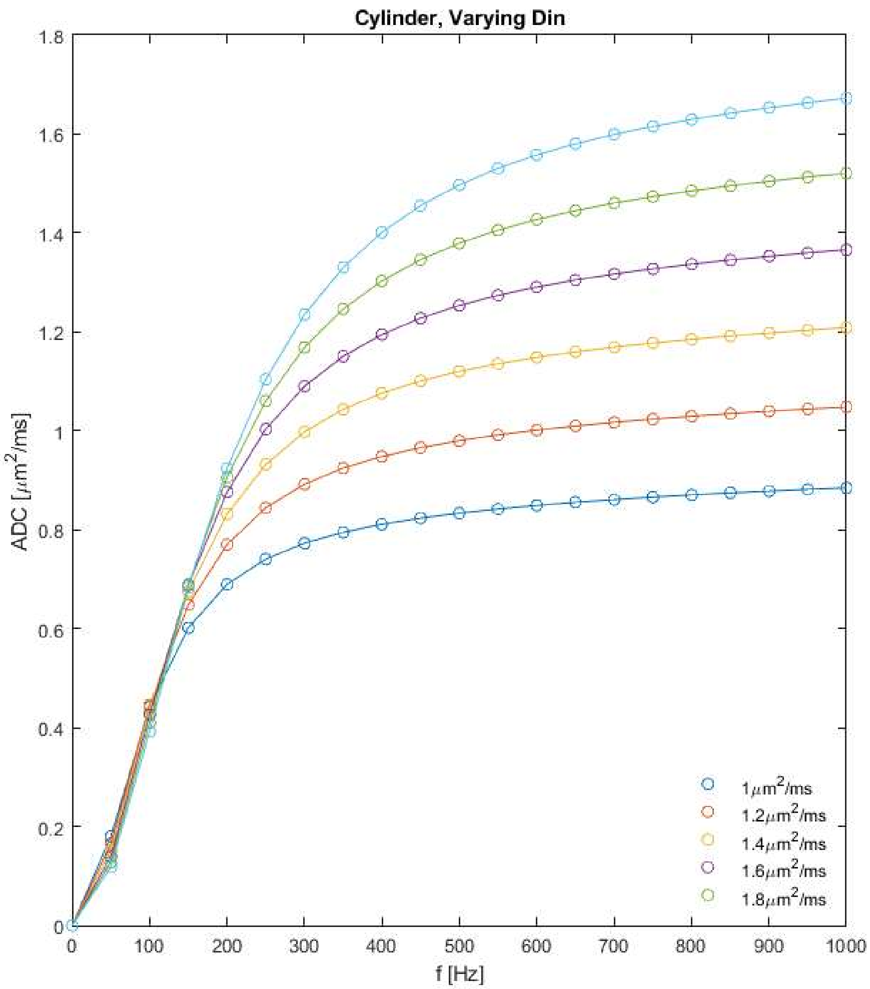
```
% Generate a structure object
structure.modelName = '1compt' ; structure.geometry = 'cylinder' ;
cylinder_model = mati.IMPULSED(structure, pulse) ;

% Set microstructural parameters of interest
d = [5] ; Din = [1:0.2:2] ; [d,Din] = meshgrid(d,Din) ; sim_parms = [d(:)'; Din(:)'] ;

% Calculate restricted dMRI signals based on analytical equations
signal_cylinder = cylinder_model.FcnSignal(sim_parms, cylinder_model) ;

% Calculate ADC values
ADC_cylinder = -log(signal_cylinder) ./ pulse.b ;

% Plot ADC spectra of restricted diffusion perpendicular to cylinders with different intra-cylinder diffusion coefficients
figure(2) ; clf ;
plot(pulse.f*1000, ADC_cylinder, 'o-') ; xlabel('f [Hz]') ; ylabel('ADC [\mum^2/ms]') ;
legend('1\mum^2/ms','1.2\mum^2/ms','1.4\mum^2/ms','1.6\mum^2/ms','1.8\mum^2/ms','Location','Southeast'); title('Cylinder, Varying Din')
```



Example#3: ADC spectra of restricted diffusion inside spheres with different diameters

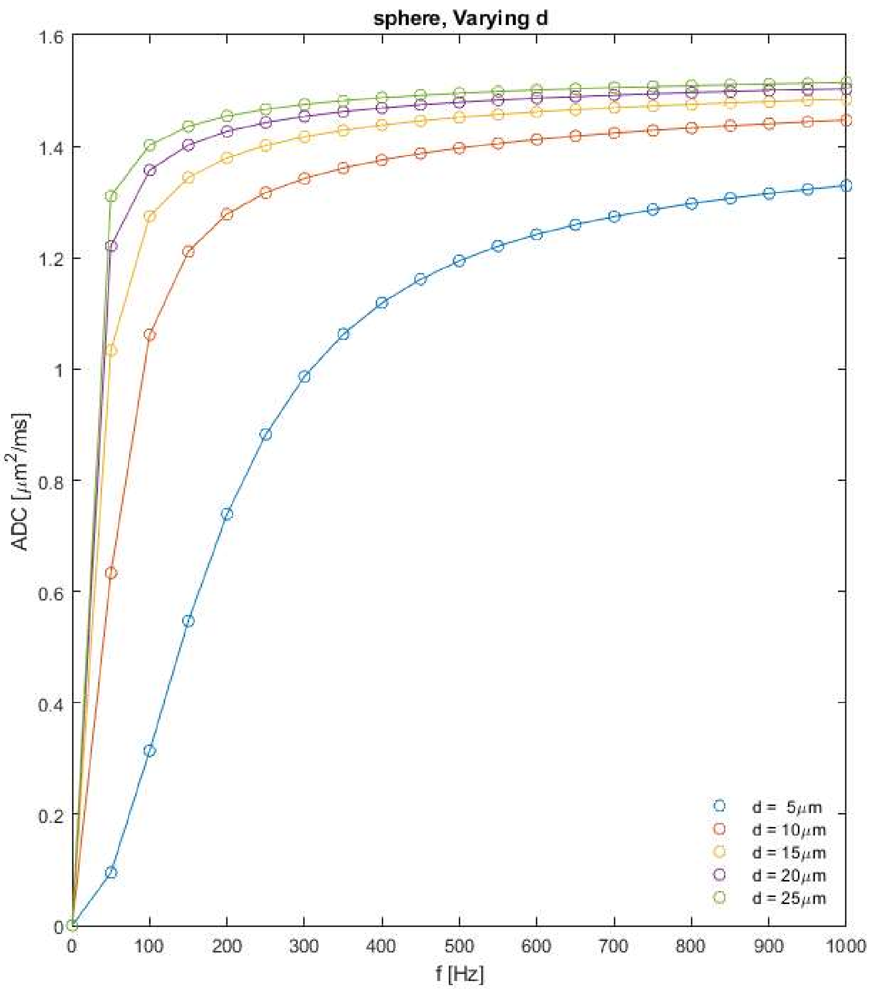
```
% Generate a structure object
structure.modelName = '1compt' ; structure.geometry = 'sphere' ;
sphere_model = mati.IMPULSED(structure, pulse) ;

% Set microstructural parameters of interest
d = [5:5:25] ; Din = [1.56] ; [d,Din] = meshgrid(d,Din) ; sim_parms = [d(:)'; Din(:)'] ;

% Calculate restricted dMRI signals based on analytical equations
signal_sphere = sphere_model.FcnSignal(sim_parms, sphere_model) ;

% Calculate ADC values
ADC_sphere = -log(signal_sphere) ./ pulse.b ;

% Plot ADC spectra of restricted diffusion inside spheres with different diameters
figure(3) ; clf ;
plot(pulse.f*1e3, ADC_sphere, 'o-') ; xlabel('f [Hz]') ; ylabel('ADC [\mum^2/ms]') ;
legend('d =  5\mum','d = 10\mum','d = 15\mum','d = 20\mum','d = 25\mum','Location','Southeast') ; title('sphere, Varying d')
```



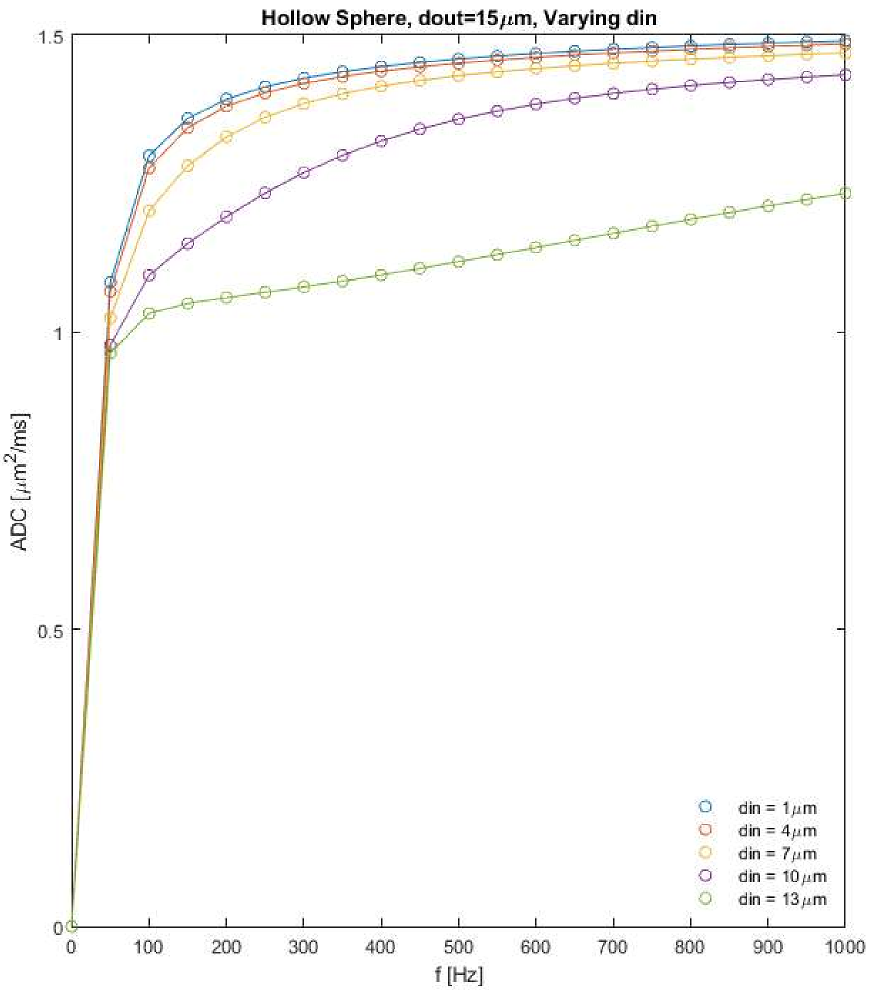
Example#4: ADC spectrum of restricted diffusion inside spherical shells (hollow spheres) with different din values

```
% Generate a structure object
structure.modelName = '1comptHollow' ; structure.geometry = 'hollowSphere' ;
shell_model = mati.IMPULSED(structure, pulse) ;

% Set microstructural parameters of interest
din = [1:3:15] ; dout = [16] ; Din = [1.56] ; [din, dout,Din] = meshgrid(din, dout,Din) ; sim_parms = [din(:)'; dout(:)'; Din(:)'] ;
signal_shell = shell_model.FcnSignal(sim_parms, shell_model) ;

% Calculate ADC values
ADC_shell = -log(signal_shell) ./ pulse.b ;

% Plot ADC spectra of restricted diffusion inside spherical shells with different din values
figure(4) ; clf ;
plot(pulse.f*1000, ADC_shell, 'o-') ; xlabel('f [Hz]') ; ylabel('ADC [\mum^2/ms]') ;
legend('din = 1\mum','din = 4\mum','din = 7\mum','din = 10\mum','din = 13\mum','Location','Southeast') ; title('Hollow Sphere, dout=15\mum, Varying din')
```



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