SubOptic 2007

Enabling Global Communications

Novel Undersea Line Monitoring Technology Enables Improved Performance and OTDR Capability

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Outline

- Loop-Back Line Monitoring System (LMS) Basics
  - Equipment and capabilities
- Design Considerations for Next Generation Line Monitoring Equipment (LME)
  - Adding an OTDR capability
- Next Generation LME Test Results

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Where is the fault?

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Loop-Back Line Monitoring Basics

- Capability
  - Alarm and locate *performance-affecting* wet-plant faults *in-service*
    - Without obtaining repeater parametric data
- Technique
  - Employs dedicated optical sidetones to probe the wet-plant
    - Uses a passive high-loss loop-back in each repeater
- Benefits
  - Simple reliable repeater design - fewer electronic components
  - No command channel equipment
  - Lower initial system cost
  - Enables data gathering for system aging studies
  - Optical probe method enables OTDR capability to be added

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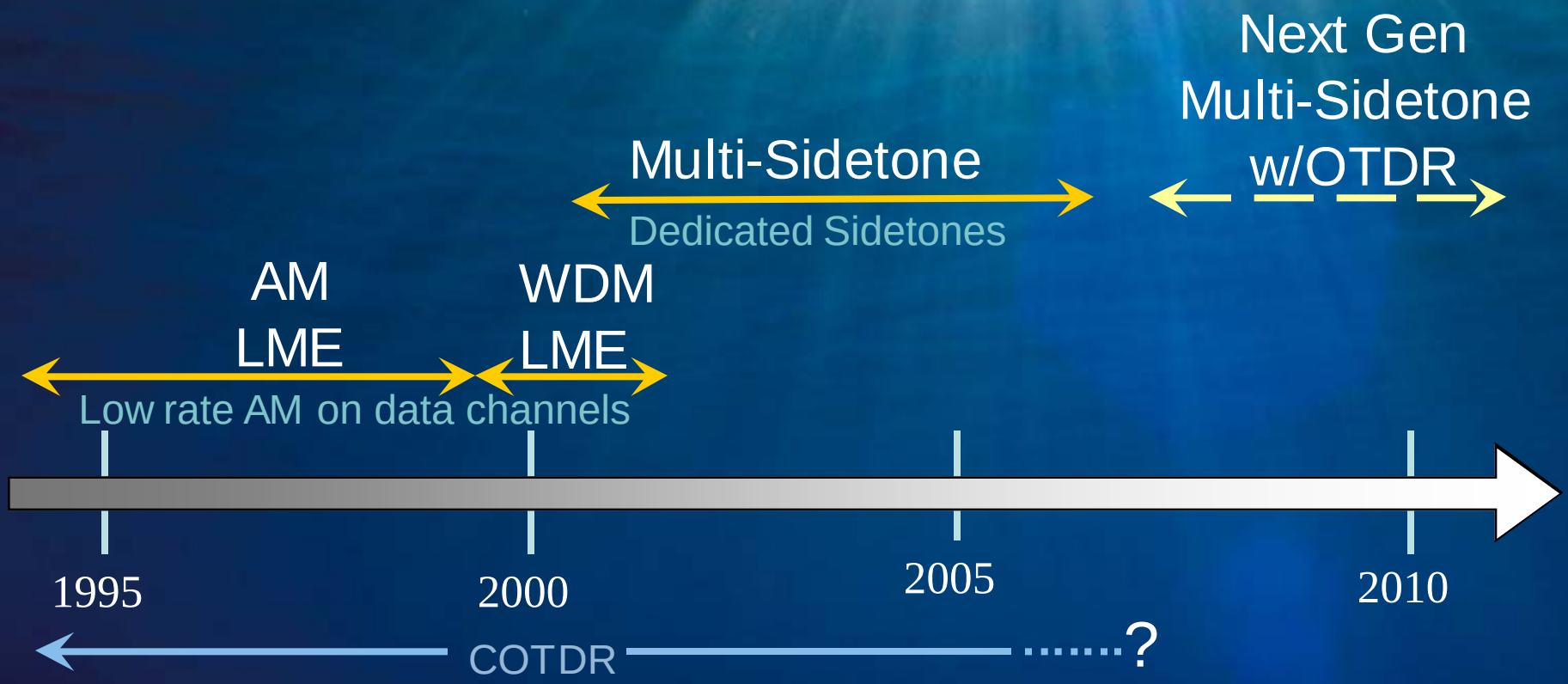
Optical Loop-Back LMS Timeline



"A Repeater Fault Locator Using a Correlation Technique for a Submarine Coaxial Cable System", Yukio Kobayashi, IEEE Transactions on Communications, Vol. Com-30, No.5 May **1982**

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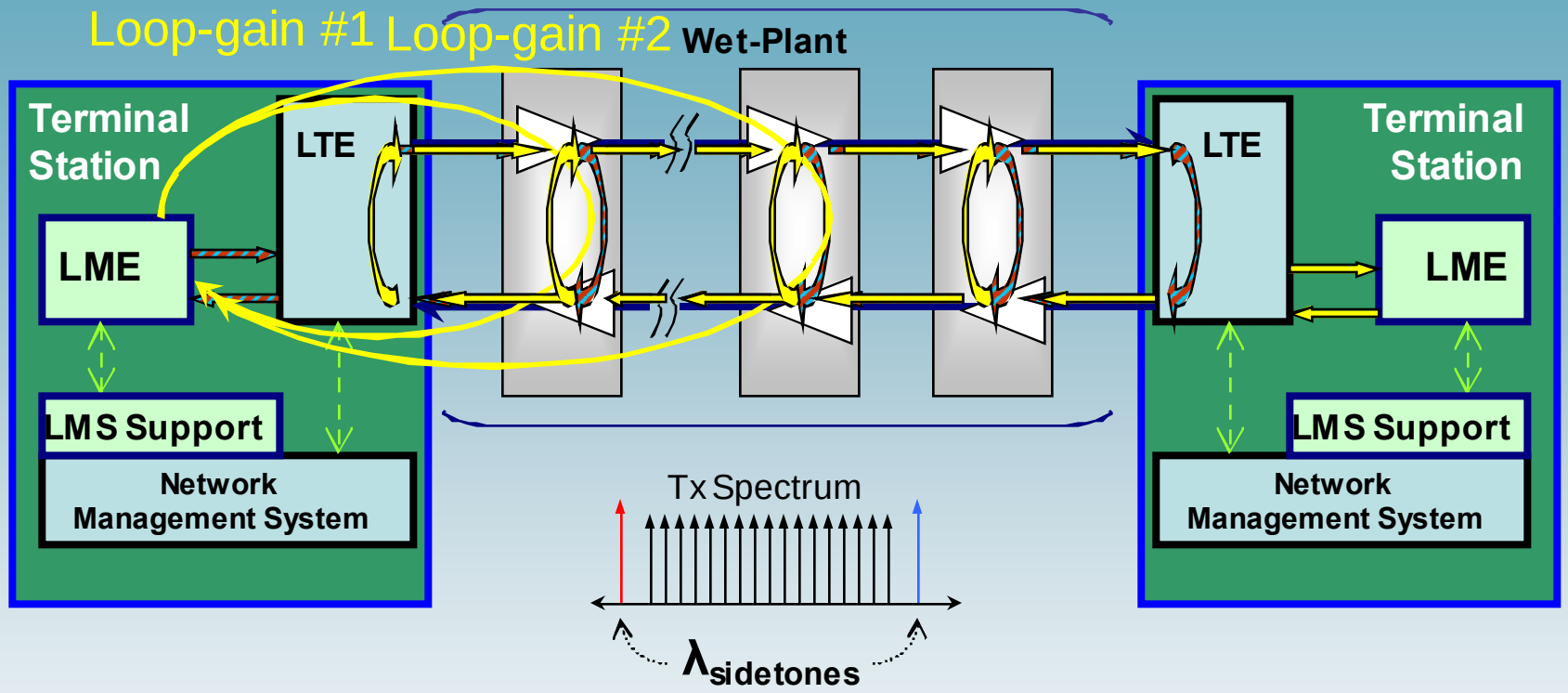
Anatomy of Loop-Back LMS



- Line Monitor Equipment
- Repeater High-Loss Loop-Backs (HLLB)
- Network Management System

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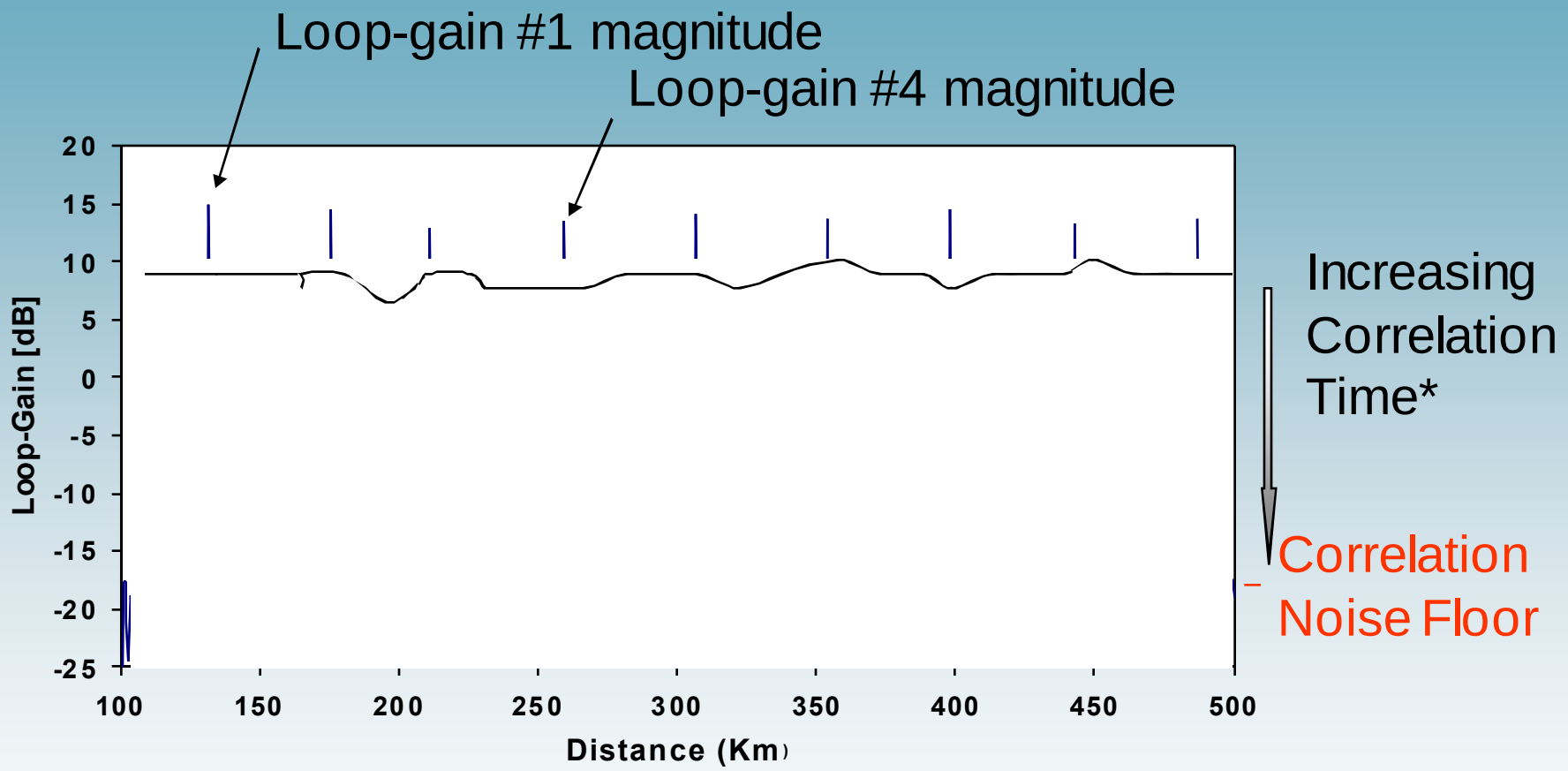
Correlation Results



* Correlation time depends on system dependent OSNR

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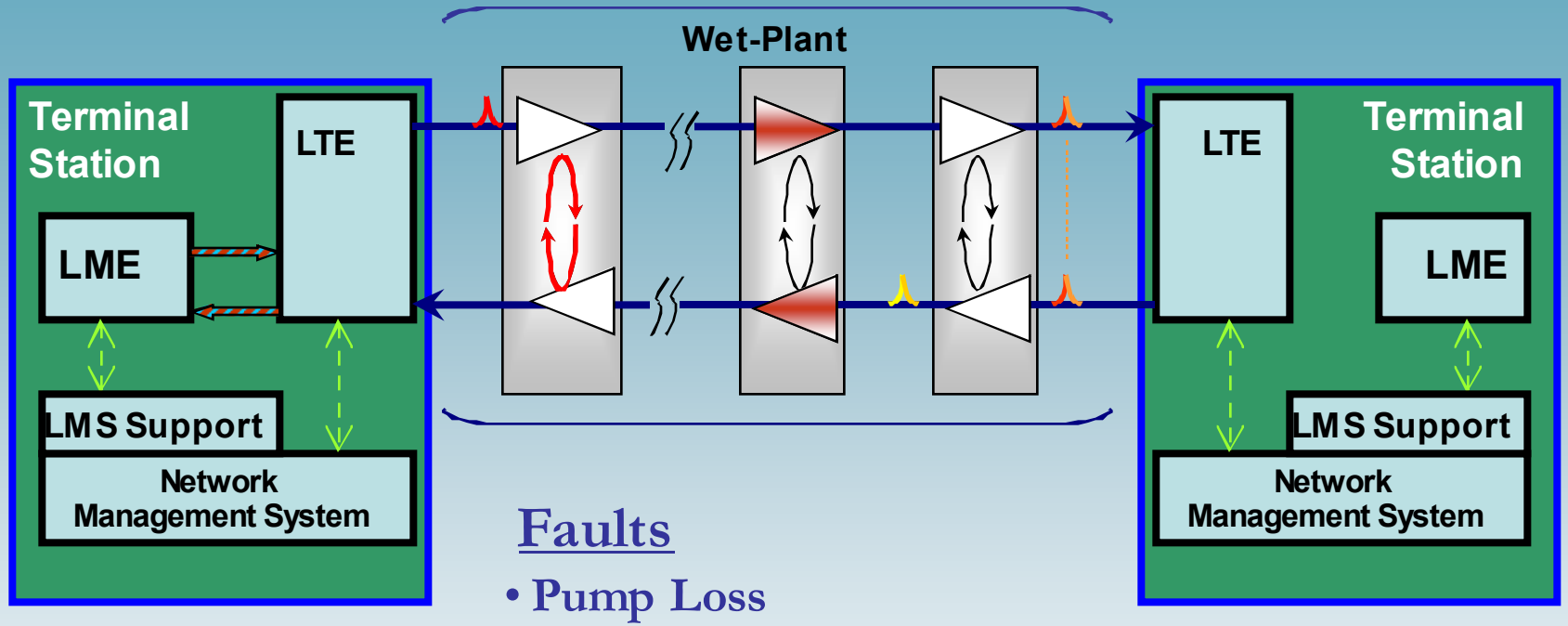
Locating Faults In-Service



Faults

- Pump Loss
- Outbound Fiber Loss
- Inbound Fiber Loss
- Cable Break
- HLLB Loss

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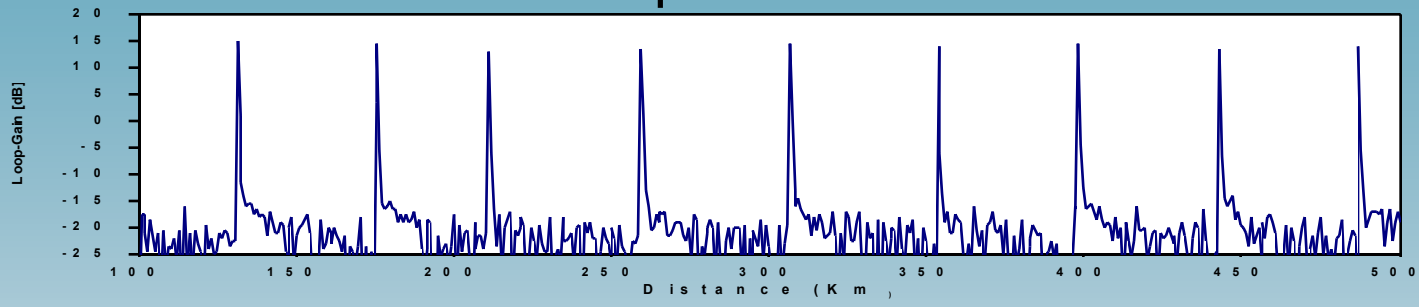
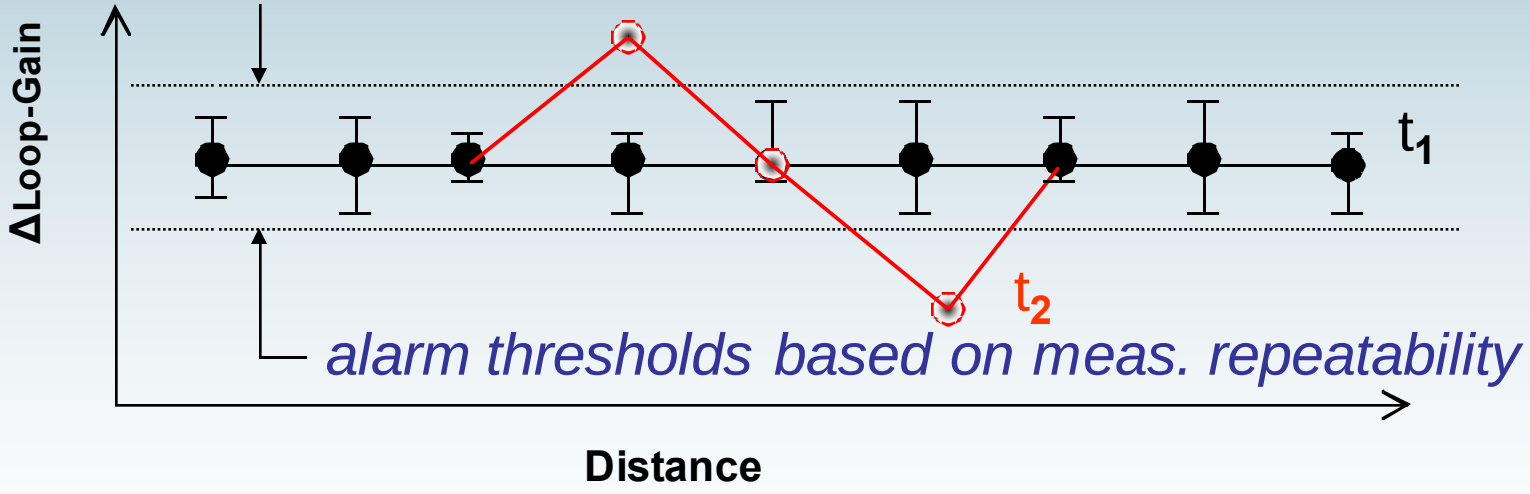
Fault Signature in Loop-Gain Data

Baseline Loop-Gain Correlation Data



Pump Fault Signature



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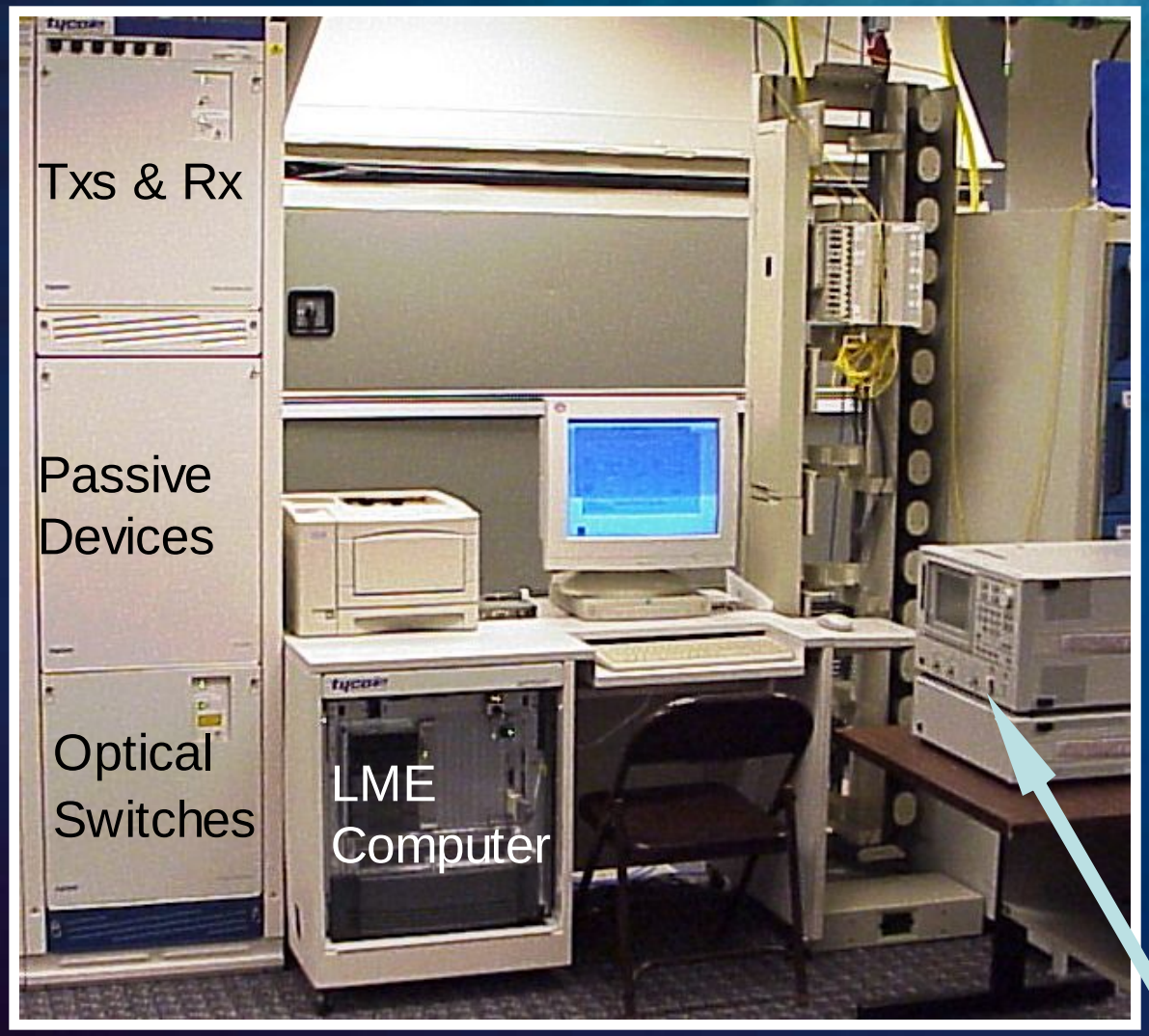
Motivation for a New LME



Desired Improvements

- fully integrated
- smaller size
- latest components
- better performance
  - accuracy
  - repeatability
  - meas. range
  - dynamic range
  - faster test times
  - finer resolution
  - more loop-gains
- simpler operation

COTDR discontinued

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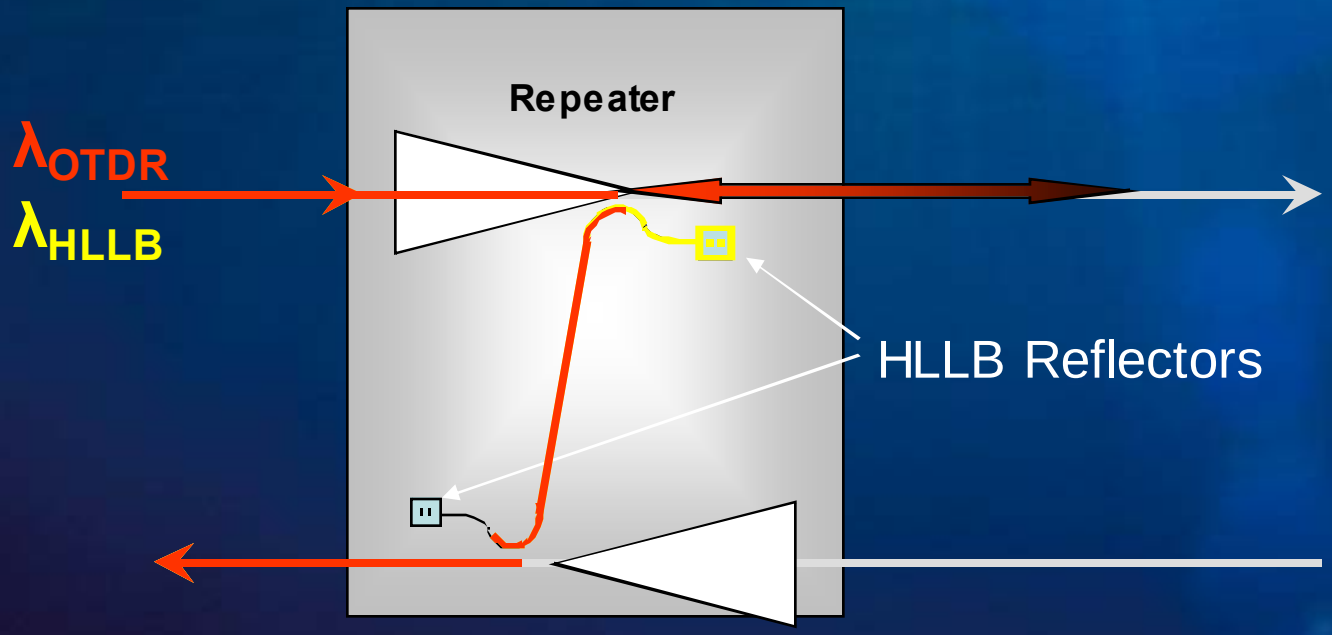
Key Design Consideration #1

- **Implement a correlation OTDR**
  - Approach uses same launch signal and correlation techniques that loop-back detection uses.
  - Tune wavelength away from narrowband HLLB wavelength
    - To avoid interference from the strong HLLB signal



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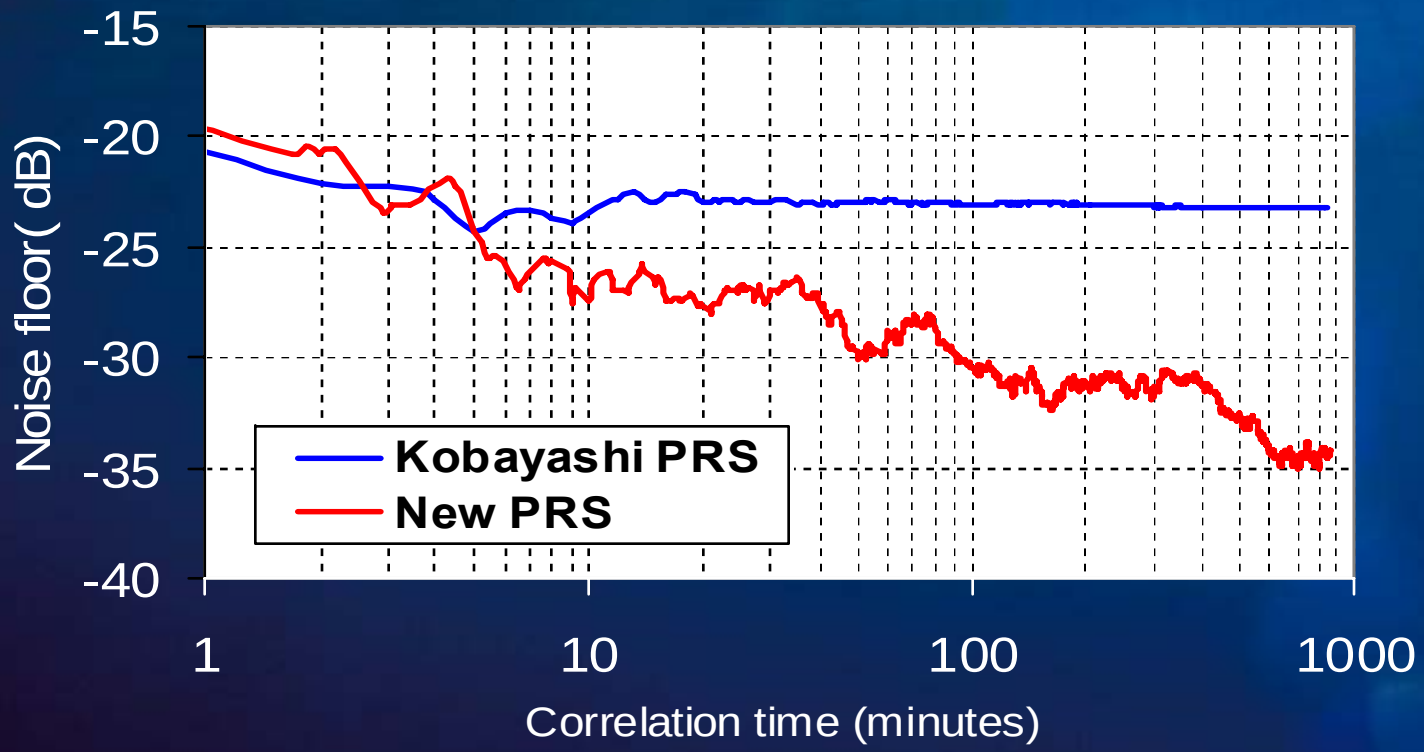
Key Design Consideration #2

- **Reduce spurious noise** **(dynamic range and sensitivity)**
  - Select a suitable (e.g., correlation properties) PRS code
  - A short code is preferable
    - avoids too many overlapping return signals in Rx



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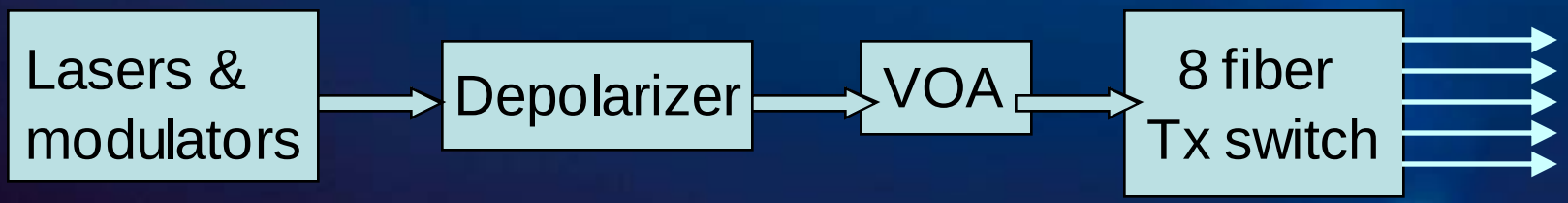
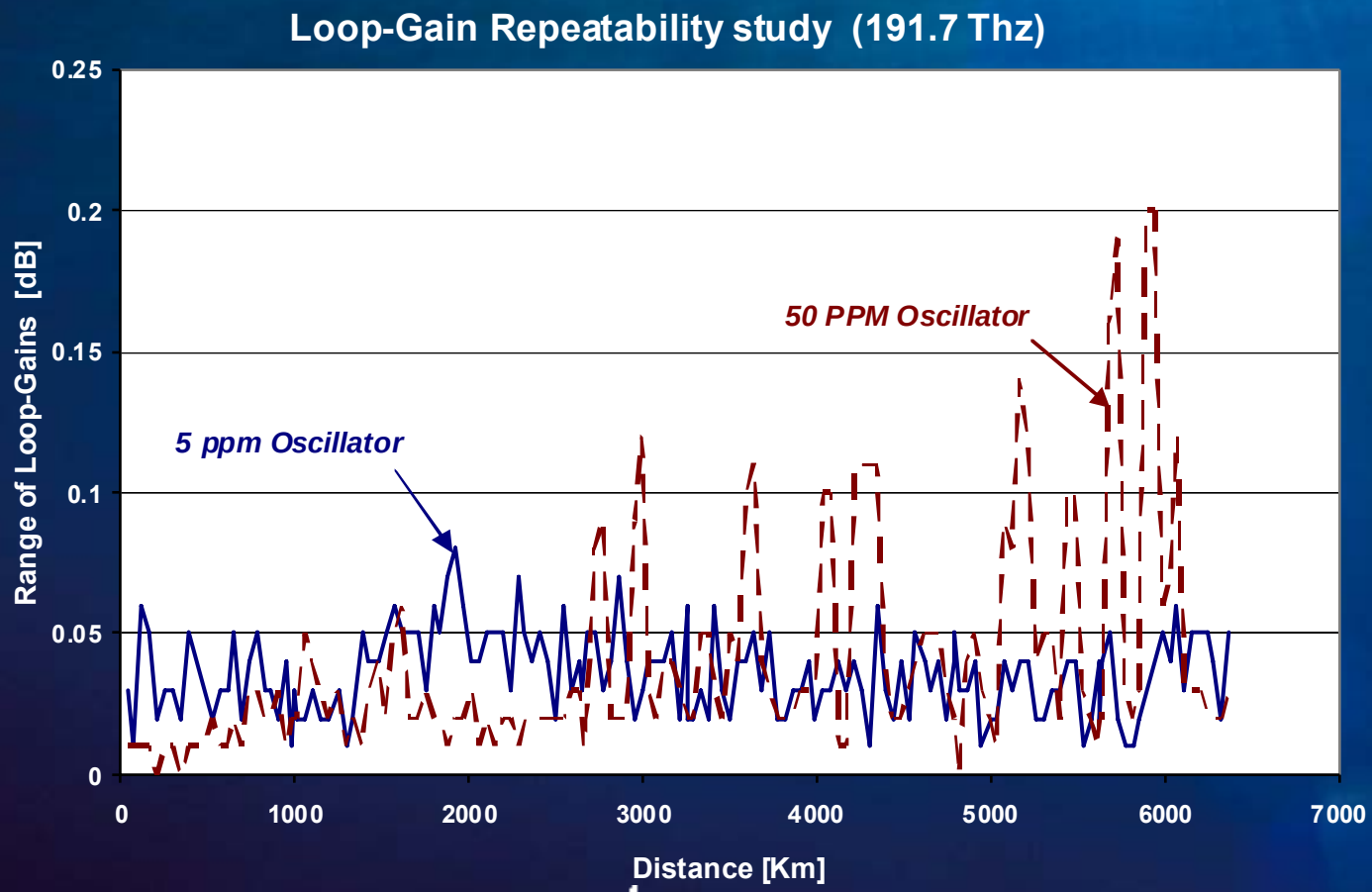
Key Design Consideration #3

- Choose a suitable Tx architecture
  - C-band Tunable Laser
  - Constant CW Load into Wet-plant
    - mitigates repeater gain modulation
  - Depolarizer
    - mitigates PHB
  - Frequency Dither Laser
    - mitigates SBS and SPM for out-of-service OTDR



Key Design Consideration #4

- Choose a very stable clock oscillator
  - Improves far-end loop-gain repeatability
  - Enables fault signature thresholds to be set lower



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Next Generation LME Results

In-Service Fault Type	Detectable Fault w/high confidence	In-service Testing Time per LME λ
Outbound Fiber Loss	>1.5 dB	≤ 1 hour
Inbound Fiber Loss	>1.5 dB	
Fiber Break	Yes	
Fault in a Repeater's HLLB path	>.75 dB	
Repeater Pump Degradation	3 dB	

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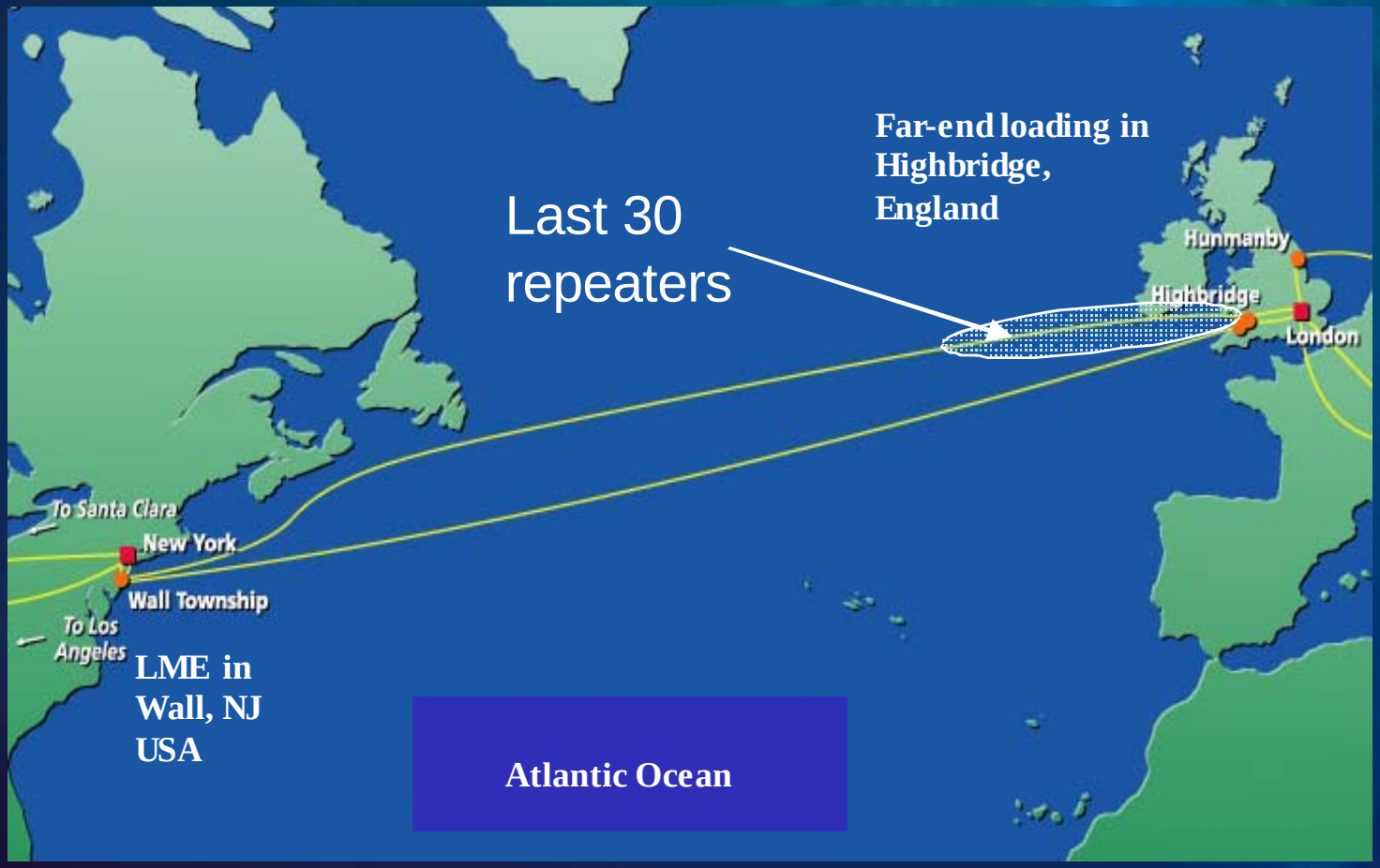
Next Gen Transatlantic Out-of-Service OTDR Test Results



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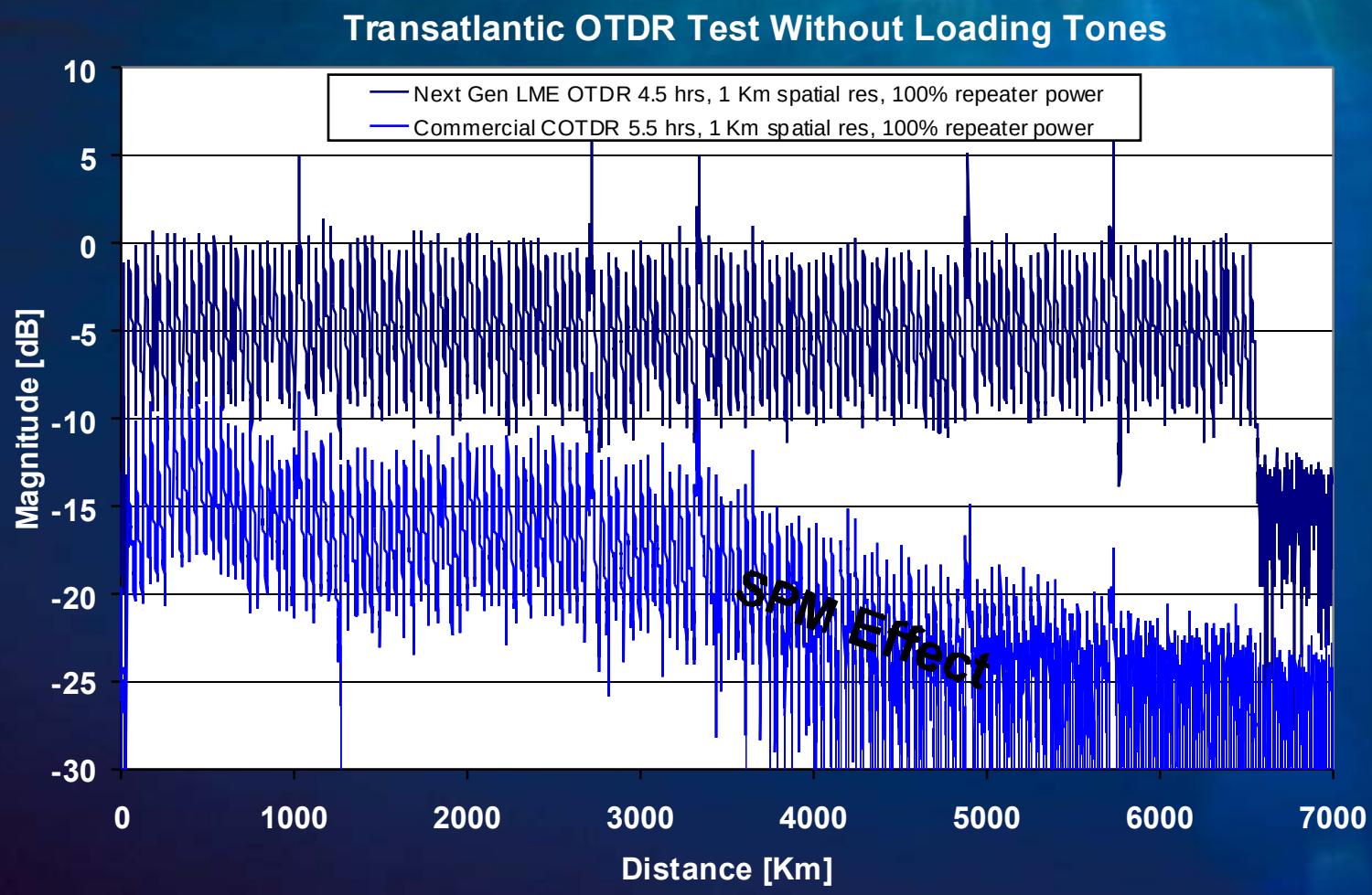
Correlation OTDR vs Commercial COTDR: Full Scan Result



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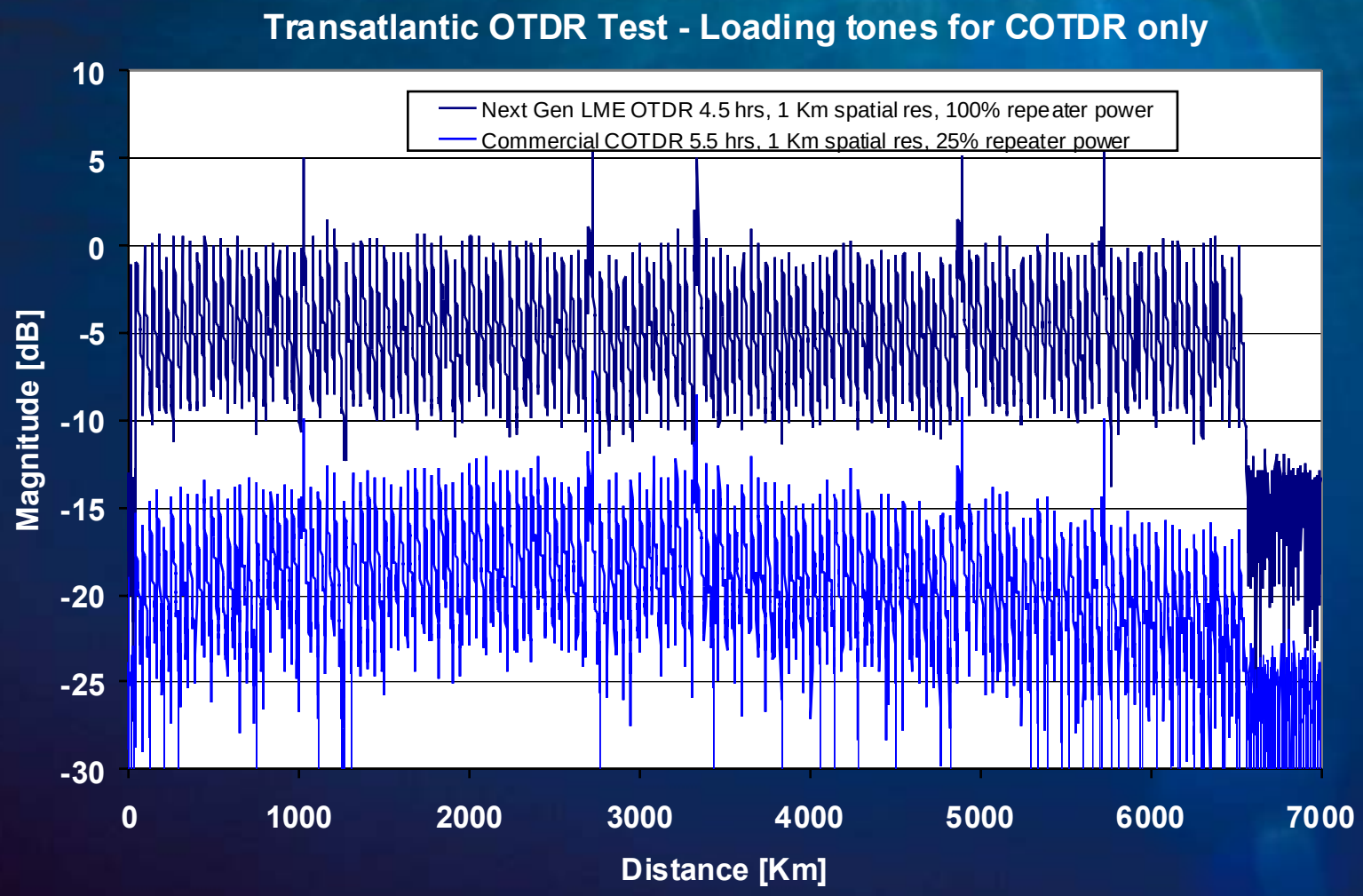

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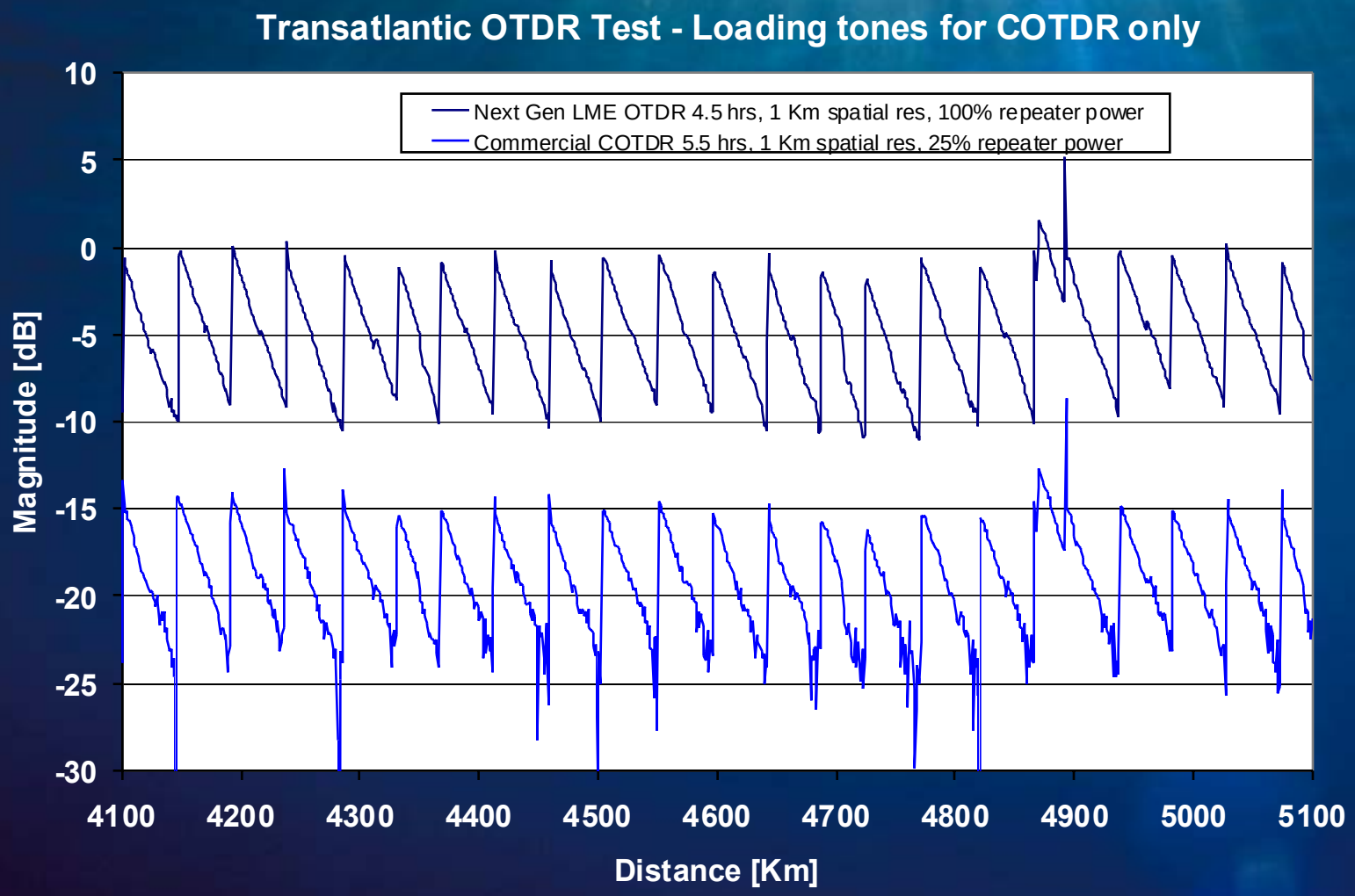

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Next Generation LME OTDR Results

Gen 3 LME Out-of-Service * OTDR Capabilities for 75km span		
Spatial Resolution	Gen 3 LME OTDR Test Time	Commercial C-OTDR Test Time
.5 km	7 days	40 days
.8 km	2.5 days	25 days
1 km	2 days*	20 days
3 km	5 hours*	7 days

* in-service OTDR testing is possible but very time consuming

COTDR limitations

- SBS limits launch power
- Loading tones required to reduce SPM
- Longer averaging time

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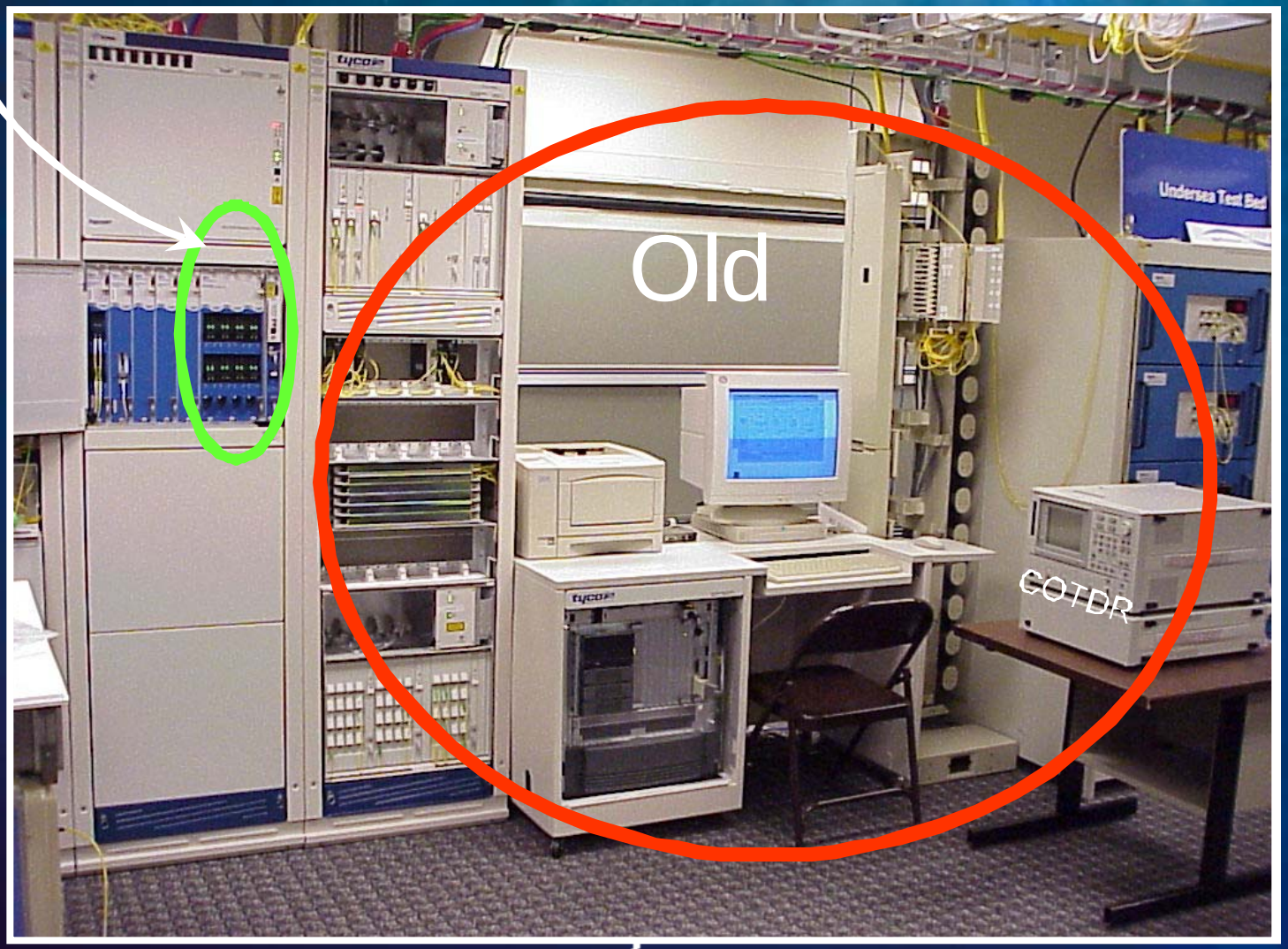
Space Savings for New LME



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Summary

- LMS provides an important wet-plant monitoring and fault detection ability.
- New technology enables an improved LME with an imbedded OTDR capability.
- Successful transatlantic testing with the dual function LME design showed improved data collection capability compared to existing COTDR design.
- The new LME reduces the need for stand-alone COTDR equipment at a cost savings for system operators.

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Thank You
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