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 (Spectrum-as-a-Service?)
  - 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 network connections

OpenWave Project Partners

- NSF and the IRNC program
- Florida International University via the AmLight Project
- Brazil via the ANSP and RNP
- 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

  – Overcoming non-linear phase noise effects

    - Optical Signal to Noise Ratio (OSNR), Bit Error Rate (BER), Chromatic Dispersion, etc.

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
  - Differential Quadrature Phase Shift Keying (DQPSK)
  - Coherent Detection technology
- 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

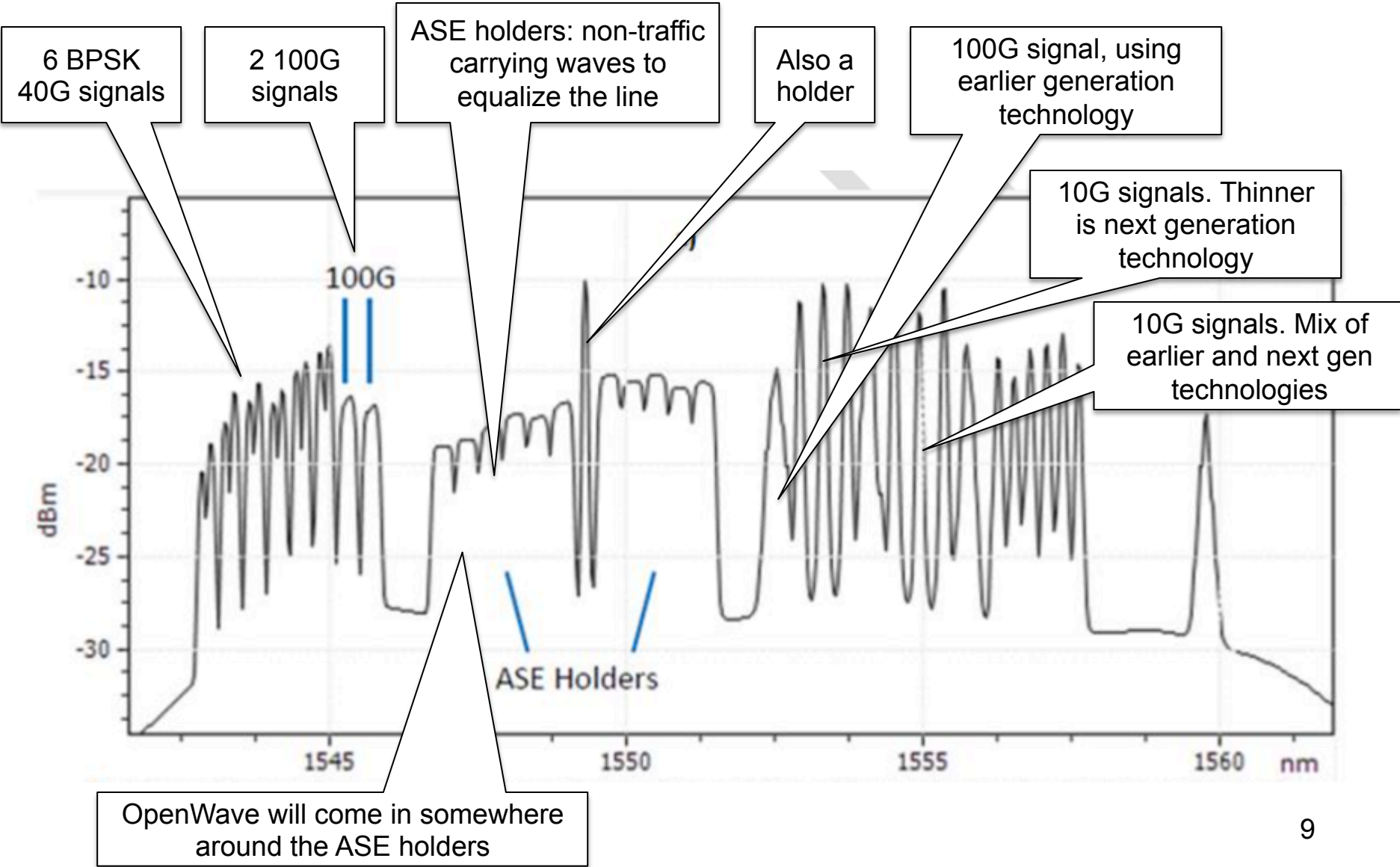# OpenWave Network Design

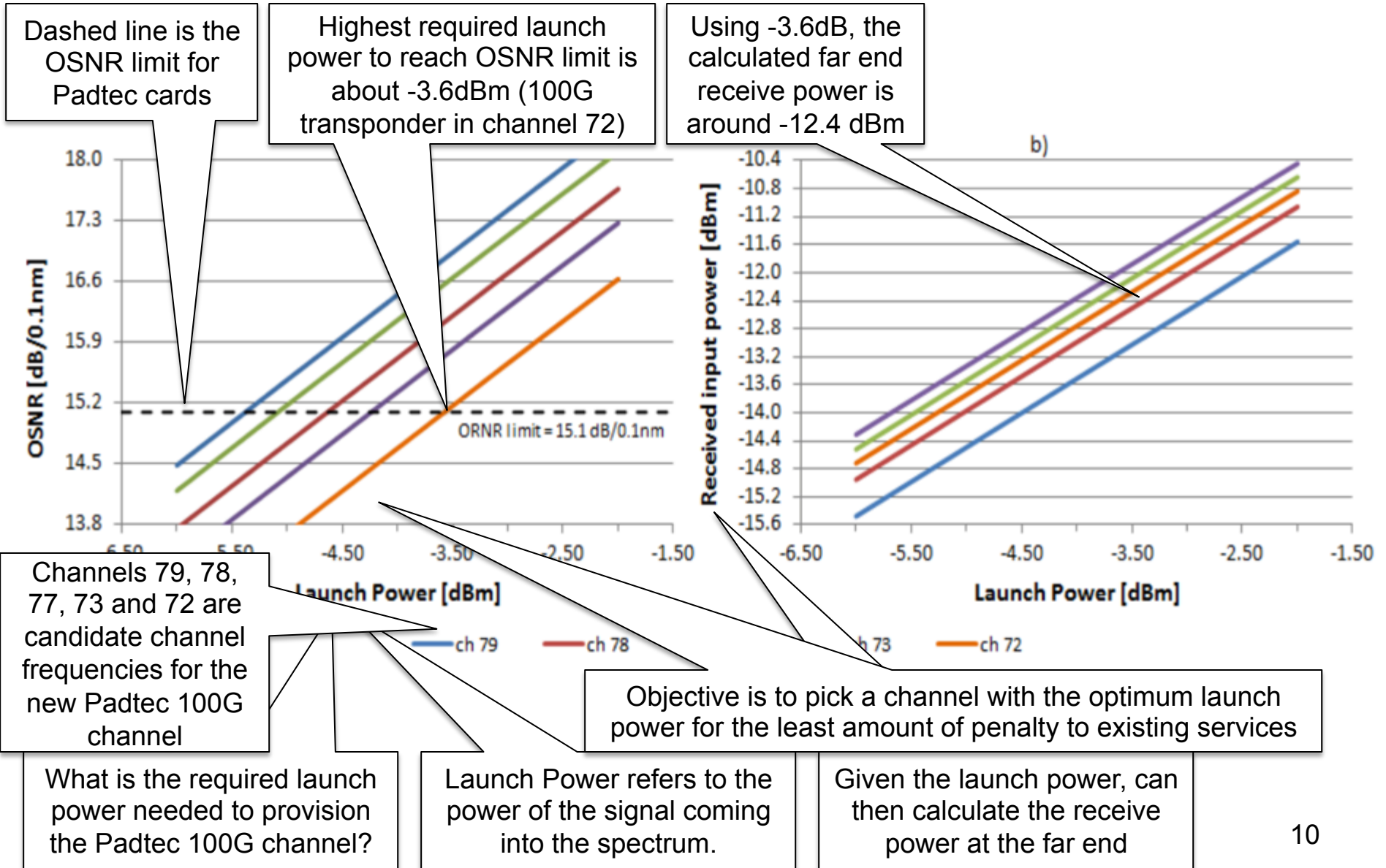## OpenWave & 100G AtlanticWave - 2014
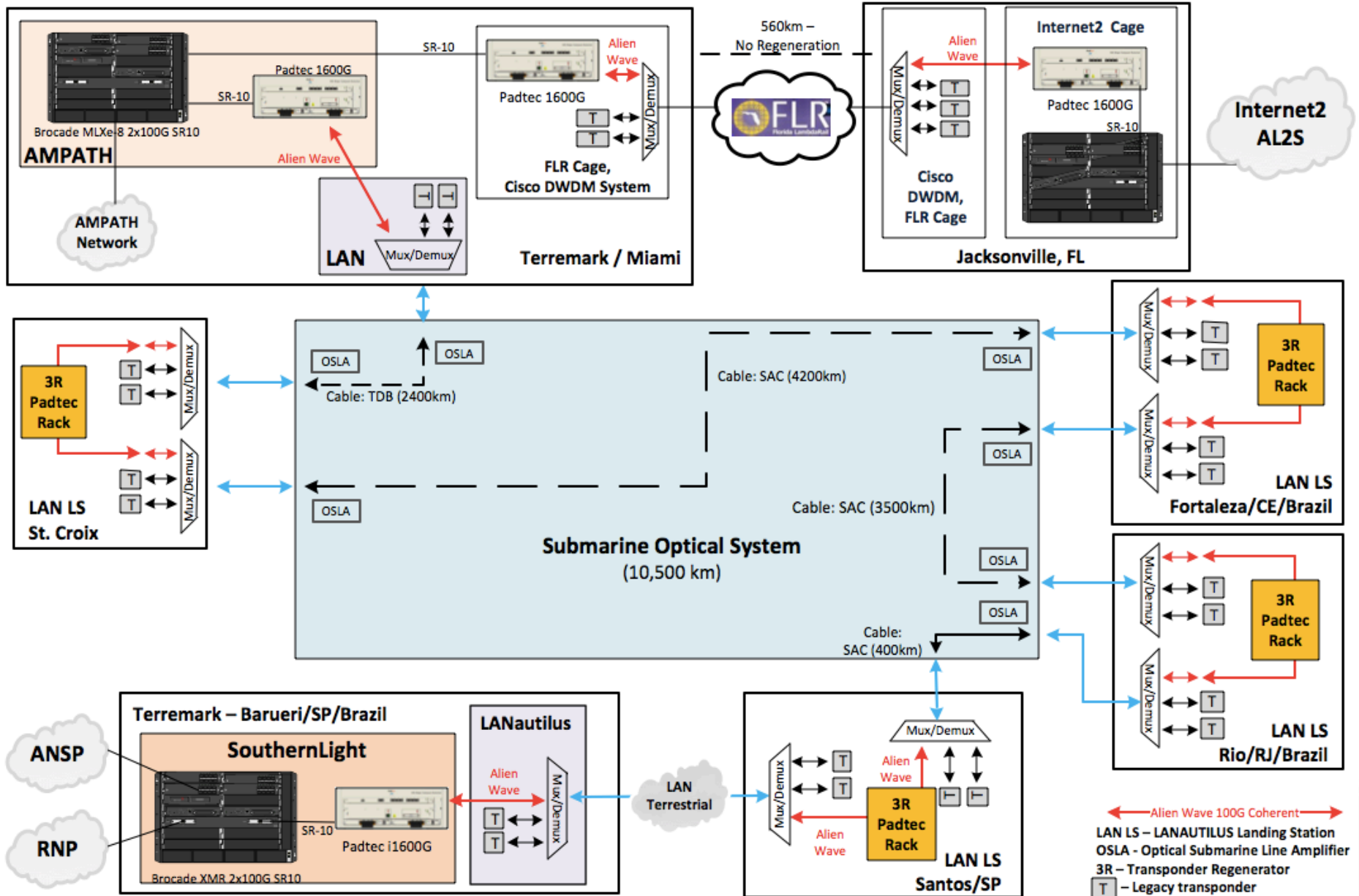
Modeling Methodology

- Modeling St. Croix – Fortaleza segment
  - Spectrum use of the real network
  - OSNR for the new 100G channel as a function of the launch power for various channel frequency

- Results

Representation of spectrum in real network

6 BPSK 40G signals

2 100G signals

ASE holders: non-traffic carrying waves to equalize the line

Also a holder

100G signal, using earlier generation technology

10G signals. Thinner is next generation technology

10G signals. Mix of earlier and next gen technologies

OpenWave will come in somewhere around the ASE holders

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

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.

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

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

ORNR limit = 15.1 dB/0.1nm

ch 79   ch 78   ch 73   ch 72

10

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

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

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 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/

Thank You!

- NSF OpenWave, AmLight, OSDC-PIRE, CC-NIE, CC*IIE, AMPATH, AtlanticWave infrastructure, science application support, education, outreach and community building efforts are made possible by funding and support from:

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