OpenWave: U.S.-Brazil 100G Experimental Alien Wave

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OpenWave 100G project

- OpenWave is a project (award# 1341895) under NSF IRNC ProNet AmLight award for U.S.-Latin America connectivity
- OpenWave is deploying an experimental 100G alien wave between the U.S. and Brazil
- OpenWave is an experiment consisting of 2 major goals:
  - Understanding how to deploy a 100G trans-oceanic alien wave on a highly constrained operational undersea cable system
  - Understanding how to operate a 100G alien wave with a total span of approximately 10,000km
- Broader Impacts:
  - Potential of increasing demand for upgrading production undersea optical fiber systems (business case for spectrum)
  - Facilitating academic access to submarine spectrum
  - Brings a new resource to U.S.-Latin American science and education
  - Preparing for future science demands, such as the Large Synoptic Survey Telescope (LSST),
    - which is expected to push to the limits of 100Gb/s networks

OpenWave Project Partners

- NSF and the IRNC program
- Brazil via the ANSP and RNP
- Florida International University via the AmLight Project
- PadTec, optical equipment manufacturer in Brazil
- Latin American Nautilus, submarine cable system operator
- Florida LambdaRail (FLR)
- Internet2

OpenWave Challenges

- 100G alien wave technology has not been field tested in this type of environment
- Complexity of LAN's undersea cable system
  - Real-world submarine cable system that is 14+ years old with many amplifiers
  - Complex overlays using multiple digital modulation schemes
    - 10G waves with Non-return-to-zero (NRZ) modulation at 100GHz, 50GHz and 33GHz spacing
    - 40G & 100G waves in an overlay using Dual Carrier (2C) Dual Polarization (DP) & Binary Phase Shift Keying (BPSK) modulation at 50GHz spacing

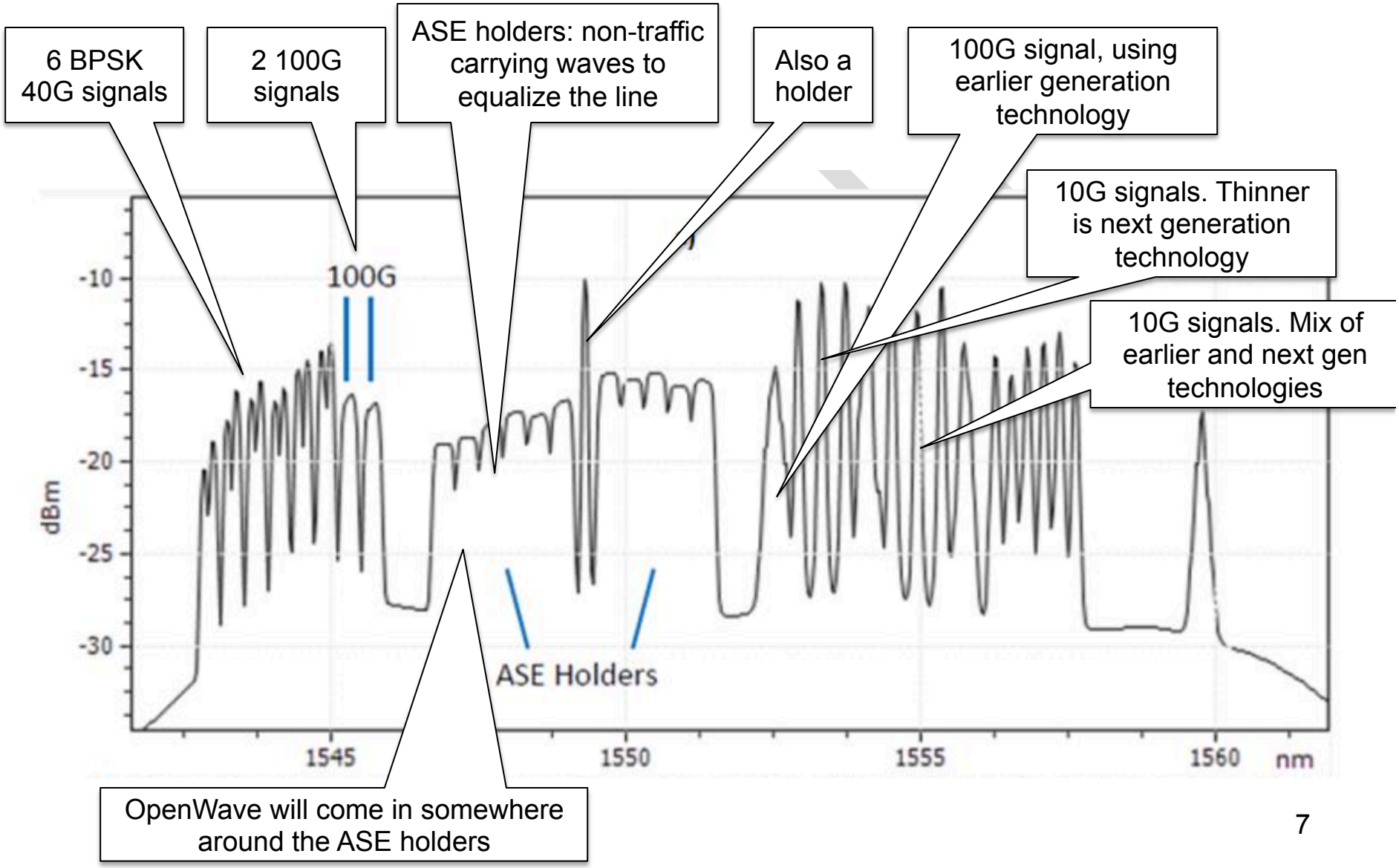
OpenWave System Characteristics

- Four spans in the path
  - Longest is measured at 4,200km
- 100G Alien Wave will be deployed using Padtec's devices with LAN's hybrid repeatered line
  - New Alien Wave deployment in the SAC cable
  - Coherent Detection technology from Padtec
    - Improves chromatic dispersion management. Significant for trans-oceanic submarine applications
    - Reduces latency by eliminating the need for optical dispersion compensation
- Use of a 50GHz channel, plus some guard channels of 50Ghz
  - Number of guard channels depends on results of simulation and lab tests
  - Prevents Non Linear Effects on production waves

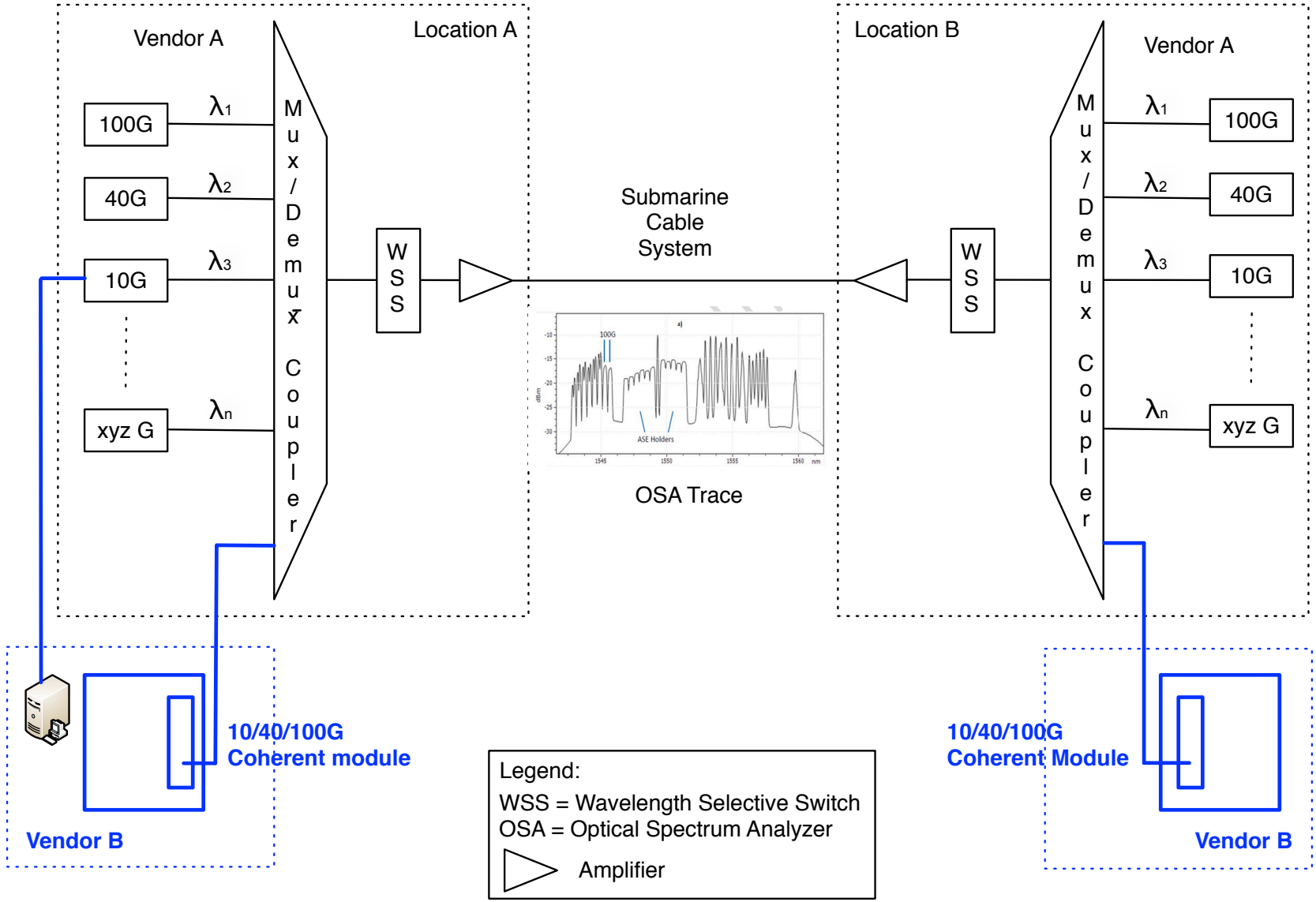
Critical Success Factors

- Overcoming non-linear phase noise effects
  - Bit Error Rate (BER)
  - Sensitivity to Optical Signal-to-Noise Ratio (OSNR)
  - Chromatic Dispersion
- Q-value performance margin
  - How well the wave is performing in relation to BER and OSNR
  - Must account for aging and faults on the fiber
- St. Croix – Fortaleza span is most challenging
  - 4,200km
  - Experiment hinges on success with this span

Representation of spectrum in real network

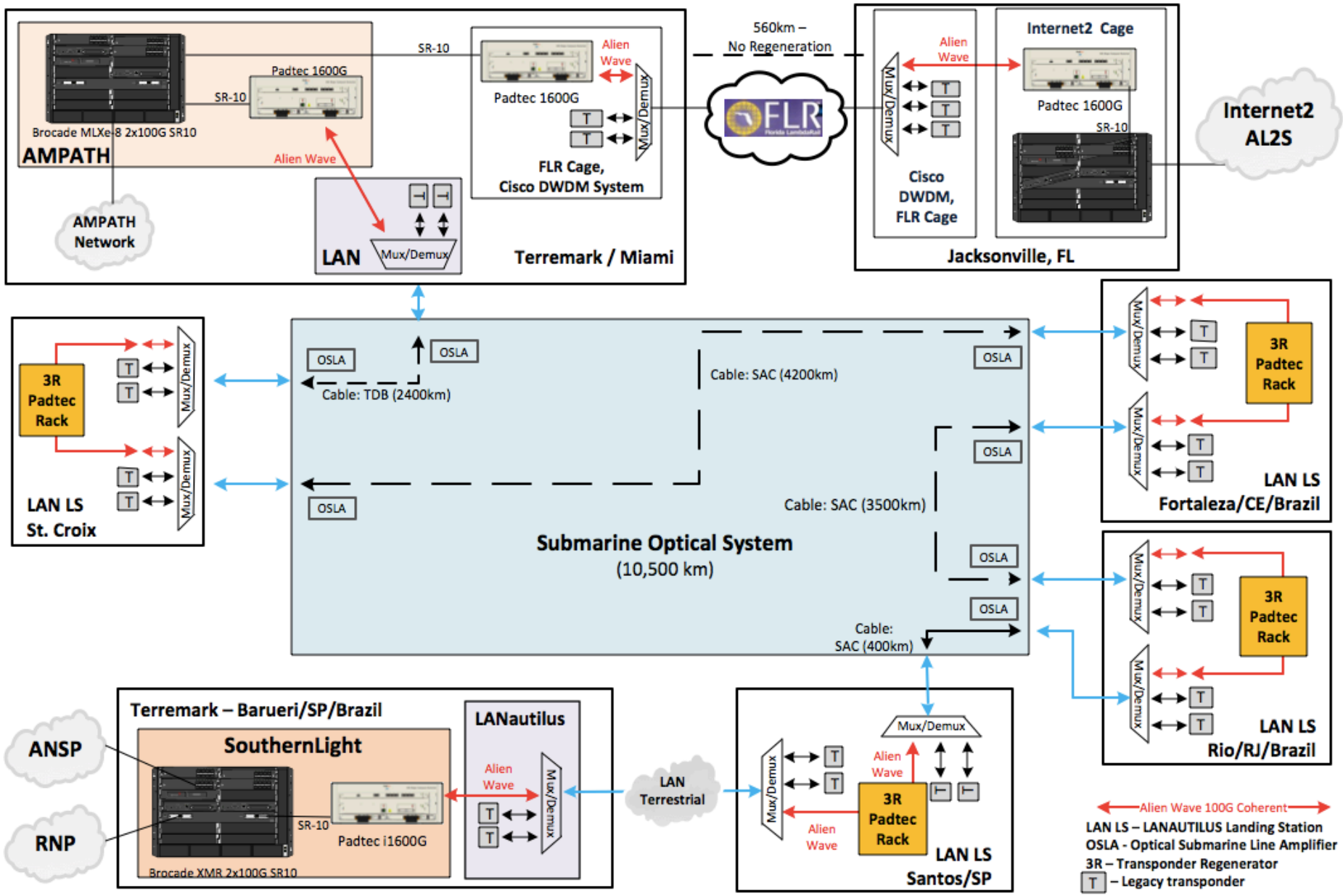


OpenWave Conceptual Design



OpenWave Physical Design

OpenWave & 100G AtlanticWave - 2014



Modeling Methodology

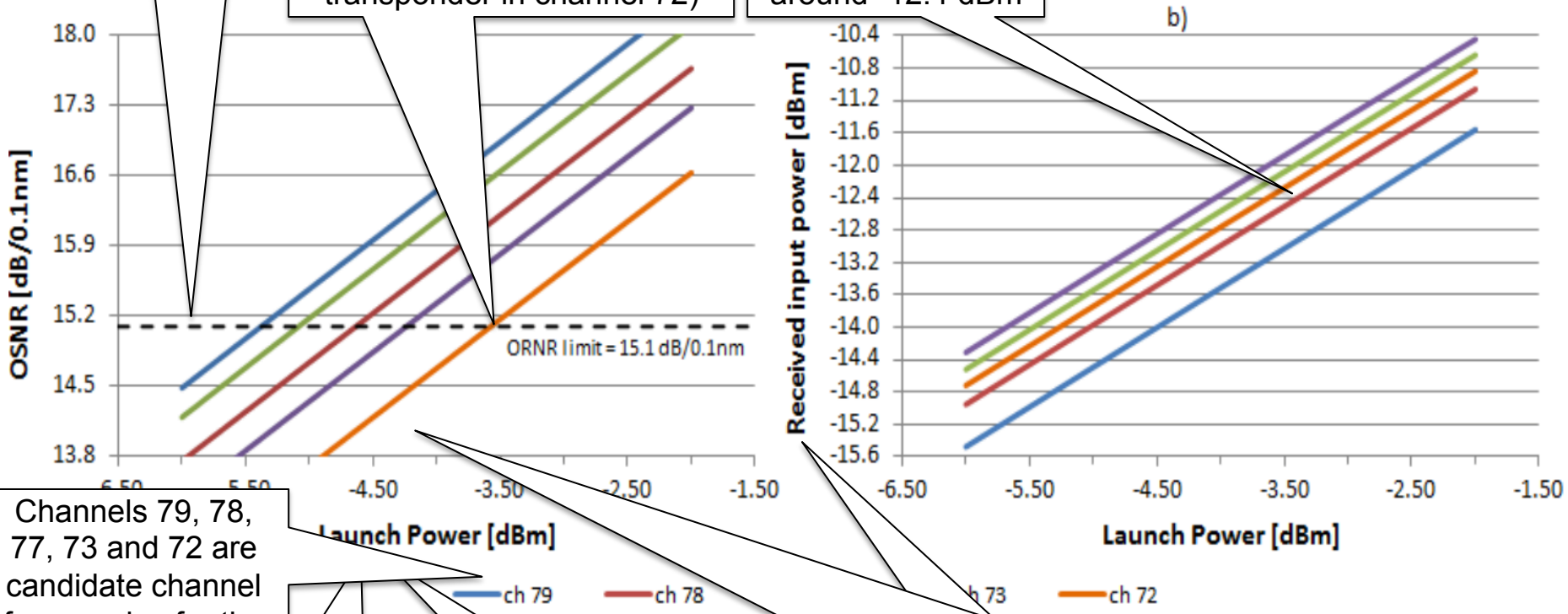
- Modeling St. Croix – Fortaleza segment
  - Model spectrum use of the real network with operating transponders
  - OSNR for the new 100G channel as a function of the launch power for various channel frequency
- Objective is to determine the residual OSNR for the 100G Padtec channel as a function of the launch power
- Results

OSNR as a function of launch power

Dashed line is the OSNR limit for Padtec cards

Highest required launch power to reach OSNR limit is about -3.6dBm (100G transponder in channel 72)

Using -3.6dB, the calculated far end receive power is around -12.4 dBm



Channels 79, 78, 77, 73 and 72 are candidate channel frequencies for the new Padtec 100G channel

Objective is to pick a channel with the optimum launch power for the least amount of penalty to existing services

What is the required launch power needed to provision the Padtec 100G channel?

Launch Power refers to the power of the signal coming into the spectrum.

Given the launch power, can then calculate the receive power at the far end

Results

- 9 additional channels could be supported
  - Each one providing capacity of 9x100 GbE
- Estimate is based upon
  - the available frequencies on the system
  - 100GHz and 50GHz guard bands for 100G and 10G respectively
- Results support the deployment of the 100G Padtec solution

Timeline

- LAN provided CPQD / Padtec with characteristics of its submarine system
- Simulation of the wave
  - Results finished April 2015
- Laboratory tests
  - Results were at the end of June 2015
- Documentation Analysis and Approval
  - Completion estimated by mid December 2015
- Field Trial
  - Projected for April– November 2016

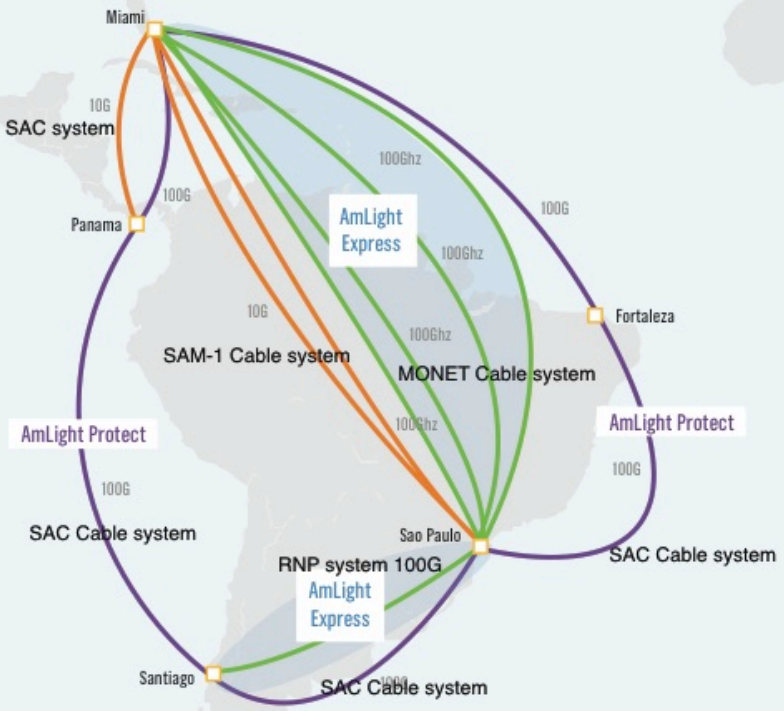
Next Steps

- OpenWave will serve as a laboratory for experimentation with spectrum
- Interpret results from OpenWave to increase understanding towards building and operating intercontinental networks using spectrum
- Apply lessons learned from OpenWave towards the AmLight Express & Protect (ExP) project

AmLight Express and Protect (ExP) - 2018

- AmLight Express (green):
  - 400GHz of spectrum: Miami-São Paulo
  - Spectrum to be configurable by RENs to meet user/application requirements
  - DWDM São Paulo-Santiago
- AmLight Protect (purple, organge):
  - 100G leased capacity ring
  - 10G segments
  - Miami, São Paulo, Santiago, Panama City, Miami
  - AMPATH, Southern Light, REUNA, and RedCLARA operated
- Multiple submarine cables for protection and high availability
- Potential for unprecedented regional resilience for U.S.-Latin America, and U.S.-Europe connectivity, supporting global science research

680G+ Aggregate Express bandwidth



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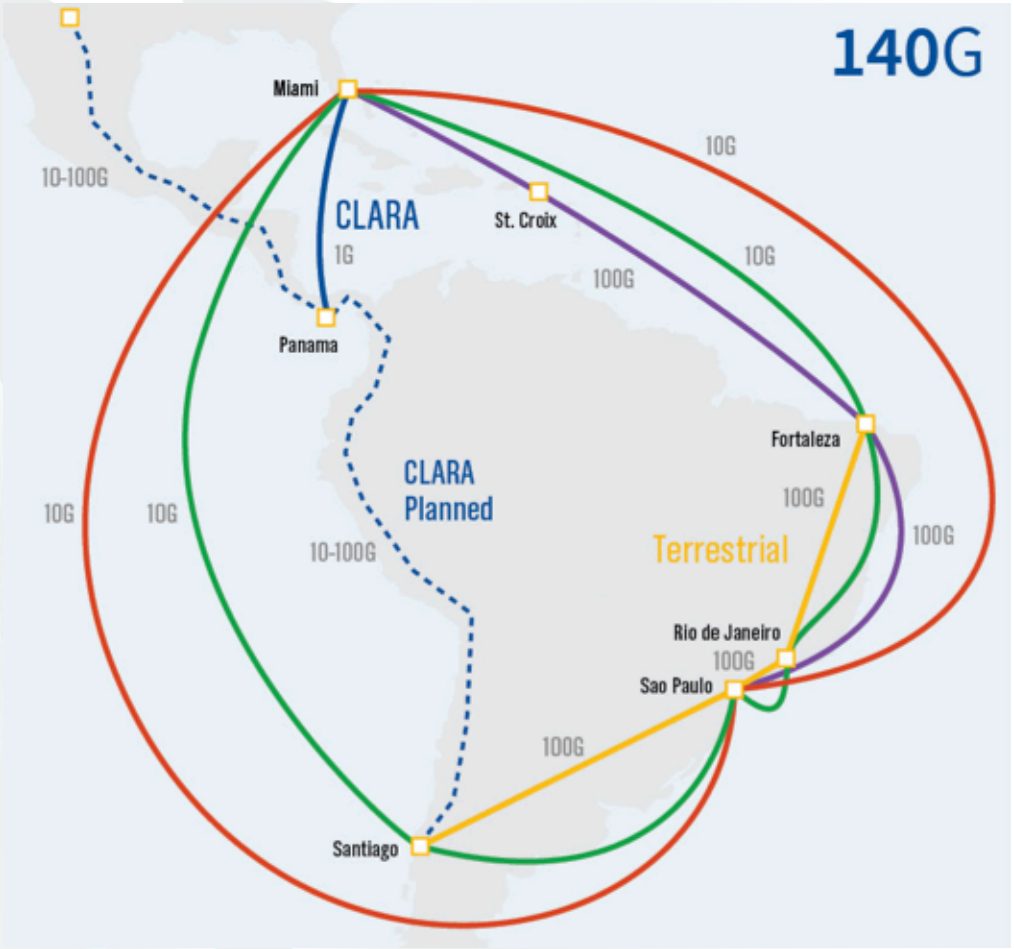
  - Association of Universities for Research in Astronomy (AURA)
  - Florida International University
  - Latin American Research and Education community
  - The many national and international collaborators who support our efforts

More Slides Follow

AmLight SDN and OpenWave

- 4 x 10G links and two topologies
  - SDN ring: Miami-São Paulo-Chile-Miami
    - 20 Gbps of total capacity
    - Full OpenFlow and network virtualization support
  - MPLS ring: Miami-São Paulo-Miami
    - 20 Gbps of total capacity
    - Layer 2 support
- OpenWave 100 Gbps between São Paulo and Miami
  - Part of the SDN domain
  - Focused on experimentation
- 140 Gbps aggregate capacity expected by June
- 100G to AL2S from Miami

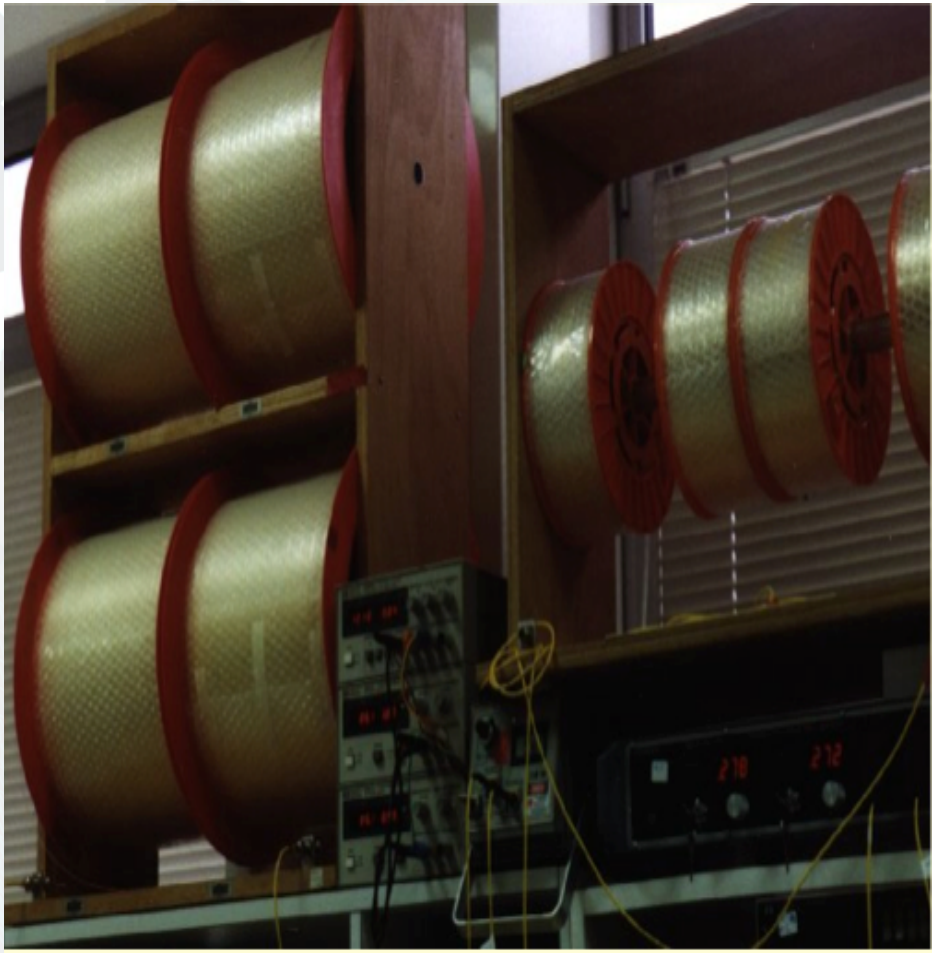


OpenWave and AmLight Topology

- 4 100G segments (future):
  - St. Croix (STX)-Fortaleza 4,200km
  - Fortaleza-Rio, 3,500km
  - Rio-Santos, 400km
  - Miami-STX, 2,400km
- ANSP: 2x 10G links
  S Paulo – Miami
  - (W) via Santiago (LAN)
  - (E) direct (Telefonica)
- RNP: 2x 10G links
  S Paulo – Miami
  - (W) direct (Telefonica)
  - (E) via Rio de Janeiro & Fortaleza (LAN)
    (+ redundant terrestrial links)

Methodology

- Separate the Miami – São Paulo path into 4 spans:
  a. Miami to St. Croix (2,400km)
  b. St. Croix to Fortaleza/BR (4,200km)
  c. Fortaleza to Rio de Janeiro (3,500km)
  d. Rio de Janeiro to Santos (400km)
- Modeling span (b): (approx. 30 days)
  – (b) is the longest span
- Simulation of (b): (approx. 30-45 days)
- Laboratory tests of (b): (approx. 30 days)
- Repeat for (a), (c), (d) and (e) – (up to 15 days each)
- Evaluation of the results by all partners
- Deploy the 100G in the SAC cable



Timeline

Activity	Duration	Start	Finish
Equipment Installation	17 days	2/18/15	3/12/15
Transponders Shipment	15 days	3/2/15	3/20/15
Sao Paulo – Cotia Link	4 days	3/3/15	3/6/15
Cotia – Santos Link	4 days	3/9/15	3/12/15
Santos – Rio Link	6 days	3/13/15	3/20/15
Rio – Fortaleza Link	8 days	3/23/15	4/1/15
Fortaleza – St. Croix Link	19 days	4/2/15	4/28/15
St. Croix – Miami Link	8 days	4/29/15	5/8/15
Sao Paulo – Miami Link Validation	2 days	5/11/15	5/12/15
Acceptance Testing	20 days	5/13/15	6/9/15
OpenWave Experimenting Regime	136 days	6/10/15	12/16/15

OpenWave Testbed Environment: Bring your experiments!

- For the OpenWave Experiment period:
  - Colocation Space (power, space, cooling) for hosting servers and other devices
  - Multiple 10G ports available
  - 100G link between Internet2, AltanticWave XPs, and AMPATH
  - 100G link between AMPATH and Brazil (using OpenWave)
  - Network Slices support (AmLight SDN) with OpenFlow 1.0 (1.3 soon)

Focused Technical Workshop: International OpenFlow/SDN Testbeds

- Hosted by Florida International University and Internet2, March 31-April 2, 2015
- Objective:
  - Bring together network, software, and data management experts to discuss International OpenFlow/SDN Testbeds
- Outcome includes:
  - Developing best practices for challenge areas
  - Expanding community knowledge base
  - Providing resources for improved testbed development and operations
- https://meetings.internet2.edu/2015-ftw-international-openflow-sdn-testbeds/