

## Yappari tutorial : Simulate a spectrum and introduction to DRT

Version 24 08 2023, author ND

Data from paper

Analysis of Impedance Spectroscopy Measurements of Biological Tissue using the Distribution of Relaxation Times Method, January 2017; DOI: 10.5220/0006253902240228

The simulated circuit discussed in this paper is

Table 1: Data for simulated  $RC$  circuits.

Circuit	$R$ ( $\Omega$ )	$C$ (nF)	$\tau$ ( $\mu$ s)	$f_0$ (kHz)
$RC_1$	200.0	48.0	9.6	17.0
$RC_2$	100.0	1000.0	100.0	1.6
$RC_3$	56.0	22.0	1.2	130.0

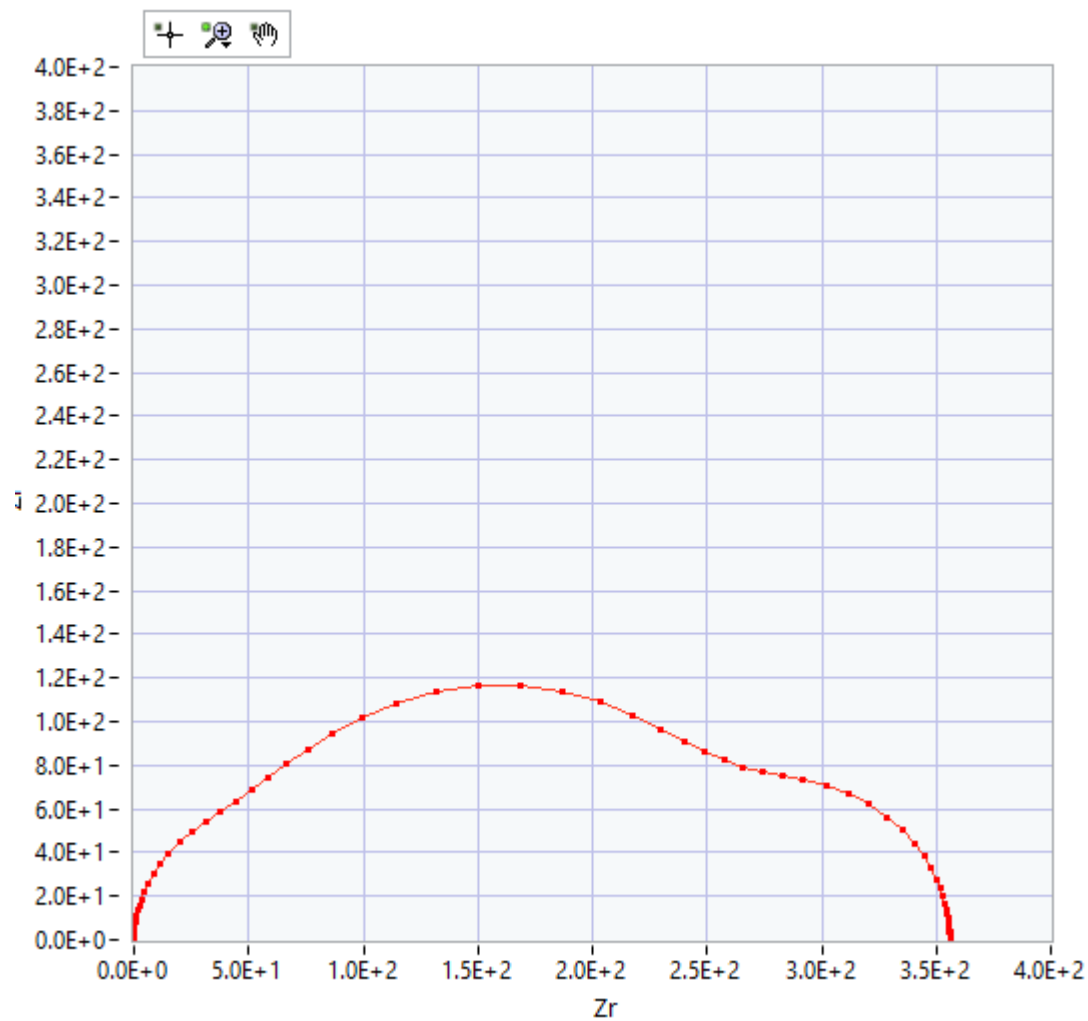
Let's make a model ; fix  $n=1$  so as to have a capacitor instead of Q. Fill the values as in this example then [Action/Simulate spectrum](#)

The screenshot displays the Yappari software interface, version 5.1.68, dated August 25, 2023. The main window shows a circuit model with three parallel branches, each containing a resistor and a capacitor in series. The circuit is labeled with 'Element 0' through 'Element 9'. The 'Model' tab is selected, showing the circuit diagram. The 'Parameters' tab is also visible, showing a list of parameters for the circuit elements. The parameters are organized into a table with columns for the element name, value, and a 'Fit' checkbox. The parameters are as follows:

Element	Value	Fit
4ZARR	200	<input checked="" type="checkbox"/>
4ZARQ	4.8E-8	<input checked="" type="checkbox"/>
4ZARN	1	<input type="checkbox"/>
5ZARR	100	<input checked="" type="checkbox"/>
5ZARQ	1E-6	<input checked="" type="checkbox"/>
5ZARN	1	<input type="checkbox"/>
6ZARR	56	<input checked="" type="checkbox"/>
6ZARQ	2.2E-8	<input checked="" type="checkbox"/>
6ZARN	1	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>
0	0	<input type="checkbox"/>

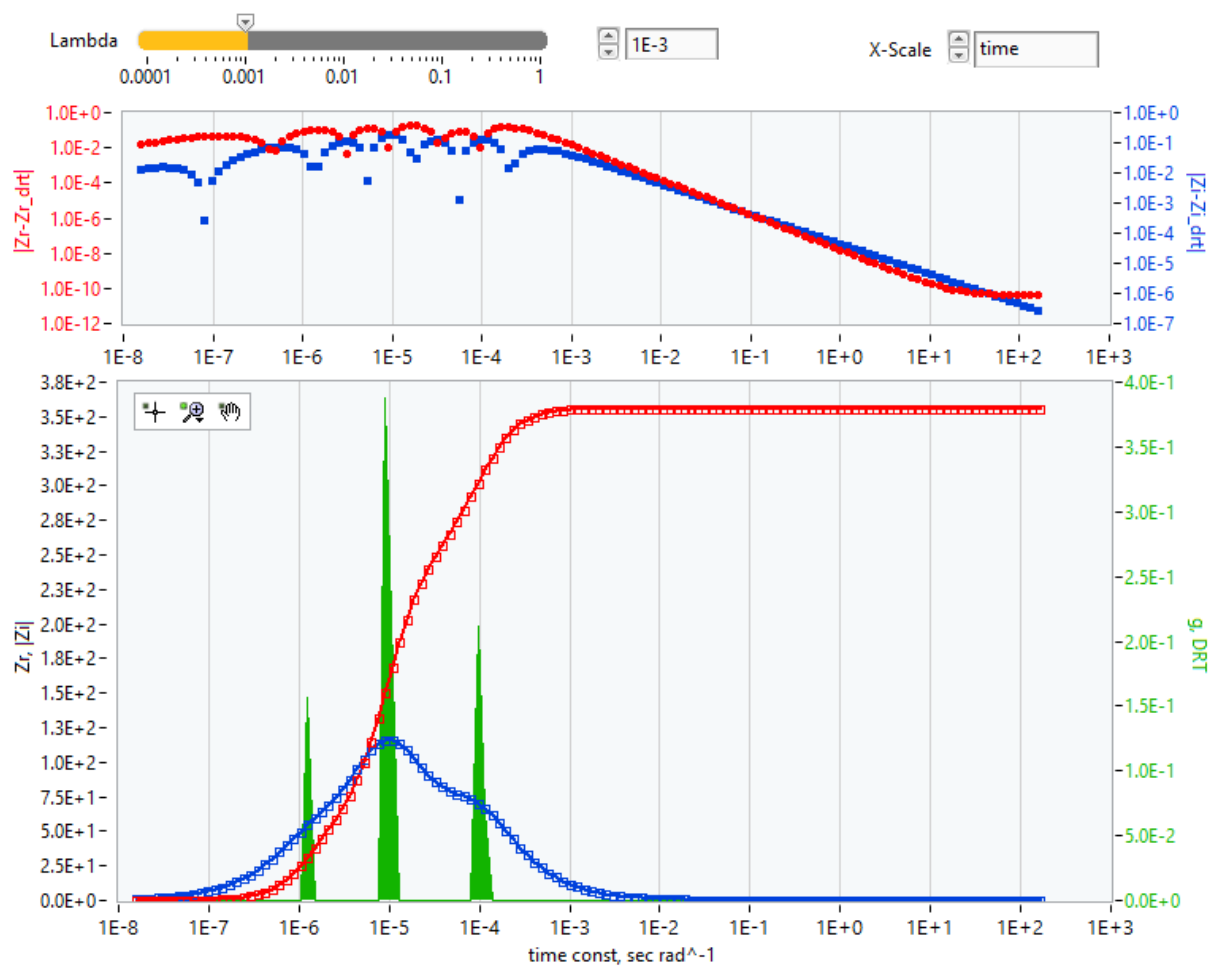
The 'Read data' section shows a 'Select ...' button. The 'Action' section shows a 'Select ...' button. The 'Datasets' section shows a list of datasets, with 'sim\_' selected. The 'Fit selected' button is visible. The 'Exit' button is also present.

We can see then the Nyquist plot (we can see there are at least three contributions)



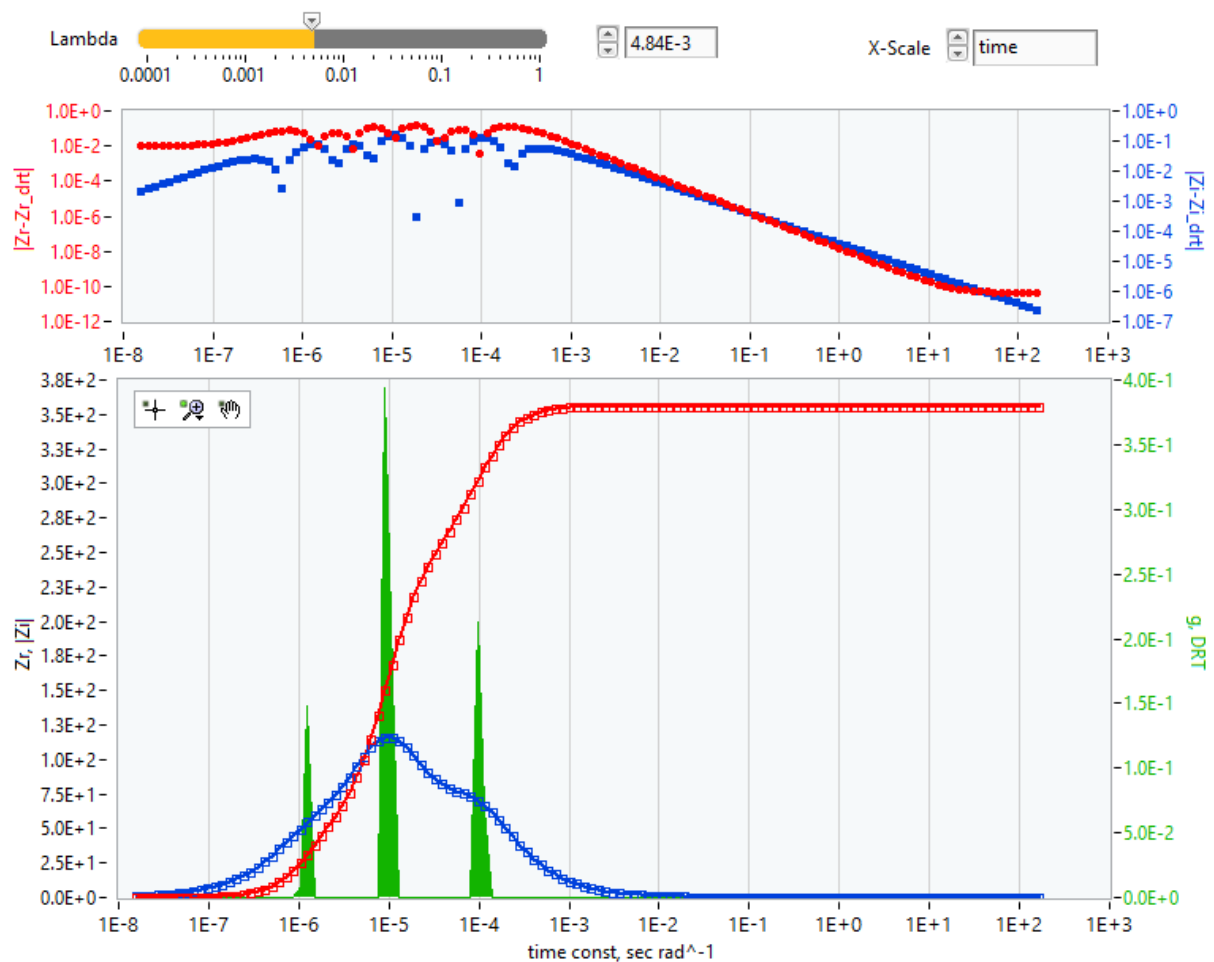
We can perform a simple DRT calculation, with default parameters : [Action/DRT active datasets](#)

Then we can see this nice result :



Three contributions, the time constants are in agreement with simulation.

Let's try to improve this, if possible, by searching an optimal Tikhonov parameter : do [Action/Search Lambda](#)



The error is a little bit smaller but not essential.

Of course, on simulated data is easy. Let's add some with noise, up to + or - 2% of value of Z. The command to do this is `rndz>>2`. See Parameters panel, Advanced commands.

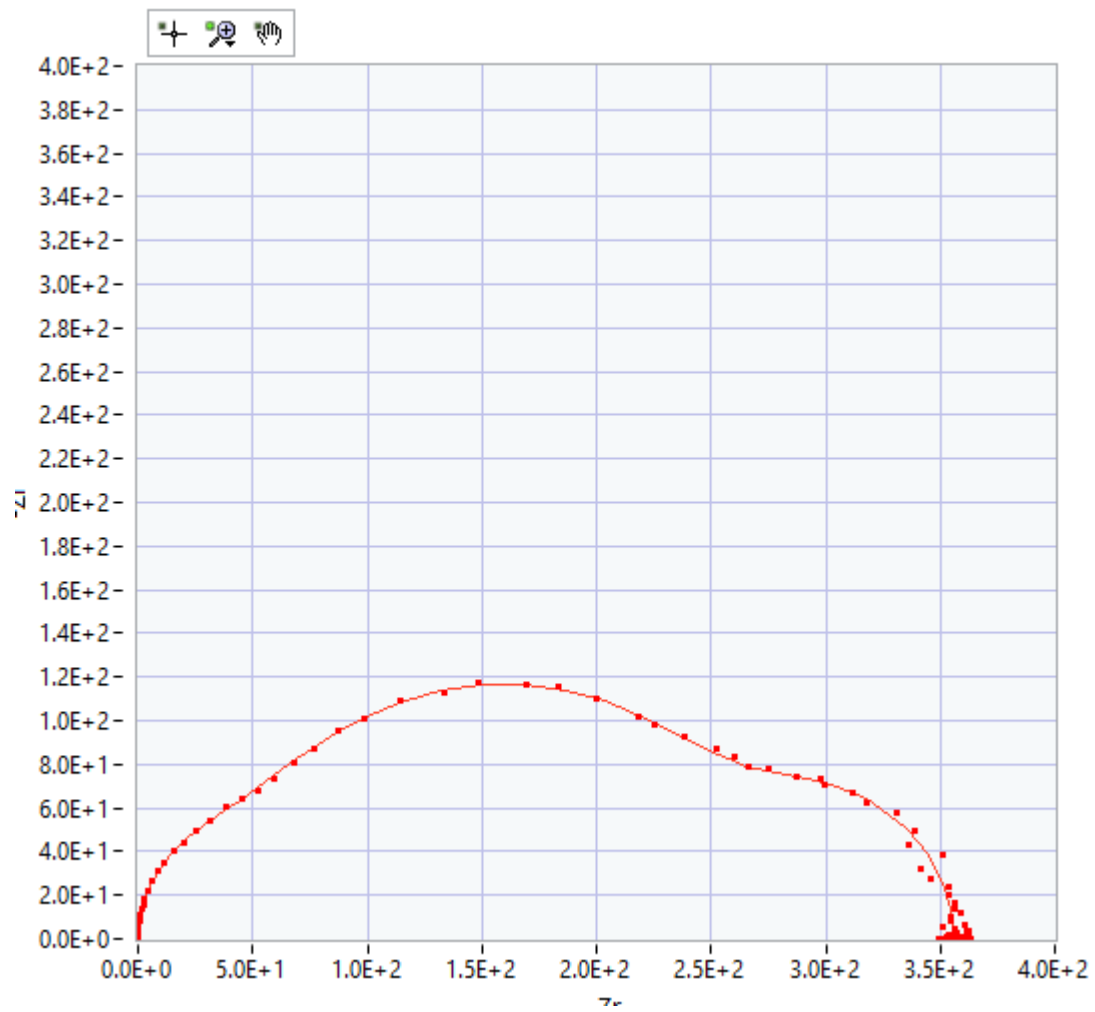
points  
128

Advanced commands

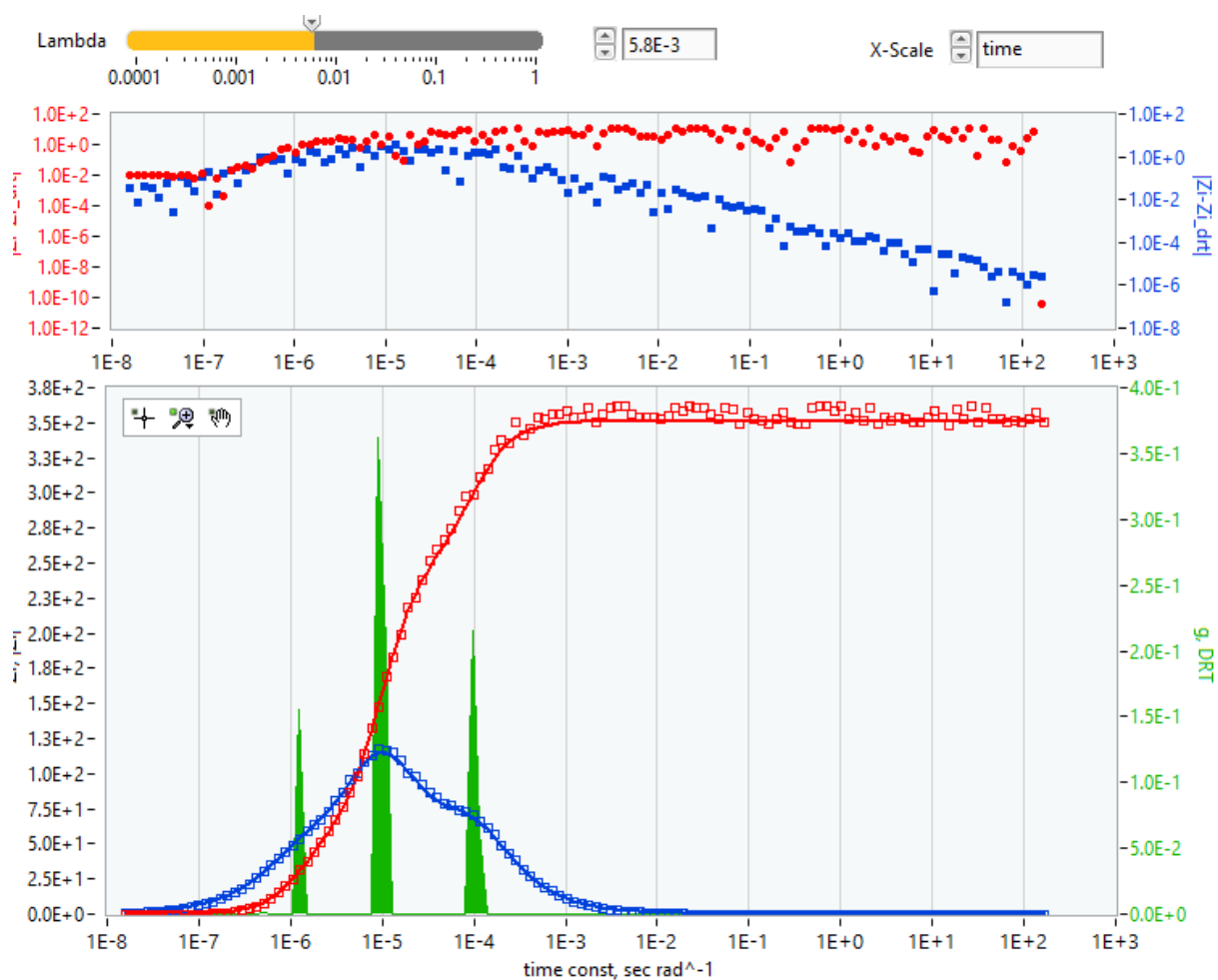
`rndz>>2`

Apply

If we look at the Nyquist spectrum it is a bit noisy, particularly at low frequency. This looks more like experimental data than the nice simulated spectrum before.



Performing DRT on this data we obtain :



Errors are much larger, it is to be expected, yet we see three contributions at the relaxation times we should.

Let's perform a classical fit with 3 zarcs, the fit is very good, and the Parameters panel shows the results (close to the simulated values).

4ZARR	197.24383	Fit	<input checked="" type="checkbox"/>
4ZARQ	5.0118E-8	Fit	<input checked="" type="checkbox"/>
4ZARN	1	Fit	<input type="checkbox"/>
5ZARR	98.08626	Fit	<input checked="" type="checkbox"/>
5ZARQ	9.47601E-7	Fit	<input checked="" type="checkbox"/>
5ZARN	1	Fit	<input type="checkbox"/>
6ZARR	58.05453	Fit	<input checked="" type="checkbox"/>
6ZARQ	2.19745E-8	Fit	<input checked="" type="checkbox"/>
6ZARN	1	Fit	<input type="checkbox"/>

And if you want also the error bars use [Report](#) or [Save parameters](#).

All parameters :

4ZARR: 1.97244E+2, 4ZARQ: 5.01180E-8, 4ZARN: 1.00000E+0, 5ZARR: 9.80863E+1, 5ZARQ: 9.47601E-7, 5ZARN: 1.00000E+0, 6ZARR: 5.80545E+1, 6ZARQ: 2.19745E-8, 6ZARN: 1.00000E+0,

Dataset name : sim\_

Fitted parameters and calculated standard error :

4ZARR 1.972E+2 +/- 5.91E+0

4ZARQ 5.012E-8 +/- 3.59E-9

5ZARR 9.809E+1 +/- 0.00E+0

5ZARQ 9.476E-7 +/- 5.13E+0

6ZARR 5.805E+1 +/- 1.12E-7

6ZARQ 2.197E-8 +/- 0.00E+0

R square: 9.984960E-1

Chi square: 1.541100E-1