WEBINAR

Ruggedized Mini-Rubidium Oscillator Launch

01

Agenda

Stavros Melachroinos
Senior Product Manager,
Atomic Clocks
Orolia

David Garigen
Director of Engineering
Orolia Defense & Security

Patrick Bark (moderator)
Senior Marketing Coordinator
Orolia

Leading Clock Technologies

- Space
- Ground

Ruggedized mRO-50

- Applications
- Design
- Performance

Use Cases

Q&A

02

Space

CLOCK TECHNOLOGIES

mRO-50 RUGGEDIZED

DESIGN

PERFORMANCE

USE CASES

Q&A

Space Ultra Stable OCXO's & Atomic Clocks

Flight heritage missions with European & International space agencies, and commercial payload providers

Application Payload

GNSS Programs, Commercial & Military Satellite Communications, Earth Observations, SAR, Master clock payload

OCXO MO

>250FM

OCXO LNMO

>130FM

Rb Atomic Frequency Standard

114FM

Ground Hydrogen Maser

53FM

CORE COMPETENCIES

Timing & frequency reference systems
Atomic clocks & oscillators

REFERENCES

International space agencies
Commercial payload providers
OEMS in industry and defense

Orolia awarded Galileo 2nd Generation (G2S)

03

Ground & Industrial

Heritage in Industry, Science & Metrology

Growing Portfolio

Recent acquisition and integration of T4Science expands Maser technology for frequency reference sources, Very Long Baseline Interferometry (VLBI), deep space tracking and navigation, timekeeping and precision time scales, and GNSS satellite monitoring and geodesy

S O L U T I O N S

Low SWaP Rb Sources

Primary Reference Sources/Frequency Stability Instruments

Passive Hydrogen Masers

CORE COMPETENCIES

Timing & frequency reference systems

Atomic clocks & oscillators

GROUND APPLICATIONS

Timing and Synchronization

Defense/Critical infrastructures/UAV

Satcom/Telecom/Audio-Video

GNSS PNT

LEO

Mobile systems/UUVs/sensors

Ground segment systems

Science & Metrology

Orolia Technology Synchronizes Black Hole Photo Telescopes

04

mRO-50 Ruggedized

Applications

Radars
Slow-moving target detection in Doppler radar
Integrated radar image from multiple sites
Surveillance capabilities In bi-static radar
Missile guidance ,e.g.by on-board radar wrt ground radar

LEO
Independent precision
LEO PNT
Earth observation
IoT

Military Communications
Jamming rejections (MILSTAR)
Enables advanced waveforms
VSAT systems
Tactical radios with limited battery life

Electronic Warfare
Interception of electronic signals
ELINT
JIED Jammers

Airbornes & Avionics
Airborne intelligence gathering
UAV/UGV/USV/UUV
Resilient navigation (holdover)

Precise Time Stamping, Inertial Navigation, and Waveform Synchronization for UAVs

05

mRO-50 Ruggedized

Specifications

Frequency Stability
ADEV : 1s < 4E-11 (Option S)

Aging (After 30 days)
Per day < (option A) 5E-12 / day

Operating Temperature
-40° to +80°C

DC power
0.45W @5V and 0.36W @3.3V

Cell lifetime/MTBF
10 years/155860 hours at +25°C

Vibration
7.7 grms/axis per MIL-STD-810

Shock
MIL-STD-202G, Test Condition A, 50g, 11 ms, half sine

06

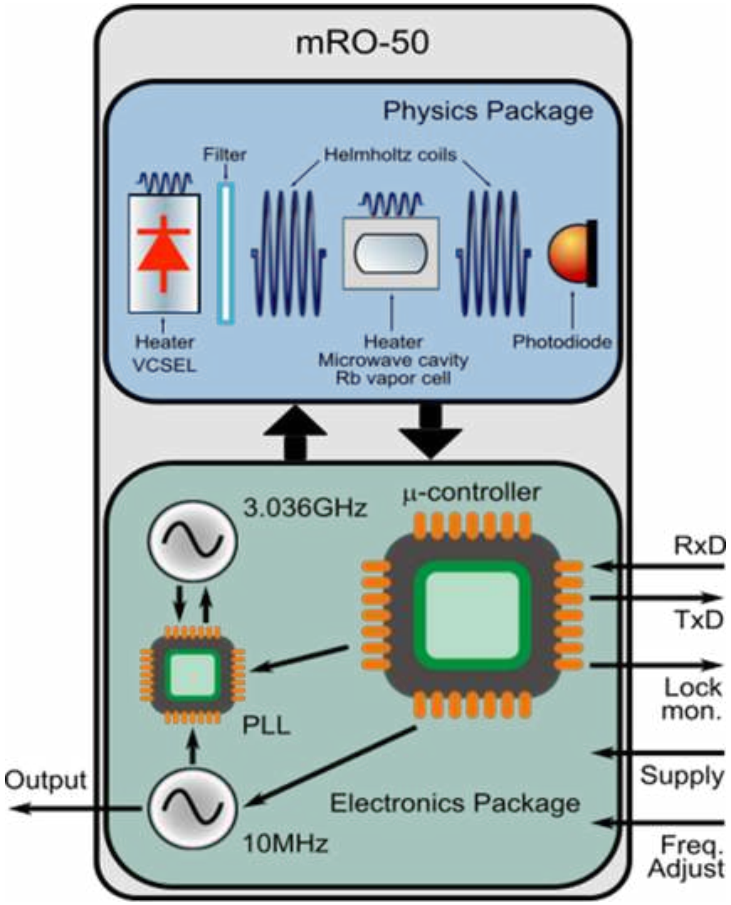
Design

Physics Package

VCSEL
Rubidium vapor cell
Cylinder coupling
Microwave to the rubidium atoms
Two C-field coils
An optical filter

Electronics Package

IMicrowave generation
Detection circuitry
Temperature controllers
Monitoring
Signal processing



07

Design

Key Elements

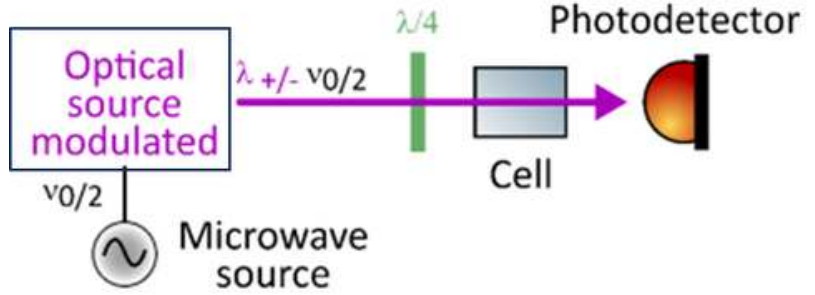
MODR without cavity allows to make compact PP (2 cm3) comparable in size to CPT solution

No need for high-frequency modulation of VCSEL diode

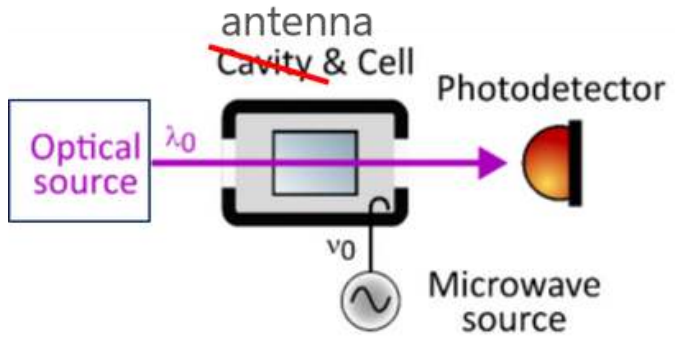
No requirement to stabilize the VCSEL modulation index

No need for quarter-wave plate (optical element) used in CPT

MODR without cavity does require an additional compact MW-antenna coupled to the Rb cell



CPT

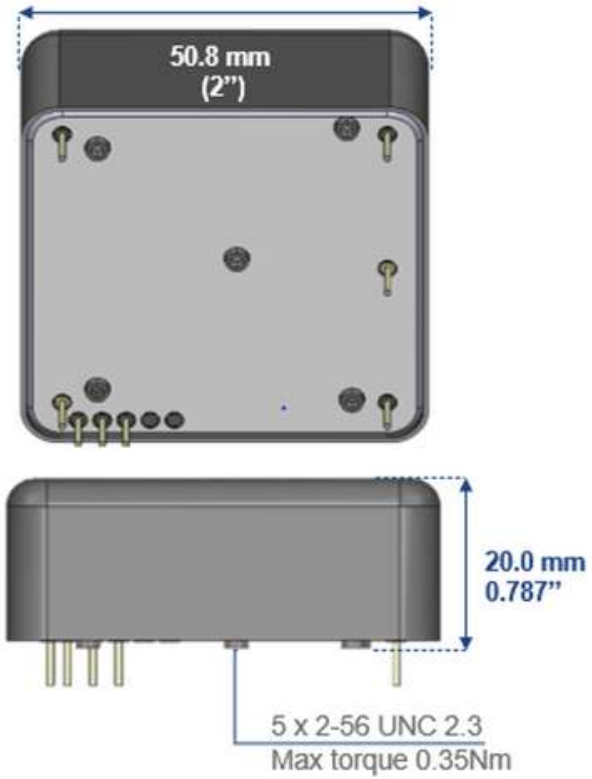


MODR (without cavity)

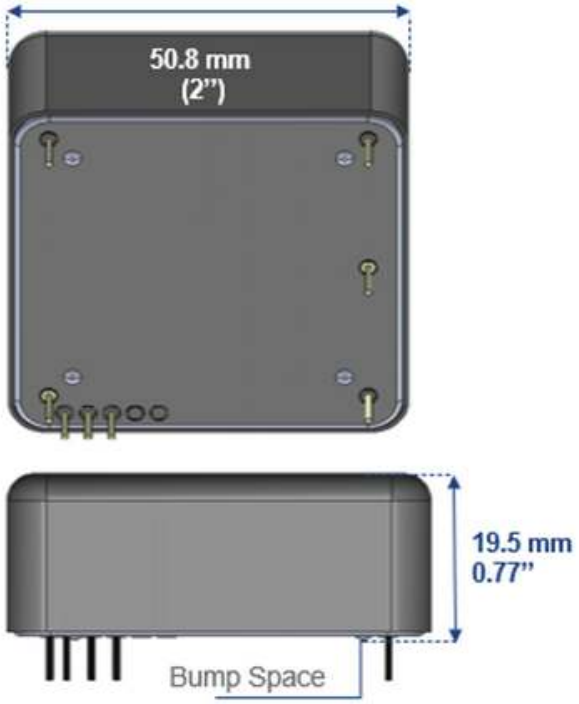
08

Design

mRO-50 Ruggedized



mRO-50 Standard



WHAT'S CHANGED

Reinforced mechanical design for

- Physics package
- Package mount

Improved Phase noise

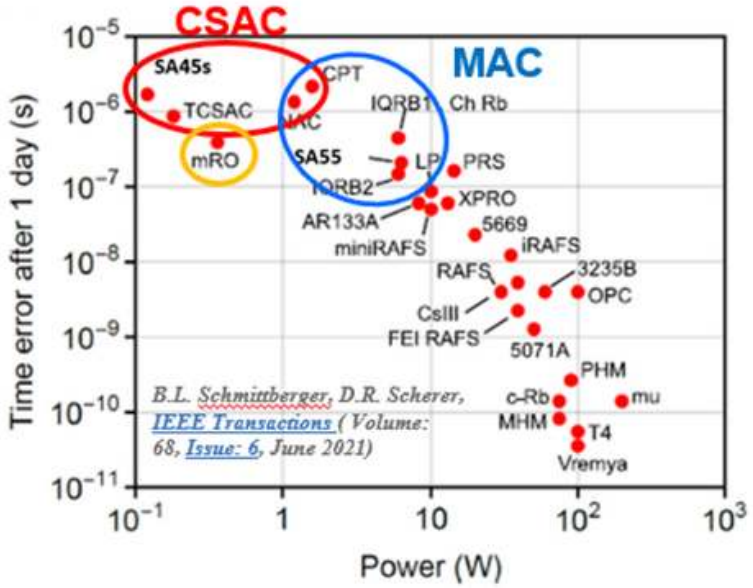
Higher temperature laser diode

Improved ADEV

09

Stability vs Temperature vs Power

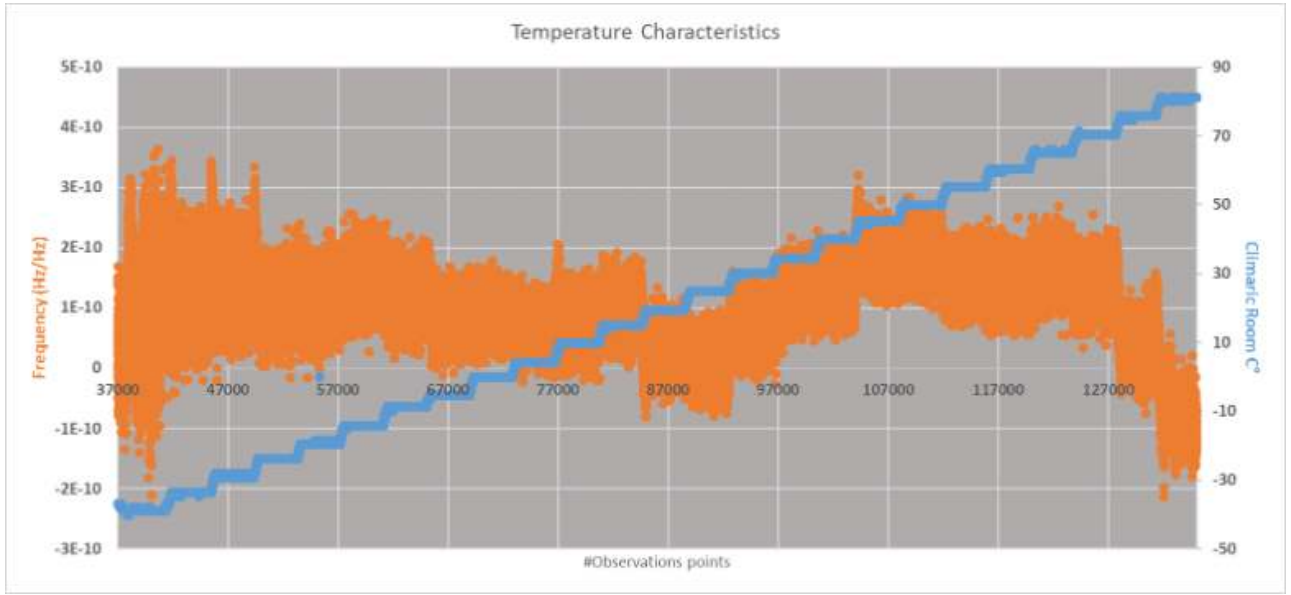
Commercial Atomic Frequency Standards



The best combination of low power & holdover amongst the MAC segment

- One day holdover below 1µs
- Consumes only 0.36W of power

Frequency Stability versus Temperature -40° to +80°C

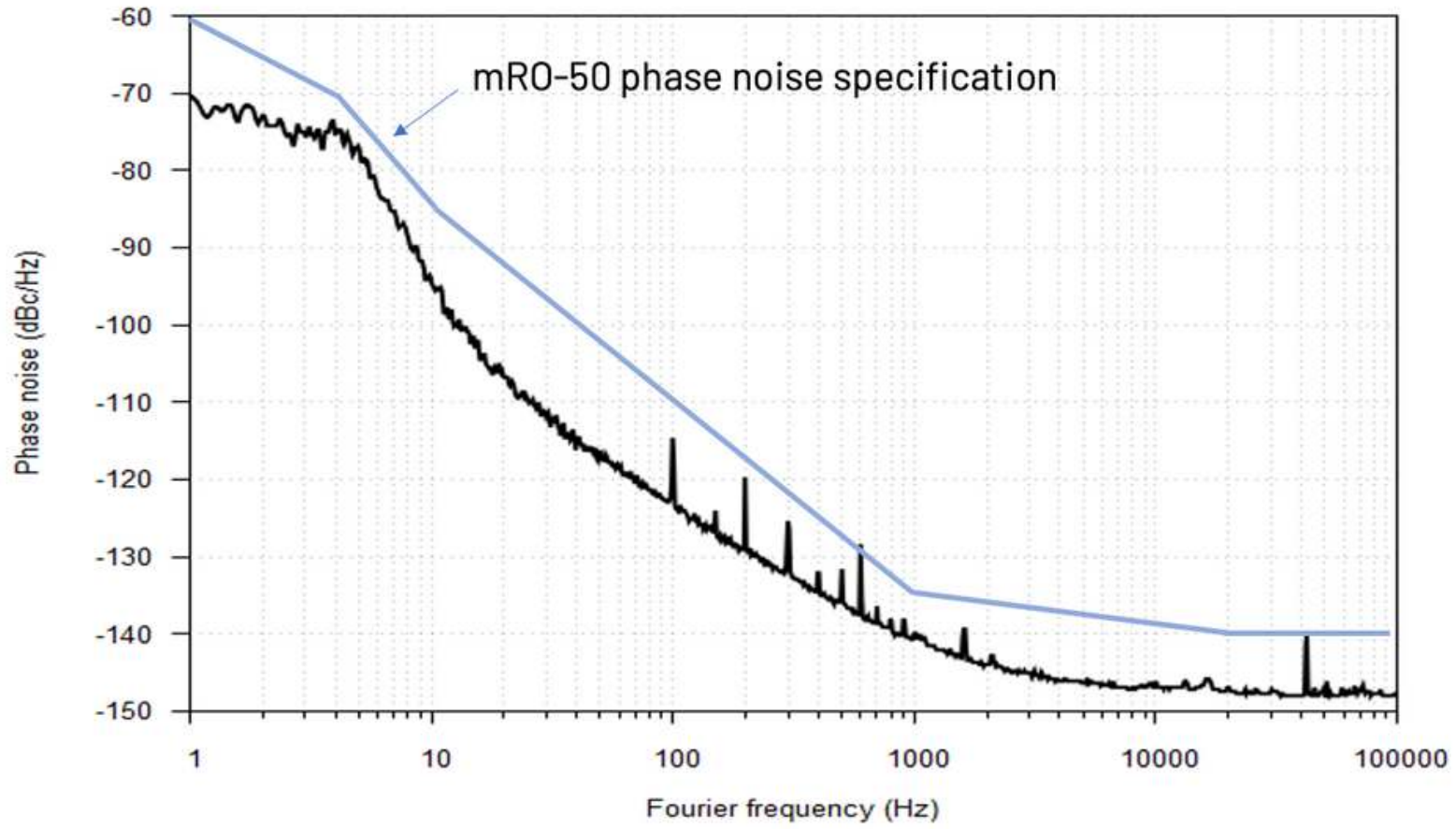


Fastest warm-up time on the market

- Wide-ranging operating temperature of -40° to +80°C

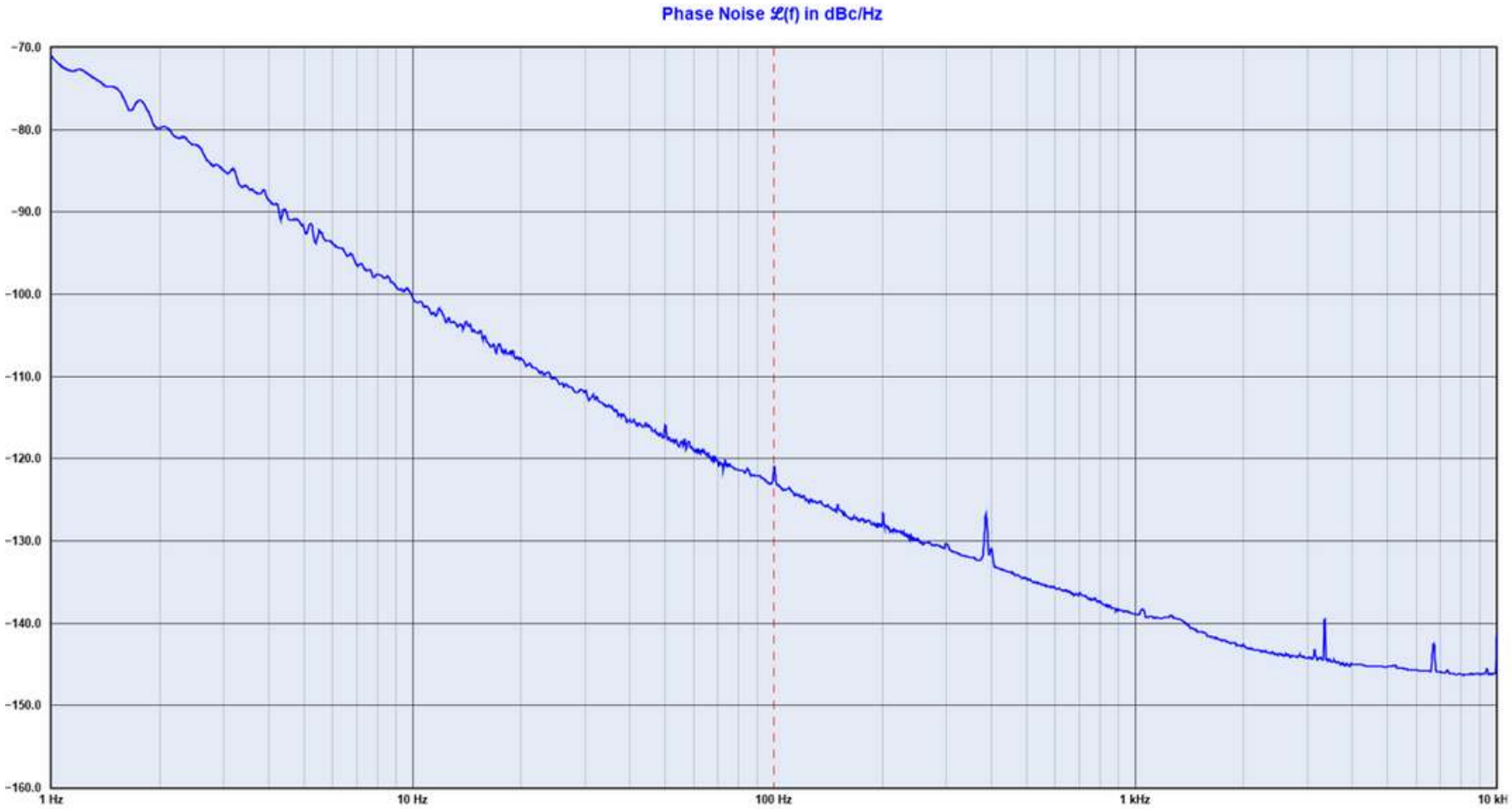
Phase Noise – @ 10MHZ

mRO-50 Standard



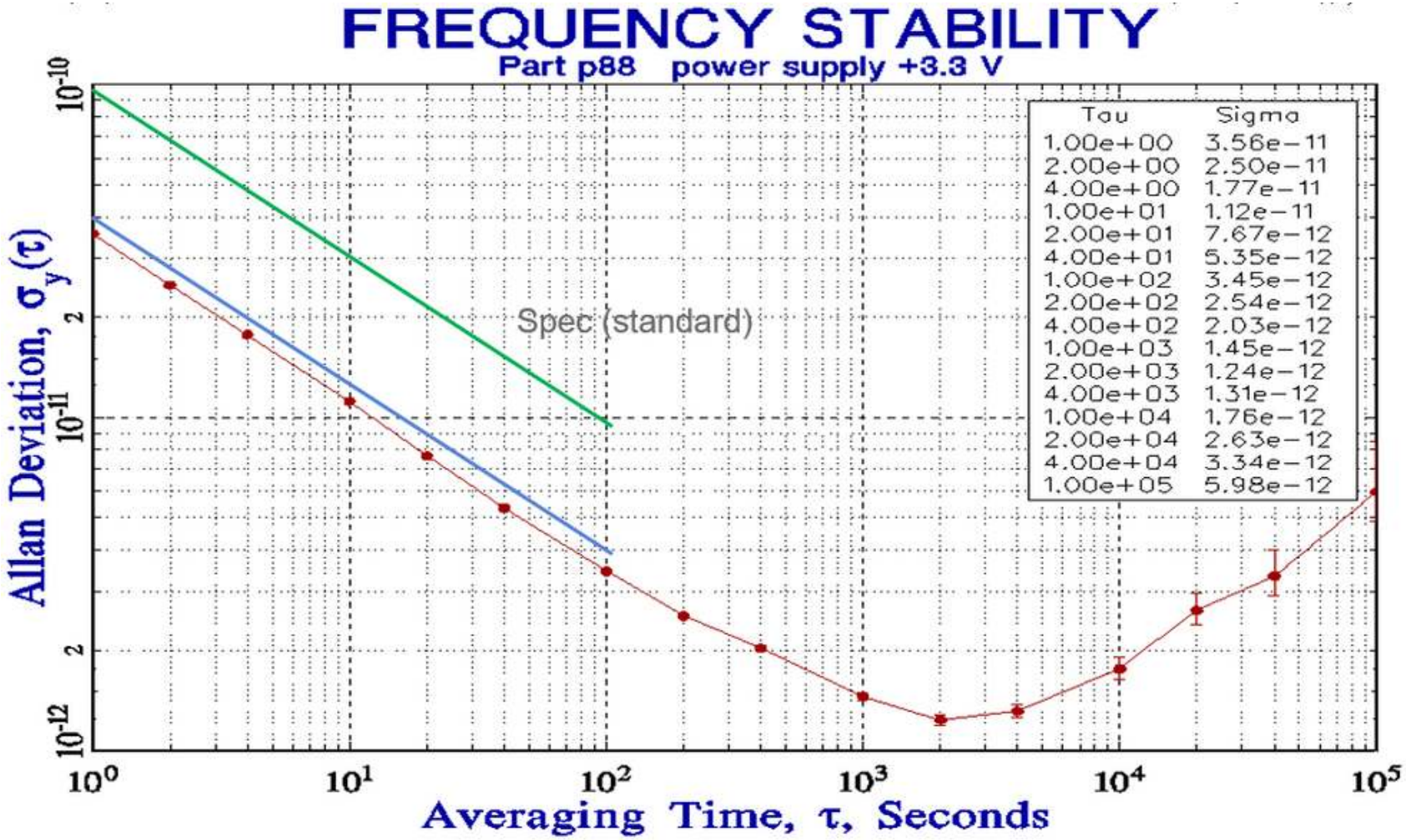
Phase Noise – @ 10MHZ

mRO-50 Ruggedized



ADEV

mRO-50 Standard



ADEV

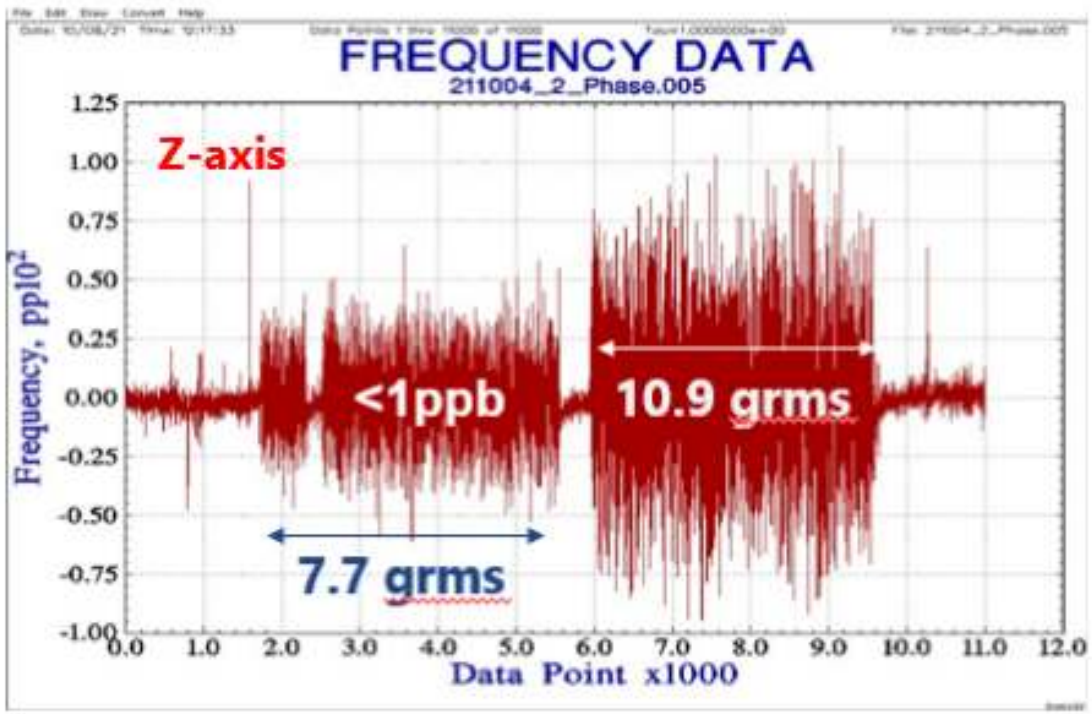
mRO-50 Ruggedized

Tau	Sigma(Tau)
1s	2.04E-11
2s	1.47E-11
4s	1.13E-11
8s	7.55E-12
10s	6.48E-12
20s	4.55E-12
40s	3.25E-12
80s	2.39E-12
100s	2.19E-12
200s	1.79E-12
400s	1.61E-12
800s	1.80E-12
1000s	1.88E-12
2000s	2.24E-12
4000s	2.09E-12
8000s	2.85E-12
10000s	3.22E-12
20000s	5.05E-12

Trace	Notes	Input Freq	Scale Factor	Sample Interval	ADEV at 10s	Duration	Acquired	Instrument
mRO50 AV P594 (Unsaved)		10.000 MHz		1 s	6.48E-12	12h	43200 pts	TimePod 5330A

MIL-STD-810 Vibration & Shock

mRO-50 Ruggedized



Vibrations:
7.7 grms - **PASS** (Maintains Lock)

Shocks:
30gs' 11ms - **PASS**
50gs' 11ms - **PASS**

Resilient GNSS

Benefits of the Low SWAP mRO-50 to R-GNSS receivers

Allows for soldiers' equipment to remain synchronized with GNSS satellites clocks

Reacquisition is quick so less processing power on the receiver will be required with less vulnerability to spoofing and jamming during the search for GNSS satellites

Faster warm-up time leads to faster time to first fix and lower power consumption on the Rx

Increased mission duration and battery life

Better time-to-subsequent fix and the capability to operate with less than four satellites

mRO-50 ADVANTAGES

1u/day Holdover
Precise time
High Short and Long term stability
Fast Warm-up time
Lowest power

USE CASE CONSIDERATIONS

Reacquisition capability
Minimizing acquisition time
Avoiding detection
System integrity monitoring
Performance in a high jamming environment
Fast time to first fix
Increased mission duration

Resilient GNSS

Oscillator Features	Impact on R-GNSS Receiver
10-100s stability	Reacquisition System integrity Performance in jamming
Long-term stability	Time-to-subsequent fix Operation with less than 4 satellites
Warm-up	Time-to-first fix
Power and size	Battery life Mission duration Weight

MILITARY GNSS RECEIVERS OFFER

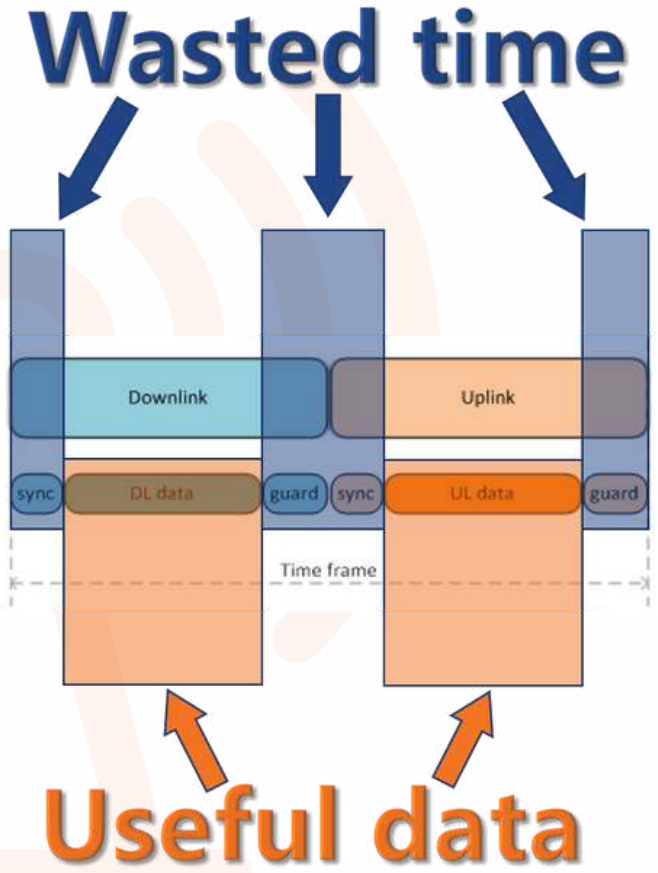
Accuracy
Integrity
Anti-Jamming
Anti-Spoofing
M-Code
Selective availability

RF Comms Systems

Benefits of the Low SWAP mRO-50 to the RF Comms Systems

Because of the tight sync between the RX and TX, the mRO-50 allows:

- Fast frequency hop rates
- Advanced networking waveforms (MANET) Mobile Ad-hoc Network
- High data throughput
- Many simultaneous users



mRO-50 ADVANTAGES

Shock, Vibration & Low Noise Acceleration

High Stability & Accuracy

Time Error & Holdover

Fast Warm-Up Time

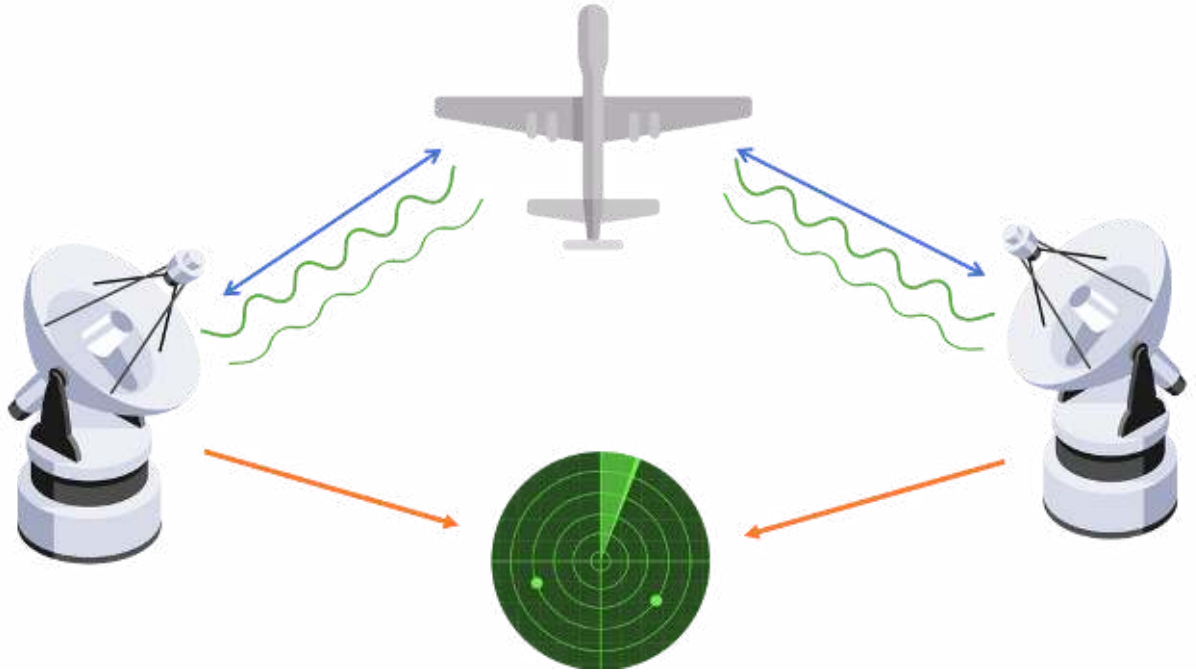
Distributed Radar/Sonar

Time Synchronization Requirement

Consist of multiple radars

All Data must be precisely timestamped and aggregated

Provides clear image of what radars see from every angle



mRO-50 ADVANTAGES

Frequency stability

Low Power

Fast warm-up

Extreme environments

High VIB and shock resistance

USE CASE CONSIDERATIONS

Integrated Radar Picture

Multiple Monostatic Radars

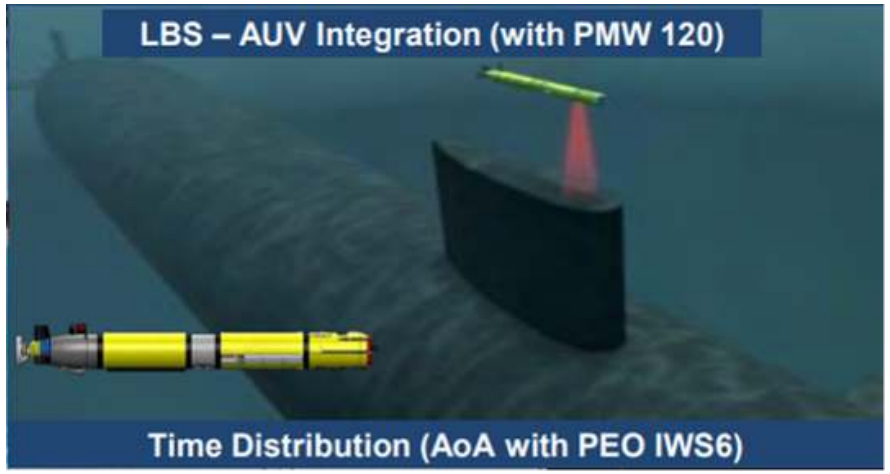
Underwater Multi-Element Sonar Systems

Requirements of UUV sonar systems

Require precise phase synchronization between sites, that is required to operate in fully GPS denied environment

Integrated sonar image from multiple UUVs to detect targets in a large underwater area.

UUV energy efficiency & Precision Navigation underwater



mRO-50 ADVANTAGES

Aging

Stability

Holdover

USE CASE CONSIDERATIONS

Precise synchronization between sites

Integrated sonar imagery

Energy efficiency

PNT in denied environments

Signals of Opportunity (SOP)

SOP Requirements

Similar to GPS/GNSS signal tracking, SOP signal acquisition and tracking will likely require tracking loops such as frequency-locked loop (FLL), phase-locked loop (PLL), and delay locked loop (DLL)

When tracking signals with high transmission rates, high accuracy oscillators are essential to keep tracking loops properly aligned

Physical oscillators provide better stability and less drift than numerically-controlled oscillators (NCOs) that are often utilized in tracking software

Software Defined Radios (SDRs) are often used for SOP tracking prototypes for their ease of use with receiving signals, but their hardware are often lacking high accuracy oscillators

Ref: IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 17, NO. 4, APRIL 2018 2173 Exploiting LTE Signals for Navigation: Theory to Implementation (Shamaei et al. 2018)

mRO-50 ADVANTAGES

Frequency

Aging

Low Power

USE CASE CONSIDERATIONS

Keep tracking loops properly aligned

Better stability and less drift

SDRs in the market often lack high-accuracy oscillators

Questions?

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