G E N I

Global Environment for Network Innovations

Milestone S2.c
Demo UMF in an Experimental Use-Case

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under Project Nr. 1631

"Embedding real-time measurements for cross-layer communications"

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1   Document Scope

This section describes this document's purpose, its context within the overall GENI project, the set of related documents, and this document's revision history.

1.1   Executive Summary

This technical note presents the outcome of the work package Milestone S2.c of Project Nr. 1631, "Embedding real-time substrate measurements for cross-layer communications." This milestone document comprises the third deliverable of ERM in Spiral 2 and involves demonstrating a working prototype of an experimental use-case. More specifically, we demonstrate a protection mechanism, whereby the UMF monitors the optical power of a 10Gb/s modulated signal. If the optical power undershoots a predefined threshold, the unified measurement framework (UMF) will export this information such that an external protection scheme can switch the signal to a protected lightpath that contains a semiconductor optical amplifier (SOA), which can amplify the power and improve the bit-error rate (BER) of the signal. This experiment is performed at the Lightwave Research Laboratory [lrl_1] at Columbia University.

A 10Gb/s modulated signal is first connected to a variable attenuator, and then to the input port of a Polatis switch [polatis_1]. UMF is used to monitor the optical power on this input port. Two different lightpaths are set up within the Polatis switch. There is an unprotected lightpath that directly connects the input signal to an output port, and there is a protected lightpath that contains a SOA in the path. When the optical power is above the predefined threshold, the input signal bypasses the SOA, which is turned off. However, when the optical power is below the predefined threshold, the input light is switched to include the SOA in the path, and the SOA is turned on. We compare the eye diagrams and BERs for the unprotected and protected paths while changing the attenuation of the input signal. For the same attenuation, we find a more open eye diagram and lower BER for the protected path as compared to the unprotected path.

In Section 2, we summarize our previous work in milestone S2.a and S2.b. In Section 3, we describe the experimental setup. In Section 4, we explain the software and hardware component of the UMF that was implemented for this experiment. Section 5 presents the experimental results. Section 6 gives a summary and conclusion.

1.2   Related Documents

The following documents are related to this document, and provide background information, requirements, etc., that are important for this document.

1.2.1 GENI Documents

Document ID	Document Title and Issue Date
ERM_S2a_Dec09	Spiral 2 Milestone 2.a Technical Note
ERM_S2b_Mar10	Spiral 2 Milestone 2.b Technical Note

1.3   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	03 June 10	M. S. Wang	Initial draft

2   Previous Work (Summary of Milestone S2.a and S2.b)

The goal of milestone S2.a [erm_1] involved the design and development of UMF, which serves as a means for gathering physical-layer measurements and conveying the data to the GENI researcher in an aggregated, unified way. Design considerations were taken into account so that the UMF could be integrated within the ORCA cluster, initially, and then extended to other GENI control frameworks in the future. Further, we discussed an implementation of the UMF by means of a NetFPGA Cube [netfpga_1], which is an integrated system composed of a general purpose processor, in addition to the proprietary NetFPGA hardware [netfpga_2]. The UMF comprises of both a software component (implemented on the general purpose processor), as well as a hardware component (implemented on NetFPGA card). Each component has a defined role in facilitating the UMF to access the networking elements and its measurement data.

Further, the goal of milestone S2.b [erm_2] involved implementing and demonstrating a working software interface between the 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 is a set of four Polatis switches within the ORCA-BEN [orca_1] network, from which we retrieved the optical power. In doing so, we have merged our UMF design with the integrated measurement framework (IMF) [imf_1] project implementation. By realizing the measurement handler (MH) for the Polatis switch and testing the functionality of the XMPP server and pubsub module (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 [orca_1].

3   Experimental Use-Case Setup

Figure 3.1 shows the experimental setup for this use-case.
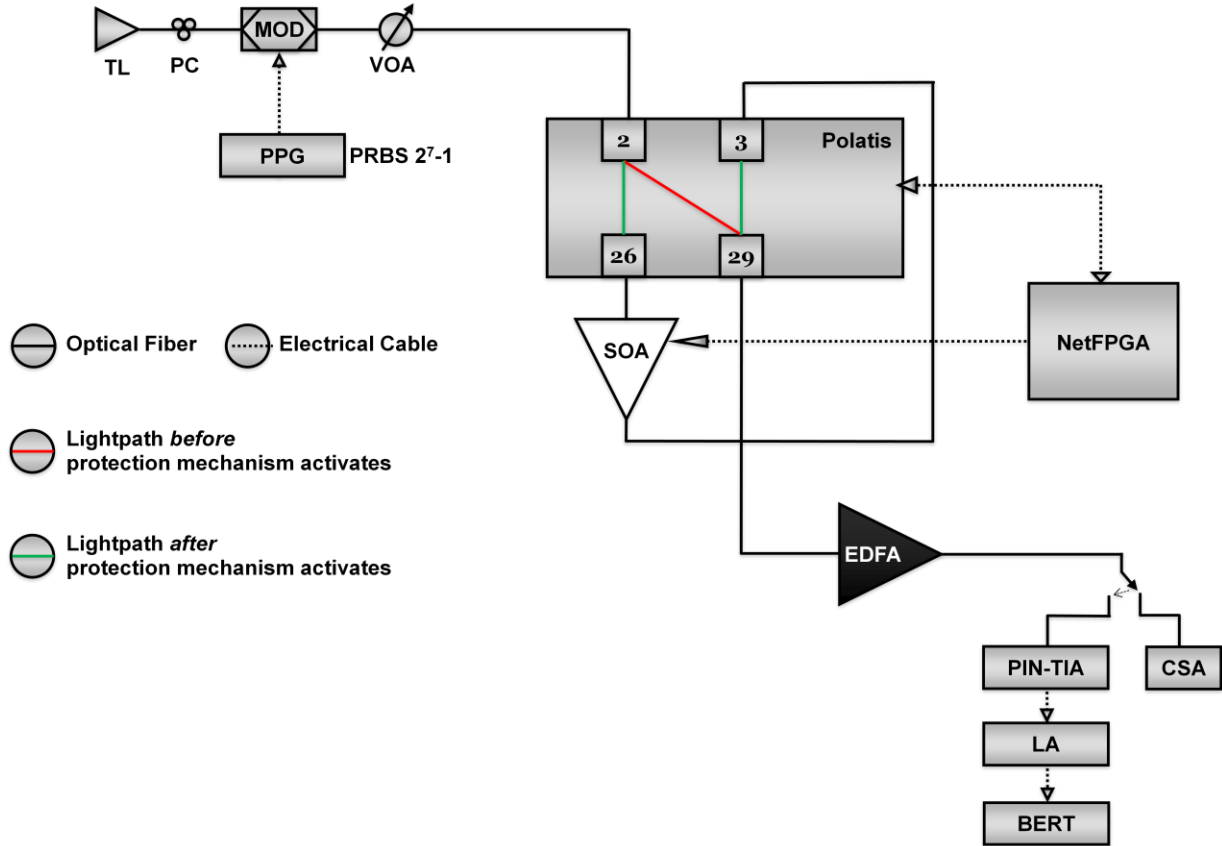
Fig 3.1 – Experimental Use-Case Setup

A 1538.98nm tunable laser (TL) 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 a variable optical attenuator (VOA), which can be hand-tuned.

The input signal is sent into input port 2 of the Polatis switch. A NetFPGA is used to monitor the optical power on this input port. When the optical power is above a predefined threshold (-20 dBm), the NetFPGA directs the Polatis switch to maintain a cross-connect between input port 2 and output port 29. 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 2 to 26 and 3 to 29. 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 port 29 is then sent through a 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. Note that the signal

coming out of port 29 is first sent through an erbium-doped fiber amplifier (EDFA). This amplification is necessary to compensate for the insertion loss incurred through the lightpath. Without this amplification, the obtained eye will not be large enough to provide a large range of attenuation from the VOA.

4   UMF Implementation for Use-Case

The UMF is implemented on a NetFPGA Cube system [netfpga_1], [netfpga_2]. It comprises of both a software component (using the general purpose processor), as well as a hardware component (using the NetFPGA card) [erm_1]. Fig 4.1 shows how the UMF is used to control the Polatis switch and the SOA for this use-case experiment.
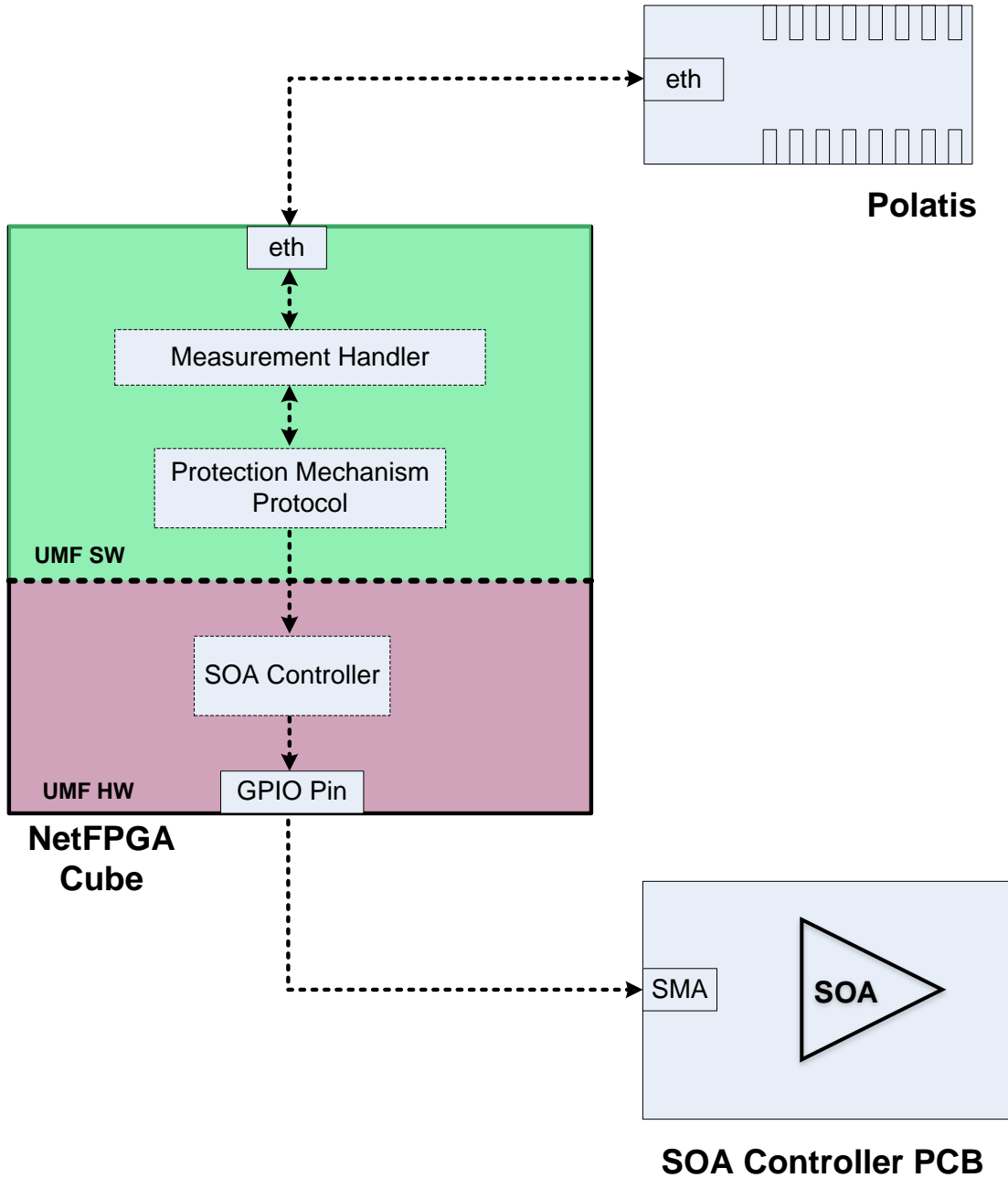

Fig 4.1 – UMF Architecture for Use-Case

The UMF SW consists of the measurement handler (MH) and the protection mechanism protocol. In milestone S2.b, we demonstrated a working MH that could obtain real-time optical power measurements from any of the four Polatis switches in the ORCA-BEN network [orca_1]. For this use-case, we ported the MH source code to work on the Polatis switch located at Columbia University. Further, we updated the MH to include not only the commands to measure optical power, but also the commands to create and delete cross-connects on the Polatis switch. Furthermore, the protection mechanism protocol is a Perl script that continuously monitors optical power of the Polatis input port 2, and determines how to set the cross-connects and SOA depending on a predefined power threshold.

The UMF HW consists of an SOA controller that either sends out a low signal to turn off the SOA or sends a high signal to turn on the SOA. The SOA controller makes this decision based on the content of a register that could be changed by the UMF SW through a PCI bus. The gain of an SOA is controlled by the amount of current driven across it. We are able to control the SOA using a printed circuit board (PCB) that contains a current driver. For this experiment, we set the current to a fixed value, and provide the programmable control of turning on or off the SOA via the Sub-Miniature Version A(SMA) connection on the PCB board.

5   Experimental Results

Output port 29 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 10 dB, at which point, the lightpath traverses through the SOA. For the unprotect path, the lightpath bypasses the SOA regardless of the attenuation.
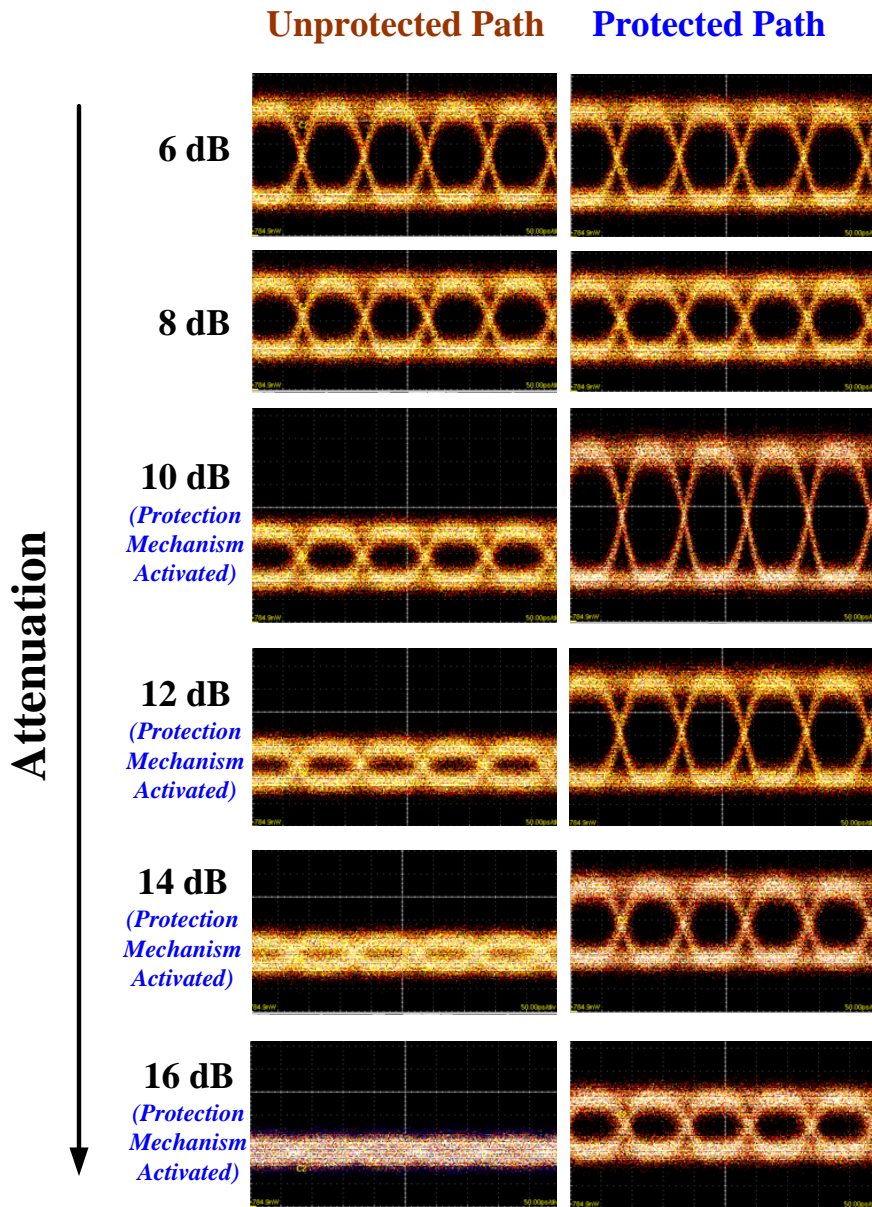

Fig 5.1 – Eye Diagrams for Protected vs. Unprotected Paths

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.
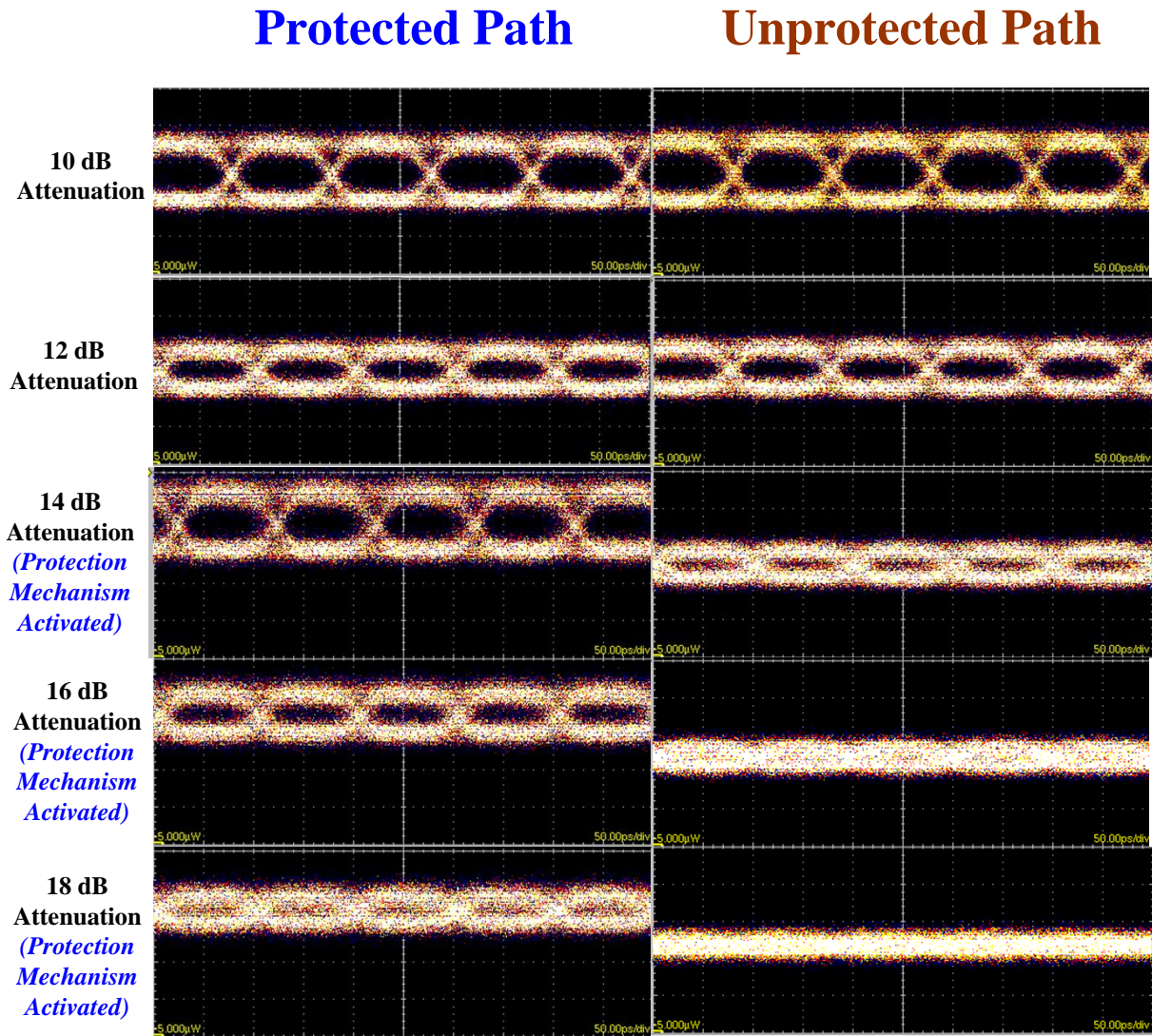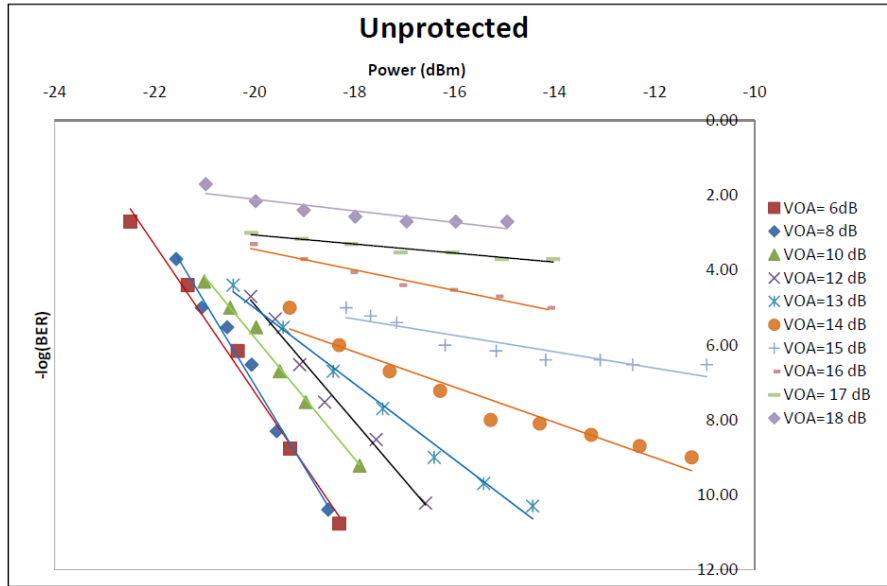
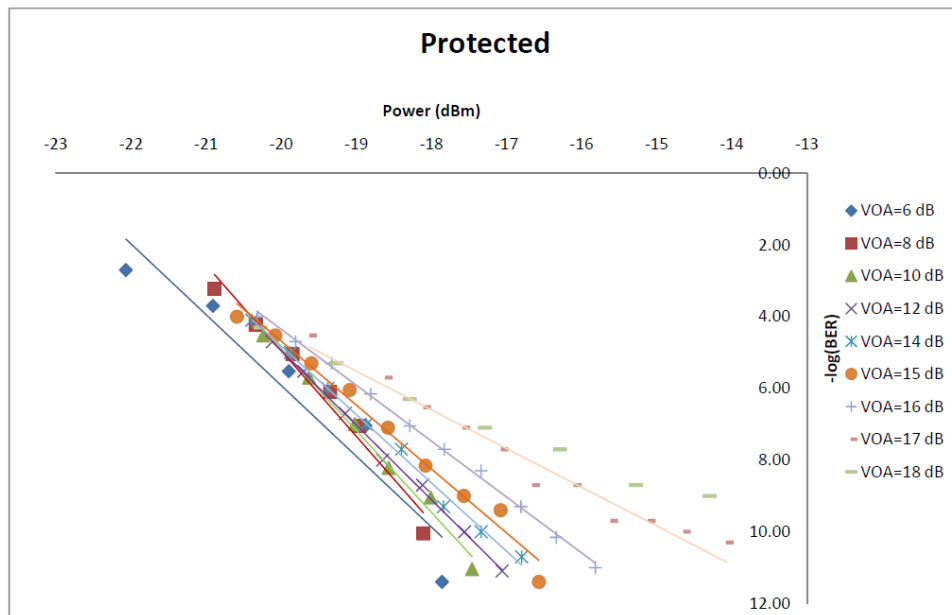**Fig 5.2 – BER curves for Protected Path**

Fig 5.3 – BER curves for Protected Path

6   Summary and Conclusion

In this report, we discuss our latest Spiral 2 milestone of demonstrating 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. For the same attenuation, we examine a more open eye diagram and lower BER for the protected path versus the unprotected path.

7   Bibliography

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