Indian Rubidium Atomic Frequency Standard (iRAFS) Development for Satellite Navigation

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Navigation is an indispensable part of everyday human life. In recent times, satellite based navigation system has proven to be indispensable in various navigation and scientific applications [1]. The *backbone* of satellite based navigation systems is very precise and highly stable atomic clocks. Satellite-based and ground-based clocks formulate the complete operability of a navigation system. The satellite-based clocks fall under the category of portable and space qualified atomic frequency standards. For the applications that demand to address the issues of performance, portability, reliability, cost, weight, volume and power consumption, the Rubidium Atomic Frequency Standards (RAFS) are advantageous over other kinds of clocks [2, 3]. These characteristics makes it is a suitable candidate for portable and onboard navigation payload applications such as Global Navigation Satellite Systems (GNSS). At the Space Applications Centre, we are indigenously designing and developing the RAFS for Navigation with Indian Constellation (NavIC) [previously known as Indian Regional Navigation Satellite System (IRNSS)].

Rubidium (Rb) clock is a *vapor cell* based time and frequency standard. Rb lamp and cell are the critical components of the clock Physics Package (PP). Therefore, a good control and precision in these components is essential in order to achieve the performances needed for space RAFS. The characteristic of RAFS depends on Rb lamp *bulb,* absorption Rb *cell*, microwave cavity, magnetic field control, temperature control units and 6.8GHz microwave synthesizer. The required RAFS' stability performances for NavIC is $<5x10^{-12}$ $\tau^{-1/2}$ (short-term), reaching the levels down to $<5x10^{-14}$ at 10,000s and drift of $<5x10^{-13}$/day. The in-depth characterization and studies of each subsystem of the RAFS will be crucial to meticulously address the questions of onboard clock's operational lifetime of 10 to 15 years. Particularly, the Rb bulb life-tests are crucial to meet the life expectancy targets. The bulbs and cells should also sustain the mechanical launch vibrations and operate more than 10-year life in the space environment.

Presently, we have achieved a stage where we have demonstrated the Design Verification Model (DVM) of indigenous RAFS. A dedicated laboratory facility for these clocks' development has also been established. Further, we are gearing up towards the Qualification Model (QM) and Fight Model (FM) clocks for the next series of NavIC satellites. This talk will address the development of IRAFS, covering the initial prototype model and subsequent flight versions that are being developed for NavIC.

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