



Spectrum Sharing

Options for Accessing Capacity

TNC Workshop:

Designing the next generation Open Optical Network

June 10, 2018

Spectrum Sharing

Overview

Agenda

- 1 What is Spectrum Sharing?
- 2 4 Pillars of Submarine Spectrum Sharing
- 3 Spectrum Sharing in Terrestrial Networks
- 4 Technical Maturity & Deployment Considerations
- 5 Conclusions

Multiple options for accessing capacity...

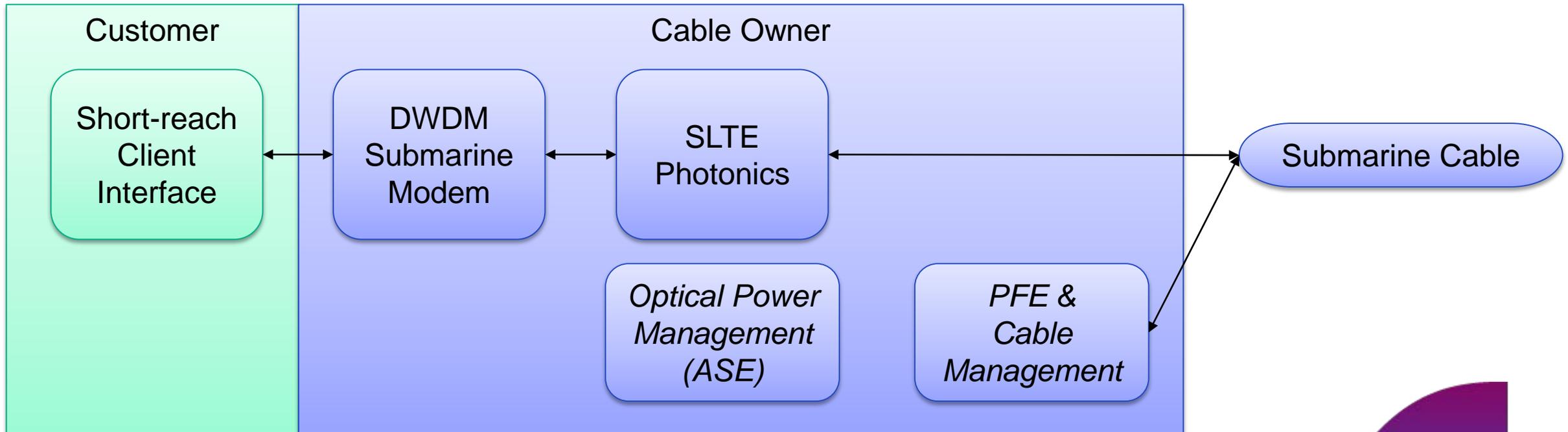
What is Spectrum Sharing? A submarine view...

Options for Adding Capacity to a Submarine Cable

When the capacity of a single fiber pair exceeds the needs of a single customer, it can be advantageous to share this fiber pair among multiple customers.

There are several different models for sharing this bandwidth, and they can be categorized as follows:

1. **Managed Services:** The customer accesses capacity through a standardized, short reach interface (e.g. STM64 or 100GE) and the cable owner provides the modems & SLTE and manages the spectrum

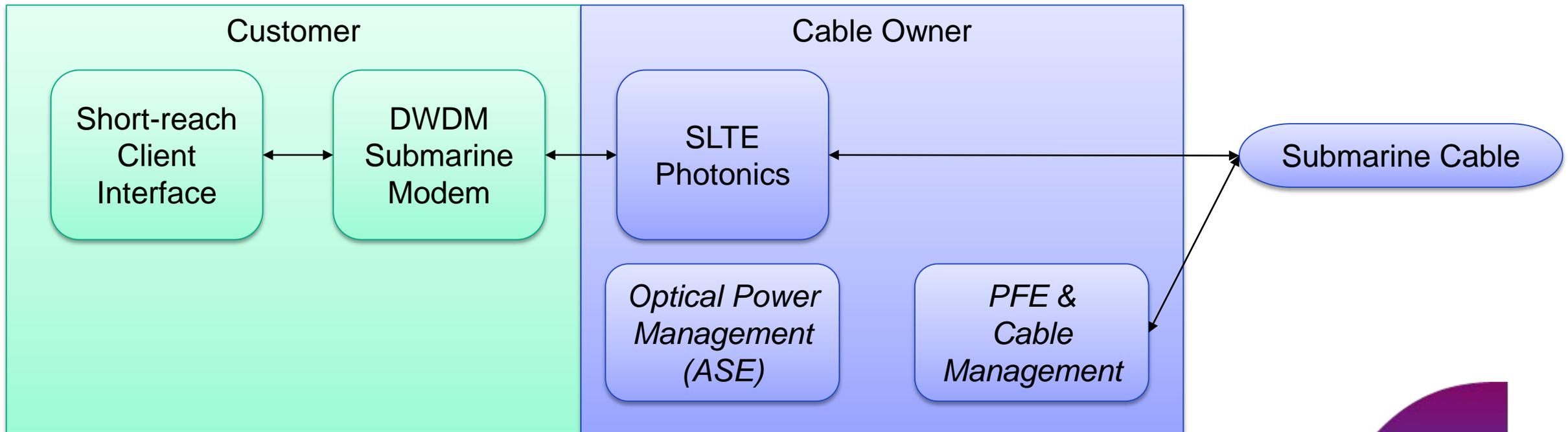


Options for Adding Capacity to a Submarine Cable

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- 2. Managed Spectrum:** The customer provides the modems, and the cable owner provides the SLTE photonics and manages all of the spectrum (aka “Alien Wavelength”)

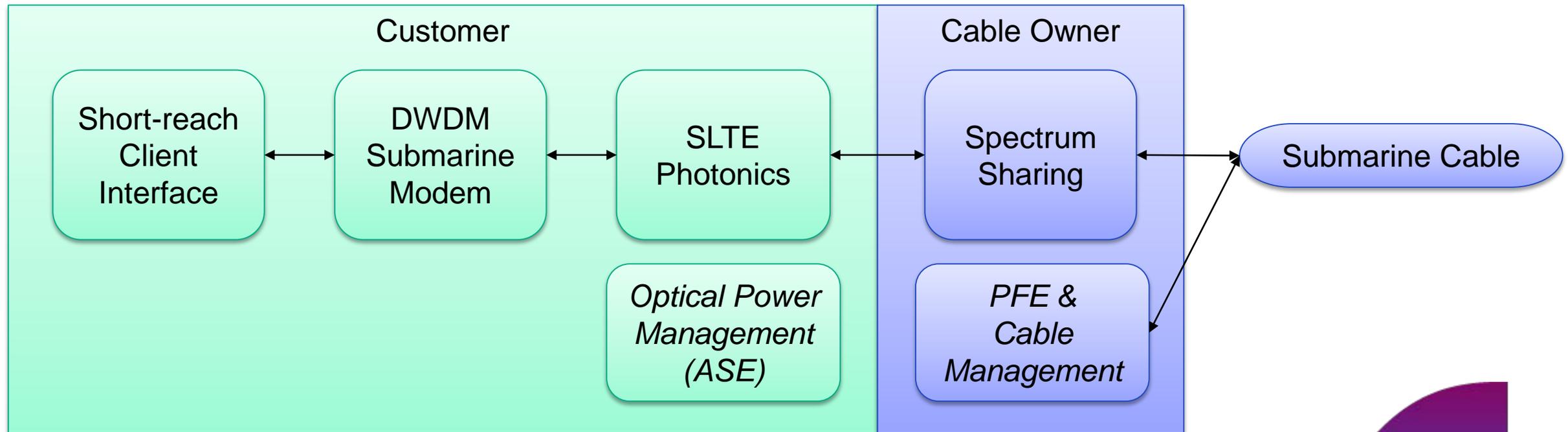


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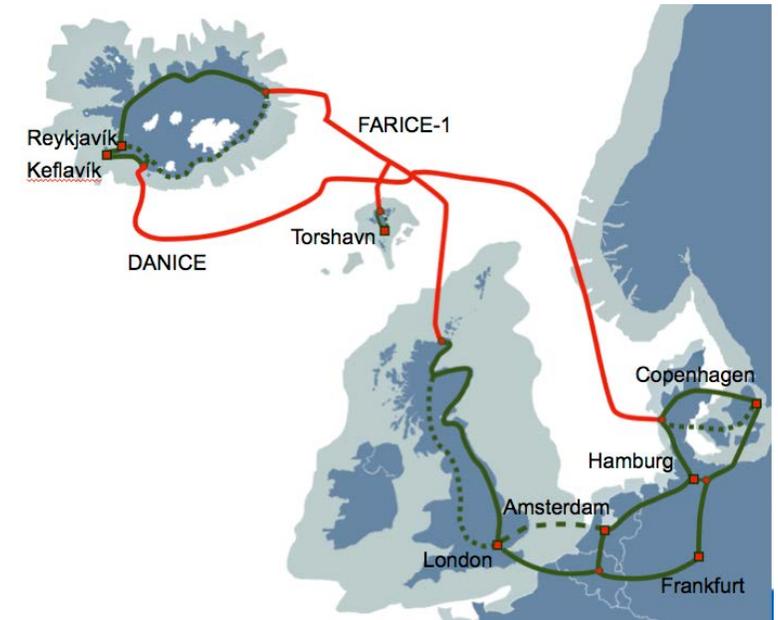
3. **Spectrum Sharing:** The customer provides their own modems and SLTE, and the cable owner provides a spectrum sharing solution with appropriate access and security features



Managed Spectrum - Some Historical Examples

TNC 2012

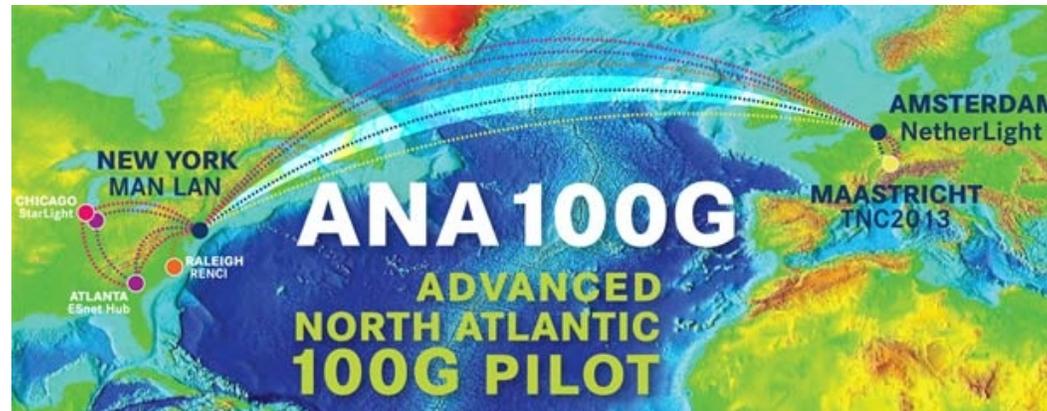
- 100G & 10G over Submarine & Terrestrial (GeoMesh) system
- Demo 4K Video From Amsterdam to TNC-2012 Venue in Iceland
 - NORDUnet and SURFnet terrestrial sections
 - FARICE submarine section (DANICE cable)



<http://www.farice.is/network/network-map/nr/194>

TNC 2013

- 100G GeoMesh circuit NY to Amsterdam
- First trans-Atlantic 100G link reserved specifically for R&E networks
- ANA-100G: <https://www.engadget.com/2013/06/04/first-100-gbps-transatlantic-link-research-education/>



Pillars of Spectrum Sharing

Key Technical Attributes of a Submarine Spectrum Sharing Solution

Primary Motivation = Technology Independence

Each spectrum owner must be able to select terminal and/or modem technology from any vendor, independent of other owners.

Spectrum Security

Independence between Spectrum Owners in the Transmit direction.

Spectrum Privacy

Spectrum Owners can only access their allocated spectrum in the Receive direction.

Spectral Monitoring

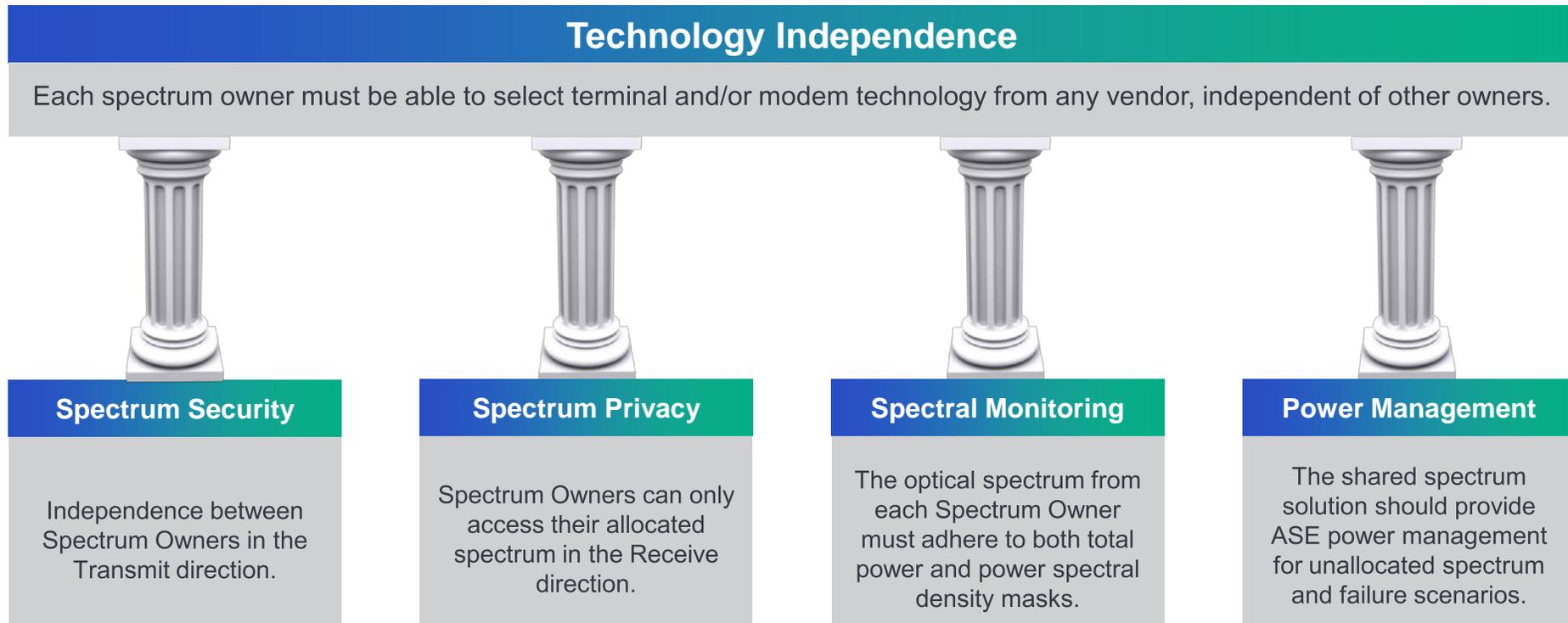
The optical spectrum from each Spectrum Owner must adhere to both total power and power spectral density masks.

Power Management

The shared spectrum solution should provide optical power management for unallocated spectrum and failure scenarios.

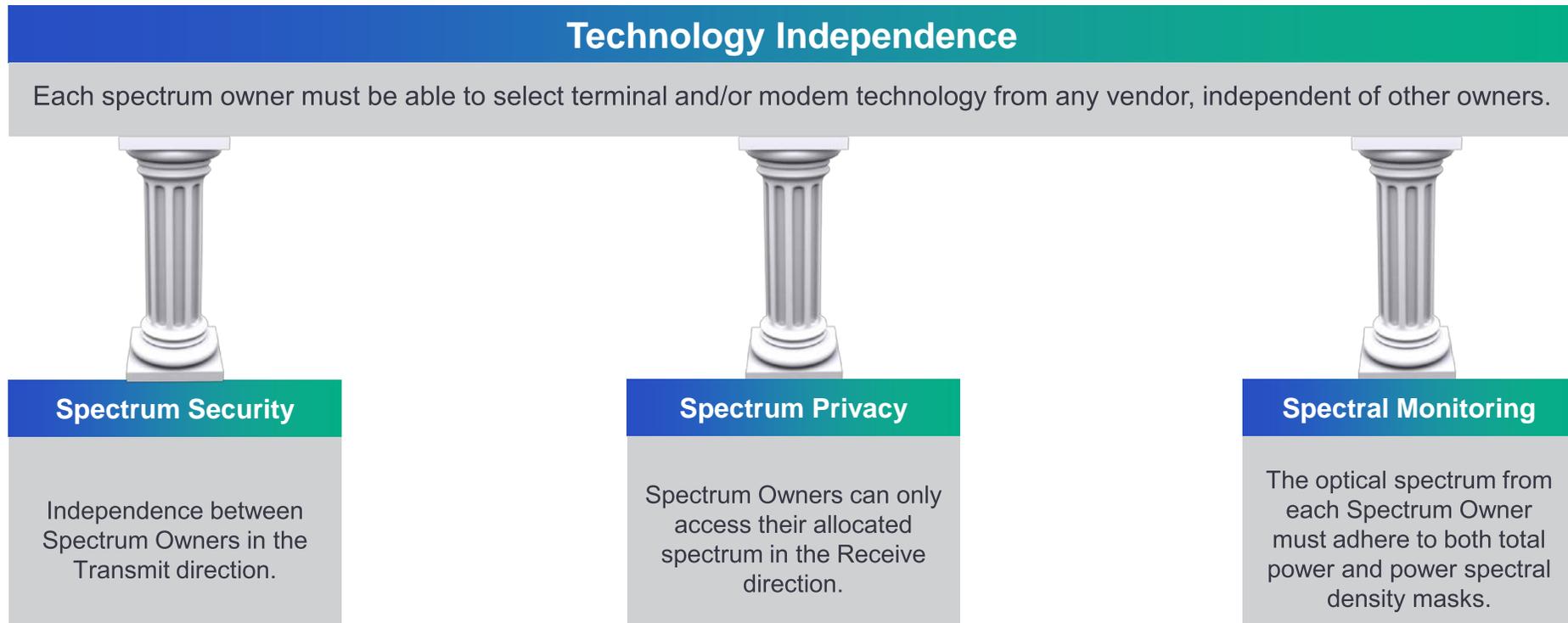
Terrestrial vs. Submarine Spectrum Sharing

Terrestrial Spectrum Sharing shares the same fundamental requirements as Submarine Spectrum Sharing, with the exception of Optical Power Management



Terrestrial vs. Submarine Spectrum Sharing

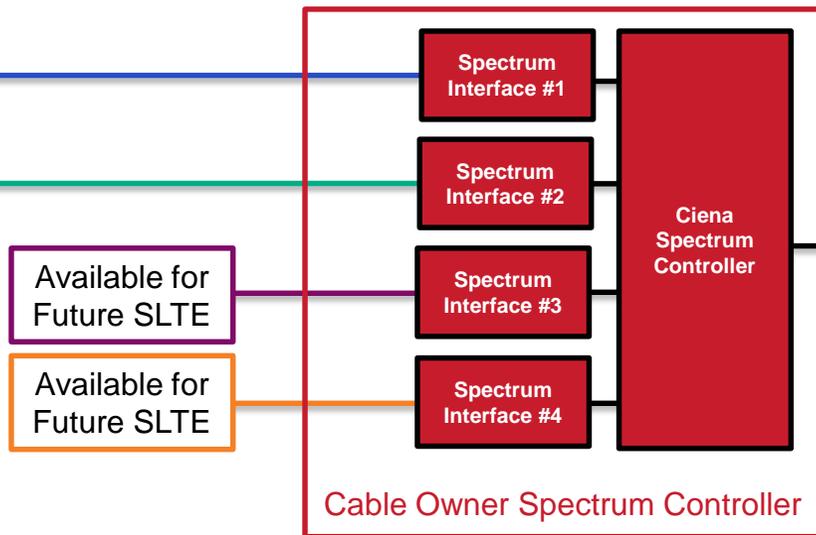
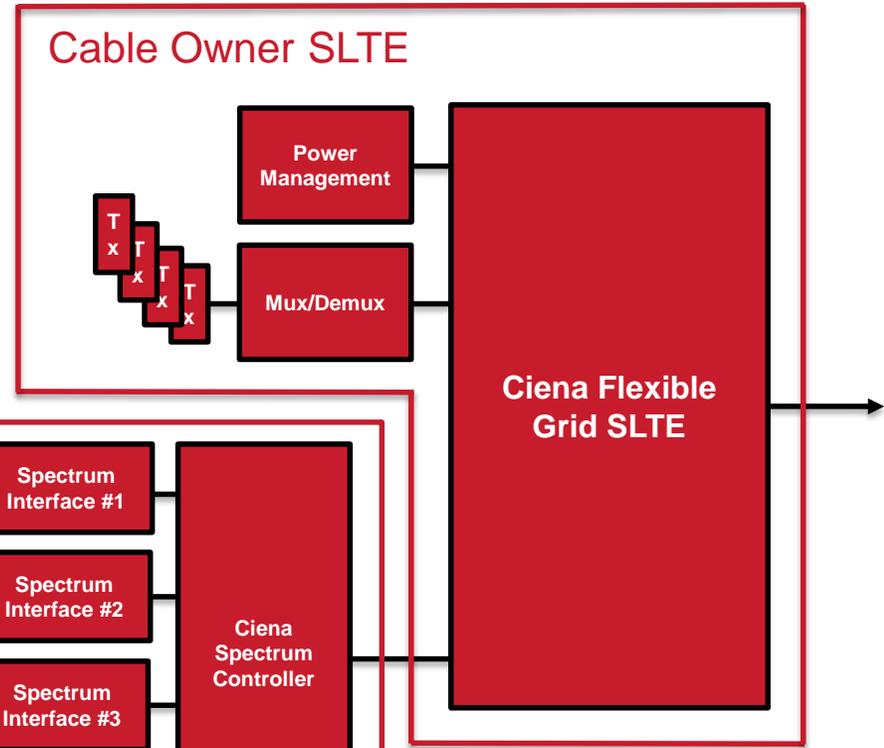
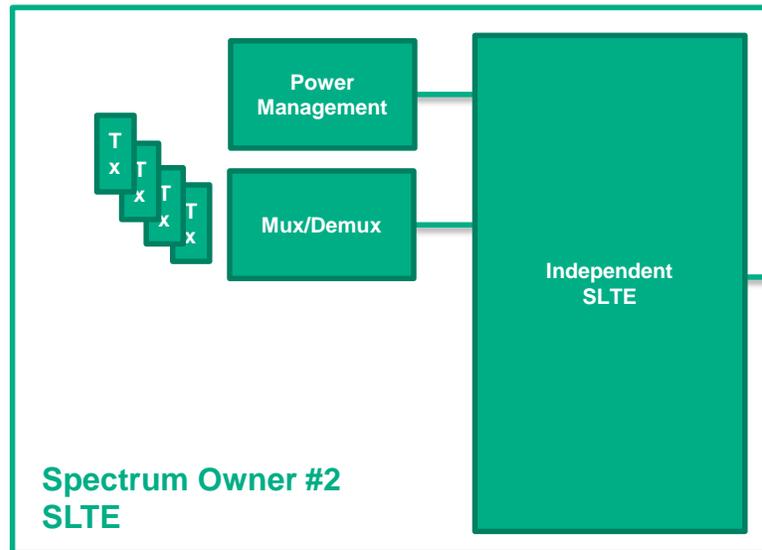
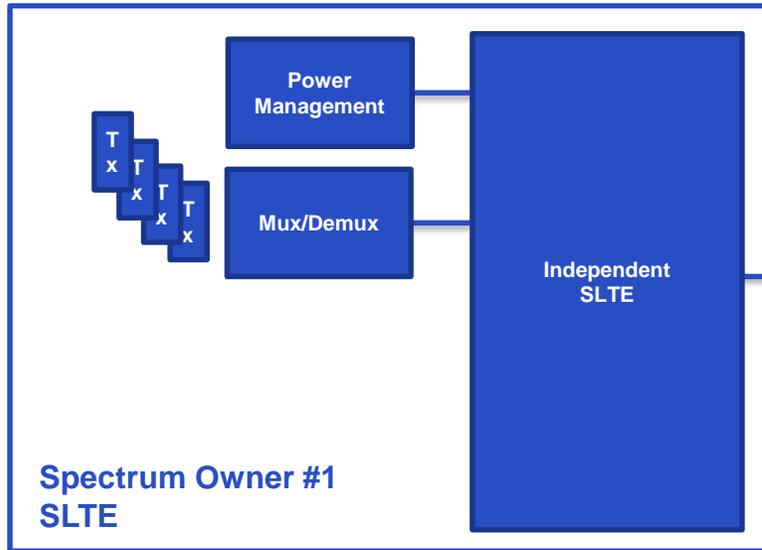
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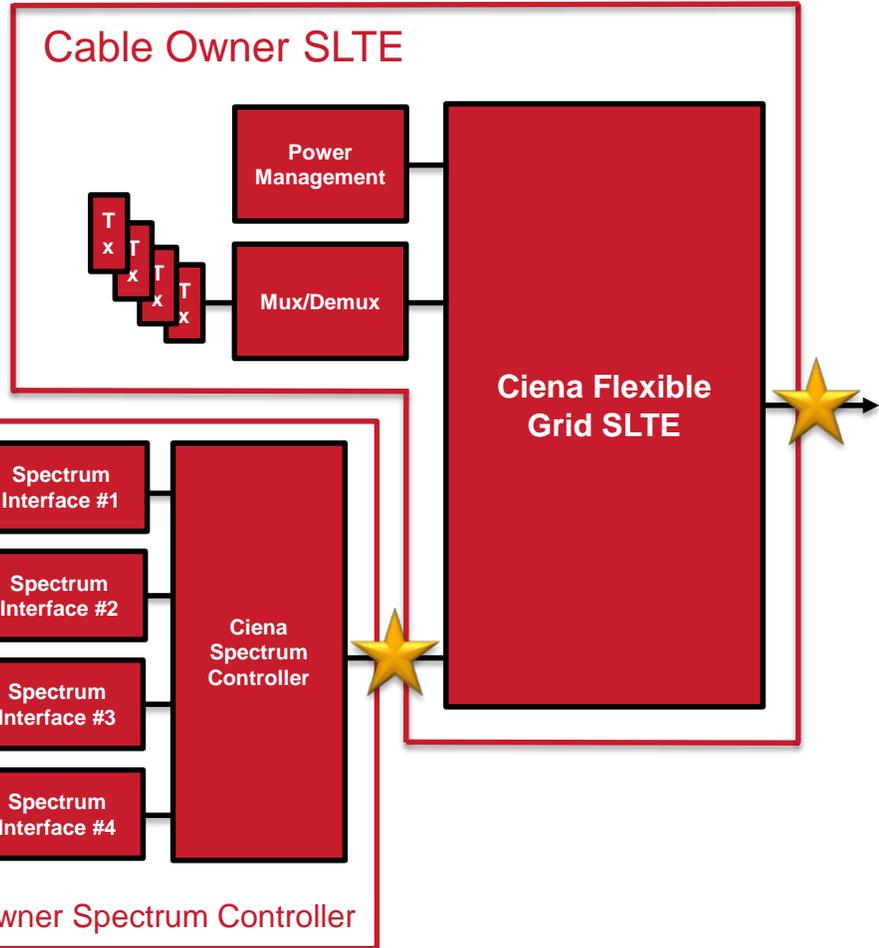
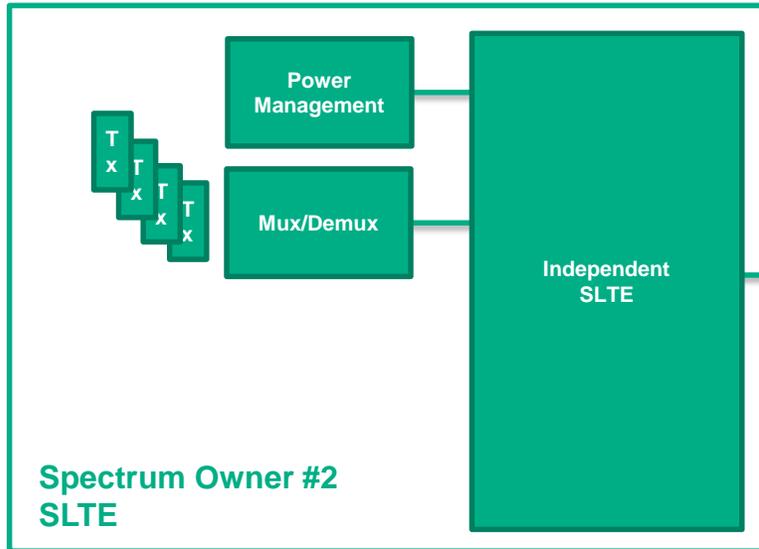
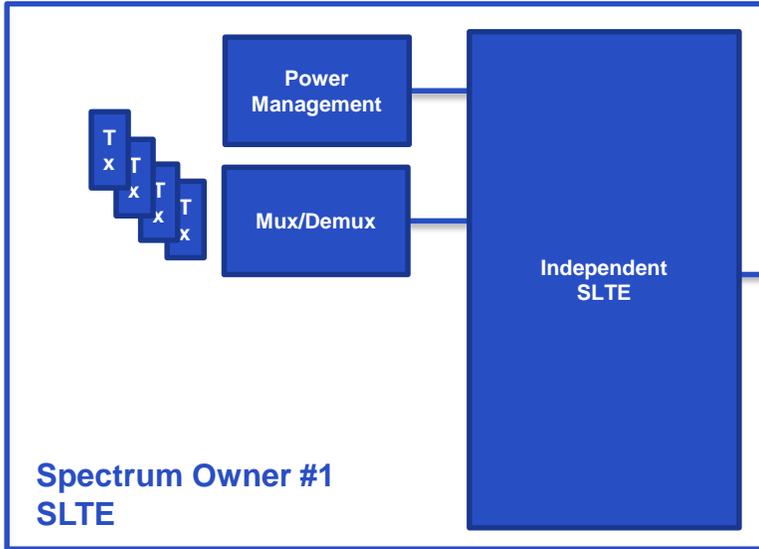
The image is a composite. The top half shows a turbulent ocean surface with white-capped waves under a grey, overcast sky. The bottom half is an underwater scene. A swimmer in blue plaid shorts and a black cap is gliding horizontally. Behind the swimmer is a large, semi-circular graphic overlay that represents a spectrum. The overlay is divided into three segments: a bright green segment on the left, a dark teal segment in the middle, and a black segment on the right. The swimmer's body is positioned across these segments, with the green segment behind his head and the black segment behind his feet.

Example: Submarine Spectrum Sharing

Spectrum Sharing: Normal Operation



Spectrum Sharing: Spectral Monitoring Points

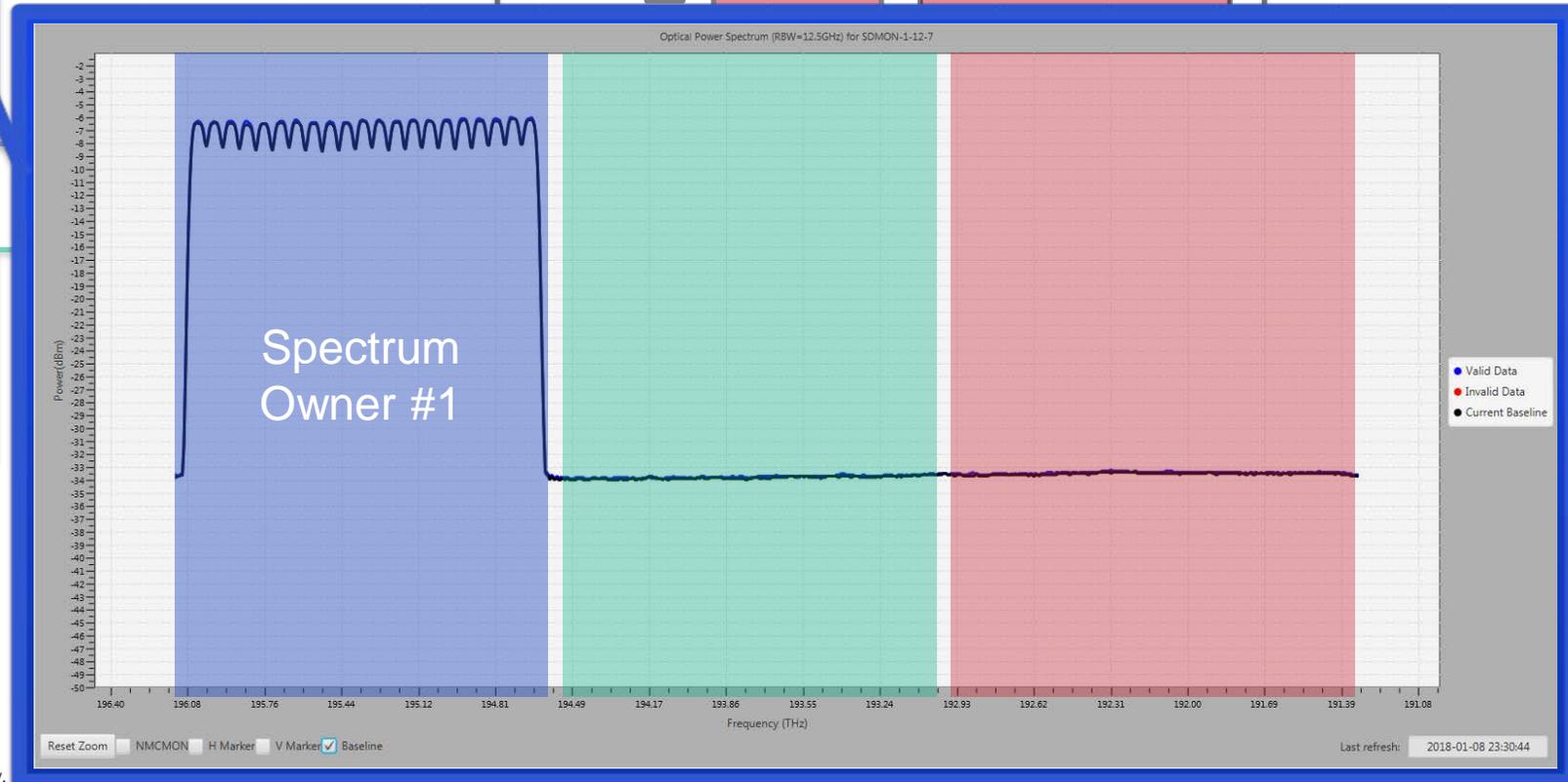
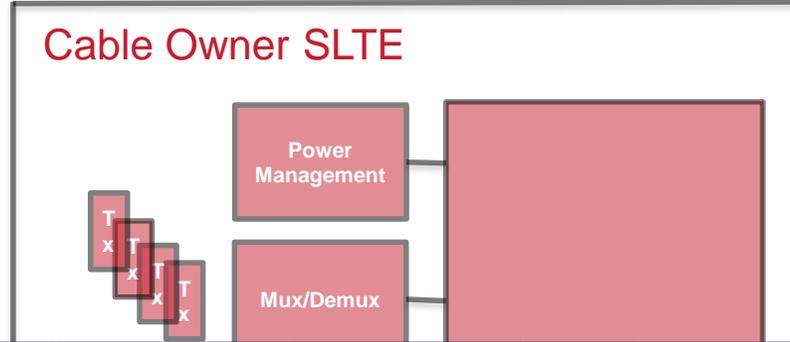
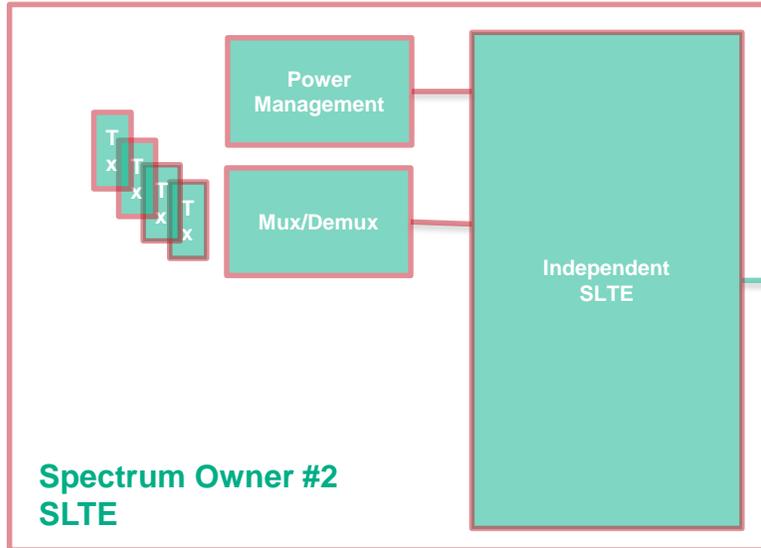
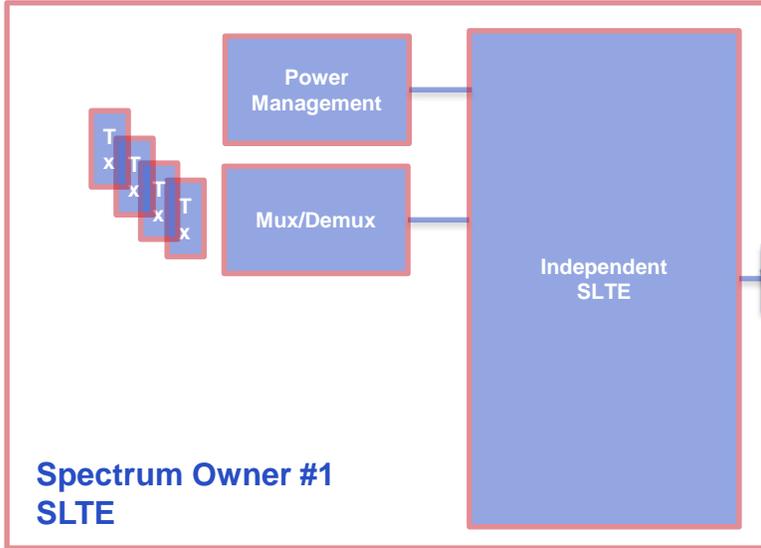


Available for Future SLTE

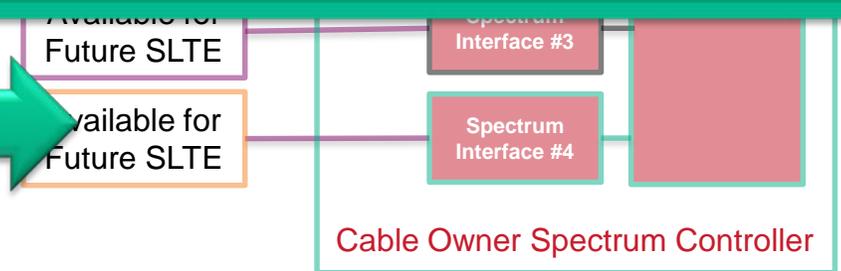
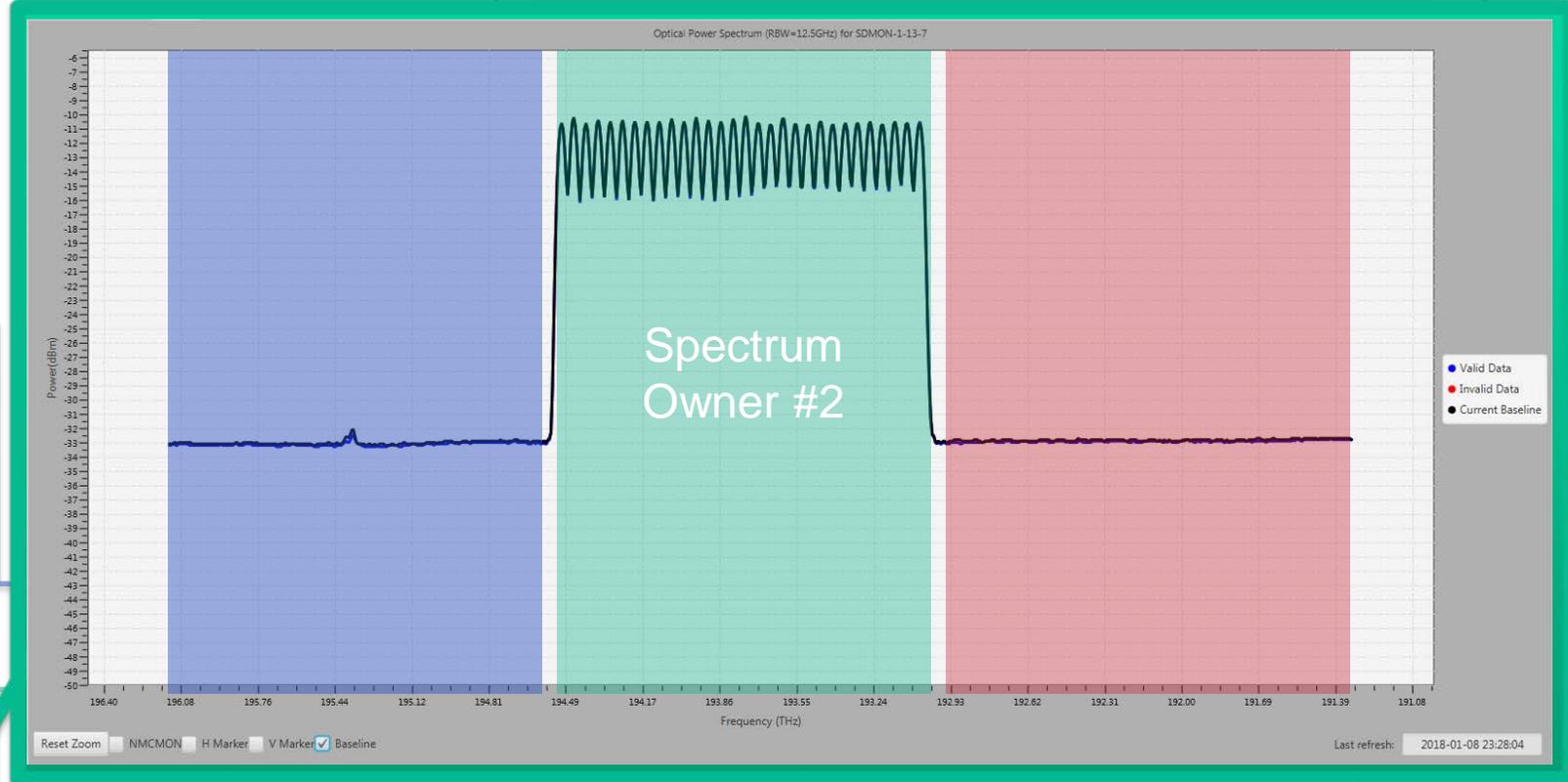
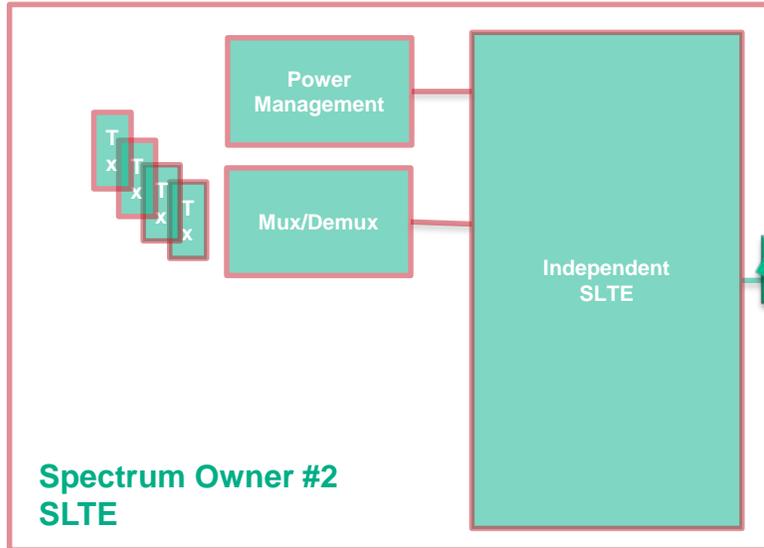
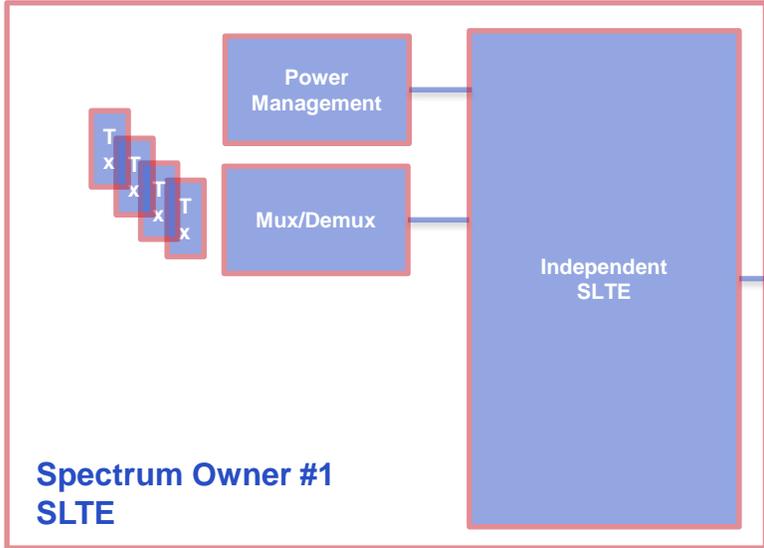
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★ = Spectral Monitoring Points for Cable Owner

Spectrum Sharing: Normal Operation

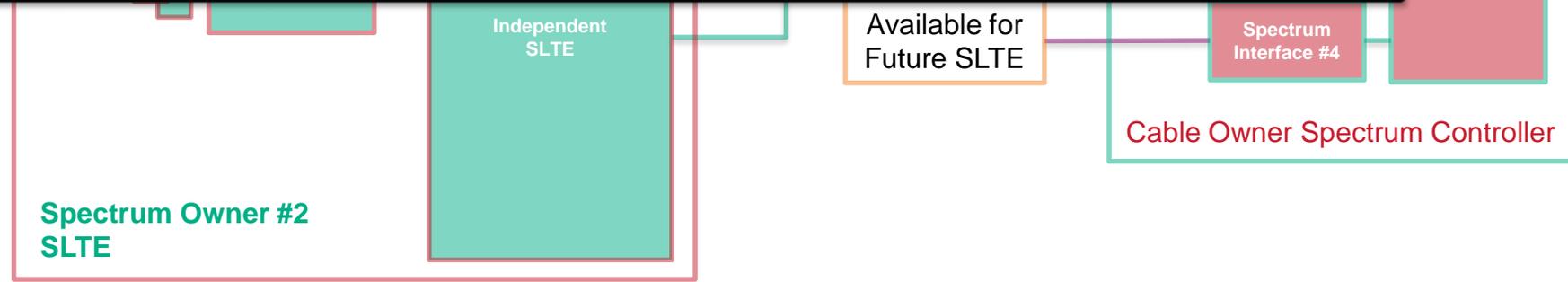
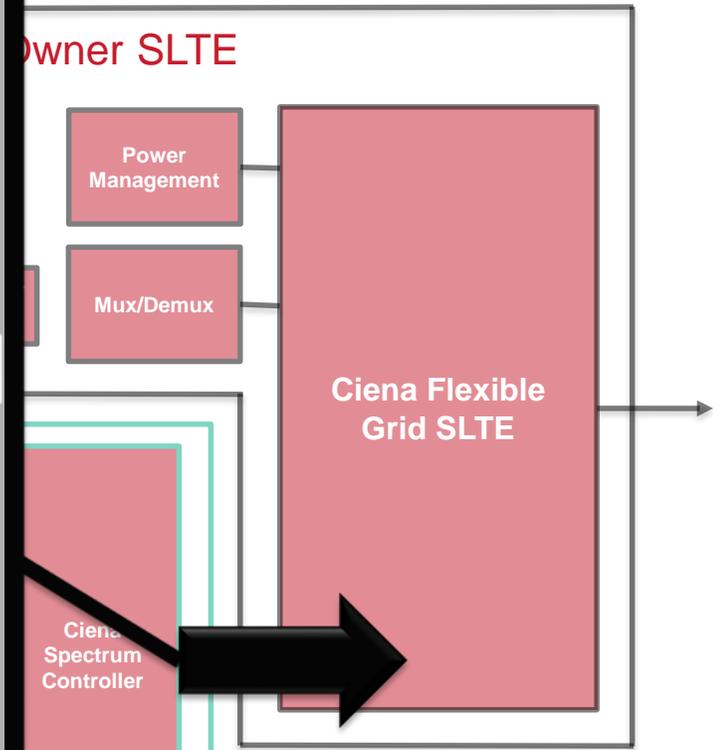
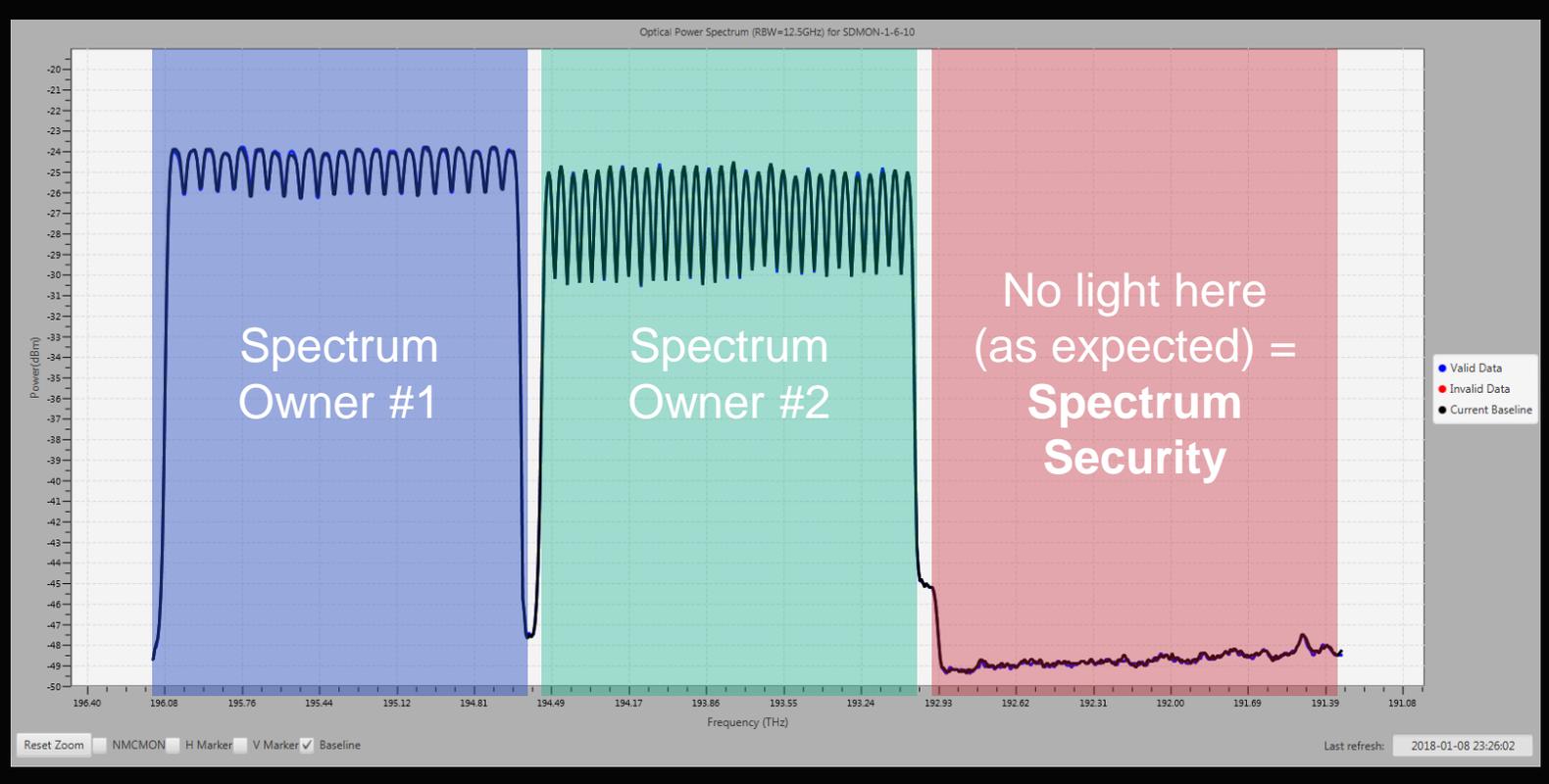


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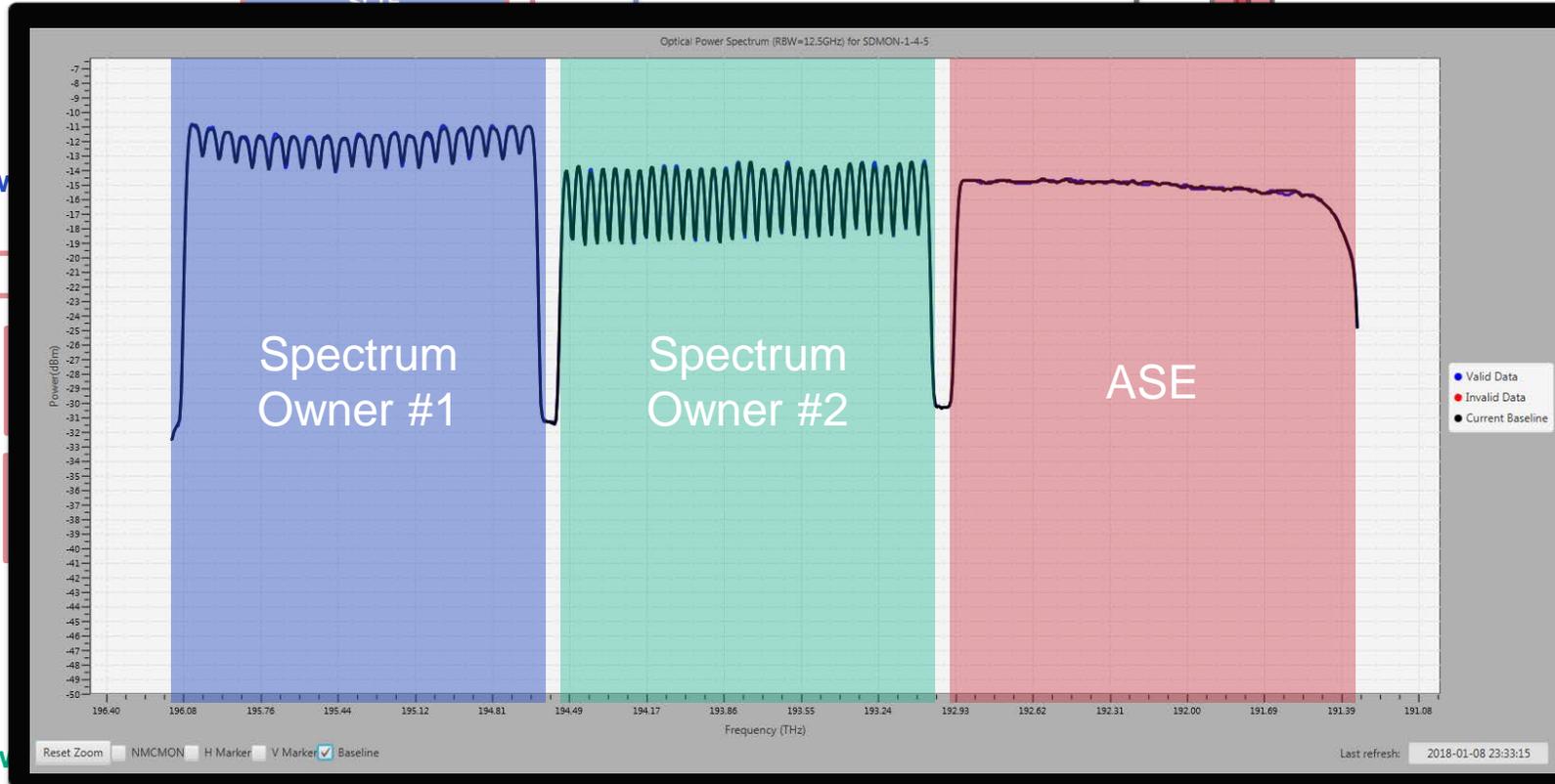
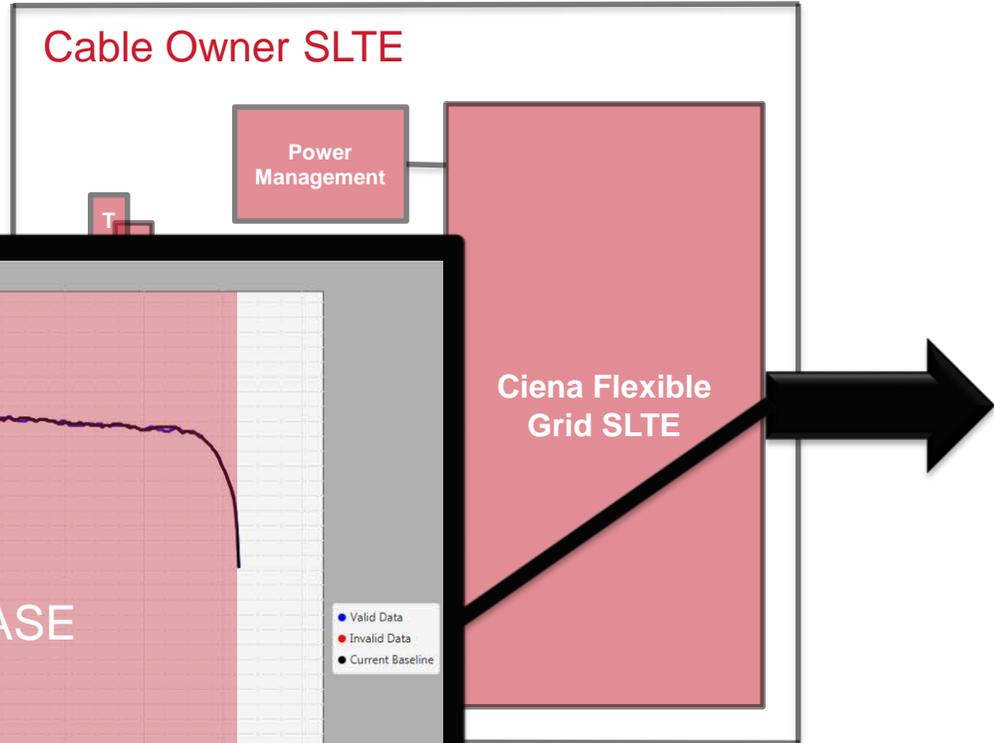
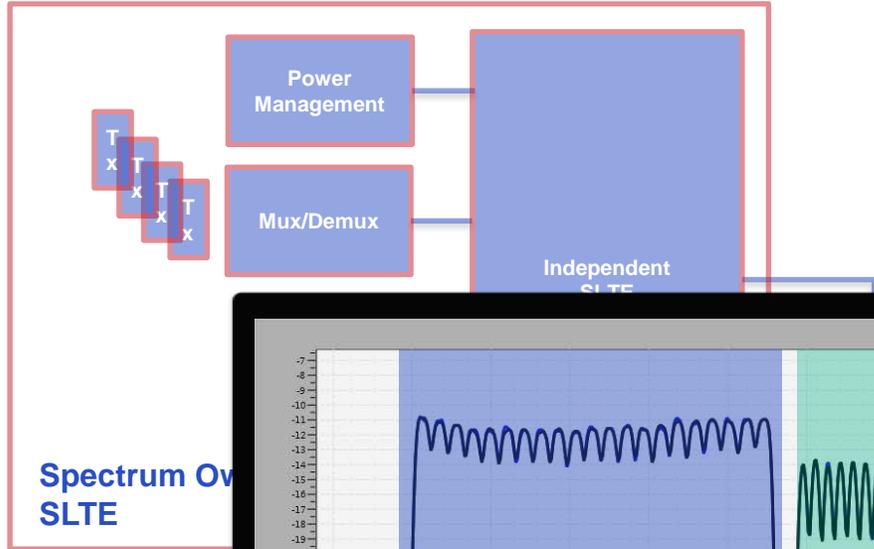


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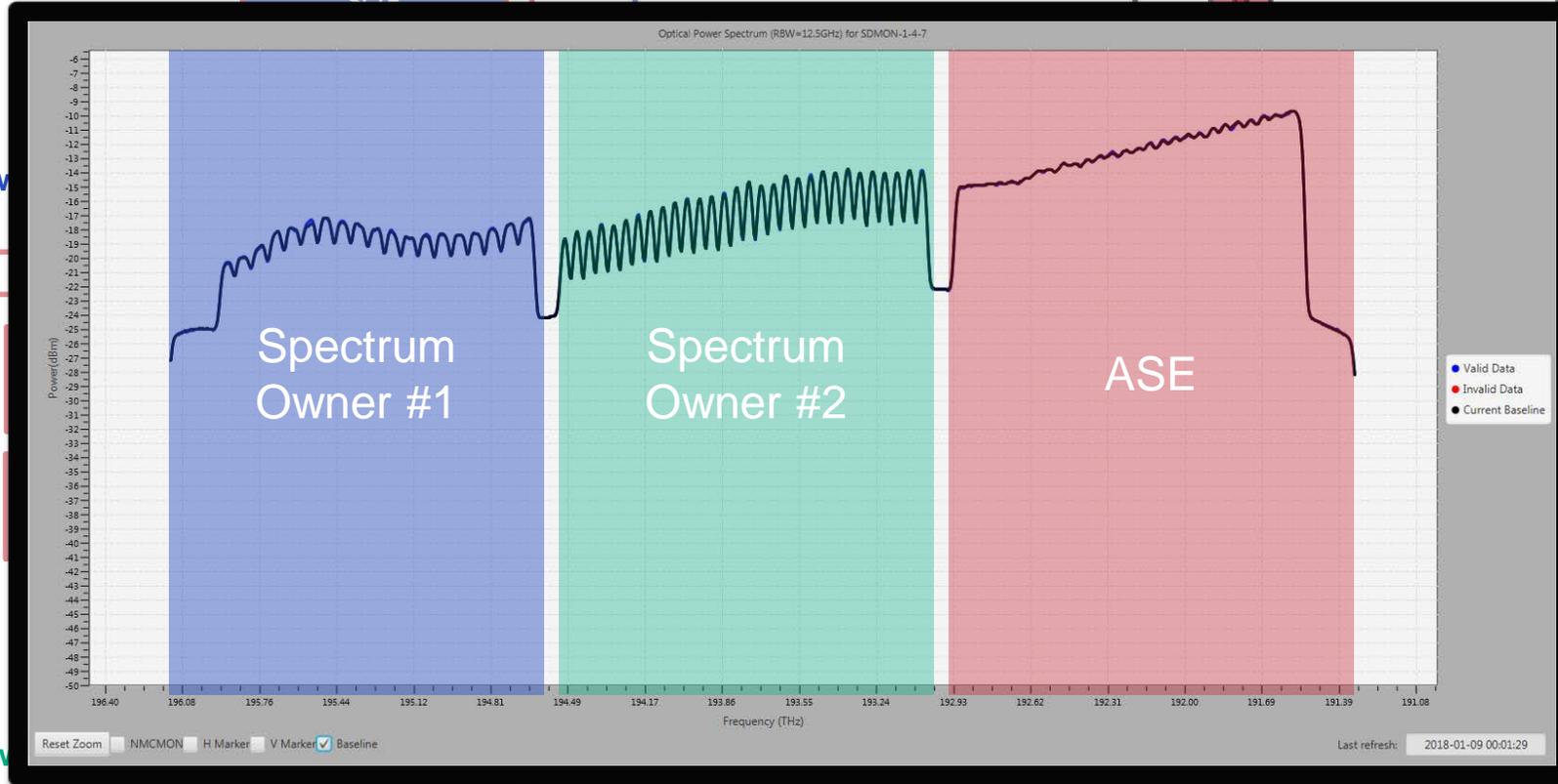
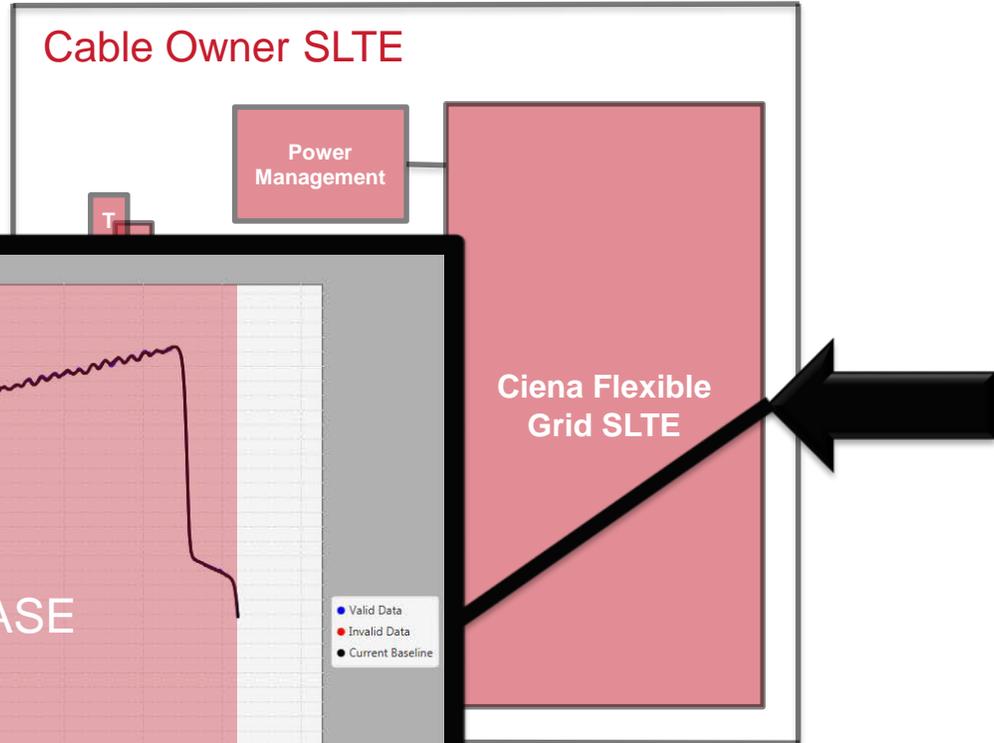
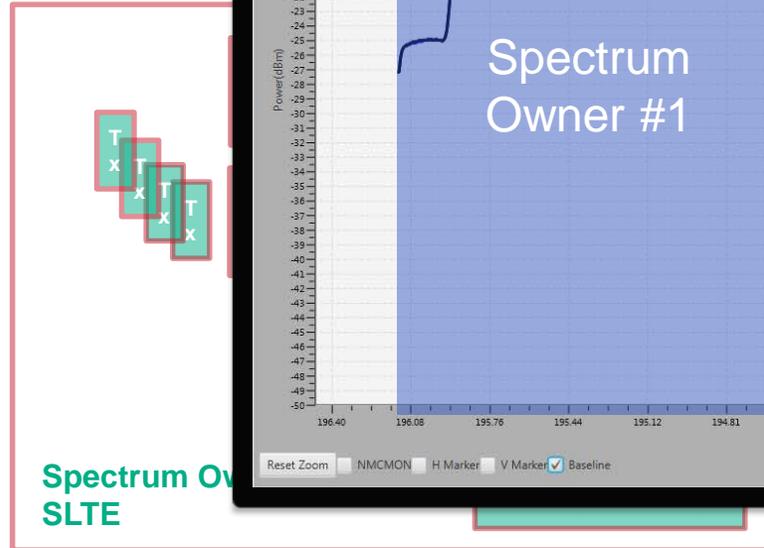
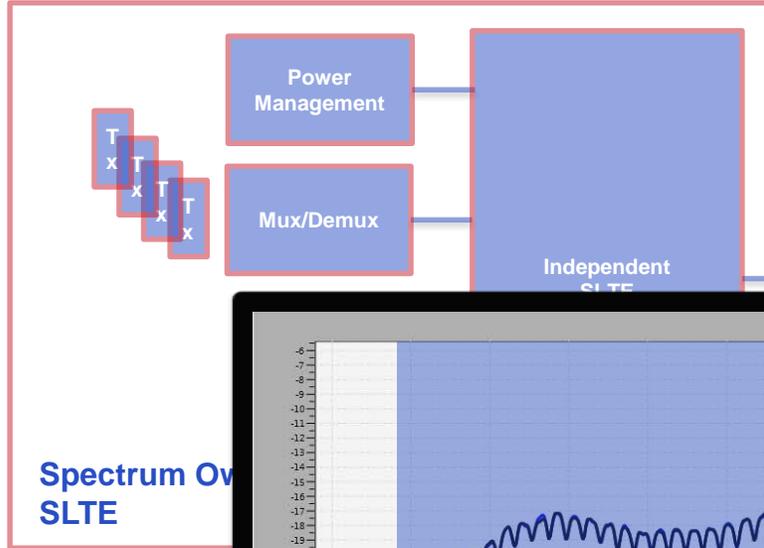
Spectrum Sharing Example



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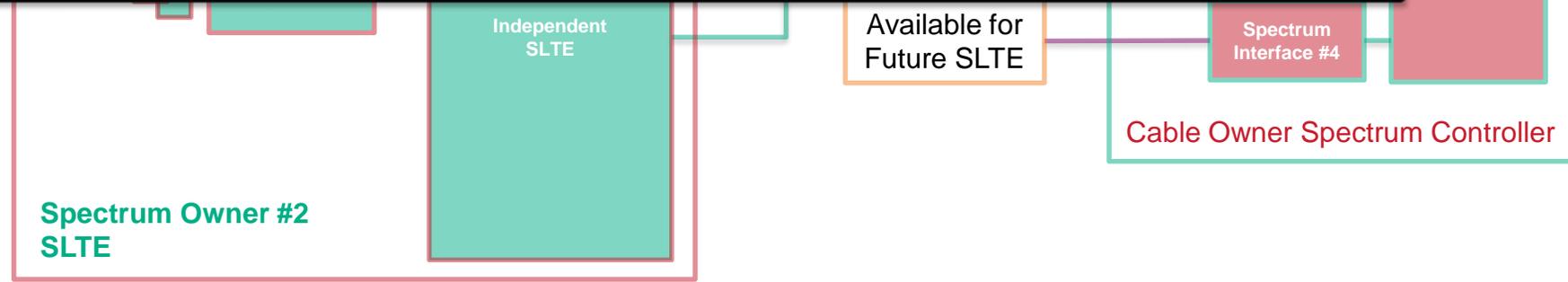
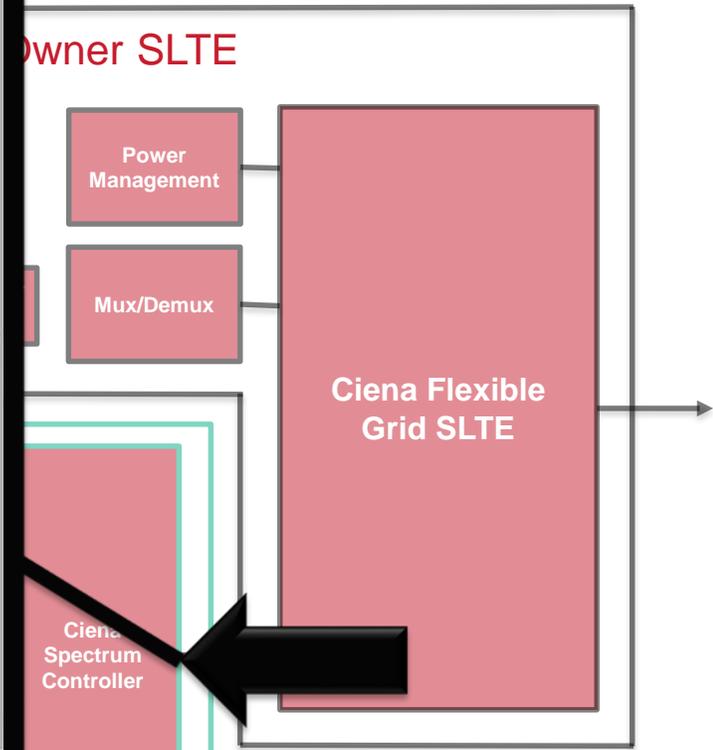
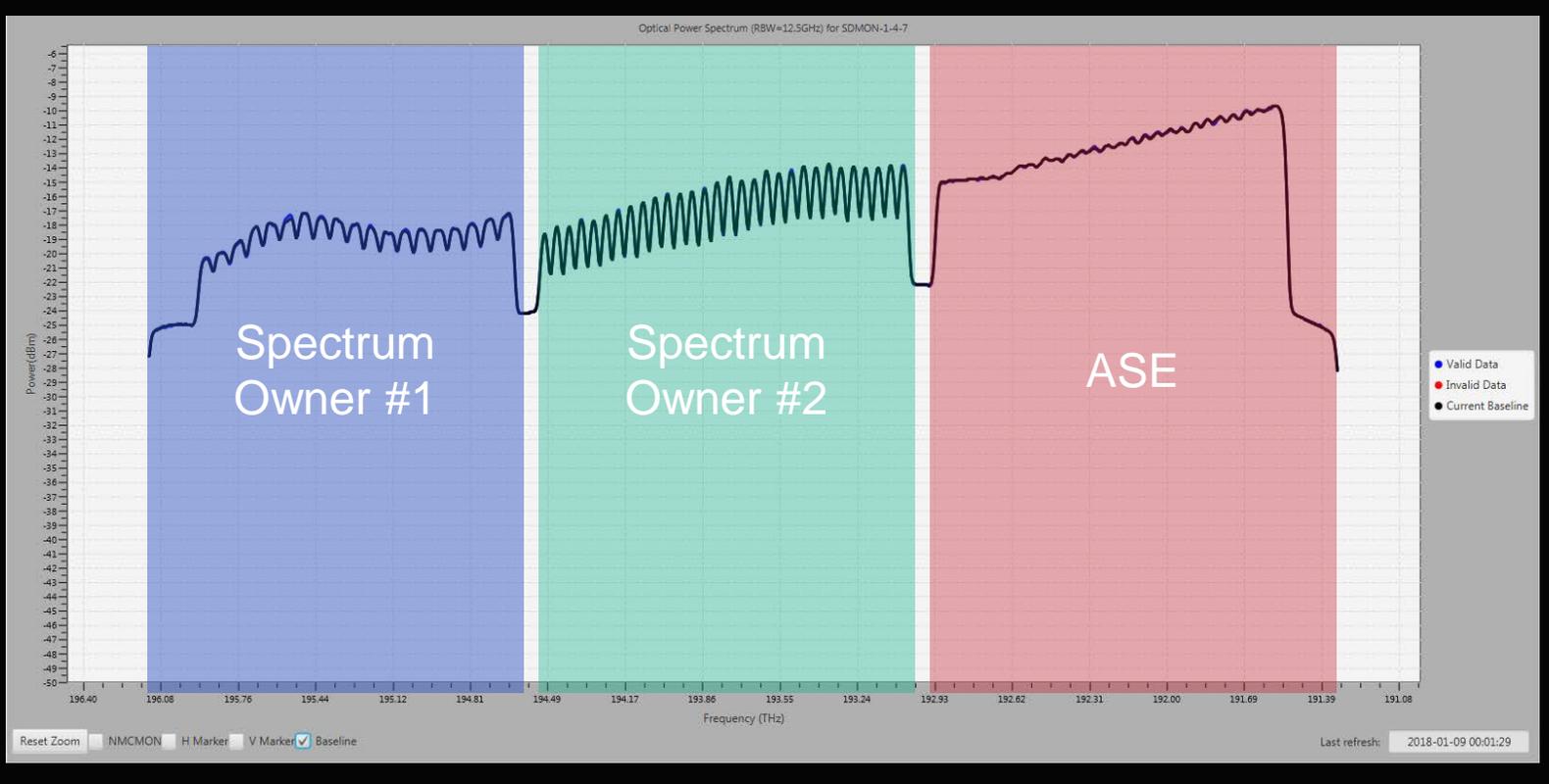


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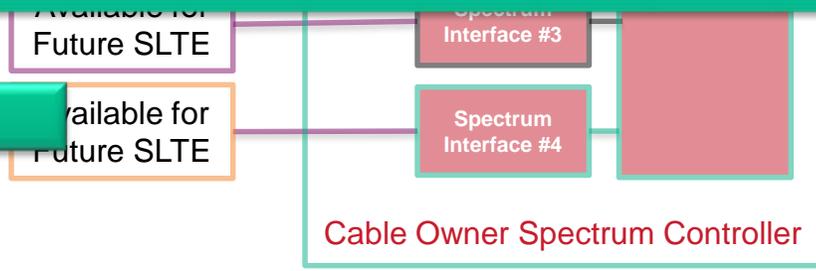
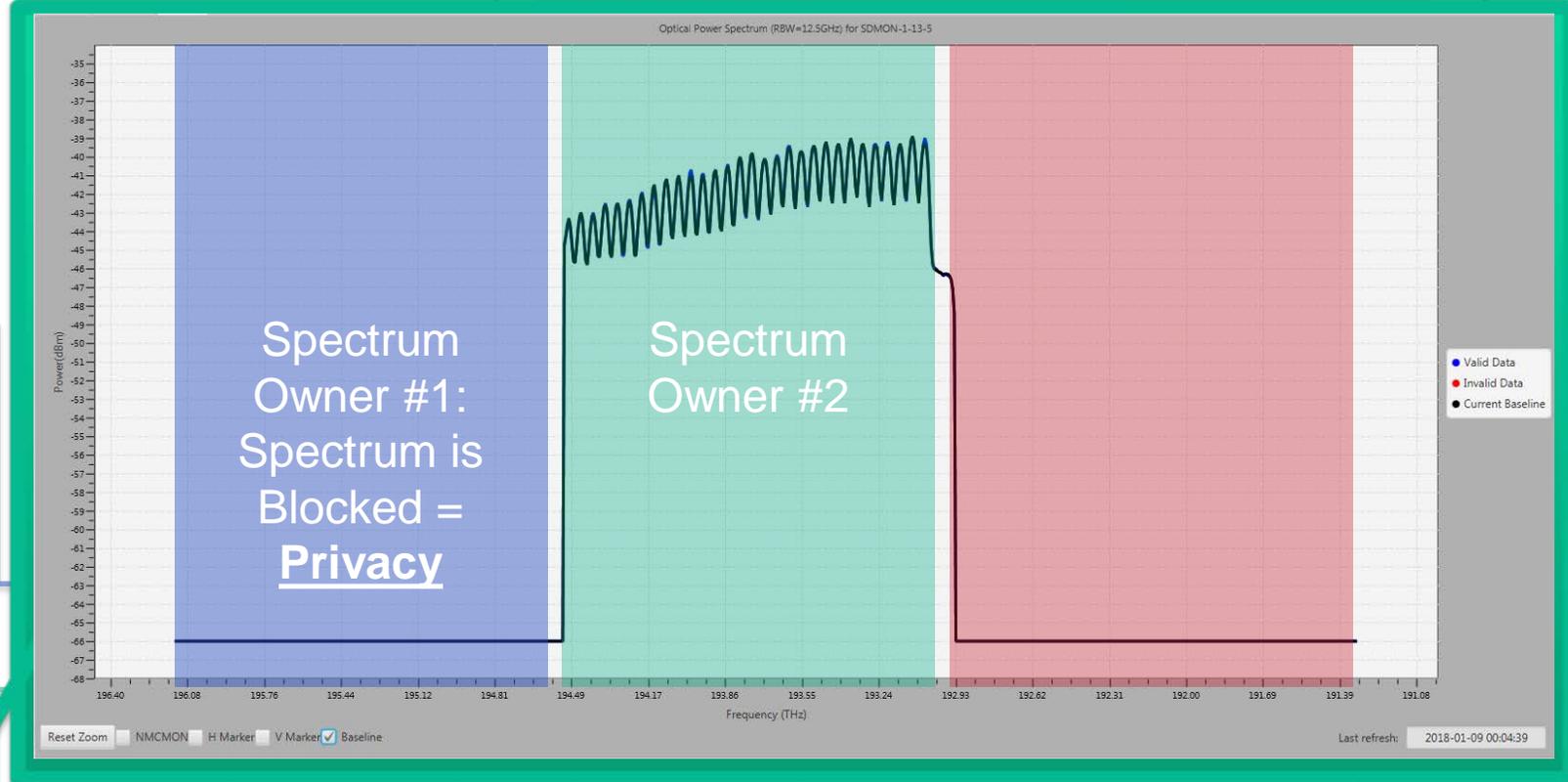
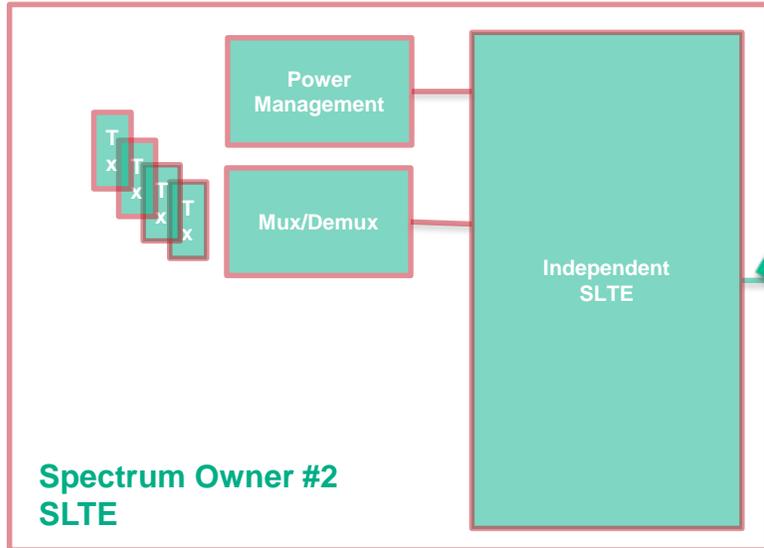
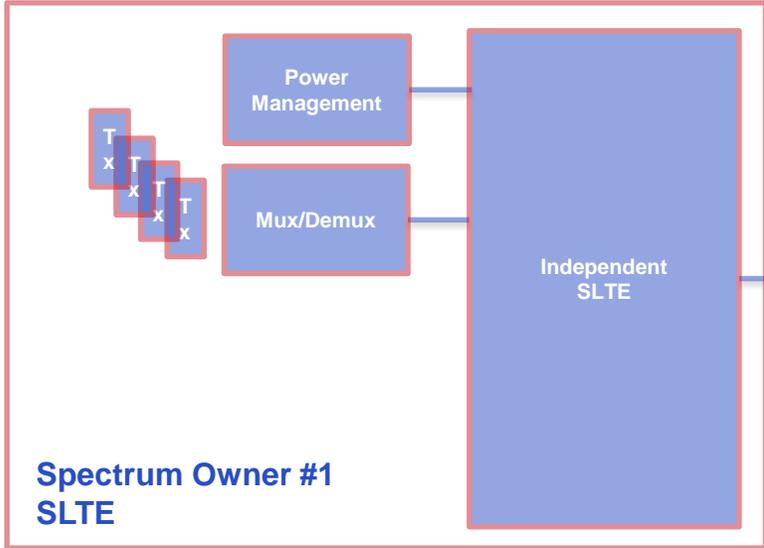


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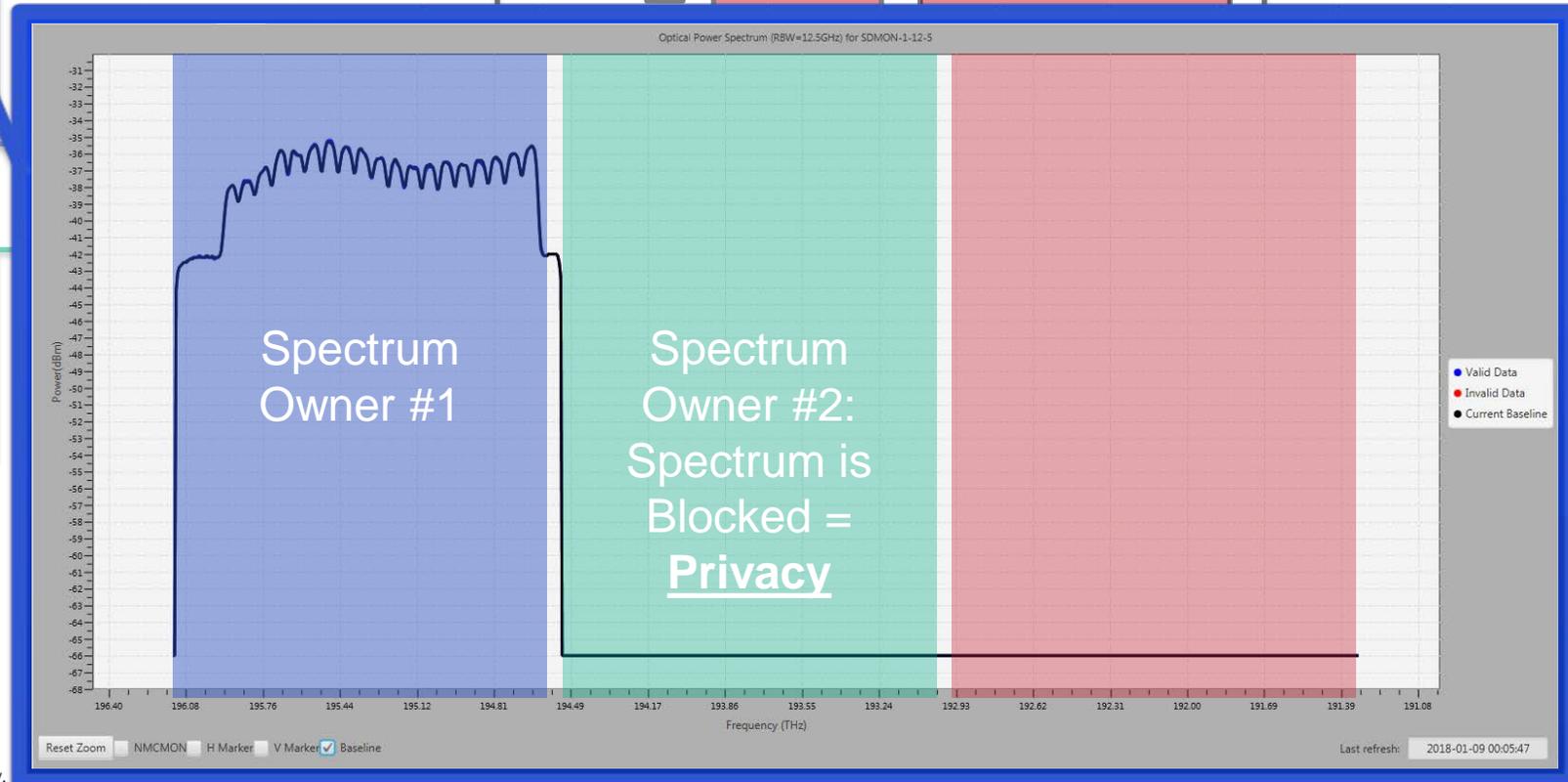
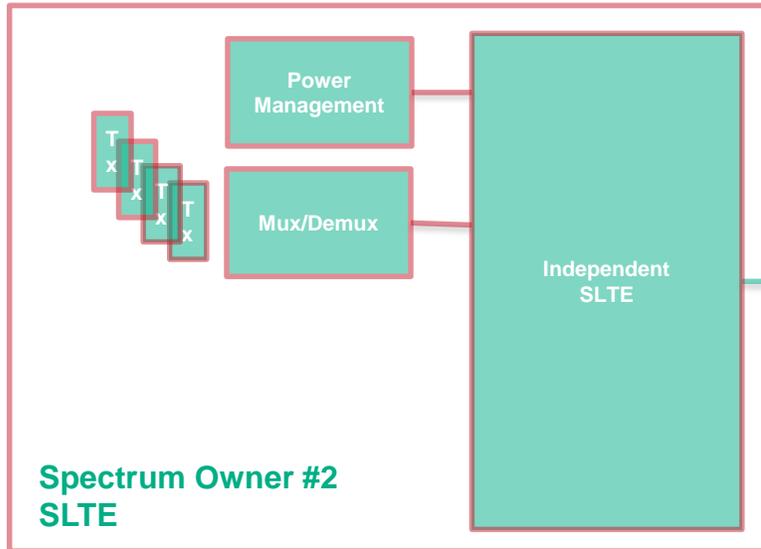
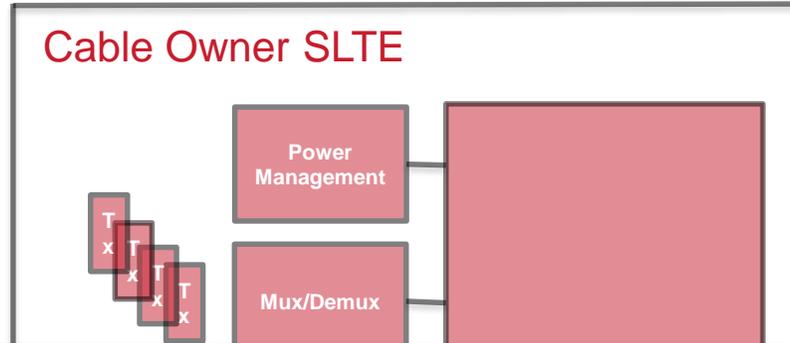
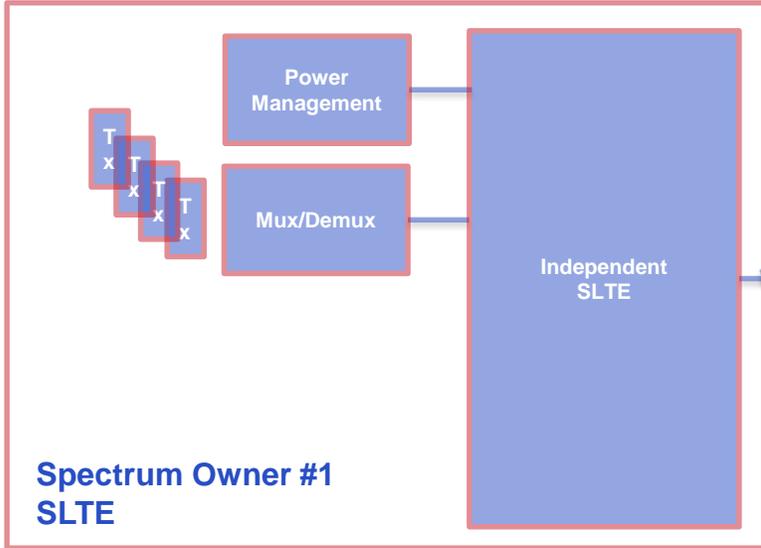
Spectrum Sharing Example



Spectrum Sharing: Normal Operation



Spectrum Sharing: Normal Operation



Any concerns we should be aware of?

Technical Maturity & Deployment Considerations

Technical Maturity

The hardware required for spectrum sharing is mature

- Essentially require Flexible Grid WSS and OCM technologies
- These have been generally available for several years and are currently shipping in product

The maturity of software required for Spectrum Sharing varies

- **Mature:** Hardware Configuration & OAM
- **Emerging:** Implementation and Enforcement of Spectrum Sharing Policies
- Open Interfaces may play a role in policy management, but are not strictly required

Commercial constructs = biggest challenge!

- Agreeing on specific constraints for Spectral Policing is a complex technical & legal task
- Consequent actions for contractual violations are obvious in some cases, less obvious in others...
- Is there a role for Open Interfaces in solving some of these commercial challenges?

Deployment Considerations

Accessing spectrum ≠ Controlling the network

Deployment of new traffic by Spectrum Owners

- With Spectrum Security, this action should pose a low risk to other Spectrum Owners
- However, the possibility of optical transients exists during such actions

Equality of Spectrum

- While most spectrum is comparable, it isn't strictly *equal* in performance (especially in Submarine!)
- Thus, it is not just a question of *how much spectrum*, but also *what spectrum* is being purchased

Automation of Policing Functions

- Not all customers want an autonomous process to squelch their traffic due to a detected violation
- Customers are concerned with the precise definition of each 'policy violation' and the associated consequent actions, as well as the handling of corner cases
- This is expected to change with time as the industry demonstrates robust policy definitions

Spectrum Sharing Conclusions

Conclusions

- 1 There are multiple options for accessing traffic capacity on a fiber pair
- 2 Spectrum Sharing is a good solution when different users need different terminal technologies
- 3 Spectrum Sharing is very similar for Submarine and Terrestrial Networks
- 4 The pillars of Spectrum Sharing are:
 - Spectrum Security
 - Spectrum Privacy
 - Spectral Monitoring
 - Optical Power Management (Submarine)
- 5 The HW is mature, but work remains on the automation and contractual aspects

Thank you

