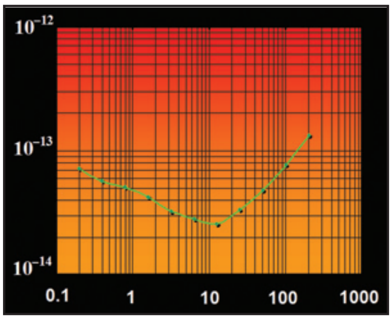
FURTHER READING
http://www.femto-st.fr/en/Joint-laboratories/LNE-FEMTO-ST/index.php

Page 1433
'Significant step in ultra-high stability quartz crystal oscillators',
P. Salzenstein, A. Kuna, L. Sojdr and J. Chauvin

The first significant reduction in the noise floor of quartz crystal oscillators for 15 years has been achieved by a European collaboration

dropping through the floor



ABOVE: Patrice Salzenstein and colleagues from the FEMTO-ST Institute, CNRS, have used recent advances in metrology to work as part of the European collaboration to measure and develop the BVA oscillator prototype
ABOVE RIGHT: The BVA oscillator prototype can reach a noise floor (Allan deviation) of 2.5×10^{-14} with an averaging time of 10 seconds

A quartz crystal oscillator that reduces the noise floor over commercial crystal oscillators by nearly an order of magnitude for the first time in 15 years has been demonstrated by collaborating researchers from the FEMTO-ST Institute, CNRS in France; the Academy of Sciences in the Czech Republic; and Oscilloquartz in Switzerland. The 5 MHz crystal double-oven prototype, which has a flicker frequency modulation (FFM) floor of 2.5×10^{-14}, opens the door to ultra-high stability oscillators for telecommunications, instrumentation and space applications.

Limiting factors

High-precision quartz crystal oscillators deliver a signal with a good spectral purity, and are mainly used in telecommunications where ultra stable signals are required. They are also used as ultra precise short-term references for scientific instruments and metrology applications, and in space applications such as the local oscillators in satellites. The noise of the oscillator is not limited by the electronics but by the crystal resonator and the short-term stability of quartz crystal oscillators is mainly sensitive to variations in temperature, humidity, pressure, acceleration, vibration and irradiation. One way to minimise these effects is to mount the oscillator in a temperature-controlled container, also known as an oven-controlled crystal oscillator. The long-term stability is mainly limited by the aging of the quartz crystal, and to improve this, a Boitiers à Vieillissement Amélioré (BVA) double oven-controlled oscillator can be used. In this configuration, electrodes are deposited on the inner sides of two capacitances made of adjacent pieces of the quartz forming a three layer structure with no stress between the electrodes and the piezoelectric vibrating element.

A more stable condition

There have been no significant changes in the noise floor of commercial oscillators for the last 15 years; the very best commercial quartz oscillators operate with a short-term frequency stability of 8×10^{-14}. Several studies have been conducted on quartz crystal oscillators to understand and reduce the noise of the resonator and its sensitivity to temperature, acceleration and irradiation. However, at this high level of stability minute details are important, which makes it very difficult to improve fabrication processes.

Despite facing these significant challenges, the researchers in the European collaboration firmly believed that there was still some way to go before they would physically reach the theoretical limits. By bringing together their knowledge and expertise they set out to design and measure state-of-the-art quartz crystal oscillators that operated beyond these limits. In 2007, Jacques Chauvin from Oscilloquartz in Switzerland began a new approach to the design of the BVA oscillator which considered all the aforementioned parameters, and optimised the packaging of the crystal, the double ovens and the electronic amplifying elements. Patrice Salzenstein and colleagues from the FEMTO-ST Institute in France then used recent advances in metrology to develop instrumentation that, with a noise floor of 9×10^{-15} at an averaging time of 1s, is sensitive enough to measure the phase noise of the resonators to enable them to select the best to be integrated into the BVA oscillator. Finally, the new prototype was measured with instrumentation developed with an even lower noise floor of 8×10^{-15} at 1s by Alexander Kuna at the Institute of Photonics and Electronics in Prague. With an FFM of 2.5×10^{-14}, the researchers have achieved the best frequency stability (in terms of Allan deviation) ever reported for a BVA oscillator. Several of these new BVA oscillators are expected to be available commercially from Oscilloquartz next spring.

Renewed interest

With these results, there is now a revival of interest to further develop the instrumentation associated with resonators and oscillators, particularly for space applications. Salzenstein's team at CNRS has support from the French Space Agency to develop the measurement benches for determining the phase noise of the resonators, and to study their limiting parameters. His team is also associated with the French National Metrology Institute which supports their work in designing new instruments. "We hope to see a new generation of commercial BVA quartz crystal oscillators with reproducible short-term stability better than 6×10^{-14} and to have some of them approaching 10^{-14}," said Salzenstein. "The recent results we obtained show that it was too early to 'bury' research into quartz and that it certainly has the potential to reach the level of 10^{-14}. With decades of experience in industry, the knowledge and reproducibility of the manufacturing processes of crystal oscillators is already there to allow the transfer of this research to production. There are, however, still more improvements that need to be made in the performance of the metrology to be able to measure the resonators and the oscillators at such levels."