Indigenous Atomic Clock and Monitoring Unit for NavIC

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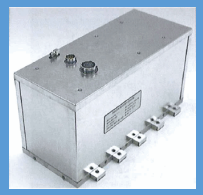
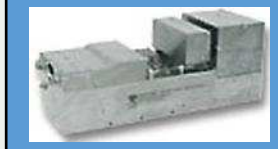
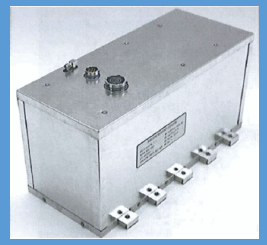
10 – Dec - 2019
ICG-14, Bengaluru

MOTIVATION & GNSS ONBOARD CLOCKS

"Develop Space Rubidium Atomic Frequency Standard for Satellite Navigation Systems"

NAVSTAR GPS	GALILEO	GLONASS		IS-QZSS	IRNSS
 	 		 		
Rubidium Cesium	Hydrogen Maser Rubidium	Cesium H-Maser*	Rubidium (1) Rubidium (2)	Rubidium	Rubidium (1) Rb (indigenous)

TARGET SPECIFICATIONS

Parameter	IRAFS target
Output frequency and Power	10 MHz; +7dBm ±1dB
Initial Freq. Accuracy	$\pm 1 \times 10^{-9}$
Frequency Drift	$< 5 \times 10^{-13}$ / day
Frequency Stability 1 sec 10 sec 100 sec 1000 sec 10000 sec (drift removed)	 5×10^{-12} 1.5×10^{-12} 5×10^{-13} 1.5×10^{-13} 5×10^{-14}
Phase Noise (10 MHz) 1 Hz 10 Hz 100 Hz 1000 Hz 10000 Hz 100000 Hz	 -85 dBc/Hz -100 dBc/Hz -125 dBc/Hz -135 dBc/Hz -145 dBc/Hz -145 dBc/Hz
Freq. temperature Stability in range of 20ºC (-5 ºC to +15 ºC)	$\leq \pm 1 \times 10^{-13}$/ºC
Size; Mass; Power (initial & stabilized)	<15 liters; <10 kg; <75 W & 40 W
Telemetries	Clock ON/OFF; Light; Signal; TRB core package; TCB-EPC; Lock/Unlock

SPACE GRADE LOW NOISE 10MHZ OCXO

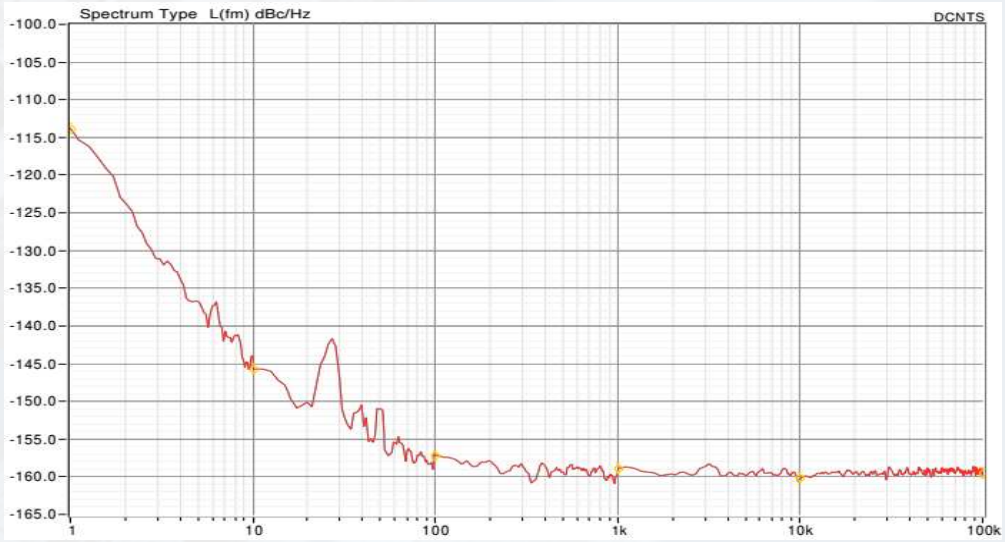
Features

- Low close-in Phase Noise
- Good Short term stability ($8x10^{-13}$ @1s)
- Capable to withstand total radiation dose of 100K rad
- Control Voltage Option

Package size	50 x 50 x 34 mm
Weight	~ 98 grams

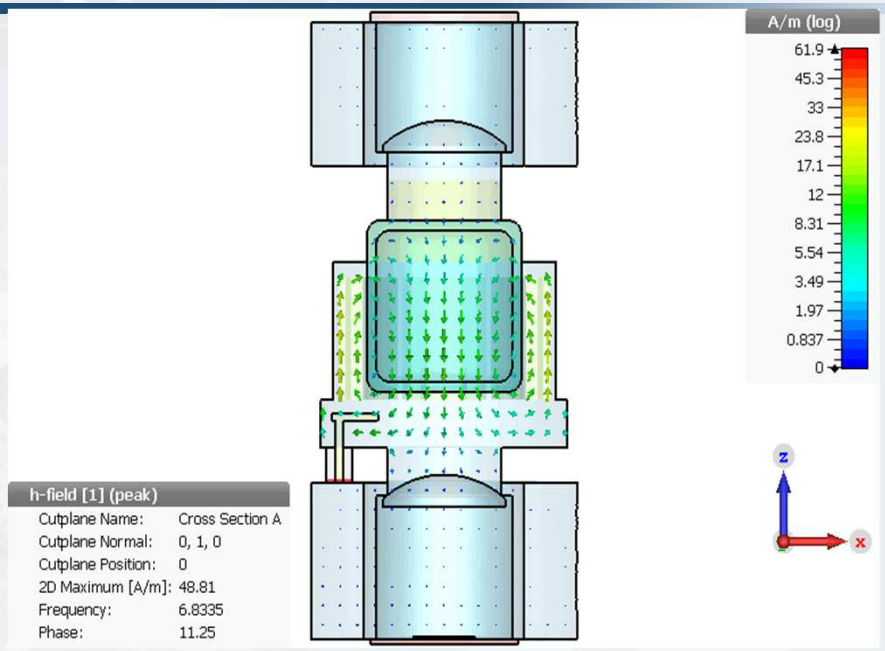
Design Consideration

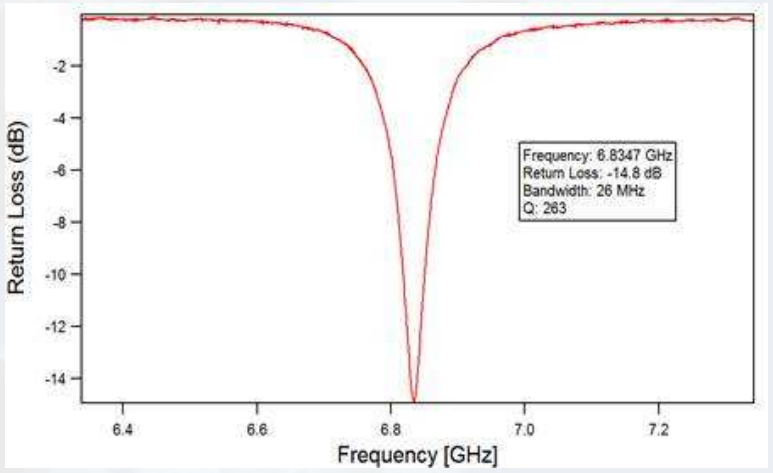
- Thermal stability of the product established using the Thermal simulation
- Structural Simulation established to meet Environmental specification.
- Improved Isolation between stages to Improve Short term stability.



MICROWAVE RESONANT CAVITY

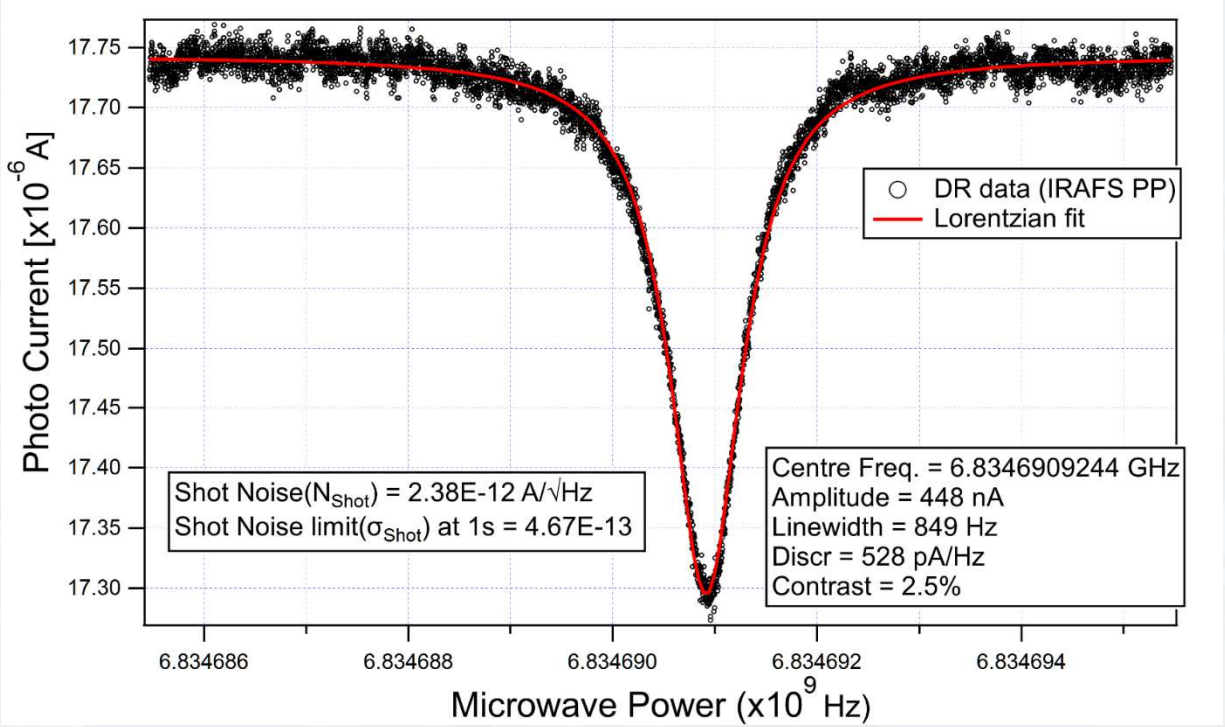
- Cavity with TE_{011} mode resonating at 6.834 GHz
- Low Q ~ 260
- Return Loss >10 dB;
- Tuneability >70 MHz





Jaydeep Kaintura et al, "Optics Integrated Compact Cavity for Rubidium Atomic Frequency Standards", Review of Scientific Instruments, vol. 90, 084701, 2019.

IRAFS DOUBLE RESONANCE SIGNAL & SHORT-TERM

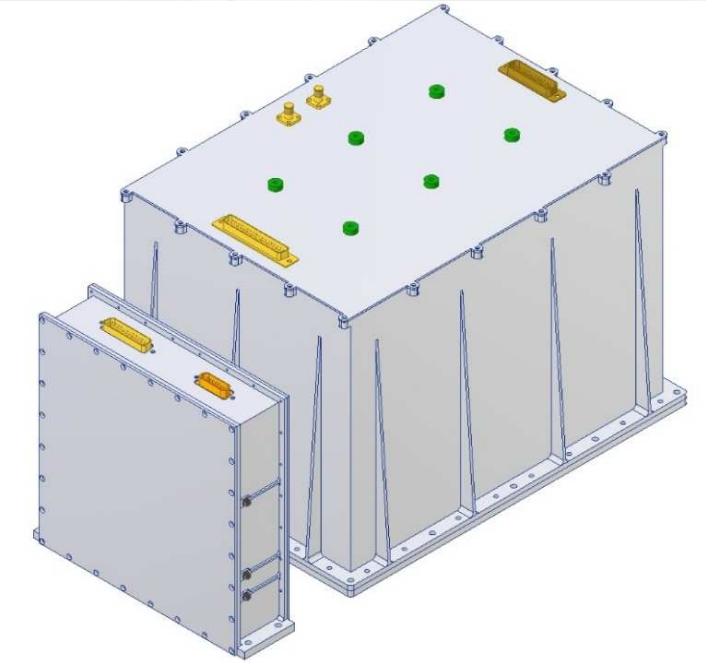


- Contrast =A/Bk = 2.5 %
- D = A/FWHM = 528 pA/Hz
- Short term stability: $\sigma_y(\tau) = \frac{N_{PSD}}{\sqrt{2}.D.\nu_{Rb}} \tau^{-1/2}$
- Shot-noise limit: $4.7 \times 10^{-13}\, \tau^{-1/2}$

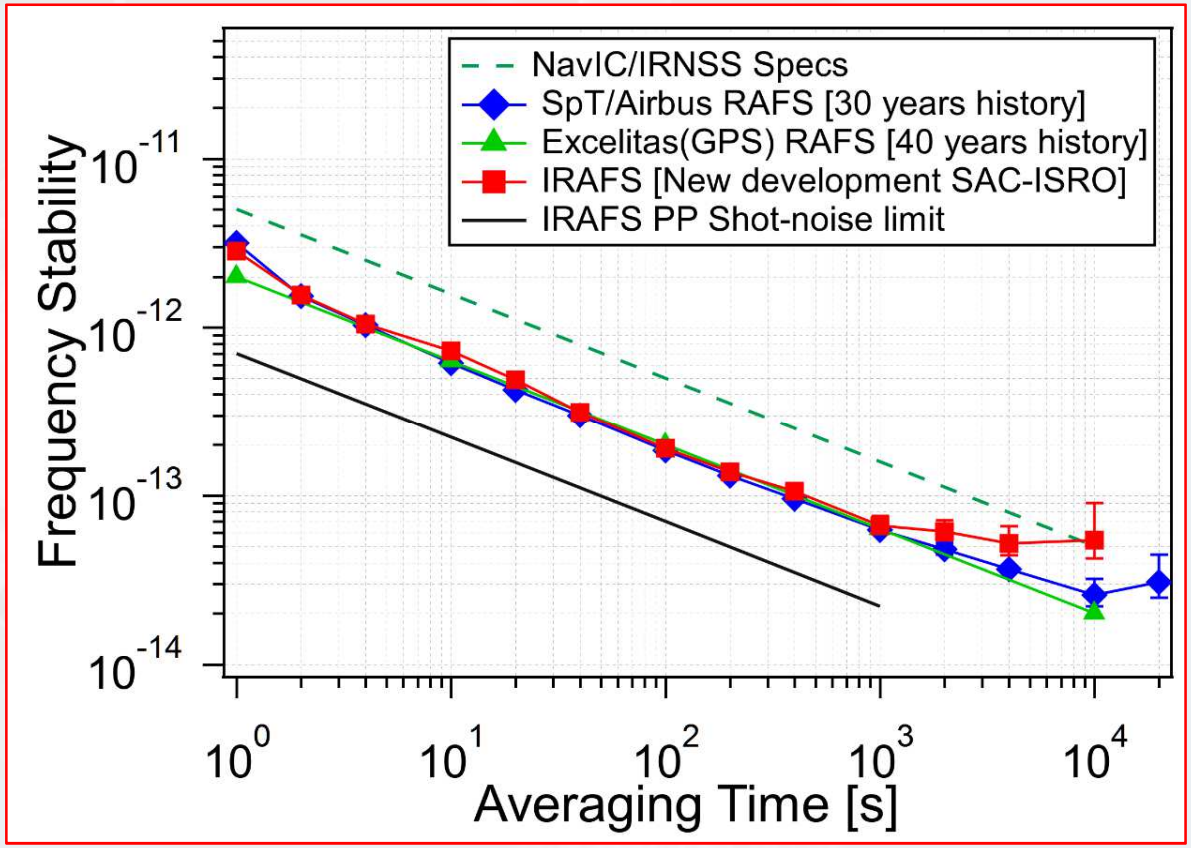
IRAFS PERFORMANCE

- **100% INDIGENOUS DESIGN**

✓ Thermal and structural analyses



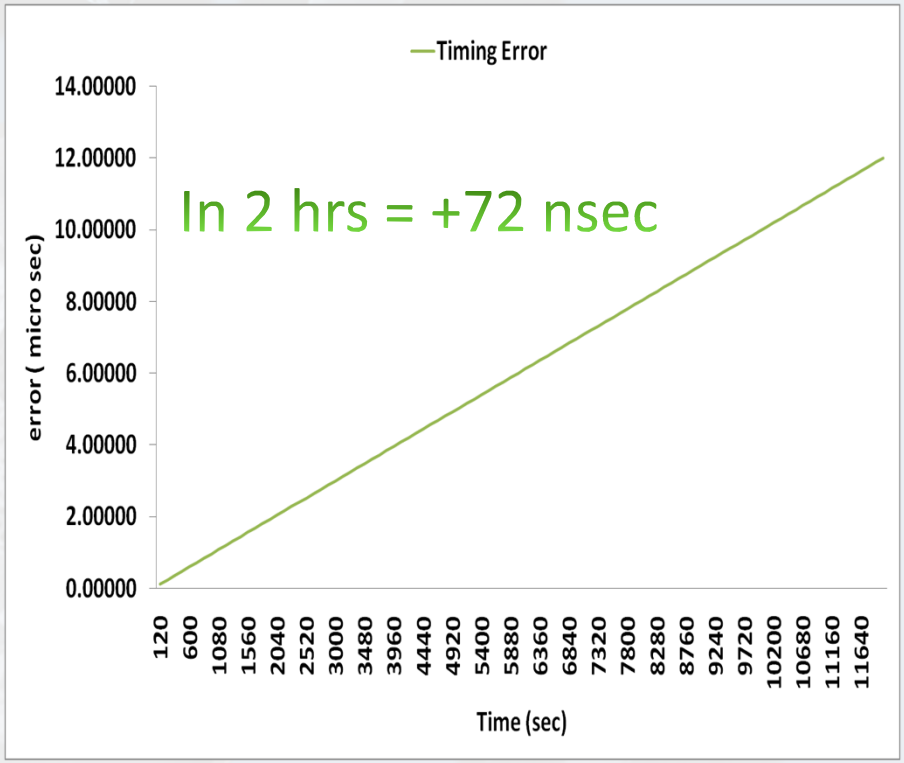
Power: <80 W (turn ON)
<40 W (steady state)
Weight: <10 kg (IRAFS+EPC)



Measured stability performance of IRAFS, also shown are IRNSS specifications and shot-noise limit of the Physics Package.

CLOCK MONITORING UNIT

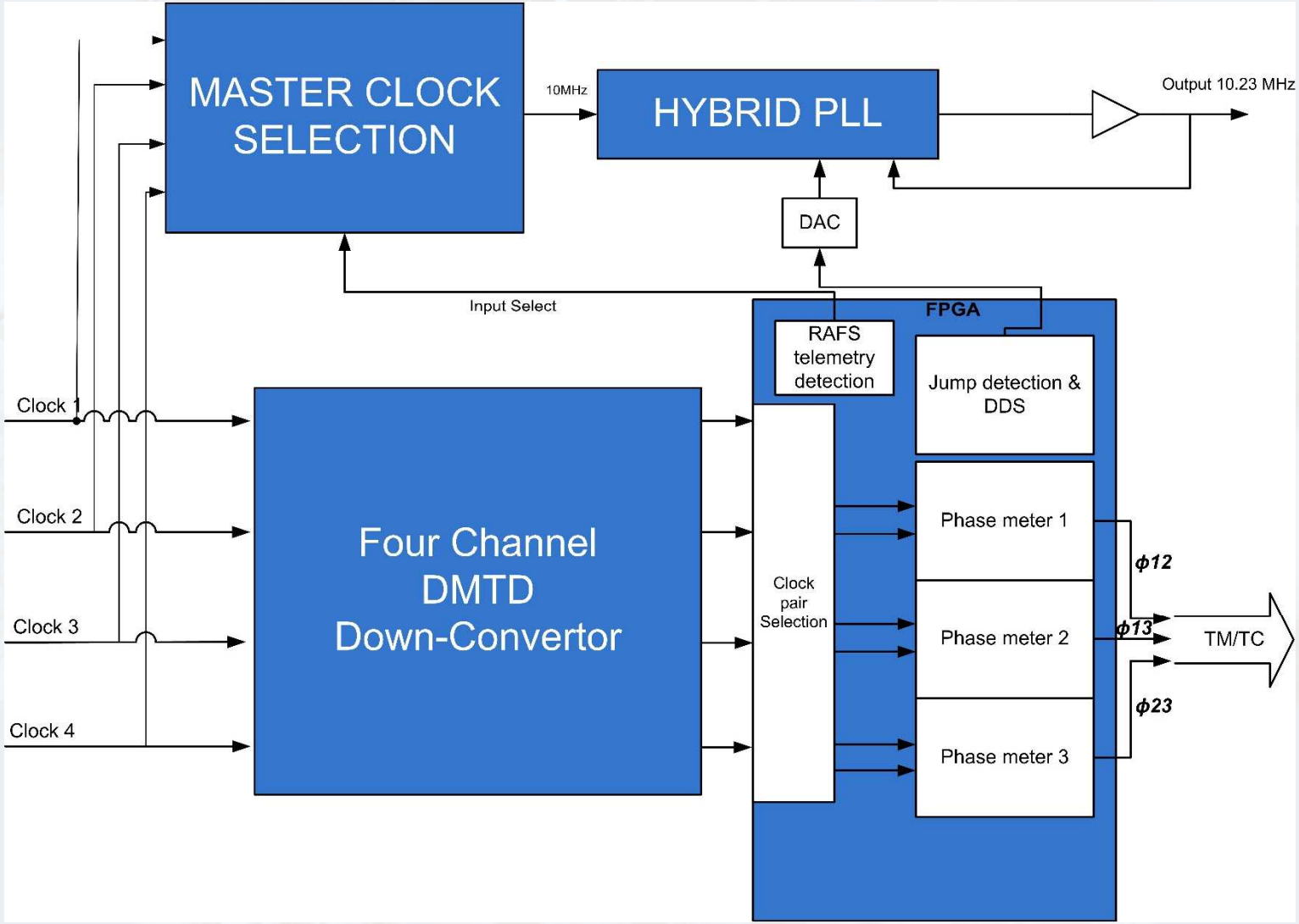
- The 10MHz RAFS input is provided to the Monitoring Unit.
- The Monitoring Unit generates stabilized 10.23MHz Master Timing reference
- Frequency jumps and drifts are common phenomenon in RAFS that affect the estimation of user position



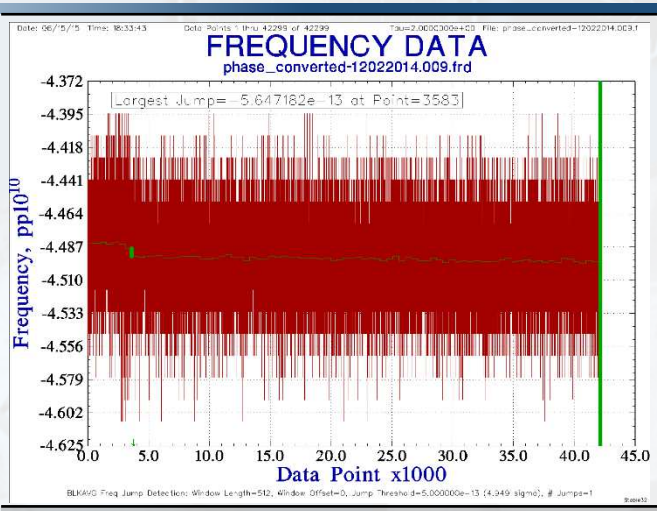
Deviation of frequency of the order of 1e-11

$\Delta T = 72ns \text{ in } 2hrs \Rightarrow 21.6m$

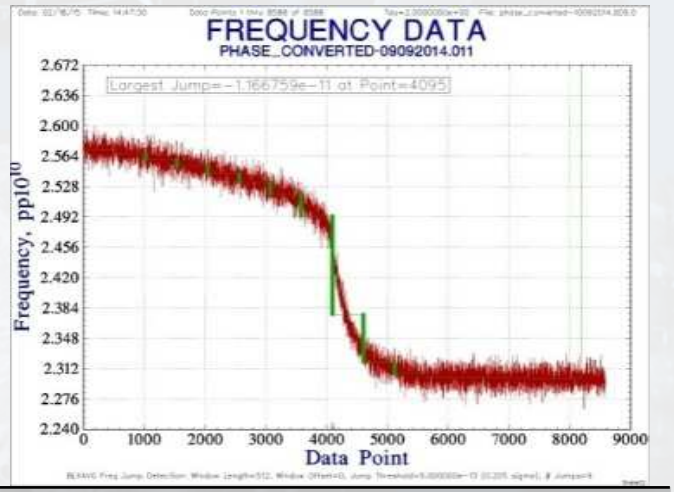
ARCHITECHTURE



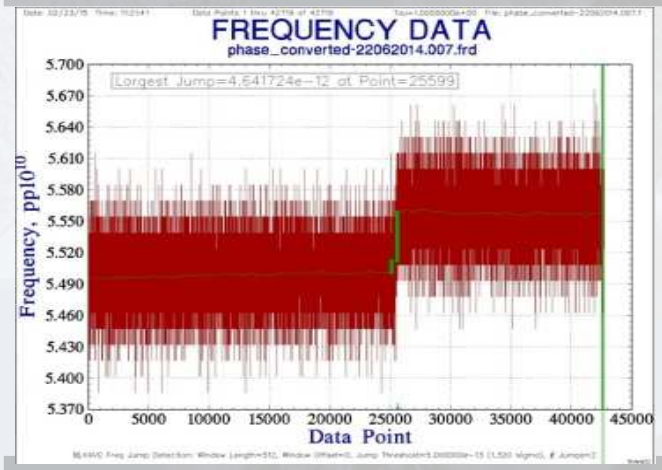
DIFFERENT TYPES OF FREQUENCY JUMPS



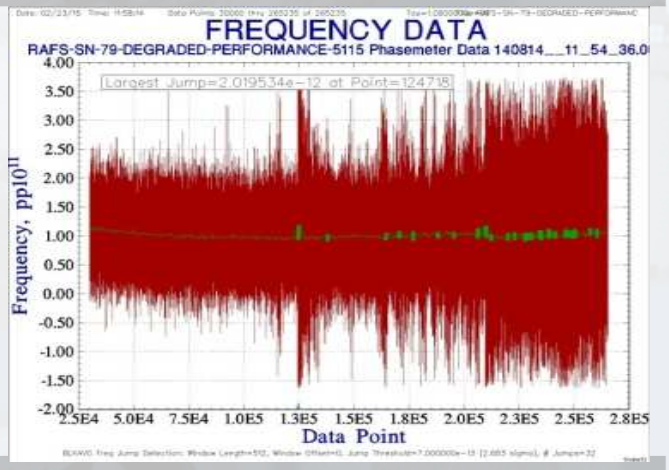
Sudden transition, weak jump of 7.2e-13



Slow transition, large jump of 2.5e-11



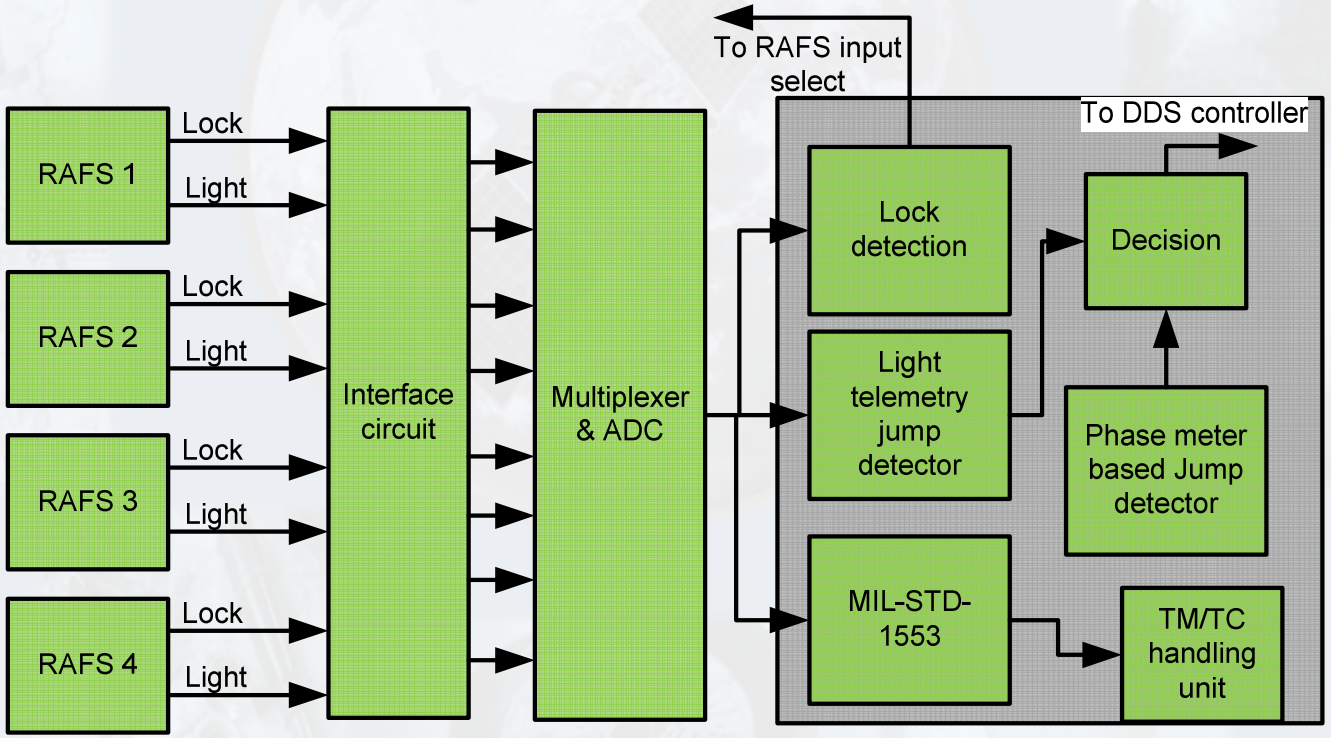
Sudden transition jump of 5.1e-12



Sudden increase in noise

RAFS TM MONITORING & JUMP CORRECTION

- RAFS provide telemetries: lock, signal and light in real-time
- Possibility for correction via RAFS TM inputs and phase meter data
- DDS tuning for frequency jump and drift correction with step size of <1 uHz
- No degradation of master clock stability and phase noise



CONCLUSIONS

- Rubidium Atomic Clock technology is reliable and proven in space.
- IRAFS protoversion demonstrated and progressing towards the Flight Models
- Indigenous clock monitoring unit (FM) has been developed and will be further tested with IRAFS.