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Hands-on learning system for Wireless laboratory courses

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Challenge to be addressed:

The challenge for the teaching of Telecommunications in the undergraduate laboratory has always been how to cover the ever expanding field of important new topics whilst maintaining a solid grounding in the fundamentals, as well as how to do this without the need for excessive and ever increasing laboratory equipment.

Ideally the equipment needs to operate at a logical level which facilitates learning but without the need for lengthy setup time and without being too much of a ready-made experiment.

Methodology:

The ‘block diagram’ acts as the universal language of Telecommunications around the world. The math of telecommunications can be expressed in a block diagram representation. The elements of this representation can be readily understood as each component block of the system is a relatively simple specific function.

The same blocks appear over and over within block diagrams. The fundamental mathematical blocks: multiplier, adder, phase shifter, integrator etc appear in most block diagrams, and along with other more specific blocks are used to build up a complex mathematical system.

To address the above mentioned challenge and create some laboratory teaching equipment it was decided to have individual hardware modules which model the function of each block in a block diagram. These individual modules are patched together according to the block diagram of the experiment of interest. This would allow simple as well as complex systems to be constructed easily by simply following the block diagram.

The system can then model a block diagram of a communications system, or part there of, with real time electrical signals and the students can access signals at each and every block within the system. In this way they have control over every parameter and setting in the experiment. They also need to measure and adjust every parameter in the system.

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That is, they measure frequency, amplitude and phase of signals in a systematic way when building and during the experiment.

This approach is the solution that has been realized in the TIMS ™ equipment. 'TIMS' stands for 'Telecommunication Instructional Modeling System'. It is a system, which is able to model just about any scheme in telecommunications because it is based on a block diagram approach to building experiments.

Operating at the block level is the crucial characteristic which makes the system so educational. Students can avoid the time consuming need to build every circuit element, instead they can concentrate on implementing the math of the scheme in real-time hardware according to the block diagram and studying the performance of the system all within minutes rather than days. Rather than build an AM radio from discrete components, and be delayed by soldering errors and component placement, the student can easily patch together an AM system and study its characteristics all within the hour allotted for the laboratory class.

This means that students can cover a greater range of topics within their limited laboratory sessions, which enhances their overall understanding of the lecture material.

They also have the opportunity to learn by making mistakes and systematically troubleshooting the system to make the necessary corrections. The corrections can be made to both the patching as well as checking that the signal levels and settings are appropriate for the experiment. They can explore 'what-if' scenarios in their own way as well as under direction from the professor and explore the performance of the system in question beyond the limits set by ready-made equipment setups.

As the system is a modeling system, it does not need to operate at RF frequencies. In fact the carrier in TIMS is 100kHz. This is because the math of the experiment is just as valid at this frequency. It is simply scaled down in frequency.

Another inherent benefit of having a carrier at 100kHz means that students can view both the carrier and the baseband message together on a scope. This reinforces the understanding of what is happening to the carrier in relation to the message. Take BPSK as an example. By being able to view the carrier inversion points alongside the message data transitions, the student is able to more fully understand phase modulation as well as issues relating to zero crossings of the carrier.

<u>Responses in the field:</u>

This equipment was originally developed in the 1970's at the University of New South Wales by then lecturer Tim Hooper. In the late 1980's, Tim's idea became the first model of the current TIMS system. Over time many new blocks, or modules, and features have been added to the product range, all the time remaining true to the

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methodology of one hardware module per each block in the block diagram to maximize the educational benefit of the system.

This equipment has been evolving and expanding over the years and we have received many responses from the end users as we encounter them at various university sites. The end users are both professors and students. One of the best responses is hearing students say that they like using the TIMS equipment. These are responses from students and professors who are using the equipment to complete important parts of their undergraduate and graduate work. The system is being used by thousands of students throughout the world every day, and has been used by tens of thousands of students since its conception. The success and popularity of the system in the educational market forms the basis of our research i.e.: market research.

From the student's point of view, having complete control over the building of the experiment gives them increased involvement and satisfaction in the laboratory class. The students 'learn by doing', as they are required to make and measure all connections between building blocks. The absence of calibration markings ensures the student avoids a simple 'cook book' approach to their laboratory work. There is maximum involvement of the student in learning telecommunications at a systems level. They concentrate on studying the concepts and principles behind the schemes. As the students control the experiment in real time, and with direct and immediate physical contact with all the controls, they utilize a kinesthetic mode of learning which reinforces their understanding. This is in contrast with the taking as given that a certain block diagram configuration will operate a certain way as discussed in classes. Particularly at the introductory levels, this kinesthetic experience serves to build confidence in their understanding of what's really happening to the signals.

What about simulation. Is it hands on?

In this age of PCs and virtual instrumentation there is an urge to replace hands-on experimentation with PC-based simulation. Our experience suggests that this is not a feasible direction for laboratory coursework in introductory courses. Responses from many professors over the years are that students at an introductory level do not learn much from using simulation packages in the telecommunications laboratory. The reason for this is too much programming and too much abstraction. Onscreen simulation is a completely different medium than hands-on equipment and requires different mental perceptual and conceptual processing by the student.

Some PC based simulation involves so much programming to the extent that students are caught up with correcting the syntax of their program rather than concentrating on the concepts at hand. Like spending time fixing wiring errors, correcting program code is not what learning telecommunications theory is about.

When a student adjusts a parameter onscreen their actions go through many transformations and manipulations before resulting in a block of data to be processed

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behind the scenes. They have to 'believe' that the computer's processing method is correct and take the results as given. This is not the same as having total control over a physical potentiometer which has no background processing capacity and always does what it is told. It is this directness of control over the experiment, which reinforces the understanding by the student. Arrays of data are not being manipulated by the PC and reconstructed into continuous signals, rather, continuous electrical signals are being analogically processed by the circuitry and the signals viewed immediately and directly via a scope. The scope is the only level of abstraction separating the student from the mathematics of the system.

Particularly for introductory students, viewing events happening on screen is no more real than an animated textbook. To really understand the experiment the student needs to figuratively "make it smoke" themselves. They also need to make mistakes and to learn from those mistakes. 'Learning by doing' is an important aspect of learning the fundamentals.

Where do PCs fit in?

Without a doubt, PCs have an important role to play in telecommunication teaching. Alongside a hands-on system, and at later stages in the learning process, the student can more readily appreciate the results presented onscreen as they have already confirmed the fundamentals for themselves with their own hands. They can appreciate the simulation because they understand its construction and its limitations, and with this understanding can concentrate on studying the concepts further through the medium of simulation.

Obviously the use of PC based instruments for data acquisition and analysis, such as spectrum analysis is wide spread and essential in laboratories. Apart from these uses there is the interesting use of the PC to control hardware in order to carry out experiments with an element of automation. Modules exist within the TIMS range that have had their manual controls replaced by electronically controlled devices which can be controlled remotely. A local PC can vary the parameters of the modules patched together in an experiment and thus facilitate some automated testing and analysis of experimental setups such as mapping the frequency response of a filter by sweeping an oscillator across the spectrum and recording the output on a PC which can then process that data and present Network Analyzer type plots.

An extension of this capability to control modules remotely is to control them from a distance via a PC connected to a LAN or Wan such as the Internet. The student would then interact with a screen-based interface to vary the parameters of the modules in the experiment and receive scope captures of the signals from that remote site. Experiments can be carried out by students on real hardware from a distance i.e.: across the Internet at any time of the day or night via a net*TIMS™ server unit. This is hands-on learning moved to a distance and positions itself between at -the -lab hands -on learning (hardware based) and using a simulator (software based).

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These PC-controlled scenarios do move the student away from the equipment and the hands-on benefits that being there brings, however they can be used as an adjunct to the hands-on laboratory classes allowing for diverse learning experiences to be available.

Equipment which allows students to build experiments and systems, patched together by hand, controlled by hand, as well as controlled by PC and complemented by simulation creates an optimum learning environment. The modular nature of this equipment allows for an affordable, all in one system, which exposes students to the maximum amount of laboratory experience. The reality of the hardware system also prepares the students well prior to using real commercial / industrial equipment in the work place. A graduate who has actually made systems with their own hands is always better prepared than one who only ever seen systems on screen.

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