

Development of an Undergraduate Communications Simulation Laboratory

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Abstract

This paper describes the implementation of a new course in communications through the creation of a computer-based laboratory for modeling and simulating communication systems. The lecture course in a typical Electrical Engineering (EE) curriculum, along with this laboratory, provide a totally integrated delivery system for teaching a wide spectrum of topics ranging from transmission/reception concepts and applications to performance analysis of fiber optic networks. The laboratory is easily implemented by constructing a PC-based computer network supporting several simulation tools. Students are able to access a variety of software packages for analysis of different communication systems. The topics covered in the laboratory can be divided into three categories: communication signals, fiber optic and wireless links, and communication networks. Senior and graduate students are the primary users of this laboratory. Typically, this laboratory can be utilized as a supplement to the existing communication courses or be taken as an elective course.

Introduction

The field of communications is dynamically changing due to the advances in the technologies that support it. Fields such as data communications, wireless networks, security, etc. demand highly trained personnel to solve the new challenges. The need for

communication engineers capable of new ideas and implementing systems that are feasible to maintain and operate is more relevant than ever. Often electrical engineering curriculums offer students one or two theoretical communication courses; however this is not enough to train communications engineers in the proper background of the newer technologies. The traditional courses and laboratories are focused on the foundations of communications theory. The equipment needed to implement laboratories with the newest technologies is expensive and changes constantly. This makes it difficult to continuously upgrade such laboratories. Consequently, employing a computer based laboratory with different software packages dedicated for communication applications might be a good approach to overcome all of the aforementioned drawbacks.

The electrical engineering curriculum at the University of Texas at El Paso (UTEP) offers several courses in analog and digital communications. In general, students can learn about many communication systems, but have no opportunity to actively learn first-hand the performance trade-offs involved in designing a system. For that reason, a new course using a combination of lectures and multiple computer assignments has been proposed to provide a practical view of communication systems using computer modeling and simulation. The course assumes that students only have a background in signals and systems. Therefore it includes a lecture covering the relevant concepts needed to understand the communication models and their applications.

The goals of this course are for students to be able to understand how to simulate real communication systems, evaluate properties for different modulation techniques, understand the effects of link noise and power budget on the transmitted signals, and design different network topologies as well as calculate the performance of network protocols.

Course Structure and Outline

The objective of this course is to familiarize students with several different communication systems through a series of laboratory experiments using computer simulation. The experiments deal with physical link properties, fiber optic links, wireless links, and network performance for packet and circuit switching systems. We use mathematical software, like MATLAB®, for modeling and analyzing signals with different waveforms such as sinusoidal, rectangular, etc. The laboratory also employs an optical link simulator, Virtual Photonic Integrated (VPI) Systems™, for the modeling and analyzing of optical devices, as well as the designing of an optical link. The third application is a discrete event network simulator, Optimal Network (OPNET®), to predict the high level behavior of the traffic in a network. Due to the variety of themes involved, the material covering these broad topics in communications are selected from several references^{1,2,3,4}; however, the majority of the material is taken from “Telecommunications by Hioki” as the main textbook.

The topics are scheduled for a semester with 8 laboratory assignments distributed over 14

weekly sessions. A list of proposed topics, including the laboratory number, related chapters in the textbook, and the related software for weekly use are shown in Table 1.

Table 1. Schedule of topics and text chapters

Week	LAB#	Topic	Software	Textbook Chapter
1	1	Introduction, Analog Modulation Part I	Matlab	3,4
2	1	Analog Modulation Part II	Matlab	3,4
3	2	Power and Noise	Matlab / VPI	2,3,4
4	3	Digital Baseband Transmission	Matlab	5, partial (6,8,10)
5	4	Digital Modulation	Matlab	13
6	4	Coding, Error Detection and Correction	Matlab	17
7	5	Fiber Optic Link Analysis	VPI	18
8	6	Multiple Access Techniques with Fiber Optics	VPI	(Extra)
9	8	Circuit Switched Wireline Networks & Wireless Networks	OpNet	12,19
10	7	Blocking, Throughput and Delay	OpNet	(Extra)
11	7	Local Area Networks (Contention based)	OpNet	15
12	7	Layer 2 Bridging and Switching in LANs	OpNet	15
13	8	IP and Routed networks	OpNet	16
14	8	Switching packet networks (ATM, FR, etc)	OpNet	16.1

Sample Experiments

Three sample experiments are selected to demonstrate the use of software packages to understand the major categories of this course. The first experiment shows how to use Matlab and its toolbox to study and implement communication modulation systems such as Amplitude Modulation (AM), Frequency Modulation (FM), Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), etc. Another experiment shows how to use VPI software to study and analyze the performance of fiber optic links. The last sample of the proposed experiments shows how to use OpNet software to evaluate different types of network topologies. The figure in each sample gives a brief picture on each category of this course and what the student should do to meet the requirements of each assignment.

A) Sample Assignment 1: Power and Noise

This experiment aims to visualize the effects of noise with common techniques of signal communications (i.e. Amplitude Modulation Double Side Band –Suppressed Carrier and

Large Carrier (AM DSB-SC and AM DSB-LC), Single Side Band (SSB), Narrow and Wide Band Frequency Modulation (NBFM and WBFM), and Phase Modulation (PM)), PSK, FSK, etc. The results of this experiment can be obtained by simulating these different techniques in the time, frequency and modulation domain using MATLAB, Simulink, and the Communication Toolbox software, which is available on each station in the Communication Laboratory (Commlab). Figure 1 below shows a BPSK diagram that the student should demonstrate using Simulink toolbox.

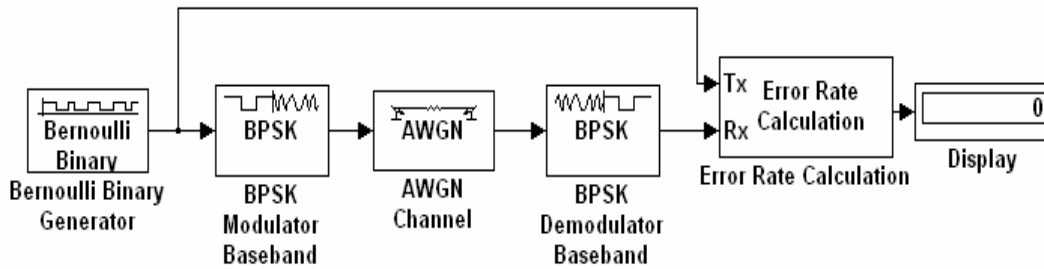


Fig. 1: Binary Phase Shift Keying Block diagram

B) Sample Assignment 2: Simple Optical Fiber Link

In this section, the student should build the link shown in figure 2. The attenuation increases from 3dB up to 30dB in the step of 3dB, 6dB, 10dB, 20dB, and 30dB. The effect of the attenuation on the signal and its relation with BER are to be studied.

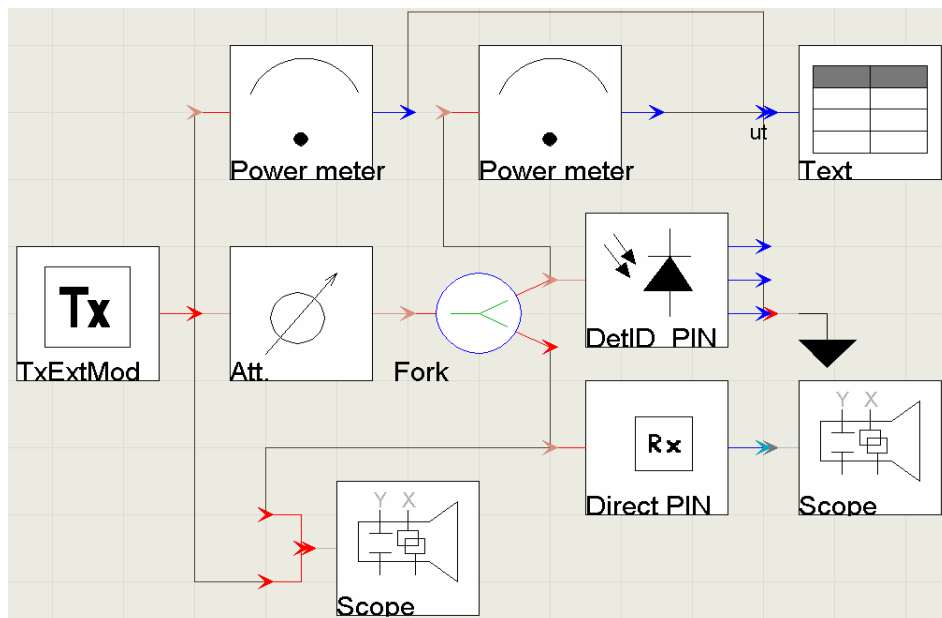


Fig. 2: Simple Optical Link

C) Sample Assignment 3: Networks and Performance Metrics

This experiment aims to observe the simulation of a communication network by utilizing a technique known as “discrete event simulation,” where a computer replicates the behavior of an event that occurs in the network. To fulfill the requirements of this experiment, a student is advised to go over the tutorial first as well as go over the provided lessons. Figure 3 shows a built network selected from the tutorial. This network should be demonstrated using OpNet, and further requirements are provided through this laboratory assignment to enhance understanding of networks design.

The Finished First Floor Network

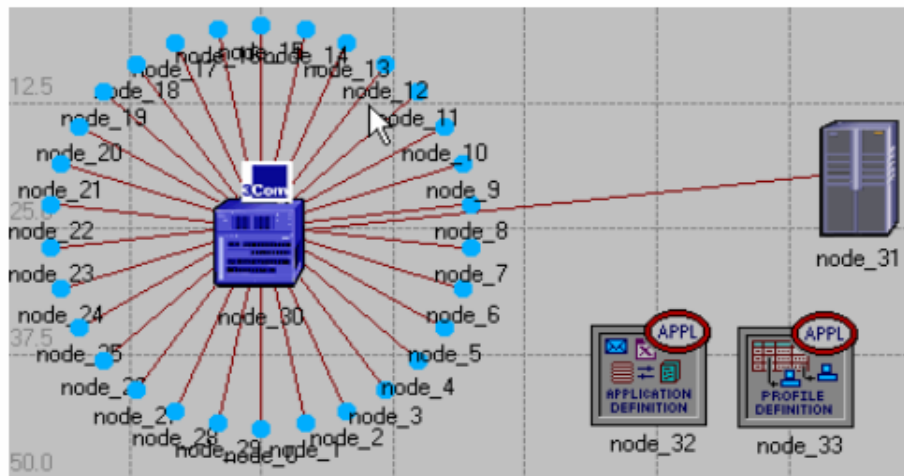


Fig. 3: Network Installed in company offices

Results from First Course

The course was offered for the first time in the fall semester of 2002. The enrollment consisted of 8 undergraduate students and 6 graduate students who elected to take the class. This required coordination with the teaching assistant to provide the tutorial sessions for each computer application employed. During the semester we encountered several resource problems with the operation of the computer laboratory; in particular the software licensing created conflicts that delayed the initial experiments. We gave extra time for assignment completion to balance the resources and accommodate the student needs.

This course only had Signals and Systems as a prerequisite, and it was intended to complement the regular lectures on analog and digital communications. However the students had some difficulties interpreting the experiment results because this was the first communications course for some of them. The lectures compensated for the problem by providing basic theory and focusing on the practical aspects. At the end of the semester all of the students were able to complete all of the laboratory assignments.

The student evaluation of the course reports that 22% took the class for their own interest, 67% as an elective and 11% to fulfill a requirement. In Table 1 there is the rating distribution for the course, and in table 2 we show some quotes from student comments from the evaluations. The acceptance was good but there are some areas that require improvement.

The lectures must be increased because many students do not have any previous background in communication systems. Also, the assignments need to be adapted to the learning curve for operating the simulators. There is not enough time to cover all the topics in detail; thus we will need to remove some themes and reduce the depth of other areas.

Table 1, Student evaluation of the course

Question \ Scale	5 Best	4	3 Avg.	2	1 Worst	Average
How much did you learn in this course?	22%	67%	11%	0%	0%	4.1
Effectiveness of this course in challenging you intellectually	33%	67%	0%	0%	0%	4.3
Overall Rating of course	44%	55%	0%	0%	0%	4.4

Table 2, some student comments of the class

“... Interesting class. I feel laboratories are important because we get more opportunity to use tools and realize results practically. Also labs help to understand concepts and more in the direction of research. ...Please make sure that labs are equipped with required software with enough licenses. Also make lab available on weekends as students work part-time ...”
“... The only problem was it covered a lot of topics. This prevented us from studying some topics in detail ...”
“... I think it will be good to continue to tweak it and turn it into a continuously offered course...”
“The communication systems simulation course presents great opportunities to any student understand with more precision the relation of telecomm at an industrial level...”
“Great exposure to simulation software.”

Conclusion

A computer simulation laboratory is an alternative approach to establishing a real laboratory. Such a laboratory has a significant advantage over a real laboratory because the capability to upgrade and update software packages to emulate the real one is much easier and cheaper than replacing the equipment found in a real laboratory.

We have designed different lab assignments. The lab assignments include analog and digital modulation techniques, the design of fiber optic links along with studying the correlation between the physical characteristics of the link and the transmitted signal, and the design of different network topologies.

To provide an initial assessment, the communication lab assignments have been assigned in senior and graduate level communication systems courses in the University of Texas at El Paso. Students run assignments using computer modeling and simulation, submit individualized lab reports, and complete evaluation forms to give a feedback in order to improve and update the assignments for coming semesters. Students find this lecture course along with lab assignments helpful to them in understanding the theory of communication systems, gaining practical experience, and learning the performance trade offs involved in setting up communication systems.

In the future, more lab assignments will be designed to cover more advanced communication topics. For example, new assignments dealing with wavelength division multiplexing (WDM), wireless network, etc. will be devised.

References

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Ahmed Musa was born in 1974, in Irbid, Jordan. He received a B.S. and M.S. in 1997 and 2000, respectively, in electrical and computer engineering from Jordan University of Science and Technology. He worked as a telecom engineer in Jordan Telecom from 1999-2001. He is currently enrolled in Ph.D. program in Computer Engineering at The University of Texas at El Paso.

Virgilio Gonzalez-Lozano was born on 1966 in Mexico City, Mexico. He obtained a BSEE with honors, and a MSIE from the Instituto Tecnológico de Estudios Superiores de Monterrey Campus Estado de Mexico (ITESM-CEM) in 1988 and 1991 respectively. He received his PhD degree in 1999 with the dissertation "Performance Analysis of a Local Area Network Based on WDM and ATM" From the University of Texas at El Paso (UTEP). Virgilio Gonzalez was employed at the ITESM South Zone Region as Telecommunications Director between 1989 and 1993. From 1996 to 2001 he worked in ALESTRA, the Mexican subsidiary of AT&T as a Technology Planning Manager. He was in charge of the development of new network architectures for AT&T in Mexico. He received in September 2001 the appointment of Visiting Assistant Professor in the Electrical and Computer Engineering Department at UTEP. Since September 2003 Virgilio Gonzalez is an Assistant Professor in the same department. His areas of interest are in data communications, optical networking, high performance protocols and telecommunication networks.

Mehdi Shadaram received a B.S.E.E. degree from the University of Science and Technology in Tehran in 1976, M.S. and Ph.D. degrees from the University of Oklahoma, both in electrical engineering, in 1980 and 1984 respectively. Since September 2003, he has served as the Briscoe Distinguished Professor and Chairman of the Department of Electrical Engineering at the University of Texas at San Antonio (UTSA). Prior to joining UTSA, he served as the Schellenger Endowed Professor and the Chairman of the Department of Electrical and Computer Engineering at the University of Texas at El Paso (UTEP). His research activities are focused in the field of optical fiber communications and photonic devices. During last few years, he has investigated the performance of analog optical fiber links, WDM networks, and application of tapered single-mode optical fibers. NASA, Jet Propulsion Laboratory, National Science Foundation, Office of Naval Research, Department of Defense, Texas Instruments, Nortel, and Lucent Technologies have funded his research projects. He has published more than sixty articles all in his area of research, most of them in refereed journals and conference proceedings. Dr. Shadaram is a registered Professional Engineer in the State of Texas. He is a senior member of IEEE, member of the International Society for Optical Engineering, Optical Society of America, and Eta Kappa Nu. He has received numerous awards for teaching and research excellence. He is cited in Marquis Who's Who in America.