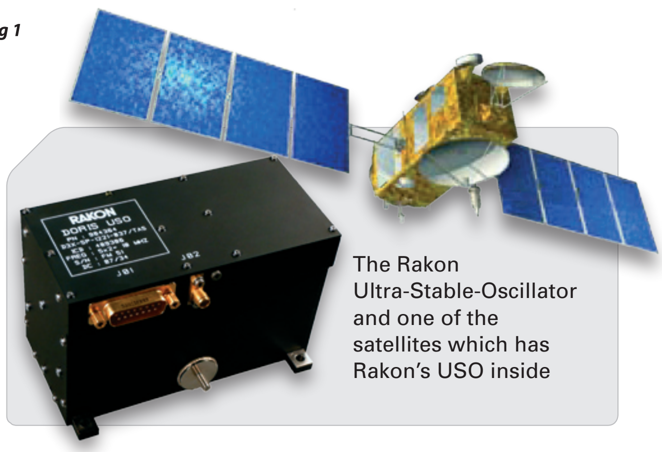
rakon

New 'State-of-the-Art' Thermal Sensitivity Achieved in Rakon's Ultra Stable Quartz Crystal Oscillator for Space Applications.*

In 2009 further research went into improving the thermal sensitivity of RAKON's space quartz crystal Ultra Stable Oscillator (USO). RAKON France (CEPE until 1998, C-MAC from 1998 to 2007, and RAKON since early 2007) has been working with CNES (the French Space Agency) to continuously improve performances of the Ultra-Stable OCXO (USO): OUS-NG[1-2]. Its frequency sensitivity has a strong influence on final performance of the DORIS system (Doppler Orbitography and Radio-positioning Integrated by Satellite, CNES system) which uses RAKON's OCXO. The DORIS system is used in satellites such as 'Jason', 'Spot5', 'Cryosat, 'Pleiades' 'Topex-Poseidon' and 'Altika'. Significant effort has been put into additional improvements, mostly with regards to the thermal performances and preparation of the new generation of a miniature USO. The quartz crystal oscillator has to be studied by taking a multi-physics approach. A part of this work has been conducted in a PhD thesis with the Femto-ST Institute and with support from CNES [3-4].

Fig 1

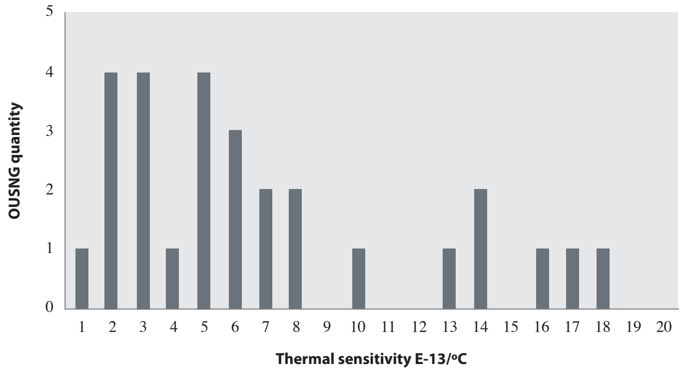


The Rakon Ultra-Stable-Oscillator and one of the satellites which has Rakon's USO inside

OUS-NG Thermal performances

To increase the resolution under the centimeter in the DORIS system, the main improvement required is to reduce the frequency thermal sensitivity of the USO. On figure 2, we present the statistical distribution of the relative frequency thermal sensitivity for OUSNG USO production. We can see a repartition with mean value at 7.10^{-13}/°C and standard deviation of 5.10^{-13}/°C. But for the new DORIS requirement, the frequency thermal sensitivity mean value must be reduced to 2.10^{-13}/°C and with a standard deviation of 3.10^{-14}/°C, which is state- of-the-art and leading in terms of space USO performance. At the beginning of the study, the usual tools used for the simulation (mechanical simulation and thermal simulation) seemed to not be sufficient in estimating and explaining the total frequency drift in temperature. So a full 3D thermo-mechanical simulation of the USO was conducted, with introduction of the piezo-electric phenomena of the resonator [3-8].

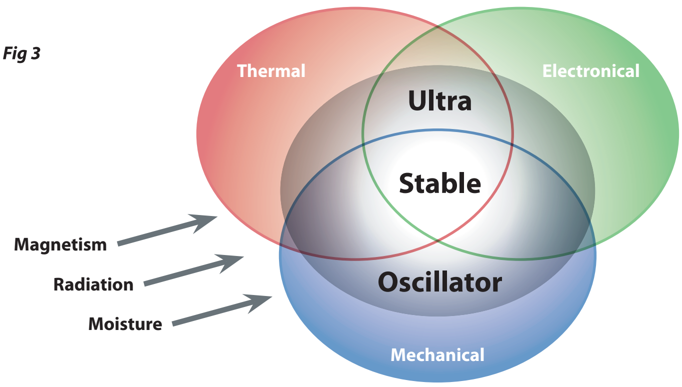
Fig 2 Statistical distribution of the relative frequency thermal sensitivity for the recently manufactured USOs (OUS-NG).



A Multi-physics Approach

The USO is a complex assembly of mechanical and electronic parts. Rakon's USO is a Double Oven Controlled Crystal Oscillator (D-OCXO) and the quartz crystal is very sensitive to temperature. So an important part of the USO is dedicated to building very stable thermal operating conditions for the quartz crystal. Figure 3 shows a possible approach to studying the USO. Each part has to be studied as an independent item at the first step; then they have to be optimized with mutual interactions between 2 items at the second step, then the three items studied together to reach the ultimate performance.

Fig 3



A way to see the different parts of a USO

* From a presentation at the 24th EFTF at ESTEC (Noordwijk, NL) from the 13th to 15th April 2010 by Luc Schneller, Patrice Canzian and Vincent Candelier from Rakon, Serge Galliou from Femto-ST and Gilles Cibiel from CNES

Thermal effect in the Rakon USO

The requirement of thermal controlled precision is conducted to a thermal structure with a Dewar vessel.
Then to meet space requirements, a mechanical structure has been designed to provide resistance to space conditions. Once combined, these two structures conduct to impose a temperature distribution on the resonator illustrated by figure 4. The resonator used in Rakon's USO is a quartz crystal with a QAS structure [3].

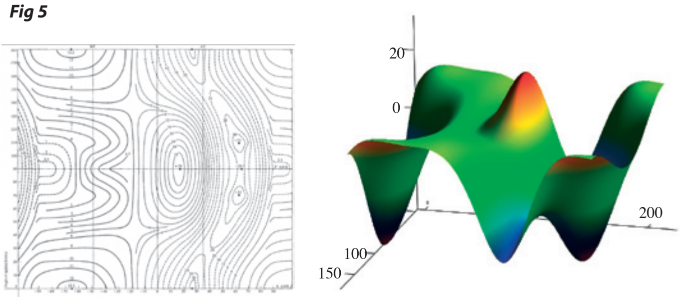
Fig 4

The distribution temperature on the resonator structure due to the USO thermal structure, the resonator is a QAS mounted in a HC40 package.
(From blue to red, difference of temperature is within less than 1.10^{-3}°C)

New tool to study the USO

To better evaluate the mechanical impact of the structure on the crystal resonator, a simple thermal study is not good enough. A new tool using a well known quartz theory [6-8] has been developed. To verify its precision, a comparison has been made with the experimental results of Ratajski [9] and this tool. Figure 5 shows the related results. The graphs show there is a good correlation between the experimentation and the simulation.

Fig 5



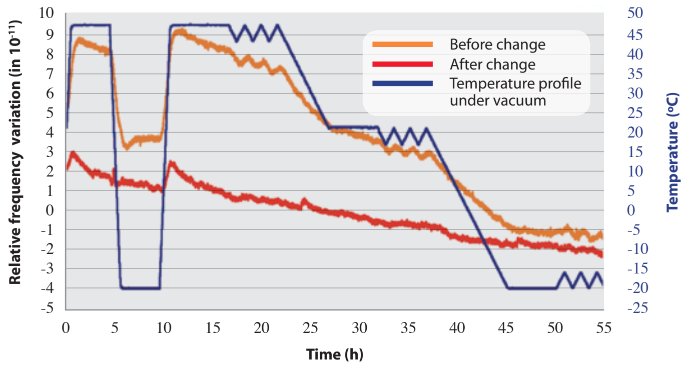
The comparison of experimental and simulation determination of the Ratajski Force-Frequency coefficient (in 10^{-15}msN^{-1}). The left figure is from Ratajski publication [9], the right is obtained by simulation with the new tool.

Results

Work carried out using the different approaches on the possible interactions of the various parts of the USO, was conducted to make significant progress in understanding the restrictive phenomenon. A USO modification has been made to minimise this phenomenon which (with regard to thermal sensitivity), has enabled the best performance achievable from a USO: 5.10-14/°C on Rakon's USO. Figure 6 provides evidence of these results.

Fig 6

Frequency drift during DORIS thermal vacuum testing of the Rakon USO



Conclusion

The results obtained from this study show a significant improvement in the comprehension of one restrictive multi-physics phenomenon. The new performance achieved of 5.10^{-14}/°C, is the best performance achieved by any space USO globally. This is a great development prior to Rakon beginning the next stage of downsizing the USO structure.

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