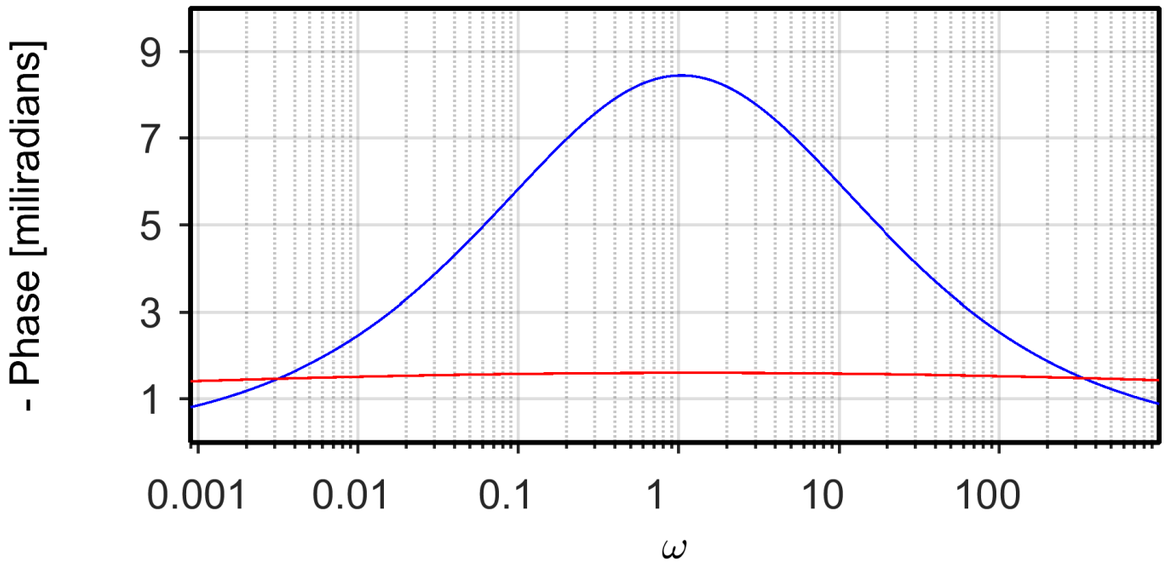
Comparison of Cole-Cole and Constant Phase Angle modeling in Time-Domain Induced Polarization

M. LAJAUNIE, P. K. MAURYA AND G. FIANDACA

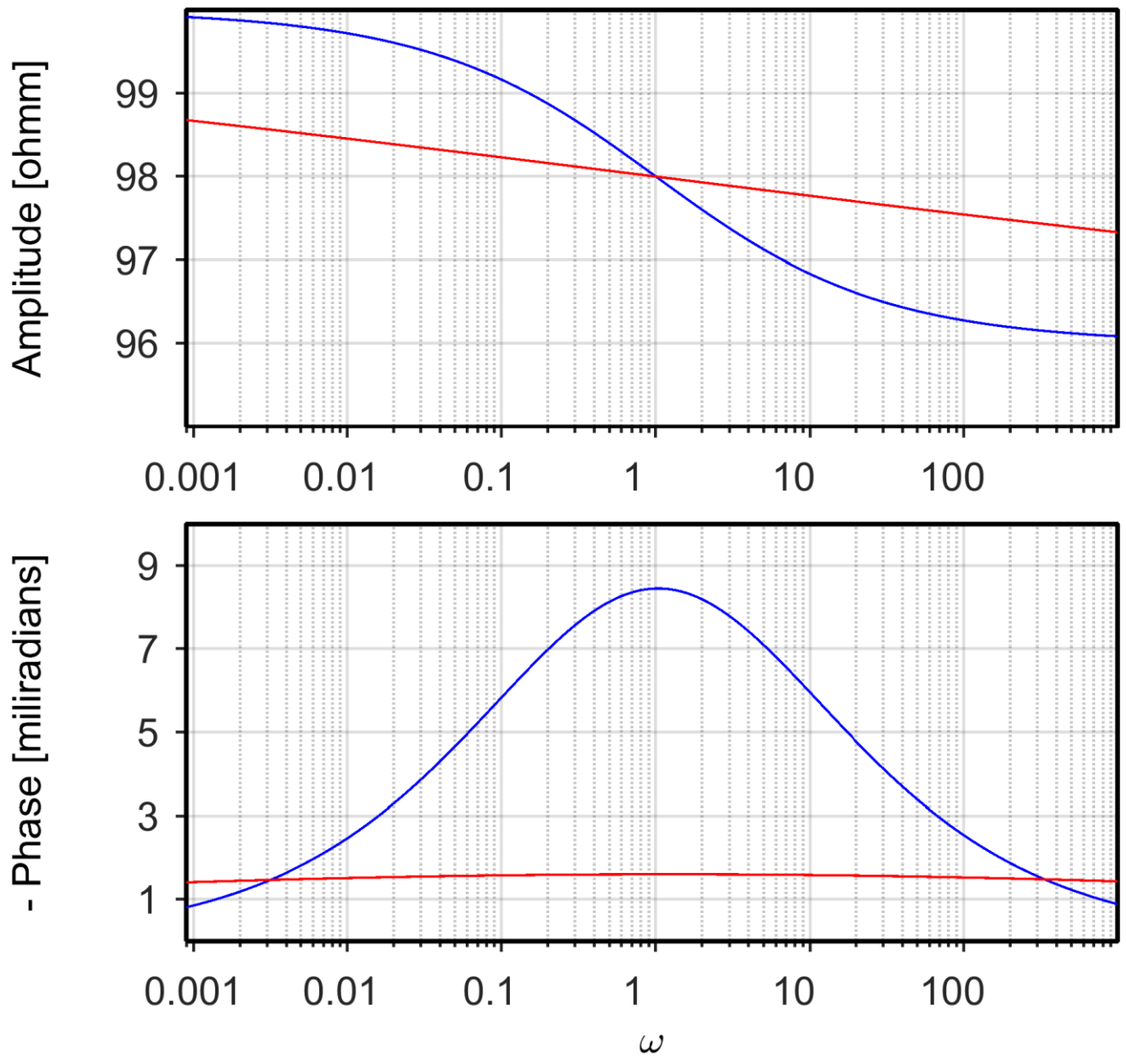
Ecole et Observatoire des Sciences de la Terre

Content

1. Analytical descriptions of the induced polarization
    - Cole-Cole model
    - Constant Phase Angle (CPA) model
    - Ambiguity in time domain
2. Synthetic tests
3. Comparison with field data



Two classes of Induced Polarization signal



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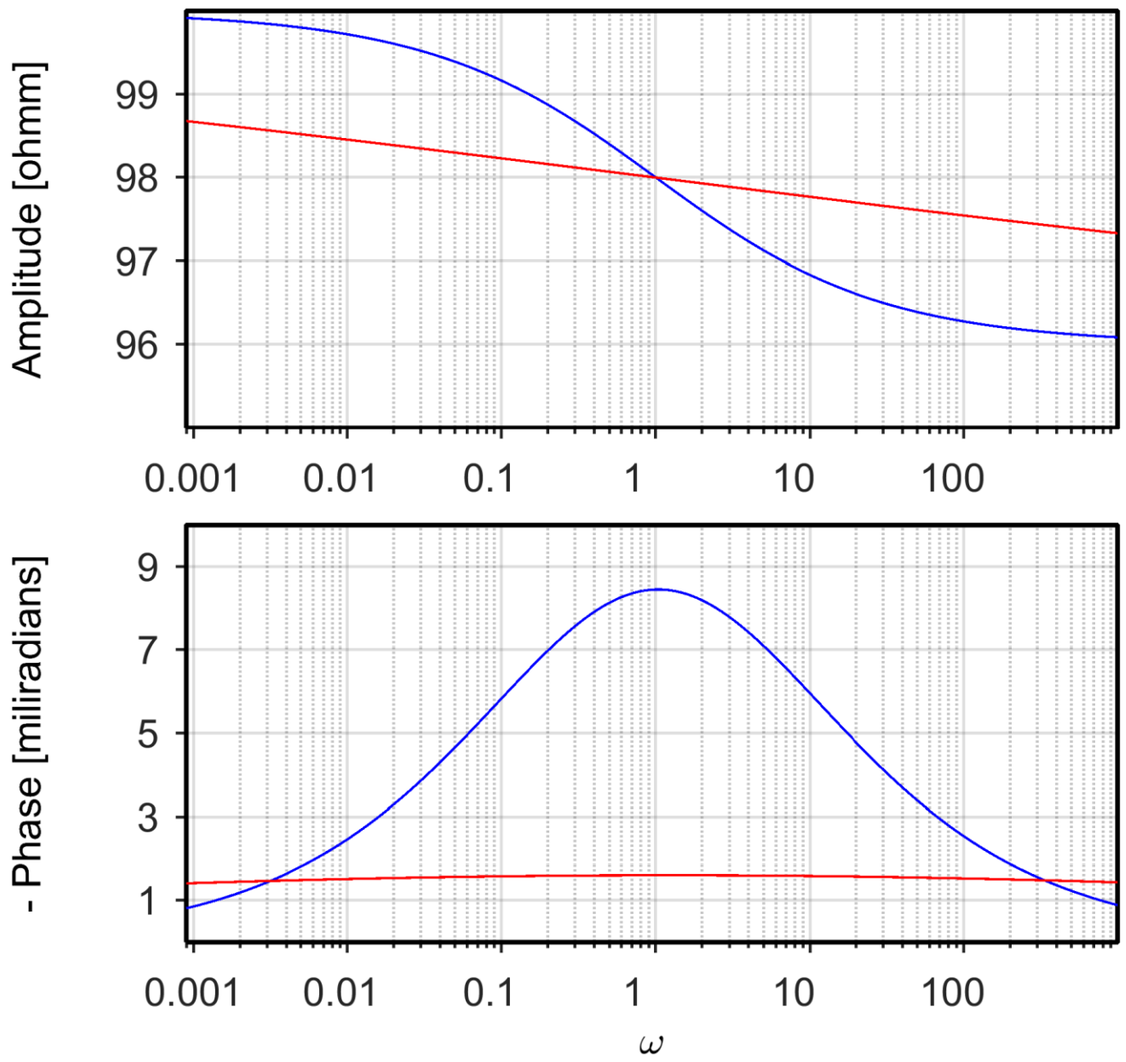


- Phase angle changing with frequency

Cole-Cole model

- Phase angle almost constant over the frequency range investigated

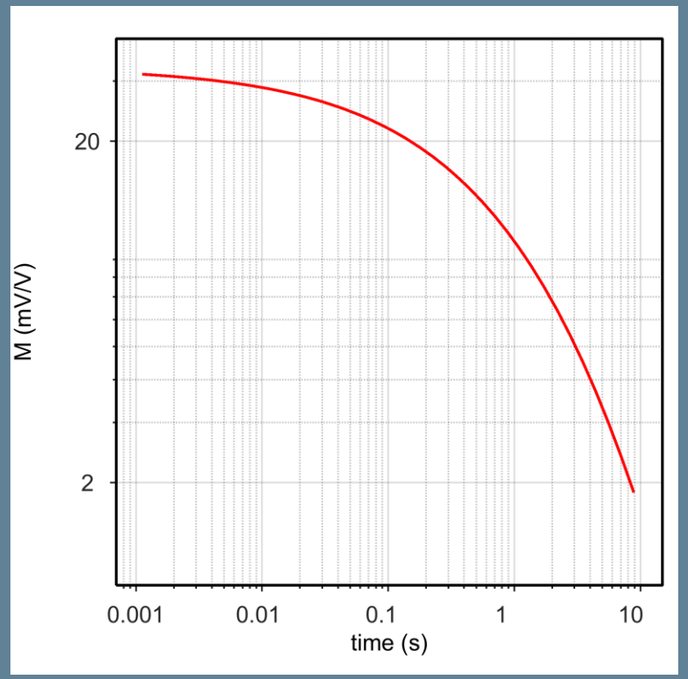
Constant phase angle (CPA) model

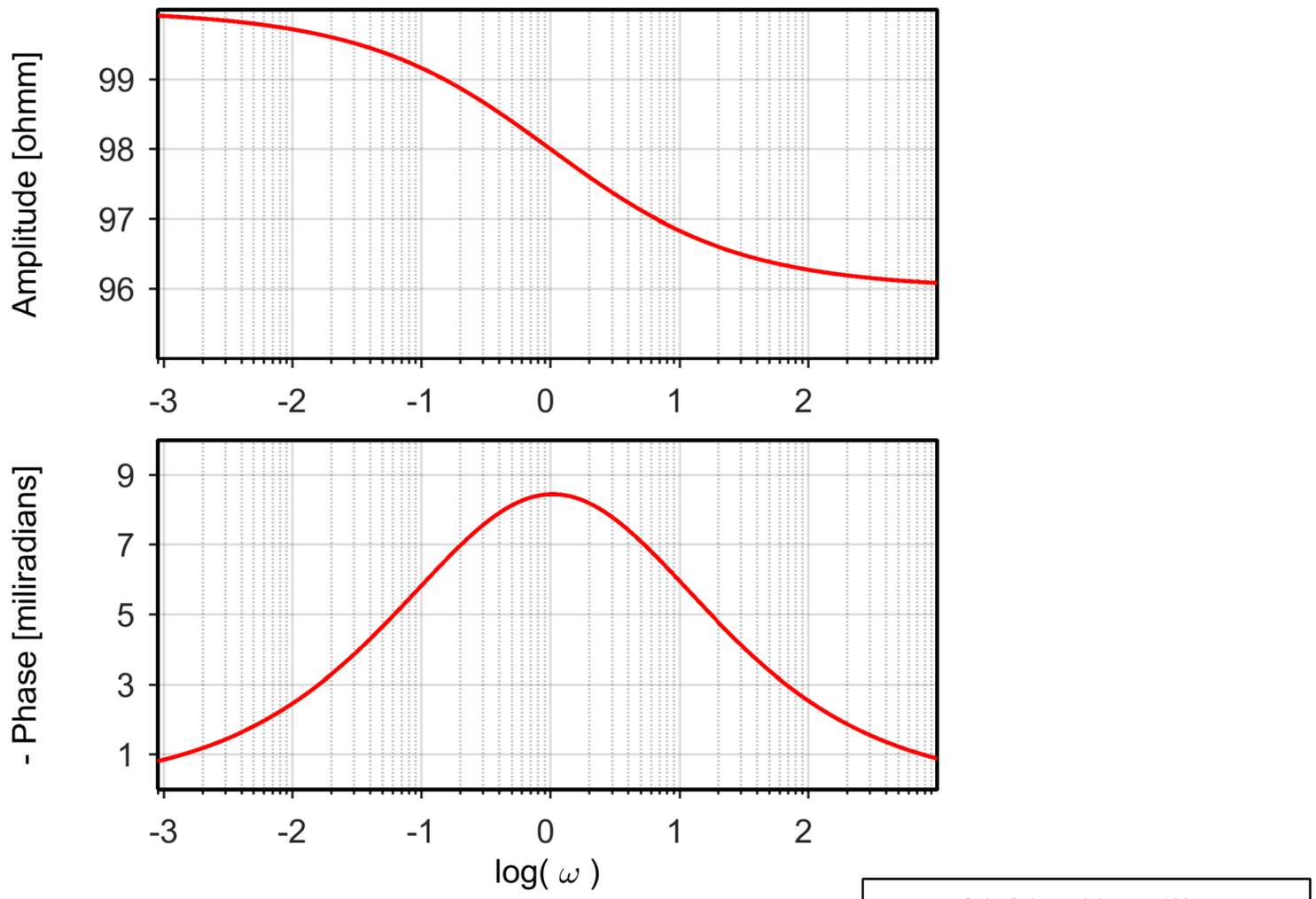
Cole-Cole model

Formula :

$$\zeta_{Cole-Cole} = \rho\left(1 - m_0\left(1 - \frac{1}{1 + (i\omega\tau)^c}\right)\right)$$

Time domain :





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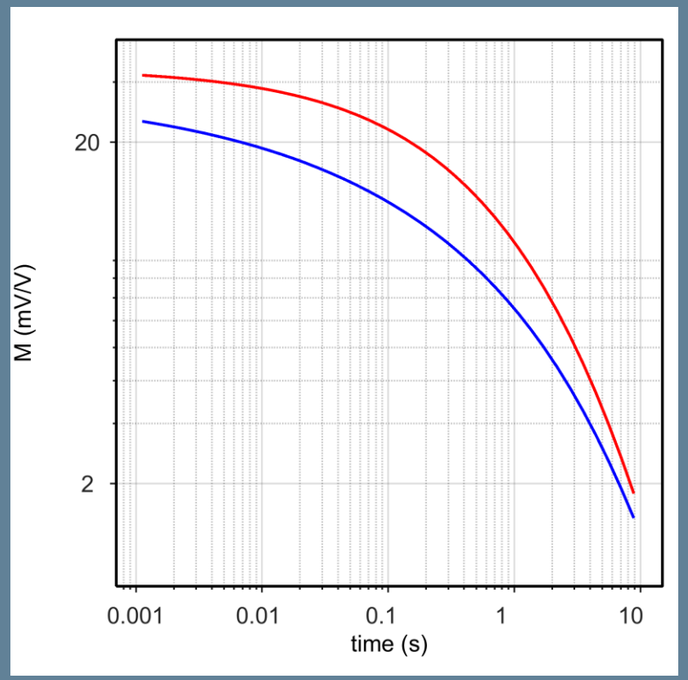

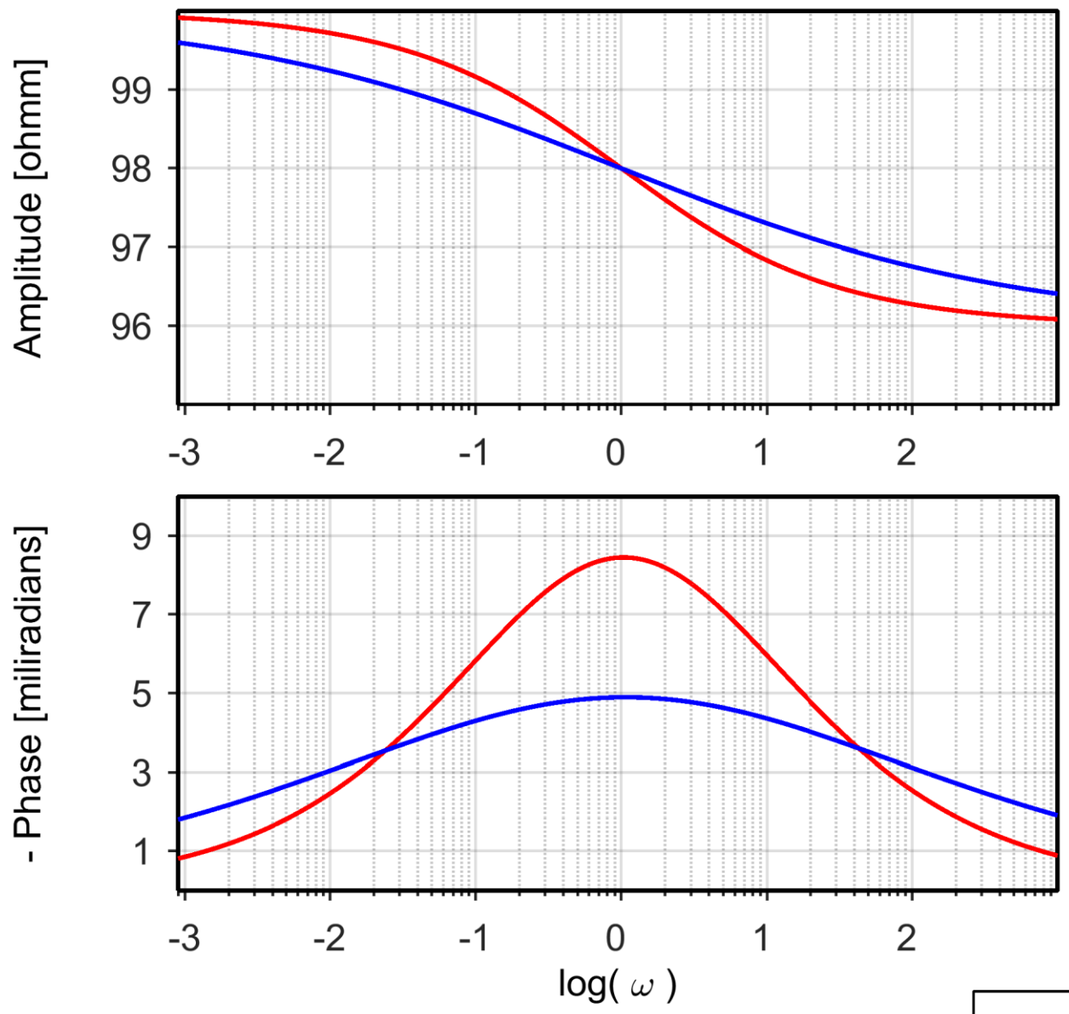

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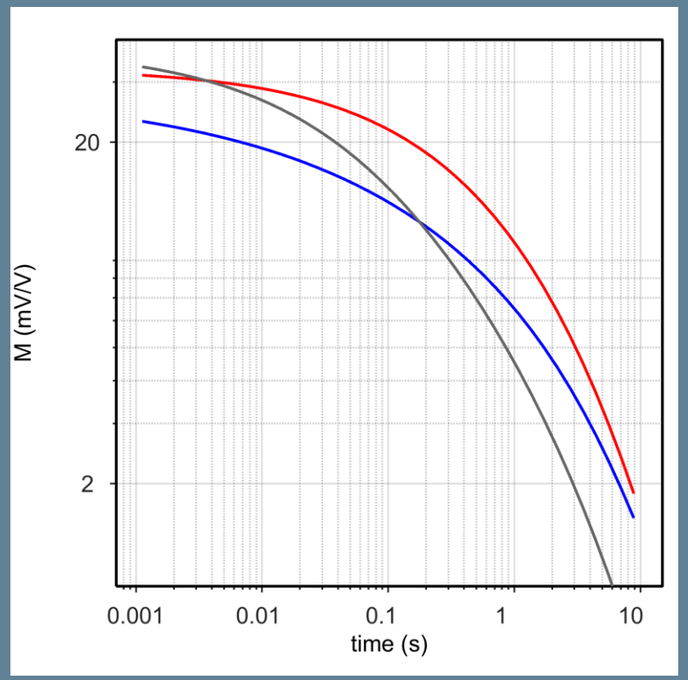

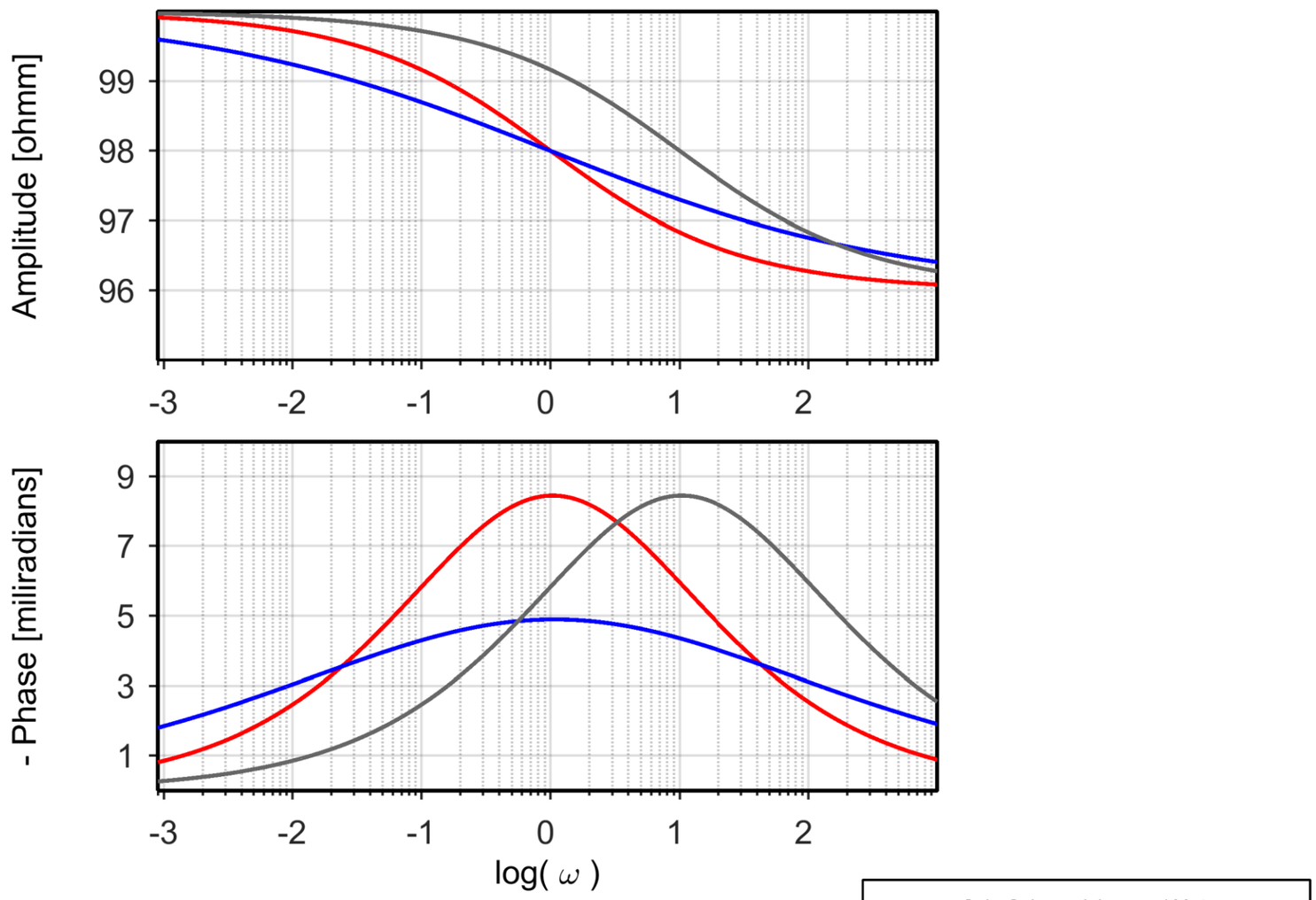

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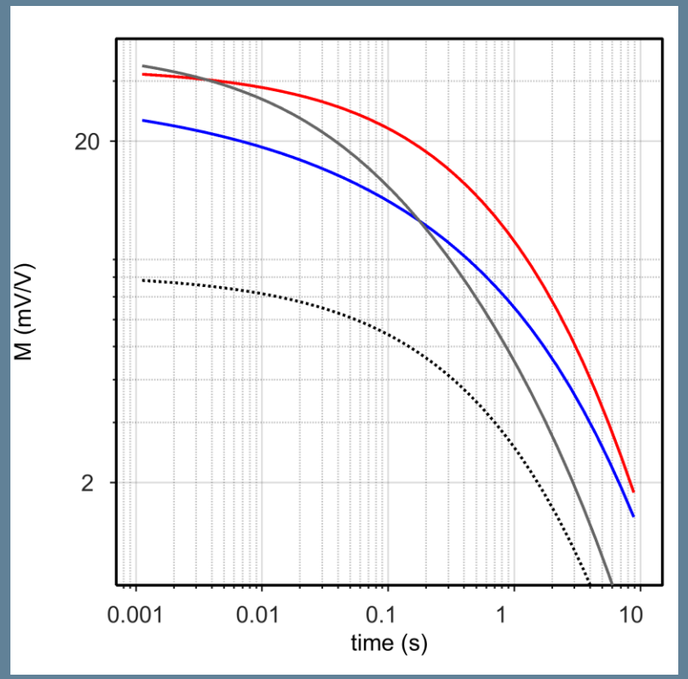
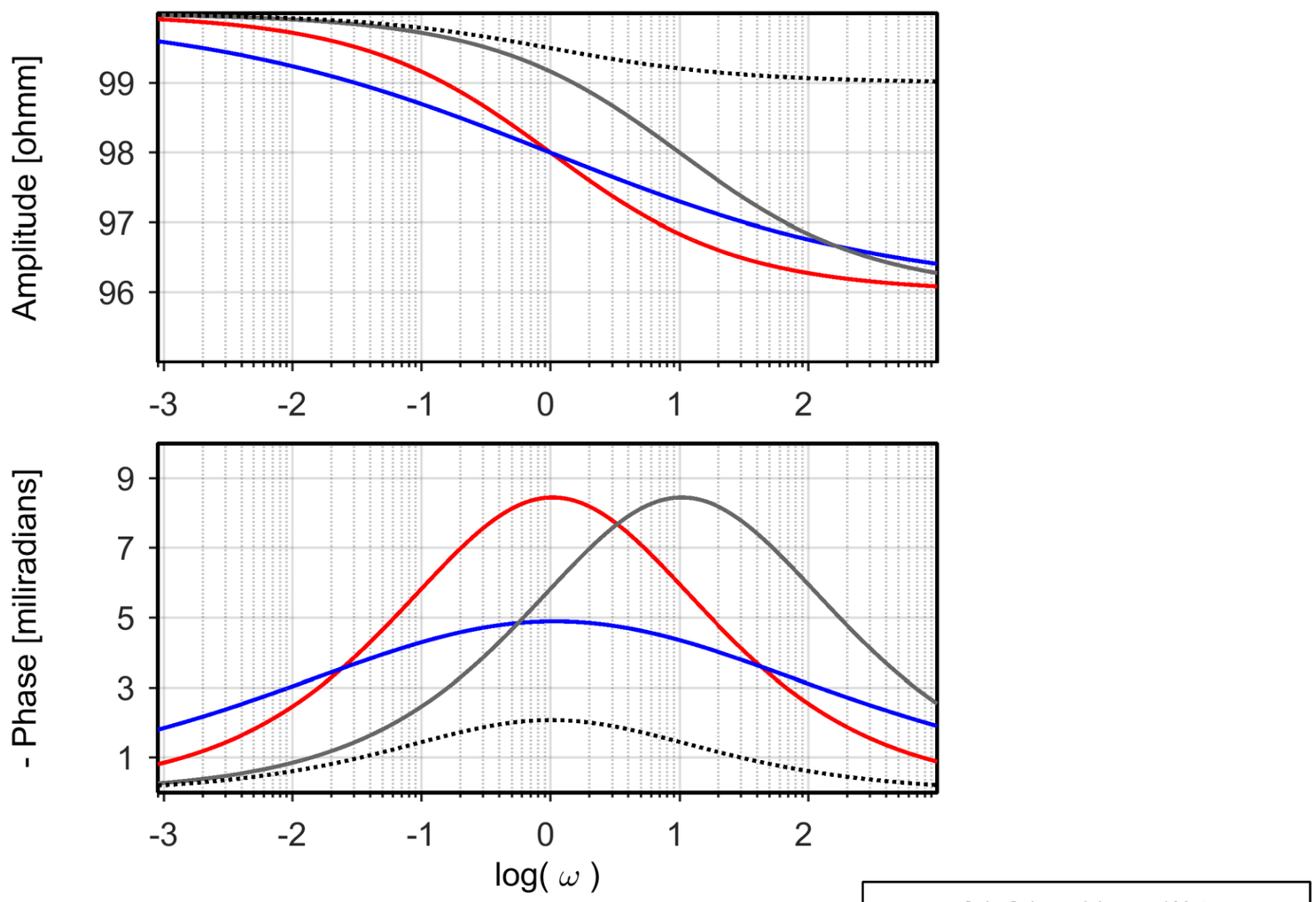


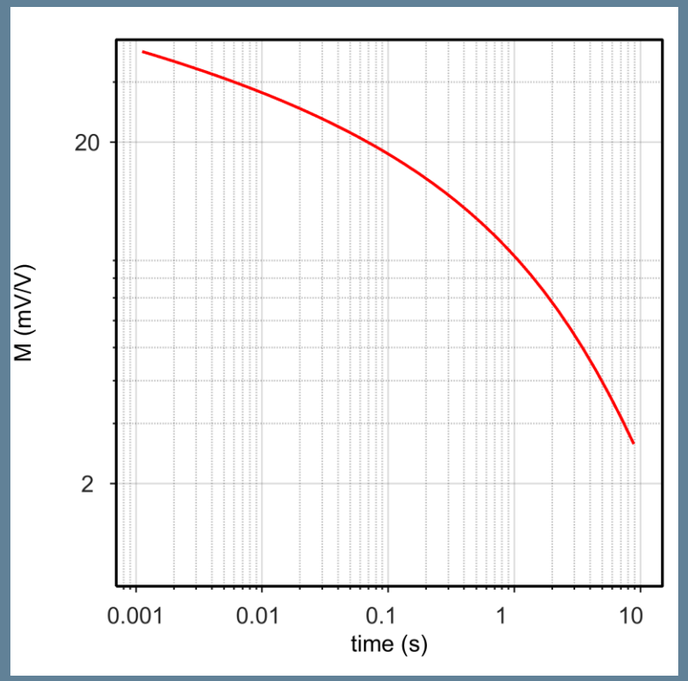


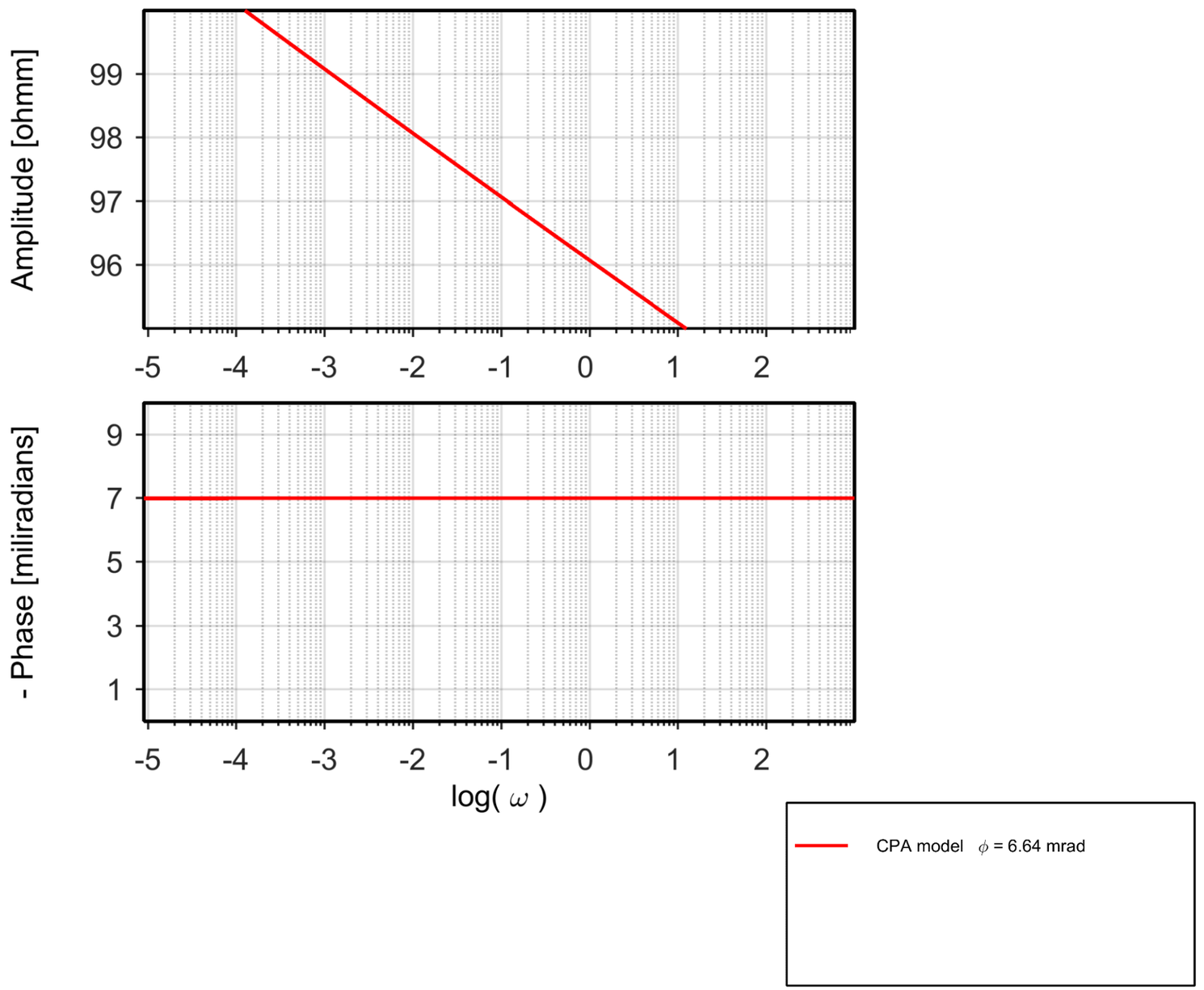
Constant Phase Angle (CPA) model

Formula :

$$\zeta_{CPA} = K(i\omega)^{-b}$$

Time domain :





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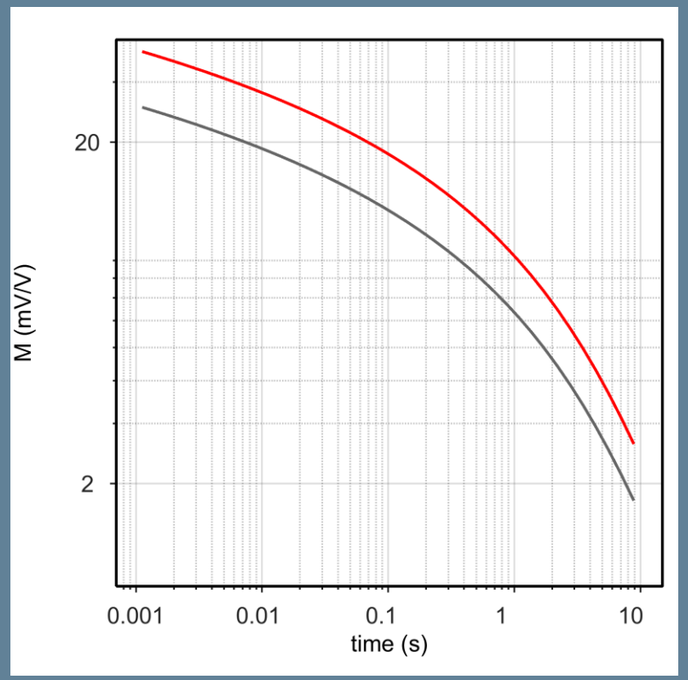
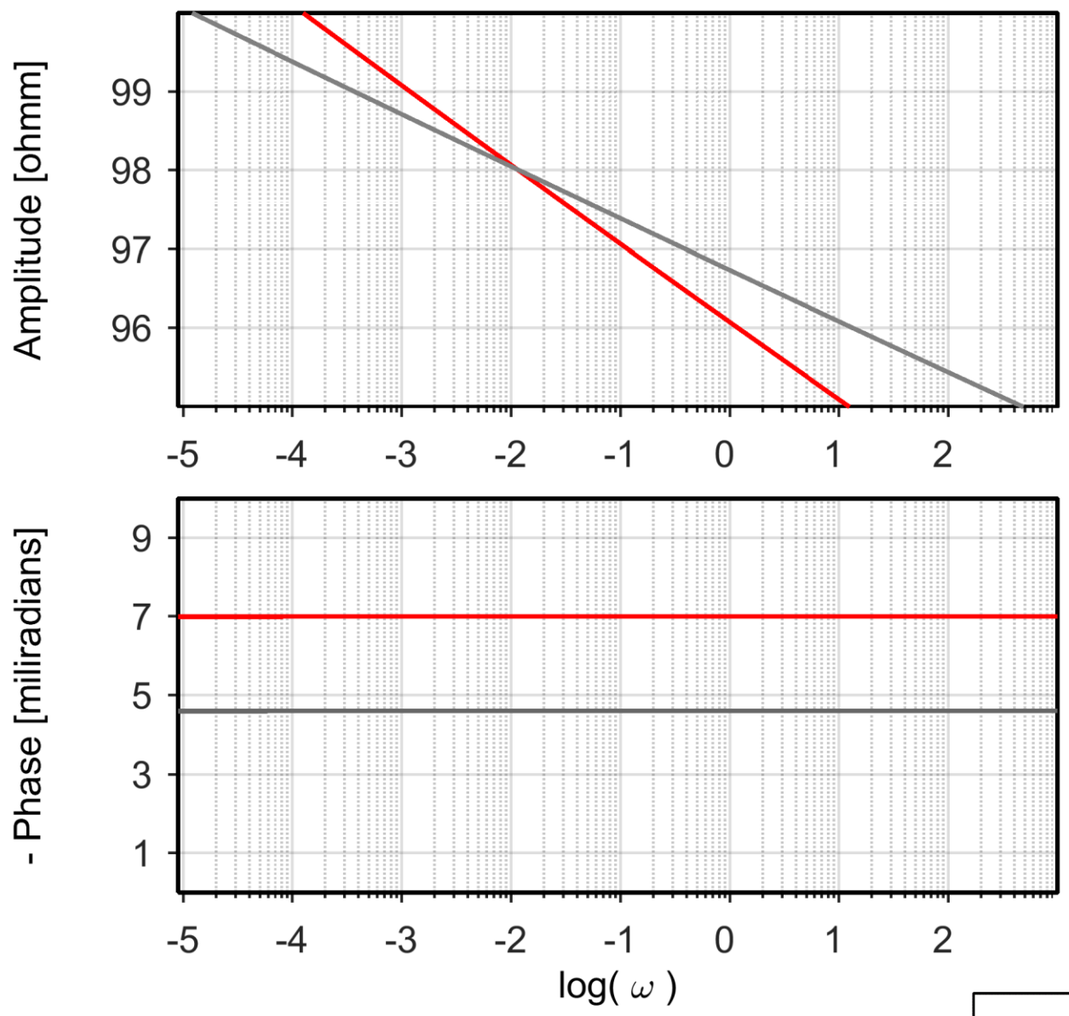


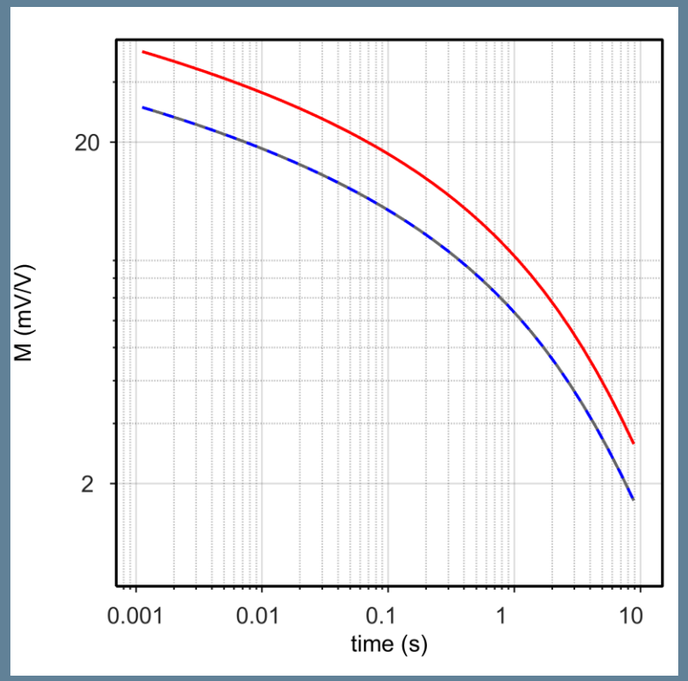


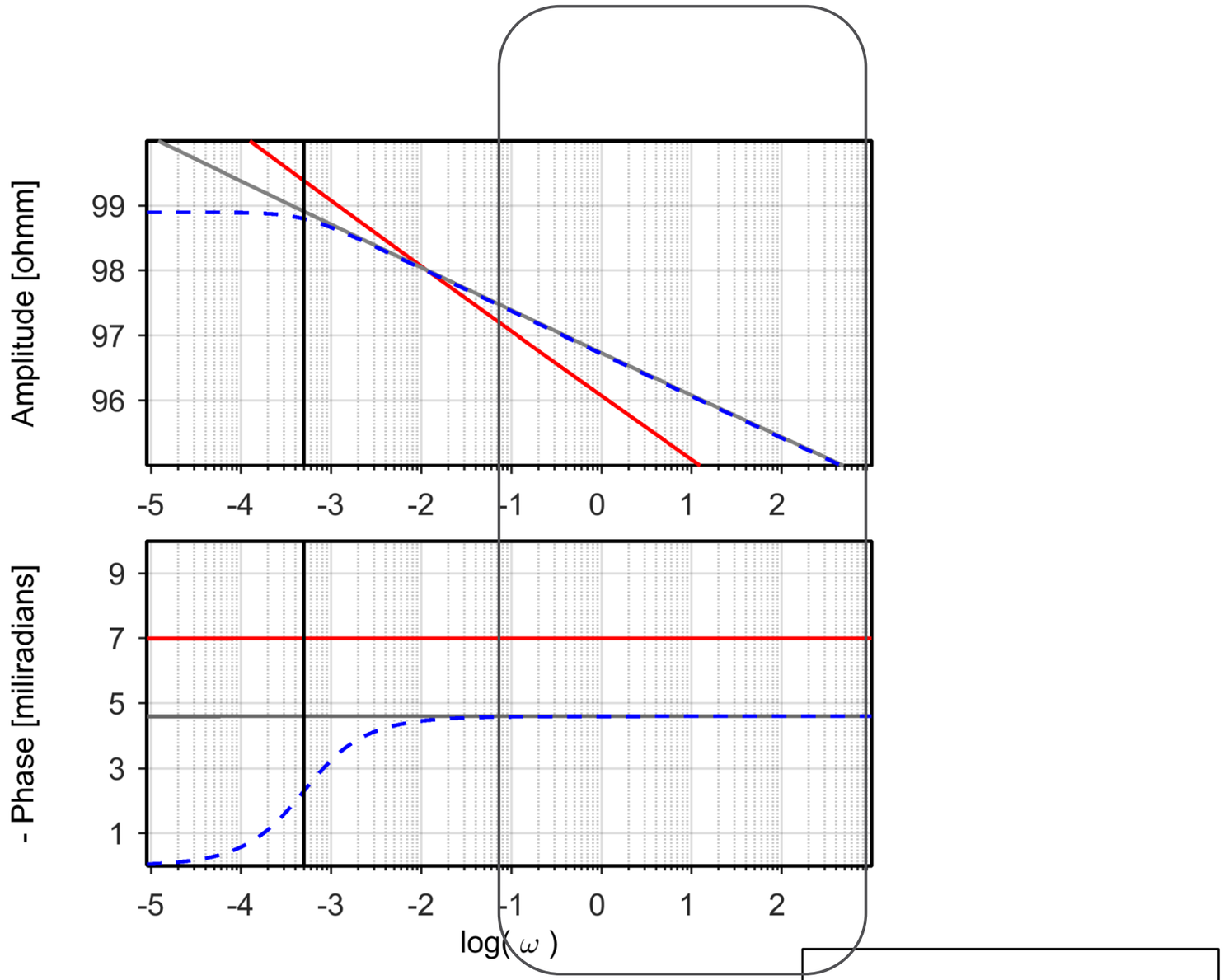
Constant Phase Angle (CPA) model

Formula :

$$\zeta_{Drake} = K(i\omega + \omega_L)^{-b}$$

Time domain :





Title

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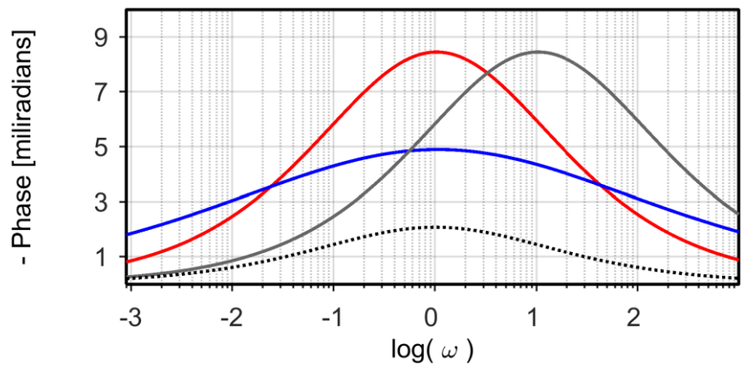

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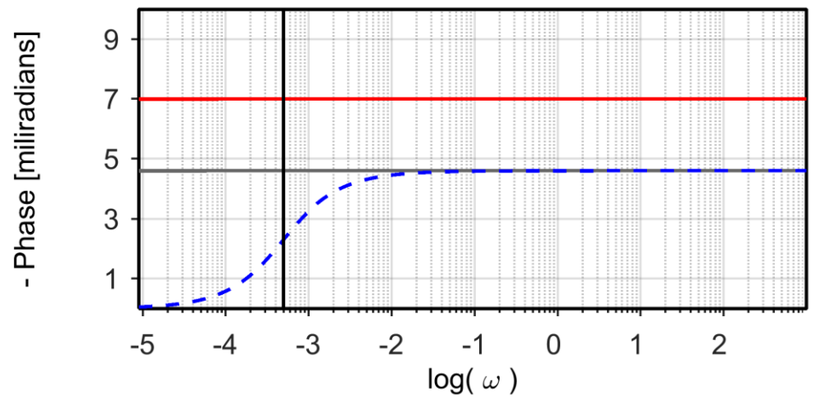

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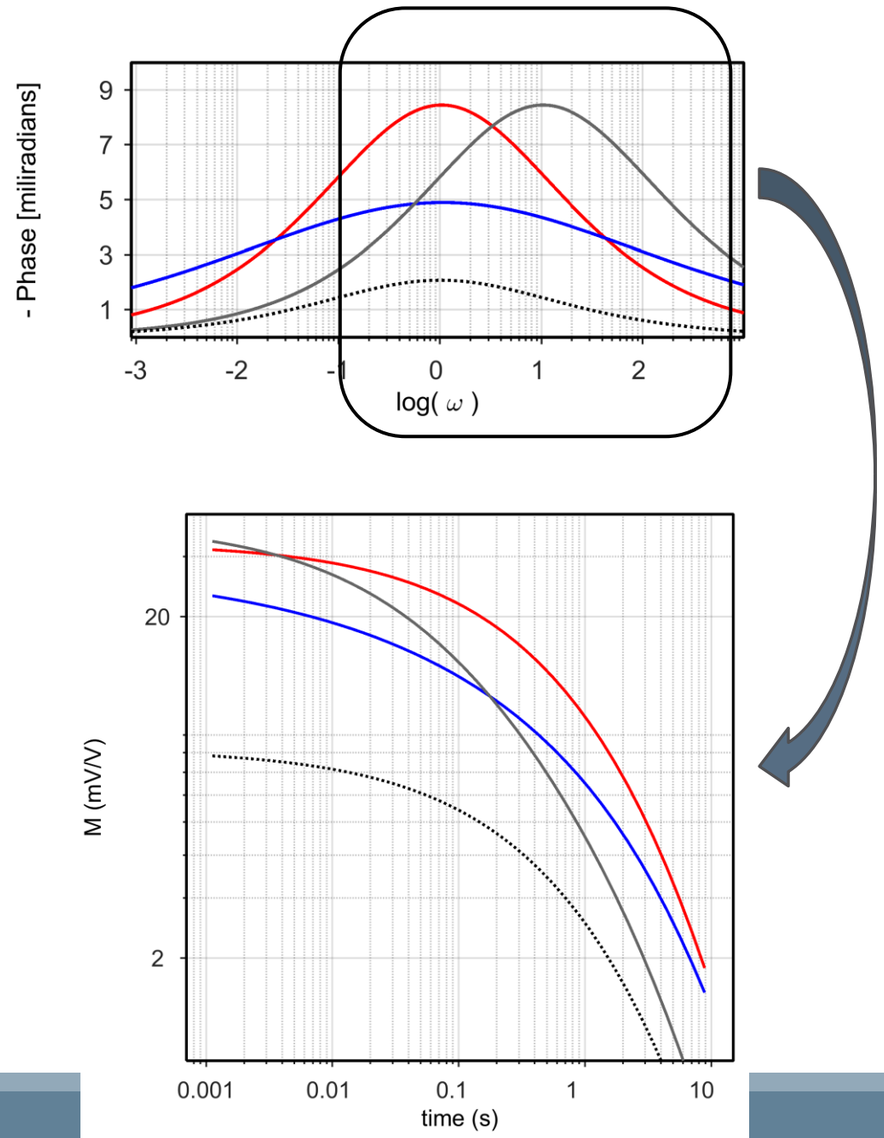

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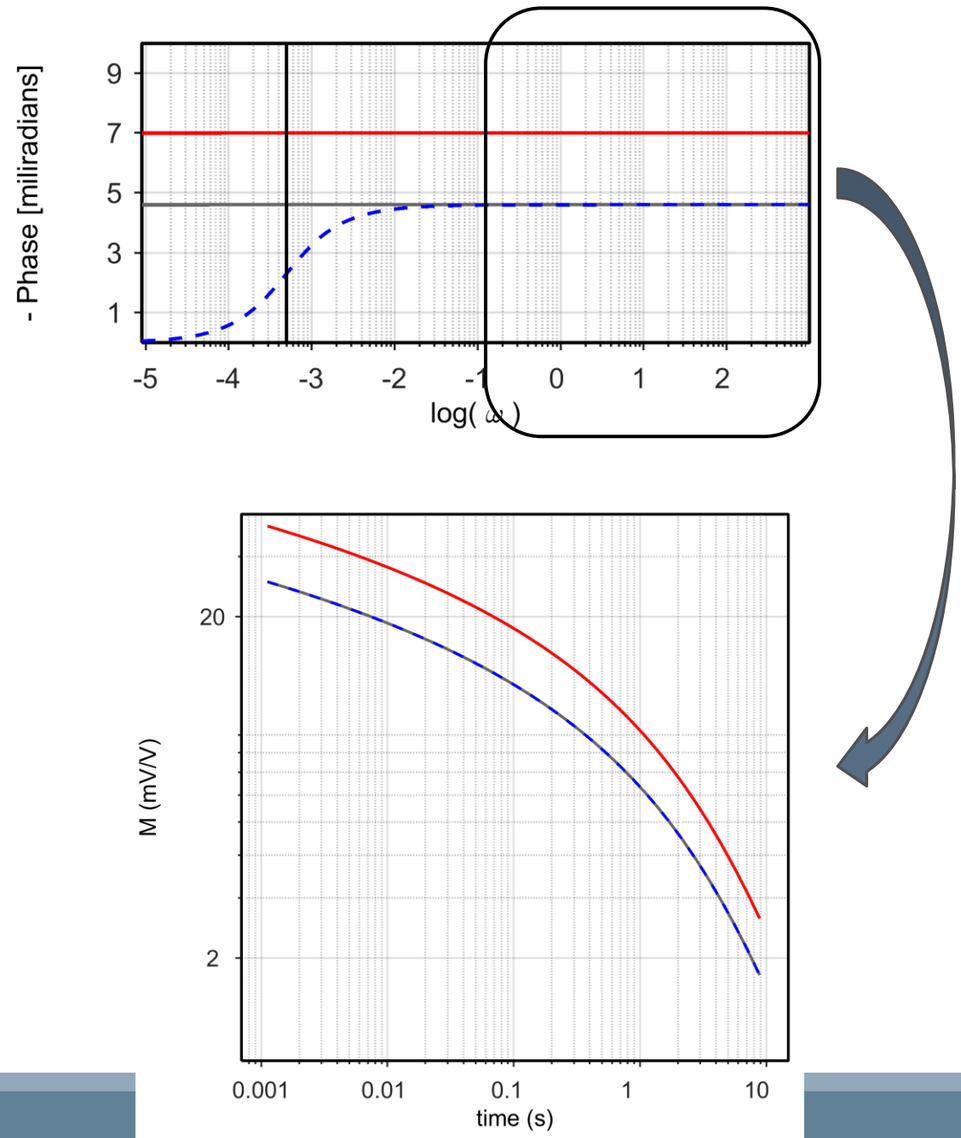
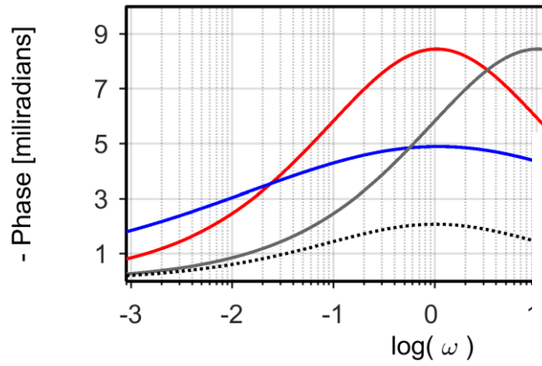


Can we distinguish between the two classes with time domain data?

COLE-COLE MODEL



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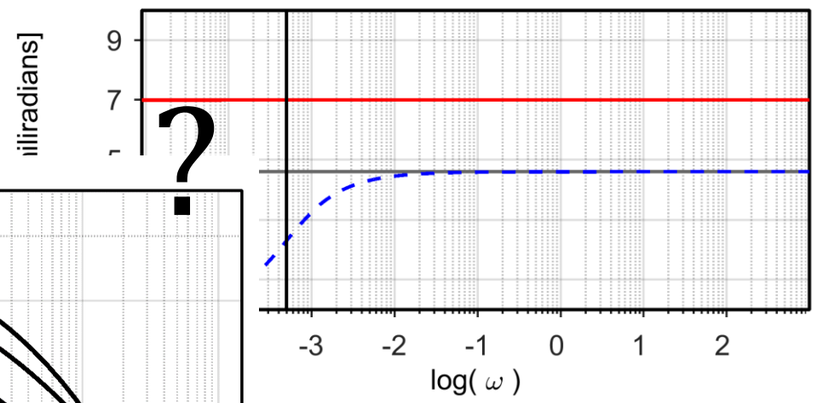

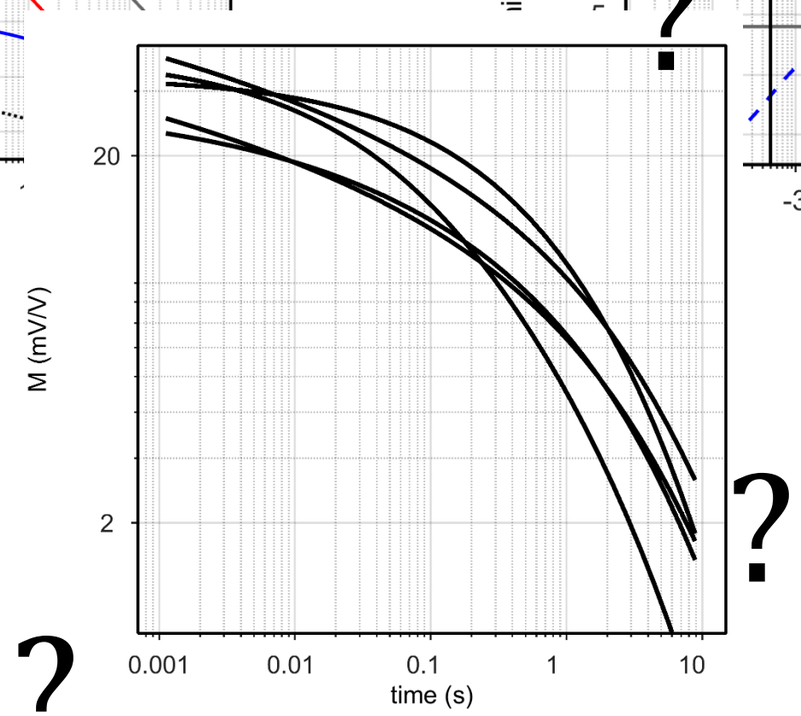

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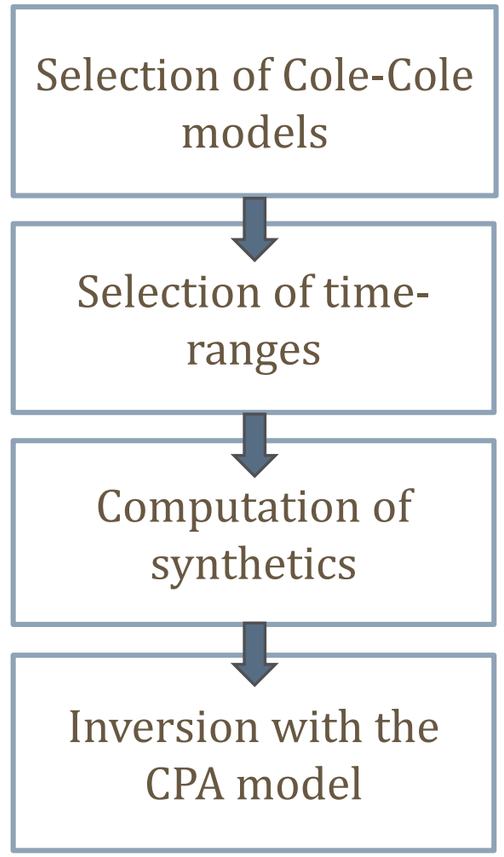

Synthetic tests

Parameters for the models

ρ	m0	τ	c
100 ohm.m	40 mV/V	[0.001 - 10]	[0.1 ; 0.3 ; 0.5]

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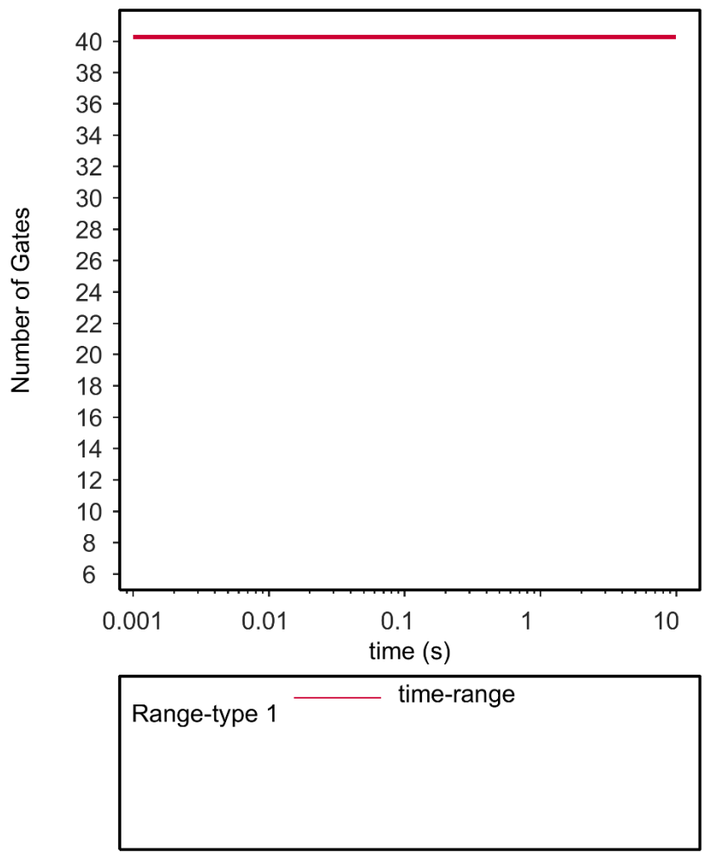

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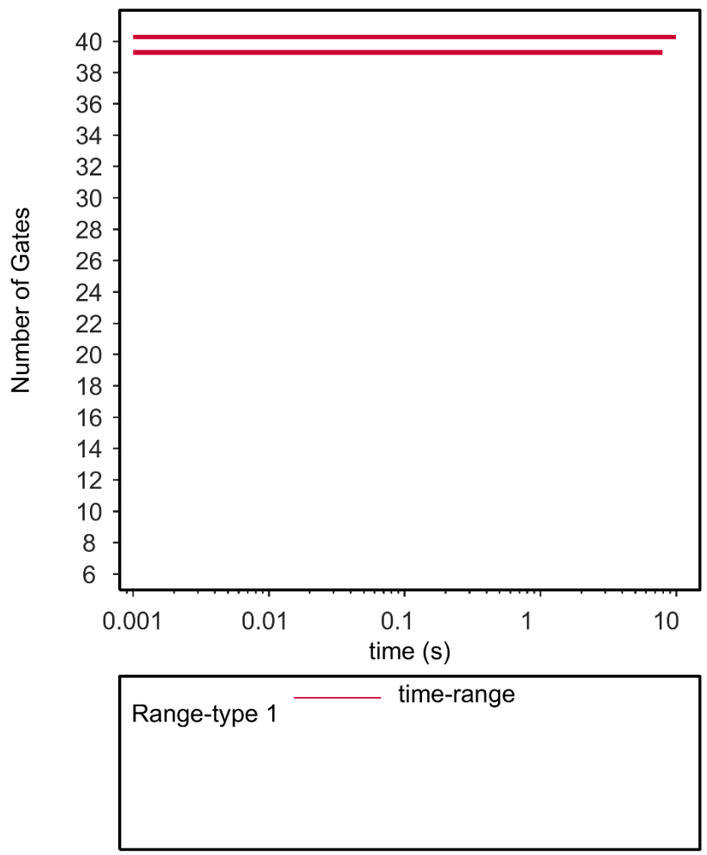

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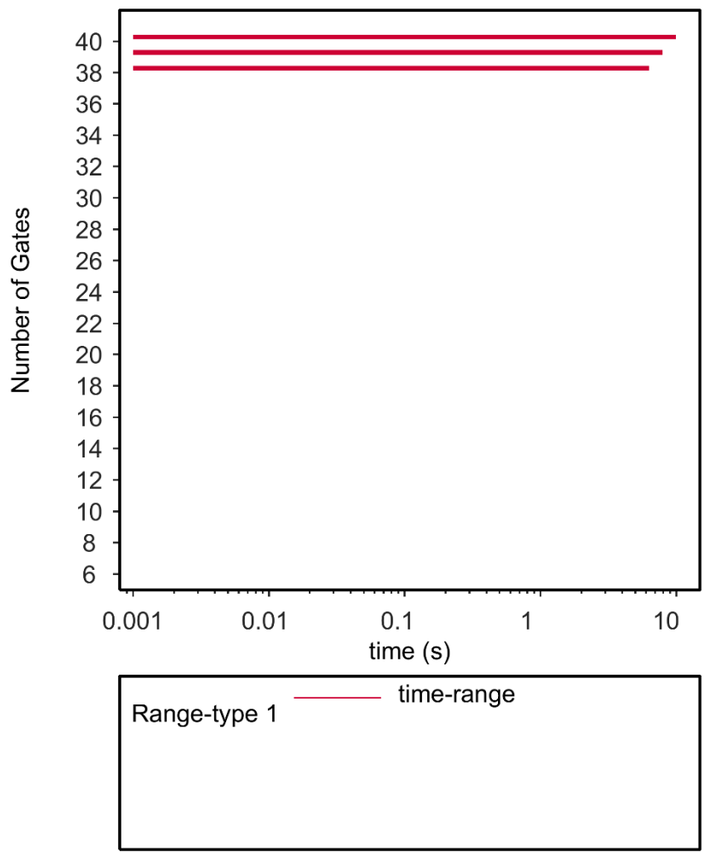

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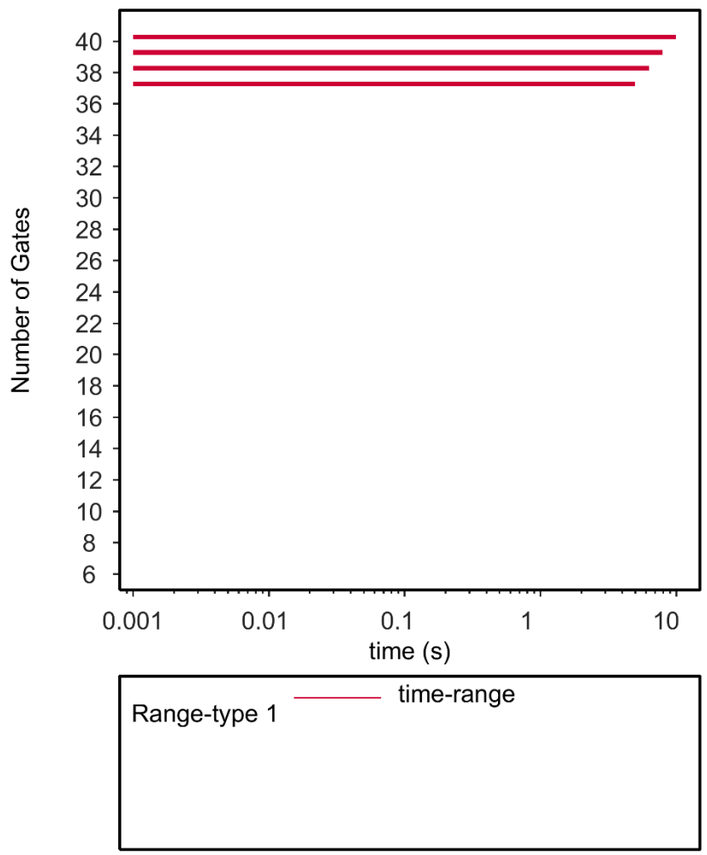

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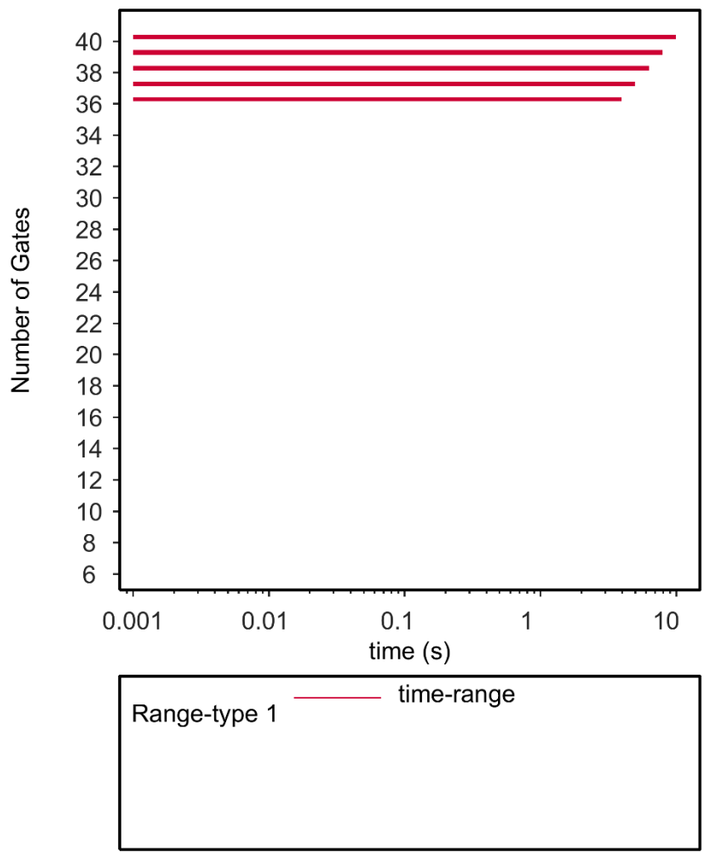

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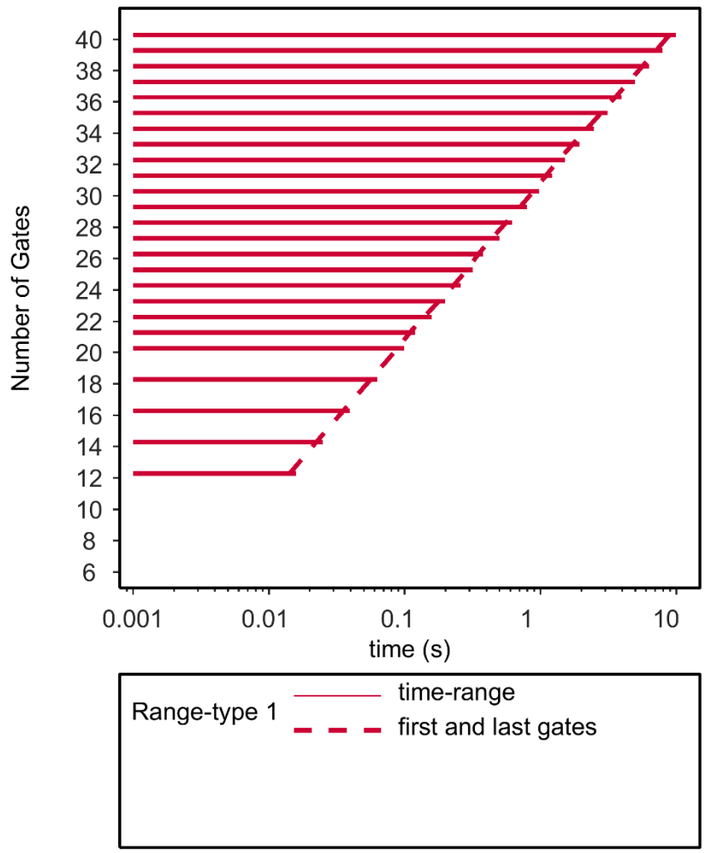

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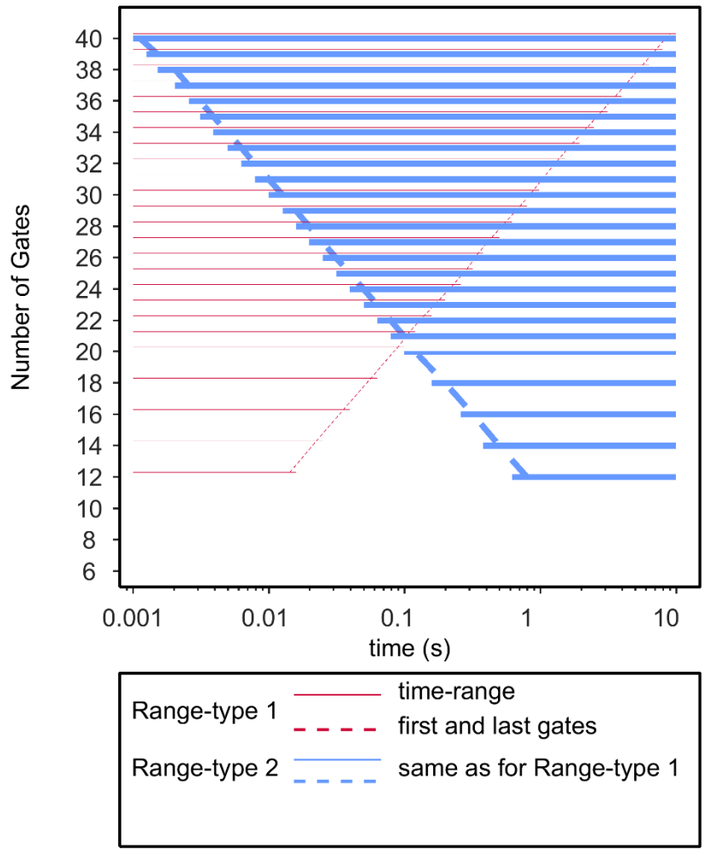

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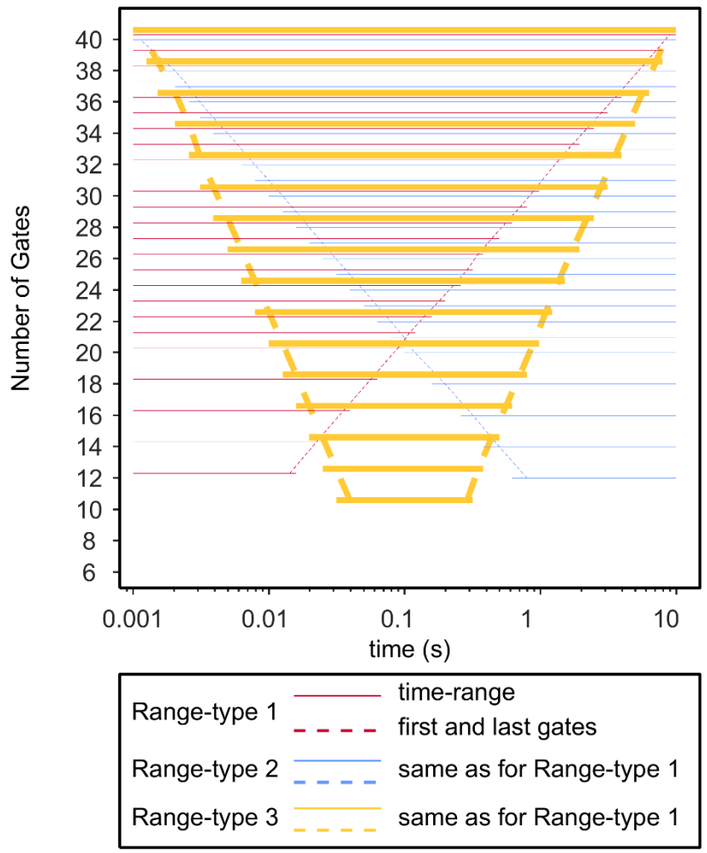

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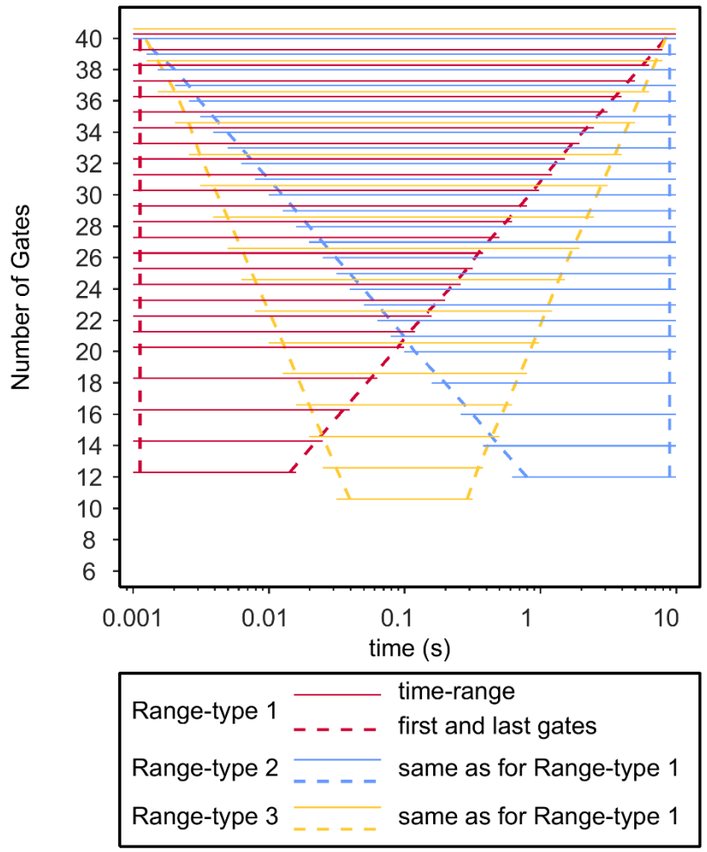

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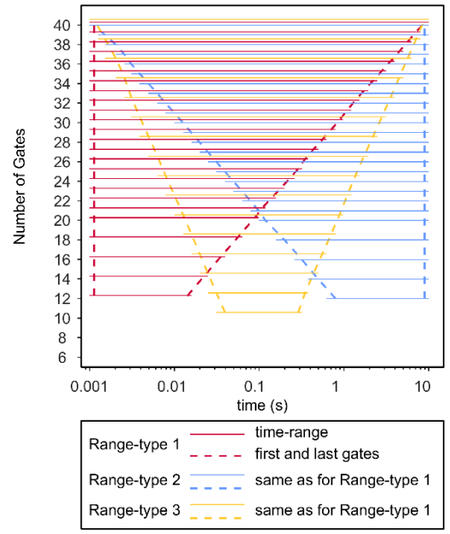
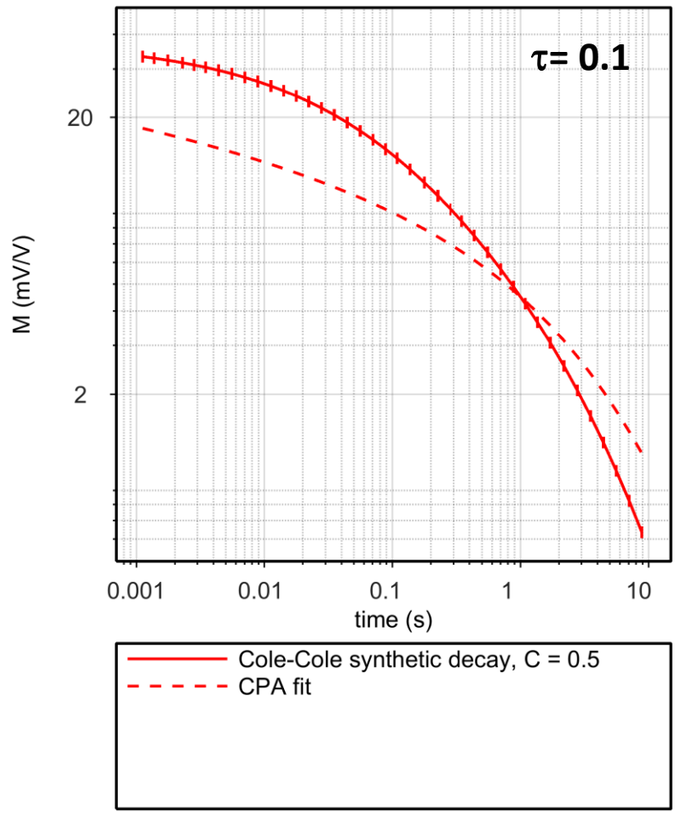


Computation of synthetics (5% error bars)

Inversion with the CPA model

Synthetic tests : results

Frequency exponent c



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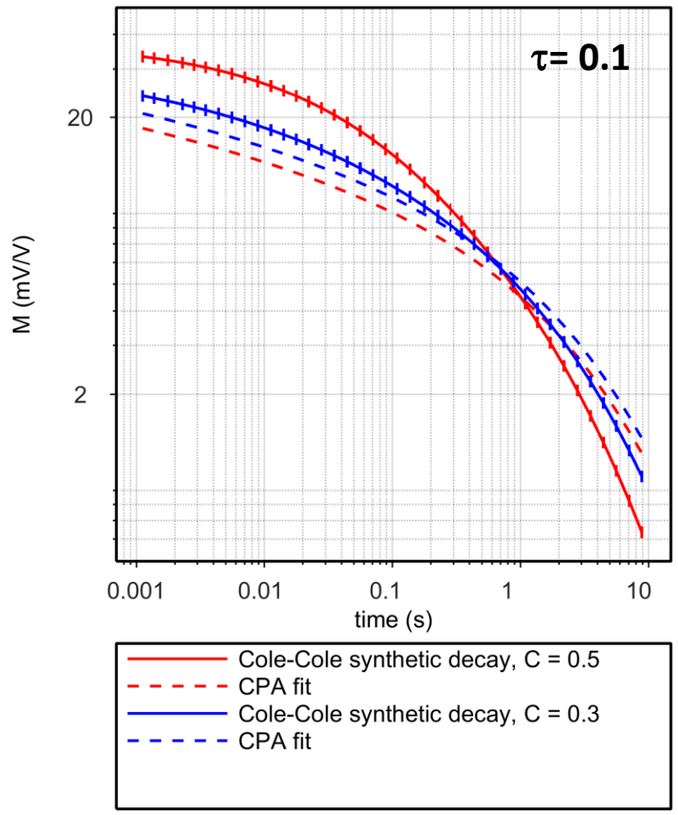

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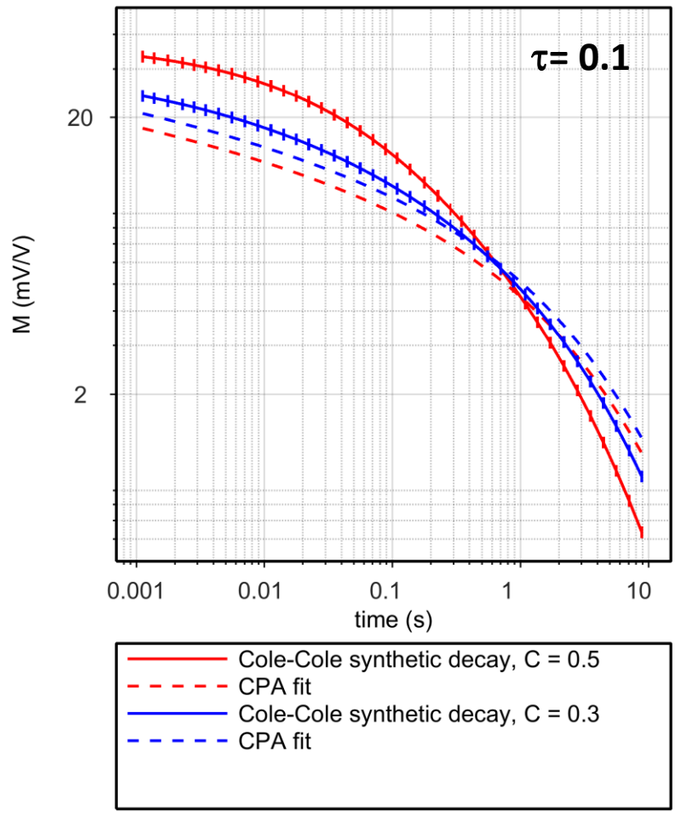

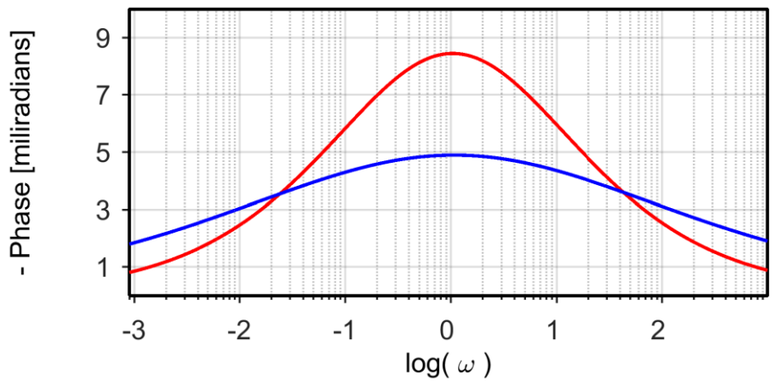

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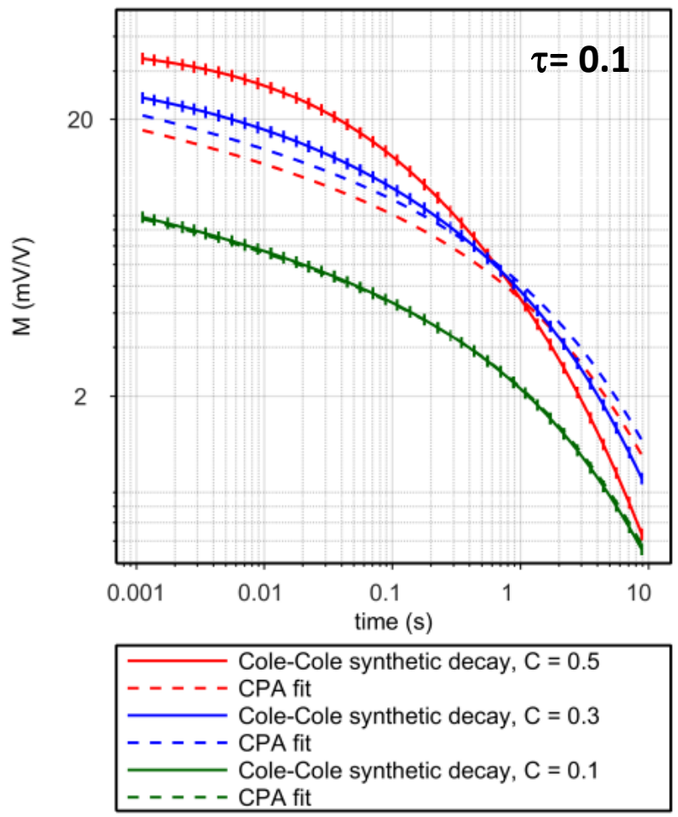
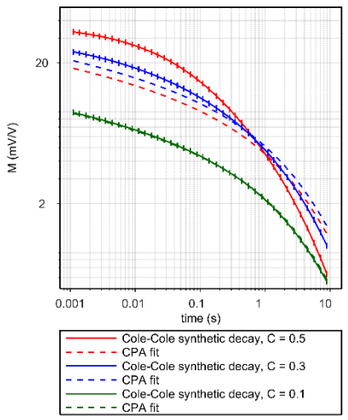


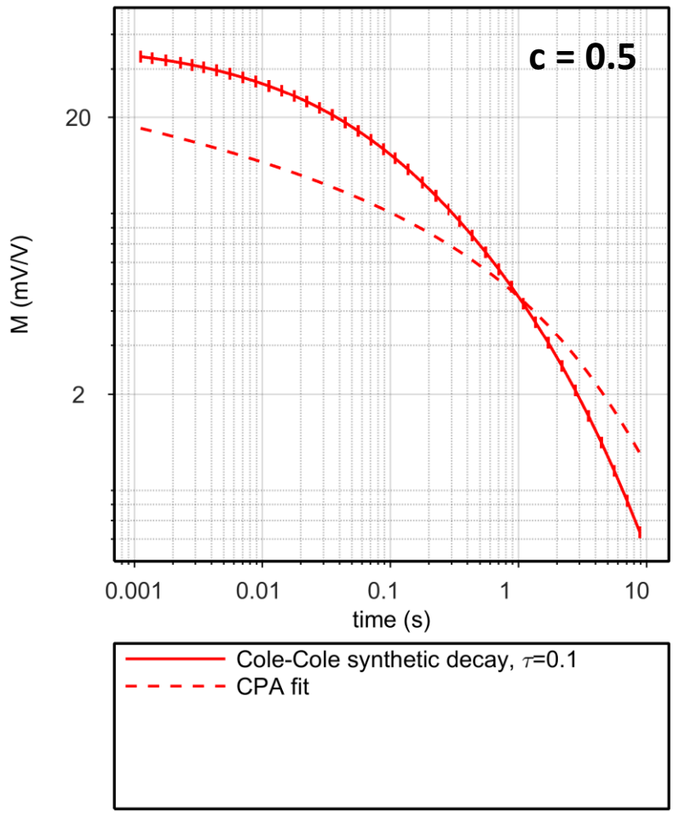
Synthetic tests : results

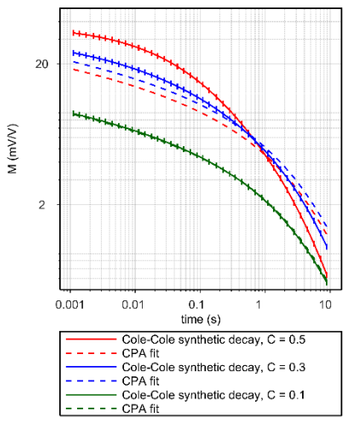
Small c values increase the similarity between the two models



Synthetic tests : results

Time constant τ





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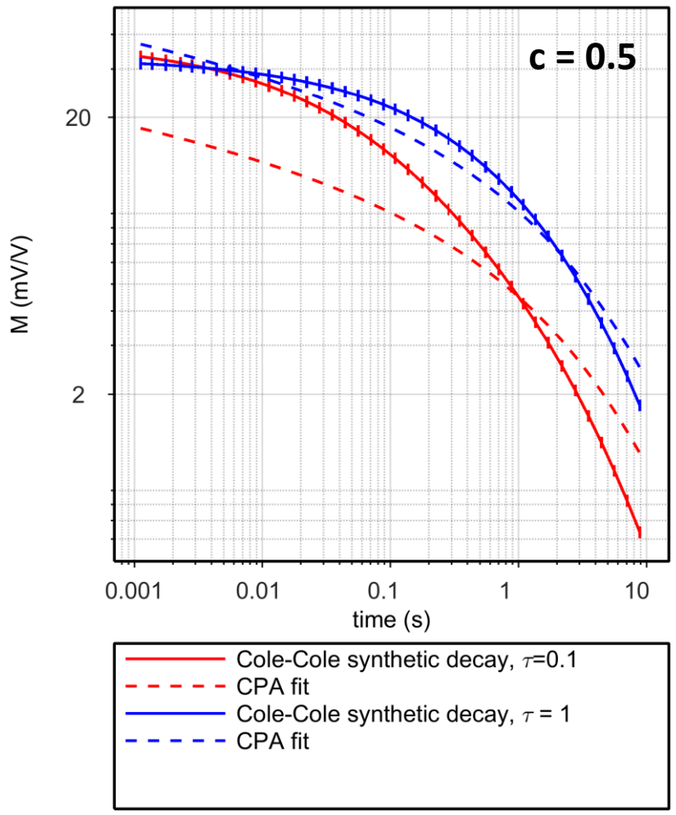

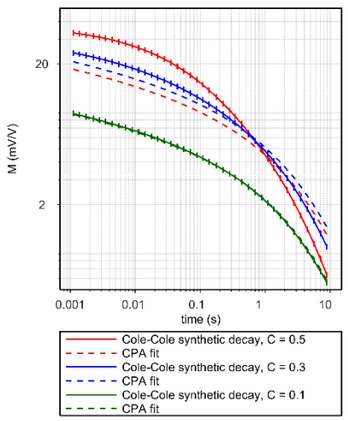

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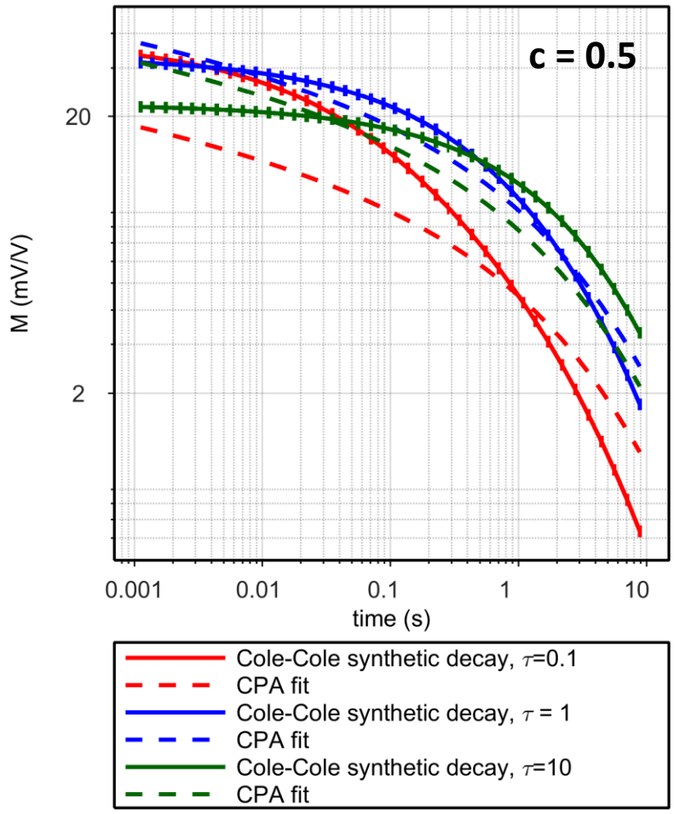

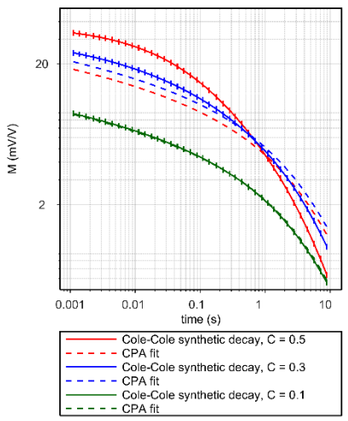

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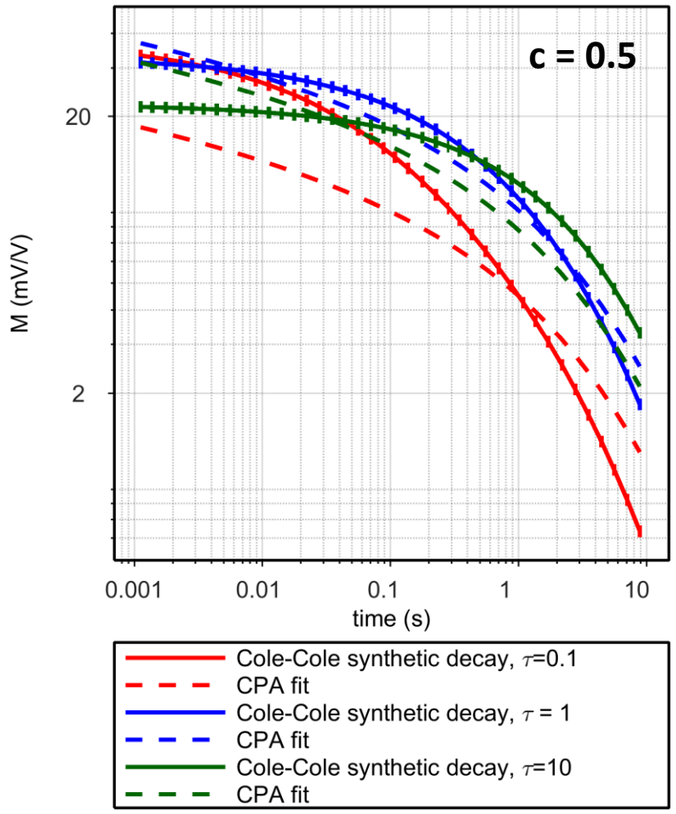
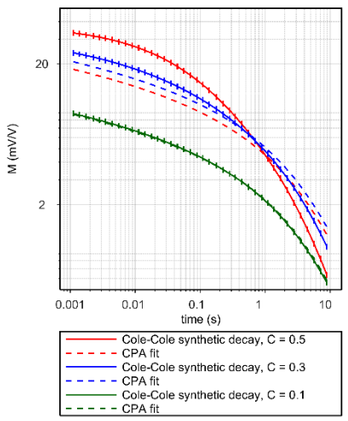
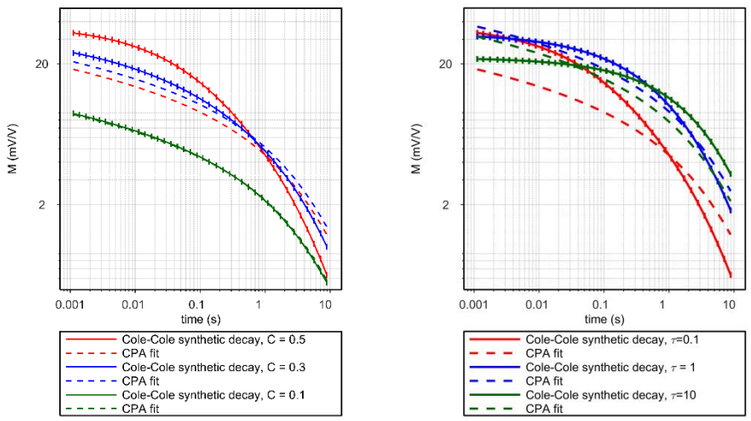




Synthetic tests : results

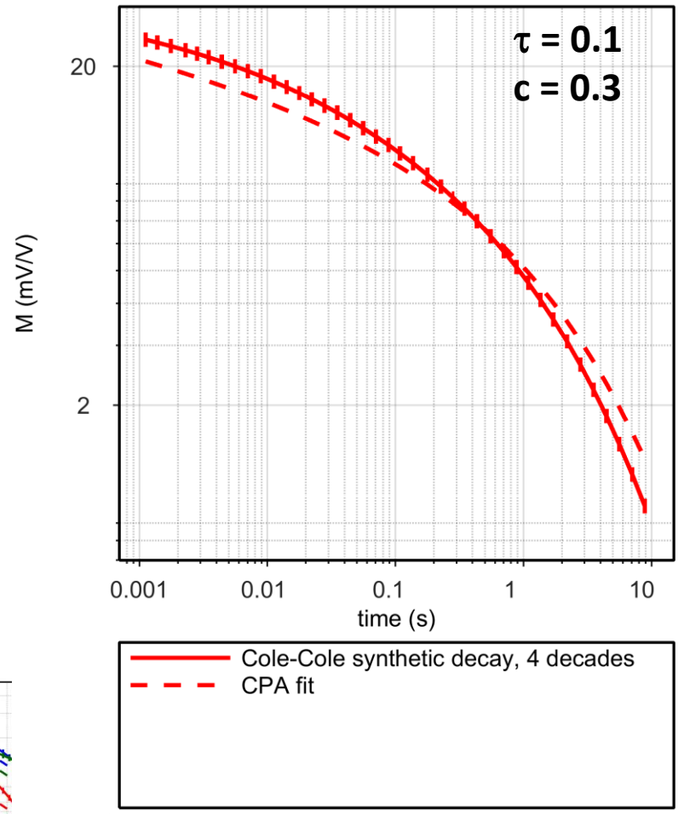
The role of τ depends highly on the acquisition time range

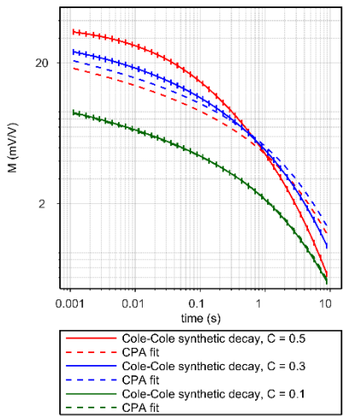
Small c values increase the similarity between the two models

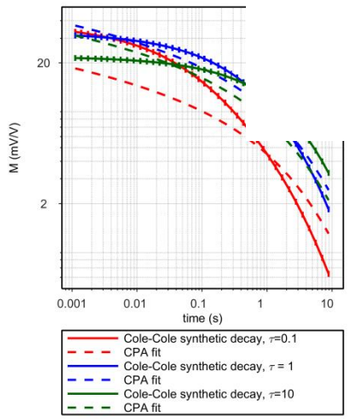


Synthetic tests : results

Length of the decay

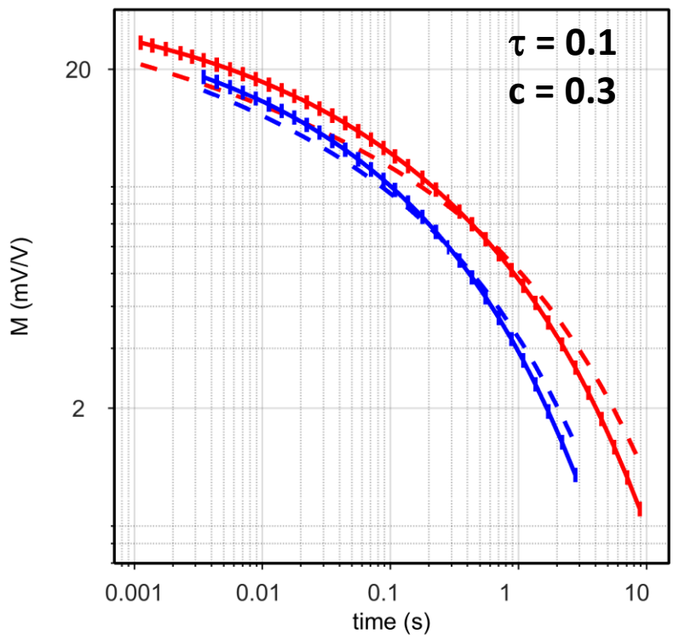


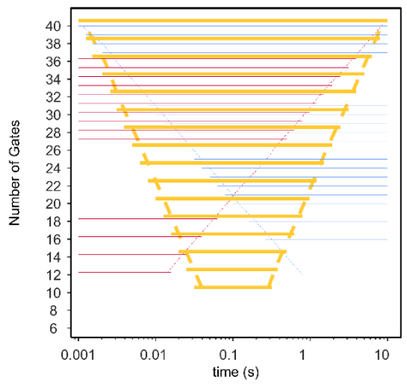


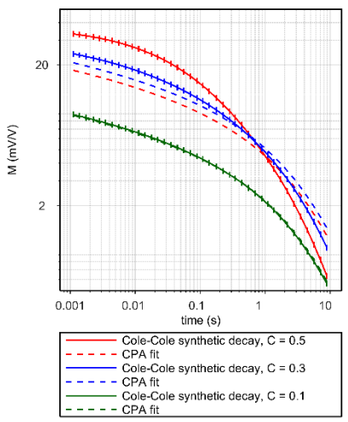


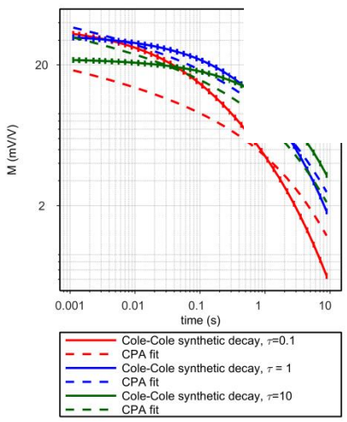
Synthetic tests : results

Length of the decay









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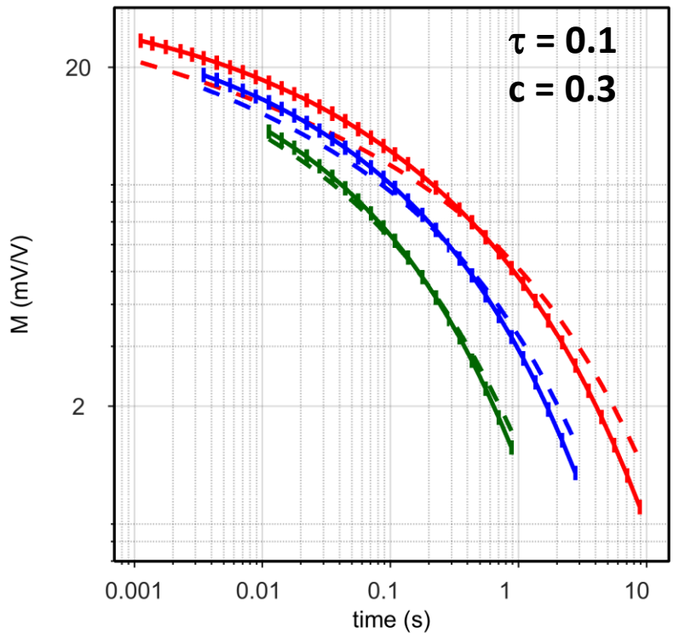
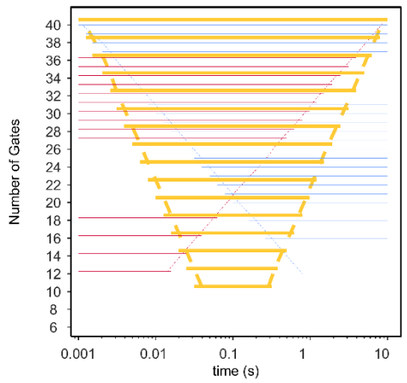
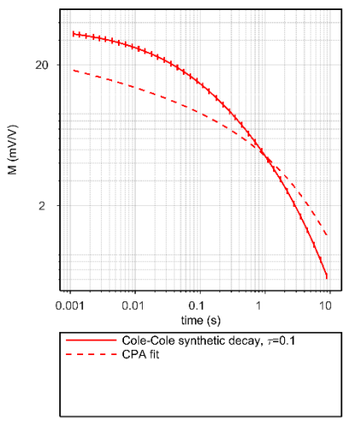
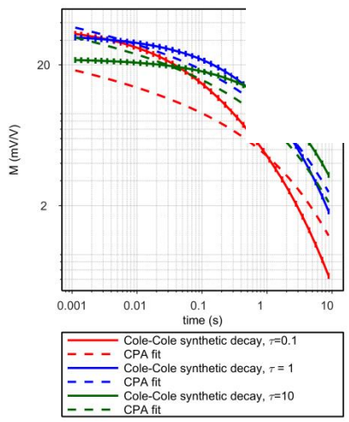






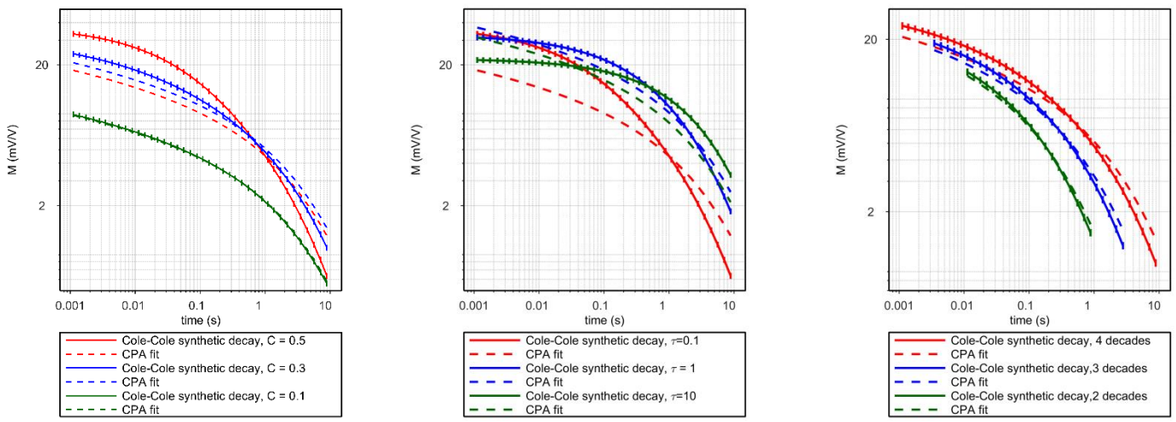


Synthetic tests : results

Two decades of data is a minimum to distinguish both models

The role of τ depends highly on the acquisition time range

Small c values increase the similarity between the two models



Synthetic tests : results

- Two decades of data is a minimum to distinguish both models
- **The shape of the CPA decays is ENTIRELY determined by the acquisition settings (current On-time and Off-time, stack…)**
- The role of τ depends highly on the acquisition time range
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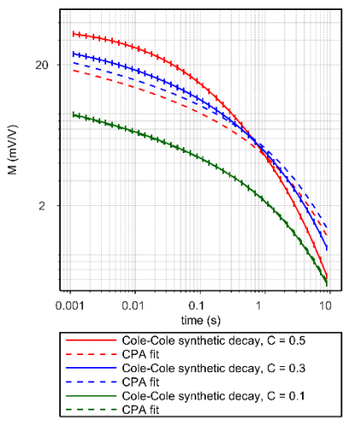
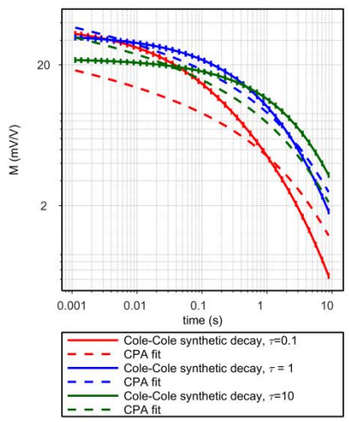
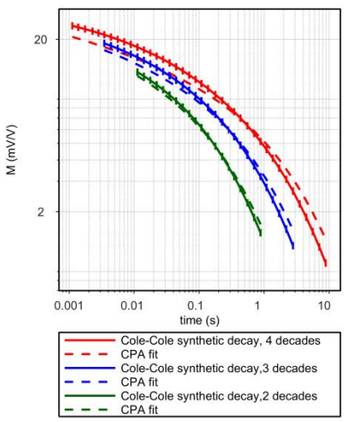
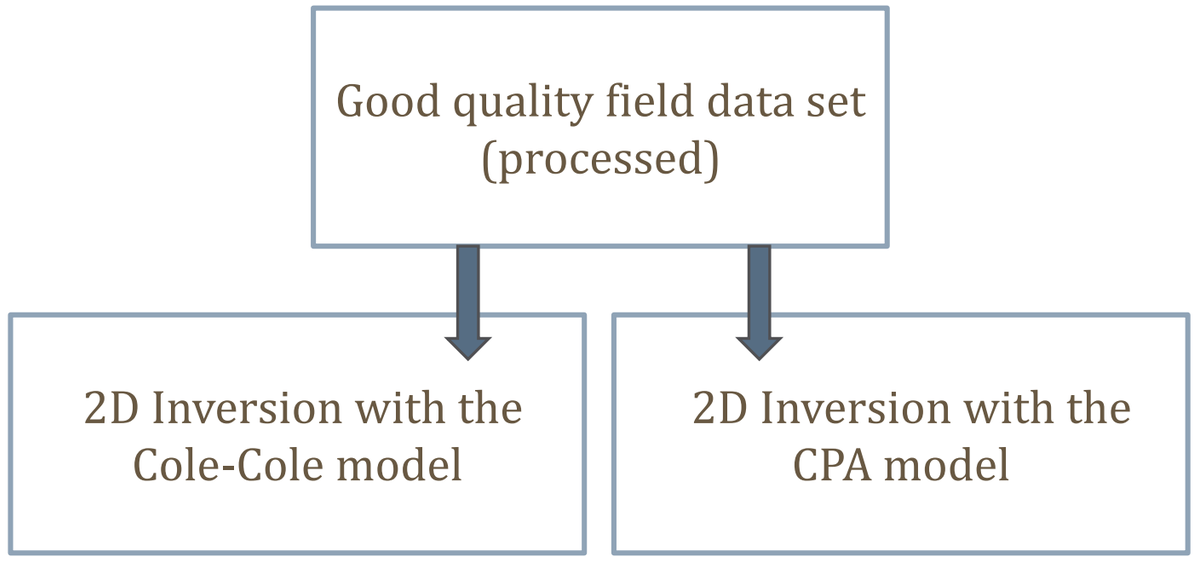




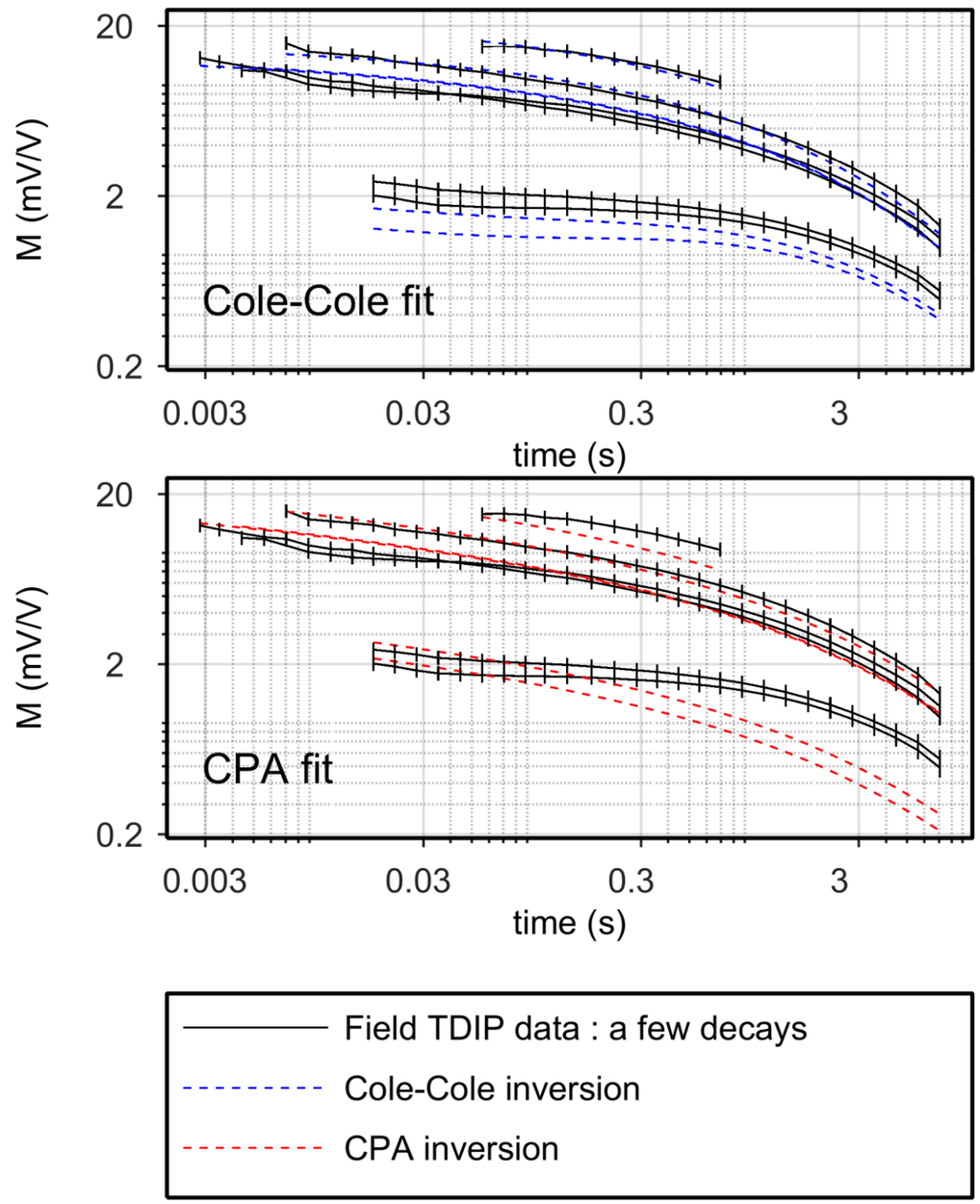


Content

1. Analytical descriptions of the induced polarization
   - Cole-Cole model
   - Constant Phase Angle (CPA) model
   - Ambiguity in time domain
2. Synthetic tests
3. **Comparison with field data**

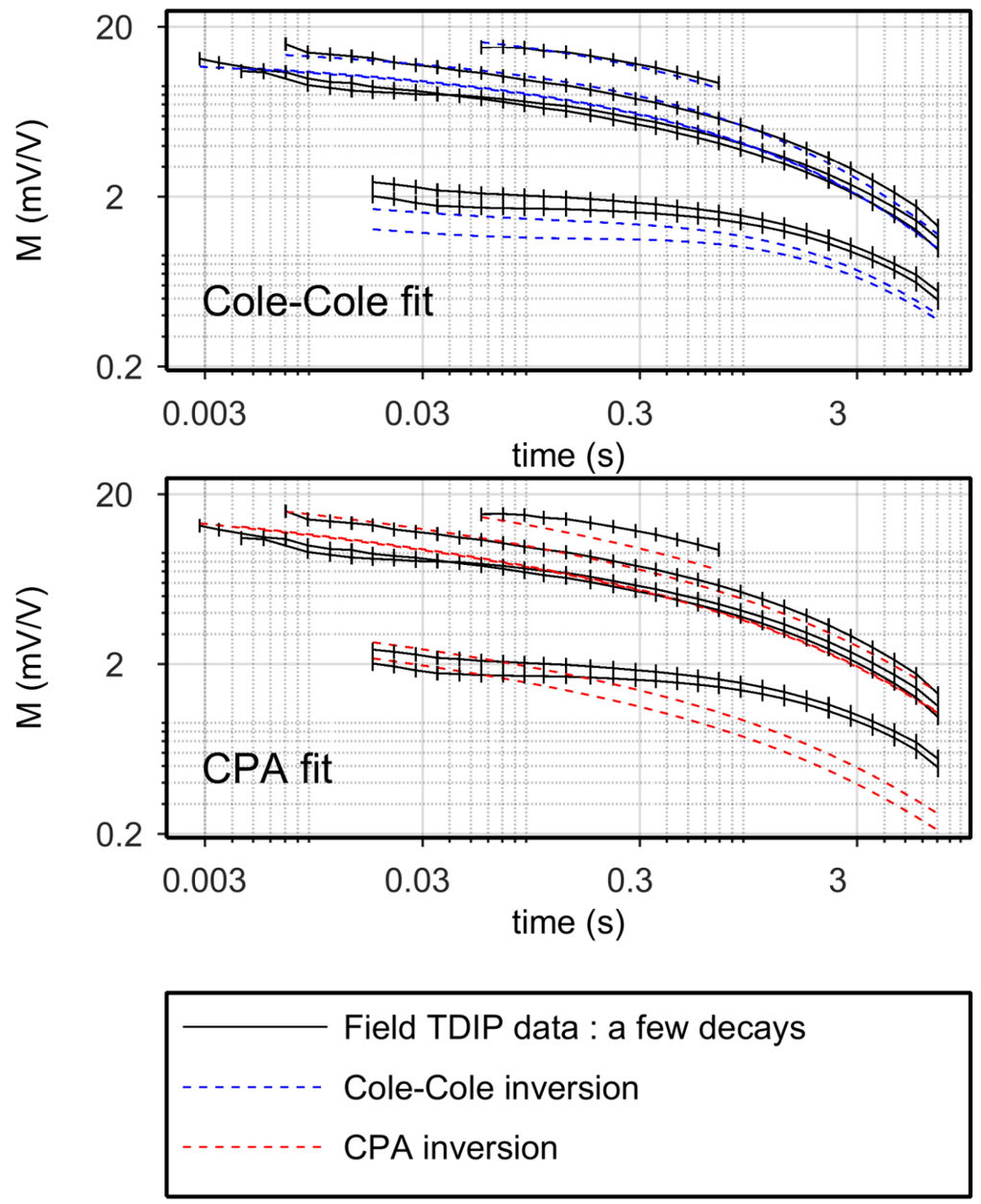


Field data – 2D comparison



Field data – 2D comparison

- 2D variations give complex shapes
- Cole-Cole : able to retrieve the complex shapes
- CPA : unable to retrieve the complex shapes



Field data – 2D comparison

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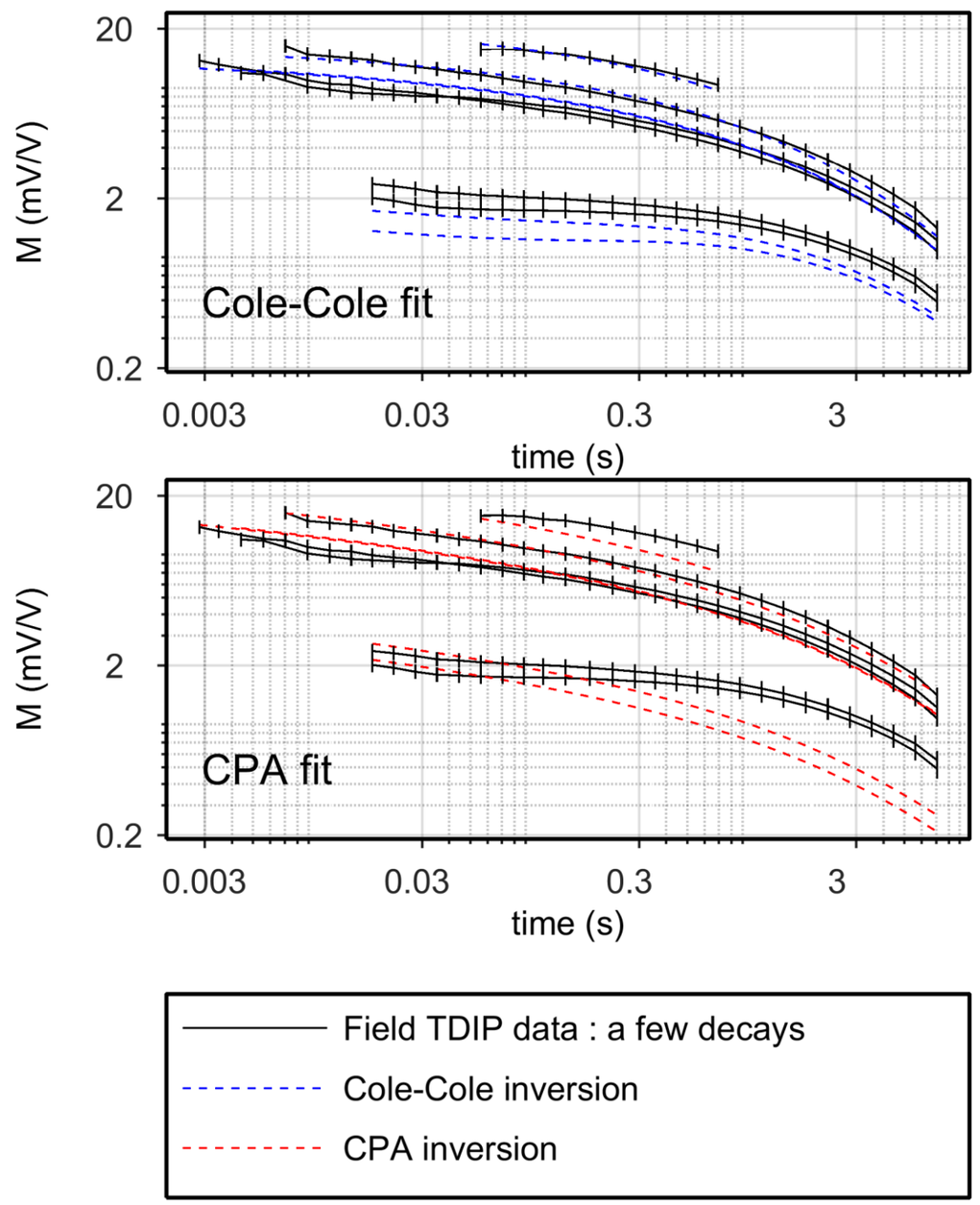
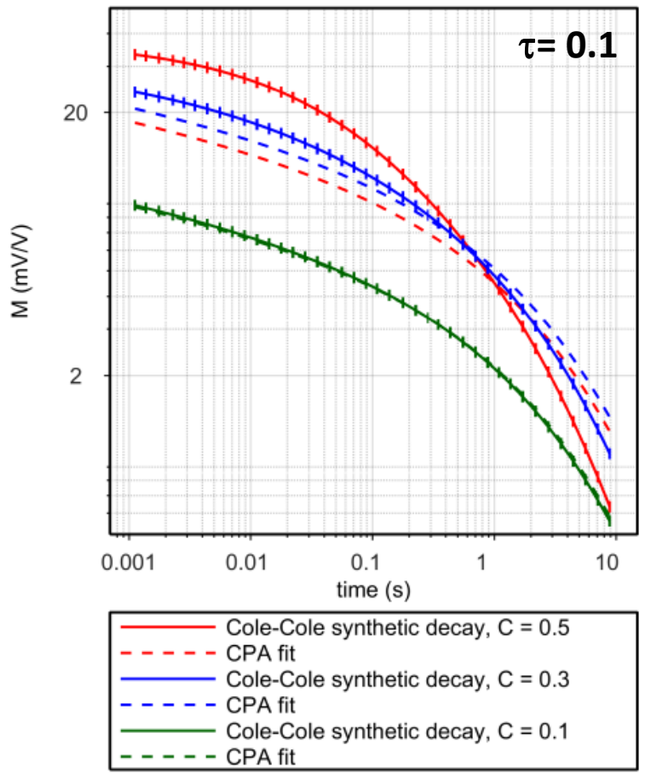
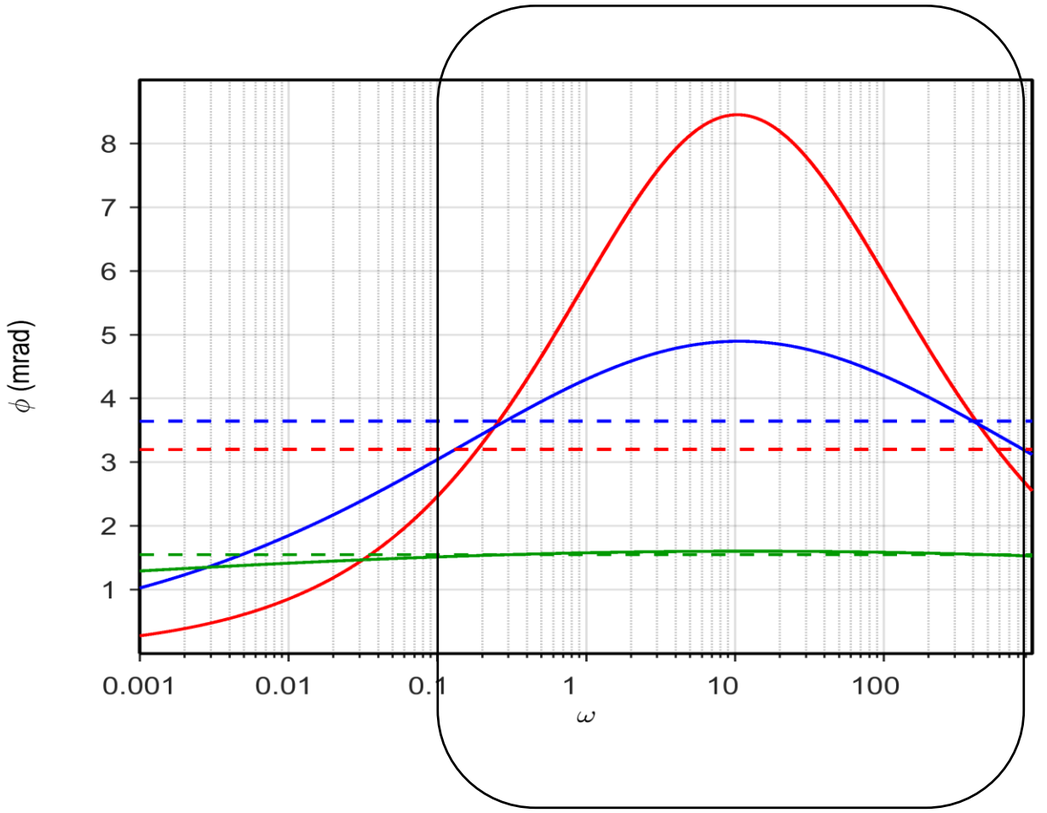
-> no variation of the shape of IP decays also in 2D



What about the phase ?





Conclusion

The distinctness depends highly on the acquisition time range :

	High c	Low c
More than 2 decades of time	Highly distinguishable	Not very distinguishable
Less than 2 decades of time	Not very distinguishable	Not distinguishable

Specific values for Tau and c increase the similarity between the 2 models

- low c
- Tau in the center of the logarithmic time range

2D field data can contain complex shapes that only the Cole-Cole model can fit.

In any case, the inverted phase shift is in very good agreement with the order of magnitude of the maximum phase shift.

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Thank you for your attention !