G E N I

Global Environment for Network Innovations

GENI Quarterly Status Report

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under Project Nr. 1631
"Embedding real-time measurements for cross-layer communications"

Document Revision History

The following table provides the revision history for this document, summarizing the date at which it was revised, who revised it, and a brief summary of the changes. This list is maintained in chronological order so the earliest version comes first in the list.

Revision	Date	Revised By	Summary of Changes
1.0	29 June 10	M.S. Wang	Initial draft

Embedding real-time substrate measurements for cross-layer communications
GENI Quarterly Status Report
Project Nr.: 1631

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1. Major accomplishments

During this past quarter, one of our main accomplishments involved the completion of milestone S2.c and the submission of the corresponding technical notes. This milestone involved demonstrating a working prototype of an experimental use-case. More specifically, we demonstrated a protection mechanism, whereby the unified measurement framework (UMF) [erm_1] monitored the optical power of a 10Gb/s modulated signal. If the optical power undershot a predefined threshold, the UMF exported this information such that an external protection scheme switched the signal to a protected lightpath that contained a semiconductor optical amplifier (SOA), which could amplify the power and improve the bit-error rate (BER) of the signal. This experiment was performed at the Lightwave Research Laboratory [lrl_1] at Columbia University.

Another main accomplishment involved working to prepare for a demo at the GEC8 conference on July 20-22 at San Diego. In preparation for this demonstration, we made a visit to the Breakable Experimental Network (BEN) [ben_1], which is a regional GENI optical network located in North Carolina. We successfully integrated two optical components, a semiconductor optical amplifier (SOA) and a variable attenuator, into the lightpath at BEN. After visiting BEN, we have worked on enabling programmable control of these two optical components. To control the SOA, we developed a wrapper (consisting of Perl script, Verilog code, and a specially designed prototype board) around the SOA. To enable programmability of the variable attenuator, we are currently deciding between controlling the attenuator via its RS232 serial port or by using LabView through its GPIB port. A few weeks from now, we plan on making another visit to BEN to combine our work with the integrated measurement framework (IMF) [imf_1], [imf_2] in preparation for the GEC8 demo.

2. Milestones
The following section discusses the progress made on the milestones for the ERM project.

Milestone S2.a: Prototype UMF Software (completed 12/3/2009)
Design and develop software for prototype implementation of the UMF by means of a NetFPGA, according to the evaluated GENI requirements for real-time measurements from year-1.

We decided to implement the UMF using a NetFPGA Cube. The UMF consists of a UMF SW component (implemented on the general purpose processor) and a UMF HW component (implemented on NetFGPA card). Each component has a defined role in facilitating the UMF to access the networking elements and its measurement data. Additional information, as well as a technical note, on milestone S2.a is available online [erm_1], [erm_2].

Milestone S2.b: Demo software interface from UMF to embedded measurement subsystem (due 3/4/2010)

We implemented and demonstrated a working software interface between UMF and at least one subsystem that is capable of embedded physical layer measurements, such as bit-error rate measurement or optical power monitoring. The specific subsystem we chose to use is a set of four Polatis [polatis_1] switches from the ORCA-BEN [orca_1] network, from which we retrieved the optical power. In doing so, we have merged our UMF design with the IMF project implementation. By realizing the MH for the Polatis switch and testing the functionality of the XMPP server and PSM, we demonstrated the ability of IMF to obtain real-time optical power measurements from any of the four Polatis switches in the ORCA-BEN network. Additional information, as well as a technical note, on milestone S2.b is available online [erm_2], [erm_3].

Milestone S2.c: Demo UMF in an experimental use-case (due 6/3/2010)

We demonstrated a working UMF prototype by implementing an experimental use-case at the Lightwave Research Laboratory at Columbia University. We set up a protected lightpath that switches the input signal into a path containing an SOA if the input optical power is below a predefined threshold, and bypasses the SOA otherwise. We compare the eye diagrams and BER curves for the unprotected and protected paths while changing the attenuation of the input signal. We find that when the power of the input signal is above -12 dBm, the SOA introduces a positive power penalty on the lightpath, and it is not useful to use the SOA to compensate for the attenuated power. However, when the input signal falls under -12 dBM, the SOA starts to have an advantage, and we examine a negative power penalty by introducing an SOA into the lightpath.

Milestone S2.d: Integrate UMF with BEN (due 8/31/2010)

Contribute to the Cluster D effort by integrating the UMF subsystem with the Cluster D network substrate. This will be done by physically migrating the developed hardware and software resources to the BEN infrastructure at RENCI.

Milestone S2.e: Design and demo XML data exchange software modules (due 8/31/2010)

Design the XML data exchange software modules for the UMF to interact with the researcher or an intermediate measurement software architecture (e.g. SILO, perfSONAR, etc.) Demonstrate the inter-operability of these software modules with BEN at RENCI.

Milestone S2.f: Plan to integrate UMF within another infrastructure (due 8/31/2010)

Work with other GENI clusters (outside of Cluster D) and/or other networking communities, such as Wisconsin's Measurement System GENI project or Internet2's perfSONAR framework, to define mechanisms to integrate the UMF within their infrastructures.

3. Deliverables made

- ERM Milestone S2.c (June 2010)

4. Description of work performed during last quarter

- Organizational work

    Working with the GPO (specifically Harry Mussman), details regarding our ongoing work and our contributions to GENI Spiral 2 were released on the GENI ERM Wikipage; this includes quarterly reports and the Milestone S2.c technical note. We have also participated in several Cluster D and GENI IMF meetings through teleconference.
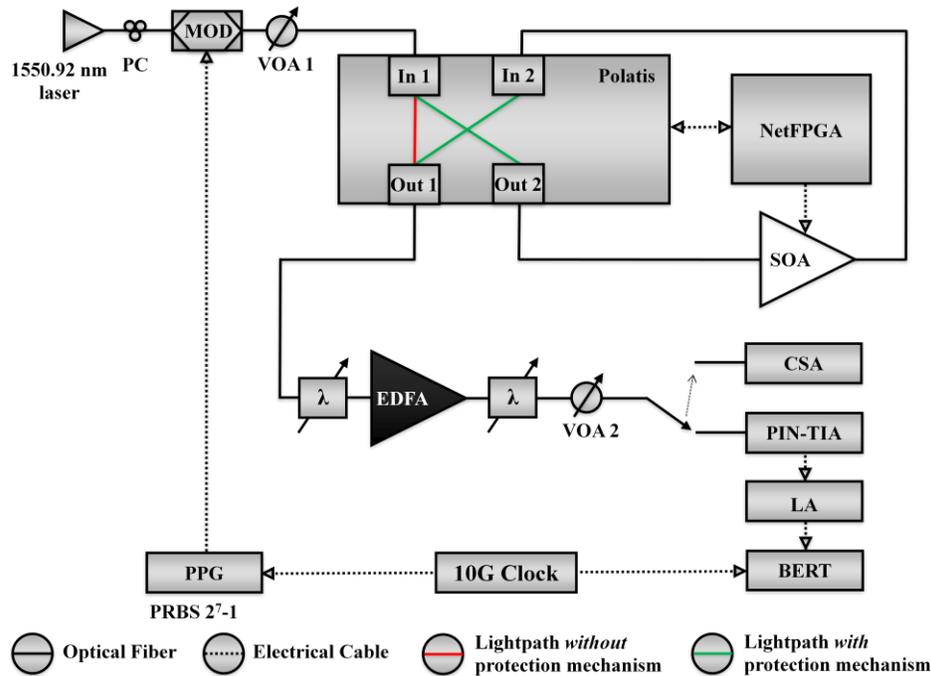
- Demo UMF in an experimental use-case

Fig 4.1 – Experimental Use-Case Setup

A 1550.92nm distributed feedback laser (DFB) is connected to a polarization controller (PC) and modulated at 10Gb/s using 2^7-1 pseudorandom binary sequence (PRBS) via a pulse pattern generator (PPG). This modulated signal is sent through variable optical attenuator 1 (VOA 1).

The input signal is sent into In1 of the Polatis switch. A NetFPGA [netfpga_1] is used to monitor the optical power on this input port. When the optical power is above a predefined threshold, the NetFPGA directs the Polatis switch to maintain a cross-connect between In1 and Out1. This path bypasses the SOA. The NetFPGA further issues a command to the SOA via a general purpose I/O (GPIO) pin to turn off the SOA. However, when the optical power is below the predefined threshold, the NetFPGA directs the Polatis switch to setup a cross-connect between In1 to Out 2 and In2 to Out1. This creates a lightpath that goes through the SOA. The NetFPGA further issues a command to the SOA via a GPIO pin to turn it on.

The output signal on Out1 is then sent through a receiver setup. This first consists of a wavelength filter, followed by an erbium-doped fiber amplifier (EDFA), and followed by another wavelength filter. The purpose of the filters is to reduce the amplified spontaneous emission (ASE) noise introduced by the SOA and EDFA in the lightpath. The EDFA is typically used in a receiver setup to amplify the signal before inputting it into the photo-diode (PIN-TIA), limiting amplifier (LA), and bit-error rate tester (BERT), which is used to obtain the BER. The signal is also sent to a communication spectrum analyzer (CSA) in order to observe the eye diagram. Based on the eye diagrams and BER curves obtained for both the protected and unprotected paths, we determine the optimal input power threshold to turn on the SOA.

- Integrate optical components into ORCA-BEN

In May 2010, we visited RENCI in North Carolina to integrate two optical components, a semiconductor optical amplifier (SOA) and a variable attenuator, into the lightpath at BEN. Before doing this, we had a meeting with two representatives from Infinera [infinera_1]. We were given permission to connect these two optical components into BEN if we made sure that we would only drive the amplification on the SOA by no more than the amount reduced by the attenuator. The reason is that the Infinera DTN is very expensive and we do not want to risk sending too much power through the DTN. We demonstrated that when the SOA and attenuator compensate each other so that net power is 0 dBm, information is successfully passed through the network, and that when the attenuation is increased beyond compensation from the SOA, Infinera raises an alarm and begins dropping packets.
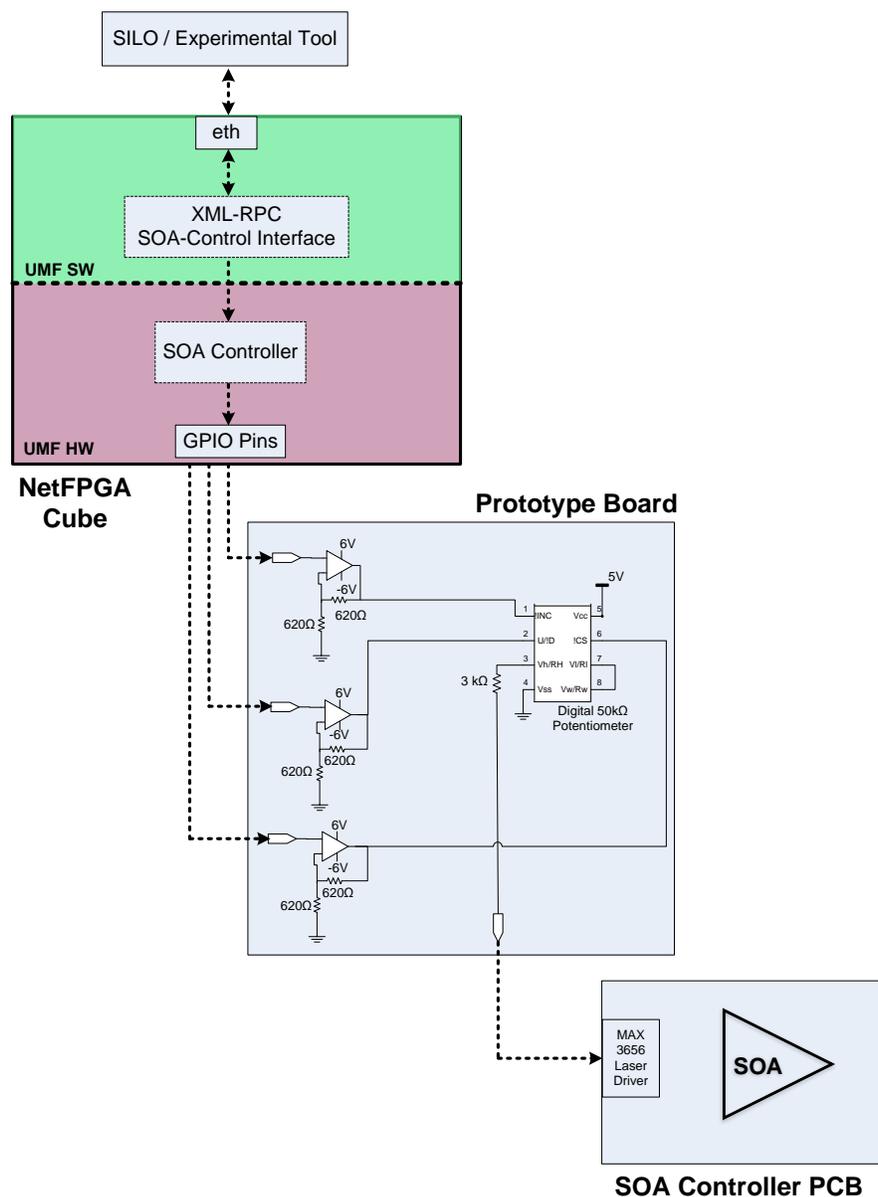

Fig 4.2 – SOA Controller

Furthermore, to ensure the programmability of the SOA, we developed a SOA Controller wrapper as shown in Fig 4.2 that consists of UMF SW, UMF HW, a specially designed prototype board, and a PCB board. The UMF SW consists of a Perl script with a XML-RPC wrapper that is used to interface with SILO and other experimenter tools. The defined set of XML-RPC commands include:

- get_gain_threshold( ) – returns the maximum gain threshold allowed by the SOA. This value changes as the SOA in the lightpath is changed.

- set_gain(absolute dB value)
    - Maps the specified absolute gain value in dB to a current value that is needed to drive the SOA.
    - Maps the current value to the pin value on the FPGA to drive the prototype board and PCB board.

- change_gain_value(+/- dB value)
    - Supports increasing or decreasing the dB gain by a delta value.
    - Return 1 if successful
    - Return 0 is the delta gain surpasses the maximum gain threshold of the SOA

- change_gain_percent(+/- %)
    - support increasing or decreasing the current gain by a percent value
    - Return 1 if successful
    - Return 0 is the percent gain surpasses the maximum gain threshold of the SOA

The UMF SW translates the commands requested by SILO to the UMF HW, which contains Verilog code that is used to control a specially designed prototype board. This board consists of three operation amplifiers that increase the 2.5V outputs from the NetFPGA general purpose I/O (GPIO) pins to 5V. These amplified signals are then sent to a digital 50KOhm potentiometer, which varies its resistance based on programmable input from the NetFPGA. This potentiometer is used to control a MAX 3656 Laser Driver, which is used to control the gain of the SOA on the PCB. Essentially, as shown in Fig 4.2, a SILO service or an experimental tool is able to remotely control the gain of the SOA or query the SOA for its maximum gain threshold value.

5. Activities and findings

5.1 Experimental Use-Case Results

Out1 of the Polatis switch is sent to the CSA to obtain the eye diagrams. We ran two separate tests: protected path and unprotected path. For the protected path, the protection mechanism activates when the attenuation reaches an arbitrary value of 10 dB, at which point, the lightpath traverses through the SOA. For the unprotect path, the lightpath bypasses the SOA regardless of the attenuation.

When the attenuation is below 10 dB, the protection mechanism is not yet activated, and the protected and unprotected paths have the same eye diagrams. After the attenuation reaches 10 dB or more, the protection mechanism triggers the SOA to turn on. As can be seen in Fig 5.1, the protected path will then have more open eye diagrams than that of the corresponding unprotected path.
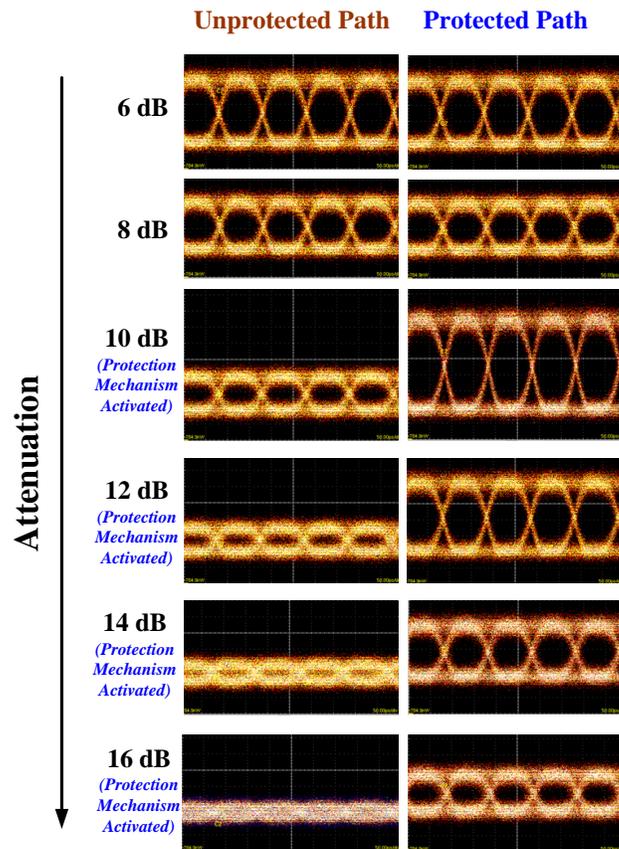

Fig 5.1 – Eye Diagrams

The eye diagrams demonstrated that for the same attenuation, the eye is more open for a SOA-compensated path than for an unprotected path. To obtain a more rigorous analysis of the advantages of using an SOA, we obtain a set of BER curves as shown in Fig 5.2. We take BER curves for varying values of attenuation for both a protected path and an unprotected path. Note that the BER curves and eye diagrams were taken on different days with different input power values.

At attenuations of 0 dB and 4 dB, the protected path introduces a positive power penalty over the unprotected paths. At these points, it is not worthwhile to use the SOA. At attenuations of 8 dB and 12 dB, the protected and unprotected paths have the same BER curves. As a result, it is still not necessary to use an SOA to compensate for the power attenuation at these points. Then, as the attenuation increases past 16 dB, the protected path introduces a negative power penalty. At this point, the SOA-compensated path starts to have a real advantage.
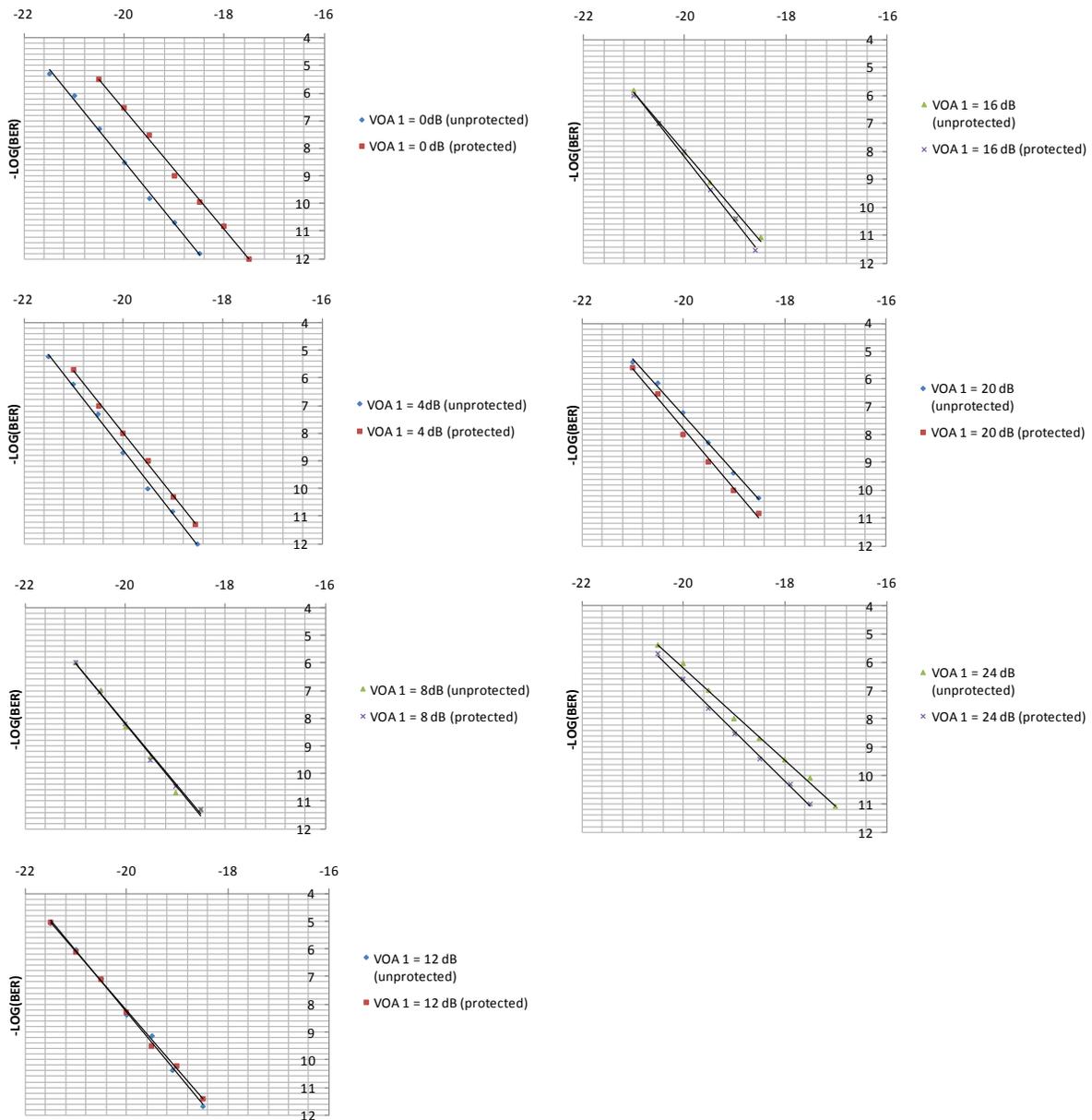
Fig 5.2 – BER Curves

Each of the attenuation values corresponds to an input power value. The power penalty taken at BER of 10^{-9} from the BER curves can be used to derive the power penalty vs. input power graph in Fig 5.3. The optimal input power threshold to turn on the SOA is at -12.22 dBm. When the power is above this point, the power penalty is positive and it is not beneficial to turn on the SOA. When the power is below this point, the SOA-protected path introduces a negative power penalty.
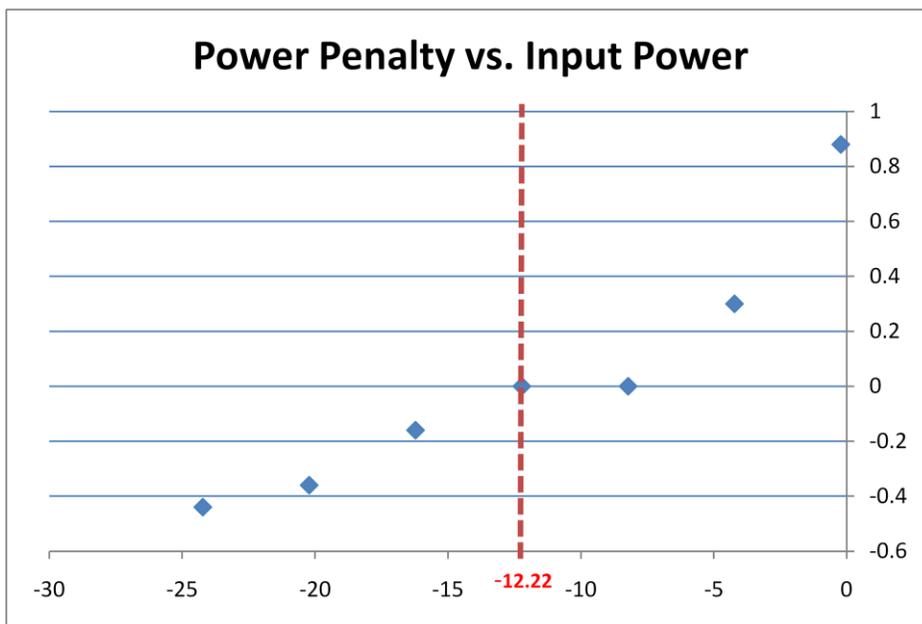

Fig 5.3 – Power Penalty vs. Input Power

5.1 perfSONAR Workshop (July 8-9 2010)

The perfSONAR Network Measurement Infrastructure shares similar goals with that of ERM and IMF. ERM have applied and been accepted to participate in the first perfSONAR Workshop from July 8-9. We will have be participating in the tutorial on July 7. Our goals during these three days are to learn about the following:

- How is perfSONAR used today? What are the major applications and institutions using perfSONAR?

- Does perfSONAR support optical layer measurements? If not, I would like to learn more on how to integrate our GENI work with perfSONAR, such as developing the schema and measurement archive for the optical layer measurements.

- Meet other researchers and engineers in the perfSONAR community

6. Project participants
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7. Publications (individual and organizational)

- M. S. Wang, C. P. Lai, K. Bergman, "Demonstrating UMF in an Experimental Use-Case (Project Nr. 1631, Milestone S2.c)," June 2010.

8. Outreach activities
none

9. Collaborations

- **Cluster D IMF Project:** Renaissance Computing Insititute (RENCI), North Caroline State University (NCSU), and University of Houston, Ilia Baldine, Shu Huang, Rudra Dutta, Deniz Gurkan Anjing Wang, and Debjyoti Majumder

We work closely with Ilia Baldine of RENCI, Rudra Dutta and Anjing Wang of NCSU, and Deniz Gurkan and Debjyoti Majumder of the University of Houston in the scope of the IMF project. More specifically, we worked with Ilia and Shu to integrate two optical components, an SOA and a variable optical attenuator, into the BEN network. We also worked with Anjing to design the XML-RPC interface to allow SILO to communicate with the SOA. We hold a phone meeting once every 1-2 weeks, and we communicate with email using an IMF mailing list.

- **GENI LEARN Project:** University of Houston, Deniz Gurkan, Debjyoti Majumder

We collaborated with Deniz and Debjyoti of the LEARN Project [learn_1] in learning more about how perfSONAR can be integrated into our work in ERM and IMF. Both ERM and LEARN will be sending representatives to participate in perfSONAR conference from July 8-9.

- **GPO:** Harry Mussman

We closely cooperated with Harry Mussman to create an updated version of the GENI Wikipage and submitting milestone reports and quarterly status reports.

10. Other Contributions
none

11. Bibliography

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