Virtual Lab Experiments in Telecommunications for Distance Learning

Dr. Samuel S. Epelbaum
CSIS, Pace University
New York, NY 10038, USA
sepelbaum@pace.edu

Abstract

Telecommunications courses in signal transmission, data communication, networking, and other areas all require comprehensive hands-on experiments or communication simulation labs. The labs and the ability to perform telecommunications experiments are not readily available to the student in distance learning.
This paper introduces industry-available software that can be used to create virtual lab experiments for distance learning. Software simulation methods can be adapted to create virtual lab experiments, and practical experiments in telecommunications based on the simulation software are introduced.
This paper also identifies the need for further research and development of software tools suitable for telecommunications experiments for distance learning.

Keywords: Telecommunications, networking, experiments, virtual laboratory, distance learning.

1. TELECOMMUNICATIONS FOR DISTANCE LEARNING

College courses in telecommunications heavily rely on hands-on experiments with communication hardware performed in the lab. These labs are generally out of reach for a distance learning student.
As proposed in this paper, a solution for this problem is to use special software products that could be downloaded on a student PC or accessed through a server, and consequently perform procedures that would simulate a real experiment.
This paper introduces a few specific examples of industry-available software and proposes experiments based on this software. These experiments could substitute real experiments in telecommunications studies in distance learning.

2. VOICE COMMUNICATION EXPERIMENTS

The following is an example of industry-available software [1] suitable for virtual telecommunications experiments in voice communication. This software provides screens of visualized electronic voice copies, voice generated signals, and their respective characteristic.

Real voice and its dynamics could be observed, measured, and experimented with. In addition, an electronic copy of the voice could be used to measure voice signal transmission characteristics that are essential for analysis and design of telecommunications network.

Figure 1 depicts the screen display of a student's voice signal copy using the software installed on the student PC.
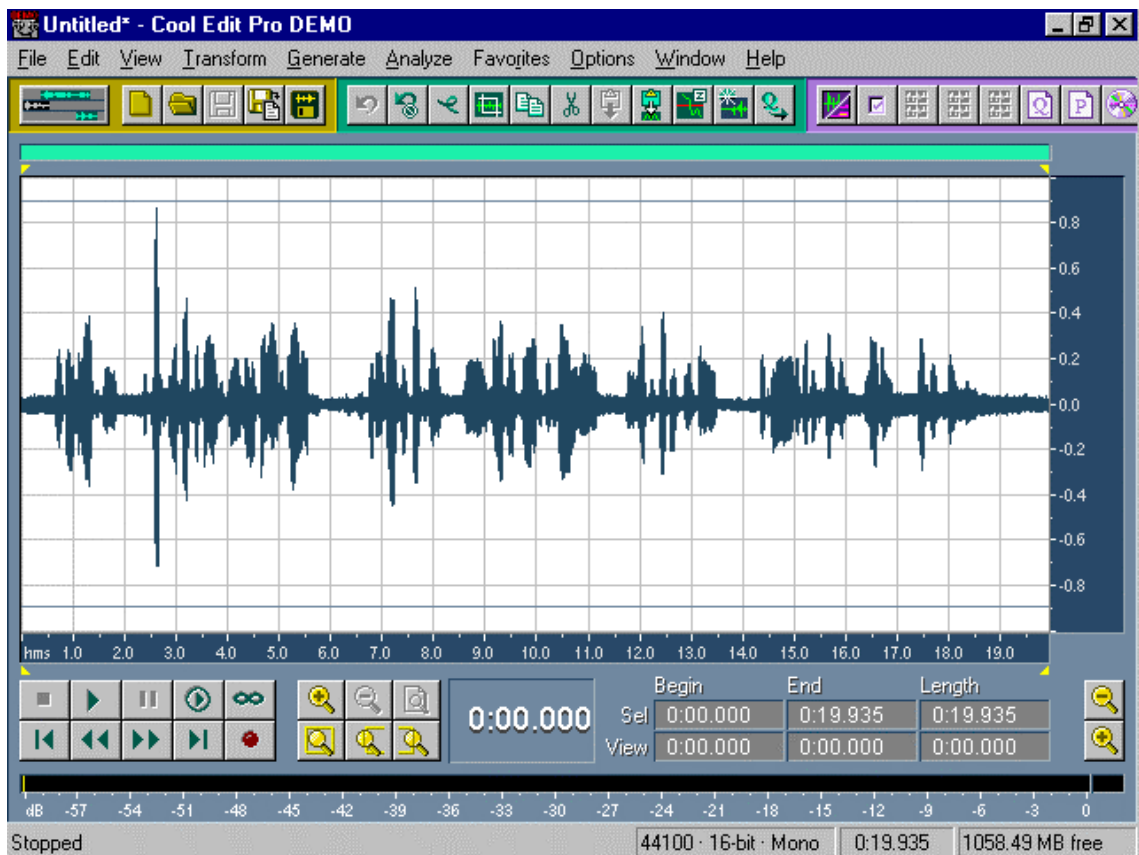
.

Figure 1: Voice Signal Copy

By experimenting with voice signals and their characteristics, students learn the characteristics of a signal's components, as well as principles of telecommunication channels that would support their transmission.

The horizontal axis in Figure 1 identifies the sample's related length of time, and the vertical axis exhibits relative levels of the signal strength that could be related to the electronic signal-copy. The dynamic diapason and the signal's variations have a direct relationship to the required electronic and telecommunications characteristics of a voice communication channel. Voice channels are characterized by the bandwidth of a communication channel needed to communicate this signal, a signal's power budget, and other telecommunications channel characteristics. Student experimentation with these characteristics— with both the voice signal copy and telecommunications channels--provide valuable experiments on the subject for distance learning. Figure 2 depicts additional signal communication experiments using the same software [1].
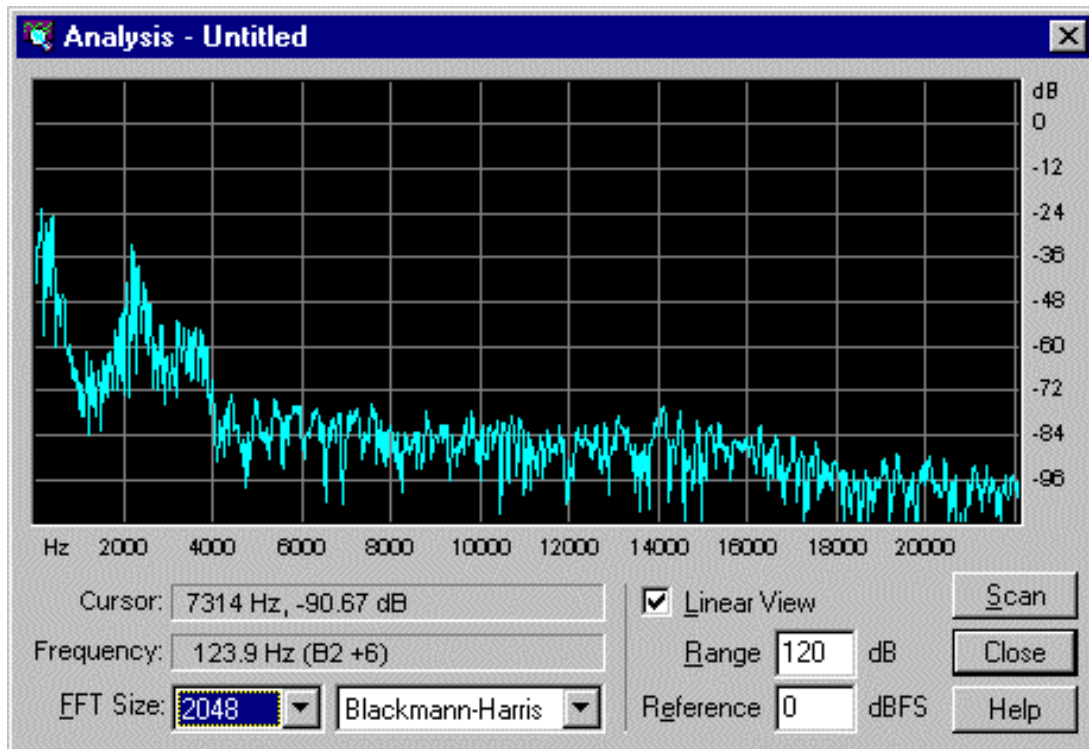
Figure 2: Voice Signal Spectrum

Figure 2 depicts a voice signal's spectrum. An analysis of signal harmonics and telecommunications channels needed to communicate this signal provide experimental basis for telecommunications studies.

The horizontal axis provides the range of frequencies in the signal's spectrum, and the vertical axis identifies the signal's relative power in decibels.

Practical experimentations and analysis with the signal's spectrum should further enhance student comprehension of the subjects in telecommunications, as well as student interest in the course material.

3. MODULATION AND COMMUNICATION TIMING EXPERIMENTS

The following experiments are based on industry-available software [2] that could be used for distance learning.

Frequency Modulation Experiments

Figure 3 depicts experiments in frequency modulation and measurements of the signal's effective bandwidth.
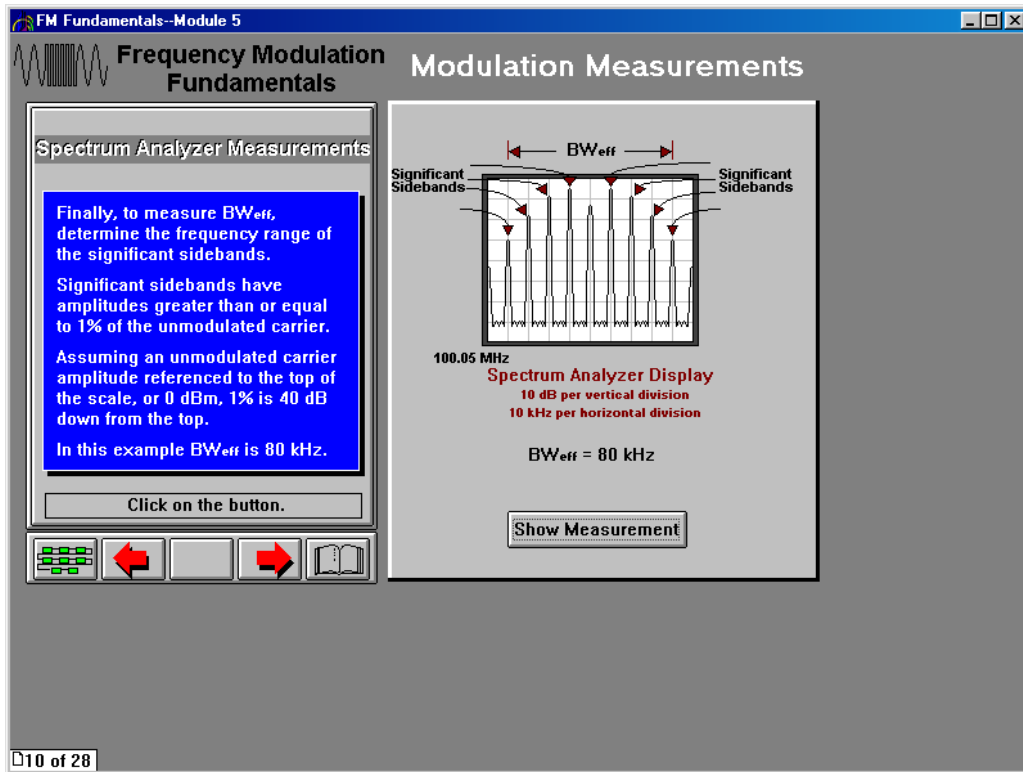
Figure 3: Signal Transmission Using Frequency Modulation

Using the experiment depicted in Figure 3, a student explores frequency modulated signals, their effective bandwidth, and measurements used to identify the signal's effective bandwidth. The student can also explore the modulated signal components, and observe experimental effects of the signal's spectrum. For example, the sidebands could be changed and manipulated on the screen in order to experiment with the relative power of the carrier frequency in relation to the power of any of the sideband frequencies.

Amplitude Modulation Experiments

Figure 4 depicts an amplitude modulated signal and an experimental base to analyze the modulation index effects. It is based on the same software [2].
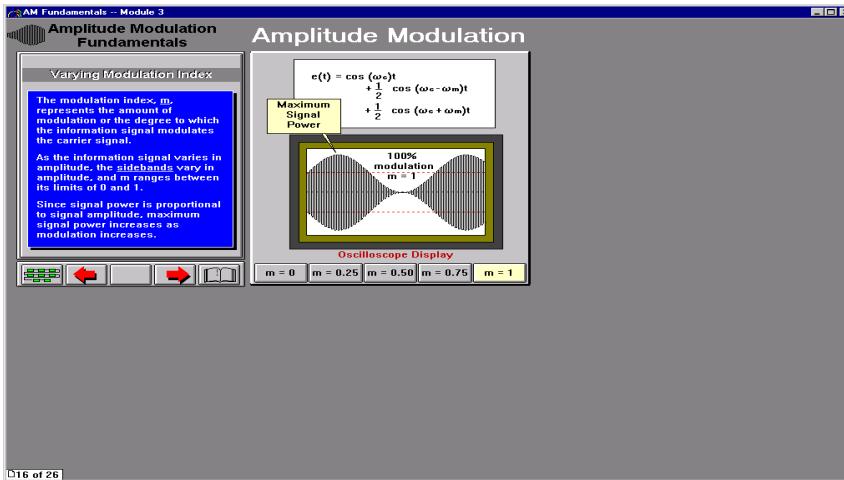
Figure 4: Amplitude Modulation Index

Figure 4 shows an experiment using the amplitude modulation display, allowing the student to develop an understanding of the effects of a change in the modulation index. The carrier signal and its changes will be displayed depending on the modulation index, permitting an experimental signal design.

Synchronous Communication and Timing Experiments

Frame synchronization and timing are most important tasks to be performed by the network nodes for synchronous telecommunication. They are used for the error-free frame hunting, signal recognition, and reliable data delivery.
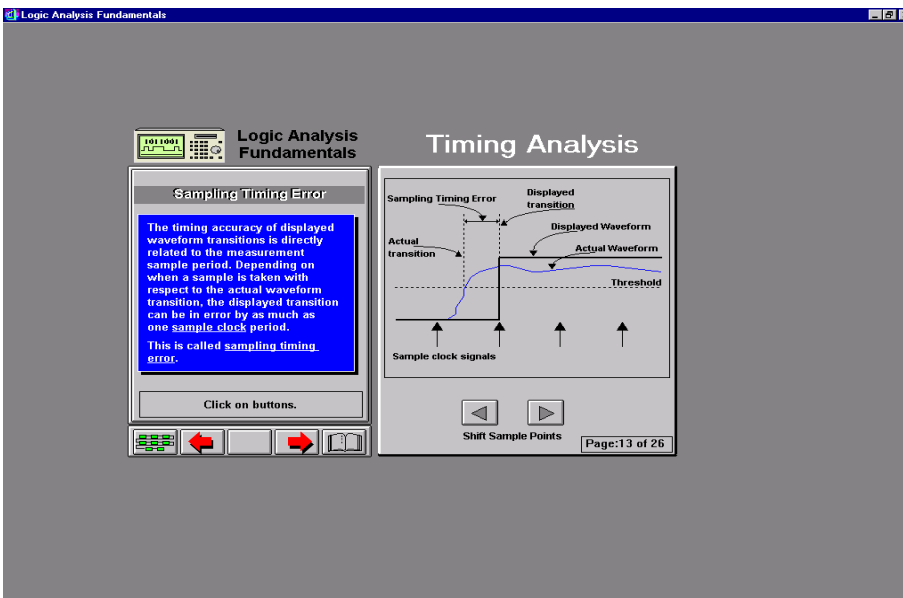

Figure 5: Synchronization and Signal Timing

The experiment depicted in Figure 5 addresses one of the most important problems in digital communication: the timing and sampling of an incoming signal. It is based on the software [2].

By experimenting with various sampling signals, either increasing or decreasing the sampling frequency and/or the sampling phase (by shifting the sampling threshold), this software will display visual changes that affect the reception of an incoming signal. Depending on the sampling experiment, the sampling phase, or its timing, the received signal will either be properly recognized or completely missed. This experiment teaches the purpose and importance of the sampling and timing processes for synchronous digital communications and digital pulse recognition.

4. DATA COMMUNICATION AND NETWORK OPERATION EXPERIMENTS

The network operation experiments can be based on industry-available software for network simulation, [3]. This software allows a broad spectrum of network topologies and protocols to be implemented in simulation models. Network operation experiments would include network performance, reliability, security, etc.
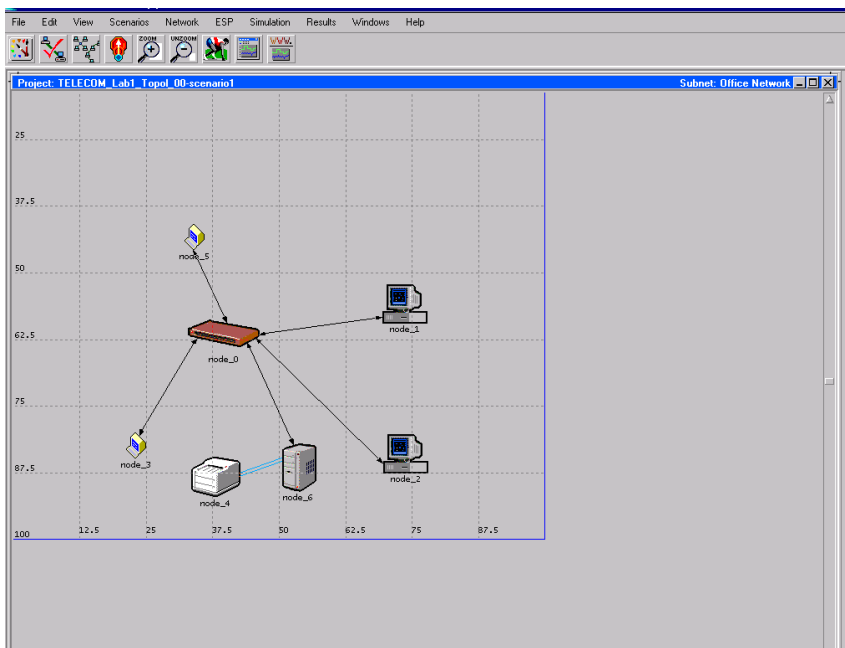

Figure 6: Simulation of a LAN Topology

Figure 6 depicts a local area network (LAN) topology for a simulated experiment. It includes a central node, the LAN Hub, two workstation nodes (1 and 3), two terminal nodes (2 and 4), and Ethernet server node (6). In addition, a printer--node 5-- is directly connected to the server, or it could be a node off the LAN's hub.

The topology in Figure 6 is a common Client-Server topology with basic network elements, a server and workstation-clients that could support file transport, print, e-mail, and other services.

In order to support these services, the network can operate using the Ethernet protocol and the 802.3 network access procedures.

The network topology depicted in Figure 6 will operate as an Ethernet LAN, and will be simulated with 10Mbps data communication links 10BaseT. These links are

shown in Figure 6 between all the nodes and the Hub. The printer in turn is connected to the server via a dedicated lower rate link.

LAN Simulation Scenarios
Multiple operation scenarios could be defined for the Ethernet LAN over the same simple topology in Figure 6. The purpose of multiple scenarios is to identify critical network operation characteristics, such as

network capacity, stability, reliability, performance, and other. These and other characteristics could be evaluated both for the network as a whole and for the network individual nodes and links.

Figure 7 depicts results of network simulation under two scenarios.
The first scenario is for a regular network operation. Under this scenario, network links and the Ethernet server are loaded only with the explicit traffic originated by the LAN nodes. The second scenario is used to evaluate the change in LAN performance under an additional workload on the links, as well as the server, that may have resulted from a background traffic. The background server traffic and workloads may

have been originated by outside sources that have create the background loads.
The two diagrams in Figure 7 are the results of the two simulations. One represents
the original LAN traffic and the server loads that would result in TCP delay shown in a set of dots as a function of the LAN simulation time.
The performance of the same LAN operating under a background traffic and with additional server loads is shown on the second graph for the first 5 min of the simulation, see Figure 7.
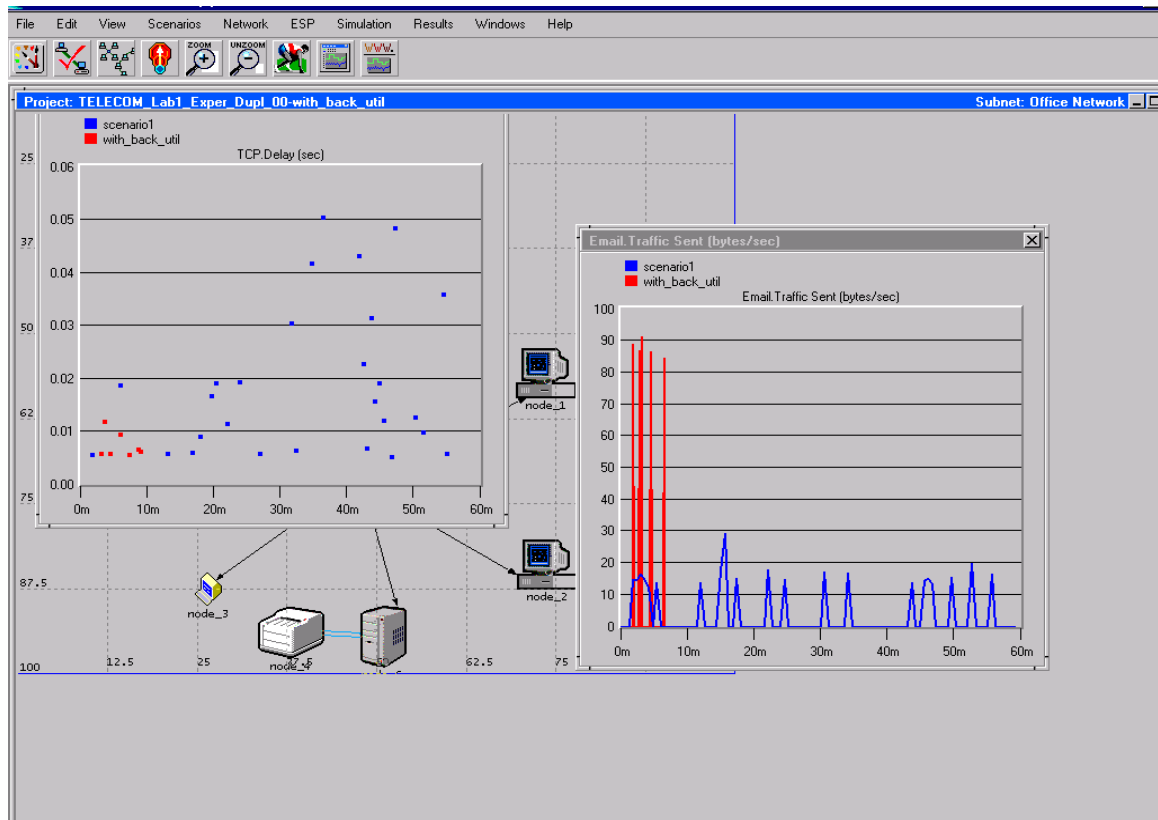

Figure 7: Simulation of a LAN Operation Scenario

As depicted in Figure 7, only the first 5 minutes of network simulation were with background loads, but these loads had an insignificant effect on the TCP delay. The effect on the TCP delay can be seen from the levels

of the dots on the TCP delay graph in the second scenario, as compared to the levels of the first set of dots.

The conclusion may be that the LAN operation is robust and reliable. The second interpretation may be that the LAN links and server have extra capacities, but are underutilized under normal loads. If the latter is the

prevailing criteria, the experiment may be the basis for this network scaled-down design.
Additional experimental topologies and LAN characteristics may be specified in order do optimize the experimental Ethernet LAN depicted in Figure 7.

5. CONCLUSION

This paper identifies the need for, and presents examples of, software tools that could be used to develop and perform telecommunications experiments by the students in distance learning.
The first two examples illustrated how voice analyzing software [1] can be used to produce and perform experiments of analog signals and their origin and components, which are essential in studies of telecommunications. This type of software does not require high processing resources, and could be installed on an individual PC.
The second type of virtual lab experiments address the signal modulation and synchronous

transmission subjects in telecommunications. An industry-available software package [2] is being used to demonstrate how experiments for telecommunications engineering could be developed and used in distance learning.
Finally, the network operation and network engineering experiments demonstrated the potential development and use by the student in distance learning. These experiments are based on network simulation software available from the software industry, [3]. The network simulation experiments include network topology, protocol analysis, and network operation experiments that are essential for studies of networking technology, computer network operations, and network management.

6. REFERENCES

1. Syntrillium Software CoolEdit, download site – 2000:
   http://www.syntrillium.com/products.htm

2. HP software, reference and information site: http://www.hp.com - 2000.

3. MIL3 software OPNET/ITDG v.6/7, OPNET reference and information site – 2000: http://www.mil3.com