Optimal measurement parameters for accurate time-domain and spectral analyses of RTN

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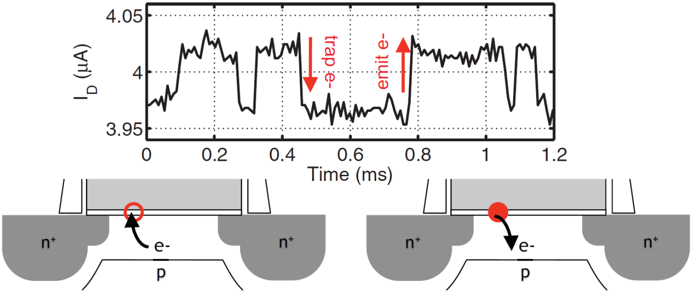
Outline

Random Telegraph Noise



Single-trap RTN and carrier trapping process. [Realov and Shepard (2013)].

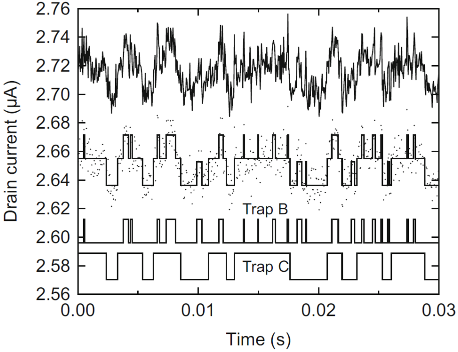
Defect-centric model:

$$\boxed{\text{One trap} \equiv \left\{ \Delta I_D \;,\; \bar{\tau}_c, \bar{\tau}_e \right\}}$$

electrical impact

mean capture and emission times

Time-Domain Analysis

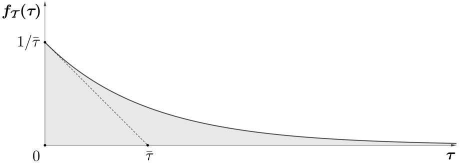


[Miki et al. (2012); Grasser (2014)].

Time-constant distribution (pdf):

$$f_{\mathcal{T}}(\tau) = \frac{1}{\bar{\tau}} \exp\left(-\frac{\tau}{\bar{\tau}}\right) \quad \forall \tau \geq 0,$$

and $\mathbb{E}\{\mathcal{T}\} \equiv \bar{\tau}$.



- How is the experimental pdf *truncated* by the digital measurement?
- Impact on the estimation of the mean time constants?
- Suitable choice of measurement parameters?

Digital measurement and miss rates

Real measurement apparatus can only acquire a finite number of samples

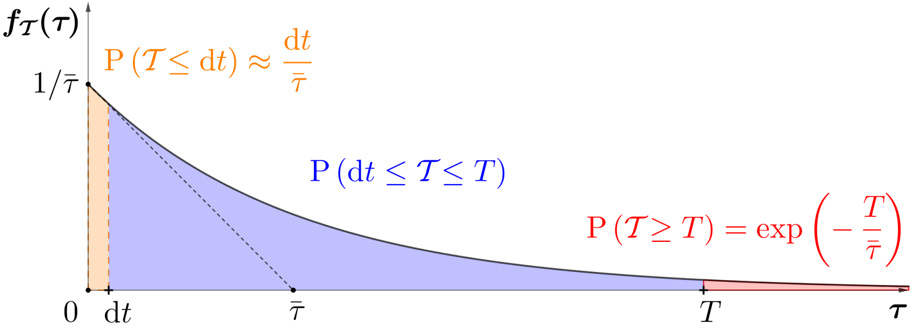
$$N_s = f_s \cdot T = \frac{T}{\mathrm{d}t}$$

$T \longrightarrow$ measurement period

$\mathrm{d}t \longrightarrow$ time step

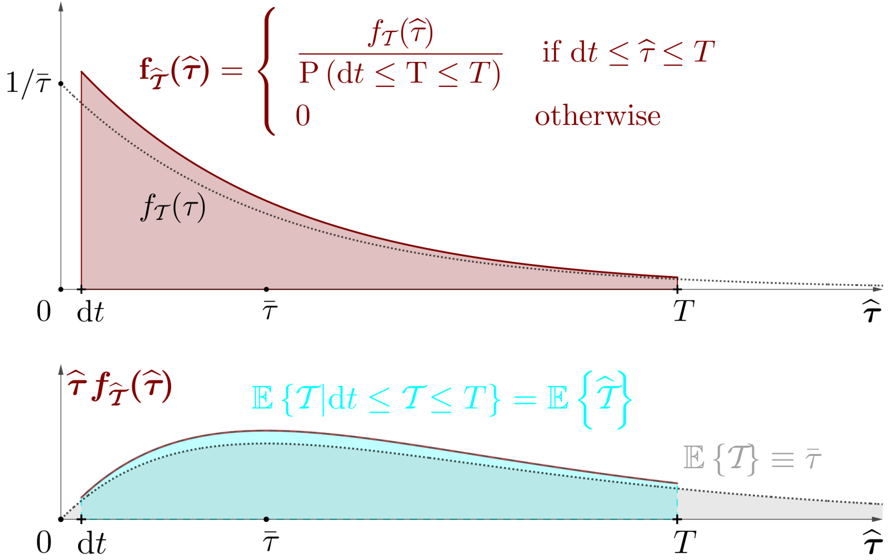
Hence, tough *tradeoff* between $\mathrm{d}t$ and T!

Short and long time-constant miss rates:



Impact on the estimation of the mean time constants

Observed random variable $\widehat{\mathcal{T}}$ has a *truncated distribution*:



Optimal measurement parameters

Imposing

- Sub-1% miss rates

$$\mathrm{P}\left(\mathcal{T} \leq \mathrm{d}t\right) \approx \frac{\mathrm{d}t}{\bar{\tau}} \leq 0.01 \text{ and } \mathrm{P}\left(\mathcal{T} \geq T\right) = \exp\left(-\frac{T}{\bar{\tau}}\right) \leq 0.01;$$

- Relative error on the mean time-constant smaller than 1%:

$$\mathbb{E}\left\{\widehat{\mathcal{T}}\right\} = \bar{\tau} \cdot \frac{\left(\frac{\mathrm{d}t}{\bar{\tau}} + 1\right) \exp\left(-\frac{\mathrm{d}t}{\bar{\tau}}\right) - \left(\frac{T}{\bar{\tau}} + 1\right) \exp\left(-\frac{T}{\bar{\tau}}\right)}{\exp\left(-\frac{\mathrm{d}t}{\bar{\tau}}\right) - \exp\left(-\frac{T}{\bar{\tau}}\right)}$$

$$\frac{\left|\bar{\tau} - \mathbb{E}\left\{\widehat{\mathcal{T}}\right\}\right|}{\bar{\tau}} \leq 1\%,$$

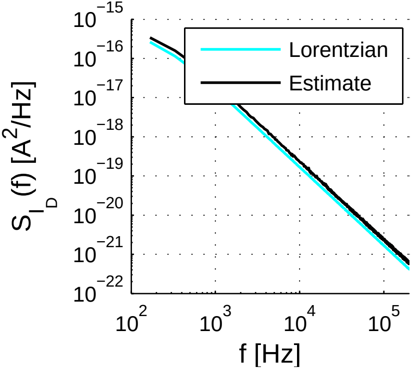
we suggest the following set

$$\boxed{\begin{aligned} \mathrm{d}t &\leq 0.01 \cdot \bar{\tau} \\ T &\geq 7 \cdot \bar{\tau} \end{aligned}}$$

Accurate spectral analysis: overview

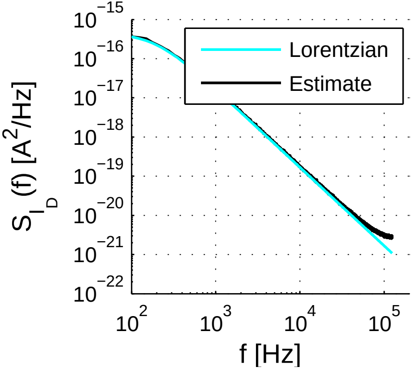
N_s is fixed: should we favour f_s or T?

$\boxed{T \sim \bar{\tau}}$



Error of $30 - 40\%$ on the PSD!

$\boxed{T \sim 7 \cdot \bar{\tau}}$



Almost unbiased estimate!

Theoretical support can be found in [Stoica et al. (2005)].

Further discussions

- Suitable number of traces;
- impact of the RTN symmetry; multi-trap case;
- requirements for accurate spectral analysis;
- convergent and systematic measurement methodology;
- *your questions and remarks?*

References I

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