

**Ph.D. Training Opportunity & Stipend – starting fall 2008**

## **Spectral analysis of phase noise and frequency stability of oscillators**

proposed by  
Enrico Rubiola

FEMTO-ST Institute, Dept. of Time and Frequency  
CNRS et University of Franche Comté, Besançon, France  
e-mail: rubiola@femto-st.fr  
home page <http://rubiola.org>

**Subject.** Time and frequency have a privileged role in physics and applications because they are the most precisely measured physical quantities. The wrist watch, for example, is the only artifact accurate within  $10^{-5}$ – $10^{-6}$  at a cost affordable to all consumers. Atomic clocks exhibit the amazing accuracy of  $10^{-15}$ , and a stability better by a factor 10. Though the accuracy of  $10^{-15}$  relates only to fundamental physics and metrology, short term stability is a major concern in telecommunications, space applications and radars.

Traditionally, frequency stability is measured in the time domain and described using wavelet variances known as the Allan variance  $\sigma_y^2(\tau)$  and its modified versions. The variable  $\tau$  is the measurement time. The stability depends on the measurement time in the same way of a balance, which is less “precise” when the mass to be measured is very different from 1 kg.

The estimation of  $\sigma_y^2(\tau)$  and of its confidence is well documented in the literature available in the past 20 years. Conversely, the spectral analysis of oscillators is still an empirical domain, in which results are usually given as a raw power spectral density of the phase noise, i.e.,  $S_\varphi(f)$  or  $\mathcal{L}(f)$ . Analysis seldom goes beyond the identification of the interference from the mains power supply (50 or 60 Hz et harmonics) and the identification of two-three fundamental types of noise. This approach is no longer suitable to the needs of emerging technologies.

This is a new domain. Hence, the minimum target is not too high: to adapt established spectral-analysis methods to the oscillator and to identify the oscillator’s stochastic phenomena. Nonetheless, this is a great opportunity for a smart student, as he can innovate in the interpretation of the oscillator physics and in the measurement methods and achieve outstanding experimental results. A side branch is the improvement of the measurement accuracy, which is currently of 2 dB in primary laboratories. The bulk of the expected work is about the statistical analysis of phase noise spectra. Besides, the student will achieve a deep understanding of oscillators and of experimental techniques.

The student will be supervised by E. Rubiola (3/4), full professor, and by F. Vernotte (1/4), full professor and head of the Observatory of Besançon.

**University and laboratory.** Ph.D. scholarship is managed by the University of Franche Comté, Besançon, France. The work site is the Time and Frequency Dept. of the FEMTO-ST Institute, affiliated to the University of Franche

Comté, Besançon. This department, merging the laboratory of chronometry (LCEP) and the laboratory of physic and metrology of oscillators (LPMO), issues from the Laboratoire de l'Horloge Atomique, funded by the Nobel prize Alfred Kastler. The T&F Dept. is the world leader in the domain of the measurement of the oscillator noise. Besides, this department is the european leader in the domain of ultra-stable oscillators and chip-scale atomic clocks.

**Candidate profile.** The best student for this subject is fond to computer programming, calculus and signal processing, and eager to learn sophisticated experimental methods of electronics. He is motivated by the will of learning and by the investment on his future life. In the longer term, he would like to do applied research in academic institutions or industry, or high-tech engineering, preferably in international environment.

**Stipend and benefits.** The student will receive a stipend from the French ministry of education for three years, together with national *health insurance* and *retirement pension*. Amount and rules are stated by French law. As a short summary, the net stipend is of approximately 1300 Euros per month, after taking away taxes and mandatory subscription charges for health insurance and pension.

Candidates unaware of the French system should know that tuition fees are very small or zero, and that the stipend is generally sufficient for a modest yet quite reasonable life standard.

#### **Requirements for the stipend**

1. age 29 years max at 31 December 2008,
2. university degree “Master 2” (5 year university degree) or equivalent, obtained during the year 2008. The equivalence assessment is managed on site. A master obtained earlier than 2008 does not fit. On the other hand, a master that “will be obtained later in 2008” fits, if supported by an official letter.