Assessing instantaneous energy in the EEG: a non-negative, frequency-weighted energy operator

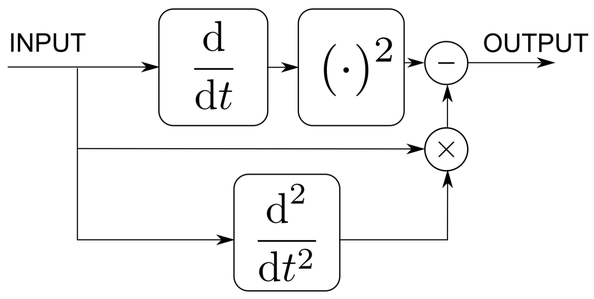
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

JM O' Toole, A Temko, NJ Stevenson
Neonatal Brain Research Group, Irish Centre for Fetal and Neonatal Translational Research, University College Cork, Ireland

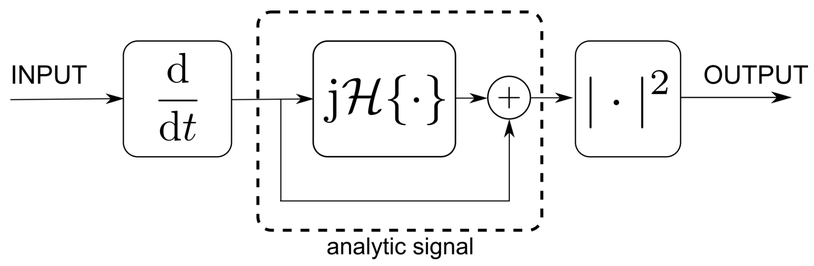
NEONATAL BRAIN RESEARCH GROUP

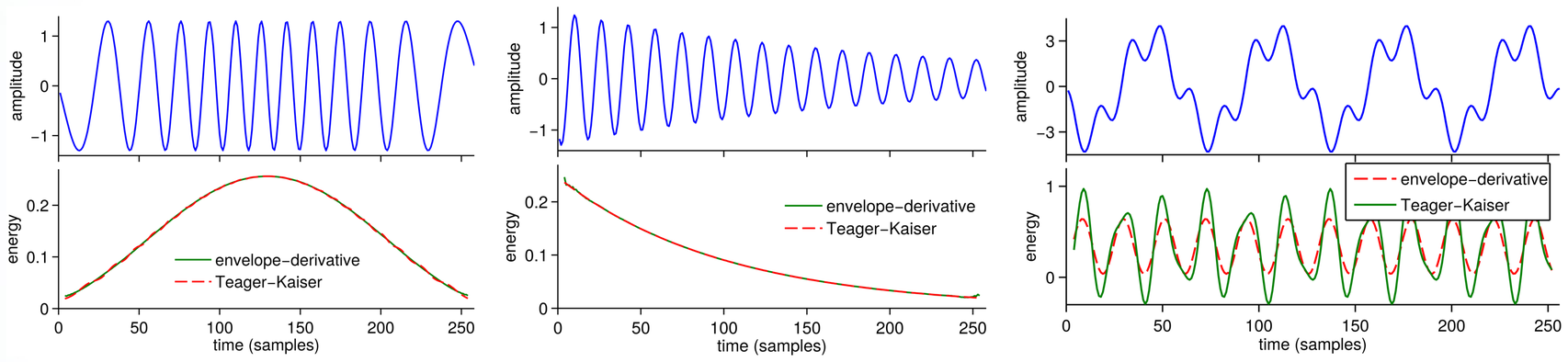
Frequency-Weighted Energy Measures

A: Teager–Kaiser (nonlinear energy operator) [1]



B: proposed: envelope–derivative operator



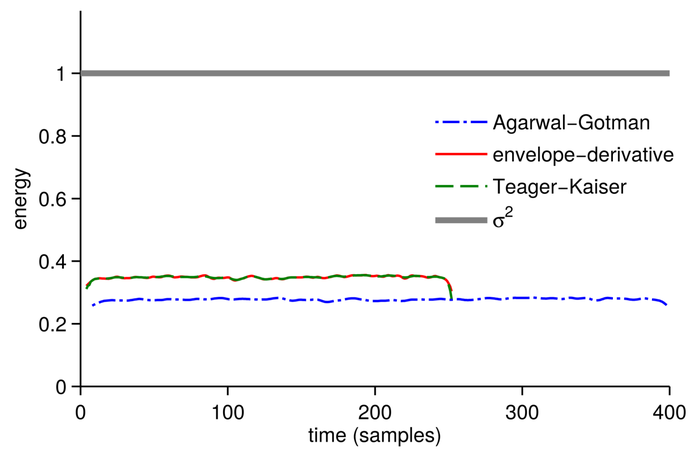


Two discrete definitions:

- Teager–Kaiser [1]
- Agarwal–Gotman, which is unbiased in white noise [3]

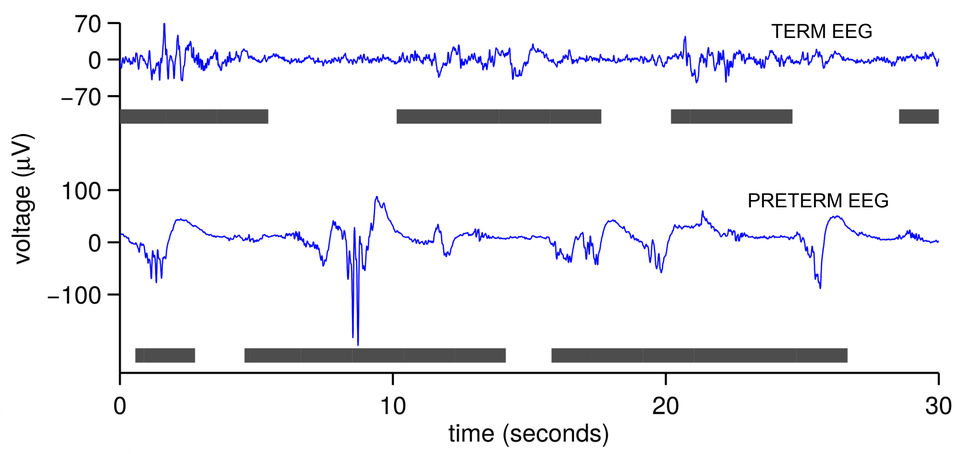
What we found:

- bias is small for coloured noise
- Agarwal–Gotman requires up-sampling of x6.33 (Teager–Kaiser x4)
- bias not important in detection problem

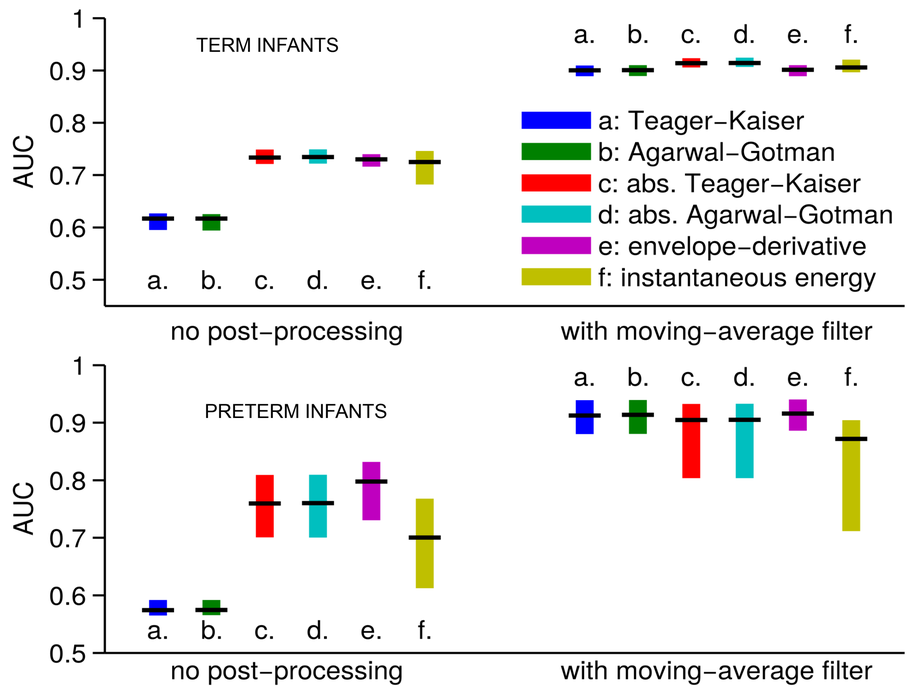


Detecting bursts in newborn EEG

- EEG recorded from10 premature infants and 10 full-term infants (recorded at Cork University Maternity Hospital, Ireland)
- 2 minute segments, annotated for burst (preterm data) and high-voltage activity (tracé alternant pattern, full-term data)
- post-processing with 1) absolute-value operator and 2) moving-average filter (1.5 seconds) [2]
- AUC (area under receiver operating characteristic curve) as performance measure
- questions for [2]:
  - why Agarwal–Gotman (and not Teager–Kaiser)? why absolute value? why low-pass filter?



Results



Conclusions

Detection Application:

- Teager–Kaiser and Agarwal–Gotman methods:
  - identical performance
  - poor performance without absolute value
- all methods similar after low-pass filtering
- amplitude-only measure is sufficient for term EEG (tracé alternant pattern)

Envelope-derivative Operator:

- non-negative
- simple interpretation (no second-order derivatives)
- disadvantage: Hilbert transform requires long duration (100+ samples) filter

MATLAB code and PDFs:
http://otoolej.github.io/code/nleo/

REFERENCES:

[1] J. F. Kaiser, "On a simple algorithm to calculate the `energy' of a signal," in Int. Conf. Acoustics, Speech, and Signal Process., ICASSP-90, 1990, pp. 381–384.

[2] K. Palmu, N. Stevenson, S. Wikström, L. Hellström-Westas, S. Vanhatalo, and J. M. Palva, "Optimization of an NLEO-based algorithm for automated detection of spontaneous activity transients in early preterm EEG.," Physiol. Meas., vol. 31, no. 11, pp. N85–93, Nov. 2010.

[3] R. Agarwal and J. Gotman, "Adaptive segmentation of electroencephalographic data using a nonlinear energy operator," in Proc. Int. Symp. Circuits and Systems (ISCAS-99), 1999, vol. IV, pp. 199–202.

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