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AGEN

Atomic Gyroscope for Enhanced Navigation

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Publishable Summary I

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1 Summary description of project context and objectives

Aircraft navigation and safety in the absence of GPS/Galileo signals can be improved by higher performances Inertial Measurement Units (IMU) and thus by higher performances gyroscopes. The “Atomic Gyroscope for Enhanced Navigation (AGEN)” project aims at showing the feasibility of the development of such an inertial grade gyroscope for aircraft navigation and delivering higher performances than Ring Laser Gyroscopes while having small dimensions and power consumption.

Atom (atomic) gyroscopes hold the promise of reaching even better performances, but their state of development is presently in the “research” stage and user’s requirements in terms of size, power consumption, cost and performances will be analyzed and targeted. Such a development may open up new application fields such as unmanned commercial flight, enhanced navigation for Unmanned Aerial Vehicles (UAVs), enhanced marine, sub-marine and Unmanned Surface Vehicle navigation. A conceptual design will be performed, allowing the trade-off between various concepts. Laboratory tests will be restrained to validating the gas cell, the heart of an atomic gyroscope, showing the feasibility of such a concept. This development will bring redundancy and will enhance the robustness of guiding systems relying on Galileo.

2 Description of work performed and main results

In the first year, the project was focused on identification of end user requirements and establishing a conceptual design supported by extensive modelling.

The system specifications was derived based on a market study, application analysis and user requirements. From the investigation of application reference scenarios, the most demanding applications are in Unmanned Aerial Vehicle (UAV) systems and applications in aircraft with no regulatory need requiring the use of a gyroscope such as Very Light Aircraft (VLA), or small rotocraft. These form the basis for the definition of the reference requirements of the system, defining the AGEN gyroscope’s technical characteristics and operation modes at system level.

A state of the art on atomic gyroscopes has been analysed, identifying two main approaches: Nuclear Magnetic Resonance (NMR) gyroscope and Atomic Spin Gyroscope (ASG) based on co-magnetometer. Their key performances, limitations and advantages were compared to the end-user requirements. These activities were concluded by a trade-off that triggered the conceptual design.

Based on specifications of and on the review of the state of the art, project has designed the architecture and key components of the atomic gyroscope. Supported by rigorous theoretical modelling, the scope of the conceptual design has covered study of various architectures, according to the number of gas cells and detection methods. The design of micro-fabricated gas cells are proposed so as to minimize magnetic field gradients and keep very small physics package. A signal and error model of the gyro has been established for conceptual design of control loops, paying special attention to the Fourier frequency bandwidth of the angular rotation rate spectrum. It has allowed us to predict main parameters of the physics package, identify main test points and specific test bench that will be addressed in the experimental testing part in the second year of the project. In what follows, it will be further extended to comprehensive noise model and will be used to optimize cell filling gas composition and pressure.

Conceptual electronics design have identified main interfaces, units and partition of the control loops between H/W and S/W implementation.

3 Expected final results and potential impacts

Atomic spin gyroscopes prototypes (ASG's) using nuclear spin angular momentum (NSAM) for rotation measurements were first developed in the 1980's by the firms Singer and Litton, replacing mechanical rotors by atomic spins. Although both designs have reached navigation grade performances, their weak point was the requirement of a stable and homogeneous magnetic field. This put stringent constraints to the design of shielding and magnetic field coils, leading to large and expensive devices.

The recent development of micro fabrication technology for chip scale atomic sensors, such as atomic clocks and atomic magnetometers means that the chip-scale atomic spin gyroscope (ASG) based on NMR will reach navigation grade precision in the near future. The most advanced demonstrated prototype approaching the final product is built by Northrop Grumman Corporation from US. Researchers and engineers form China has demonstrated and alternative approach utilizing Spin-Exchange Relaxation Free regime.

The rotation measurement sensitivity and stability reached by these ASG's is either similar to or better than that of Fibre Optic Gyroscopes (FOGs), but in a much smaller package, so in terms of Size, Weight and Power (SWaP), there is a step change with respect to the present generation of FOG aircraft navigation gyroscopes. This will enable ASG's to be introduced on smaller size aircraft, as well as using multiple ASG's on large aircraft to provide significant redundancy, ensuring safety when easily disturbed GPS signals become problematic or simply unavailable.

An analysis of exiting demonstrators and prototypes all over the globe has revealed an issue related to the Fourier frequency bandwidth of the angular rotation rate spectrum. AGEN concept is free of this drawback. If the project successful, Europe may recapture a supremacy in the field of ASGs.

4 Project public website

The project website is available for the public access at the following address:

http://agen.tekever.com/

Sections concerning project members' publications, project highlights and related events are regularly updated.