

and the phase. So even if the frequency is slightly changing, this estimate will guide us through the calculations. This is unlike TEO where you are not sure about the real values of the frequencies.

The presented stochastic calculus based approach could be extended to the case that both the amplitude and phase are randomly changing. This and other issues are currently under investigation.

References:

- [1] IEEE Proceedings, Sept 1996, Special Issue on Instantaneous Frequency Estimation, Vol. 84, #9.
- [2] J. Van Zaen, 2012, Efficient Schemes for Adaptive Frequency Tracking and their Relevance for EEG and ECG, Ph. D. Dissertation, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE AUSANNE, Switzerland.
- [3] Q.H. Huang, J. Yang, Y. Zhou, 2008, "Bayesian nonstationary source separation, Neurocomputing, Vol. 71, pp. 1714–1729.
- [4] P. Maragos, J. Kaiser, T. Quatieri, 1992, "On separating amplitude from frequency modulations using energy operators", [Proceedings] ICASSP-92: 1992 IEEE International Conference on Acoustics, Speech, and Signal Processing.
- [5] S. Pal and B. Biswas, 2012, "On The Fundamental Aspects of Demodulation", Signal Processing: An International Journal (SPIJ), Volume (6) : Issue (3), pp. 86-96.
- [6] R. Guido, 2019, "Enhancing teager energy operator based on a novel and appealing concept: Signal mass", J. Franklin Institute, Vol. 356, pp. 2346-2352.
- [7] C. Kamath, 2014, "Automatic seizure detection based on Teager Energy Cepstrum and pattern recognition neural networks" , QScience Connect2014:1http://dx.doi.org/10.5339/connect.2014.1
- [8] D. Wehner, 1995, High Resolution Radar, Artech House, Mass, USA.
- [9] H. Van Trees, 1970, Detection, Estimation and Modulation Theory, Part III, John Wiley, NY.
- [10] B. Barkat, 2001, "Instantaneous Frequency Estimation of Nonlinear Frequency Modulated Signals in the Presence of Multiplicative and Additive Noise", IEEE Trans. Signal Processing, Vol. 49, #10, pp. 2214-2222.
- [11] M. Benidir, and A. Ouldali, 1999, "Polynomial Phase Signal Analysis Based on the Polynomial Derivatives Decomposition", IEEE Trans. Signal Processing, Vol. 47, #7, pp. 1954-1965.
- [12] S. Goto, M. Nakamura, and K. Uosaki, 1995, "On Line Spectral Estimation of Nonstationary Time Series Based on AR Model Parameter Estimation and Order Selection with a Forgetting Factor", IEEE Trans. Signal Processing, Vol. SP-43, #6, pp.1519-1522.
- [13] B. Boashash, 1992, "Estimating and Interpreting the Instantaneous Frequency of a signal", Proc. IEEE, Vol. 80, #4.
- [14] A. Abutaleb, 2013," The estimation of the instantaneous amplitudes of sum of sinusoids with unknown frequencies and phases: The martingale approach", Signal Processing, Vol. 93, #4, pp. 811-817.
- [15] A. Abutaleb, 2005a," Instantaneous Frequency Estimation When the Amplitude is a Stochastic Process Using Stochastic Calculus and Bootstrapping", Circuits, Systems and Signal processing, Volume 24, #1, pp 35–52.
- [16]A. Abutaleb, 2005b," Instantaneous Frequency Estimation Using Stochastic Calculus and Bootstrapping", EURASIP Journal on Applied Signal Processing, Vol. 12, pp. 1886–1901.
- [17] A. Abutaleb and M. Papaioannou, Introduction to the Stochastic Calculus and the Malliavin Calculus with Applications in Engineering and Finance, Forthcoming, 2023
- [18] A. Abutaleb, 1988," IMPROVEMENT IN ADAPTIVE NOISE CANCELING USING A NONLINEAR FILTER BASED ON THE PONTRYAGIN MINIMUM PRINCIPLE", Circuits, Systems and Signal processing, Volume 7, #1, pp 57–78.
- [19] S. Neftci, 2000, An Introduction to the Mathematics of Financial Derivatives, Academic Press, New York.