Thesis proposal

Title: Investigation on the noise origins of bulk acoustic wave resonators and the application to the pure synthetic material like $GaPO_4$, LGS and LGT.

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Candidate profile: Physics or Engineering Science master with solid-state physic and materials knowledge.
Description:
Space applications of precise location/altimetry, navigation and science require better frequency stabilities and higher spectral purities, to achieve the objectives. Frequency stabilities are required for both ultra-stable oscillators (USO) using quartz crystal and atomic clocks in which the quartz crystal gives the limitation of stability in the short term domain. In each case, it is necessary to have a very low noise oscillator, and for that we should select and control the noise sources of crystal resonators. There are still noticeable side effects, whose causes are now clearly attributed to the resonator but not explicitly, and that remain harmful to the performances of USOs. Other synthetic materials like gallium orthophosphate ($GaPO_4$) and langatate family (LGT, LGS, …) shown their potentialities in such field applications. Today, model and study of intrinsic resonator noise of these materials are completely unknown.
A first CNES project led to build a high performance measurement system of crystal resonator noise (working at 5 and 10 MHz, the usual reference frequencies). A second project is currently intended to open the field of powerful experimental investigations in collaboration with leading European manufacturers of bulk acoustic wave resonators (ARélectronique, Oscilloquartz, Rakon, Temex). However, it is necessary to supplement this approach from a more fundamental point of view.
The doctoral objective will be focused on finding the origins of ultra-stable resonator noise from the analysis of experimental data. A comparison between pure synthetic materials and quartz crystal should be investigated. It will be done trough different theoretical methods (molecular dynamics, continuum mechanics, …)
A preliminary literature review, commented on the current state of knowledge regarding the noise of resonators and their manufacturing technologies, will be carried out.
Particular attention will be paid to the inventory of technological limitations and physical mechanisms that might be causing the observed noise.
The study will produce an experiment plan to identify the causes of resonator noise. This plan will involve:

- Materials (growing, macroscopic and microscopic defects, …),
- Different kinds of resonator and manufacturing technologies (cutting, vibration modes, electrical coupling, energy trapping technique, surface state …)
- Thermal and mechanical environment, …

The measurement campaigns, engaged in R&T projects, will feed and allow the validation of the assumptions made on the influential parameters of resonators. The determination of the influence of the quartz crystal parametric transfer function (R, L, C and C_0 model) should be possible with these measurements, as well as the development of a practical model according to the parameters controlled by the manufacturing process.