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# Laboratory exercises for optical communications: Hardware and simulation

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**Laboratory Exercises for Optical Communications: Hardware and Simulation**  
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**Abstract**

A key goal of the Telecommunications Engineering Technology program at RIT is to prepare our students to work with sophisticated communications technology by giving them hands-on experience with the technology to support what they learn in the classroom. Most courses in the program, including the courses on optical communication, have associated laboratory exercises. Ideally, the laboratory exercises should include working with actual optical communication components and systems and some of this equipment is available in our laboratories. However, this equipment is limited to low bit rate (OC-3) and short distance because of cost and space constraints. Because of these constraints, we complement hardware-based exercises with software-based exercises that simulate the long-haul high bit rate systems that graduates will encounter on the job.

This report presents the current state of our laboratory instructional program with emphasis on the dual roles of hardware and simulation exercises. It describes the philosophy behind the exercises and provides some examples. It also describes how, using the simulation tool that we have chosen, we can make simulation exercises available to online students who do not have full access to the simulation software. And it describes our current hardware configuration and the complementary exercises that the hardware supports.

**Introduction**

The Telecommunications Engineering Technology (TET) program at RIT was launched in 1990 and in 1994 the program became the first of its kind to be accredited by the Technology Accreditation Commission of ABET. The program now offers a Bachelor of Science and a Master of Science degree as well as three certificates. Nearly all of the courses in the program include an associated laboratory or some kind of research paper or project to add to the learning experience.

The program is under continuous review, especially in light of the dramatic and rapid changes in telecommunication technology and the telecommunication industry. In recent years, some of the most significant technological developments have been in the area of optical communication. In 2001 the TET program began offering a course in fiber optic telecommunications technology [1] as an elective for advanced undergraduate students. This initial offering attracted a good number of students, not only from the TET program but from other engineering technology programs as well, especially electrical. Feedback from students was very positive.

The fiber optic course is contains a technology track and an engineering track. The technology track is designed to introduce students to the components of a fiber optic communication system. Starting with optical fiber itself, the course proceeds to cover

optical sources (light-emitting diodes and laser diodes) and transmitters, optical detectors (photodiodes) and receivers, optical amplifiers and passive optical components. The engineering track covers theory and methods for analyzing and designing optical communication links. Topics include power budget and attenuation-limited fiber length, dispersion and dispersion-limited fiber length and bit error rate calculations.

Primarily because of lack of equipment, the course was offered initially without associated laboratory sessions. Toward the end of the first offering of the course, we scheduled a meeting with the students to discuss the course and how it could be improved. The students had many positive comments about the course and recognized the importance of the topic. They all agreed, however, that the course needed associated laboratory exercises.

Since that initial offering, we have developed a number of approaches to providing laboratory experience in optical communication. The development is ongoing and this paper is essentially a snapshot of where we are today.

### **Laboratory Exercises**

Our currently repertoire of laboratory exercises for optical communication consists of three kinds of exercises:

- Basic hardware exercises
- Computer simulations
- Optical networking exercises

Each of these is discussed in this section

#### *Basic Hardware Exercises*

As part of the engineering track of the course, students learn how to account for the effects of attenuation and dispersion in fiber optic systems. The basic hardware exercises support this by giving students the opportunity to observe and measure these effects in the laboratory. With support from the Society of Manufacturing Engineers, we obtained a set of fiber optic communication kits from OptoSci Ltd. Each kit includes a multi-function box that provides an electrical signal generator, two optical transmitters (one LED based and one laser diode based) and one optical receiver. The kit also includes two reels of multi-mode fiber and additional cables and connectors. The optical receiver displays optical power received and therefore functions as an optical power meter. Figure 1 shows some students performing measurements in the lab.



Figure 1 – Students Measuring Fiber Attenuation and Dispersion

Students can use the configuration shown in Figure 2 to measure fiber loss due to attenuation. First, the transmitter is connected to the receiver using a 1 m fiber jumper, which inserts negligible loss. Then the jumper is replaced with a fiber reel containing 1 or 2 km of fiber. By comparing the received power, students can calculate the loss due to fiber attenuation in dB. Since the two optical transmitters operate at somewhat different wavelengths, students can also note the wavelength dependence of fiber attenuation.

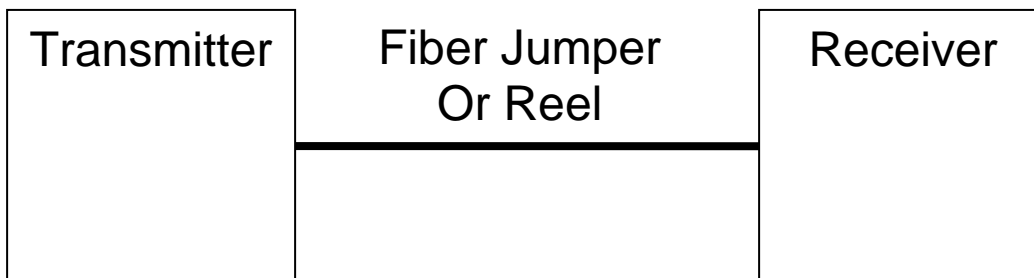


Figure 2 – Fiber Attenuation Measurement

Figure 3 shows the configuration used to measure dispersion. The oscilloscope (not included in the kit but a standard item in engineering technology laboratories) is configured to measure the rise time of the received signal. When the transmitter is connected to the receiver via the fiber jumper, the measured rise time is entirely due to the transmitter and receiver rise times. When the jumper is replaced with a fiber reel, the rise time increases due to dispersion in the fiber. By comparing the rise time differences, students can calculate the component due to dispersion in the fiber.

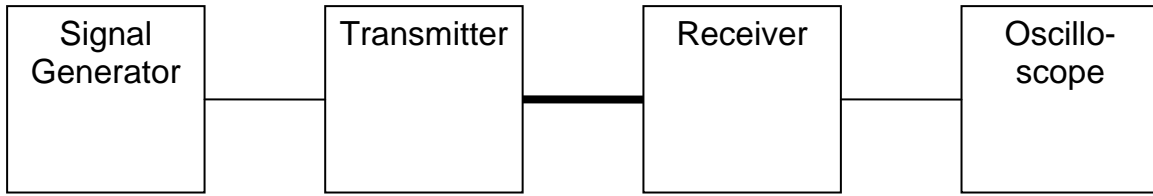


Figure 3 – Fiber Dispersion Measurement

These kits and the exercises they support have been a valuable addition to the course, but they have significant limitations. The optical power levels, operating wavelengths and pulse transmission rates have been chosen to keep the kits affordable. Although the kits do an adequate job of demonstrating basic principles, they differ sharply from the kind of equipment that telecommunication engineers encounter on the job.

### *Computer Simulation*

Computer simulation provides a way to observe and measure the behavior of complex systems without actually purchasing and configuring the hardware. At least two optical communication simulation systems are commercially available and Koontz and Mandloi [2] have investigated one of these products: OptiSystem. The TET program obtained a license for OptiSystem that allows up to twenty students to use the software simultaneously. Koontz and Mandloi developed a set of laboratory exercises that allows students to simulate system designs, evaluate their performance and compare results of the simulation with pre-lab calculations. More detail about these exercises is provided in [2].

The simulation exercises have been part of the optical communication course since the winter quarter of 2004-5 and have been well received by the students. The exercises are designed to introduce features of the software gradually and no significant training is required. Students normally work on the exercises during “open lab” time and complete an average of one exercise every two weeks.

Initially, it was not practical to offer the simulation exercises to online students who could not access the RIT campus. Even with an academic discount, the cost of optical communication simulation software is significantly higher than the cost of most software tools that students are expected to purchase. And the TET owned software can only be accessed from the laboratory in our building. Fortunately, Optiwave Corporation (the OptiSystem vendor) has provided a solution called OptiPerformer.

OptiPerformer, which is available as a free download, can run a simulation model exported from OptiSystem. Moreover, OptiPerformer allows the user to vary specific parameters of the model. The instructor (or anyone with access to OptiSystem) constructs the model, determines which parameters can be varied and exports the model in OptiPerformer format. The OptiPerformer model can then be distributed to the online students by simply posting it on the course web site or attaching it to an email. Students can then set the parameters and run the simulation. Although the online students miss the

full experience of constructing the model and using advanced features of OptiSystem such as parameter optimization, they do have the benefit of seeing their designs validated by a simulation.

### *Optical Networking Exercises*

The laboratory kits and the simulation software provide students allow students to perform experiments and apply the theory discussed in the classroom. But these tools do not provide experience with real optical networking equipment. Fortunately, we have been able to acquire a limited amount of this equipment and install it in our Telecommunications Systems Laboratory (TSL).

The TSL is a nearly symmetrical configuration of telecommunication equipment with the left and right halves referred to as Side A and Side B. Each side includes residential telephones, a private branch exchange, loop cable and terminals and a local switch. The sides are connected by a number of different trunk circuits including wire, microwave and optical. Recently, some voice over IP equipment has been added, but that will be the subject of a future paper.

Currently, the TSL contains four optical network elements, two of which were just installed last year. The older equipment is a pair of Nortel SONET terminal multiplexers. These units have been used to provide a point-to-point OC-3 link in the laboratory, which has been mainly used to carry DS1 circuits between Side A and Side B.

The more recent equipment is a pair of Cisco ONS 15454 multi-service SONET platforms equipped with interfaces for OC-3 fiber lines and DS-1 electrical tributaries (Figure 4). The ONS systems have been configured as a two-node unidirectional path switched ring (UPSR), thereby providing a protected OC-3 link.



Figure 4 – Student Working With Cisco ONS 15454 System

Figure 5 is a schematic of the configuration of the Cisco and Nortel optical systems in the TSL. Note that the DS1 interfaces are terminated on digital signal cross-connect (DSX) panels. DS1 interfaces from other equipment, including the local switches, channel banks, routers and other DS1 transport systems (microwave and wire), are also terminated on the DSX panels. This arrangement provides a variety of ways to provide DS1 paths from Side A to Side B.

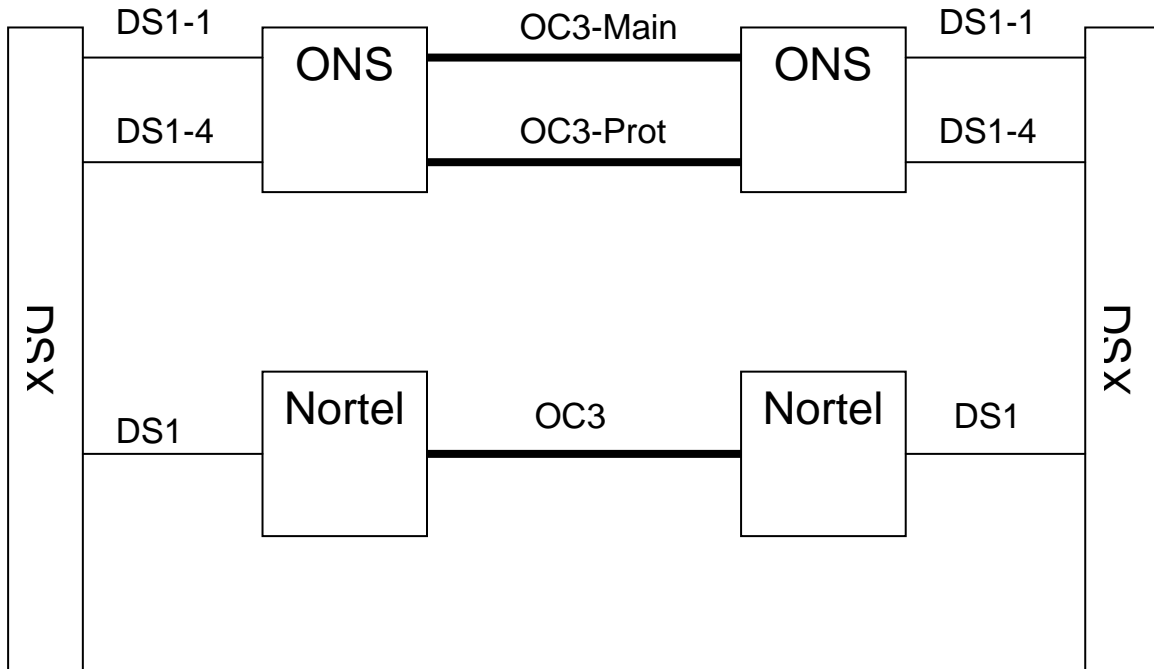


Figure 5 – SONET Equipment in the Telecommunications Systems Laboratory

Figure 6 shows how the Nortel systems are configured to provide a DS1 trunk group between the two local switches. This is a default configuration established by wired cross-connections in the DSX panels. The default configuration can be overridden by using DSX jumper cables to connect the local switch DS1 interfaces to another transport system, such as the ONS. To switch from the default configuration to the configuration shown in Figure 7, students have to provision the DS1 ports in each ONS, provision a VT1.5 path through the ONSs and connect the jumpers at the DSX panels. They use the ONS element management system, which runs on a PC in the TSL (Figure 8), to complete the provisioning.

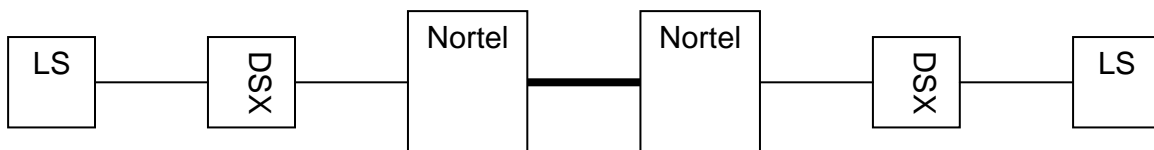


Figure 6 – “Default” Optical Trunk Network

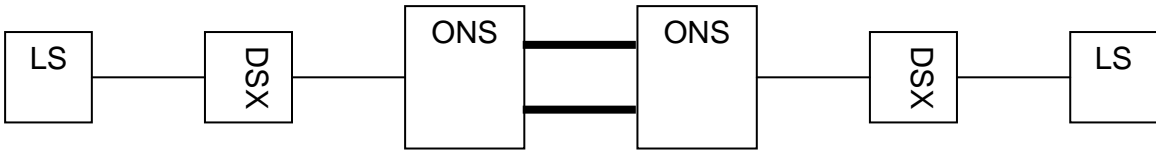


Figure 7 – Protected Optical Trunk Network

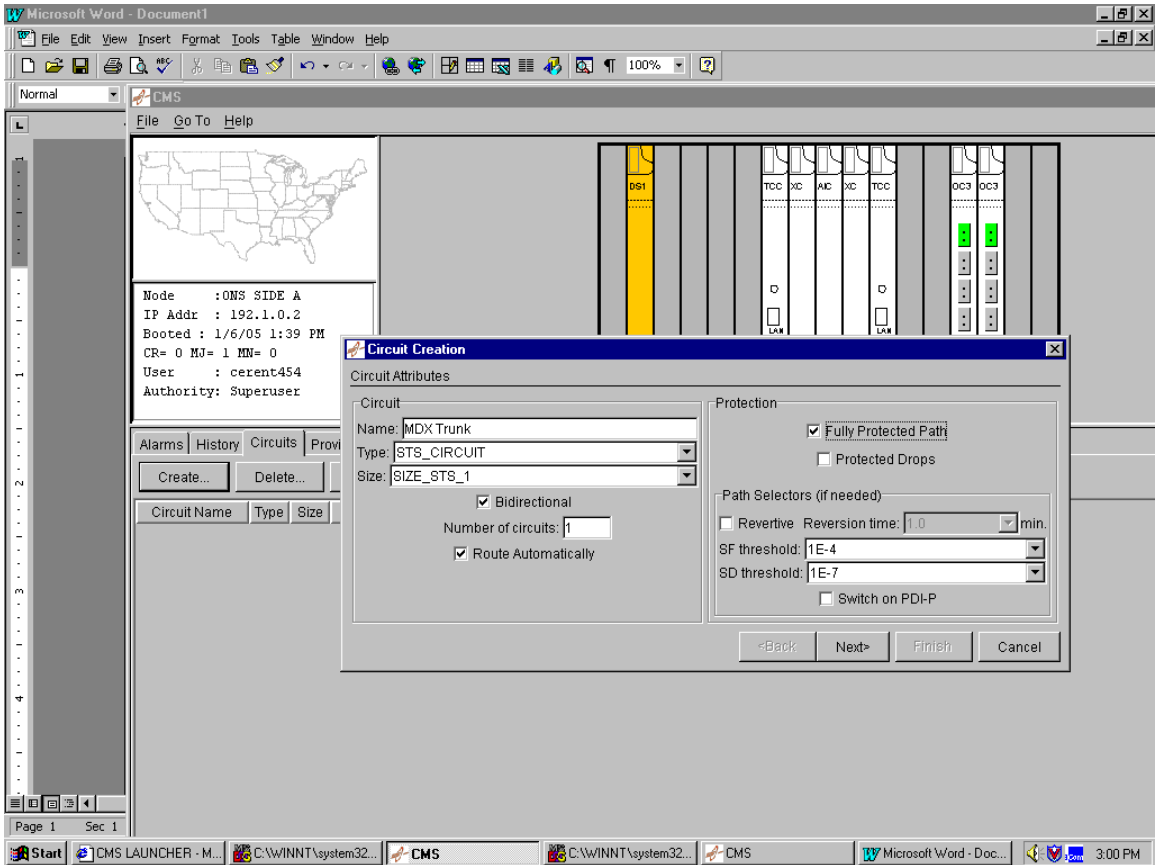


Figure 8 – ONS Element Management System Interface



Figure 9 illustrates a more elaborate realization of the DS1 path that passes through our entire complement of SONET equipment. This exercise not only gives students a chance to work with a more complex circuit, but it frees up the DS1 interfaces on the ONS to carry a second circuit (although the ONS is currently provisioned to carry 14 DS1s, it is only provisioned to switch at the STS-1 level, so all DS1s have to switch together).

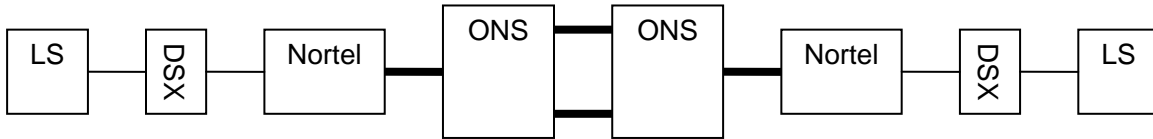


Figure 9 – Trunk Network Using All Optical Network Elements

The exercises with the SONET equipment in the TSL are still under development and have been used mainly as demonstrations. They will be integrated into future offerings of the course or advanced versions of the course.

### **Summary and Future Directions**

The primary challenges faced in developing laboratory exercises for optical communication courses are obtaining equipment and designing exercises that truly relate to and reinforce concepts learned in the classroom. Opportunities to obtain equipment may come with the annual budget cycle or may arise in the form of a pleasant surprise from a donor. We have been able to take advantage of these opportunities and the result is a set of exercises that integrate nicely with the course and the program.

We plan to continue our development by both seeking new equipment and making more and better use of the equipment that we have. For example, we propose to add Ethernet interfaces to the ONS systems and thereby achieve more integration between our data networking equipment and our traditional telecommunication equipment. We are also considering adding wavelength division multiplexing capability.

In the end, all of this activity is focused on the biggest challenge of all: keeping the TET program in step with the rapid advances in telecommunication technology.



References:

1. W. L. G. Koontz, "Fiber Optic Telecommunications Technology and Systems – A Two-Course Sequence for a Telecommunications Engineering Technology MS Program", ASEE Annual Conference, Portland, OR, June 2005
2. W. L. G. Koontz and D. Mandloi, "Application of Optical System Simulation Software in a Fiber Optic Telecommunications Program", SPIE Photonics North Conference, Ottawa, September 2004