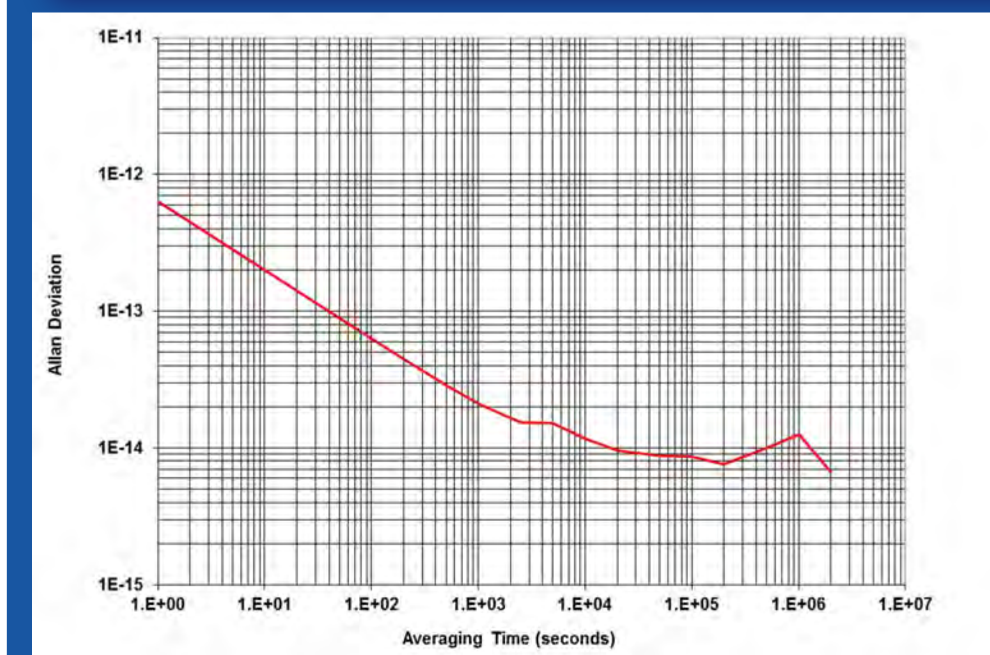
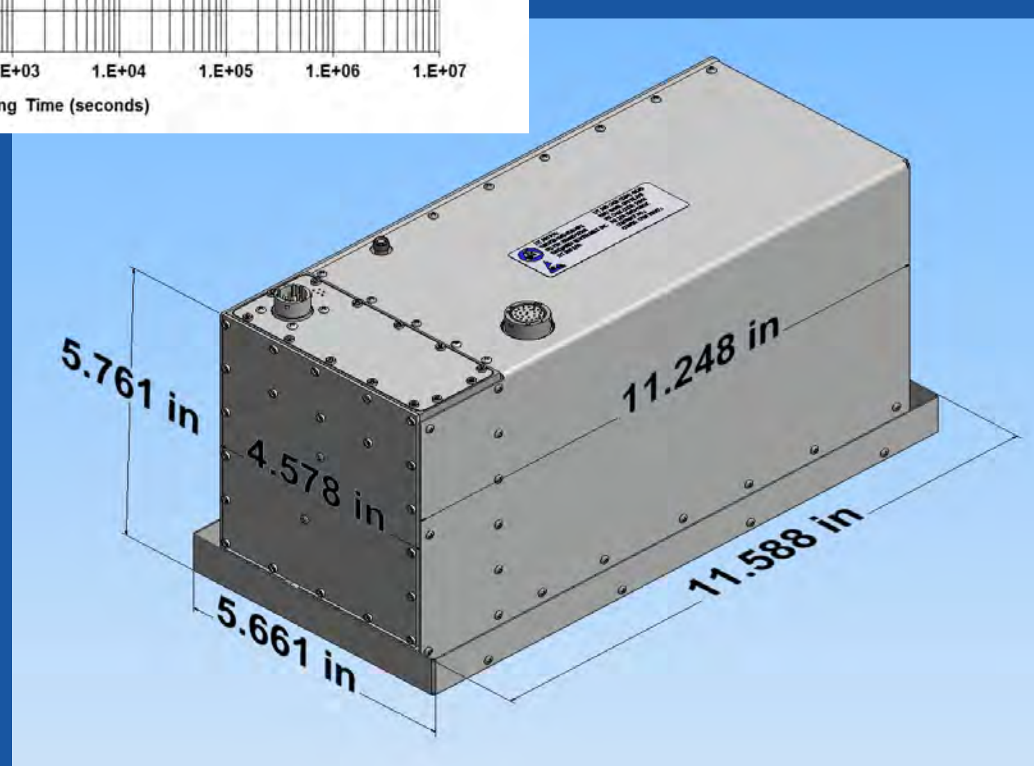
4.0 RADIATION HARDENING

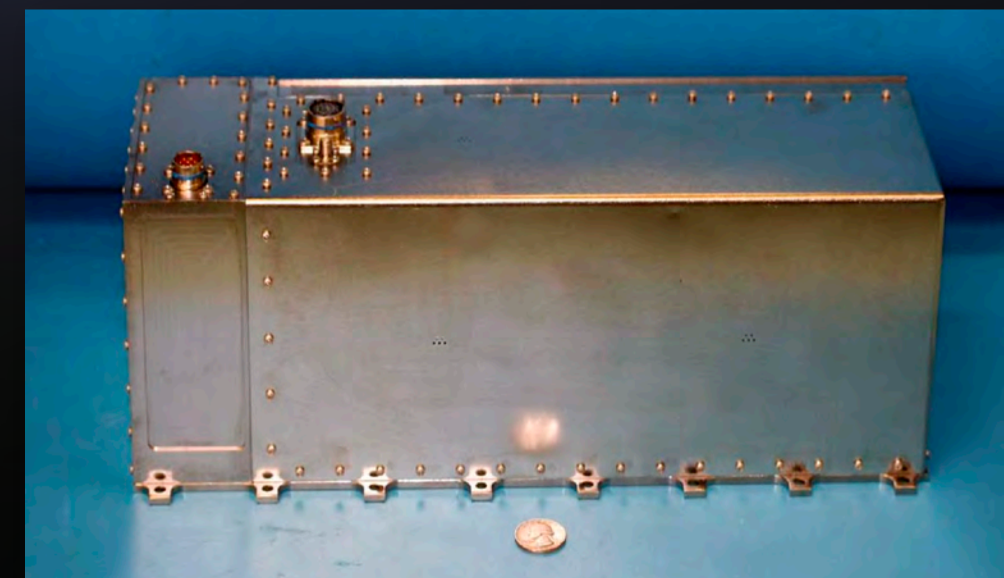
- » Rad Hard Parts
- » FPGA
  - • Frequency setting stored on select resistors connected to input pins (no use of upsetabble memory)
  - • Fuse programmed (write once)
  - • Hardware triple redundant logic, with three way voting to minimize single event effects
  - • Software triple redundant logic with 3 way voting of critical values (digital output to DAC (quartz oscillator control voltage)
- » Radiation shields
  - • Spot shields for critical components

5.0 ALLAN DEVIATION IN VACUUM





FEI's Next-Generation Rubidium Atomic Frequency Standard For Space Applications



KEY FEATURES

- » Allan Deviation: $\sigma_y(\tau) = 6 \times 10^{-13}/\sqrt{\tau}$; $2 \times 10^{-14}/10^5$sec
- » Drift: 3×10^{-14}/day at 1 year
- » Designed to operate in space for a minimum of 20 years
  - • Based on heritage design of RAFS operating in space for over 18 years
- » Radiation hardened to 100K Rads
- » Modular design
- » Integrated DC to DC Converter (EPC)
  - • Bus Voltage 28 V
  - • Available with other bus voltages from 28 to 100 V
- » Internal high-precision VCXO
- » Digital rubidium control loop implemented within a space qualified FPGA - locks the integrated VCXO output to the rubidium hyperfine resonance frequency
- » AS 9100C : 2009-01 Qualified
- » Designed and built by a company that made its reputation with over 50 years of reliability and over 5000+ systems In Space

Frequency Electronics, Inc. 55 Charles Lindberg Blvd., Mitchel Field, NY 11553
Phone: 516-794-4500 Fax: 516-794-4340 E-mail: sales@freqelec.com

1.0 INTRODUCTION

Frequency Electronics, Inc. (FEI) has developed a rubidium atomic frequency standard (RAFS) for precision time-keeping and stable frequency generation for global navigation satellite systems (GNSS). FEI has leveraged its experience from rubidium standards provided to the Milstar constellation and to the Advanced Extremely High Frequency (AEHF) satellite program. A total quantity of 19 rubidium standards were delivered for Milstar and launched starting in 1995. For AEHF 15 rubidium standards have been provided with an additional 6 on order. The first AEHF satellite was launched in August 2010, the second was launched in May 2012 and the third was launched in September 2013. The fourth AEHF satellite is scheduled for launch in 2017.

2.0 BLOCK DIAGRAM

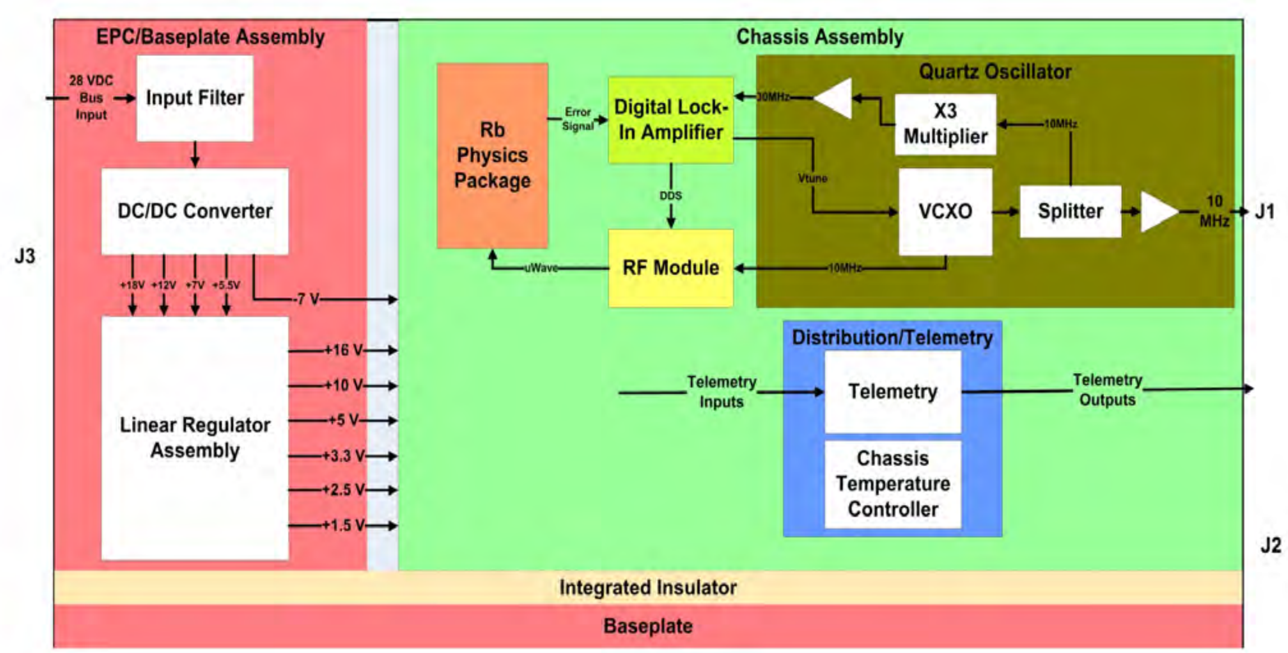
» The RAFS is built in a modular fashion as shown in the below block diagram. The two Major modules are:

- The EPC/ Baseplate Assembly
- The Chassis Assembly

» Both assemblies are mounted within a temperature controlled environment that is thermally isolated from the RAFS baseplate by an integrated insulator. The baseplate temperature controller (BTC) maintains an environment of ±1°C from -34°C to +25°C. In addition, the physics package, VCXO, RF module, and digital lock-in amplifier are designed, built and tested as separate, connectorized modules. This allows for an easy upgrade path to accommodate design changes necessitated by obsolete parts or to incorporate future design improvements.

» Other aspects of the RAFS include:

- Ease of alignment and test
- Optional digital frequency tuning in steps of 10^{-14}



RAFS Block Diagram

3.0 SPECIFICATIONS

RF Output	10.0 MHz or 10.23 MHz Sinewave (other frequencies can be provided) + 18 dBm ± 1.5 dB Harmonics ≤ -50 dBc Spurious ≤ -85 dBc
Analog Monitors	Lock, Light , Signal, VCXO, Baseplate Temperature, Ovens, Power Supplies , ALC, C-Field, BTC
Accuracy	± 1 x 10^{-9} at shipment
Trim Range	None (Fixed C-Field)
Stability σy(τ)	6 x 10^{-13} τ-½ 2 x 10^{-14} (1≤τ ≤ 105 seconds, drift removed)
Drift	≤ 1 x 10^{-13}/day at BOL operation ≤ 3 x 10^{-14}/day after 1 year of continuous operation
Phase Noise, f(f)	-110 dBc/Hz at 1 Hz offset from carrier -138 dBc/Hz at 10 Hz -148 dBc/Hz at 100 Hz -158 dBc/Hz at 1 KHz -160 dBc/Hz floor
Temperature Sensitivity	≤ 2 x 10^{-13}/°C typical w/o BTC, below noise level for ± 1.5°C with BTC
Voltage Sensitivity	≤ 3 x 10^{-12}
Magnetic Sensitivity	≤ 1 x 10^{-12}/Gauss
Barometric Sensitivity	≤ 1 x 10^{-13}/mbar typical
Retrace	≤ 5 x 10^{-12}
Input Power	28.0 VDC ± 4.0 VDC (Available with other bus voltages from 28 to 100 V)
	≤ 39 W total steady-state with BTC (-4 to + 21C)
	≤ 20 W basic clock at +45° C baseplate
	≤ 65 W during warm-up
Warm-up	≤ 1 hour to ± 2 x 10^{-10}
Size (L x W x H)	11.2 x 4.6 x 5.8 in 285 x 117 x 147 mm
Mass	16.5 lbs/7.5 kg
Operating Temperature	Full performance with BTC range between -4°C and +25°C panel temperature. Functional between -20°C to +45°C panel temperature.
Storage Temperature	-34°C to + 71°C
Altitude	Sea level to vacuum
Vibration	12.4g rms, 20 Hz to 2 kHz
Pyroshock	1500 g max to 10 kHz
Acceleration	20 g
Radiation	100 K Rad
EMI	Per MIL–STD-461E
SEE (Single Event Effect)	1 in 1,000 Years
On-Off cycling endurance	≥1000 cycles