2006-2119: INTEGRATION OF INTERACTIVE SIMULATIONS AND VIRTUAL EXPERIMENTS IN TELECOMMUNICATIONS COURSES FOR ONSITE, ONLINE AND HYBRID DELIVERY

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Integration of Interactive Simulations and Virtual Experiments in Telecommunications Courses for Onsite, Online and Hybrid Delivery

Abstract

The rapid pace of technological growth and the convergence of Information Technology, Biotechnology and Nanotechnology are placing new demands on the knowledgebase and skill-sets of engineering and engineering technology graduates. The engineering and engineering technology graduates are not only expected to understand the theory behind state-of-the-art technologies, but also to exhibit hands-on, analytical, problem solving, expert thinking, and complex communication skills. To address these changing needs, it is essential that new technological tools and teaching methodologies be incorporated in the curricula so that students can acquire Digital-age literacy for becoming "Deep Learners.". However, incorporation and implementation of state-of-art technological tools requires considerable investment of time and economic resources. Keeping curricula and lab resources current with respect to the swift pace of technological advances in the field is another challenge for faculty.

Educators can address these challenges by using the simulation and virtual experiments. With the availability of broadband technologies, which offer high data rate connections, simulation-based e-learning is rapidly becoming a significant and effective component of the teaching and learning process. The use of virtual systems enables students engaged in distance learning to master practical skills at any time and at any place. This paper presents an introduction to "Active Learning Suite (*ALSuite*)" software developed for interactive simulations and virtual experiments, and discusses its application for Telecommunication (Fiber Optics and Wireless Communications) Courses, for onsite, online and hybrid delivery modes.

I. Introduction

To achieve success in learning and in pursuing a successful career, a student in the 21st century needs to attain proficiency in science, technology, and culture, in addition to the reading, writing and calculating skills. The Digital-age literacy requires students to gain understanding of information in all its forms: basic literacy, scientific literacy, economic literacy, technological literacy, visual literacy, information literacy, multicultural literacy, and global awareness. Moreover, a student has to become proficient in " Deep Learning" in contrast to :Surface Learning" (See Table 1).[1]

In the book *In The New Division of Labor: How Computers are Creating the Next Job Market*, Harvard Professor Richard Murnane and MIT economist Frank Levy have examined the role of computers in reshaping the job market and types of human skills required in today's marketplace. Professors Levy and Murnane contend that the jobs growing in numbers share two general skills that the computer cannot replicate: expert thinking and complex communication. The first skill, expert thinking, addresses the ability to solve new problems that cannot be solved by rules. The second general skill, complex communications, addresses the ability not only to transmit information, but to convey a particular interpretation of information to others in jobs like teaching, selling, and negotiation. [2,3] According to Professor R. Murnane "Training all students to engage in complex communication and expert thinking is the challenge American schools have never met, there is an enormous capacity building challenge…. It is the problem solving skills that will trump that digital technology." [4]

Table Deep Learning Versus Surface Learning

Attributes of Deep Learning	Attributes of Surface Learning
Learners relate ideas to previous knowledge and experience.	Learners treat the course as unrelated bits of knowledge.
Learners look for patterns and underlying principles.	Learners memorize facts and carry out procedures routinely.
Learners check evidence and relate it to conclusions	Learners find difficulty in making sense of new ideas presented
Learners examine logic and argument cautiously and critically.	Learners see little value or meaning in either courses or tasks.
Learners are aware of the understanding that develops while learning.	Learners study without reflecting on either purpose or strategy.
Learners become actively interested in the course content.	Learners feel undue pressure and worry about work.
Source: Weigel, Van. (2002). Deep Learning For a Digital Age: Technology's Untapped Potential to Enrich Higher Education, Jossey-Bass, San Francisco, CA. p.6	

The phenomenal growth in the wide spectrum of technologies has led to an increase in the productivity of the workplace. Therefore, industry seeks graduates with appropriate background and training. The engineering and engineering technology graduates are not only expected to understand the theory behind state-of-the-art technologies, but also to exhibit hands-on analytical, problem solving, expert thinking, and complex communication skills.
To address these changing industrial needs, it is imperative that new technological tools and teaching methodologies be incorporated in the curricula so that students can acquire Digital-age literacy for becoming life-long learners. However, incorporation and implementation of state-of-art technological tools requires considerable investment of time and financial resources. Keeping curricula and lab resources current with respect to the fast pace of technological advances in the field is another challenge for faculty.[5]

College and university professors can address these challenges by using the simulation and virtual experiments. With the ubiquitous availability of broadband technologies, which offer high data rate connections, simulation-based e-learning is rapidly becoming a significant and effective element of the teaching and learning process. The use of virtual systems enables students engaged in distance learning to master practical skills at any time and at any place, and thus become "Deep Learners."

II. Active Learning Suite (*ALSuite*)

> *Technology should enrich the experience of learning. E-learning technologies may save some costs and add a measure of convenience, but if they do not deepen the learning experiences of students, they are not worth much.*
>
> Van B. Weigel[1]

To address the pedagogical and laboratory needs of students, advanced simulation-based e-learning software, "Active Learning Suite" (*ALSuite*) has been developed. It uses real-life processes and objects, such as those related to fiber optics, wireless and wired communications as the context for science and technology investigations. This enables students to: (a) learn the relationship between the scientific theory and its practical applications in technology, and (b) explore the processes occurring in the system and constraints between its parts and parameters, and (c) observe system limitations and bottlenecks. *ALSuite* is based on a proven pedagogical assumption that students learn effectively and master science and technical concepts efficiently if they can understand the concrete phenomena that are being studied and if they become aware of the potential applications of the theoretical knowledge they are acquiring.

The realistic *ALSuite* simulations enable students to experience workplace-like virtual environments. State-of-the-art graphical interfaces and realistic models provide an "insight" view of the process and allow students to imitate authentic tasks that are similar to or identical with real tasks they will encounter in their potential workplace. Students can quickly and safely experiment with a variety of scenarios and see the effects of their experimentation, become familiar with internal structure and operation of complex telecommunication systems and devices, and learn effective sequential processes, along with the development of other professional and vocationally appropriate skills.

III. Features of Active Learning Suite

The *ALSuite* software implements technologies that can provide instructional opportunities in many ways, whether at a campus/school (traditional teaching), at home (warm-ups, post-class tasks, or self-learning), in a corporate setting, or through distance learning. ATeL's realistic simulations (complex JAVA and Macromedia Flash applets with associated HTML/XML parts and scripts) enable learners to:

(1) observe the physical processes insightfully at different levels of detail
(2) analyze constraints between relevant parameters
(3) push these parameters beyond normal allowed values to simulate infrequent operating conditions or casualty situations,
(4) run "what if" scenarios,
(5) acquire data from virtual experiments[*] for detailed analysis and comparison to actual operating conditions in a theory to practice approach.

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[*] The difference between a simulation and related virtual experiment lies in the presence of a step-by-step instruction for students in the virtual experiment. Hence in a virtual experiment the student is expected to follow the instruction to accomplish an assignment, whereas there are no restrictions on the student's action when he/she works with a simulation. In addition, as real hands-on experiments, virtual experiments include objectives, assignment, and assessment.

ALSuite virtual labs incorporate simulations and virtual experiments that facilitates both conventional sequential learning paradigm and "just in time" learning. In conventional approach studying design and operation of telecommunication systems and devices precedes with learning basic scientific and engineering principles. Just-in-time learning strategy proposes to study underlying fundamental concepts and laws as they needed in the context of f the specific applications.

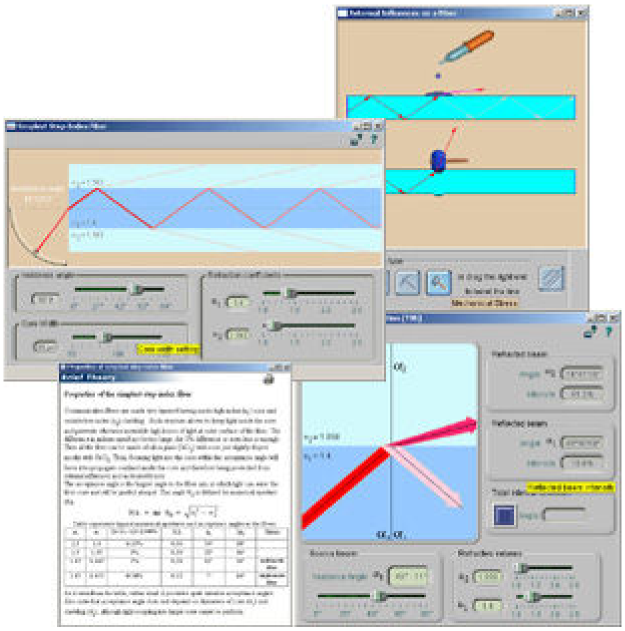

Figure 1. Thee simulations designed to assist students in studying the basic concepts of fiber optics. Using the bottom right simulation a student can explore what happens to a light beam crossing the boundary between two media with different refraction indexes. Varying light angle and refraction indexes the student will explore how these changes affect the light energy distribution between refracted and reflected beams, as well as total internal reflection.
The left simulation enables a student to investigate how light propagation in an optical fiber depends on incident angle, core diameter and core/cladding indexes."
This top right simulation helps the student understand why optical fibers require a protection cover and why there is a limit for bending cables.
From a simulation a brief theory (bottom left) can be open in a separate window and printed.

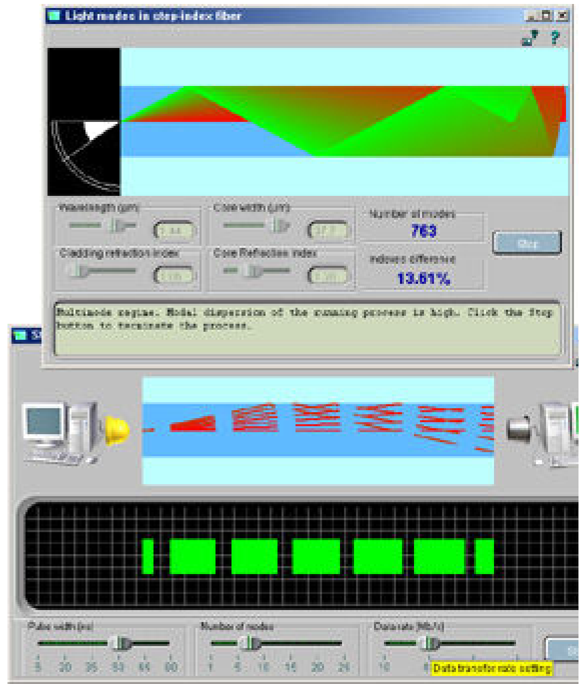

Figure 2. The simulation ***Light modes in a step-index fiber*** (top) enables a students to investigate how the quantity of traveling light modes in a step-index fiber depends on wavelength, core diameter and core/cladding indexes.
The ***Step-index fiber-optical link*** simulation (bottom) helps to understand how a modal dispersion affects data-transfer rate in the fiber-optical link.

Control devices and testing equipment used in the telecommunications industry enable technicians to measure and define correlations between virtually all internal and external parameters that describe a process or object's properties. The majority of technical college students and corporate maintenance/service staff are more empirical than abstract learners.[6-8] Often they struggle to understand processes at a qualitative level and prefer to learn through "hands-on" activities. Vast majority of experiments in real photonics laboratories look like sets of boxes linked with wires, this provides only an “external” view of the process, phenomena or operation of a device without visual exposure to what is going on inside and how it is related to fundamental laws and principles. This does not excite students’ imagination or visual perception. *ALSuite’s* simulations and virtual experiments provide both “inside/insight” and “outside” views of the process. The simulations shown in the Figures 1 and 2 reveal the processes taking place inside the fiber optic devices and components and links parameter changes with quantum mechanical concepts and with the internal device design and structures.

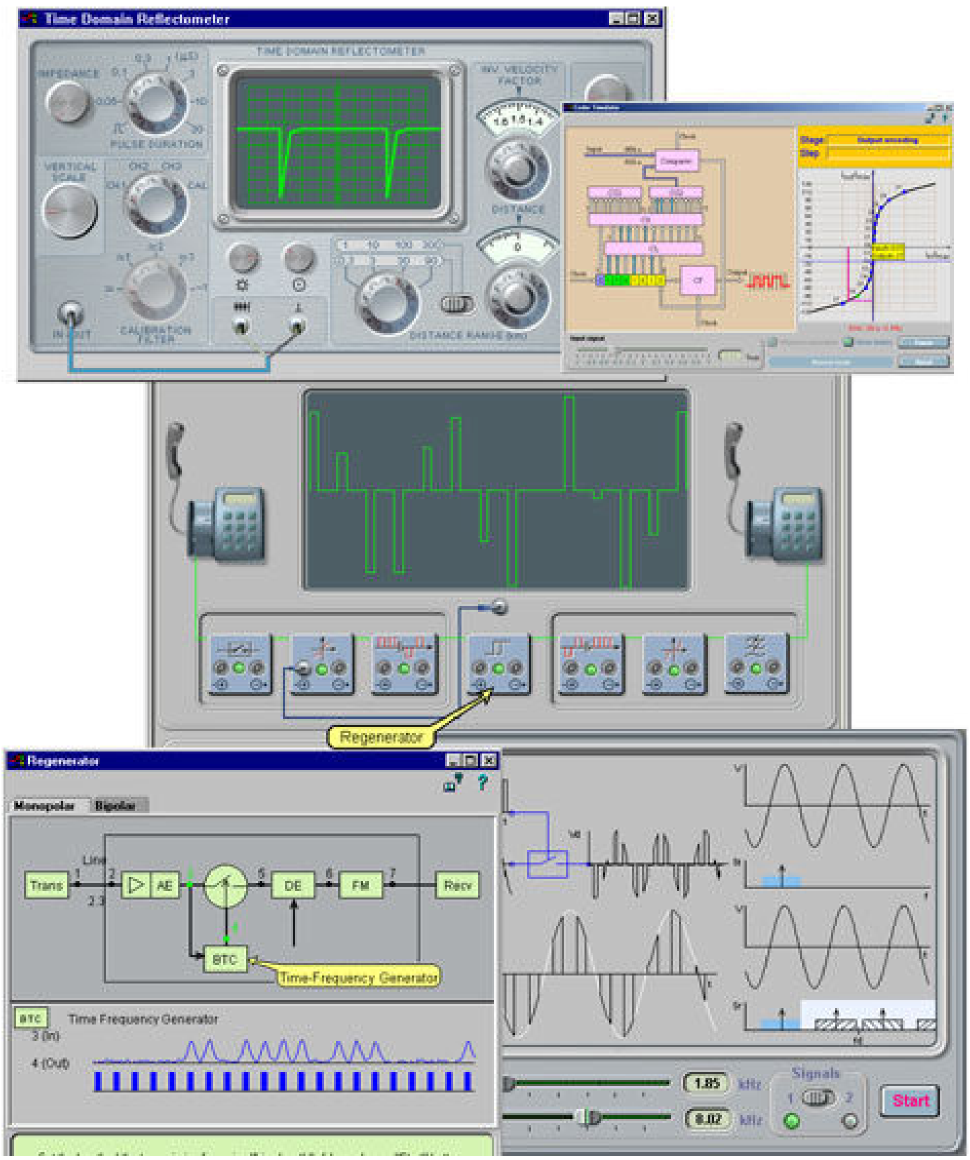

Figure 3. The simulations on the right are designed to assist learners in exploring the architecture and operational principles of a wired telephone system and its parts. The simulation in the middle presents all major devices that form a communication track as well as input and output signals for each device. A click on a device icon launches the second level program that simulates the design and operation of the chosen device (Regenerator- bottom left and Non-linear decoder – top right). It enables the learner to fully explore the device functionality and structure. The embedded tool enables the student to digitize graphs and convert them into tabular data. The bottom right simulation visualizes all sequences of the processes occurring during the voice transmission from trigger the simulation screen into a display of a virtual oscilloscope and examine signals in detail. The virtual Time Domain Reflectometer (top left) allows a student to analyze signals and master the use of the apparatus for tasks in the field.

All computer simulations are based on scientific-mathematical models, which contain certain assumptions and neglect some phenomena. Depending on the topic under study, the purpose of simulations, and available recourses, the model can be more or less sophisticated and thereby describe the original phenomena for better or worse. For prospective engineers, it is crucially important to understand the accuracy of simulated results and limits of their applicability. *ALSuite* simulations enable students to export virtual data to MS Excel or other data acquisition software. The ability to compare data acquired from student hands-on experiments with data generated by a simulation based on various models (from simple to more sophisticated ones) provides a unique opportunity for the professor to discuss with students the discrepancies between real-world processes and theoretical schemes, as well as the accepted assumptions, limitations and applicability of science models.

In addition, realistically looking *ALSuite* simulations can help students conceptualize the physical principles underlying the operation of a real device.

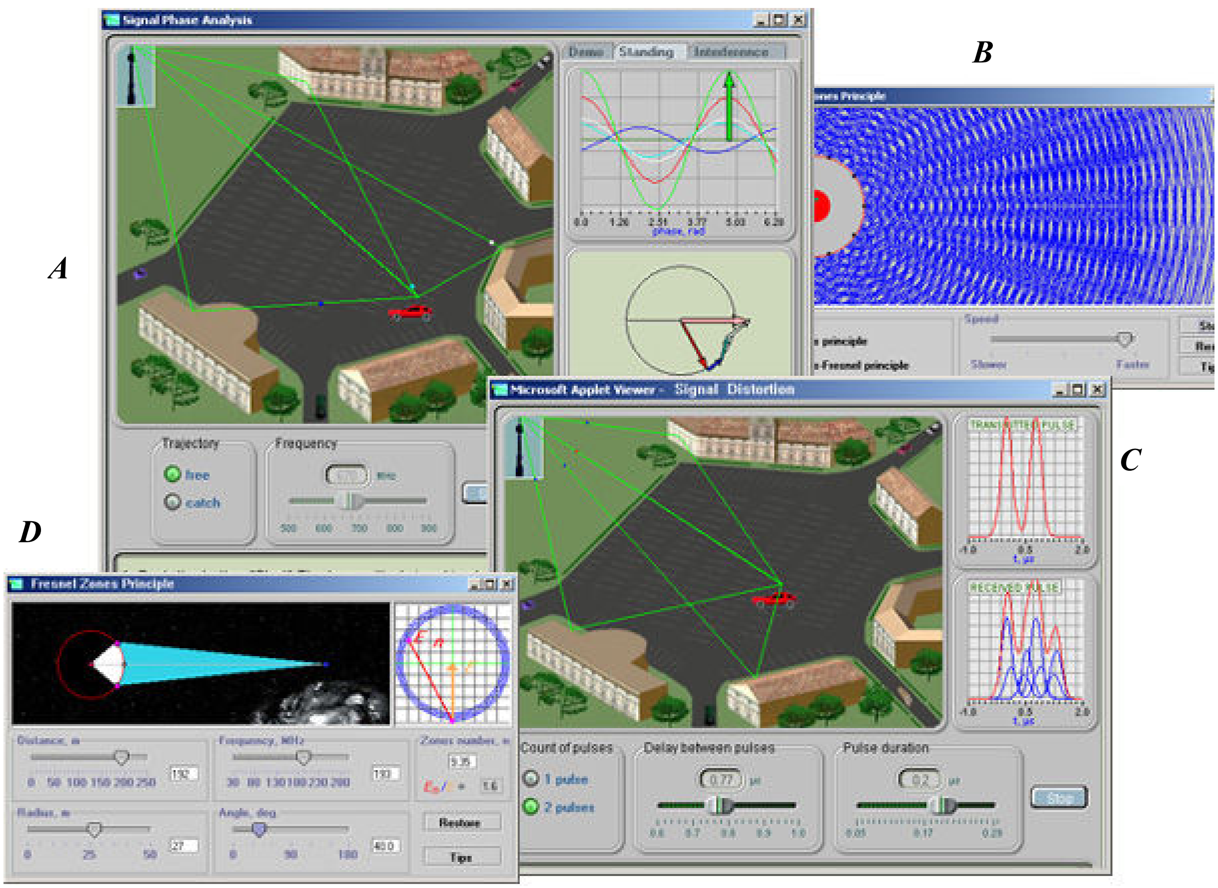

Figure 4 Simulations above are designed for virtual exploration of the signal reflection and distortion effects. Using the drag and drop option (on the simulations ***A*** and ***C***) a student is able to move the car around a parking lot and see how the different reflections from surrounding buildings affect the signal shape, phases, and amplitudes. He/she can choose between one or two pulse signals, vary signal frequency, pulse duration and delay between pulses. The simulations ***B*** and ***D*** help the student understand the Huggens-Fresnel principle, and the impact of various parameters on the structure of Fresnel's zones, as well as what sources of secondary waves should be taken into account during the calculations.

A virtual experiment can provide an opportunity to separate the particular impacts of each of several parameters that affect the outcomes of measurements. Using simulations the student is able to isolate and analyze the contribution of a specific process and by this means to recognize and evaluate errors in actual measurements made in laboratory experiments.

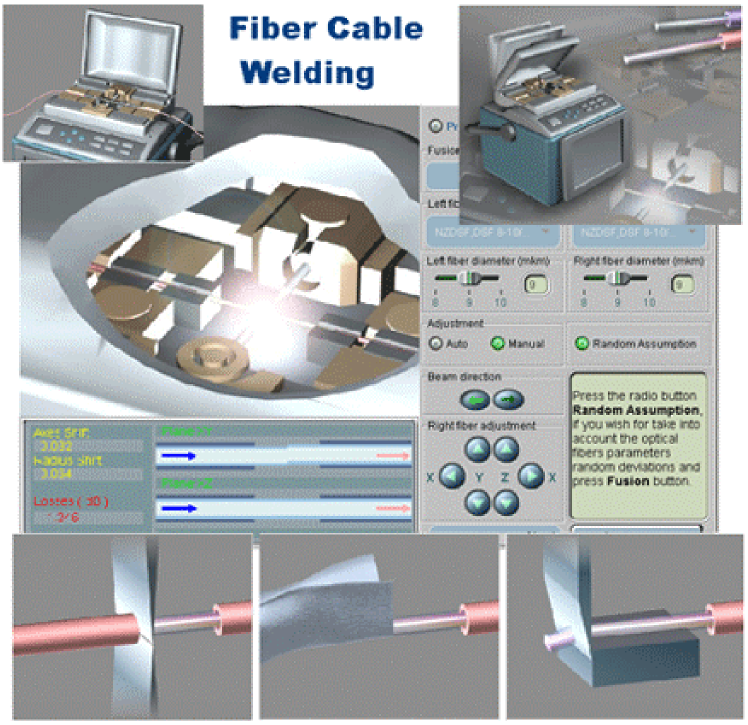

Figure 5. The virtual experiment **Fiber Cable Welding** is designed to introduce to students, in detail, all steps of a welding process, welding equipment, and factors which affect the quality of welded cable and signal losses. The learner is able to explore all stages of the preparation phase, select the cables for welding either from a list of standard industrial products or set up customer cable parameters. In the Fusion phase, he/she can launch an automatic Fusion Splicing or adjust the cables manually and measure the losses if the adjustment was not perfect.

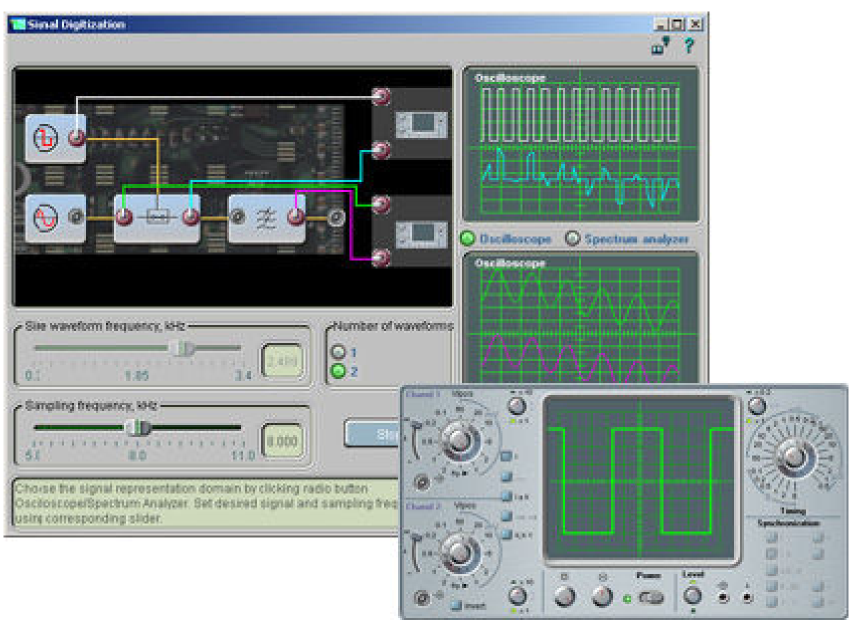

Figure 6. The virtual experiment ***Signal Digitization*** is designed to explore in detail what is going on in the course of signal transmission between subscribers. Such issues as waveform sampling, impact of various frequencies interference due to incorrect sampling frequencies and others are studied.

Input and out of each component can be connected with either built-in oscilloscope or spectrum analyzer to investigate signal on each stage of its transformation. For detailed exploration fully functional virtual oscilloscope can be used.

There are a number of hands-on labs that require unique and expensive equipment, complicated multi-step actions, or require specific training. In contrast, simulations and virtual experiments allow students to perform realistic hands-on labs efficiently online. For example, *ALSuite*'s "*Fiber Cable Fusion"* and "*Signal digitization*" virtual experiments (see Figures 5 and 6) can be used to guide students virtually through all the steps of the splicing/welding process before a student has mastered real splicing/welding techniques. Such warm-up preparation will increase the effectiveness of hands-on labs, making student's learning more proactive, and thus reducing the time to understand the functionality of unique equipment. Distance learners can use virtual experiments on a regular basis from a college web site while occasionally performing a hands-on laboratory session at the college.

The *ALSuite* software implements technologies that can provide instructional opportunities in many ways, whether at a campus/school (traditional classroom settings), at home (warm-ups, post-class tasks, or self-learning), in a corporate setting, or through distance learning.

When used in a lecture-lab environment, learning can be very efficient because students can immediately apply their theoretical knowledge by conducting a virtual experiment. When incorporated in online courses, virtual experiments dramatically enhance the quality of distance learning. For example, Figure 7 illustrates various strategies for cell splitting and their effect on traffic loads.

ALSuite is intended for problem-based learning and "learning-by-doing." [9-12] However, it can facilitate more traditional learning and teaching strategies as well. The interactive exercises and virtual experiments in *ALSuite* are designed to challenge learners to develop effective problem-solving, critical and expert thinking skills. This enables the learner to discover the connections between theoretical concepts of the technology and their practical applications in the real world.

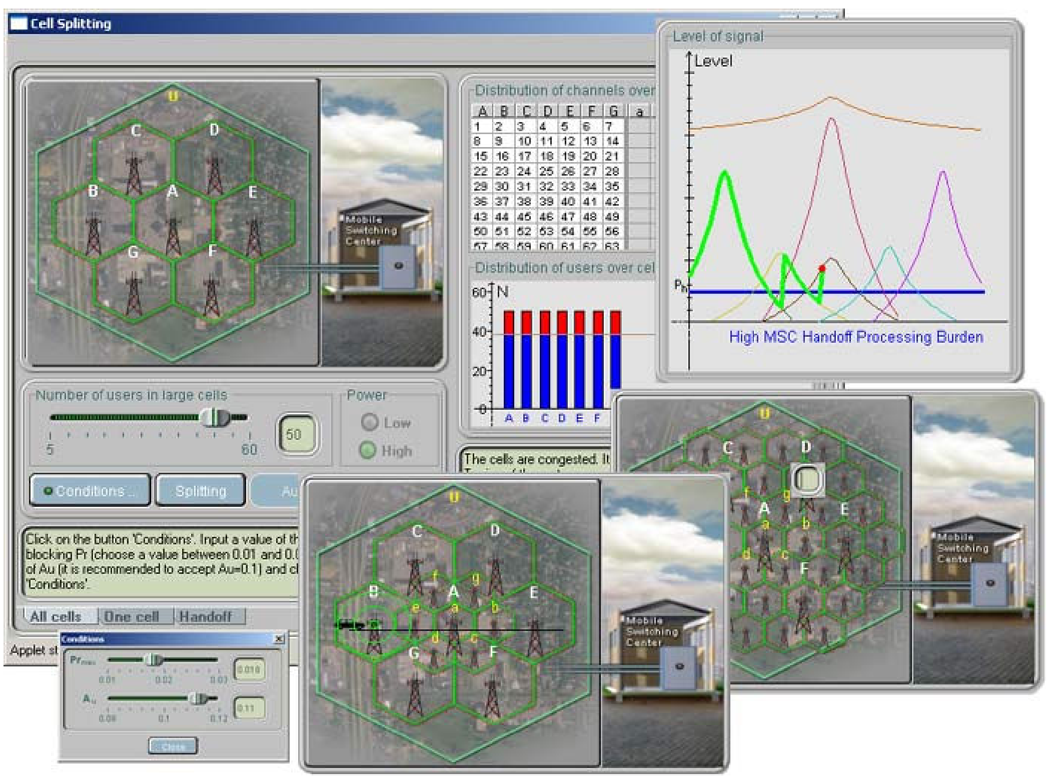

Figure 7 The simulation enables a student to explore the situations when cell splitting is appropriate and various strategies of cell splitting. The student can study how the total maximum number of users in a system increases as cells are split. The procedure of switching handing off a mobile phone from one cell to another, as it moves across cell boundaries in a system of different sized cells, can be explored as well. The student is able to change values of the probability of blocking, traffic intensity A and the number of users in initial cells.

ALSuite software can be run from:

- Web site over the Internet,
- a server via a local school or corporate network,
- CD, or hard drive of a stand-alone computer.

ALSuite modules and components are compliant with SCORM and compatible with major learning and content management systems

IV. Interactive Simulations and Brain-based and Constructivist (or Deep) Learning

The use of interactive simulations and virtual experiments in Telecommunications (Fiber Optics and Wireless Communications) Curricula support the brain-compatible teaching principles outlined by Caine and Caine:[13] (1) the brain is a parallel processor, (2) learning engages the entire physiology, (3) the search for meaning is innate, (4) the search for meaning occurs through "patterning," (5) emotions are critical to patterning, (6) the brain processes parts and wholes, (7) learning involves both focused attention and peripheral perception, (8) learning always involves conscious and unconscious processes, (9) the brain has at least two different types of memory: a spatial memory system, and a set of systems for rote learning, (10) humans understand and remember best when facts and skills are embedded in natural, spatial memory, (11) learning is enhanced by challenge and inhibited by threat, and (12) each brain is unique.

Active Learning Suite experiments also support the Deep Learning or the constructivist approach of teaching. According to the *Thesaurus of ERIC Descriptors,* [14] constructivism is a "viewpoint in learning theory which holds that individuals acquire knowledge by building it from innate capabilities interacting with the environment" (p. 64). Constructivist teaching is based on recent research about the human brain and what is known about how learning occurs. It is an approach to teaching and learning based on the premise that cognition (learning) is the result of "mental construction." In other words, students learn by fitting new information together with what they already know.

V. Incorporation of ALSuite software into the Wireless Communications Engineering course at DeVry University

A number of simulations and virtual experiments based on ALSuite software have been incorporated into the Wireless Communications Engineering course (EET-455/L) at DeVry University, Addison, IL. The students' assessments of ALSuite software-based experiments reveal that these simulations and virtual experiments provide a systems overview, and help students develop a good conceptual database. Students also believe that they are easy to use and their effectiveness can be enhanced by interfacing them with external systems in order to provide a hand-on experience for users. Three sample experiments related to Cellular Communications are reproduced below.

EET-455L Wireless Communications Engineering
DeVry University, Addison, IL 60101

Virtual Experiments and Simulations

Expriment 1: Introduction to Cellular Concepts

Expriment Description
In this virtual experiment, the concept of a cellular telephone system based on the division of the service area into comparatively small zones (cells) is illustrated. You will be able to explore how the cells are grouped into clusters and which shapes of cells are preferred over other shapes. Also, you can learn the dependence of size of clusters and cells on the number of users, size of the area served, and the width of radio channels.

Procedure:

1. Using Internet web browser go to the website of Active Learning Suite (Atel) http://atelearning.com
2. Select virtual experiment.
3. Select experiment titled "Cellular Concepts."
4. Observe the effect of changing the following parameters on mobile system Construction:
   - Coverage area
   - Number of subscribers
   - Duplex channel bandwidth
   - Total Spectrum Available
   - Path Loss
   - Minimum S/I ration

5. Observe the effect of changing the shape of cells on the coverage area. Which cell shape provides the smallest (R/r) ratio and offers the largest coverage area.

6. Observe the effect of changing the cluster size on frequency reuse.

7. Observe the effect of changing the following parameters on signal-to-interference ratio:
    - Number of clusters
    - Number of cells per cluster
    - Path loss

8. Answer the following assessment questions:

(1) Was this virtual experiment helpful in understanding the cellular concepts?

(2) What are the 5 things you liked about this virtual experiment?

i. ii. iii. iv. v.

(3) What are the 5 things you did not like about this experiment?

i. ii. iii. iv. v.

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Virtual Experiments and Simulations

<u>Experiment 2:</u> Cell size dependence on user's movement speed

Experiment Objective

To examine the procedure for switching a signal in a system containing different cell sizes as a mobile telephone moves between cells.

Experiment Description

In this virtual experiment you will explore how the 'handoff' procedure can be performed in a system containing cells of different sizes. The distinctive feature of the handoff procedure in such a system lies in the fact that it is advisable to assign certain cells to different users. In practice, different size cells and so-called umbrella cells are assigned to mobile phone users, which move at different speeds (low, middle or high). In the experiment you should determine the optimal type of cell sizes for three different MS speeds.

Procedure:

1. Using Internet web browser go to the website of Active Learning Suite (Atel) http://atelearning.com
2. Select virtual experiments.
3. Select experiment titled “Cell size dependence on user's movement speed.”
4. Study the dependence of user’s movement on cell size for the following types of cells:
   - Micro cell
   - Large cell
   - Umbrella

5. Answer the following assessment questions:

a) Was this virtual experiment helpful in understanding the cellular concepts?

b) What are the 5 things you liked about this virtual experiment?

i.
ii.
iii.
iv.
v.

c) What are the 5 things you did not like about this experiment?

i.
ii.
iii.
iv.
v.

EET-455L Wireless Communications Engineering DeVry University, Addison, IL 60101 Virtual Experiments and Simulations Experiment 3: Exploration of Signal Transformation Stages in a Cell Phone

Experiment Objective:
To explore the block diagram of a cell phone and learn the signal processing and transformation at sub-block level.

Procedure:

1. Using Internet web browser go to the website of Active Learning Suite (Atel) http://atelearning.com
2. Select virtual experiments.
3. Select experiment titled "Exploration of Signal Transformation Stages in a Cell Phone."
4. Press the 'Open' button to see the structure of the phone.
5. Press the 'Show Diagram' button to see the logical component diagram of the phone.
6. Describe the function of each block in the following table:

Block	Function
Compressor	
Pre-emphasizer	
FM Modulator	
Transmitter and RP power amplifier	
Duplexer	
Receiver LNA	
Demodulator	
De-emphasizer	
Expander	

7. Click on the keypad component to activate a dialing pad. Dial any phone number (at least one-digit long) and click the 'Dial' button.
8. Observe the signals at the input and output of each block using spectrum analyzer and oscilloscope and recording your observations in the following table.

Block	**Input/output signals**	
	Time domain	**Frequency domain**
Compressor		
Pre-emphasizer		

FM Modulator		
Transmitter and RP power amplifier		
Duplexer		
Receiver LNA		
Demodulator		
De-emphasizer		
Expander		

Answer the following assessment questions:

9. Was this virtual experiment helpful in understanding the cellular concepts?

10. What are the 5 things you liked about this virtual experiment?

i.
ii.
iii.
iv.
v.

11. What are the 5 things you did not like about this experiment?

i.
ii.
iii.
iv.
v.

VI. Conclusion

The use of interactive simulations and virtual experiments in Telecommunications (Fiber Optics and Wireless Communications) courses delivered via online, onsite and hybrid delivery modes enables students to acquire "Deep Learning" literacy by developing critical and expert thinking skills.

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